Compass & Tape

Volume 16 Number 4 Issue 56

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

Survey and Cartography Section

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

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

Dues: Does are $4.00 per year and includes four issue of *Compass & Tape.* Four issues of the section publication are scheduled to be published annually. However, if there are fewer, then all memberships will be extended to ensure that four issues are received. Dues can be paid in advance for up to 3 years ($12.00). Checks should be made payable to *"SACS"* and sent to the Treasuer.

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

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

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

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

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

INSIDE

Front Cover: Mapping the crawlway:
Daniel Thomas (instrument), Ashley Williams (tape), Scott McCrae (sketch) Photo: P. Kambesis

Back Cover: Scenes from the Survey and Cartography Section's Cartographic Salon 2004, Marquette, Michigan Photos: P. Kambesis

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SUBMISSIONS

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

Patricia Kambesis
Hoffman Environmental Research Institute
Dept. of Geography/Geology -
Western Kentucky University
Bowling Green, KY 42121
270-745-5201
Email: pnkambesis@juno.com

2004 Surveying and Cartography Section Meeting

by George Dasher

Meeting Attendees: Darrell Adkins, Stan Allison, Pauline Apling, Luc le Blanc, Paul Burger, Chris Chenier, Jim Coke, Thomas Cothell, George Dasher, Thom Engel, Allison Lynn Henry, Dan Henry, Bob Hoke, Nigel Dyson Hudson, Howard Kalnitz, Pat Kambesis, Jim Kennedy, Judy Ormeroid, Steve Reames, Bob Thrun, Carol Vesely

The 2004 meeting of the Survey and Cartography Section (SACS) met on Monday, July 12th, 2004 in the Ontario Room of the University of Northern Michigan in Marquette, Michigan. Chairman Carol Vesely called the meeting to order at 1:06 PM.

Carol first mentioned that SACS currently had no Vice President, and the Bob Hoke had been filling in and running the session, which had been that morning. She thanked Bob, and she said that there had been a good turn out for the session.

Bob Hoke then gave a Treasurer's Report. He said that the Section currently has about $4900; however, because we owe members for pre-paid issues, we really have only about $3600 in available cash. He also said that we make a little money on each issue of *Compass and Tape*, and that 18 people dropped out in 2003. The Section currently has about 210 members.

Pat Kambesis next gave the Editor's Report. She said that another issue of the *Compass & Tape* is almost finished, and she urged people to write articles.

George Dasher then gave a report on the Cartography Salon. He said that there had about 25 entries this year and that he had hung the maps that morning. He also said that he had, during the spring, put together a 70-page book on the history of the Salon. He had brought several copies to Convention. Pat Kambesis took one of these and she asked that the data be sent to her in digital form.

Carol said there was a digital mapping class that afternoon. She also announced that there would be a laser-point talk from 2 to 5 PM on Wednesday.

Carol then wanted to address the Vice President problem. She said that she had asked Bob Richards to accept this position, but Bob was not at the meeting and had not agreed to take the job. There was some discussion on this issue, while an effort was made to find Bob. Bob, once he was found, was very hesitant about becoming the Vice President; however, Nigel Dyson Hudson volunteered to fill the position. There was also some discussion on whether to replace Robin Barber as the secretary, as Robin was not at the meeting, but Carol said she wanted to talk to Robin before doing this.

There was then a short discussion regarding a special issue of the *Compass &Tape* that will be edited by Jim Kennedy and that George's Salon publication should be put on the SACS website as a pdf file. Elections followed, and the slate of officers was elected unanimously. Carol made a plea that everyone should renew their dues, and she adjourned the meeting at 1:24 PM.

2004 Cartographic Salon

by George Dasher

The 2004 Cartographic Salon had 25 entries including 14 in the novice category, 7 in the experienced category and 4 in the expert. In addition, 13 maps were shown as "display only". The maps were of caves in Guatemala, China, Mexico, Malaysia, India and the United States.

This year's judges were:

Novice Category:
Jim Coke, Carol Vesely, Pat Kambesis

Experienced/Expert:
Hazel Barton, Steve Reames**,** George Dasher

Tie-Breaking Judge: Jim Kennedy

Cartographic Salon judges: (front to back) Jim Coke, Carol Vesely, Hazel Barton, Steve Reames, George Dasher. Photo: P. Kambesis

The results of this year's Salon are:

Novice Category

Green-Honorable Mentions:

Timpanogos Cave System
Timpanogos National Monument, Utah County, Utah
Brandon Kowallis, cartographer

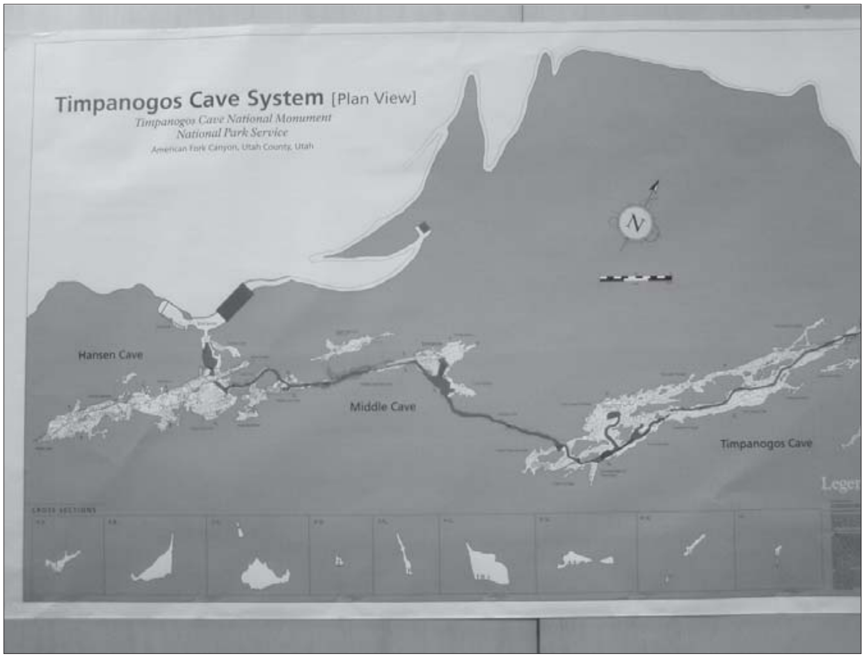
Kooken Cave
First Entrance to Second Entrance,
Huntingdon County, Pennsylvania
Bryan Crowell, cartographer

Kooken Cave
Second Entrance to Terminal Dome,
Huntington County, Pennsylvania
Bryan Crowell, cartographer

Blue-Merit Awards:

Ixobel River Cave "One Day Cave"
Poptun, Petén, Guatemala
Howard Kalnitz, cartographer

Clay Cave (color version)
Napa County, California
Matthew Leissring, cartographer



Honorable Mention Novice Catogeory: Profile section of Timpanagos Cave System by Brandon Kowallis.
Photo: P. Kambesis

Experienced Category:

Green-Honorable Mentions:

Tuberance Cave
North Hilo District, Hawai'i
Bern Szukalski, cartographer

Krem Maw Tynhiang (Rock Slab Cave)
Meghalaya, Inda
Stan Allison, cartographer

Krem Dita
Meghalaya, India
Stan Allison, cartographer

Nirvana Quad, Lechuguilla Cave
Carlsbad Caverns National Park
Eddy County, New Mexico
Rod Horrocks, cartographer

Blue-Merit Award:

Jerusalem Cave
Wayne County, Kentucky
Lee Florea, cartographer

Expert Category:

Green-Honorable Mentions:

Mossy Abyss
Dall Island, Alaska
Carlene Allred, cartographer

Cueva de Villa Luz
Tabasco, Mexico
Bob Richards, cartographer

Blue-Merit Award:

Main Upper Level of Marengo Cave
Crawford County, Indiana
Bob Richards, cartographer

No Medal award was presented this year.

