Proc. Univ. Bristol Spelaeol. Soc., 2013, 26 (1), 27-36

A NEW SURVEY OF GOUGH'S CAVE, CHEDDAR GORGE, SOMERSET

by

G.J. MULLAN and A. ATKINSON

ABSTRACT

A wholly new survey of Gough's Cave is presented. This was carried out using a variety of different techniques, including magnetic and non-magnetic measurements and different methods of data collection. The resultant survey has been presented in a number of different ways, on paper and on computer.

INTRODUCTION

The authors have been involved in building a comprehensive model of the caves of the Cheddar catchment as an aid both to exploration and to the understanding of their geomorphology. Gough's Cave, the major show cave situated at the downstream end of Cheddar Gorge, close to the risings is clearly a key component of such a model. The show cave has been surveyed three times in the past, by C.H. Hayes in 1935. by the Stride Brothers and Manning in 1948 (Stride and Stride, 1951) and by W.I. Stanton in 1952 (Stanton, 1952). The extant copy of the Hayes survey comes from the archive of the late D.J. Irwin and is believed to be that carried out at the instruction of Lord Weymouth and briefly mentioned by Stride and Stride (1951). Irwin's copy has been annotated in pencil at a later date, but the version given here as Figure 1 has been restored to its original state. Although it is known that more of the cave was surveyed in the 1930s than is shown on Hayes' plan, no drawings were published at the time and neither the data nor the drawings of this work seem to have survived (Balch, 1935). Stanton's 1952 survey was republished with minor changes as part of his larger survey of the caves of Cheddar Gorge in 1965 (Stanton, 1965).

All subsequent published maps have been based on Stanton's survey with various additions showing new discoveries, see for example Farrant, 1991, but have been to a greater or lesser extent schematic. The significant discoveries made by diving in the 1980s were all mapped at the time, but doubts have been cast on some of the data collected then, both by subsequent divers and by the original explorers themselves. Stevenson, for example, has cast doubts on the accuracy of his own survey of Bishop's Palace, between sumps one and two (*pers comm.*).

The modelling referred to above requires original raw data to be available, rather than just drawings. Although Stanton had made his available to us, before his death, it unfortunately proved impossible, nearly sixty years on, to identify his fixed survey stations on the ground with any degree of certainty and thus to tie his work to surveys of later extensions. A number of modifications have been made to the cave in the ensuing period as well. It was thus decided that a complete re-survey was required.

