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Compass Points

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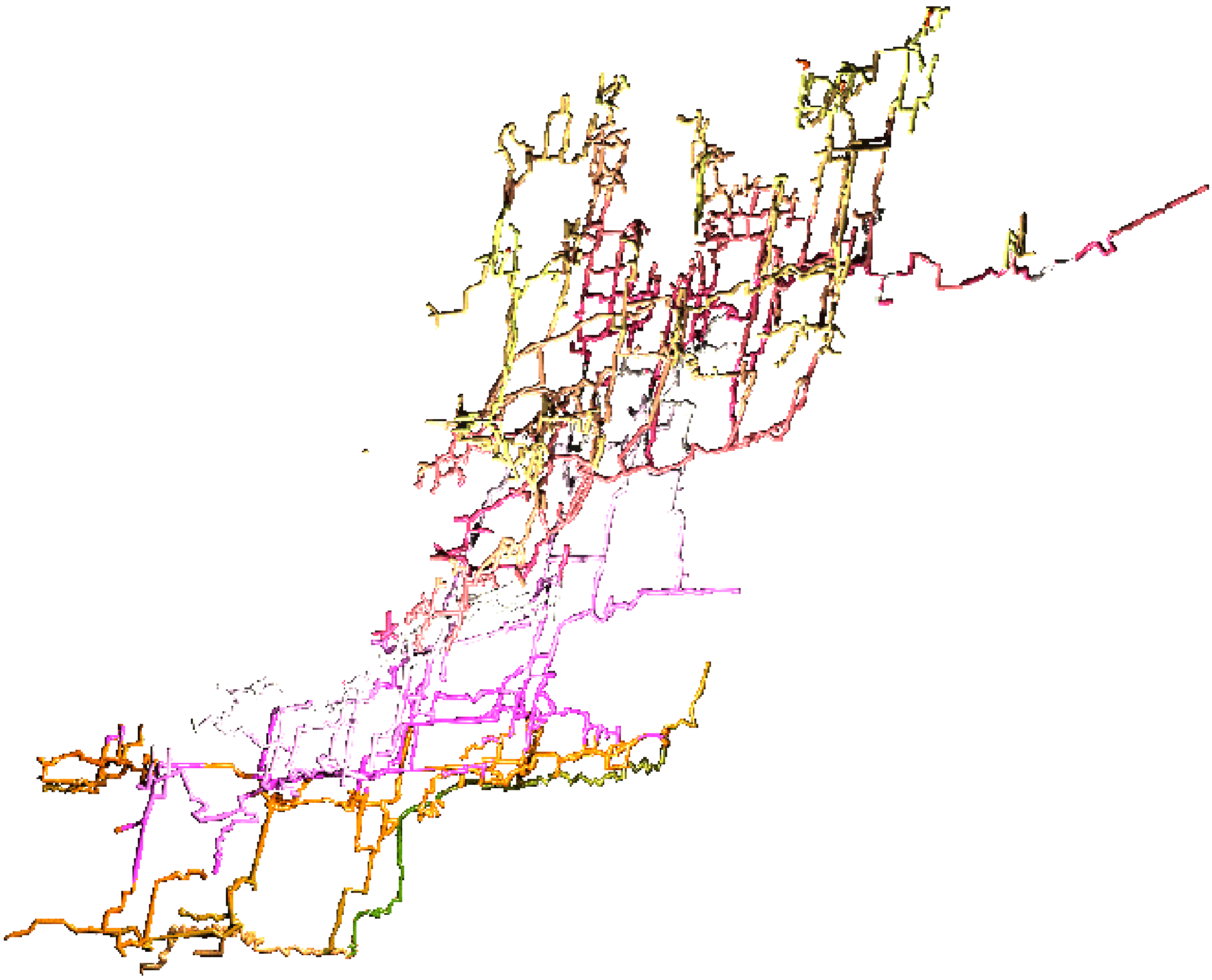
BCRA



Managing Large Survey Projects

Errors in Radio Location

Hidden Earth Details

The Journal of the BCRA Cave Surveying Group

COMPASS POINTS INFO

Compass Points is published quarterly in March, June, September and December. The Surveying Group is a Special Interest Group of the British Cave Research Association. Information sheets about the CSG are available. Please send an SAE or Post Office International Reply Coupon.

NOTES FOR CONTRIBUTORS

Articles can be on paper, but the preferred format is ASCII text files with paragraph breaks. If articles are particularly technical (i.e. contain lots of sums) then *Microsoft Word* documents (up to version 7.0) are probably best. We are able to cope with most common PC word processor formats. We are able to accept disks from other machines, but please check first. We can accept most common graphics formats, but vector graphic formats are much preferred to bit-mapped formats for diagrams. Photographs should be prints, or well-scanned photos supplied in any common bitmap format. It is the responsibility of contributing authors to clear copyright and acknowledgement matters for any material previously published elsewhere.

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The CAVE SURVEYING GROUP of the BCRA.

OBJECTIVES OF THE GROUP

The group aims, by means of a regular Journal, other publications and meetings, to disseminate information about, and develop new techniques for, cave surveying.

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courtesy of Doug Dotson, Speleotechnologies.

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THE CSG Web pages are at http://sat.dundee.ac.uk/~arb/CSG.html

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***Cover** : OFD. Plot generated by expanding Survex centreline, coloured by passage level, by Brian Clipstone. (It looks much better in colour than black & white!)*

Editorial

As you may well have seen by now the CSG has started to try and raise it’s profile a bit with an article in Caves and Caving. A piece in Descent will follow. We hope a few new members and contributors will come out of the woodwork and bring their ideas and projects to the group.

This is 20th edition of Compass Points which means we have now been going for 5 years. The Journal has been regularly produced over that time, and I hope you’ve found it all interesting. If there are things you’d like to see more of, then please tell the editor. We’ll see what we can do.

CSG Admin

If anyone particularly wants to join the committee you should apply in writing before the end of July. We’d really quite like some help, and it would be good to have a bit more variety in the group (i.e. not all ex-CUCC members!)

The existing committee is currently:

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

It would be especially useful if someone would step forward to be Treasurer or Secretary, as Andy has rather too much to do at the moment! This is a very informal group and we promise to be nice to anyone who volunteers.

Forthcoming Events

BCRA Conference - Hidden Earth

This is in Southport this year (see p10 for details). CSG will be holding it's AGM there, as usual, and will have a stand showing the latest software and the group's activities. We also intend to organise a Survey Salon like the Photo Salon for the first time. If you have any decent surveys then please send them to the organiser, Wookey. There will be separate classes for short and long caves if there are sufficient entries. Computer drawn surveys may also be entered.

Autumn CSG field Meet

The CSG will be holding it's first Derbyshire field meet on the weekend of the 17th/18th October based at the Orpheus Caving Hut.

