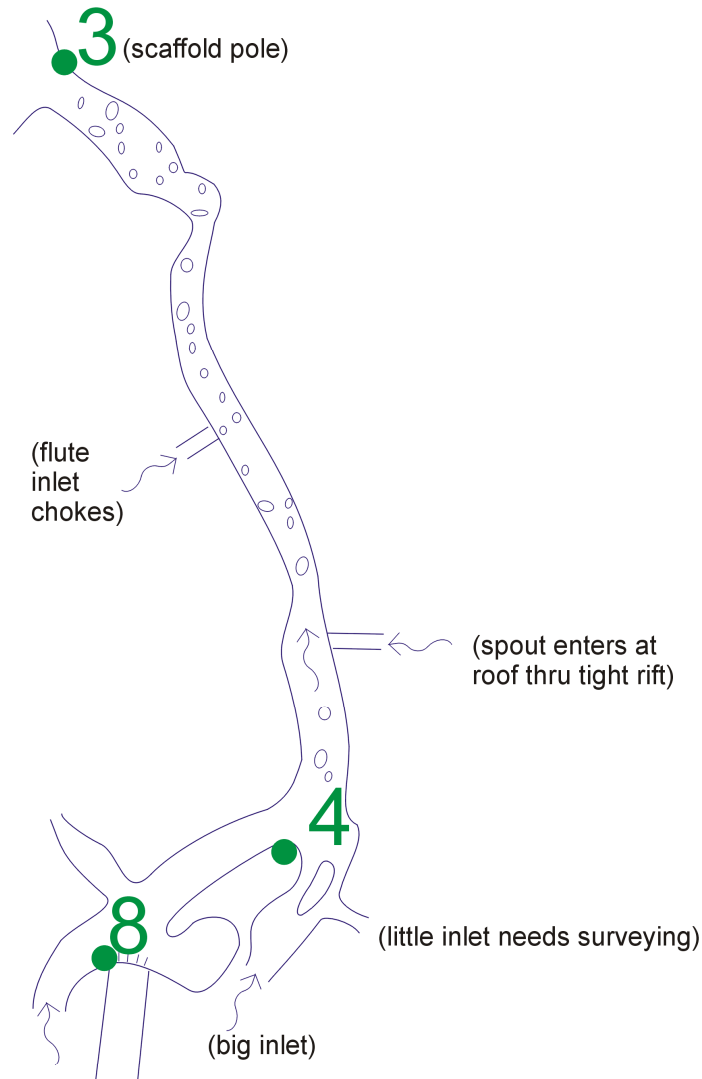


COMPASS POINTS



BCRA



Part of the Trident Series in County Pot, surveyed during the February CSG field meet

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Editorial

Here it is at last – issue 27 of Compass Points, a mere 27 months late. This extreme delay was caused by your usual editor going down with a wrist injury, and then being far too busy, along with everyone else involved in CSG administration. Your publicity officer has finally managed to conjure up enough spare time to step into the breach for the time being and put this issue together.

We have a fair mix of articles in this issue. David Gibson has contributed an example of how Excel can be used to display and rotate simple cave surveys. Mark Shinwell gives an overview of current developments in cave surveying software. This is particularly relevant to the forthcoming Summer field meet, the primary objective of which is to get some feedback from users as to what features they would like to see implemented in future surveying software. We also have an introduction to the subject of geodesy from Michael Behm targeted towards GPS users. Rounding things off is an article from Bob Thrun describing the complicated relationships between instrument manufacturers Brunton, Silva and Sisteco.

We hope to resume quarterly publication, though this will ultimately depend on how much material we receive – so get writing! It doesn't have to be a learned theoretical treatise, we are interested in any material of relevance to cave surveyors – who's surveying what, techniques that worked, techniques that didn't etc. If you have any ideas for articles or subjects that you would like to see tackled, get in touch with the committee, or (better) come to the field meet and discuss them with us face to face.

Anthony Day

CSG Admin

Pleas for assistance from your overworked committee have regularly put in an appearance in Compass Points over the years. The two year gap in activities should hopefully have convinced you all that we weren't kidding. The committee currently comprises the following:

<i>Chairman/Editor:</i>	Wookey
<i>Treasurer/Secretary/Journal Mailer:</i>	Andy Atkinson
<i>Webmaster:</i>	Andy Waddington
<i>Publicity/Acting Editor:</i>	Anthony Day
<i>Technical Editor:</i>	Olly Betts

It would be especially useful if someone would step forward to be treasurer or secretary, as Andy has rather too many hats. If you have any ideas on how the group should be run, projects you would like to organise, or just have a bit of spare time that could be employed to assist in the general administration of the group, we'd love to hear from you. Please get in touch with the chairman or come to the field meet. This is a very informal group – we don't bite and we promise to be nice to anyone who volunteers.

Forthcoming Events

Summer CSG Field Meet

The next CSG field meet is to be held at the headquarters of the Orpheus Caving Club at Parsley Hay on the weekend of 29th-30th June 2002. Cost will be £3.50 per night, unless you are a member of OCC. This field meet is open to anyone with an interest in cave surveying, from beginner to expert alike. You are encouraged to bring your own surveying gear if you wish.

The primary focus of the meet will be a round table discussion on future developments in cave surveying software. Input is invited from anyone who uses such software - developers and users alike. There will also be the opportunity for underground training for beginners and inexperienced surveyors if required. This is an evolving programme - keep watching the field meet page on the CSG website for the latest details, and please contact the organiser with any suggestions of other things you would like to do.

You do not have to formally "book" a place on this meet, but it would be helpful if you could tell the meet organiser, Allan Richardson (contact details below) if you intend to turn up, your level of expertise, what you would like to do, and what equipment (if any) you intend to bring.

For more information contact Allan Richardson at:

87 Hacking Drive,
Longridge,
Preston,
PR3 3EP
Tel: 01772 783194.
email: allanr@caving.demon.co.uk
Web page: <http://www.sat.dundee.ac.uk/~arb/csg/meet.html>

Hidden Earth 2002

Hidden Earth is the UK's annual caving conference, hosted by the BCRA. Hidden Earth 2002 will be held in Monmouth, South Wales on 27-29 September. The venue is Monmouth Leisure Centre & Community School. Further information can be found on the BCRA website at <http://www.bcra.org.uk/hidden-earth/>. Details of surveying related events will be published in the next issue of Compass Points, which will (hopefully) appear before the conference. (See also the Arthur Butcher Award item in the Snippets section of this issue).

