Alan Warild

VERTICAL

A Technical Manual for Cavers

VERTICAL
A Technical Manual for Cavers

41 Northwood St
Newtown 2042 Australia

Published by the
Speleological Research Council Ltd
P.O. Box 183
Broadway, NSW. 2007 Australia
1988

ISBN 0 9589253 4 8

Front Cover: *Nita Xongá, Zongolíca, Mexico. Photo by Dave Barlow*
Back Cover: *Alan Warild in Drum Cave, Bungonia, Australia. Photo by Chris Probst*

Caving, by its very nature is a risk activity. The author and publisher accept no responsibility for any accident or injury arising from the use or misinterpretation of information contained in this book. The reading of this book alone cannot be considered adequate training for a vertical caver. Knowledge must be coupled with first hand experience.

Printed in Australia by Lion Graphics.

CONTENTS

FOREWORD

Over the last decade deep cave exploration has undergone many changes as Single Rope Techniques have been refined. Siege tactics involving large numbers of cavers and underground camps are being replaced by the fast attacks of small fit teams using lightweight equipment. These changes have, in part, been made possible by improvements in the materials and design of caving equipment but more important has been the change in attitude of cavers to small teams and solo caving.

It is a privilege for me to write the foreword to Alan Warild's book, VERTICAL. It encourages cavers to think for themselves, whether purchasing equipment, descending a cave or rescuing a colleague. The book describes deep cave exploration methods; emphasising the importance of efficient caving and throughout has strong underlying themes of safety, conservation and documentation.

Alan Warild, during twenty years of intensive caving, has trialed many new devices and techniques, frequently designing his own equipment to obtain the best. He is ideally qualified to write about lightweight caving as in recent years he has regarded it as the only way to descend and explore deep cave systems. Some may believe that he has taken lightweight to the extreme in descending six of the world's 1000 metre plus caves solo, including the Reseau Jean Bernard (1535 m), which he rigged and derigged in 39 hours. Feats such as this require considerable practical expertise in the ultra-lightweight techniques presented in this book.

The book may, at first glance, appear to be for caving experts who wish to improve their efficiency in deep vertical systems. However, I am of the opinion that it is of immense value to the embryo vertical caver, helping him make informed decisions about selection of equipment and to learn safe and efficient techniques from the start. The book clearly stresses the need for experience and training in the basic techniques before attempting lightweight and especially ultra-lightweight caving.

Alan Warild commenced writing VERTICAL because he observed the need for the full range of vertical techniques to be described in English. During its production other books on Single Rope Techniques have been published, this book compliments them by giving a "world view" of vertical caving. VER TICAL is an important contribution to the technical caving literature.

Julia James

ACKNOWLEDGEMENTS

My thanks must go to all those who have knowingly or otherwise contributed to this book. The who-knows how many people I have caved and talked caving with over the years.

Special thanks go to Julia James for her continued support from start to finish. Also my proof readers who tidied up the Warildisms and put things into English: Carey Barlow, Dave Barlow, Vicki Bonwick, Judy Furby, Dave Martin, Nick Melhuish, and Tony White.

Jacques Orsola for the use of his library and the house it was in during the early writing.

Chris Probst, Pete Nieuwendyk, Carey Barlow, Dave Barlow and Nick Melhuish for help in taking and posing for photos.

On the production side, Bruce Welch's help and advice on printing and setup was invaluable, as was Keir Vaughan-Taylor for his aid in laser printing the text.

INTRODUCTION

For thousands of years caves have been little more than forbidding dark holes in the ground. In that time caves have not changed, but people have. One by one the natural challenges of our world have disappeared with the unstoppable civilising of our planet.

This book is about that "last great challenge" - the deep cave, or more precisely, how to get down it and out again. It is a guide to the technical side of vertical caving, which will be of use to both the beginner and expert. There are two major philosophies of Single Rope Techniques (SRT) in vogue at the moment. For ease of description I will call them "Alpine" as used in Europe and "American" as used in the USA.

Alpine caving stresses the need for light rope and rigging which keeps the rope free of the rock and water. It requires an effort to rig carefully and precisely. One must be willing to spend the time putting bolts into awkward positions; to swing around and find that perfect deviation. It is slow to rig the first time but once rigged it is very fast. Big pitches broken into short sections reduce waiting time for groups and the large number of belays increases safety. Once bolts have been placed anyone following needs only a minimum of lightweight gear - they can travel fast and easily. American rigging stresses the need for abrasion resistant rope used with a minimum of anchors, no fancy rigging and few bolts. American style is fast to rig. If a belay is strong enough it is fine, if the rope does not rub too badly, all the better. Descent is also fast for the individual - no need to stop and cross rebelays. On the way up though, a long pitch can have people waiting around for hours and the extra weight of thick rope will certainly slow the group down. The next group down the cave will have the full challenge of rigging it themselves with few ready-made anchors.

No one technique is not the only way to explore vertical caves and I have tried to cover the range of caving styles without giving overt value judgements or "writing-off" ideas simply because I prefer not to use them. The emphasis is on comparison of the current technologies and use of what is appropriate for the job at hand.

There is never one correct way to do things and to think so leads to the narrow views and unwillingness to change so often seen when cavers from different countries get together.

For the moment there is the range both between continents and even from club to club. I hope I have done justice to all concerned and this book will show "the other side" how "we" do it. So saying though, I must admit to being a confirmed user of Alpine technique. Given the choice it is the way I explore caves. I am of the firm opinion that just as ladders were largely superseded by the advent of SRT - despite considerable opposition so too will IRT (Indestructible Rope Technique) be superseded by Alpine technique as the best solution.

The ideas presented in this book are not all original, many were picked up during my development as a caver and I have not the faintest idea to whom they are attributable. Most of my ideas on American Style rigging have been formed by caving with Americans in Mexico while my version of Alpine and the lighter techniques has grown from experimentation with ideas coming out of Europe and reinforced by recent trips there.

Also in Europe I encountered some of the best caves in the world disgustingly littered with rubbish of all kinds. Most of it left because of an attitude that caves (indeed nature in general) are objects to be conquered no matter what the cost. It simply does not matter to many people what damage is done along the way or what is left behind when they leave so long as their mission is accomplished - If you can get it in there then you can get it out. There is simply no excuse for excessive bolting, carbide dumps, throwaway rigging, entire abandoned camps or even lollie papers in Caves, let alone the more subtle things like trampling a whole chamber when a single path through is adequate. It saddens me to see cavers thoughtlessly destroying the very objects they come to explore.

Caving is a sport, which is done for fun so let’s keep it that way for by doing it safely and cleanly, and in so doing we'll leave some challenge for those who follow us.

Alan Warild,
November 1988.

1 PERSONAL EQUIPMENT

The condition of the life support components of personal gear have an obvious effect on a caver's well being and while the rest of his gear is of less immediate importance, considerable care should still go into its selection. Appropriate clothing and equipment for the job increases safety by increasing comfort and reducing the amount of energy expenditure for any given cave.

CLOTHING

Protection from cold, water, mud, sand and rock is needed to varying degrees in all caves. The selection of one's caving apparel will depend on the nature of the cave and personal preference.

UNDERSUITS

In caves colder than 10° C a one piece garment of chlorofibre or polypropylene is ideal. Synthetic suits dry quickly, are reasonably comfortable when wet, are not too bulky to hinder movement and wash easily. However, care must be taken when drying them; too much heat will convert them into crunchy miniatures of the real thing. One-piece fibrepile "furry suits" are bulky and in most cases will be too hot when dry. Once wet they hold an enormous weight of water, which is slow to drain and dry out. For cavers who really feel the cold, multiple layers of light clothing are better and any undersuit can be augmented by an extra synthetic top should the cave be cold enough or the rate of travel so slow as to require it.

Woollen underwear is adequate but does not perform as well as synthetic fabrics. Cotton in any form should not be used in cold wet conditions. Once wet it dries slowly and feels uncomfortably damp.

In caves warmer than 10° C light polypropylene ski underwear is ideal (e.g. Helly Hanson "Lifa"). It removes water from the skin very rapidly, keeping the skin feeling dry and is more comfortable against bare skin than an oversuit.

Sewing light neoprene or fibre-pile patchpads onto the knees and elbows of the undersuit will offer protection without appreciably restricting movement. Pads need to be positioned carefully by marking their position with the suit on and the arm or knee bent. The pads then end up positioned a little lower than expected but in the correct position to protect the caver.

Even the lightest-undersuit is too warm in some caves and it is then necessary to wear nothing more than normal underwear as an "undersuit."

Pontoniere

Pontoniere

The safest and most comfortable way to explore cold caves is to stay dry. If a cave involves wading but no swimming a "ponto" is the way to keep one's undersuit dry.

Pontonieres can be made of latex, polyurethane coated nylon or pVe. Latex versions are the most popular as they are formed in one piece with no seams, feet included. Pontos keep a caver waterproof to the armpits with only minimal restriction of leg movement. Weighing around 500 g and packing down small, pontos are normally carried to the beginning of the wet section, then put on over the undersuit but beneath the protective oversuit. A pair of thin long socks and garters may be worn over the ponto to keep it fitting neatly and protect its feet.

Contrary to the popular belief pontos do not flood badly. I have swum 20 m or so in one and took in only about one litre of water, which went straight to the feet, leaving me tolerably warm and "dry".

All pontos are delicate. Latex is tougher and easier to repair than polyurethane (a repair kit comes with the ponto) but latex perishes if not adequately cared for. Polyurethane versions require less care and are lighter (350 g) although there have been some problems with the seams splitting.

After use the ponto should be rinsed in fresh water then dried out of direct sunlight. When packing a latex ponto away, it should be dusted inside and out with talcum powder to prevent the rubber from sticking to itself.

OVERSUITS

Protection from cold is rarely enough; warm gear must stay dry and clean for it to be effective. It must also be covered by something tough in order to keep it in one piece.

Waterproof

Brightly coloured plastic suits have been the mode in Europe for some years. Made of PVC coated polyester with welded or taped seams, velcro front and integral hood, they offer exceptional protection against water and abrasion, are tough, long-wearing and look good in photos. Being made from non-absorbent material they do not increase in weight by soaking up water and the smooth surface sheds mud and water rapidly to prevent heat loss through evaporation. The tough fabric has a certain "suit of armour" feel about it, especially at low temperatures and its impermeability can cause a good deal of condensation to form if worn in warm caves or when working hard. Nevertheless they are unbeatable in cold, wet caves when the water is not too deep. Repairs are easily done by glueing a patch on the inside with the PVC glue normally used for plastic plumbing or with contact adhesive.

Non-waterproof

Suits made of "proofed" nylon, cordura are more comfortable to wear than impermeable plastic suits. They are light and flexible and are the ideal choice for warm or dry caves. They have the added advantage that they can be home made in countries where impermeable suits can only be imported at great expense. In mild conditions ordinary cotton overalls are suitable.

EXTRA CLOTHING

For serious or slow trips (surveying, photography) a balaclava and undergloves make a world of difference. For even colder conditions or for emergencies a thermal top can be carried in a waterproof bag until needed.

WETSUITS

Wetsuits are excellent for wet caves in which one is constantly in and out of the water or swimming. They offer an all over padded skin, buoyancy in deep water and a streamlined profile for nasty passages. However, there are some disadvantages. When inadequately designed for caving they restrict limb movement considerably, adding to fatigue and making climbing difficult. A wetsuit is uncomfortable in a dry cave as it seals in sweat, keeping the wearer constantly wet so that after a long trip most cavers will emerge looking as wrinkly as a prune. The efficiency and amount of insulation that a wetsuit provides is small, so it is necessary to stay active in order to keep warm. If forced to stop for some time it is easy to become dangerously cold. On the other hand, prusiking or moving quickly through dry passage can cause severe overheating and it is not uncommon to find a wetsuit wearer taking a quick dip in some tiny pool in an attempt to cool down.

A "surfsuit" made of soft neoprene with thinner patches behind the knees and elbows to increase flexibility are the better alternative to a diver's wetsuit. This design accommodates all prusiking movements and allows one to reach both hands above the head. The neoprene should be double lined, no thicker than 5 mm and even thinner for warm caves.

A suit, which is a slightly loose fit, will give better freedom of movement and allow one to wear an undersuit for cold conditions. One piece wetsuits are lighter and cheaper but less versatile than two piece models. Female cavers will find a two piece suit more comfortable while males can get by in any suit with a fly zip. A hood for diving sumps will complete the suit.

FOOTWEAR

The most popular cave footwear must be rubber "gumboots" or "Wellies". They offer good protection to the feet and lower leg, are robust, keep the feet dry in most caves and are cheap. Rubber soles grip better than plastic but wear out faster. If the boots are unlined they will dry out quickly. The legs of a waterproof oversuit are worn over the boot tops, which effectively keep out gravel and water. Rubber bands cut from car inner tubes are perfect for keeping overalls from slipping down the wellies and restricting leg movement and also serve as repair material for damaged lamps.

For those who do not like wellies then ankle length lace-up rubber boots are a good alternative. They do not keep out water as efficiently as wellies but are still durable and do not become soggy or heavy when wet.

For easy trips, clean caves, or where a lot of swimming must be don~, running shoes are suitable. Leather walking boots are not made for wet caving. They become heavy when wet, are expensive and wear out too quickly to be good value for money.

Socks

Neoprene wetsuit "booties" are very popular. They keep the feet toasty warm and well padded. Wetsuit booties go well with wetsuits but when wearing wellies long wool or chlorofibre socks are ideal. Even after long trips it is possible to emerge with dry feet.

GLOVES

Many people scoff at the use of gloves, "you can't feel the rock" etc. When caving day after day or on long trips one cannot afford to lose dexterity due to cold or damaged hands. Gloves are essential but good ones may be hard to find. Ideally a neat fitting pair of PVC industrial gloves with long gauntlet wrists is the best. Once used to the feel of gloves they can be worn all the time to keep the hands clean, dry and protected- The long gauntlets will serve to keep water and dirt from getting in both the gloves and sleeves. If a good pair of gloves is unavailable any gloves will be better than none.

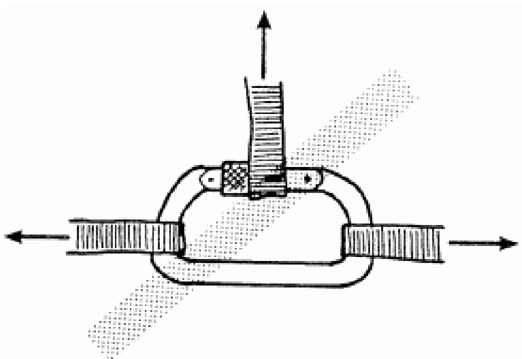
SEAT HARNESSES

Seat harnesses are usually made from flat tape 25 mm to 50 mm wide. When well sewn or fastened with suitable buckles they are stronger than the caver who is wearing them. However, strength is not all that is necessary, there are other requirements:-

- It should have two independent suspension points as a fail-safe. If one breaks there must be a back-up.
- A harness must be comfortable, it may be necessary to sit in it for a long time.

- It must be lightweight, and not made with lots of bulky, water absorbent padding.
- It should fit neatly, even tightly, without restricting leg movement. Any slack in a harness will ultimately have an adverse effect on prusiking efficiency.

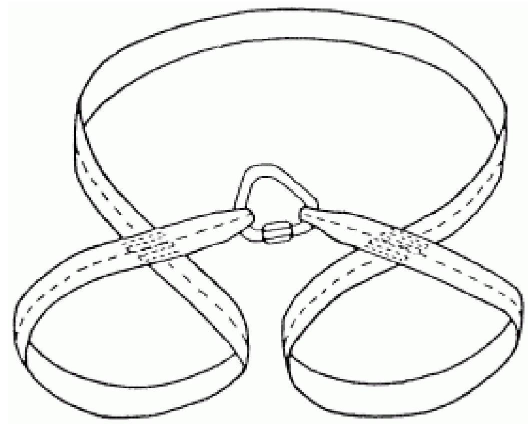
A number of commercially available caving harnesses fit these requirements but one should be careful of climbing harnesses as they are almost always too loose for efficient prusiking.



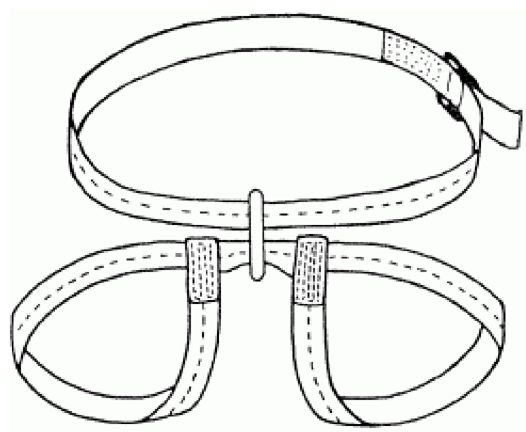
3-way loaded karabiner

A seat harness should be held together at the front with a "Maillon Rapide". Never use a karabiner, the 3-way loads, which can occur at the harness attachment point, make it dangerously weak. **Always** use a 10 mm diameter maillon made of either steel or aluminium in a delta or half round shape. An 8 mm steel delta maillon is also strong enough but has very little weight advantage over a 10 mm aluminium delta and will be very crowded by the time everything is clipped into it. A seat maillon, which becomes jammed closed, can be loosened by wrapping a piece of clean tape around the gate or by using a steel maillon as an adjustable spanner.

The "seat maillon" can either si t flat against the abdomen or at right angles to it, depending on the harness. Quite apart from comfort in squeezes and crawls the orientation of the seat maillon can have a significant effect on the prusik rig. Most chest-mounted ascenders have a preferred orientation so one must use a seat harness which complements the ascenders and prusik rig used. Another feature to check is adjustment buckles - once set they will probably never need to be touched again but, if badly positioned they dig into some people's hips or expose the tape to severe abrasion. In some cases turning the harness inside out can help. On many people the legloops slip down and some manufacturers are reluctant to fit uplift straps at the back. Any harness can easily be modified at home if it is otherwise suitable.



European style seat harness



Leg-loop seat harness

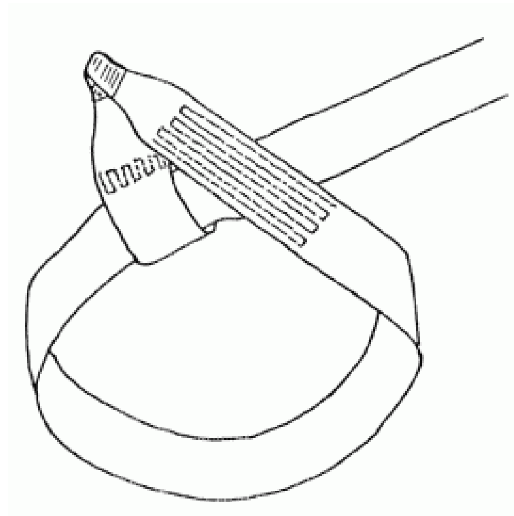
HOME-SEWN HARNESSES

If a suitable harness is too hard to find or outrageously expensive, it is not too difficult to make one. As it will be a specific item adjustment buckles can be left off and the harness made to fit, making it lighter and neater than a comparable commercial version. Stiff flat tape makes the best harnesses as it is less prone to rolling than soft tape and maintains its width for better weight distribution. Tape joints can be machine sewn as strong as the tape they are made of. The best stitch pattern is long parallel rows along the grain of the tape. This puts as many stitches through the tape as possible and allows the stitches to be pulled into the tape enough to protect them from abrasion. Stitches, which run across the tape, stand out from the surface and are in danger of being scraped off. On heavy wear areas or to stiffen the tape a protecting patch can be sewn over the surface. Stitch lines should be neat and parallel and each run should be the same length so as to keep load stresses even. The number of stitches required to form an adequate joint of similar strength to the tape will depend on the thread and tape used.

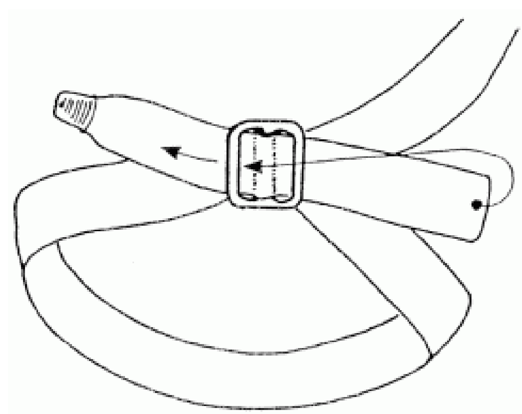
The following can be taken as a rough guide using good quality No 20 polyester thread (never use cotton as it rots).

50 mm tape - 200 stitches
25 mm tape - 150 stitches
15 mm tape - 80 stitches

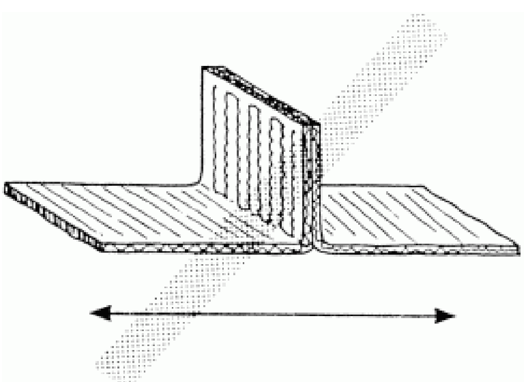
(At 5 stitches per centimetre and sufficient tension to pull the thread into the tape.)



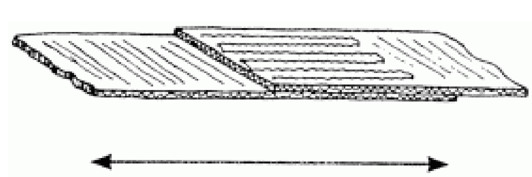
Sewn leg loop



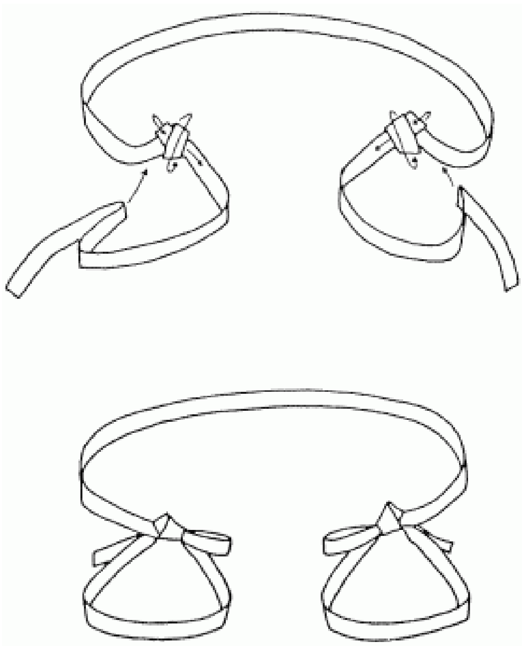
Buckled leg loop



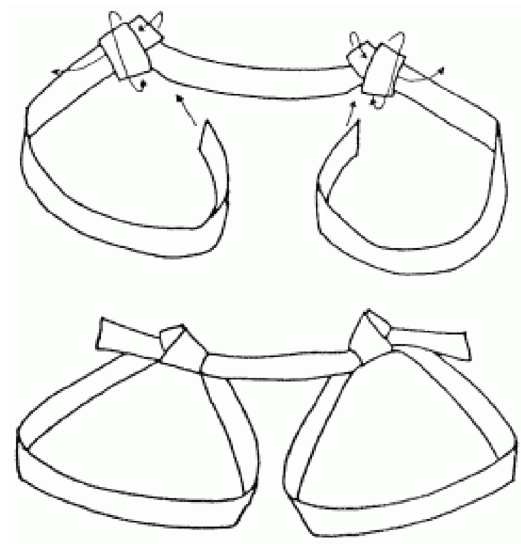
Joints must not be formed so that they are ripped apart one line of stitches at a time



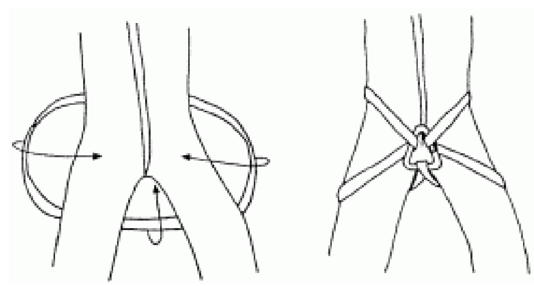
Stitched joins should be formed to load in shear so that all stitches bear the load



Tying a European style harness



Tying legloops



Nappy seat

KNOTTED HARNESSES

Cavers who do not trust their own sewing can replace stitched areas with buckles or knots using sewing for only the parts, which are not "life support". However knots are less suitable than sewing for making a harness because they are bulky which can make them uncomfortable and wear badly. The most suitable knots are tape and overhand knots, which reduce the tape's strength by around 50%. Knots have one great advantage over sewing - a knotted seat harness can be tied quickly and easily, even ill a cave.

IMPROVISED SEAT HARNESS

An adequate harness is easily improvised. First make a strong "life support" belt or waist loop then take a short sling, twist it to form a figure-8 then put one leg through each loop and clip the crossed part to the waist loop.

A longer sling can be made into a nappy seat, which can also be clipped to a waist loop to keep it from slipping down. Should there be some distance to go it could be worth the effort to tie a knotted harness from a length of tape or rope.

Seat harnesses are made of tape to spread the load comfortably over the pelvis but whenever tape is abraded its strength is reduced considerably as surface damage affects all the fibres. Nylon also loses strength with age so even lightly used harnesses should be replaced at least every three years or more often if they become badly worn.

WAIST LOOP

Many cavers wear a waistloop made from several metres of tape wrapped around the waist and tied with a tape knot. As well as forming the second suspension point of some harnesses, a waistloop can be used as a handline or made into a harness in times of need.

Neck loop

Sash

CHEST HARNESSES

Chest harnesses tend not to be "life support" equipment so they do not always need to be heavy, overstrong or particularly well sewn. For these reasons most cavers make their own -" chest harness even though there are commercial models available.

The choice of chest harness used will depend on the prusik rig - it may simply be needed to lift a chest ascender and perhaps support some of the weight of a cave pack and so can be of thin light tape. Then again it may be needed to keep the body tightly against the rope and will need to be of wider, stronger tape to spread the load. Some prusik systems do not even need a chest harness (see Prusik Systems, Chapter 7).

NECK LOOP

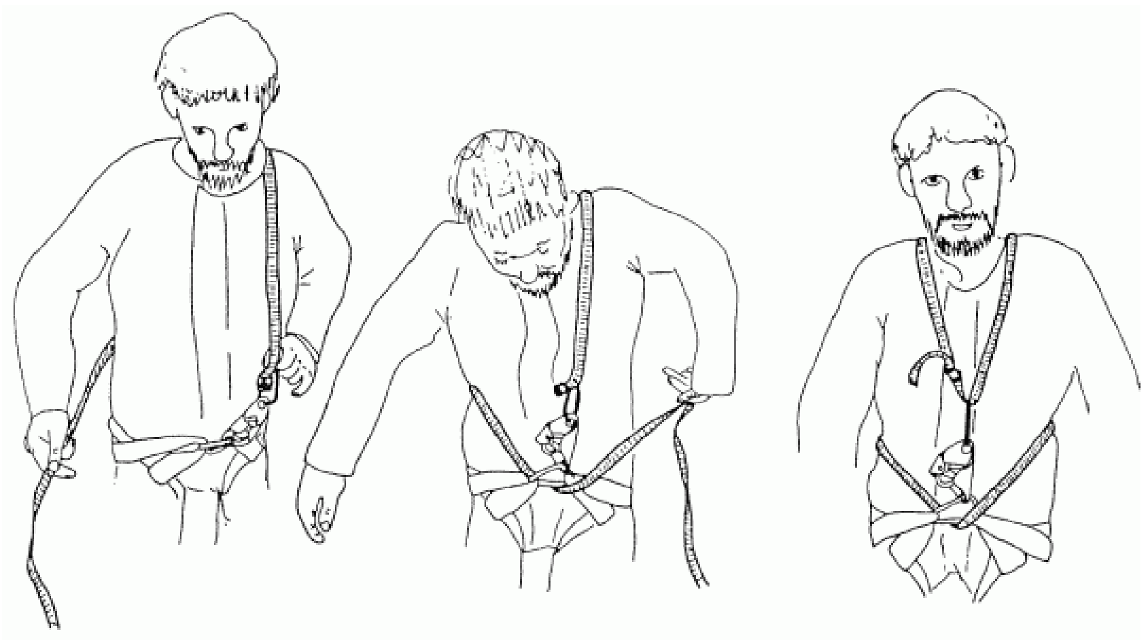
The simplest chest harness available is a loop of shock cord threaded through the top of the chest ascender and put over the head.

A neck loop works fine except when prusiking with a heavy pack or leaning back to rest. More sophisticated versions use a tape with a buckle or even a quick release buckle, which can be used to convert instantly from tight for prusiking to loose for walking.

A neckloop can be fashioned from almost anything, light tape, shock cord, or even a metre cut off the bottom of a rope.

SASH

A tape worn over one shoulder like a bandolier gives a convenient, light chest harness for short drops when not carrying heavy loads. However the diagonal nature may give problems because it pulls the chest ascender to one side, which can affect its running. The chest ascender will probably run best with the-harness over the left shoulder so that it pulls the ascender to the right. Short chest ascenders also run adequately with their top eye clipped directly into a short carbide lamp sling.



Putting on a wrap-around harness

Wrap-Around Harness

The wrap-around harness needs about three metres of flat, 15 mm tape with a good, easily adjustable buckle at one end.

The tape is threaded through the eye at the top of the chest ascender so that the buckle is just to the right of the ascender. Alternatively it can be connected to the top of the ascender with a small maillon or mini-krab. The rest of the tape is thrown over the left shoulder, collected from behind the back with the right hand, brought under the right armpit and threaded under the seat maillon. Next it runs around under the left arm and across the back and over the right shoulder down to the buckle. It may sound complicated but once it is on it is an exceptionally comfortable harness even when carrying a cave pack.

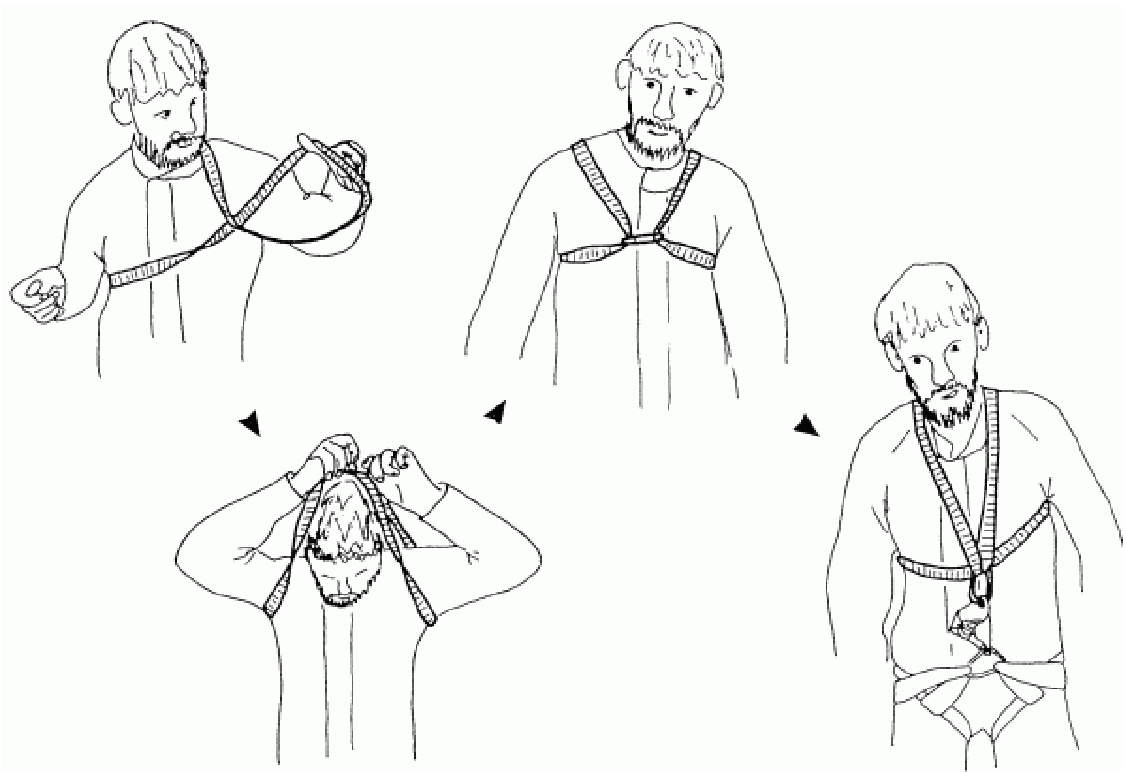
In use, the harness is pulled as tight as possible without restricting one's breathing. When walking between pitches, slack is obtained by feeding tape through the buckle, or releasing the mini-krab from the ascender.

Figure-8 Harness

The Figure-8 chest harness is a simpler and popular alternative to the wrap-around harness. All that is required is a correctly sized pre-tied tape loop or bicycle inner tube and a karabiner.

One arm is put through the loop which is then crossed in front of the body to make an "8" and the other arm put through the other hole. The crossed part is then put back over the head. The two loops, which sit in front of the shoulders, are gathered together at the front and clipped with a karabiner.

The harness should be a snug fit without being tight and some experimentation may be required to get it just right. To ascend, one simply bends over and clips the karabiner through the top of the chest ascender. The system works well, it is light, simple and will not slip< off the shoulders so can comfortably be worn throughout the cave. It is not as comfortable as the wrap-around and is definitely uncomfortable when prusiking with a pack.



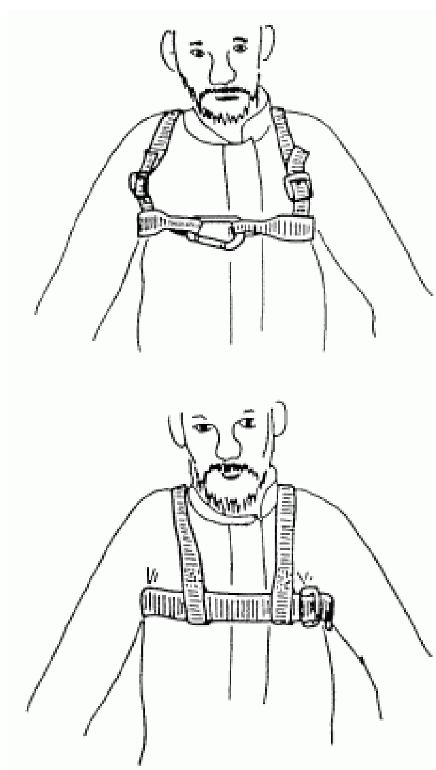
Putting on a figure-8 harness

The chest harnesses so far described are most suited to prusik systems, which require a chest ascender to be lifted rather than the caver to be held close to the rope (see Frog System, Chapter 7).

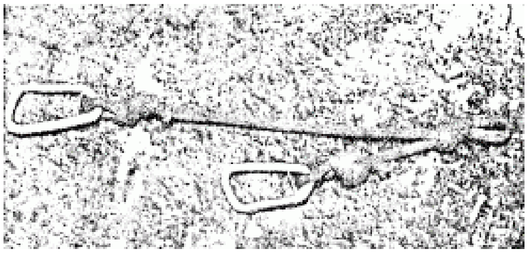
CLIMBING CHEST HARNESS

Most climbing chest harnesses consist of a wide adjustable band, which goes around the chest just below the armpits and two lighter weight shoulder straps to hold it up. Often a karabiner is used to hold it together at the front. Commercial types are readily available. The major drawbacks of climbing chest harnesses are that to be effective for prusiking they must be tight, which restricts breathing, and comfortable, which means using wide tape (50 mm+), making them bulkier and heavier than lift harnesses.

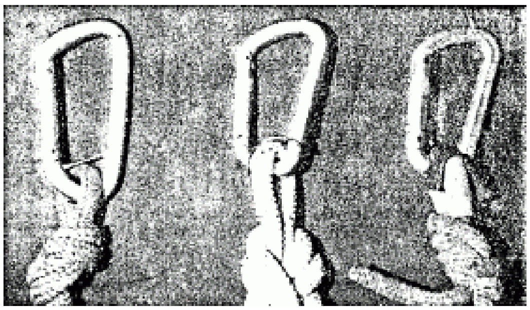
While they work with most prusik systems, climbing chest harnesses are more suited to holding the body in close to the rope rather than lifting a chest ascender. As such they are better used for Rope-walking rather than Frog style prusiking (see Chapter 7).



Climbing chest harnesses



Double cowstail



Cowstail fixes

COWSTAIL

A cowstail is a **MUST** for crossing rebelays efficiently and for safety on traverses, pitch-heads and knot crossings. The main requirement is that the cowstail is strong enough. It is conceivable that it could be subjected to a Factor 2 fall so anything less than 9 mm dynamic rope is unsafe (see Chapter 2).

The classic double cowstail is made from 2.0 to 2.5 metres of rope tied with Figure-8 loops so that the short length reaches to the elbow with the karabiner held in the palm of the hand and the long length is about 50% longer. If the long cows tail is to be used as a safety for an ascender it should reach from the seat maillon to the upstretched wrist when hanging on the rope but never be so long that the ascender is out of reach (see Frog System, Chapter 7).

For those who feel that the normal cowstail is not strong enough, 11 mm or even 11.5 mm multifall climbing rope can be used though of course it will be bulkier and heavier. The karabiners used must be of the highest quality, one does after all hang everything off them. A steel karabiner on the long cowstail can double as a brake karabiner during descent (see Chapter 6). For convenience cowstail karabiners should be fitted with a bar, clip or rubber bands to keep them oriented correctly for quick action.

Some kind of belt loop to clip the cowstail's karabiners to when not in use keeps them from getting in the way when walking.

Many cavers who never cross rebe13ys use a single ascender on a sling to give protection when needed. While this practice is popular, a shock load could damage the rope, sling (especially a tape sling), or the ascender, and cannot be recommended.

Cowstails should be replaced often. While it is normally loaded gently, one slip could subject a cowstail to a severe shock load. Nine millimetre dynamic rope is only a minimum, 10 mm or 11 mm is even safer. Do not wait until the core is peeping through the sheath and **replace any cowstail after 2 years, worn out or not.**

HELMET

The function of a caver's helmet is to protect his head from falling rocks, blows from a tumbling fall or standing up when he should not. The other is to support a lamp.

UIAA * approved climbing helmets can withstand blows from all directions and have a strong chinstrap which if kept tight, will keep the helmet from falling off under all conditions. Any UIAA approved helmet is safe, though not all are ideal for caving. People who protect their heads with a construction helmet to save money are making a definite statement about the value of its contents.

There are some special features worth looking for when buying a helmet:

- It should be UIAA approved.
- Lightweight (less than 400 g) and not lined with water absorbent padding.
- It should be small and not ride high or it will be a nuisance in tight passages.
- It should sit well on the head, be comfortable and have jugular straps, which do not block side-vision.

UIAA - Union Internationale des Associations d'Alpines.
The association sets standards for mountaineering equipment; no similar standards exist for caving gear.

A good caving helmet

- A quick action "Fastex" type buckle, which is far more convenient than a thread buckle but can be fitted after purchase.
- It should not fall off the back of the head, nor should the weight of a lamp drag it down at the front.
- Lamps should be fitted so that the mounting screws, nuts or rivets do not project into its interior.

Moulded plastic helmets survive the bumping and scraping of caving better than the fibreglass models, which tend to crack.

It is not reasonable to use a battered old helmet for caving when it would not even be considered for use climbing. Any helmet which becomes cracked, badly knocked about or receives a severe blow should be discarded.

LIGHTING

The light a caver chooses will be dictated by the type of caving he intends doing. Electrics are fine for short trips of ten hours or so but for long trips or visits to areas remote from cars or power points carbide must be considered.

ELECTRICS

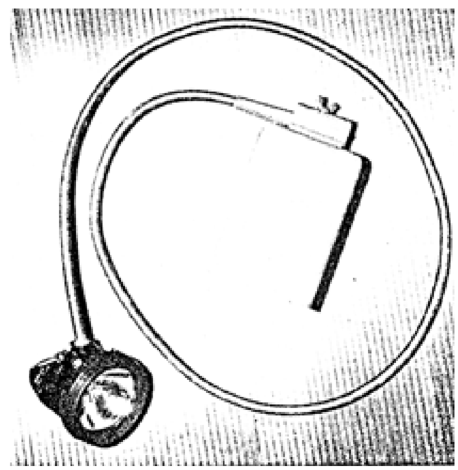
Electric caving lights are convenient to use. Most cast a strong beam, which is useful for Spotting up and down pitches. Their disadvantages are a poor light to weight ratio and the need to recharge or replace used cells, especially on long trips. Rechargeable cells need mains power, a car battery or solar cell (and sunlight!) to recharge them, while those, which use dry cells, are expensive to run in the long term. Electrics therefore, are the ideal choice for short or easy trips when their convenience outweighs the need for a long duration light output.

Lead-Acid Lamps

The heavy lead-acid miner's light is almost a thing of the past, mainly because they have priced themselves off the market. They also too often leak acid onto non acid-resistant caving gear and are troublesome to maintain. They do however give good light output, which can be extended by replacing the standard screw-fit high beam bulb by a 4 volt, 0.5 amp halogen bulb.

NiCad Lamps

The new breed of "Speleo Technics" NiCad electrics from Britain are an excellent alternative to lead acids. Designed specifically for caving, their cells are sealed into a block of plastic while the headpiece is the traditional solid miner's light. They are half the weight and bulk of a miner's light and produce around half the power.



"Speleo Technics FX-2" lamp

The two NiCad cells produce only 2.4 volts and they owe their brightness to an efficient halogen bulb. The battery pack is designed to unclip easily for charging and so that for longer trips an extra battery can be carried and just clipped on when the first one dies.

Many cavers simply build their own electric. A miner's light headpiece wired to 3 "D" sized NiCad cells or "Gel-cells" soldered together inside a case provide 8 hours of good light when running a 4 volt, 0.5 amp halogen bulb.

For occasional caving, easy trips and prospecting, a dry cell headlamp such as the Petzl "Zoom" can prove adequate especially when fitted with a halogen bulb and alkaline batteries.

All electrics blow bulbs. One or two spares should always be carried.

Premier, Fisma and Ariane carbide lamps

CARBIDE LAMPS

Carbides are still the most popular lamp for long trips or expedition use. Their main advantage is that they can be run for as long as carbide and water can be put into them. They are very efficient and produce more usable "light hours" per kilo than any electric. Carbide is also the cheapest form of caving light yet invented.

The carbide plus water reaction and the flame produce enough heat to be a valuable asset in emergency situations. On the negative side, carbides produce waste which must be disposed of, do not light instantly, take some practise to run and are banned for conservation reasons 111 some areas.

There-are two basic varieties of carbide light - the European "bomb" and the cap lamp.

The European "Bomb"

A large waist or shoulder sling mounted acetylene generator is connected to a burner on the helmet by a flexible tube. They are exceptionally robust and easy to use. Whilst cavers can be found using all sorts of generators, there are only two types commonly available.

FISMA

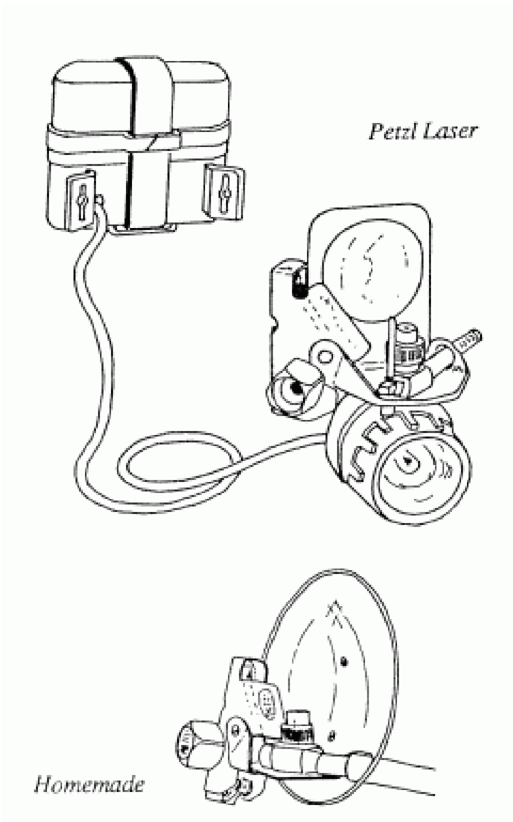
The generator is made of pressed steel and comes in a standard version with manual water drip control and an automatic version, which has a waterpump for that extra blaze of light when needed. Two different sized bases are available. The large one gives light for around ten hours and the small one about six hours. A design fault means that the brass thread, which holds the top and bottom of the generator together sometimes, falls off or cracks in half.

ARIANE

Petzl make the plastic Ariane, which is considerably lighter and smaller than the Fisma, does not spill water everywhere and runs for around six hours. Early models suffered from a sponge spacer pad, which effectively blocked the gas outlet hole once pressure built up in the generator. This problem can be solved by placing a "Scotchbrite" filter uppermost in the reaction chamber and makes the Ariane run better than any other carbide available.

HEADPIECES

As far as the lamp half of the system goes there is very little choice. Petzl make the "Laser" with built in back up electric and the "Junior" which is a simple carbide. There are other lamps available but they are not readily obtainable and despite some good ideas like good parabolic reflectors they consistently lack the lighting reliability of the Petzl piezo-electric ignition system. Petzl lamps are supplied with a 21 L jet (21 litres per hour) but this can be replaced with a 14 L jet which runs more efficiently and therefore gives a similar light output while burning cleaner and more economically.



The ideal system however is a lamp, which lights easily, has a good reflector and a reliable electric backup. While not commercially available, they can be constructed in a home workshop from spare parts. Anyone who has tried this has probably had problems with the soot blackening the reflector. Stainless steel reflectors clean up the best or the reflector can be covered with a sheet of aluminium foil and replaced it when it becomes dirty.

Cap Lamps

Brass cap lamps such as the "Premier" are fast becoming unavailable as cavers turn to waist mounted carbides and manufacturers cease production. Within a few years they are likely to be little more than collector's items.

The whole lamp is mounted on the front of the helmet, avoiding the need for a dangling generator but replacing it by a 350 g weight on the front of the head. Cap lamps are at their best in small nasty passages or long crawls where the "bomb" gets in the way. They are however a bit of an art to run and relight, the flint lighter being unreliable under wet or muddy conditions. The 7 L jet makes one charge of carbide last around 3 hours, using carbide at half the rate as a bomb. Of course they give only half the light even though this is slightly compensated for by a good reflector.

Carbide Lamp Spares

On any trip the minimum spares carried should be:

- 1 spare jet
- 2 or more spare bulbs
- 1 pricker
- 1 spare battery (or set) for back-up
- 1 lighter, waterproof matches or spare piezo

The first three items can be carried in one's helmet or battery pack while the others should be kept close at hand.

When caving as a group it is possible to get by with group spares but for serious trips it is well worth being self sufficient.

BACK-UP LIGHTS

Even "all-electric cavers" need a back-up light for safety. Most miner's lights are built with a low beam bulb and if caving in a group this is usually adequate, although one can still be left in the dark due to a failure in the battery or cable. In order to provide a totally independent back-up most cavers use a compact drycell powered electric, ideally with the lamp mounted on the front of the helmet and the battery as a counterweight on the back. A "Laser" electric or similar with an alkaline battery will give light for around 15-20 hours although it is normally only required for carbide changes and exceptionally wet sections of cave.

Cavers whose lamp does not incorporate a back-up can best construct one based on a robust torch or headlamp. A simple version can easily be built by attaching two rubber rings to the side of a helmet to hold a robust "penlight" which can be removed when not needed. Cave divers mount one or even two electrics on each side of their helmet using this type of fastening. In drier caves it is possible to get by with a small hand-torch on a neckstring but for serious work nothing beats a helmet mounted back-up.

LAMPS

Table 1:1

Lamp	**Weight** (g) Empty	Full	**Duration** (hrs) 21 L	14 L	**Comments**
Fisma L	1000*	1600	8	11	good light with either a
S	900*	1400	5	7	21 L or 14 L jet
Petzl Ariane	680*	1190	5	7	good light with either a 21 L or 14 L jet
Premier cap lamp	220	330	2 - 3		adequate but dim in large passages
Lead acid miner's light	2400	2400	12+**	24+#	low beam for emergency only! Battery life approx. 2 years
NiCad **"FX-2"**	1250	1250	8 - 10		Virtually maintenance free
Petzl "Zoom"	175	325##	8#	20	Low cost, standard bulb dim zoom threads may jam with cave dirt
Tekna (2xAA cells)	50	100##	3 -4##		emergency use only

** Weight includes "Laser" headpiece, gas tube and alkaline battery*
*** Using 1 amp bulb*
 # Using 0.5 amp halogen bulb
Alkaline batteries

LAMP PROBLEMS

Electric

Lights, which use a flat 4.5 volt battery normally, run an overrated bulb, i.e. a 3.5 V bulb on a 4.5 V battery, to increase their light output. For this reason they bum out about every 20 hours or so. There is usually some advance warning as the bulb gets a shiny grey appearance when it is old. Bulb failure can be reduced by replacing grey bulbs before they fail, especially before visiting a section of wet cave where a blown bulb could have serious consequences. By using the "correct" bulb for a battery, it is possible to increase bulb life at the expense of light output and battery duration.

Batteries usually give a few minutes of yellow light in which to find a spare before they die completely. Whether the lamp uses disposable dry cells or is rechargeable one should keep track of how many hours it has been running for so as to have some idea when it will run out. A common cause of failure in any electric light is dirty contacts either at the battery end or at the base of the bulb. This problem is easily avoided by regular maintenance and drying of the lamp after it has been wet.

Carbide

New carbide lamps seem to take some "running in" and after a few charges of carbide they settle down a bit. A new lamp owner also needs some running in but after a while he learns the moods of his lamp and how to respond to its needs.

When a lamp goes out and will not relight there could be any number of things wrong. The following can be used as a check-list. By working down it the lamp will eventually function again.

- Check for gas flow. Put the tip of the tongue above the jet and taste for gas coming out.
- If "no" check for a blocked jet and clean it with a pricker.
- If there is gas but it will not light, check the lamp's lighting mechanism. Piezo lighters may short circuit when dirty and cap lamps need a build up of gas behind before they light.
- Check to see if the lamp has water.
- Check to see if it has carbide.

Usually the lamp will be going by now. But if not:-

- See if the water-drip is working correctly, dirty water easily blocks them.
- Blow back through the gas tube from the jet end. Bubbles should gurgle in the lamp's water tank. If not unplug the gas tube and flick it to clear the blockage.
- Using a flame, check the whole system for leaks.

Other Carbide Problems

- *Strobe flame* - Water in the gas feed tube. Unplug it and flick the water out.
- Lamp goes out when bumped - Lamp is overfilled or choked with carbide waste. Tap it against a rock to loosen the waste (interim measure), remove some of the waste or change the carbide.
- *Smoky Flame* - Clean or change the jet. The gas flow, hence the flame, may be too small for the jet size in the lamp.
- *Leaking Seal* - Usually indicated by an occasional whiff of carbide or the lamp bursting into flames. Clean the seal and seating areas and check for damage. Try screwing the generator closed tighter, replacing the seal, using two seals or cutting a new seal from a tyre tube "carbide banana".
- *Holed Gas Tube* - Trim it shorter if the damage is close enough to one end or cover it with a wide rubber band cut from a carbide banana.
- *Hopelessly blocked jet and no spare* - Force as small a hole as possible through the porcelain with a spike, knife etc and suffer a horribly smoky flame.
- *Not enough water* - Suck up clean water from small pools by mouth or scoop it up with the cap of a battery pack. In more desperate times turn the empty tap off and spit or put snow directly into the carbide chamber. In even more desperate times piss into the water tank.
- *Lost Lamp Base* - Replace the base with a small carbide banana done up tightly around the bottom of the water tank.

In General

Part of the reason for using carbide is that provided the lamp has fuel it can always be made to function, even if only just. When short of carbide try and economise - stay near someone else with a light. In the event of total light failure it is almost always impossible to find the way out unless there is a rope to follow **all** the way. The only real choice is to get comfortable and safe and wait...............

EXTRAS

CAVE PACK

Cave packs can be bought, or home-sewn on a robust sewing machine. The model of pack chosen will depend on supply, ability to make one and the cave trip to be done. Features of a good cave pack are:

- Made of heavy PYC coated polyester fabric, which wears well, is waterproof and nonabsorbent.
- Two shoulder straps made of stiff tape, which will not bunch up. Both straps may not be needed all the time but that is better than suffering a heavy single strap pack in a walking passage.
- Round bottomed sacks are the easiest to manage in awkward situations. Being symmetrical they jam much less often than other shapes and have no preferred orientation in squeezes.
- Maximum diameter of 25 cm, any greater and the pack may not fit through the cave. Large cave packs need to be oval or rectangular with a short axis 25 cm or less to make them practical.
- Seams protected or reinforced against wear, especially those around the base.
- A handle on the side so that it can be carried like a suitcase and another on the bottom to hang it upside down and make it easier to handle in squeezes.

- Closed through at least 6 eyelets by a thin cord fastened with a cord grip or 5 mm cord tied with a Reef knot.

- A lid flap to keep water and dirt out and the contents in.

- Permanently attached knotted haul cord, which hangs the pack just below the feet.

Many cavers also prefer a small personal pack to carry their lunch, spare carbide or prusik gear, which hangs from the waist or is carried as a shoulder bag. If this means having two sacks to handle it is better to wear the prusik gear and pack everything else in one ropesack.

SURVIVAL BLANKET

Do not even walk to the entrance without it! There are robust re-usable models or "Chocolate Wrapper" single use ones which lose their silvery coating in a year or less (though this has little effect on their efficiency). For budget cavers a large plastic garbage bag is better than nothing. Carry it in a boot, pocket or helmet.

KNEEPADS

Light padding for knees and elbows will make caving a lot more comfortable as well as reducing damage to these joints. Small fibrepile patch-pads sewn to an undersuit should be adequate for all but the worst caves. For those worst caves basketballer's knee and elbow pads are good but bulky. Neoprene pads can be bought from diving shops and go quite well with wetsuits without the need to sew on permanent pads.

Cave Pack

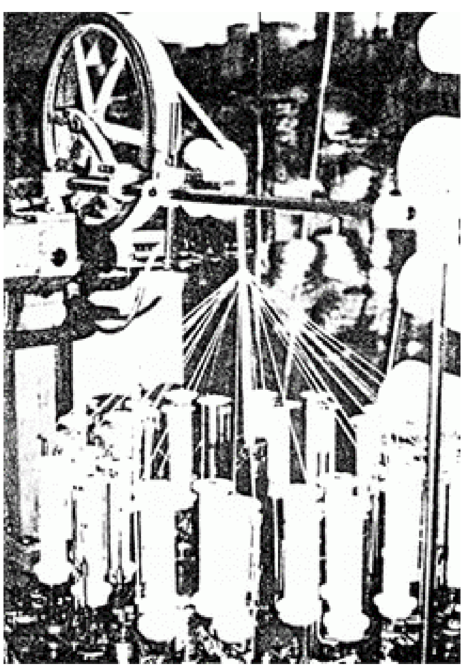
KNIFE

A small Swiss army knife makes a handy portable tool-kit and is much better for opening sardine tins than a bolt-hammer.

WHISTLE

Some cavers may find a whistle useful for signalling on big or wet pitches and when navigating from the cave back to camp after dark. In most cases however yelling is more than adequate.

2 RIGGING EQUIPMENT



Kernmantel rope under constructions

ROPES

The rope is usually the weakest link in Single Rope Techniques and one, which rarely has any back-up. For this reason alone, caving rope should be of the highest quality and treated with care. There is a dazzling range of ropes available but which one is the best has been a source of spirited debate for many years.

