Compass & Tape

Volume 13, Number 3, Issue 43

Survey and Cartography Section

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

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

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

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

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

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

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

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

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

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

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

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

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

Inside

Front Cover: Another fine Linda Heslop graphic

Back Cover: Peter's Mountain #2, WV
by Mike Futrell

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SUBMISSIONS

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

Send all submission for *Compass & Tape* to:

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

Section Business

At last year's annual SACS meeting, Arnie Wiesbrot submitted a motion to the Section proposing that a size standard be adopted on all cave maps. The motion was seconded by Bob Hoke. Kambesis suggested that before calling a vote on the motion, that it be circulated to section members and be reconsidered at the 1998 Section meeting. The motion was published in the last issue of *Compass & Tape (Volume 13, No. 3, Issue 43)*, within the Section minutes. The motion is reprinted below and everyone who plans to attend the SACS meeting in Sewanee is encouraged to consider the proposal and vote their preference.

A Proposal for Standardized Sizes of Maps

Arnie Weisbrot moves that the Survey and Cartography Section of the National Speleological Society adopt the following standard for use on all cave maps.

1. Adapt these parts of American Society of Mechanical engineers Standards Y14.1 and Y14.1M:

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

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

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

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

Letters to the Editor

Dear Pat,

The last issue of *Compass & Tape* (Vol. 13.2) was very interesting (I particularly enjoyed the timely article on computer graphics).However, in the interest of giving credit where it's due, I should point out that the idea of adding altitudes to complex cross-sections in Mammoth Cave (Cartographers' Corner, p. 24) originated with Scott House, who was at the time CRF's chief cartographer for Mammoth Cave. It certainly does add to the information content without a lot of extra effort

It would be equally easy to use elevations relative to a zero entrance datum rather that the absolute elevations above sea level used on the Mammoth Cave sheets.

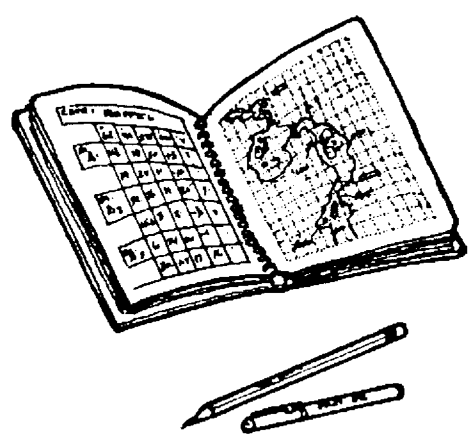
Sincerely,

Mick Sutton.

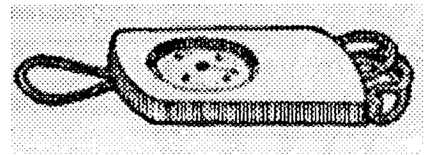
PK,

I got *Compass & Tape* today. It looks great! Thanks for the plug; a caving BOG member, what a concept.

Philip L. Moss



MAGNETIC INFLUENCES UPON COMPASS ACCURACY



by Doug Strait

Most cave surveyors understand that some metallic objects will affect the reading of a nearby compass. What is less well understood is which commonly encountered objects should be of concern and at what distances the influence is likely to be significant. In this article I will attempt to provide some understanding of these issues.

Background

The earth produces its own magnetic field. At most points on (or under) the earth's surface this magnetic field has both a horizontal and vertical component. Compasses determine direction by aligning their own internal magnetic object (needle or disk) with the direction of the horizontal component of the earth's magnetic field.

Some metals (known as ferromagnetic metals) will distort the shape of the earth's magnetic field in their vicinity. A nearby compass will respond to the now-distorted magnetic field and thus read incorrectly.

Compasses will also read incorrectly in the presence of a nearby magnet. In this case the compass senses the magnetic field that results from the combination of the earth's field and that of the magnet.

Testing

I assembled an assortment of items that cavers typically might have in the immediate vicinity of a compass. I then tested each item for its degree of influence on the true compass reading. It should be noted that for a given distance between an object and the compass, the error will vary depending upon the orientation of the compass

TABLE 1

Worst Case Deviation for Various Equipment as Typically Worn or Mounted

Equipment	Deviation	Notes
Electric Justrite Headpiece	35	
REI Green "waterproof headlamp" (4 "AA")	30	1
Safesport "waterproof headlamp" (4"AA")	30	1, 2
Petzl Micro headlamp (2 "AA")	6	1
MiniMag flashlight mounted on side of helmet (2 "AA")	3	
MSA Comfocap	3	3
Nitelight headpiece	2	
Wheat 5200 headpiece	1.5	
Justrite carbide lamp with 4" steel reflector	0.6	
Petzl Duo (4 "AA")	0.5	
Petzl Zoom (3 "AA")	<0.5	
Petzl Mega (3 "C")	<0.5	
Premier carbide lamp with aluminum reflector	0	
L1 lamp bracket	0	
MSA lamp bracket	0	
Metal glasses frames	0	4

Notes:
1 Mounted flush with front edge of helmet
2 Similar headlamp sold under "Optronics" and "Eveready" brand names
3 Effect due to metal in liner suspension
4 My four pairs tested, may not generalize to all frames

TABLE 2

Distance For Compass Deviation at Worst Orientation

Equipment	Distance	Notes
8 foot chain link fence	10 feet	4° at 5'
Weak refrigerator magnet	18"	1
Electric Justrite headpiece	10"	
3/8" Self drill with bolt	2"	
Steel carabiner	4"	
Watch with metal band	4.5"	
Justrite carbide lamp with 4" steel reflector	4"	
Premier carbide lamp with aluminum reflector	N/A	
MiniMag flashlight (2 "AA")	7"	2
2 "AA" cells end to end	9.5"	3
2 "AA" cells side by side	8"	3
4 "AA" cells side by side	11"	3

Notes
1 Proxy for dive lights which contain magnet
2 Held as if to illuminate compass
3 Proxy for headlamps containing "AA" cells in this configuration

with respect to North and with respect to the object influencing the compass.

For the purpose of measuring the degree of influence, the worst case orientation was used. Data for the various objects tested are tabulated in Tables 1 and 2.

Table 1 lists the number of degrees error caused by each object as it is normally worn, e.g., headlight mounted on helmet, with the compass positioned as it is normally read. Except for the test of the MSA Comfocap and the eyeglasses frames, all objects were mounted on a Petzl "Ecrin" helmet. This helmet contains no metal and therefore exerts no effect on the compass.

Table 2 lists the distance at which each tested object will cause a 1-degree error. The amount of error at other distances can be approximated by the inverse of the square of the distance, e.g., 1/2 distance =3D 4 times error, twice distance =3D 1/4 error.

For many of the lights tested, all of the measured error is caused by the battery (cells) contained within the light. Groups of 2 or 4 cells can be used as a proxy for many lights not tested. The outer case of cells is made from steel, which is what influences the compass. A number of cells were tested and an unexpected discovery was made. This discovery was that the cells are magnetized and that the strength of this magnetism varies greatly from cell to cell. This magnetization likely results from the rolling or stamping operations used to fabricate the steel casings.

Fourteen AA cells representing three different brands were tested and the strength of their magnetization found to vary by a factor of ten.

If one were unaware of this large variation in the magnetization of cells, it would be possible to test a headlamp for its degree of influence and conclude it was acceptably low and then have a large error at a later time due to a different set of more highly magnetized cells. I selected the worst four cells for use in the testing listed in Tables 1 and 2.

There are a few miscellaneous items that can cause significant errors. Some dive light style flashlights incorporate magnets, which can have noticeable influence at several feet. Beware of concrete items as they often contain steel reinforcing wire or rod, e.g., concrete culverts, power poles, paving, etc. Chain link fencing can cause a 4-degree error at a distance of 5 feet. One factor that theoretically can cause an effect is electric current flow associated with headlamps. This was tested and found to have negligible effect.

Conclusion: What To Do?

Be aware! If the instrument reader is wearing or using an object that may influence the compass, that object must be moved away at least to the distance listed in Table 2. If a station is placed on or near an object such as a concrete power pole or chain link fence, shoot bearings to rather than from that station. Apply common sense.

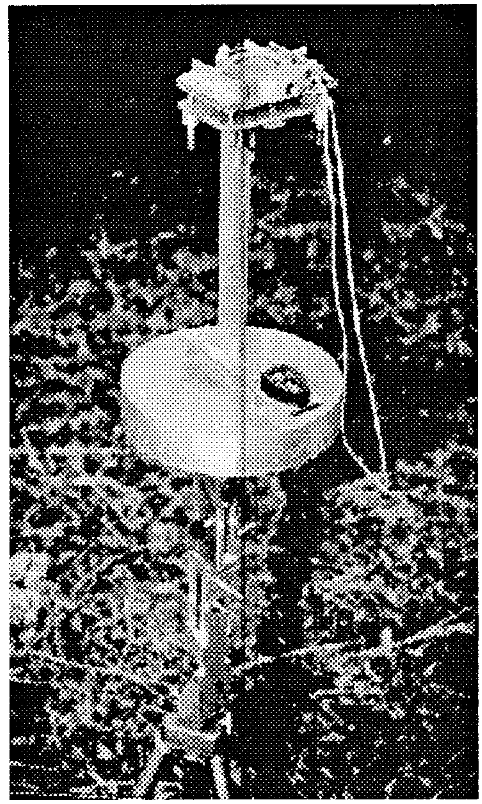
Errors In The Suunto Compass Used For Cave Surveying

by Lang Brod

Many of the recent articles on compass errors have dealt with errors encountered in the utilization of hand-held compasses in an underground environment. Furthermore, many of the articles treat errors made during the use of Suunto compasses, which have become a popular cave surveying compass in recent years. Errors have been further subdivided into small random errors arising during sighting the target or reading the compass, and larger errors (blunders), resulting from gross misreading of the compass dial or problems in transcribing the reading. The impression conveyed by these articles is that the authors consider all errors to be external to the compass. This attitude is understandable; the drum dial and the superimposed cursor of the Suunto compass are readily visible, and it is easy to read the dial to the nearest half-degree. Such apparently accurate readings may in fact mask inherent errors, which may not be evident to the user.

Over 20 years ago, in 1974, I began an attempt to measure internal compass errors in preparation for a proposed NSS mapping manual. For that purpose, I constructed a small non-magnetic rotary table calibrated in one-degree increments, topped by a small adjustable platform upon which a compass can be fastened. The table can be leveled so that its rotation axis is vertical; the platform can then be adjusted so that the compass rotates in a plane. In use, the turntable is turned so that it reads approximately zero when the compass is reading zero degrees magnetic. The turntable is then rotated until the compass reads exactly 005 degrees, and the resulting turntable position is then read and recorded. This procedure is repeated until the full 360 degrees has been covered. Data reduction simply consists of subtracting the compass reading from the corresponding table reading.

If the turntable and compass were both perfect, the difference between the two readings would be constant, or zero. This difference in the general case is not constant, and the variation in the difference permits an assessment of compass error. It should be noted that the calculated difference tells nothing about the relation of compass zero to magnetic north. Such a relationship can, in principle, be determined by sighting on a distant landmark from a known position.



Compass Test Instrument
photo by Lang Brod

The non-magnetic turntable is constructed of two aluminum discs 8 inches in diameter by 3/4 inch thick; the upper disc rotates on a closely fitting brass shaft set in the lower disc. The lower, fixed disc has been graduated from zero to 360 degrees in one-degree increments; the other disc bears a single cursor line. The degree scale markings are accurate to +/-0.1 degree and can be read to an accuracy of +/- 0.1 degree; the compass can be read to an accuracy of about 0.2 degree. Assuming the errors are random, the root mean square error can be calculated as about 0.25 degree. Inasmuch as the angular difference variation for many compasses is greater than 0.25 degree, that variation is a valid measure of the compass error.