All surveyors are welcome, novice or experienced. Training will be provided for anyone who wants it, and we expect to visit a few interesting caves or mines in the area, perhaps to see some of the unique problems of mine surveying, such as magnetic ores. We'd also really like to hear from surveyors in the area about anything they'd like to do or discuss.

Survey Software will be available for hands-on demonstrations, and a selection of instruments will be there for people to try out, including the better Suunto and Silva devices.

There is accommodation for 18, although this may be shared with other visiting cavers. Cost is £3.00 per night unless you are a member. The contact for this meet is Andy Atkinson (address in masthead).

SNIPPETS

GPS system improvements announced

The US government has announced that they will be upgrading the GPS system. They will be making 3 signals available for civilian use, as opposed to the one which is currently available. This will improve accuracy by allowing atmospheric effects to be eliminated by comparing signals at different frequencies. This, combined with the 1996 announcement that the artificial innacuracies introduced by 'selective avaialability' will be removed by 2006, will make GPS accurate to better than 10m, instead of the current 100m.

The existing military-only signal will be made available for civilian use by 2005, and a new, third signal will be added to the system at some point after that.

Wakulla II surveying device

The Wakulla Springs Project is developing a high-tech all-in-one surveyor, to deal with the problems associated with conventional underwater surveying being a slow business, which thus has a severe decompression penalty at the 100m depth typical of Wakulla.

The device will be mounted in a scooter, and uses an inertial guidance system, with backup dead-reckoning, to get a centreline. This is augmented by a sonar and DSP system to get wall distances. These will be taken at 5 degree intervals as the device progresses, giving a helical scan. All this data is logged to twin 2Gb drives.

The only catch with this marvellous device, apart from the cost? It's 1.9m long and weighs 140Kg, although that does include a free dive scooter. The Software is by Fred Wefer, who has been a proponent of digital cave mapping for years. The project is scheduled for October 1998, and it will be interesting to see how well this device works. You can see more on the web at:

`http://www.wakulla2.com`

Web Updates

- **NSS Cave Surveyors**

The US-based Survey and Cartographer Section (SACS) of the NSS now has a website which can be accessed from the NSS home page or directly

`http://www.cave.org/section/sacs`

The page includes information about the section, upcoming issues of Compass & Tape (section newsletter) ,and details about the 1998 NSS Convention SACS meeting, session and Cartographic Salon.

- **Cave Survey Software**

There is also a very good Cave Surveying Software site maintained by Jon Jasper at

`http://www2.wku.edu/www/geoweb/karst/survey_programs`

He has copies of all the readily available cave survey software and keeps the site very up to date. This does the same job as the CSG cave survey software page but is prettier, and gives a different viewpoint.

Toporobot for PCs

Toporobot has been at the forefront of Cave Survey Software for over 20 years now. Since the early 80s it has been Macintosh software, and thus not available to the ever-increasing number of people that have x86 PCs. In the last year this problem has finally been solved. A small company called ARDI have produced a Mac emulator, called 'Executor'. Despite not having Apple's blessing they have worked out how to emulate all the Mac toolbox functions on a PC. Martin Heller, Toporobot's author, was very pleased with this, as he finally had a solution for all those cavers who kept asking him if he was going to do a PC version. He worked closely with the ARDI team to sort out a few remaining problems, and now Toporobot runs perfectly on Executor. You will need a reasonable PC (preferably a Pentium of some sort) to run the emulator and Toporobot at acceptable speed.

You can get a Demo version of Executor off the net that will run for 10 minutes to get an idea what the software is like. Toporobot is also available free on the net, and Stefan Naeff maintains a page with details of how to use it with Executor.

Executor:
`http://www.ardi.com`

Toporobot:
`http://www.geo.unizh.ch/~heller/toporobot`

Stefan Naeff's pages: `http://www.datacomm.ch/~babsi/toporobot/index.html`

There is also Executor for Linux, so Unix people can run Toporobot too.

If you are feeling perverse it is even possible to run Executor on a PC Card in a RISC PC, and thus run Toporobot on your RISCOS machine, but it's pretty slow.

Compass Update

Larry Fish never rests, it seems, so this quarter sees yet more improvements in his Compass software.

1. CaveTools. There is now a wonderful new third party support program for COMPASS called CaveTools. CaveTools allows the ArcView GIS program to directly import COMPASS files. ArcView GIS is recognised as the leading desktop mapping and GIS software product from ESRI, Redlands, California, a leading vendor of GIS and mapping technology. ArcView is widely used worldwide for a variety of GIS and mapping applications. The conversion software has been provided by Bernie Szukalski a caver and employee of ESRI. As a result, CaveTools was designed specifically to meet the needs of cavers and it plugs directly into ArcView and become a part of the program.

2. Compiler and Viewer. COMPASS now supports the concept of "sections." Section are large blocks of surveys that have been grouped together into a single unit. A section may consist of single cave, a section of a cave or a surface survey. Once you have organised the cave into sections, you can then individually highlight, colour or exclude the sections.

3. Viewer. The Viewer now has depth bars that can be printed on the plots. There are six different modes of depth bar including: scaled, cave height, screen height, mono mode, colour mode and date mode. You also have control over the number of tick marks that appear on the depth bar.

4. Viewer. You can now optionally drag the cave into position with the mouse. This makes panning and positioning easier to do in some instances.

5. Cave Editor. The Editor has a new feature that allows you to modify survey heading information for large blocks of surveys. This means that you can modify the cave name, survey name, declination, instrument correction factors and survey team for hundreds of surveys at a time. The feature allows you to selectively search-and-replace, replace, prefix, and postfix.

6. Editor. The Editor can now cut, copy and paste large blocks of data. This makes it easy to copy and move large blocks of data both inside surveys, between surveys and between files.

7. Viewer. The "action multiplier" is now much easier to set. There is a drop box that allows you to select any of the multipliers with a single mouse movement. I have also cleaned up the status display so it easier to see what mode and view angle are active.

8. Viewer. The measurement tools now can be set to measure values relative to origin of the cave as well as absolute readings. This is useful when you are working with caves whose entrances are referenced to a UTM or other large values.

9. Editor, Loop Closer and Compiler. The Editor now accepts missing data items when you are doing backsights. The Compiler and Loop Closer can process missing data.

10. Compiler. COMPASS normally associates the LRUD information with the "From" station. The Compiler now has an option that can associate it with the "To" station.

11. Cave Editor. The Editor now supports Grads as an inclination measurement.

12. Editor. The Editor now can handle 300 shots at a time.

LETTERS

Geology for Surveyors

P.R.Cousins

In compass Points No. 18, Andy Farrant suggests that surveyors should collect more geological data as they work and subsequently include more geological information on their published surveys. However; I venture to suggest that whilst working as a professional geologist he has never had to collect the topographical data; always basing his work on an existing area map such as those provided by the Ordnance Survey!