Snippets

Winter Field Meet Report

Ray Duffy

The survey meet at Bull Pot Farm on the 9th and 10th of February 2002 was well attended, with surveyors and virgin surveyors from several clubs, though mainly the CUCC and RRCPC. Some basic surveying techniques were outlined and some ideas of what the person finally using the notes needs to have to do a half decent job. Some practice was undertaken around the farm to give people a start at actually using the equipment and also writing in a fashion that allowed others to easily read their data.

Some of the hardier people headed off to Ease Gill to survey parts of the Trident labyrinth in County Pot. It must be pointed out that this took place in some of the worst weather we've had this Winter, gale force driven hailstones and sleet. We could have had a much better response to going underground if the weather had been like it has been all April. I know that some of the inexperienced surveyors found the session most informative and the Red Rose has actually had offers to help with the Ease Gill re-survey from new surveyors. My thanks to everyone who took part and to the RRCPC for allowing us to use their base for the weekend.

Arthur Butcher Award

The Arthur Butcher Award is presented annually by the BCRA for, broadly speaking, "excellence in cave surveying". As well as a cash prize, there is a trophy to be kept by the winner for a year. The Award is judged and announced at the National Caving Conference. In 2001, the award was made to Ray Duffy and Red Rose CPC for their Easegill Survey. The citation from the judges (Wookey, Juan Corrin and Trevor Faulkner) reads as follows:

"The judges thought this was an excellent example of a long-term surveying project and the use of electronic drafting methods. Ray has invested countless hours in surveying, in persuading other people to do surveying, and especially in drafting. Andy Hall has also contributed greatly, and a large number of others have also done their bit. The finished survey (sheet 1) correctly balances the need for accurate representation and route-finding showing a good understanding of the target audience. The accompanying guide is also commendable. The judges also commended Steve Warren's surveys as being well done in the traditional style."

To be considered for the 2002 award, individuals or caving clubs must bring their work to the attention of the judges. For a cave survey, you can easily do this by displaying it on your club stand at the conference - or you can create a poster describing your work. If, however, you want other work to be considered - such as a report or publication on a surveying topic, or other more general achievements - then you should contact the judges in advance. BCRA is aware that there are a number of excellent cave surveyors "out there" as well as several innovative projects to do with cave surveying. The judges can interpret the rules broadly - but they cannot recognise your achievements unless you bring them to their attention.

The rules for the award are as follows:

1. The Award will be made at the National Conference...
 - ...to any one person or a nominated person from a group of surveyors, club or expedition.
 - ...for any one survey map, series of survey maps, report or publication on a cave survey or surveying topic; or for effort put into cave surveying by an individual or group; or for any other achievement relating to cave surveying that the judges consider warrants recognition.
2. ... by a panel of three judges approved by BCRA Council.
3. The judges will award the trophy called the "Arthur Butcher Award" and any other prizes which from time to time may be donated for that purpose.
4. The Arthur Butcher Award will only be made to a BCRA member or to member(s) of a BCRA member club, but the judges may award supplementary prizes to any other person.
5. Nominations for the Award (e.g. for a report or publication on a surveying topic, or other more general achievement) should be made in advance. The judges will also consider any cave map, published information etc., that is displayed at the National Conference. They will take into account a range of factors - effort and enthusiasm will be considered alongside skill, accuracy and presentation.
6. A copy of the award-winning material shall, if appropriate, be retained in the BCRA library.

It is not essential to notify the judges in advance, because work displayed at the conference will automatically be considered for the award. Please return advance nominations at least a week before the conference, to the Conference Manager (see Hidden Earth web page for contact details).

Compass Review: Suunto KB-14/360D

Erin Lynch

Last year I bought a Suunto KB-14/360D with a focusable bezel and declination adjustment. It was not a well thought out purchase, but rather the only thing my local vendor had in stock. 12 months and 60km of surveying later, I definitely regret my haste. The compass had a few serious design flaws.

My focusable bezel leaked. No matter how briefly I dunked the eyepiece underwater, water inevitably got into the body of the compass. Once that happened it was not merely a matter of unscrewing the bezel and dumping the water out. The eyepiece came with a piece of plastic a third of the way along its interior that made it difficult to clean out whatever condensation or water-borne grit has accumulated on the lens.

In compasses with the declination adjustment feature there is a strip of clear plastic between the eyepiece and the capsule. This strip has a black line on it and its position can be adjusted by the user. For most cavers this just adds extra confusion as you have to remember which line to use for the reading. Luckily after a few wet trips the declination line on my compass went smeary and then disappeared completely.

However the strip of plastic remained a problem. After the compass got wet I often got a thin film of water between the capsule and the declination strip that completely obscured the numbers. Getting the water out of there usually took heat or time in a dessicator. But there was no easy way to remove the associated grit, which gradually became more of a problem. Eventually I resorted to a pair of tweezers and removed the plastic strip from the compass. This dramatically improved the situation.

It is also worth noting that the capsules on all Suunto KB-14 compasses are fairly delicate. I recently saw a capsule crack and start leaking oil when someone lay on it whilst taking an awkward reading in a popcorn crawl.

Compass Reviews: Brunton Eclipse 8099 and the Outback digital compass

Bob Thrun

The two most recent Brunton compasses are the Eclipse 8099 and the Outback digital compass. I have seen both of these compasses. The Eclipse has too many pieces to be a cave surveying compass. It has a removable rubber boot that holds a plastic card. It is harder to read than the pocket transit. The Outback does not have good enough sights for accurate measurements. Precision Navigation, the company that makes the magnetic sensors, claims that the sensors are gimbaled so that the Outback can be tilted up to 15° and still be accurate. Perhaps it was just the unit I saw, but I could tilt the compass slightly side to side and the indicated direction would change plus or minus 15°. This was a continuous change, not the gimbaled sensor hitting its stops.