Tests on several Suunto compasses using this equipment reveal that there are two components of compass error. The first is a systematic error, which is a function of dial reading, and which appears to be repeatable. Many years ago, John Walker described a systematic error encountered in a Brunton compass. The error was caused by a bent pivot pin, possibly caused when the compass was dropped, displacing the pivot from the center of the

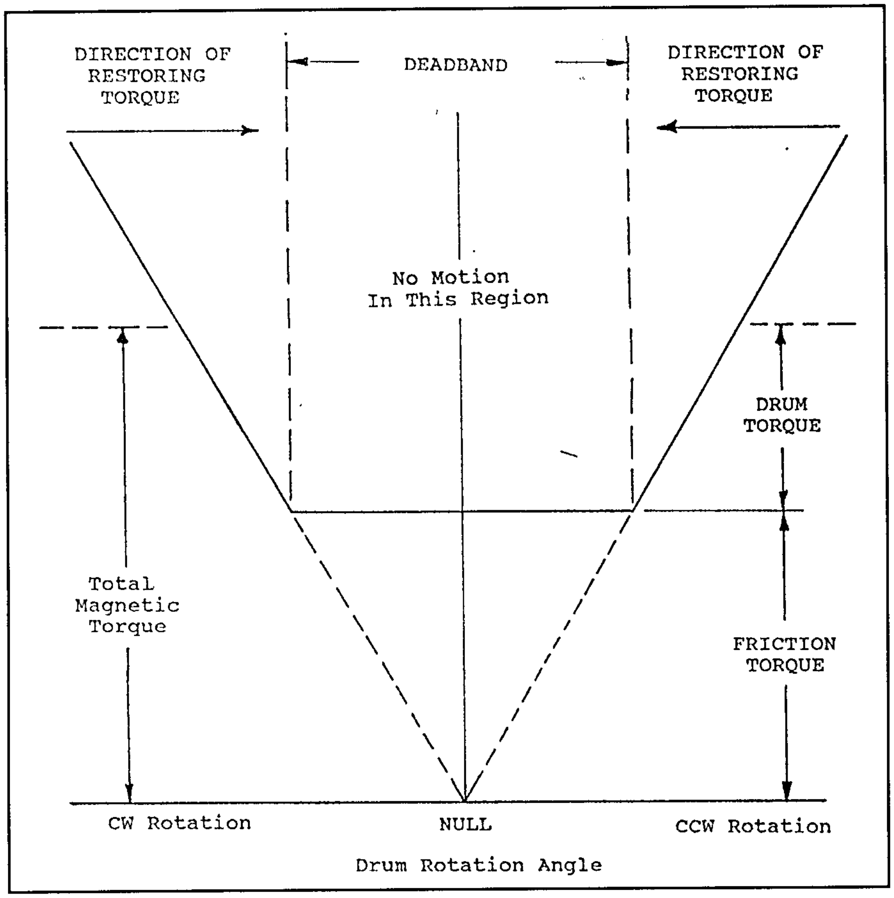


Figure 1. Compass Drum Rotation vs Torques

where the needle or drum ceases to turn; this region is the deadband, as shown in Figure 1.

All good compasses, including the Suunto, utilize a jewel pivot bearing to minimize friction and reduce deadband to a very small angle. The bearing, which is fastened to the drum center, is supported on a small steel pivot pin which has been sharpened to a point. The point is actually a small spherical surface which is sufficiently tiny to reduce friction to a minimum but large enough to support the weight and the forces acting on the jewel bearing without being deformed. In the Brunton compass, the pivot pin is protected by a mechanism, which lifts the needle off the pivot when the lid is closed. The Suunto instruments do not have such a protective device and may not need it, because of the damping liquid support.

In the undamped Brunton compass, the inertia of the needle will cause it to swing past the null position and overshoot until the increasing countertorque causes it to stop and begin swinging in the opposite direction. The damping liquid in the Suunto keeps the overshoot from occurring.

dial. In such a condition, the compass reads correctly in only two positions 180 degrees apart, and which has maximum positive and negative errors at 90 degrees from the zero-error positions. A similar systematic error can occur in the Suunto compass if the center of the drum at the pivot is not perfectly coincident with the center of the degree graduations on the periphery of the drum. Inasmuch as the centering is the result of a manufacturing operation, it is potentially subject to error. Tests performed on several Suunto compasses indicate that there appears to be a small systematic error present in all of them. Calculations indicate that a centering error of only 0.004-inch will produce an error of +/-0.3 degree, for a total error excursion of O.6 degree.

Superimposed on the systematic error is a second error, random in nature, which is the result of a defect termed “deadband”. The force which causes a compass needle to align with the Earth’s magnetic field is proportional to the sine of the angular difference between the field and the needle, which goes to zero as the angular difference goes to zero (2). As the compass needle or drum swings into alignment, the force causing the motion decreases, so that ultimately, at some position, the force is equal to the pivot friction and the motion ceases. Thus, there is a small angular range, symmetric about the null position,

Details of Compass Tests

The testing protocol was developed over time during a number of repeated tests designed to gain experience. First, the compass was mounted in the test fixture, with the compass-magnifying window on the rear side of the clamping fixture, above the cursor line on the upper disc. The tripod was then rotated with the compass stationary so that the cursor line on the upper disc was approximately coincident with 000 degrees on the lower disc when the compass was aligned with magnetic north. The tripod is then carefully adjusted so that the rotating disc is accurately leveled; next the compass is leveled with adjusting screws on the compass clamping fixture. After leveling, the compass is ready for test.

The test begins by rotating the compass about its vertical axis until the dial reads about 005 degrees and then leaving it quiet until rotation has stopped. The compass is then slowly turned in one direction until the dial reads 000 degrees. Because of damping, the compass drum dial will rotate with diminishing speed until it comes to rest.

If the drum dial falls short of 000 degrees, it can carefully rotated a small incremental angle to bring it to the correct reading. However, if the drum dial overshoots 000 degrees, it is necessary to go back to 005 degrees and allow the drum dial to come to rest before restarting the test. Once the compass reads exactly 000 degrees, the turntable reading for that position is recorded.

For the next step, the compass is again unidirectionally rotated from 000 to exactly 005 degrees, again allowing no overshoot, and the corresponding turntable reading for that angle is recorded. For the third reading, the compass is aligned to about 015 degrees and allowed to come to rest before carefully turning it back to 010 degrees. In this manner, each five-degree increment is approached from an alternating direction so that the deadband can be determined. When the full 360 range of the compass has been tested in this way, the difference between the compass reading and the turntable reading is calculated, and the difference angle is plotted as a function of compass angle.

Tests utilizing the rotary table were performed on 8 KB-14/360 Suunto compasses of various ages and construction, as listed below:

1. old KB-14/360, S/N 706088, tested March, 1989
2. new KB-14/360, S/N 636557, tested March, 1989
3. new KB-14/360, S/N 945389, tested March, 1990
4. new KB-14/360, S/N 034254, tested c. 1991
5. new KB-14/360Q, S/N 033808, tested October, 1992
6. new KB-14/360, S/N 106495, tested c. 1992
7. new KB-14/360, S/N 118397, tested June, 1993
8. new KB-14/360, S/N 130571, tested March, 1996

Results of these tests are plotted in figures 2 and 3. In addition, three tests were performed on Suunto plastic compasses, as shown in figure 4.

It is certainly difficult to draw many conclusions from such a small sample, but a few conclusions may be possible. The seven new KB-14 metal compasses all exhibited very good performance, with minimal deadband and most had little systematic error. In contrast, the old KB-14 showed a larger amount of deadband and apparently some systematic error also. It is probable that this compass pivot has been somewhat blunted by impacts during usage, resulting in greater pivot friction.

Both new KB-20 plastic compasses appear to have an amount of deadband error I would consider excessive. If this error is really characteristic of this type of compass, it should not be used for cave surveying. The lack of a serial number on these compasses may indicate that they are not manufactured to be as accurate as the KB-14. Interestingly, the old KB-20 with much cave usage had smaller deadband error than the two newer compasses.

At about the time I was testing compass seven, a Sisteco compass/clinometer was submitted to me for testing, and I was interested in comparing the Sisteco compass with the Suuntos. The Sisteco combination instrument is housed in an aluminum block about twice as long as used for a Suunto compass or clinometer, and each part is essentially identical to the Suunto counterpart. The test of the compass (figure 5) showed that the systematic error was about 1.3 degrees, somewhat high but certainly comparable with the sixth instrument tested. What was interesting was that the deadband error was surprisingly low, averaging roughly about 0.1 degree, at the very limit of resolution for this type of error.

The one aspect of this compass that did appear to be different was a noticeable tilt of the dial, despite the leveling of the compass body. I determined the approximate compass angle at the maximum tilt condition and then turned the compass 180 degrees so that the tilt was a maximum in the opposite direction. I then tilted the compass body until the drum dial was tilted at about the same angle as previously with the aid of a plate and a shim of known thickness. The total tilt required for compensation was about 5 degrees, corresponding to a actual tilt of about 2.5 degrees. That angle may not seem appreciable, but it is sufficient to tip the drum dial until it almost touches the top of the transparent case in one direction and the bottom in the other direction.

This observed tilt apparently results from insufficient or excessive balance weight to compensate for the vertical component of the Earth's magnetic field, which varies with latitude. The tilt in itself is not a major problem. However, if the drum dial is used to level the compass for inclined sights, it can cause appreciable error in the sighting direction.

To the best of my knowledge, there was never a comparable tilt problem with any of the Suunto compasses, and I never attempted to estimate the magnitude of whatever tilt was present. On several occasions I observed a slight tilt, at most a fraction of the 2.5 degrees tilt observed in the Sisteco compass.

It is unwise to attempt to make any comparisons between the two compass types on the basis of such limited data. It is only possible to say that, on the basis of a single test on a Sisteco compass, the two compass types appear to be comparable. In addition to drum dial tilt, other differences may be significant. The combined Sisteco is about twice the size of either Suunto clinometer or compass. Unlike the two separate instruments, which can be carried to different locations in difficult surveying situations, the two sections are irrevocably tied together in the Sisteco. If one section fails, the entire unit must be returned to the dealer for repair. Finally, if a plastic or glass rod is affixed to the housing for inclined sights with the compass, it somewhat obstructs the sighting for the clinometer. It is advisable to consider such potential problems before purchasing the Sisteco.