I almost agree with Andy that Faults should be identified and shown on the survey; but in practise this can often be surprisingly difficult underground. As an example; the three metre throw of Waterfall fault in Southern Stream Passage of Agen Allwedd is very easy to determine as the passage here has cut in to the distinctive transitional beds below the Pwll-y-Cwm Oolite. However; about a kilometre away, between third and fourth chokes in the same cave is another fault. This time, although the displacement of strata is just as real and probably much greater, a match of corresponding beds has always eluded me.

Whilst it is true that caving geologists are a rare breed; the basic principle surely still holds true: Cave Surveyors should produce an uncluttered base map for all specialists to use. To be of real use to scientists this map must include all three elements of a good survey; Plan, Elevation and passage cross-sections. The full elevation data – typically neglected in the Grade IV plans of the 1960's – must always be provided if the survey is to be of use in a geological project.

In summary, cave Surveying requires long hours of meticulous work just to collect the basic centreline, passage outline, and cross section data. Diversions off route to evaluate geological clues are best left to a later specialist party when both elevation and plan co-ordinates have been computed and plotted.

Waterproof Paper

Bob Thrun

Cave mappers have problems writing on wet paper. One solution is "Rite-in-the-Rain" paper. This has problems in really wet caves, and does not erase well. I usually cross out numbers, but find I have to erase and redraw parts of my sketch. Incidentally, you can make your own waterproof paper from ordinary paper by using Scotchguard (R)

silicone spray. Some mappers use plastic drafting film. It is translucent, which can be a disadvantage because something white must be placed under the sheet. At last year's NSS Convention, someone showed a white plastic material meant for use in copiers. It was a clear sheet of plastic with a white coating on each side.

Unfortunately, it had been discontinued.

I recently found a better material, Xerox Never Tear Paper, intended for use in laser printers. This is not paper. It is a sheet of white plastic with a white coating on each side. Like most plastic sheet materials, it will tear if a cut is started with a knife or scissors.

I tested it with various types of pens and pencils. Ordinary pencil writes well, but can smudge off when wet. Ordinary felt tip pens are water-based and wash right off. The permanent markers will not wash off, but must go on dry. Ballpoint pens and inks for drafting film work well on dry sheets. I was able to write underwater with a bold Space Pen, but not with a fine pen. The plastic pencil leads meant for drafting film work very well, even underwater, and are smudge-resistant.

The material can be erased. More than one erasure in the same spot removes the coating and gets down to the white plastic base. The base can be written on, but the writing does not go on as dark and is more easily smudged than the coating, about like drafting film after erasing.

Since it is meant for laser printers, surveyors can make their own forms. I made a faint grid for sketching. The material is expensive, $12 for 20 sheets at a Staples office store.

Errors Due to a tilted loop - continued from page 12:

$$\tan(\alpha+\beta) \approx \beta \sec^2\alpha + \tan\alpha \qquad (1)$$

which, if $\alpha = 45°$, gives

$$\begin{aligned} \tan(45°+\beta) &\approx 2\beta + 1 \\ \tan^2(45°+\beta) &\approx 4\beta + 1 \end{aligned} \qquad (2)$$

which is not particularly inspiring, and so I'll leave the details for a future exercise.

One final point worth noting: Although stated in the past that a tilted loop implies that the null might not be as deep as it could be, this is probably a minor concern, given the effect of secondary fields on a good null.

Summary & Conclusions

We have proved a 'thirds' rule that says that the displacement of Ground Zero is a third of the axial displacement on the surface, due to a buried horizontal transmitting loop with a slight tilt. Another way of expressing this is that the ratio of Ground Zero error to true depth is ${}^1\!/_3\beta$ where β is the tilt in radians.

We have shown that this tilt gives rise to an error in depth determination when the method of measuring the field line angle is used. The error is complicated to express, but is given by equation 20 together with 13 and 16. Under normal circumstances this error seems to be of a similar magnitude (as a fraction of true depth) to the GZ error.

These results may not be of earth-shattering importance, as they only become significant for large depths; and it is usually easy to level a loop to much better than 5°. Other sources of error are likely to be more significant, such as measurement accuracy and effects due to secondary fields, as discussed in Gibson, 1996. It is, however, satisfying to be able to prove an observation made by practical experimenters, and to verify that loop tilt is not often likely to be a serious problem.

In a future article I will explore an important new method of depth determination utilising field gradient measurements.

References

Gibson, David (1996), *How accurate is radio-location?*, Cave & Karst Science, **23**(2), pp77-80, October 1996. (An earlier version of this article appeared in Compass Points **10**, pp5-9, Dec. 95).

Gibson, David (1997), *Cave Radio notebook. 16: The 'thirds' rule for radiolocation*, CREGJ **28**, pp23-3, June 97

Managing a large survey project - CUCC's experience in Austria

Andy Waddington

Abstract: Cave survey projects which deal with single long caves, large numbers of (potentially linked) caves in one area, or which extend over many years of changing personnel and improving technology meet with a variety of problems not seen in a survey of a short cave over a few weeks of exploration. This article identifies a number of the problems unique to large projects and suggests methods of mitigating their impact.

It is based on the authors' experience of managing survey data from CUCC's expedition area in Austria, where exploration has been continuing for a few weeks each summer since 1976. Technology and personnel have changed considerably over this period, during which a number of significant systems and many smaller caves have been explored. The methodology evolved is very dependant on the history of the project and the style of the exploration.

It illustrates just one possible approach to a large survey project and is offered in the hope of stimulating discussion and ideas, rather than as a "how to do it" manual.

Large Projects

What do we mean by a 'large' cave survey project ?

Essentially any cave survey where a surveyor cannot find or identify a previously used survey station from recent memory. This may be because personnel has changed and the surveyor hasn't been in the cave before, or because the station to be found was last used a long time ago and has been forgotten, or because the cave is so extensive that it exceeds what one person can remember. Thus, a project which seems 'large' to one set of surveyors may seem quite manageable to another set who are better at remembering the cave, have more time to carry out the survey in a single expedition, or who have experienced large projects before and start out on the right footing.

Background

In 1976, CUCC first visited Austria and explored caves on the Loser Plateau, an extensive area of limestone karren with few distinct landmarks, but rough enough to make navigation circuitous and difficult. Initially, a few small caves were marked and explored. Expeditions returned over a few years and explored more and deeper caves, some taking two or three years to finish, but mostly being pushed by the same people each year. In these early years, surveying was not regarded as a priority, and grade 1 elevations were often thought quite adequate.