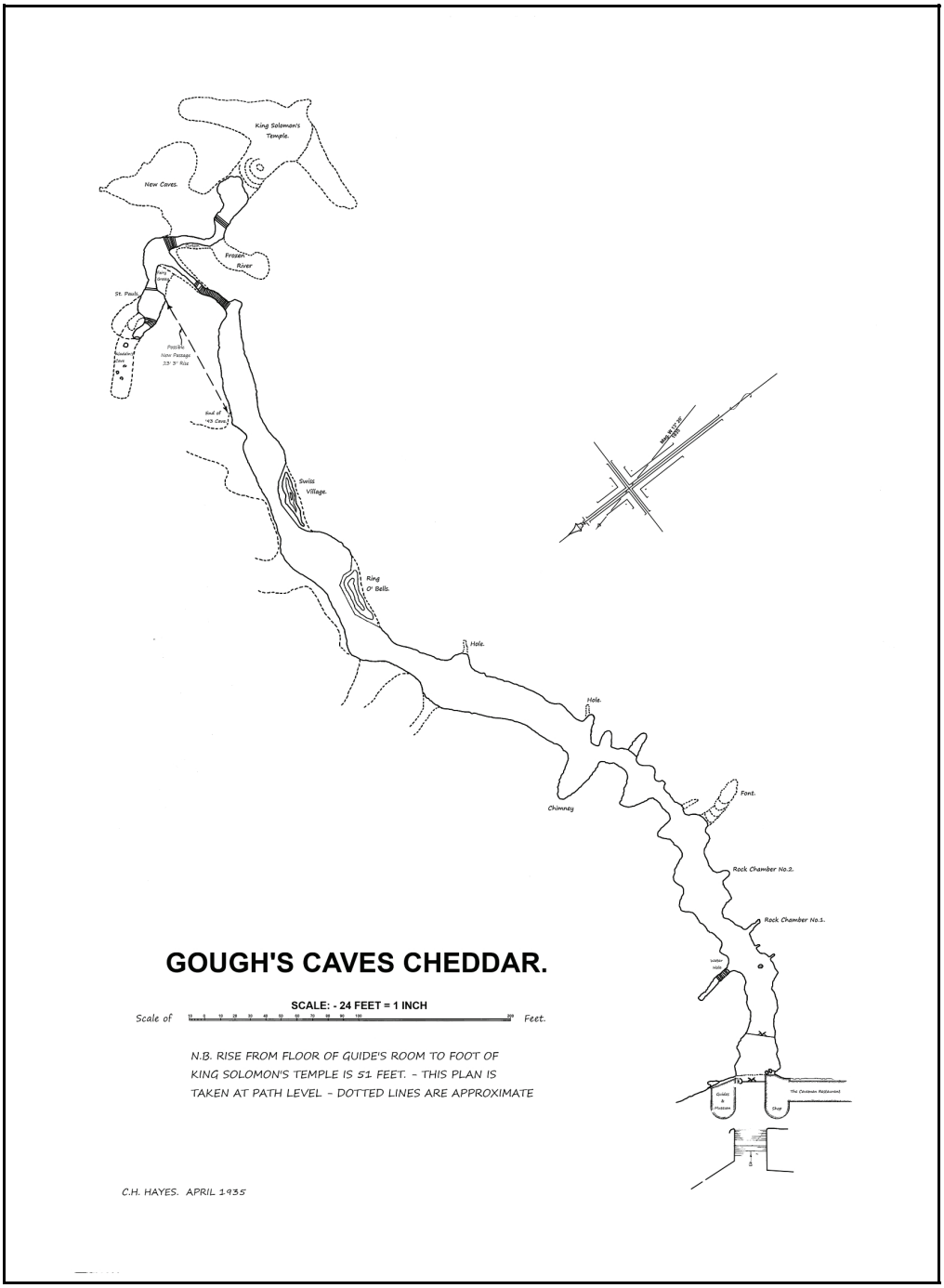

Figure 1. *C.H. Hayes' 1935 theodolite survey of Gough's Cave.*
Redrawn for publication by G.J. Mullan.

TECHNIQUES

The Show Cave - magnetic survey.

Show caves can present a particular problem to the surveyor in that they generally contain significant amounts of iron work, as handrails and, sometimes, stairs and electrical fittings. It was thus necessary to run a test loop to verify whether magnetic surveying would be possible. This test showed that it could be done successfully using magnetic instruments but only when the electricity supply was turned off. It was thus necessary to undertake this part of the work during the evening, when the show cave was closed. In addition, the "paperless surveying" technique (http://paperless.bheeb.ch/), enables the surveyors to keep track of the data as it is collected and remain aware, whilst working, of any problems arising from proximity to either live electrical cabling or significant amounts or ironwork. Interestingly Stanton (1979) had commented that the concrete floors of the show cave contained too much steel reinforcing for magnetic surveying to be possible anywhere in the show cave but we did not find this to be a problem, although we doubt that large amounts of reinforced concrete have been removed since 1979. The technique used is quite rapid, as well as being of good accuracy. It uses a DistoX, a modified Leica A3 disto meter which as well as measuring length also measures inclinations and magnetic bearings. Survey legs between stations and offsets to passage walls and other features are all measured. This information is passed via a "bluetooth" wireless connection to a handheld computer. The data can be displayed on screen both in tabular and pictorial form and, using a stylus, the latter can be used as the basis for a drawing begun at the time the fieldwork is done. This ensures that any blunders and systematic errors can be picked up immediately, improving both the speed of working and the accuracy of the finished survey. This method was used both in the show cave and in the extensions to the cave that are above water.

The Show Cave - Total Station survey.

In two areas of the show cave, where there are flights of steps, the iron handrails cluster quite closely together and it was found that the magnetic instruments became unreliable. It thus became necessary to use non-magnetic methods to measure angles. In 1948-50, the Society used such techniques in the survey of G.B. Cave, also part of the Cheddar catchment (Bendall and Crickmay, 1950). This same instrument is still in the Society's possession, but we chose instead to use a modern Leica 'total station' as its laser sighting allowed greater speed and accuracy as well as the same straightforward collection of passage dimension data. All the data was entered directly into the handheld computer as well as being recorded on paper, so that the drawing could be begun in the cave, as with the magnetic survey.