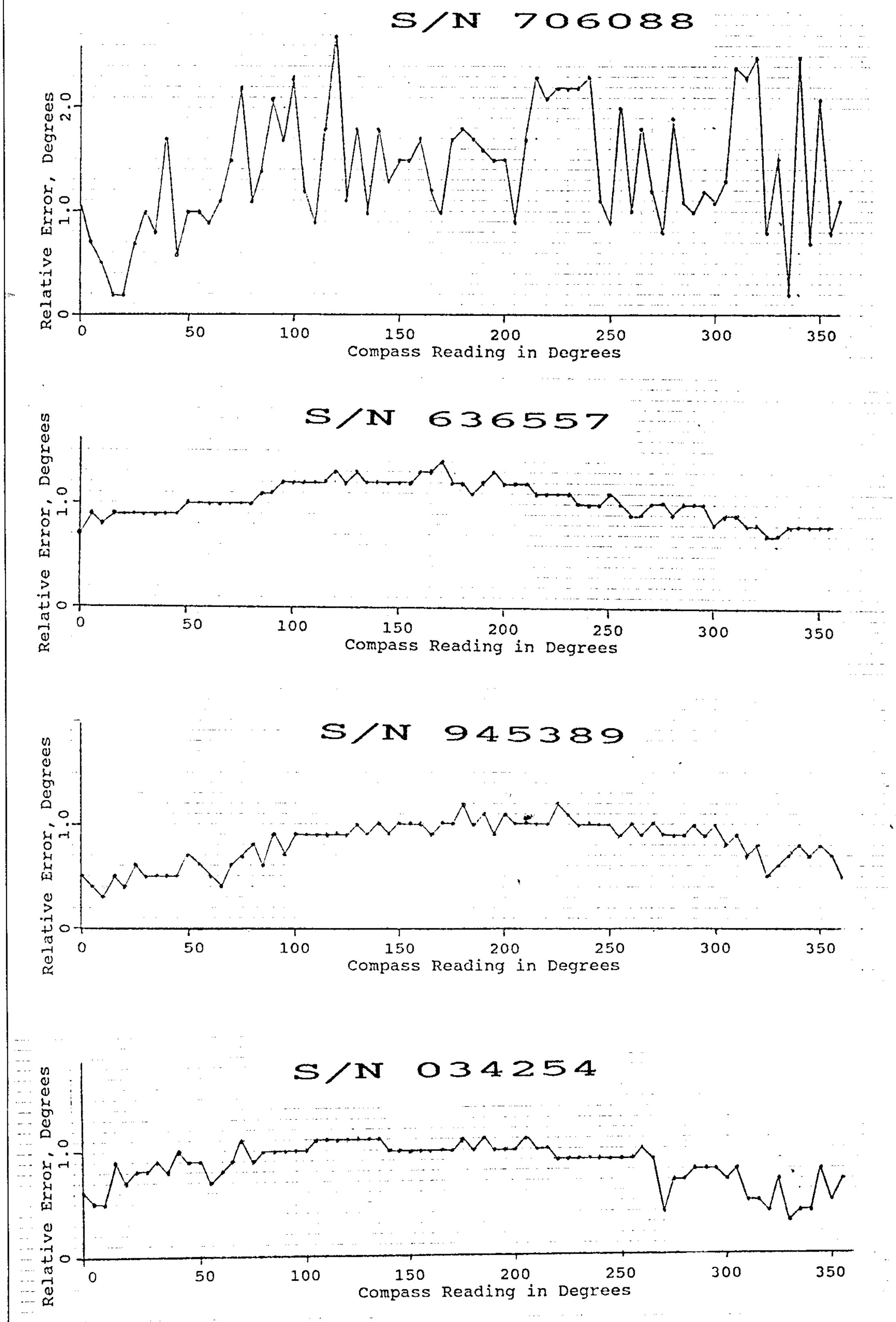


Figure 2. Deadband Tests of Suunto Metal Compasses

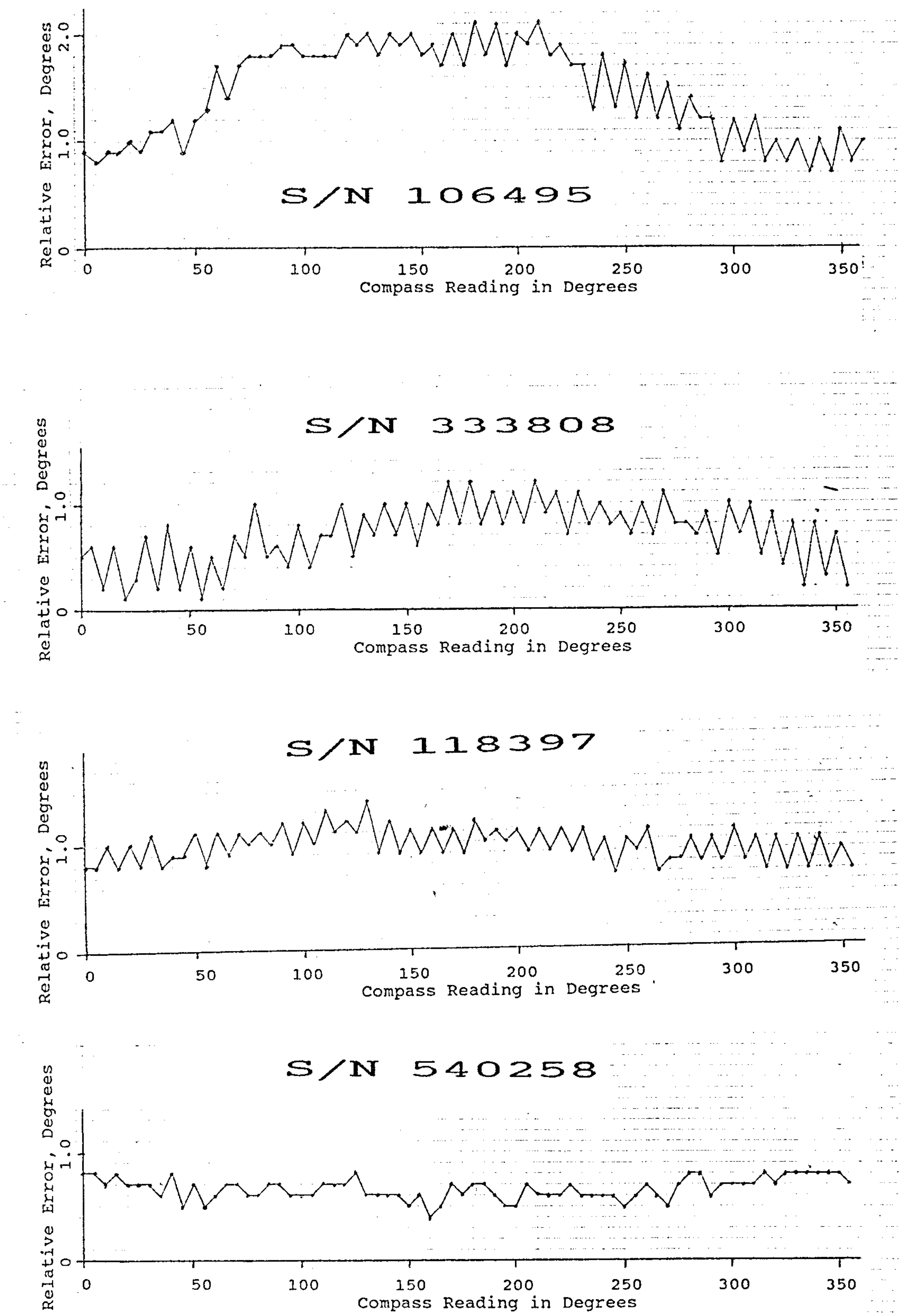


Figure 3. Deadband Tests for Suunto Metal Compasses

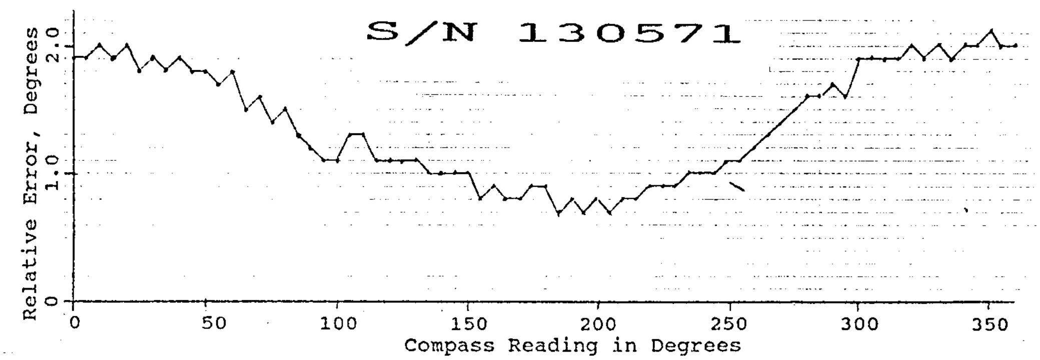


Figure 4. Deadband Test of Sisteco Compass/Clinometer
(Compass Section Only)

The one test not carried out on these compasses was the absolute accuracy, that is, their correspondence with magnetic north when reading 000 on the dial. One reason for this omission is that I have no good sighting landmark where I reside and where I carry out these tests. Testing at a remote site would have required the expenditure of time I could not spare when many of these tests were carried out. A second reason is that there is a basic question about what constitutes a good definition of absolute accuracy.

In the case of compass no. 6, if zero degrees is used as a reference angle, the compass reading will be in error by about one degree at an angle of 180 degrees. For this specific compass, a better solution might be to select a reference such as 270 degrees where the median occurs; thus the deviation from the median would reach a maximum equal to only one half of the total excursion. As the magnetic/optical correspondence is adjusted at the factory, it is unlikely that the manufacturer pays attention to such minor details.

Figure 6 shows a hypothetical situation for a Suunto with one degree of systematic error and factory setting errors of zero, plus 0.5 degree, and minus 0.5 degree. This figure demonstrates how the systematic error and north setting errors interact to produce bias errors of plus 0.5, plus 1.0, and zero degrees. Bias error, being nonrandom, will persistently enter into every reading, and the entire survey will be skewed by the bias error angle. For a survey in which the entire cave is surveyed with a single compass, there should be no great problem; the only difficulty is that the north arrow position will be in error by the amount of the bias angle.

A different situation occurs when several compasses are used to survey a larger cave, particularly one, which has rather complex interconnectivity. In that case, if one or more compasses exhibit a bias error, the resulting surveys might be difficult to join correctly. I would imagine that in any cases of this type, the surveyors would attribute the difficulty to closure error and to force a closure. The problem is that no survey is necessarily more accurate than any other. One can only hope that closure correction solves the problem.

The following tabulation is a summary of compass/sighting errors and their relative magnitude:

1. Deadband: A relatively small error, smallest in new instruments; the magnitude should be only a few tenths of a degree. This error is truly random; because of r.m.s. addition, this error can probably be disregarded.

2. Systematic Error: This error is a direct function of compass angle; the total angular deviation may be as high as one degree. In a complex, circuitous cave, the error can probably be treated as a random error, but in caves with long, straight passages, the error constitutes a bias error.

3. North Alignment Error: A discrepancy between the compass dial reading and the optical sighting path when the instrument is pointed toward magnetic north. Any angular discrepancy here will be nonrandom (i.e., constant) and will be a bias error which affects every reading. In the preceding text, it has been shown how a systematic error can interact with the north alignment to increase or diminish the bias error.

4. Sighting Error: In my tests, performed under ideal conditions with the compass firmly mounted, the sighting errors were very small, probably on the order of 0.1 to 0.2 degree. It can be expected that under conditions encountered in the cave, the sighting error would be larger. The best condition is when the compass is firmly held against a firm surface, such as a breakdown boulder. With less solid sur-

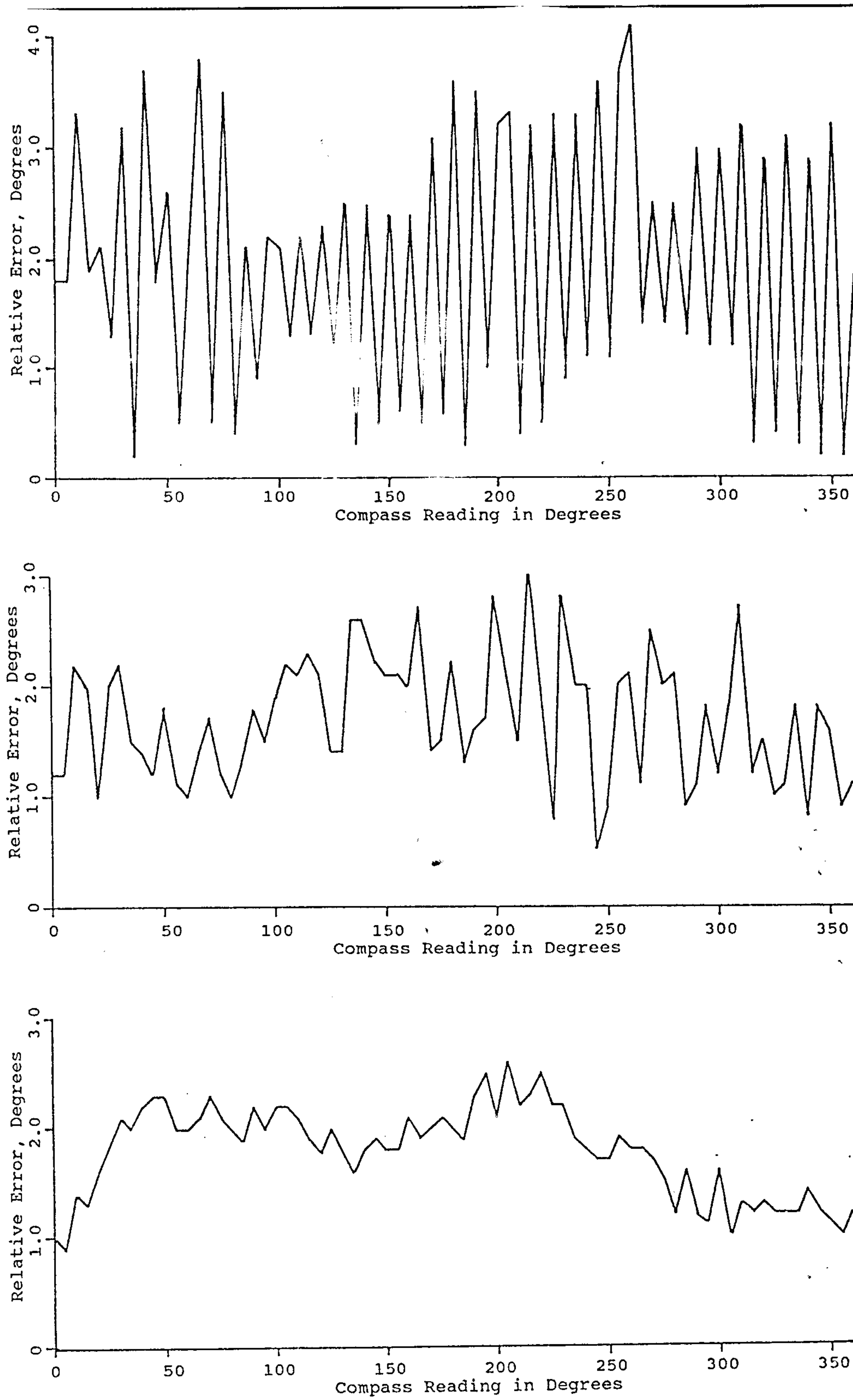


Figure 5. Deadband Tests of Suunto Plastic Compasses

faces for support, or with no support at all, the quivering of muscles and motion of chest muscles and diaphragm will contribute a significant amount of positional instability. In addition, other factors, such as the target light not being directly over the target station or the compass not being over the sighting station, would introduce error. All of these sighting errors are truly random.

