Cave Science

The Transactions of the British Cave Research Association

BCRA

Volume 14 Number 1 April 1987

Sediments and palynology in Marble Arch Cave

Sump Rescue Symposium

Caves of Jordhulefjell, Norway

Cave Science

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Cave Science

TRANSACTIONS OF THE BRITISH CAVE RESEARCH ASSOCIATION

Volume 14 Number 1 April 1987

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Cover: The Grand Gallery section of the main stream passage in Marble Arch Cave, Co. Fermanagh. This is now seen on the tour in the recent show cave development, and sediments in a tributary passage are the subject of a paper in this issue of Cave Science. By Tony Waltham.

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CAVE SCIENCE Vol. 14, No. 1, April 1987
Transactions of the British Cave Research Association

The Sedimentology and Palynology of some Postglacial Deposits from Marble Arch Cave, Co. Fermanagh

Gareth Ll JONES and Madelaine McKEEVER

Abstract: Sediments and pollen from a sandbank in Marble Arch Cave, Co. Fermanagh, suggest that they may have been deposited between 7,500 and 3,500 years BP during flood events in a mature cave system.

INTRODUCTION

Two organic rich bands in a sand and gravel bank in the Skreen Hill I passage of Marble Arch Cave were sampled for pollen in 1981, and suggested Postglacial dates for the sediments. Later that year two short cores were taken from the sand bank and they are described here. It was not possible to trench the bank, since most of the section was below water level.

The Sample Site

The Marble Arch Caves are part of an upland karst system receiving the drainage from an extensive area on the north side of Cuilcagh Mountain (Jones 1974). It is a large mature system with features suggesting that it dates from a glacial if not pre-glacial period. These include the drift-covered dolines, described by Ternan (1966) and exposed during the opening of the new show cave entrance to Skreen Hill I. The Aghinrahan is one of three major streams which sink into the limestone. Its waters flow into Pollasumera Cave (not shown), and then through Pollnagollum Cave and the Skreen Hill Passages of Marble Arch Cave before joining underground with the other streams to form the Cladagh River, which resurges at the Marble Arch (Figure 1).

The sample site is a sandbank situated half way up the Skreen Hill I passage (Figure 2), at the point where the stream emerges from Lake 1. Immediately downstream a minor tributary emerges from the small Crystal Palace passage. Since the cores were taken, Marble Arch has become a show cave and the 'Moses Walk' has been contructed through Lake 1; the sandbank remains intact.

Core A1 was drilled in the centre of the sand bank and penetrated 720mm of sediment. At this depth there was loss of the final part of the sample and the hole was redrilled (as A2) and taken to a final depth of 960mm. Core B1 was drilled close to the edge of the sand bank upstream of A1 and terminated at a depth of 720mm (see Fig.3).

SEDIMENTOLOGY

Both cores consist of beds of mostly unconsolidated arenaceous material varying from silt, through fine and medium to coarse quartz sands, with some scattered quartz pebbles near the base of both holes. Organic layers were present in both cores, but were thicker in hole B1, and it was from this core that the pollen samples were taken. Recovery was variable in both boreholes, and sediment was either lost through compaction or being washed out (see Fig.3). Although correlation is possible between the two holes, the variation over such a short distance bears out the

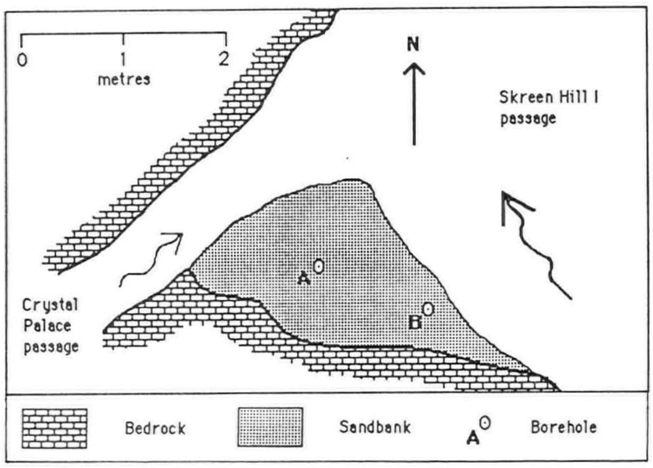

Figure 2. Borehole locations on the Skreen Hilll sandbank.

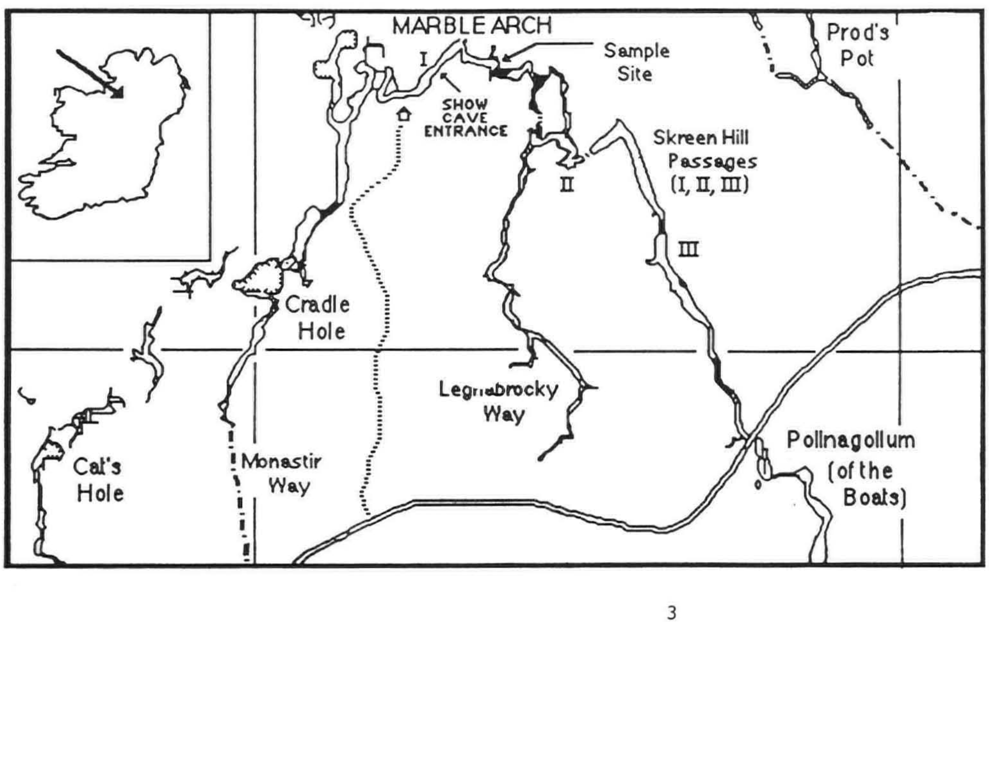

Figure 1. The Marble Arch Cave System, Co. Fermanagh.

comments of Osborne (1984) with regards to the prevalence of rapid lateral facies changes in cave deposits.

Sediments elsewhere in the Skreen Hill I passage, both upstream and downstream of the sample site, include clastic material up to large boulder size. Some of this is autochthonous, derived from breakdown of passage walls and roof, but a large proportion is allochthonous and consists of sandstone clasts up to boulder size which have been brought in through sinkholes and transported by the Aghinrahan River, probably predominantly under flood conditions (Ford 1975). The finer grade material is considered to be mostly allochthonous since it is composed largely of quartz grains. It is considered that the lighter elements of the bed-load were deposited in a region of quieter flow, and that subsequent erosion by the stream has left the sandbank in its present position and condition. Although the sediments are currently within a fluvial regime, it is probable that the earlier stage of their history was fluvio-glacial as meltwater streams carried products of glaciation into the cave entrances, in the manner suggested by Ford (1975).

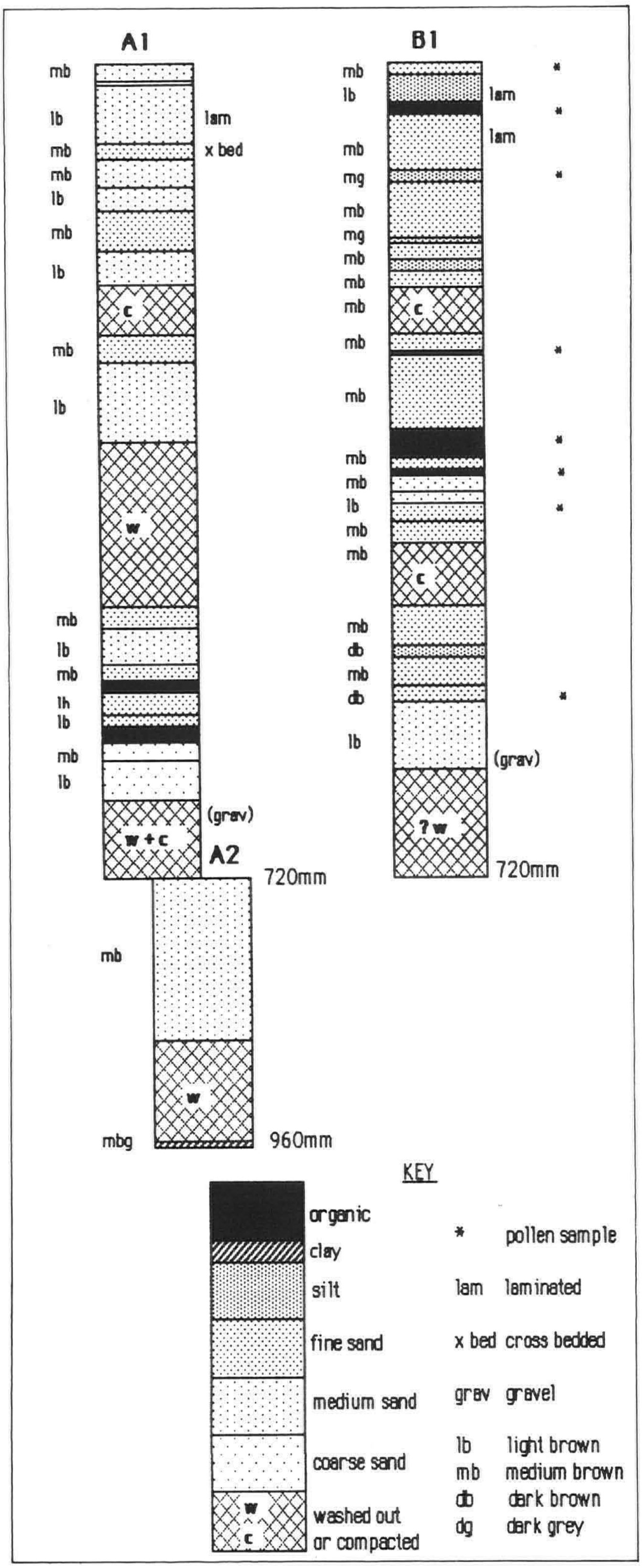

Figure 3. Cores A1-2 and B1, Skreen Hill.

The core sediments consist mostly of silts through to coarse sands and fining-up sequences were not evident. They may represent episodes of flooding when turbid waters dropped their load in quiet corners. Modern water level monitoring shows a rapid drop in water level following a flood pulse in these passages (Show Cave Management pers. comm. 1985). This would not allow gradual settling out to produce fining-up sequences but the deposit would vary with each bed-load content. However the uppermost beds of both cores do show some lamination and it is possible that there were prolonged stillwater conditions in the recent past, perhaps caused by damming of the stream to form Lake 1.

The pollen record indicates that the upper 550mm of the deposits are at the most 7,500 years old and perhaps much younger, so that these sands and gravels have been reworked by the post-glacial streams running through passages that are probably much older.

The basal part of Core A-2 is poorly represented, but the upper part contained gravel and coarse sand, whilst the hole bottomed in plastic grey-brown clay. The gravel suggests that there was an interval when more turbulent flow occurred at this side of the passage. The clay interval suggests exactly the opposite, though a large input of clay into the system can not be ruled out. Such an input might have occurred as fresh glacial deposits were being reworked at the end of a period of glaciation.

CAVE BIOSTRATIGRAPHY

Most biostratigraphic records from cave environments tend to be of faunas, and there are many papers on ossiferous deposits from fissure fills and cave shelters. The literature on palynological studies is remarkably scarce, perhaps due to the poor chances of pollen surviving in the cave environment, but also to the lack of attention that this aspect has received. It is hoped that this paper will encourage some detailed floral studies.

PALYNOLOGY

In general the pollen counts are low and this partly reflects the aggressive cave environment which easily destroys the fragile grains. However some trends can be seen which may be significant, and they may be of interest in future years. The pollen records (see Table 1 and Fig.4) are compared with those from the Littleton Bog, Co. Tipperary (Mitchell, 1981 emend. 1965), unless stated.

Hazel is the dominant pollen recorded and this is typical for the period of Climax Woodlands (ILWC) starting at about 7,500BP up to the start of intensive Farming (ILWd2) at about 1,700BP (see Table 2). The large amount of Alder in the sediments suggests that they are younger than about 7,500BP which is when Alder first became prominent in Ireland. Pine flourished during the Beginning of the Woodlands (ILWB), but became a minor constituent during the Climax Woodlands (7,500BP on). It persisted at this level until about 3,500BP when it became locally extinct. At Slish Wood, Co. Sligo, Dodson and Bradshaw (1985) showed that pine disappeared at two localities only 8 kilometres apart at about 4000 years BP and at 1850 years BP. Therefore detailed local

Depths	550mm	400mm	360mm	255mm	0mm
TREES:	39.9	52.5	42.6	46.6	56.6
Hazel *(Corylus)*	27.8	32.3	27.1	38.9	37.2
Oak *(Quercus)*	----	2.5	1.4	0.5	0.6
Alder *(Alnus)*	5.2	8.9	7.1	2.4	9.7
Elm *(Ulmus)*	0.9	2.4	1.4	0.5	4.3
Birch *(Betula)*	4.3	1.6	2.8	1.9	3.0
Pine *(Pinus)*	1.7	4.8	2.8	1.9	1.2
Ash *(Fraxinus)*	----	----	----	0.5	0.6
SHRUB					
Holly *(Ilex)*	----	----	1.4	----	0.6
HEATHER					
(Calluna)	21.7	25.0	30.0	28.4	32.9
HERBS					
Grass *(Gramineæ)*	6.1	2.4	7.1	0.9	1.8
Sedge *(Cyperaceæ)*	13.0	2.4	2.8	2.8	3.6
Compositae *(Ligulifloræ)*	1.7	----	----	0.9	0.6
Plantain *(Plantago)*	4.3	----	----	----	1.2
Fern *(Polypodium)*	5.2	4.0	----	0.9	1.2
Moss *(Sphagnum)*	1.7	11.2	11.4	2.4	1.2
Unknown/corroded	6.1	2.4	4.3	0.9	2.4
Actual totals	115	124	70	211	164

N.B. Yields from samples at 330mm, 100mm and 40mm were too small to be significant.

Table 1. Pollen percentages for samples from core B1.

years BP	UK STAGES	IRISH STAGES	IRISH WOODLAND DEVELOPMENT PHASES	
0–250	FLAND-RIAN	LITTLE-TONIAN	ILWe	
250–1650			I L W d2	Expansion of Woodland by Afforestation
1650–3500			I L W d1	Advanced farming destroys woodlands
3500–5000				Primitive farming Damages Woodlands
5000–7500			I L W C	Climax stage of Deciduous Woodland
7500–10,000			I L W B	Beginning and Immigration of Woodland
10,000–	DEVENS-IAN	MIDLAND-IAN	I L W A	Absence of Woodland Open Vegetation

after Mitchell 1976 & 1981

Table 2. Irish Woodland Development phases.

information is vital to the accurate interpretation of pollen diagrams including that from the Marble Arch cores. Although Pine was later reintroduced to the area by man (in the last few hundred years), the other pollen results are more consistent with the older period.

The appearance of Ash (albeit a very low record) in the later sediments may be of note since it flourished from 4,500BP on, whilst the general decline in the Herbs fits in with the Woodlands periods (ILWB, ILWC and perhaps ILWd1). The large amount of heather is notable, and probably relates to the mountainside position of the cave entrances. The Compositae are at a low level which may be significant - at Red Bog, Co. Louth they did not appears until about 2,800BP (Mitchell 1981).

Taken together we can tentatively assign dates as follows:

Top	Not younger than 3,500BP	ILWd1 lower
255mm	Not older than 4,500BP	ILWd1 lower
550mm	Younger than 7,500BP	ILWC

The basal samples may have been deposited during the Climax Woodlands (ILWC), and the top during the first part of the Damaged Woodlands (ILWd1) periods. The bottom of the hole gave no information, but may represent a much older period according to the sedimentology.

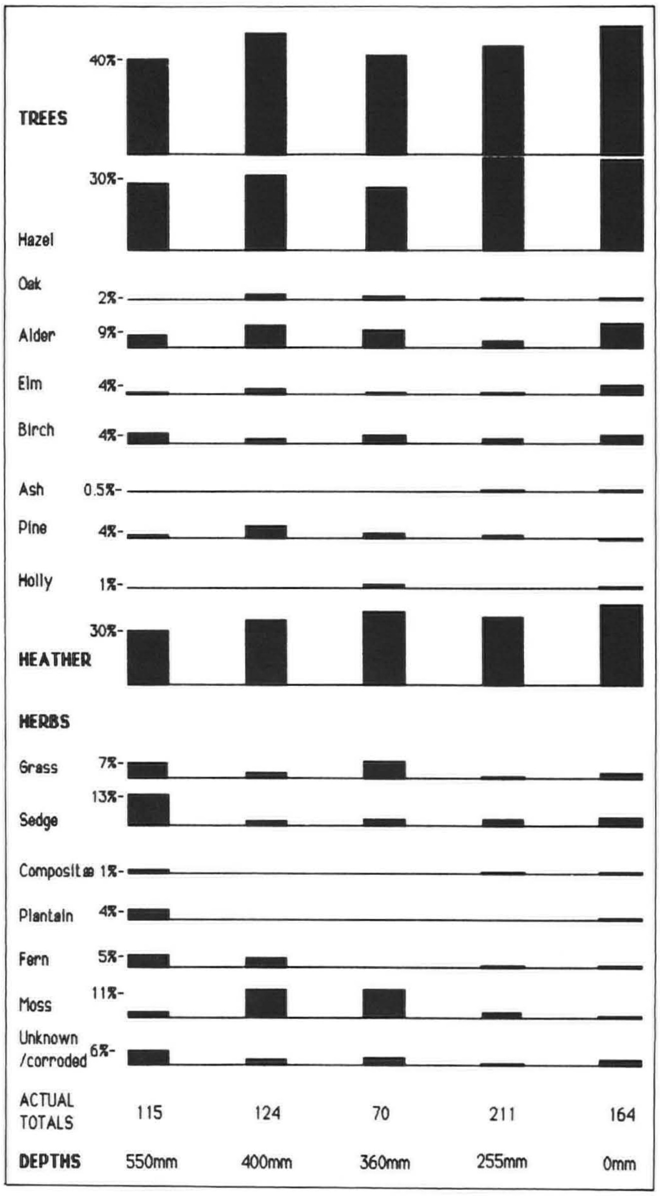

Figure 4. Histogram of pollens for samples from core B1.

Although these sediments were probably deposited by floods, and the possible effect of scouring cannot be calculated, the results represent a maximum sedimentation rate of 550mm in 4000 years or 1mm per 7.2 years. It is however possible to argue that the above dates represent the widest parameters, and that the section was deposited during as short a period as 1000 years, with a sedimentation rate of about 1mm per 2 years.

Most cave sediments are reworked to some degree, but the clear bedding influence, plus the correctly sequenced biostratigraphy suggest that the sediments were deposited at this location separately and in stratigraphic sequence.

The presence of man is recorded in the Bann valley and the Shannon basin at about 8,500BP, and the impact of his farming is documented by the Woodlands Damaged (ILWd1) period from 5,000BP onwards (Mitchell 1981). His presence is known in the Marble Arch area (Jones 1974) from the human skulls found by the 1972 Ulster Museum dig in Pollnagollum of the Boats Cave (800m southeast, see Fig.2). These skulls were radiocarbon dated at 4,500BP (P.Doughty, pers. comm.), and would thus have been contemporaneous with the ILWd1 period seen in the upper part of the section. Recent work on clays from the shattered terminal aven at the south end of Legnabrocky Way (see Fig.1) has revealed the presence of charcoal (A. Hamilton, Coleraine, pers. comm. 1986). This may also relate to the Woodlands Damaged period or might simply be derived from accidental fires.

CONCLUSIONS

This paper suggests that the top half metre of sands sampled in the Skreen Hill I passage of Marble Arch were deposited, by a series of flood episodes, between 7,500 years BP and 3,500 years BP. This is important in demonstrating that there are identifiable pollens surviving in the cave environment. It is hoped that further sediments can be dated and may throw light on the previous history of the cave.

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The First British Sump Rescue Symposium

Proceedings of the Symposium

Organised by the Cave Diving Group and the British Cave Rescue Council

Castleton, Derbyshire, June 7th 1986

CONTENTS

PREFACE

Anyone who has been on a cave rescue, whether as rescuer or as victim, will appreciate just how difficult they can be. Any cave, even the easiest, presents a series of obstacles seemingly designed to make transportation of a helpless person as difficult as possible. It is probably true to say that a sump is the ultimate obstacle and there has been little opportunity to evaluate the multitude of problems associated with rescue through one.

These problems are not restricted to Britain. In 1985 the French held an international sump rescue symposium in order to bring together leading European divers to discuss the problems involved. John Cordingley represented Britain and collected a great deal of information (see Appendix 1). The French event, and the urgent need to discuss sump rescue problems in a British context, provided the impetus for a British sump rescue symposium which was held in Castleton Village Hall on June 7th 1986. Cave Rescue Organisation personnel, cave divers and other interested cavers from all over the country attended the meeting both to hear the various speakers and to contribute information of their own.

In the month before the meeting a small group of divers discussed the various problems of sump rescue and compiled a list of subjects for presentation at the symposium. Each subject was assigned to an individual caver with known expertise in the given field and they were asked to present a talk on the subject in Castleton.

These proceedings record the talks given at the symposium and include some other relevant information. A brief review of the day's events has already been published by the Cave Diving Group in their Newsletter number 81.

Although very few of the problems received concrete solutions we now have a much better understanding of what the problems actually are. Meetings of this sort should be held from time to time to take stock of progress and to disseminate the findings as widely as possible. Meetings are useful and informative but it is important that cave rescue organisations and their local CDG sections organise practise rescues in their areas; and that the findings of these are publicised. Only by carrying out practises in the water can the real nature of any problem be ascertained and overcome.

Opening Address

Bill WHITEHOUSE

It is appropriate that Castleton should have been chosen as the venue for today's symposium because less than half a mile from here there occurred what was probably the first ever sump rescue. It happened one day in 1773 when a party of visitors being guided round Peak Cavern were shown the Buxton Water sump. Suddenly one of the party, a Mr. Day, plunged into the sump and vanished! After he had been gone some time...

"... the bystanders supposed he was drowned, they heard a voice and then a plunging, upon which Mr. Daykin, the guide" (realising of course, that DCRO was not due to be formed for another 179 years) "... ventured as far as he dared, and very happily put his hand down and caught hold of Mr. Day's arm and a man behind Daykin caught hold of him and saved the drowning man. Mr. Day," the report continues "was speechless for some time. (However) no sooner had his senses returned , but he said he would take another plunge: but those present, finding him disordered, prevented him!"

It wasn't only the first sump rescue, it was probably the first recorded cave dive; and when Mr. Daykin and the others stopped the "disordered" Mr. Day from making a second dive, they carried out the first ever exercise in cave diving accident prevention. If Mr. Day hadn't drowned himself a few months later trying to live on the bottom of Plymouth harbour who knows what he might have done for eighteenth century speleology!

Now, why have a sump rescue symposium at all? After all, the incidence of sump rescue has not been increasing faster than cave rescues generally. It is necessary to look at what has been happening to cave diving in the last few years and what is likely to happen in the near future.

Primarily, there has been a rise in the popularity of cave diving. In 1975 the CDG newsletters reported a total of 270 dives including training dives. In 1985 787 dives were reported excluding training dives, meaning that cave diving has increased fourfold during the last decade.

It would be nice if the fact that diving accidents have not also increased fourfold was wholly attributable to the care and expertise of those diving. In fact I am sure that this, together with improvements in equipment and techniques, is most of the answer; but the pessimist (or is it realist?) in me cannot help but attribute part of the reason to luck. And luck, sooner or later, has a nasty habit of running out.

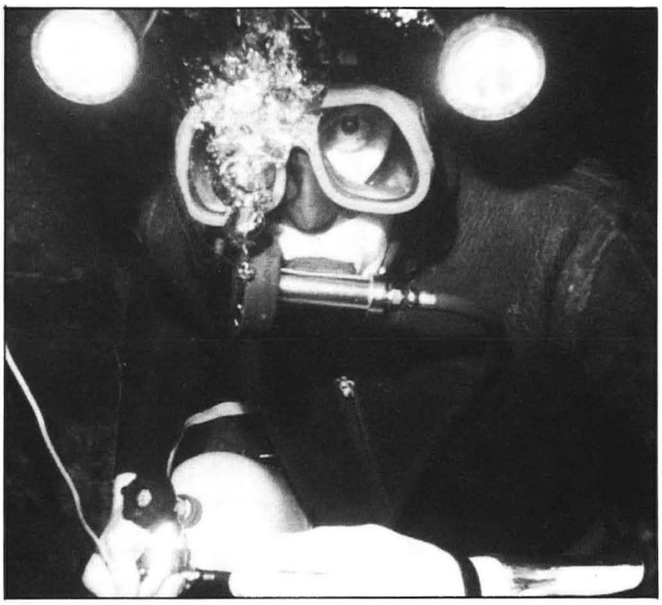
More divers and more dives have meant the exploration and, on many occasions, the conquering of increasingly long, deep and sometimes horrible sumps. The longest, deepest and most horrible have invariably been pioneered by well equipped and very experienced divers, but in years to come, as numbers increase further, they will inevitably be followed by the less well equipped, less experienced and less careful, while the sumps will be no shorter, just as deep and, in all probability, no less horrible!

At a gratifying rate cave divers are discovering and exploring more and more dry passage beyond sumps. Many long extensions have been made throughout the country in recent years but most remain inaccessible to non-diving cavers. This is, and will continue to be, an incentive to cavers to take up diving in order to visit these passages; and also, perhaps, extend them or find others by diving in other locations.

So, the potential problem becomes clearer. The future will see more divers diving more sumps more often to get at more dry passage, and perhaps more sumps, on the other side. Regrettably a small proportion will have accidents either in sumps, beyond sumps or even beyond several sumps.

Cavers of both amphibious and non-amphibious persuasion surely owe themselves, and future generations, the duty to exercise a little forethought and to prepare, train and equip for the worst. That is really why it is necessary for us to be here today and it is gratifying to see that so many divers and rescuers have been able to attend.

This is a rather unusual caving symposium in that none of the caving organisations can really take credit for bringing it about. The Cave Diving Group have helped, the British Cave Rescue Council



A poorly equipped cave diver using just the bare essentials (Photo: G Attwood).

A well equipped cave diver with two independant breathing supplies, three lights, navigation equipment and two decompression slates (Photo: J Cordingley).

have helped to finance it (with a Cave Rescue Organisation bridging loan) and various other cave rescue organisations and caving clubs, such as the Technical Speleological Group, have chipped in. However the really hard work of getting it all together has been put in by three individual cave divers whose idea this was: Chris Danilewicz, John Cordingley and Barry Sudell. If this weekend is a great success it will be largely due to their efforts.

Safe Cave Diving

Phil PAPARD

It has been found that some of the most accepted safety precautions taken by "open water" divers are not applicable to cave diving. Techniques have been learned and developed over many years by cave divers to meet their needs. These techniques are applicable to all "closed water" environments.