Silva and Suunto instruments available through the CSG

The CSG has an account with both Silva and Suunto and can thus obtain their instruments at a discounted rate. Silva instruments are

generally cheaper than their Suunto equivalents and are at least as good. With expedition season just around the corner, any clubs/groups in need of new instruments should get in touch with Wookey by email at wookey@aleph1.co.uk, or by post (see "Compass Points Info" box on page 2 for address). It would be a good idea to contact Wookey in good time – although delivery typically takes about three weeks, delays of several weeks are not unheard of.

Note that this is offered as a service to surveyors – neither Wookey nor CSG make anything out of this apart from extra work. Hence there are no money back guarantees, swapping bits if you got the wrong thing etc., and if things get lost in the post that's tough. If you are worried, you can have things sent by registered post and pay the few extra pounds.

Contact Wookey for prices of instruments and postage, who can also offer advice on what to buy if you are unsure what you want. For orders of over £100 from Suunto or £150 from Silva there is an additional delivery charge on top of the cost of postage from Wookey to you.

BCRA Cave Surveying Book

The Cave Studies series of booklets published by the BCRA aim to provide an introductory text for the sport caver who has become interested in some other aspect of speleology. Number two in this series was "An Introduction to Cave Surveying" by Bryan Ellis, published in 1988. This booklet has been out of print for some time. A replacement is in preparation, and it is now almost complete. The text has been extensively rewritten to reflect the changes in methods of surveying and presentation over the last 14 years, especially the increased use of computers for data processing and presentation. It is anticipated that the new booklet will be published in July/August and will be number 11 in the Cave Studies series.

Using Excel to Plot Cave Surveys

David Gibson

Occasionally, when a Cave Survey Plotting program is not available, a general-purpose spreadsheet will suffice. David Gibson explains how Microsoft Excel can not only process the data, but plot the cave too.

There are several excellent computer programs for data-processing and plotting cave surveys but, even so, there is bound to be an occasion when none of them are available to you, and you have to resort to "pocket calculator stuff". For example, you are on an expedition and someone thrusts a laptop PC into your hands and says "please process this survey data."

Spreadsheets are an extremely useful general-purpose computing tool and are not, of course, limited to accountancy applications. You may prefer other specialised or esoteric tools for general-purpose graph plotting and data manipulation, but it cannot be denied that, for most people, a spreadsheet package - and in particular Microsoft Excel - is likely to be the most easily available general-purpose tool they have. Bedford (2001) outlined some uses of Excel in the CREG journal. Here, I am going to concentrate on a cave surveying application.

Using Excel

Of course, once we've said "use Excel for cave surveys" there is not really a lot else to say about the subject. The point about using a general-purpose tool is that you must understand precisely what you want it to do. If you don't understand what you want, you shouldn't be trying to do it with Excel or you will get into a mess. So, if you are not familiar with Excel, please do not try this at home.

On the understanding that this article is just a memory jogger for you, I will describe how I used Excel to plot the data from a cave in northern Spain - Cueva Negra - which was surveyed in September 2001 on Chris Danilewicz's GPF-sponsored expedition.

Stages to data processing

- i) Conversion of the raw "compass, tape, clino" data to X, Y and Z co-ordinates.
- ii) Plotting these co-ordinates using Excel's graphics routines.
- iii) Making the cave rotate on the computer screen.

The Maths

Given a tape distance d , a compass bearing b , and a clino elevation reading e the first stage is to calculate some intermediate data - the vertical (z) and horizontal (r) distances are simply

$$z = d \sin e, \text{ and } r = d \cos e.$$

The horizontal distance is then resolved into x (east) and y (north) distances using the compass bearing as follows:

$$x = r \sin b, \text{ and } y = r \cos b.$$

Summing the x , y and z increments from previous stations gives us the absolute co-ordinates to plot. The plan view is y plotted against x . To plot the elevation we need to choose a direction to view from (unless, of course, we simply plot z against x or y).

Bearings are measured clockwise from north - the y axis. If we want to look at the cave on a bearing of θ , the horizontal co-ordinate on the graph is

$$(x - x_0) \cos \theta - (y - y_0) \sin \theta,$$

where x and y are the absolute plot co-ordinates, and x_0 , y_0 are the co-ordinates about which we want to rotate the cave. Choosing a point in the middle of the cave is helpful. We can verify the above equation by noting that if $\theta = 0$ we are looking north, and the expression evaluates to $x - x_0$; and that if $\theta = 90^\circ$ we are looking east, and the expression evaluates, correctly, to $-(y - y_0)$.

I chose not to include any special feature to allow for back-sights. This is easily possible, but it was also easy to type in the data as if all the readings were forwards.

Spreadsheet details

An example datasheet is shown in Figure 1. The spreadsheet columns used are.

- A) sequence number
- B-C) From & To Station Numbers
- D-F) Tape, Compass, Clino readings
- G) I used this to perform some checks on the data sequence.
- H-K) The intermediate Z, R, X, Y data. In Excel notation these rows were typically,

In H8: =D8*SIN(F8*PI()/180)

In I8: =D8*COS(F8*PI()/180)

In J8: =I8*SIN(E8*PI()/180)

In K8: =I8*COS(E8*PI()/180)

Note that trigonometric functions in Excel require angles measured in radians, hence the compass and clino readings (in degrees) are converted by multiplying by /180 as above.

- L,M and O) The absolute X, Y, Z plot co-ordinates, e.g.

In L8: =J7+L7

In M8: =K7+M7

In O8: =H7+O7

- N) The rotated X-Y data...

In N8: =(L8-\$O\$2)*COS(-Elevation!\$G\$1*PI()/180)+(M8-\$P\$2)*-SIN(-Elevation!\$G\$1*PI()/180)

Here, you need to know that cells \$O\$2, \$P\$2 are the x_0 , y_0 origin referred to above, and \$G\$1 in the Elevation worksheet contains the direction of view (i.e. above).

- P) The cumulative passage length, found by summing the R values, that is

In P8: =I8+P7

Plotting the Data

I plotted a plan and projected elevation in two separate worksheets, using Excel's Chart menu. The type of chart to use is "XY Scatter", and the option I chose was "data points connected by smoothed lines, with markers". Example charts are shown in Figure 2 (plan) and Figure 3 (projected elevation). A word of caution here: if you are not familiar with Excel charts you may find this taxing the first time you try it!

