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WATER TRACING — PART ONE

A recent USA publication, "Water Tracer's Cookbook" (Missouri Speleology Vol 16 no.3) has just been received by the Editor. It seems to be an invaluable publication for anyone interested in water tracing, but since availability may be a problem, I have assembled a series of articles from an edited version of the cookbook. Where necessary I have summarised less important sections and included some comments of my own - the change in typeface will suffice to show those sections which are not part of the original text.

Don't be surprised if some of the ideas differ from your previous reading. The most important point to remember is that the main author of the Water Tracers Cookbook is a practising karst hydrologist, not a weekend amateur or a naive academic. Unfortunately, optical brighteners arrived on the water tracing scene too late for the authors of the Cookbook to carry out tests and compare results with other tracing agents. Dye detection is particularly easy with optical brighteners, and it was perhaps for this reason that this agent has gained popularity here in recent years. However the method of detecting fluorescein in the charcoal 'watchers' outlined in the Cookbook is so simple that when the overall suitability of fluorescein as a cave water tracing agent is considered, the reader must surely agree that fluorescein is perhaps the best agent to use.

Unfortunately, a substantial portion of the water tracing attempts made in the United States are unsuccessful; this is particularly true with groundwater tracing in cave and karst regions. The major causes of tracing failures are: (a) insufficient hydrologic field work before the tracer is injected, (b) tracing attempts during low flow conditions, and (c) failure to allocate sufficient time to the tracing effort. These are problems which *The Cookbook* cannot solve, but problems which must be kept in mind as one considers possible tracing attempts. Best of luck!!

MATERIALS USED AS TRACERS

A number of different materials has been used to trace water movement. In the late 1800's, painted ducks were used in French cave systems. Bales of hay, wheat chaff, corn cobs, and geese have been used in Missouri. Revenue agents in Tennessee poured 2,000 gallons of illegal whiskey into a sinkhole and inadvertently learned that liquids from this point flowed to a spring supplying water for a local high school. Fortunately, better tracing materials are now available!

Four classes of tracing agents will be discussed in detail:

1. Soluble chemicals such as salt and phosphates.
2. Radioactive materials
3. Fluorescent dyes. (We recognize that these are soluble chemicals, but we wish to consider them separately from the materials discussed in the first category.)
4. Minute biological materials such as bacteria, *Lycopodium* spores, and bacteriophage.

SOLUBLE CHEMICALS (EXCLUDING DYES)

Common salt (sodium chloride), phosphate, and ammonium chloride have been used in groundwater tracing in the past. Chemical tests are used to detect the tracer, and frequent testing is necessary. The concentrations of tracer necessary are often so great that they degrade water quality and, in some cases, injure aquatic life. In general, these tracers should not be used, especially since other materials (particularly fluorescent dyes) do a better and easier job with less water quality damage.

RADIOACTIVE MATERIALS

A number of isotopes (including Cl^{36}, I^{131}, and H^3) have received some experimentation in water tracing work. The safest and most generally useful is tritium (H^3). Tritium is the only radioactive tracer which we will consider in *The Cookbook*.

Tritium is not readily adsorbed on rock, gravel, clay, or organic material. It deteriorates slowly enough (half-life is 12.3 years) to be an effective groundwater tracing agent. When combined with oxygen, its movement is essentially identical to normal water. However, tritium has the following drawbacks:

1. It is radioactive, which presents problems with permits, handling, and transporting. Merely obtaining the material is difficult.
2. The analysis is difficult and requires expensive equipment.
3. All sampling must be done with grab samples, and a long time often elapses between collection and analysis of the sample.

FLUORESCENT DYES

These include fluorescein, rhodamine B, rhodamine BA, rhodamine WT, and pontacyl pink. These are all xanthine dyes; each has been used to some extent in water tracing work. All of these dyes are water soluble, highly detectable, harmless in low concentrations, inexpensive, and reasonably stable in natural waters. One of the chief attributes of these dyes is that they can all, to some degree, be adsorbed on activated charcoal. By using activated charcoal packets, it is simple to determine if dye has or has not passed a given point. In many groundwater cases, the purposes of the investigation are to determine if water moves from one point to another, and then to get some general idea of travel time. This can readily be done with dyes and activated charcoal packets. Furthermore, the techniques are simple and require only limited equipment and expense.