5. Inclined Target Error: Because of the sighting method used in Suunto compasses, targets cannot be accurately sighted when they are more than a few degrees above or below a level plane. For this reason, reflective/refractive glass rods are used for sighting targets at high angles of inclination. For accurate readings, the glass rod and compass body upon which it rests should be perfectly level. Approximately, the error angle is proportional to the compass tilt angle times the tangent of the inclination angle. At 45 degrees, where the tangent is 1.0, the error is equal to the tilt angle. I had suggested using the position of the compass drum dial in its window as an indication of tilt. However Roger Bartholomew has pointed out that the dials are not always balanced to be level. Also,even in the case of well balanced dials, levelling the compass to the dial is not easy or very accurate. The resulting error is random in nature and in actual mapping situations can and does reach magnitudes as high as 5 or 6 degrees.

Although present data is insufficient, there may be a tendency for degradation in accuracy resulting from an increase in deadband error caused by rough in-cave treatment. Relevant data may possibly be obtained by retesting the compasses after several years of usage to see what changes the wear and tear of surveying may produce.

My primary objective in writing this report was to describe the errors inherent in the Suunto compass and its use, so that users are aware of its capabilities and limitations. Obviously, one should not expect more accuracy than the compass can provide. Also, the compass should preferably be used in situations where it can perform most effectively. Ideally, the compass should be used in large, fairly level caves where inclination angles rarely exceed 10 degrees and where both backsights and foresights can be made from every station. In caves where high inclination readings require the use of a glass sighting rod, the user should be aware of the need to level the compass and should recognize the potential for error if the drum dial inside the compass is used for this purpose.

On the basis of limited data, it appears that extended usage will degrade the performance of the Suunto. Consequently, a Suunto compass owner should treat the instrument with care, being careful that it does not impact upon hard objects or fall upon a hard floor. Again, on the basis of limited data, it does not appear that the KB-20 plastic compass is an advisable investment, even for a benign cave environment, except perhaps as a training compass or for hiking.

For Suunto compass users who do not have access to facilities for testing the compass, there is a quick hand test one may carry out. Set the compass on the edge of a wooden table or other level, non-magnetic surface and let the drum dial come to rest. Then quickly rotate the compass body five to ten degrees and observe the drum dial, which should quickly rotate to a fixed position and come to rest without any apparent sluggishness or hang-up. If a target of limited angular width is available, one may sight on this target several times, alternating on-target and off-target sightings; the compass readings for the target should all be approximately the same. Rapid, non-sticky response and closely clustered readings on target will indicate that the compass is probably performing at an acceptable level.

For many years, I have maintained that the ideal cave surveying compass has not been manufactured. The internally lighted Suunto has been a step in the right direction. What I would like to see is a Suunto with the light and an internal bubble level, and a fixed or retractable external glass rod for highly inclined sights. Finally, it would be nice to have a compass that can be sighted while lying prone in a low passage with one's chin in the dirt, but perhaps that's asking too much.

Appendix

Terminology and Description: Suunto compasses utilize a small rotating drum dial rather than a pivoted needle; I have referred to this dial as a drum for convenience. The drum is not really a right circular cylinder but actually a truncated cone, with a reentrant upper surface. The primary degree scale, that one visible through the magnifying lens at the rear of the compass, is formed upon this conical surface. The scale consists of thin lines of three lengths: short lines occur at one-half degree increments, medium length lines occur at one degree increments, and the longest lines occur at 10 degree increments. All lines appear to be parallel, though all have an imperceptible tilt, all pointing to a vertex coincident with the conical surface upon which they are inscribed, one which is some distance above the compass itself. The longest lines, those at 10 degree increments, terminate close to an associated number consisting of three digits and ranging from zero to 350 for the Suunto KB-14/360. These numbers comprise the degree scale and indicate the orientation of the compass body with respect to magnetic north; when the observer reads zero, the black cursor line on the transparent housing (through which the drum dial is read) is visually aligned toward magnetic north.

A second set of numbers, also printed in black but one-half the size of the primary numbers, occur at the top of the conical scale, directly above the larger primary numbers. On this scale, the numerical positions are 180 degrees offset from those on the larger scale, so that backsights can be directly read as if they were foresights. On this scale, the zero occurs directly above the larger 180, and the smaller 350 occurs directly above the larger 170. The difference in numeral size is distinctive, so misreadings from the presence of two scales should be minimal.

A second scale occurs on the top, reentrant surface of the compass drum, which is visible through the transparent window on the top side of the compass housing. This scale, unmagnified, is marked in five-degree increments, with degree numbers occurring at every 30 degrees from 0 to 330. The zero on this upper scale, as indicated by a short red cursor line inscribed on the periphery of the window, occurs at magnetic north. A third, smaller scale is inscribed inside the five-degree scale on the top side of the drum. This last scale consists only of the four cardinal directions, which are abbreviated and shown in block letters: N, E, S, and W.

If one holds the compass horizontally with the transparent window up (with the observer looking down) and then rotates the compass in a clockwise direction, say from north to east, the drum will appear to rotate in the opposite direction. The sequential appearance of the numbers in the primary number sequence, indicated by the black cursor line, will, however, increase. This direction of number increase is considered to be clockwise rotation, while the opposite direction is considered to be counterclockwise. The same concept also holds when the drum is driving toward a null position, as shown in Figure 1.

A second type of scale occurs on Suunto compasses in which the scale is marked in quadrants, with zero degrees occurring twice, at magnetic north and magnetic south, and 90 degrees occurring at magnetic east and west. I tested one compass of this type, and it appears to be functionally identical to the compasses with azimuth scales. Quadrant scales are typical on the Brunton type compasses, which were almost universally used for cave surveying in the early days of the NSS. I personally dislike the quadrant scale because of the possibility of error in reading and transcribing the compass measurement. In addition, for those surveyors who sketch to scale, the possibility of an erroneous angle plot is not a trivial problem.

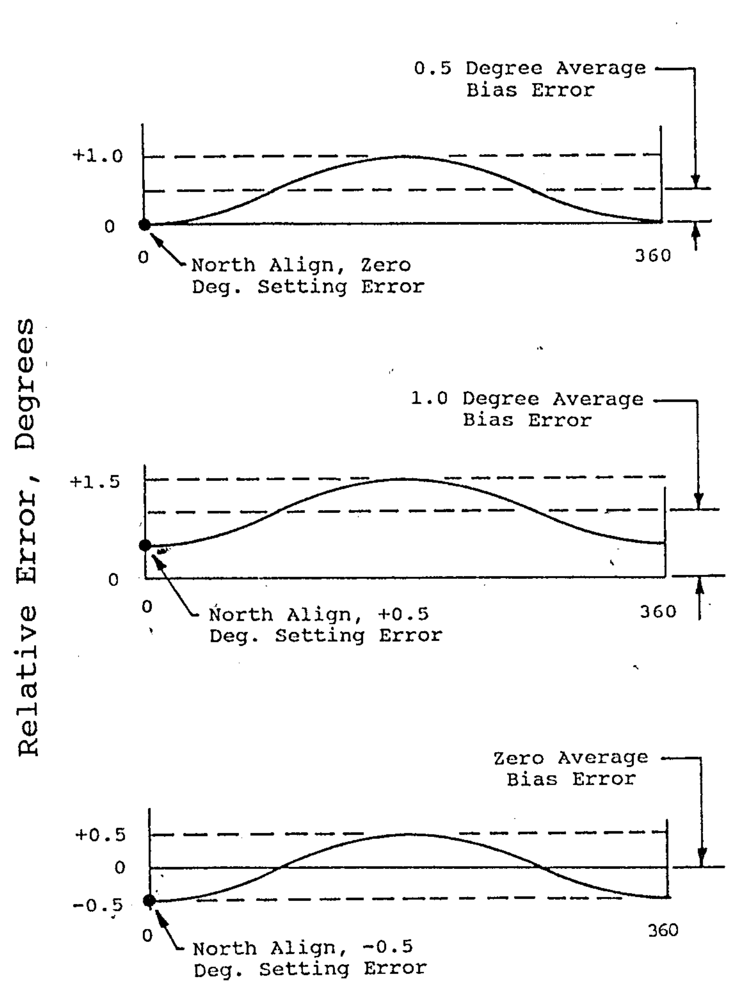
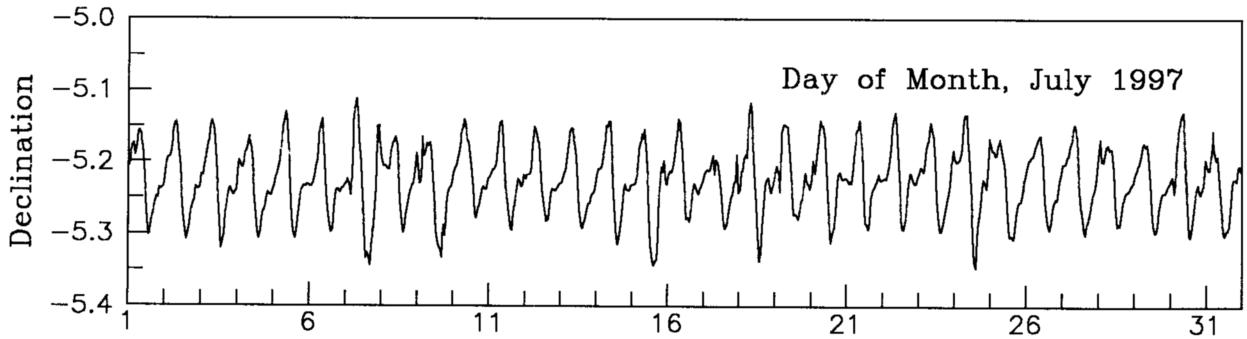


Figure 6. Average Bias Erros for a Compass, assuming a Systematic Error One Degree and various North Set Errors

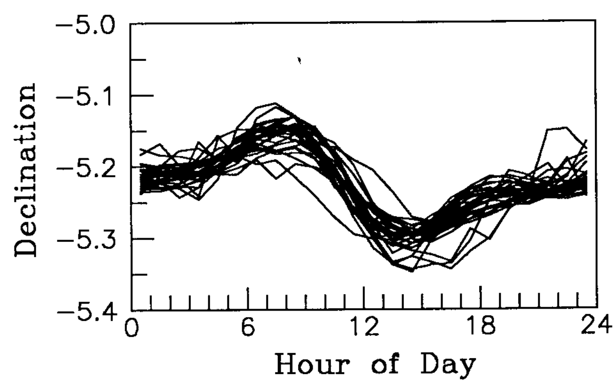
Hourly Variation of Magnetic Declination

by Robert Thrun



Magnetic declination is the difference between true north and magnetic north. There are both long-term and short-term changes in the Earth's magnetic field. The long-term, wide-area changes are predicted by models such as the International Geomagnetic Reference Field (IGRF). The values from these models are used for the values given on the bottom of topographic maps. Surveyors should be aware that the printed declination value may not accurate for their time and place. A more accurate value may be gotten from a surface survey using landmarks on the topographic map.

The differences between individual magnetic compasses are another source of error in a cave survey. Some cave survey projects establish a compass correction by sighting between reference points, thus accounting for both declination and compass differences. Ultimately, the limit of accuracy of a magnetic survey is established by the short-term variations in the Earth's magnetic field. Land surveyors have long been aware of this and use more accurate ways of measuring angles.



Measurements of the Earth's magnetic field are available on the Internet. The British Geological Survey has the Geomagnetism Information and Forecast Service at:

http://ub.nmh.ac.uk/gifs/on_line_gifs.html

The US Geological Survey has the National Geophysical Data Center at

http://www.ngdc.noaa.gov/seg/potfld

and at **ftp://ftp.ngdc.noaa.gov**

The British site will give a table of hourly means for a single day at one of three magnetic observatories. The US ftp site has all the data for a magnetic observatory, sometimes going back to 1901, in one huge file with a complicated format. Data at 1-minute intervals are available on CD-ROM in both countries. I requested 31 days of July 1997 hourly means from the UK Hartland observatory at *50° 59.7' N,* 355° 31.0' E.

Data were given for hours 0 to 23. I added a half hour to place the mean at the middle of the hour. I plotted the declination for the entire month to see if there were noisy and quiet days. I also overlaid all 31 days on one plot to see the reproducibility of the daily pattern. It should be noted that the data consist of hourly means, so there is some smoothing of instantaneous peaks.

The largest change in one day was 0.232 degrees. The hourly variations are small enough so they are hidden by other errors. Those who calibrate a compass with reference points might want to do the calibrations at the same time of day. The variations will not swamp out accuracy gains from reading to better than a half degree, though other factors might. Perhaps we should record the time of the compass readings on our surveys.