Serial	From	To	Tape	Compass	Clino	Z	R	X	Y	plotX	plotY	Xrot	plotZ	plot
1	0	1	8.02	338	-22	-3.00	7.44	-2.79	6.89	0.00	0.00	-419.02	0.00	
2	1	2	14.5	3	-10	-2.52	14.28	0.75	14.26	-2.79	6.89	-425.92	-3.00	
3	2	3	8.79	342	-15	-2.28	8.49	-2.62	8.07	-2.04	21.15	-435.66	-5.52	
4	3	4	3.5	9	-6	-0.37	3.48	0.54	3.44	-4.66	29.23	-443.29	-7.80	
5	4	5	3.95	3	-2	-0.14	3.95	0.21	3.94	-4.12	32.67	-445.38	-8.16	

Figure 1: Example data worksheet.

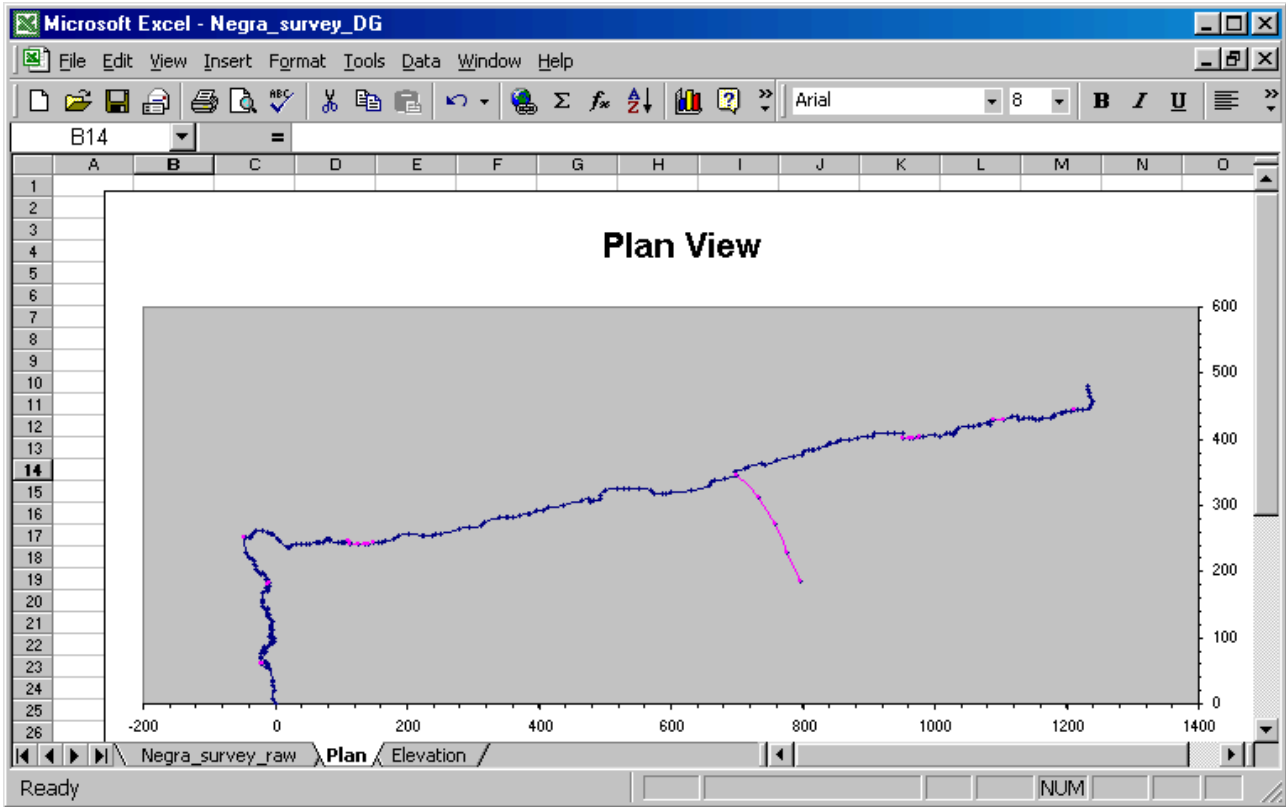


Figure 2: Plan survey

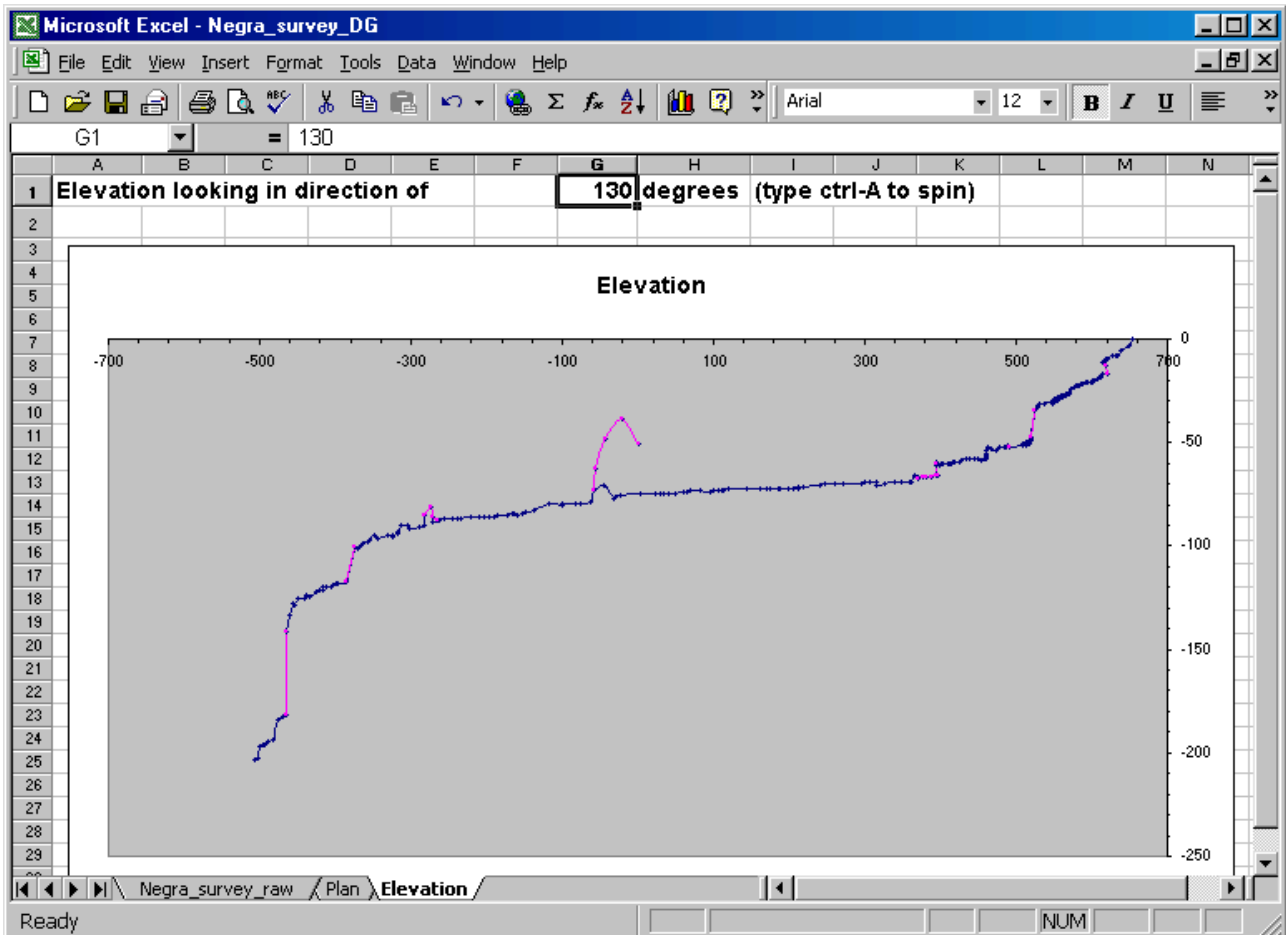


Figure 3: Projected elevation

Multiple Passages

You may be thinking "this is all very well, but how do I plot more than one passage?" This can be done but - as I implied in the introduction - you need to have your wits about you or you can get in a muddle. There are three requirements.

- a) Where one passage ends you must include a blank row in the data. Excel will continue to plot the column of data you have instructed, but it will not join the two points above and below the blank cell.
- b) In the first row below the blank line, you need to re-start your calculation of absolute co-ordinates. For example, if rows 6 to 258 contain data for a single passage, and there was a branch that began at row 180 then you should copy the X, Y, Z co-ordinates to row 260.
- c) Begin the new tape/compass/clino readings in the next row. Thus, the X co-ordinate in column L will be

```
In L258: =J258+L257
In L259: [blank]
In L260: =L180
In L261: =J261+L260
```

This example is illustrated in Figure 4.

Highlighting sections of passage.

Using a similar technique, it is possible to highlight parts of a passage. I did this by creating two new data columns that were copies of the data for the elevation. I then went through the columns and deleted the data I didn't want to re-plot. I instructed Excel to plot this data in a different colour over the top of the data from the first plot. In this way I was able to highlight pitches and climbs, and an inlet passage.

Rotating the Data in Real Time

Rotating the cave on the screen is a fun thing to do, and is easy to achieve. As mentioned above, there was a cell (G1) in the spreadsheet containing the direction of view. You simply have to instruct Excel to increment this cell continuously. There are probably neater ways of achieving this than the crude macro I wrote, which was simply...

```
Sub rotate()
' Keyboard Shortcut: Ctrl+a
Rot = 0
Increment = 2
While Rot < 360
  Rot = Rot + Increment
  Range("G1").Select
  ActiveCell.FormulaR1C1 = _