The Cave Rescue Organisation (CRO) has been concerned for some time at the number of cave diving accidents involving inexperienced or poorly trained cave divers. In addition, we have been concerned at the possibility of open water divers having fatal accidents in flooded caves and mines in the UK. Incidents of this nature have occurred in other countries, for instance Australia, seven lives in six years (Lewis, 1977), and the USA. To date there has only been one accident of this type here (Hodge Close), but there have been some near misses (Watkinson, 1982). I think it the duty of all divers to encourage new entrants to train properly and learn the techniques that have been and are being developed by experienced cave divers.

DIVING SAFETY

Some cavers are approaching cave diving by training as open water divers. I should like to consider the difference in safety techniques between closed and open water diving.

Open Water Diving Safety

Over the years a number of safety techniques and specialised equipment have been used by most open water divers. The following is a list of twenty one of them. It is by no means comprehensive.

Open Water Check List

** 1 Never dive alone
2 Know your limitations
3 Check equipment before dive
4 Plan dive
* 5 Use life jacket
* 6 Quick-release weight belt
7 Knife (on leg)
8 Depth gauge
9 Watch
** 10 Buddy line
* 11 Surface marker buoy
* 12 Fluorescent hood
13 Contents gauge
* 14 Snorkel
15 "Safety" face mask
* 16 Never ascend with empty cylinders
** 17 Keep in training (eg air sharing)
** 18 Know your buddy's equipment
19 Compass
20 Know the site (Currents)
** 21 Know the signals (and know that your buddy does)

Looking at the list, it can be seen that the items fall into three groups:-

a) Those promoting mutual help (**)
b) Those aiding safety via the surface (*)
c) The rest, of which the most important (2,3,4 and 20) are matters of experience.

We can say that the philosophy behind the rules is "mutual help within reach of the surface".

Closed Water Safety

By closed water I mean flooded caves, mines, pipes etc where access to the surface is severely limited. In this environment there is no easy access to a safe surface. This basic fact led Oliver Lloyd to state that we should "emphasise the need for the cave diver to learn independence and to feel, when he is diving, that he is entirely on his own. Diving in pairs has no real advantage, unless there is plenty of room and good visibility". We can thus eliminate certain items from the "open water list" and add others to produce the "closed water list".

By analysing the new list we see that the philosophy for closed water diving is "complete self reliance in equipment, the use of the equipment and the ability to find the way back to base in all eventualities." This is achieved by using a line search reel to find a lost line (Fig. 7), compass and slate to assist in finding the way out if the line is lost or broken, two independent air supplies in case one fails etc. In cave dives in this country space and visibility may be severely limited hence the need to have all equipment accessible even if it is not possible to bend down. Figure 1 shows the normal set up for each type of diver. Note that the open water diver's equipment is positioned such that it is not all accessible and various items could easily be caught in a line. Also note that the use of a hand lamp results in the diver not having his hands free.

Closed Water Check List

1 Know your limitations
2 Check equipment
3 Plan the dive
4 Knife (on arm)
5 Compass
6 Depth gauge
7 Watch
8 Contents gauge
9 Safety mask
10 100% air safety margin
11 Two independent air supplies
12 Be independent
13 Always be connected to base by line
14 All equipment in reach
15 Minimum of two independent lamps
16 Hands free
17 Slate + pencil
18 Search reel
19 Training (Line laying)
20 Safe demand valves
21 Helmet

THE DANGER AREA

Until ten years ago it was considered in open water and cave diving circles that the two sports were separate (Pearce, 1972). This view is represented by the top of Figure 2. At this time cave diving had an appalling record: 0.161% deaths per man-dive (1957-1977) in closed water as opposed to 0.0011% deaths per man-dive in open water (Churcher and Lloyd, 1980). All cave diving accidents involved cavers and resulted from pushing new caves with inadequate equipment and/or training.

The dual sport situation is, in fact, artificial and stemmed from the hostile nature of most British caves. Looking at the bottom diagram in Figure 2 we see that the two environments merge and there are a number of sites of restricted surface access that an open water diver is liable

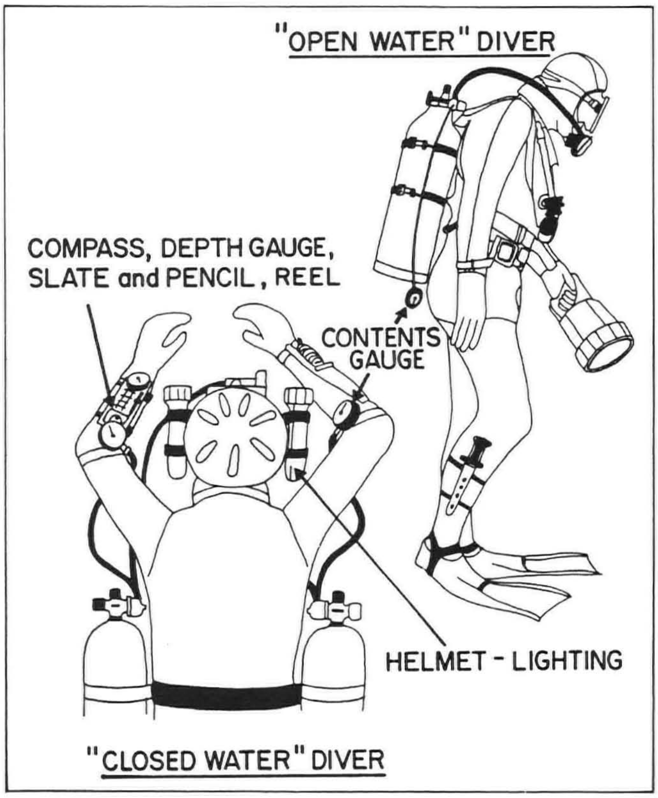


Figure 1

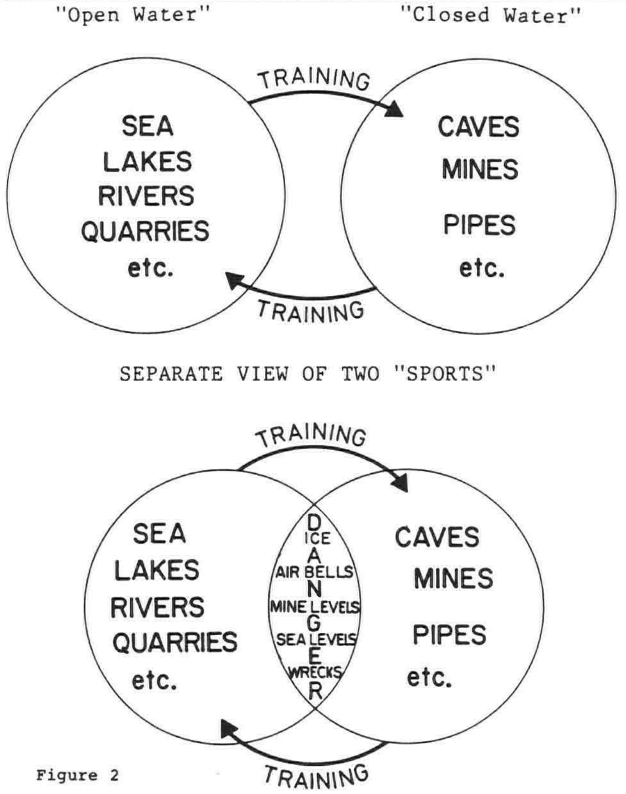


Figure 2

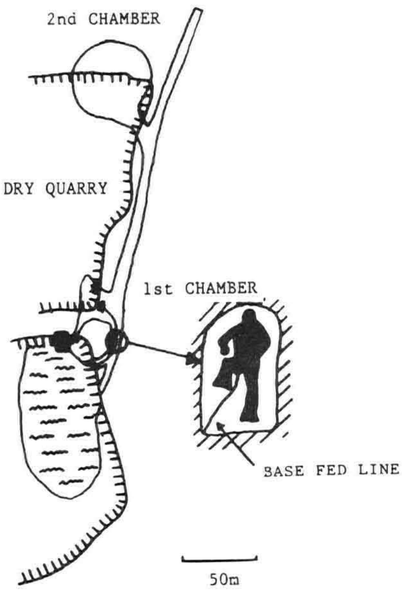


Figure 3a HODGE CLOSE

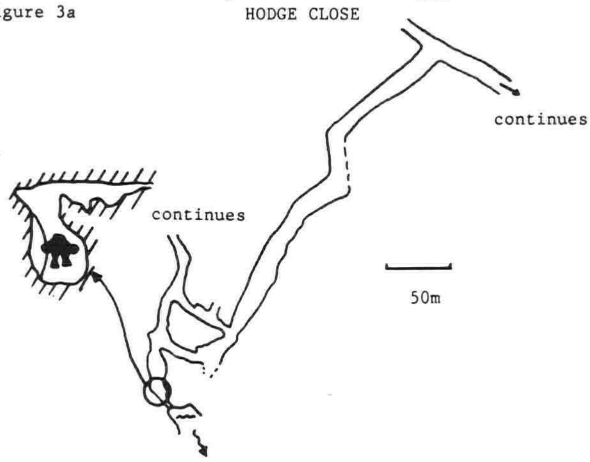


Figure 3b KELD HEAD

to encounter. This happened at Hodge Close (Fig. 3a) where a girl lost her way in a tunnel and ran out of air. The opposite type of accident happened at Keld Head when a cave diver drowned near a large air bell with a buddy present. This latter is more akin to open water diving accidents in some respects than to other cave diving accidents.

We must be on the look out for signs of a recurrence of the Hodge Close incident at perhaps a large resurgence. We, as cave divers, will be in the best position to rescue or recover such a person. Police divers must not be put in the position they were in at Hodge Close where they recovered the body using base-fed line and back-mounted bottles. At Hodge Close it worked (just) because the tunnels were square cut with no bedding planes. In a cave like Keld Head (Fig. 3b) a base-fed line would soon pull into a bedding plane. In future we may be responsible for dealing with a similar incident. Publicity of exciting cave dives litters the open water diving press and now appears on television. How long will it be before there is a multiple accident like the one in Australia involving seven sports divers?

TRAINING

With the advance of cave diving, CDG divers now use many open water techniques, particularly in large clear sumps. These techniques include buoyancy aids, back packs, diving in pairs and decompression stops. The British cave diver of old never had to consider such matters. The modern cave diver needs to be an excellent open water diver, as well as a caver, prior to his cave dive training. The basic diving skills can be gained by a number of methods. Most new cave divers in the North of England either join a diving club or try to train themselves. The latter route has in the past produced some of our best cave divers, but has also killed.

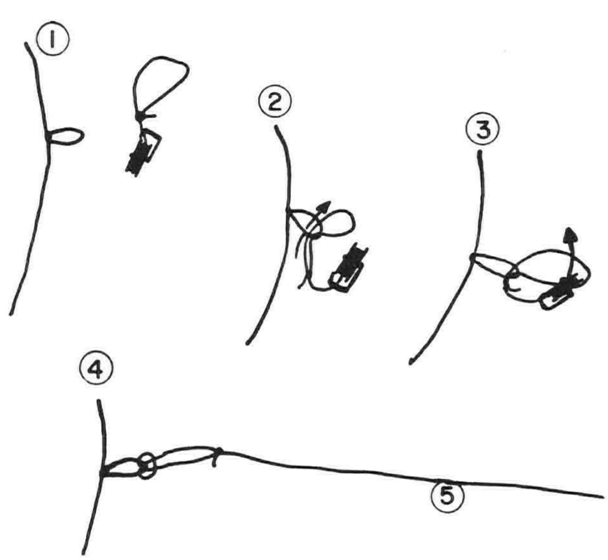
I would like to make a plea to all cave divers. Consider cave diving as much an extension of open water diving as of caving and make certain you get the necessary training.

Cave diver training has advanced a long way in the last ten years after the introduction of "The Cave Divers Training Manual" (Lloyd, 1975) and "Line Laying and Following" (Yeadon, 1981). I do not purpose to repeat these books here. I will however emphasise three basic techniques.

i) 100 % Air Safety Margin.

This basic safety technique is often used wrongly. The object is always to have two sets of breathing apparatus each with enough air in it to get you out. The simplest method to achieve this is to use 1/3 out of one tank, change to the second tank and turn round when it is 2/3 full.

Figure 4 JUNCTIONS AND JOINTS



Finally, swap back to the first tank when the second is 1/3 full. You should then reach your base with 1/3 in each. I have heard of divers using 2/3 out of the first tank before swapping over! What happens if the second tank is inoperative? This simple method is often modified to changing over tanks every ten minutes so the diver knows that both sets are working and can take action early if one fails.

ii) Line Laying.

It has become the custom of late to become a cave diving tourist; laying no line but just going on established dives on existing lines. This is fine as long as the diver knows how to lay line, recover a line that is lost or find his way out using his compass etc if this fails. I get the impression this does not always occur. Every cave diver must train himself in line laying and recovery. He must also always carry a compass, slate, pencil and emergency reel on every dive except the very shortest. In laying lines he should be familiar with joining lines, using loops to fix new lines and avoiding knot tying under water (at least one death has resulted from a knot coming undone)(Fig. 4). He should also use different coloured lines for side passages and clearly mark destinations. Belaying the line at bends and junctions can be done using several methods. Different aids have their own advantages and disadvantages. The diver must be familiar with them all. (Figs. 5 and 6).

A useful carrier for "snoopy loops" is shown in figure 6. It is cut from a piece of sink waste pipe cut to the length of the "snoopy loops" in use. The "snoopies" are so attached to the carrier that only the top "snoopy's" cord loop is free. By pulling down on the cord loop the "snoopy" is removed and the next "snoopy's" cord loop is released.

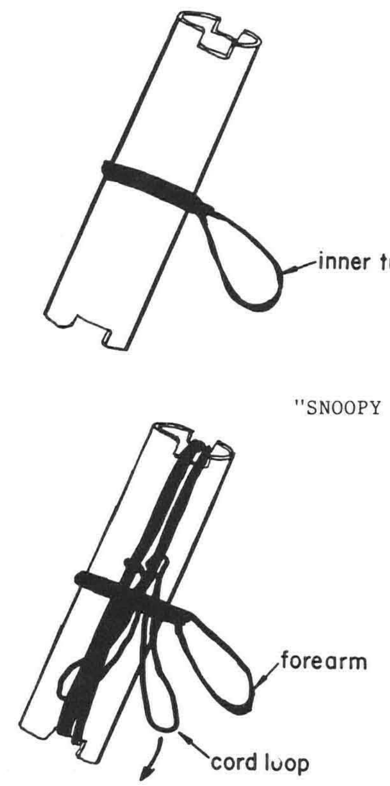


Figure 6

"SNOOPY LOOP" HOLDER

iii) Recovering lost line.

Yeadon (1981) explains this procedure as follows:-

1) Don't lose the line (technique!) but if you do:-

2) Know the bearing of the passage direction.

3) Be aware of your position relative to the line.

4) Slowly scan the side on which the line was lost. Don't move more than one metre away.

5) If you are being followed by other diver, stay where you are, watch and listen. Be ready to attract attention by light and sound (knocking rock or knife on tank).

6) If all the above fail then search across the passage floor, walls and roof using the emergency search reel (Fig. 7). Note that if you have looped the entire cross-section of the passage you should have ensnared the line in the search reel line.

7) A last resort would be to use your compass and notes on direction, made during the inward dive, to find the way out.

Figure 7 RECOVERING LOST LINE

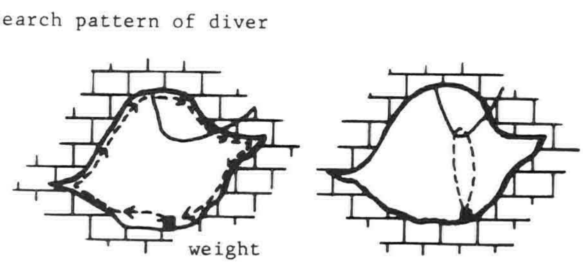
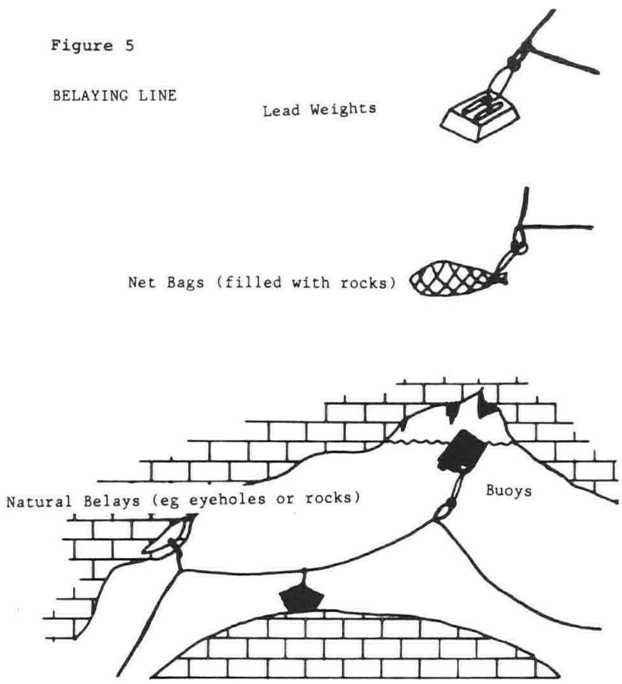


Figure 5

BELAYING LINE



CONCLUSIONS

The modern cave diver has a lot of skills to learn. Not only caving but also open water diving skills. For those who are content to follow others, they still need to know the basic skills of line laying and have the correct equipment. The most important piece of equipment the diver has is his brain. If he fully understands the implications of a dive an experienced diver will either take the necessary precautions or postpone the dive until he has gained the required knowledge, equipment or skill.

Sump Rescue Arrangements in Northern England

Julian GRIFFITHS

Two equipment dumps have been established, one at the Cave Rescue Organisation (CRO) depot in Clapham and one at Upper Wharfedale Fell Rescue Association (UWFRA) depot in Grassington. These comprise sufficient diving gear to kit out two divers who only have wetsuits to hand. A drysuit is also available at each location but there is a need to acquire pressure resistant containers to ferry medical supplies through sumps.

A list of divers in the region who would be able to assist in a diving rescue is maintained and is used by the CRO and UWFRA rescue controllers. Great emphasis is placed on calling out divers when it is felt that they might be able to help rather than having them on standby.

A number of practice rescues have been attempted in short sumps. The conclusion drawn from these is that in most cases, it is not safe to take the victim through a sump on a stretcher. It is far better, where possible, to splint the part of the body affected and for two divers to "drag" the victim. One at the front provides the motive power while the one behind keeps the victim's legs together. It should be noted that this technique increases the lead divers air consumption appreciably.

Familiarity with sumps and communication with rescue controllers are important in diving rescues. While there may be a case for a national list of divers who are available to assist at rescues, the diving rescue function should not be put onto a national basis. Ideally each rescue organisation should appoint their own diving controllers.

Sump Rescue Arrangements in Derbyshire

Richard BARTROP

Sump rescue arrangements in Derbyshire were radically modified as a result of the Ilam Risings Rescue in 1977. Before this the arrangement was that the Derbyshire Cave Rescue Organisation (DCRO) would contact one or two local cave divers who assisted DCRO under a controller who was not a diver. The system proved inadequate on this rescue. The divers at the scene refused to enter the sump for various reasons. This caused some animosity between the cavers and the divers. After the event, through informal conversation, a new system emerged. Diving was becoming more popular at around this time and there was a larger pool of divers to draw from for rescue purposes.

Al Harrison is the present controller of a diving section of the DCRO. Being a diver and a rescuer, he is best suited to provide liaison between the normal cave rescue personnel and the divers and to iron out differences in attitude and practise in the event of an incident.

Divers from other regions are included on the call-out list because of the small number of local divers who are eligible for inclusion. The list currently being expanded to include even more personnel. Divers are called out in a set order. Criteria for the order include; time required to get to the DCRO store in Buxton, availability due to work and holidays and present level of diving activity. This list is revised regularly by John Cordingley who assesses the changing situations of the divers concerned.

The callout procedure was bypassed in the case of the Bagshaw Cavern incident when the DCRO callout officer realised that divers could be contacted at the Technical Speleological Group's headquarters at Castleton. This enabled the divers to get to the incident sooner and to do what was important to them: sort out their gear. Divers, cave rescuers and controllers worked together well in an attempt to rescue a fourteen year old boy who had entered a sump unequipped. Assuming him to be alive, speed was of the essence even though the chances of a live rescue were minimal. The drowned victim was located 12 m. into the sump.

The DCRO owns a Kirby Morgan Band Mask (KMM) and a small amount of cave diving equipment. Two complete sets of diving equipment (minus wetsuits), peripheral equipment to modify the KMM for rescue purposes and 600 m. of line combined with telephone wire to provide through-sump communications are required urgently. The sump rescue stretcher also needs modifying. Money to fund this equipment has yet to be found.

However, on a brighter note, DCRO divers have been practising with the equipment available (see appendix 2). Hopefully the problems identified during these practises can be solved before the equipment is required in earnest.

Sump Rescue Arrangements in Wales

John ADAMS

The present equipment holding for use in sump rescue in Wales is one sharkskin neoprene wetsuit sump bag (with arms) and two double lined neoprene drysuit sump bags (without arms).

The wetsuit bag and one of the drysuit bags are held by South Wales Cave Rescue Organisation (SWCRO), the other drysuit bag is held by the equipment officer of the Welsh Section CDG.

There are, however, several immediate issues of concern with regards this equipment. Firstly, the drysuit bags have drysuit zips but do not have either neck or face seals. Therefore the victim would become wet and cold unless a barrier to water can be added. Secondly, if the victim had sustained head, neck or back injuries a seal could prove troublesome or even dangerous.

Although the Welsh Section has nine cylinders none are designated for rescue purposes. If the concept of a national rescue squad becomes a reality then cylinders will need to be provided.

There is also the most immediate problem of obtaining a full face mask. Two sections (Somerset and Derbyshire) currently own a Kirby Morgan Band Mask but the Welsh Section has refrained from any such purchase because of the lack of a suitable mask at a price it can afford.

Although a successful sump rescue was effected in Wales last year there are other potential problem areas. The terminal sump of Daren Cilau connects with Agen Allwedd Risings some 500 m downstream. However, the work on the Agen Allwedd Risings has not yet completed a connection which would allow the possibility of a rescue via this route. When the through dive is achieved it will undoubtedly become a possible rescue route. This will of course be an extremely serious undertaking and a team of proficient divers will be required to effect such a rescue.

In conclusion there are several problems which plague the Welsh Section with regards to sump rescue. These include a shortage of funds and subsequent lack of equipment; difficulties in organisation and coordination caused by the complicated relationship between the SWCRO and the separate police authorities which cover the caving area and finally the attitude of some cavers who assume that a rescue through a sump is a simple affair.

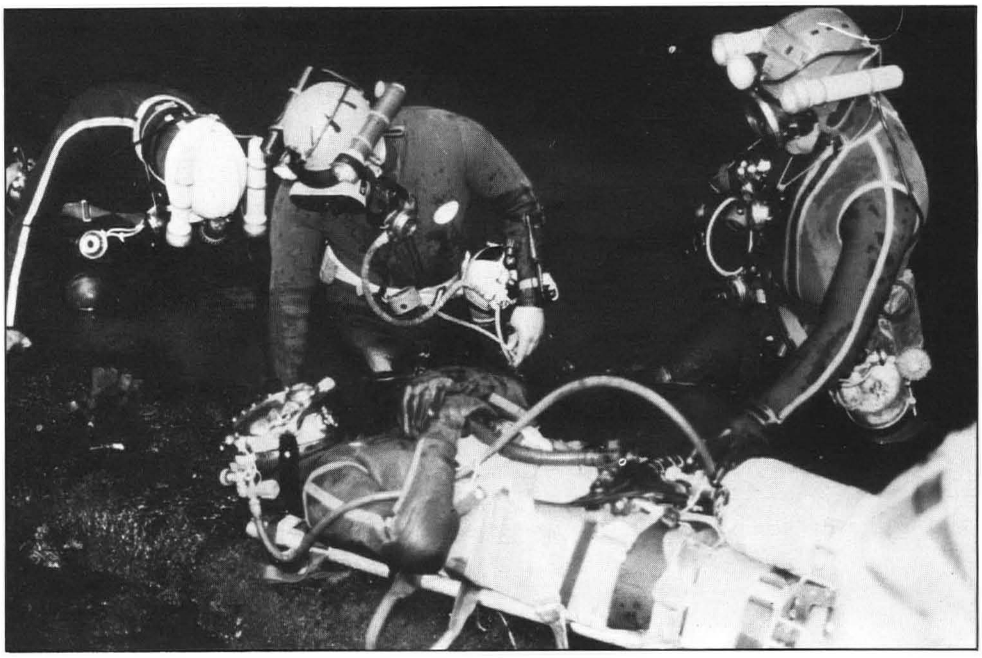
Sump Rescue Arrangements in Somerset

Bob DRAKE

In Somerset any initial call received by the Police is passed on to the Mendip Rescue Organisation (MRO) and the appropriate warden is then contacted.

The Somerset Section of the CDG and the MRO have been using sump rescue apparatus for over 20 years; first with a Normalair full face mask unit and more recently with a Kirby Morgan Band Mask (KMM) 10. They have had the KMM for about five

The Mendip Rescue Organisation sump rescue apparatus at a practice session at Wookey Hole. A 2000 litre cylinder supplies a Kirby Morgan bandmask, and neutral buoyancy is achieved with a chest mounted adjustable buoyancy life jacket (Photo: R Bury).



years and various sump rescue practices have been organised using different recovery techniques. The first technique was with the victim strapped to the stretcher and the air supply to the mask carried separately by a support diver. A long hose was required. The next method was with a self-contained air supply was strapped on the stretcher between the victim's legs. Both these techniques involve the use of two or more backup divers to manoeuvre and hold the stretcher. They can be assisted in this by the use of an adjustable buoyancy life jacket (ABLJ) mounted across the chest of the patient and a weight belt strapped around the middle. Buoyancy can then be adjusted as necessary. However these methods are only suitable for the larger sumps. More recently the idea has been to do away with the stretcher altogether and just use the KMM together with a localised support for the injury. It is then possible for a single diver to effect a recovery. This would save a great deal of time and manpower but is dependent on the type of injury and nature of the sump.

There are still problems to overcome with long and deep sumps. For instance, the KMM uses a lot of air therefore a change of bottle could be necessary underwater. This can be made possible with the manufacture of a valve and connection but the practical application could still be very difficult. For very short sumps, such as Swildons 1, the air can be fed from the base to the mask with the long hose; however problems of hose length, hose volume and pressure differences between first and second stage valves are all yet to be dealt with.

All the rescue apparatus is stored at a central base on Mendip together with lists of telephone numbers where backup facilities and extra equipment can be obtained quickly. The Somerset Section feels that it is well prepared but we must keep an open mind for new ideas.

An Analysis of Cave Diving Incidents

John CORDINGLEY

The writer is grateful to Bill Gascoigne, Jim Hanwell, Ian Watson and Bill Whitehouse for supplying him with a large amount of information on diving rescues. It is difficult to know how to present these data without drawing misleading conclusions. To keep it simple I decided to categorise incidents according to their prime reason. The results are given in table 1. It has to be stressed that there must inevitably be some degree of overlap, especially between categories 2,3 and 4. It is also possible that the list is not comprehensive because it reflects the response I received and not an exhaustive search of the literature. There have been numerous "stand-by" incidents and, whilst these are not included on the list, it should be noted that these are almost all associated with category 5. The incidents have been fairly evenly distributed throughout the main British caving areas, and although statistically speaking they represent only a small sample from 50 years of cave diving, they are broadly similar to statistics from other countries.