There are quiet and noisy locations and years. The magnetic field varies with sunspot activity. I will leave it to others to look at the variations at other times and places.

Surveying and the Role of Geological Data

by Dr. A. R. Farrant
Dept. of Geography, University of Bristol

Reprinted from Compass Points 18, December 1997 BCRA Cave Surveying Group.

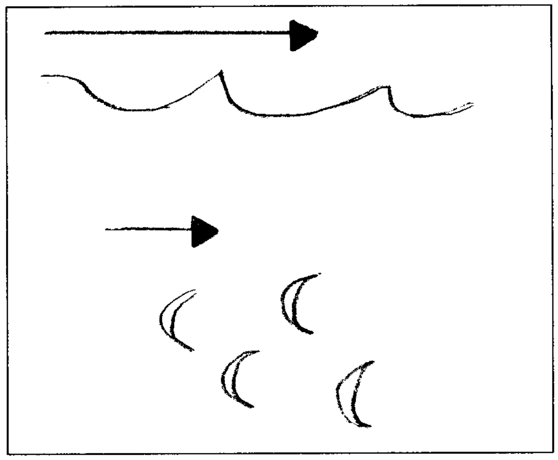


Figure 1. Cross sections through a scallop, with flow direction

Geological information is rarely portrayed on surveys. Although the role of geology in determining the plan and style of cave formation is often acknowledged, few surveys record this crucial information. This is primarily because most cavers are unfamiliar with basic geologic knowledge or feel that inclusion of geological data on surveys is irrelevant. However, much information can be usefully added onto a survey with little extra time and effort, and greatly enhances the use of a survey. Several types of data can be included without more than a basic understanding of geology or cave geomorphology. These can be divided into three categories: flow indicators, passage morphology, and geological structures.

Flow Indicators

Several methods can be used to determine the direction of water flow in abandoned 'fossil' passages. Determination of flow direction is critically important in understanding how the cave functioned, especially in horizontal passages or phreatic passages where flow direction may not be immediately obvious. Scallops are the most common flow indicator and generally provide a reliable guide to flow direction. Furthermore, they can also be used as a flow velocity indicator. Scallops are asymmetrical solutional depressions etched into the limestone usually between 0.5 - 1 m across (Figures 1). The steep face of the scallop always lies in the upstream side. Hence by examining a large (>20) number of scallops, flow direction can be established. When recording flow direction, care should be taken to note scallop directions over a relatively wide area to eliminate the possibility of recording anomalous flow in eddies. The size of scallops gives an indication of flow velocity. The smaller the scallop, the faster the flow. Thus in a fast, turbulent vadose stream, scallops will tend to be elongate, unidirectional and small (0.5-5 cm). In slower flowing phreatic passages, scallops will be much larger (10-100 cm) less asymmetric and more irregular, often merging into wall pockets.

Another method of looking at flow direction is examining structures commonly preserved in undisturbed cave sediments. Alas, in many caves, mud banks and sandy floors have too often been trampled and disturbed. Adequate taping is needed at an early stage to preserve these highly delicate features. Several indicators can be used to determine flow direction such as cross-bedding, imbrication and ripple marks. These are sketched in figure 2.

Cross bedding is best developed in fine sandy sediment and can be observed where a section has been cut into a sediment bank. However, care must be taken, as the type of structure seen will depend on the orientation of the section with respect to the flow direction. The clearest cross bedding will usually be seen in a section parallel with passage orientation.

Ripple marks are common on sandy-silty floors and, like scallops, the steep lee side of the ripple is on the upstream side. Imbrication is the orientation of gravels in the direction of flow. Platy clasts such as shales and thinly bedded sandstone is easily aligned in the direction of flow. The clasts generally dip upstream. With a little practice, these observations can be made within a few minutes and easily added to the survey notes.

An example where flow indicators provided an important insight to understanding the evolution of a cave system is in the Ogof Draenen. From a simple examination of the survey it appears that Gilwern Passage is an inlet to the Beyond the Choke streamway. However, ripple marks, scalloping and cross bedding all indicate flow to the north. Similar evidence from Megadrive indicates a southward flow (Simms et al., 1995)

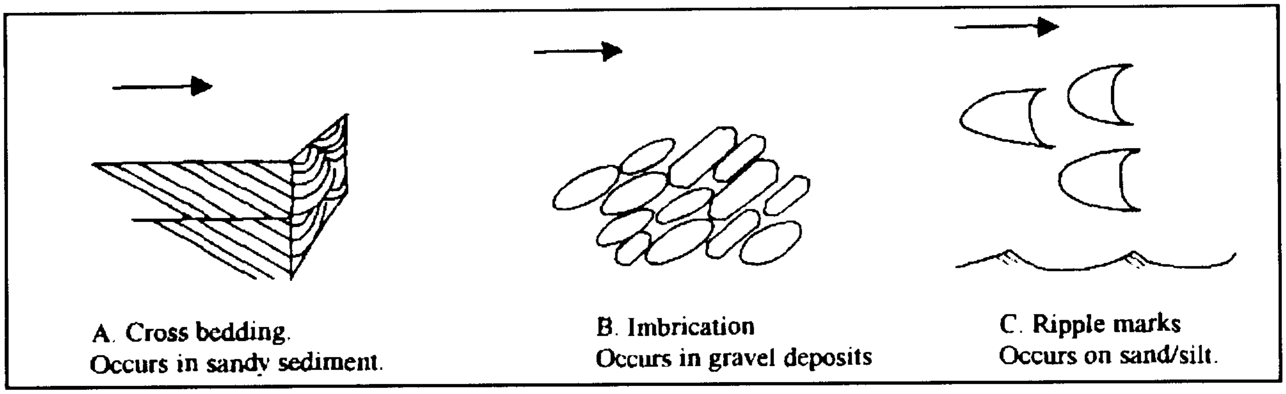


Figure 2 - Flow indicators in cave sediments

Passage morphology

Passages can be divided into three basic types: vadose, phreatic, and paragenetic. An accurate, well-drawn cross section through a passage, with the relative vadose or phreatic portions marked, is invaluable. An example is shown below (Figure 3).

Vadose passages are characterized by trench shaped passages, which are often well scalloped and fretted. Phreatic passages are often more rounded in profile and have generally smoother walls. Paragenetic passages are the most difficult to recognize and are less common. In shape they often resemble vadose passages, yet have a phreatic sculpture. They are formed by sediment infilling a phreatic passage such that the floor becomes armoured with a sediment cover and thus solution can only proceed upwards. Characteristic features of paragenetic passage include a phreatic canyon passage, parasitic half tubes etched on the passage walls and roof, and evidence of previous total sediment fill. Many of the passages in the upper series of Ogof Ffynnon Ddu show characteristic paragenetic canyons (e.g. between Selenite Tunnel, and Cross Rift). The choked caves exposed in Elson Hill quarry, Derbyshire are another superb example, many of which are still infilled with gravel

Geological structures

Perhaps the simplest thing to measure while surveying is the dip of the rock. The dip is the maximum slope of the bedding, while the strike is an imaginary line at right angles to the dip (Figure 4). This can be measured with a clinometer on convenient bedding plane and takes only a moment. Many passages are oriented either down dip or along strike. Joints and fault lines are also important in determining potential flow routes and can be easily marked on a survey. Joints are fractures in the rock with little or no evidence of movement, and are often infilled with calcite. Faults are less common, but usually more obvious, being marked by a zone of shattered rock often several meters wide and heavily veined with calcite. As a fault is a plane where rocks have moved in relation to each other, individual beds are not continuous across the fault. A good example is the Hall Fault exposed at the base of the 40' pitch in GB Cavern. This is marked by a shattered, heavily veined rock dipping at an angle of 40o which determines the location of the pitch.

Folds can also be noted. if they are small and prominent enough to be marked on a survey. Large-scale folds can be picked out if enough dip measurements are taken throughout the cave system. Two basic types occur - anticlines and synclines (Fig 5). Many small examples can

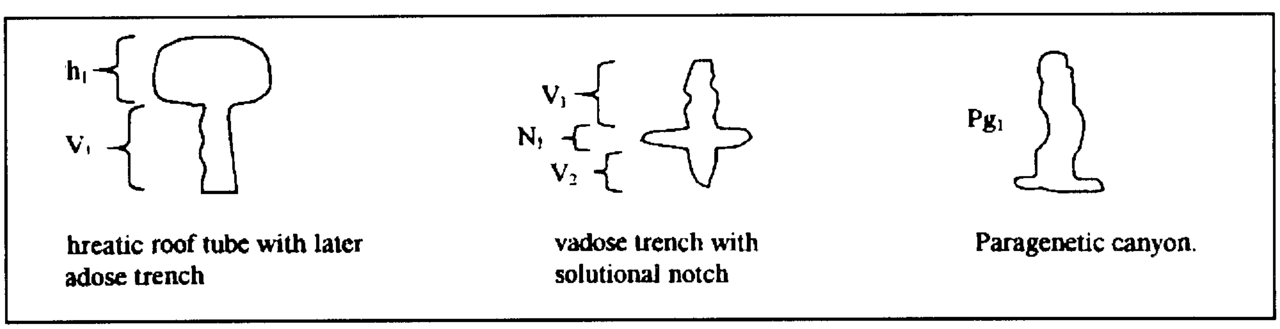


Figure 3. Cross sections through several passages showing each phase of development

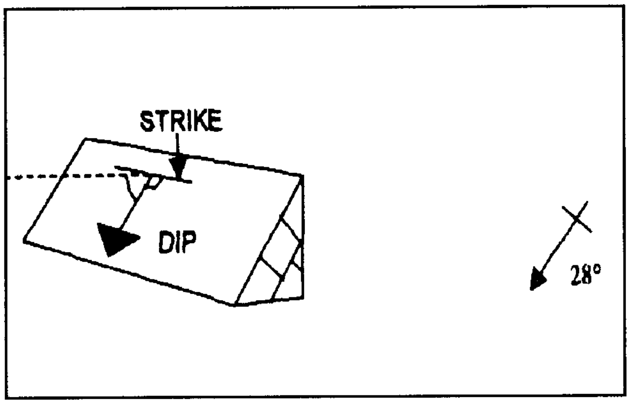


Figure 4. Dip and strike as measured on a bedding plane.

be seen in the walls of the Swildons streamway below the old 40' pot and in G.B. On a larger scale the position of anticlines and synclines in OFD determines the location of many of the inlets. This is shown in the OFD Chapter on Limestones and Cave of Wales (Smart and Christopher, 1989).

Other features

Many other observations can be easily noted on surveys. Abrupt changes in passage shape, size or orientation usually have a geological or geomorphological control, and if significant, should be noted. Major changes in roof elevation at junctions are especially important as then often provide evidence of the relative age of each passage. Similarly, changes in rock type, the presence of shale beds or a particular marker horizon should be noted. Which, if any of these observations will depend on the cave being surveyed. For example, in Ogof Draenen, three rock units can be easily distinguished, even by the non-geologist and their location noted. The presence of non-limestone boulders in chokes is another easily identifiable feature which can be noted on a survey.

Conclusion

Much information about caves and how they functioned can be obtained from relatively few easily observed features. However, very little of this information is ever marked on cave surveys. Furthermore, most of these observations can be recorded on a normal surveying trip without spending much time and with only a little practice. I hope that anyone involved with surveying a new cave will consider the geological aspect and plot the relevant data - it makes the geological interpretation a lot easier!