Based on experience and a literature survey, fluorescein and rhodamine WT are the two fluorescent dyes most useful in general water tracing work. These two dyes will be discussed in detail in *The Cookbook*.

Since the first version of *The Cookbook* was prepared in 1971, other fluorescent dyes have received some attention as possible water tracing agents. Significant among these are Direct Yellow 96 (manufactured by Ciba-Geigy Corporation, Greensboro, N. C., under the brand name "Dipheny Brilliant Flavine 7GFF"), and Fluorescent Brightener 28 (an optical brightener manufactured by American Cyanamid, Bound Brook, N. J., under the brand name "Calcofluor White ST--solution"). Both of these have been used by Quinlan and Rowe (1977); their use is described by these authors as follows (p. 16):

> *"In brief, a piece of unbrightened cotton such as Johnson and Johnson Surgical Cotton is suspended in a stream or spring. If optical brightener is present in the water, it reacts with the cotton and is retained. Detectors are changed every few days, washed under a high-speed jet of water, and examined under a long-wave ultra-violet lamp for the blue-white fluorescence of the brightener.*
>
> *...Direct Yellow 96 is eminently suitable for water tracing. It is used like an optical brightener, but it turns cotton a bright canary yellow."*

We have not had any experience with the use of optical brighteners or Direct Yellow 96, and are thus not able to provide recommendations for the use of these agents. Since optical brighteners are used in detergents to make clothes "whiter," their use in water systems contaminated by domestic sewage may possibly be limited.

MINUTE BIOLOGICAL MATERIALS

Some water tracing has been done with the bacteria *Serratia marcescens* and *Serratia indica* (Omerad, 1964; Winpenny et al., 1972). Bacteria tracing could be useful in some sewage pollution problems, particularly those where dispersal of pathogens is of great importance. Among major disadvantages are the degree of sophistication necessary for culturing the bacteria and the necessity of working exclusively with grab samples. At present, it seems unlikely that bacterial tracers would be essential for the types of investigations normally conducted by hydrologists.

Some interesting work has been done (Glantz and Jacks, 1967) with water tracing using naturally occuring *Escherichia coli*-serotypes. Unfortunately, the authors state that there are only two laboratories in the western hemisphere capable of serotyping this bacteria. Regardless of this, the paper is recommended for those with a major interest in fecal coliform.

Winpenny et al. (1972) considered the use of two species of *Bacillus* and two pigmented yeasts. We would anticipate interference problems from native populations with these materials.

Bacteriophage seems to be a very promising microbial water tracer. Bacteriophages were used successfully in a groundwater trace in the soluble rock lands of Missouri; they will be discussed in detail later in *The Cookbook*.

Lycopodium spores, which are spores of a genus of club mosses, are another minute biological material which has been used in water tracing. *Lycopodium* spores are commercially available through biological supply houses. When stained, the spores are easily identifiable under a microscope.

One of the major advantages of groundwater tracing with spores is the fact that you get an indication of the size of openings through which the water is moving. The mean diameter of the spores is about 33 microns, which is at least an order of magnitude larger than most pathogenic bacteria. Similarly, the spores are about 300 times larger than most viruses, and about 15,000 times larger than hepatitis virus, which can be transported through water systems. If the spores move through groundwater from one point to another, pathogenic material can potentially follow the same route. The value of this type information in water contamination problems is apparent.

Although *Lycopodium* spores may be suitable for work in very open groundwater systems (such as karst aquifers, fractured rock aquifers, and coarse glacial deposits), the size of the spores makes them poorly suited to finer textured aquifers. In some crude tests, we found that the spores would not pass through 0.6 meters of sand. The sand which we used was the sort sold by building supply firms for masonry purposes.

Another disadvantage of water tracing with *Lycopodium* spores is the substantial amount of time required for sample analysis. Furthermore, the analysis requires a centrifuge and microscope; most practicing hydrologists do not have ready access to this sort of equipment. Still, these disadvantages are not so great as to preclude *Lycopodium* spore tracing in those cases where questions of "natural filtration" (or the lack of it) are important.