  ActiveCell.FormulaR1C1 + _
  Increment
Wend
ActiveCell.FormulaR1C1 = _
ActiveCell.FormulaR1C1 - 360
End Sub
```

Not being familiar with Visual Basic, that's about my limit. In the listing above, the underscore (_) is the VB line continuation character.

This macro runs "as fast as possible" and, to change the speed, you just need to change the angle by which it increments. There

are timer functions you can use if you want to make the speed independent of the computer clock speed.

Reference

Bedford, Mike (2001), Using Excel for Technical Number Crunching, CREGJ 46, pp15-18, Dec. 2001.

	A	B	C	D	E	F	H	I	J	K	L	M	N	O	P
255	251	27	28	6.1	352	-7	-0.74	6.05	-0.84	6.00	1234.49	464.64	104.29	-195.88	1767.32
256	252	28	29	8.2	332	-46	-5.90	5.70	-2.67	5.03	1233.65	470.63	99.39	-196.63	1773.01
257	253	29	30	5.6	357	-9	-0.88	5.53	-0.29	5.52	1230.97	475.66	93.92	-202.53	1778.55
258											1230.68	481.19	89.74	-203.40	1778.55
259															1778.55
260	254	48	97	48.7	134	12	10.13	47.64	34.27	-33.09	698.29	344.81	-181.98	-73.13	1826.18
261	255	97	98	49.5	146	17	14.47	47.34	26.47	-39.24	732.56	311.72	-134.37	-63.01	1873.52
262	256	98	99	47.5	158	12	9.88	46.46	17.40	-43.08	759.03	272.47	-87.76	-48.53	1919.98
263	257	99	100	49	156	-14	-11.85	47.54	19.34	-43.43	776.44	229.39	-44.68	-38.66	1967.52
264											795.77	185.96	0.00	-50.51	1967.52
265															1967.52

Figure 4: Example of how to include a side passage.

Current Developments in Cave Surveying Software

Mark Shinwell

The main focus of the forthcoming CSG field meet will be a discussion on the direction that future developments in cave surveying software should take. In this article, Mark Shinwell, one of the principal programmers for the Survex project, presents a personal view of the current state of the art.

Current developments in cave surveying software appear to be trending towards methods of drawing up finished plans and elevations using dedicated software packages.

Those currently drawing up final surveys on computer have little choice but to use standard off-the-shelf drawing software such as Corel Draw. This can produce very good results - such as the excellent first sheet of the new Easegill survey - but also takes a lot more time than it would if one had a custom cave drawing application.

There is also the major issue that when one's centreline changes (due to loop closure, for example) the drawing software does not (quite reasonably!) do any intelligent manipulation of the final print-quality survey to fit the new centreline.