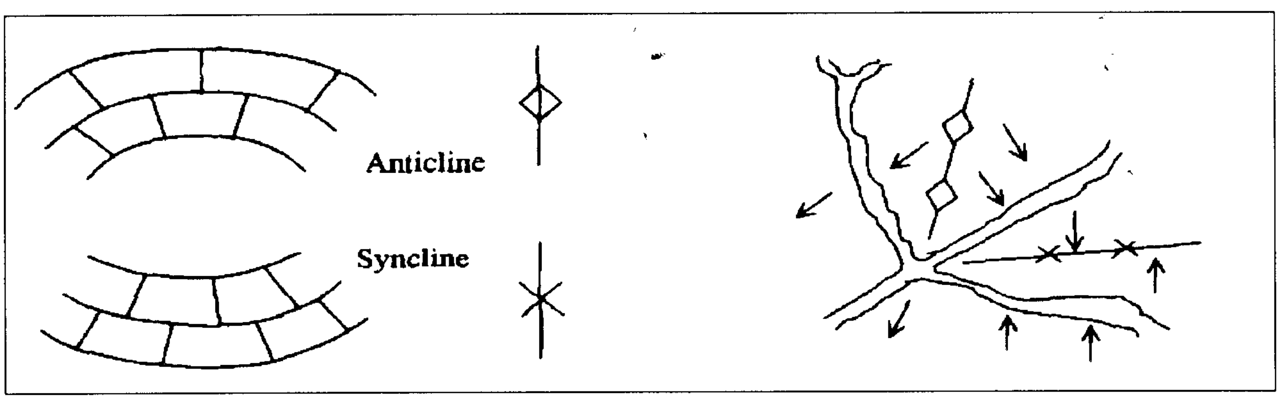
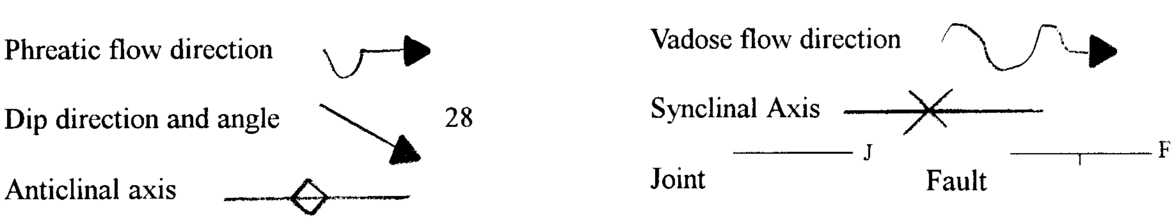


Figure 5 Basic fold types: Plan of cave with dip arrows, anticlines, and synclines marked.

Geological data symbols:

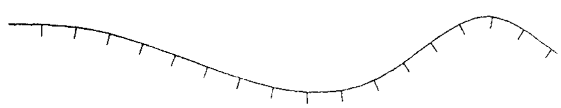


Two AutoCAD Linetypes for Cave Cartography

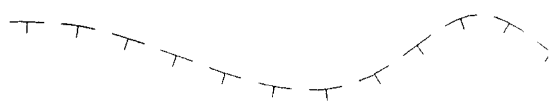
by Bert Ashbrook, NSS 25104

Several Cave Cartographers who use AutoCAD softward (including me) have complained that drawing floor ledge and ceiling ledge symbols are a pain. AutoCAD release 13 and higher supports complex linetypes, which make these symbols much easier to draw. Here's how I create linetypes like these.

FLOOR:



CEILING:



1. Create a shape file called "tick.shp" in your c:\autocad directory. The shape file simply tells AutoCAD what a "tick" symbol is. "Tick.shp" can be created with any text editor and is just two lines long. Note that in some text editors you have to enter a return after both lines.

```
*1,2,TICK
010,0
```

2. Create a linetype file called "cave.lin." This file tells AutoCAD how to use the tick symbol when drawing a line. In this case, we are making two linetypes called "floor" and "ceiling." "Cave.lin" can be created with any text editor and is four lines long. "Floor" draws a continuous line, with ticks 1 unit long sticking out perpendicular to the line and spaced every 3 unites along the length of the line. "Ceiling" draws a space 1.5 units long, then a dash 3 units long, and repeats. In the middle of the dash, the tick sticks out perpendicular and is 1 unit long.

```
*FLOOR
A,1.5,[TICK,c:\autocad\tick.shx,S=1,R=90],1,5
*CEILING
 A,0,-1.5,1.5[TICK,c:\autocad\tick.shx,S=1,R=90],1.5
```

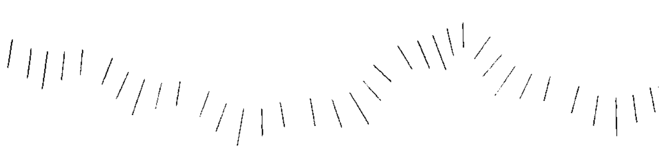
3. Compile "cave.shp" into "cave.shx." The compiled file has the same information but is in a language read by AutoCAD Command: prompt, enter COMPILE and select tick.shp.

4. Load your two new lintypes into the drawing. At the AutoCAD Command: prompt, enter LINETPE LOAD *. Then select the linetype file cave.liln which you just created.

5. Change the object creation mode to make one of your new linetypes the default, and draw a line (or pline or spline). If it doesn't look right, you may just need to change the linetype scale with the change properties command. Voila!

6. Experiment with cave.lin to create different linetypes. The AutoCAD Customization guide will help. For example, I have separate linetypes for ticks on the left side of the line and ticks on the right. Lately I'm using a linetype which uses tick.shp (Figure 2)

Figure 2: FLOOR_SLOPE:



Ceiling Height Determination in Large Rooms with Common Cave Surveying Equipment

by Jim Glock

For years I have been occasionally concerend with a method of determining cave ceiling height with reasonable accuracy. In many cases we are limited to cumbersome or expensive equipment, such as helium filled balloons or visible light electronic distance meters. Fortunately in large rooms we can use a flashlight hung by a string, a clinometer, and a tape.

I have been developing this method in a small cave in northwest Arkansas that I frequent. There is a permanent statio marker in a large room from which I can make repeated trails. After the first two attempts (five triangulations), I decided that the major problem was not the size of the target on the ceiling, but getting that target very nearly vertically over the station.

I hope to try this in a place where I can confirm the results by going to the point on the ceiling and lowering a tape, but until I do, I will have to be satisfied with checking it with a Leica visible light laser rangefinder that seems to be as accurate as a tape for measuring distance.

I stalked to a number of people about finding a point on the ceiling over the station. Pete Lindsley said that if I rotated a beam around a vertical axis, the center of any circle it describes on the target will be on that axis. When talking to Bob Glock about how to mount a shaft vertically, he said, "Hang it from a string!" The method I used follows:

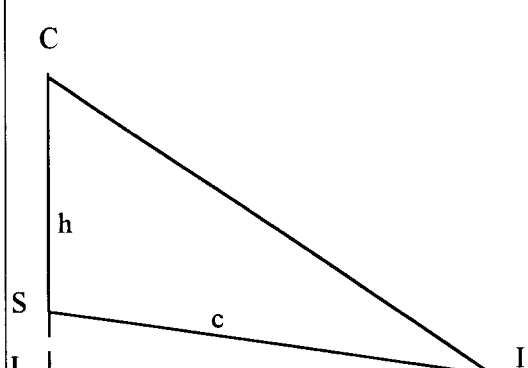
I taped a short (6 to 12 inch) nylon string to each side of the lens retainer of a Pelican Super Saber Light (any flashlight with a tight beam will work). In the cave, I found it best to hold the string with one hand above the station while twisting the string and light with the other. The circle thus described on the ceiling can easily be seen by the instrument person. If the beam comes to rest it is often near the center of that circle.

The instrument person then chooses a comfortable place as near level with the station and as close to the ceiling distance as possible. He then puts a temporary mark on the point from which he will take an inclination both to the ceiling and to the station on the floor. The distance is then measured from the instrument position to the station and all data is recorded. This is then repeated for at least two more instrument locations for verification of the calculated height.

Each of the data can then be applied to the following general formula which I developed after reviewing my high school trigonometery.

$$h = \left(\frac{c}{\sin(90^\circ - \angle LIC)}\right) \text{X} \sin(\angle SIC - \angle LIS)$$

It would be best to do the calculations in the cave so gross errors can be corrected immediately. This can be done with a hand calculator, with the trigonometric tables on the compass if your arthimetic is better than mine, or with a graphical solution if you carry a protractor and ruler.



S=Station on floor for which ceiling height is calculated
C=Point on ceiling at zenith of S
I=Instrument position from which inclinations are shot
c=Distance from S to I
h=Ceiling height
$-90^\circ <$ LIS $< +90^\circ$
∠LIC=Inclination to ceiling
∠ ISC=Should be as near as possible to 90°
∠ ILC=90°
Line LI is horizontal
Line LC is vertical

NOTE: The term (∠LIC -∠LIS) can be simplified to (∠LIC = 2∠LIS). This eliminates a subtraction in the field.

Report on the UIS Proposed Symbols List for Cave Survey

For the past several years, the European cave mapping community has been discussing the adoption of a unified cave map symbols list. During the 10th National Congress of the Swiss Cavers Association in Breitenbach, a session was held at the Second International Topography Meeting for the purpose of compiling a standard list of symbols for cave survey. The proposed list was distributed amongst European cave mappers and cartographers for review and comment.

A discussion session on the symbols list (now proposed as the UIS standard) was held at the International Congress UIS 1997 in La-Chaux-de-Fonds (Switzerland). Following is a summary of the discussion which was excerpted from an article published in *Compass Points 17*, September 1997. Wookey (the editor) reports:

> In general, the discussion proceeded quickly without much dissent, although a few symbols caused some debate. Despite a general desire to distinguish between "underneath" and "wall position not clear/known," which are both currently dashed lines, no satisfactory other solution was found so they remain the same, although changes were agreed on the representation of leads (also dashed lines). Dotted lines were rejected as they already represent sand, tend to disappear on photoreduction, and the symbol for "hidden lines" in CAD is already a dashed, rather than a dotted line. On compter-drawn maps a greyed line for underneath was suggested at the Surveying Workshop, and this may be adopted in the forthcoming session to further discuss symbols, which will include color as part of its remit.
>
> Roof steps also caused some discussion but we eventually agreed on the proposed symbol (like floor steps but dashed). The most acrimonious debate occurred on the subject of pitch/climb/aven depth indications. The Austrians insisted that this was a topographic survey, not a rigging guide and that it was not necessary to indicate the difference between a drop that needed gear and one that didn't - also this was a subjective decision. Nearly everyone else thought that it was a very important thing to indicate, subjective or not. The problem is that the current use of a letter e.g. 'p' for pitch and 'c' for climb (in the UK) does not translate well (the French use 'p' and 'e' with 'c' meaning aven, the Germans use 's' for pitch, the Turks use 'm', etc.) Finding an international solution proved difficult. We thought about using a little crab or ladder symbol. Or a random letter like 'X', but all these were dismissed for one reason or another; the crab just looks like a G, it was thought that the ladder would be interpreted as "fixed ladder in place", the X didn't really help, so eventually we decided to just have a number with no letter for a climbable drop, a number preceeded by a letter (varied by country, but 'p' recommended) for pitch. A great deal of debate occured for the stalagmite/stalactite symbols. Eventually they had two options, a little 'Y' or (on plans) a perfect circle, circle with dot or filled circle for stalactite, stalagmite and column. A few of the symbols were declared unnecessary, such as 'entrance pitch' and 'cuesta scarp line'.

Garry Petrie, who serves as the US representative to this UIS committee, reports that the list of symbols will be finalized and adopted as the UIS standard sometime this summer.

Following is a condensed version of a proposal for the UIS symbol list by Ph. Hauselmann and Y. Weidmann (translated by N. Ruder). The complete version can be found at the following website:

http://www.unine.ch/uis97/misc/praezis/welcome.html

A Suggestion for a Unified Symbol list for Cave Surveys

by Ph. Hauselmann and Y. Weidmann

General comments:

This list is meant to be an international basis of understanding on which the different countries, if necessary, can build their own extra lists.

In order to keep some consistency between the old and the new list, and based on the idea that several special symbols may be most useful, there is an addendum to the list referred to as "additions". The symbols on this list couldn't be put on the main list due to their limited or strictly regional occurance. Despite of this we would like to insist on the fact that these symbols represent a sensible and often very useful additional help to clarify the map.

Todays active cave surveyors all know that the map with figures and symbols only makes out half of the work of a good cave explorer. The other equally important part consists of the description of the cave including all the facts and presumptions that cannot be shown on the map. Observations on geology, sedimentology, hydrology, climate, flora and fauna, a historical summary of the exploration, a list of special equipment needed or already installed and so on, should be part of a good cave description and are not to be neglected. Guesses on continuations and maybe some thoughts about cave genesis complete the description, which gives a reliable basis for further work.

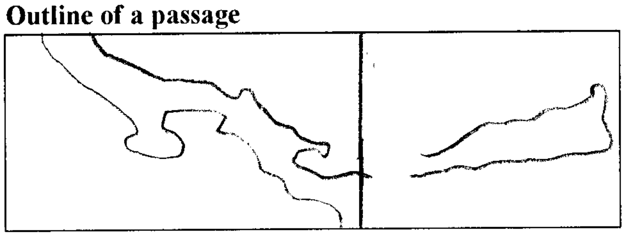
It seemed sensible to give some explanations for the different symbols in order to make our reasoning and ideas clearer to the reader.