Table 1

Summary of main causes of incidents attended by rescue team divers in Britain

Category	Cause of Incident	Number of Incidents
1	Cause not known	4
2	Line problems	7
3	Gear failure / Unsuitable gear	2
4	Inexperienced/"Unjustified panic"	4
5	Problems to cavers or would-be divers	23

Several useful comments and observations can be made concerning Table 1. Firstly it is extremely important that full details of an incident are recorded at the time. My correspondents who supplied the information were able to give me detailed accounts of many of the incidents referred to. Only by making this information more widely available can we hope to avoid similar accidents in the future. Although incidents may be categorised the fact is that they often arise as a result of a number of seemingly trivial problems occurring simultaneously. Inexperience is often a factor. The following was overheard recently in a Dales pub: "No one is a perfect cave diver but almost everyone could be a safer one." This is food for thought indeed!

There have been too many deaths from "unascertained" causes; reflecting the need for exhaustive investigations by coroners in every case. Loss of, or inability to return along, the line has been a major cause of diving deaths whereas problems with equipment are rarely responsible. Cave divers sometimes spend hours preparing their gear yet they have often laid lines quickly and badly. Fortunately this tends not to be the case nowadays. The most common cause of call-outs involving diving teams is still to assist ordinary cavers in trouble and this should be borne in mind when requests to rescue organisations for money to buy more equipment are made by their diving teams.

It is difficult to make predictions about future trends but it seems to me that there are two main problem areas which need adequate preparation by diving teams. Firstly, there is going to be a serious accident to a diver who is caving beyond a long sump. All the major British caving areas now have extensive passages beyond sumps of between 200m and 600m in length. There are not yet any which require decompression on the inward dive but this will become an added complication in future. Secondly, with the regular exploration of deeper sumps there will be situations where divers with decompression sickness have to be evacuated. This will require special arrangements and casualty treatment. It is to be hoped that the rescue organisations and cave divers will continue to work together to overcome the difficulties involved in these types of incidents, before they happen.

A Review of Sump Rescue Types

John CORDINGLEY

Table 2 shows a summary of the kinds of incidents likely to be encountered in cave diving situations and some comments on how rescues might be carried out. This is based on ideas collected from the international symposium in France last year with a few modifications to make it relevant to the British situation. Much of it will seem obvious to cave divers but I would like to add the following comments and suggestions for the benefit of cave rescue controllers who may not be familiar with the problems associated with cave diving.

Firstly, an overdue diver must be assumed to be alive until his body is actually found. If the victim is alive the cold will quickly render him helpless. It is essential to get the rescue diver(s) into the sump as quickly as possible. Although speed is vital delays should be anticipated because any diving operation needs to be carried out safely. More cave divers than it is expected to be needed should be called out. "Stand-by" calls lead to long delays. Sump rescues happen fairly infrequently and most divers agree that a good turn out of competent people is needed even if some are not required. If nothing else they will be bringing more equipment to the scene.

Never over-estimate what divers can realistically achieve. They must be allowed to make their own decisions; bearing in mind such constraints as safety, logistics and available manpower. Information from divers with recent experience of the sump should actively be sought; even if they are not able to attend. Do not let divers do anything dangerous just to satisfy the hopes or wishes of the victim's relatives. Alternatives to the use of divers (eg pumping, digging and by-passing) should always be borne in mind. It is also important to be aware that diving operations are hampered by redundant helpers who congregate around the diving base. It would be useful if supplies of oxygen were available in sump rescue stores as this can significantly shorten the decompression times of rescue dives in long deep sumps.

An excellent discussion on how to organise sump rescues and recoveries is given in an American publication edited by Exley and Young (1982).

Rescue through Long and Deep Sumps

Rob PALMER

The problems of rescuing an injured person through a deep or long section of flooded cave have yet to be solved. Current techniques of sump rescue will probably prove woefully inadequate in coping with such an eventuality. It is also likely that the particular problems associated with a particular incident will make forward planning largely conjectural. Let us assume that a long sump is one in excess of 100m long and that a deep one is in excess of 20m deep. These figures are arbitrary and are guidelines only. The combination of length, depth and complexity introduce other factors (such as time spent underwater) which add a secondary meaning to the word "long".

The use of stretchers and full face masks of varying types may have some application in serious

Table 2

TYPE OF INCIDENT	RESCUE PERSONNEL	TYPE OF RESCUE OPERATION	SPECIAL EQUIPMENT
		ACCIDENT BEYOND A SUMP	
simple incident eg gear failure	co-divers	repair and assistance	repair kit & spares as necessary
"non-serious" accident	cave divers diving doctor	first aid assistance and evacuation	comprehensive medical kit
serious accident	diving doctor diving nurses rescue divers	hospitalisation	hospitalisation kit communications food and air
victim dead	cave divers	evacuation	buoyancy and stretcher
trapped non-divers	cave divers	evacuation by diving in extremis only	survival kit, food communications
		ACCIDENT OCCURRING WHILST DIVING	
diver in difficulties	co-diver	immediate rescue	-
diver overdue	cave divers	RAPID search, assistance	air and lights
diver dead	cave divers	evacuation	tow rope
		PHYSIOLOGICAL PROBLEM AFTER DIVE	
outside of cave	specialist doctor	evacuation to recompression chamber	medical kit, oxygen, rapid transport
inside cave	rescue team and specialist doctor		

long distance rescues where the casualty is unable to assist himself due to additional injury or unconsciousness. However the likelihood of successfully evacuating an unconscious casualty through a very long or deep sump is remote. The first major point to make when discussing such a rescue attempt is that it has to be a last resort. The probability is that, unless the victim is able to help to a considerable degree and is fully conscious throughout, the rescue attempt will probably prove fatal. The risks to both casualty and rescue divers are extreme.

PROBLEMS

The problems faced in any sump rescue are worth re-considering. The likelihood of good visibility is remote. The floor of the sump may consist of mobile sediments making forward movement a problem and decreasing visibility further. The tunnel itself is likely to be irregular in shape, possibly constricted, and visual communication between rescue divers and casualty is going to be extremely difficult. Visual observation of the casualty may not be possible. In other than the shortest of sumps there are likely to be considerable problems in maintaining a continual air supply to both rescue divers and casualty. Stress levels in all concerned, even in short or shallow sumps, will be high. All these basic aspects will be compounded manyfold in the case of long or deep sump rescue. Additional aspects to consider are decompression, recompression, hypothermia and gas toxicity.

Decompression and recompression

The need to decompress is a function of the duration of the dive and the depth involved. Long and relatively shallow dives may be just as likely to involve casualty and rescue diver decompression as would short and deep ones. Never underestimate how long it would take even a slightly injured diver to pass a difficult sump. In the event of a rescue dive involving decompression it is imperative that the rescue divers should be thoroughly familiar with the practice of decompression diving in underwater caves. If possible gas mixtures for decompression stops should be supplied from the surface via an umbilical thereby reducing the practical task-loading on the rescue divers. When possible the use of oxygen at shallow depths will not only reduce underwater time but may also be of considerable benefit to the casualty.

On any rescue involving decompression diving a chamber capable of providing recompression support to cover the depth, the duration involved and the gas mixtures used must be put on immediate stand-by to accept casualties. Rescue teams should be aware that not all recompression facilities can cope with recompression to depths of over 50m or with gas mixtures such as Trimix.

Hypothermia

Hypothermia could prove to be a major problem for casualty and rescue divers alike. Rescue divers should use drysuits with thermal undersuits to allow long duration diving. There is the possibility that divers and victim could be in the water for several hours. It may be worth considering the use of active heating systems for the casualty. Breathing Heliox or Trimix will hasten hypothermia by encouraging cooling of the core tissue. Conversely, oxygen will stimulate core activity; but this may cause a long term drain on the divers' physical reserves and creates its own problems when used for long periods. Cold will affect the judgement and physical capabilities of the divers. This must be borne in mind and contingency plans made to rotate diving teams.

Gas Toxicity

With increasing depth problems can arise with breathing gas mixtures (Sisman, 1982). Oxygen becomes toxic at depth exceeding 20m and has a normal use limit of -10m. Ordinary air mixtures become toxic at depths of over 100m due to the partial pressure of the oxygen. Also ordinary air cannot be breathed below 40m without some degree of nitrogen narcosis. It follows that breathing ordinary air at depths exceeding 40m on a rescue is not to be recommended. Unfortunately the use of gas mixtures (eg Heliox, Nitrox, Trimix) is expensive. In a rescue careful consideration must be given to the use of ordinary air below 30m, the ability of the divers to perform at depth on air and the availability of mixed gases. It should be noted that tolerance can be present in individuals who regularly dive to greater depths. Also, decompression procedures and times for mixed gas diving are different to those for diving on ordinary compressed air.

Factors affecting gas toxicity levels include psychological stress, workload, exposure and general physical health. Certain drugs may be affected by breathing gas and may not be suitable for long and deep sump rescues.

Psychological Stress

This has been mentioned in several respects already. Stress and its associated effects are too commonly overlooked in underwater rescue and can contribute to some of the more lethal combinations that might be encountered. Rescue divers will be under extreme stress and this will affect their abilities to concentrate, to perform even the simplest of tasks, to monitor the casualty accurately, to communicate and even to look after themselves. Stress can be a trigger for narcosis, "depth blackout" (Exley, 1982), carbon dioxide poisoning (Sayers, 1986) and other depth related problems. Anything that can be done to reduce stress levels on a deep or long sump rescue should be done. Divers should be warm, communications should be good, tasks should be as simple as possible and everyone should be working well inside their own physical and mental limits.

Casualty monitoring and communications

Monitoring and communications go hand in hand. Presuming the rescue divers are more than capable of looking after themselves, the next most important person is the casualty. Ensuring that the casualty is alive and keeping him alive are of prime importance. The ordinary problems of cave diving (low visibility, constricted passages etc) make underwater communication and observation difficult. Some way of instantly monitoring the casualty's condition underwater in low visibility would be of great help. It might be possible to produce a digital display, monitoring internal and external temperature, pulse rate and breathing rate, which could be strapped to the leading rescue diver. It is equally important to monitor how much air the casualty is consuming and how much air he has left. Vocal communication between divers, the casualty and the dive base would be an advantage. Such a system should also, if required, be able to isolate the casualty from communications between divers and the dive base. The technical equipment for such communications is readily available in the commercial diving world (Sisman, 1982) and in the caving world (Mackin, this volume). In the absence of such equipment a set of visual or tactile signals between the rescue divers should be agreed in advance. Underwater slates can be used to pass more complex messages. Finally, if possible, divers who are used to working together should be kept as a team.

Continual air supply

One of the major problems on long and deep sump rescues will be that of ensuring a continual supply of breathing gas to the rescue divers and the casualty. Possible solutions would be to use either umbilicals connected to the diving base or to use rebreathers.

An immediate problem with umbilicals is manoeuvrability which would be severely impaired. Were each diver to use one there would be at least two separate umbilicals in the passage. Though it would be possible to attach a single umbilical to a stretcher and to take separate air lines from this to two or more rescue divers and the casualty, this would require experience of working with such equipment for all the divers involved. For a straightforward, deep and unrestricted sump (or possibly even a long and unrestricted sump where support divers are available to move the umbilicals) such a method might prove practicable. It would certainly allow an unrestricted supply of breathing gas, the surface control of gas mixtures for depth and decompression and high-quality underwater communications. However, the nature of most long and deep sump passages makes the use of such a technique highly unlikely.

Rebreathers, which are likely to come into increasingly common use in cave diving exploration over the next decade, could revolutionise sump rescue. Equipment allowing a stay of several hours underwater, to depths of several hundred metres, already exists (Sisman, 1982). Most rebreather systems in current commercial use work in conjunction with an umbilical but there are several remote systems which might be used in sump rescue. The advantages are mixed gas use becomes considerably cheaper, no exhaust bubbles to interfere with roof sediments and both rescue divers and casualty can spend more time underwater with less backup. Problems arise with current models when the physical conditions underground are considered. Though their future use in regular cave diving should help solve many of these problems they have only a conjectural role in sump rescue at the time of writing. However, it is worth considering the use of a rebreather for a stretcher-bound casualty where the system can be mounted and protected.

The major problem with using ordinary SCUBA equipment is the vast number of independently valved cylinders required. Cylinders would have to be placed in the sump at predetermined intervals before the start of the rescue attempt. Experiments by the Upper Wharfedale Fell Rescue Association on the use of low-pressure connectors could well solve some of the problems of cylinder changing. In such a system only the cylinders themselves need to be changed thereby reducing the number of regulators required. The logistical problems generated by the use of SCUBA equipment for a long, deep rescue involving decompression are staggering.

<u>Additional aspects</u>

There are a few additional items which should be mentioned. For instance, all diving lines within the system should be removed or rebelayed well away from the main exit line. This should in turn be replaced by a high visibility line suitable for hauling on. Carefully belaying of this line is necessary to ensure that it can be pulled on without being drawn into constricted sections of passage. The numbers of rescue divers with the casualty should be kept to a minimum. Additional experienced divers should be available at base for support if required. Whenever possible the the most experienced diver or divers should remain with the casualty for the duration of the rescue attempt.

All personnel involved should realise that there may come a point on a deep or long sump rescue where it may become unacceptably risky to continue. Any modifications to a rescue plan must take place when divers and casualty are in an airspace where the rescue attempt can be safely interrupted. Rebriefing underwater must be avoided unless absolutely vital.

CONCLUSIONS

The problems posed by long distance or deep sump rescue attempts are extreme. Techniques exist and equipment is commercially available to solve many of the basic problems of underwater communications and air supply. However, experience is lacking in both cave diving and cave rescue circles.

Cave rescue organisations should only consider evacuating a casualty through a long or deep sump if no other form of evacuation is possible. In all cases the operation should be kept as simple, and be carried out as quickly, as is safely possible. Self - rescue, where conditions allow, may be the best solution. Risk levels are extreme. Therefore only the most experienced personnel should be used. Otherwise, both rescuers and casualty are placed in a situation of unacceptable risk.

Medical Aspects of Sump Rescue

Peter GLANVILL

The aim of this paper is to give those at the scene of an accident on the wrong side of a long or deep sump some idea of the options that are available to them in the event of certain injuries being present. One can practice triage; a medical term used when assessing a large number of casualties with a limited supply of medical resources.

1) Those victims who would be able to use normal breathing apparatus and make their way out through a sump with minimal assistance.

2) Those victims who by virtue of the nature of their injuries could not possibly be transported through a sump.

3) Those victims whose injuries are severe enough to prevent them using normal breathing apparatus but are able to be transported through a sump.

Obviously there are some sumps which are so awkward that rescue of victims in group 3 would be impossible anyway. Also in some cases it may be preferable to ship a non-diving caver out through a sump instead of a prolonged and difficult dry rescue; especially if the nature of the injury means rapid treatment is required. It should be borne in mind that time spent waiting for sump rescue apparatus to arrive may amount to many hours. Finally, in "do or die" situations one may have to push victims in category 2 into category 3 simply because hospitalisation underground may be out of the question.

Fortunately, up to now accidents beyond sumps have resulted in injuries of the type described in 1. Two incidents have happened on Mendip. In one case a caver injured his hand by falling down Victoria Aven in Swildon's 12. He was able to dive out under his own steam. There have been several near disasters here and sump rescue would be technically very demanding if not impossible. In the more recent incident a film cameraman fell and injured his leg whilst in Wookey 22. With assistance he was able to make his way out. He subsequently required a general anaesthetic and surgery to set the ankle fracture he had sustained. Incidents in the other two groups have not occurred yet as far as the author is aware.

<u>Group 1</u>

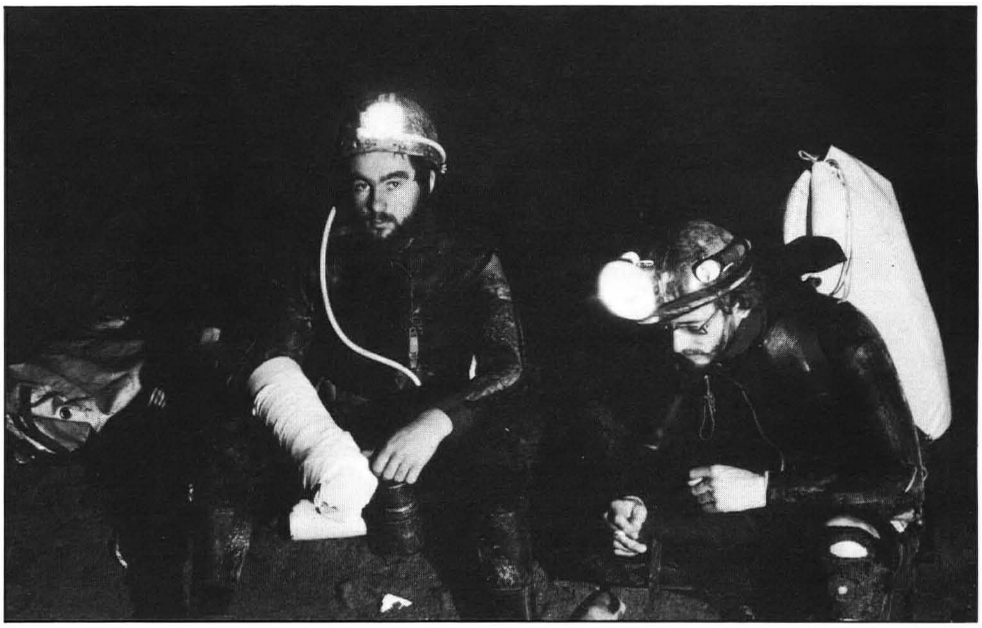
The commonest cause of injury is a fall but boulder falls may cause injuries as well. In the main, injuries to limbs should not prevent the diver making his own way out with his own equipment.

Lacerations can be crudely stitched up to prevent bleeding and improve function. Fractures can be simply splinted. Pain relief should be kept to the minimum prior to a dive as powerful analgesics can affect the concentration and their effect on a submerged diver is quite unpredictable. Usually, in such a, situation the victim will not be experiencing much pain; particularly in the acute stages when he is worrying about self-preservation.

Some fractures may be more troublesome than others and will be mentioned in other groups. Broken ribs should not prevent somebody from diving provided the lung or its surrounding membrane (the pleura) have not been damaged. The injection of local anaesthetic around the site of injury will often temporarily relieve pain and allow a diver to breathe effectively.

If a diver has head injuries but has not been

A typical self-rescue: the caver on the left was evacuated from the end of a 7 km long cave with a fractured radius splinted with a rolled Karrimat (Photo: J Cordingley).



rendered unconscious he may dive out provided that bleeding has been stopped (scalp wounds usually bleed dramatically but stop with simple pressure).

To summarise if a casualty is conscious and alert, is not suffering from shock (due to blood loss), can breathe normally and move through a sump on his own, or with minor assistance, then he would be better off going out through the sump under his own steam. Waiting for rescue will have the effect of lowering morale and body temperature and the clinical condition is likely to deteriorate. Long waits may allow infection of open fractures to develop: as happened during the rescue from Southern Stream Passage in Agen Allwedd a few years ago.

Group 2

Here are included those whose injuries are not compatible with transport underwater using any form of breathing apparatus.

Firstly, there is the unconscious victim who, presumably, will have some form of head injury. An increase in pressure may make his condition worse and a skull fracture with leakage of cerebro-spinal fluid would predispose the victim to infection of the central nervous system. There is also the possibility that the victim may vomit and block his airway. Short of intubating the victim prior to transport through the sump this hazard is impossible to prevent.

Injuries of the rib cage causing its instability would prevent transport of somebody through a sump. With multiple rib fractures a lung may collapse or the chest may move the wrong way (flail chest) preventing the lung from receiving fresh air and thus reducing oxygenation of the blood.

Abdominal injuries may also prevent transport through a sump. Here, as in most of the preceding, not enough is known to be sure. However if, for example, a hollow abdominal organ is ruptured or injured and compressed air is introduced into it then when the pressure is taken off the gaseous expansion may make matters worse. To illustrate what could be called the "Alien" syndrome is the story of the American cave diver who during the course of a rescue swallowed compressed air and was unable to belch it up on surfacing. When his grossly expanded stomach was operated on it scattered its contents around the theatre. Other abdominal organs, such as the bladder and spleen, may initially rupture quietly before the worst becomes apparent. Fluctuations in pressure might make matters worse more rapidly.

People in a state of shock due to blood loss could not be transported out underwater until their condition had been stabilised. Rupture of internal organs such as the spleen or liver might cause shock but more likely to be associated with a caving accident is a fracture of the femur when a couple of litres of blood may be lost. Shock often leads to "air hunger" as the victim is deprived of his normal quota of oxygen-carrying blood and also may lead a fall in body temperature.

Group 3

Here there is that tiny group of individuals whose injuries are severe enough to prevent them from diving out under their own steam but are insufficient to prevent them from using a sump rescue apparatus. I think suspected spinal cord injuries fit the bill and, possibly, fractures of the pelvis or femur. Provided the spinal cord injury is not high enough (in practical terms the neck) to compromise breathing then the victim could be carried out through a sump. Obviously he could not dive out on his own. Stabilisation of the spine would require a spinal splint and this could be compatible with the current sump rescue apparatus.

PRESSURE EFFECTS IN SUMP RESCUE

Ear, nose and throat

Most victims will be able to clear their ears but in the case of an unconscious diver there may be damage to the air containing spaces in the skull (ie the middle ear and the sinuses). This could result in the victim rupturing his eardrums or getting a sinus squeeze. It may be possible with the new sump rescue apparatus to squeeze the victims nose intermittently to encourage pressure equalisation.

Chest

Theoretically there should be no problems here as the victim will be breathing pressurised air. Ascent should be safe providing there is no obstruction but it should be ascertained that he is breathing out during the ascent to avoid burst lung.

Abdomen

Pressurised gas trapped in the gut by swallowing will expand at shallower depths and may cause splitting of the diaphragm with embarrassment of respiration. This could happen with an anxious victim.

Unconsciousness

This would be tricky. Transporting an unconscious patient through a sump should only be done in a life or death situation where urgent surgery is required or where the victim is deteriorating steadily. The airway may be restricted with the added risk of victim vomiting and the only way to ensure it remains clear is by intubation. How this would work with sump rescue apparatus is not known by the author.

Drugs
Divers are advised not to take any kind of medication before diving. Little research has been done into altered effects of drugs under pressure and probably none at all in wet conditions. Giving drugs to sedate a victim sounds potentially very dangerous in that they may affect the respiratory drive or, in an unconscious patient, alter valuable neurological signs. Whether the effects of pain killers would be reversed is debatable as they act in a different way to anaesthetic gases. However the opiates also have the effect of altering the neurological signs. On the whole drugs should be avoided.

The Management of Decompression Sickness

Peter GLANVILL

As cave divers go to greater depths and adopt more experimental techniques, including some decompression schedules, so the risk of them developing decompression sickness (DCS) must increase. However, having stated this, the usual steady descents and ascents of cave dives act as natural checks against decompression problems. For example the problem of air embolism in a cave diver would be an extremely rare occurrence as it usually depends on rapid uncontrolled ascents to the surface. The only problems come when a series of relatively steep dives are made to reach the start of a main dive: as in Wookey Hole. Here the modern computerised meters come into their own; allowing the diver more leeway in calculating his final decompression stops.

It is to be hoped that all divers are aware of the cause of decompression sickness. DCS is a consequence of the fact that, under pressure, inhaled gases which are relatively insoluble at atmospheric pressure are absorbed into body tissues. The rate of absorption is dependent on the type of tissue. After a period of time at a particular pressure the tissue is said to be saturated; ie it cannot absorb any more gas. Hence the term saturation, or "sat", diving where the diver is kept in a gas pressure similar to that of the depth at which he is working. This avoids the long periods of decompression that would be necessary after each working dive. When a diver starts to come up from depth the gas dissolved in his tissues begins to come out of solution in the form of tiny bubbles. If his rate of ascent is too rapid then these bubbles can become large enough to obstruct blood vessels or develop in joint fluid. The end result is that the diver develops DCS with symptoms dependent on where the bubbles are forming. Factors such as cold, exercise, obesity, age, alcohol, diver acclimatisation, gas mixture used, carbon dioxide build up, state of hydration, fitness of the diver and pre-existing medical problems may all contribute to the development of DCS. Then there are post-dive triggers to DCS such as flying in a plane shortly after diving or being given inhalation analgesics such as nitrous oxide.

DCS is classified as being of type 1 or type 2 depending on its severity but in the author's personal experience this division is purely artificial. Type 1 bends are said to be those not affecting the central nervous system or joints; eg skin rashes, itching etc. In practical terms these symptoms may precede more serious manifestations. However type 2 DCS may occur and develop insidiously without any prior warning. It is important that divers are aware of the many manifestations of DCS so that they can recognise them and take appropriate action. Although a minor skin bend after a cave dive may not develop into anything else many cave diving locations are a long way from a recompression chamber and prudency suggests the diver might be advised to seek advice early rather that late.

Therapeutic recompression
This basically involves putting the victim under pressure to shrink the bubbles and relieve the symptoms. Pure oxygen is usually breathed at a depth of 18m over six hours in the treatment of most cases of DCS. Oxygen has the effect of increasing the rate of elimination of nitrogen from the body and also helps any tissues starved of oxygen as a result of obstruction of blood vessels by bubbles. Recently some chamber operators have been using Heliox mixtures to increase the rate of nitrogen elimination. Current evidence also suggests that some symptoms may take longer than expected to improve.

SOME SYMPTOMS OF DECOMPRESSION SICKNESS

Skin irritation
Skin rash
Skin swelling
Bruising sensation without history of injury
Aching in shoulders or around lower limbs
Malaise
Nausea (sometimes vomiting)
Lightheadedness
Fatigue
Girdle pain
Visual disturbances
Patches of numbness or pins and needles over any part of the body
Headache
Loss of use of limbs
Vertigo
Difficulty in breathing (the "chokes")

In fact anything out of the ordinary!
85% of DCS occurs in the first hour,
95% within 3 hours and
only 1% over 6 hours.

What to do if DCS is suspected

DO:-
Stop the victim doing anything energetic.
Give him plenty to drink - electrolyte mixtures such as dioralyte may be helpful.
Keep him warm but do not actively heat up (heat makes DCS symptoms worse).
Contact the nearest therapeutic recompression chamber as soon as possible.
Take notice if the diver says he has symptoms.
Monitor urine output.
Give pure oxygen at atmospheric pressure if available.
If the symptoms seem severe and the skill is available then an intravenous line will allow fluids to be given and their volume measured.
Suggest normal saline.

DON'T:-
Give large meals.
Give aspirin.
Give steroids intravenously.
Give sugary fluids intravenously.
PANIC!

A rope stretcher supported by tree branches used to transport a caver with a fractured tibia. A wetsuit jacket is used for padding between the legs, and roll-bar buckle belts keep the legs immobile.
(Photo: P Halliwell)

Hospitalisation Underground

John FRANKLAND

I am frightened that naive discussion on hospitalisation is becoming fashionable. Some seem to feel that it is an end in itself and that apart from a few custodians of the patient it will absolve rescue teams from worry, effort or responsibility. Nothing could be further from reality.

After twenty years of tending to Yorkshire Dales cavers who are lost, fatigued, cold, dead or occasionally sorry for themselves I have developed a philosophy which is that rescue gets better results with a pick them up and drag them out approach (with some calculated medical and first-aid input) rather than with a "carry all intensive care unit, major surgery team, psychotherapy and rehabilitation personnel down to the victim" approach.

The term and concept emerged sixteen years ago. Pippikin Pot had just "gone" and everyone was full of foreboding about the inevitable accident in its entrance series. Those new squeezes frightened even slender cavers at that time. It has now, of course, become a routine non-tigers trip as it has two larger entrances. Spurred on by fears of rescue from Pippikin the Cave Rescue Organisation (CRO) and Upper Wharfedale Fell Rescue Association (UWFRA) met and considered generally the problems of rescue from extremely tight and difficult cave systems. They produced a list of fifty six Yorkshire caves in that category. By now there are many more.

To put the matter in perspective we have in the intervening sixteen years had a number of rescues from caves on this list (including Pippikin Pot) and never yet resorted to hospitalisation. We are conscious of extreme good fortune in having been spared from the "worst case scenario" incident which will come one day. When it does suppositions and ideas will be put to the test. Until then there is much speculation and theorising.