Julian Todd's Tunnel software aims to address this issue and has been in existence for some time, although use appears not to be widespread. Cambridge University Caving Club (CUCC) are currently experimenting with it for the production of a plan of a 4.7km long system in Austria, with some success.

Tunnel has some disadvantages: despite reading Survex survey files it bypasses the entire Survex system for calculating loop closures, etc. and is not as well integrated with Survex as one might like. Furthermore, the use of the Java programming language has (somewhat ironically) caused some difficulties with getting the software to run on various platforms, and CPU requirements are high. However, it provides useful insights into various problems associated with drawing up cave surveys (for example how areas of different textures - boulders, boulders and sand, etc. - should be implemented).

On the subject of Survex: development of the system continues apace; this now stands at version 1.0.9 and includes a fast graphical cave viewer, Aven, which runs natively on Microsoft Windows and UNIX/Linux systems using the X Window System. This is a major step forward in terms of usability for the suite; further plans are afoot to incorporate the processing and visualisation of left-right-up-down (LRUD) data and surface terrain data in the relatively near future. Prototype versions of the latter have been exhibited in CUCC's presentations at the BCRA conference over the last two years.

It is hoped that a version of Survex (including Aven) will be available for Macintosh computers running Mac OS X in the not too distant future.

The Spud system - the second generation of Survex software - will begin development in earnest shortly. This will provide a totally integrated environment for cave survey data processing and visualisation. Plans are also afoot to include an advanced application for the production of print-quality surveys. Currently this is at the design stage; coding will not start for several months.

There is a relatively new project called Carto which takes scanned survey notes and morphs them to fit processed survey data. Facilities are then provided to draw a final survey over the top of the assembled morphed notes. Carto is again written in Java.

It should be noted that Carto does not operate (to the extent of the author's knowledge) in the way in which one might expect: the actual scanned notes are morphed to fit the loop-closed centreline, rather than the drawn-up vector graphics survey. This means that if your centreline changes significantly due to loop closure, you will have possibly a

significant amount of work to do to refit your drawn-up survey. If one takes the approach of morphing the final vector graphics, then the software can semi-automatically move the drawn-up cave when the centreline changes. Of course, matters of personal preference arise here.

Algorithms to morph the drawn-up cave with respect to the centreline are not easy to develop, but it is intended that one such will be used in the future version of Survex touched upon above.

The Therion project are also producing a system which takes this approach of storing your drawn-up cave in such a way that it can be manipulated if the centreline changes. This software is based on a collection of applications and uses

Survex for the data processing. See the Therion web site (details below) for the current state of progress.

So there is a wide variety of development in the cave surveying software community at the moment. One of the most essential ingredients in this is input from users in the field, and it is hoped that the CSG field meet at the end of June will provide a useful forum for the exchange and discussion of ideas in this area.

Relevant Websites

Survex - <http://www.survex.com/>

Carto - <http://www.psc-cavers.org/carto/>

Therion - <http://www.therion.sk/>

Ellipsoids, the Geoid, GPS and Map Projections - an Introduction

Michael Behm

When it comes to GPS and map readings, the practical user (for example, a caver) does not always obtain either useful or correct results. The reason is that the basic principles of all these things require some fundamental geodesy. One of the many definitions of geodesy is the following: it is the science which tries to define and map the shape of the earth's surface or parts of it, and also the science of the earth's gravity field. We need to follow exactly this definition when we want to understand geodesy for practical applications like GPS and map reading. In the following article the key words will be geoid, ellipsoids, map projections, co-ordinate transformations, GPS and UTM.

The Geoid

The geoid is a model of the earth's gravity field and represents a surface of equal potential ("a level surface" in plain English). The "popular" explanation of this abstract definition is quite simple: when you move along any level surface, you do it without any effort; also, you don't gain any potential energy from moving along. But as soon as you leave a particular level surface with a particular potential (let us assume this surface has a potential with the value P1), you step to another level surface (value P2). The corresponding work can be expressed as the difference P2-P1 - exactly the amount of work needed/gained to overcome the force of gravity, which acts perpendicular to the surfaces of constant potential in the direction of increasing potential. We know that the potential decreases with height, at least outside the earth - that's why it is more exhausting to walk 1 km upwards than along, because we walk against the force of gravity. (Just for completeness, it has to be pointed out that the potential is not identical to gravity, but, for a basic understanding, the simple relation "potential means gravity" is good enough.)

The potential and the gravity, and hence the shape of the level surfaces, result from the distribution of mass inside the earth's body. There are infinitely many level surfaces, and each one is closed. Since the potential is a unique property of any point in space, the level surfaces do not intersect (as this would imply that the intersection point had two values of potential). Any liquid at rest represents such a level surface, and in fact the surface of the oceans is part of the actual geoid (if effects like waves and ocean currents are ignored). The geoid is defined to be the level surface which coincides with the ocean surface, and it can be thought of as continuing beneath the continents. Since there is only one geoid for the whole earth, it is a unique reference system. Hence - and this is fundamental for understanding geodesy - the geoid is a physically, not a geometrically, defined surface!

One often reads that the shape of the earth is called a geoid. This is not quite true - because "shape of the earth" makes one think of the physical surface (topography), which does not have much to

do with the geoid. The geoid can be determined by combined height and gravity measurements or by means of astronomical observations. Nowadays, on a large scale, it is mainly determined by the analysis of satellite tracks. These tracks are a result of the mass distribution of the earth and it is possible to derive the shape of the geoid mathematically from them.

Ellipsoids

To a rough approximation, the shape of the geoid can be represented by an ellipsoid because the "main feature" of the geoid is that it is flattened at the poles - which is an effect of the rotation of the earth (the faster a planet rotates around its axes, the more flattened it becomes). Since the physical earth is flattened and the geoid follows the physical earth on a large scale (mass distribution) the geoid is also flattened. There are also many "small" deformations of the geoid, resulting from mass anomalies on a large scale (in the earth's mantle, for example).