THANKS to everyone who helped with this year's Salon!!

Abstracts from the Survey and Cartography Session 2004 NSS Convention, Marquette, Michigan

Session Chair: Bob Hoke

Tips for Efficient Cave Surveying

Bob Hoke, 6304 Kaybro Street, Laurel MD 20707 bob@hoke.net

This presentation describes some ways that a survey team can improve their productivity and efficiency by "working smart, not hard." Among the techniques described are allocating tasks so that no team member is overloaded or under-utilized, defining the responsibilities of each team member, placing stations to facilitate easy shots, taking readings in a consistent order, taking advantage of geometry to make shots easier to read, avoiding reading and recording errors, testing instruments before each trip, agreeing in advance on how dimension data is to be recorded, carrying instruments to faclitate quick use, using a small flashlight to l ight stations for backshots and knowing when to quit and head out of the cave

An Analysis of Random and Systematic Surveying Errors

Dale Andreatta, SEA Limited, 7349 Worthington-Galena Road, Columbus, OH 43085 dandreatta@sealimited.com

An analysis was performed on various types of surveying errors, with the errors falling into two categories: random and systematic. Random errors are errors that are likely to be off in one direction more than the other, and may be large or small in magnitude. Random errors come from instrument readability (usually on the order of 1-2 degrees) and "blunders," which can be small or large. Systematic errors are errors that are consistently off in one direction. Systematic errors generally come from instrument offset. This analysis concentrated on compass and inclinometer readings in longer passages.

Analysis was performed using statistical methods and by numerical experimentation where 50 shots of actual survey data was taken and errors were assigned to the data. The differences between the data with errors and the data without error were calculated.

The conclusions were as follows: Random errors caused by instrument readability consistently cancel out in longer passages. Therefore, meticulous matching of the foresight and backsite readings beyond that which serves to catch large blunders is not helpful. Instrument offsets of even a half degree give much larger final errors, even if the instrument offset is smaller than the readability of the instrument. This is because systematic errors accumulate rather than cancel. Fairly frequent blunders of 10 degrees make less difference in the final answer than instrument offset. Aside from preventing major survey blunders, the best way to improve survey data is to carefully take into account the differences between survey instruments.

Suvey and Cartography of Marengo Cave, Indiana

Bob Richards, 1206 Spinnaker Way, Sugar Land TX 77478 brichards@earthlink.net

Marengo Cave is a beautiful show cave in southern Indiana that was originally mapped by the state in 1932. A new survey was done in September 2003. Using modern cartographic techniques, a more accurate and detailed map was generated. Surveying caves using laser technology and mapping caving using computer software will be discussed.

Enhancing Workflow in Digital Cartography

Brandon Kowallis, Timpanogos Cave, RR1 Box 200, American Fork, UT 84003
brandon@brandonkowallis.com

While the advent of computer mapping has greatly improved the potential of the cave map, digital maps often sacrifice that timeless human fluidity of a hand-drawn map for machine-like repetitions that make us say, "thats definitely digital." This presentation will focus on various features in Adobe Illustrator that allow you to speed up the cartographic process while creating maps that allow a digital cartographer to keep that timeless hand-drawn appearance. We will use layers to make global changes to specific features, generate brushes to cut time from drawing the minute details, and copy and manipulate forms to create repeating shapes that don't resemble computerized duplicates.

"Field" Cartography for the Xiangxi Expedition to Hunan Province

Pat Kambesis, Hoffman Environmental Research Institute, Dept. of Geography & Geology, Western Kentucky University, Bowling Green, KY 42101. pnkambesis@juno.com

In March of 2004, a team of cavers sponsored by Hoffman Institute and The Guilin Institute of Karst and Geology assisted with field assessment for a hydrologic project that was being conducted by the Xiangxi Engineering/hydrology Group. The purpose of the expedition was to evaluate the Dalong Cave System and surrounding karst area for the feasibility of constructing an underground dam and a surface reservoir. Using various data reduction, plotting, 3D analysis, cartography, and GIS software, field maps were generated in order to help the Chinese hydrology project group visualize the caves, karst features and topography of the area. This talk will review the methods used to produce useful maps in the field from basic cave survey data, GPS data, and digital elevation models.

Auriga, or Trading Your Survey Notebook for a PDA

Luc Le Blanc 5980, rue Saint-Anre, Montreal, Quebec, Canada H2S 2K4, lleblanc@cam.org

The Auriga cave survey software for Palm OS was originally written to assist in the development of an electronic sensor box designed to automatically acquire azimuth and slope measurements, but has now evolved into a small survey notebook replacement for in=cave use and a lighter weight laptop replacement while at camp. Surveyors can see the cave map on the screen while doing their survey, and data does not need to be transcribed later, thus preventing many blunders throughout the process. Despite the smaller screen and slower CPU of Palm devices (vs PCs), Auriga offers graphical and spreadsheet rendition of cave passages, survey stations, and survey shots between them. Thanks to sessions, a concept already present in most cave survey software, surveyors can free their mind of instrument calibration, varing magnetic declination, and mised measurement units. This allows Auriga to faithfully store survey data exactly as input, applying corrections and conversions when computing coordinates. Several efficient design aspects provide the cave surveyor with a highly configurable and ergonomi interface, even when operating through a windowed protection box. Once back on the surface, survey data can be sent to other Palm devices through an IR bean or uploaded onto a computer and converted into common cave survey file formats via a software "conduit". The Auriga freeware is under intensive and constant evolution; support for networks of severa caves and loop closure are currently in the works, while on-screen freehand sketching of cave walls and details remain the ultimate goal.

The Effects of Lava on Compass Readings: Part I

By Dale J. Green
4230 Sovereign Way
Salt Lake City, UT 84124-3138
dajgreen@burgoyne.com

Abstract

Cavers mapping lava tubes well know that compass readings are not always what they should be. This is many times incorrectly attributed to the attraction of the magnetized compass needle to the magnetic material (magnetite) contained in lava. However, the main causes of unwanted needle deflections are due to distortions of the magnetic field because: (1) A property of magnetic material called susceptibility which causes magnetic lines-of-force to be diverted away from a void: (2) Magnetization of magnetite from lightning strikes: (3) Minor magnetization when lava cools below the Curie temperature. Measurements of compass needle deflections internally and externally of lava tubes show that all readings may be in error of a few degrees because of susceptibility effects and in some cases they may be over 10 degrees. Errors from magnetization by lightning strikes may cause needle deflections of 10s of degrees. Fore- and back-sights cannot correct for erroneous readings caused by distortion of the earth's magnetic field.

Introduction

When standing a lava surface or inside a lava tube, it is impossible to determine true azimuths when using a magnetic compass. These errors are due to the presence of the mineral magnetite. Magnetite has properties which cause variations, or anomalies, in an otherwise uniform magnetic field. As stated by Breiner, 1973: "The [magnetic] anomalies from naturally occurring rocks and minerals are due chiefly to the presence of the most common magnetic mineral, magnetite ($FeFe_2O_3$), or its related minerals, ulvospinel, titanomagnetite, maghemite, etc. which will collectively be referred to as magnetite, a dark, heavy, hard and resistant mineral. The rust-colored very common forms of iron oxide are not usually magnetic and are seldom related to the source of magnetic materials." "Magnetic anomalies in the earth's magnetic field are caused by two different kinds of magnetism: induced and remanent (permanent) magnetization. Induced magnetization refers to the action of the field on the material wherein the ambient field is enhanced and the material itself acts as a magnet. The magnetization of such material is directly proportional to the intensity of the ambient field and the ability of the material to enhance the local field - a property called magnetic susceptibility." (p. 8.)