CONSTRUCTION

Caving ropes have a "kernmantle" or "core and sheath" construction. The core is the loadbearing portion of the rope as well as constituting most of the rope's strength. It forms about 60% of the rope and is usually made of several bundles of fibre, half of which are lightly twisted clockwise and the other half anticlockwise to stop the rope from spinning when it is loaded. Many ropes have a single coloured thread in the core to indicate the year of manufacture. Unfortunately the colours have not been standardised between brands and one must write to the manufacturer to find out which colours they have used.

To protect the core, it is encased in a sheath-made of 16 or more bundles of fibre, which are plaited to form a tube around, but not attached to the core. The sheath fibres may be straight or they may be lightly twisted so as to run along the axis of the rope to increase abrasion resistance. When a rope is in use the sheath takes the wear while the load bearing core remains intact.

A loose sheath gives a soft rope, which flattens when used and generally wears badly. A loose sheath may also creep down the rope and the excess slide off the end of the core. If this happens descend with the rope hung the same way up for the first few times to force all the excess sheath off, then remove the "tail" which has formed. If this tail is excessive (more than 1 m in 50 m), or the sheath continues to slip after two or three wettings, try a better rope! The sheath can also be plaited very tightly to improve abrasion resistance and reduce din penetration, which makes the rope stiff and hard to handle. Fortunately most ropes lie between these two extremes.

The sheath is also the pan of the rope to which ascenders and to a lesser extent descenders are attached. An excessively thin or loose sheath is dangerous both because it may prove inadequate in protecting the core and also because, if it fails with a caver attached, both caver and sheath may slide freely down the core.

Several rope makers have tried variations to the "kernmantle" design with such changes as double sheaths, low stretch mini-cores and plaited core-bundles to improve desirable properties. One rope was even made with the core encased in a waterproof membrane intended to reduce its water absorption!

MATERIAL

Almost all caving ropes are made of type 66 nylon because of its suitable strength and shock absorbent characteristics. In most ropes both the core and the sheath are made of the same nylon - possibly with some of the sheath bundles coloured to identify the rope.

Pure polyester ("Terylene") ropes, while once popular, should be avoided due to their exceptionally low shock resistance. Polypropylene and polyethylene are **NOT** suitable for SRT ropes due to their low abrasion resistance. They are, however, very good for redirection cord and in canals and pools where a cheap rope which floats is useful.

Some experimental ropes have been made with a low stretch mini-core of Kevlar or polyester in an attempt to give the rope good static as well as dynamic properties. The results have been varied but so far none have remained on the caving market for long.

PROPERTIES

Some rope properties are critical but most amount to a matter of convenience or personal preference. The properties, which are most important, depend on whether the rope is intended for "Alpine" or "American" style rigging, and the skill of the user.

Strength

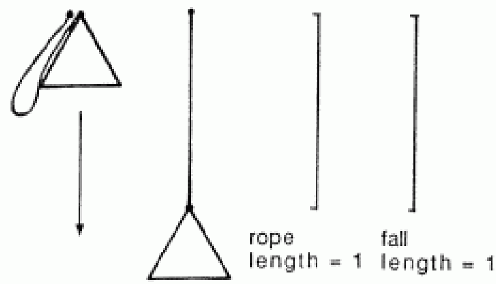
The quoted "strength" of a rope is its "Ultimate Tensile Strength" or static strength and is obtained by gently increasing the load on a dry, new rope until it fails. Each end of the rope is wrapped around smooth, large diameter bars on the test machine to eliminate small radius and knot effects. Such a test has very little to do with the way a rope will be loaded in a cave. A rope's static strength only has relative value for comparing strength losses and ropes to one another.

Any new caving rope must have a minimum breaking strength of 1500 kg. This will allow for the strength losses caused by knots, wetting and poor rigging and still leave the rope with an adequate margin of safety, **provided** it also has sufficient shock resistance.

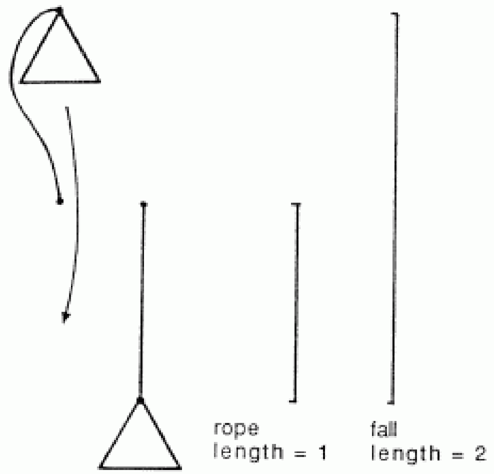
Shock Resistance

The most realistic way of assessing a rope's strength is to subject it to a shock load. This is similar to what it may suffer in extreme caving situations. For example, when a caver slips at the top of a pitch and falls some distance before the slack in the rope takes up or when an anchor fails and the caver takes a fall onto the back-up anchor.

The severity of a fall is often described in terms of Fall Factor (FF) with a standard 80 kg weight. The Fall Factor is the ratio between the length of fall and length of rope. e.g. If an 80 kg caver is tied onto 10m of rope and falls from the belay until he is stopped by the rope 10 m below, he subjects the rope, belay and himself to a FF1 fall. If he is 10 m above the belay and falls 20 m before stopping he incurs a FF2 fall, the maximum possible and hopefully non-existent in caving.



Fall Factor 1



Fall Factor 2

Theoretically, the fall length is irrelevant. A FF1 fall of 0.5 m onto a cowstail is as severe as a FF1 fall of 30 m (30 m rope will have about 60 times the rope to absorb the shock of a fall which is about 60 times as far). In practice this is not quite so, as there is an "end effect" of knots tightening and harness and body absorbing shock, which effectively reduces the severity of falls under 1.5 m.

Drop tests using 2 m of rope knotted to form a length 1 m long consistently show that new, dry, static ropes rarely survive more than one FF2 fall, if that. Most will survive several FF1 falls but after each fall the rope loses elasticity and becomes progressively less able to absorb future shock loads. i.e. The first drop may generate a shock force of 50% of the rope's breaking strength. The second 80%, the third 100% - so it breaks.

The shock resistance of a rope is largely a factor of its stretch, or more precisely its "elongation under load". As a rope is shock loaded it stretches and absorbs the energy of the shock. Greater stretch means more energy absorbed and less force applied to the anchor, rope and falling caver. People too have a limit as to how much shock force they can withstand - the UIAA standard for human shock resistance is 1200 kg. That is, the rope must arrest a falling climber without the load ever reaching 1200 kg. In caving this limit is rarely approached due to the relatively low forces incurred from FF1 falls as compared to FF2 falls for UIAA Standard climbing ropes. Indeed most caving ropes would not even survive a shock load of 1200 kg! A very strong rope is not necessarily a safe rope unless it can also adequately absorb shock. **A safe caving rope must be able to survive two or more FF1 falls.**

The lack of shock resistance of caving ropes could well convince some cavers to use the strongest rope available. One must remember that a FF1 fall on 1 m of rope is only a comparative test with a built in safety factor and virtually cannot occur in caving even with poorly rigged ropes.

Take a "worst case" of two bolts rigged 15 cm apart at the same level with a 1 m standin loop between them - yes, they do exist! If the critical bolt fails when an 80 kg caver is connected directly to it or perhaps just below it he will attempt a 2 m FF1 fall but will not succeed. The knots and loops at each end will absorb some energy, just as in test samples but more importantly the caver's body and harness will absorb around 30% of the shock force. There will also be some pendulum effect and no doubt the caver will fall outwards or crash into the wall and so absorb even more energy. Perhaps he would occasion a FF0.6 fall - serious enough if the rope was not up to standard but still well short of FF1. The same two bolts rigged with 30 cm of rope between them and taking into account the mitigating factors would be unlucky to occasion a FF0.3 fall. This gives a good safety margin considering that FF0.3 is the maximum expected for well rigged ropes.

Probably the most convincing evidence that caving ropes are strong enough is the complete lack of accidents due to ropes failing under shock loads and this includes polyester ropes, which have extremely low shock resistance compared with nylon ropes.

Stretch

Static ropes are often defined as those, which have less than 4% elongation under a load of 80 kg when new and dry. Manufacturer's stretch figures often differ considerably from reality. Most ropes are stretchier than claimed with the percentage stretch increasing over the first few uses. Prusiking up a rope which has more than 4% stretch is like climbing up a giant rubber band. Apart from being uncomfortable, excessive stretch makes rigging difficult and increases "sawing" if there are rub points. On the positive side the shock-absorbing capacity of the rope is directly related to its stretch.

Insufficient stretch (less than 2%) will be marvellous for prusiking, will make rigging easier, will reduce abrasion problems caused by sawing but could make the rope dangerous if subjected to a shock load. A lack of stretch means a greater shock force win be generated in the event of a fall. A good example are types of polyester ropes, which have very little bounce and are a dream to prusik on. This gives them such low energy absorbing properties that even a FF0.2 fall could exceed their strength. A low stretch, superstrong rope just transfers the shock to the anchors and the caver on the rope.

There must be a trade-off. Static ropes are used largely as a matter of convenience but it cannot be taken so far as to prejudice safety (See Table 2:4).

Diameter and Weight

The diameter of a rope affects most of its other properties. Caving ropes range from 7 mm to 11.5 mm in diameter and any over 8 mm are safe **when rigged appropriately**. When choosing a rope it is necessary to consider the weight of the rope, the space available to carry it in and the manner in which it will be rigged. If weight and volume are no problem a thick rope is better; it will last longer and allow a greater margin for error over a thin rope. If the rope is to be carried up a mountain or down a deep cave the weight advantages of 8 mm or 9 mm ropes cannot be ignored.

Some cavers have taken the obvious weight reducing step and tried 7 mm "rope". To my knowledge there is no safe 7 mm rope in production. Cavers are left with the dubious alternative of using accessory cord instead of caving rope. None of these satisfy the minimum 1500 kg breaking strength requirement. However some are sufficiently elastic to survive two or more FF1 falls and can be used **with extreme care** by those who wish to.

With thin rope there is no choice when rigging, it must be Alpine style. Thin rope will wear out more rapidly than thick rope and cost more in the long run because of its shorter lifespan (See also Table 2:4).

SUITABILITY OF ROPES TO RIGGING STYLE#

Table 2:1

Rope	**Rigging Style**				
(mm)	**American**	**Alpine**	**Ultralight**	**Cord Technique**	**Climbing**
11	Ideal	fixed rigging	too heavy	too heavy	ideal*
10	Marginal	general use	too heavy	too heavy	**CAUTION***
9	**DANGER**	sport/ exploration	heavy	ideal	**CAUTION***
8	**DANGER**	sport/ “push” rope	ideal	ideal	**DANGER**
7	**DANGER**	**DANGER**	**Expert Alpine cavers only**		**DANGER**

** Dynamic rope only, thinner ropes must be used double*
 # Rigging is discussed in Chapter 4

Flex and Handling

The flex of a rope is partly due to its diameter and partly due to its construction mainly the "tightness" of the sheath. Soft flexible ropes are more pleasant to handle, knot and pack better than stiff ropes but may not run as well through ascenders.

Any rope will stiffen with use and lack of cleaning, and obviously a rope, which is stiff when new, will have a headstart. A rope, which does not bend enough to pack efficiently into a rope sack, can be made a little more flexible by wetting it. If space is at a premium, favour must be given to pliable ropes, but this has a limit - very soft rope generally has low abrasion resistance as well as often suffering from sheath slippage.

Abrasion Resistance

Many cavers consider abrasion resistance the most important characteristic of a caving rope. All commercially available caving ropes and most climbing ropes are adequate when rigged appropriately. The question is more one of the life-span of the rope than one of safety.

When correctly rigged Alpine style causes no immediate abrasion problem. American style uses a thick rope, which by its bulk should handle the immediate problem of an abrasion point. In both rigging styles though, there have been numerous incidents due to bad rigging and poor judgement of abrasion points.

Generally, hard and thick ropes are more abrasion resistant than soft and thin ropes. Thick rope has greater bulk to cut through than thin rope and each fibre is under less tension and so is more difficult to cut (try cutting a slack rope with a sharp knife, then see how easy it is to cut when under tension).

As already mentioned there is a "sawing" effect as a rope moves up and down with the changing loads caused by prusiking and rough abseiling. More sawing will naturally occur on longer drops. Sawing does not spread the wear, as old time users of bouncy laid ropes once insisted. It increases the wear and is a major reason why dynamic ropes are less suited to fixed rigging than static ropes.

Resistance to abrasion can be increased by increasing the tightness of the rope sheath as well as increasing its bulk in comparison to the Core. Such "improvements" make the rope hard and difficult to handle as well as reducing its shock absorbency.

Abrasion resistance can also be improved by twisting the sheath fibres so that the left trending bundles are twisted to the right and the right trending bundles are twisted left. This aligns all exposed rope fibres along the axis of the rope thereby rendering them less easily cut as the rope moves up and down against the rock. For the much less common problem of sideways movement such construction would possibly lose some resistance.

Shrink

It is an unfortunate fact that nylon ropes shrink up to 15% (lengthwise) during their first few wettings and dryings. This is unavoidable and all that can be done is to buy ropes 15% longer than the length needed and to make allowance when rigging new rope so that it does not pull tight between rig points or lift off the floor of long pitches as it shrinks.

Water Absorption

A soaking wet rope is about 35% heavier than its dry counterpart and takes days to dry out. In some cases it is worth packing a long rope in a plastic bag to keep it dry and it is always worth stacking a pack of wet rope upside down whenever possible to allow it to drain.

Water affects nylon rope, making it less abrasion resistant than dry rope and reducing its static and shock strength by up to 30%.

ROPE STRENGTH WHEN WET*

Table 2:2

Age	**Wet/Dry**	**FF1 Falls** (80 kg, 1 m)
new	dry	41
new	Wet	25
4.5 years	Dry	4
4.5 years	wet	4

** Tests done with 9 mm Bluewater II*

Melting Point

The nylon used in caving ropes melts at between 210° C and 250° C, depending on the type. A more relevant figure is the softening temperature: about 150° C. Above this temperature the rope becomes soft enough to pull apart under a caver's weight. Fortunately it is almost impossible to do this in the caving situation. Most descenders are capable of reaching instantaneous temperatures high enough to melt the fuzz on a rope but the volume of hot metal in the descender contains insufficient heat energy to melt the entire rope. When abseiling fast on dry ropes it is possible to superficially damage the rope sheath. Provided the caver does not remain in one spot with a hot descender this does little structural damage to the rope. Low melting point also means low abrasion resistance and this is the main reason why polypropylene and polyethylene ropes are unsuitable for SRT

Chemical Deterioration

Nylon is a polyamide polymer. That is, it is made of long parallel chains of molecules with the chains linked to each other less strongly. With time these polymers disintegrate to form simpler structures but the breakdown is very slow and not a problem in itself. It is active attack by chemicals, which must be avoided. Chlorine has adverse chemical effects on many polymers so chlorine bleaches and washing powders, which contain it, should not be used on ropes. Many other substances which are commonly found in garages and car boots have more drastic and possibly invisible effects on nylon - be especially careful of acids, solvents, paints and **any** concentrated solutions.

Ultraviolet radiation in sunlight accelerates polymer disintegration but fortunately caving does not involve much sunlight. Nevertheless, drying ropes in direct sunlight, leaving entrance pitches "permanently" rigged and storing ropes in light should be avoided.

Physical Deterioration

Quite apart from the effect of dirty descenders grinding the rope sheath, the constant intricate bending under load that a descender gives the rope has no measurable effect on the strength of a nylon. This is not the case with Kevlar however, after 100 descents it can lose 75% of its original strength! Possibly a more insidious physical deterioration could well be caused by the minor shock loads caused by prusiking, rough abseiling etc. Just as a caving rope may be seriously weakened by two FF1 falls could it also be damaged by ten FF0.1 falls? Perhaps an avenue for investigation, in the meantime, caves gently.

Age Deterioration

The effect of time on the strength of nylon rope varies greatly with the researcher. One claims 50% strength loss after only ten uses (Smith, 1980) while another assures us that there is no loss of strength over two years! (Stibranyi, 1986). The most consistent indications are that ropes rapidly lose shock resistance with age - used or not though heavy usage will further accelerate the degradation. Taking a pessimistic view one must assume that within a year a rope will be only half as strong as when it was made. This may even have occurred by the time the rope is sold.

It is interesting to note that while absolute strength deteriorates with age and/or use the percentage effect of knots and wetting diminishes with age. i.e. An old wet rope is almost as strong as it is dry whereas the same rope when new would be considerably weakened by wetting.

ROPE STRENGTH WITH AGE*

Table 2:3

Age	Condition	FF1 Falls (80 kg, 1 m)
new	unused	41
6 months	approx 40 ascents/ descents	10
4.5 years	worn, stiff	4

** Tests done with 9 mm Bluewater II*

Strength loss is possibly connected with changes in other characteristics such as loss of handling properties and flexibility but how everything ties in and what to do to avoid it is any body's guess. Until more is known about this it would be wise to not buy old stock or at least treat it as "used" rope and not as good as "this year's model". Any rope left in a cave for long periods should be treated with extreme caution and old ropes relegated to the junk heap.

Strength Loss

A rope is only new once. Its strength diminishes rapidly with its first few uses or wettings and dryings, thereafter the rate of strength loss slows considerably. Tables 2: 1 and 2:2 show how age and water can affect a rope and these are both an unavoidable part of using the rope in a cave. It must also be noted that even to perform the tests the rope strength had been reduced considerably by tying knots in each end of the rope.

Even taking care to minimise all of the factors discussed above, the rope is without doubt the weakest part of any SRT system.

Coatings and Treatments

Many attempts have been made to improve handling properties and reduce water absorption using pre-treatment processes. "Everdry" sheath treatments have little effect on water absorption although the improvement in handling is noticeable. Everdry core treatments and waterproof membranes around the core certainly reduce water absorption when the rope is new but how long the treatment lasts and whether it is worth the extra cost only time will tell.

Waterproof membranes seem to be especially dubious because water can leak through the tiniest hole and thereafter become trapped inside making the rope almost impossible to dry out.

REQUIREMENTS FOR NEW SRT ROPE

As can be seen, rope properties interrelate and often conflict with each other. The perfect rope, which maximises on all desirable properties, has not yet been invented, nor is it possible to get cavers to agree on what those properties would be. As yet there is no official standard for caving ropes such as the DIAA standard for climbing ropes. A caving rope should be chosen to suit the cavers who intend to use it and the rigging style to be employed so long as it fits the following set of minimum requirements.

- Kernmantle construction
- Static strength in excess of 1500 kg
- Shock resistance of two or more FF1 falls
- Stretch of 1.5% to 4% with an &0 kg load
- Diameter of 7 mm to 11 mm
- Melting point in excess of 200° C

It must be emphasised that these are **MINIMUM** requirements and that in most cases more than minimum performance is required, primarily in the properties of abrasion and shock resistance. The only way these two properties can be significantly improved is to increase the rope diameter.

ROPE COMPARISON

Table 2:4

Diameter (mm)	**Av. Weight** (g/m) Dry	Wet	**Av.Stretch *** 80 kg (%)	**Metres in 25 L sack**	**Static* Strength** (kg)	**FF1 Falls*** 80 kg, 1 m
11	75	98	1.25	75	3000	10+
10	62	81	2	100	2500	8 - 20+
9	50	65	3	120	1800	3 – 10+
8	38	49	4	180	1500	2 - 3
7	33	43	4	220	1000	0 - 2

** Figures from manufacturers and suppliers catalogues*

Note the difference in shock resistance between ropes above and below 10 mm. This indicates that much greater care must be taken in the selection and use of "thin" ropes than "thick" ropes.

CARE OF ROPES

New Ropes

A new rope should be washed or soaked overnight in water with a little detergent. This will remove the manufacturing lubricants and "slow the rope down" so that the first person to use it does not scare himself silly on the first descent. Washing also shrinks the rope, increasing its abrasion resistance and if done before use, keeps dirt from becoming trapped inside the rope as it shrinks. If the rope is to be cut to set lengths, allowance should be made for shrinkage.

Washing Ropes

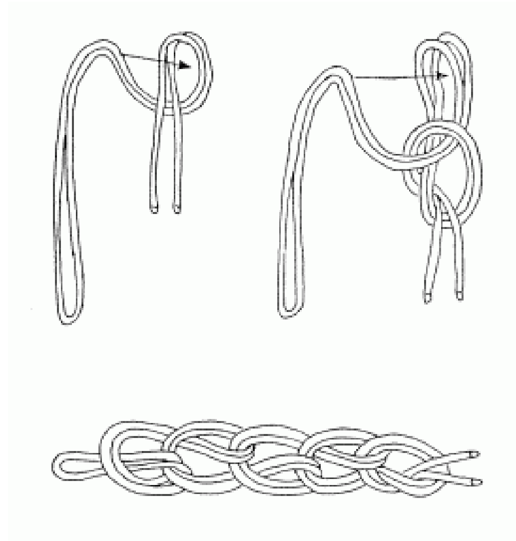
Washing increases the life span of a rope and helps keep it flexible and pleasant to handle. It is best done by "chaining" the rope and washing it in the biggest washing machine available using non-chlorine detergent and a little fabric softener in the rinse. Failing this, pulling it several times between two scrubbing brushes or "Scotchbrites" in the creek or even a simple rinse is better than nothing. After washing, ropes should be dried away from direct sunlight and stored in a dark place. If drying is not possible, wet storage causes no damage to the nylon.

Length Markings

Codes of bars and stripes can be used but it is better to stick a band of pale electrical tape on each end of the rope and mark the length on it with a waterproof marking pen then cover it with clear heat-shrink plastic. For simplicity, only the rope length needs to be marked, although clubs may find that the year of purchase and some positive identification markings useful as well. Rope can be adequately identified within a small group by having each caver mark their rope with their "personal" colours.

Rope Pension Plan

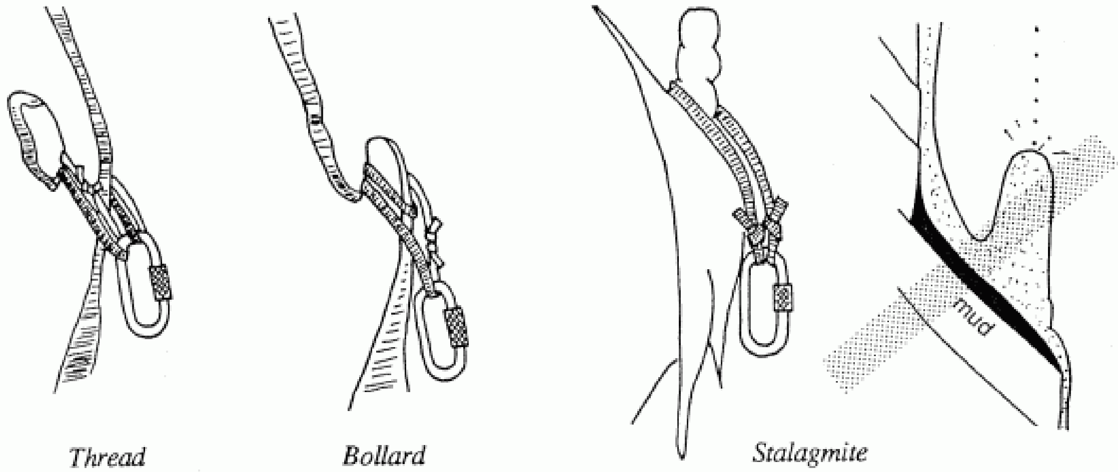
A well cared-for rope will last for many years but loss of shock resistance due to time alone could render it unsafe. Ideally, two metres off the end of any rope over five years old should be shock tested with a FF1 test every two years and should survive at least one FF1 fall. Most cavers do not go to the trouble of shock testing, they merely pension off the rope when it looks badly worn, becomes too stiff, or has suffered a severe shock load.



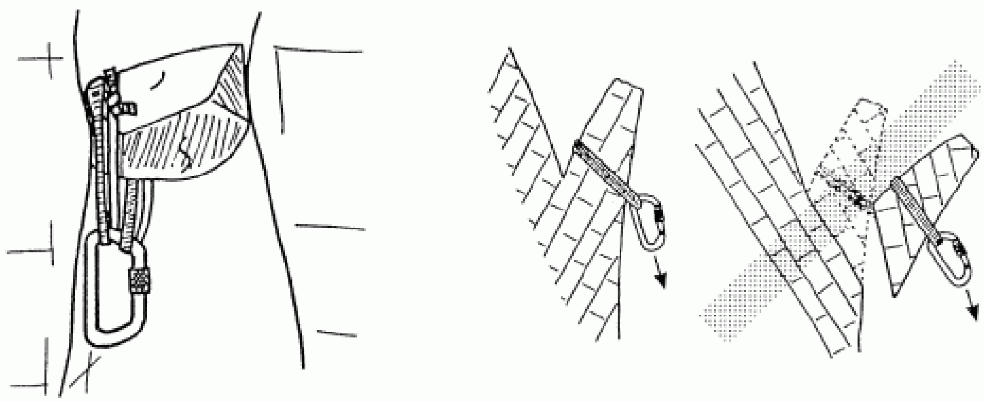
Chaining a rope

Rope length mark

All ropes will eventually deteriorate enough to become unsafe, however deciding exactly when to stop using a rope is often difficult. In normal use ropes tend to be cut shorter and shorter due to minor damage and rigging requirements so that eventually the pieces are so small as to be useless. Any sheath damage, which causes the rope to lose its normal flex, requires cutting as does any section, which becomes unusually hard, soft or lumpy.



Thread *Bollard* *Stalagmite*



Chockstone *Be careful of bedding or fracture planes*

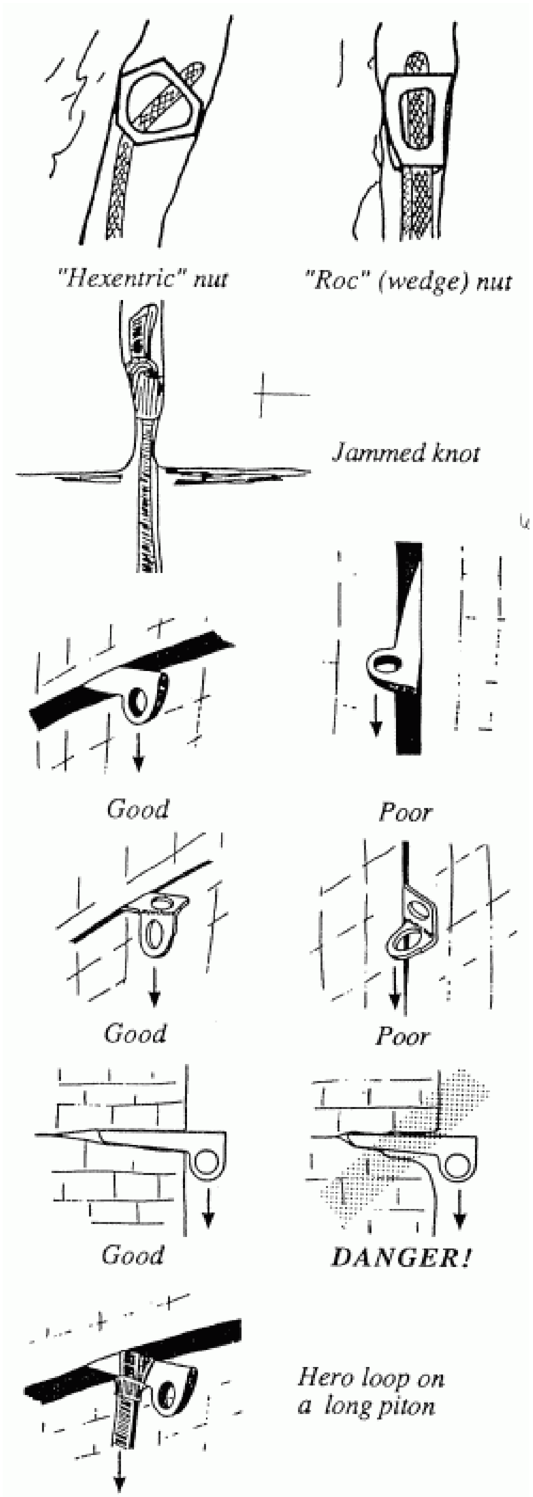
ANCHORS

NATURAL ANCHORS

Any part of the cave to which a rope can be attached is, a natural anchor. This includes bollards, threads, stalagmites, stalactites, jammed boulders (chockstones) and even boulders which are just sitting there but are stable and too heavy to move.

At many entrances trees make obvious anchors and nothing more than common sense is required to choose one, which is suitably tough and well anchored. If a good natural anchor can be found it is to be preferred over any artificial anchor as its use will cause minimal damage to the cave.

"Naturals" are not always as strong as they look - stalagmites can provide tempting and often adequate anchors but they should be used with care. Their regular crystalline structure renders them surprisingly easy to snap so "they should always be tied to as low as possible to reduce leverage. Stalagmites and flowstones can form on rotten rock or mud and there is a danger of uprooting the entire belay. Similarly bedrock is often subject to fracture along cleavage planes. These can occasionally be seen as thin lines in clean rock or inferred by the way other rocks break'. If in any doubt at all give the belay a good swift kick or tap it with a hammer. Fractured or loose rock will often give a hollow sound. The availability of good natural anchors varies greatly from cave to cave and often there will not be one where it is needed.



NUTS

The usefulness of nuts is highly dependant on the nature of the rock. When set well they can be as strong as the wire on which they are threaded but care must be taken so that they can not be lifted out sideways by a passing caver. Often a knotted tape or rope can work as well or better than a real nut. The knot can be tied to suit the size required and the soft nylon will often bite better than aluminium. Nylon "nuts" are not as durable as the gerniiheJanic1e and are best reserved for one-off exploration use or low load applications like deviations.

Nut placement takes some practise before it can be done safely. One must always try to find a. "bombproof" placement in good rock. The wedging force exerted by a nut can be many times the load on the nut and can remove flakes and loosen jammed blocks.

Small nuts are only held in place by a tiny amount of rock as are larger nuts held by minor irregularities in a crack. In sound rock they may hold but in a cave it is not worth the risk. Take only medium sized nuts (large ones are heavy) and make sure they are well seated. In the case of both nuts and jammed knots be careful that the attachment cord does not wear through with continued use. "Friends" and similar devices work well in caves but they are expensive and1he-damp and dirt of caves damages them easily.

Jammed nuts can be removed by tapping them with a hammer. A long piton can be handy for small nuts when the hammer will not fit into the crack.

PITONS

Pitons can work well in some rock and it is largely a matter of luck and some experience as to whether they are useful in any particular cave. The most often used models are small to medium angles and thinner versions such as "knifeblades" and "lost arrows". The security of pitons is often doubtful and even when an ideal location can be found the constant flexing caused by prusiking cavers can work them loose. Pitons may be used to good effect in thinly bedded, soft or otherwise poor rock where other artificial anchors are often useless. Their main value comes as a fast anchor for prospecting or first descents, as easy back-up anchors (where they are not usually loaded) and for deviations where the loads are low and the consequences of failure not too severe.

Pitons must be placed carefully. The ideal placement is one in which the piton is loaded at 90° to the crack in which it is placed. e.g. A horizontal crack for a downward load. Thought must also be given to the load changing direction so that a securely placed piton does not suddenly become loaded badly.

The piton should fit 1/2 to 2/3 of the way into the crack by hand then be hammered home firmly. If the eye hits before the piton is firm it should be changed for a thicker version. Should the ringing sound of a piton being hammered suddenly become dull, the rock has probably fractured and another placement should be tried.

Should the tip of a piton hit the bottom of a blind crack (a common problem with solution widened joints) the piton should be replaced by a thicker one. The piton should grip over its entire length or at worst its outer edge. A piton, which grips only at its tip, is prone to levering out or snapping in two. Pitons, which stick out too far from the rock, should be tied with a "hero loop", a short sling tied around the shaft to minimise leverage, rather than the piton eye.

Once placed the head of the piton can be tapped with a light sideways blow to check its security. A piton is removed by hitting it from side to side until it is worked loose.

BOLTS

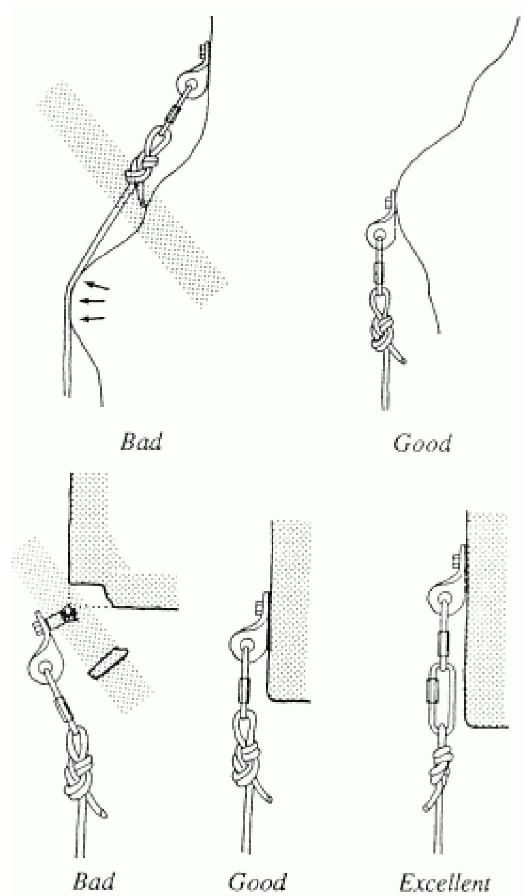
When removable anchors are inadequate there is no choice but to cease exploration or use bolts.

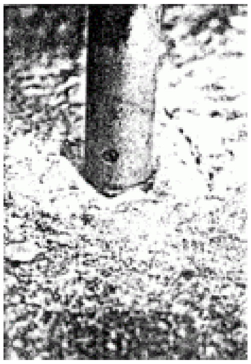
Bolts (Spits, self-drilling anchors) give a caver the ability to place an anchor virtually wherever he wants it. Bolts are different from other anchors in that they are not removed from the cave after use. Therefore, when a bolt is placed, the cave is permanently damaged by the drilling of a hole and smoothing an area of rock around it. As such, bolts should always be used with discretion.

The "international standard" is 8 mm selfdrilling anchors. Anything else will be of little use to the next person and should not be placed unless large diameter bolts with hangers or eyebolts are used. The exception is in the USA where imperial measurement is still standard and American cavers may also use 3/8 inch (or very rarely 1/4 inch) self-drilling anchors. Cavers intending to visit an area where the bolt sizes are in any doubt should check first.

Placement

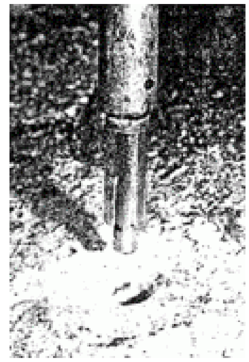
Placing a bolt is not difficult, most of the skill is choosing the correct location and being able to hang there long enough to place the bolt. Once the general location for the bolt is chosen a smooth, solid looking piece of rock must be found. Try tapping around with a hammer to be sure it is really as good as it looks and makes no hollow sounds. Whenever possible solution holes, cracks, calcite veins and thinly bedded rock must be avoided. Ideally one should avoid scoops and pockets and prefer rounded bosses, flat areas or gentle overhangs so that the rope or knot will not grind against the rock just below the bolt.





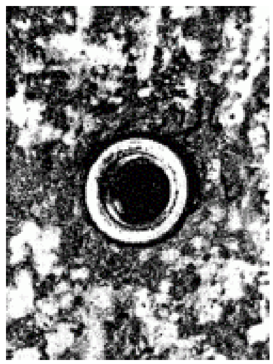
Drill until the anchor is 2 mm to 3 mm below the surface

Smooth the surrounding rock

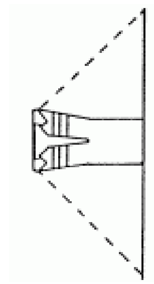


Wedge in, bolt ready set

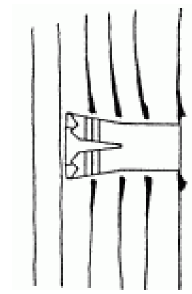
Sideways pressure can cause the rock to crack



The finished product



The stressed zone has a radius at least as big as the anchor length



Bolts in thinly bedded rock are always suspect

- The drillhole is begun by fully screwing an anchor onto the driver then tapping the driver lightly while rotating it clockwise until the drill begins to form a neat hole.

- Always keep the driver at 90° to the rock surface and be careful not to unscrew the anchor from the driver.

- Too much vigour in the early stages and sideways movement at any time may cause the hole to crater. Hard and brittle rock requires more care.

- Once the hole is started - 4 mm to 5 mm will do - the driver may be hit a little harder.

- Hold the driver steady, give it two or three hits, then move it 1/4 of a turn, hit and so on, removing it every 10 to 15 hits to blowout the rock dust.

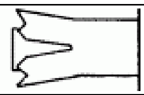
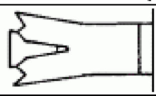
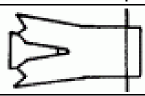
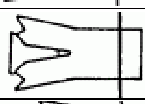
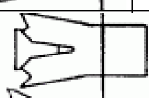
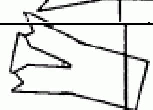
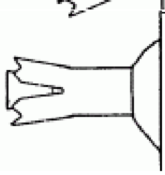
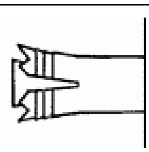
- Keep drilling until the retaining nut on the driver is about to touch the rock surface, or until the top of the anchor is 2 mm to 3 mm below the edge of the hole.

- Before the bolt is set, use the drill as a chisel or the pick of the hammer to gently sculpt the surrounding rock so that the hanger sits well.

- Make sure the hole and the drill are clear of debris, place the expansion cone into the end

BOLT STRENGTHS - Placement*

Table 2:5

Placement		Rock Quality	Failure (kg)
	ideal	hard	1400 – 2200
	2 mm below surface	hard	2200
	2 mm above surface	hard	1000
	6 mm above surface	hard	900
	12 mm above surface	hard	600
	12° positive angle	hard	1000
	12° negative angle	hard	1200
	8 mm deep crater	hard	1200
	10 mm deep crater	hard	600
	ideal	soft	700
	ideal	flowstone	variable

** Adapted from Brindle and Smith, 1983*

All tests with the load parallel to the rock. For angled loads within the range of the hanger, strength depends on the burst strength of the rock - as good as an ideal placement in hard rock.
Less than 5 mm play between the hanger and rock has very little effect on the bolt or anchor's static strength.

of the drill and tap it lightly so that it will not fall out.

- Insert the assembly carefully into the hole, and still holding the driver set the bolt with firm but not violent blows until it goes in no further.

Occasionally the driver will be stuck fast. It can be removed by gently tapping the handle or by tying a small sling to the driver with a Lark's Foot knot. The pick of the hammer is then put though the other end of the sling and wound anti-clockwise around the driver until the hammer can be used as a lever.

The rim of the anchor should be level with the rock surface. A little below is fine, any distance above will weaken the anchor. The whole operation should take from 10 to 30 minutes, depending on the hardness of the rock, awkwardness of the position and skill of the person bolting.

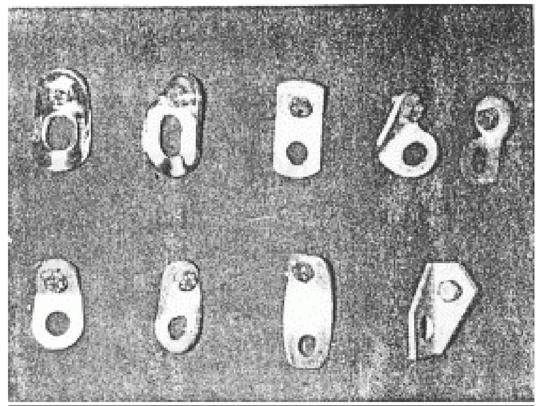
Strength

A correctly placed bolt in good rock will theoretically fail at the shear strength of the hi-tensile steel bolt - in excess of 2000 kg. Even in softer rock most anchors come adequately close to this figure. Only poorly placed bolts or those in bad rock or flowstone have given dangerously low test figures. Most testing however has been done with static rather than shock loads and there is definitely a different failure mechanism involved due to the brittle nature of the hi-tensile steel from which the bolt and anchor are made. Nevertheless it is impossible to shock load a good bolt enough to break it - the rope or cowstail would be the weak link.

Bolt Hangers

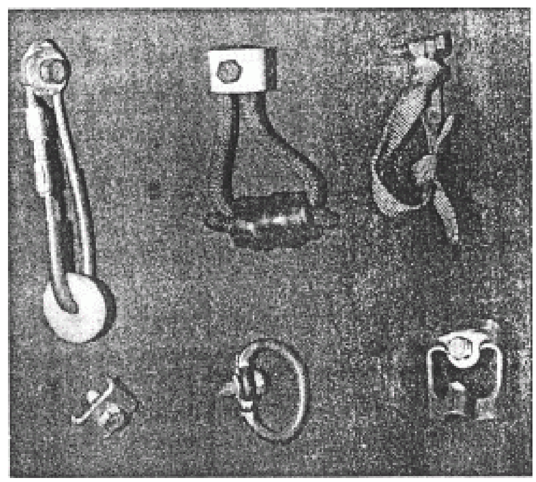
In order to attach the rope to a self drilling anchor some form of bolt hanger is needed. There is a wide variety available but by far the most popular models are those made of aluminium plate with a captive bolt at one end and an eyehole for a karabiner at the other. The plate may be bent, twisted or made of angle stock to give a twisted effect. Plate hangers require a karabiner or a maillon rapide to attach the rope while the bent hangers specifically require an oval karabiner.

Considerable effort has been put into designing hangers, which hold the rope directly



Top- Petzl: bent, twist TSA FFS Simond
Bottom- Petzl: (old) bent, twist. homemade (2)

Plate hangers

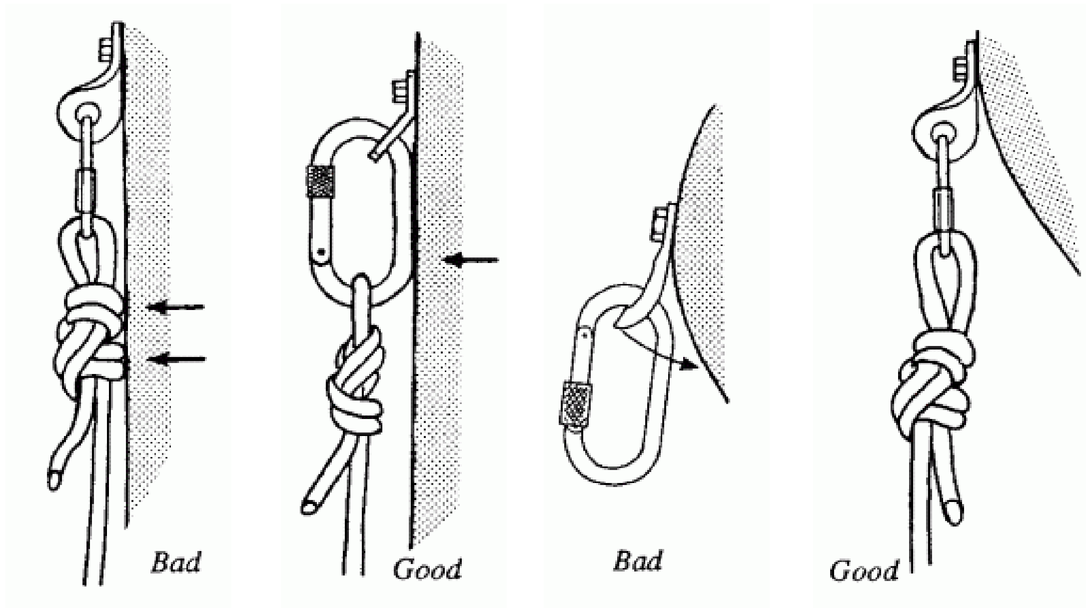


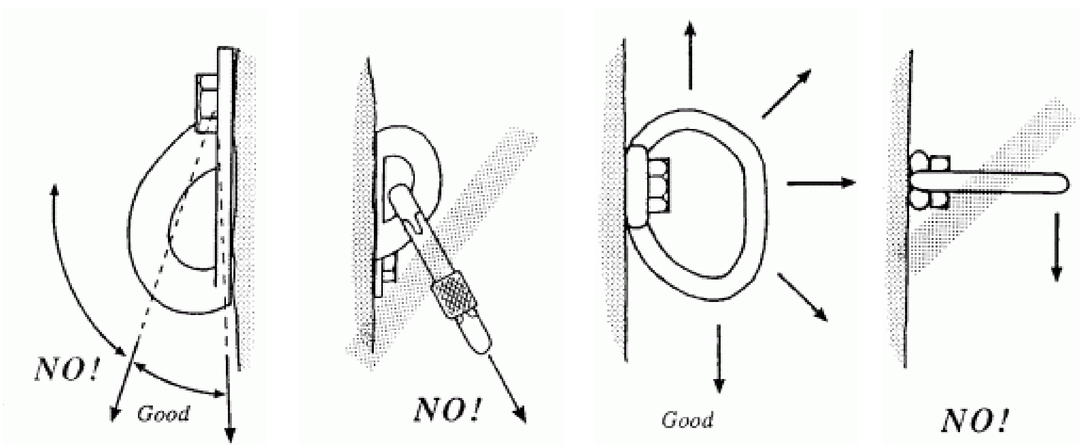
Top- CAT cord hero loop
Bottom- bent washer Petzl ring, Clown

Direct attachment hangers

but no one has yet invented one, which is entirely adequate. They may be awkward to tie the rope to, not keep the rope off the rock, difficult to clip a cowstail to, or all three! However, for back-up anchors and many "Y" belays direct attachment hangers can work fine and save some weight.

It is unfortunate that CAT (Cable Amarrage TSA) hangers are no longer available, while they never quite made it as karabiner-free hangers they are excellent for poorly placed bolts where a plate hanger sits badly. Ring hangers come close to solving the problem - they are strong and easy to cross on rebelays but are fiddly to tie the rope





to, then difficult to screw into place once the rope is tied. Ring hangers also have a tendency to work loose, rotate and load themselves sideways, which can bend or break them. Their one great advantage over other hangers is that they are excellent for overhanging bolt placements where the rope is not hanging parallel to the rock.

Bolt hangers are generally overstrong, breaking at 1000 kg or better. Simple hangers are easily made in a small workshop, although care must be taken to find a suitable aluminium alloy. As a final check, a test hanger can be severely drop tested with a low stretch rope. Five FF1 falls would be a minimum.

MAILLONS RAPIDES

Apart from tying the rope directly, a "maillon" is the cheapest link between a rope and an anchor. A 7 mm "GO" (Grande Ouverture) "wide opening" maillon is the most suitable. They open enough to take any rope. There is space for a cowstail karabiner and 7 mm is not too severe a bend to put in the rope. Maillons are available in steel or, for twice the price, in aluminium. Seven millimetre aluminium maillons with twist hangers are easily the lightest, most versatile hanger/rope link available. Unlike karabiners, maillons are safe under 3-way loads and are ideal for linking the rope to traces and slings.

KARABINERS and MAILLONS

Table 2:6

Type	**Material**	**Weight** (g)	**Strength** (kg)	**Relative Cost**
locking oval karabiner	aluminium	60	1600	5
non-locking "D" karabiner	aluminium	60	2000	4
locking "D" karabiner	aluminium	60	2000	5
mini krab	aluminium	25	550	3
7 mm GO maillon	steel	60	2500	2
7 mm GO maillon	aluminium	20	1000	3
6 mm maillon	steel	35	2000	1
10 mm delta maillon	aluminium	55	1750	7
10 mm half- round maillon	aluminium	55	2000	6

CORDS AND TAPES

Table 2:7

Cord Diameter (mm)	**Dry Weight** (g/m)	**Strength** (kg)	**Use**
9	50	1800	dynamic only for cowstails ascender safety
8	40	1600	handlines, rig slings, deviations, ascender safety (prefer dynamic)
7	30	1000	light rigging slings, deviations, footloop cords
6	23	700	deviations, rigging when doubled footloop cords
5.5 Kevlar	22	2000	footloop cords, not for life support usage.
5	15	500	deviations, pack closures
3	4	200	Cord Technique pack closures
2	2	100	Cord Technique
Tape Width (mm)			
50	50	2000	seat harness chest harness
26	40	1500	rigging, deviations, light seat harness
20	30	1050	light rigging, footloops, chest harness
15	20	780	deviations, chest harnesses

Average values from manufacturers and suppliers catalogues

KARABINERS

Small aluminium locking karabiners provide the easiest and fastest means of attaching a rope to an anchor. They are by far the easiest of links to cross on rebelays and are necessary to make bent bolt hangers hang properly. There are many karabiners made which are suitable for cave use and some manufacturers make a special "speleo" model, which is oval to suit bent bolt hangers and has a mud resistant screw-gate. Oval locking karabiners distort under load so that if the gate is tightened, it is impossible to undo once unloaded. The common result is that the caver is unable to remove his descender or a belay. The karabiner must be reweighted in order to be undone. Hang from the descender and loosen the karabiner gate and when derigging loosen karabiner gates while still hanging from them.

Even cavers who prefer maillons need some karabiners (preferably non-locking) for deviations. Strength is not a consideration so the lightest, cheapest karabiners are fine. For rigging, karabiners have three major disadvantages - they are heavy, bulky and expensive.

TAPES

Tube or flat tape makes useful slings for anchoring to natural belays, deviations, and for step-in loops on small obstacles. Tape is especially useful on marginal natural anchors where its flat form resists rolling off the anchor. The only reservation is that while strong enough when new, tape has no core as does rope, so any wear on the surface drastically affects its strength. Drop tests have shown exceptionally rapid strength losses so tape under 25 mm wide should never be used in critical positions where it could be shock loaded (e.g. cowstails, harnesses). In many respects 8 mm or 9 mm cord makes safer slings than tape as any sheath damage is easily seen.

CORDS

Light accessory cord of 5 mm to 7 mm can be used in much the same way as tape. It is cheaper than tape and adequate for most deviations. For more critical use such as belays or short handlines it can be doubled or tripled to give adequate strength and abrasion resistance.

WIRE TRACES

Traces are excellent for sharp, natural belays which would eat into tape or rope very rapid1y. They shou1d be used with care as their lack of stretch makes them high1y susceptib1e to shock failure. A good size is 4 mm diameter stainless cable and 1.5 m to 3 m long with an oversized eye large enough to allow a karabiner gate to pass through it swaged into each end. The "C" clips found on the ends of most ladder traces should never be used due to their failure at very low loads.

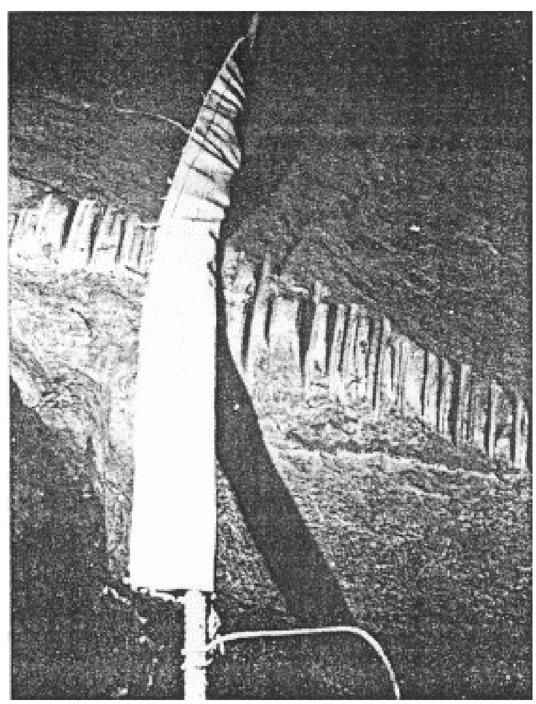
OTHER EQUIPMENT

HAMMER

A hammer is essential for placing bolts and pitons and useful for removing the sharp edges from natural anchors and for removing tight chocks. A good caving hammer has a compact head and short pick for use in the close confines of a cave, weighs 500 g to 600 g and is 25 cm to 30 cm long.

ROPE PROTECTORS

In order to reduce the chances of the rope being cut over sharp edges or to reduce wear, rope protectors or pads can be used. In many cases an empty tackle bag is sufficient. If not there are two alternatives worth considering:-



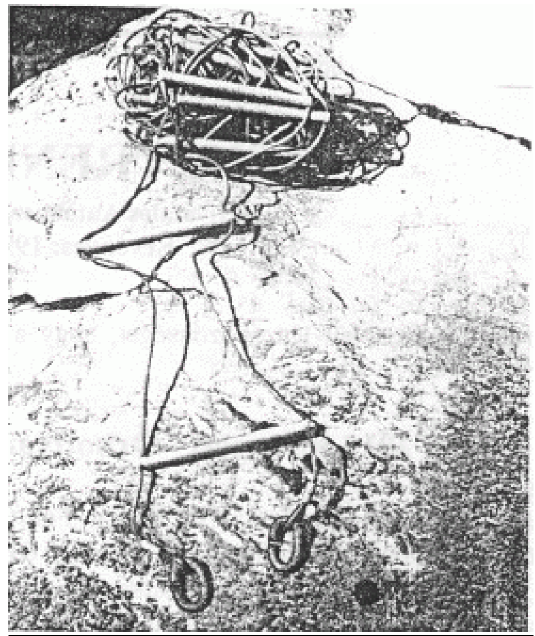
Wrap-around rope protector

One is a flat pad about 30 cm by 50 cm long with a tie-on sling at the top. The other is about half the width but with velcro along the edges so that it can be closed to form a tube around the rope. Both are ideally made of PVC-coated polyester fabric so they do not become heavy when wet. Protectors made of split garden hose or similar tubing are simply not worth having. Once they are bent the split works its way to the inside of the bend and opens to expose the rope in precisely the spot where a protector is needed - against the rock.

LADDERS

While generally out of fashion these days, ladders still have their uses. They are particularly good on isolated small pitches where it would otherwise be necessary to rig up ones abseil/prusik gear. Ladders are often easier to use than ropes in vertical squeezes and in cases where there is a small "up" in an otherwise down passage. They do however, quickly lose their advantage on longer pitches where a belay (and therefore a rope) is required.

Any metal equipment suffers from corrosion in the humid atmosphere of a cave and ladders should be cleaned and dried between uses. Ladders made with aluminium, stainless steel and galvanised iron do not suffer badly but those with copper suffer electrolysis between the cable and the rungs. This may be hard to detect but can cause catastrophic failure. Ladders left as fixed rigging in a cave for a long time should always be treated with caution.



Wire ladder

Ladders still have a role for club use. Beginners require less expertise in rigging and climbing than is necessary with rope, as well as not requiring an expensive personal descent/ ascent rig. Whenever ladders are used a belay must also be used. This may take the form of either a self-belay, or a normal belay provided the belayer is adequately trained (see Self Belays, Chapter 7 and Belaying, Chapter 5).

3 KNOTS

A good knot has certain characteristics:-

- Easy to tie
- Readily verified as correctly tied
- Secure once tied and not slip when loaded
- Easy to untie after it has been loaded
- Weakens the rope to a minimum

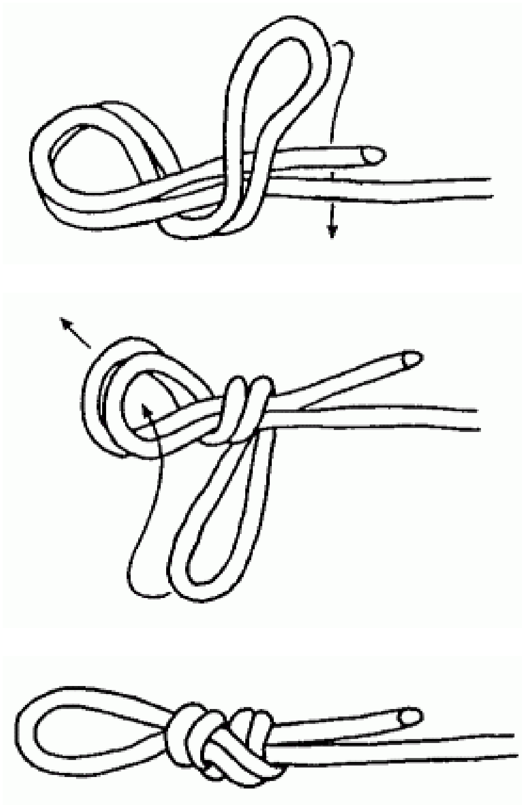
There is no need to learn a vast repertoire of knots. Rather it is preferable to learn only those few knots, which work well under all conditions. This aids efficiency and safety as greater familiarity increases speed and reduces the probability of tying the knot incorrectly.