FLUORESCENT DYES FOR WATER TRACING

GENERAL PROPERTIES OF FLUORESCEIN DYE

Fluorescein dye has been used since the late 1800's for groundwater tracing in cave regions. Much of the early work with this dye was pioneered by the French because of the waterborne disease outbreaks in that country.

Fluorescein is most commonly sold in powder form. When mixed with water, it has a brilliant yellow-green color which is readily detectable visually by experienced observers at concentrations of 1 part per million or less. However, it is not very suitable for surface water tracing as it deteriorates rapidly in sunlight; sunlight obviously does not affect the dye in groundwater situations.

Much of the distinctive yellow-green color of fluorescein dye is lost when it is used in water with a pH of 5.5 or lower. As a result, fluorescein dye may be poorly suited for groundwater work in coal strip mine areas or other areas with very acidic waters.

There is some debate in the literature on sorption tendencies of fluorescein. It is clear, however, that fluorescein has a higher sorption tendency than rhodamine WT; this helps explain why the activated charcoal packets (to be discussed later) work so well with fluorescein. The packets work less well with rhodamine WT. Based on our experience, adsorption of fluorescein on fine textured materials does not negate the utility of fluorescein dye for tracing water through soils, residual or alluvial materials. We have successfully used fluorescein dye to trace groundwater from septic fields and dumps to springs. Although there may be a significant loss of dye due to adsorption on fine textured materials, at least some of the dye passes completely through the septic fields or dumps and appears at distant springs. It should be noted, however, that our field experience is somewhat biased; most of our tracing work involving septic fields and dumps dealt with those which were hydrologically poorly located, and were suspected of being sources of groundwater contamination.

GENERAL PROPERTIES OF RHODAMINE WT DYE

Rhodamine WT is a du Pont product and is apparently unavailable from any other producer. It is sold as a 20% solution with a specific gravity of 1.19. Rhodamine WT has a moderately low photochemical decay rate, a low sorption tendency, and high detectability. These factors make it a good tracer, particularly for surface water work where fluorescein is generally unsuitable.

Our experience indicates that rhodamine WT is inferior to fluorescein for most groundwater work for the following reasons:

1. It is not as readily adsorbed on activated charcoal as is fluorescein.
2. In comparison with fluorescein, the amount of rhodamine WT which can be elutriated once it is adsorbed on activated charcoal is low.
3. Tracing with rhodamine WT requires the use of a fluorometer; fluorescein detection can be done with the naked eye.

4. The quantity of rhodamine WT required for positive tracing is typically much greater than the quantity of fluorescein required. Furthermore, fluorescein is a less expensive tracer.
5. Rhodamine WT is not as biologically safe a tracer as fluorescein.

Effective tracing with rhodamine WT requires a fluorometer with 546 and 590 millimicron filters. The cost of such equipment is between $2,000 and $3,000. The U. G. Geological Survey, which has done a substantial amount of work with this dye, has established a policy of keeping concentration of the dye to less than 10 parts per billion where water is withdrawn for human consumption. Similar limits for other workers seem prudent.

Rhodamine WT is the dye we recommend for surface water use. We do not recommend this dye for general groundwater work except perhaps in special cases where high adsorption is a problem. We lack information on the effects of pH on rhodamine WT; if it is less sensitive than fluorescein to pH effects, it might be the better dye for groundwater investigations in very acidic waters.

It would be helpful if two or more kinds of dye could be used simultaneously. Since rhodamine WT is a red dye and fluorescein is a yellow-green, it would initially seem that these dyes could be used simultaneously. Unfortunately, this is not the case as the two dyes interfere with one another in the low concentrations typical of tracing situations. In laboratory experiments we have been unable to find any chemicals which would selectively elutriate only one of the dyes. Fluorescein will fluoresce on a fluorometer equipped with rhodamine WT filters (546 and 590 millimicrons), so fluorometric separation does not appear reliable. We were also unable to separate the two dyes with paper chromotography. As a result, we have never simultaneously used fluorescein and rhodamine WT in tracing work.