In 1970 after a meeting of a sub-committee of the CRO and UWFRA I summarised our views on the subject. These thoughts still seem appropriate even though the concept has never been tested on rescues apart from a planned delayed evacuation which has never exceeded two hours. During this time the team profitably worked on arranging a smoother evacuation from the injury site to cave entrance.

HOSPITALISATION

"This we understand as attempting, with all practical means, to treat and improve the condition of injured cavers, prior their removal to the surface, using all the appropriate portable medical and nursing facilities.

"The principle of treating patients underground other than essential first aid requirements is probably new to Cave Rescue Organisation techniques. Efforts having been previously directed at expedient removal of casualties to the surface. The sub-committee appreciates that in certain situations underground, rescues may be virtually impossible by conventional methods so that underground treatment of casualties may be imperative. We therefore suggest that hospitalisation facilities might be necessary in the following situations:-

1) To allow an extremely difficult or "impossible" exit to be improved.

2) Where the patient is physically trapped (eg fallen rock on leg).

3) To improve the general condition of a patient to facilitate his extraction from a difficult system perhaps thereby allowing his removal without stretcher.

"The suggestion is also put forward that the technique may be worthwhile to rescuscitate a badly shocked patient who would not otherwise survive extraction from the system. As an example of this, a patient with two fractured femurs or thighs would be so shocked from the resulting blood loss that he would be highly unlikely to survive any further buffeting or stress. With intra-venous fluid replacement (possibly including blood transfusion), splintage, warmth, rest and pain-killing drugs his general condition could be improved over perhaps six hours so that his chances of survival would be increased. This latter type of circumstance would present the most difficult decision as to the necessity of treating a patient underground. Inherent in keeping a patient underground are many risks which can never be overcome. These must include:-

1) The problem of exposure, or hypothermia, either present initially or developing during treatment. The levels of hypothermia from which one can rewarm a patient underground are not

known. It should be theoretically possible for patients with exposure to be treated underground if changed into dry clothing and allowed to rewarm spontaneously in dry and insulated sleeping bags (Laufmann, 1951). It is suggested that body temperature should always be monitored and that a low reading (to 75F) thermometer is available.

2) Deterioration due to undiagnosed, possible undiagnosable, injuries not amenable to treatment underground; principally intra-thoracic and intra-abdominal injury or intra cranial bleeding.

3) The stress on the patient's morale.

4) The inconvenience, risk and extra administrative problems involved in respect of all rescuers by prolonging the rescue.

5) Possibility of criticism or litigation if the patient deteriorates and dies.

"Because of these factors it would be negligent to decide to delay any patient underground unnecessarily. These factors must represent inevitable hazards where a patient is treated underground as a necessity. In borderline cases the decision must be taken after due consideration and consultation and with an awareness of the risks involved. It is suggested that medical supervision should be sought if practical. The equipment requirements must include dry clothing and dry sleeping bags for the patient and rescuers and also camping equipment (such as a shelter, cooking facilities, food etc) together with a comprehensive kit of medical supplies and equipment. It is not anticipated that this procedure will be needed frequently. Indeed it would be ideal if it were never needed at any time."

This was written in May 1970 and by 1986 cave divers had added a new dimension to cave rescue problems. Their exploits beyond sumps, in particular with exploration in caves with unknown hazards, means that the whole spectrum of injuries to which cavers are prone may be sustained in a setting where perhaps a lengthy dive has to added to evacuation. Only a limited number may be able to reach the victim and the feasibility of their carrying more than a limited amount of equipment compounds the problem. Delay before help arrives is normal down easy caves but likely to be very protracted beyond sumps.

In any hazardous situation the rescuers must accept that some victims will not survive. Over many years of British cave rescue 10% of call outs have involved a fatality (or, to be more optimistic, 90% have a successful outcome) with the majority succumbing before help arrives.

For accidents beyond sumps some likelihood of fatalities must exist. We have no experience on which to estimate death rates but they could exceed 10%.

The first rule of cave rescuers should always be do not get killed yourself whatever the circumstances and however sad the lot of the victims. (There has been just one example of this happening in the UK in a tragic incident in Rowten Pot in March 1986). In sump rescue those involved face a bigger risk than in conventional rescue and could, because only a small number are capable of helping, be put under pressure from others to carry out acts beyond the boundaries of sensible judgement. They should always remember the first rule of rescue even though their decisions could be interpreted as being callous to the victims.

There may be pressure to get a doctor to the accident site. In the UK at present we have just a small number of doctors with cave diving skills. Only some being up to prolonged and difficult dives. This may not always be the case and it wants stating now, before an incident happens, that the risk of pushing a diving doctor beyond his competence should be considered. He may feel moral pressure to attempt the dive, especially if others are concerned about the patient's condition and feel unable to help, when good judgement dictates that he should not. As a non-diving doctor I feel safe pontificating on this subject.

I also feel after twenty years of attending to injured cavers that my role has generally been to do, with more confidence, what others could in fact have done with the same competence given appropriate, but not a formidable amount of, training.

Thus I would argue that, given adequate first aid training by all cave divers, the benefits of medical assistance for even a badly injured diver beyond a sump may be less than many suppose. Sensibly all cavers should undergo some training in first aid but for divers who venture beyond sumps perhaps it should be mandatory. It will sensibly follow on from the understanding of respiratory physiology that they will have acquired in their dive training.

A basic St. John's or Red Cross course is an ideal start and easy to obtain anywhere but the more specialised teaching put on by most rescue teams for their members based on casualty handling in the underground environment should be much more relevant. There is, sadly, more emphasis on gaining the "Certificate" than on developing competence at "hands on" skills. Even the Mountain Rescue Committee specialist first aid certificate falls into this category occasionally. If these divers can then consolidate their knowledge with some sharp end experience in their local cave rescue team so much the better. They really are going to be on their own with their injured colleague whether they fancy this or not. Our own experienced CRO controllers can now treat, package and transport injured cavers with totally adequate competence and if they can acquire these skills so can cave divers.

Where the doctor may be of particular value in sump rescue is in providing advice, reassurance and guidance via the molefone. This will offer technical guidance and, perhaps as important, moral support and the acceptance of responsibility. If a fatality occurs beyond a sump the Police and Coroners will prefer medical certification of death for the sake of tidiness and to ease their subsequent formal investigations. In my view this certainly does not warrant sending a cave diving doctor for this purpose unless the dive would be totally routine for him. Inquests have been completed with the bodies still underground and not seen by any medical persons but, to my knowledge, only when the victim has been submerged and unrecoverable. The question arises as to whether, when a caver dies beyond a sump, attempts should be made to recover his body? In some circumstances this would present a degree of hazard to the divers taking on the task. Bodies have generally been recovered but not through the long, constricted and low visibility dives now being undertaken. The decision must rest with those who face the task and who will probably be under emotive pressures to recover the body of a colleague, possibly a friend. It is important that they feel under no pressure to attempt this task when their judgement says that this puts themselves at risk. I know of no British precedent when bodies have been left underground without confirmation of death by a doctor except in the case of Niel Moss or when they were submerged. (Dr. Hugh Kidd of Buxton undertook this task with the six cavers left underground in Mossdale in 1967). This does not mean that this could not happen. It should surely happen if recovery makes another fatality a possibility. Those responsible could experience some pressures from the statutory services to undertake the task and the senior officers involved may have no concept of the hazards involved in such a recovery. My reason for introducing this topic now is purely to provoke discussion and to document the fact that the caving community would be prepared to stand their ground against pressure from senior Police officers. In the case of Mossdale a Home Office decision was necessary when recovery attempts were abandoned, on Police orders, so that inquests could be held with bodies remaining underground. If Home Office consent again becomes necessary then the magnitude of the administrative problems this could provoke should not dissuade those expected to take the risks of a recovery dive from standing up and defending their decision. One hopes, of course, that this situation will never arise so that these thoughts will remain as purely theoretical platitudes.

The role of "get them rescued fast" must be modified when the victim needs more help than his companions can offer. The delay before help arrives could be formidable when back up divers have to be sought and then to pass a sump. His comfort will be enormously increased if a basic first aid kit and survival equipment has been carried through a sump beyond which exploration caving is taking place. This was organised in early 1986 at Notts Pot. It would seem a sensible precedent for such undertakings in future. Particularly important is the need to provide thermal insulation to injured victims who will usually be in neoprene suits and will all have had total immersion on the dive in.

In open cave exploration beyond a sump the hazards faced will be those of ordinary exploration caving perhaps magnified by the likelihood of ascents of vertical pitches as compared to routine descents from an optimal belay. Loose rocks approached from below may increase the risk.

The most common cause of injuries to cavers are falls; followed by injuries sustained from falling rocks. Lower leg injuries predominate; their main requirements being adequate splintage and pain relief. In a sump the lack of the need to bear weight will be a bonus for the victim and to my knowledge two divers have swum out through sumps, unassisted, with significant fractures. This will not apply during transport to the sump so that if a stretcher and adequate manpower to handle it is not available the carry could be painful, laborious and demand ingenuity. With spinal, neck and head injuries the CRO's spinal splint could be valuable; adding minimal bulk to the victim and being more feasible to carry through a sump than any stretcher (supplied by Rescue and Medical Equipment, Vale View, Black Rock, Abergavenny, Gwent, NP7 OLW).

For arm fractures and below knee fractures the "Add-a-splint" set from the same supplier is compact, efficient and versatile. For an above knee fracture the Heyes Splint would be appropriate. Using this splint plus the spinal harness would probably be the best method of transporting the seriously injured or unconscious victim when a stretcher is not available. Although the technique has only been used once in earnest it proved very suitable and probably prevented paraplegia.

Insulation and sustenance for the rescuers, first aiders and any other divers delayed beyond the sump may be necessary to prevent their deterioration. The more beyond the sump requirements are increased the more frightening becomes the logistic problem of transporting these through a difficult dive. Some compromises are going to be inevitable but the idea of a planned rescue dump beyond a sump with exploration potential becomes more attractive.

The possibility of the need for rescue through a sump depends on the care taken by, and good fortune experienced by, the cave diving fraternity. A plea for caution and a low level of risk seems in order.

Anyone planning prolonged hospitalisation to full recovery should remember that uncomplicated fractures take six weeks to heal and perhaps as long again before normal mobility is resumed!

The problem faced by a hospitalised patient have previously been considered. The problems faced by rescuers are potentially formidable.

During Sump Rescue these problems could include:-

1) The risk to themselves when distracted from attending to their own survival.

2) The planning problems of who does what at various points of difficulty and the logistic problems of transporting equipment.

3) Communication problems.

4) Possible decompression problems.

5) Difficulties in transporting the patient; especially through constricted passage.

6) Adequately packaging the patient. Self-help would be invaluable but grabbing his diving colleagues in panic could be disastrous.

Beyond the sump problems could include:-

1) Manpower.

2) Patient support and treatment.

3) Equipment shortages.

4) Conserving the rescuers strength and body heat.

What can be done in general principles for cavers injured beyond sumps (Frankland, 1975)? Some aspects will be covered in summary. Some suggestions made are untested, may be controversial and are open to discussion.

<u>Temperature Control</u>

Early insulation in dry clothing within a plastic exposure bag would be ideal. Fibre pile fabric would be optimal and valuable even over a wet suit. Rescuers could provide useful insulation by "body piling" or could share an exposure bag with the victim. Temperature should be monitored with a subnormal thermometer. Chemical heat packs are compact, effective and safe when applied to the trunk. Food and hot drinks will help all.

<u>Incomplete Diagnosis</u>

This is possible in a hostile cave environment even with a medical person to hand. Those present can only do their best. Have you done your first aid course?

<u>Stress</u>

The patient's psyche will be tested. The role of medication in helping this problem is minimal and probably nil. All sedation can impair performance but may be of value if a delay is anticipated and the injuries do not make it inadvisable. The attitudes of the rescuers and their skills at verbal reassurance will be of considerable importance.

<u>Pain Relief</u>

The ideal drug would give relief from severe pain, no sedation, be safe after head injuries and have no undesirable side effects (such as vomiting; which could be fatal during a subsequent dive). It awaits discovery. Opiates like Morphine and Pethidine in adequate dosage will cause drowsiness so that the self-help likely to be necessary during rescue is interfered with. They need injecting, can be slow to act in shock, are subject to stringent requirements on storage and security and can cause vomiting. They can still be of value. A "best buy" for the likely circumstances is the drug Temgesic (Buprenorphine). It can be given under the tongue where it is rapidly absorbed (approximately 10 mins), is a fairly strong pain killer, sedates minimally, acts for eight hours, is safe after non-life threatening head injuries and can be legally carried by those at risk. A small proportion of patients will vomit which some would do anyway after trauma. Those likely to need to administer it should seek personal instruction from a doctor familiar with its use in pre-hospital care. The value of simpler preparations eg Aspirin, Paracetamol, Distalgesic (Co-Proxamol), should not be ignored. Entenox (a 50:50 mixture of nitrous oxide and oxygen) is an effective short duration inhaled pain relief agent but should never be given after diving as it increases the risk of decompression problems (the bends). Ambulances carry this and when the victim is transported to hospital ambulance crews should be warned against its use.

<u>Shock</u>

Pain relief and replacement of circulating fluid are the mainstays of treating this ubiquitous problem; with good splintage, reassurance and insulation as other factors. Establishing intravenous infusions in cold shocked cavers tests the most experience as peripheral veins are likely to be collapsed. In the Falklands conflict service personnel found rectal infusions of saline from the drip set more feasible and of definite value. Untested in caves it is still worth considering as any but the most inhibited could establish such an infusion and the fluid is absorbed through the rectal mucosa fairly effectively. Divers are warned that such equipment is in the Notts Pot medical kit so that if they break a leg beyond this and find their colleagues attempting such a technique their motives are purely honourable.

Specific Injuries

Have you done your first aid course yet? Can you protect the airway of an unconscious patient? You may also wish to pray for him in this situation! If by now you think that hospitalisation does not solve problems but merely delays them or gains time then I will be delighted (Daren Cilau rescuers please note). In fifty one years the Cave Rescue Organisation has assisted 1600 victims with a survival rate underground of 90%. Our divers have carried out sump rescue on five victims with a survival rate of 80%. The one death was from hypothermia after sump rescue and the other four were not injured but trapped by floods.

Perhaps the final message to divers should be: "Cheer up but be bloody careful."

The Use of Gas Mixtures for Cave Diving

John CORDINGLEY

Introduction

In recent years divers have had to use various breathing mixtures other than air in order to explore longer and deeper sumps. This brief review attempts to outline the advantages and dangers of such mixtures so that non-divers will gain understanding of the implications of these advanced techniques in the context of a rescue.

Air Diving

In order to understand the advantages of mixtures it is first necessary to appreciate the constraints imposed by the use of air for normal diving. Air is composed of approximately 79% nitrogen, 21% oxygen and trace amounts of other gases. Nitrogen gas is not metabolised by the body tissues and its concentration in the body remains in equilibrium with that in the lungs. Therefore there is no net transfer of nitrogen under normal conditions. The gas is then said to be inert. Some of the oxygen is absorbed and is carried by the blood to the body tissues which use it. By the time the blood has returned to the lungs it no longer contains as much oxygen so more is absorbed from the air in the lungs. At the same time the waste carbon dioxide produced by the body tissues, and which the blood has collected whilst circulating, is also passed back to the air in the lungs. This is periodically removed from the lungs by the normal ventilation process we call "breathing".

However, when air is breathed at the higher pressures associated with diving (Boyle's Law) the partial pressures of the constituent gases are raised proportionately (Dalton's Law). The nitrogen and oxygen are therefore absorbed from the air in the lungs into the body to a greater extent (Henry's Law). If the body tissues become saturated with these gases beyond a certain amount, both can cause physiological problems for the diver. Dangerous symptoms of oxygen poisoning occur as the partial pressure of the oxygen approaches two atmospheres absolute. Hence the theoretical maximum depth to which air can be used is 90m, where oxygen will be at two atmospheres partial pressure. Unfortunately compressed air is probably unsafe to use at depths exceeding 50m due to two problems associated with the extra nitrogen

Buoyancy control devices help rescue divers avoid reducing visibility which simplifies the return of the victims to base (Photo: S Dudley).

being absorbed by the body as depth (and therefore pressure) increases.

The first of these is the well known narcotic effect of nitrogen referred to variously as "The Narcs" or "Rapture of the Deep". This seriously decreases mental ability and co-ordination and therefore renders a diver unsafe. It is probably unsafe under British conditions to descend to more than 50m depth on air and it should be noted that nitrogen produces measurable effects on diver performance at much shallower depths.

The second problem due to raised nitrogen partial pressures at depth is related to the rapid rate at which certain body tissues (especially fat) absorb it and the relatively slow rate at which they release it. Too rapid an ascent rate will cause bubbles of nitrogen to form in the blood leading to decompression sickness or "The Bends" (as described elsewhere in this volume). To avoid this a diver must delay his ascent with "decompression stops" of which the level and duration are dependant on the length and duration of the dive. However decompression sickness is still a significant danger even if a suitable decompression schedule has been followed.

Decompression Whilst Breathing Oxygen

A technique gaining in popularity is to switch from air to oxygen for all or part of the decompression phase of a dive. This has been used both to shorten the time needed for decompression (as absence of nitrogen in the gas breathed speeds up nitrogen elimination from the body) and to reduce the risk of decompression sickness (by breathing oxygen instead of air but still following the recommended air decompression schedule). The safety of reducing decompression times in this way has been questioned by some authorities and should be regarded as experimental diving (with all the necessary safety precautions). There is little doubt that breathing oxygen whilst following a normal air decompression schedule significantly reduces the risk of decompression sickness.

However, breathing pure oxygen whilst under pressure seriously increases the possibility of acute oxygen poisoning; the symptoms of which include the sudden onset of uncontrollable convulsions often leading to death by drowning. Pure oxygen reaches it's theoretical toxic threshold value of two atmospheres absolute at a depth of only 10m but there are so many variables affecting the tolerance of individual divers that symptoms may arise at shallower depths. Therefore, although cylinders of compressed oxygen (compatible with normal demand valve fittings) should be available in cave rescue stores, only divers who are fully conversant with it's physiological and practical implications (from personal experience) should use it on a sump rescue. Another problem with high pressure oxygen is that it forms highly explosive mixtures with only tiny amounts of many substances which often contaminate the insides of cylinders, manifolds, filling adaptors and demand valves. Only equipment which has been satisfactorily cleaned in a suitable manner should be brought into contact with high pressure oxygen.

Diving on Nitrox

If the depth of the dive is expected to be relatively shallow (eg 30m) but of long duration a "nitrox" gas mixture which is similar to air but with some of the nitrogen replaced by oxygen has certain advantages. Two standard mixes of nitrox are 32.5% oxygen with 67.5% nitrogen ("Nitrox32") and 40% oxygen with 60% nitrogen ("Nitrox40"). Theoretical maximum depths to which these two mixtures may be used are 49m and 40m respectively, due to the raised concentration of oxygen (and risk of oxygen poisoning). At 30m both these mixtures would be safe, yet their lowered partial pressures of nitrogen (compared with air at the same depth) would allow much shorter decompression schedules as well as reducing the level of nitrogen narcosis during the dive. Both these factors could significantly improve the efficiency of a sump rescue operation. Nitrox mixes for diving are available commercially but it is also possible to mix them directly by diluting air with medical oxygen provided that gauge accuracy is satisfactory.

Diving on Heliox

In order to dive safely to depths greater than 50m it is necessary to use a different inert gas mixed with oxygen. A suitable inert gas is helium because it causes less narcosis than would the same partial pressure of nitrogen at the same depth. However at depths exceeding 300m helium causes a physiologically dangerous condition known as "high pressure neurological syndrome" (H.P.N.S.). Furthermore, if the descent is not made slowly (eg over about two days) the onset of H.P.N.S. usually begins at much shallower depths (eg around 150m). Clearly such long dive durations are incompatible with the use of open curcuit diving equipment. This kind of diving is normally carried out in "saturation"; a technique which requires long and carefully controlled decompression schedules in a hyperbaric chamber.

It is also essential, for reasons already stated, that the proportion of oxygen in the heliox mixture does not allow partial pressures of oxygen to rise to the extent where acute oxygen poisoning becomes likely. However, the very long dive durations (including decompression) associated with very deep diving can also cause another form of oxygen poisoning referred to as "chronic". It is possible to calculate the "dose" of oxygen which will be absorbed into the body on the dive in units known as Units of Pulmonary Toxicity Dose (U.P.T.D.). In order to avoid chronic oxygen poisoning the number of U.P.T.D. anticipated during the dive added to the number of U.P.T.D. which would have to be administered during an emergency therapeutic recompression must not be above a certain accepted level.

Another complication is that helium removes heat from the body much more rapidly than does nitrogen and so some artificial heating system within the diving suit is normally necessary. Because of the high level of expertise and expense involved in heliox diving, it has so far not been used by cave divers in this country. However, it has been used on the continent (eg on a 200m deep dive at Vaucluse) and will no doubt play a part in the exploration of British sumps in the not too distant future.

Diving on Trimix

If the inert component of a breathing mixture is itself a mixture of nitrogen and helium, the advantages of both can be utilised in certain situations (eg a 70m deep dive of "medium" duration). Such a mixture of oxygen/nitrogen/helium is known as Trimix. It has proved invaluable in the exploration of certain British sumps (Wookey 25 and Gavel Pot) but only by very fit and well trained individuals. Nitrogen narcosis at depth is minimised because the partial pressure of nitrogen is very low. The cooling effect of helium is reduced because it's partial pressure is also relatively low. The oxygen concentration is a compromise between avoidance of oxygen poisoning and maximum dilution of both inert gases to reduce their undesirable effects.

Unfortunately, the currently available trimix decompression schedules are based on far less experimental data than are those for the other gas mixtures already mentioned. Some authorities also describe "settling out" of the gases (due to their different densities) occurring in stored cylinders, which could lead to irregular and possibly fatal variations in the gas breathed.

General

A sump rescue involving gas mixtures would without be doubt among the most serious of situations which could face a cave rescue team. It is vital to obtain competent personnel to carry out the operation and a doctor with extensive experience in hyperbaric medicine must be sought. Sufficient numbers of suitable divers could not normally be obtained from one area's rescue team divers list alone. Full and adequate emergency therapeutic recompression facilities should be made available in case of need by victim(s) and/or rescuers. A controller should be selected who has a good knowledge of cave diving and, if possible, the use of gas mixtures. Cave diving rescuers should not be allowed to attempt to use techniques in which they are not fully trained and competent. Even if the victim is able to supply information, efforts must be made to arrange for analysis of the gas(es) used by him because incorrect mixing might have been a contributing factor in the incident.

In view of the anticipated problems, it is essential that any cave divers currently embarking on mixed gas exploration do so responsibly, as it may not at present be possible to carry out a satisfactory rescue attempt.

Through-sump and Diver Communications

Bob MACKIN

In this article I propose to cover some of the methods and problems associated with through sump and diver communications. I think it should be said that I am not a diver and my understanding of the subject is limited. Therefore I shall be more concerned with the technicalities of communications albeit applied to your subject.

Electrical methods are usually used to communicate with a person over long distances. This requires that transducers convert the sound pressure waves from speech into electrical signals (microphones) and conversely electrical signals back into sound (loudspeakers) so that it may be heard. (fig. 1).

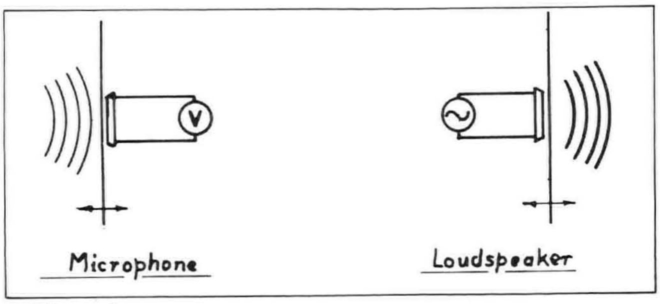


Figure 1

In the majority of cases through sump communications are probably best provided by conventional telephones. The conductivity of the water and surrounding rock prevent conventional radio from being used. Although inductive systems such as Molefone may be used it is far easier and the equipment much simpler, cheaper and more compact (if the cable is excluded) to use telephones. In a situation where the cable can be laid easily, and possibly left for future use, a practical and reliable system can be installed very cheaply.

To construct such a telephone system two (or more) telephone handsets, a battery and, of course, sufficient cable are required. Telephone handsets are available from a variety of sources ranging from electronic component surplus shops to friendly telephone engineers. The handsets from Trimfones are ideal being light, fairly strong and, because of their obsolescence, cheap and available. The handsets from the standard dial telephones are equally suitable; in fact they are more rugged, and are also obsolete and freely available. However they are larger and heavier.

To prepare two such handsets refer to figure 2. The blue and green leads in the curly cable should be connected together and the red and white leads, via more robust tails, to crocodile clips. Heat shrink sleeving is ideal for making these joints rugged. The telephones then consist of handsets with curly cables and two flying leads to go to the line. Should the handset not have its curly cable then the microphone and earpiece inside it must be wired in series. To do this connect one terminal of the microphone to one terminal of the earpiece and then connect the other two terminals, via tails, to the crocodile clips.

To connect two such handsets as a telephone refer to figure 3. A four to six volt power supply is required. The small 4.5V Duracell batteries used in the Petzl lamps is ideal. Only one battery is required and this should be placed at the most convenient end. It should be connected in series with the handset and line. To do this connect one brass terminal of the battery to a handset tail and the other to one side of the line. This can be conveniently done by a short wire with a crocodile clip on one end and a

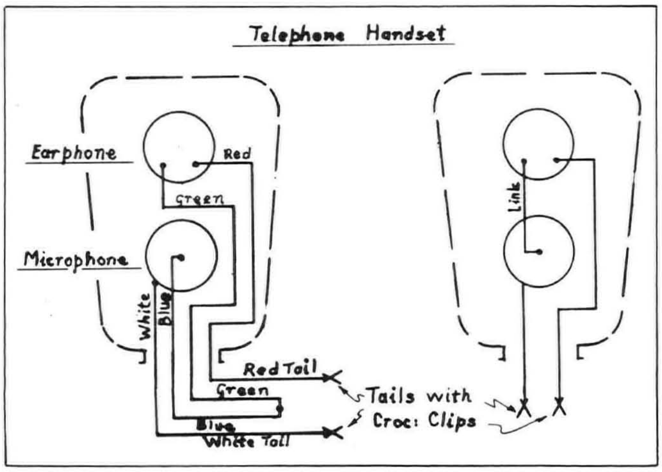


Figure 2

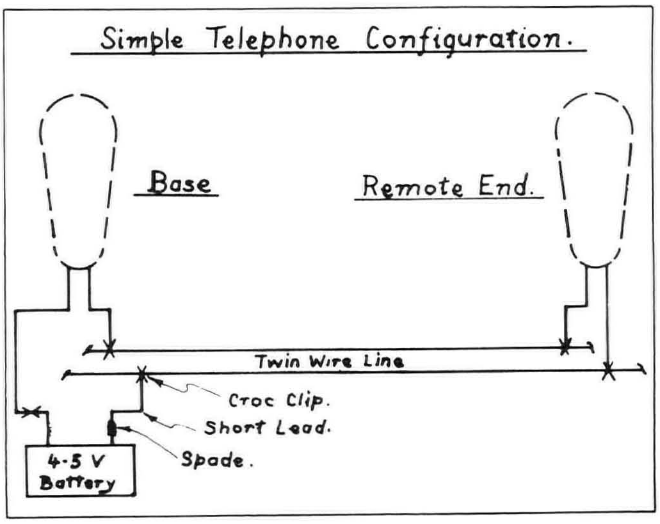


Figure 3

quarter inch spade terminal on the other. The spade will fit the brass terminal of the battery if it is trimmed and the clip will attach to the end of the line. At the other end the handset should be clipped directly to the line. All polarities are unimportant therefore both handsets and the battery can be connected either way round. There is no provision for a call facility on this simple arrangement and it is usually not necessary because whistling and shouting to attract attention works equally well over telephones as it does in pubs and this has never been a problem to cavers.