It is generally assumed that knots weaken a rope because of the tight bends the rope makes as it winds through the knot. This is not entirely true. Consider an 11 mm rope with a loop knot connecting it to a 6 mm maillon at one end. When the rope is loaded to failure, it typically breaks at the point where the loaded rope exits the knot. It does not break at the small radius where it passes through the maillon nor at the minimum radius bend in the knot.

Nylon fibre fails when the stress concentration from pressure and tension is sufficiently high to soften it, in much the same way as snow can be melted into a snowball by squeezing it. The rope does not get much hotter, it softens at a lower temperature when under pressure. Inside the knot there is a combination of tension and pressure as the rope wraps around itself and the forces are concentrated to such a degree that the rope fails at a much lower load than it would without the knot. The way to reduce the strength lost in a knot is to use one, which has a maximum of "active surface"; one, which spreads the pressure over as much rope as possible. This is difficult to determine visually though generally the bulkier the knot the better it will perform.

Any knot is likely to perform better if it is tied neatly rather than with strands needlessly crossing one another creating extra pressure concentrations. The main value of neatness however, is that it makes a knot easier to verify.

Knot strength is not so important with new 11 mm ropes, which can afford considerable strength loss and still remain safe but when using thin rope cavers should tie the best knot available.



The Figure-9 is the strongest loop knot
and a must for thin ropes

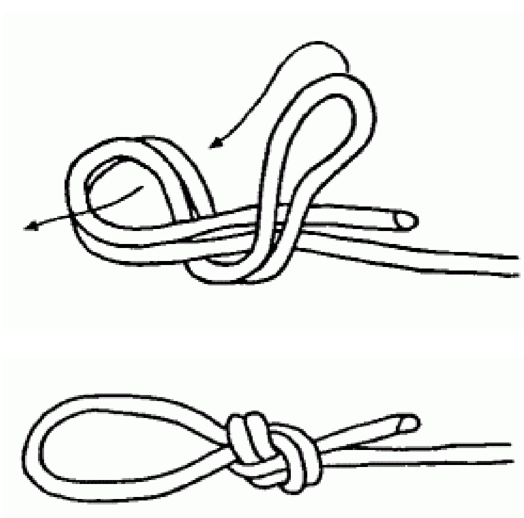
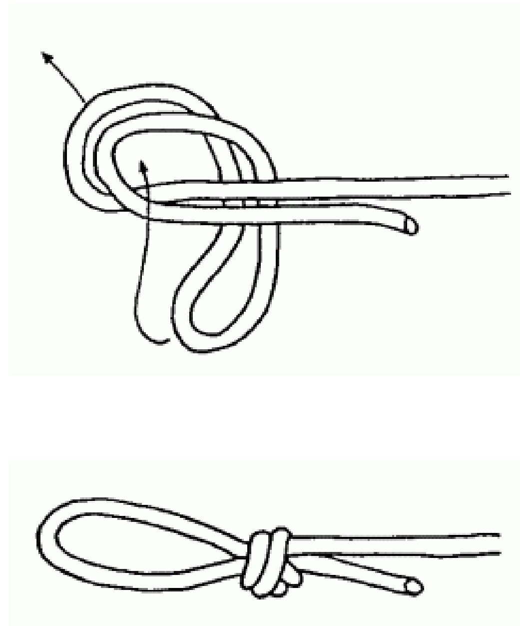


Figure-8 loop, the most versatile
and popular of loop knots



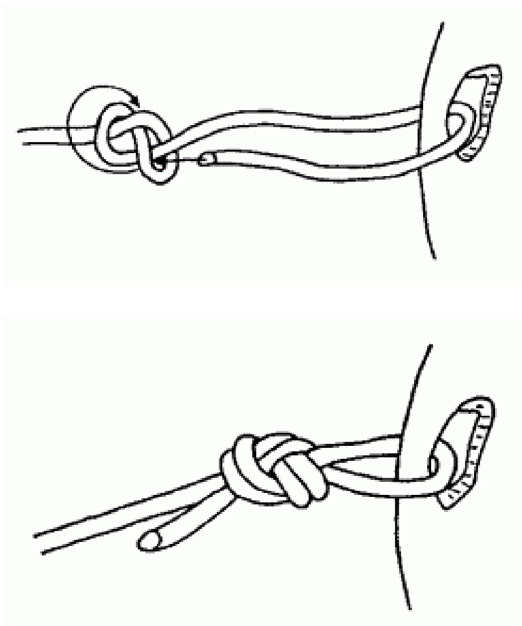
Overhand knot, the simplest loop knot

END LOOP KNOTS

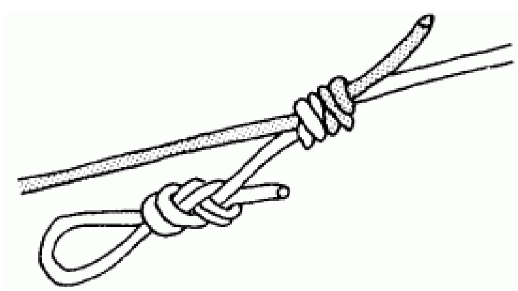
In order to attach one end of the rope to a belay an end loop knot is needed. The most suitable knots are the Figure-9 loop for ropes of 9 mm or less because of its unequalled strength and the Figure-8 loop for thicker ropes where strength loss is less important. A Figure-9 can be used for stiff ropes but it will be difficult to tie and uses a lot of rope. In either case the loop is tied then clipped to a maillon or karabiner or the loop is put over a natural anchor such as a stalagmite.

When the anchor is a large natural or a thread, Figure-8 and Figure-9 knots are slow to tie. The Bowline on the other hand is quick and easy to tie around large objects. Despite its popularity the Bowline is a potentially dangerous knot, it is easy to mis-tie, can be jiggled undone by continued movement of the rope and undoes very easily when loaded wrongly. For these reasons alone, the Bowline cannot be recommended for any life support application. Anyone who still wishes to use a Bowline must "lock" it with an extra Thumb knot or half a Double Fisherman's knot around the standing rope.

All ends of rope knots should be tied with ten or more centimetres of "tail" hanging out of them so that as the knot tightens under load it does not come undone.



A Figure-8 tied through an eyehole

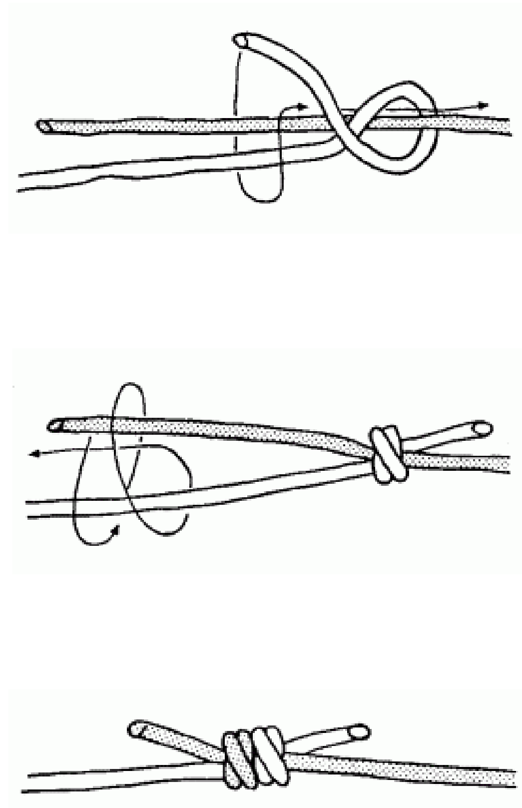


Safety loop on a Double Fisherman's knot

MID-ROPE KNOTS

Often a rope must be tied off somewhere along its length. Here the loading of the knot becomes more complicated. Take for example a rebelay: the knot would be acting as an end loop in normal use but if the belay was to fail the knot would be pulled apart ("abnormal" loading). The mid-rope loop must be good under these two distinct types of loading.

When the rope is to be pulled tight between anchors many cavers use an Alpine Butterfly knot because it "looks right". Both the Alpine and standard Butterfly are only other knots to learn and neither is very strong. The simple expedient of using a Clove hitch also looks good but unfortunately its performance is highly variable depending on whether it slips or not. Figure-9's and Figure-8's still come out on top (see Table 3: 1).



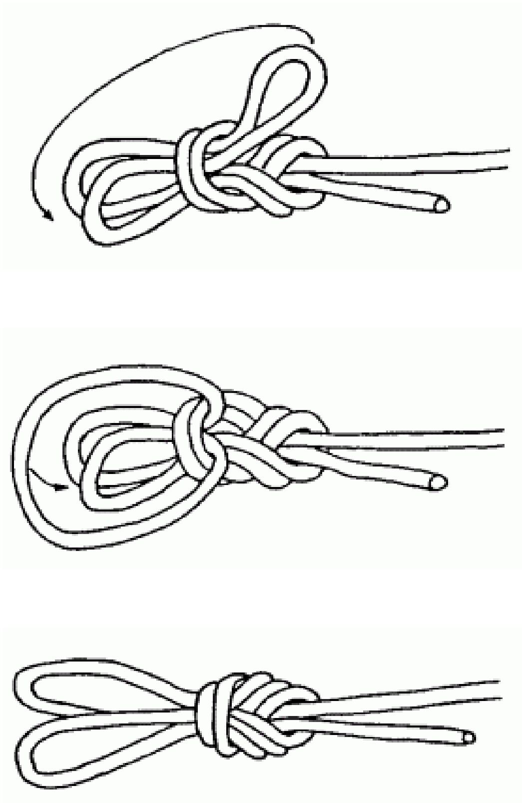
The Double Fisherman's knot, probably the best all round rope joining knot

ROPE JOINING KNOTS

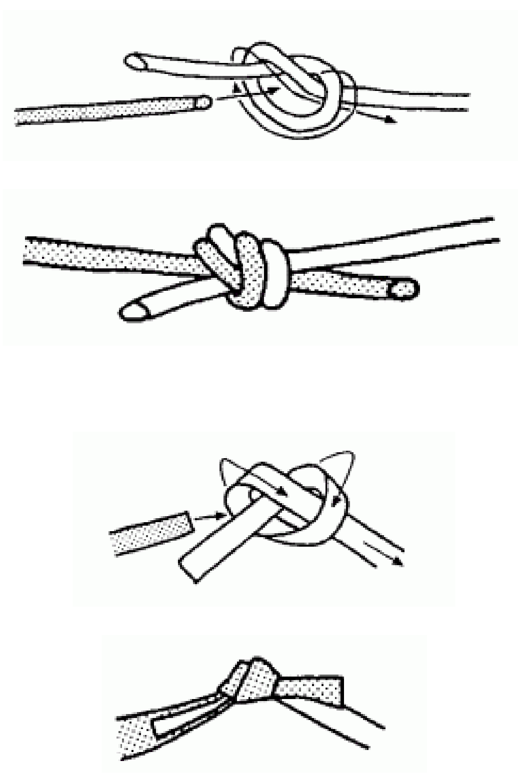
The Double Fisherman's knot is one of the strongest ways to tie two ropes end to end. It is easy to tie, can be untied and works well for joining ropes of unequal diameters.

The other knot, which can be used for joining ropes of equal diameters, is the Figure- 8, which some say is easier to untie than the Double Fisherman's. Similarly, a Figure-9 can also be used. It is more awkward to tie but has the advantage that it may be easier to untie after loading - jamming is a major problem with any rope joining knot.

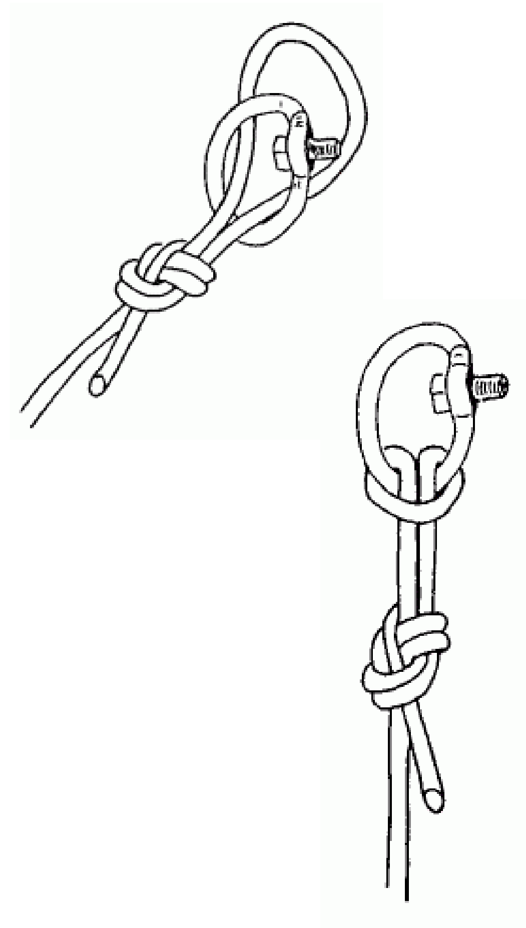
Whenever a rope join is to be made on a pitch a tail about a metre long should be left hanging out of the bottom of the knot so that-a-Figure-8 loop can be tied. This will provide a "safety" to clip a cowstail to when crossing the knot and avoid the risk of hanging on only one ascender.



Double Figure-8 knot



Round knot (Tape knot when tied in tape)



Lark's Foot knot

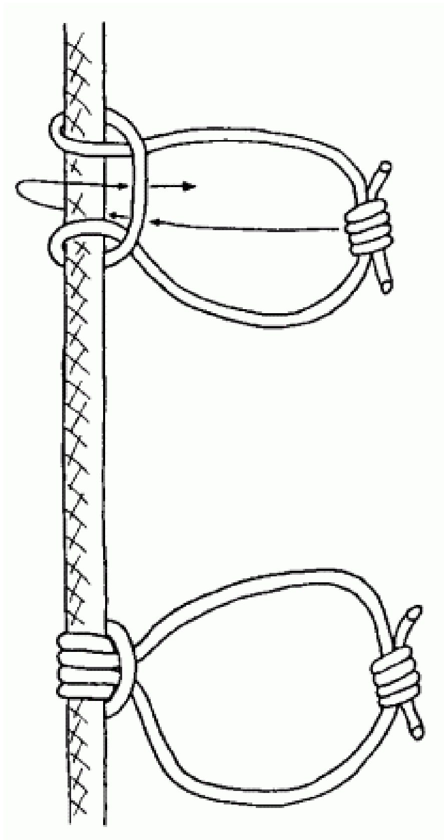
OTHER KNOTS

The knots described so far can be used to rig everything but there are a few other knots, which are handy to know.

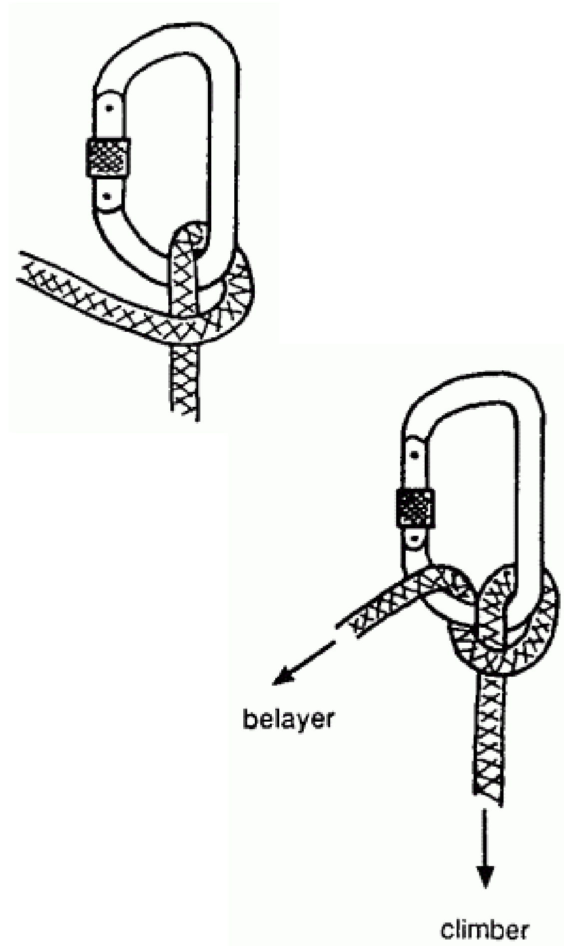
The Double Figure-8 is good for "Y" belays and can be tied as a mid or end loop knot. The two loops formed can be attached to separate anchors, tied to a ring hanger or used on the same natural anchor to reduce the wear, which would occur within a single loop.

A Tape knot is **the** knot for tape. It is not very strong but other knots may not hold in tape. A Round knot is a Tape knot tied in rope. It too is not very strong but makes a small neat knot, which is most useful for the "Cord Technique". Overhand knots are suitable for making an eye in the end of a tape and as stopper knots.

The Lark's Foot knot (Girth hitch) is the best way to tie the middle of a rope to a ring hanger. It must always be tied in a loop knot as illustrated and never used alone as it may slip. The Lark's Foot should not be used for attaching tapes to trees or natural anchors as it can be arranged in such a way as to increase the load on the tape.



Prusik knot



Italian hitch

The Prusik knot is one of a family of knots, which is designed to slide along a rope when the body of the knot is held but will grip when loaded through its sling. Some years ago it was the only means available for *prusiking* up a rope. Today they have been almost completely replaced by mechanical ascenders. However, Prusik knots are still very useful in emergency situations for replacing a damaged or lost ascender or for temporarily tying off a rope. They are best tied with cord, which is one or two millimetres thinner than the rope they are to be tied to, with a minimum of 6 mm cord for life support uses. A reasonably supple cord is best although tape may also be used with less success. The knot illustrated is a Four Layer Prusik knot. An extra wrap of the prusik sling makes a Six Layer Prusik knot which gives more grip if needed (see also Chapter 7).

The Italian hitch (Münter hitch) is not so much a knot as a friction hitch. It is exceptionally useful for creating extra friction while abseiling and for emergency abseils. As a belay friction device, an ltalian hitch is very effective and requires no more than a locking karabiner and a rope.

STOPPER KNOTS

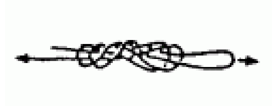
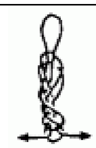
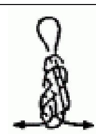
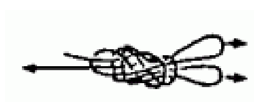
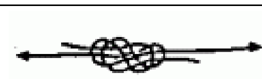
Every rope should have a stopper knot tied in the end before anyone descends it so that the first caver down does not slide off the end if the rope is too short. A stopper knot is tied in both ends of every rope when the ropes are being packed and should be checked as the rope is put down the pitch. The type of knot is not important - a Figure-8 loop is often used. The main thing is that it must not untie itself and has enough tail so that it can not be pushed off the end of the rope if hit hard.

One way of being sure that there is a stopper knot in the end of the rope is to tie all ropes with an end loop in each end, then cover them with heat-shrink plastic so that they cannot be undone (Expé, 1987). However the knot is then prone to jamming as the rope is hauled up pitches.

When there is excess rope at the bottom of the pitch a stopper knot becomes superfluous. Instead, the first to descend should roll up the rope so that it hangs off the ground. This will keep people from stepping on it, stop it from being damaged by falling rocks and give a little bottom weight when prusiking the pitch.

RECOMMENDED KNOTS

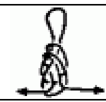
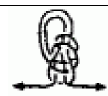
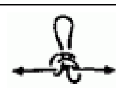
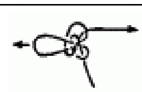
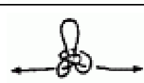
Table 3:1

Knot	**Form**	**Static Strength*** % of original	**FFI Falls#** rated /10	**Use**
Figure-9 loop		70	10	general, thin rope
Figure-9 loop (abnormal)		55	8	rebelay failure
Figure-8 loop		55	8	general
Figure-8 loop (abnormal)		40	5	rebelay failure
Double Figure-8 loop		-	10	rebelay, Y belay
Double Fisherman's		55	10	rope join
Figure-8 join		50	-	rope join
Overhand loop		50	5	Tape knot stopper knot
Tape/ Round		45	-	Cord Technique tape join

** From G. Marbach and J-L. Rocourt.1980 and Courbis.1984*
 # Ratings for old rope, any midrope knot has a much greater % effect on new rope.

NON-RECOMMENDED KNOTS

Table 3:2

Knot	**Form**	**Static Strength*** % of original	**Falls#** FF1 80 kg rated /10	**Use**
Overhand loop (abnormal)		45	7	rebelay failure "shock absorbing" knot
Clove Hitch		-	2	midrope tie-off
Lasso Bowline		-	5	natural belay
Bowline		50	8	general
Double Bowline		50	7	rebelay, Y relay
Double Bowline (abnormal)		40	5	rebelay failure
Butterfly		45	5	midrope tie-off Y belay
Butterfly (abnormal)		47	5	rebelay failure Y belay
Alpine Butterfly		-	3	midrope tie-off Y belay
Alpine Butterfly (abnormal)		-	5	rebelay failure Y belay
Figure-9 Stopper**		-	3	direct tie to bolt hanger
Reef		10##	0	pack closure
Single Fisherman's		40***	-	rope join

** From G. Marbach and J-L. Rocourt, 1980 and Courbis, 1984*
 # Ratings are for old rope, any midrope knot has a much greater % effect on new rope.
*** Only when used as shown*
Knot unties when loaded
**** Knot may untie when loaded*

4 RIGGING BASICS

Rigging is technically the most demanding part of vertical caving and no matter how difficult a cave is rigging must conform to three basic constraints.

1. **Safety**

2. **Negotiable by the whole party**

3. **Conservation**

While both Alpine and American styles have a lot in common - they are after all trying to accomplish the same thing, practices which are acceptable in one style may be regarded as dangerous in the other. This is now here more evident than the concept of allowing rope to be hung in contact with the rock; taboo in Alpine rigging and the norm in American.

ALPINE RIGGING

The aim is to keep the rope free of the rock at all times and a safe distance away from water and loose rock whenever possible. Often it is necessary to go to great lengths to achieve this but allowing a thin rope to rub on sharp rock is suicidal.

ANCHORS

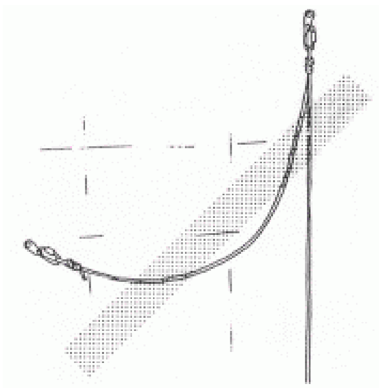
To obtain a free hang and have the rigging negotiable by the whole party usually requires extensive use of artificial anchors. To hang the rope just right often requires an anchor in a specific spot and there may not be a natural anchor there.

The rope must be tied to at least two anchors at the top of the pitch to form a belay, which has minimal risk of failure. Possibly one will be a little back from the edge and another out where it will give a good "hang". Below that, one or more anchors may be required as rebelays to keep the rope hanging free to the bottom.

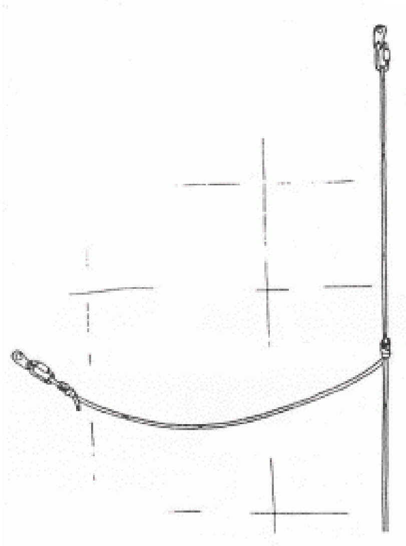
Primary Anchors

When a caver clips onto the rope to descend a pitch there should be two or more secure anchors above him. The exact arrangement will depend on the pitch and the caver who rigs it. The two anchors may be connected so that both share the load ("Y" belay) or tied in separately so that one takes the bulk of the load. Most often one anchor is in a position, which gives a good hang and the other one where it is easier and safer to reach.

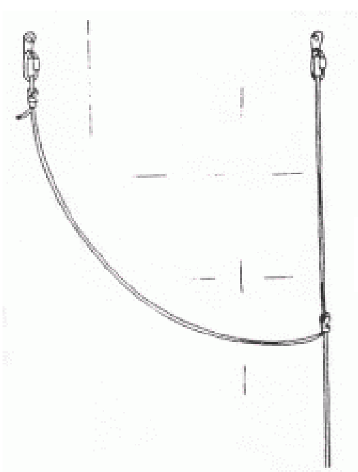
Rigging must NEVER allow the possibility of sever shock loads



FF >1
LETHAL

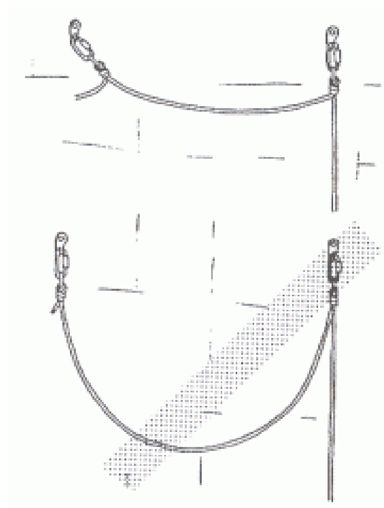


FF0.3
Safe



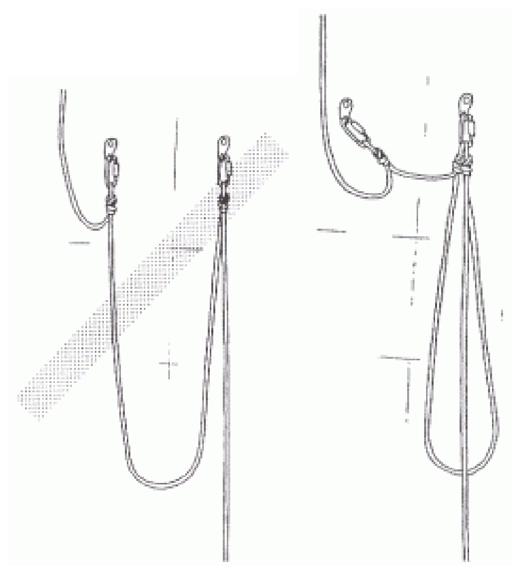
FF < 0.3
Even better!

In any belay, slack rope should be kept to a minimum so as to reduce shock-loading in the event of anchor failure. Anchors placed close together can be particularly prone to this as it is difficult to tie two knots side by side with no slack between them.



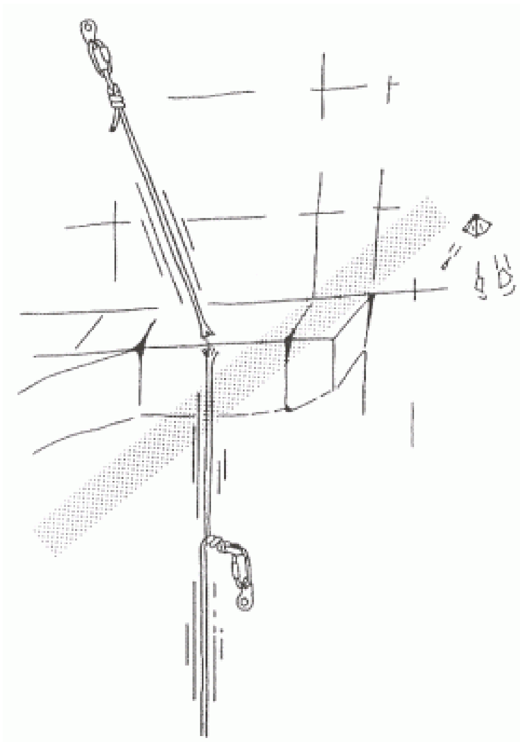
Good

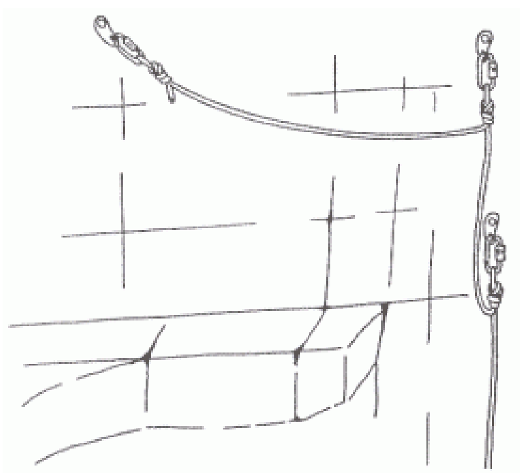
Danger!



Dangerous stand-in loop *OK*

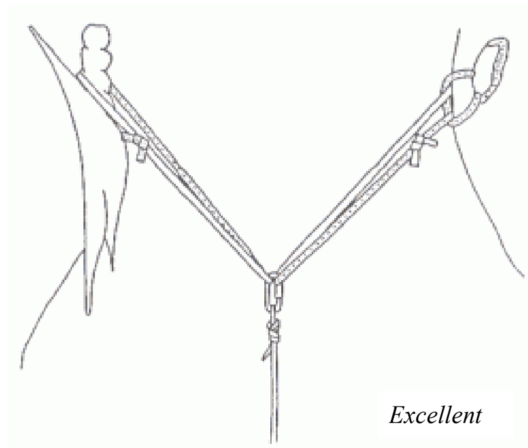
In the event of double bolts they should be at least 30 cm apart to avoid any interaction between the stressed areas of rock caused by the bolts. Anchors a little apart will also be easier to rig with minimal slack. Two anchors, which are side by side, should never be rigged with a stand-in loop between them. A FF1 fall is possible should either anchor fail! They will be safer if rigged with a tight sling between them or the rope is tied tight and the stand-in loop rigged from one anchor. In any double anchor belay the individual anchors must be totally independent.

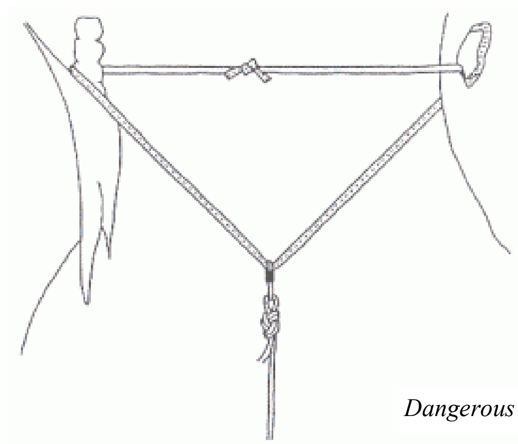


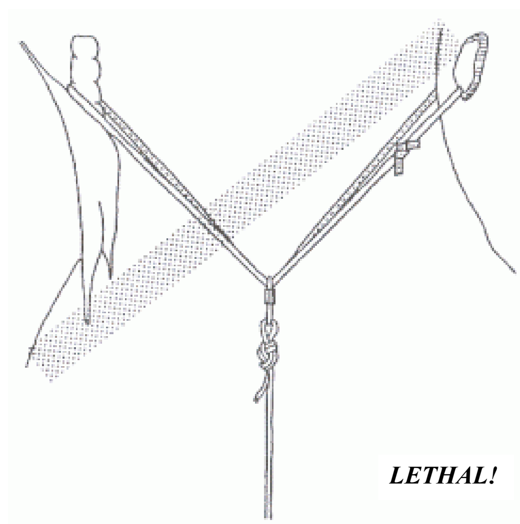


The back-up line must always be protected from the possibility of failure

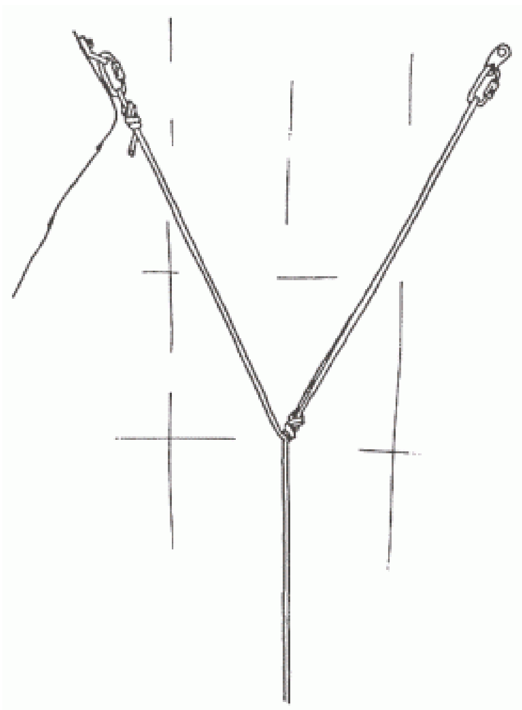
At the same time the rope must be protected from sharp edges should the lower anchor fail even if it involves putting in a double anchor, removing the sharp edge or rethinking the entire belay.



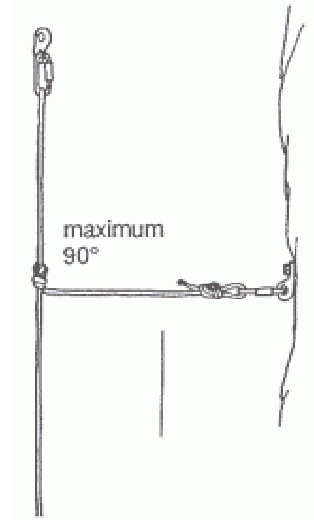




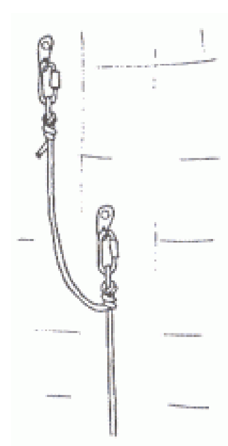
It would be disastrous if the failure of one anchor automatically led to the failure of the other. If dependant anchors are used they must be regarded as a single anchor.



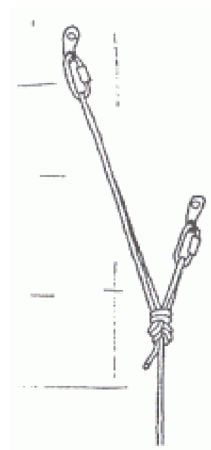
"Classic" Y belay



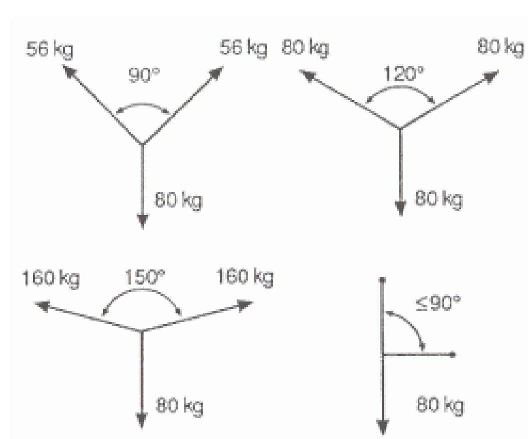
Only just a Y belay



Superimposed anchors



Y belay



Y belay anchor loads

"Y" Belays

An obvious extension of double anchors is the "Y" belay where both anchors are always loaded. In theory, each anchor bears a less than full load and therefore has a lower chance of failure. In the unlikely event of an anchor failure the other arm of the "Y" would take the load without being shock loaded, thereby maximising its chances of survival.

Sharing the load between two anchors does not divide it in half. Too great an angle between the "Y" will only serve to overload both anchors simultaneously. The angle is best kept below 90° and 120° is certainly the upper limit. Keep in mind also that most plate type bolt hangers should not be outward loaded at more than 45° from the wall and ring hangers may be necessary instead. "Y" belays are ideal for situations where a single anchor on either wall of a narrow pitch would not give a free hang while a "Y" with an anchor on each wall creates a belay in mid air.

"Y" belays are versatile and can be used whenever there are two anchors at about the same level. In fact some cavers like them so much that they use them everywhere. While such practice is mechanically safe it can lead to awkward starts to pitches and excessive use of rope and anchors.

Asymmetric "Y" Belays

The position of the arms of the "Y" can be varied to the extreme where one of them approaches the horizontal. This should never be exceeded as once the knot at the centre of the "Y" is above either anchor a greater than FF1 fall is possible. A ring hanger will be needed if the lower anchor is a bolt, which takes some load.

Knots for "Y" Belays

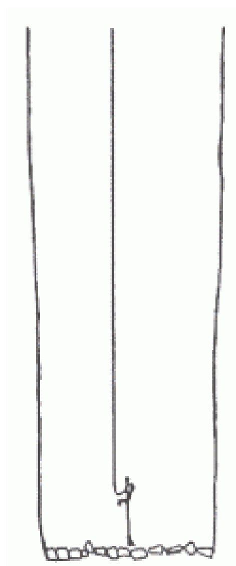
Arranging a "Y" belay can be problematic for the unpracticed and there is a vast range of possible knot configurations. The strongest and often easiest to tie and adjust is a separate sling. When no sling is available the end of the rope can be used though this is less economical on gear. Most often a double end loop knot will be used, the Double Figure-8 being the most adequate although Figure-9 and Bowlines can also be tied double.

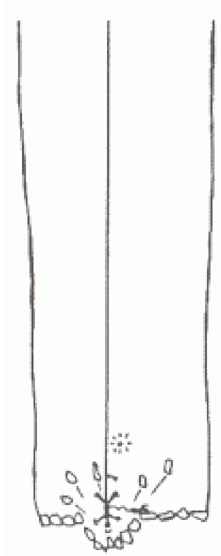
Back-up Anchors

As often as not the primary anchor will be in a position which is not safe to reach without a safety line. It must then be "backed-up" to another anchor in a less than ideal position which is safe to reach.

The back-up may constitute the second anchor at a pitch top or it may be the anchor for a handline out to a double anchor primary belay. As well as providing security for the primary belay a descending caver can clip a cowstail to the line for safety while moving out to the descent rope.

When pitches come one after another the rope from the previous pitch can be used as the back-up for the next pitch. So long as one makes sure that if the lower anchor does fail the back up will take up before the caver hits bottom.





This is especially relevant when a big pitch is followed by a small one. If in doubt use double anchors and only use the previous rope to make them easier to reach.

REBELAYS

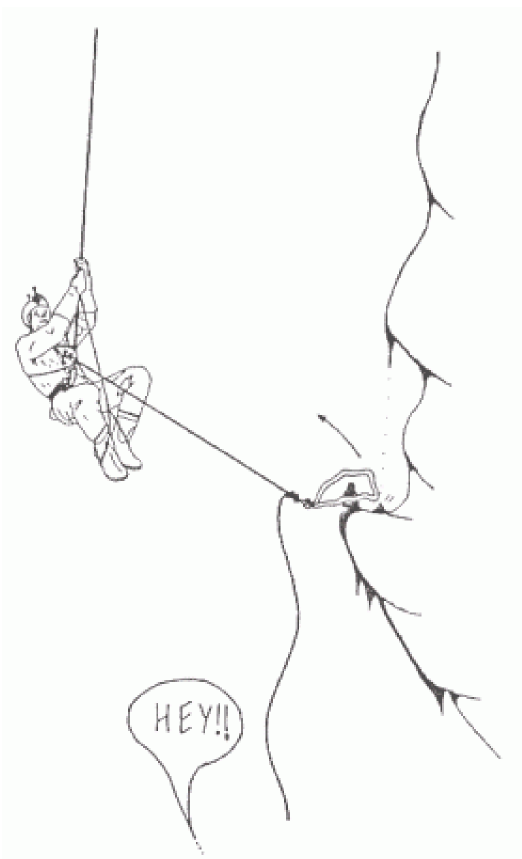
If the rope hangs from the primary belay to the bottom without hitting the wall or being hit by water then the pitch is rigged. If not, a rebelay (intermediate anchor) may be needed to keep the rope hanging free. It may be necessary to swing sideways to avoid obstacles or water. The rebelay is best placed in a position where the rope will hang as far as possible before it touches the rock again. Usually this is a simple case of identifying a potential rub point and putting the anchor right on it or in a position where the rope is pulled away from it. Choose a suitable anchor position by dropping small rocks from likely spots or hanging some rope down the pitch and holding it against the wall to see how well it really does hang. On long drops rebelays can be used to keep the pitch length less than 40 m, which is a good maximum for a heavy traffic pitch.

When tying the rope to the rebelay anchor only just enough slack is allowed to unclip a descender - no more than one metre when the upper rope is not loaded. Allowing for stretch can be difficult on long drops.

A caver rigging with karabiners or slings can ensure the correct amount of slack by clipping a short cowstail to the rebelay and abseiling onto it before tying the rope in. Without uncliping his descender the caver ties a loop knot in the rope below him and clips it in. The caver then finishes crossing the rebelay as normal and continues his descent. Maillons should not be used in this way as they deform if opened under load.

A single anchor is normally sufficient for a rebelay. They are always backed up to an anchor above and their greatest chance of failure occurs when someone is at them. Once lower, the rope between the caver and the anchor will be able to absorb some shock. The possibility of having to ascend a long pitch with a rub point created by belay failure is virtually non-existent. A double anchor should be considered when a single anchor failure would risk the rope being cut on a sharp edge, cause a dangerous pendulum or if the rock/anchor is of such poor quality that its integrity is in doubt.

When natural anchors are used for rebelays care must be taken to rig them so that a passing caver cannot lift the sling, nut, etc out of position on his way past. It is best to rig this as "fool proof" as possible by tying down the rebelay or using a long sling so that it cannot escape.



Some belays must be tied down!

DEVIATIONS (REDIRECTIONS)

A deviation can often be placed as an alter native to a rebelay. It will be faster to rig than a rebelay and in most cases will merely be a sling attached to a natural anchor at one end and clipped to the rope with a karabiner at the other. The sling needs to be long enough to deviate the rope from its natural path and take it away from the rub point.

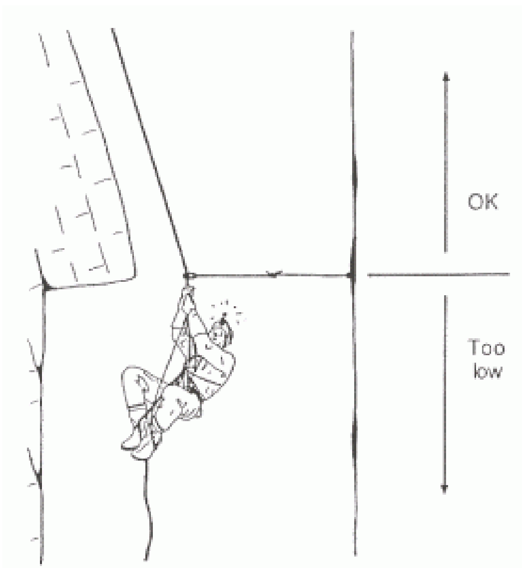
The anchor used for a deviation never receives full body weight, nor is it possible to shock load it as can be done with a rebelay and therefore does not need to be as strong. In most cases a rock spike or jammed knot, which is nowhere near strong enough for a rebelay, is fine. The sling and anchor need not be of the highest quality either, cheap 5 mm cord and a mini-krab is strong enough and saves weight.

In those rare cases where there is no natural anchor a bolt can be used and because the loads are low some cavers half drill the hole to save effort. While this is strong enough it is better to drill **all** bolts properly so that the next caver does not place a "good" one beside it. The type of hanger and its load angle is unimportant, as the load on a deviation should be low.

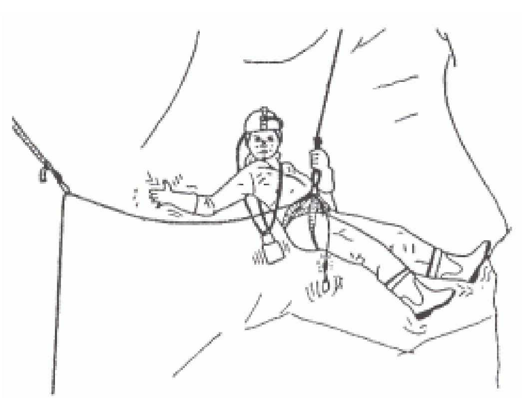
Deviations are good for rotten rock where a rebelay may be unsafe or where it is better to hang the rope down the centre of the shaft and avoid the walls altogether. When prospecting or when short of rope, deviations are fast to rig and use less rope than rebelays.

To be effective and easy to pass a deviation must be set up properly. The anchor should be as near as possible to the same level or a little above the rub point. The rope only has to avoid touching, not miss the rock by metres. The sling used should be long enough so that the caver can easily reach it with his feet on the wall. If the sling is too short and does not allow this, the deviation may be difficult to pass and easily dropped, especially on ascent. Extremely short deviations such as one or two karabiners on a bolt hanger should not be used; they have so little movement that they are difficult to pass. Severe deviations should be avoided. The forces on them work similarly to "Y" belays and it is possible to overload the anchor or sling, or make it difficult to pass.

Deviations do not break pitches into shorter units, while a deviation is faster in the short term a rebelay may be better if many people are going to pass.

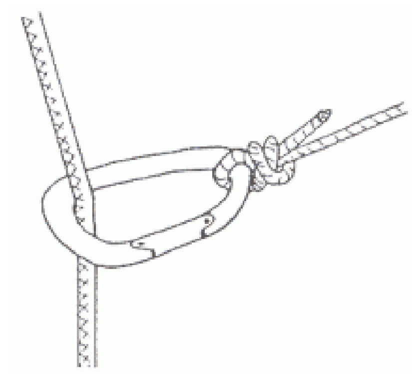


Correct position for a deviation



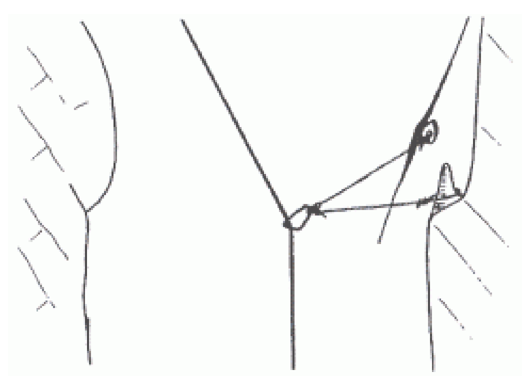
Too short – difficult

Correct length – easy



The karabiner, while not critical, should be a snaplink rather than a locking karabiner

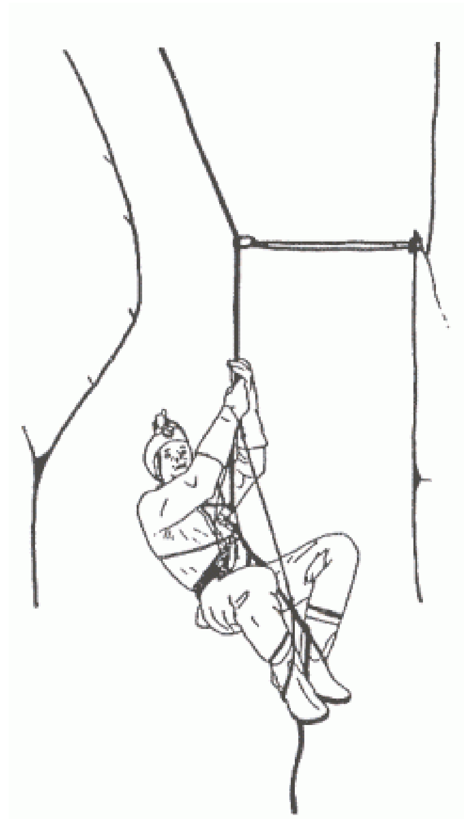
A deviation can also be placed in the floor



Double deviation

At times the descent rope must be constrained precisely. It is then reasonable to use two slings on opposite walls clipped to the same karabiner in order to hang the rope in exactly the right spot.

REBELAY? **OR** **DEVIATION?**



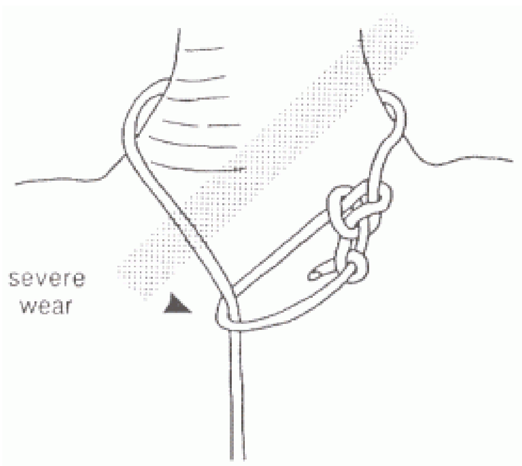
Rebelay?		or Deviation?	
+	-	+	-
secure	slow to rig	rope less constrained	fast to rig
more cavers can climb at once	rockfall danger increased	rockfall danger reduced	only one caver can climb at a time
easier to climb (less rope bounce)	needs more gear	uses minimum gear	can be difficult to climb

AMERICAN RIGGING

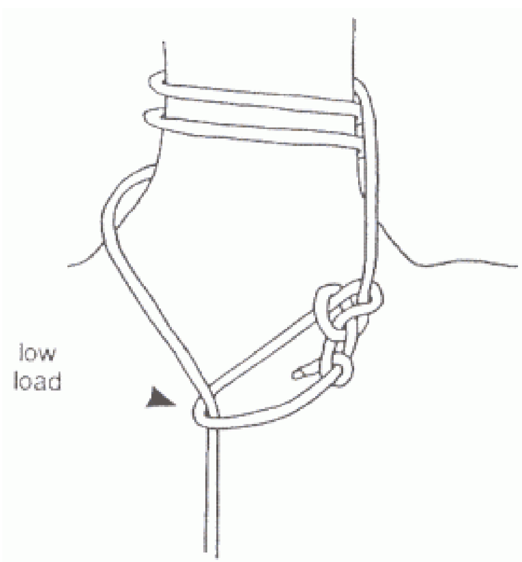
Rather than relying on complex rigging and large amounts of hardware to keep the rope intact, American rigging relies on a tough heavy rope, which can withstand some abrasion. Rigging is simplified considerably when one is not too concerned about whether the rope touches rock or not. Without doubt the strongest point of American Rigging is its simplicity.

ANCHORS

American rigging avoids hanging the rope in contact with rock or water as much as possible but rarely to the extent of placing bolts or needing a handline to reach difficult anchors. A single "bombproof" anchor is normally all that is used, the position not being vital. Above all it must be easy and safe to reach the rope and as with any rigging, high belays make this easier.



Poor



Good

A popular knot for the natural belays normally employed is the "Lasso" Bowline, which tightens securely onto the anchor. A Figure-8 knot can be tied in the same manner for improved security. Separate slings are considered, unnecessary as they weaken the system and are extra gear to carry.

Should the only good anchor be at floor level it may be difficult to exit the pitch on the way up. Under these circumstances some cavers hook the rope over or wrap it around a knob near the edge to lift it up a little. Should the rope slip off or the knob fail a large shock load would occur. The danger to the rope is usually not too great as 11 mm rope is very strong, but the consequences for the caver could be severe. Most of the time however, the opportunities for generating a shock load in American rigging are rare.

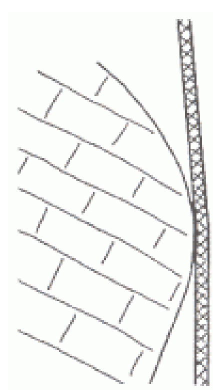
Pitches are rarely broken into short sections. In fact an effort is made to make them as long as possible so as to take advantage of the fast but unmanoeuverable prusik systems usually employed - even to the extent of crossing ledges and turning corners on the way. The pitch is only ended when a big ledge or the bottom is reached.

Rope Protection

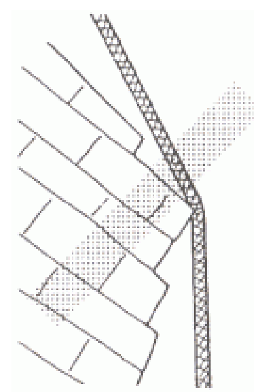
American rigged ropes are often in contact with the rock, making rope protection of paramount importance. Recently the trend has been to tougher ropes, which are better, able to withstand the wear and tear. Even so it is of ten necessary to pad pitch edges.

Once below the edge of a pitch the rope will move around too much and pads become ineffective, so one must resort to wrap around pads. In most cases the worst abrasion will occur in the top 20% of the pitch or at the last edge that the rope touches. Apart from obviously serious problems rope protection is rarely considered lower down the pitch.

In practise I have found all rope protectors unreliable unless they can be placed above where one clips on the rope. Protection on the main lip works tolerably provided everybody replaces the rope and pad in the right position, which is not always the case! Even then they are ineffective once the rope eats a hole in them. Once more than five metres down a rope, all protectors can be expected to fail at least 50% of the time: the rope pulls to one side, cavers of different weights stretch the rope different amounts and make the protector sit too high or low or it is simply placed wrongly.



Slight



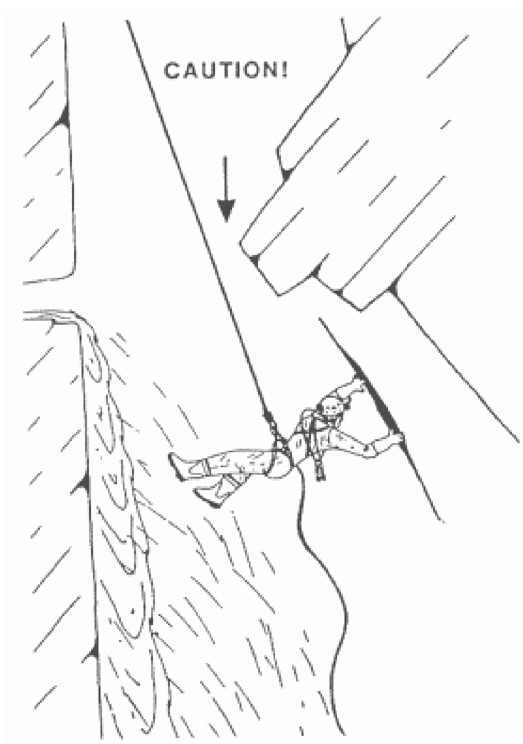
Use a pad

Abrasion damage to the rope varies with the nature of the rub point. Acute bends in the rope are more dangerous than blunt ones. Smooth polished rock will usually be completely harmless to the rope while sharp bedding ridges or crystals can damage a rope very quickly indeed. Mud covered or dirty rock is a particular hazard as it may look smooth but hide rope-eating edges beneath.

COMPROMISE

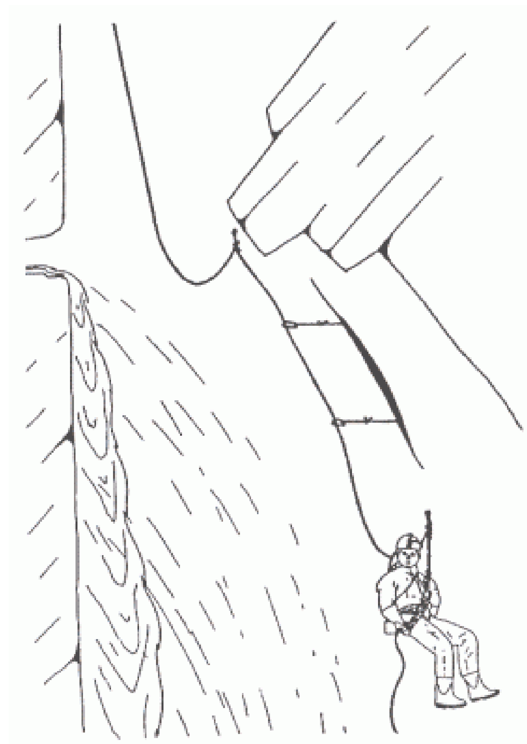
The use of American rigging is terrifying for Alpine cavers who cannot afford to tolerate the slightest rope abrasion. American riggers find Alpine style far too light, flimsy and complex to be at all safe.