TECHNIQUES FOR INJECTING FLUORESCENT DYES

When the dye is injected into a stream, lake, or groundwater system, the intention is to get an adequate mix and to place the dye where it will function effectively. Hopefully, the following suggestions will aid in this effort:

Stream Systems

1. Use a riffle or turbulent portion of the stream for injecting dye
2. Before injecting dye, clean away leaves or other organic material. Often you can redesign a riffle to increase turbulence, and thus produce better mixing.
3. When using fluorescein, pour the powder in slowly to insure adequate mixing.
4. Wind can cause substantial drift of fluorescein powder. Keep your materials clean by placing them upwind of the injection site.
5. It takes about 50 liters of water to mix one kilogram of powdered fluorescein. When possible, avoid mixing in containers as it is difficult to clean them effectively. Lining mixing containers with plastic bags does not work well because lumps of dye will sink to the bottom and cannot be mixed without tearing the bags.
6. You can avoid contaminating charcoal packets if you place them before injecting dye. If you cannot do this, have someone else place the packets.

JENOLAN TRIP REPORT:

THE HAIRY DIPROTODON REVISITED

JULY 7-8

Present:

Bruce Welch
Paula Guard
Michael Lake
Guy Cox
Tony White
The Yugoslavian (Maleckar Frank)
Geoff Innes
Paul Mattes
Ian Mann
Helen Turton
Peter Campbell

Pirates Delight and the Irreducible Minimum stopped Peter again. HAIRY DIPROTODONS DON'T LIKE DOCTORS! Hopefully he will try again some other time. The rest of us proceeded onwards with little difficulty. After everyone had seen the major features of the H.D. many of us busied ourselves with our various activities.

Thanks go to Geoff and Tony for starting the survey while Guy and myself explored the mudslope in Glop Hole Gallery, the high level tunnel north of where we enter (I hear that Geoff used Khan Passage for the southern end at least) and The Yugoslav took photographs.

I haven't a clue what the others did during this time. At the top of the mudslope is a pitch and an interesting passage with a speleothem blocked chamber at its end. At both these points, especially the chamber, you can distinctly hear voices from the river below. Later on Guy moved some of the speleothems to press on.

No easily visible damage was done and the passage leads to a lookdown some 60 feet up the eastern side of the mausoleum. A ledge , 20 feet long, leads from this to a large passage which is at a level higher than Glop Hole

Gallery. Hence cave development is on 3 main levels.

Guy said he was going to do this traverse next trip with a belay, but as you will read in the next report, Ross Franklin and myself beat him to it, and discovered another 300' of passage!

Guy and myself tried to climb an aven at the top of the talus slope on the western side of the mausoleum, however, the foot and hand holes ran out. Guy will do this next trip, as it holds good prospects for exciting discoveries (he had better be quick!)

Tony White went to push the next rockpile at the down-stream end of the M.D. while I helped Geoff to survey. There are some very high areas which would require scaling poles. Some of the mud and earth hills in Glop Hole Gallery are directly below avens hence some indication is given of their formation from mud/dirt falling down from above.

Tony has found that the rockpile is slightly unstable and that a wet suit would definitely be required for further pushing.

After I had been surveying for a while Ian Mann and his group which had left 1 hour previously to go out, returned and asked to be shown the way out of the rockpile! After guiding them out we were joined a short time later by Geoff and Guy who surveyed up to the mudslope.

The Yugoslav took numerous photos on the way out of Ian in the squeezes.

(Sorry about the proliferance of I's but this report was written 1 month after the trip and I've forgotten what most of the others did.)