If the remote end of the wire is left open circuit a dive base or surface party can easily tell when it is connected; because they will be able to hear themselves in their handset when the remote end is connected. The wire may be any two core type of reasonable resistivity such as mains cable, instrument cable or, of course, telephone cable. The handsets although robust and splashproof should be transported in containers while underground and certainly while underwater. Further handsets may be interconnected if desired by connecting them in series with the existing two. Three will work off the 4.5V battery described but above this number it would be better to choose a battery providing about 1.5V per handset; up to a maximum of about 9V to be perfectly safe in wet conditions. PP9 9V radio batteries are suitable. Small tingles can be felt even from these voltages in certain circumstances when soaked.

If a call facility is required refer to figure 4. It may be provided by connecting an audible warning device and bridge rectifier, available from electronic component suppliers, in series with each handset. This must have the normally closed switch contact of a push button switch connected across it. When the switch is pressed the tone will be heard from the warning device and in both handsets. The warning device is polarity conscious and must be used in a diode bridge. It should be connected to the + and - terminals respectively and the AC terminals go to the handset and line. If this were not done correct polarity would have to be observed round the circuit which is impractical. If this technique is used the battery voltage should be increased by 1.5V for each handset to allow for the voltage drop across the diodes. This limits the number of handsets to three or four in very wet conditions. In dry conditions the supply could be increased. In view of the increased complexity I do not think the call facility is worth implementing except in specific circumstances.

The telephones just described are a simple and cheap arrangement which can be constructed by anyone: communicating with divers is a very different problem. Firstly the fundamental task

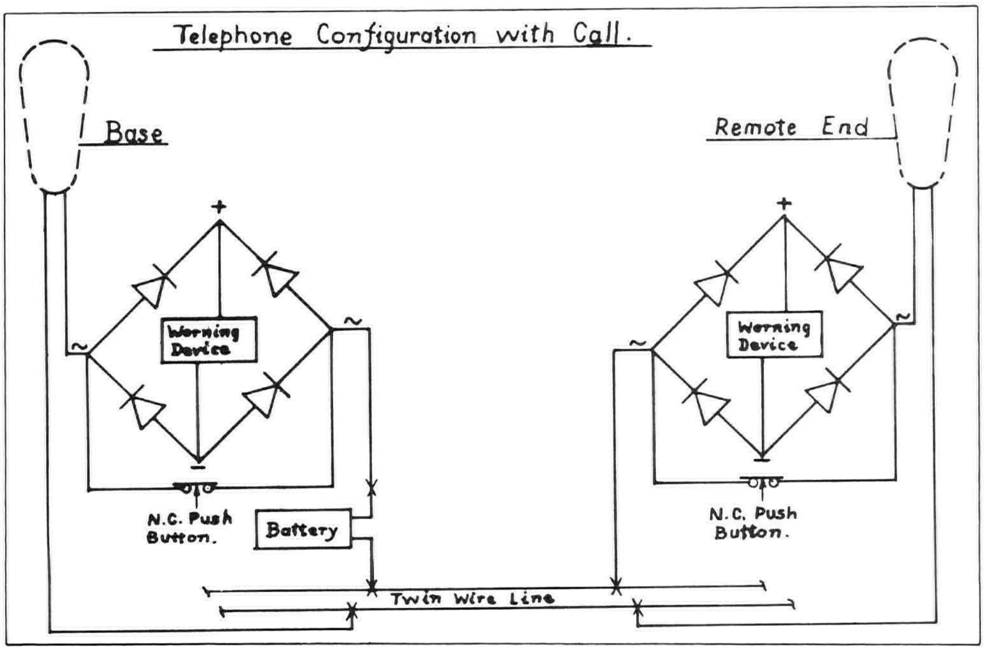
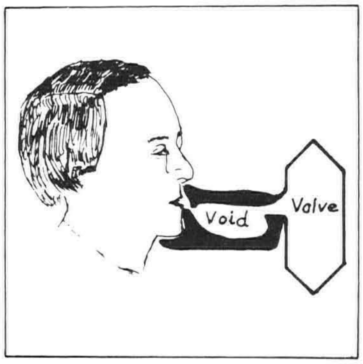


Figure 4

Figure 5



of collecting and reproducing the speech are totally different. Sound is conveyed (both in air and water) as changes in pressure. The widely different viscosities, densities and compressibilities of these media mean that transducers to transmit or receive sound in air and water must be totally different. Even the changes in air characteristics as the depth increases can cause problems with conventional microphones and speakers. With divers whose heads are enclosed in helmets it is possible to use fairly conventional microphones and loudspeakers; with diaphragms of fairly large area which detect or cause movements of the air or gas in the helmet thereby detecting or producing sound. This may be of use when a person is being rescued in a full face mask but is of little use to most cave divers as they do not, as a rule, use such masks.

In order to communicate with a submerged diver using demand valves and gags two things are necessary; a void for him to speak into (so that he can form words correctly) and transducers that can put sound into the ear without obstructing the external ear canal. The void is usually provided by a speech mask which provides a seal round the mouth, a void to speak into and allows some articulation of the lips. It accommodates a demand valve to provide air (fig. 5). The most popular transducer is the bone conductor which, when placed on the skull where the bone is near the surface and coupled by water, will introduce sound to the ear or receive it from speech without physical interference with the diver.

Bone conductors work by producing and responding to high forces over short distances; unlike conventional microphones and speakers which produce small forces over large distances. They are therefore capable of producing or receiving sound directly from dense media such as water and cavers heads. They are peculiar to listen to, the sound seeming to appear from the centre of the head, and similarly the sound sent by them is unnatural. Some people prefer to use them inside speech masks for transmission working in air. This provides much better speech quality but is more prone to interference from breathing and makes the masks more clumsy with the trailing cable. The cables from bone conductors inside hoods can be kept tidier and the reduced clutter is probably to be preferred on safety grounds. The main physical problems are timing pauses in the speech to allow the diver periods to breathe (because while breathing he cannot hear) and dealing with the modulation of his speech by the fluttering air pressure in the mask caused by the exhaust valve and formation of bubbles.

Having discussed how to communicate with a diver the next problem is obviously how to transmit the information to another diver or the surface. The simplest of these where practical is cable. Small battery powered amplifiers could increase the signal level from the microphone to a point where it can drive a speaker. Two such units could be plugged together by divers approaching and connecting them via leads with suitable plugs and sockets or clips. They could then hold a conversation and disconnect them when they had finished. This method has the disadvantage of being tethered while talking but the advantage of being simple and cheap.

If communication is required over larger distances or without tethers then a "wireless" method must be used. One which is commercially available is ultrasonics. Here speech is made to ride on a much higher frequency carrier by changing its frequency. It is then put into or taken from the water by transducers which turn the electrical signals into corresponding vibrations or, conversely, vibrations into corresponding electrical signals. This method works well in open water but the high frequency sound tends to leave shadows behind obstructions and, worse still, in confined places the reflections from the walls produce unpredictable dead zones where communication is impossible. For these reasons it is not really practical to use ultrasonics in sumps. Hydrophones may also be used in some circumstances. These send or receive sound directly and anything in the water within range may hear or be heard. Unfortunately I am not aware of any source of these devices at reasonable prices although, over very short ranges, some bone conductors may be used as hydrophones.

Conventional radio may not be used to transmit or receive speech under water because a radio wave is made from energy alternating between an electric field and a magnetic field. Within the relatively high conductivity of the water the electric field is quickly absorbed and the signal strength diminishes rapidly. Even at very low frequencies megawatts of power are necessary and only very low data rates are possible; much too low to convey speech in real time. This type of communication is used with submarines but is obviously of no use to divers. However, if only the magnetic field is used and the frequencies are kept low, especially in fresh water, reasonable ranges are possible. This may be achieved by using coils as the sending and receiving devices in the following manner.

Transformers consist of two or more coils wound on an iron core. The core is there to provide a low resistance path for the magnetic flux to circulate thus minimising losses. They work by

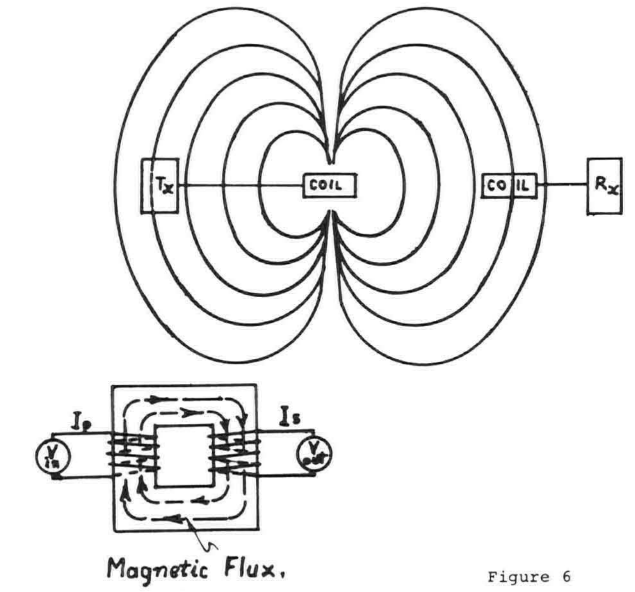


Figure 6

taking input power and current in a primary winding and converting them into a magnetic flux circulating in the core. This flux passing through the secondary windings produces volts across them and current in a load connected to them.

If the core is removed this process still works but with much reduced efficiency. This is the basis of all inductive communication and control systems which use two coils. The transmitter energises the primary coil producing the flux, or field, and the receiver intercepts a small portion of this flux via the secondary coil (fig. 6).

Over short distances inductive communication can be achieved by amplifying the signals from the microphones and driving multi turn loops with them. At the receiving end the loop is connected to an amplifier with the output going to the speaker. Suitable switching is required to reverse the amplifier for transmit and receive. A single bone conductor could be used for microphone and speaker (fig. 7). This method could be made to work over a range of several metres underwater and would be relatively simple and cheap.

To communicate over greater ranges the speech information must be carried on a higher frequency, like in the ultrasonic system, but the output fed to coils to produce a magnetic field instead of the transducers used to produce high frequency sound. These systems are costly, complex and difficult to design and construct. They also require access to sophisticated test and calibration equipment to ensure that they comply with their licensing restrictions, which puts them outside the scope of many enthusiasts. However the field is relatively unexploited and still provides some exciting challenges for those prepared or demented enough to pursue them.

Alternatives to Diving

Terry JACKSON and John CORDINGLEY

If a casualty needs to be evacuated from beyond a sump it is not always necessary to dive the sump. All the possible alternatives should be carefully considered from an early stage in the rescue operation. It may be safer to stabilise the victim's condition temporarily until the sump can either be bypassed or removed rather than to attempt a sump rescue.

Bypassing Sumps

As much recent information as possible about dry passages on either side of the sump must be collected. This might include referring to the relevant surveys, guidebooks and journals or contacting local active cavers by telephone. It may indicate connections likely to be made within the cave or to the surface. The exact location of strategic points on either side of a sump can easily and rapidly be confirmed in many British caves by devices such as the "Molefone". It is not appropriate here to review the various digging techniques which might then be employed as these have more than adequately been described elsewhere (Judson, 1984).

Removal of Sumps

Many sumps can be shortened or removed altogether using the resources available to modern cave rescue teams. The main types of sump may be classified as static, streamway (ie having inflow and outflow) or backwater sumps (where a static sump is connected with a flowing streamway at one end; such as Peak Cavern's Treasury Sump). Suitable methods for sump removal include bailing, siphoning, pumping (with manual, electric or compressed air equipment), blasting off the roof or removal of the "lip" holding back the sump (by digging or blasting). Static sumps are theoretically the easiest to drain and keep open but streamway sumps can sometimes be made static by diverting the flow down other passages further upstream or temporarily holding back the inflow with dams. Whether or not this is possible, it is preferable to bail, siphon or pump sumps from their downstream end. Backwater-type sumps can be isolated from the flowing water with which they are connected by damming. This is much easier if the moving water is on the "cave entrance side" of the sump so that materials and dam-building resources need not first pass the sump. In all cases, water removal is more difficult if the "elbow" of the sump is a long way from the start.

If pumps are to be used it should be remembered that an inverse relationship exists between the rate of water removal which a pump can sustain and the head which can be overcome by the outflow pipe. Some pumps have interchangeable impellors intended for the differing heads of water with which the pump is designed to operate. A high lift impellor will overcome a greater head of water than a standard one but usually at the expense of flow rate.

The length of time required to drill and blast away the roof of a sump probably restricts this

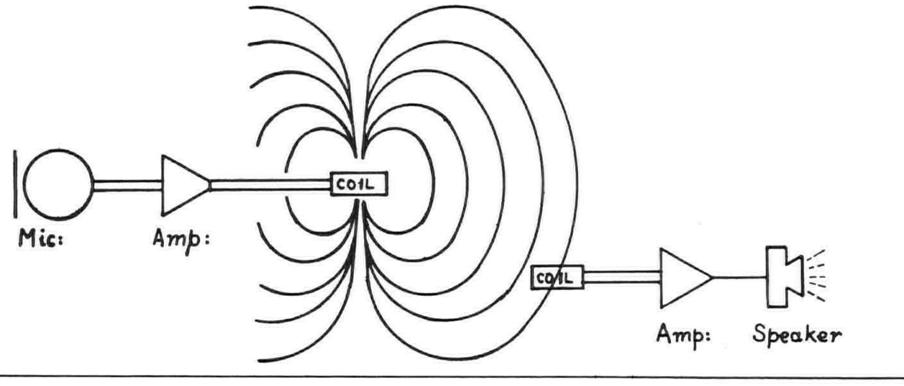


Figure 7

method to short and shallow sumps. Also, this approach would prevent divers from passing the sump to tend to the casualty.

In practice, a combination of the above methods would probably bring the fastest results. The decision as to whether to delay a sump rescue attempt in favour of an alternative method of evacuation will depend on many factors; not least of which will be the appraisal of the situation by the divers. It is not possible to give definitive guidelines here; the controller on the scene will be in the best position to make this decision.

A National Sump Rescue Call Out System?

Jim HANWELL

I must argue against setting up a national team of cave divers for sump rescue calls. Also, I cannot see that a central store of equipment would be practical. One team simply could not respond fast enough despite the improved access to caving areas by motorway. Nor would they have a "first strike" capability anywhere. Equipment must be on the spot when needed and must be familiar to those who must use it. This means regular practise. If one team and a central base were to be available then local initiatives may well be stifled. Even worse, I can envisage the Police Authorities, who are ultimately responsible for rescues, resisting steps being taken locally during a sump rescue incident until the national team has responded. We must not step backwards on such important matters.

There are many reasons why the needs of sump rescue have to be met locally. Foremost is the need for good cave divers and, in my experience, they are active people who are invariably found caving rather than standing by awaiting emergency calls. Therefore they should be part of each local rescue team and not a separate team set up by the CDG's regional sections. In the MRO, for example, cave divers have always been represented on the wardens committee. They have an equal say in how things should be done and what equipment needs to be obtained. Training is organised jointly because it is important for all concerned to know what to do. During an emergency every diver would be needed for diving and must not be tied up by all the other organisational aspects that accompany rescues.

It is worth emphasising the truism that real rescues are very different from training sessions. There are stresses and strains during emergencies which do not appear during practices however seriously and solemnly they are taken. The question of who can work together as a team on a rescue is quite different from the usual self-reliant outlook required on most cave dives. Risks that are acceptable to an individual diver become out of the question in other circumstances where people have to work together. Cave diving is a serious business. Although not a cave diver myself, I have been a member of the CDG for over twenty years and my experience, in an area blessed with more cave divers than most, is that everyone must know each other well to make the most effective judgements when on the spot. For this reason CROs must liaise closely with their CDG sections. Up-to-date CDG call out lists must be maintained and, because cave divers retire, it is important to know who is currently active and where.

At a national level, the CDG ought to consult with the British Cave Rescue Council (BCRC) concerning the availability of divers and equipment. Contingency plans for the assembly of divers and their deployment around the country should be made. This would have to be done within the existing call out procedures through the Police. This is strictly a matter for BCRC. An inventory of sump rescue equipment would be helpful and there is a strong case for standardisation of equipment to ensure compatibility. This is something for the CDG to work on. It would be up to each CRO to handle its own likely sump rescue problems locally.

However, if the worst comes to the worst, we can still call out neighbouring teams when needed. This system has worked well in practise.

Discussion

<u>Cold Water Drowning</u>

Phil Papard, CRO, stated that because divers are warm when wearing a full diving suit they would be unlikely to survive cold water drowning for the forty minutes mentioned by John Frankland.

Pete Riley, NPC, opined that, regardless of the time elapsed since the start of drowning, exhaled air resuscitation should be applied.

<u>Bends</u>

Fred Winstanley, BSC, was concerned that Dr. Glanvill had dismissed the difference between type 1 and type 2 bends as irrelevant.

John Adams, SWCRO, replied that diagnosis for classification was difficult. Therefore a suspected bend should, for rescue purposes, be considered as a very serious condition requiring immediate evacuation regardless of its type. Always assume the worst and seek help immediately.

<u>Emergency Dumps</u>

Chris Danilewicz, NPC, stated that a call out to an injury accident beyond a sump may well be a protracted affair. Therefore, when exploration begins beyond a sump a comprehensive first aid kit (including a saline drip and an airway) should be the top priority item to be taken through and dumped. Further, such dumps should be established (either by CROs or CDG) beyond the more popular sumps where there is a high risk of injury accidents, for example Boreham Cave.

Ian Watson, UWFRA, believed that the number of such sites was too great. It was also unclear as to whose responsibility such a dump would be.

Bob Grimes, TSG, emphasised that prevention is better than cure and divers must take full precautions when working beyond sumps.

<u>Diver Call-out Problems</u>

Jim Hanwell, MRO, stated that call-out lists must be kept scrupulously up to date and include telephone numbers. Every diver on a call-out list must realise his responsibility in the maintenance of that list.

Julian Griffiths, CDG, emphasised that only active divers should be included on call-out lists. The inclusion of non-active divers on a list is a hindrance and may cause unnecessary delays in an emergency.

Perry Millward, CDG, stated that he had been called out during a recent mine incident. However he was not at home at the time and his parents took the call. They were given no details so consequently when he returned home it took a long time to establish whether he was still needed.

Ian Watson, UWFRA, also stated that there were similar problems with the UWFRA call-out system. He believed that this was due to the Police having responsibility for the call-out whilst not being fully aware of the problems faced by rescue teams on complicated rescues.

Anon, MRO, stated that their call-out system was based on MRO wardens running the call-out from the start. This system has the advantages of having a cave rescuer involved from the start and the consequent call-out went to the most suitable people first. The system worked satisfactorily.

Julian Griffiths, CDG, stated that it would be useful if some basic details were given on a call-out. Then a diver could select the most appropriate equipment to bring.

All. The general consensus was that when called out a diver should bring all his diving gear as there is either not enough gear or the situation is entirely different to that first planned for.

Rescue of non-divers through sumps

Anon, MRO, asked for details of the recent rescue of non-divers from Little Neath River Cave through Bridge Cave.

John Adams, SWCRO, answered that the non-divers had been trapped by flooding. The sump was approximately 30 m long and a technically easy dive. SWCRO had, in fact, had a practice rescue through the sump earlier in the year. Although there was an alternative (ie waiting for the flooding to subside) the non-divers had been offered the chance of diving out and this they had accepted.

Bob Cork, MRO, stated that on several occasions non-divers had been rescued through short sumps in Swildon's Hole.

Graham Proudlove, NPC, believed that some cavers would refuse point blank to be rescued through a sump and rather sit it out. In such a case no pressure should be applied to try and force the rescuee to change his mind.

Rescue Controllers

Phil Papard, CRO, stated that, on occasions, he had seen non-diving controllers encouraging divers to go in when perhaps it was unsafe to do so. He emphasised that the decision to dive must be left entirely to the diver. The use of a controller who is also an active diver on a diving rescue has many advantages and should be the norm.

Ian Watson, UWFRA, agreed and stated that if a controller is pushing, the diver should tell him where to get off.

Equipment

Bill Whitehouse, DCRO, stated that the DCRO had placed emphasis on establishing a tackle store from which two divers could be fully kitted out. The store is secure and all gear is maintained and serviced by divers. However there is a marked reluctance by divers to use the equipment.

Martin Grass, MRO, believed that most divers would use equipment from a rescue team store if they knew it was well maintained.

Phil Papard, CRO, foresaw no problems if the equipment was of good quality. In any case the experienced diver should easily be able to give a valve a quick once over to check its servicability.

Richard Stevenson, CDG, stated that he would be loathe to use unfamiliar equipment from a store.

Ian Watson, UWFRA, urged that divers should make an effort to familiarise themselves with the diving equipment available to their local rescue team.

Jim Abbott, BPC, stated that divers must place more emphasis on self reliance. There is no cavalry waiting to come to the rescue. Divers must carry sufficient equipment and tools to effect minor repairs to their equipment or to decant air via first stages.

John Cordingley, NPC, agreed but warned that high pressure hoses with built in restrictors were becoming more common. These prevented decanting via first stages due to incompatibility of threads.

False Assumption in sump rescue incidents

Ray Fairholme, Chief Engineer TSG, related a successful rescue of an army cadet from beyond a sump in Carlswark Cavern. Pumping had been used to drain the sump. It had been assumed that the cadet was dead.

Al Harrison, DCRO, emphasised that an overdue diver must ALWAYS be assumed to be alive. Therefore time is a crucial factor and every effort must be made to get a search diver to the sump as quickly as possible.

Inquests

Julian Griffiths, CDG, asked if any progress had been made in appointing a specialist pathologist to conduct autopsies following cave diving deaths.

Dr. John Frankland, CRO, answered that the problem is that the coroner is responsible for the appointment of a pathologist to a case. The answer would seem to lie in approaching the coroner, perhaps through the local rescue team and police, prior to the opening of the inquest.

Hospitalisation and Evacuation

Anon. stated that it seemed obvious that after prolonged underground hospitalisation the condition of the casualty was bound to deteriorate.

Dr. John Frankland, CRO, agreed but emphasised that the aim of on site hospitalisation was to allow time for the patient to stabilise prior to evacuation. A doctor is probably the only person qualified to make the decision as to when the patient is in the optimum condition.

Closing Address

Bill WHITEHOUSE

As a non-diver I have found the symposium both fascinating and informative; informing me mostly that I'm better off staying out of sumps!

As a cave rescuer I have found today both interesting and frightening but not as frightening as cave divers among you have no doubt found it!

A lot of people have put in a lot of thought today (and for today) and a lot of problems have been identified and a lot of questions have been asked. It is worrying, however, that, so far, we seem to be rather short on solutions to many of the problems and answers to many of the questions.

Although we have made an important start today we must remember that it has only been a start. We must as cave rescuers and cave divers continue to work together towards finding the solutions and the answers. So far we have been relatively lucky; but time is not on our side and sooner or later some of us will be confronted with one or other of the nightmare possibilities postulated by so many of today's speakers. So as John Frankland said earlier today, just be bloody careful.

On your behalf I would like to thank all the speakers for the very high standard of their lectures, the caterers (Angie, Gabi, Ceily and Dawn) for the excellence of both their products and their service and John, Dani and Barry for putting the whole thing together and keeping it going so successfully.

Appendices

APPENDIX 1

THE INTERNATIONAL SUMP RESCUE SYMPOSIUM, DIJON (FRANCE) 1985

John CORDINGLEY

I attended this event last year and would like to take this opportunity to thank those caving bodies who generously sponsored me to go. I was accompanied by G.Proudlove (at his own expense) who came along as an interested observer. It was the first event of its kind and British caving has benefitted from sending a representative in many ways. Apart from collecting good ideas on cave and sump rescue techniques numerous useful European contacts were established. The many problems associated with sump rescues were highlighted and a great number of accident statistics were presented. This will allow a wider knowledge of accident causes which should promote safer cave diving. The Europeans were very keen to learn about British techniques, developed in our more difficult diving conditions, and we learned quite a lot about their long deep diving methods. Finally, I would like to think that it helped to encourage us to get our act together, and organise our own meeting.

The French have produced a large "proceedings" of the symposium and which I have only just received. It will take some time to translate but I hope to be able to circulate it within the Cave Diving Group at a later date. Our own report was written soon after our return to England and copies have been given to British Cave Rescue Council, British Cave Research Association, National Caving Association, Cave Rescue Organisation, Upper Wharfedale Fell Rescue Association, Derbyshire Cave Rescue Organisation, Mendip Rescue Organisation and South Wales Cave Rescue Organisation. Also to the libraries of Craven Pothole Club, Northern Pennine Club, Technical Speleological Group, Derbyshire Caving Association, Wessex Cave Club and South Wales Caving

Club. Shorter reviews have also been published in the newsletters of CPC, NPC, TSG, WCC, DCA and CDG and in Caves & Caving (BCRA).

It should therefore be possible to get access to the report in any of Britain's four main caving areas. However, in view of the pressing problems associated with sump rescue in Britain, I hope it rapidly becomes out of date!

APPENDIX 2

NOTES ON A PRACTICE RESCUE THROUGH LAKE SUMP, PEAK CAVERN, BY DCRO EASTERN TEAM AND DIVERS

Richard BARTROP

Lake Sump is an airspace duck with a 10mm rope in situ. For practise purposes it was assumed to be a 2m sump.

Order of Events

1) Three divers plus an assistant arrived at the sump and started to kit up.
2) On arrival the "victim" was given warm air treatment using the Little Dragon.
3) The assistant fitted the Kirby Morgan Band Mask (KMM) to the "victim's" head and set it to minimal free flow. The cylinder was strapped to the stretcher on top of the "victim".
4) The "victim", wearing only a wet suit, was delivered, feet first, to the divers who were waiting in the sump pool.
5) The "victim" was immersed in the sump pool to check the apparatus.
6) With one diver at the feet and one at each shoulder the "victim" was passed three times through the sump.
7) The "victim" was given further warm air treatment using Little Dragon.

Observations by the victim

1) The mask was on demand flow and not free flow as initially set.
2) Although water entered the victim's ears through the back of the mask, he felt confident that no water would enter the facial mask.
3) He did not experience a lifting action on his head due to the buoyancy of the mask. This had been noted on previous occasions.
4) Once underwater the victim felt "cosy" and, though he could not discern which way was up, he knew when he was moving and felt the occasion when he was dropped by one of the shoulder divers.
5) The victim had carbon dioxide poisoning for two days after the event, this included feelings of nausea. This was due to incorrect use of the Little Dragon.

Divers' observations highlighting potential difficulties

The stretcher involved was made from a Neil Robertson heavily strengthened with steel tubing and designed for normal cave rescue. The use of this stretcher highlighted several points:-

1) The stretcher was too heavy (approximately 15kgs underwater) making progress over the boulder floor difficult. One of the shoulder divers dropped the stretcher whilst he was trying to "hop" along with one hand on the floor. The foot divers felt it necessary to pull on the rope.
2) The centre of gravity of the stretcher was felt to be too high; causing it to roll too easily.
3) The tape handles attached to the stretcher were found to be useless. It was considered that metal or stiff rope would have been easier to handle.
4) The line can become secondary in the thoughts of the rescue divers.
5) Undue stress can occur on the line if it is pulled out of true (eg by a heavy stretcher on the line in mid-water).
6) The stretcher may scrape the line over sharp rocks.
7) Divers may inadvertently rest on, or pull on, the line. The weighting of lines and the use of snoopy loops could not be relied on in such situations.
8) Concern was raised about the time difference between fitting the mask and actually diving. One answer could be a removable face plate which could be fitted immediately prior to diving.

Conclusions and Actions

A stretcher specifically designed for sump rescue is needed.

The KMM worked very well on this occasion; though it was possible that the free-flow valve had been accidentally moved which reduced air flow.

Wing nut fixture of the face plate would reduce air expenditure as discussed above.

The buoyancy of the mask needs to be investigated further.

The use of the Little Dragon promotes an increase in air consumption, due to higher CO_2 levels. Consequently the use of this device in sump rescue procedures may need to be reevaluated. If the device is used then divers need practical experience in its use.