Induced Anomalies Caused by Magnetic Susceptibility

Magnetic susceptibility may be thought of as the equivalent of electrical conductivity. In an electrical conductor, the higher the conductivity, the easier it is for current flow to be enhanced. In a magnetic material, the higher the susceptibility, the easier it is for magnetic lines-of-force to be enhanced, or concentrated. Therefore, because the void of a lava tube contains no magnetite and the surrounding area of solid lava does, flow of the magnetic lines-of-force are enhanced at the sides of the tube and decreased within the tube. A compass needle must align itself with the direction of the magnetic lines-of-force. Thus, when the direction of the lines-of-force is altered, the direction that the compass needle points to is altered. In summary, the presence of a void in lava will cause deviation of a magnetic compass from true magnetic north. As will be shown, these deviations can be substantial. The higher the percentage of magnetite that lava contains, the higher the susceptibility will be. Basalt lava containing only 1% magnetite has a magnetic susceptibility of 1,000 times that of air.

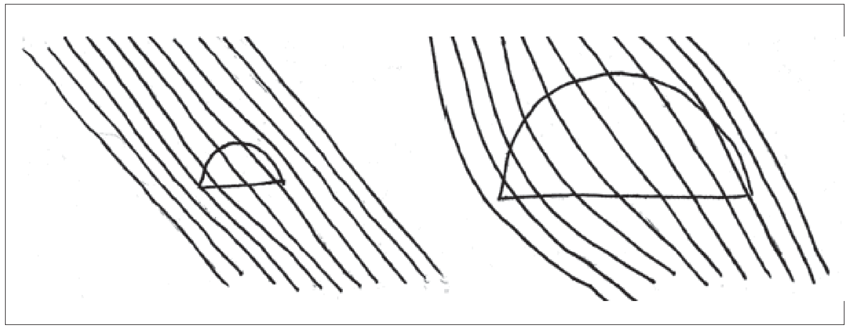


Figure 1. A large void deflects the magnetic lines of force more than a small void.

In the cases of deviation of the compass due to the presence of a void, the size of the lava tube is the most important factor. Small tubes do not redirect the lines-of-force as much as large tubes do. For tubes less that about 15 feet wide and 10 feet high, compass errors are relatively small, but not zero. The overall thickness of the lava bed relative to the diameter of the lava tube is also a factor in determining the amount of compass deviation. Remember, the larger the lava tube, the larger the induced compass error. Fig. 1 illustrates the principle.

Voids are not the only cause of anomalies due to magnetic induction. In all lava fields the percentage of magnetite, and hence value of susceptibility, can vary widely internally and externally to a lava tube, creating much the same effects on a compass needle as voids do.

Anomalies Caused by Remanent Magnetism

There are two basic configurations of magnets: Dipole and Monopole as seen in Fig. 2. Of course a monopole cannot actually exist in nature, but a magnet's opposite pole can be so far away that its field does not appreciably affect the pole in question.

The magnetic field strength around a dipole decreases with the cube of the distance. Twice the distance away has 1/8th field strength; 3 times the distance has 1/27th the field strength. The magnetic field strength around a monopole decreases with the square of the distance. Twice the distance away has 1/4th the field strength; 3 times the distance has 1/9th the field strength.

Both types of magnet configurations are encountered in lava fields although they are hard to tell

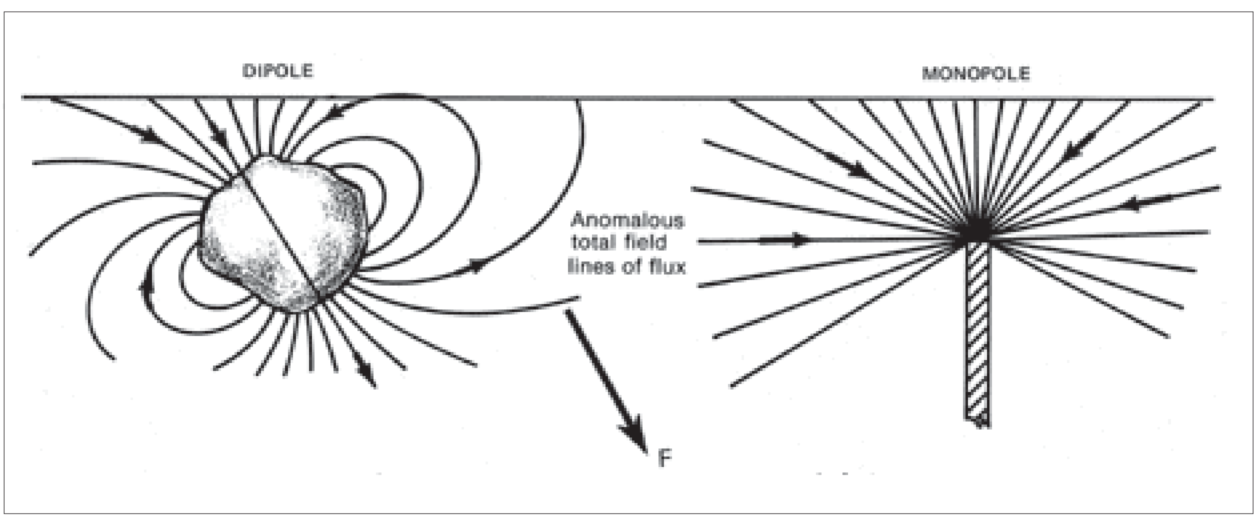


Figure 2. Dipole and Monopole Magnets. (From Breiner, 1973)

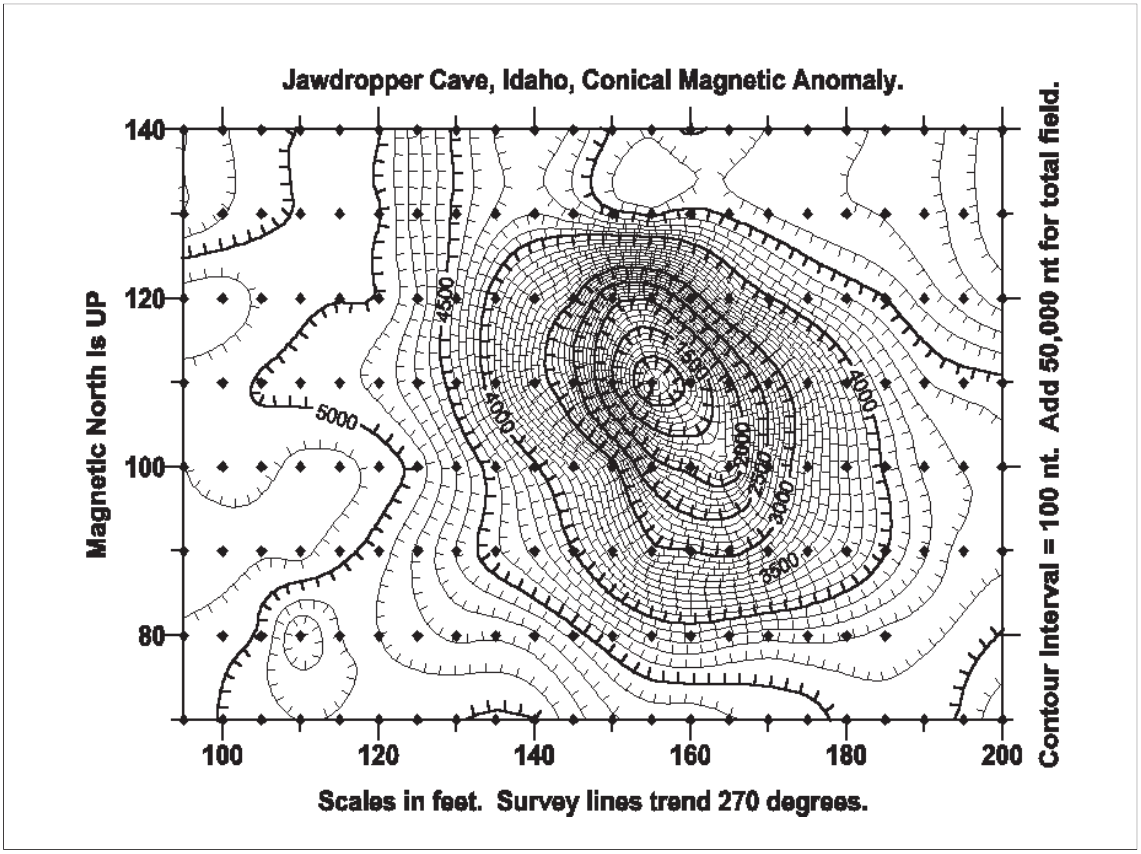


Figure 3. 'Monopole' magnetic anomaly.

apart by using only a compass. Most lightning strikes create dipole magnets where the effect on the compass may be intense near a pole, but dies out rapidly as one moves away.