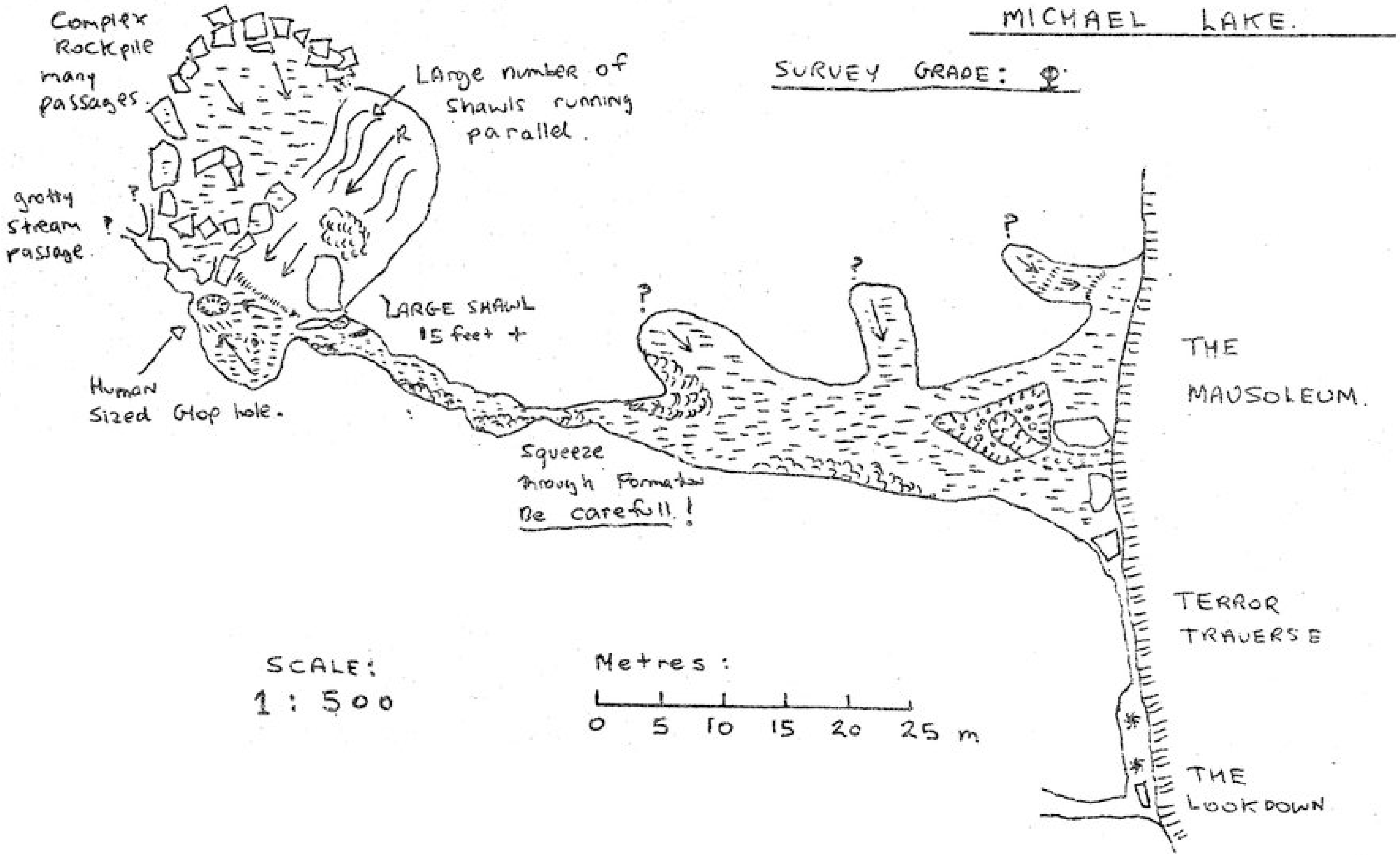
Michael Lake

HIGH LEVEL PASSAGE IN THE MAUSOLEUM, SPIDER CAVE, JENOLAN.

The Eyrie

Drawn by ROSS FRANKLIN and MICHAEL LAKE.

SURVEY GRADE:



TRIP REPORT : JENOLAN 14-15 JULY

Present: Michael Lake (TL), Randall King- tourist, Ross Franklin- dare devil, Ian Mann- monkey, Richard Panick Mackay, Mark Twigg- water baby.

Ross Ian and myself arrived at the flat on Friday night while the rest of our intrepid cavers arrived at 11.00precisely on Saturday morning

Spider Cave was entered by 6 trogs, a camera and associated paraphenalia, an ammuhition box of surveying gear, another pack of more surveying gear and ample supplies of chocolate.