Due to its complex and irregular shape (due to deformations), we cannot use the geoid as a geometric reference system. However, an ellipsoid is a fairly simple surface and can be described by analytical equations, and we can find an ellipsoid which, geometrically, fits the geoid quite well on a global scale. This ellipsoid is defined by the length of 2 axes; the 3rd axis is the same as the 2nd axis: axis 1(minor axis)= length from pole to pole; axis 2=axis 3 (major axis)= diameter of the equator. If we give this geometrical surface a mass, a rotational axis (=minor axis) and a rotation speed equal to that of the real earth, and then centre it on the centre of mass of the real earth, we can also use it as a physical reference system. This has been done and is called WGS84: A global, geometrical and physical earth reference system.

Geodetic Datums (also called local datums)

Every country tried to find a geometrical reference system (an ellipsoid and some other things as we will see) that fits the geoid well in its area. For example, in Austria WGS84 deflects up to 45 m from the geoid in Austria, whereas the Austrian system deflects only up to 4 m. This is called a "geodetic datum" (or "local datum"): A geometrical ellipsoid (without physical properties) which can be related to WGS84 or any other datum as follows:

- a) different major and minor axes - 2 parameters;
- b) the centre of the local ellipsoid does not coincide with the centre of WGS84 (or another datum) - a translation vector (x , y , z), 3 parameters;
- c) the three axes of the local ellipsoid are rotated about the axes of WGS84 (or another datum) - tiny amounts only, but also 3 parameters.

These 3 things (8 parameters) apply to almost all local datums. A fourth one is the different height reference (which is quite a complicated problem). The ellipsoids also have a different scale, but this difference is only a tiny amount. (Here "different scale" means that one metre in WGS84 is not exactly one metre in the local datum. An explanation of why there are different scales is beyond the scope of this article.)

All in all, we need 10 parameters when we want to transform ellipsoidal coordinates (latitude, longitude, and maybe height) from the surveying system of one country to the system of another country (remember, so far we haven't considered UTM - or any other map co-ordinates). In practice (for example GPS), 7 parameters have to be specified directly: The translation vector (x , y , z), the rotation angles and the scale. By choosing a certain ellipsoid (for example, "Bessel" for Austria), the lengths of the axes are determined indirectly. Mostly, heights are simply ignored.

Often one reads about the "local ellipsoid", (for example, the "German ellipsoid") when the whole geodetic datum is meant. Here lies a prominent source of error, arising from this inaccuracy: many countries, like Germany, Switzerland and Austria, use the same ellipsoid (Bessel in this case), but the 7 other parameters mentioned before are different. When they are forgotten, final errors in the range of 1 km can be expected! So, the term "local ellipsoid" should not be used.

Each Datum has a name, e.g. "MGI" (Military Geographical Institute) for Austria. "MGI" means the Bessel-Ellipsoid with the 7 transformation parameters for Austria.

Map Projections

A map projection is a mathematical rule which converts ellipsoidal co-ordinates (latitude, longitude) to cartesian (planar) co-ordinates (x,y) and is, essentially, independent of the datum. Of course, a single point in space has different ellipsoidal co-ordinates in different datums, and so it will result in different (x,y)- co-ordinates. However they are independent in the sense that one can apply any map projection to any datum.

There are many map projections that can be grouped according to different aspects, but they will not be covered here. Only the UTM projection will be explained in any detail, by way of an example.

We must be careful to distinguish between any map of an area of a country and the "official" (x,y) co-ordinates of a country. Like a

datum, every country uses a certain projection (which, of course, is based on the local datum of this country) to obtain "official" planar co-ordinates. But anyone can produce a map of any area using any projection, thus producing "unofficial" planar co-ordinates.

UTM

UTM stands for Universal Transverse Mercator (projection). To start with, let us forget the U. Transverse Mercator is a widely used type of projection and was originally invented by Gauss - that is why in Europe the names of types of this projection are often something with "Gauss" (Gauss-Krueger) for Germany and Austria or Gauss-Boaga for Italy). Transverse Mercator Projection (TMP) is ideally suited to map areas along and close to a meridian - for example, a zone which extends 3° (in longitude) from a certain meridian, called the "central meridian". This zone then has very little distortion (distortion means a difference in length/direction/area, between a "real" length/direction/area on the ellipsoid and the corresponding length/direction/area on the map). TMP is not limited to any area of latitude, so really the whole zone from the north pole to the south pole is mapped with one central meridian. Theoretically, with only one central meridian, one could map almost the whole earth. However this would result in extreme distortions far away from the central meridian. Also, in areas of high latitude, TMP leads to large distortions.

Since the distortion is only small enough for precise geodetic application within approximately 3° of the central meridian, every country which uses TMP has several central meridians. For example, Austria has 3 - and thus 3 groups of (x,y)-coordinates which can't be compared directly.

UTM is a system which maps the whole earth using a slightly modified TMP with 6 broad longitude zones. The zones are numbered from 1 to 60 beginning with the zone between 180° and 174° West of Greenwich - incrementing eastwards. The central meridians are thus 177° W, 171° W, 165° W... (it is interesting to note that Greenwich is not a central meridian in this system).

It is not possible to directly compare (x,y) co-ordinates from different zones. To do this, the (x,y) co-ordinates must be re-mapped to the ellipsoid that the maps are based on. If, and only if, the datums of both the maps are the same, latitudes and longitudes may then be directly compared.

To keep distortions small, UTM is not extended to polar regions. The Polar Stereographic Projection is used instead for these areas.

NATO uses UTM based on the WGS84-datum. So ellipsoidal coordinates from a UTM NATO map from Australia can be compared with those from a UTM NATO map from Germany since they are co-ordinates from the same datum.

Normally, using the term UTM also implies the WGS84-datum, but this is not strict. So when one reads co-ordinates from a UTM-map (or from any map), you should always check which datum the map is based on.

Conversion from GPS Co-ordinates to Map Co-ordinates

The Global Positioning System works in WGS84. Using GPS, ultimately you usually want to obtain (x,y)-coordinates which are the "official" co-ordinates of a country or some other co-ordinates from a particular map. How is this done?

- a) Check which datum the surveying system of the country/the map is based on.
- b) In the GPS, choose this datum; directly - by naming it, or indirectly - by specifying the 7 parameters (if possible with your GPS unit). When specifying a datum by name, you have to be careful: For example, the Austrian datum, which is properly called "MGI", can usually be found under the name "Austria" in GPS-receivers.
- c) In the GPS, choose the map projection (often called "Grid" in the GPS).