The technique is a simple one. The instrument measures the angle between one survey leg and the next and this is converted to a bearing by reference to a base, magnetic, leg at the start of this section of survey. The instrument also measures inclination and leg length, the latter by using similar laser technology to the Leica disto.

The sump survey.

Sump 1a was re-surveyed from Dire Straits in 2011. New tagged guidelines were placed marked at 5 m intervals. Depth and passage cross-sections were taken at every tag and also at changes in direction (line belays) when the heading was also noted. A diving compass

was read to the nearest 5°. Passage dimension data has been collected by measuring splays to the left, right up and down from the relevant point using a Vexilar LPS 1 sonar wand. The sonar wand reads to ± 0.1 ft (approx. 0.03 m). Sump 1b and sump 2 were surveyed during 2005 from Lloyd Hall with distances determined using a tape measure read to the nearest 0.1 m between belay points and a Silva walking compass read to ±2°. Passage dimension data was added in 2012 for Sump 1b using the same sonar wand as used for Sump 1a and a tape measure for distance. Passage dimensions for Sump 2 have been estimated rather than directly measured. All depths were recorded using a digital depth gauge or dive computer with a precision of ± 0.1 m. This compares with the DistoX which reads to ± 0.001 m (length) and ± 0.01° (azimuth and declination). The sonar wand reads to ± 0.01 ft (approx. 0.03 m).

The overland survey between Sump 1b and Sump 2 was done on 7 May 2011 using a Shetland Attack Pony for azimuth and declination (± 1°) and a Leica Disto D3 for distance (± 0.001 m). The data for Sump 3 was collected the same day. Sheppard's Crook was surveyed using a Suunto Compass and Clinometer (± 1°) and tape measure (± 0.1 m).

Sump 3 is much longer and deeper than those preceding it. In situations such as this, divers prefer not to spend more time than is necessary for exploration. As collecting survey data by traditional methods is both time consuming and distracting, a device has been designed and constructed to collect data without user intervention. This device, the *Lazy Boy Sump Mapper* was used by John Volanthen to map a centreline for Sump 3. It records data including the direction it is pointing (bearing), depth, distance and accelerometer data every second. This data can be converted into survey legs and a survey can be constructed.

The device is designed for scootering. The accuracy is very variable for a number of reasons, primarily water flow round the scooter or diver. When swimming, it is not easy to keep it orientated correctly. On a tow-behind scooter in clear water over a 1 km course, loop closure errors of 2 - 4%, have been achieved. However on a ride-on scooter, or swimming in a cave, the error will be much greater. Accuracy is also affected by water flow and any magnetic equipment on the diver. For calibration purposes, the survey generated by the device has been compared with previous survey work in this sump and adjusted accordingly. No passage dimension data has been collected; this has been collated from estimations made by other divers previously.

Cave location

The location of the cave was determined by taking the survey through the entrance out to an identifiable fixed point on the surface. The location of this point was determined using a differential GPS unit.

RESULTS

Data manipulation

The data has been reduced using the open-source computer program *Therion*. The advantage of using such programs is that, all being well, this job will not need doing again. Providing that the data is kept secure and that at least some of our fixed points can be identified within the cave, any new survey data, of new extensions, may be reliably tied into ours. It is also the case that the drawings do not need to be redone, as the program is used to store and manipulate these as well and will manipulate the current ones to allow for new finds, including the discovery of new closed loops that might skew existing data.

Far too much cave survey data has been lost over the past fifty years, though now repositories, such as that at http://cave-registry.org.uk/ exist to help ensure that it can be properly archived