Despite a general lack of understanding between cavers on different continents some uses of one "pure" technique be it Alpine or American, lack either efficiency or safety. Prospecting is faster without spending time putting in bolts and careful use of rope protectors can save a lot of effort in Alpine rigging. Similarly, American cavers could use some Alpine techniques to keep them away from water and make their ropes last longer.



Pendulum to avoid water

SPECIFIC RIGGING PROBLEMS



Several small swings are easier than one big one

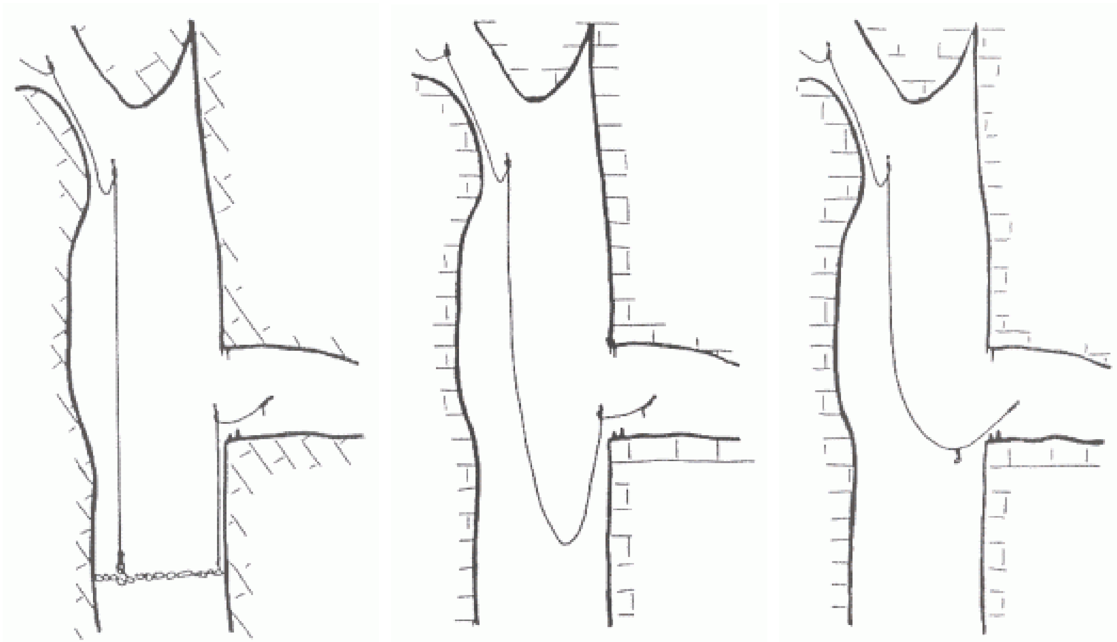
PENDULUMS

The need to swing sideways on descent often occurs on wet pitches or if there is a deep pool at the bottom. Occasionally a drop will be encountered where the passage continues through a window partway down.

To pendulum sideways while hanging in space is exceptionally difficult. When there is a wall to push off from or claw across one can expect to go sideways a maximum of 25% of the distance below the last anchor. To go further will require lassoing something or jamming a knot or grappling hook and prusiking across. The price of failure may be a horrifying swing back to one's starting point and beyond!

On long wet pitches one solution is to make a series of small pendulums rather than one large one. In any case the anchor from which one swings must be placed so that the rope does not grind as it swings sideways and a second anchor or deviation may be required to achieve this.

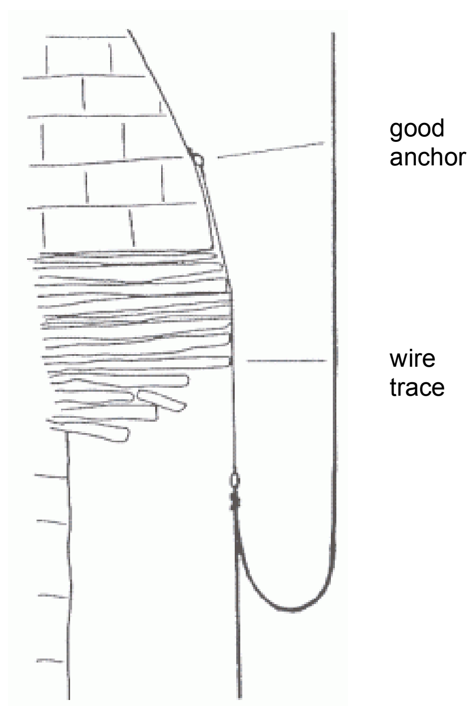
OPTIONS FOR RIGGING PENDULUMS



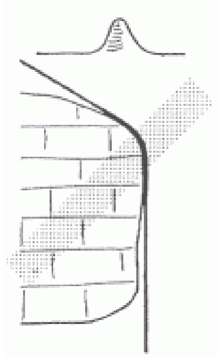
Once across a pendulum, the rope must be well anchored and enough slack left so that the next caver can cross. The amount of slack rope in the pendulum usually means that double anchors are necessary before descending the next part of the pitch. A loop knot tied in the rope to indicate when to stop descending and when to start swinging may also be useful. The sideways pull from the pendulum may be sufficient to require a stand-in loop to facilitate crossing the lower rebelay. Each of the various rigging options has its merits, depending on the pitch.

Rotten Rock

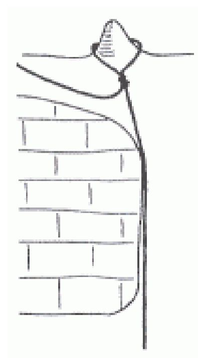
If the rock is bad it may be difficult to place a secure rebelay. Often a deviation will work or perhaps a rebelay can be placed higher up; if not a wire trace could be used. Find an anchor above the problem and connect the trace to it so that it runs down over the poor rock, then put a rebelay on the end of the trace. It will not be comfortable to negotiate, and the rope will twist around the trace, but it works! If a trace is not available a well padded rope or tape (possibly doubled or tripled) can serve the same purpose.



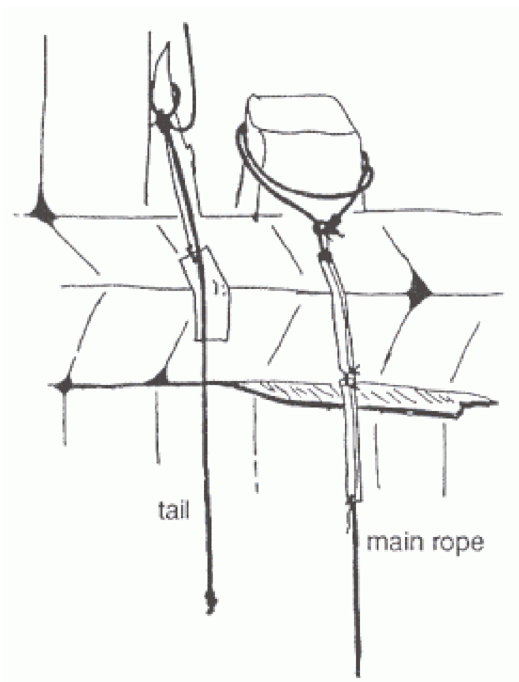
A secure method of rigging past rotten rock



Poor



Better



Tail

PITCH EDGES

Negotiating pitch edges is often the most difficult part of an American rigged cave. The rope is forced into contact with the rock and passing on descent and ascent may require considerable strength and technique.

The most significant factor in reducing such problems is placing the anchor as high and close to the edge as practical. This decreases the angle that the rope is bent through, making the edge easier to pass as well as reducing rope wear.

When an edge is unavoidably difficult, it can be made easier by hanging a stand-in sling over the edge so that on ascent it is not necessary to lever the rope out from the rock in order to pass.

Another device, which has gained some popularity, is to hang a "tail" over a difficult edge or on one, which requires excessive padding. The idea is to descend the tail past the lip, then change over to the main rope below the padding. In this manner rope pads stay in place and there is no problem with rope weight. Unfortunately, tails use a lot of rope and are slow to pass, especially on descent. A more efficient rig is to use a "floating rebelay" as already described in this chapter under "Rotten Rock".

HANDLINES

As well as giving security at pitch heads, handlines can also be rigged to avoid the risk of falling down rifts or holes across which one must traverse. The line is normally not weighted, a cowstail is simply clipped in and slid across with the caver. Double cowstails make it a simple procedure to pass "rebelays" in the line without detaching from the line. The rope should be rigged loosely to avoid overloading the anchors and shoulder high to minimise the length of a fall. As the rope is normally not loaded it can go around corners with little risk of severe wear.

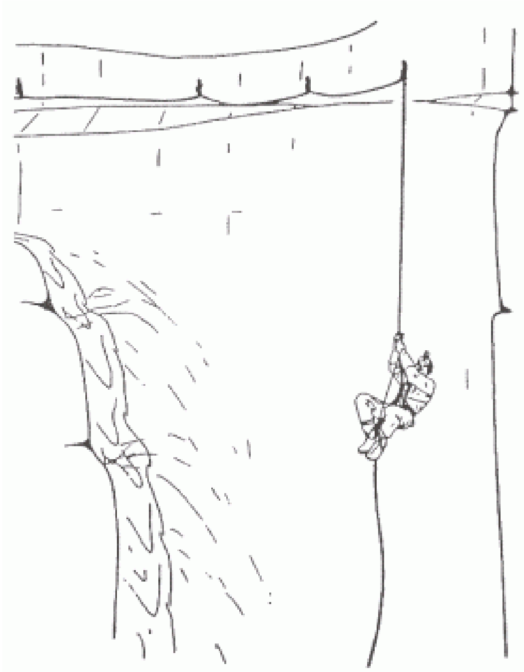
TRAVERSE LINES

On occasions a "handline" must be rigged to give direct aid to a caver climbing out to the descent rope. More often a traverse will be rigged along a deep rift or to protect cavers climbing along a narrow ledge. Horizontal traverses with the rope tied in to several anchors along the way are both slow and strenuous to cross if there are no footholds and the passage is too wide to bridge. Fortunately they are also very rare.

A rope rigged to a line of anchors about a metre apart and tied in to each one is negotiated by swinging ape-like from one anchor to the next. Clip a cowstail to the first anchor. Put a foot in or haul across on the slack between the anchors and clip the second anchor with the other cowstail. Lean back and release the first cowstail. Repeat until the end of the traverse!

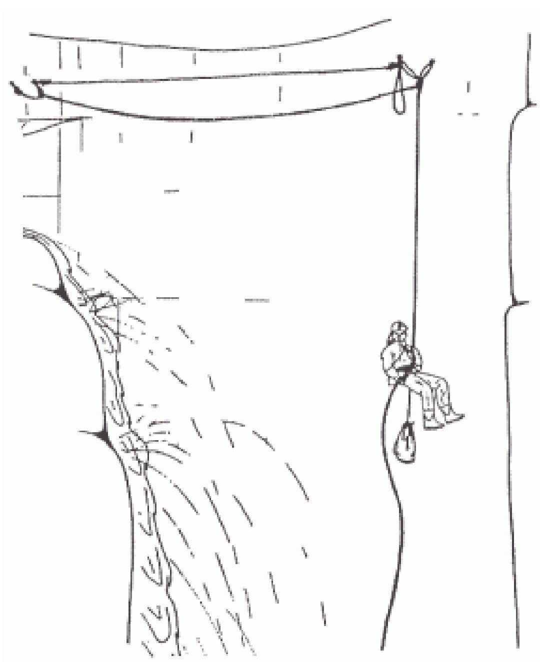
Such traverses are rarely necessary and can usually be done as a series of small tension traverses by descending a few metres, placing an anchor as far sideways as possible, descending again and so on or by rigging a Tyrolean traverse.

OPTIONS FOR RIGGING TRAVERSES



Protected traverse on a ledge

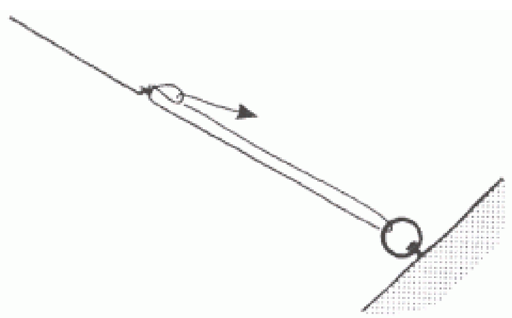
Small pendulums



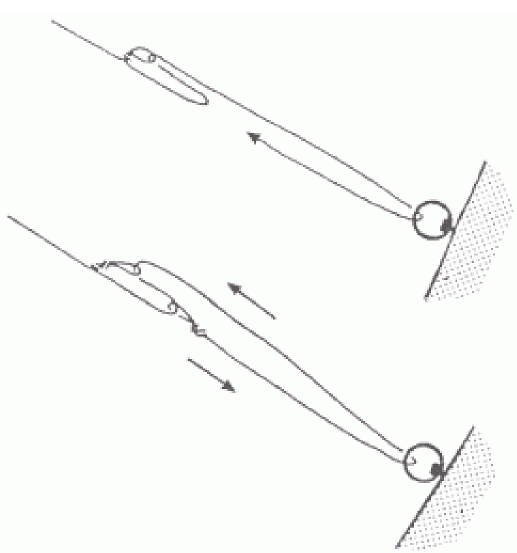
Tyrolean without a ledge

Bolt traverse

Sloping tyrolean



Pulley hitch



The Pabsabloq

TYROLEANS - SLOPING

Should one be faced with a long stretch of rotten rock, which overhangs at the bottom or a cascade, which ends in a pool a diagonal Tyrolean, can be set up.

Initially, descend straight down, protecting the rope with pads if necessary, and set up a belay well away from the base of the pitch. Rig the least stretchy rope available (heavy fencing wire is great, but who carries that?) from a separate belay of its own and pull it as tight as possible; the gentler the slope the tighter the rope will need to be. A simple block and tackle, pulley hitch or "Pabsabloq" may be helpful and while illustrated with rope loops, karabiners can be used to increase efficiency. Those following descend on a separate rope with a cowstail attached to the Tyrolean - as they descend the tight line will pull them safely to one side.

TYROLEANS – HORIZONTAL

Should there be a traverse across a pitch or pool a Tyrolean traverse is faster in the long run than reclimbing the traverse each time or paddling a boat back and forth. Once someone has climbed or floated across, a tight and a loose rope are rigged, each using separate anchor points. The tight one is to ride on with a cowstail and the loose one acts as a safety should the tight one fail (the load on the tight rope can be very high). When the tight line is not quite horizontal or sags, the loose rope can be used to abseil/prusik on as well.

A dynamic rope is safer for the loose line, otherwise just use a good rope. On low level Tyroleans over pools people normally dispense with the safety and just risk a dunking - in most cases the slack line would take up after they had hit the water. The tighter the tight line can be pulled the easier it will be to cross but as the Tyrolean becomes more horizontal the strain on the anchors, even with body weight, can be enormous. The maximum load occurs when a caver reaches the middle of the rope.

Caving ropes have enough stretch that even when rigged as tight as possible, without using a mechanical advantage to tension them, it is not possible to generate dangerous loads. However care must be taken when using low stretch line such as wire cable or Kevlar rope.

Tyroleans cannot safely be run around corners. The heavily loaded rope undergoing side to side abrasion wears through very

TYROLEAN ANCHOR LOADS*

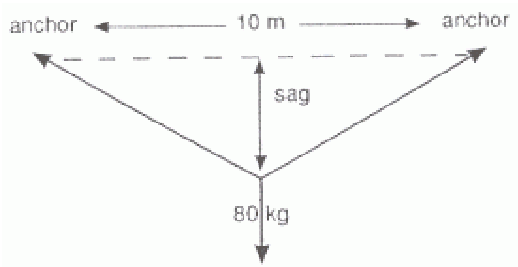


Table 4: 1

Sag (m)	Load per Anchor (kg)
3	80
2	100
1	200
0.5	400
0.1	2000

** For an 80 kg caver in the middle of a 10 m Tyrolean Initial anchor loads of 0 kg*

quickly. Wherever the rope touches rock an intermediate anchor must be placed and preferably fitted with a stand-in loop to make it easier to pass.

WATER

Water is best avoided. Most stream caves have a clean-washed zone, which can be regarded as the flood risk level. Depending on this risk and the water temperature, pitches should be rigged a safe distance from the water. In extreme cases this may require a traverse to it the far side of the pitch to descend in safety.

Ropes rigged in or close to water can be dangerous in several ways. Should a caver become soaked in a cold cave it will lead to undue fatigue and possibly exposure. If there is a flood while a caver is on the rope he could be at immediate risk of drowning. Anyone below a wet pitch when a flood occurs may find it impossible or dangerous to ascend and the rope may become "thrashed" by the flood waters so that it is unsafe to ascend when the flood has passed. Even in non flood conditions ropes have worn to a dangerous degree when rigged in moving water.

When there is no choice but to rig in or close to the water the rope should be hung as far from the walls as possible to avoid the rope being thrashed against the rock. At the same time the rigging should be kept uncomplicated so that it never becomes necessary to cross a knot, deviation or rebelay while under a waterfall. Once the group is down and there is no one following the rope can be pulled away from the water and rock and tied tight so that it cannot touch the rock no matter how high the water becomes. If the cave is to be left rigged the rope should be hauled up by the last person on the way out and coiled at or above the belay to keep it out of danger.

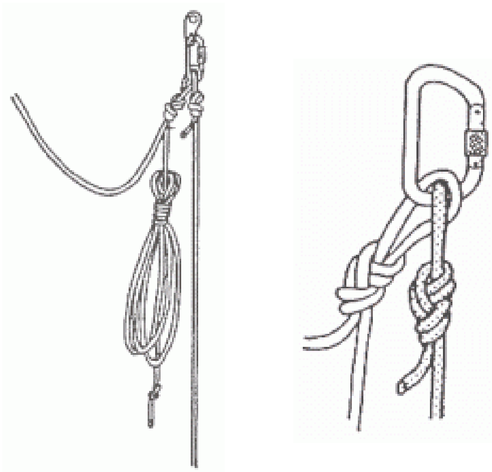
"HORIZONTAL" WATER

When the water is cold it is desirable to stay as dry as possible. If a Tyrolean cannot or has not been rigged over deep water one can float across on a large inner tube with a cross of tape or cord tied to sit on. Balance is delicate and progress slow but it is better than full immersion. For long pools, inflatable boats can be used but they are heavy and bulky to carry and there may be problems with hauling them back and forth across the pool for each person.

Boats are only worth the trouble for exceptionally long pools or those near the entrance. Swimming should be a last resort especially in cold caves. If it must be done stay buoyant. A partly inflated garbage bag or wine cask liner in side one's oversuit works wonders. The same goes for packs. A well loaded pack will fill with water and sink like a stone, and take anyone who fails to let go with it! The pack can either be made buoyant or left behind and hauled across with a rope once the pool has been negotiated. Wetsuits of course go a long way to solving most of these problems. In passages with a low airspace it is well worth rigging a tight line through the best route so as to have something to follow for a "roof sniff" or short dive

SHORT ROPES

If it looks as if the rope will not be long enough extra rope should be tied on before starting the descent, it can always be removed at the bottom if it is not needed. Knots are always a nuisance to cross. Wherever possible arrange them so that there is a ledge to swing onto to pass and definitely avoid knots near



Ropes joined at a rebelay

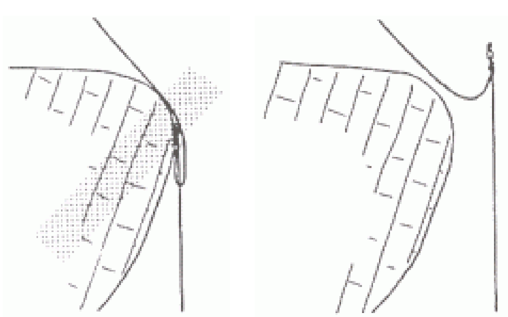
falling water. A smooth wall to balance against makes crossing easier than free space and psychologically, it is better to cross a knot closer to the ground.

It is better to join ropes at a belay even if it means wasting some rope. This is done by tying two end loops linked through each other and then clipping the down loop (or both) to the anchor. Any excess rope can be used to make a stand-in loop or bundled at the anchor and fitted with a stopper knot so that nobody can descend it by accident.

RIGGING FOR COMFORT

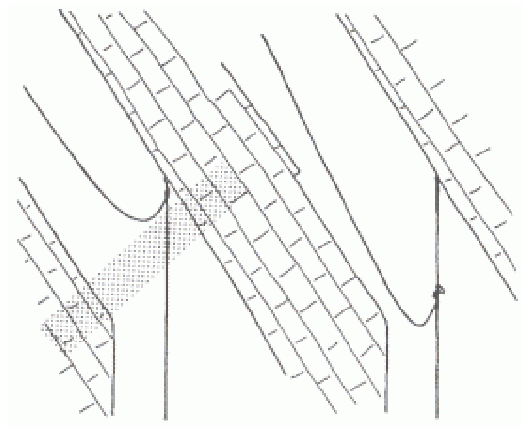
During exploration, prospecting or one-off sport trips some difficult rigging can be tolerated. However, when a cave is to be rigged for a large group or heavy usage it should also be rigged for ease of travel, so long as safety is never compromised. Comfort considerations are a collection of small, often subtle features, which are usually learnt by experiencing uncomfortable rigging.

Some hints:-



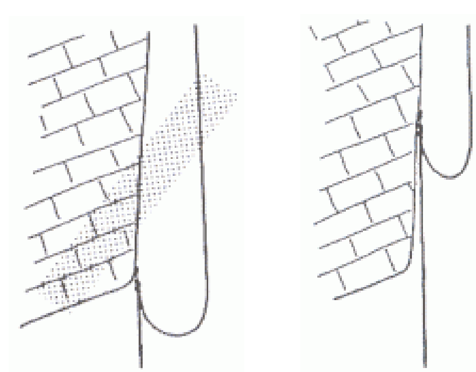
Safe *Easier*

- Rig high. Look for anchors, which must be reached up to rather than down to, both at the top of the pitch and for rebelays. High anchors avoid the need to grovel over edges and often provide a free hang with no immediate need for another anchor.

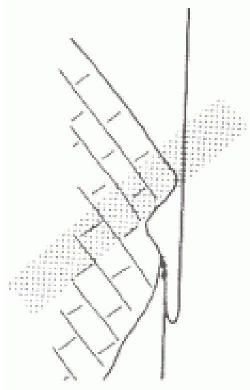


Safe *Easier*

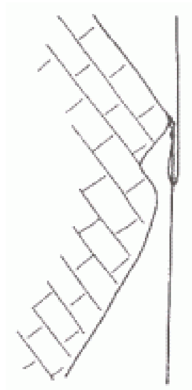
- When rigging it is often necessary to make long reaches and acrobatic moves but once the rigging is installed there is rarely a need for the whole party to suffer the same inconvenience. A sling or long rope loop can be attached to a distant anchor so that a caver can pull the belay toward him rather than stretching across to the anchor itself. This also reduces the fall factor should the anchor fail and is a good, economical way of rigging pitch heads. When this type of rigging must be crossed as a rebelay a karabiner or maillon can be placed at the knot to make insertion and removal of a cowstail easier and faster than trying to force a karabiner in and out of a loaded loop of rope.



Safe *Easier*

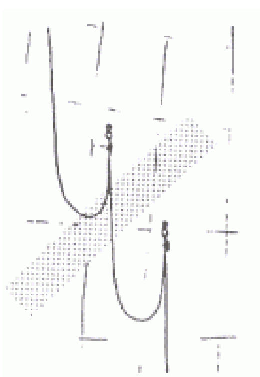


Safe

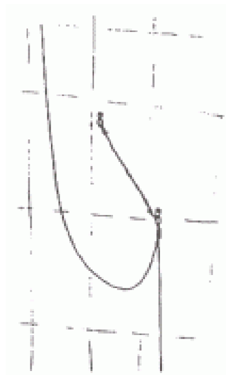


Easier

• Keep aerial rebelays to a minimum. Place rebelays where there is a landing platform or at least footholds to aid crossing over.



Dangerous



Safe and Easier

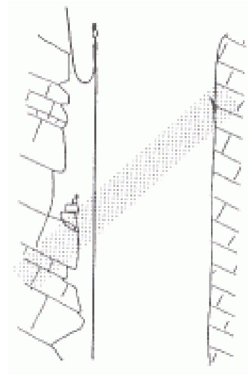
• Double anchor rebelays, when considered necessary, should be rigged so that it is only necessary to cross one rebelay.

• Do not insist on a free hang from the start of a pitch. It may be easier to descend a short way against a wall or slope and then place a rebelay, which gives a free drop.

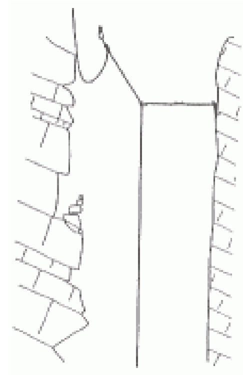
• When a swing after a pendulum is extreme, a stand-in loop may be useful.

• Do not be tempted by "bolt farms" or an abundance of natural anchors to use more anchors than needed. A complicated lacing together of several anchors can be confusing for all but the person who rigs it.

• A rope hung just off a smooth wall so that a prusiking cavers feet touch but there is no need to fend off, is easy to climb.



Messy



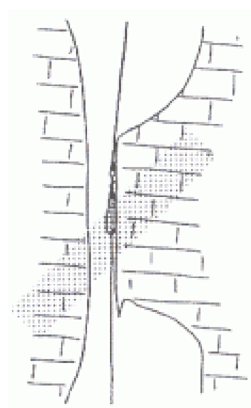
Safe and Easier

• Rig rope clear of spiky walls, which can make prusiking difficult.

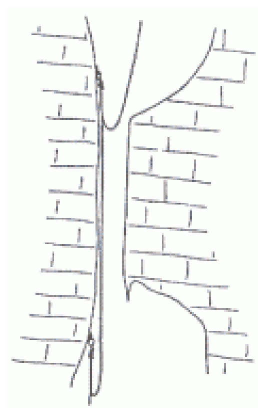
• Rig away from loose rock. Loose rock may mean that it is only safe to have one person on a pitch at a time.

• A rope only needs to be rigged so that it is free when in use, not as far from the rock as possible. It is often acceptable to have the rope laying against the rock so long as it will be pulled free when someone is on it.

• Awkward rebelays require more effort to make them easily passable. Save direct attachment bolt hangers and tight loops, which do not easily take cowstails for tiebacks and anchors, which do not need to be crossed.

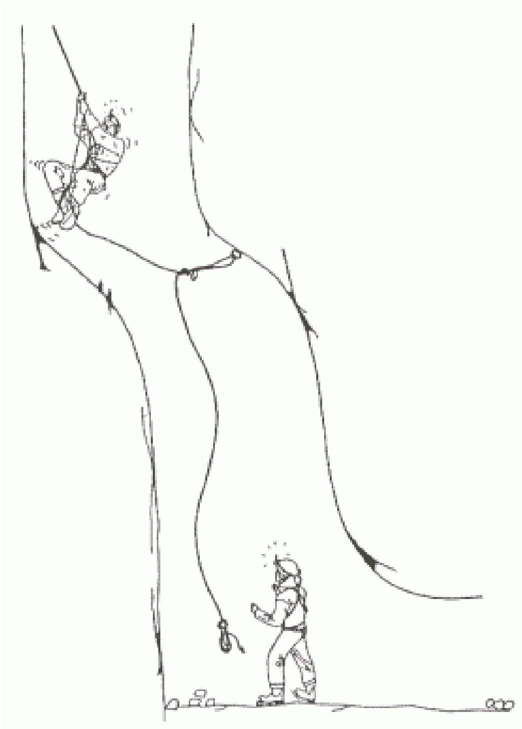


Difficult



Easier

• Avoid placing rebelays or deviations in narrow sections. One above and a second below a constriction would be easier to pass.



- If there is a ledge to stand on during the changeover, it is possible to leave no slack in the upper rope. This may be worthwhile if the anchor is of poor quality but if there is insufficient slack it will be impossible for two people to be climbing (one either side of the rebelay) at the same time.

- Avoid rigging deviations with no footholds.

- Make deviations as gentle as possible.

- Avoid rigging deviations with very short slings, which reduce their manoeuvrability.

- Rig difficult traverses high enough to allow the rope to be weighted rather than forcing everyone to climb unaided all the way.

- Rig clean. A rope or caver, which is not covered in mud, is much easier to handle than a dirty one.

- Do not regard all these hints as compulsory. Indeed some are contradictory! Ultimately each pitch has its own rigging requirements.

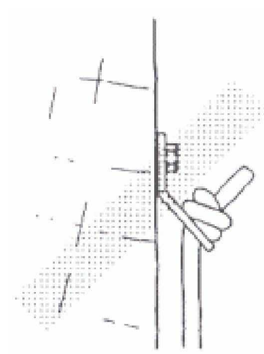
5 ADVANCED RIGGING

Ultralight and Cord Technique have a reduced safety factor when compared with traditional rigging. They therefore demand totally competent Alpine caving technique and then extra precision. These rigging techniques are most useful for prospecting or light sporting trips when wear and tear on gear is not too severe.

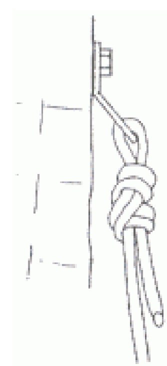
ULTRALIGHT RIGGING

Ultralight rigging is not so much a technique as a philosophy of reducing equipment weight, then rigging carefully to compensate. Rope makes up the bulk of the load so the lightest available is used - 8 mm, 7 mm and hopefully in the not to distant future even thinner "super fibre" ropes. Deviations instead of rebelays and an absolute minimum of slack in rebelays gives considerable rope savings. Thin ropes are not at all tough so only "pure" Alpine technique, with **NO** rubbing of rope against rock can be tolerated.

Rigging gear can also be reduced. Seven millimetre aluminium maillons on belays and mini-krabs on deviations are lighter than standard karabiners. Direct attachment bolt hangers or tying the rope into the eye of suitable hangers will also save weight. Pitons and nuts can be left at home and jammed knots and slings used instead.



Risk of rope damage



OK

The greatest risk in Ultra-light Rigging is that 7 mm and 8 mm ropes cut very easily as they zip across rock edges under the weight of a falling caver. Ropes must therefore be rigged to avoid this with tight backups and Y-belays. The chances of any shock loading of the rope must also be kept to an absolute minimum. Seven millimetre ropes made specifically for caving are rare and even when found, cannot be guaranteed safe. Extreme care must be taken in choosing one, even to the point of shock testing prospective ropes until a good one is found.

Even with the lightest equipment, one caver can only reasonably carry about 300 m of rope in an easy cave, making any known cave possible with a group of four.

CORD TECHNIQUE

La Technique Cordelette or Cord Technique takes lightweight one step further. Instead of fixing rope down the entire cave, the rope is retrieved from each pitch and a double length of string left behind so that the rope can be replaced from the bottom on the way out. It is a technique to be used only when nothing else is possible. It is frustratingly slow, fiddly and demandingly precise but is also the lightest rigging style yet devised.

Cord Technique is rarely considered for rigging an entire cave. It is more convenient to carry as much light rope as possible, to be rigged as soon as possible and reserve the Cord Technique for when there is no more space for normal rope. What is "possible" is quite subjective. There is usually no great problem with being overloaded for a series of entrance pitches where the load will diminish rapidly on the way down but dragging 300 m of rope to - 600 m is a different proposition. The upper length limit for a Cord Technique pitch is 40 m to 50 m so longer pitches will either need to be rigged Ultralight or broken into smaller pitches and this is not always possible. On longer pitches it is feasible rig a fixed rope to within 50 m of the bottom and retrieve the last length using Cord Technique. In virtually all caves a certain amount of fixed rope must be carried.

Cord Technique is most suitable for solo or two person trips. More people only spend a lot of time waiting around and considerable problems occur on small ledges, as the group is forced to keep close together.

Cord Technique may also be useful to leave on an "up" pitch without the need to leave a rope on it. This is especially useful for flood prone pitches where the integrity of the rope will be in doubt after a flood or two.

Poor judgement could leave the caver trapped below his mistake. Cord Technique must be practised on the surface and in easy caves before taking the more committing step of using it in a deep cave.

EQUIPMENT

Cord Technique requires very little equipment that Alpine cavers would not already have. In fact the lack of need for vast amounts of expensive rope means that it is cheaper to rig "string" than any other method.

The normal range of Alpine caving hardware is needed as well as one 6 mm steel maillon for each pitch. These open just enough to take a 9 mm rope, wear well and are strong enough. Seven millimetre aluminium maillons are also adequate but while, lighter they wear quickly as the cord runs across them and are three times the price. For pitches in the 30 m to 50 m range the sliding friction through a small maillon makes re-installation of the rope difficult. It is then worthwhile using a 10 mm aluminium maillon or if none are available, two smaller maillons side by side.

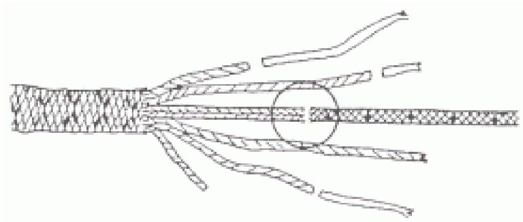
The cord used is usually 3 mm nylon "venetian blind" cord although 2 mm cord can be used for small drops when the loads are low. Despite a considerable weight advantage 2 mm cord tangles easily and makes a lumpy knot, which pulls through maillons badly. The cord is stuffed into light proofed nylon sacks 30 cm long and 15 cm in diameter and fitted with a suspension loop at the top and a small loop inside at the bottom to tie the end of the cord to. The top is then closed with a drawstring and cordgrip. The only other equipment needed is a few 7 mm aluminium maillons as links things where knots are not suitable.

The rope

One or two ropes with specially prepared "tails" are required. I normally take a long and a short one so that there is no need to handle a long rope on short pitches. Using a 50 m rope on a 5 m pitch usually involves a tangle. The rope should be 8 mm and of a flexible design so that it runs through the rigging easily. Remember also that as it is the same rope being used over and over again, it will wear out faster than fixed rope.

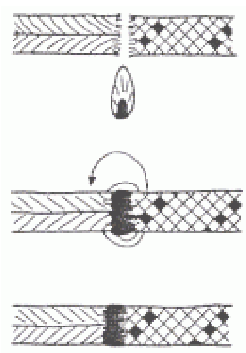
PREPARATION

The rope must taper smoothly from 8 mm down to a 3 mm diameter, 30 cm long tail.



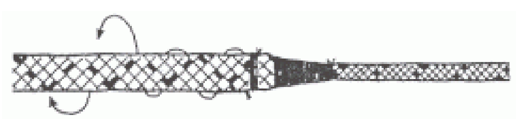
1 The sheath is pushed back to expose 30 cm of the core.

2 Two central bundles of core are selected and 15 cm is trimmed off.



3 The trimmed bundles and the end of the 3 mm tail are fused end to end over a small flame or "hot knife". The joint is then reinforced with stitching.

4 The rest of the core bundles are trimmed to give a gradual taper over a length of 15 cm.



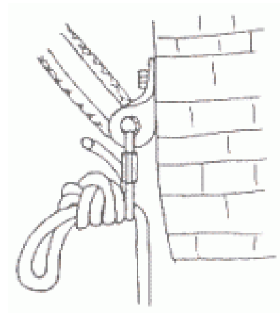
5 The sheath is pulled back and a 3 mm long whipping is made 5 cm from its end.

6 Four strands of sheath are trimmed out to increase flexibility then a tapered whipping is started 5 mm from the first whipping. Once started, the remaining sheath can be unraveled and progressively trimmed to give a conical whipping no longer than 15 mm. A small amount of rubber glue will help hold the whipping in place as it is being tied and a coating of glue will protect the thread.

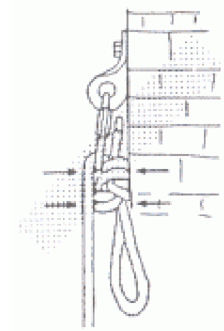
7 The rope is stitched through to further lock the tail in place being careful to not stiffen the rope with too many stitches.

RIGGING CORD TECHNIQUE

Pitch heads are rigged as for Ultralight technique with double anchors and handlines to exposed anchors. Several ropes 4 m to 5 m long as well as shorter slings to tie between the easier to reach anchors are required.



Good



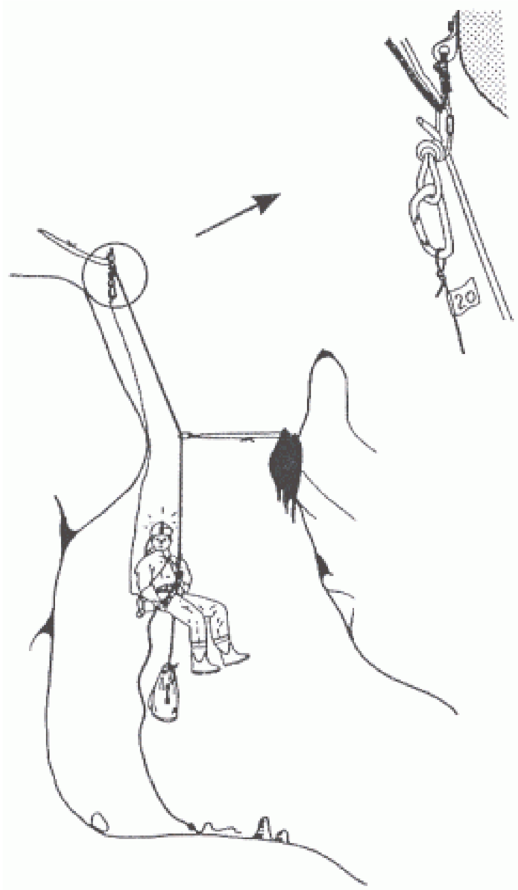
Bad

On short uncomplicated pitches it may be possible to attach the 6 mm maillon directly to the last anchor. When this is a bolt it will mean that the maillon is very close to the rock. If this is the case one must be careful to orient the knot on the descent rope so that it is outwards and will not jam between the maillon and the wall. The maillon itself is hung with its gate uppermost so as to allow a maximum of space for the rope to pass at the bottom. The tieback is pushed to the top of the maillon and any loose ends tucked out of the way. For a rig, which will run better, a short tail or sling can be attached to hang the final maillon in space.

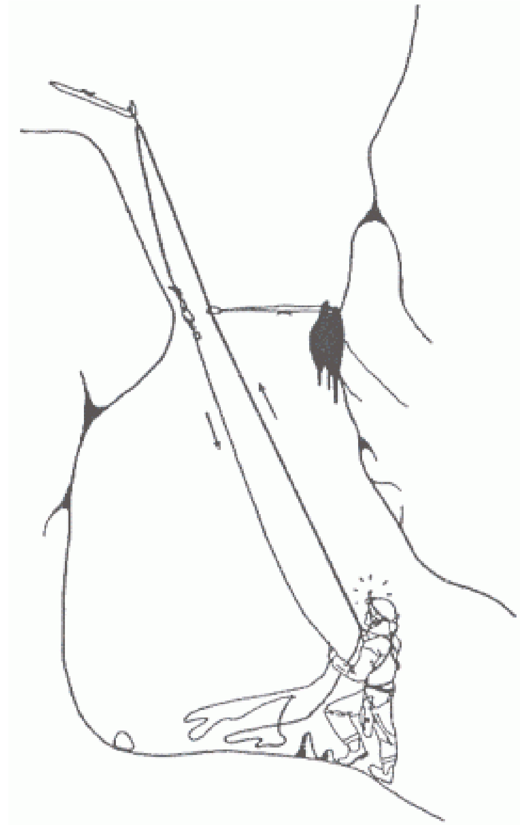
On pitch heads, which found over it is better to fix a rope at the top down to an anchor which gives a free hang. Lower down, rebelays, which are not possible with Cord Technique and must be treated as separate pitches, are avoided and replaced with deviations wherever possible. Deviations must be arranged such that the rope can be pulled down without the cord fouling against the rope, rock or slings - this is usually possible simply by standing back a little from the base of the pitch.

Placing the Cord

Initially the cord is packed in bulk with joins tied by Round knots and the end tied to the tag at the bottom of the sack. On the first trip the cord is cut to suit with a carbide flame as each pitch is rigged. Afterwards the cut lengths are measured and tagged with small flags of adhesive tape at one end. On future trips appropriate lengths of cord are chosen just as one would choose ropes for any other trip.



Cordelette descent



Rope retrieval

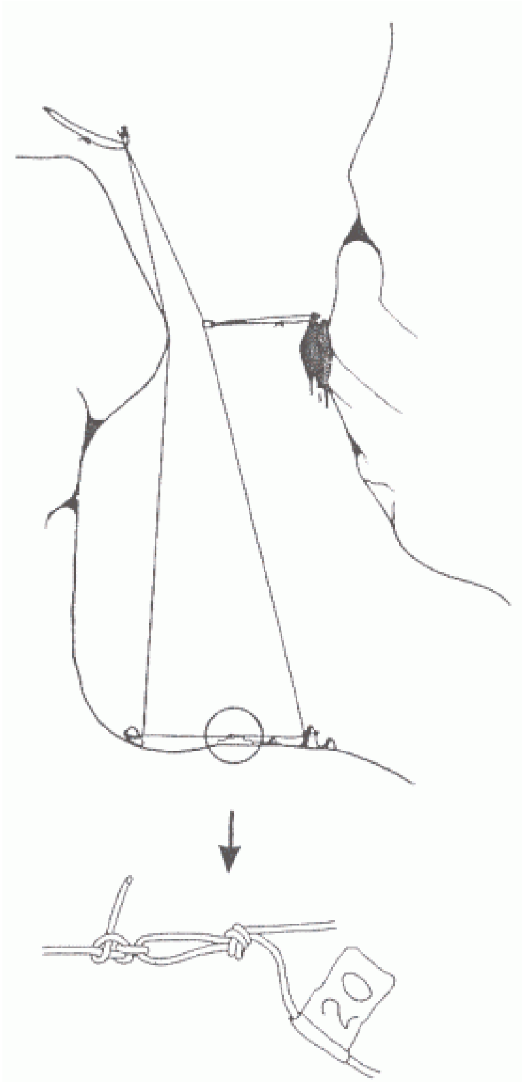
When exact lengths of cord are not available several cords can be tied end to end with Round knots. Neither the knots nor the tape flags cause any problems sliding through the maillons.

To descend, the rope is jammed in place with a Figure-9 loop, which is far too large to fit through the maillon. A karabiner is clipped to this loop in order to attach the pull-cord. This cord is allowed to run freely from its sack as the caver descends taking care not to spin and twist the cord around the rope. When the cord is packed in bulk, it is simplest to use a separate pull-cord. At the bottom, the end of the cord is removed from its sack and tied onto the tail with a Round knot.

The rope is retrieved by pulling on the cord until all the rope is on the bottom and the pitch is rigged with a double length of cord. The cord is cut if necessary and the ends are "coded" by tying an overhand loop in the "pull" end and attaching the end untied from the tail to it with half hitches. Coding is not always necessary but it is a good habit to get into and avoids problems such as trying to pull the rope up through a deviation.

The knotted the strands of cord are separated and lightly anchored with rocks or onto spikes to prevent tangling due to air or water movements. The caver is now free to move on, having left a minimum of equipment.

Ascent is simply the reverse of the descent procedure. The rope tail is tied with a Round knot to the end of the cord and the rope is pulled back up until the Figure-9 loop is once again jammed against the maillon. As the rope is pulled through it begins to move by itself and when the pitch is long or its walls are jagged it is recommended that the free end of the cord be clipped to the Figure-9 loop so that the rope can be eased gently into place or retrieved should it snag on the way up. The rope is ready for the caver to ascend, the cord is progressively stuffed into its sack on the way up after being untied from the end of the tail.



String coded and ready to go

ORGANISATION

A detailed tackle list for both rope and cord should be drawn up (see Tackle Lists, Chapter 8). In the cave the rope is stuffed directly into the sack between pitches so that it runs freely out and down (or up) the next pitch without needing to be rehandled. With so many bits and pieces, equipment organisation is of the utmost importance for a smooth trip.

Two cavers working together can move very fast using the Cord Technique. One can travel in front rigging while the other stays behind and fixes the cord, the result is very little dead time and rigging speeds almost as fast as for conventional rigging.

The need for care cannot be over emphasised. The Cord Technique demands an attention to detail and neatness not necessary in any other rigging style. The string especially must be handled so that it does not become tangled or wound around itself. Should this happen and it becomes impossible to rectify, the caver will be unable to rerig his rope. At **best** he will suffer a long uncomfortable wait for his rescuers.

RIGGING STYLES COMPARED

Rigging which suits one caver may horrify another. Any comparison between styles must be highly subjective, depending largely on which style is preferred by the caver making the comparison.

Issues such as safety, conservation, speed and enjoyment lead into pointless arguments, which ultimately come back to the competence of the cavers concerned. The only clear comparison, which can be made, is that of relative weight. To this end, let us compare the loads required for Khazad Dúm, Australia's best vertical classic - a cold, wet 320 m deep cave. It has a total of 170 m of pitches with several permanent eyebolts.

It must be borne in mind that the lighter a rigging style is, the more care and time it takes to rig. Lighter styles only have an advantage over heavier ones when the equipment becomes too heavy for the group to carry.

For example. A group of two in Khazad Dúm would have a hard time carrying their American gear. Two and a half sacks of Alpine gear would be a reasonable load. Their two light sacks of Ultralight gear would cause them no trouble but they would spend more time or compromise safety rigging it. One sackload of Cord Technique gear between two would leave the cavers underloaded and they would be even slower rigging it.

However, triple the depth of the cave or halve the number of cavers and the balance would be pushed in favour of the lighter styles.

SHOCK ABSORBENT RIGGING

Caving ropes are often exposed to the risk of shock loading. Ideally, what is required is a static rope, which will readily survive shock loads or rigging which will absorb such loads. Various attempts have been made to solve the problem. Some tried a "Dynastat" rope - a thin low stretch core surrounded by dynamic sheaths. A severe shock load would break the core and in so doing absorb some of the energy, thereafter the sheaths would act as a dynamic rope, stretch a lot and absorb the rest of

WEIGHT COMPARISON TABLE FOR KHAZAD DUM

Table 5:1

Equipment	**Style**				
	American	**Alpine**	**Ultralight**	**Cord Technique**	
Rope (mm)	11	9	8	8	3#
Length (m)	250	210	210	86	190
Weight (kg)	18.8	10.5	8	3.3	0.9
Protectors	10	-	-	-	
Weight (kg)	0.6	0	0	0	
Tape slings	-	8	8	14	
Weight (kg)	0	1	1	1.7	
Hangers,	-	5	5	5	
Links*	-	16	16	3	9
Weight (kg)	0	1.1	0.5	0.1	0.4
Gear Sacks##	4 (3.6)	2 (2)	2 (1.2)	1 (0.7)	
Weight (kg)	3.4	1.7	1.7	0.9	
Total Volume (L)	**90**	**47**	**31**	**18**	
Total Weight (kg)	**22.8**	**14.3**	**11.2**	**7.3**	

* *Aluminium karabiners for Alpine. 7 mm Aluminium maillons for Ultralight. 7 mm aluminium and 6 mm steel maillons for Cord Technique*

 # 3 mm venetian blind cord

Figures in brackets indicate actual 25 L sackfulls. Alpine style would need an extra sack for food, spare clothing and carbide while all others should be able to fit this into the left over space in the sacks.

the energy. During the fall the rope would lose its static properties forever and be excessively bouncy - a good indication that it was time to throw it away.

Another possibility is to use shock absorbing slings - lengths of tape, which are bunched and sewn "concertina" fashion so that under shock loads the stitching progressively bursts and in so doing absorbs energy. The idea has not really been tested in caves, the slings are expensive and bulky, one or more may be needed for each pitch. Their reliability after a year or two of cave use is uncertain.

SHOCK ABSORBING KNOTS

A third option, shock absorbing knots, at first appears more reasonable. By tying a suitable knot in a length of static rope it is given some dynamic properties. Unfortunately they do not work reliably enough to be safe (see Table 5:2, p 66). The abnormal loading of any knot is exceptionally hard on the rope and almost invariably reduces the number of FF1 80 kg falls it will survive.

Shock absorbing knots have some chance of working in new rope, which normally fails within two FF1 80 kg falls (i.e. 7 mm or some 8 mm ropes). Their performance however is so variable as to make them more dangerous than no shock absorbing knot. The only possible advantage that a shock absorbing knot may give is that the extra "end effect" created by another knot tightening may dampen the shock of the first fall and reduce the chances of one's ascender biting through the rope sheath. The problem is that the shock absorbing knot may not slip as it should and the rope may break on its first fall instead!

SHOCK ABSORBING? KNOTS

Table 5:2

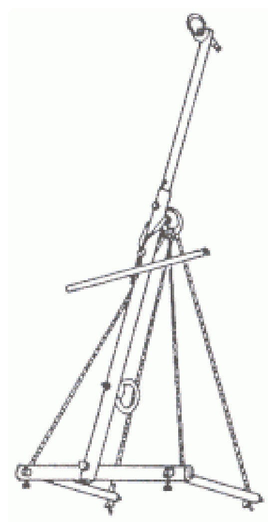
Rope (mm)	**Age** (years)	**Shock Absorbing Knot**	**Falls** FF1, 80 kg, 1 m
9	new	none	40
9	new	Overhand loop	4
9	new	Alpine Butterfly	3
9	4.5	none	3
9	4.5	Overhand loop	2
9	4.5	Double Bowline	1
8	new	none	1
8	new	Overhand loop	2
7	**1**	**none**	**1**
7	**1**	**Overhand loop**	**0**

9 mm rope was BluewaterII
8 mm rope was Bluewater accessory cord
7 mm rope was Beal accessory cord
In only one test out of thirteen did a Shock Absorbing Knot give a clear improvement. The 7 mm rope results are especially frightening.
See also Marbach and Rocourt, 1980 for a positive appraisal of Shock Absorbing knots.

CLIMBING

It occasionally becomes necessary to climb up a pitch or wall to reach a continuation passage in a cave or for that matter an "up" cave has to be climbed all the way. Most cave climbing is done using standard rock climbing techniques and should not be attempted without first gaining climbing competence above ground.

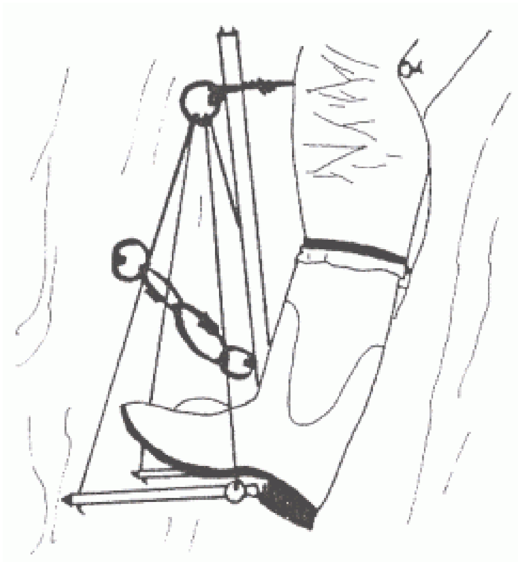
Underground, extensive use is made of artificial aid where there is more emphasis on security and less regard for ethics. The idea is not to put up a new route but rather to gain access to cave, which cannot otherwise be reached. Maximum use is made of quick anchors such as slings, nuts and pitons, which may not be bombproof but will support bodyweight plus a bit. Caves often have blank walls with few natural lines of weakness to follow so climbing often comes down to placing a line of bolts up the wall to make a "bolt ladder". Traditionally this has been done by hand drilling and has been limited by the strength of the average cavers bolting arm, which is only good for five to ten bolts per session. The appearance of portable battery-powered hammer drills, which can place up to twenty 8 mm anchors on one charge, will change bolting tactics considerably over the next few years.



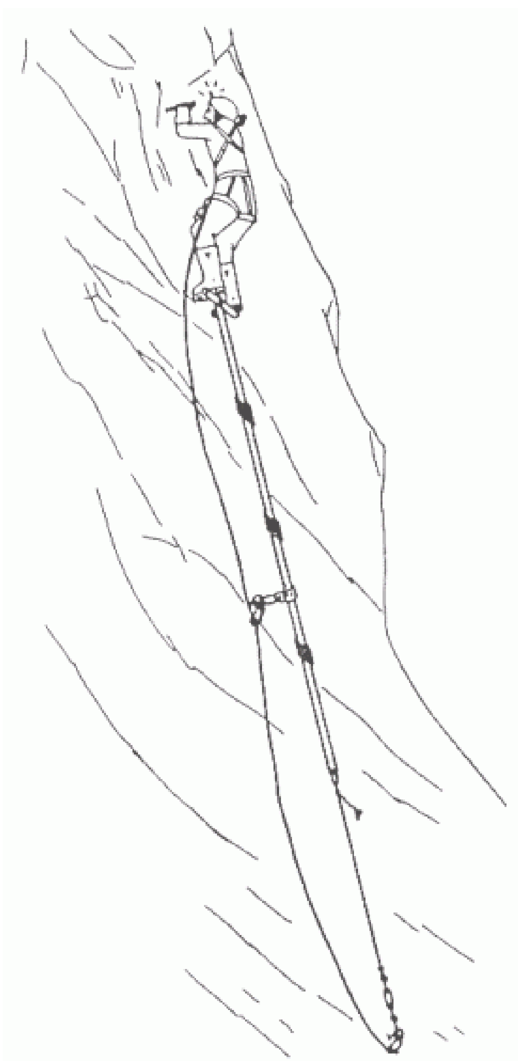
Climbing Platform

CLIMBING PLATFORM

For long lines of bolts a bolting platform can be constructed from aluminium tubing. Such compact, collapsable platforms weigh only 1.5 kg and make it possible to stand higher than with etriers and reach 1.5 m between bolts.



Climbing Platform in use



Climbing Pole

CLIMBING POLE

A vast improvement in reach can be obtained by using a climbing pole. This can be thought of as a lighter version of the oldstyle "scaling pole". It is a 3 m to 5 m long aluminium pole which telescopes or bolts together and has three attachment points: an eye at the top, a moveable ring which can be clamped anywhere along the lower half of the pole, and another eye at the bottom. The moveable ring is clamped in position and clipped directly to the uppermost bolt and a low stretch rope such as Kevlar or steel cable is attached to the eye at the base of the pole and tensioned as tightly as possible to a lower anchor with a turnbuckle or pulleys. A prusik rope attached to the top eye of the pole allows the climber to ascend and place an anchor from the top of the pole. Once placed the pole can be lifted up to the new anchor and re-anchored as before. The loads, which can be generated on the anchors, are enormous and a light pole is liable to bend or break. These problems are further increased on vertical or overhanging walls, thus a climbing pole is of most use on walls, which are less than vertical. Climbing poles are heavy at over 5 kg+ and need a brave climber, good rock and an excellent belay.

Both platforms and poles, while giving valuable increases in reach, involve a considerable amount of extra paraphemalia, which must be brought into the cave, assembled and organised. Once in use, the danger of being injured in a fall while attached to a big hunk of metal must also be considered.

SCALING POLE

The Scaling Pole is the traditional solution to reaching high passages. It is assembled from tubular aluminium sections held together by threaded or angle-section joints and a ladder or rope hung from the top. A scaling pole has a range of around 10 m under good conditions, often making a climb feasible in one "hit". In narrow pitches the pole can occasionally hauled up to the high point and used again.

Scaling poles are heavy and bulky and therefore unsuitable for use in difficult or very deep caves or when a large team is not available to carry the pieces and help support the pole while the climber is ascending. It may not be possible to use a separate belay so the pole cannot be allowed to fall.

In rotten rock there may be no alternative to a scaling pole.