In the early eighties, a very deep system, with several linked entrances, was explored, and a rather minimal survey produced (although we thought it was pretty good at the time ☺. After this system was 'finished', enthusiasm waned for Austria and expeditions became much smaller. In 1988, with mainly new people, an entrance was found which led to a cave which rekindled CUCC's enthusiasm, and which is still being explored today, at 22km long and over 500m deep. In 1988, no-one present really knew what they were doing, and it is something of a tribute to their keenness and imagination (!) that a survey was produced at all. In 1989, it was realised that such an obviously complex and extensive cave could not be explored without a good survey to guide future work.

CUCC's ability to produce good surveys stemmed from the stimulus presented by Kaninchenhöhle, but the learning curve was not too steep, and we had a great legacy of poor surveying from the previous decade. Managing the project became something of a nightmare as new surveys had to connect with those done whilst still low down on the learning curve, and the volume of data and number of unexplored leads increased.

New members join the expedition each year, most having not done any surveying before. Without any experience of drawing up and tying together surveys, new personnel find it difficult to understand why so much apparently irrelevant detail needs to be written down. Enforcing the high standards required is a problem for the survey 'managers', and relies on a transfer of skills to new people 'in the field'. It is very difficult to persuade newcomers to read a long and turgid 'how to survey' manual when there is so much else new to learn. Managers must spot problems and see that they are dealt with while the expedition is in the field, as there will be no chance to go back and correct problems later.

Despite this, CUCC are now managing to produce a respectable survey (in plan at least) of Kaninchenhöhle each year in time for the BCRA conference a month or so after our return to the UK. We are also managing to pull together old survey information from the early eighties, find errors and do new surveys to connect up and document caves explored years ago, many of which were not surveyed at all at the time.

Identifying the problems

There are four areas of difficulty:

1) those problems common to any survey, including small caves
2) problems which are unique to long and complex caves
3) problems which arise because of the timespans involved
4) problems caused by different groups working in the same cave or area

1) Common Problems

Most people who have done any amount of surveying at all will have met the problems in the first class. These include lack of calibration of instruments, sloppy recording, inadequate sketching, lack of cross sections, magnetic lights used near instruments, instruments incorrectly read (e.g. Gradient rather than angle for clinos), lack of motivation to draw up surveys until too late to check any errors found.

Although at first sight, one might imagine that a large survey project would avoid all these problems because of the past experience of the surveyors, this is not the case if most of the field work is carried out by people who have not surveyed before. On a typical expedition, maybe a third of the members (in some years far more than this) will not have been on expo before, and have probably not done any surveying at all. Often, another third may have done surveying on a previous expedition, but will not have been involved in drawing up, and will not have any feel for the problems that arise with poor quality data.

Every year, all the errors common to novice surveyors crop up. These need to be spotted quickly by the more experienced and if this is done, many can be corrected fairly readily, perhaps simply by writing down information which is known but has been overlooked, such as which instrument set was used. More often, a return trip is needed to add detail or check a suspicious reading. This can often be combined with the next exploring trip, and if these problems are spotted quickly, little effort need be wasted on repeat surveying trips.

2) Complex Cave Problems

The problems which arise specifically in long and complex caves are less amenable to easy solution. These fall into two subclasses:

a) problems which arise in the cave, such as an inability to find or identify previously used survey stations when passages are connected to ones not previously seen by the surveyors. In this context it should be noted that, apart from the occasional carbide mark, CUCC mostly does not mark survey stations and almost never labels them in the cave - identification is entirely reliant on good sketching and description. It is becoming increasingly likely that this will change in the future.

b) problems which only become apparent when the data are being reduced or the survey drawn up. These would include inadvertent duplication of station names (particularly likely when previously unconnected caves are included in one survey) or mistyping of connecting station names. Sketching of supposedly the same junction, seen from a different perspective, may bear no similarity to previous surveys. Although all these are possible in short caves surveyed by one team, they are far more likely in a complex cave or an area of connected caves explored by many different teams.

3) Time-span Problems

Problems which arise because of the time-span involved include all the above problems not being spotted in the year they arose, and the people who should be able to answer vital questions not being available or not being able to remember. ‘Data degeneration’ is a constant worry. Notes may be lost, books may be thumbed into illegibility, notes which seemed perfectly clear at the time are incomprehensible without the context in which they were set.

Meanings of names used for parts of a cave may change over time, leading to old data being misinterpreted. Things may simply not have been written down because they were common knowledge to those on the trip, but are a complete mystery to the current generation.

4) Multiple Group Problems

Finally, working in any area for a prolonged period will often impinge on exploration by other groups. Expedition caving within Europe is especially prone to this and there may be no contact with the other clubs involved. Indeed, CUCC laboured for many years under the illusion that no other groups were working in ‘our’ area at all, an idea that seems ludicrous now. Exchanging survey data with groups when there is no direct contact is almost impossible. When compounded by long time-spans, the problems are almost insoluble - maybe the best you can hope for is to get copies of drawn-up surveys of caves explored by others. These can be extremely difficult to integrate into one's own group's survey data.

Solution strategies

Problems in classes 1-3 are all amenable to solution through two main approaches: training and management. Project management is all about deciding what needs to be done and ensuring that it happens. Training is all about ensuring that surveyors know what needs to be done and how to do it. It follows that many of the important aspects of training cannot happen if there is no overall management to decide what needs to be done.

Management itself can be split into:

- Management of the existing data and integration of new data as it is brought back ‘from the front’ and
- Management of the surveyors, by which we mean ‘in the field’ direction (making sure people actually survey what they find) and ensuring that standards are being maintained.

These aspects do not have to be carried out by the same person - indeed, a lot of the data management takes place back in the UK, whilst all the survey direction occurs on the expedition.

Training can be divided into:

- What to do in the cave and afterwards - what data needs collecting, how to ensure it is useful, how to make sure it is not lost, how to get it into a computer etc.
- Why it needs doing. This may not seem immediately relevant, but university caving clubs are filled with intelligent people who are not mere ‘cannon fodder’ and won't do what you want just because you have written a tedious surveying manual saying what that is. It is only by exposing people to the problems which arise from inadequate recording that they understand the need, and will become more motivated to actually go out and do the job properly.

Ideally, both of these aspects should be addressed before surveying ‘for real’ in cave that matters. However, in the ‘real life’ of expo caving, this rarely happens.

CUCC's approach

CUCC have something approaching a ‘system’ which has evolved piecemeal over the last ten years. Part of this evolution has been co-evolution with the survey processing technology (which, of course, is still continuing).

Part of this evolution has been fire-fighting specific problems as they occurred. Mostly this has meant dealing with intractable problems in old surveys and adding more bits to the ‘how to do it’ manual to ensure that the problems don't arise again. When they (inevitably) do arise again, the advice is modified until it works.

Three possible approaches to surveying are common:

(1) Survey as you explore

(2) Survey later, but survey what you found

(3) Surveying done by a dedicated team.

The last approach minimises many of the problems of large surveys, but fails unless you have a number of people who would rather survey than explore – a rare situation. The first approach is most useful in mainly horizontal cave where little effort is expended in bolting and rigging. Caves in our area of Austria are mostly cold and vertical and this approach is not practical most of the time.