When selecting UTM, nothing else has to be specified. For some countries, the map projection can also be found in the list of the GPS. If this is not the case, one has to choose "User Specified Grid" or something similar. What follows is usually a TMP which can be adapted to the system of a certain country.

Of course, there often are some obstacles, especially in steps b) and c). I don't know how many GPS-receivers allow you to enter

the 7 parameters and, even if a GPS does, a non-geodesist will have some difficulty finding out the correct parameters. On the other hand, sometimes the included datums are inaccurate or there are problems finding the correct one because of inconsistent naming.

The user-specified map projections are rarely anything other than a TMP. A counterexample is Switzerland, which doesn't use a TMP (they are always a bit different, aren't they?). Even if a country uses a TMP (and most countries do), it is adapted with certain parameters to suit the country well. Then it needs someone with some background information on the surveying system of this country and that used for the map. To be absolutely sure, one should always note down the ellipsoidal WGS84-coordinates as well. These are true, free of inaccuracies resulting from incorrect transformations, and, with some geodesist's knowledge, they can be transformed to any planar co-ordinates afterwards.

Compass Brands and their Manufacturers

Bob Thrun

Years ago I bought a Sisteco compass and clinometer set as a backup and alternative to my set of Suunto instruments. More than a year later I checked out the Sistecos and found that the clinometer pivot had too much friction. I did not write to the importer at the time and then the importer changed. I heard that the Sistecos became Silvas.

Even longer ago I helped map a cave with Richard Schreiber. He used a Silva Ranger compass. This year I bought a Silva Ranger to round out my collection of cave surveying instruments. The manual said the compass was "Guaranteed Accurate for Life" and the registration card gave a toll-free phone number to call for warranty service. I called and was informed that there were two Silvas and my Sisteco clinometer was made by the wrong one. I then tried to track down who makes what on the Internet.

Silva in Sweden has a catalogue of Professional Instruments posted on its web site. It shows a line of instruments identical to the former Sisteco line. There is a history of Silva that says that Silva acquired the Finnish instrument maker Sisteco in 1990 and the US company Brunton in 1996.

The Brunton website shows a line of instruments that look like the Sistecos, but have a Brunton label. This is in addition to the traditional Brunton, called a pocket transit, and a line of other outdoor items.

The Silva Sweden catalogue and the British Compass Points both refer to the former Sisteco designs as Silva instruments. I found a website with a 1997 article from Outdoor Retailer that explains the confusion of brand names. When Silva bought Brunton, Silva terminated its arrangement with its importer, Johnson Worldwide Associates, and decided to import its instruments into the US through Brunton, dropping JWA. However, JWA claimed ownership of the Silva trademark in the US and Canada. The inevitable lawsuit ended with JWA owning the trademark, but unable to import compasses made by Silva Production AB in Sweden. Silva decided to market through Brunton under the new brand name of Nexus. JWA arranged for Suunto to manufacture compasses with the Silva brand name. The head of JWA was quoted as saying "No matter who makes compasses for us, they will still be Silva compasses." This is true only under a strict reading of US trademark law.

The article makes it sound like the ownership of the Silva trademark by Johnson Worldwide Associates was an oversight on the part of Silva. I have encountered situations involving photographic equipment where the ownership of the trademark by the importer was deliberate. If a trademark is owned by someone other than the manufacturer, the trademark owner can have US Customs block the importation of "grey market" goods. The grey market arises when a manufacturer sets different prices in different countries. A dealer is able to buy merchandise in a country with lower prices than the US and sell it for lower prices than the officially imported merchandise.

The fine print on the packaging of the Silva Ranger model 515 I bought says "Made in Finland". I have a 1989 Forestry Suppliers catalog with full pages devoted to the Silva type 15 Ranger and the Suunto MC-1. The Silva Ranger that I have is almost identical to the Suunto MC-1. The most notable difference between the Swedish-made Silva Ranger and the Finnish-made compasses is in the hinge lugs on the cover of the compass. I also purchased a Brunton Nexus compass. The fine print says "Made in Sweden by Silva Production AB" with a small Swedish flag.

I was able to find the history of some of the compasses. I don't know when the the metal-bodied Suunto KB-14, the compass model we are all familiar with, was first made. It was described in the May 1969 NSS News with a reference to a 1967 Arkansas Caver article. According to an official of Brunton, Sisteco was founded in Finland in 1978. The first mention of the Sisteco instruments for cave surveying in the US that I could find was an article by John Ganter in *Compass & Tape*, Volume 5, Number 3. He said that Sistecos were available in June 1987. As I mentioned before, Sisteco was bought by Silva in 1990. Production of the Sisteco designs, renamed to Silva, was moved from Finland to Scotland.

The Brunton pocket transit has a long history. It was patented in 1894 by David W. Brunton, a mining engineer. He contracted with William Ainsworth, a watchmaker, to make it. Ainsworth founded the Ainsworth Gold Scale company in Denver. For many years, "D.W. Brunton's Pocket Transit" was made by Wm. Ainsworth & Sons, Denver, Colo. Starting in 1965, the company was owned by a series of corporate conglomerates, which were the fad on the stock market. A large corporation would own a

bunch of unrelated businesses. The theory was that if one business went into a slump, the others might be unaffected. In practice it meant that top management did not know how to run most of the individual businesses. Ainsworth was successively owned by Xavier Science, Taste Freeze, Beaver Mesa Exploration, and US Energy. I recall that quality went down during this period. In 1972 a group of Riverton, Wyoming businessmen bought the business and formed the Brunton company. They added lines of binoculars and hunting knives. In February 1996, Brunton was acquired by Silva Production AB of Sweden, makers of the famous orienteering compasses. The knives have been discontinued.

With all these mergers and name changes, it is no longer clear what someone means when he says a cave was mapped with a Brunton compass.

Since Brunton offers a "limited lifetime warranty" for its current products, I asked about fixing my Sisteco. At first I was told that Brunton was not affiliated with Sisteco. After informing the service representative that Silva bought both companies, I got a return authorization. I sent the clinometer in with a letter emphasizing that it was in mint condition, but defective from the factory. I got a replacement clinometer with a Brunton label, but otherwise identical to the Sisteco.