Proposed Symbols List - Motivations and explanations

Main survey points: 

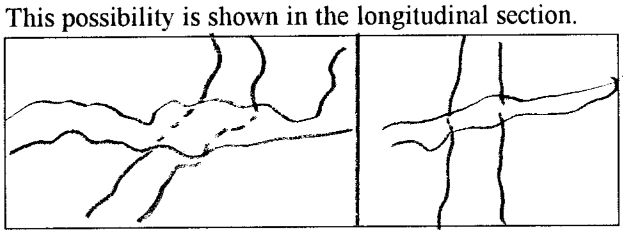
Subordinate survey points 

Outline of a passage



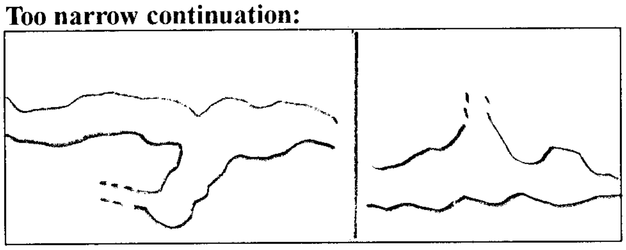
Plan **Profile**

Underlying passages: As an additional help to distinguish the lower from the upper passage it is possible to cut the lower one shortly before it crosses the upper one. This possibility is shown in the longitudinal section.



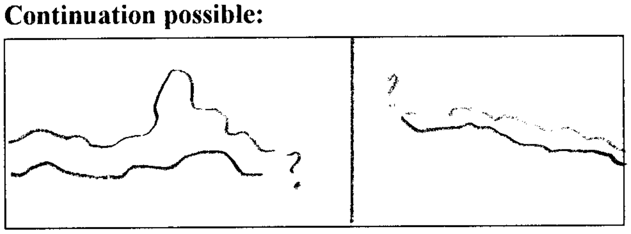
Plan **Profile**

Too narrow continuation:



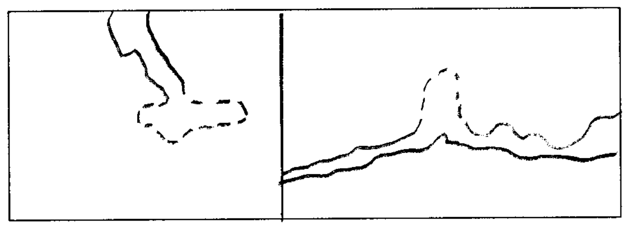
Plan **Profile**

Continuation possible:



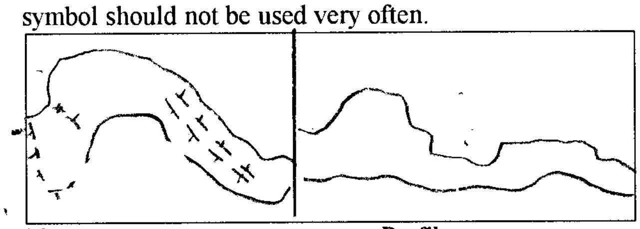
Plan **Profile**

Presumed dimensions of space:



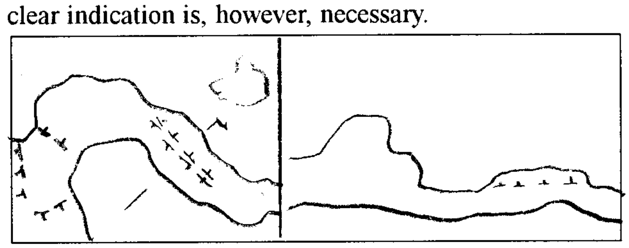
Plan **Profile**

Ceiling form: The symbol for the form of the ceiling of a cave can be useful for those cavers who do not draw longitudinal section, but as a developed longitudinal section is highly recommended (see also documentation on the 9. National Congress 1991, Charmey) this symbol should not be used very often.



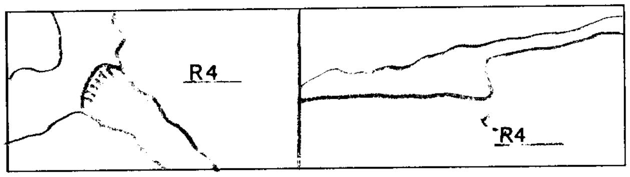
Plan **Profile**

Cross-section: Cross-sections are of major importance for the understanding of a passage. For each map passage cross-sections must be drawn. The arrows indicating the direction of view are done differently, a clear indication is, however, necessary.



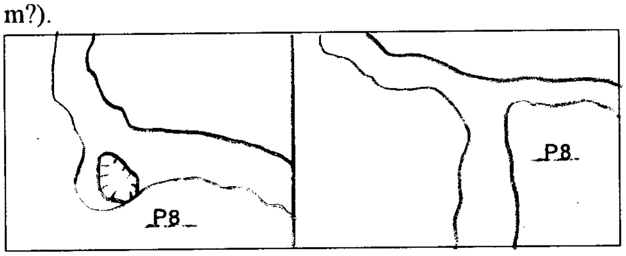
Plan **Profile**

Steps: This symbol is well known, just don't forget that the little dashes are always to be orientated downwards!



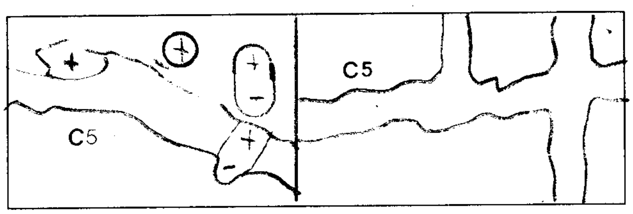
Plan **Profile**

Pits: The filled or empty triangle have been replaced by dashed lines for two reasons: First, the dashed line is easier to draw, secondly it is unclear even to most draughtsmen whether the empty triangles represent the smaller or the higher steps or when they should be filled (at 5 m or 10 m?).



Plan **Profile**

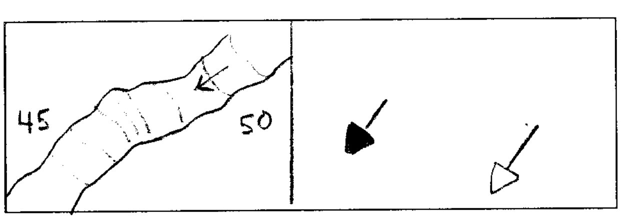
Chimney / Chimney-pits: The plus and minus signs can be written inside or outside the cave. For reasons of clearness they should be encirced when written outside the cave.



Plan **Profile**

The symbols: P. for an unclimbable pit, R. for a climbable step, C. for an unclimbable chimney or pit, E. for a climbable Chimney-stepare now internationally understood and are also shown here.

Contours: (lines of same altitude) with altimetric measurement as done on geographic maps are seldom used, as the exact ground level is not always easily established and precise drawings can cause serious problems. Gradient lines are used more frequently.

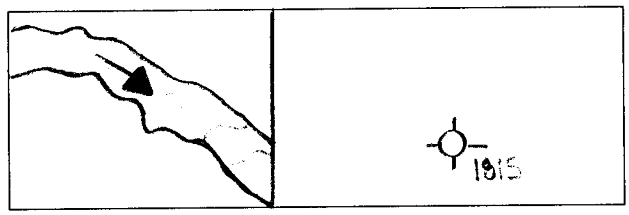


Contours **Gradient arrows**

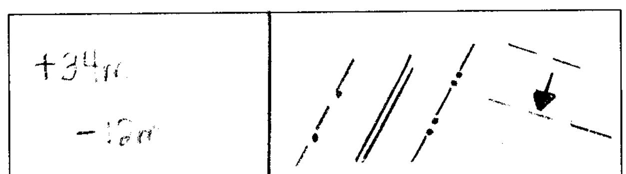
Gradient arrows: for reasons of consistency with older symbol lists the differentiation between gradient arrows inside and outside the cave have not been changed. The difference should still be clear from the drawing itself!

Gradient lines: Gradient lines are the most common methods to illustrate the ground structure. As on geographic maps narrow spacing indicates a steep and wide spacing a slow slope.

Altitude above sea-level: This symbol has also been kept for reasons of consistence and designates the altitude above sea-level used in the map. It is highly recommended to write 1880 m. instead of just writing 1880. Generally maps are all to be done in SI units.

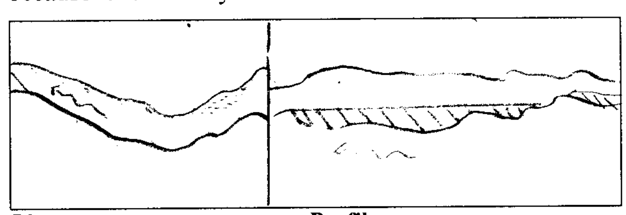


Gradient lines **Altitude above sea level**



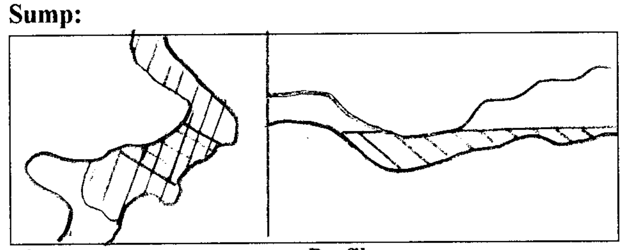
Difference in elevation in relation to the entrance: **Joint, fault, bedding plane**

Lake / flowing water: as before. It is recommended not to draw the hatching at right or 45 degreè angles because it might interfere with other symbols and because it looks silly.



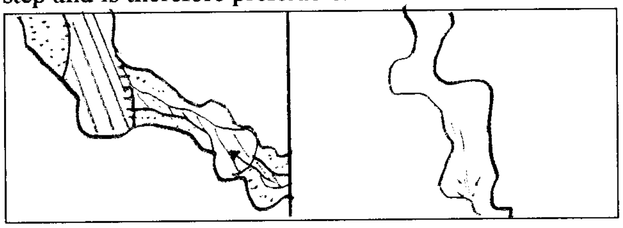
Plan **Profile**

Sump:



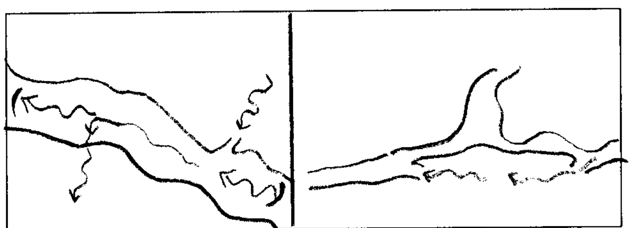
Plan **Profile**

Cascade / waterfall: Two versions are presented in the plan. The left one is connected with the symbol for a step and is therefore preferable.



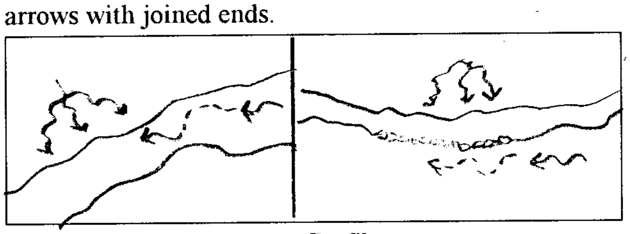
Plan **Profile**

Spring / sink: Springs or sinks which flow sideways in or out of a cave don't need a half circle to be characterised, whereas water inlets and outlets in the ground should be marked with a half-circle to distinguish them clearly from normal flowing water.



Plan **Profile**

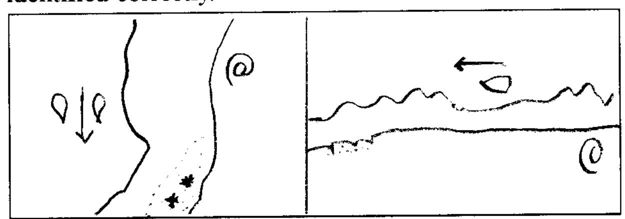
Widespread water inlet: An old and very confusing symbol which was also used for drainage water has been omitted and replaced by three normal water arrows with joined ends.



Plan **Profile**

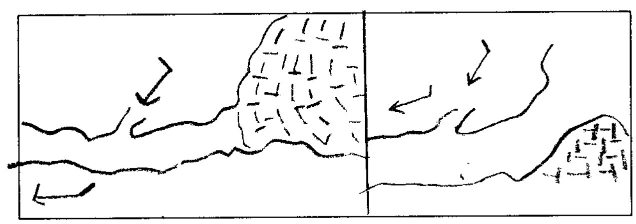
Seeping of a water course in a sediment: Unlike the waterhole, the half-circle is omitted as the seeping usually takes place over some distance. In return a dashed arrow is connected to the full arrow to make things clearer.

Flow casts (Scallops): Even for geomorphologists it is sometimes difficult to work out in which direction the water used to flow, so all we suggest is to add an arrow, representing the old flow direction, to the known symbol.
Driphole: For reasons of consistence this symbol has been kept for holes made by dripping water in sediment.
Flute: The differentiation between erosional and corrosion flutes has been omitted, because, especially with flutes on lateral walls, they cannot always be identified correctly.