In molten lava, small regions called domains within each magnetite crystal orient themselves more or less in the direction of the ambient magnetic field, and thus parallel to each other. Upon cooling below the Curie temperature (576^{O} C) they retain this orientation and thus create a net remanent magnetization. (Paraphrased from Breiner, op. cit.) Remanent magnetism is magnetism that remains after the inducing magnetic field is removed.

As far as I have been able to measure, this permanent or remanent magnetization of the lava has a negligible effect on the compass needle as long as everything remains in place. An exception is around a large block of breakdown that is not in its original orientation with respect to when the material cooled below the Curie temperature

Method of Presentation

In the following discussions, I will use contour maps to illustrate the magnitude of compass deflections and the corresponding total magnetic field responsible for the deflections. In all cases, hachure lines appear on all contours to indicate direction of decreasing values. The dots on both types of maps represent data stations. The maximum or minimum value of all anomalies is always plotted directly on a data station. However, this rarely represents the actual max/min. It is the location where the grid or tape indicated that a measurement should be made.

At the start of this investigation it was not obvious to me which way a specific magnetic anomaly would deflect the compass needle. An isolated, deep

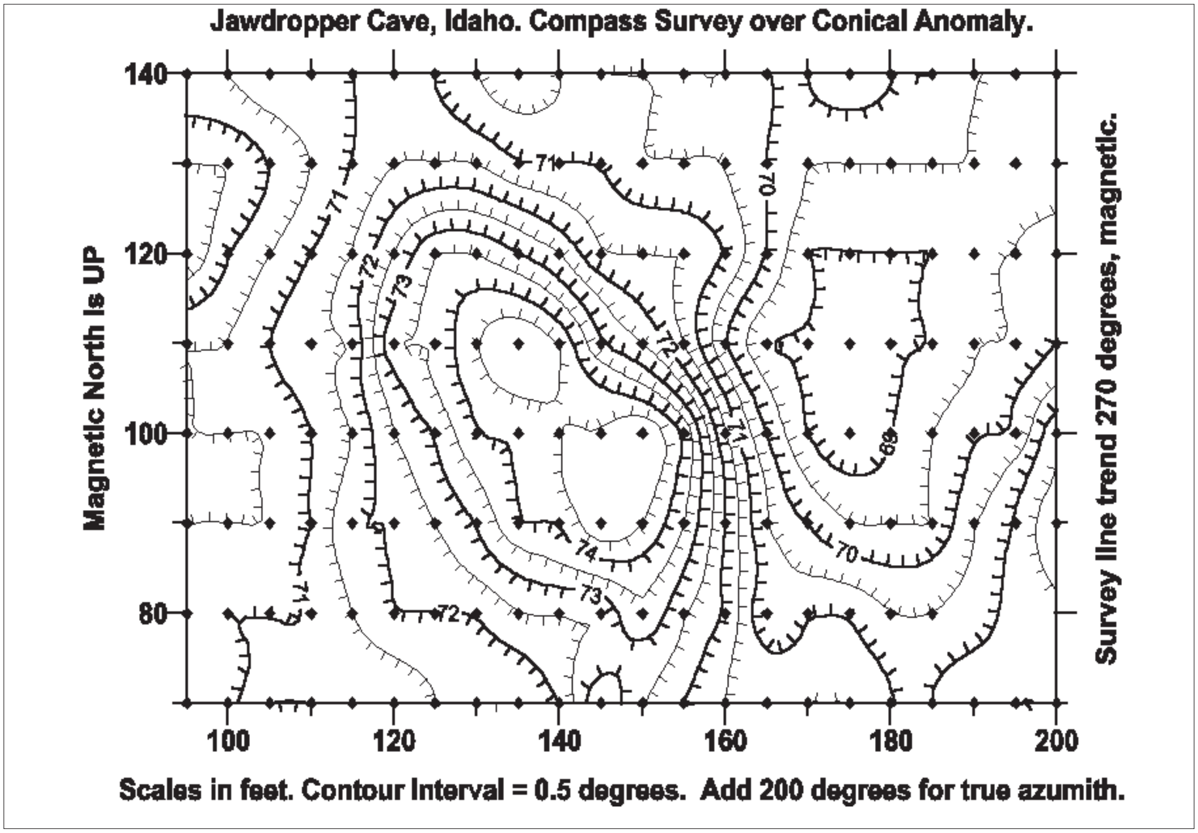


Figure 4. Compass azimuths around a magnetic low.

magnetic low over Jawdropper Cave in Idaho was selected for a trial survey because it almost represents a magnetic monopole. This magnetic anomaly is probably a manifestation of a large, but inaccessible, collapse cavity directly below. Figure 3 shows that the magnetic anomaly is approximately 4,000 nano-teslas (nt) centered about155E and 110N. Figure4 shows compass directions around the anomaly. What we see on this map is that to the left (west) of the anomaly the compass needle swings clockwise, increasing the reading value. The opposite is true on the anomaly's right. Therefore, a magnetic low acts in a similar fashion to the north magnetic pole, attracting the north-seeking end of the compass needle. This knowledge aids somewhat with interpretation of needle-deflection contour maps, but in cases of complex magnetic anomalies it is nearly impossible to decipher which anomaly is attracting or repelling which end of the compass needle.

Anomalies from Lightning Strikes

Intense currents from lightning strikes magnetize the magnetite in lava hundreds of times stronger than the remanent magnetization left by the earth's field when the lava cools. The effect is accumulative. Magnetic patterns from lightning strikes may fade somewhat over time, but they never disappear completely. Thus, we may expect far more problems from lightning in old lava flows than in recent flows. Surveyors working on recent lava flows in Hawaii may not have the problems with lightning strike anomalies that surveyors have on most fields on mainland US. Because the magnetic field strength from a lightning strike dissipates rapidly, a survey team may chose stations that completely bypass the anomaly, and the team is unaware of its presence. On the other hand, if they make an unlucky choice, the result may be a large compass