Data Output

Relative error	Absolute error	Total length	Stations	X-Error	Y-Error	Z-Error
87.53%	13.5m	15.4m	2	3.5m	11.3m	6.5m
2.00%	0.5m	25.2m	3	0.2m	0.4m	0.3m
1.93%	8.1m	422.6m	72	-8.0m	-0.7m	-1.2m
1.82%	0.7m	36.4m	11	-0.5m	0.4m	0.1m
1.49%	1.1m	71.0m	6	0.1m	1.0m	0.4m
1.26%	3.0m	240.4m	29	1.4m	2.7m	0.1m
1.04%	0.5m	47.4m	5	-0.3m	-0.4m	-0.1m
0.98%	0.2m	24.1m	10	-0.2m	-0.1m	0.1m
0.96%	1.1m	112.2m	12	-0.2m	1.0m	0.4m
0.91%	1.0m	111.8m	11	0.3m	-0.7m	-0.6m
0.91%	0.6m	70.7m	9	0.0m	0.6m	0.2m
0.87%	0.3m	32.5m	5	-0.2m	0.2m	0.1m
0.85%	0.5m	62.7m	13	0.2m	-0.5m	0.0m
0.82%	0.7m	84.2m	26	-0.5m	0.4m	0.1m
0.77%	0.5m	64.1m	7	-0.1m	-0.5m	-0.1m
0.73%	0.4m	50.8m	11	0.2m	0.3m	0.1m
0.70%	0.3m	41.8m	3	0.3m	0.1m	0.0m
0.67%	0.7m	100.6m	15	0.4m	0.5m	0.3m
0.56%	0.4m	76.9m	11	-0.2m	0.4m	0.0m
0.53%	0.2m	29.4m	8	0.1m	0.1m	0.1m
0.53%	0.2m	30.6m	8	-0.1m	0.1m	0.0m
0.51%	0.4m	78.1m	22	0.2m	0.3m	0.1m
0.38%	0.2m	46.0m	14	-0.0m	-0.1m	0.2m
0.32%	0.2m	77.0m	16	-0.2m	0.1m	0.2m
0.27%	0.2m	80.1m	15	-0.1m	0.1m	-0.1m
0.22%	0.1m	35.4m	9	0.0m	0.0m	-0.1m
0.20%	0.2m	107.7m	20	-0.2m	0.1m	-0.1m
0.18%	0.1m	30.7m	5	0.0m	0.0m	-0.0m
0.16%	0.1m	37.5m	6	-0.0m	0.0m	0.0m
0.15%	0.2m	129.7m	21	-0.1m	0.0m	0.2m