The method that CUCC has evolved is based on ‘survey what you find’. The often-vertical nature of the caves, together with low temperatures, tends to militate against surveying into virgin ground, so pushing teams are encouraged instead to survey what they find before pushing further.

Sometimes this will be on the way back from the push, but there are problems with this and more commonly, the survey will be on the next trip, often in parallel with another team pushing ahead. This tends to avoid teams exploring more than they can survey without missing their call-out, which can lead to hanging surveys, rushed and inadequate surveys, or missed call-outs which can lose everyone a day's caving.

First: get good data in the cave.

This is not directly under the control of the person(s) managing the project, so depends on getting those doing the work to do it properly, and being able to identify cases where they have not. Like management in any endeavour, this depends on motivating people to do well, and ensuring that they know how to do so.

The more quickly survey data can be turned into visualisable cave survey and used to direct new exploration, the more valuable it will seem to those at the front end and the more likely it is that errors will be spotted. Having those people draw up their own data into something that looks like a ‘finished’ survey serves the dual purpose both of getting the drawing done quickly, and enabling the surveyors to experience directly any difficulties which their surveying methods cause the survey drawer. Seeing the problems themselves is much more constructive than any amount of criticism from a ‘project manager’.

Through surveying with more experienced members, exhortation, and by reading a detailed ‘surveying guide’, people are encouraged to do calibration, and to gather high quality data in the cave, with good notes, sketching of both plan and elevation, cross sections wherever the passage changes, LRUD data and detailed descriptions of survey stations. Since small sheets are used in the cave to avoid them becoming too muddy over many legs, it is essential that the note-taker concatenates the sketches into a bigger (and clean) survey book at the earliest opportunity.

This is best done using a printed centre line derived from the survey data, so the first step is to get the survey data into the computer and linked to the rest of the survey - we are increasingly trying to define standard methods of doing this to make dataset maintenance less of a nightmare – see later. A centre line is printed out, both for plan and elevation, and the sketch is redrawn, accurate to scale and direction. Often this will result in any blunders being spotted in time to correct them on the next trip while memories of station locations are still fresh. At this point the original notes are put in an envelope, stored securely *and not taken underground again*.

Ideally, a passage description should be written at this stage, which helps to clarify anything un-obvious on the survey, and defines the scope of passage names. Any survey points that may need to be found again should be clearly documented.

At this point, the main advantages of the approach become clear:

The combination of the full drawing and the centre line linked to rest of the cave on the computer screen is now available to clarify relationships either with other passages, or with potential blanks on the map. This helps to direct further exploration, and is a powerful motivating force for the surveyors.

Any blunders, ambiguities or inadequacies in the data which can be detected by processing or drawing up will have been spotted, and if the survey was not done on a derigging trip, there is still time to go back and sort them out. If this was not the case then, at best, such errors could not be fixed until next year, at worst, no-one may ever go back to those passages.

The surveyors quickly see all the steps involved in producing a survey, except the final assembly into the huge published survey. This tends to produce a much steeper learning curve in the novice surveyor, resulting in fewer poor surveys, less trips to resurvey, and more time spent exploring new passage !

Most of the work is done before expedition personnel disperse, making it possible to produce a draft survey in time for the BCRA conference (typically a month after the end of the expedition). It helps to avoid the situation of phoning people up late at night asking them about minute details of trips that they did ten or more years ago (which still happens, since this system wasn't in place ten years ago)

Managing the survey data - using Survex effectively

The software CUCC uses is Survex, which has the unique advantage of running on a variety of platforms, and thus being available whatever computer the expedition manages to scrounge. Survex was designed to cope with a wide variety of surveying styles, but this means that it does not enforce any rigid structure for the data on its users. As the complexity of a project rises, it is important that those who will be responsible for maintaining the data choose a structure, and that new survey data is entered using this structure. Whilst cave survey programs are designed to cope with almost any level of complexity likely to be met, the human users of the data need a little organisation to keep track.

One obvious idea is to keep surface surveys and underground data separate. This has particular advantages when using CaveRot to view the survey. If many small caves are linked by surface traverses, it makes sense to keep each cave in a separate file, or, for longer caves, group of files. Within the files, each survey (i.e. a set of legs done by the same people on the same trip in the same area of the same cave) has its own prefix. This needs to be unique within either the whole cave, or within any area of the cave which is grouped together under one prefix. Thus both caves 161 and 182 have surveys called "entrance", with survey stations 1 and 2, but these are kept unique by the system of prefixes which ensures that there is no clash between 161.entrance.1 and 182.entrance.1. To avoid huge directory listings, logically associated files can be grouped into subdirectories, more for the convenience of the maintainer than for Survex itself.

The structure which is currently in use on Loser has a base directory which contains all of our existing survey data from the last two decades. One or more ‘controlling’ files will use `*include` directives to call up whichever of the individual survey files are required to build a particular survey view. This works at every level - thus all the surveys of the cave 161 are in a 161 subdirectory, which itself contains a controlling file to include all the 161 surveys, which are, in fact, grouped into several areas of the cave, each in turn with its own subdirectory and controlling file. The structure is shown in Fig 1.

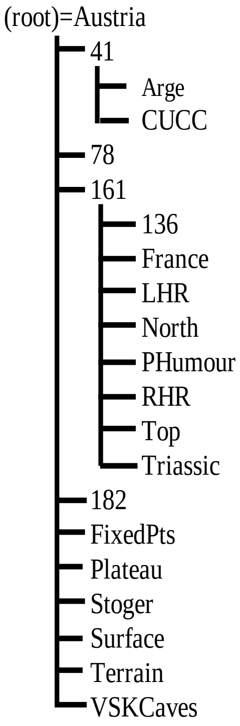

Figure 1

The cave 41 (Stellerweghöhle) has various entrances, one of which is being explored by another group (Arbeitsgemeinschaft Höhle und Karst Grabenstetten e.V (ARGE)) who are also doing some resurvey work in passage explored both by CUCC and yet another group. Their survey data is kept in a separate subdirectory from CUCC's own data.

The cave 161 is our longest and most complex, but splits fairly neatly into a number of areas, each of which link to one another at a fairly limited number of points.

The FixedPts directory is used to contain location data which are inputs to the cave and surface surveying process, such as positions from a map, GPS fixes, and high-quality survey benchmarks fixed by much more accurate methods than those used for cave surveying. It is regarded as important that this sort of data be gathered together and not distributed through the survey data where it would be harder to find and maintain.

The Surface directory contains all the surface surveys.

The Terrain directory contains various representations of the surface terrain above the caves in our area. This includes digitised contour data and a digital elevation model on a 50m grid.

Small caves are grouped into three directories Plateau, Stoger and VSKcaves depending on which area they are in.