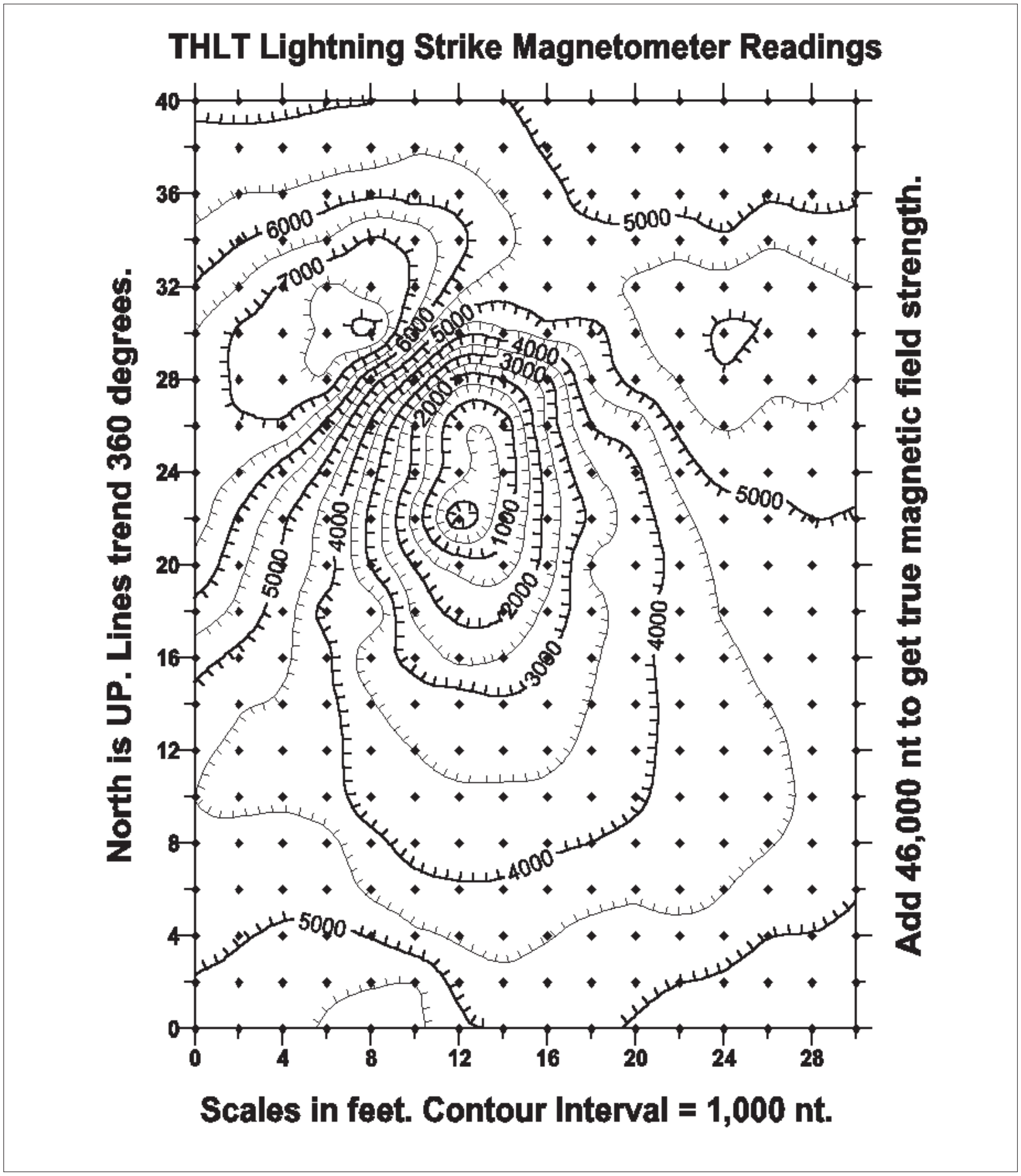


Figure 5. Magnetic field around a lightning strike in lava.

error. I have measured compass deviations inside a lava tube of over 40 degrees due to a lightning strike.

To gain an appreciation of the magnitude that a lightning strike affects a compass reading, a surface survey was conducted over a typical strike just north of the Tabernacle Hill Lava Tube (THLT) in central Utah. Such surveys are difficult to perform inside a lava tube because much of the magnetic anomaly lies within solid walls and cannot be sampled.

In this survey, a 2-foot by 2-foot grid was laid over the ground. Proton-precession magnetometer readings were taken with the sensor on a 6-foot staff. In areas near the anomaly's center, some magnetometer readings could not be taken because the change in magnetic strength, or gradient, across the sensor head was too high, which

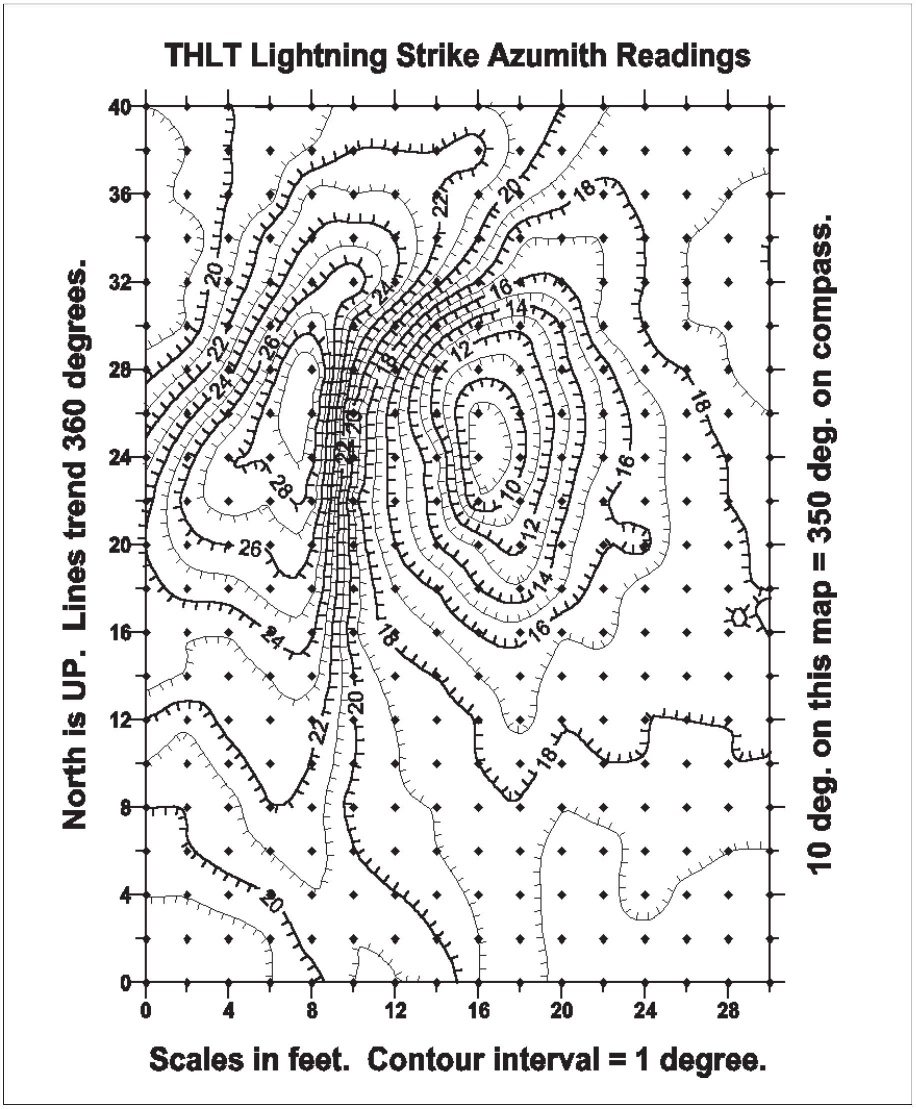


Figure 6. Compass readings around a lightning strike.

didn't allow the electronics to lock on one coherent value. Compass readings were taken at eye level, about 5 feet off the surface.

The magnetic anomaly at 6 feet off the surface produced by this particular lightning strike was 8,000 nanoteslas (nt), about 15% of earth's total field (Figure 5). Note that the anomaly is very definitely bipolar. Compass readings varied from 349.5^{O} to 9^{O}, or 20.5^{O} total over a distance of only 8 feet. At one point, the change is 11^{O} in only 2 feet horizontally (Figure 6). As high as these compass deviations are, they increase markedly if the compass is lowered closer to the surface. (Remember that for a dipole, the magnetic strength increases 8- fold if the distance to the pole is halved.)

A practical illustration of the effect of a lightning strike on an actual survey is presented below. Cairn Cave is too small to present significant compass errors due to magnetic induction. However, during the survey a station was chosen that was adjacent to a large magnetic anomaly, which could only be due to a lightning strike. A survey over the surface did not reveal the strike site, but lightning can travel large distances both over and inside the earth.