Table 1. *Closed loops and misclosure errors.*

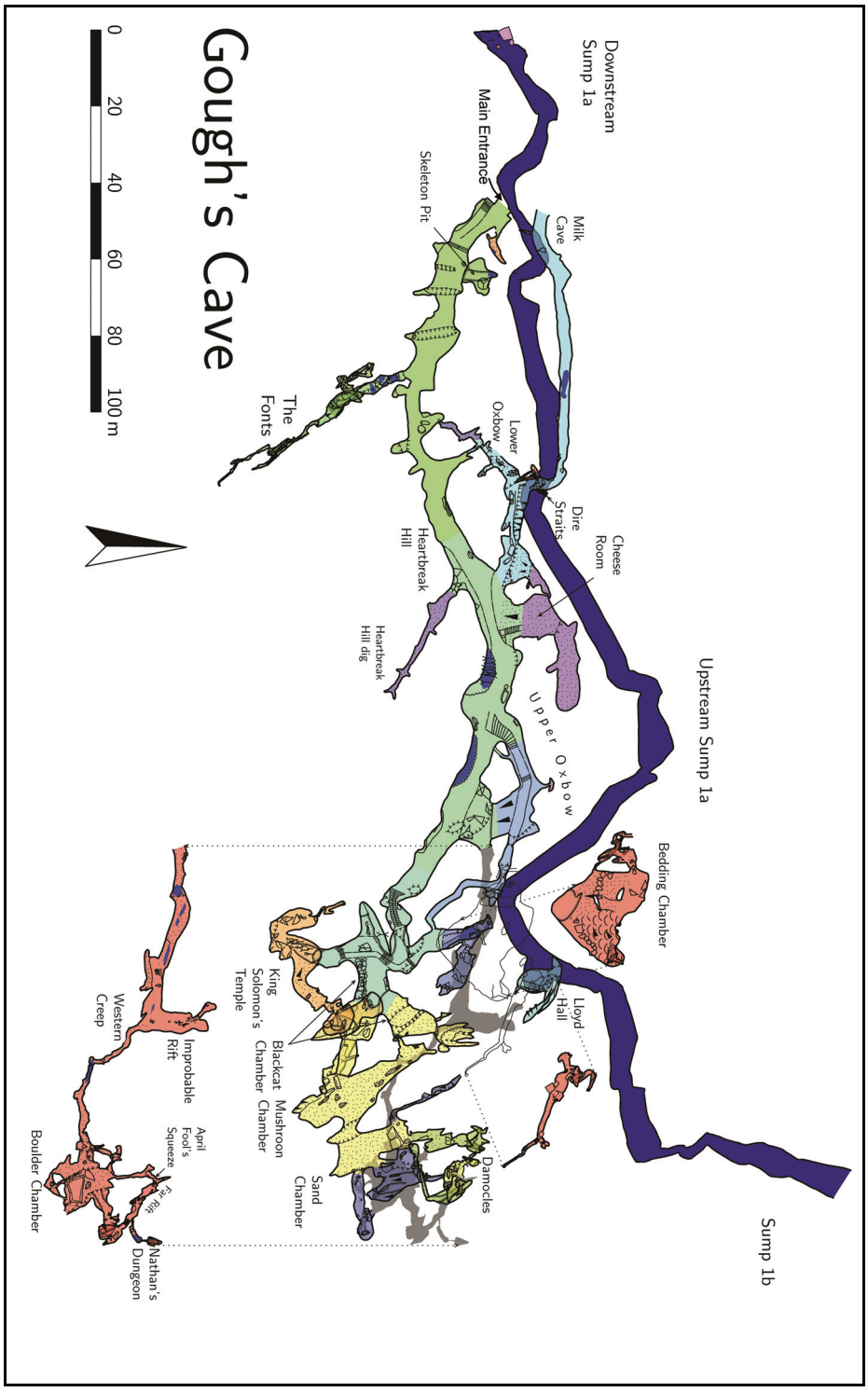

Figure 2. *2011-12 Plan survey of Gough's Cave, Cheddar, to the end of Sump 1b.*

The total surveyed length of the cave is 3326.70 m and the vertical range is 114.91 m. There are 4072 survey stations, joined by 4101 legs. There are 30 closed loops.

Table one lists the statistics for the closed loops, sorted by error magnitude. Clearly the first one, error 87.53%, shows a blunder of some sort. However this loop is quite short and has little effect on the overall accuracy of the survey. It is from surveying in Bishop's Palace, beyond Sump 1b. Water conditions were such that diving was not practical over the summer of 2012 and so it has not been possible to check these particular figures as yet. The third loop, error, 1.93%, also includes diving data from sump 1 which is expected to be less precise than the above water surveys. Ignoring these figures, the average loop error drops well below 1% and is acceptable for a survey taken to be BCRA Grade 6 (Day, 2002). We consider that the removal of the parallax errors inherent in reading optical instruments and the use of marked fixed points and targets does bring down station position error to 2.5 cm or less, without the need for the use of tripods. Although it is not obvious from the Table 1, as the relevant loops incorporate data from both the DistoX and the total station, there seems to be little difference in misclosure between these two techniques in practice, which is something of a surprise. It also seems that there is no clear relation between misclosure error and the other obvious variables of number of stations, leg length or total loop length.

Although the BCRA's grading system has been consistently used by UK cave surveyors for many years, it is now slowly being superseded by an internationally recognised alternative system devised by the International Union of Speleology (UIS) and based on a previous system put together by the Australian Speleological Federation (ASF). Details of the system can be found at http://www.uisic.uis-speleo.org/UISmappingGrades.pdf . This system has a number of advantages over the BCRA's version and it is probable that surveys carried out by the Society, especially those using the Distox or similar instruments will be defined in this way in future. Under the UIS scheme, the survey of the cave, not including the sumps may be graded UISv1 6-4-BEF. The survey of the sumps as far as Sheppard's Crook is equivalent to UISv1 3-1-B. No grade is claimed for Sump 3. The UIS scheme does not allow for different grades to be applied to different parts of one cave, but we believe that the dry cave and the show cave are sufficiently distinct for this to be acceptable.