AID CLIMBING

On an expedition or for a short climb, slings or etriers will probably be used to gain around a metre between aid points. In order to reduce time bolts only need to be half drilled to hold body weight with a full depth one placed every fourth bolt for safety. Smaller bolts also mean smaller drill holes. Six millimetres self-drilling anchors are adequate as are 6 mm "Dynabolts" which require a smaller hole still though both are too weak for the loads generated using platforms or poles. Further time can be saved when on good rock by drilling shallow down-angled holes and using a skyhook in them for a move or two between good anchors.

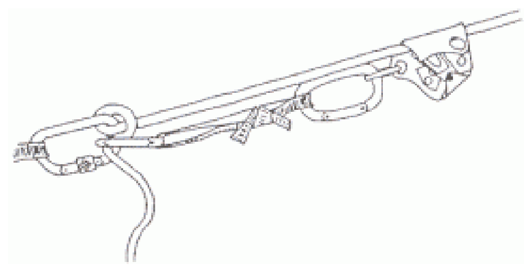
Another handy device for aid climbers is a "cheat stick". In its simplest form, this is any light stick with a rubber band or hook on the top, which can be used to place a sling or sky-hook onto a hold, which is out of reach.

The technique for aid climbing with etriers is simple but strenuous. The climber begins by placing an anchor as high as possible and fitting it with a karabiner. He then hooks one of his etriers into the karabiner and climbs it until he is able to clip in a cowstail as well. He moves up the other etrier to the top karabiner to provide one for each foot then climbs as high up the etriers as possible and clips himself to the anchor with a karabiner, chain of karabiners or short cowstail, depending on the angle of the wall. Only now does he clip his belay rope to the upper anchor - any earlier would have introduced excess slack into the system at the same time as the climber was about to weight the untested anchor for the first time. Once standing in the top of his etriers the climber can once again place an anchor as high as possible.

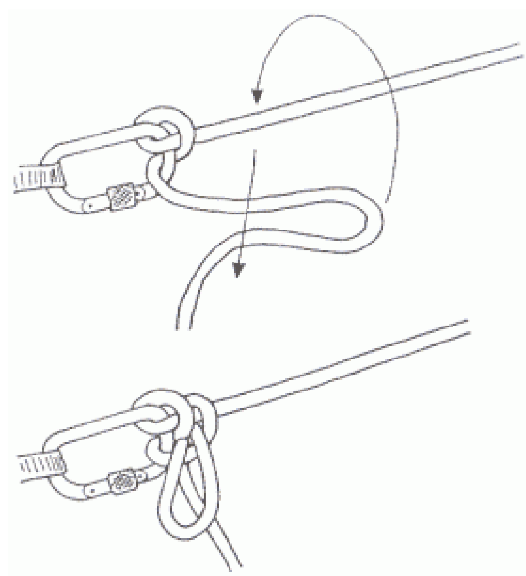
Placing a bolt at arm's length above one's head is slow and tiring and it is often better to stretch a little less in order to place the bolt more easily, especially if there are a number of them to be placed. The reach between anchors depends largely on the angle of the wall and to a lesser extent on the strength and height of the climber. Despite its appearance and abundance of insecure anchors, aid climbing is usually safer than "free" climbing as the runners are rarely more than a metre apart.

Double ropes clipped into alternate anchors improve safety even further as they continuously provide a belay, which has as little slack as possible, and a backup rope. At no stage is the belay rope used for direct support. Tension from the belayer only increases the loading on the top anchor, increasing its risk of failure.

Fifi hook



Belay rope locked off with an ascender



Locking off an Italian hitch

DESPERATE MEASURES

At times more desperate measures are called for. One can try to lasso a projection or throw a rope with a big knot in the end and try to jam it in a crack. The problem, apart from getting the knot to jam at all, is that one never knows exactly what has been caught until someone gets up - or it is pulled down!

More sophisticated than a jammed knot, a grappling hook can be used for getting a line across a fast flowing river or up a small pitch. A positive grip can be obtained by using three equally spaced small replaceable ice axe picks bolted to the end of a short handle twice the length of the picks. Grappling hooks get good grip in rotten rock and have a tendency to become snagged wherever they hit so a spare may be necessary.

When climbing a rope whose anchors may be dubious a separate rope with a dynamic belay and runners must be used. All climbing should be done with a relay using a **climbing** rope. Climbing with a static rope as a relay is dangerous and is not recommended.

BELAYING

Some rig points are in such precarious positions that the rigger may require a relay to place them. The chance of holding a fall using **ANY** body relay is negligible and in a fall both belayer and climber would probably be injured. **ALWAYS** belay using a well anchored ltalian hitch on a locking karabiner or a Sticht plate of the correct size or similar relay device.

The belayer should be anchored separately to the climbing rope in a comfortable position to one side of the anchor. This allows the belayer to escape from the belay and aid the climber in the event of a fall. He should seek a position, which is sheltered from both falling water, and rock yet still provide a view of the climber.

The rope is paid out straight towards the climber or his first runner so that in the event of a fall the rope will not be whipped sideways and out of the belayer's hands. A belayer must wear gloves and **NEVER** let go of the slack end of the rope unless he ties it off or the climber calls "safe". Should the climber fall and not be able to regain the rock the belayer ties it off or locks it with an ascender before going to his aid.

More detailed treatment of belaying can be found in most rock climbing manuals but take care to avoid out of date books, which describe "body belays". Any prospective belayer is well advised to take a practise session on a drop test rig before trying the real thing.

Safety can be improved by using runners, a high belay and having the belay set up well back from the pitch edge. Anything, which reduces the possible fall length, is a help and in any case the Fall Factor should never be allowed to approach FF1 unless a good climbing rope is used. If the rope is not new and less than 10 mm use it doubled.

Using a descender as a self-belayer for rigging is popular and acceptable if done correctly. When rigging, an ascender used to give a self-belay is dangerous and should not be used in any circumstances (See Strength of Descenders, Chapter 6 and Strength of Ascenders, Chapter 7).

Belayer in position, protecting both the climber and himself

FIXED RIGGING

There are many reasons for leaving a cave wholly or partially rigged. A cave in the course of exploration is easier to work on if it does not need re-rigging for each visit. Some rigging, traverses and climbs especially, can be difficult to derig and once derigged may be difficult or dangerous to repeat. Then again some caves are so horrible that the rope is left in them until someone finally sums up enough enthusiasm to remove it.

Ropes can wear dangerously with repeated usage and floods, yet the damage may not be apparent until the rope has been used. Even rigging which receives no apparent wear in the course of normal usage will still be suspect after five years due to the ageing of the rope and tape. Once equipment is left any number of people may use it and their competence may not be all it should be. Fixed rigging should be as "idiot proof" as possible - do not rely on an unknown caver who may not understand what he is doing to replace a deviation or rope protector.

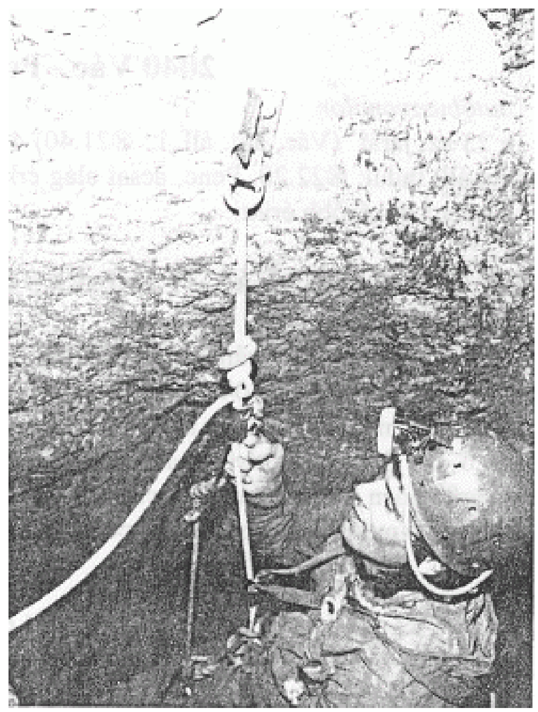
All fixed rigging must be backed up exceptionally well and be totally abrasion free, even when using 11 mm rope. Some potential rub points, notably those on traverse lines can be protected with unsplit plastic hose threaded onto the rope. In popular caves the problem of wear can be reduced by using wire or steel cable for traverse lines.

On low-level traverses across pools it may be acceptable for a caver to cross wires attaching himself by a single steel karabiner (an aluminium one will wear rapidly). When the consequences of failure are more serious than a dunking in cold water the first person should be belayed across and then fix a rope to separate anchors from the wire for the rest of the party.

Wire ladders are often fixed and they are particularly suspect due to electrolytic corrosion of their aluminium/stainless steel/copper joints in the presence of water - copper is especially bad. Their failure rate is unacceptably high for them to be used without a self-belay rope and one should always be left rigged for this purpose.

Bolts have their own particular problems. They were originally designed for single usage rather than the repeated use they get when placed in popular caves. Even so, their failure rate is acceptably low. After several years the thread degrades with corrosion or wear and many suffer from misuse such as cross threading and over-tightening which can leave the anchor plugged with a sheared-off bolt stub. It is also good practise to quickly inspect the anchor for cratering, chipped casing or hairline cracks before using it and with a hanger in the way this is not possible. Unless they are well greased fixed hangers can also accelerate corrosion in the anchor, thus negating the good intentions of the person who left the hanger in the first place.

Heavily trafficked caves can and have been equipped with heavy duty bolts and even metal bars for belays. While perhaps a little un-sightly, heavy bolts are infinitely better than the 8 mm "bolt farm" which may otherwise appear. They can be either 10 mm self drilling anchors with stainless steel set screws or 12 mm "Loxins" with angle iron or welded eyebolt hangers. The Loxins are to be preferred as the anchor can be readily removed for inspection and replacement thus making the bolt last "forever". The hole they require may seem enormous at 2.5 cm diameter and 10 cm deep but with two people it takes as little as 40 minutes to drill.



12 mm Loxion with angle iron hanger

Anything left in a cave should not be left without thought. Fixed equipment may well make a cave easier and perhaps safer for everyone who follows but inevitably reduces the challenge as well. Remember also that the person who places fixed rigging has a responsibility to leave something which is neither dangerous to others nor a piece of junk which someone else will eventually have to carry out.

Ice build-up on fixed ropes occasionally causes problems in alpine areas. Apart from rendering the rope unusable for a time an ice coating does no real damage. The only potential danger occurs in spring if the ice melts first where it is in contact with the rock and leaves a heavy blob of ice hanging on the rope to stress the rigging.

On a less spectacular although considerably more dangerous scale there have been instances of a rope becoming lightly iced, causing cavers to lose control on their way down and get ice clogged ascender teeth on their way up. On more heavily iced rope it may even become necessary to break the ice crust off a rope before being able to use it.

PULL-DOWN RIGGING

Through trips done *en rappel*, or derigging a rope from a climb to leave behind a minimum of gear are a special case in vertical caving.

A through trip is easier if the cave has already been rigged with eyebolts or steel rings. If not it can be left with double ring hangers or backed-up slings on natural anchors. To rig "on the cheap", light cord or tape hero loops can be tied to 2 cm long bolts (no hangers). Slings are usually required for pull-downs from natural anchors so as to reduce friction.

The rope used on a through trip can be thicker than normal. Far less rope needs to be carried than for a normal trip but it will get considerably more wear with the repeated use. The rope needs to be twice as long as the longest pitch and two equal lengths can be knotted rather than carry a double length rope. For safety it is advisable to carry extra rope or cord so that if the rope becomes stuck during a through trip the descent can be continued. Never try to climb a jammed rope as it may suddenly unjam with a climber on it. Once that first rope has been pulled there is no turning back!

Standard rigging safety precautions such as double anchors and avoiding abrasion points are still needed although slight abrasion can occasionally be tolerated for a single descent. It is also necessary to rig so that the rope can be pulled down with little risk of it jamming as it falls down the pitch and to abseil in a manner that does not twist the ropes. To be sure that the rope will pull freely a test pull of a metre or so should be routine before the last person descends. Do not forget to untie the stopper knot from the end of the rope before trying to pull it down and be sure to pull on the correct rope!

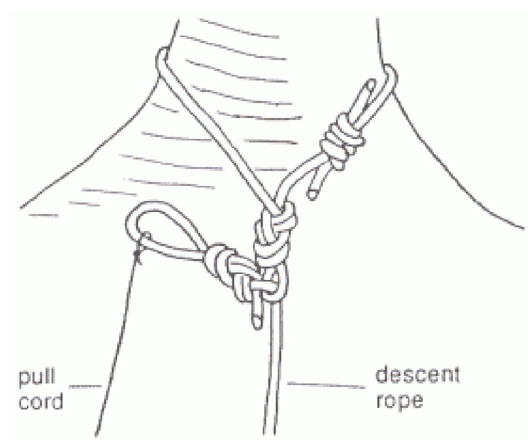
Most bobbins only work on single rope. Double rope descents can be done using a rack or double bobbin. Figure-8 descenders can also be used but they twist the rope and make the pull-down difficult.

CORDELETTE STYLE

Just as one would do for the Cord Technique, a single rope as long as the longest pitch and fixed at the top with a jammed knot can be used. The rope is retrieved using 3 mm cord or any collection of shorter ropes and slings on hand. There is no need for a special Cord Technique "tail" on the rope unless one intends leaving a string in place but some means of jamming the knot at the top is required. This can be a ring hanger, small maillon or closed ring attached to a sling or simply a knotted eye tied in the sling itself.

DECROCHEURS "Unhookers"

Decrocheurs are mechanical devices, which allow the descent rope to be unhooked from the belay once the caver has reached the bottom of the pitch. None of them offer any advantages over a cordelette style pull-down.



"Double roping", Cordelette system

6 DESCENT

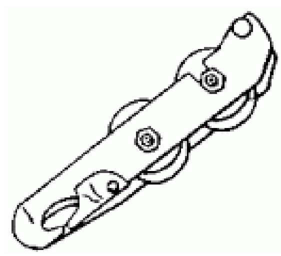
Classic abseil

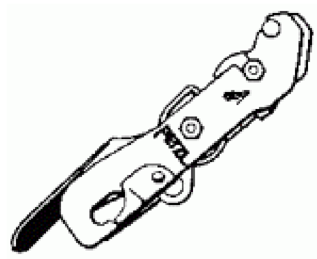
Before the days of mechanical descenders, cavers descended pitches using a classic abseil. This was done by running the rope between the legs, forward across one hip, diagonally across the front of the body and over the opposite shoulder with one hand to control the rope below and one above for balance. Not very comfortable, safe or used much these days.

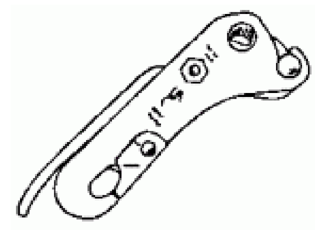
Shoulder abseil

A more comfortable classic abseil runs the rope across the back with one arm holding above for balance and one arm below with a twist of rope around the wrist. The Shoulder abseil is still a good way to descend slopes without a descender or for use on knotted ropes and tapes. In most cases though, a descender is needed to safely get down a rope.

DESCENDERS

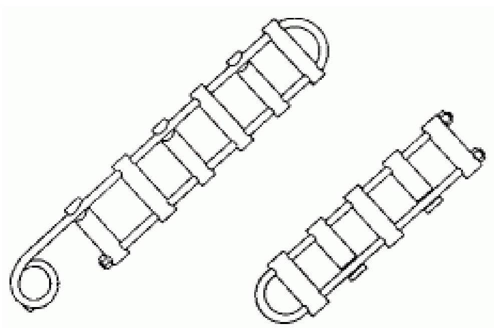


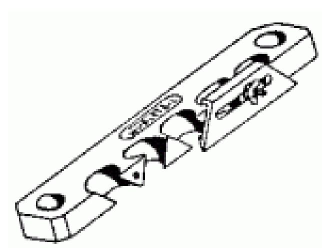




Bobbins

Petzl „Simple” *Petzl „Stop”* *SRT descender*





Racks

Open (long) *Closed*

Others

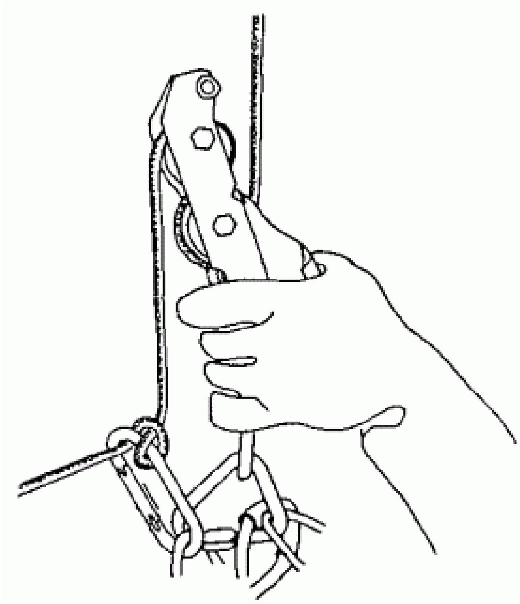
Spelean Whaletail *Figure-8*

BOBBINS

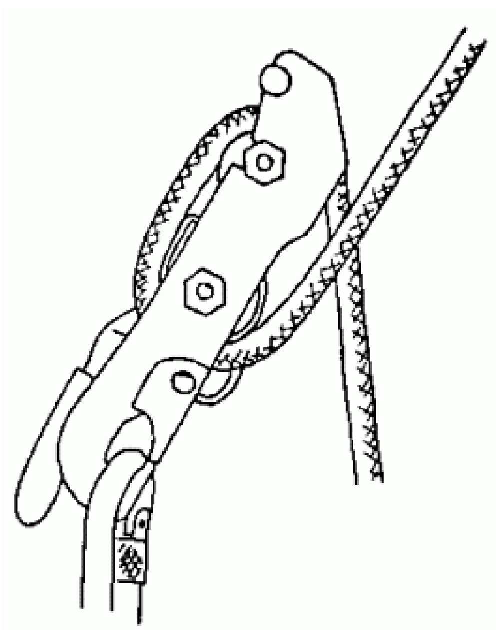
All bobbins work on the same principle. The rope is inserted by opening a moveable plate (like operating a pair of scissors). It is threaded under the bottom pulley, does a tight "S" bend through two pulleys fixed to a plate and exits at the top of the device on the other side. The pulleys are made of either aluminium or stainless steel.

Descent with a bobbin is controlled by varying the tension on the rope on the lower side of the descender. Extra friction can be gained by using a "brake" karabiner attached to the seat maillon and clipped onto the rope below the descender. Descent rate is then controlled by lifting or lowering the rope to change the bend through the brake karabiner. Should the rope be too fast an Italian hitch can be used on the brake karabiner, should it be too slow the bobbin can be threaded backwards in a "C" or only the lower pulley engaged.

Some models allow the rope to be pulled backwards through the descender, a handy feature. Bobbins are not variable friction devices but they do work well over a wide range of ropes and rope weights, working best on pitches shorter than 50 m and ropes 10 mm or less (though they can safely be used on any pitch). At first a bobbin may seem fast and uncontrollable but with practice it is possible to go fast or slow with ease without adjusting the device. **A word of caution** - while the control is excellent, bobbins with stainless steel pulleys can heat up enough to melt the fuzz on dry rope after only a few metres of fast descent.



Italian hitch brake



„C" threaded bobbin

Autostop Bobbins

Some bobbin descenders have been modified by the addition of a jamming action controlled by a handle. To "go" the handle is squeezed and the rope is controlled as for a simple bobbin. If the handle is released the caver is automatically stopped on the rope. The "stop" handle is just that. It must only be used as a "stop" or "go" lever while full control is maintained by the lower hand.

Not all autostops are the same, some work better than others and the stopping quality varies on different ropes or even the same rope wet or dry, new or old. Autostops, which allow the rope to be pulled backwards through them, can be used as tolerable ascenders. Another desirable feature is some means of disabling the "stop" action. This typically takes the form of an eye through which a karabiner can be clipped.

When intending to hang in one place for some time, even with an autostop, it is well worth locking off the descender as one good bump to the handle could start an unwelcome slide.

Once one has seriously used an autostop it is difficult to settle for another descender. Safety at pitch tops and rebelays is vastly superior to **any** other type of descender and the ability to stop easily, exactly where necessary is a tremendous aid in rigging and when crossing rebelays and deviations.

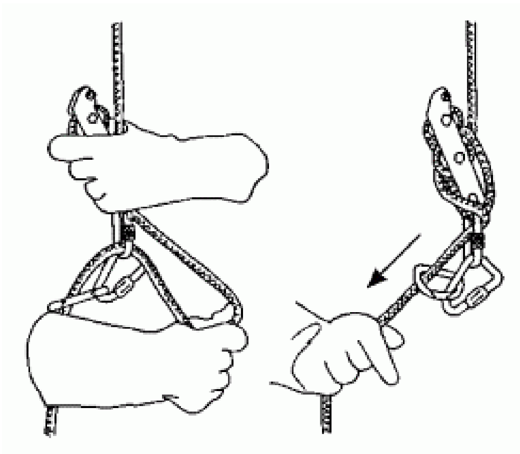
Orientation

All bobbins are best attached to the seat maillon by a **locking** karabiner or 10 mm maillon so that they sit with the moveable plate facing the user. This allows them to be easily manoeuvred when being clipped on or off the rope. The rope enters on the right and exits on the left (left handed people may find it easier to have the moveable plate facing away or choose a model which they can thread backwards).

Some bobbins simply have two eyeholes for attachment and must be removed completely from the karabiner to get them on or off the rope. More sophisticated models have a spring loaded gate on the moveable plate which allows them to be opened faster and with no risk of dropping them.

Wear

A solid aluminium pulley must be replaced when it wears down to the bolt, which secures it. On simple bobbins the pulleys can be inverted when one side wears out but on autostops the pulleys are asymmetric and when worn, must be discarded. Stainless steel pulleys are hardwearing; the lower pulley on a Petzl Stop can last as long as nine aluminium top pulleys on the same descender. On extended trips or expeditions it is often necessary to take along one or two spare aluminium pulleys to be left in camp until needed.



Locking off a bobbin

Locking Off

It often becomes necessary to "lock" a bobbin so as to safely free one's hands for other manoeuvres.

Lock

- Clasp the left hand around the descender and incoming rope.
- Take a loop of rope from between the bobbin and the brake karabiner and pass it through the descender's linking karabiner.
- Loop the rope over the top of the descender and pull down tight to provide a firm lock, which has no tendency to come undone.

Unlock

- Loosen the loop around the descender and take it back over the top of the descender.
- **DO NOT LET GO!**
- Bobbin and rope are clasped as for locking.
- Drop the rope loop and pull the rope below the brake karabiner until all slack is taken out of the system.

A less secure but faster lock is made by taking the rope from below the brake karabiner and looping it over the top of the descender. This method is ideal for extra security on rebelays, deviations or whenever a short, quick stop must be made.

RACKS

Some types of "Rappel Rack" are the ultimate in variable friction devices, being equally effective on any size rope, double or single, wet or dry. While their variability gives them excellent control and makes them usable anywhere, racks are definitely at their rest on long uncomplicated drops. The price paid for versatility is that of a bulky, heavy device which is clumsy and slow to put on and off the rope. In a cave with numerous small drops or rebelays, a rack is a nuisance and the 35 cm (14 inch) variety is almost guarantied to remove kneecaps!

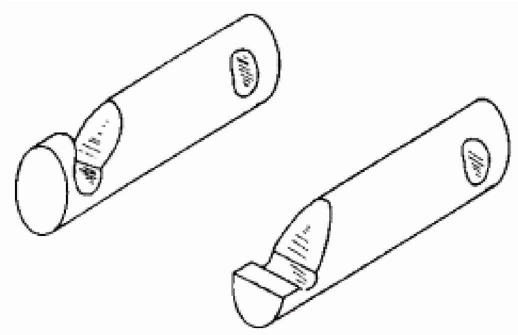
A rack is loaded by weaving the rope through a series of bars, usually five, some or all of which hinge open to allow the rope to be inserted. Friction is varied by threading the rope between different numbers of bars, and sliding the bars up or down the rack. Pushing the bars up the rack increases the bend in the rope and the amount of bar/rope contact to increase friction while spreading bars down the rack decreases friction. When descending heavy ropes as few as three bars can be used and they can be spread the full length of the rack, thus giving the rope only a slight bend. During the descent one must jam the bars upward to maintain control as the rope weight diminishes. Eventually it will become necessary to clip in one or two extra bars, do not leave it too late!

Rack bars are made of aluminium or steel tube. Either type wears rapidly on dirty rope so be sure suitably sized replacement bars are available when buying a rack. Bars can also be made in a home workshop.

Open-Ended Rack

The standard rock is a long inverted "U" of stainless steel rod with an eye bent into one end of the "U" and the other left open to allow the rope to be inserted. The frame is springy and the bars are threaded onto it by means of a hole drilled in one end of them and held in place by an angled slot in the other end. The slot is cut so that the bars will open with a light squeeze of the rack but will otherwise stay closed. This makes the rack neat and easy to carry without the bars flopping about when not in use.

Rack bars can be threaded onto either arm of the rack. When on the long arm the bottom bar can be out of the way to allow a greater spread between the remaining bars. Bars on the short arm are more confined and so easier to clip on and off and also easier to replace.



Rack bars - clip closed *Safety*

When loading the rope into a rack care should be taken not to load it backwards because when weighted the bars may be forced open leaving the rack and caver completely detached from the rope. Some manufacturers have reduced this risk by fixing the third bar closed and fitting the second bar with a slot that does not click closed. The rack is then less convenient to carry but safer to use. If the rack is always worn the same way it is easy to get into the habit of loading it correctly each time.

Closed Rack

Closed racks are made from a "U" shaped piece of stainless rod with a nut threaded onto the end of each arm. The bottom of the "U" is used as the attachment point - upside down compared to a standard rack. Again they usually have five bars but with the first, third and fifth fixed and the second and fourth slotted.

The Open rack is loaded by passing a rope loop between bars one and three and then, closing the second bar through the loop. When more friction is needed, bar four can also be loaded in the same manner. The frictional variability is not as good as for an open rack and while it is possible to remove a bar during descent it is much more difficult to add one - the opposite of what is normally required!

The homemade "SupeRack" is specifically for long pitches. This extra long closed rack has heavy, square, heat-sink aluminium bars and virtually all its control is obtained by jamming the bars together or moving them apart to suit. Control at the bottom of pitches is very difficult.

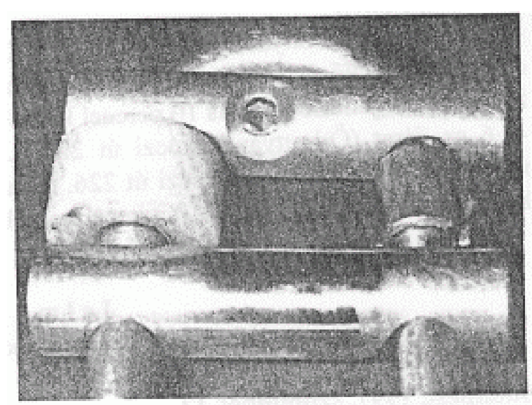
Orientation

The orientation of a rack is a matter of personal preference. An open rack is easier to load when it opens to the right for right-handed cavers. A link karabiner between the rack and the seat maillon makes the rack manoeuvrable although a long rack may then reach above head high and so increase the risk of catching hair or beard in it. For this reason and also to stop them from swinging about so much racks are often clipped directly to the seat maillon.

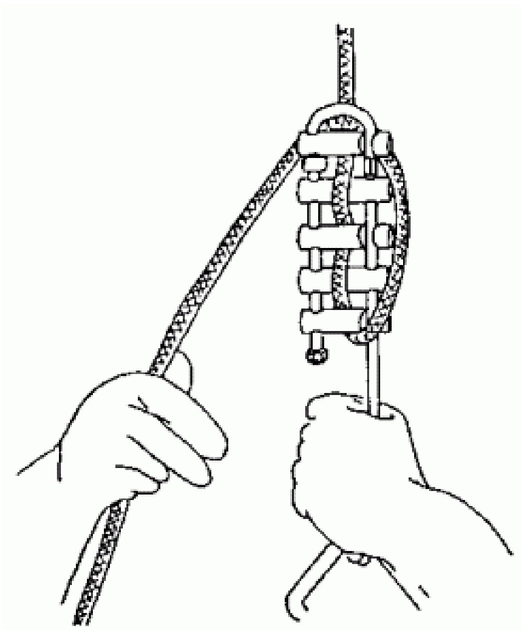
Wear

The rope should run down the centre of the rack, rather than to one side. Here the groove the rope cuts in the bars is safely away from the bar mounting holes and slots and will not damage the rack frame. To keep the rope centred "trainer" bars can be used or a small groove filed in the top two bars. Steel bars need a wide spacer between the top two bars to give the same result as they cannot be effectively grooved. No rack is designed to have the rope rub against the frame.

A 10 mm to 15 mm long spacer between the top two bars is useful as it stops them pinching too close together and impairing the smooth running of the rack. Solid bars need replacing when they begin to pinch the rope and stop it running well; about 1/3 to 1/2 worn through. Hollow bars are replaced when the rope groove wears a hole through the wall of the bar. Before this happens the bars should be swapped up and down the rack so that all bars wear out at the same time. Steel bars are essential for continual use in muddy caves and spare bars plus a spanner to change them may be needed for a descent of a deep muddy cave.



Rack spacer and worn hollow brake bar



Locked off rack

Locking Off

Any rack can be locked off by pushing the bars up hard and putting the rope over the top between the rope and the rack. This is adequate for short stops but if the tension is taken off the rack by standing on a ledge or crossing a rebelay etc. the rope will drop off. A more secure lock for open racks is obtained by pushing up all but the bottom bar, putting the rope over the top of the rack and then clipping it in place using the free bottom bar. A third alternative is to put the rope over the top as usual and then take a loop through the connecting karabiner and taking it over the top as well in much the same way as locking off a bobbin.

WHALETAIL

A whaletail is a cast or machined block of aluminium with a series of overlapping wedge-shared pegs down one edge, which give the de-scender its name. The rope is woven between the pegs so that the whale's tails hold it in place with a sliding gate at the top for security. Friction is varied by weaving the rope between more or less pegs (minimum of three). Whaletails are fast to load and easy to use but their major positive feature is the excellent heat sink provided by the block of aluminium. This would make the whaletail ideal for use on big drops if it were not for the fact that it is not particularly easy to increase the number of pegs, hence friction during descent. Most whaletails are designed for thick rope and are dangerously fast on 8 mm or 9 mm rope. At 525 g it is also one of the heavier descenders.

FIGURE-8

Figure-8's have some use as caving descenders but they are too fast for easy control on single thin ropes and wear out too quickly to be good value. The classic Figure-8 must be completely removed from both the rope and seat maillon during loading and unloading, thus risking dropping it. To alleviate the risk there are several varieties with "ears" or "spikes" to keep the rope in place and allow the descender to be loaded and unloaded without being unclipped. Figure 8'S are cheap, light and simple and can be useful in caves with only a few short pitches or for some through trips. The spin they give the rope often causes tangles and may make it difficult to pull the rope down on double-rope through trips.

STRENGTH OF DESCENDERS

Descenders can be one of the stronger points in the SRT system. The body of most descenders is overstrong and the smooth, running surfaces means that under FF1 tests, neither descender nor rope is damaged.

However there are some exceptions. When locked-off or jammed hard against a stopper knot autostops are as strong as any other bobbin. If allowed to slide uncontrolled for two or so metres from an anchor then stopped suddenly by releasing the handle they will certainly damage the rope by partially cutting or lightly melting the sheath. Autostops which jam the rope at the top of the upper pulley (SRT, Bonaiti) instead of between the two pulleys (Petzl, Dad) are less brutal on the rope but it is then difficult to pull the rope backwards through them.

The damage an autostop can do to a rope in severe falls is still an infinitely brighter prospect than continuing in an uncontrolled slide to the bottom as could happen with any other descender. Losing control on abseil is a common cause of accidents, chopping the rope with an autostop is not.

Some open ended racks begin to unwind their attachment eye at surprisingly low loads (as .low as 250 kg!) and even locked-off cannot be relied upon to survive shock loads. Racks with welded eyes are obviously to be preferred. Closed racks are much stronger, some models testing in excess of 2000 kg. Nevertheless, descenders are very useful as self belays when rigging at the top of pitches. This should be done with safety in mind by keeping the

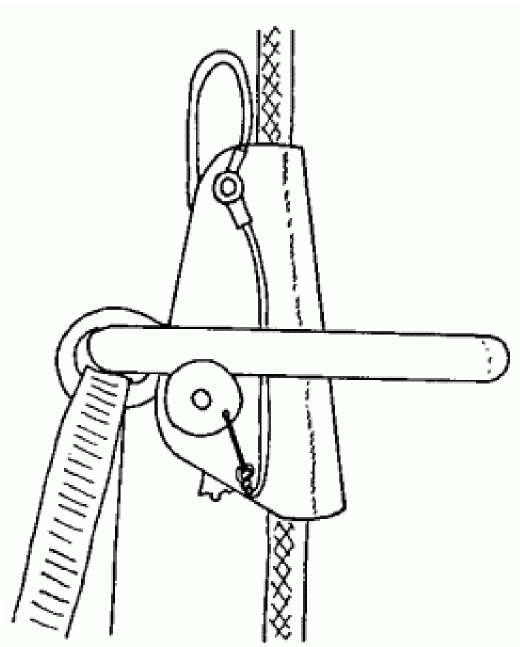
SOME COMMON DESCENDERS

Table 6:1

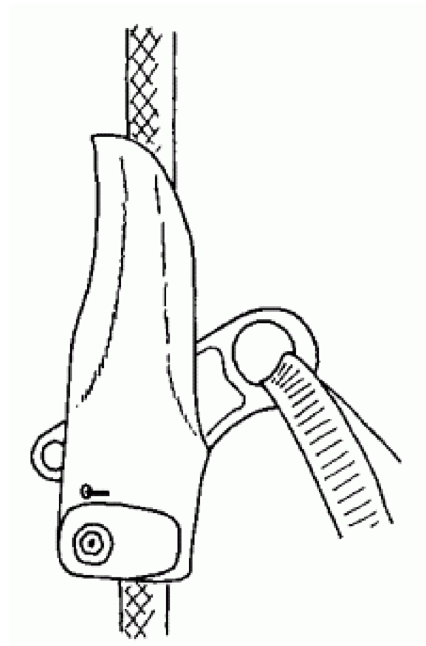
Descender	**Weight** (g)	**Length** (cm)	**Replaceable Wear Surfaces**	**Best on Rope Diameter** (mm)	**Best on Pitch Length** (m)
Petzl Simple	260	21	yes	7 to 10	< 50
Petzl Stop	325	22	yes	7 to 10	< 50
SRT (single) (double)	400 470	22.5 22.5	yes yes	7 to 13 7 to 13	< 50 < 50
Bluewater Rack (long) (short)	700 600	35 30	yes yes	7 to 13 7 to 13	> 50 10 to 100
Petzl Rack	475	30.5	yes	7 to 13	10 to 100
Closed Rack	280 to 500	20 +	depends on model	10 to 13	depends on model
Spelean Whaletail	525	30	no but can change ends	10 to 13	<100
Figure-8	100 to 300	14 +	no	10 to 13	< 50

descender locked-off as much as possible, locking-off through the descender's attachment karabiner so as to reduce the possible load on it, allowing minimal slack in the rope and keeping the potential fall factor low. Provided one never climbs up, most of the energy of any fall would be absorbed as a pendulum - a maximum of three times bodyweight minus the energy absorbed by crashing into things. This would be unlikely to harm the descender but the consequences for the caver may not be as good. On long or difficult climbs it is better to set up a "real" belay using runners and save the descender for descending.

While generally safe against breaking, most descenders can be damaged if used carelessly. Descending over a sharp edge with a rack can bend the frame enough to stop the bars from sliding and a twisted karabiner acting as a lever can unwind the attachment eye. The fixed plate on most bobbins can become badly bent if the descender is weighted with the moveable plate open. This is most likely to happen when trying to unclip from a tight diagonal rope.



Spelean/Gibbs shunt



Petzl Shunt

SHUNTS

Shunts were originally conceived as "deadman" safety devices for abseiling. They are attached to the seat maillon with an arm's length or shorter sling and must be held open to descend. When released they hold and allow a caver to hang there for rigging or save him from falling should he lose consciousness. Getting started again is not always easy.

The efficiency of shunts has been tested by getting a blindfolded victim to abseil off the end of his rope and catch himself by releasing a shunt attached to a parallel rope. In very few cases was a victim able to catch himself (Webb, 1978) and it was even found to be a difficult manoeuvre without a blindfold! A shunt can hardly be recommended as a safety device for a conscious caver. Bobbin users have effectively replaced them in favour of autostop descenders where the frequent use of the stop handle conditions the user to let go in the event of an emergency. While not 100% effective it is definitely better than the totally unconditioned response the occasional use of a shunt gives.

For the price of some extra weight, SRT Equipment makes an attachment for their autostop descender, which applies the brakes when the "go" lever is squeezed too hard, as well as when let go.

Spelean (Gibbs) Shunt

A Gibbs ascender can be modified with a large karabiner or specially fabricated bar and pin to make a shunt, which can only be used on single rope. It has the advantage that it can be fitted with a short sling to the seat harness via a chest harness. This allows the shunt to sit on top of the descender and slide down the rope by itself to be triggered by leaning back instead of letting go. However it only works well with long descenders such as racks or whaletails.

Petzl Shunt

The Petzl Shunt works on double ropes when both strands are the same diameter and has the advantage that it will slide with a force of more than about 350 kg, giving it shock absorbing capability. However it must be held firmly open to descend and thus would be almost impossible to release in an emergency.

Prusik Knot Shunt

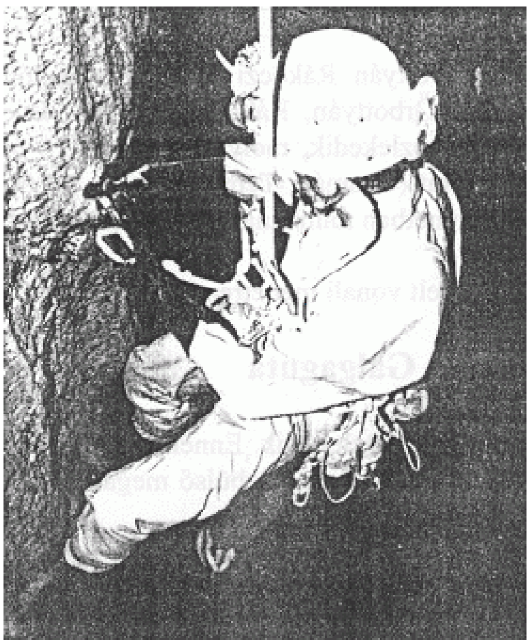
A prusik knot can be tied above the descender as a psychological shunt. A good knot will hold very well under a static load but if shocked or loaded while the caver is moving it, the knot can slip and melt through the prusik sling. Once loaded it may not be possible to unload a tight knot without a stand-in loop.

THE DESCENT

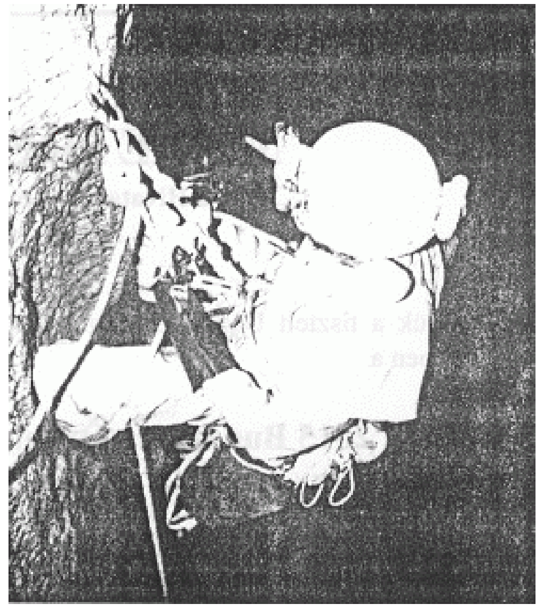
In caving, abseiling should be treated solely as a means of descending a pitch and be done carefully and in complete control. Going too fast risks the caver smashing into walls and projections puts melt marks on the rope and causes a shock load when he stops suddenly. When abseiling in a cave it is advisable to have a cowstail ready for use (Alpine cavers) and prusik gear attached or readily available.

REBELAYS

With practise, crossing a rebelay becomes easy and fast.



- The caver descends until he is level with the anchor and clips his short cowstail to the karabiner in front of the rope.
- He **GENTLY** continues his descent until his cowstail takes up.
- He then unclips his descender.
- Still keeping his descender behind his cowstail, he puts the rope he has just unclipped to one side and clips onto the downward rope as high as possible.
- He locks his descender (except autostop).



- In order to unclip his cowstail the caver stands up on a convenient ledge or puts a foot or knee in the loop of rope from above.
- He checks his descender. **If it were not clipped in correctly he could step off, COMPLETELY unattached.**
- The caver sits back on his descender, unlocks and continues his descent.

Should the loop be too long a Figure-9 loop can be tied to shorten it or preferably the rebelay knot repositioned. When the rebelay involves a pendulum to reach it the caver descends to just below the level of the anchor, locks his descender to free both hands, then swings across and clips in (see also Rebelays, Chapter 4).

DEVIATIONS (REDIRECTIONS)

Ideally a deviation is rigged so that its sling is unloaded by a caver putting his feet on the wall. Passing is then simple:-

- Abseil right onto the deviation karabiner, perhaps pushing it down a little.

- Unclip the deviation and reclip it above the descender.

- The operation can usually be done with one hand so that there is no need to lock-off the descender.

Occasionally a deviation must be passed in space with no wall close enough to push off from. In this case the caver descends until his descender is 30 cm below the level of the deviation karabiner if its sling had remained horizontal. He then locks-off his descender so as to allow him to spring out and grab the sling with one hand and clip the karabiner past with the other.

If a deviation is extra difficult it can be clipped with a cowstail so as not to drop it or swing away.

CAUTION: A deviation is NEVER crossed as a rebelay.

Anchors and slings used for deviations are not necessarily strong enough to hang from and are not backed-up.

KNOTS

On a pitch where a suitable rope is unavailable it may be necessary to knot two or more ropes to make up the length required. There is no easy way past a knot hanging in space. A prusik rig, which has a long leg-loop to an upper ascender and a cowstail, is required.

- The caver descends until the knot is about 5 cm below his descender.

- He attaches his ascender just above his descender so that when he stands in the long leg-loop the descender will be unweighted.

- His long cowstail is clipped to the Figure-8 eye that is **always** hanging out of the knot (see Chapter 3).

- By standing up and clipping his short cowstail to his ascender he can rest on it (optional). While still standing he also unclips his descender.

• He sits back onto his short cowstail and at his leisure reclips his descender as close below the knot as possible. If the descender is not an autostop it must be locked off.

• Standing again in his leg-loop he unclips his cowstail(s) then sits onto his descender and unclips his ascender.

• He is now ready to continue his descent to the next knot.

It is easier to have no safety cord attached to the ascender during this manoeuvre. A short safety cord will take up the load before the descender does and will be impossible to unclip.

This method is fast but some arm strength is required for the unclipping of the descender. Strong cavers or those with a wall to lean against can dispense with the short cowstail, further simplifying the procedure. Many cavers are not so strong and to reduce the effort required it is feasible to attach both ascenders before unclipping the descender. It is then a simple matter of reclipping the descender immediately below the knot and prusiking down to the knot until the weight is taken on the descender, no need to prusik past it and removing both ascenders, chest one first. While the movements are no more strenuous than prusiking this second method is slower and more complex than the first.

Prusik systems, which do not allow a high ascender to be weighted with a long leg-loop (Texas, Ropewalker), make crossing knots almost impossible. The difficulty lies in unweighting the top ascender so that the descender can be reweighted. The easiest "escape" is to carry a spare ascender with a long stand-in sling especially for knot crossing. Failing this a sling tied with a Lark's foot or Prusik knot just above the knot in the rope also works.

Like any other new manoeuvres, it is better to try crossing a knot outside a cave first.

BIG DROPS - Longer than 150 - 200 m

Quite apart from the psychological problems involved with "throwing yourself" off a big pitch there are some specific physical considerations as well. The rope weight below can be enormous. 300 m of dry 11 mm rope weighs around 25 kg. Cavers using bobbins will have to haul themselves down the rope with both hands for a large part of the way and an autostop must be disabled in order to use both hands. Friction can be minimised by not using a brake krab but always having it ready to clip in before it is needed.

Better still, use a rack! Clip in four bars and spread them. Give a light "starter" pull. If this does not cause movement, the rare case of a very light caver on a very long pitch, jam the bars up and unclip the fourth. When using three bars one must be extra careful, the bars are spread slowly until one begins to move bearing in mind that during the descent the loss of rope weight below will make it harder and harder to maintain control. Be cautious and do not leave it too late to add an extra bar. With a smooth dry rope, less than 50 m of rope weight below and only three bars clipped in, it is next to impossible to maintain control.

The most difficult part of any long drop is getting on and off at the top and special rigging is often used to make life easier.

Alpine technique treats a long drop as a normal pitch except that perhaps a double anchor is placed just over the edge. This provides a slack rope over the edge and only a marginally more difficult rebelay cross-over onto the heavy rope below.

For American Style cavers there are two alternatives.

- An assistant at the top can use an inverted ascender on a short rope to pull up the main rope and provide enough slack for the descending caver to clip on and get over the edge. Once under way, the assistant lowers the main rope back into place and the descending caver can unclip the inverted ascender and replace it above him. The reverse of this procedure can be used on the way up.

- A tail with a stopper knot in its end can be rigged over the edge from separate anchors (see Pitch Edges, Chapter 4 for rigging details). A descending caver drops over the edge on the short, light rope and changes over to the main rope for the descent. The idea of a tail can be taken one step further by using one, which is 50 m to 100 m long. This allows cavers to swap ropes in "mid-flight", allowing two cavers to descend simultaneously.

Rope protection, if used on long drops must be infallible. The best solution is to rig so that none is required but if this is not arranged then the rope transport sacks, possibly with a foam pad inside them can be used.

The longest free pitch found in a cave to date is 333 m into El Sótano de las Golondrinas and it is regularly descended using normal caving techniques. Ultra-specialised equipment such as artificial "rope trees" and edge rollers are not needed for caving. For a detailed treatment of drops over 500 m read Chapter 7 of "On Rope" (Padgett and Smith, 1987).

On a long drop with a clean, supple, dry rope any descender is liable to overheat if the descent rate is too fast. Wetting the rope beforehand is one way of assuring a cool descent but is not always feasible. If the top rack bar or bottom bobbin pulley sizzles when spat on, slow down, but do not stop. Be careful not to catch hair, beard or get a burnt tongue when doing this! Descenders made with solid aluminium components provide the best heatsinks while hollow stainless steel bars and pulleys heat up fast. A "bottom belay" (see page 84) should always be given to inexperienced or nervous cavers provided it can be arranged safely.

ROPE PROTECTORS

Flat rope pads are easy to pass. They are rarely tied to the rope and it is a simple matter of making sure that the rope is replaced on them after passing. It is only a slightly more difficult task to not create sideways movement and displace the rope once past them.

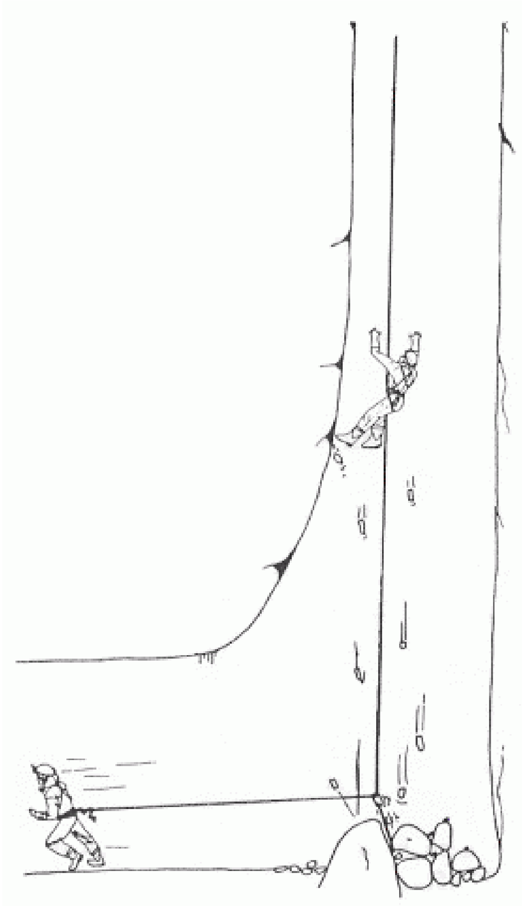
Wrap-around protectors are crossed by descending to just above the protector, locking-off, removing the protector completely from the rope and putting it back on the rope above the descender. The descent is continued to just below the rub point, sliding the protector down with one hand on the way. After locking-off again the protector is tied in place being careful to replace it correctly.

Often the protector will be so near to the anchor that it can be removed or pushed up enough for a caver to clip on below it without the need to remove it completely.

It is a good habit to check the integrity of the rope whenever a protector is encountered as they are never 100% reliable.

DIAGONALS

The rope may not always run vertically to the bottom of a pitch. When it makes a pendulum to reach a passage or avoid a pool the unprepared caver may become stuck in a tight loop of rope. To avoid this, unclip the brake karabiner or one or two rack bars as soon as the rope begins to pull significantly sideways. Keep going until the rope pulls tight and haul across to the belay with both hands. Depending on the severity of the diagonal it may be necessary to disable an autostop.



Bottom Belays

Descenders are controlled to a large degree by the tension on the rope below them and it does not matter whether this tension comes from the person abseiling, rope weight or someone pulling on the rope from below. Cavers lacking confidence or experience can be bottom belayed by stationing someone at the bottom who hauls on the rope and thus stop the person above if the need arises. This works on short drops but rope stretch on long drops may make it difficult to create sufficient tension quickly enough. In this case the belayer can clip on to the rope beforehand and run away from the base of the pitch if necessary.

If there is a danger of falling rocks and the passage is suitable a pulley or karabiner on a sling can be rigged at the bottom of the pitch. This allows the belayer to remain in a position safe from falling rocks and keeps the abseiler from being pulled sideways.

Bottom belays are not used as a rule as they slow the caving party's movement through the cave.

Narrow Pitches

With gravity to help narrow pitches is rarely a problem on descent but at times they can be so tight that there is not enough room for a caver and his descender to fit at the same time. One solution to the problem is to clip the descender to the end of a cowstail and let it ride above head level. Autostops should be disabled and the friction adjusted so that the descender will run without further adjustment while negotiating the squeeze.

Pitch Edges

Pitches, which begin with a sharp overhanging lip, are often awkward to negotiate. In most cases it is best to forget any pretence of grace or style, clip on and slide over the edge on one hip until it is possible to do a half turn and brace one's feet against the wall. Most "bad tips" are primarily due to bad rigging - go back to Chapter 4!

DESCENT PROBLEMS

Lack of Control

Wrap the rope once or twice around one leg to add friction. If this gives the required security then continue. Otherwise, with the rope securely around the leg, an Italian hitch can be tied on a brake karabiner - this will give sufficient friction with any descender. A bobbin can also be loosely locked by looping the control rope over the top of the descender. It is still necessary to maintain a hold on the rope but such a lock does provide enough quick friction to stop and tie an Italian hitch or clip on an ascender.

Autostop Does Not

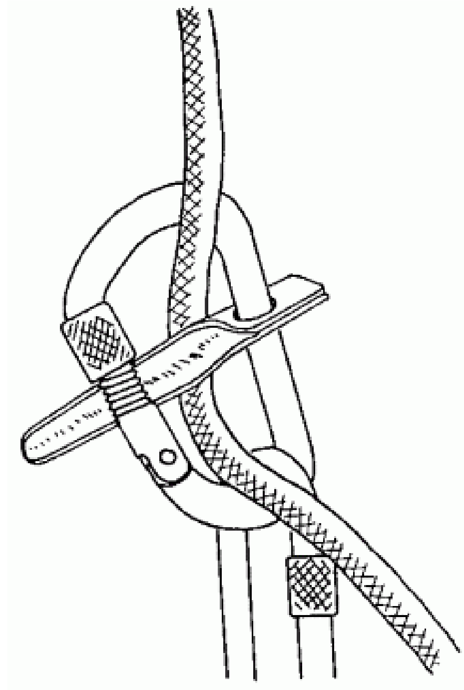
Few autostop descenders are 100% effective on all ropes. One must be careful about trusting an autostop on an unknown new rope, slippery or hard rope and of course, a rope on which the autostop has previously failed to stop. Sometimes forcing the stop handle will work but the stop achieved is tenuous at best. Even when an autostop does not work perfectly it still gives some "autobrake" action and at worst will function as a normal descender.

NO DESCENDER

Specialist descenders can be replaced by other abseil devices. They do not work as well as the real thing and wear out rapidly but are considerably safer than classic abseiling.

"Crossed krabs", using one or more karabiners or angle pitons as brake bars work fine on thick ropes but on single thin rope it can be too fast to control. Two brake bar units in "series" are more controllable and also give a back-up should one of the karabiner gates fail or open due to the sideways loading it receives.

The "Bicephale" is a variation on crossed krabs, it gives more friction than the standard set-up although the descent may not be as smooth. With considerably less equipment one can abseil on an ltalian hitch, it is easy and fast to tie and the control is excellent. Either crossed krabs or an ltalian hitch will ruin aluminium karabiners very quickly on a muddy rope, while a locking steel karabiner will last indefinitely. Locking karabiners are preferred for the critical karabiners in any of these methods. If none are available two non-locking karabiners can be stacked on top of each other with their gates on opposite sides.

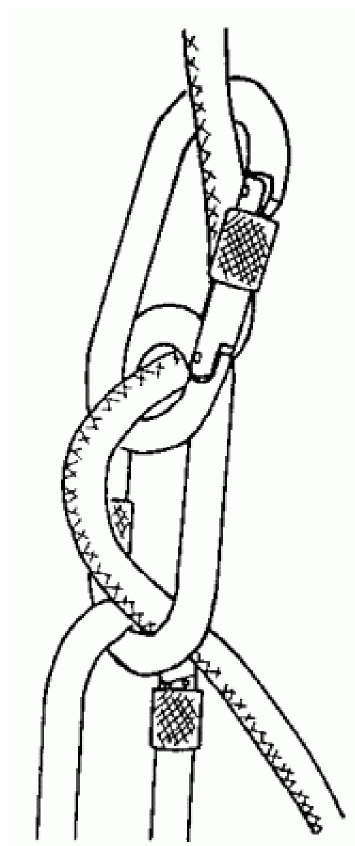


Crossed krabs

LONG HAIR

Long hair and beards are easily caught in long open descenders like racks and whaletails. Loose clothing such as scarfs and long chinstraps are also at risk. Should something get caught, stop descending immediately and try ripping the offending item from the descender. If it is too well entrapped the safest move is to attach an ascender with a long leg loop above the descender and stand up. The unweighting of the descender should make it easy to extract the offending item.

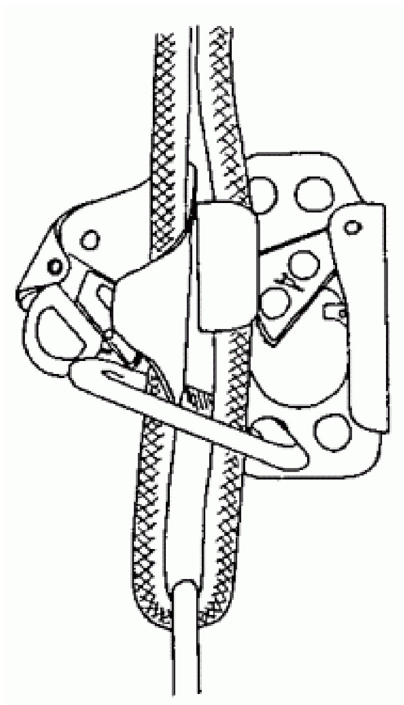
Only as a last desperate resort should a knife be used **carefully** to cut the hair, not the rope! Ropes under tension cut extremely easily. Try to avoid the problem entirely by having hair tied and tucked in and no loose clothing, jewellery or dangling item in range of a descender or ascender.