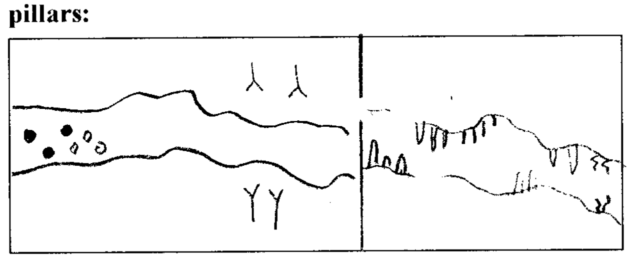


Plan **Profile**

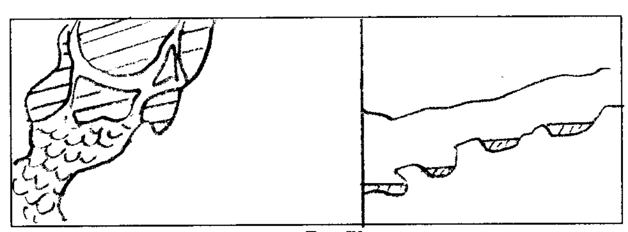
Air draught: This is a well known symbol. It should always include the date of measurement. Three feathers (not drawn) stand for a very strong draught.
Ice / snow / firn: The old star symbol used for snow hasn't been satisfactory for quite some time as it is very time consuming to draw and the ground structure cannot be shown. Added to this, it can easily be mistaken for the crystal symbol. The old symbol for ice is confusingly similar to true gradient lines. Taking all this into consideration we agreed on the following solution: Snow is transformed to firn and subsequently to ice. By morphology and composition all three substances are the same, therefore it should be represented by the same symbol. The one that has been chosen is easy to draw, shows the ground structure and cannot be mixed up.



Stalagmites, stalactites, calcite curtains, Calcite pillars:

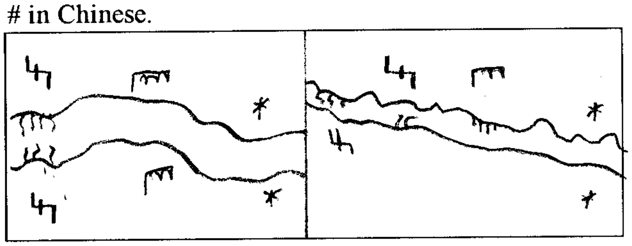


Gour pools:



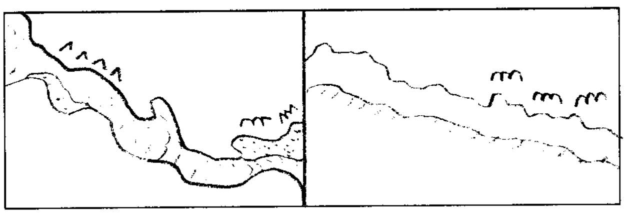
Plan **Profile**

Helictites, Straws, Crystals: For reasons of international understanding the letters identifing the minerals should be avoided, first because correct mineral identification is often not as easy as it may seem, and second because a C for calcite is an K in German and a # in Chinese.

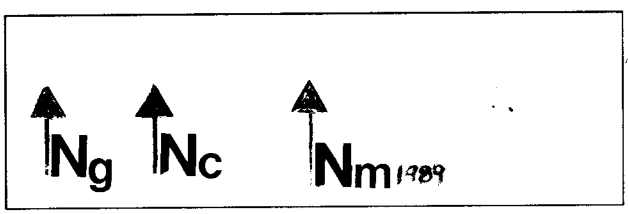


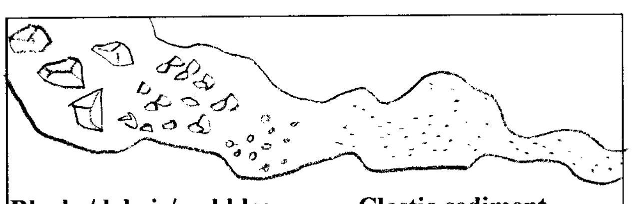
Plan **Profile**

Floor calcite, Wall calcite/calcite in general, Moonmilk: To avoid mistaking this symbol for the guano symbol an additional bow has been added to the usual m.



Georgraphic North, Cartesian north, Magnetic North:

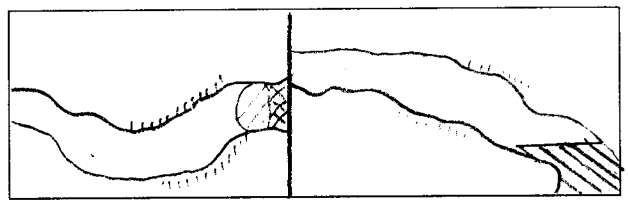


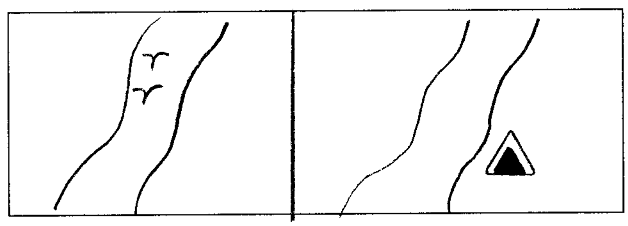


Blocks/debris/ pebbles **Clastic sediment (sand, silt, clay, humus)**

For **Clastic sediments: Sand, silt, clay and humus:** With the exception of humus this group is a sediment whose grain size and therefore names depend on the velocity of current of the carrying water. In flowing water sand is deposited whereas in standing water clay is deposited. In contrast to this the flowstone (see there), which is a chemical precipitation, does not represent the velocity of flow but the chemical equilibrium. As flowstone occurs quite frequently a special symbol needed to be found. The small parallel dashes did a good job as they also showed the ground structure. Unfortunately several surveyors characterised clay by a series of small dashes, which can lead to some confusion. For the mentioned reasons, a geologically correct solution has been worked out. For those who absolutely don't want to abandon the dashes there is an alternative symbol for clay on page 25.

Clay covered walls: This symbol can also be used to show stagnation zones.

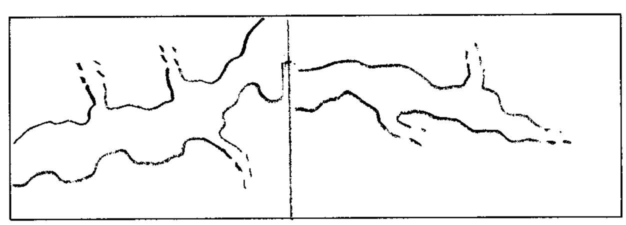




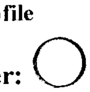
Guano **Camp**

Additions:

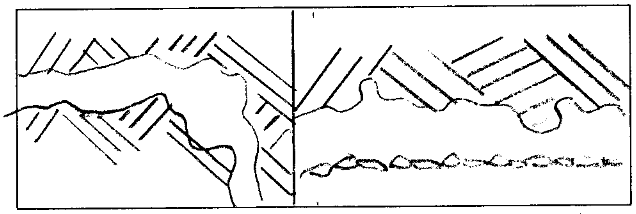
Continuation: An indication on the effort needed for further exploration is especially recommended for bigger cave systems where complete descriptions have not yet been done. A single dot stands for easy continuation, two dots stand for continuation with a certain effort (digging, blowing-up....), three dot stand for an (almost) impossible continuation.



Plan **Profile**

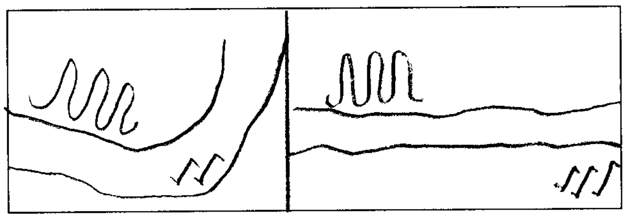
Height of a passage / chamber: 
An indication on height can be useful for a caver who doesn't draw longitudinal sections. But since this is highly recommended (see documentation of the 9. National Nongress 1991, Charmey) this symbol is not going to be used very often.

Passage in disturbed rock: This symbol means that a cave lies in highly disturbed / mechanically deformed rock. It should be used for caves lying in natural inhomogenous blocks of rock.

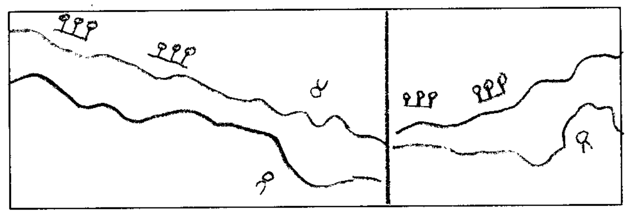


Plan **Profile**

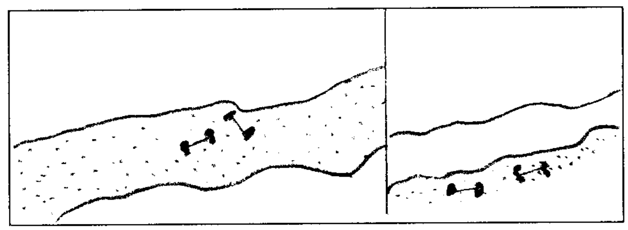
Anastomosen / Karren:



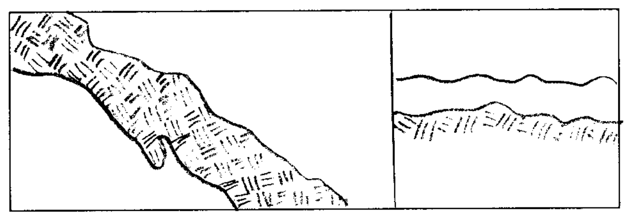
Cauliflower-calcite / discs: These two symbols for calcite are of a regional importance and can be quite useful.



Bones: This symbol does not need any further explanation



Clay, 2nd version: see also clastic sediments



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PETER'S MOUNTAIN #2

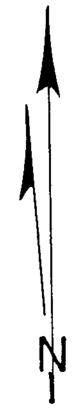
MONROE COUNTY WEST VIRGINIA

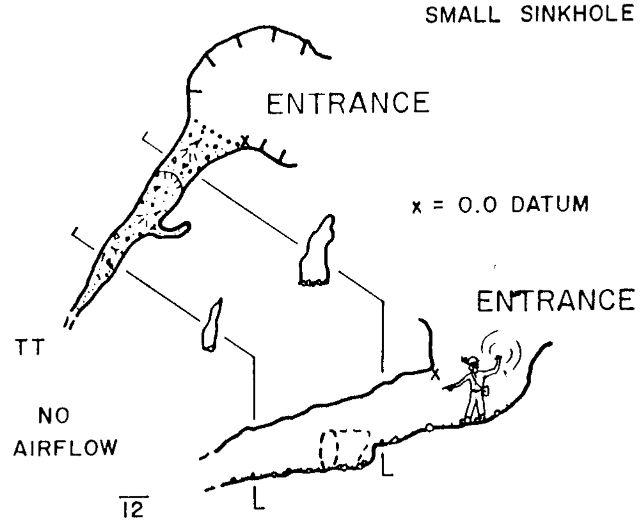
MONROE #167

LATITUDE 37° 23' 23" N
LONGITUDE 80° 45' 17" W
ELEVATION 2160' MEAN SEA LEVEL

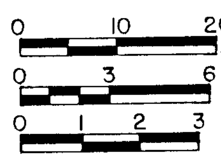
UTM 4137880 N
521725 E

GRADE 5 BRUNTON COMPASS AND FIBERGLASS TAPE SURVEY MADE ON MARCH 21, 1987 BY MIKE FUTRELL, PAUL GILLIS, AND JACK KEHOE
TOTAL SURVEYED LENGTH 20' (6.1 M)
TOTAL CALCULATED DEPTH 12' (3.7 M)
FORESIGHTS AND BACKSIGHTS AVERAGED
DATA REDUCTION BY SMAPS III
CROSS SECTIONS ARE TO SCALE
ALL DIMENSIONS ARE IN FEET UNLESS OTHERWISE NOTED
FORMED IN BEEKMANTOWN LIMESTONE OF ORDOVICIAN AGE
CARTOGRAPHY BY MIKE FUTRELL
AUDIO BY G. DEAD





LEGEND
- DRIPLINE
- CAVE WALLS
- COBBLES
- ORGANIC DEBRIS
- hi lo SLOPE
- hi lo CEILING CHANGE
- hi lo DROP
- TT TOO TIGHT
- 12 DEPTH
- VIEW DIRECTION



* CAVER BODY LENGTHS (APPROX.)