In the context of this structure, there is still scope for users to generate difficult to maintain datasets, either through ignorance of the ‘right’ place to put new data, or through failing to put sufficient detail into the computer file when typing up. The latter can occur because more information is needed to keep the datasets easily maintainable than is needed by the survey software itself to compute a centre line. One approach to this has been to provide a number of ‘template’ data files in which it is made more obvious that information is missing because partly filled-in lines show where details are needed. Perhaps a more effective methodology would be to use a data-entry program which insisted that various fields be filled in before proceeding. However, this would defeat the very flexibility of Survex's easily editable plain-text input format, and might discourage users from adding comments providing information which the data-entry program didn't insist on. Currently we rely mainly on there being someone at base camp who knows what they are doing, and who can provide advice and assistance when needed. This is not a single person - the role is filled by whichever of several people may be available.

The system which is being tried this year is to have a section of the data in which stations which are expected to be found again are specifically identified. Adding this information to the existing dataset has been a long and tedious task, but has had the benefit of finding a number of errors which would otherwise not have been detected, as well as highlighting many cases where better description of the stations would make life easier in the future.

The future

It remains for this year's expedition to demonstrate that this newest part of the system can be worked on ‘live’ data as it is incorporated. This is very much an evolving area of ‘the system’, which is also being influenced by the potential need for more ‘structured’ data which will be needed for the next generation of visualisation tools, such as ‘Tunnel’ (see article in Compass Points 16). As always, surveying techniques and protocols are co-evolving with advances in computing and surveying technology.

Areas where existing data are deficient include detailed sketching on surface surveys, and permanent, identifiable marking of survey stations. It is hoped that the former will be amenable to the same techniques of management and training that have so much improved underground surveying over the last decade. Marking of entrances and surface survey points is evolving, partly in the light of a prohibition on using paint marks on the surface. We are now using stamped metal tags bolted in place to mark entrances and major surface points, and may perhaps use the Easegill resurvey technique of using plastic tags (actually intended for identifying cattle ☺ for important underground points. These would be marked with a unique serial number in advance (to avoid the risk of duplication) and would be related to the run-of-the-mill station names by means of the Survex `*equate` directive.

A more detailed account of the methodology in use can be seen in the surveying section of CUCC's expedition handbook on our website (and of course on expedition computers). The full CUCC Austria survey has been available as an example dataset with releases of Survex and it is likely that the recently ‘fettled’ version will be made available soon (it isn't quite finished yet, but will have to be finalised before mid-June). I'm hoping to incorporate it into the surveying guide itself, which currently contains an index to all the data with references to all the paper documents and names of (but no links to) all the survey files.

Start at `http://www.chaos.org.uk/cucc/Expo/Handbook/Survey/OvView.htm` for the expo surveying guide, including

`http://www.chaos.org.uk/cucc/Expo/Handbook/Survey/SvIndx.htm` for the index to the data.

Cave Surveying at 'Hidden Earth 98'

*This year's National Caving Conference – **Hidden Earth '98**, hosted once again by the BCRA, will take place on the weekend of 18-20th September. Here are details of the Surveying Competition, and the Arthur Butcher award. Report compiled by **David Gibson**.*

Surveying competition

As usual, Juan Corrin will be organising a competition to test your skills in surveying caves. Contestants, working in pairs, are required to survey a short, undulating course outside the conference building, The course will have previously been mapped out, and it has the same start and finish point. The survey data will be processed on a computer and the winners will be the couple who manage the loop with the smallest misclosure error. Easy! Some thought and care is needed however, as many of the courses in previous years have been affected by reinforcing rods in buildings, sign posts, etc.

The prizes have been very worthwhile including compasses, light sticks, Fibron tapes and free advanced surveying lessons. The competition will be open from 10am on Saturday until 2.30pm on Sunday and you can enter by presenting yourself at the Matienzo stand. Surveying equipment is provided. Most contestants manage to complete the course in about twenty minutes. Try out your surveying skills on the surface - you may win a prize!

The Arthur Butcher Award

This is presented by the BCRA for, broadly speaking "excellence in cave surveying". As well as a prize, there is a trophy to be kept for a year. If you or your caving club want to be considered you should make yourself known to the judges. You would usually do this by displaying your surveying work at the conference. If this is not possible, you should inform the judges (by writing to the Conference Secretary, Peter Cousins), and submit the material in advance – see rule 6 below.

Rules

The Award will be made at the National Conference ...

1. ... to any one person or a nominated person from a group of surveyors, club or expedition.
2. ... 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.
3. ... by a panel of three judges approved by BCRA Council.
4. 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.
5. 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.
6. The judges will consider any cave map, published information, or other material that is displayed at the National Conference or submitted prior to the Conference. They will take into account a range of factors – effort and enthusiasm will be considered alongside skill, accuracy and presentation.
7. A copy of the award-winning material shall, if appropriate, be retained in the BCRA library.

[Rules revised for 1997. See also Caves & Caving No. 41 (1988) and No 60 (1993)]

Previous Winners

1988 Dave Ramsay and Arthur Millett for the Llangattwg cave survey

1989 University of Leeds Speleological Soc. for effort put into cave surveying.

1990 Colin Boothroyd on behalf of the Mulu expeditions for the Clearwater/Blackrock cave map

1991 Dave Irwin for perseverance with the St Cuthbert's Swallet survey

1992 Cambridge University Caving Club for contributions to the theory and practice of cave surveying

1993 Juan Corrin for continued service to cave surveying.

1994 Steve Neads, for his survey of Box Mines, and his Cave Surveying software

1995 Chelsea Speleological Society, for the club's strict adherence to Grade 5 standards; and for John Stevens' development of computer survey software.

1996 Brian Judd, for innovative use of multimedia in his computer presentation on the China Caves.

1997 not awarded – see below.

Calling all Cave Surveyors!

Last year, the judges reported that they were disappointed at the small number of new surveys and surveying projects that were available to be considered for the award. After much discussion it was a majority decision not to make an award for 1997/8. There were a couple of ongoing projects that were given serious consideration but both had already received the award and the majority of the judges felt that it was too soon to award it again.

It has already been commented in *Compass Points* that this award does not seem to have a high profile – so if you have any projects worthy of consideration please let BCRA know, and please come along and display your surveys at the conference.

A Cave Survey Salon?

Wookey has suggested (CP **2**) that a proper 'salon' for surveys, similar to the photo salon, would be a good idea, with the judges commenting on the surveys during the closing ceremony. This may help to improve overall standards, and show people what is achievable. A separate award for "best survey" has also been suggested.