PRESENTATION

The data, once reduced, can be used in a number of ways to present the survey of the cave. Traditionally, this was done by printing a paper version at an appropriate scale, however, a much wider variety of presentation methods are now available to us. The printed version, as shown at a small scale in Figures 2 and 3 is derived from the PDF output from *Therion*. Two variant presentations have also been generated, intended for printing at larger scales. These may be found on the survey archive page of the Society's website:

<http://www.ubss.org.uk/cave_survey_archive.php#Cheddar>

Presentation as a pdf file allows one further advantage, in that layering within the file makes it possible to view or hide specific layers, which here correspond with specific survey trips. This is useful in viewing parts of the cave which overly each other in a much clearer fashion than is possible using offset parts. This is particularly useful in this cave, where the passages may be stacked more than three deep in places.

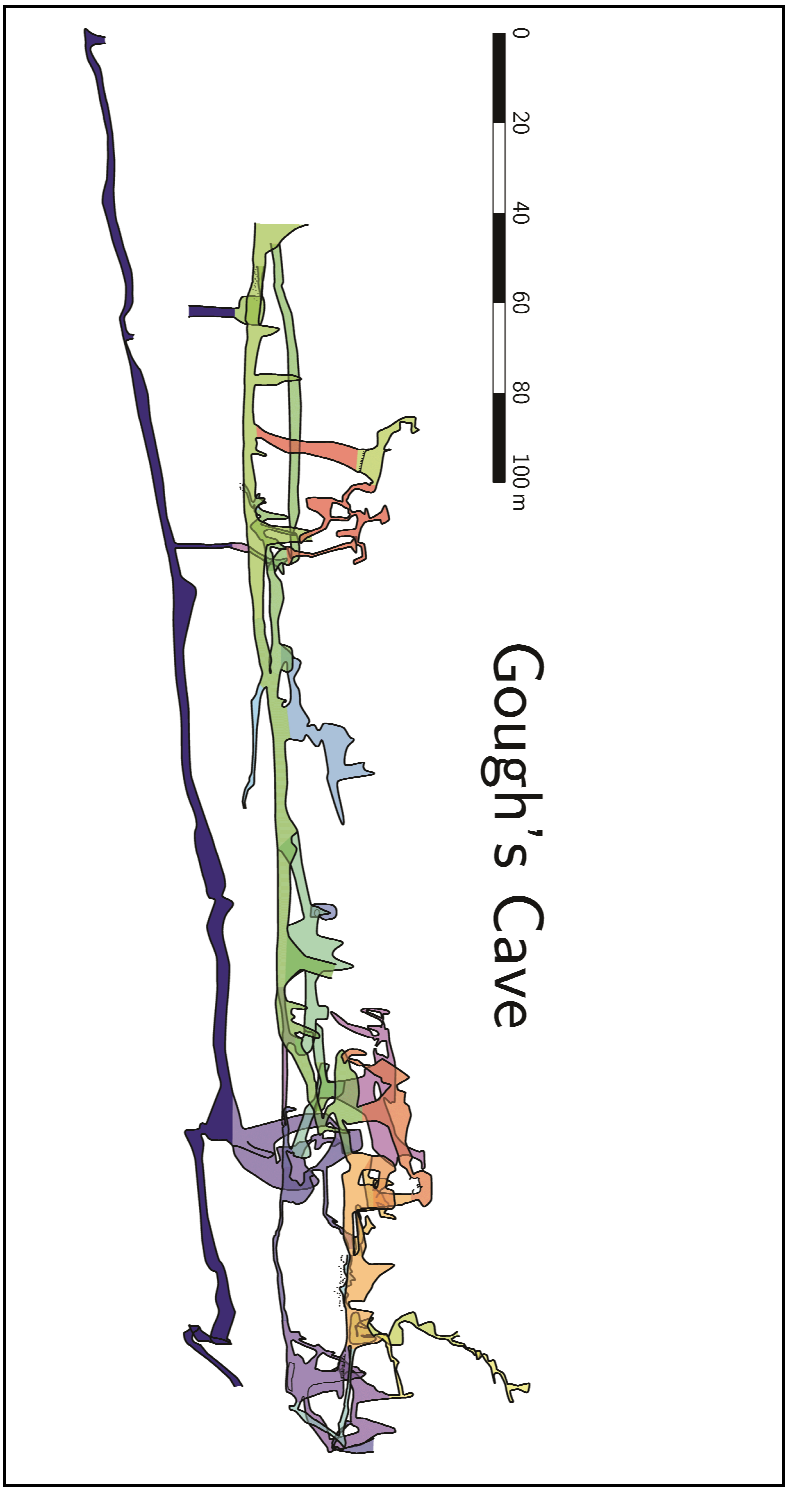

Figure 3. *Elevation of Gough's Cave, to the end of Sump 1b, projected on a bearing of 000 degrees.*

The use of *Therion* allows for the generation of a number of other file types, designed for on-screen viewing and manipulation. These include a .kml file which produces a plan survey which can be overlain on Google Earth and several types of 3D file which are capable of being manipulated in the appropriate viewing software. They can be rotated, moved and zoomed in all directions.