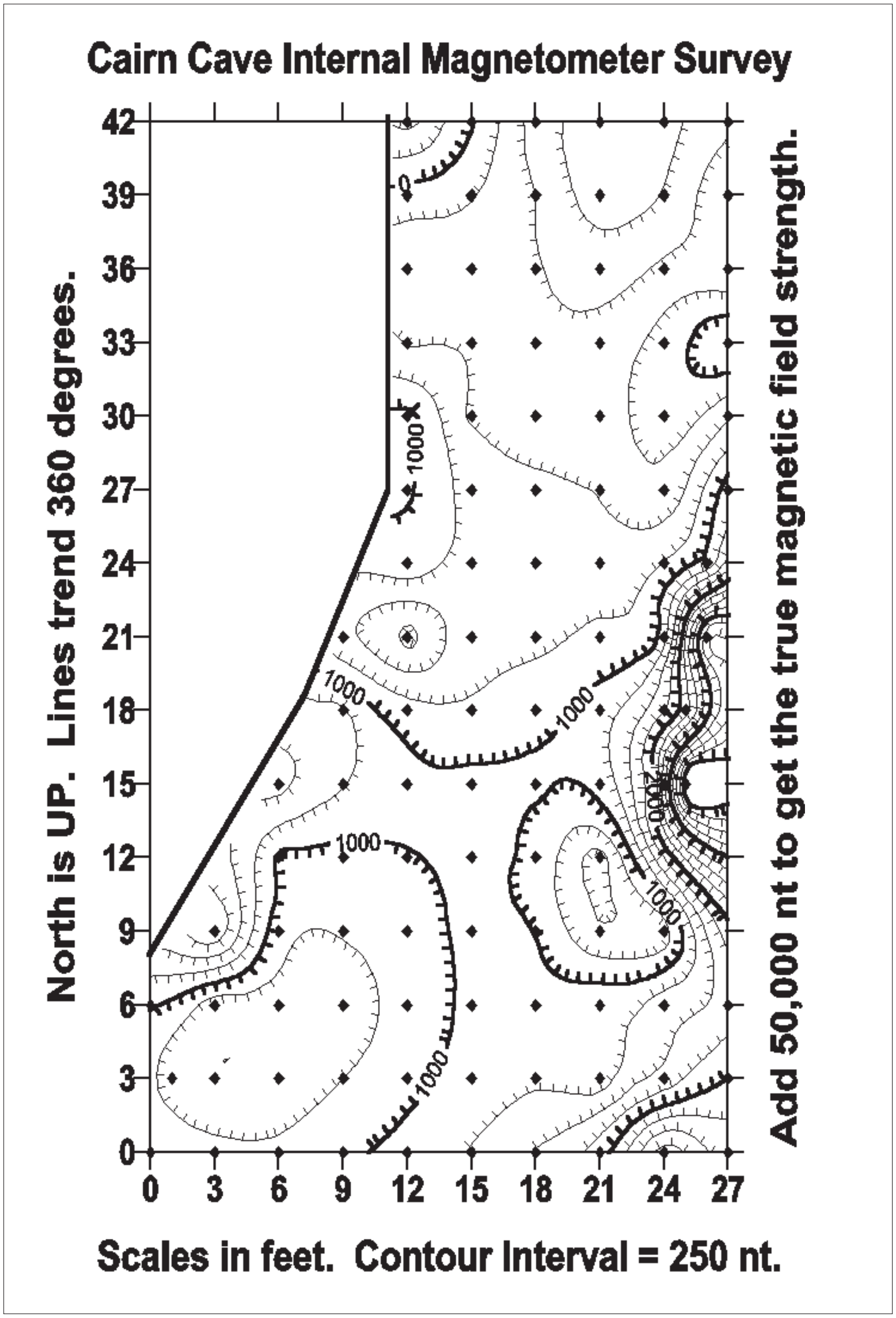


Figure 7. Magnetic field strength inside Cairn Cave.

A 3-foot by 3-foot grid was laid over the nearly flat cave floor. Cross ties assured that all lines were parallel. The magnetometer showed a large anomaly at approximately 24E and 15N, near the site of the bad compass reading. Figure 7 shows the anomaly's value at about 4,000 nt, but the actual value was much higher. It could not be determined because of the high gradient. This anomaly dies out rapidly, and the rest of the cave has a relatively uniform field.

Compass readings were taken by sighting on a light at one end of each line with the compass held over a taut tape. Because of physical constraints, it was not possible to take readings at stations on the west end of the line. The data, plotted in Figure 8, shows that compass readings varied from 5° to 30° over the grid. Near the anomaly, even higher deviations were read when the compass was moved toward the roof, but these were not used for the plot because they were unrealistic positions for the compass reader.

This map illustrates why fore- and back-sights cannot correct for compass errors due to distortions of the magnetic field. Without an independent measurement that doesn't depend on a magnetic compass, it is impossible anywhere in the cave to know which way the distortion is causing the compass to deviate from the true heading. At either end of the tape field distortions may cause the compass to deviate left or right. In some cases this may reduce errors, but in other cases it may increase errors. All we can definitely say is that it is impossible to know which case fits the situation. A magnetically-independent method to determine the true azimuths would be to survey using turning angles, such as a land surveyor with a theodolite might perform. This is not a practical solution in most caves.