BCRA have always said that they will give extra prizes *ad lib* if there is sufficient reason (and sufficient sponsorship!) so this should be a good incentive for members of the Cave Surveying Group to organise a display. It doesn't even have to be done officially by the CSG – anyone can book a club stand or poster space. Don't forget to bring your own computer if you want to display an electronic survey or a multimedia package (but please let the organisers know in advance). If enough good quality surveys are displayed, then you never know, a prize might be forthcoming!

he98@caves.org.uk

Hidden Earth '98

The National Caving Conference will take place from 18th-20th September at the newly refurbished Floral Hall Complex, Southport, in the north-west of England. Once again, BCRA are pleased to host this event for the benefit of all cavers. There are discounts on advance bookings from Groups and Students.

Trade & Club Stands ♦ Photography, Video & Art Salons ♦ Late Bar & "Stomp" ♦ Lectures & Discussion Groups ♦ Surveying Competition ♦ SRT Races ♦ Field Trips ♦ SRT Training

General Enquiries / UK Bookings: Peter Cousins,
8 Giffords Croft, LICHFIELD, Staffs., WS13 7HG
Tel: (01543) 251791

Offers of lectures to: Paul Mann,
57 Argyle Street, OXFORD, OX4 1ST
Tel: (mobile) 0467 702263 paulmann@compuserve.com

Official delegations from overseas caving clubs should contact us well in advance so that we can make arrangements for your admission & accommodation.

International Liaison: Nick Williams, The Hall, Great Hucklow, BUXTON, Derbyshire, SK17 8RG. Tel. +44 (1298) 837800, fax +44 (1298) 837801. nick@conformance.co.uk

www.caves.org.uk

Radiolocation Errors Arising from a Tilted Loop

***David Gibson** analyses the errors in depth and Ground Zero that arise if an underground transmitter loop is not precisely levelled for radiolocation.*

Introduction

In CREG journal 28 (Gibson, 1997) I quoted the “thirds” rule for radiolocation, which describes how an error in Ground Zero can occur if the radiolocation transmitter loop is tilted. I invited people to send in a proof of this rule. As I reported later, the only entrant, and therefore the prize-winner, was Olly Betts.

Not only Ground Zero, but depth measurement is also affected by a tilted loop, as I will explain in this article, which also contains a description and proof of the “thirds” rule.

The “Thirds” Rule

In my articles on the accuracy of radiolocation I discussed the error that was introduced by the underground antenna not being horizontal. Figure 1 shows the field lines from a loop that is tilted by an angle β (which is exaggerated in the diagram). The axis of the loop, *QX*, when projected as far as the surface, will be displaced from ground-zero (*O*) by a small amount. For example, if β is 5º and *D* = 50m then the displacement is around 4.4m.

Because of the curved nature of the field lines, the line that is vertical as it leaves the ground will be displaced by a smaller amount than the axial field line. This can easily be seen from Figure 1 where a curved field line leaves the ground vertically at *W*. Since it is this vertical field line which is used to determine ground-zero, the error in the measurement of ground-zero will not be as great as *OX*. In fact, for small values of β is it exactly a third as much. In other words, *OW* = $^1/_3$*OX* – ***the apparent Ground Zero is a third of the axial displacement from true Ground Zero.***

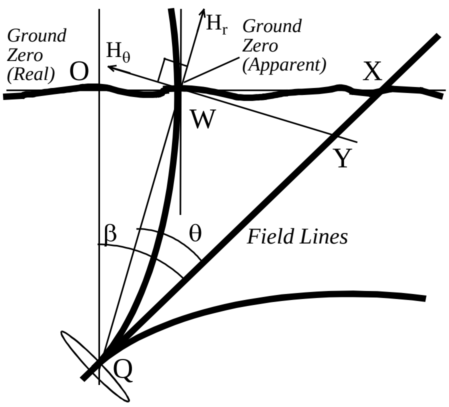

Figure 1 – field lines from a tilted loop.
The apparent ground-zero (W) is 1/3 the displacement (X) from true ground-zero (O)

As far as I know, this had not been published as a proven fact prior to my article on radiolocation errors (Gibson, 1996). I have referred to it as the “thirds” rule. Brian Pease brought it to my attention as an observation he had made but not proved.

Proof [1]

The radial (*r*) and transverse (θ) fields from a quasi-static magnetic dipole are known to be

$$H_r = \boldsymbol{M}\frac{\cos\theta}{2\pi r^3}, \quad H_\theta = \boldsymbol{M}\frac{\sin\theta}{4\pi r^3} \qquad (3)$$

where θ is measured from the axis of the loop, *r* is the distance from the loop and ***M*** is the dipole moment.

The radial field at point *W* is in the direction *QW* and the transverse field is at right angles to this, as shown in Figure 1. The angle between the radial field and vertical is β-θ so the overall vertical field is

$$H_v = H_r\cos(\beta-\theta) + H_\theta\sin(\beta-\theta) \qquad (4)$$

and the horizontal field is

$$H_h = H_r\sin(\beta-\theta) - H_\theta\cos(\beta-\theta) \qquad (5)$$

The condition we require is that the field is entirely vertical; i.e. $H_h = 0$ so from (5)

$$\tan(\beta-\theta) = \frac{H_\theta}{H_r} \qquad (6)$$

and from (3),

$$\tan(\beta-\theta) = \tfrac{1}{2}\tan\theta\,, \qquad (7)$$

If angles are small, then tan*a* ≈ *a*. This is correct to 1% if *a* < 0.17rad, or 9.7°. We can therefore write

$$\beta-\theta \approx \tfrac{1}{2}\theta \quad \Rightarrow \quad \beta-\theta \approx \tfrac{1}{3}\beta \qquad (8)$$

Using the approximation for small tangents it is now trivial to show that this implies that distance *OW* is a third of the distance *OX* – which is the result we are looking for.

It is useful to express this error in Ground Zero estimation as a fraction of the loop depth below the surface. Referring to figure 2 for the definition of *x* and *d*,

$$\frac{\textit{error in } x}{d} \approx \tfrac{1}{3}\beta, \quad \beta < 0.2\text{rad} \qquad (9)$$

where β is measured in radians. With β in degrees we would have

$$\frac{\textit{error in } x}{d} \approx \tfrac{1}{172}\beta^\circ, \quad \beta^\circ < 10^\circ \qquad (10)$$

Radiolocation formula

This is a suitable point to explain the derivation of the standard radiolocation formula, which has been quoted by many people. Let α be the angle that the field line makes with the ground, *x* be the distance to ground-zero and *d* be the transmitter depth below the surface (see Figure 2 below).