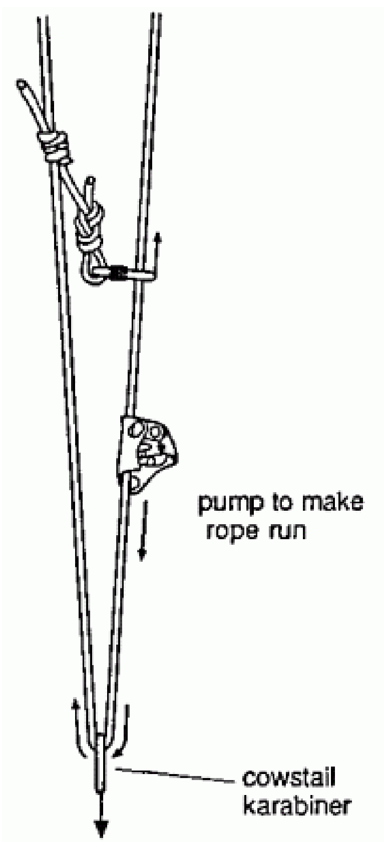
Bicephale

ROPE TOO SHORT

The most immediate concern when descending a short rope is to not slide off the end due to lack of a stopper-knot. When the rope is rigged correctly in the first instance the problem is no more serious than having to change over to prusik and ascend. However if



Ascenders used to lock a double rope



Running karabiner

protectors are used and the intention is to have the last man down place them the situation could be far more serious. The rigger must be able to turn back at any stage, especially in difficult or wet caves.

In the event of descending a double rope, which is too short, manoeuvres using ascenders are complicated by the lack of either rope being fixed at the top. To get the first caver down, the ropes can be locked at the top by an assistant using two ascenders and the descending caver then tie an extra rope onto either strand and finish his descent.

Should there be no spare rope available and nobody at the pitch head, the rope can be locked using a *Mousqueton Coulant* or "Running karabiner" (Frachon, 1980), then climbed with caution.

• Stop a metre above the ends of the rope.

• Tie the rope ends together with a short safety loop hanging out and separate the two strands of rope.

• Clip the loop formed (not the safety loop) to the seat maillon with a karabiner.

• Continue descending to the knot.

• Attach an ascender with footloop immediately above the descender.

• Hold both ropes together with one hand to keep them from slipping and ease onto the ascender, then remove the descender.

• Allow the rope to slide until hanging from the seat maillon karabiner.

• Clip the safety loop from the knot to the other strand of rope with a karabiner above the ascender.

• "Pump" the knot up to the belay by successive steps in the ascender footloop.

• Once the knot reaches the top and locks, the rope is ready for ascent.

If this is tried with a rope or tape tie-off sling, the friction produced as the full length of the abseil rope is dragged through the sling under load could easily cut the sling. In this case there is little choice but to prusik up the double rope using prusik knots.

7 ASCENT

Climbing a long rope is a hard way to get out of a cave and should be done as efficiently as possible. The traditional method of using a pair of Prusik knots made of a thinner cord (minimum 6 mm) than the main rope works.......slowly and is worth knowing for emergency use.

A few cavers still use Prusik knots for caves with only one or two isolated pitches because they represent the lightest, most compact prusik system available, a pocket-sized prusik system! Knots do not slide up the rope freely, so only really work on rigs that allow the rope to be pulled through the knot by hand (sit-stand rigs).

SRT now relies on the use of two or three mechanical ascenders attached to the caver in two basic ways.

Sit/Stand systems where the caver climbs with a frog-like sit/stand motion.

Ropewalking, where the caver uses a natural walking motion to climb the rope.

MECHANICAL ASCENDERS

Mechanical ascenders work by means of a cam, which jams the rope so that the ascender, will slide up the rope but not down. Most rely on a spring to keep the cam in contact with the rope and small teeth to give positive grip. Once the cam "bites" it will only hold more strongly as the load increases so a strong spring is not necessary. Other ascenders use the climber's weight to activate the cam via a lever. This gives the advantage that teeth are of minor importance so the device has good grip even on muddy or icy ropes. A second advantage is that non-spring ascenders have very little rope drag. They move up the rope more easily and last longer. The choice of ascenders should be made in terms of suitability for a prusik system; ease of use, simple loading of the rope, cam open setting and overall weight. As will be explained later, the relative strength of ascenders is of minor concern.

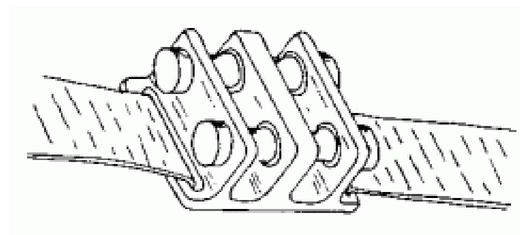
Desirable Features

- Single-handed loading or a lock-open cam, which is released to close on the rope.
- Single-handed unloading.
- Shaped to fit -comfortably in the hand, on the chest, knee or ankle.
- Cord attachment eyes in line with the rope. Attachment eyes away from the rope cause the ascender to twist when loaded.

- Simple streamlined shape with no bits and pieces hanging off to get snagged or damaged.

- Adequately strong - better than 400 kg breaking strain. Most ascenders cut the rope before they fail structurally. The attachment eyes must be strong enough to allow for wear.

- Robust - the cam and body should be hard enough that it will not wear out quickly.



Gossett chest box

HANDLE ASCENDERS

Many ascenders are made with an integral handle in left and right versions to allow them to be used comfortably. While the handle adds to ease and comfort while using the ascender, especially on sloping pitches it also adds to the weight and bulk of the device. Handle ascenders are cumbersome when not used in the hand and while the handle is nice for a top ascender it is by no means essential.

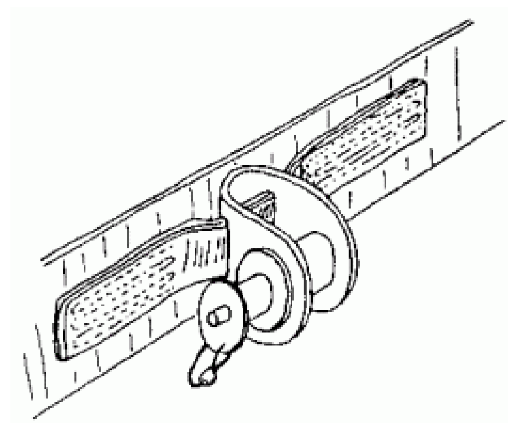
NON-HANDLE ASCENDERS

Short, compact ascenders can be used for virtually any application. Some are especially designed for use as a chest mounted ascender and as such work exceptionally well. Others are less specific and can be mounted anywhere on a prusik rig, but may not be as good as a specifically designed device.

Gibbs ascenders are designed for Rope-walk rigs and 7/16th inch (11 mm) rope where they work better than any other ascender. They are also the strongest of ascenders and probably the surest on muddy or iced ropes. For other applications their design is overly restrictive and the need to dismantle them into three pieces often makes them difficult to place on the rope. As a foot-mounted ascender on 8 mm and 9 mm ropes a Gibbs does not always grip immediately making it difficult to maintain a good ropewalking rhythm.

CHEST BOXES

Chest boxes and rollers are not ascenders but guides to hold the caver close to the rope while using certain prusik systems. They are made from "U" shaped pieces of aluminium channel. The most popular designs have the closed end of the "U" mounted against the chest and the rope is inserted into the open end before a roller is slid into place to lock it. Chest boxes

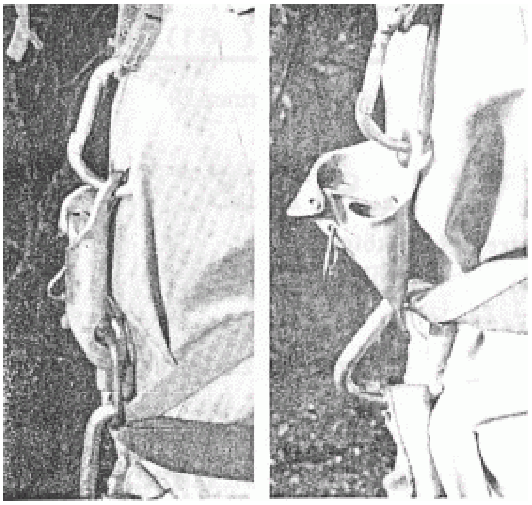


Simmons roller

come with single or double rollers and a variety of closure mechanisms including wing-nuts, bolts and quick release pins. The double models are a large chunk of metal which is made even heavier when connected to the heavy chest harness the require.

ATTACHMENT

Chest mounted ascenders can be connected directly to the seat maillon or by a short link such as a maillon or a loop of tape or rope. The exact configuration will depend on the harness, ascender and prusik rig to be used. For example, Croll ascenders are shaped to sit flat against the chest when connected directly to a seat maillon, which is also flat. When connected directly to a harness, which has the seat maillon at 90° to the body a Croll, sits badly, runs badly and may slip. A small maillon as an intermediate link cures the problem although the Croll then sits little high for an efficient Frog system!



Good *Bad*
Chest ascender orientation

Cords and tapes can be connected to the ascender by tying in directly to the eyeholes at the top and bottom or by using light maillons as intermediate links. Light tape or 5 mm to 8 mm static cord is used and reinforcing at the ascender connection will make it last longer.

"Life support" safety cords should be tied separately from other attachments to the bottom of the ascender and made of 8 mm or 9 mm dynamic rope.

WEAR

Old spring ascenders begin to slip when their teeth become excessively worn or their springs weaken. This usually becomes apparent when climbing muddy or clay covered ropes where the already blunt teeth become clogged. It is possible to buy replacement cams and springs for most ascenders. However, the frame of less durable ascenders may also be sufficiently worn that it is better just to throw away the ascender and buy a new one. When the frame wears out first, the leading or trailing edge may become razor sharp as the rope wears it away. This will do neither the rope nor a caver's fingers any good. Ascenders require very little other maintenance apart from the obvious need to clean and oil them occasionally.

Worn Croll

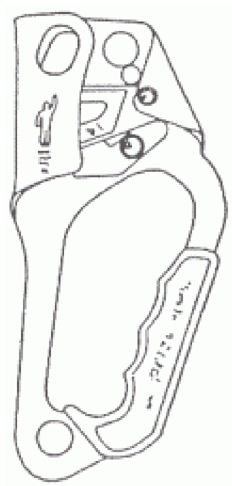
STRENGTH

The connection points between ascenders and rope are the weakest points in any SRT system. Under static load tests, "weak" ascenders usually fail when the wrap around channel unfolds or breaks enough to allow the cam to turn "inside-out". "Strong" ascenders typically fail by chopping the rope sheath and sliding. Under FF1 shock-loads however, most ascenders chop the rope sheath and slide down until stopped by the sheath binding or the bottom of the drop, leaving the ascender intact.

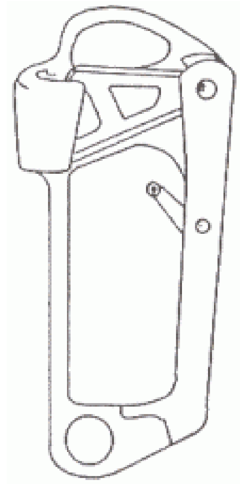
Thick ropes do not perform much better than thin ones in this respect. Many ascenders or the rope they are connected to begin to fail at loads as low as 450 kg; hardly a marvelous safety factor.

Only two mechanical ascenders can be expected to stand any chance under FF1, 80 kg shock loads. The Gibbs because of its inherently strong design and gentle gripping action and the new Petzl, which has a stud to stop the cam from closing enough to cut the rope. No doubt other manufacturers are also working on the problem. The obvious solution is to avoid shock loading ascenders. Do not climb above a belay point while an ascender is attached below and **NEVER** use ascenders as belay devices when rigging or climbing.

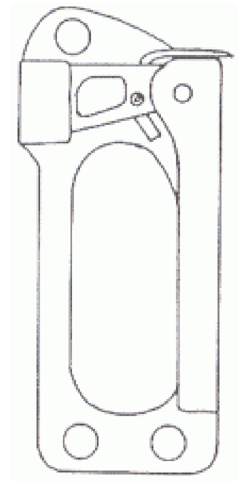
SOME COMMON HANDLE ASCENDERS



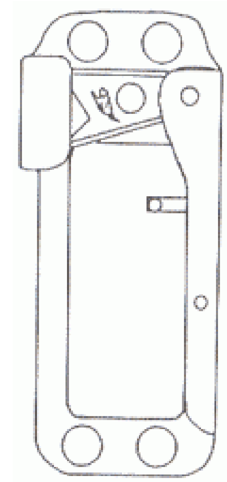
Petzl "Expedition"



Jumar



CMI "5004"



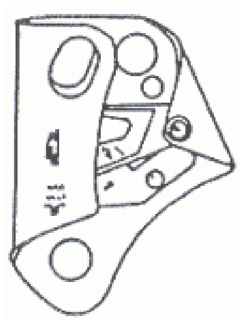
SRT "Caver"

Table 7:1

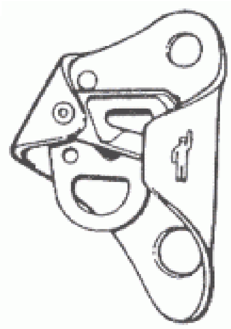
Ascender	**Weight** (g)	**Length** (cm)	**Single hand** On	Off	**Cam Open**	**Comfort /Ease***	**Dura -bility***
Petzl Expedition	195	19	Yes	No	Yes	1	3
Jumar	260	18	Yes	Yes	Yes	2	2
CMI 5004	250	18.5	Yes	Yes (just)	No	5	1
SRT Caver	260	18.5	Yes	Yes	Yes	3	1
Bonaiti Handle	260	21	Yes	Yes (just)	Yes	2	3

** Ratings 1 = best 5 = worst*

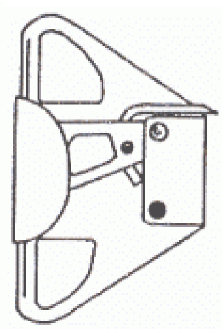
SOME COMMON NON-HANDLE ASCENDERS



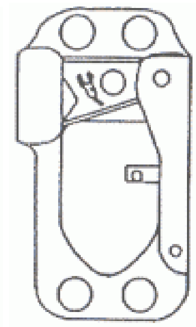
Petzl "Basic"



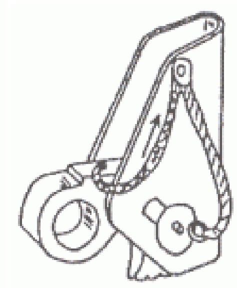
Petzl"Croll"



CMI "Shorti"



SRT "Climber"

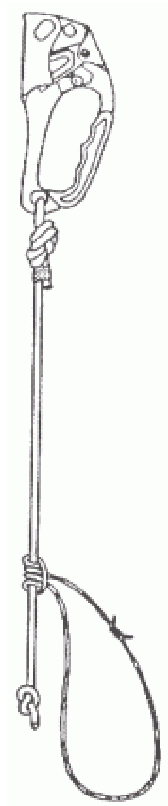


Gibbs

Table 7:2

Ascender	**Weight** (g)	**Length** (cm)	**Single Hand** On	Off	**Cam Open**	**Comfort /Ease***	**Dura -bility***
Prusik knots	60	-	No	No	No	6	6
Petzl Basic	140	10	Yes	No	Yes	2	3
Petzl Croll	140	12	Yes	Yes	Yes	1 (chest only)	4
Bonaiti Cam Clean#	140	12	Yes	Yes	Yes	1 (chest only)	4
CMI Shorti	200	12	Yes	Yes	No (just)	4	3
SRT Climber	220	13.5	Yes	Yes	Yes	3	2
Gibbs	175	10	No	Yes	No	5	1

** Ratings 1 = best 6 = worst*
 # A copy of the Croll but slightly rougher and with no rivet to help it survive FF1 falls



Adjustable footloop

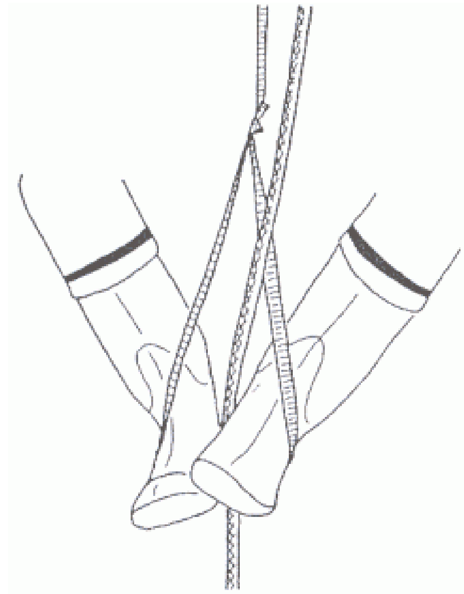
FOOTLOOPS

Connecting an ascender to one or both feet can be done in many ways. The main need is to provide a secure foothold in the right place.

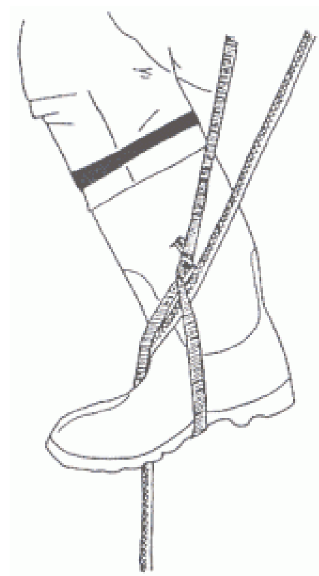
Footloops are normally tied in a pre-set length, which can only be determined exactly by a personal fitting. If adjustability is required the footloops can be attached by tying an 8 mm rope tail to the ascender and attaching the footloop with a prusik knot. Adjustable footloops are not necessary unless a convertible prusik rig is used or it must fit different sized people.

TWO-IN-ONE

For Sit/Stand prusik rigs by far the best root loop is a single loop about 90 cm in circumference into which one, both or no feet can be slipped as required. Its size allows it to be kicked off or put on easily and with only a little practice it stays on while prusiking. Its biggest advantage over other footloops is that by placing the rope between his feet after they are put in the footloop a caver can give himself "bottom-weight". It is only a matter of separating both feet slightly as they are lifted then allowing them to clamp the rope during the stand cycle.



Two-in-One footloop



Single footloop

SINGLE LOOP

Rope walkers or lightweight fanatics can tie a loop just big enough to take one foot. It can be a tight fit to keep it in place or loose so that it can be kicked off easily and for comfort can incorporate an etrier step underfoot. For Sit/Stand systems it uses a minimum of cord while still allowing both feet to be used by doubling the "spare" foot on top of the instep of the other. While light, a single loop lacks comfort on long drops and it is difficult to give oneself bottom-weight.

Separate Single Loops

Separate small loops for each foot can be tied which connect independently to the ascender. The only advantage in Sit/Stand systems is some independence of the feet. An extension of single loops is to use small loops of tape or "Foot Loops" which stay attached to the feet at all times and are held in place with shock-cord. On top they bear a small "C" clip to attach the cords to the ascender or to be left unattached for walking. "Foot Loops" can be troublesome to detach at the top of pitches and have no advantage over other loops.

Chicken Loops

Chicken loops are loops of car tyre tube or tape tied around the ankles. Before putting on a single foot loop it is threaded through the chicken loop then over the foot so as to firmly tie the loop to the foot. They are only worth using for ropewalking where an accidentally detached or failed top ascender makes it possible to fall upside down or "heel hang". For Sit/Stand prusik systems chicken loops are a useless encumbrance.

Prusik Systems

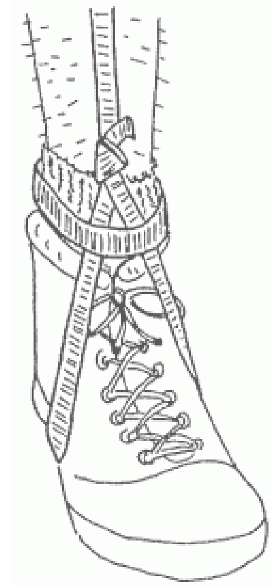
Two or three ascenders can be arranged in an endless variety of configurations, many of which provide an efficient means of climbing a rope. Prusik systems can be divided into three groups:-

Sit/Stand
Ropewalking
Convertible

Each has its strong and weak points. Sit/Stand systems are light, simple, easy to use on complex rigging and slow up the rope. Ropewalking systems are heavy, complicated, difficult to use on complex rigging and fast up the rope. Convertible systems are compromises between Sit/Stand and Ropewalking.

Sit/Stand

Sit/Stand systems are characterised by the motion of lifting the feet and one ascender while sitting in a seat harness then standing to bring up the other ascender. Sitting back and lifting the feet completes the cycle. All lose a little height in the sitting back but are very powerful when both legs work together.



Chicken loop

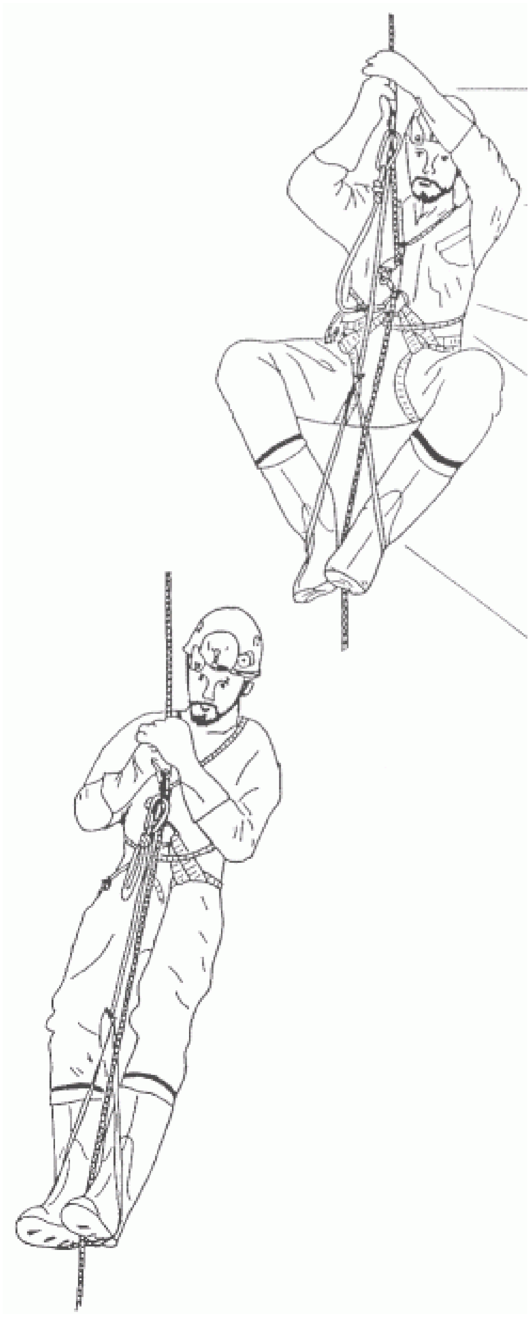
Frog System

The Frog or 'Ded' System could well be the most popular prusik system in the world. It is almost the only system used in Europe. A chest ascender is mounted as low as possible on the chest and held up by a chest harness. The other ascender is attached to the rope above the chest ascender with a long enough foot loop so that when standing the chest ascender is 2 cm to 3 cm below the top one. A safety cord also runs from the top ascender to the seat maillon. It can be either a long cowstail clipped into the bottom of the ascender or an entirely separate cord. The safety should be of such a length that the top ascender can never be out of reach but not so short that it restricts the upward push in the "sit" part of the sit/stand cycle.

The final choice of ascenders and trimmings is up to the individual but in any form the Frog is a system of unequalled versatility, being at home on any length and angle pitch. Both ascenders are within easy reach in front of the caver's body simplifying tricky movements and giving a fast on/off rope time. The position of the ascenders makes them easy to wear without getting in the way and many cavers wear them ready to go for the entire cave.

Climbing is done by pushing up the top ascender with one or both hands and lifting the feet at the same time while hanging in a sitting position from the chest ascender.

FROG SYSTEM



FOOT ASCENDER - Petzl Basic,
SRT Climber,
CMI Shorti

LIFT CHEST HARNESS - 3-3.5 m of 18 mm flat tape, buckle and optional mini-krab

CHEST ASCENDER - Croll, Cam Clean

DOUBLE COWST AIL - 2-2.5 m of 9 mm dynamic rope and 2 karabiners

or

SAFETY CORD - 1.5-2 m of 8 mm attached directly to the foot ascender

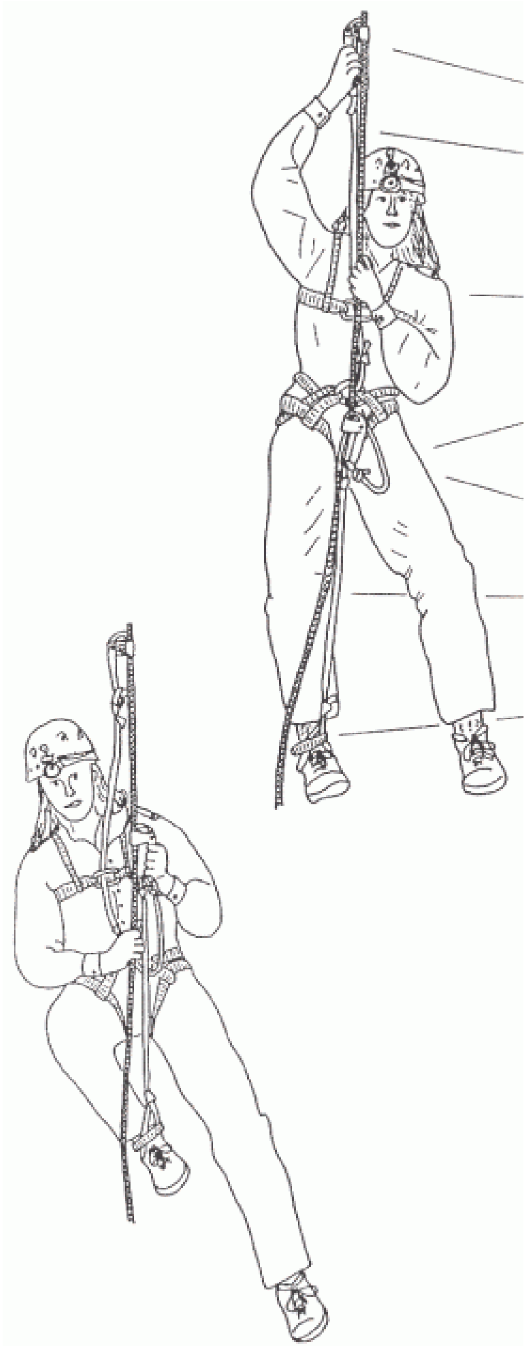
FOOTLOOP - 3-3.5 m of 18 mm tube tape or 6 mm static cord attached to the foot ascender by a 7 mm maillon or tied directly

As the caver stands up, his chest ascender moves up automatically provided there is sufficient bottom weight on the rope. If not the rope is run over one hip and pulled through with one hand, usually his left one. This is not efficient and should only be used for short distances.

Running the rope between the feet with a "Two-in-One" root loop not only provides bottom-weight but also helps maintain an efficient prusik position. In the "stand" part of the cycle the feet are tucked under the body to reduce arm strain and the body moved up with no wasteful sideways movement.

The double leg action is slow and will set no speed records but it does moderate energy expenditure and allows a caver to climb further between rests than he could with a "faster" prusik system. This and the versatility makes the Frog system the fastest and most energy efficient prusik system for multipitch caves.

TEXAS SYSTEM

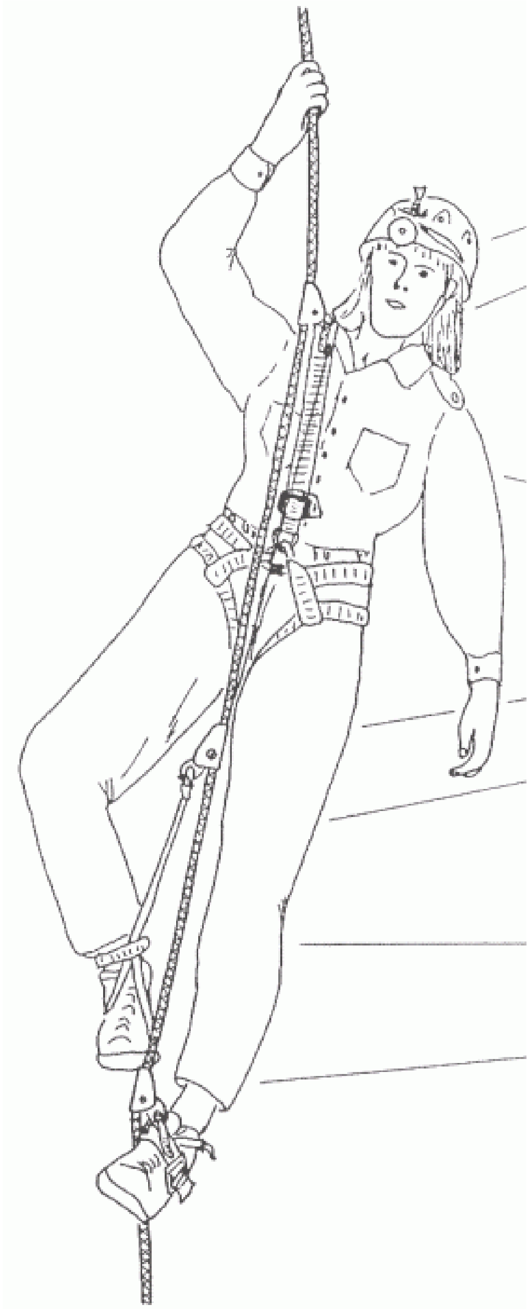


The Texas system is almost an inverted Frog system. An upper ascender on an arms length sling is attached to the seat maillon and the other ascender has a short footloop to one or both feet (usually one) such that when standing the ascender reaches to thigh level and is still within reach. A safety cord also links the lower ascender to the seat maillon.

Climbing is done by pushing up the top ascender and standing simultaneously then sitting back to rest and moving up the lower ascender. Although the motions are simple enough they can be strenuous, especially on free drops. This and its lack of speed are the two main drawbacks of the Texas system.

Texas is simple, light and versatile being good on sloping broken drops when used with one foot. Its popularity is probably due to the way it converts readily to a Mitchell system giving it the boost required for free drops.

3 GIBBS ROPEWALKER SYSTEM



ROPEWALK SYSTEMS

Ropewalk systems attach a separate ascender to each foot so that the legs move independently allowing the caver to "walk" up the rope. Their chief advantage is speed up the rope. Compared to Sit/Stand systems they are fast but complex and heavy.

3 Gibbs Ropewalker

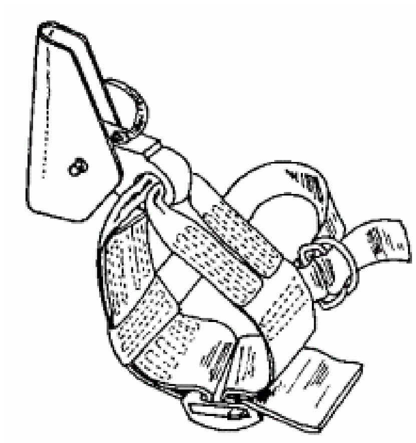
The "genuine" Ropewalker employs three Gibbs ascenders, which have very low rope drag to allow a maximum of speed up the rope.

Instead of a chest harness an adjustable "Butt-Strap" runs from the seat maillon up over the right shoulder and down to a fixture on the back of the seat harness at the belt level. On this strap at the point of the shoulder is sewn the upper Gibbs. The other two ascenders are connected one to each foot. One floats at thigh level with a shock-cord running from its shell to just below the shoulder Gibbs - a small clip will allow it to be disengaged for walking. A safety sling should also be fitted between this Gibbs and the seat maillon. The bottom ascender is sewn to a tight foot loop and ankle strap, which is mounted on the other foot.

Once everything is on the rope it is easy to walk up it in a vertical position with both hands completely free to hold the rope above, fend off the wall or read the topo guide. For obstacles or slopes the Butt Strap can be popped off the shoulder to allow the caver to lean back from the rope. When starting, bottom weight is arranged by passing the tail of the rope under the foot, which has the lower Gibbs, and holding it in one hand. This will only be necessary for the first few metres and only possible if there is enough spare rope at the bottom of the pitch.

A variation of the 3 Gibbs Ropewalker replaces the top Gibbs with a chest roller on a climbing chest harness. This holds the climber more vertical than when using a Butt Strap, but allows no easy resting position.

The advantages of ropewalking are speed and the ease of ascent once on the rope. Disadvantages are complexity, weight and very slow on-off rope time because of the Gibbs ascenders used. On simple pitches it is merely slow but when the rope is diagonal at the bottom or hanging at the top it is difficult as well. For this reason "Ropewalk cavers" normally carry a cowstail ascender for difficult pitch heads and sometimes even a spare Texas rig for simple pitches.



Foot mounted Gibbs

Mitchell System

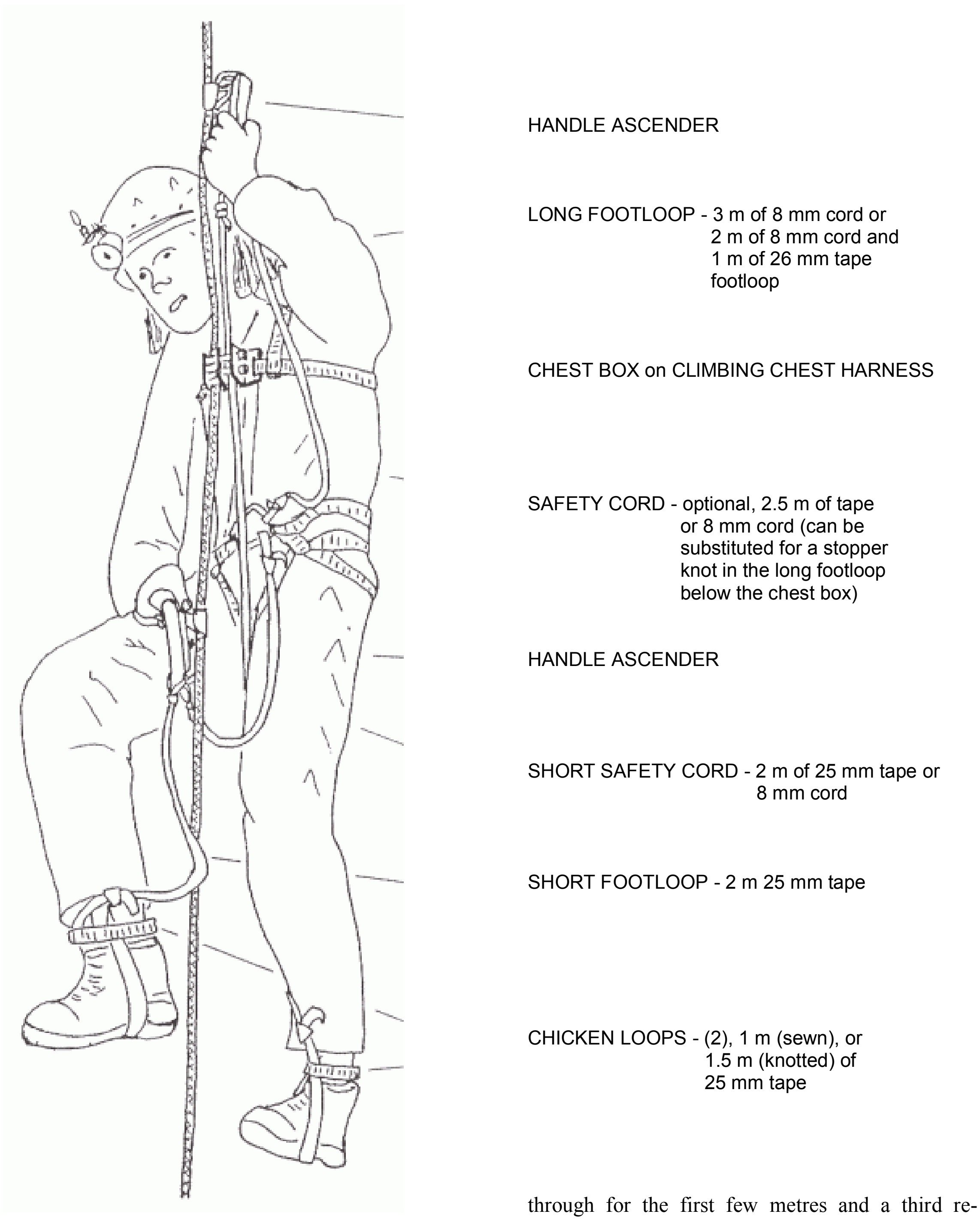
An upper ascender is fitted with a long footloop so that it reaches to high chest level when the caver is standing upright. A safety cord should also run between this ascender and the seat maillon but many people do not bother. The other ascender is mounted as for Texas on a short footloop so that it reaches to high thigh level when standing and should also be fitted with a safety cord.

In order to stay upright a chest box is worn with the rope in one channel and long footloop in the other. A single channel chest box is connected to the rope only. Note that with no safety cord attached to the top ascender a failure of the chest box could leave the caver hanging upside-down by her feet!

Climbing is a matter of walking up the rope with one hand on each ascender and moving the right hand up in time with the right foot and left hand with the left foot. A variation is to swap hands, some cavers claiming that the diagonal movement is easier as it is more akin to walking. The actions are easy and on freehangs or smooth walls it is possible to climb very quickly. On slopes one may undo the chest box and climb with the body vertical even though the rope is not.

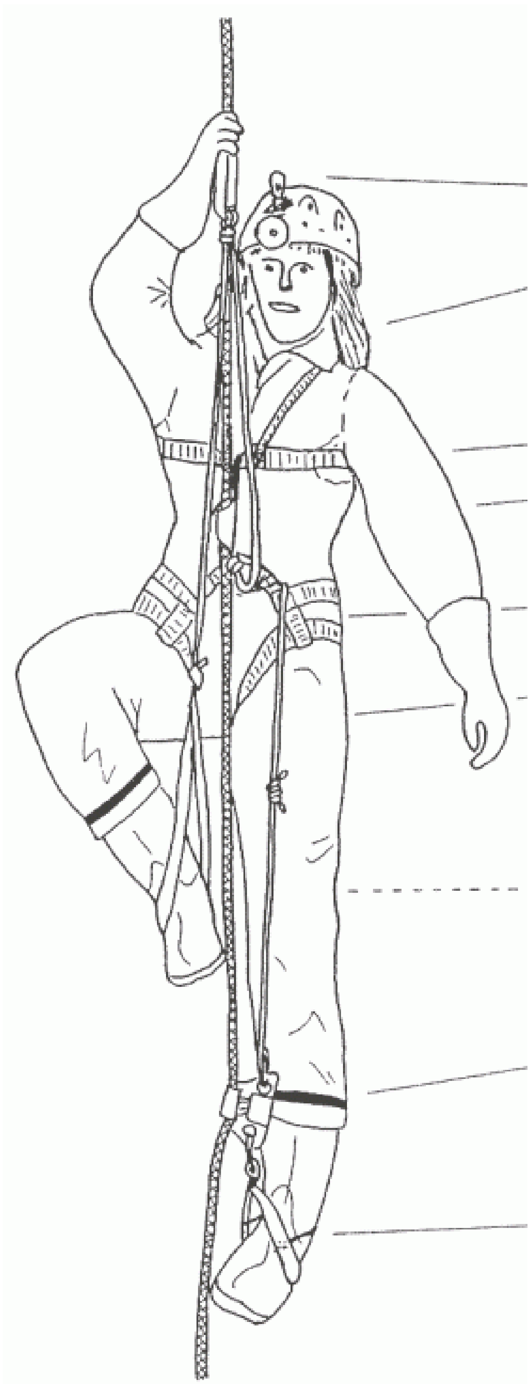
The main drawback of the Mitchell system is that both hands are always occupied operating the ascenders so it is not easy to fend off from a sloping wall and maintain a smooth ascent motion.

MITCHELL SYSTEM



When starting, bottom weight is needed to make the lower ascender run properly. When there is none, one hand is needed on the lower ascender, another is needed to pull the rope through for the first few metres and a third required to operate the top ascender. With practise though, this can be alleviated by "thumbing" open the cam on the lower ascender to make it run easier. The chest box is cumbersome in narrow passages and is slow to get on and off the rope.

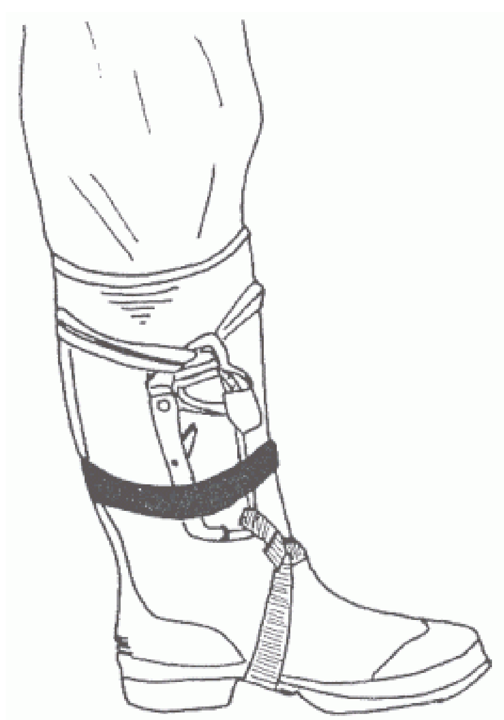
A FLOATING CAM SYSTEM



Floating Cam System

Some of the problems of a Mitchell system can be overcome by making the lower ascender move up automatically or "float". This is done by running a length of shock-cord from the top of the lower ascender to the chest harness or by the more complicated means of mounting a small pulley from the seat maillon or below the chest box. A shock-cord then runs from the top of the lower ascender up through the pulley and down to the other foot. By design it is only loaded when it needs to be and the long length of the shock-cord gives a good lift action. A simpler, neater method is to "lash" the lower ascender to the inside of the calf using an adjustable strap or car tyre tube rubber band though it takes a peculiar leg action to make it run correctly.

When a chest ascender is used instead of a chest box, the floating cam ascender is not a life support ascender so it can safely be modified to make it run better or be easier to use. Sprung ascenders can have their spring unwound a turn or two or replaced by a weaker spring so that the cam touches the rope lightly and therefore drags on the rope as little as possible. With a Gibbs ascender the cam can be mounted on a stud on one side of the shell and the other side cut away so that the ascender no longer needs to be disassembled to get it on and off the rope.



"Floating" ascender lashed to the leg

CONVERTIBLE SYSTEMS

Variation is the essence of evolution. There is a myriad of minor changes and adjustments, which can be made to the basic systems in an effort to make them perform better. Ropewalkers are best on long free drops and Sit/Stand systems are best for crossing rigging obstacles and short pitches. No prusik system is the best in all situations. For cavers who want to try to capture the best of both styles there are convertible systems.

Frog-Floating Cam System

It is possible to convert a Frog system to a "Ropewalk" by mounting a floating ascender on one leg and using the usual two ascenders of a Frog system. The Frog system is set up to climb one-legged. The spare leg carries the floating cam and with all three ascenders on the rope it is possible to ascend with either a walking or a sit/stand action. To convert to a true Frog system is a simple matter of disengaging the floating cam.

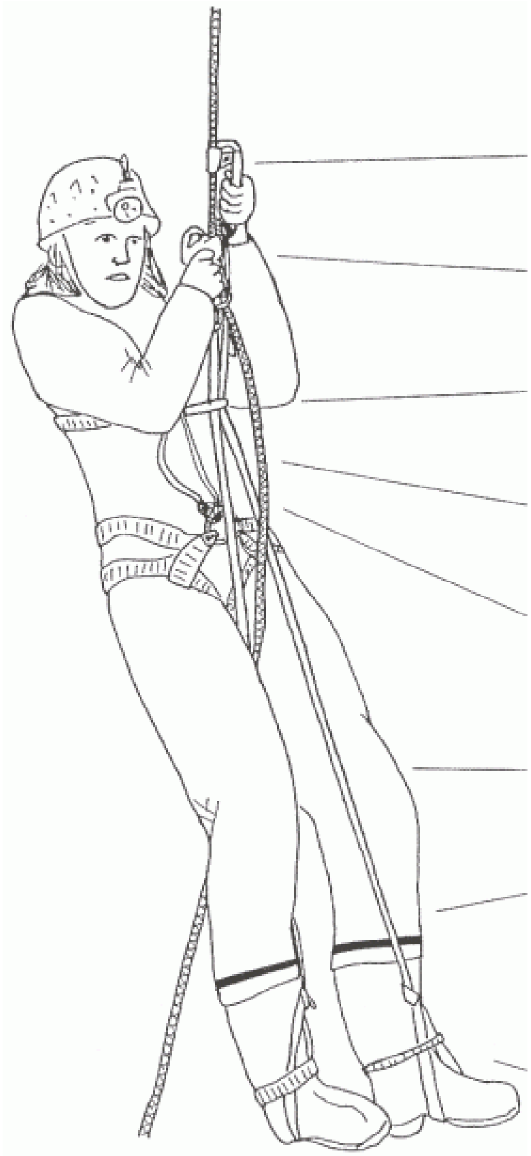
While the system works well enough, in order to stay as upright as possible the chest ascender must be mounted high on the chest. This increases the efficiency of the Floating Cam action at the expense of the Frog. The ideal Frog footloop is a little shorter than the ideal for ropewalking so an adjustable footloop or one with two loops at different heights is needed to overcome this problem. For efficient ropewalking a climbing chest harness is required to stay close to the rope.

Any convertibility to ropewalking adds to the complexity and weight of the basic Frog system and somewhere a decision must be made as to whether it is worthwhile.

Mitchell-Texas

A Mitchell system with safety cords is a Texas system once the chest box is disengaged and the foot in the long leg loop released. The two systems can be thought of, and are often used as a pair; Texas on small drops and only engaging the chest box where the pitch is long enough to warrant it. The chest box can even be removed or left behind for a series of small, sloping or tight pitches.

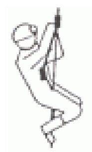
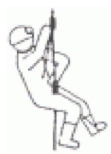
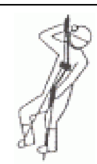
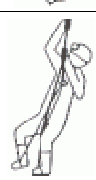
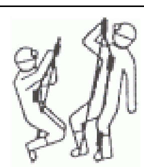
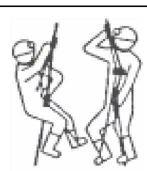
JUMAR SYSTEM



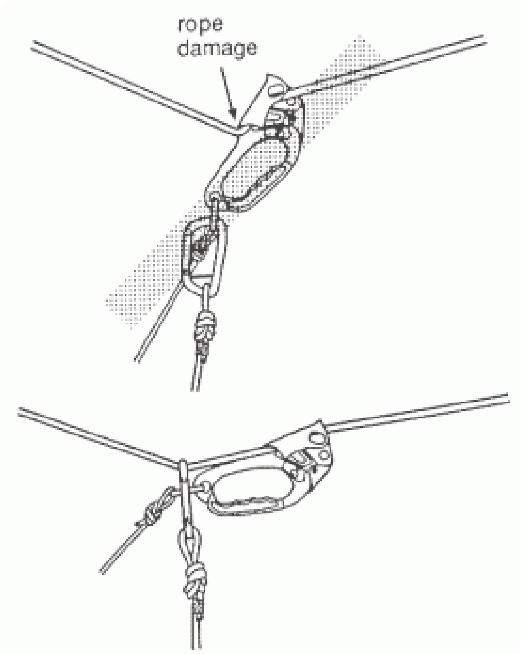
The ascent system as outlined on Jumar pamphlets works - but only just and is rarely considered seriously for caving use. The right ascender is connected with a long footloop to the right root so that it is about face level when standing. The left is mounted similarly so that it is just below the right. To stay upright the footloops run through a chest harness mounted karabiner. The footloop lengths require a little experimentation but it is possible to walk up the rope. Both hands are always busy above head height and there is no resting position.

ASCENT SYSTEMS

Table 7:3

System	Ascenders	Extras	Weight* (g)	Advantages	Disadvantages
 **Frog**	2	cowstail	500	simple, light easy to use, copes any manoeuvre, fast on-off time	slow climb rate
 **Texas**	2	ascender + sling	1000	simple, light easy to use	slow climb rate some manoeuvres may be difficult strenuous
 **3 Gibbs Ropewalk**	3 Gibbs	ascender + sling	1100	fastest system (up to 50 m/min) both hands free	extremely slow on-off time, midrope manoeuvres difficult complex
 **Mitchell**	2 + box	ascender + sling or cowstail	1600	fast up rope	very slow on-off time box cumbersome, difficult on manoeuvres, both hands busy, heavy
 **Floating Cam**	3 or 2 + box	ascender + sling or cowstail	800	fast up rope, versatile copes well with mid-rope manoeuvres (with chest ascender)	slow on-off time, complex
 **Jumar**	2	ascender + sling	1100		strenuous, both hands busy above head, copes poorly with all manoeuvres, low safety
 **Frog/ Floating Cam**	3	cowstail	750	fast up rope versatile, copes well with all manoeuvres	convertibility not always useful
 **Mitchell/ Texas**	2 + box	ascender + sling or cowstail	1600	systems complement each other, versatile	slow on/off time, heavy, midrope manoeuvres difficult

** Includes ascenders, tapes/cords, chest harness usually employed. Does not include seat harness or "Extras". Add 280 g for cowstail and 350 g for ascender + sling.*



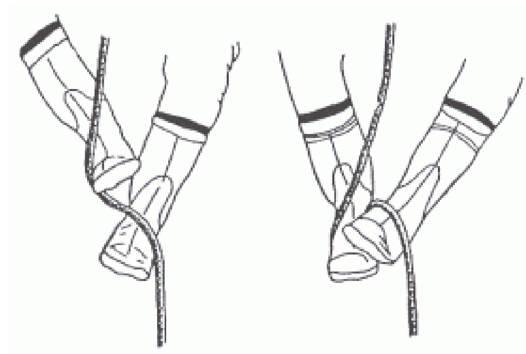
Gripping "cowstail"

SINGLE ASCENDER/SELF BELAYS

One ascender on its safety cord is often enough to help climb short slopes and steps where the consequences of a fall are minimal. For handlines a karabiner linked into the bottom of an ascender or an ascender attached to a long cowstail gives a "gripping cowstail" which can be useful for angled lines should one require a more positive grip than a simple cowstail provides. The karabiner would also take some of the load in a fall and acts as a backup for the single ascender.

While an ascender on a sling may be convenient as it provides a "portable handhold" it also introduces a lot of slack into the system, which could result in a shock load in the event of a fall.

When climbing a ladder, a single spring loaded ascender is often used as a "self belay"; non-sprung ascenders may slide before gripping. The simplest procedure is to mount the self-belay ascender as if it were the chest ascender in a Frog system. This is adequate for the occasional use that an "SRT caver" would have. For more serious self-belaying the ascender is better mounted to one side so that it does not catch on the ladder.



Footlock

A prerequisite for anyone using a self belay is that they be able to get "unhung" should the ladder break or they fall off and are left hanging in space. Waiting on rope for rescue is more than inconvenient. It is dangerous in the extreme. A descender is all that is needed to get down safely:-

- The caver attaches his descender to his seat maillon and as high as possible below his ascender.
- He then takes a footlock high on the rope and stands up.
- His descender will invert and his ascender be unweighted enough to be released.
- The bobbin is ideal for this but other descenders may not allow enough movement unless they are connected by a chain of karabiners.

SAFETY

Cavers must protect themselves from the failure or accidental disengagement of an ascender. All prusik systems must be backed up with safety cords so that if any ascender in the system is undone or otherwise fails the caver will hang in a sitting position. This requires at least two points of contact with the rope at all times and the use of a cowstail to maintain these points during mid-rope manoeuvres.

Risking a "heel-hang" or worse is simple stupidity! The failure of the chest box in a Mitchell system will result in a heel-hang if no safety cords are used. Worse still, a Frog system with no safety to the top ascender puts the caver at risk of complete disengagement from the rope should his chest ascender fail.

Rope bundled at the bottom

THE ASCENT - AT THE BOTTOM

Do not start in a hole. If the pitch can easily be started from the top of a rock or ledge at least a few metres of prusiking will be saved. Take out the stretch in the rope in a standing position by clipping on and "pumping" the rope down with one leg before trying any true prusiking motion. When there is a pendulum start make sure to have both ascenders on the rope before gently swinging out, they are both easier to attach while standing rather than hanging and it is not at all safe to swing into a void on only one ascender.

Some help with bottom weight can be arranged by tying any excess rope in a bundle off the ground. On a long drop there may be several metres of stretch and a rope bundled to hang just off the ground under the weight of a caver may be out of reach once the rope is unweighted. Anyone really desperate for bottom weight can tie a **small** rock to the rope. The rope must never be pulled tight and tied off or it will be difficult to descend next time with no slack to clip a descender into.

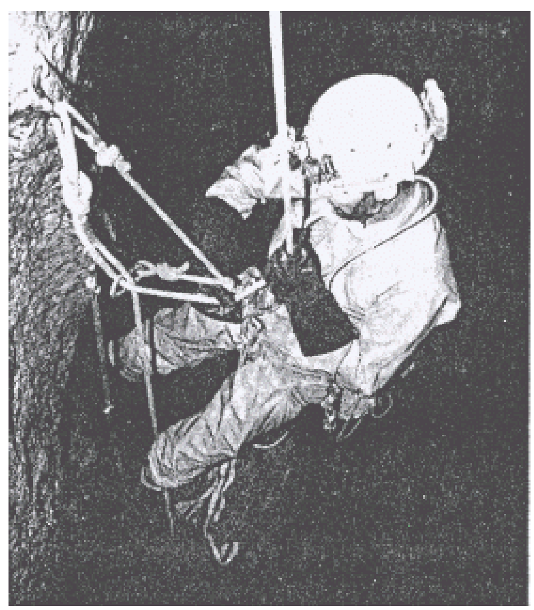
ON THE WAY UP

Prusik gently, violent prusiking can generate forces in excess of three times body weight and these forces are transmitted all the more effectively as the length of rope between caver and anchor decreases.

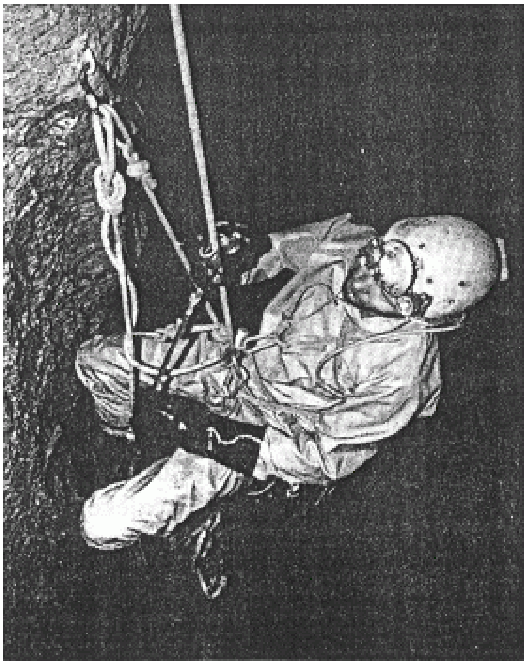
Crossing a Rebelay (Frog System)

- The caver stops one or two centimetres below the knot. Most ascenders require a slight upward movement to release them and when crashed into a knot can be difficult to undo.

- He stands, clips his long cowstail into the belay and in the same "stand" movement undoes his chest ascender.



• If he is in balance and there is enough slack rope above, he reclips his chest ascender to the "up" rope before sitting back: Where there is no wall to brace against he sits back onto his cowstail and reclips his chest ascender at his leisure if there is enough slack.