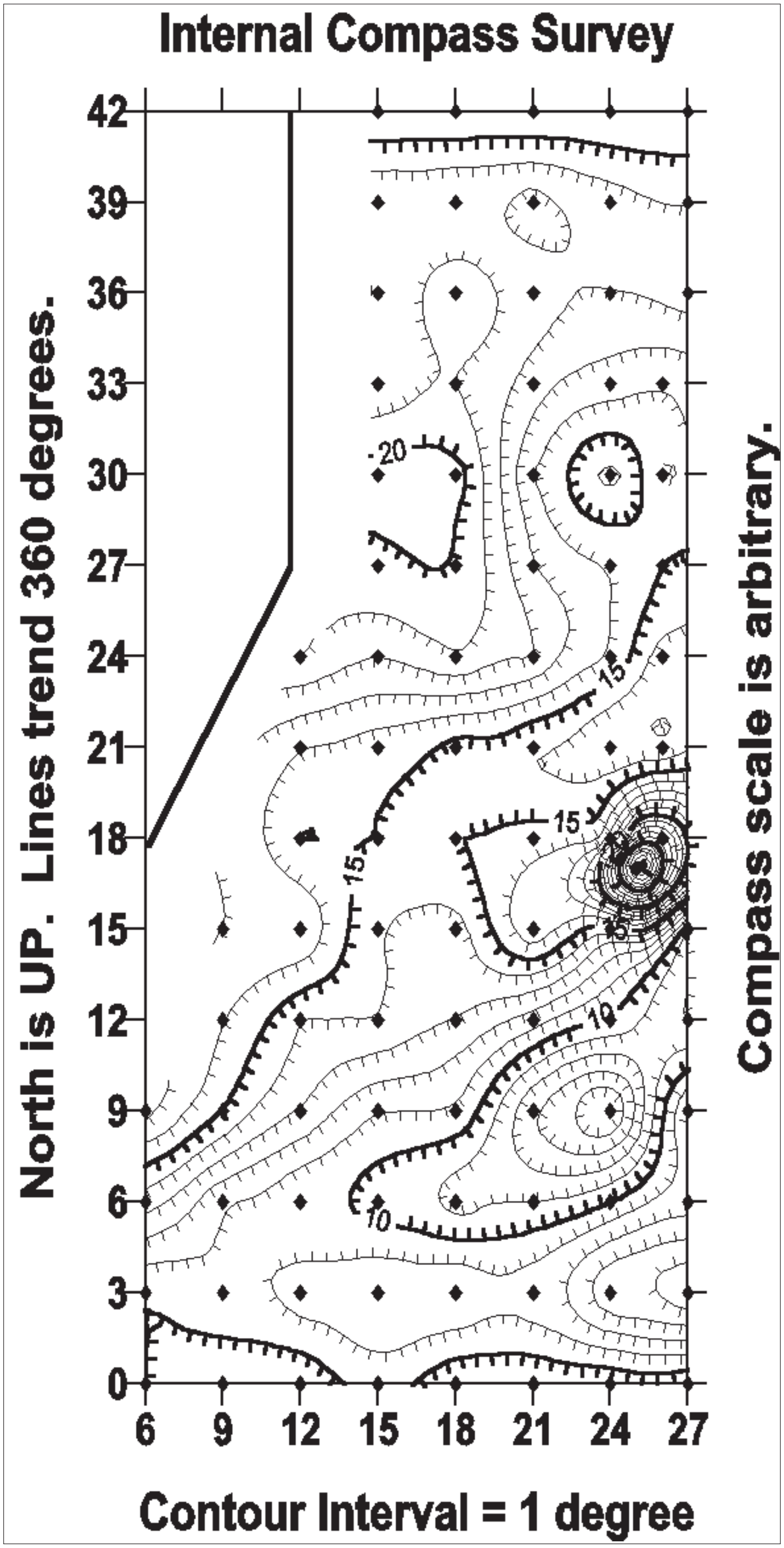


Figure 8. Compass azimuths inside Cairn Cave

Surveys at Tabernacle Hill Lava Tube

The Tumbleweed Section of THLT demonstrates a combined effect of a lightning strike and of breakdown that has changed its physical orientation since it was originally deposited. Because of an uneven floor, large breakdown, and steep slopes, it was not possible to lay out a grid. Instead, lines were placed roughly perpendicular to the passage at 10 foot intervals. The plotted bearing of these lines is based on a reading taken at the approximate center of the passage. No effort was made to determine the relative bearing between the lines. The cave is about 30-40 feet wide and 20 feet high. The first half of this survey is floored by breakdown and the second half is nearly devoid of rocks until the last line which approaches another breakdown pile.

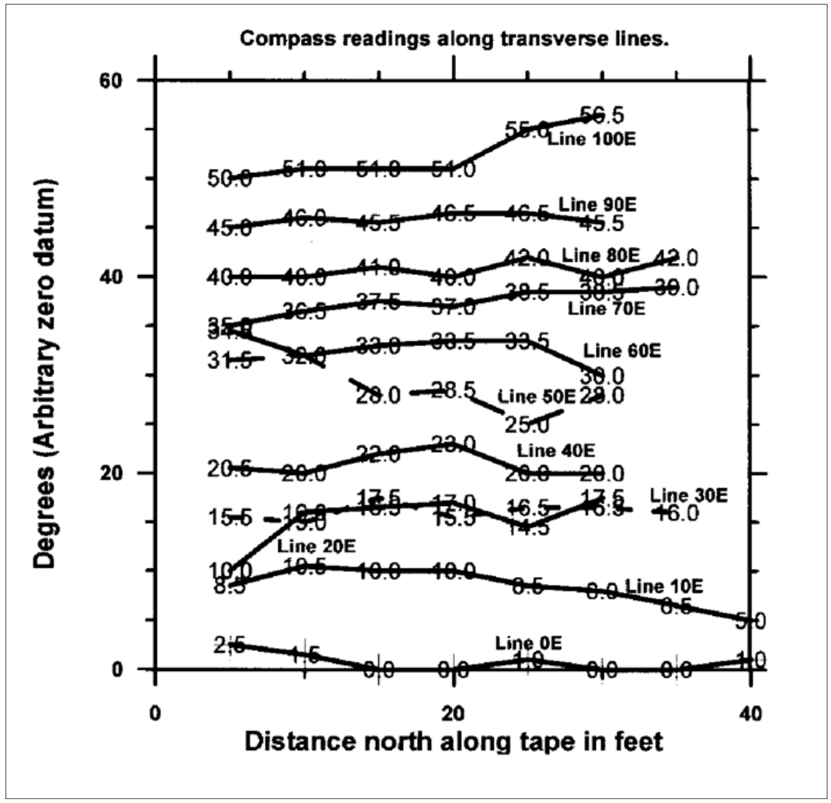


Figure 10. Interior azimuth readings along lines of Fig 9.

Of note is a large anomaly at the south end of line 10E. Actually, the anomaly is to the east, between the two lines, but the gradient was too high to obtain a reading. A surface survey shows a distinct lightning strike in the vicinity. Most of the south wall has elevated field readings that are several thousand nt above surface values. This may be because magnetic lines-of-force are hitting the earth at a 65^{O} angle from the south and they are crowding along the southern edge of the void. Whatever the cause, the effect is noted in other lava tubes that trend E-W. The rest of the magnetometer map is rather flat.

Figure 10, showing the compass readings along each line, reveals the information we are really interested in. For clarity of presentation on this chart and others, the lowest numeric reading of each line was assigned a value of 5 degrees higher than the line below it. The numbers along any line are arbitrary with regard to any other line, but are relative to other readings on the same line. Lines 60E through 100E are on a flat floor, devoid for the most part, of breakdown. The north end of 100E approaches breakdown just off the map and shows a sudden deviation of 5.5^{O}. The south end of line 60E is over breakdown and shows an anomaly of 2^{O} but the deviation on the north end is unexplained. Except for what is explained above, the compass bearings along the lines are very regular and may be due to normal reading variations as much as deviations caused by lava magnetics.

Lines 0E through 50E are over breakdown. Except for Line 0E they all show considerable variation in azimuths at each station. The south ends of lines 10E and 20E show obvious deviations caused by the magnetic anomaly. By holding the compass off line, these deviations were much larger, but since there was no light to sight on, no readings were taken. Consider the two readings of 7 degrees difference on Line 50E at distances 10' and 25' along the tape. If a mapping station was chosen at the 10 foot mark, all bearings from that station would be 7 degrees different from a station chosen at the 25 foot tape mark. Without more information, such deviations are almost impossible to account for, and there is no way to tell which reading is more correct.