The purpose of our expedition was to survey the Hairy Diprotodon and perform any exploroation neccessary. (This will require more trips)

All of us breezed through Piratee Delight (even Mark who managed it in his usual cool manner after removal of much clothing) Alas, the Irreddcible Minimum is now a part of SUSS history. Richard, in rearranging the furnituure, has created the Expandable Minimum, that bypasses the Irreducible (Hear that Peter Campbell)

After providing Randall, Ross and Mark a quick tourist trip, (making sure Randall's stray legs and arms didn't approach any long straws, we proceeded to survey-
"Mike, didn't Bruce show you how to use the forestry compass?"
"Er yes, but I seem to have forgotten how"

Fortunately we had the Suunto's and the 30m tape with the 30cm knot in it. While surveying was in progress, Richard played photographer and Mark went swimming in Pike Lake! BBrrrrr, water baby. Ross and I were inspired by the high level passage 60 feet up the wall of the mausoleum. If we didn't do the traverse to it from the lookdown, some other "Guy" would. Dare devil Franklin didn't hesitate to cross and I rather nervously followed to the tune of
Quote" Michael, I don't think you're experienced enough to do this" Richard Panick Mackay. Ross has prepared a full report of this incident and our high level discoveries.

Meanwhile, surveying was progressing in leaps and bounds. The end of the Khan passage was investigated by myself and found to be impassable after 5 feet and after I had become half soaked due teapool of water

The outward journey via the Expandable Minimum was uneventful except for Mark who was reduced to the irreducible mimimum in decency. We exited Spider Cave at 10.00, Saturday night and had a late dinner with some $1.57 a bottle port(UUH!)

Sunday was spent in a more leisurely fashion with a trip to Bushrangers Cave up on the hill. Ross, Mark and myself them enjoyed a pleasant walk up to the sink. Twigg Hole, a nettle filled doline, was investigated by Mark on the way back. The Rift was climbed and we investigated Warbo Cave to the first drop. A great cave to take some freshers into.

Michael Lake

Sub Trip Report : Saturday 14th July 1979
Present: Ross Franklin, Mike Lake.

The Eyrie, Yet another Discovery in Spider Cave.

Leaving the rest of the party surveying the Hairy Diprotodon, Mike Lake offered to show me the passage that Gut Cox had recently cleared of formation which led to a balcony overlooking the Mausoleum . Mike repeatedly warned me that although there was a passage leading off from the end of the balcony it would be foolhardy to attempt the traverse without a rope.

Those that know me will agree that I am definitely a fool of the first degree and once I saw the passage beckonig me onward I couldn't rest until I had entered and explored it thoroughly. Actually the traverse was not too difficult. Its just that with a 70' drop 4 or 5 " to your right whilst crawling across a sloping muddy ledge doesn't inspire confidence of success. If you forget about the drop and just look ahead the traverse is surprisingly easy.

Once across the other side and having run down a large gallery and established this to be an extension of some note, I went back to the traverse to see if I could persuade Mr Lake across. True to his name, and reputation, (Miker the Piker) he put up an extremely convincing argument on why we should not attempt the traverse.

Of course I wasn't beaten yet and after I slid back across the traverse and then back to the new passage again in the twinkling of an eye, Mike had to agree it didn't look dangerous and finally proceeded across the traverse with very little difficulty. His nerves were not helped by Mr Mackay who had crawled onto the balcony also and kept reminding Mike of the problems associated with conducting a cave rescue in Spider Cave.

Once across, Mike and I ogled at the pretties and generally considered the possibilities of this extension. The main gallery is a sedimented passage and the most obvious lead along this was checked out first. After approx 40m the passage tightened considerably and it was only with the utmost care that Mike and I could proceed via a very light squeeze past large and active straws and other formation. (Extreme care must be taken here by future parties) Further on one enters a small cavern with shawls down the right hand wall. The largest and most beautiful of these was estimated to be in excess of 15' in length.

Retracing our steps we proceeded to check most other possibilities of extension again without result although a larger party of active climbers and micropods might have some success in cracking an aven or the rockpile.

We returned to the others after 3 hours exploration with a further extension to the ever lengthening Spider Cave.