Careful thought should be given, before entry into the sump, as to whether the victim is carried head or feet first.

The diving line should be large in diameter and in good condition before a sump rescue is attempted.

A telephone line through the sump should be available to the rescuers. Stocks of wire and diving line combined as a single rope could be an asset.

Line holding and following should be reappraised. For example should only the foot and one shoulder diver hold the line? Should the divers attach themselves to the line with a karabiner?

Manoevering a stretcher through a sump creates a new level of difficulty for divers. Therefore practice is essential.

Divers may need to administer first aid and perform full rescue procedures (eg on pitches) on the far side of a sump.

A communication facility between the victim and one of the divers should be considered since the soothing effect on the victim may cause a reduction in his air consumption. Also air supply problems may be rectified as they occur.

The facility of changing cylinders on the stretcher should be appraised.

APPENDIX 3

NOTES ON THE USE OF THE KIRBY MORGAN BAND MASK (KMM)

Richard BARTROP

These notes deal primarily with a practice rescue through Wookey Hole Sump 1 and compares it with one in Holme Bank performed by DCRO using their own equipment.

Events at Holme Bank using DCRO KMM

The diver entered the sump with the KMM using a bone mike which was connected to base with a length of wire. Whilst conversing with base he attempted, with difficulty, to regulate the variable air pressure on the side of the second stage. Either too much air came through causing a free-flow of air which drowned conversation or there was not enough air which caused considerable difficulty in breathing and a further corresponding lack of communication. The mask was very buoyant on the dive causing the divers head to stick to the roof.

Events at Wookey 1 using MRO KMM

The diver first dived around the sump pool using the KMM, with about 10kgs of lead and a side-mounted bottle. The MRO mask felt more comfortable than the DCRO one. Although the diver's nose was pressed against the valve the level of discomfort was not too great. The nose/mouth mask also felt more comfortable on the diver's face.

The MRO have taken out the external nose-clip, blanked off the end and have supplied a standard nose clip to enable self-clearing of the ears. This proved very satisfactory and avoided the problems associated with the external clip.

Swimming in the sump pool also proved satisfactory as the diver was properly weighted. However, the diver tended to roll onto one side; the uneven distribution of weight and the buoyancy of the mask caused a tilting up action unless it was constantly countered. This could cause a problem in the case of a broken neck or back. In such cases the use of weights on the chest or mask might alleviate stress.

The MRO mask was much less buoyant than the DCRO mask. It appeared that the MRO mask was more compact around the head causing less wasted air to accumulate. The spider on the MRO mask appeared to cover the head more comprehensively thus reducing the ballooning effect of the hood. Another factor which should be considered is the amount of air around the neck if the hood is not secured properly in that region.

A leak from an external nut setting occurred at the start of the day. This was cured with an adjustable spanner.

The MRO mask was felt to allow much easier breathing than the DCRO mask. THe divers was able to regulate the variable pressure control much more effectively. This could be due to increased diver experience or the DCRO valve requiring retuning.

The majority of those present were reluctant to volunteer to pass the sump as an inert "victim"; probably due to mistrust of the mask. This attitude could be a problem on a real rescue. Once the volunteer was returned intact others felt more confident about the mask.

The "victim" lay inert in the sump pool with his mask on but wearing no fins. The lead diver was to lead through holding the "victim" around his chest. The second diver was to push the "victim" and found it best to grasp his ankles. The volunteer admitted that he had kept his legs stiff to allow this. Another position would have to be adopted if the "victim" was unconscious or had sustained leg injuries. Grasping the "victim" by the ankles allowed the second diver to avoid having his mask knocked off by the lead diver.

A third diver followed in case of difficulties such as misplaced masks etc. Both lead diver and "legs" diver held the line through sump 1 which has a low section of between 45cm and 75cm high through boulders. On the way back positions were reversed and the new lead diver found no difficulty in manoevering the "victim" through the sump. Approximately 360 litres of air was used each way.

The line became caught around the "victim's" bottle in the low section and it was easier for the "legs" diver to sort out the problem as it was in front of him. On surfacing the "victim" felt quite calm and relaxed and, though he had knocked his head against obstacles on the way through, he was not unnerved by the experience.

A loose procedure has evolved following on from the dive and ensuing discussions. N.B. This is not intended to be a definitive procedure as the whole subject requires further consideration to tie up loose ends.

The MRO KMM is contained in a large ammo can with a small toolkit and check lists of procedure and equipment. There is a second can which houses a long length of low pressure hose which can be attached to the second portal of the KMM.

Proposed procedure

Attach one or two bottles to the victim with one hose attached to the KMM second stage. Attach a long hose leading from a further bottle to the second portal on the KMM. This bottle may be left on a suitable ledge as it will be discarded.

Place the nose clip and mask on the victim having previously tested them on a rescue diver. The victim should be placed in a convenient position in or next to the sump pool. Ensure that no loose neoprene is left on the hood. Taker off the victim's fins if he is unable to use his legs. The air he uses at this stage should come from the long hose and the spare bottle. The victim's buoyancy should be adjusted as necessary.

The divers should then kit up and change the air flow over to the body mounted bottle. The long hose and bottle are now discarded and the second body mounted bottle can now be connected in it's place.

At least two divers, preferably three, should accompany the victim through the sump. If the sump is tight, allowing only one diver to take hold of the victim, a second diver should be close behind to sort out any snags around the victim's body or feet.

The victim appears to be best in the prone position and facing the floor. The lead diver should monitor the breathing of the victim by watching for the rhythmic escape of air from the mask. He should also view the victim's face (if conscious) to check on his mood and assess any difficulty in breathing. It is easier for the second diver to check the air pressure. The lead diver will be working the hardest in propelling and manoevering the victim with the second diver helping where he can whilst avoiding the lead diver's fins.

Additional Notes

By discarding the stretcher the problem of transporting a victim was made much easier. It was thought that splintage and the support of the water would suffice if the victim had fractured bones.

There seemed little need to communicate orally between the divers since they were all keyed up for the rescue.

Though some problems remain with the DCRO KMM a viable system is well within sight.

The need remains for diver-confidence and training in the use of the KMM.

Update

1) The MRO KMM is a different and more compact model than that used by DCRO.

2) The spider straps are the same.

APPENDIX 4

NOTES ON THE FILM ON SUMP RESCUE BY THE MRO

Jim HANWELL

The Swildon's Hole streamway beyond Sumps two and three was discovered in 1957 after blasting through Blue Pencil Passage from the Paradise Regained Series. This higher level fossil series bypassed much of the streamway; a Godsend in the days before wetsuits. It was hardly surprising that no attempts were made to dive back upstream from Swildon's Four to Two straightaway. All efforts were directed at further downstream pushes through Paradise Regained.

In those days the divers used bulky oxygen rebreathers, wore large drysuits, carried Aflos and were heavily weighted for bottom walking. Scores of cavers acted as sherpas humping packs of gear through Paradise Regained to Four and they would wait there for hours whilst the divers pushed on through sumps Four and Five to explore Swildon's Six. With so many people using the already stale air in Paradise Regained, headaches, vomiting and extreme exhaustion became noticeable and worrying. The author once remembers carbide lamps and candles guttering out. The concern about foul air was highlighted by the Neil Moss tragedy at Peak Cavern in March 1959. His death was brought about by a carbon dioxide excess rather than a lack of oxygen.

Dr. Oliver Lloyd, then secretary and treasurer of MRO, took on the problem of what would be done on Mendip in the event of rescuing cavers through sumps and from places where the air was bad. He enlisted the help of Dr. Allan Rogers, a colleague in the School of Medicine at Bristol University. Allan had just returned from Antarctica as the physiologist on Sir Vivian Fuch's successful crossing of the continent. He had a particular interest in respiration and was a seasoned Mendip caver as a member of the University of Bristol Speleology Society. Within little time it had been agreed that breathing apparatus with extended high pressure hoses and full face masks would cover both eventualities. It so happened that Normalair-Garrett, an engineering firm based at Yeovil, manufactured such equipment. They had provided the oxygen apparatus used on several Himalayan expeditions, notably the successful ascent of Everest in 1953. MRO was given bottles, hoses and three masks with attached demand valves for trials and evaluation. These became MRO's Sump Rescue Apparatus Mark I by the summer of 1959. Apart from Mines Rescue equipment in use, this was the first light-weight equipment suitable for rescue work in caves. A few modifications were made and Mark II remained the only Sump Rescue Apparatus in the country for the next twenty years.

A Dexion and alloy model of Swildon's Sump One was made and the Normalair equipment exhaustively tested in swimming baths until both cave divers and non-diving wardens of MRO were confident in using the equipment. All took turns at being strapped into Dr. Lloyd's carrying sheet and were towed back and forth through the "sump". It was decided that the first operation at the actual Sump One would be filmed; and so another mammoth porterage trip into Swildon's was organised for May 1960.

The film was entitled "Cave Rescue" because it also included scenes of hauling patients up the old Forty Foot Pot. It was shot by Tony Morrison, and a cast of "hundreds", it was directed and narrated by Dr. Lloyd who also made an appearance in a scene showing Mr. Albert Main helping out as he liked to do on such occasions. The premiere was given in the Edward Long Fox Memorial Lecture before a large and eminent gathering of physicians at the University of Bristol in 1960. A cast of invited cavers packed the gallery. The lecture was subsequently published in the Medical Journal of the South West (Ref Vol 76(ii) Number 280 April 1961). Dr. Lloyd last screened the film at the opening of the BCRC conference on Mendip in the Hunter's Lodge Inn, Priddy in May 1985. He died three days later. For the past few years, the MRO has superceded the old Sump Rescue Apparatus with a Kirby Morgan Bandmask 10 system. The Normalair equipment was loaned to Wookey Hole Caves and is on display there among many other historic items from pioneer cave diving days on Mendip. A video has been made of the original Cave Rescue Film for the record.

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Caves of the Jordbruelv and Jordhulefjell, South Nordland, Norway

Compiled by Trevor FAULKNER

Abstract: The Jordbruelv is a large river draining Jordhulefjell and other high mountains in South Nordland, Norway, which forms an impressive gorge when it meets the limestone. Jegerhullet and Etasjegrotta are two tributary cave systems in the vicinity of the gorge and downstream the whole river flows undergound at the Jordbru (Rockbridge). A high altitude karst area lies along the flank of Jordhulefjell with shafts leading down to phreatic passages unrelated to modern summer drainage. The caves and limestones found in the Jordbruelv area are described, together with caves in other parts of South Nordland, particularly at Jengelvatn, Skindfjelddal and Eiteraadal.

INTRODUCTION

This is the report of the 1984 Expedition to South Nordland, supplemented with information from South Nordland 86. The inspiration for the expedition arose from the success of the 1982 Expedition to Fiplingdal. Local reports there had also mentioned the existence of a long cave somewhere in Børgefjell and so we started by visiting possible sites for this. After Børgefjell, the plan was to visit the valley of the Jordbruelv and then visit a list of sites long enough to keep the expedition busy even if all leads were negative.

The members of the expedition were: Trevor Faulkner, Alan Marshall and Geoff Newton, who had all taken part in 1982; David and Shirley St.Pierre with Paul and Tanya St.Pierre; and Edgar Johnsen who drove down from his farm in Beiarn to join us in the Jordbruelv area.

South Nordland has been little visited by the small but active Norwegian caving fraternity, none of whom live in the area. The record of the several British visits is referenced in the Report of the 1982 Expedition to Fiplingdal (Faulkner, 1983). Other recent reports are: Faulkner & Marshall, 1982; Newton & Faulkner, 1983; Newton, 1985a & b; St. Pierre & St.Pierre, 1984. Most limestone in South Nordland occurs as thin bands of marble, often nearly vertical, and grouped in roughly N-S linear outcrops. The geology of the area is covered in St. Pierre and St. Pierre, (1980). This describes a Pre-Cambrian basement overlain by Cambro-Silurian rocks which have undergone regional metamorphism.

The 1984 expedition found and surveyed nearly 4 km of new passage in 42 new caves. The principal discoveries were a 700m stream system at Jengelvatn, on Børgefjell, and a new caving area near the river Jordbruelv. Much higher up the Jordbruelv on the side of the mountain Jordhulefjell is a long outcrop of marble, very frost shattered on the surface, where we found several shafts and a long cave passage. The 1986 Expedition revisited the Jordbruelv area, amongst others, and the complementary discoveries made then are included in the Report. The other work of the 1986 Expedition will be reported separately.

EXPEDITION ACTIVITIES

With the withdrawal of the Oslo ferry, used in 1982, the expedition reverted to the Newcastle - Bergen route and left England on Saturday 21 July, 1984. Following the long drive over the mountains to the E6 Arctic Highway we reached our first basecamp at midnight at the farming community of Tomåsvatn near Børgefjell (Fig.1). Four days were spent in this area, exploring,

The Jordhulefjell karst, just left of the snow gully across Kidney Lake.

usually in two parties, sites at Sløkskar, Jengelvatn, Steinelv, Baafjelddalen and Lille Fiplingdal. The route to Jengelvatn was along an 18 km boggy path. Fortunately, the St. Pierres were guided across the river crossing at Storelv by Asbjørn Hortman, a local man, who also arranged for us to hire a hut at Jengelvatn (Fig.2).

The full expedition, including Edgar Johnsen, assembled in the main area of the Jordbruelv on Friday 27 July, camping near the end of a track at the junction with the Gaasvaselv. This was still some way from the target area and for the next four days we had to start and finish by walking along a 2km section of unfinished new road to Bjørkåsen before following the Jordbruelv up through birch forest to the Rockbridge, where the whole river goes underground. All the major features of this fascinating area were found during this period, including River Cave, Vatnhullet, Etasjegrotta and Jegerhullet. On Tuesday 31 July the St. Pierres left to meet commitments further north, and the main party managed to drive along the new road to move camp to Bjørkåsen. Over the next few days surveys were completed of Jegerhullet and Etasjegrotta, the latter taking three visits due to its complexity. Edgar Johnsen made a preliminary walk to the Jordhulefjell limestone outcrop, noting several entrances in poor visibility. After his return to Beiarn a tremendous thunderstorm on the night of Thursday 2 August cleared the cloudy weather and next day the remaining three climbed the Jordhulefjell ridge in warm sunshine, reaching the cave area at 5.00 p.m. Jordhulefjellhullet was party explored and surveyed and the fuller potential of the area realised.

Needing to plot surveys and make area maps before progressing further at the Jordbruelv, we decided to leave on Sunday 5 August to visit sites on our itinerary in Hattfjelldal. In terrible weather we went to Akfjell, and then Skindfelddal. Camping at Skjelmoen, we met the farmer who has kindly written later giving information about the names and legends associated with the caves near Favnvatn. The final phases in 1984 were tourist visits to the area of the Stor Grublandselv (Heap 1968, 1969, 1975, 1979 and 1985) and to Sirijordgrotten in Eiteraadal (Faulkner 1980). Håpgrotta was discovered here and incompletely explored before we drove south to catch a ferry at

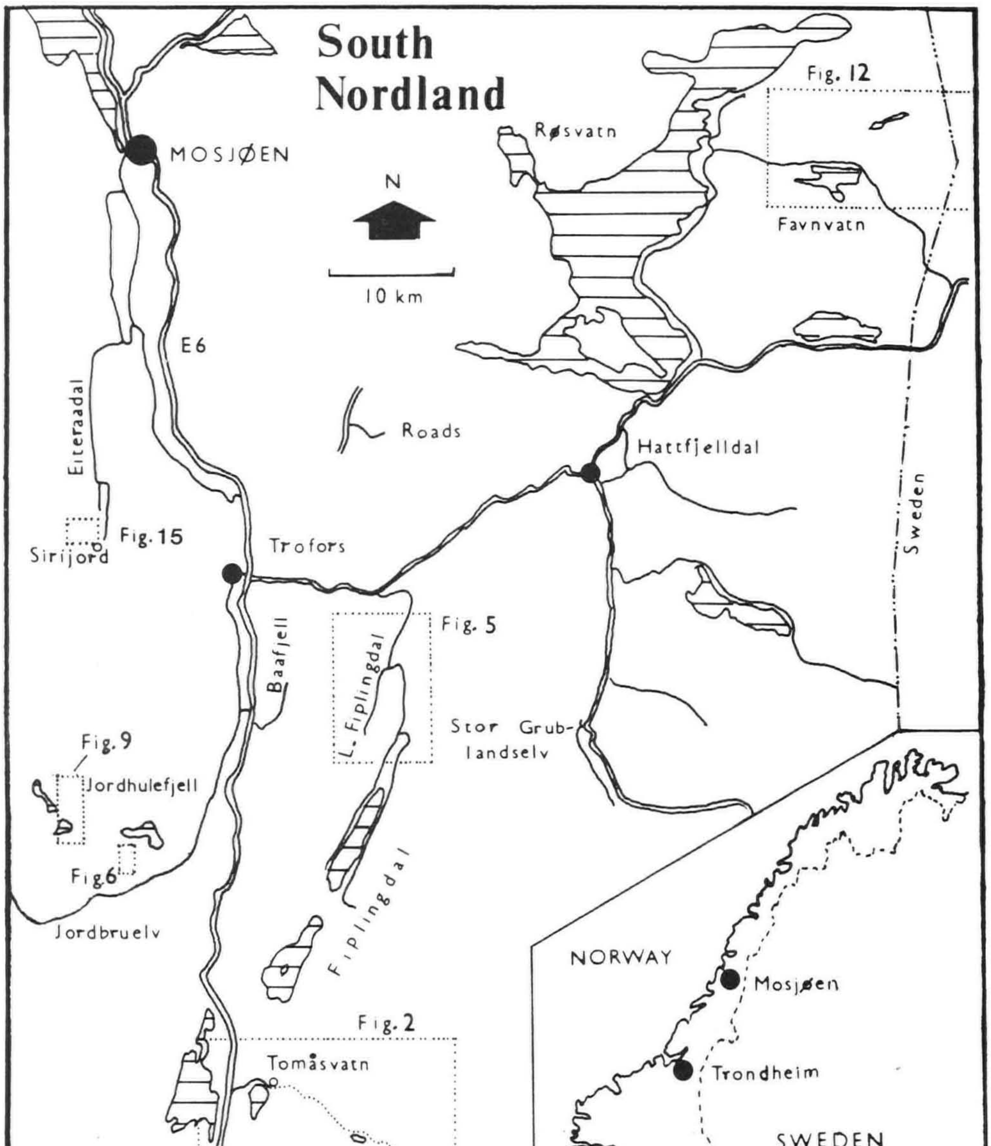
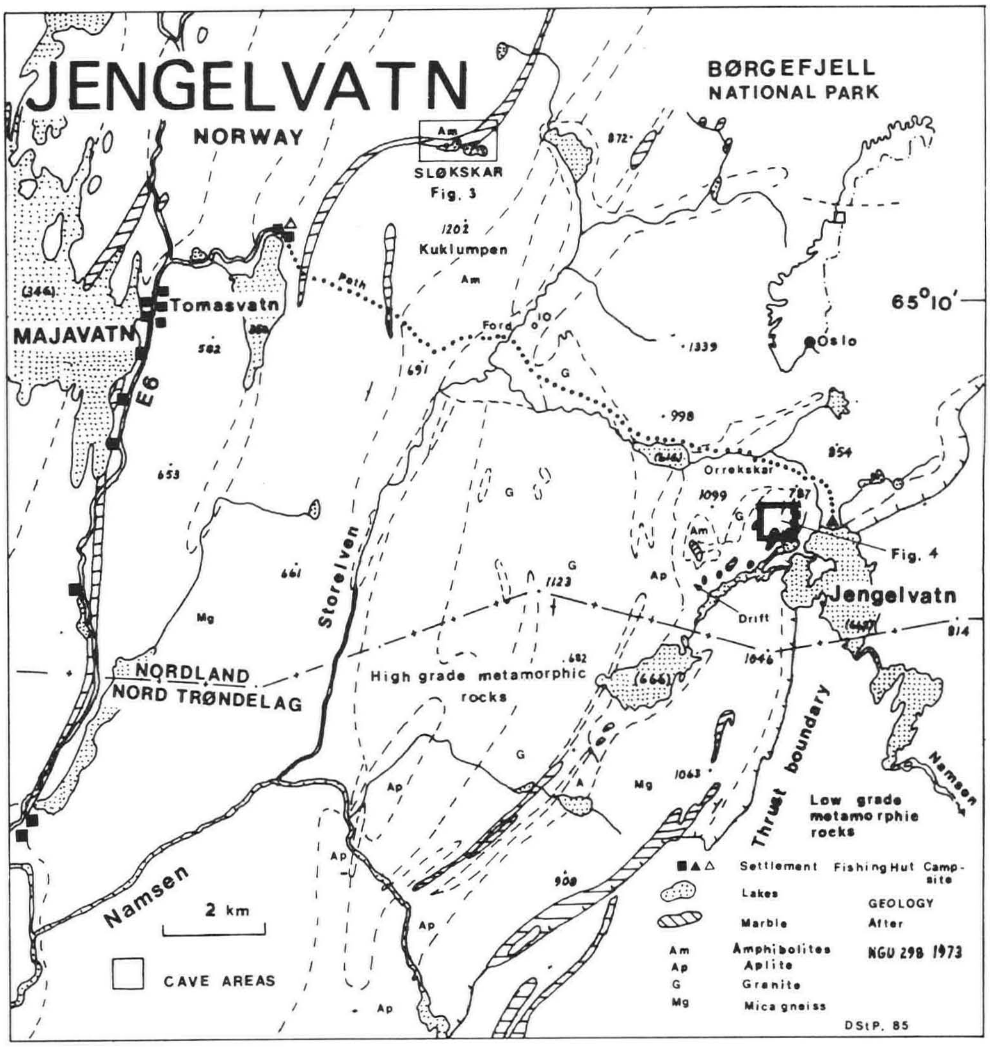


Figure 1

Figure 2



Gothenburg in Sweden on 10 August.

The 1986 Expedition to South Nordland had a similar team, with the addition of Peter Hann. The Jordbruelv area was revisited from 5-11 August. Whilst there Etasjegrotta was extended to over 1 km long, and other features were found. A mountain camp was also established at Jordhulefjell from 8-11 August, enabling us to complete our exploration of this area. Håpgrotta in Eiteraadal was fully explored and surveyed, and Kapfjelddal was also visited. Prior to our visit, Paul Whybro and Karen Jones had visited South Nordland to push undived sumps in Sirijordgrotten and at the Jordbruelv. A presumed link between the Etasjegrotta Surveyors Sump and Vatnhullet was practically confirmed by diving the Vatnhullet sump for 260m, about halfway to Etasjegrotta. Both the diving party and our own expedition made friends with Odd Johansen, a local hunter, who gave us great assistance and developed an interest in caving.

Survey notes

BCRA Grade 3 surveys were made using techniques described in the 1982 Report. These achieve grade 5 accuracy for horizontal distances if not for depth measurements. The station positions in Jergerhullet, Etasjegrotta and Håpgrotta were calculated by computer program: others were plotted graphically. Area maps have been prepared by extrapolation of smaller scale topographical maps and aerial photographs, or by field measurements using either pace and compass or tape and compass methods.

All longitudes in the report are measured from Oslo, which is 10 43'22.5" E of Greenwich. The coordinates given omit the degree quantities for longitude and latitude. Thus 02°46'40"E, 65°11'35"N is represented by 46401135. In the following cave descriptions, A = altitude, L = length, D = depth, VR = vertical range, with all units in metres. The surveys of some of the shorter caves are not published, but are available from the author.

SLØKSKARVATN

Sløkskarvatn is a lake split into two parts by a bridge of land about 90m wide through which lies an outcrop of limestone. The water from the first lake sinks at its edge, flows underground, and reappears from at least one of a pair of resurgences on the shore of the second lake. (Fig.3).

THE RAT RUN(1) 46401150 A800 L35 VR c8
Stream resurgence from tiny opening leading to low sloping crawls

SOUTH SHORE CAVE (4) 46251125 A748 L8
A prominent stream sinks at a shakehole into a crawl, becoming too low.

LAKE SINK CAVE (5) 46401135 A744 L c45 D8
Sink between boulders leads to a duck and chamber with upper shaft entrance and sump.

LAKE RESURGENCES (8,9) 46391135 A740 L7
Two prominent resurgences, the north one being a sump pool the south one leading 7m to a sump.

Three km east, a cave was reported to exist just north of Store Sløkskarvatn, but this could not be found. Also, an entrance (10, Fig.2) was viewed below a fault on the eastern Storelv valley side, about 1 km north of the Jengelvatn footpath ford. This looked like a mine entrance, but no spoil heap was noticed below it. The marble

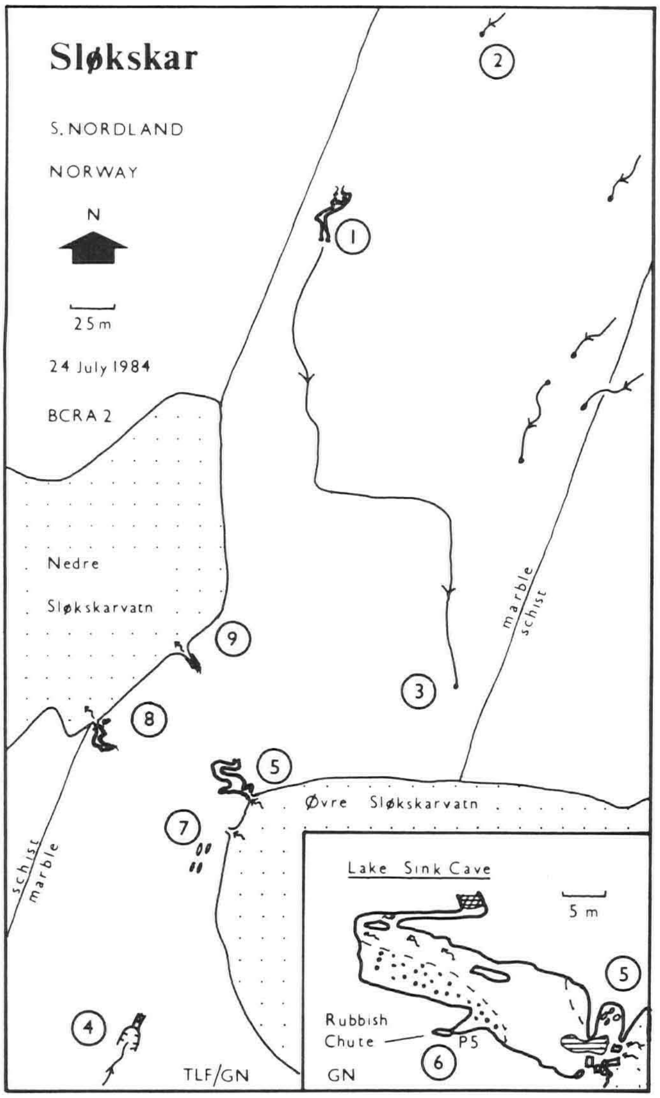


Figure 3

outcrop which extends southwards and terminates part way along the eastern side of Tomasvatn was followed by the St. Pierre family as far as the large stream rising on Kuklumpen mountain, but no karst features were found.

STEINELVEN

The Steinelv is a small stream just south of the Nordland border in Nord-Tondelag (Fig.1). It runs along a narrow limestone band for 2-3 km before draining into the lake Mellingen. The course of the stream was followed up from Mellingen to Stor Steinvatn without noting any sinks, resurgences or changes in water volume. However, the limestone was lost at a waterfall, 2 km from Mellingen. It may repay a walk along the final 1 km along the limestone to Fiskevatn, although the depth potential is small.

BAAFJELDDALEN

A limestone band is believed to run for 10 km or so along the valley bottom. The 1:100000 Hattfjelldal map shows a stream sinking on the hillside about 0.5 km from the valley floor. However, this stream was followed to the valley floor across the limestone, without it sinking. The area is generally unpromising, with little potential, although the NE continuation of the limestone was not followed (Fig.1).