• He then changes over his leg ascender and is ready to continue prusiking until his cowstail is unloaded enough to be retrieved.

When there is insufficient slack in the "up" rope it is necessary to proceed as normal until both ascenders are off the rope and the caver is hanging from only his cowstail. He then attaches his foot ascender to the up rope and pulls down enough slack (or stands up enough) to connect his chest ascender. The procedure is exactly the same whether using a cowstail as an ascender safety cord or a separate safety cord to the top ascender.

When transferring a cowstail from ascender to belay and back again there is a moment when the caver is hanging by only his chest ascender. This can be avoided by clipping a short cowstail into the loop of the up rope if deemed necessary. A lesser risk is that of dropping the unattached foot ascender as it is transferred.

Deviations (Redirections)

Deviations are only slightly more difficult to cross on ascent than descent.

• Prusik up to the deviation karabiner and push it up until its sling is horizontal and one's top ascender is immediately below it.

• Push off the opposite wall to unload the deviation, then unclip it.

• Pull up a loop of rope from below and clip the deviation to it.

It is possible for an inexperienced or long legged rigger to rig a deviation, which is exceptionally difficult to pass on the way up. If a wall cannot be reached to unload the deviation, the bend in the rope should be gentle enough to unload the deviation by pulling across on the sling with one hand while unclipping the karabiner with the other. If there is a danger of dropping a deviation or it is severe, a cowstail can be clipped in for safety. Never try clipping ascenders past a deviation. Anyone who has been strung up with one ascender each side of a deviation will never try it again!

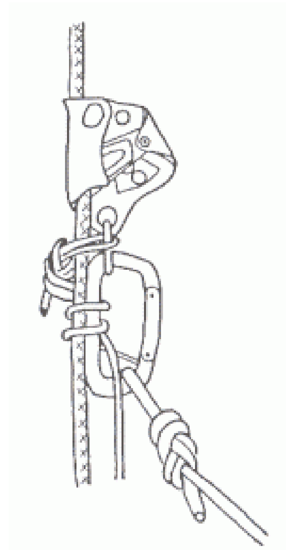
Rope Protectors

Crossing flat rope pads is no problem; it is only a matter of making sure the rope is left in the right position after passing. Brave people cross wrap-around protectors by clipping their ascenders past the protector and while it may leave them hanging on one ascender for a time it does ensure that the protector stays in place. More often, people untie the protector completely when they reach it, prusik a few strokes and replace it beneath them. At times the correct replacement position is hard to judge and it is common to arrive at a rope protector and find that it has been replaced wrongly and is doing nothing. In order to reduce this possibility, rope protectors should only be placed on unmistakable rub points and preferably where there is no need to cross them.

Crossing Knots

Passing a knot on ascent is a simple matter. Clip a cowstail into the safety loop which hangs out of the knot, then clip each ascender past one by one. Once two ascenders are past the knot, the cowstail can be undone and the caver continues. On ascent it is not worth swinging onto a ledge to cross a knot.

Prusiking a diagonal rope



Ascender rigged for muddy rope

Diagonals

Ascending a diagonal rope such as a pendulum or Tyrolean is only a little more difficult than climbing a vertical rope. It is easiest to hang upside down below the rope and try to prusik more or less as normal. Prusiking one-legged and with the free leg hooked over the rope so that the body runs parallel with the rope is a big help. High mounted chest ascenders do not run well as they are a long way from the body's centre of gravity. A karabiner between the seat maillon and rope give the rope a straight run through the chest ascender and allows it to run more smoothly. Extra care should be taken when using "Croll" or similar chest ascenders. When the rope enters the ascender from the right it can depress the cam and stop it from gripping - the result for the unwary is a frightening zip back down the rope for half a metre or so.

Muddy Ropes

Some types of mud and clay have the ability to clog ascender teeth so badly that the cams grip poorly or not at all. There are various solutions to the problem and some ascenders have slots in the cam-face to extrude mud away from the teeth. Washing the cams is also a reasonable precaution before ascending a muddy rope.

If ascenders do slip, try:-

- Pushing the cam in by hand as the ascender is loaded to force it against the rope more strongly than the spring would. Once the ascender grips it will rarely slip again until moved.
- Wrapping the footloop around the rope once or twice then through its attachment karabiner before it goes to the foot.
- Tying overhand knots below the bottom ascender and replacing them every few metres to limit the length of slide.
- Carrying a toothbrush to clean mud-choked ascender cams.
- Making a special prusik rig using Gibbs ascenders, which have excellent grip on muddy and icy ropes, for exceptionally muddy caves.

Sloping Pitches

When a pitch is not vertical the problem of fending-off the wall while pushing up one's ascenders may arise. Too bad if the prusik rig requires both hands to operate. With one or two hands free a Floating Cam or Ropewalk system tackles slopes with ease. Depending on the prusik rig it may be worth releasing or loosening one's chest attachment to maintain an upright stance even though the rope is sloping.

Fending-off on a sloping pitch

Frog and Texas users can tackle just off vertical slopes by pushing-off with one hand while moving the feet and other ascender up. On more pronounced slopes it is better to release one root to fend-off with and prusik one-legged with the other.

Tight Pitches

Ropewalkers should have no special problems. The independent leg action is ideal and the lack of a chest ascender makes a caver as thin as possible. Chest-box users may have to remove the box and convert to Texas and Frog users will find it easiest one legged. On extremely tight pitches a low, flat-mounted chest ascender will cause little problem as it pushes into the stomach whereas a high-mounted one could jam painfully against the rib-cage or even make the user too thick to fit through. If this occurs a solution is to use just the leg ascender and jam one's body between stand strokes or remount the ascender on the spare root using the now obsolete chest harness and "ropewalk" up. Any rearrangements should be made before becoming jammed into the tight spot as it may be extremely difficult to down-prusik and even easily kicked-off footloops may not be so easy to remove without room to move.

Tandem Prusiking

Tandem prusiking is occasionally used on big drops on the assumption that two people climbing simultaneously halve the total prusik time. This may well be the case for slow prusikers but those who climb quickly may find that they are hampered by the presence of the other person.

Tandem climbers should keep together. The usual practice is for the upper climber to prusik about 20 steps, then rest while the lower climber catches up. Two cavers prusiking simultaneously must be careful to climb out of step with each other so as not to generate a dangerously large harmonic bounce. When at a lip or against a wall tandem prusikers must stay within a few metres of each other as the lower caver will be directly below any rocks, which the upper caver may dislodge.

Tandem climbing places more than twice the usual loads on a rope and must therefore only be done on good, well rigged 11 mm rope. As part of that rigging, it is well advised to use a tail or rebelay to make it easier for the upper climber to exit the top of the pitch.

Down Prusiking

A slow descent of a rope can be made by reversing the usual ascent movements; releasing each ascender with a slight upward push then holding the cam open for the move down. Some care must be taken to manipulate just the cam and not the safety latch as the ascender may then become detached from the rope. It is easiest to take several small steps rather than few large ones. When using more than two ascenders remove them until there are only two to manipulate. Prusiking down a pitch is very slow and for a descent of more than a few metres it is faster to change to abseil.

Ascent to Descent

Changing from ascent to descent while on the rope is a similar manoeuvre to crossing a knot. There is little problem with prusik systems, which use a long footloop, but others (Texas, Ropewalk) require a spare ascender or prusik knot with a long sling to stand in.

While the caver is in a resting position the descender is clipped to the seat maillon and onto the rope as high as possible and locked off. Foot-mounted ascenders are released. The top ascender is positioned as low as possible but still high enough to stand in to release the chest ascender/box. Once the chest ascender is released it is only a matter of sitting back onto the descender and releasing the top ascender.

Descent to Ascent

The top ascender is clipped high on the rope and then one stands up in its footloop. The chest ascender is then clipped in and the descender removed. If using a long descender or foot-mounted ascenders it may first be necessary to hang from the top ascender and pull some slack through the descender so that the lower ascenders may be clipped in. Once two attachment points have been placed on the rope the descender can be removed.

It is possible to put on prusik gear while on abseil should the need arise. Anything, which must be connected to the seat maillon, is clipped into it with the brake or a spare karabiner and other ascenders snapped on as well as possible. The prusik rig can later be arranged properly on safe ground. **Do not even think about undoing the seat maillon while hanging on it!**

Gear Sacks

On sloping pitches a sack is best carried on one's back where it will not snag or drag against the rock. Anything but an empty sack on a caver's back for vertical pitches will lean him back enough to tire his arms rapidly. Climbing is much easier with the pack connected by its haul cord to one side of the seat maillon or rigging a short "V" of tape from the harness attachment points to hang it from. The pack's haul cord should be long enough so that the pack does not foul against the feet but still within tiptoe reach so that it can be freed should it become snagged on the way up. Light packs can develop an annoying harmonic swing when hanging below. Shortening the haul cord may help as well as putting more weight in the sack! On wet pitches the open top of a sack may well act as a tunnel and fill the pack with water, unnecessarily slowing down a caver in a place where he wants to move fast. Suspending the pack upside down will put the biggest hole at the bottom and save needlessly hauling a sack of water up a pitch.

At the Top

On arrival at the top of a pitch the caver's first move is always to clip his long cowstail to the tieback rope, anchor, knot loop. He is then free to get off the pitch in complete safety.

- Next he must release his root mounted ascender or one root from a Sit/Stand rig then stand on the other root and release his chest ascender.

- He can then step onto the lip and release his root ascender.

- If his cowstail is clipped to a tieback rope he walks away from the pitch and unclips.

- If it is clipped directly to the belay or similar he must first attach a short cowstail or an ascender on a sling to the tieback and then unclip the cowstail.

Swing-out pitch heads can be more difficult.

- Clip a long cowstail to the knot loop, rigging link or anchor, but not the tieback rope.

- Release restrictive root and chest ascenders, hang back on the cowstail and transfer the long footloop ascender to the tieback rope so that it can be used as a handhold.

- Pull across to the lip.

- Once across and safely clipped in, the cowstail can be released.

In general terms a pitch head can be negotiated like a rebelay, always remembering to undo the chest ascender before attempting to leave the line of the rope.

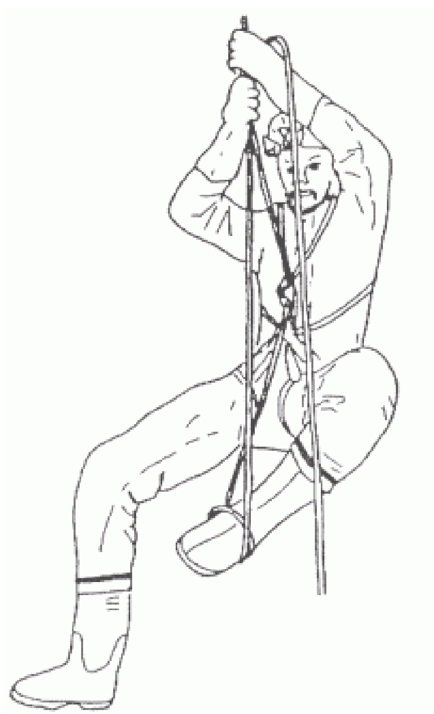
ASCENT PROBLEMS

One Ascender

The situation is not too critical provided a caver still has one ascender. An autostop de-scender can be connected to the seat maillon as for descent and the rope pulled backwards through it to make it function as a chest ascender. The one good ascender can then be used as a leg ascender for a Frog system with footloops fashioned from whatever is at hand - the end of the rope, pack haul cord spare clothing. With a Texas system the autostop should be connected to the feet and the real ascender to the chest.

Without an autostop the one ascender is chest mounted and a prusik knot used for a leg ascender in a Frog or Texas rig. To tie an effective prusik knot a length of cord, which is thinner than the rope to be climbed, is needed

Climbing with one ascender and an autostop



Climbing with one ascender

and this may not be easy for cavers using 7 mm or 8 mm rope!

With nothing, which will work as a prusik knot, it is possible to climb "Inchworm" style with a chest mounted ascender and footlocks for the feet but it will not be easy.

NO ASCENDERS

With no ascenders or autostop the only choice is to construct a prusik rig using knots and a Texas system. Texas is easier than Frog as both hands are free to manipulate the bottom knot. But the main problem is finding cord, which is both strong and will grip for the prusik knots. Some imagination may be required. Try carbide lamp sling, pack cords, sheath or core stripped off the bottom of the rope. Should the situation be desperate enough to try 3 mm cord, boot laces for prusik loops a self belay must be arranged by clipping in one or both cowstails to a Figure-8 or Figure-9 loop tied just below the bottom knot. In order to minimise the potential fall the knot should be replaced for every few metres climbed. Prusik knots on hard kernmantle ropes are often of dubious security and once they begin to slide they may continue to do so until they melt through. When security is in doubt a self-belay is worth the extra time.

FOOTLOOP CAUGHT IN CHEST ASCENDER

With the Frog and similar systems it is possible to catch both the rope and the long footloop in one's chest ascender. In the next "stand" move the chest ascender climbs the rope and footloop and *voila!* Stuck! Dangling knot tails and thin tape are the most likely offenders. To escape, the chest ascender must be moved up a little before it can be released and inclined cam teeth make this more difficult. When jammed as high as possible extra height can be gained by tying a knot in the footloop to shorten it. It is then a matter of standing up hard and pulling down strongly on the ascender release at the same time. If that fails escape may only be possible using a separate stand-in sling to unweight the entire prusik rig. The probability of such incidents occurring can be reduced by using brightly coloured footloops and safety cords which do not look at all like prusik rope, by taping all knot tails out of the way and by using cord instead of tape footloops if one's prusik style causes them to rub against the chest ascender.

8 ORGANISATION

The best equipped caver in the world would not get far without having his gear and himself organised. The level of organisation required will depend on the cave and the cavers but in general the more serious the trip the better organised a group needs to be.

INTEGRATED SYSTEMS

While vertical caving can be dealt with as a series of separate units such as "Prusik Systems", "Descent", "Ascent", the units must be put together properly with other compatible units for them to work as a vertical caving system. It is no use setting up the hottest 3 Gibbs Ropewalking rig and then cursing at the first rebelay only ten metres up. From the choices available a caver must first decide how he intends to rig caves and then attach other units, which fit.

Alpine rigging goes with thin rope, Frog prusik rigs, cowstails, bobbin descenders, bolts, staying dry at all costs and rope packs. American rigging goes with thick rope, Ropewalking, spare ascenders on a sling, racks, bowlines around boulders, wet suits and "wagon wheels". This is not to say that there is no room for compromise but simply that caving methods and equipment cannot be chosen in isolation from each other.

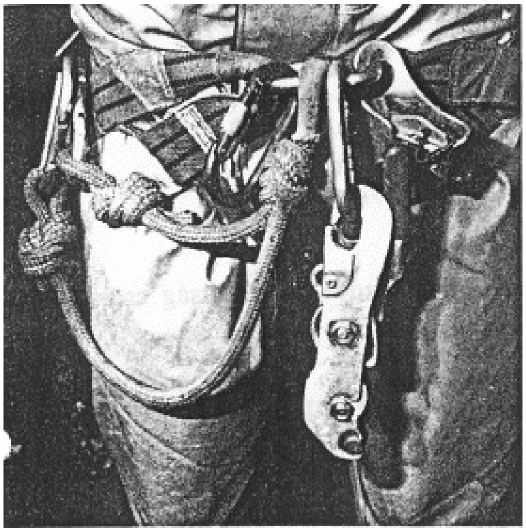
PERSONAL ORGANISATION

Each caver in the party must be physically fit and be organised to do the cave. It is important to be confident in one's fitness and caving ability so that moving through the cave becomes "second nature". This invariably means building up to hard trips by practice in continually more demanding caves to get an idea of one's personal limits, be they physical or psychological.

Before starting down a cave, everything should be pre-arranged ready for use. Prusik gear can be worn ready for action with footloops rolled up out of the way so they will not snag or packed into a small but secure sack and hung from the caver's belt. Prusik gear should not be carried in a rope sack, if the sack is left behind or swapped with someone else the gear could be left behind. Similarly, on the way up each caver should keep his descender on him in case he must redescend a pitch. Personal equipment should be arranged neatly. The more odds and ends hanging off the more they will get hung up.

A caver's seat maillon is the focal point, which connects him to his equipment. It often has many things clipped into it, all of which must be in an orderly fashion so that they interfere minimally with each other.

From left to right they can be organised:-



Pack haul karabiner Croll
Descender on a locking karabiner
Cowstail
Brake karabiner
Ascender safety cord

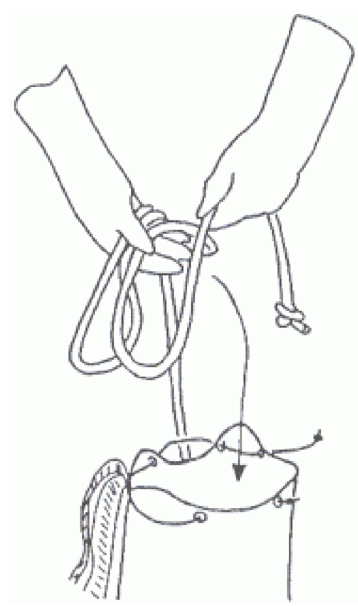
When arranged this way the pack haul karabiner is easy to undo and its cord hangs against the harness leg loop instead of more delicate objects. The Croll moves up to the top of the delta maillon when in use, otherwise it drops out of the way to the left. The descender also moves to the top when in use and can be removed if prusiking any distance. The cowstail is a minor problem. It also moves to the top when loaded but as well pulls to the left or right depending on the rebelay. When it pulls left on ascent it conflicts with the Croll, putting it on the other side is a poor solution for right-handed cavers. The ascender safety cord is as far out of the way as possible. It is rarely necessary to wear everything at once.

GEAR MANAGEMENT

ROPES

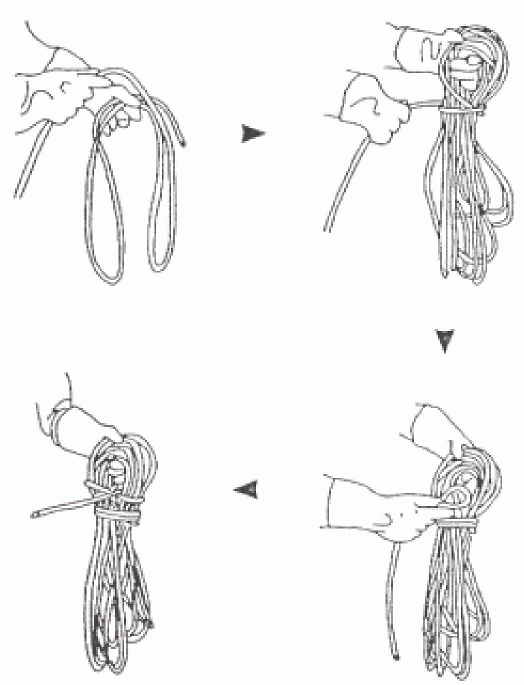
If it is not done properly a lot of time can be wasted handling ropes. Most cavers would agree that the only place to carry rope is in a rope sack.

Rope is best carried in a sack on loose pitches



Stuffing a rope pack

When the cave is known or a long rope is cut to fit a pitch a stopper knot should be tied in the end and the rope "stuffed" into the sack, ideally in handfuls, which do not twist the rope. Consecutive ropes can be tied to each other either loosely if the pitches are not continuous or with a knot and safety loop ready to cross so that it will not have to be done while hanging in space. Descending a pitch with the rope pulling out of a sack vastly reduces the danger of a falling rock damaging the rope or it becoming tangled as often happens when it is thrown down.

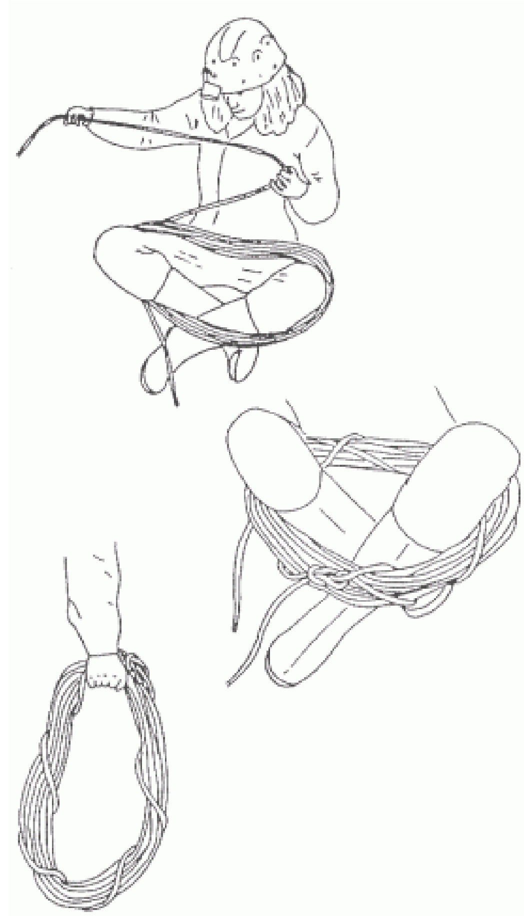


Rolling a rope - climber's style

When the cave is unknown it is necessary to choose a suitable rope as each new pitch is encountered. These can be carried as a selection of ropes, each rolled up separately, with the longest one stuffed into the bottom of the sack. The specific selection carried will depend on what is known of the cave or other caves in the area. As each rope sack is emptied the load can be split more evenly between the party or the empty sack can be left hanging from a belay for refilling on the way out.

Stiff thick ropes do not easily fit into rope sacks but they can be rolled around the knees and tied into "wagon wheels" which are worn over a caver's shoulder, hanging below on pitches or rolled along ahead in narrow passages.

Occasionally the rigging of a pitch requires delicate climbing which would be difficult with a heavy pack. In this case it could be better to descend a loop of rope with a "second" paying out rope to the "leader" until the difficult anchor is rigged or the loose rock is passed or removed. When everything is secure the pack can be lowered or brought down by the second. Never clean a pitch of loose rocks with rope hanging down it.



Rolling a rope - wagon wheel

GEAR SACKS

The selection of gear sacks depends on the nature of the caving. Long thin sacks for nasty narrow caves and fatter, more comfortable ones for caves in which there is a chance to wear them. No matter how much gear a cave requires there is no point putting it in a sack, which is so big that it must be unpacked to fit through every tight spot.

Hard items such as hammers and kara-biners should be packed in the centre of the pack to keep them from damaging the pack fabric or the caver's back. Odd items like food or rigging gear can carried in a light nylon sack within the cave pack so that they can be easily removed to get at the rope below. If the cave is known every item can be prepacked in the reverse order of when it will be needed.

While the bulk of a vertical caver's load is rope there are several other items, which also must be carried.

ANCHORS

Bolt hangers are pre-clipped to their karabiner or maillon and linked in chains often for convenience. When the chains are split between rope sacks to spread the load they should be clipped to the drawcord or rope so they cannot be lost. When rigging a series of pitches it is a simple matter for a caver to hang a chain with hangers and another of karabiners and maillons without hangers from his belt ready for use. In dirty caves hangers are better kept in a small sack to keep the bolt threads clean.

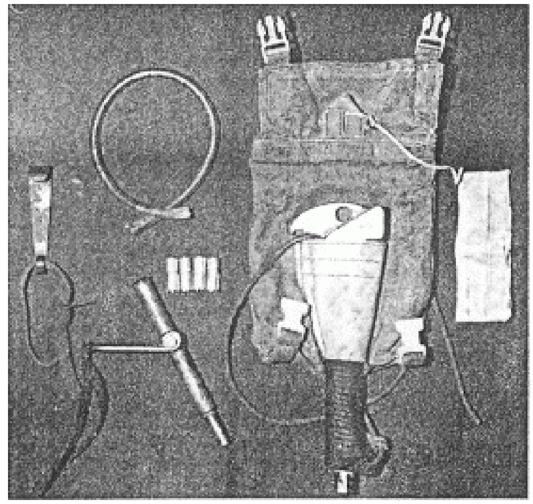
Do not carry hangers or any small metal items loose in a cave sack, as they are adept at finding their way to side or bottom and eating their way out. Pegs and nuts carry well on metal peg rings or short lengths of knotted cord. Slings can be knotted loosely to make them easier to handle and a number clipped to a karabiner to keep them together. Wire traces should be tightly wound into a 15 cm diameter ring and the two ends joined with a karabiner or maillon to keep them from unraveling.

When a cave is well known or there is a good tackle list available the rigging gear for each pitch can be attached to the top of each rope. This avoids the need to rummage in a tackle bag at each belay point and saves time.

BOLT KITS

Everything needed for bolting can be packed together into a pouch which doubles as a hammer holster that can hang at a caver's side when in use. When closed the pouch should keep the contents of the kit from escaping and trap the hammer head inside to stop it damaging the gear sack. The anchors, driver and blowtube can then be carried loose in the pouch while the expansion cones are kept in a small velcro closed pocket to make them easy to find and avoid losing them. The hammer and cone pocket are tied to the pouch with cords while the driver is fitted a with wrist loop. Some cavers also throw in a skyhook to help keep them in position when placing difficult bolts.

Before packing the anchors it is worthwhile checking the threads and never taking many more than will be needed on the trip or they will only become wet and dirty and difficult to thread next time around.



Bolt kit

A 13 mm spanner, with a tube or ring spanner at one end and open at the other is best carried separately from the bolt kit as it is often required for rigging to fixed bolts or adjusting rigging during exploration. It can be attached to a string and mini-karabiner and hung beside one's carbide lamp or put on a car tyre tube armband. When derigging without a spanner, the attachment eye on a Petzl bobbin can be used as a spanner to save abandoning hangers.

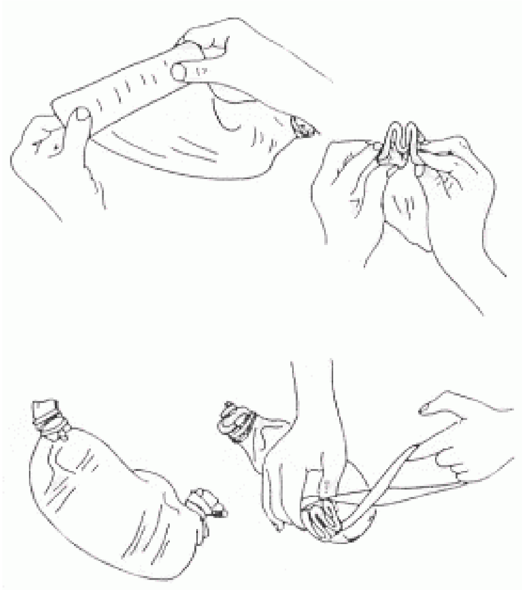
When exploring previously bolted caves an anchor cleaning tool made from a sharpened length of wire can be added.

SPARE CLOTHING

Dry clothing is an absolute joy to put on if trapped by floodwater or when moving too slowly to keep warm. A silk balaclava fits easily in a top pocket or top of a helmet. A spare thermal top wrapped in a garbage bag to keep it dry has the added advantage that a caver can climb inside the garbage bag for extra warmth.

CARBIDE

Small wide-mouthed plastic bottles are popular carbide containers among cavers with cap lamps. Larger chunks and quantities of carbide are better carried in lengths of small diameter car tyre tubes with the ends closed by robber bands to make "bananas". They are robust, waterproof, malleable and unlike plastic bottles they get smaller as the carbide is used. One third of a tyre tube filled with carbide is about the maximum anyone would want to



Carbide banana

carry and it is usually more convenient to take several smaller ones rather than one big one for longer trips.

The quantity of carbide carried can be calculated as for a cave diver's air. One third to get in, one third to get out and a third for spare. Though, because the consequences of running out are less drastic for carbide than for air the spare third is cut down for most trips.

TACKLE LISTS

When planning a trip down a known cave it is advisable to do as much research as possible to find out exactly what is in store. The two most valuable pieces of information are a tackle list and a map, a copy of which can be encased in "contact" plastic or a clear plastic bag and carried through the cave for ready reference.

If a tackle list is not available one can usually be drawn up from the cave description or map. In it include information for each pitch - pitch length, rope length required, nature and location of anchors, special characteristics such as water, pendulums etc. Even an incomplete list is better than nothing. When rope lengths are not indicated they can be calculated roughly by counting each knot (of any type) as using one metre of rope and each rebelay as using two metres. With the help of the map extra allowance can be made for a long tieback,

CREEK CAVE Tackle List

Table 8:1

Pitch	**Length** (m)	**Rope** (m)	**Anchors**
1	12	20	nat + b, b-6
2	3	6	pr + b
3	90	100	2nat, nat-20, b-30, ledge b-50 2b-60, b- 70
4	20	25	nat + b
5	30	35	b, b-5
6	30	30	nat + b
7	45	50	b+nat,nat-15
8	2C	6	climb up/ladder
9	30	35	nat, r-5, r-20

nat = natural belay b = bolt
r = redirection (deviation) pr = previous rope

traverse, stepwise pitch or large natural belay, all of which require more rope. If in doubt take too much and pack a few five to ten metre lengths as spares if the information is lacking.

Arrange the ropes so as to use the lighter and better fitting ropes at the bottom of the cave and save the ones which are too long or heavy for the top. When it is all decided lay everything out side by side, check it against the tackle list and note down each rope to be used on the list, then stuff them into the rope sacks in order from the bottom of the cave up.

The rigging gear can be either split between the sacks so that there is an appropriate amount to rig each load of rope or it can be concentrated to make one small but heavy rig pack. Food, carbide and spare clothing can be put into the packs which are lighter to even up the loads and later transferred to the first empty sack so it will not have to be unpacked each time rope is needed. When there are a large number of sacks it is worth marking each one with a number or tag so as not to get them confused.

NEW CAVES – PROSPECTING

When surface prospecting for new caves it is best to walk the area first with minimal gear, perhaps a torch and short handline at the most. Once some reasonable holes are found one can return with light caving gear to check them more thoroughly. Try to be systematic when prospecting an area. Mark the entrance of each hole with a spot or cross to indicate it has been looked at and goes nowhere or with a number and perhaps letter code for any significant holes. If possible note the location of each hole on a surface map and take separate notes as to what each numbered cave is like.

DEPTH ESTIMATION

Before descending any shaft it is useful to know how deep it is. Small pitches can be estimated visually by shining an electric light down them to spot the bottom and see if the rope is long enough. Once a pitch is longer than about 20 m or rounds over at the top the most convenient estimation is by sounding with a falling rock. A solid, fist-sized rock is dropped down the pitch with care taken to give it no initial velocity, although a light outwards toss may be necessary to make it fall down the centre of the shaft.

DEPTH ESTIMATES

Table 8:2

Time (sec)	**Rough Depth** 5 x T^2 (m)	**Actual Depth*** (m)
2	20	19
2.5	30	29
3	45	41
3.5	60	55
4	80	71
4.5	100	88
5	125	108
6	180	151
7	245	210
8	320	257
9	405	319
10	500	386

* Using D= 340 x T + 11784 (1- { EQ \r(2, 1 + 0.0577 x T) }
(Hoffman, 1985)

Fall time is counted to the nearest half second using a watch. Using this time a rough estimate can be calculated with the formula:-

$$D = 5 \times T^2$$

D = depth in metres, T = time in seconds.

i.e. A three second drop would give -

$$5 \times 9 = 45 \text{ metres}$$

In most cases this will give an exaggerated figure but it is better than nothing. Once the rock bounces accurate estimation is not possible though it still gives some indication as to whether the hole is "big" or "small". Table 8:2 shows time versus depth more accurately for those who wish to write it on the lid of their cave pack.

WHAT TO TAKE

In most karst areas the majority of surface shafts are blind so any initial descents should be done with this in mind. Take only the lightest of personal equipment and carry no more than two or three ropes; one 30 m to 40 m long and two shorter ones are usually sufficient. Rig the most suitable length down the entrance drop and carry another if it looks hopeful. Eleven millimetre ropes and American rigging will save a lot of time and effort if there are a number of holes to look at. Confirmed Alpine cavers or those who only have thin rope will also need a bolt kit, some slings, perhaps a few pegs and nuts and some rope protectors to cut corners without cutting the rope on the initial descent.

EXPLORATION RIGGING

For the first descent of an entrance shaft the rope can be rigged roughly and quickly, though always safely just to see if the hole "goes". Heavy use is made of natural belays with little consideration given to comfort or ease. Should the cave go it is not much trouble to rerig one pitch and if it does not go time and effort will have been saved. A slight exception is for bolts. If forced to spend the time placing a bolt, do it properly so that it can be used again if necessary.

Once the cave is going and looks as if it will continue to do so it should be rigged properly the first time. All too often cavers rush on down in the excitement of a new discovery and leave behind a trail of shaky anchors, half drilled bolts and chopped ropes. It may get them down a little faster but apart from being dangerous it is a thankless task having to completely rerig a section of cave before breaking new ground.

The amount of rope and rig gear the group carries underground will vary with what they expect to find. Take a lot and find the cave ends or a little and run short. On average a competent team could expect to rig up to 200 m of rope and place up to ten bolts in a days exploration of a cave, which goes with no major complications. When a selection of different length ropes is carried there is a good chance several will be the wrong length but it is not too difficult for the following day's party to change them for more suitable lengths and carry the unsuitable lengths along to rig the next new section. So long as the anchors are properly placed, changing the ropes will be a minor exercise.

GENERAL ORGANISATION

PARTY SIZE

Modern lightweight caving definitely works best with small groups. Any number from one up to four is a reasonable caving "party". Beyond four it is preferable to split into sub-groups, which are more manageable and can move faster. All rigging is slow and as there can only ever be one person in front at a time there is no point having the rest of the party shivering along behind.

When rigging, the ideal is two, one to do the rigging and the other to help when needed. A fast rigging descent rate for a known cave is around 100 m per hour and with this in mind a group of six can split into three twos and stagger their entry times so as to arrive at the limit of rigging just as their ropes are required. An alternative strategy is to split into a rig and derig team so that the riggers can reach the bottom and exit with minimal loads of excess gear and rope and the deriggers can arrive after the riggers leave the bottom and immediately begin the derig.

TRIP DURATION

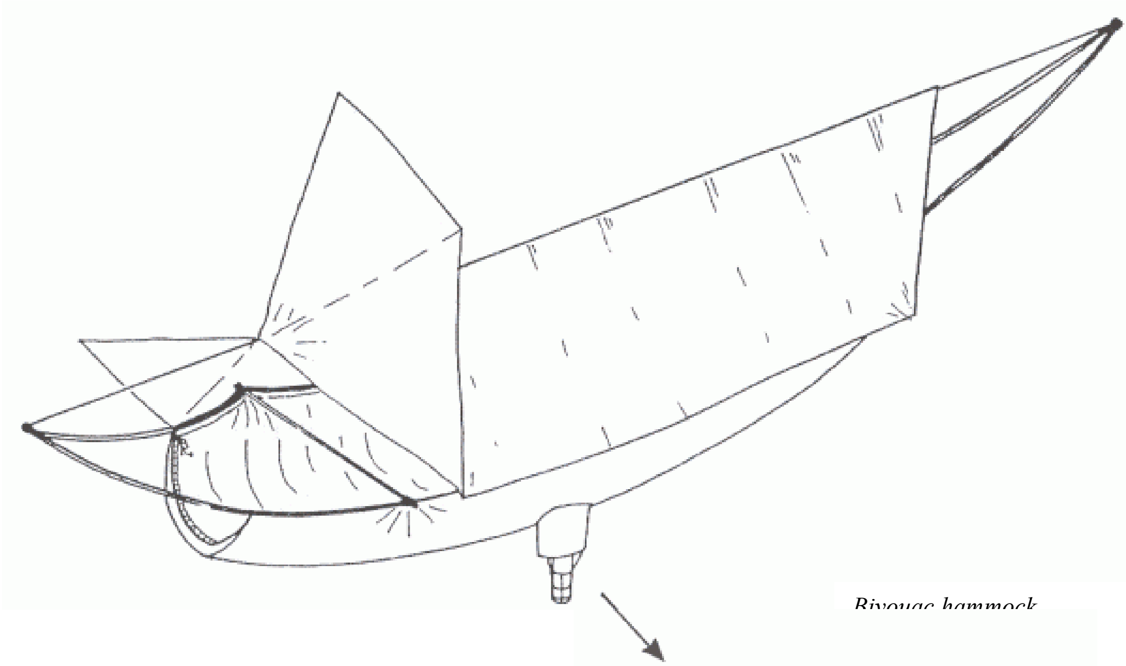
While estimates can be made of descent rates for "average" known caves, the actual rate will depend on the nature and state of rigging in the cave and the competence of the cavers involved. A pre-rigged cave could bring descent rates of 200 m to 300 m an hour while a vast amount of complex rigging or re-rigging could slow things down considerably. When researching information about a cave there is usually some indication as to trip durations.

For most people a trip of five hours would be no problem, five to ten hours would be reasonable and ten to twenty hours becoming se- rious. Beyond twenty to thirty hours people start considering bivouacs. While this is reasonable on expeditions when several trips of this duration may be necessary, one-off sport trips can, with training and the right attitude, go for longer - thirty, forty or more hours without sleeping. Once a trip goes overnight allowance must be made for the body's slowing down during normal sleeping hours. Often this problem can be reduced or avoided entirely by getting an early start so that as much caving as possible is done during normal waking hours. This does not mean setting an alarm for an "alpine start" but merely getting going quickly and efficiently after waking and not spending most of the day sorting equipment or mending gear when it should have been done the day before. Contrary to popular belief "Gentlemen do go caving before noon".

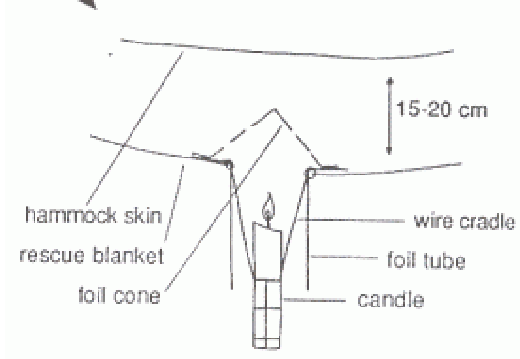
BIVOUACS AND CAMPS

The need to place an underground camp or not is largely a matter of caving style rather than an absolute "It is not possible to go further without a camp". Most cave camps are a waste of time and effort. The same end result is usually achievable from the surface with less expenditure of time and manpower. The effort involved carrying in camping equipment, food and carbide often ties up several people for a few days when the same effort could be put toward exploring the cave. Granted, camps are often set up by weaker cavers who feel they have no chance of reaching the bottom so that the stronger cavers can put a greater effort into the exploration though this is hardly reasonable justification for unnecessary camps.

Underground camping has a devastating effect on the cave environment. I seriously doubt that there has ever been a cave camp which has not left its mark on the cave, be it a rubbish heap, human waste dump, abandoned gear or rearrangement of the cave to build kitchens and beds.



Bivouac hammock



If camping truly is the only solution, make it as light and short as possible. Long duration camps inevitably waste a lot of time with people sitting around on rest days eating valuable food. Using specifically designed gear will help reduce the load. Sleeping bags should be synthetic so that they still insulate when damp and of a narrow "mummy" shape to keep their bulk down. Light, heated hammocks cut weight even further as they do not require a sleeping hag. The heat source is a solid fuel burner, long burning candle or carbide lamp. An "Isohamac" is available commercially from Expé but can be improvised using a light nylon hammock and three rescue blankets.

The lightest available canned gas stove can be taken or the menu revised so that only limited cooking need be done using a carbide lamp flame. Carbide lamp stoves have been designed, built and used with good results or water can be heated directly over the jet. A lamp running a 21 L jet can boil 250 mL of water in 9 minutes from 15° C using an aluminium foil windshield.

In caves the roof will leak and/or it will be draughty so it may be necessary to make a rough tent or roof from light plastic sheeting. Once the camp has been installed and inhabited it should be used as efficiently as possible and wasted on nothing other than its intended purpose - to explore the cave.

DERIGGING

On sport trips everyone wants to get to the bottom and they usually end up there at the same time, looking at each other and trying to put off what comes next.

In order to derig efficiently each caver should ascend slowly and wait at a predetermined spot one rope sack-full apart to take their turn at derigging or to collect a load. The last person up then begins pulling the ropes. As he ascends he should dismantle belays and undo knots and loops so as to reduce the chances of a rope snagging when it is pulled up. Any knot left in the rope will grind against the rock on its way up and cause unnecessary rope wear. On long pitches with ledges it may be necessary to haul the rope up to each ledge and re-stack it so that when it is hauled up the next section it pulls from the top of the pile.

When a pack is full the derigger either takes it to the surface or passes it on to someone who does. Anyone with a full load gets priority so as to get the gear moving as fast as possible. People should move singly or at the most in pairs with the last two staying together to help each other with difficult derigs, long ropes and packing the sacks.

If a cave is to be left rigged from one season to the next it may be desirable to "stage derig" especially in flood prone caves. All this means is that the ropes are pulled up and stacked every few hundred metres in a dry "safe" location to save them from being destroyed. Derigging whereby a sack is brought out part of the way and then left for a later derig trip while the caver exits empty-handed is highly inefficient.

GEAR HAULING

Hauling gear up pitches on the end of a rope is not compatible with lightweight caving. It is hard work, causes unnecessary wear on gear, risks the rope not being replaced correctly after the haul and will not work at all with rebelays. Flying foxes (ziplines) and pulley lifts are a thing of the past, any caver who needs them should rethink his approach to **lightweight** caving.

The most efficient way to move gear is for each caver to carry his own load. A full 30 L cave sack is enough in tough caves although more can be carried in easier caves. When loads exceed this for any distance two trips are more efficient than gear hauling sessions. Only rarely will there be a section of cave, which is so nasty that it requires an extra pair of hands to pass sacks through. Long chains of cavers passing packs take a lot of time to set up and gain little distance. Efficient vertical cavers are self-sufficient.

WEATHER

Many caves are little more than stormwater drains in wet weather. As part of any pre-trip organisation it is important to get some idea as to the local weather patterns and choose a stable period or season to visit. This will vary greatly from waiting a few days for unsettled weather to pass to visiting an area in the dry season. In tropical areas this may actually be the "least wet" (euphemistically called the "dry") season and it may be necessary to modify caving schedules to suit - if it rains most afternoons caving is safest at night/early morning with everyone out of any danger zones before the rain begins.

In alpine areas the worst times are during snowmelt, spring or when there is heavy rain on a light snow cover and far less predictably from thunderstorms. After waiting out bad weather it may not be wise to sun down a cave on the first good day, the water will still be high and the ground will be soaked so that any more rain will run off into the caves immediately instead of being absorbed at least a little by the soil.

FOOD

The main requirement for cave food is edible, followed by high energy. Suitable energy foods are sugars of any description, dried fruits, sweets and chocolate. This can be premixed to make a "scroggin" and save having to pack each item separately.

Starchy foods such as fruit cake and biscuits give longer lasting energy than sweets and are more filling.

Most caving trips are too short for fats, oils and proteins to be essential, nevertheless nuts, cheese and salami are filling and help one feel well nourished, which is half the battle. Most cavers on extended trips soon tire of a diet of sweets and more traditional meals like sandwiches are often appreciated so long as they are kept intact.

Cave food can be carried wrapped in plastic bags though on rough trips in wet caves they usually leak. Wide mouthed plastic bottles and lunch boxes keep food in better shape and keep it dry. In wet caves food can also be kept dry in plastic bags inside tyre tubes like carbide.

Even minor dehydration can cause a severe fall-off in performance, it is therefore essential to drink enough to maintain the body's needs. When exercising heavily thirst is an inadequate indication of water need and it is necessary to drink more than one's thirst indicates. In many areas this may mean taking water purification chemicals and a small water container for long trips.

Stoves to make cups of tea and soup are often carried for cold caves but they give little extra energy. The psychological boost they give is more than counteracted by the time spent sitting around in the cold waiting for them to cook-up as well as the weight of carrying them. The only times a stove is needed is for bivouacs, long trips such as when climbing, and more importantly in the case of an accident when any psychological boost to the patient is worthwhile.

Just as important as what a caver eats in the cave is what he eats before the trip. As in any other endurance sport, cavers should eat as much complex carbohydrate, especially pasta as they can tolerate before the trip so that they enter the cave with a maximum of energy reserves already in their bodies. On returning to the surface it is good to have something "nice" to eat at the entrance so as not to starve on the walk back to camp or while cooking dinner.

Due Out Messages

Before going underground it is advisable to leave word with somebody on the surface as to when the party expects to be out. This can be on a casual basis such as someone in the group who is not going caving but knows when to expect them out. Or it can be more formal such as filling in an intentions book in a caving hut and being obliged to call back before a stated time.

Most of the time however cavers simply rely on a friend or relative noticing that they have not come home from a weekends caving. This could leave them stuck underground for two to three days. Better alternatives are to leave a message as to when help is wanted with someone who knows exactly who to call should the caving party exceed the deadline or leave written emergency instructions with some responsible person.

Pre-trip research should include the call-out numbers for the local cave rescue if there is one or the police or fire brigade if not. Expeditions to remote areas do not enjoy such luxury, they must be self-sufficient.

Calls and Signals

Much fuss is made over the need for good whistle signals or communication between cavers at the top, bottom or middle of pitches while in practise there is rarely a need to say much at all. Perhaps it is a hangover from the days of ladders when communication was needed between belayer and climber. SRT cavers are largely independent of one another and it is only necessary to give a simple call such as **"OK"**, **"Rope Free"** or **"Off Rope"** when each caver has unclipped at the top or bottom of a pitch or has passed a rebelay. If there is loose rock, water or some other reason why the next person should not follow close behind the call can be withheld until it is safe for the next caver to proceed.

It is good practice to always give a call if there is any chance the following caver is within earshot, that way they will know the rope is free before they even reach it and not wait for a call, which may never come. Similarly, in Alpine rigging, it is usually possible to see the rig point ahead but this is no reason for someone to not call because they think others have seen them pass it.

When a rock is knocked free any urgent call such as **"Below!"**, **"Rock!"** will elicit the appropriate response though it is better for cavers waiting at the bottom of pitches to stay under shelter whenever possible. If there is any chance of rockfall it is safer to give some advance warning rather than wait until something actually falls.

CONSERVATION

It is a sad fact that the world's caves are slowly filling up with rubbish and it is the job of every caver to take out all that he takes in and whenever possible a little bit more to make up for lazy cavers who have left things behind. Carbide is a particular problem. The calcium hydroxide waste is strongly alkaline and harms cave life. It should always be removed from the cave system and then disposed of correctly. Do not go to the effort of packing the waste into old carbide containers or plastic bags and then leave it in the cave.

Throwaway rigging is another irrespon-sible and unnecessary habit. While anyone can appreciate that things may be accidentally left behind or even abandoned in times of stress there is absolutely no excuse for cavers who deliberately take along old or low quality rope with the express intention of abandoning it in the cave simply because they are too lazy to derig. e.g. In September 1986 a group of cavers rigged Reseau Jean Bernard down to -600 m almost entirely on new but poor quality 8 mm rope. "Derigging" was done by removing the bolt hangers and karabiners and leaving the rope in a heap at the top of each pitch! On a smaller scale the everyday rubbish like chocolate wrappers weigh very little and take a negligible amount of effort to carry out, yet in many caves they are abandoned in profusion.

At least rubbish is removable even if effort is required to do so. Other things such as bolts are not. It is up to the first riggers to place bolts well enough so that future visitors will not be tempted to put in alternative rigs. Bad bolts, both in terms of position and the anchor itself only lead to "bolt farms"; new anchors popping up like mushrooms with each season whereas good bolts will be used by everyone. Part of this is psychological. Many caves are well bolted, though not overbolted until a large pitch is encountered then there will be a bolt farm, most of them safely back from the edge where they are useless and perhaps one or two well located so that they are useful.

When doing a known cave it is worth being a bit tolerant of weird rigging provided it is safe. Taking along something to clean out clogged bolts rather than just putting in new ones beside the "old" saves time and the cave. A small piece of stiff wire with a curved point at one end is light and with some work can make rosty or mud-choked bolts usable again and more than once I have wished I had an 8 mm tap with me. When a bolt is unquestionably bad some cavers bash it to a mangled mess to render it "safely" unusable. This attitude and that of filling anchors with glue or mud only serves to compound pollution problems. When a bolt is no good it should be left alone or removed. Many loose, half drilled or otherwise bad bolts can be neatly removed using a simple bolt puller made from a steel plate with three 8 mm threaded holes through it and three long 8 mm bolts through the holes.

Sometimes bolts can be difficult to locate. This is both good and bad. A bolt, which cannot be found, is effectively not there but also increases the chance of a superfluous bolt being placed. Obscure bolts can be marked with flagging or "Scotchlite" tape but giant carbide arrows and spray paint are out. Nylon bolts with marker tags and a thread or fishing line set in with the anchor so they cannot be dropped can be used as cap screws. This makes the bolt both easy to find and stops it filling up with debris. Also effective as a marking device is to set a short length of track marking tape in with the bolt. Often, practice and a few minutes searching in likely areas will locate a "lost" bolt - a better solution than placing a new bolt, both time and conservation wise.

TRAINING

Caving is not directly competitive enough to require a rigid training schedule, as do other sports. Nevertheless being fit is a big help and any stamina building exercise like cycling, swimming or bushwalking is worthwhile. This is best done as a part of everyday life rather than a crash get fit campaign for the few weeks before a big trip.

A large part of being fit for caving is being able to move through a cave without wasting energy and this comes with practice. Training on cliffs or even in trees can be useful in becoming completely familiar with vertical gear and rigging which will in turn leads to increased confidence underground. Even so, no amount of simulated practice can replace the training gained from caving itself.

9 DISASTERS

Caving is not a dangerous sport but the harsh environment of caves can turn even a mi-nor accident into a tragedy. Accidents happen to anyone so First Aid and rescue cannot be left to one person. How well a caver copes with adverse conditions is as much a measure of competence as how well he copes with the more expected problems of caving.

FIRST AID

It is the responsibility of every caver to do an accredited first aid course such as one of the St John's Ambulance courses. A basic grounding in First Aid helps a caver to assess the condition of a victim and thus make a decision, which could save his life.

A First Aid kit should always be available on the surface. What the kit contains will depend on where the group is caving; the further away from civilisation, the more comprehensive medical supplies must be. Some cavers carry first aid kits underground, some do not. In an emergency, most cavers wear enough clothing from which to improvise bandages.

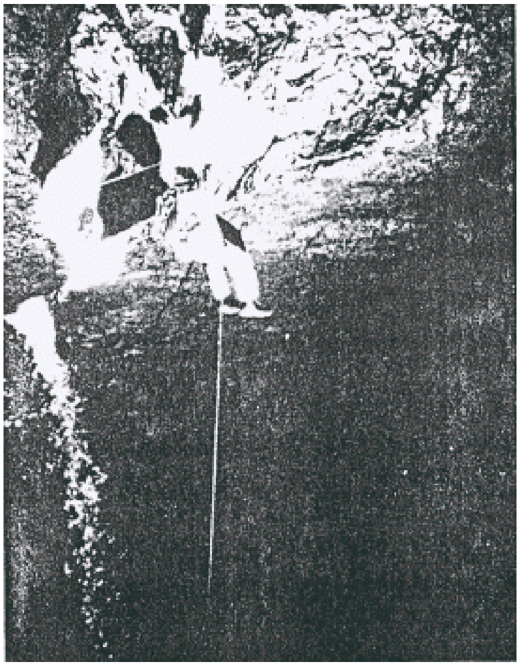
EXHAUSTION

Cavers must learn their limits. Being "done in" at the bottom of a deep cave can make for a slow and desperate ascent and ruin the trip for everyone. It is hard to admit that a trip is too difficult but this will certainly be better than having been rescued. It may well be the trip leader's duty to simply tell someone they cannot do the trip or must satisfy themselves with a shorter version of it.

People become tired faster when caves are cold, wet and strenuous and this can eventually lead to exposure. Ropes, which are badly rigged or rigged wetter than they need to be, will also tire people out. Never start up a pitch if there is any serious doubt of having enough energy to reach the top. A doctor investigating why climbers caught hanging on ropes can die relatively quickly found that healthy "victims" simulating unconsciousness blacked out in as little as six minutes. He stopped the tests for fear of injuring someone (Elliot, 1985).

EXPOSURE/HYPOTHERMIA

Exposure results when a person's body temperature drops lower than 34° C. Below this, they are unable to generate sufficient heat to warm themselves and maintain correct body function. Those most at risk are cavers who are ill equipped, those who become cold, wet, exhausted or injured. Exposure symptoms include exhaustion, uncontrollable shivering, clumsiness, irrationality and inability to move through the cave. All cavers should watch others in the group, especially if there are weak cavers, swims, wet pitches or an injury in-volved.



Six Molar Pitch in normal flow

Six Molar Pitch in flood

The only treatment available to cavers is to rewarm the patient. Once hypothermia has set in the victim will be incapable of rewarming himself. The best external heat source is another caver or two jammed into the same sleeping bag or more likely under the same rescue blanket with several carbide lamps. The chances of rewarming a severely hypothermic caver in a cave are very low and the situation should simply not be allowed to arise.

FLOODS

Caves are natural drains that can fill up with water. In potentially dangerous passages always keep an eye open for good escape routes. Not necessarily to escape from the cave but at least escape to a safe zone where one can wait for the water to drop. If there is no safe zone do not waste time in high risk areas. Should the water rise or suddenly turn cloudy brown get out of the water flow as fast as possible. Do not try to race the water down the cave or float with it.

If a pitch is flooding and a caver will be hit by a lot of water on the way up or down it is much safer to sit and wait. Once on a rope escape is limited and ascending waterfalls is exceptionally dangerous both from the possibility of drowning as well as from heat loss, exhaustion and eventual exposure caused by a heavy flushing with cold water. Only by experiencing a cave in flood can one truly appreciate the need for rigging ropes clear of the water.

When trapped in a safe zone there is little choice but to sit and wait for the water to drop. If wet, wring out all clothing and put everything on except a waterproof oversuit. This will allow underclothing to dry out and once dry the oversuit can be put on. Make a seat from a sack or ropes and sit in a foetal position under a survival blanket. Forget how ugly cavers are and form a tight group to share body heat. If there is enough carbide keep at least one lamp running under the survival blanket to provide extra heat. When a choice exists find a dry open place out of the breeze where everyone can stretch out occasionally and try to sleep as much as possible. Every now and then check on the water level and turn the survival blanket over to let any condensation dry off. Ration what food and carbide remains so that it will last as long the expected stay allowing enough to get out when the time comes.

CAVE ACCIDENTS

The most common cause of cave accidents is falling off short, unprotected climbs or slopes. The most common "technical" accident is abseiling off the end of a rope. Clearly, both are easily prevented by careful caving practices. Clearly too, once an accident does happen, the cause is academic. The injured victim must initially get to a safe zone then out of the cave in order to fully recover.

WHAT TO DO

Every rescue situation is different and there is no formula to decide exactly what must be done. The rescuer's response must be based on two main factors - The degree of injury and the availability of outside rescue.

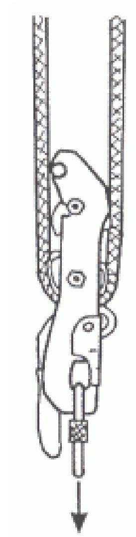
In the first instance, the accident victim's condition must be assessed and First Aid rendered. Only then, the victim moved, if necessary, to a location where both he and the rescuers are in no immediate danger. In most cases, the victim will recover and be able to exit the cave under his own power or perhaps with a little help from the party. If it can be done safely, the victim can be rescued by his own group. However, anyone who is severely injured will certainly benefit from the expert medical attention and stretcher that a trained rescue team provides.

If a victim does require rescue, the decision must be made immediately to despatch someone to the surface to raise the alarm. Those who remain in the cave can then concern themselves with stabilising the victim's condition and perhaps preparing the way for the Cave Rescue.

In remote areas an organised rescue group is a long way away and the best proposition may then be for the group to run their own rescue. Even this could be overridden in an extreme case. An untrained group would probably kill a severely injured victim in an attempted rescue from a difficult cave. Their solution may then be to create an "international incident" by visiting their embassy and importing a rescue team.