If the loop axis is vertical, so that β=0 then we can uses similar expressions to those in the previous section (allowing for a slight change in geometry) to write

$$\begin{aligned}\tan\alpha &= \frac{H_v}{H_h}\\ &= \frac{H_r\cos\theta - H_\theta\sin\theta}{H_r\sin\theta + H_\theta\cos\theta}\\ &= \frac{2\cos^2\theta - \sin^2\theta}{3\sin\theta\cos\theta}\end{aligned} \qquad (11)$$

Dividing throughout by $\cos^2\theta$ gives

$$\begin{aligned}\tan\alpha &= \frac{2-\tan^2\theta}{3\tan\theta}\\ &\Rightarrow \tan^2\theta + 3\tan\alpha\tan\theta - 2 = 0\end{aligned} \qquad (12)$$

which is a quadratic in tanθ that we can solve to give

$$\tan\theta = \frac{\sqrt{\left(8+9\tan^2\alpha\right)} - 3\tan\alpha}{2} \qquad (13)$$

in which we choose the correct sign of the square root, to give a sensible answer, and we note that

$$\tan\theta = \frac{x}{d} \qquad (14)$$

1 My version of this proof differs slightly from Olly Betts’, in that it is based on a more fundamental expression of the fie

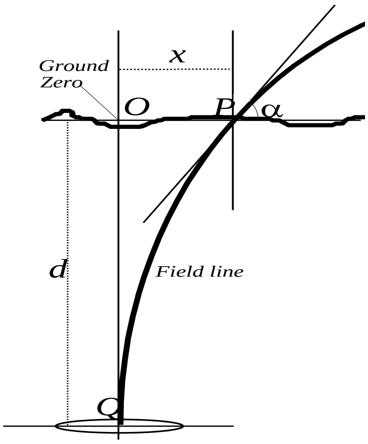

Figure 2 – depth determination with a horizontal loop

Depth error due to tilted loop

We have already seen that a tilted transmitter loop leads to an error in Ground Zero. It is now interesting to investigate the effect a tilted loop has on this depth estimation. The algebra is somewhat tricky, so it is best to begin by giving an example.

Example

Suppose the loop is 50m underground and it is tilted by 5° (0.087rad). What do we actually measure?

The 'thirds' rule, as stated in equation 9, tells us that Ground Zero will be in error by 2.9% of the loop depth, which is 1.45m.

Now suppose we do the depth measurement in the usual way, by finding the distance at which the field angle is 45°, for which we know (from equation 13) that $x/d \approx 0.562$. If the loop was absolutely level then we would expect to measure x = 28.1m, and so we would obtain the depth as 0.562 ÷ 28.1 = 50m. When we measure the field line to be 45° from horizontal we will, because the loop is tilted by 5°, be looking the 'wrong' field line. We will not know this, of course, because we will be assuming that the loop is horizontal.

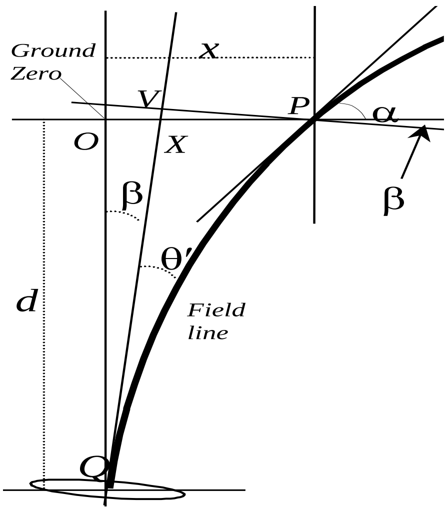

Figure 3 – depth determination with a tilted loop

Within our tilted frame of reference the angle we should, in fact, be putting into equation 13 is α+β, i.e. 50°. This gives a value for tanθ′ of 0.492, where the prime denotes that θ was derived from the tilted loop. Tanθ′ is ***not*** now x/d because the field lines are tilted. Instead, it is VP/QV as shown in Figure 3. (For clarity, Figure 3 does not show W, the apparent Ground Zero).

We noted earlier that for small a, $\tan a \approx a$. Similarly $\cos a \approx 1$ so we can say that $QX \approx OQ$, $VP \approx XP$, and we can go on to derive

$$\begin{aligned} x &\approx OX + XP \\ &\approx d(\beta + \tan\theta') \end{aligned} \qquad (15)$$

In our example, d = 50m, β = 0.087rad and we have just derived tanθ′ = 0.492 so we know from this equation that x/d = 0.579 and x must be 29.0m.

At this point you may be getting a little lost – what we have shown is that the *real* value of x is 29.0m. However, because Ground Zero is displaced from O by 1.45m we will actually measure it as 29.0 – 1.45 = 27.5m. Because this is in error it will affect our derivation of the depth, but the depth error is further complicated by the error in α. When we measure the field line angle, we assume that the loop is completely level and so we assume (with α = 45°) that x'/d' = 0.562. Using the measured value for x' (to the displaced Ground Zero) of 27.5m this gives an apparent depth d' of 48.9m.

The error in GZ causes us to underestimate d but, due to the tilt, x' is larger than we would expect. This compensates to some extent, so the error is less than it would be.

Formula

We can encompass the above example in the following set of formulas. The apparent depth d' is given in terms of the angle of the field line α that we measure at a distance x' from the apparent GZ.

$$\tan\theta' = \frac{\sqrt{\left(8 + 9\tan^2(\alpha+\beta)\right)} - 3\tan(\alpha+\beta)}{2} \qquad (16)$$

(in the example, α=45°, β=5° and so tanθ′=0.492). We have seen that

$$\frac{x}{d} = \beta + \tan\theta' \qquad (17)$$

(in the example, with β=0.087rad this was 0.579). But we do not know x, mistaking x' for x, and working out the depth with

$$\frac{x'}{d'} = \tan\theta \qquad (18)$$

(in the example this was 0.562) In addition, we know the error in x to be

$$x - x' = \tfrac{1}{3} d\beta \qquad (19)$$

(In the example, with d = 50m this was 1.45m), and so, from these three equations, we can express the ***error in depth determination*** as

$$\frac{d' - d}{d} = \frac{\frac{2}{3}\beta + \tan\theta'}{\tan\theta} - 1 \qquad (20)$$

Verifying this for the example given earlier, the fractional depth error is

$$\frac{\frac{2}{3} \times 0.087 + 0.492}{0.562} - 1 = -2.1\% \qquad (21)$$

which, with a depth of 50m, is 1.1m, as we obtained before.

Comment

We would not normally operate with 5° of tilt but, if we did, the errors in GZ and depth would still only be 2.9% and 2.1% which, for a depth of 50m, are 1.45m and 1.1m. Whether you consider this to be serious, or just an academic observation probably depends on your circumstances. The errors will be proportionately smaller for shallower depths or smaller amounts of tilt.

It is worth noting that if we do the measurements with α = 18° then tanθ = 1 and (for β=5°) tanθ′ = 0.914; the depth error increases only slightly, to 2.8%. On the other hand, a shallow angle for α might lead to other inaccuracies.

Any further insight into the depth error is difficult because it is tedious to try to simplify the tanθ′/tanθ expression. Since β is small we can derive

continued on page 5…