Survex.3d file
This file shows a centreline-only model. The *Survex* viewer, *Aven*, has the advantage of incorporating a tool for measuring between survey stations, thus allowing for precise measurements between parts of different passages or, indeed, different caves. To use *Aven* it is necessary to install Survex (http://www.survex.com) on your computer.

Figure 4. *Screen capture of the Therion 'lox' file.*

Lox file
Lox files are intended to be viewed with *Therion's* viewer (http://therion.speleo.sk/). They can show passage size and shape as well as centreline. The view can be rotated and zoomed to visualise relationships between different passages and different caves. It is also possible to combine surface data and overlay maps to produce complete 3d representations of an area.

VRML files
These can be viewed in an ordinary browser, with the appropriate plugin installed. However the file type is considered obsolete and as it is straightforward to download and install the viewers for the dedicated cave survey software it is unlikely that this type will continue to be used.

The Society has been involved in producing versions of these files covering most of the catchment of the Cheddar springs, including, of course, Gough's Cave. The latest versions can be found on the Society's website at the url given above.

ACKNOWLEDGEMENTS

The authors are grateful to Clive Owen, Tony Boycott, Alison Moody, John Williams, Liz Green, Stuart Alldred, Amy Matthews and Rosie Tulloch for their work with us in the cave. Lee Hawkswell kindly lent us his time and used his total station to great effect. The differential GPS unit used to fix the entrance was kindly loaned to us by the Department of Archaeology and Anthropology of the University of Bristol. The sump surveys were carried out by members of the Cave Diving Group of Great Britain, Jon Beal, Chris Jewell, Duncan Price, Mike Thomas and John Volanthen, who have generously shared their data with us. John Volanthen has also generously made available the detail of his *Lazy Boy Sump Mapper*. We are particularly indebted to the management and staff of Cheddar Caves and Gorge, especially Hugh Cornwell, Bob Smart and Chris Castle, for allowing us free access to the cave at all times. Final thanks are owed to Wookey for his comments and criticisms of an earlier draft of this paper.

REFERENCES

BALCH, H.E. 1935. *Annual Report of the Mendip Nature Research Committee.* **28.** 40-43.

BENDALL, R.A., and CRICKMAY, J.H., 1951. A Survey of G.B. Cave, Charterhouse-on-Mendip. *Proceedings of the University of Bristol Spelaeological Society.* **6.** 2. 174-185.

DAY, A.J. 2002. Cave Surveying. *BCRA Cave Studies Series.* **11.**

FARRANT, A.R. 1991. The Gough's Cave System: Exploration since 1985 and a reappraisal of the geomorphology. *Proceedings of the University of Bristol Spelaeological Society.* **19.** 1. 3-17.

STRIDE, AH. and STRIDE, R.D. 1951. Gough's Cave, Cheddar: A survey and some explanatory notes. *Cave Science*. **3.** 18. 62-65.

STANTON, W.I. 1952. The survey of Cheddar Caves. *Annual Report of the Mendip Nature Research Committee*. **44/45**. 16-23.

STANTON, W.I. 1965. Notes on the survey : The caves of Cheddar and neighbourhood. *Journal of the Wessex Cave Club*. **8.** 103. 324-329.

STANTON, W.I. 1979. The new tunnel at Gough's Cave, Cheddar. *Journal of the Wessex Cave Club*. **15.** 175. 112-114.

G.J. Mullan
38, Delvin Road
Westbury on Trym
Bristol BS10 5EJ
graham.mullan@coly.org.uk

A. Atkinson
31, Priory Avenue
Westbury on Trym
Bristol BS9 4BZ
andrew@wotcc.org.uk