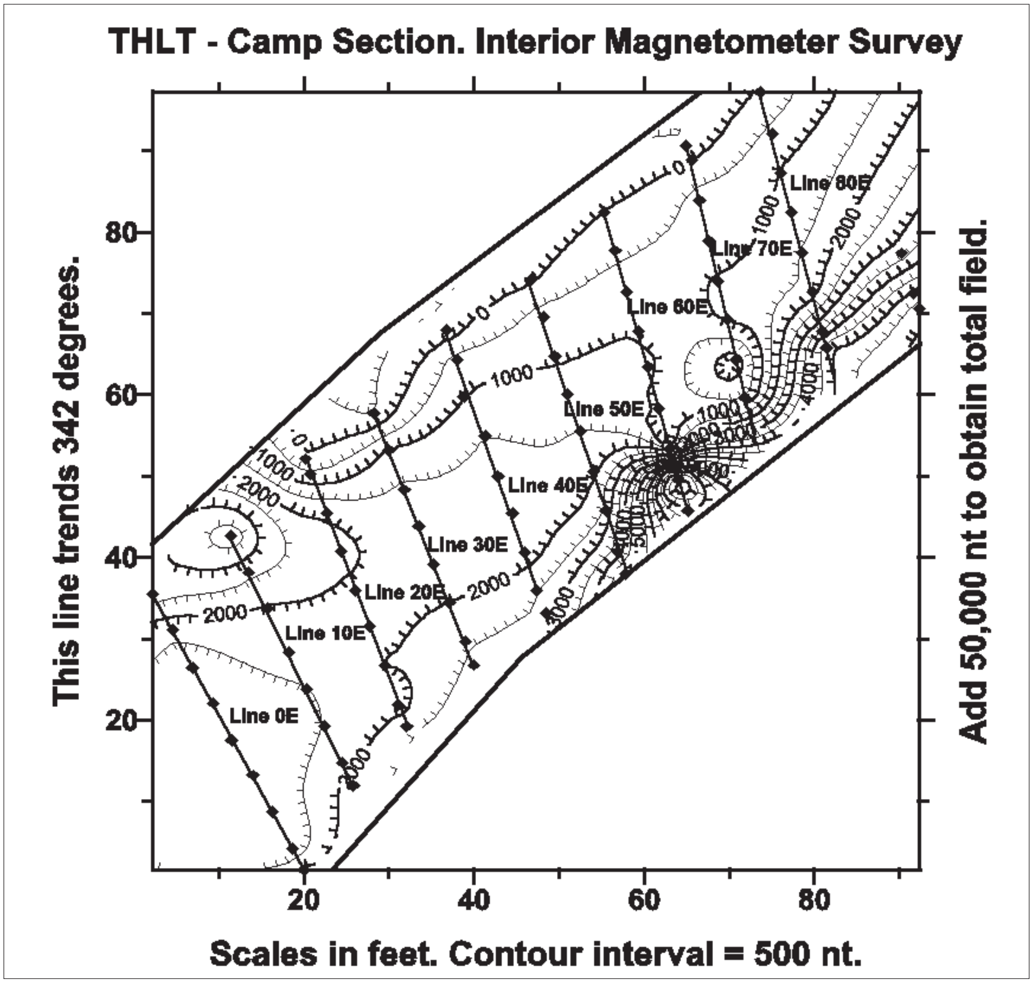


Figure 11. Interior magnetometer survey, THLT Camp Section.

The Camp Section of THLT has a larger passage averaging over 40 feet wide and 15 to 20 feet high. Most of the floor is covered with breakdown, with few clear areas. As seen in Figure 11, this section also exhibits a lightning strike, shown on the south end of line 60E. The map indicates an anomaly magnitude of 10,000 nt but it was not possible to get readings close by because of high gradients. It is reasonable to assume that the actual anomaly is even greater. This anomaly is over 20% of the earth's total field.

Examining the azimuth map (Figure 12) shows a feature not seen on the previous maps. Lines 50E through 80E exhibit a very pronounced decrease in readings from south to north. At first, this was attributed to the lightning strike anomaly, but the direction of deflection is the opposite of what is expected based on the experiment at Jawdropper Cave. The deviations are real and were reread to verify the values. No explanation is offered. Line 60E shows the obvious effect of the lightning strike. Line 80E is particularly 'scary'. Almost anywhere along this line would have made a good survey station, but the readings could vary by 10 degrees, depending on which point was chosen. Again, there is no practical way to determine which reading would be correct. The other lines look typical of traverses over breakdown. Most of this breakdown was relatively small, and the effects from remanent magnetism are probably random. Three lines show sudden changes at one end. These may be

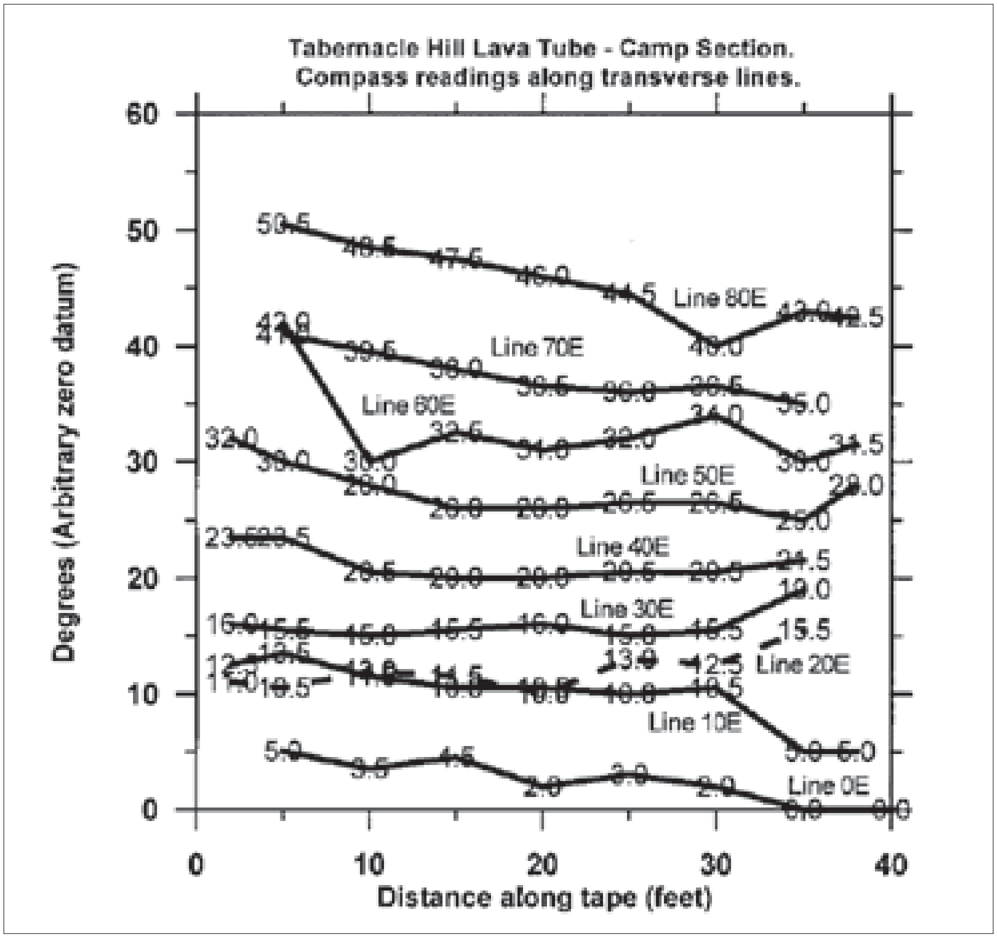


Figure 12. Internal azimuth readings along lines of Figure 11.

due to proximity to the wall and due to the effects of magnetic induction, to be discussed later.

It should be said here that the evidence is entirely circumstantial that traversing over breakdown causes variations in the readings. I have not conducted controlled experiments to prove this. However, all surveys made to date have been mostly consistent - bearings over flat floors with little or no breakdown, and variable bearings over large breakdown.

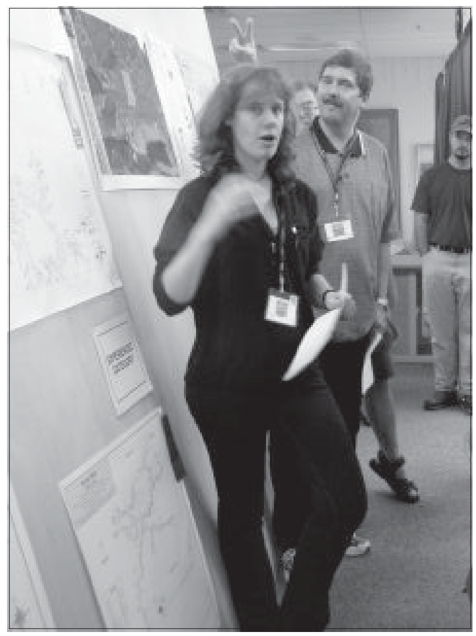
End of Part I.

The Effects of Lava on Compass Readings: Part II will be published in the next issue of *Compass & Tape (Vol 17, No1. Issue 57)*

Scenes from the 2004 Cartographic Salon Marquette, Michigan

Carol Vesely and Jim Coke give advice during the Cartographic Salon critique

Maria Perez, John DeLong, Lacie Braley, Lee Florea and Judy Ormeroid taking in the Cartographic Salon critique.



Rod Horrocks offering input on Hazel Barton's critique.

Tie-breaking judge Jim "Crash" Kennedy

Brandon Korwallis displays his quad book of Timpanagos Cave

Merit Award winning map of Ixobel River Cave by Howard Kalnitz