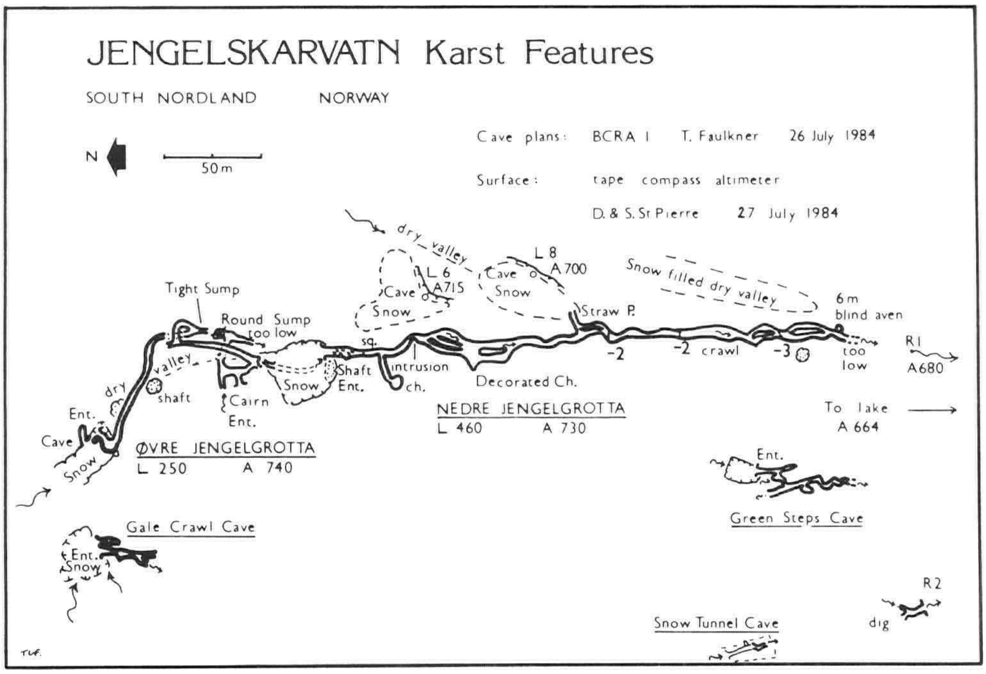
JENGELVATN

The Jengelvatn karst (Fig.2), which is 18 km from the nearest road at Tomåsvatn, lies above the tree line in the Børgefjell National Park, east of Majavatn and some 87 km south of Mosjøen. From Tomåsvatn a footpath can be followed for most parts of the route, which involves wading the braided course of the Storelv (large river). The existence of caves in this area was recorded by Einar Hortman. He marked the location on the 1:100,00 Børgefjell map sheet and described numerous openings and one cave that he had explored containing some stalactites and having two levels in places.

Small surface outcrops of marble occur to the west of Jengelvatn in a partially drift covered area (Fig.2). This marble lies close to the thrust boundary between the overlying high grade metamorphic rocks of the Helgeland Nappe to which it belongs, and the low grade metamorphic

The Jengelvatn karst and the entrance to Øvre Jengelgrotta (photo: S. St. Pierre).

Figure 4



Seve-Koli Nappe complex of probable Silurian age (Gustavson 1973). Well-defined terraces of a former very extensive ice dammed lake are found on the NW side of Jengelvatn and around both Jengelskar lakes some 30m above present lake levels. The ice-dammed lake is thought to have caused reversed drainage westwards from Vestre Jengelskarvatn across the present watershed at Jengelskaret (682m), which is shown on the map to be some 10m below the 30m terrace level (Oxall 1910, p.21; Foslie and Strand 1956, p.63). The altitude of the lowest Jengel spring, R1 (c.680m) is very close to that of the Jengelskaret watershed. In the karst area rising above Jengelvatn (662m), comprising sinks, springs, dolines, rock-bridges, kluftkarren, caves and dry and blind valleys, snow still occupied many large depressions at the end of July 1984.

The caves (Fig.4) have formed in grey banded marble which contains numerous impurities and is much fractured and collapsed. Most of the 800m of cave passage is associated with the most westerly stream draining the slopes of hill 787 and flowing into lake Jengelskar. This stream has several small tributaries with associated sinks and resurgences and some small dolines. Below these tributaries it sinks at an altitude of 740m into Øvre Jengelgrotta, reappears briefly on the surface before sinking into Nedre Jengelgrotta and finally resurges from a flooded conduit (R1) 15m above lake level. Some 50m to the west of Øvre Jengelgrotta two streams sinking in a depression at the same altitude give access to Gale Crawl Cave.

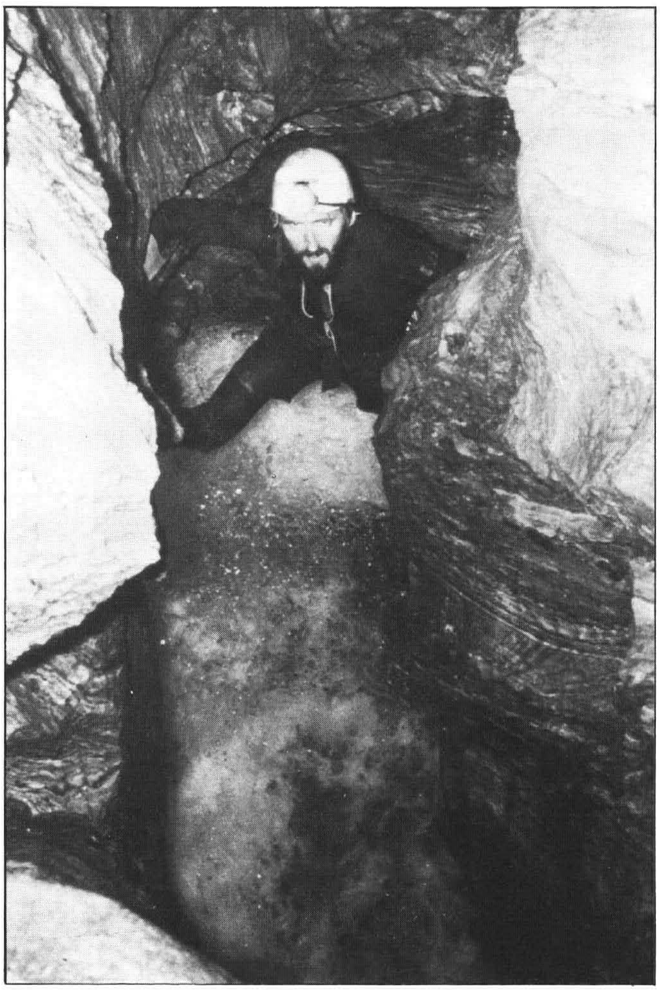
GALE CRAWL CAVE 54450755 A740 L30
Low streamway leads to intimidating dry tube with powerful draught.

ØVRE JENGELGROTTA 54500755 A740 L c250 D c10
Small hole leads to streamway ending at tight sump, and ramp to upper series, Round Sump and Cairn Entrance.

NEDRE JENGELGROTTA 54500750 A730 L c460 D c45
Descent between ice and rock into unroofed section with large passage to south. Down rift to the stream, and passage enlarges to Decorated Chamber containing stalagmites and stalactites. Clean-washed streamway continues with fine water falls and then becomes too low. There are several side passages in the folded marble, and the cave warrants a better survey.

GREEN STEPS CAVE 54450735 A700 L55
West of the Jengel cave system, a way was forced into a dry silted phreatic tube with a connection into a streamway with tight meanders.

A brief reconnaissance was made westwards from Jengelgrottene along the slopes above the narrow Jengelskar lake, including some of the small marble outcrops shown on the map, but apart from occasional surface karst and an inclined shaft



Stream passage in Lilleengaasgrotta (Photo: A. Marshall).

2-3m deep at 02°53'50"E, 65°07'35"N, no further caves were found. However the larger marble outcrop to the west was not examined.

LILLE FIPLINGDAL

This is a valley parallel to Fiplingdal, visited in 1982. A long strip of limestone generally occupies the main valley floor, with other NW trending outcrops crossing several tributaries. The Lilleengaas area is best reached by driving to Bruhola, from where a bridge across the Lille Fiplingsdalselven is taken. The ensuing gated track, not marked on the NGO 1:100000 map J18, can be followed to its conclusion at a gravel quarry on the west bank of the Lille Fiplingdalselven (Fig.5). The 900m underground course near the Kapfjeldelv is impenetrable, close to the surface and with few surface features.

LILLEENGAASGROTTA 52502600 A570 L130 D14.
A distributary of the Lilleengaasbekk sinks into a 20m wide vertical band of marble at a horizontal joint. The streamway becomes a deepening canyon in striped marble to a 3m waterfall. Downstream becomes lower and wider until difficulty is had in breathing due to the volume of water.

FLOOD ENTRANCE 52502605 A560 L62
Conspicuous flood entrance at head of short dry valley soon meets stream and is too wet to follow.

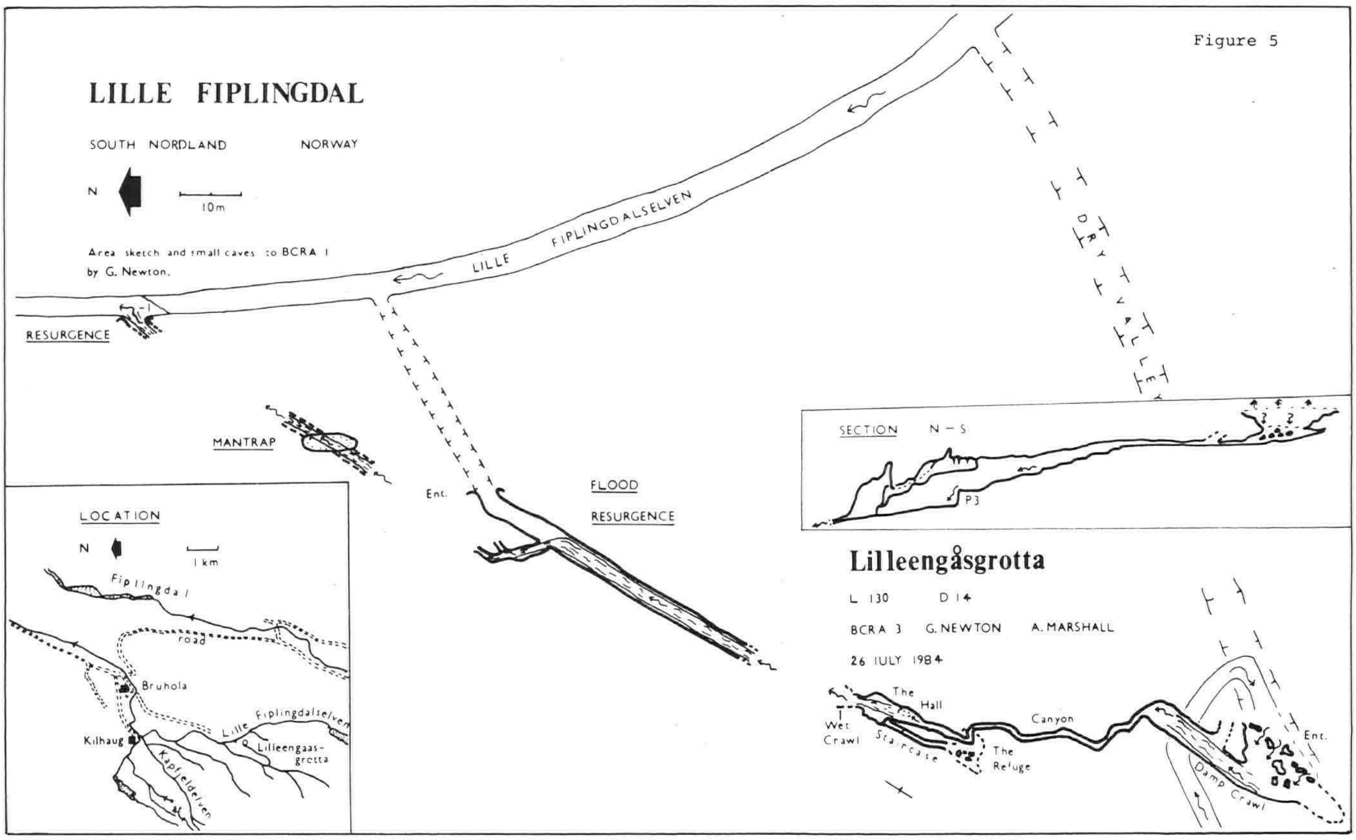
The resurgence is reached by following the river downstream. The Mantrap has a climb into the tight streamway.

JORDBRUELV

Starting from large mountain lakes Øvre and Nedre Jordbruvatn, the Jordbruelv runs south of Jordhulefjell and Gaasvatn before being joined by the Gaasvasselv. From here it flows north to join the Vefsna, the principal river of South Nordland. The southern end of the caving area at Bjørkåsen can be reached by driving along a new road after leaving the E6 at Brenna towards the Tosen Tunnel into what had previously been a remote area. The local scenery of silver birch and spruce forest is dominated by long high ridges of mica-schist striking towards the northwest, the main one leading up to the summit of Jordhulefjell, 1040m. Long outcrops of metamorphic limestones and dolomites of Cambro-Silurian age run parallel to the mica-schists, sweeping down from Elgfjell in the north, across Gaasvatn, to reach the Jordbruelv where the whole river goes underground and various caves occur. A ridge of mica-schist is breached and the river falls into the end of a gorge carved out of limestone at the impressive Jordbruelv Waterfall. North of The Waterfall two tributary streams are captured underground forming large caves and downstream the river partially disappears at each of three sink areas before forming a final lake at the fourth sink area. (Fig.6).

BIENJENBAEKTIEGROTTA 28002050 A450
A small cave at the north end of the Jegerhullet ridge.

JEGERHULLET (Hunter's Hole) 28202000 A480 L650 D34
A small stream flows from a series of two lakes and runs down a limestone gully and small passages into a tight passage at the foot of a shaft (Figs. 6 and 7). A few metres further an open shaft looks down into the cave, 12m below. Just beyond this, a small cliff overlooks two more entrances; the larger entrance leads to a 14m shaft and the Angel's Walk traverse. The normally used entrance is at the west end of the cliff and descends over an ice floor, and then into a complex of passages around and above the 7m waterfall into Edgar's Leap Chamber. Side passages reveal daylight in places, contain some ice stalagmites, and include one ending in a silt choke which contains numerous bones of field vole, bank vole and willowgrouse. Downstream, a series of dry oxbows and the streamway unite into a roomy passage to Slot Chamber, with a rising boulder slope ahead. The stream drops down the slot into a very wet lower series. The roof of the chamber is close (see fig.7) to the foot of a low cliff in the dry valley above. This could have been the site of a main rising acting throughout the phreatic development of Jegerhullet. The falling level of the resurgence as the continuing valley cut down



The Jordbruelv Waterfall.

below it is matched by the emergence of the various passages at different levels in the entrance series. The later capture of the cave water via The Slot and the final streamway drained the cave, leaving vadose modification to continue to today.

WATERFALL HOLE 28301950 A430
The Jegerhullet stream resurges close to the explored end of the cave and runs for 100m down the wooded valley to a sinkhole with large boulders on the floor. Dye was put into the sink, but surprisingly this was not seen in the Etasjegrotta streamway within the next 4 hours.

T-POT 27552015 L20 D10
Between Jordhulefjell ridge and the Jordbruelv, above The Waterfall 6m climbable vertical shaft into chambers and crawls.

BOULDER STREAM SINK 27502010 L16
South of T-Pot, further from ridge. Stream crawl blocked by collapse.

ETASJEGROTTA 28301945 A410 L1055 D42
An unnamed stream flows south towards The Waterfall, sinking before reaching it. The dry streambed continues a little further to the large entrance to the cave from where a big rectangular tunnel slopes gradually down until a hole breaks the floor. A complex of multiple high-level passages continue to the south, with various links into a largely flooded active stream route. As can be seen from the survey section, (Fig.8) Etasjegrotta is a complex vertical maze. It has formed along the strike of the nearly vertical banded marble, and mostly lies to the east of a 0.3m wide impermeable band of mica schist. The zone of passages east of this barrier is rarely wider than 10m, giving the cave a very linear plan, with development along mainly horizontal joints connected by vertical joints. The mica schist barrier frequently forms the right hand wall of the cave as in the Entrance Passage. The left hand wall of the Entrance Passage also appears to be composed of this material, but a parallel continuation along the cave has not been recorded. All breaches of the mica schist are small in cross section due to the lack of solutional enlargement. The cave seems to be a prime example of development via phreatic loops, with a sequence of lifts along the strike. The line of the cave along the strike from the entrance is under the east wall of the gorge below The Waterfall. It is anticipated that the underwater continuation is heading for Vatnhullet, some 600m away. Dye put in the main surface stream sink was not seen in the cave in the next 2½ hours, perhaps indicating the existence of an independant route for this water.

Just north of Etasjegrotta, a small stream sinks among rocks. It is presumed that this is the water which enters the cave via the upper entrance passage.

Entrance to Etasjegrotta.

Figure 6

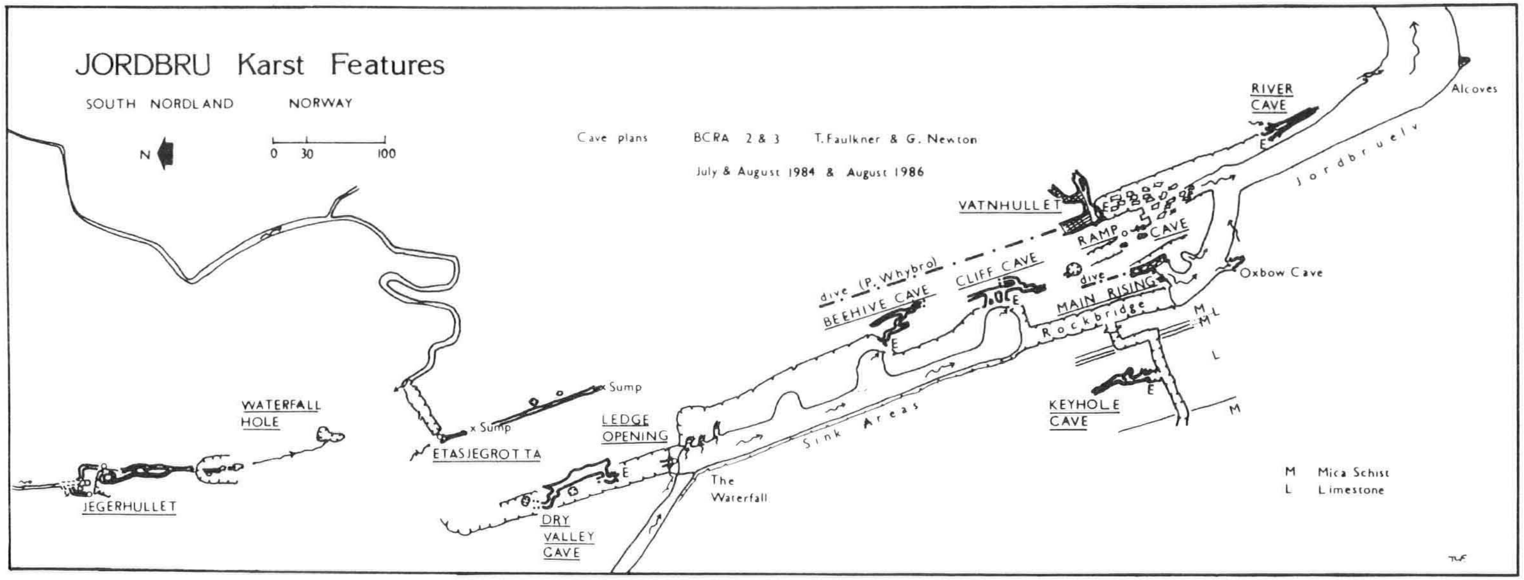
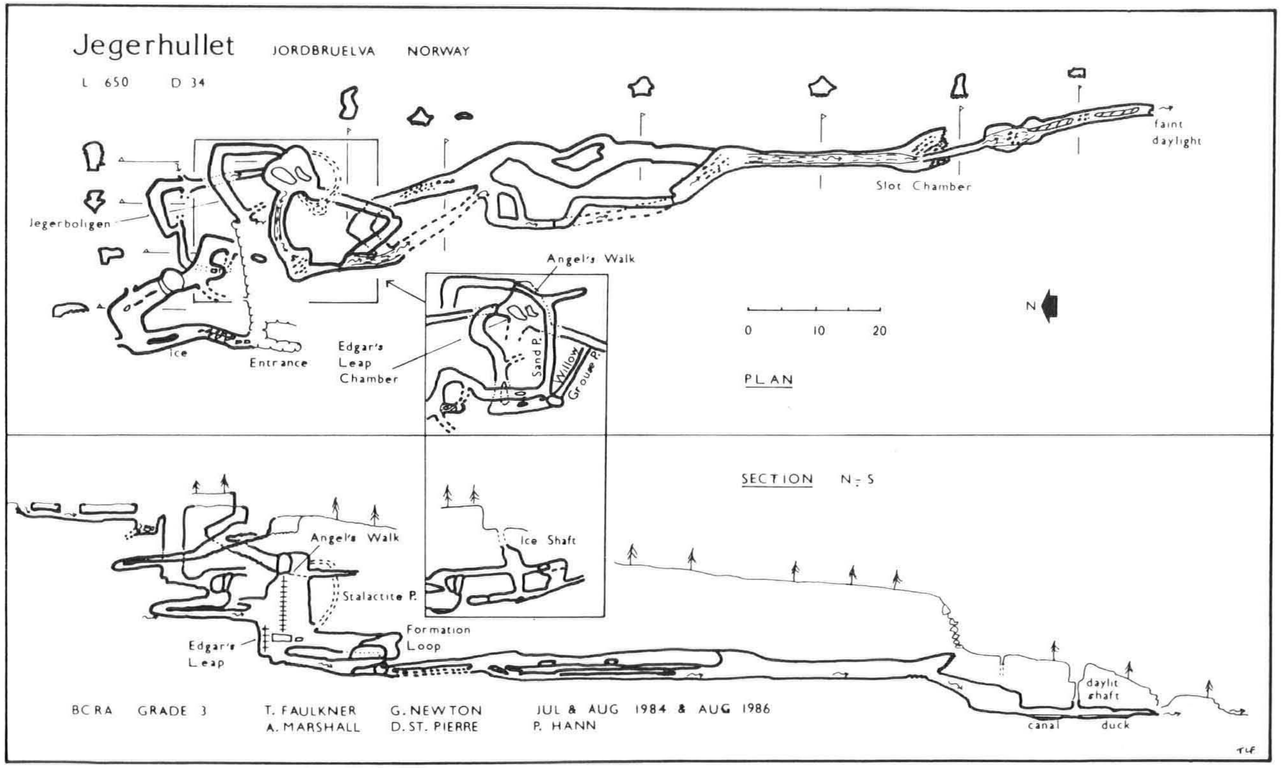
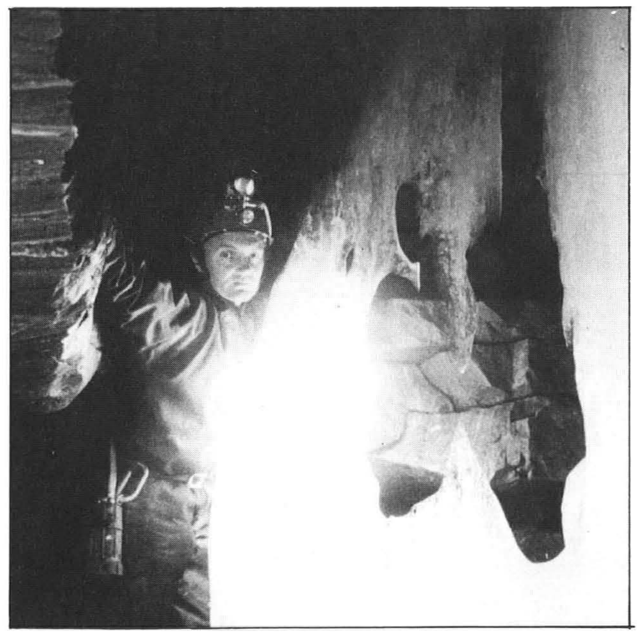
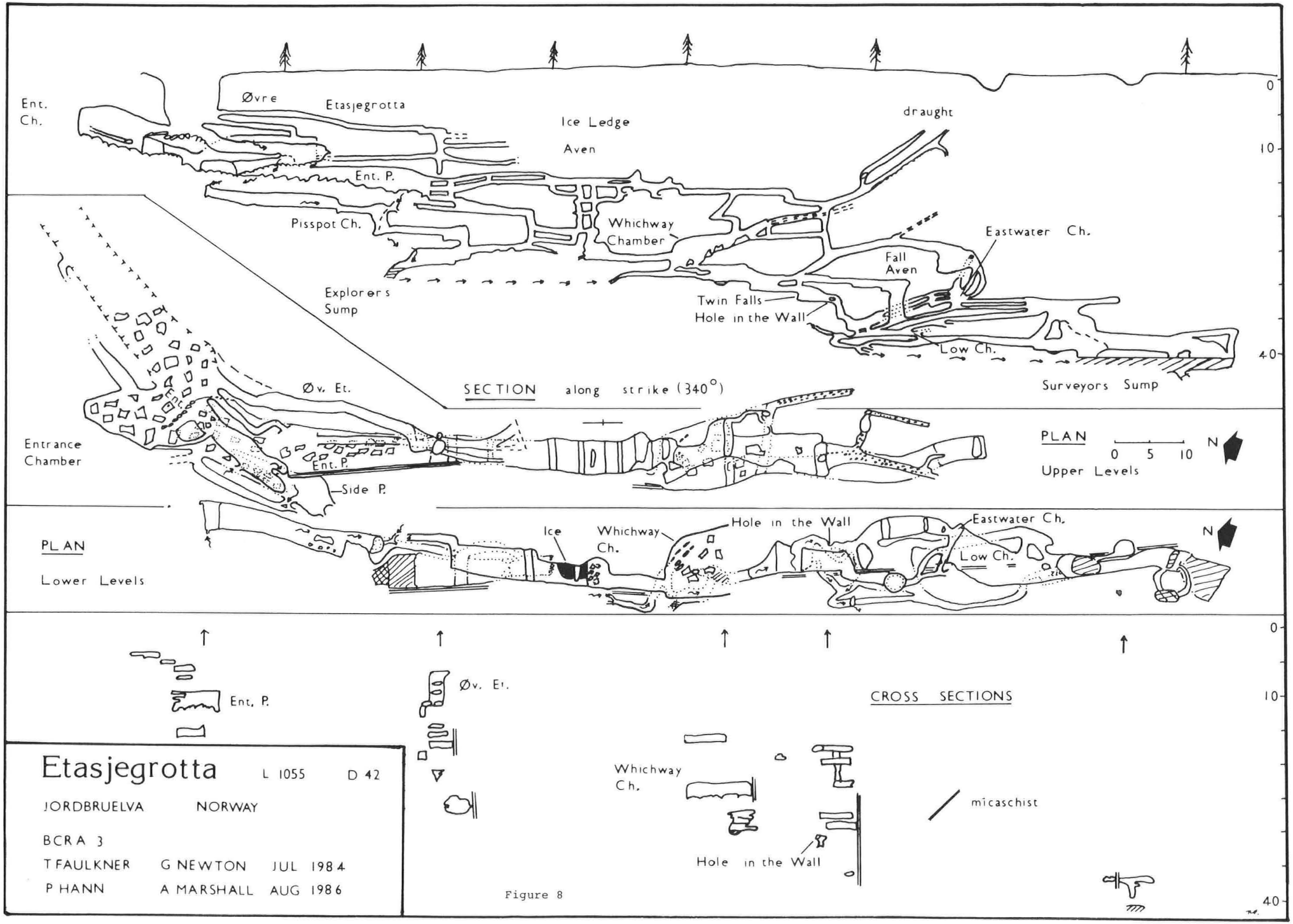


Figure 7



Ice formations in Etasjegrotta.