Ross Franklin

MEDICAL MATTERS with DR CAMPBELL

Seeing what was in the last few issues of the Bulletin, and having not contributed for some time, combined with holding the traditionally slack position of Safety Officer, I felt that there may be some value in publishing some medical information in the hope that something read will stick and be of use in an emergency. Here therefore, is part 1 of a series on Cardio-Pulmonary Resuscitation, for better or worse. I assume a basic knowledge about what the lungs, heart and blood vessels do.

If someone recieves an injury to their respiratory, circulatory, or central nervous system, they may be at risk of dying within a very short space of time. The possibilities in a cave are numerous.

Below is an incomplete list.

CENTRAL NERVOUS SYSTEM

Trauma - Fractured skull; if there is swelling or bleeding around or in the brain, its vitalfunctions can be stopped. i.e. breathing.

rarely a high spinal injury can lead to paralysis of the muscles of breathing, whist lower spinal injuries can be complicated by low blood pressure by blocking the nerves that maintain blood pressure.

CARDIOVASCULAR.

Shock - low blood pressure due to blood loss from an injury.

Disrhythmias, i.e. irregular heart beat. The important one is ventricular fibrillation - a complication of hypothermia. The heart beats in a totally unco-ordinated fashion and cannot pump blood

RESPIRATORY.

Obstruction - unconsciousness, with lax muscles in the Pharynx (back of the mouth and throat) which collapse together
- inhalation of vomitus
- inhaled foreign bodies; rare in adults
- severe facial and neck injuries.

Interference with lung movement

Pneumothorax - air between the lungs and the chest wall due to thoracic (chest) injuries. This prevents the lungs expanding properly.

Haemothorax - blood instead of air.

Drowning, Anoxia, and Asphyxiation.

- Gas or water in the place of air, displacing Oxygen in the lungs and blood or preventing its metabolism. Lack of air as in obstruction is also asphyxia.

e.g. CO_2, CO, cave diving

MEDICAL CONDITIONS.

Myocardial Infarction (heart attack, Coronary) - don't think it is impossible or limited to fossils - people in their 20's can get these in Western Civilisation. Blood supply to part of the heart is specifically blocked.

Other Conditions - these are rarer e.g. strokes
intracerebral bleed
severe asthma

DRUGS - always a possibility with our Bohemian Caving Population.

Narcotics - e.g. heroin leads to unconsciousness, low blood pressure and loss of the stimulus to breathe

Alcohol - severe inebriation can lead to the inhalation of vomitus, or hypothermia if the victim "sleeps the night out" In SUSS the traditional risk is of severe burns.

DEHYDRATION AND HYPERTHERMIA

- worse in the hot weather and in the unfit or those pushing themselves, or without adequate fluid intake. When severe these are associated with low blood pressure and profound shock which can lead rapidly to death.

RARE CAUSES OF SUDDEN OR IMMINENT DEATH WHILST CAVING.

Electrocution - tourist caves
- climbing metal ladders up entrance pitches during thunderstorms

Severe burn - early death due to shock if the victim survives the initial burning

Foul Play - Knifing has been recorded.

Snake Bites - causing cardiac irregularities and respiratory depression.

[redacted] the causes, the one to put in big letters is TRAUMA.

Peter Campbell

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Contact the above for details of short-notice trips most weekends - or persuade them to organize one !

FUTURE EVENTS

29th Sept - Oct. 1st. JENOLAN . Spider Cave- surveying the Eyrie and other excesses. Contact - Mike Lake, 524 5229

29th Sept - Oct 1st. COOLEMAN PLAIN. Frustration cave and other tight and wet delights. Contact - Graeme Smith, 524 6447

Thursday October 4th. SUSS General Meeting. Common Room, Holme Building, 7.30 pm.

6th - 7th October. JENOLAN. The BIG DIVE - upstream in Spider Cave. Will the divers reach Mammoth ? Come along to help and to find out.

27th October. NSW Speleological Council Meeting. Cabra-Vale RSL Club, 1 Bartley Street, Canley Vale. 10 am.

Thursday 1st November. SUSS General Meeting. Common Room, Holme Building, 7.30 pm

Tuesday, 23rd October (yes, this is out of order) SUSS Committee Meeting, Graeme Smith's place, 7.30.

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