Ent.
Ch.
Øvre Etasjegrotta
Ice Ledge
Aven
draught
Ent. P.
Pisspot Ch.
Whichway
Chamber
Eastwater Ch.
Fall
Aven
Explorers
Sump
Twin Falls
Hole in the Wall
Low Ch.
Surveyors Sump
0
10
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SECTION along strike (340°)
Øv. Et.
Entrance
Chamber
Ent. P.
Side P.
PLAN
0 5 10
Upper Levels
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PLAN
Lower Levels
Ice
Whichway
Ch.
Hole in the Wall
Eastwater Ch.
Low Ch.
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Ent. P.
Øv. Et.
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Hole in the Wall
Etasjegrotta L 1055 D 42
JORDBRUELVA NORWAY
BCRA 3
T FAULKNER G NEWTON JUL 1984
P HANN A MARSHALL AUG 1986
Figure 8

Inner end of the Etasjegrotta Entrance Passage, with the right wall formed along the impermeable barrier (Photo: A. Marshall).

DRY VALLEY CAVE 18251940 A380 L60 D12
The last of three shakeholes opens into a sloping rift which chokes after 45m.

The gorge below the Jorbruelv Waterfall has a series of sinks beneath its eastern wall, and only the last two have any caves associated with them (Fig.6). Beyond the last sink, the dry valley is the Rockbridge, or Jordbru, after which the area is named.

LEDGE OPENING 18251940 A380 L13
Wide level crawl becomes too low.

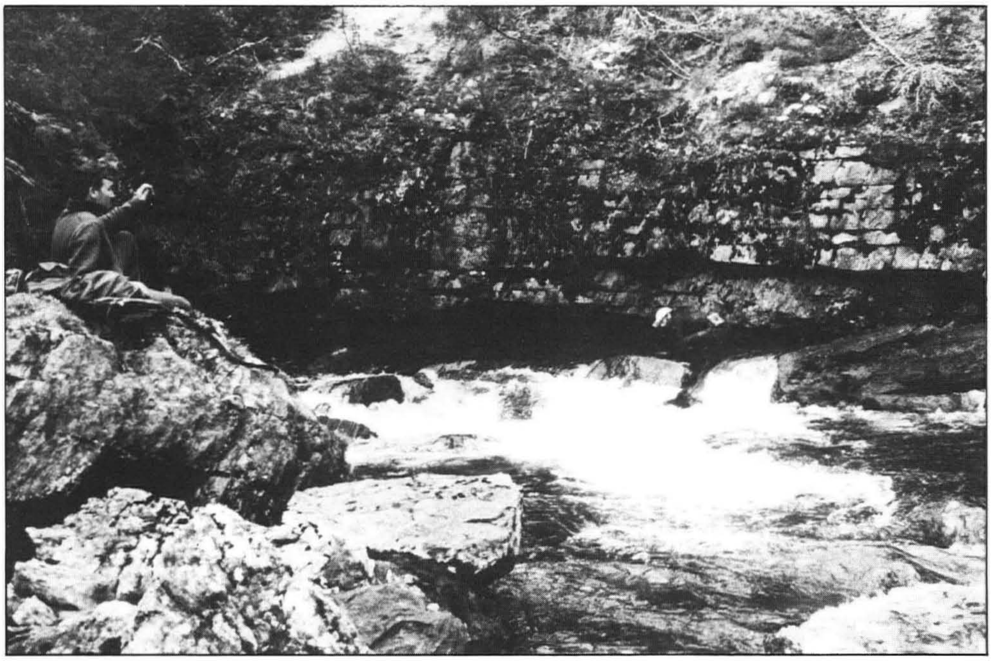
BEEHIVE CAVE 28301935 A380 L61
Walking size passage with very low crawl to a parallel passage, with ice formation and ice columns ending at a choke.

CLIFF CAVE 28351933 A380 L66 VR4
The river goes underground at the largest of the lakes. Several entrances occur in the cliff 10m up, all lead to a spacious level gallery running parallel to the main valley. A deep conical shakehole in the forest on the valley side has a silted crawl passage from it, and, along with Beehive and Cliff Caves may be a remnant from an old high-level phreatic route.

MAIN RISING 28501930 A365 L60
This is normally a fast flowing sump pool and has been dived for 60m in a passage 5m wide by 3m high to a junction (Whybro, 1986). In very dry conditions the water level drops up to 3m giving short airspace.

RAMP CAVE 28501930 A373 L15 D8
A slot descent to streamway with sump and lower entrance below a shattered tower with a large square cut cave near the top going in 5m.

VATNHULLET 28501930 A385 L360 D43
A black loose shakehole right against the overhanging cliff with an impressive ramp leads to a gloomy lake. The large sump has been dived so far for 260m to a depth of 18m in clear visibility. The underwater route is often complex with parallel passages and pillars (Whybro, 1986). In very dry conditions the water level falls and it is possible to swim for about 40m. This



Main Rising of the Jordbruelve

The high altitude karst
near Jordhulefjelhullet.

feature is clearly linked to Etasjegrotta and possibly to other sumps near the Jordbruelv Waterfall.

RIVER CAVE 28551928 A365 L45
5m above the river a rocky passage slopes down to a deep canal and a large sump.

THE ALCOVES 29001925 A360 L6
Three prominent openings in the west bank of the Jordbruelv about 1.6km upstream from the roadbridge. Diving revealed the absence of passage continuation (Whybro 1986).

KEYHOLE CAVE 28301930 A375 L50 VR4
The spacious entrance passage rapidly funnels down to Boulder Chamber, and Keyhole Passage leads to a crawl which chokes, with daylight visible.

The next few caves lie outside the immediate Rockbridge Area, but are included here for convenience.

BJØRKÅSTJERNGROTTA 29101905 A285 L56
In steep valley NW of Bjørkåstjern. Climb down to chamber, and low decorated crawl to larger passage and choke, and also low side passages.

RESTDAY CAVE 29201850 A310 L55 D4
A stream from Vesterfjell follows a course parallel to the Tosen road, and into Bjørkåstjern. In dry weather the stream sinks into its bed about 200m from the lake. The cave entrance is a prominent arch, but the passage soon chokes.

THROUGH CAVE 32252300 A830 L15
Short cave on the slopes above Gaasvatn.

A reconnaissance was made along the Gaasvasselv, above its confluence with the Jordbruelv, where it flows along a narrow marble band for a kilometre but no caves or other karst features were found, probably due to the high dolomite content of much of the marble.

JORDHULEFJELL

This area "Ground Hole Fell" was recorded by Helland (1907). The limestone is at a high altitude, well above most vegetation or even soil cover. It occurs as a number of bands of yellowish-grey marble up to 200m wide on the flank of Jordhulefjell to the east of the upper Jordbruelv and near Nedre Jordbruvatn. The marble is mostly shattered into small chippings on the surface and is obviously covered by snow for most of the year. North of a kidney-shaped lake, the outcrop forms an ascending ridge with a sharp east wall overlooking a stream gorge, and has many small caves (Fig.9). A fault crosses the marble after about 1km, displacing the northward continuation 50m to the west. 1km further north, a shallow tarn marks a watershed. The marble continues north, gently descending for nearly 2km, but thins down to 5m width. All the caves found are dry, except for tiny invading streams.

COLLAPSED CAVE (1) 24202105 A780 L10
Short stream passage ends in collapse.

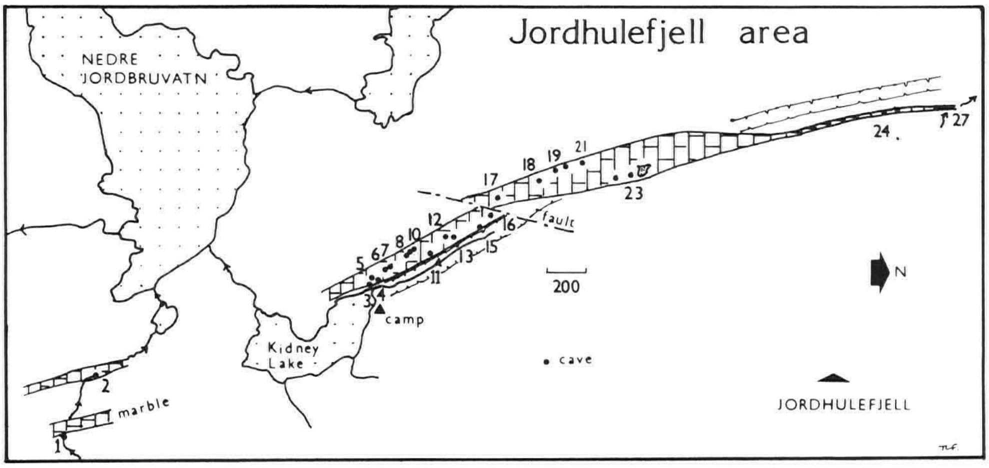


Figure 9

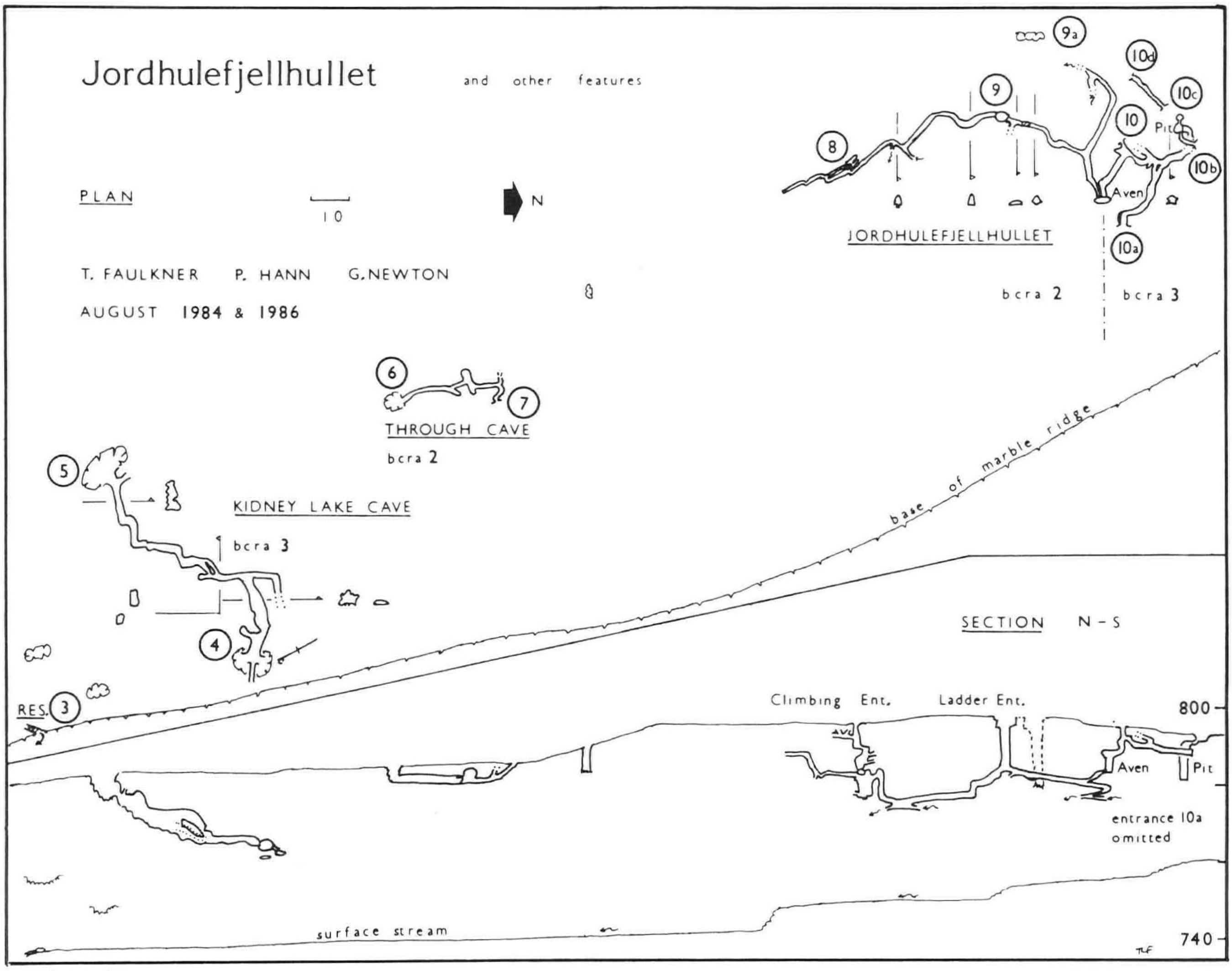


Figure 10

COLLAPSED CAVE (2) 24102110 A740 L8
Enters a chamber where the stream sinks in the boulder floor.

KIDNEY LAKE RESURGENCE (3) 23302205 A738 L1
Short passage to sump, and source of water unknown.

KIDNEY LAKE CAVE (4) 23302205 A765 L114 VR16
Lower entrance 30m up the limestone slope. Dry generally large passage in very rough marble leads to upper entrance (5) in shakehole near ridge crest. (Fig.10)

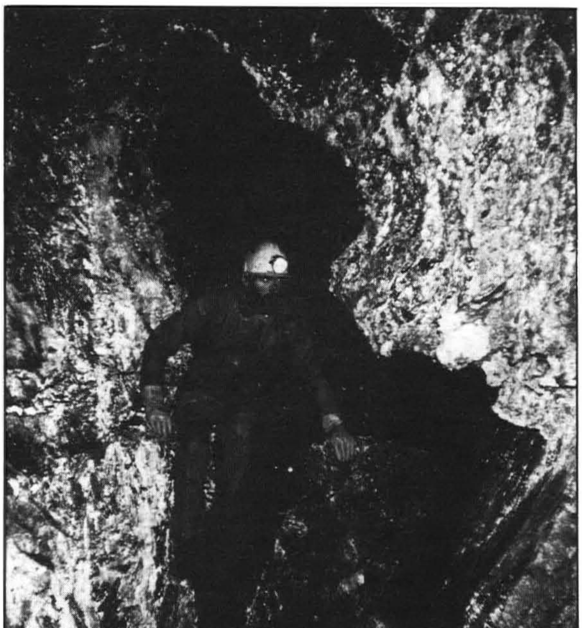
THROUGH CAVE (6) 23252205 A788 L40
Small chambers and crawls to exit at (7) (Fig.10)

JORDHULEFJELLHULLET 23202210 A795 L290 D23
A total of five entrances (nos. 8, 9, 10, 10a and 10b on figure 10) have climbable descents or shafts into generally small upper passages and a larger lower conduit with two sections of streamway.

TWIN SHAFTS (12) 23152215 A820 D15
The smaller easterly one was choked with snow at -6m. The western shaft is 12m deep into a choked passage with the sound of a stream.

SLANTING SHAFT (13) 23152220 A825 L16 D6
35m north of the Twin Shafts a tight sloping shaft can be climbed to a small passage not pushed to a conclusion.

PIT CAVE (14) 23152220 A825 L43 D6
Just 8m north, an entrance below a crag leads to a freeclimbable pit and lower passage.



Kidney Lake Cave (Photo: P. Hann).

CRESCENT CAVE (11) 23202215 A790 L30
Low entrance to short passage.

FAULT CAVE (16) 23002225 A840 L119 D16
On the south side of the lower level fault area a drop between ice and rock leads into this larger entrance. The passage descends to a corner with many small straws above a ledge. Down pitch to a low passage floored with silt (Fig.11). Site 15 has two short caves, and 17 is a 7m choked shaft.

MOONMILK CAVE (18) 23052235 A865 L24
Shallow through cave with deposits of moonmilk. Site 19 is an 8m shaft, 20 is a 10m deep rift, and 21 is a short through cave, all formed at the limestone contact.

DUG CAVE (22) 23052245 A870 L27 D10
About 150m south of the watershed tarn, it descends as a gentle meander to a final pit and sump.

TARN CAVE (23) 23052250 A870 L27
Just south of the tarn itself is a ravine with choked passage going south.

STRIKE CAVE (24) 22302325 A785 L25 D8
4m drop to passage 2.5m high and 2.5m wide.

STRIKE CAVE (25) 22302330 A780 L40 D15
Climb down into large cavern with daylight at far end.

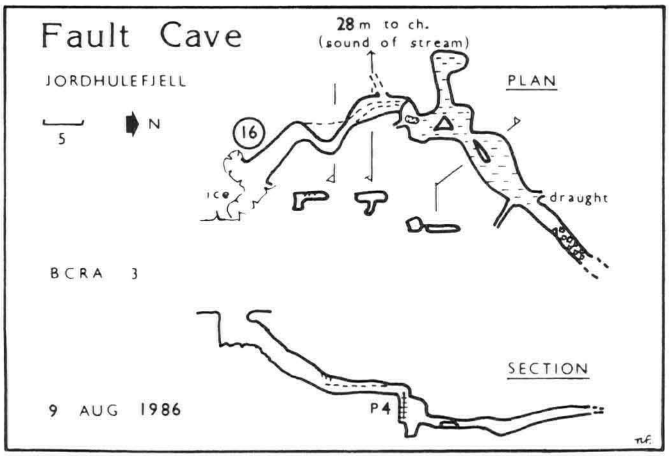


Figure 11

STRIKE CAVE (26) 22302345 A765 D9
200m north, a deep sloping shaft.

STRIKE CAVE (27) 22302340 A760 L6
75m north, near a stream sink.

FAVNVATN

East of the "Inland Sea" of Røsvatn are several long outcrops of limestone north of the lake Favnvatn. Previous visits to this area are recorded in D & S St. Pierre (1971), Heap (1975) and Sjøberg (1978 & 1979) which describe the mainly disappointing nature of the long underground stretches of the Tverelv. Heap (1975) also mentions a small cave at Jupmelvandet. The longest outcrop runs for 15km from Skindfelddalen to the upper slopes of Akfjell, where the 1:100,000 NGO map Krutfjeld (K17) shows a mountain stream running underground for 500m as it crosses a parallel band of marble (Fig.12). A geological map of the area from Favnvatn to Røsvatn is being prepared by Werner von Scheibler, whose thesis will be lodged at the State University of Utrecht, Holland.

AKFJELL AREA

The limestone was found to dip at 45° with cliffs of greenschist 10 to 20m high overhanging the limestone contact forming a steep wall along the line of a limestone terrace. The stream falls over a waterfall at the east end of the terrace and sinks at shakeholes. The terrace has a dry valley leaving to the south after 500m and the stream resurgence is among boulders in its bed, with little fall from the sinks.

SKINDFELDDAL AREA

The upper limestone band from Akfjell passes the end of the lakes occupying Skindfelddal, with the outflow stream running underground for about a kilometre on its route to the Swedish border (Figs. 12 and 13). A band of limestone north of Øvre Skindfeldvatn also captures a mountain stream on its way to the lake (Fig.12). The caves are in a grey marble often with distinct platey fracture, and are devoid of formations.

SKINDFELDDAL SINK CAVE (1) 50005025 A650 L30 D10
The river from the final lake sinks among rocks at the base of a small limestone cliff. 10m above, a

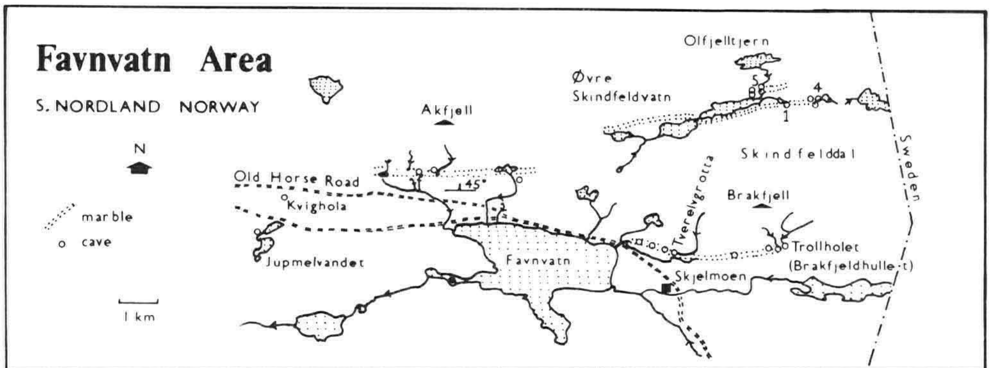


Figure 12

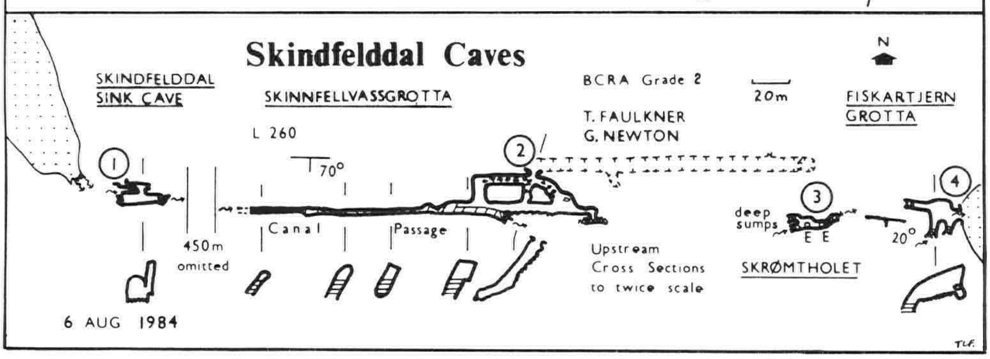


Figure 13

Fiskartjerngrotta, the main resurgence in Skinfelddal.

narrow rift drops into chamber and choked streamway (Fig.13).

SKINNFELLVASSGROTTA (Cairn Cave) (2) 51005130 A640 L260 D15
Small entrance at the top of a bare limestone hummock into a large cave, basically consisting of a wide inclined rift. Sumps and a deep canal occupy some of the lowest part of the rift (Fig.13).

SKRØMTHOLET ("Ghost Hole") (3) 51105030 A630 L12
Two 3m deep interconnected holes to deep sump pools containing many white and brown fish. These may be Brønn-hull, referred to by Helland (1907).

FISKARTJERNGROTTA (4) 51155030 A630 L30
80m east the river resurges from a 10m wide cave entrance to flow to Nedre Skindfeldvatn. A deep sump lies at the back of the rocky chamber (Fig.13).

ØVRE OLFJELLTJERNBEKKGROTTA (5) 49155040 A680 L25
The powerful beck flowing from Olfjelltjern meets the limestone at a waterfall and enters this low cave at a depression. 20m in, the passage becomes too low and wet.

ANDRE OLFJELLTJERNBEKKGROTTA 49155040 A670 L25
A small entrance into a dry sloping gallery.

MARTINUSGROTTA 49155030 A660 L86
Large hole in the hillside with the stream flowing across its floor. Upstream reaches a sump pool. Downstream leads through to the resurgence.

EITERAADAL

This area was first visited in 1978 and 1979 (Faulkner, 1980), when Eiteraadalgrotten and Sirigordgrotten were explored. The valleyside above Sirijordgrotten (Fig.15) had still not been exhaustively searched.

HÅPGROTTA 26003250 A270 L195 D20
Two entrances, at each end of a long depression, give access to one large passage and a lower network (Fig.14), which could relate to the upper end of Sirigordgrotten.

SURPRISE CAVE 26303255 A290 L15
Located about 50m from Elk Shaft it consists of a single tubular passage.

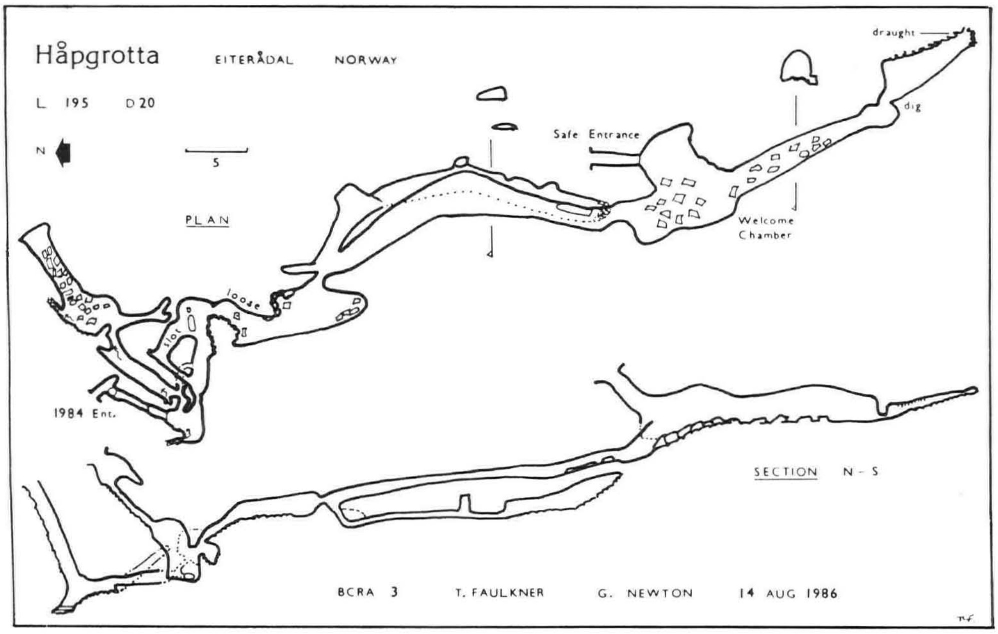


Figure 14

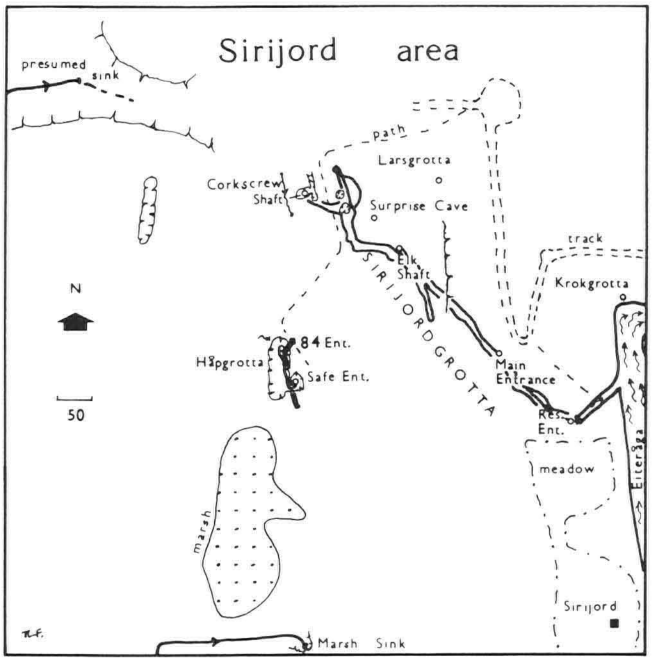


Figure 15

LARSGROTTA 26503300 A260 L19 D10
Dig at base of prominent shakehole west of forestry track into steep well developed passage soon choked.

SIRIJORDGROTTEN 26403250 A200 L1411 VR90
The cave is fully described in Faulkner (1980) pp60-67. Various extra short passages were added to the master survey, and the sump at the end of Twin Ducks Passage was found dry and choked. In 1986 the Mainstream Rising was dived for 11m to where the passage continues, but only 0.3m high (Whybro, 1987).

CONCLUSIONS

As in 1982, the 1984 Expedition demonstrated the praticality of finding significant new caves in this part of Norway, provided that suitable research and preparation are undertaken before departure. The larger size of the team for part of the 16 days in the field enabled rather more passage length to be explored than in 1982, and we were perhaps fortunate in the initial choice of sites to find three mature cave systems over 600m long. As happened in Eiteraadal in 1978, some areas could not be completely explored in one visit and the return was necessary in 1986 to complete the exploration and survey work at Jordbruelv and Jordhulefjell. This will probably be the pattern for future visits, which will combine searches of new areas with further investigation of some of the known ones, so that as an overall picture of the scattered marbles of South Nordland is built up, the more promising ones can be examined in greater depth.

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