RESCUE

Full scale cave rescue is the province of trained cave rescue groups who make it their business to keep abreast of the latest techniques and practise their craft. Those interested in cave rescue are advised to get in touch with their local cave rescue group. In keeping with this book's theme of lightweight, I will leave cave rescue and medical treatment to the experts and concentrate on the mechanics of rescue as may be required by a small group in a remote area.



Bobbin used as a pulley

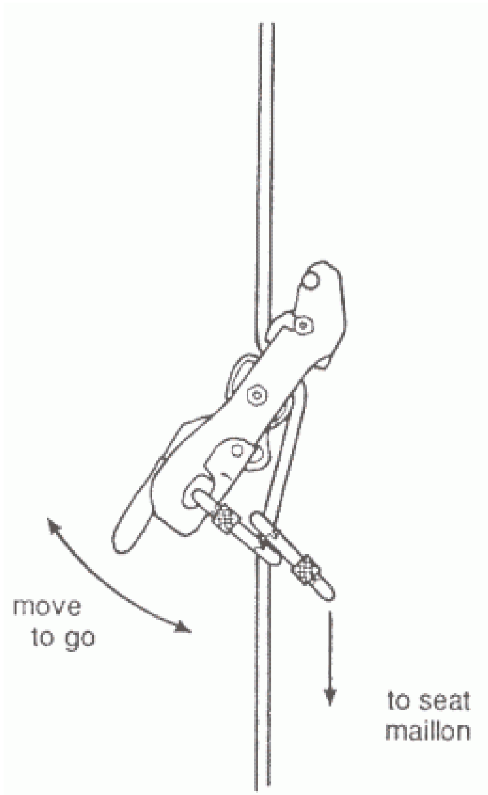
If the victim must be moved to a safer area to await a complete rescue it is much easier to go down rather than up even though this may mean moving further into the cave. Lowering a victim can be done with no specialist equipment and little effort whereas any lift system requires at least two pulleys to work efficiently. Few cavers make a habit of carrying rescue pulleys with them but all should at least have some available on the surface. If no pulleys are available then the "pulleys" on bobbin descenders work better than karabiners.

Accidents to cavers while on the rope are rare. However, the worst possible case of an incapacitated victim hanging on the rope is assumed, with the rescuer carrying nothing more than his normal caving gear.

Obviously, there are several possibilities as to where the victim and rescuer are in relation to each other - victim above or below, on abseil or prusik, heavier or lighter than the rescuer.

GETTING TO THE VICTIM

There is no real choice if the victim is trapped above. The rescuer must prusik up the same rope to the victim before any other action can be taken. If the victim is below, the rescuer faces the problem of descending a taut rope. If



"Abseiling" a taut rope

it is not far he can prusik down but it is slow. For longer descents a bobbin can be clipped on specially to descend the light rope or a rack can be used similarly with two bars (Michel, 1982).

"Abseiling" a taut rope is a delicate procedure. Should the victim somehow unload the rope by climbing onto a ledge the rescuer will immediately commence to freefall. With such dire consequences this form of descent should be used with the utmost caution so as to avoid having two victims. Any form of shunt will provide some security provided it can be activated in advance at the first sign of movement from the victim.

LOWERING

The easiest and safest way a single rescuer can lower an incapacitated victim is to abseil with him hanging below like a heavy sack. In this way he can be fended off rocks and be kept in close contact during the descent. On arrival at the bottom there is a rescuer immediately at hand to keep the victim from drowning in a pool or move him to a safer area. Whenever descending with a load as heavy as a person the rescuer's descender must be rigged with extra friction in the form of an Italian hitch on the brake krab or similar.

Victim on Ascenders

The rescuer must be on ascenders above the victim.

LIGHT VICTIM

- Attach a long cowstail to the victim's seat maillon and undo as many of his ascenders as possible.
- Prusik up until his last attachment point is unweighted then reach down and unclip it.
- Change from ascent to descent and descend carefully.

HEAVY VICTIM

The rescuer may not be able to lift the victim in order to release his ascenders or change from ascent to descent.

- For security the rescuer clips a short cowstail to that of the victim.
- He releases the victim's ascenders until only his chest ascender remains attached.
- He connects a footloop or a 1.5 m long sling to the victim's seat maillon then threads it through a karabiner or pulley on his top ascender then down to his own seat maillon.
- The rescuer then pushes his top ascender up to pull the footloop tight.
- A descender is clipped to the victim's seat maillon and attached to the rope as high as possible. Extra friction is added and the descender locked-off.
- By unclipping his chest ascender and sitting back the rescuer counterbalances his own weight against that of the victim. Pushing the victim up with his arms and legs the rescuer unweights the victim enough to release his last ascender.
- The descender can be sneaked further up the rope before the victim is lowered onto it.
- The counterbalance footloop is removed.
- The rescuer prusiks down and attaches himself as directly as possible to the victim's seat maillon; a chain of two karabiners is ideal.
- He then prusiks down until he is also weighting the descender already attached to the victim.

- He is now ready to remove his ascenders and descend in tandem with the victim.

Victim on Autostop

Using any other descender the victim would probably already be on the bottom! The victim can be approached from above or below.

- The rescuer ties an ltalian hitch on the victim's brake krab and locks-off his descender.
- He then clips as directly as possible to the victim's seat maillon and prusiks down until all his weight is on the victim's descender.
- He releases his own ascenders and descends using the victim's descender.

Larger groups with enough rope will find it easier to lower the victim on a separate rope threaded through a descender, which is anchored to a backed-up belay at the top of the pitch. One person should abseil with the victim to keep him clear of rocks and call stop/go signals to the top. The victim can have the lowering rope attached to him then be detached from his own rope as already described and descended with until the lowering rope takes up.

If enough manpower or pulleys are available a lowering rope can be attached to the victim's rope at the belay above him, lifted a little to release the belay then the victim and rope lowered to the bottom. The lowering rope should be kept attached through a descender at all times to avoid dropping the victim and a totally separate belay rope and belayer can be attached for extra safety.

Organisation takes time and the victim may only have a few minutes. Getting to an unconscious victim quickly and putting a chest harness on him is far more important than the comfort of the rescuers.

LIFTING

Lifting an incapacitated victim requires considerably more time and energy than lowering but may still be preferable in the first instance if the bottom of the pitch is a long way, wet or otherwise unsafe.

Direct Lift

Clipping the victim onto the end of a cowstail and prusiking with him towing along behind will only work for suitably strong cavers and then only for short distances but may be worthwhile to remove him from immediate danger quickly.

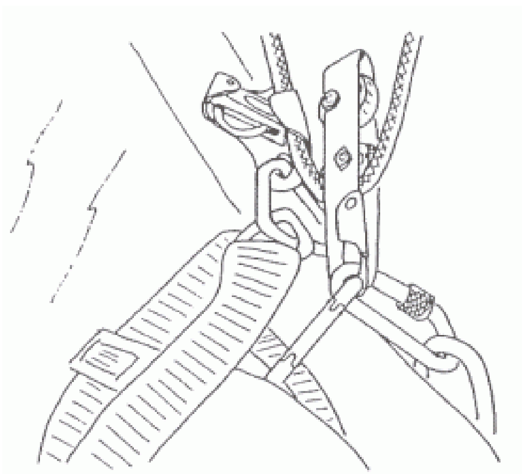
Counterbalance Lift

(Frog system, Gutierrez and Lopez, 1985)

The rescuer must be on ascenders above and the victim arranged with only his chest ascender attached to the rope.

- Fix a pulley on the victim's seat maillon so that the rope comes out of the bottom of his ascender and then through the pulley.
- When his chest ascender is mounted high on his chest the pulley can be fixed to the seat harness attachment loops parallel to the seat maillon. This is the best arrangement to use when starting from a ledge or the ground.

Climbing phase



Pulley attached to legloops

Lifting phase

- On a mid-rope rescue the victim's cowstail karabiners (or two spares) can be clipped to his harness legloops and the pulley attached to them.

- From the victim's chest ascender, the rope runs up and through a pulley, which is hanging from the bottom of the rescuer's top ascender.

- To lift the victim, the rescuer prusiks up a few metres above the victim or as far as the rope will allow.

- He then removes his chest ascender from the main rope and attaches it to the rope coming down from his pulley.

- With a normal sit/stand prusik motion he lifts the victim up, countering his own bodyweight against that of the victim whose chest ascender will lock in position after each stroke.

- When the victim reaches the rescuer he changes back to the main rope and ascends again.

On rebelays the rescuer crosses first then suspends the victim from his cowstail while he undoes the rebelay and feeds the rope through ready to go again. The real difficulty lies in getting off the top of pitches. With a high belay it is feasible to lift the victim high enough to clip his cowstail to a tight handline and slide him away from the edge but for low belays and awkward starts it may not be possible without another rescuer or a specially constructed belay.

Lifting from the Top
(Marbach and Rocourt, 1980)

This method will only work if the rope is not attached below and the rescuer is at the top of the pitch but it does have some advantages over the previous method.

1. The rescuer hauls from a position of safety.

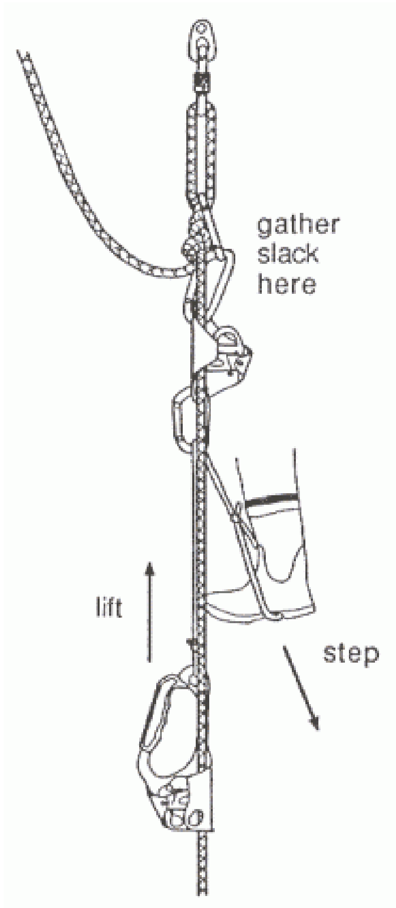
2. There is no need to double load the rope.

3. Lifting can start almost immediately.

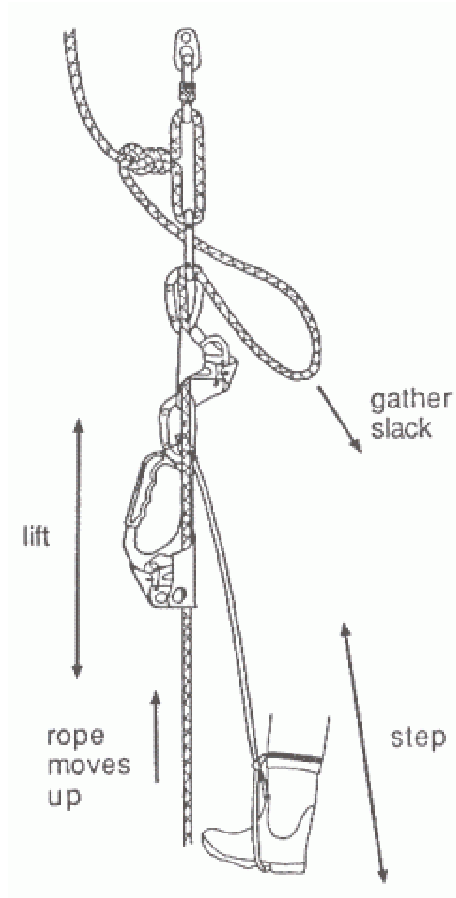
- The rescuer clips his cowstail to the rope anchor.

- He **inverts** his chest ascender and clips it onto the rope just below the knot then attaches it by a karabiner through its bottom eye to the knotloop.

- To the ascender's top (now lower) eye he attaches a pulley.



Getting slack into the system



Lifting

• Next he inverts his footloop ascender, clips it lower down the rope and puts its footloop through the pulley.
• Lifting is done by standing in the footloop while simultaneously pulling up on the ascender and the slack gained is pushed through the chest ascender.

• When enough slack is fed through the chest ascender it is put through the ascender anchoring karabiner so that it can be pulled through with one hand white lifting with the other and standing in the footloop.

• The root ascender is pushed down between strokes and the procedure is continued until the victim's cowstail can be clipped to the anchor or handline.

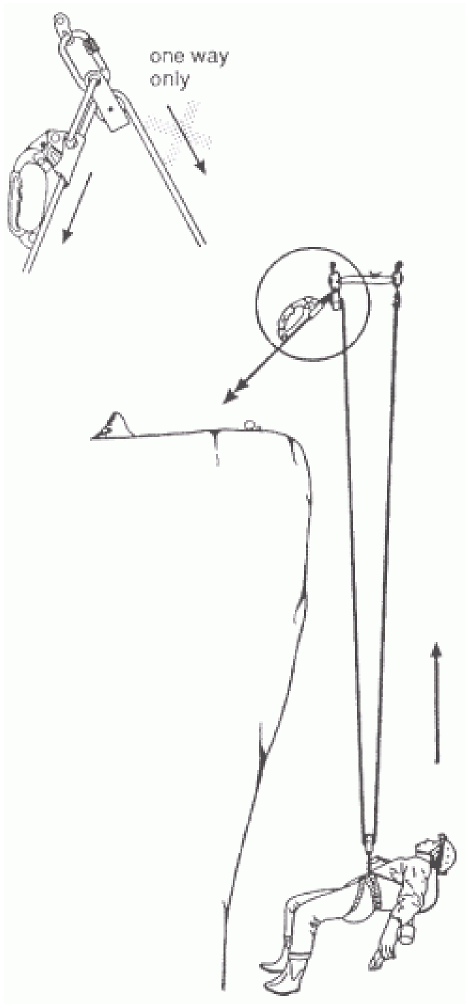
• The initial movements of this method are a good way of gaining slack at the top of the rope in order to set up a heavier haul or lowering system.

All of the lowering and lift systems described so far can be done with nothing more than what a vertical caver normally carries. Real pulleys, even those light nylon rings which clip directly to a karabiner, make lifting much more efficient than using bobbin pulleys, but few cavers carry them. A useful suggestion is to thread one onto the haul cord of every cave pack where it will always be handy but never in the way.

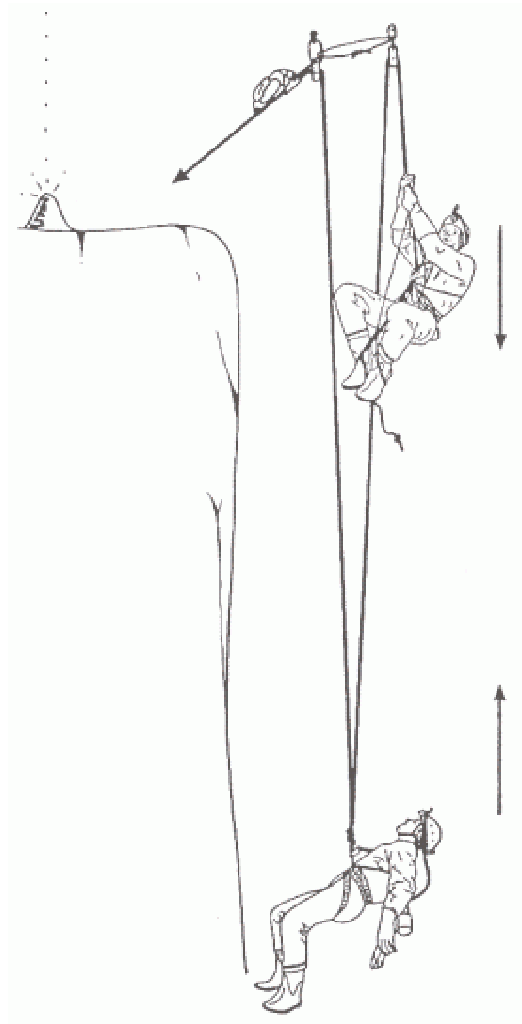
These and other rescue techniques should be practised before they are needed so that in the event of an accident the appropriate action can be taken as quickly as possible. Practise will also make it blatantly obvious that a single rescuer stands very little chance of getting an incapacitated caver out of a deep cave.

Heavy Lift Systems

When there are enough rescuers and equipment the victim can be fitted with a single pulley and the rope attached at the top of the pitch so that it runs down to the victim, through his pulley and back up to the top. There it runs



A simple 2:1 lift



The Counterbalance method

through another pulley and ascender so that it cannot slide back. A group hauling or one or two cavers with ascenders pulling downwards can then lift the victim.

Another possibility is to mount a pulley at the top of the pitch and run a rope up from the victim and through the pulley to a person who will act as counterweight (Martinez, 1979). A separate rope from the victim to the top is then used to lift. In either case it is desirable to have a rescuer prusiking alongside the victim to fend off and give instructions to those above. All this takes time to set up and while it may well be the way to get the victim out of the cave in the long run, small parties with little equipment or victims caught on the rope need a faster, lighter approach.

10 SURVEYING

A survey is the only way a vertical caver can find out how deep a cave is and where it is going. It is a guide, which indicates where to look for a continuation or passages, which are likely to connect with nearby caves. A high quality survey is "proof" of a cave, indeed many cavers will not even believe a cave exists until they have seen a good map of it!

SURVEY INSTRUMENTS

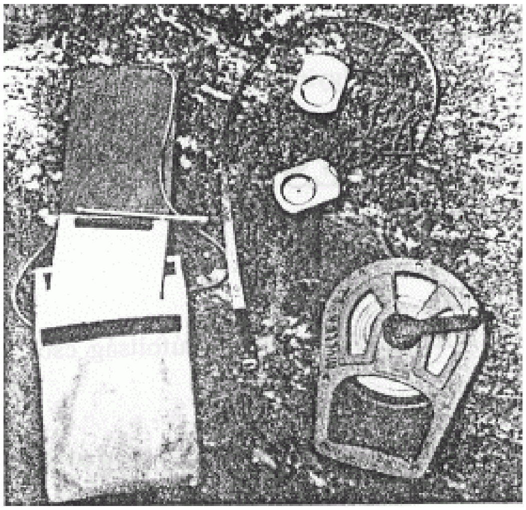
Vertical caves are typically steep, irregular and often confined, not to mention cold, wet and dirty. Obtaining an accurate representation on paper is never easy. In all but the easiest caves, hand-held instruments are the most suitable if not the only alternative. Sophisticated tripod mounted instruments such as theodolites with EDMs are impractical due to their inability to take steep sightings and setting-up constraints.

The instruments must be light, compact and easy to carry. They must be fast to use and allow sights to be taken in any direction with minimal loss of accuracy. Even so, surveying is painfully slow and takes five to ten times as long as a normal trip through the cave.

TAPE AND COMPASS

A Suunto KB-14/360RT sighting compass and PM360PCT clinometer with a fibreglass tape are the "International Standard" for vertical caves. Both the compass and clinometer are neat units in solid aluminium blocks and are robust enough to survive a considerable beating. Contrary to their appearance though, Suuntos are far from waterproof and only a minor dunking or even an unusually humid cave can cause the insides to mist up and render them unreadable. An immediate solution which some times works is to warm them over a carbide lamp flame. Careful, the plastic parts do burn and the mist usually reappears as the instrument cools. Limited waterproofing success has been achieved by covering all joints in the instruments with epoxy resin. This allows them to leak more slowly.

After each day's surveying Suuntos should be brought out of the cave to be dried in the sun or in a jar of silica gel or carbide. At special request to the manufacturer it is possible to buy them with small screw-in plugs in the side, which can be removed to simplify drying. Other compasses such as the Silva 54NL and a



Suunto kit

similar Suunto KB-77 model have a direct sighting lens on top of the instrument which cannot mist up, making them far superior to the KB-14. Unfortunately complimentary clinometers are not available.

Suuntos are easy and fast to read in the full light of day, but once underground the face of the dial needs a good light to be read clearly. Some Suuntos have a tritium light in side which gives just enough illumination, provided everyone in the party has a dim light. In most cases it is necessary to externally light the face of the instrument. A hand held electric is ideal as it is safer and easier than removing one's helmet for each reading.

A light is often placed hard up against the instrument to make the dial easier to read and while this is fine for the clinometer the electromagnetic effect and steel components in the lamp will affect the compass. Carbide lamps too, may have enough steel pieces to upset a compass. Keep any lamp or generator a safe distance away.

Always read the left side of a Suunto clinometer. The right is a % slope scale. Also remember that the scale on the compass is backwards (right to left).

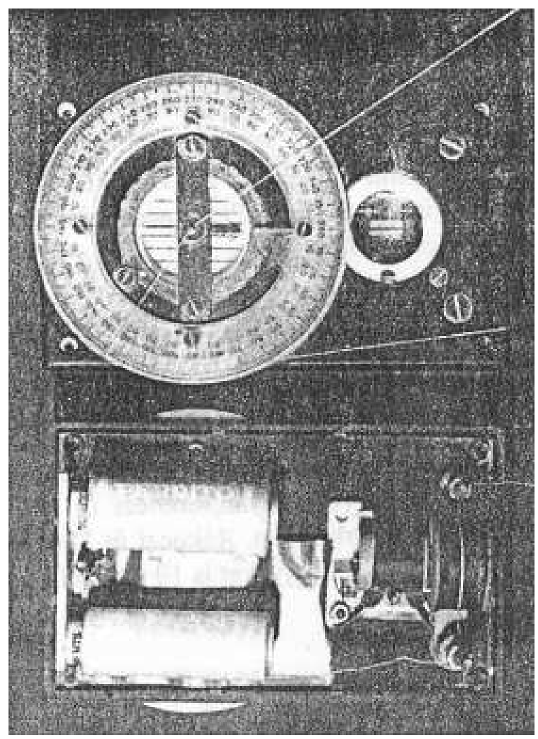
Most compasses only work in a horizontal plane, or close to it. When taking a steep reading, there is no option but to sight to an imaginary point above or below the station. This is easier to do when sighting up rather than down and for the sake of accuracy, steep down-sights should be avoided. If a steep sight must be taken, the clinometer can be dangled from its string as a plumbob to line up the low survey station with a spot on the wall at the same level as the surveyor. The compass is then sighted to the spot.

The tape used is usually a 30 m PVC coated fibreglass tape in an open reel so that it will not clog with mud. Steel tapes are heavy, break easily, difficult to use and may affect compass bearings.

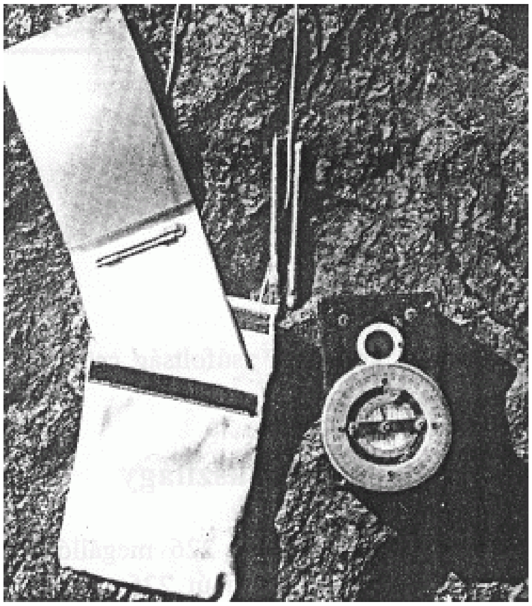
Topofil

In its simplest form a topofil consists of a small box, which contains a roll of thread and distance counter. Topofils offer some advantages over tapes:-

- They are lighter.
- No distance limit, which is ideal for big pitches.
- The thread is sighted along, increasing the accuracy of high angle compass shots.



Topofil construction detail



Topofil kit

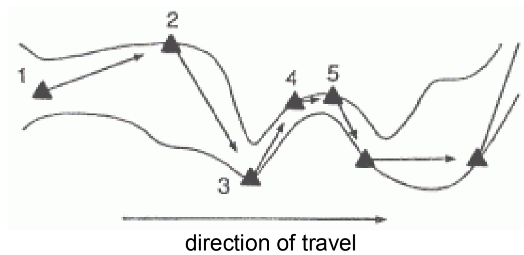
More advanced topofils use a compass and clinometer adapted to read along the thread laid from one station to the next. These can be carried as a separate unit or mounted in the topofil box provided it does not contain any magnetic components. The only commercially made topofil specifically for caving use and readily available is the TSA model. It is a counter and a separate compass/clinometer, making it less convenient than a single unit. Complete units are in short supply and the waiting list for them is so long that it is faster to make one.

Unlike Suuntos, topofils have no optical sighting, therefore there is never a problem with them misting up or the need to put one's head in strange positions to read them. They are fast to use, can be operated by a single caver and with practise offer a degree of accuracy unequalled in other hand-held survey instruments.

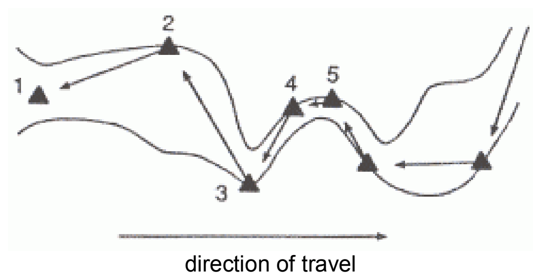
Topofils do, however, have more working parts than tape and require a "light touch" to run well. If used roughly the thread can break or snag as it pays out and the instrument must be opened to insert a new roll of cotton when the old one runs out. Topofils leave a thread line throughout the entire cave, which must be collected by the surveyors on their way out. Cotton thread should be used so that if any is accidentally left behind it will eventually rot.

TACTICS AND PROCEDURE

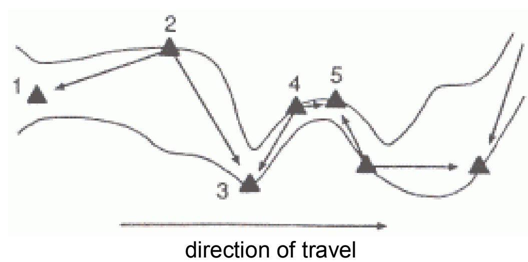
"Survey what you explore" is a good rule and one which has caused many an argument when broken. A reasonable compromise is to have one or two cavers rigging and a survey team of two following along behind them. On the next trip the two teams can swap places.



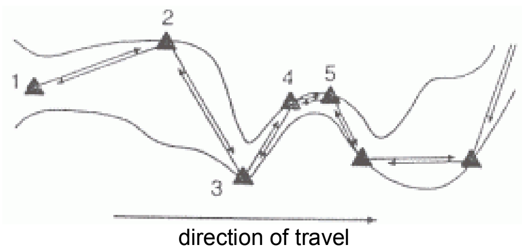
Foresights *are taken in the direction of travel. From station 1 to 2, then 2 to 3, 3 to 4 etc. It is the simplest, least confusing method of gathering data, especially when using tape and compass.*



Backsights *are taken facing opposite to the direction of travel. From station 2 to 1, then 3 to 2,4 to 3 etc.*



Leapfrog *is taken in both directions alternately. From station 2 to 1, the 2 to 3, 4 to 3, 4 to 5, etc.*



Fore *and* ***Backsights*** *are taken in both directions from and to each station. From station 1 to 2, then 2 to 1, 2 to 3, 3 to 2, 3 to 4,4 to 3 etc.*

Reading a Suunto compass

Reading a Suunto clinometer

For ease of understanding the data and its later reduction, it is best to maintain the survey direction. If the survey is begun at the entrance of a cave it should thereafter continue down the cave starting each new day's surveying at the end point of the day before or some other "known" point along the way. Surveying down one day then the next day going past the end point and surveying back to it leads to confusion. Consistently surveying from a known point keeps survey data as a continuous series instead of a collection of little pieces, which must be tacked together or reversed to calculate the total displacement from the starting point.

The collected data is also easier to understand and therefore mistakes are less likely if all survey sights are taken in the same sense; either all forward sights looking in the direction of travel or a series of backsights looking back along the cave just traversed but not a mix of both. When forced to take a sight in the opposite sense, note it well in the data and avoid mentally reversing it in the cave. A mistake could well be undetectable except that in the final map, something "looks wrong".

Topofils run easily down a cave making a series of backsights and leaving a trail of thread behind. If the thread breaks on a pitch or difficult passage that one sight can be left for the return trip rather than having to do the pitch an extra time.

TAPE AND COMPASS

A team of three is the ideal for a tape and compass survey: one to read the instruments, one to manage the tape and a third to take the notes and sketch the passage. The note-taker is the "boss" and in easy passage the survey will move only as fast as he can sketch while in difficult passages the instrument reader will be the rate determining factor. When there are only two surveyors the note taker handles an end of the tape as well.

Tape and compass surveys are often done as a series of forward sights. In essentially "down" caves however it is far better to survey facing uphill, taking "backsights" so that the compass can be read more easily. The survey begins at a cave tag or marked point at the entrance. The tape man waits at the entrance while the instrument reader runs the tape down the cave and finds a "station" from which the tape man is visible as well as providing a good view toward the next station. The distance is measured and perhaps the forward station is moved a few centimetres so as to coincide with a full decimetre on the tape. The measurement is called out to the note-taker who repeats it.

The tape man "lights" the station by holding a light on or behind it or by putting his finger on it and lighting that. While lighting the station he calls out "left", "right", "up" and "down" estimates and rewinds the tape. Meanwhile, the instrument reader sights the compass and calls the figure to the note-taker, who repeats it, then the same for the clinometer. Before he moves on he makes sure that the note-taker knows where the station is so that it can be included on the sketch. The tape man then moves to the next station where the instrument reader points out the station's precise location, takes the end of the tape and moves down the cave in search of the next station. The note-taker travels either between or behind the other two surveyors.

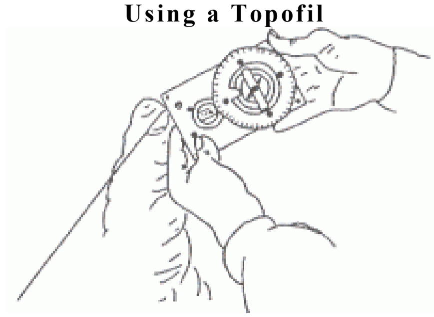
TOPOFIL

A topofil survey is most efficient with two surveyors: one to read the topofil and the other to take notes. When a team is short-handed a topofil survey can be done alone with no loss of accuracy although it will be slower.

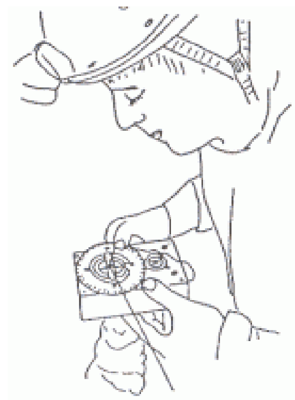
Topofil surveys are best done as a series of backsights. The instrument man begins by pulling out enough thread to tie off to the entrance station then calls out the initial counter reading or "first topo" to the note-taker, who repeats it. He then runs out a straight line of thread to the next station. This is preferably a small projection he can later wrap the thread around, which also has a view forward. After calling out the counter reading, he holds the topofil above the station or in line between the stations and takes a compass reading, which he calls to the note-taker. He next holds the instrument beside or in line with the station and takes the inclination. All readings are repeated by the note-taker. Care must be taken to ensure that the thread is not snagged between stations and that it is not allowed to sag while taking compass and clinometer readings.

After the readings are taken, the thread is wrapped around the station two or three times by pulling sufficient thread as stretch from the leg just measured. Finding the exact point on the thread can be facilitated by making a mud mark on it at the correct point when the distance is taken or by running the topofil past the station until the thread begins to run and taking the point on it where it passes the station. If there are no projections to tie the thread to it can be anchored by a rock or held by the note-taker.

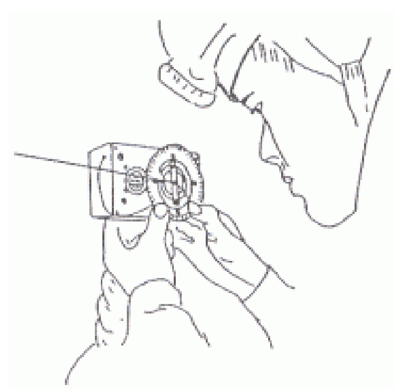
Using a Topofil



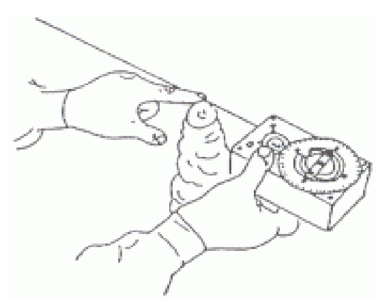
Taking the distance



Compass bearing



Clinometer reading



Finding the correct point on the thread

Survey Stations

The stations should be chosen so as to give as long a sight as possible in each direction as well as being easy and comfortable to reach while taking the sight. Stations should always be a fixed point on the wall, roof or floor. This minimises station error and makes it possible to accurately mark points for future use.

In complex caves, cave systems or areas with several separate caves the station labels or names should be systematised so that each survey is readily identifiable. This can be done by assigning an alphanumeric label for each station.

E.g. N 2 7 0 6

where:

N = letter to indicate the cave or area within a cave

2 7 = two digits to indicate the day or date and thus identify each section of the N survey

0 6 = two digits to indicate the station number within the N27 survey

When more than 100 stations are surveyed in one day the date numerals can be changed. i.e. The station after N2799 could be NB700 or N2800. All of this information does not need to be noted for each station in the field. What is required is that each page of data be clearly marked with its appropriate letter and number. In simple or isolated caves it will suffice to assign no more than station numbers.

Some stations such as those at junctions and the end of a day's surveying need to be marked. This should be done in some semi-permanent manner like a strip of note paper tied to the station or a cairn built with one of its rocks bearing the station number written in carbide. There is no need to go through and label each station nor is it necessary to write station numbers on the cave walls. When a station is labeled it should be the complete station number so as to make it readily identifiable should another survey need to be connected to it.

Before entering a cave to continue a survey, the tie-in station should be noted down, as should the correct series of station labels to be used that day.

Surface Surveys

At the cave entrance the survey should be "tied" to a permanent station whether it be a tag, painted number or even a point chipped into the rock. The exact position of the cave entrance is located by surveying to some known point such as another cave tag, local bench mark, trig point or corner of a building marked on a topographic map of the area.

In some areas it is valuable to survey to the resurgence of the cave be it proved or only suspected so as to give a more precise estimate of depth potential than is available from some topographic maps.

Surface surveys should be done with Suuntos or more accurate instruments and topofils only used to measure the distance component. Even a light crosswind will displace a topofil thread enough to give a compass error of several degrees.

In open country it may be difficult to use fixed stations, which are not on the ground. Rather than lay on the ground for each sight, a vertical stick with a bright mark on it at the same height off the ground as the surveyor's eye level can be used to sight to each time. Length measurement can be made with a tape, topofil or rangefinder though for accuracy the temptation to use long sights should be avoided and survey legs kept to a maximum of 30 m.

Data Collection

The notes and sketches that a surveyor makes should be of such a standard that the cave can be drawn up by someone who has no prior knowledge of the cave. To this end, data must be noted systematically and consistently. A reliable method is to use a small pad with removable sheets of waterproof paper, which have been printed with boxes to format the data on one side and a grid to make sketching the passage shape easier on the other.

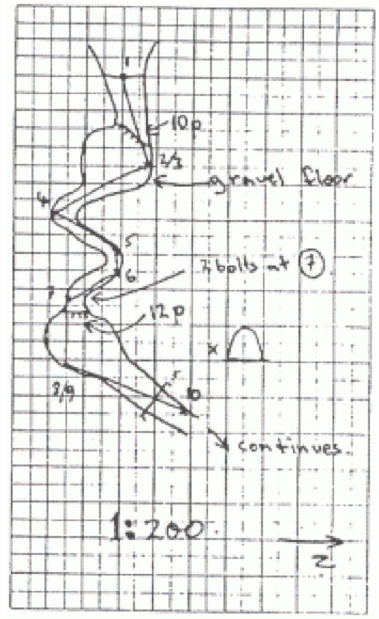
The minimum data to be collected in the cave is station number, distance, bearing and inclination. To these can be added estimates of left, right, up and down (LRUD) distances to the walls, roof and floor. There is no universal convention for these. However it is most reasonable to take LRUD data while facing in the direction that the survey is traveling. Remember, they are estimates, which reflect the general passage form and should be the average distance that the walls, roof and floor lie from the station.

CAVE Nada Cave						DATE 15/5/88	
SERIES N2701 – 10						SHEET 1/1	
SURVEY BY AW, JJ							
STN	TOPO	COMP	CLINO	←	→	↑	↓
N2701	062	—	—	1·2	1	0	1·5
2	119	250	20	0	4	1·5	10
3	217	0	90	0	4	11·5	0
4	281	330	-15	1·4	0	3	2·5
5	328	208	41	0	0·8	4	2
6	344	262	-8	0	0·8	4	2·5
7	389	332	52	1	0	5	1·5
8	415	270	-20	3·5	0	10	12
9	555	0	90	3·5	0	22	0
10	637	198	-7	0	1·2	1·5	1·2

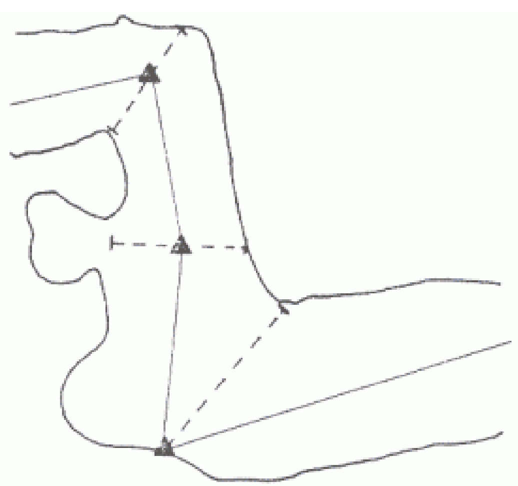
Topofil

CAVE Nada Cave.						DATE 15/5/88	
SERIES N2701 – 10						SHEET 1/1	
SURVEYORS AW, JJ, DJM				Backsights			
STATION	TOPOFIL TAPE	COMPASS	CLINO ±	←	→	↑	↓
N2701	5·7	250	20	1·2	1	0	1·5
2	9·8	0	90	0	4	1·5	10
3	6·4	330	-15	0	4	11·5	0
4	4·7	208	41	1·4	0	3	2·5
5	1·6	262	-8	0	0·8	4	2
6	4·5	332	52	0	0·8	4	2·5
7	4·6	270	-20	1	0	5	1·5
8	12·0	0	90	3·5	0	10	12
9	8·2	198	-7	3·5	0	22	0
10				0	1·2	1·5	1·2

Suunto



Sketch



Left and right data convention

Another convention required is that of the exact direction of left and right. The option, which involves the least notes and gives a good representation, is to take the left and right data in the direction, which bisects the angle between the two sights. Up and down are best left as true vertical.

LRUD data are essential for good computer graphics and also give scale to the sketches, making drawing up of the final map easier than relying on sketches for information which is difficult to show. e.g. If the surveyor is sketching a plan as he goes the up and down data automatically give a passage height.

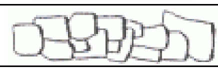
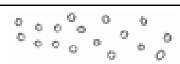
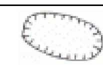
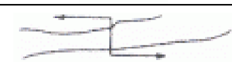
Sketches of the cave passage are done as a series of small plans or occasionally sections, with all stations and pitches marked to simplify the drawing up. As a check the plans should be kept to scale and orientation so that a wrong figure from the instrument reader will be noticed in the first instance. Cross-sections can be drawn, perhaps at a larger scale, to show passage shape or help explain a complex piece of passage. A provisional tackle list should also be noted along with the sketch.

Sketches and data are best taken down with a soft mechanical or self sharpening pencil. The pad, pencil, spare pencil, marking pen and flagging tape can then be carried in a pouch which hangs around the drawer's neck.

If a mistake is made during note taking, it should be neatly crossed out and rewritten. Never obliterate an original, as it may useful in sorting out a more serious problem later. Sketches on the other hand may become an unreadable mess if errors are not erased.

STANDARD SYMBOLS

Table 10:1

	marked survey point		mud
	change of survey grade		flowstone
	cross-section plane		stalagmite
	unsurveyed passage		stalactite
	abrupt change in floor		flowing water
	sloping floor		standing water
	boulders or blocks		sump
	rockfall		airflow
	crystals		doline
	gravel		shaft
	sand		change in rock type
10p	pitch (with height)	5c	climb (with height)

After Anderson. 1978

At the end of each day's surveying the used data pages are removed from the pad so as not to risk losing them in the cave on a later survey trip and the numerical data transcribed into a master data book or computer to give a neat duplicate copy.

Information such as members of the survey party, full name of the cave, date and instruments used should be written on the first page of any series of data or attached as a separate title page.

As soon as possible after the survey is done a traverse line is plotted and the wall detail drawn on by the person who took the original notes. Pitches, climbs and squeezes should be marked and an accompanying tackle description drawn up or noted beside each pitch. As much information as possible should be completed by the original note taker so that the final drawing up will be as easy and accurate as possible.

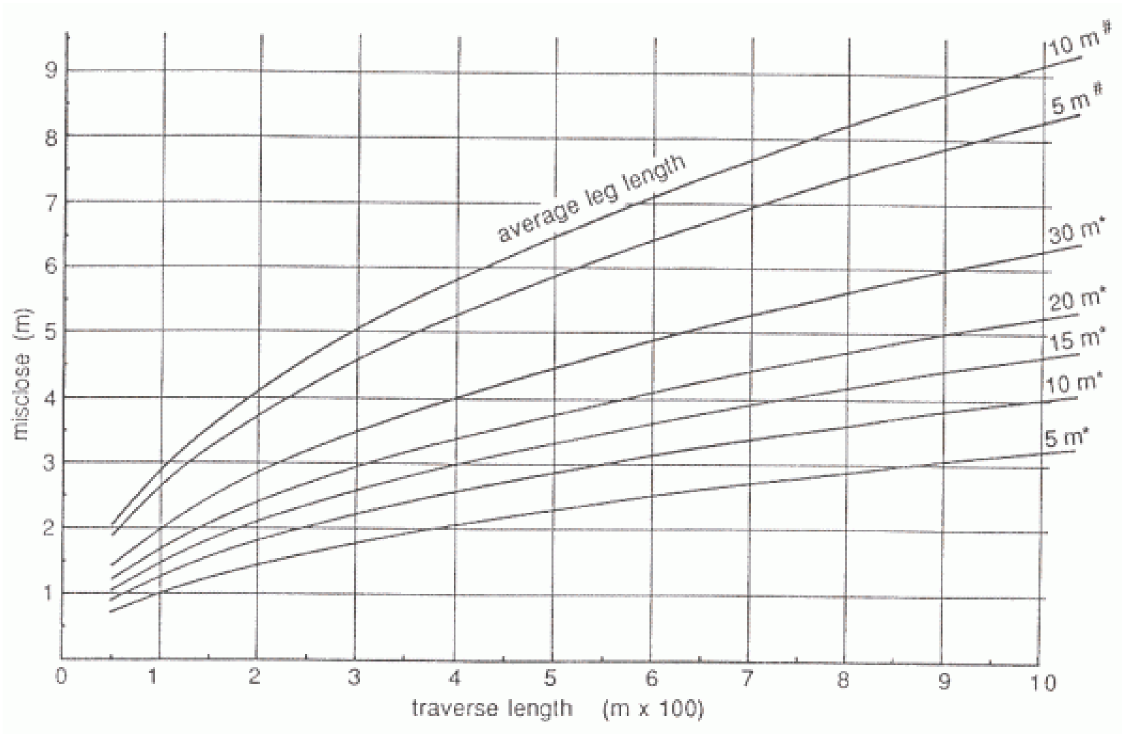
STANDARD SYMBOLS

Only the neatest of note takers can use the full range of symbols in their original cave sketches and have them correctly interpreted later. A few written words and an arrow to indicate "where" cannot be mistaken and the pretty symbol can be saved for the final drawing. Large caves are often presented at scales of 1:1000 or more so it is impossible to note much more than the passage outline, water, airflows and the occasional large block.

SURVEY ACCURACY

Precision is the reproducibility of data and is reflected by the fineness to which the instruments can be read; theoretically half of the smallest unit marked on the scale. Topofils should be readable to half a degree in compass and clinometer and half a centimetre in distance. With Suuntos and tape this is quarter of a degree for the compass and half a degree for the clinometer and usually half a centimetre for the distance. In any survey, the station error (distance the instrument actually is from the station) and movement in the hand-held instrument is so great that anyone who reads to that precision is fooling themselves. It is only reasonable to read to the nearest degree and nearest 5 cm when a survey is done <u>carefully</u>.

RANDOM ERROR CURVES FOR SUUNTO AND TOPOFIL SURVEYS



traverse length (m x 100)

** Good survey - station error ± 5 cm, distance error ± 5 cm, compass/clinometer error ± 1°*
 # Rough survey - station error ± 20 cm, distance error ± 20 cm, compass/clinometer error ± 2°

Accuracy is the distance a surveyed point lies from the "truth". It is largely affected by the skill of the surveyors and the precision of the instruments. Any survey point lies within an area of - uncertainty, the size of which can be estimated. The simplest means of checking the accuracy of a survey is to map a closed loop and calculate the difference between the two end points, which are supposed to be the same. This difference is the "misclose" and is rarely zero. A loop, which closes within acceptable limits, is probably all right, one, which is outside the limit, suffers from one or more gross errors.

ESTIMATING SURVEY ACCURACY

The theoretical accuracy of a survey can be calculated using the "Random Error Curves" above. These give an expressions of the possible accuracy that the instrument and survey can produce given certain parameters but can not take into account gross errors such as how well the instruments were really read, excessive station error, data collecting errors, magnetic errors or systematic errors.

The curves can be used to estimate the expected accuracy of an open survey as well as to check if the misclose in a loop is within acceptable limits.

A "perfectly" executed survey could be expected to lie within the theoretical range and in practice this is usually the case for the vertical while the plan is usually within twice this value. Surveys lying up to twice the theoretical value for the elevation and three times for the plan can still be regarded as acceptable even though they are obviously affected by some gross error. This difference between the magnitude of the acceptable error in plan and elevation is due to the comparative difficulty in getting accurate readings from a compass as compared to a clinometer.

Most of the potential gross errors in a survey can be eliminated by taking back-bearings on each leg with a separate compass and clinometer as a check on misread instruments.

In most vertical caves it is not possible to survey a loop which takes in the extremities of the cave though minor loops will at least indicate if the surveying is up to standard. As a rough form of control an altimeter should be used to take a series of readings at known stations on the way down and back up the cave and if possible a second altimeter left stationary on the surface to record pressure variations caused by weather changes. In practice an altimeter should give readings, which are within ± 25 m of a good survey, unless the cave has strong draughts or blowing squeezes. The pressure difference either side of a blowing squeeze can give altimeter errors in excess of 100 m.

SYSTEMATIC ERRORS

Systematic errors are those inherent in the design or calibration of the instruments as well as the way they are read. Systematic errors are not random but accumulate, making the accuracy of the survey worse with increased length.

A wrongly calibrated tape for instance adds to or subtracts from each measured distance making the cave bigger than it really is. A poorly calibrated compass will give a constant error, which has the effect of turning the north arrow on the finished map through the number of degrees it is out of calibration. Similarly a maladjusted clinometer will affect the overall angle of the map, reducing or increasing its depth and possibly "causing" streams to flow uphill. If the entire cave is surveyed with the same instruments it only requires a minor adjustment in the final drawing up but when several instruments are involved, all with different calibrations, it can result in considerable confusion.

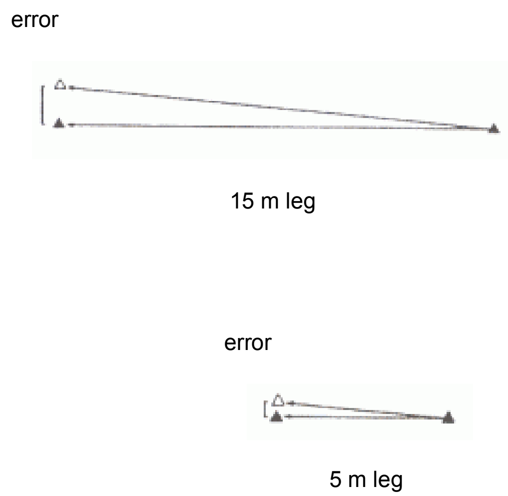
Systematically misreading instruments can also accumulate errors. A surveyor sighting with a Suunto to the light of an assistant of the same height would effectively be adding 15 cm to the vertical difference between the two stations and this would accumulate for the length of the survey. A 200 leg survey could be 30 m out from this error alone!

Instruments should be checked before a surveying project and periodically during it to ensure that they really do point north, horizontal and measure distance correctly. Compasses should be checked against each other. Clinometers can be checked quickly by putting them on a flat surface, taking a reading, turning them through 180° and taking a reciprocal reading. Test surveyors and instruments by surveying a known non-horizontal test triangle in both directions.

Any errors in the instruments should be noted and corrected if possible. Otherwise, the amount they deviate by can be added or subtracted as a zero error when calculating the data and the original notes clearly marked.

MINIMISING ERRORS

Random errors tend to compensate for each other as the number of survey stations increases. Compensating errors may allow a rough survey to give a good closure even though each individual point on the map is well displaced from where it should be. This is not to say that random errors should be ignored. There are several procedures, which should be followed in order to minimise both random and systematic errors.

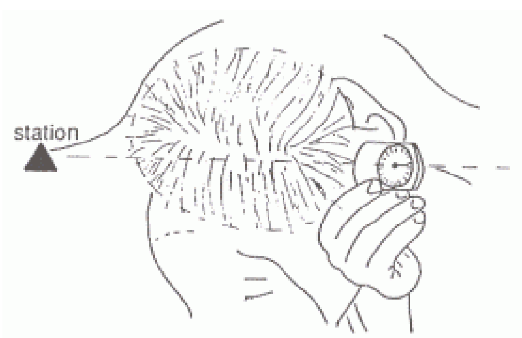


Comparative error in short and long survey legs

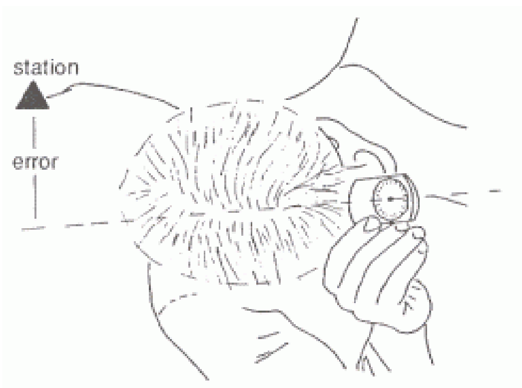
Leg Length

Long leg length magnifies compass and clinometer errors and gives a less accurate final displacement than a series of short sights. When using a topofil or rangefinder, avoid the temptation to take sights longer than 30 m.

The optimum leg length is a compromise between station error and instrument reading precision. Roughly located stations favour long survey legs while low compass precision favours short survey legs. On pitches where the difficulty of getting any sight may outweigh the need for accuracy, try to keep the pitch length as a true vertical.



Good



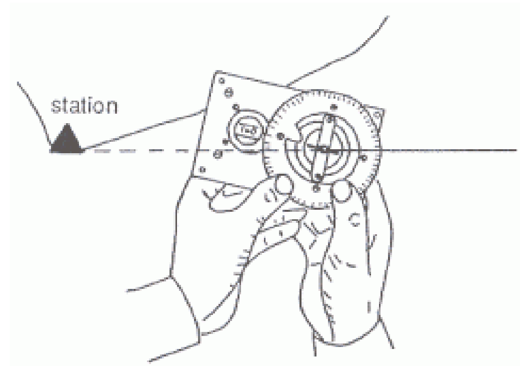
Poor

Reducing station error - Suuntos

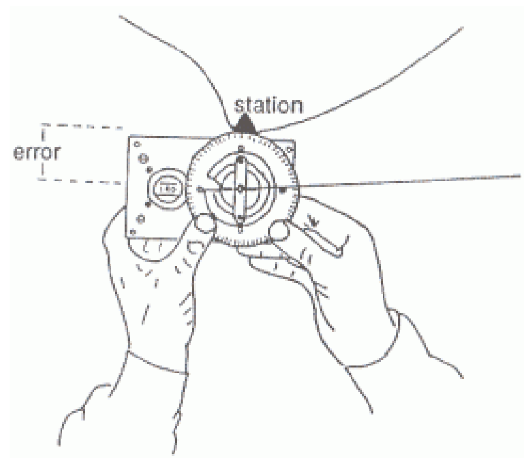
Station Error

Avoid "floating" stations such as sighting to the light of someone standing in mid-passage, they can never be faithfully relocated by the person holding the other end of the tape. When sighting it is often better to hold the instrument in line between the two stations or behind the station rather than as close to it as possible. This is especially relevant to Suuntos where the thickness of the surveyor's head can create a considerable station error. Topofils are more naturally held in line and their small size keeps the station error small when this is not possible.

The significance of the station error is especially great for short survey legs and diminishes with increasing leg length.



Good



Poor

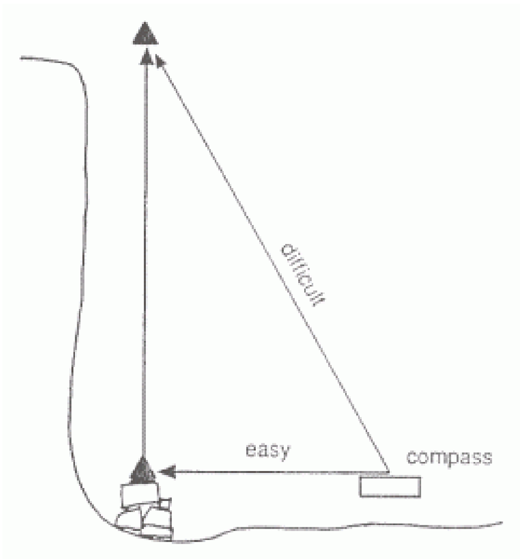
Reducing station error - topofil

Transcribing Errors

One mistake when taking survey notes can make an entire survey useless. Do not remember readings, note them down as they are read. A roughly oriented sketch will help pick up wrong compass readings. Have the note taker call back all readings including the sign of the clinometer angle for confirmation. Short leg length will aid communication. Do not mentally reverse readings while in the cave. Note the reading as given and indicate clearly beside it that it is a back or fore sight.

Magnetic Errors

Keep anything electrical or magnetic well away from compasses. The bigger the piece of steel the worse the problem.



Reducing error on a steep sight

High Angle Readings

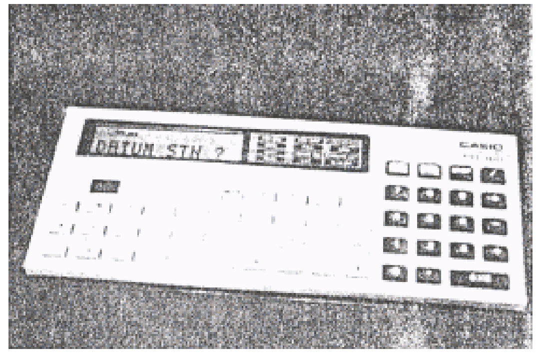
Compasses become increasingly difficult to read accurately as the angle of the sight leaves the horizontal. On high angle legs accuracy is improved by taking a vertical then a low angle sight rather than one high angle sight. On "up" sights the tape can be dropped between the stations after the length is taken and the compass sighted to the tape. Most Topofils do this automatically. High angle compass error is mitigated by the fact that as the angle of the sight becomes steeper the possible displacement error from a rough compass reading decreases (a similar effect applies to law angle clinometer readings).

Rope Lengths

Do not measure pitch length by using a "known" rope length. The rope will almost certainly have shrunk since it was last measured and knots, rebelays, deviations and non-vertical hangs upset the calculation further. At worst measure the rope length after derigging provided it was rigged as a freehang.

Training

Be sure all surveyors and assistants know what they are doing, have practised using the instruments and understand the surveying style required.



Casio PB-l00

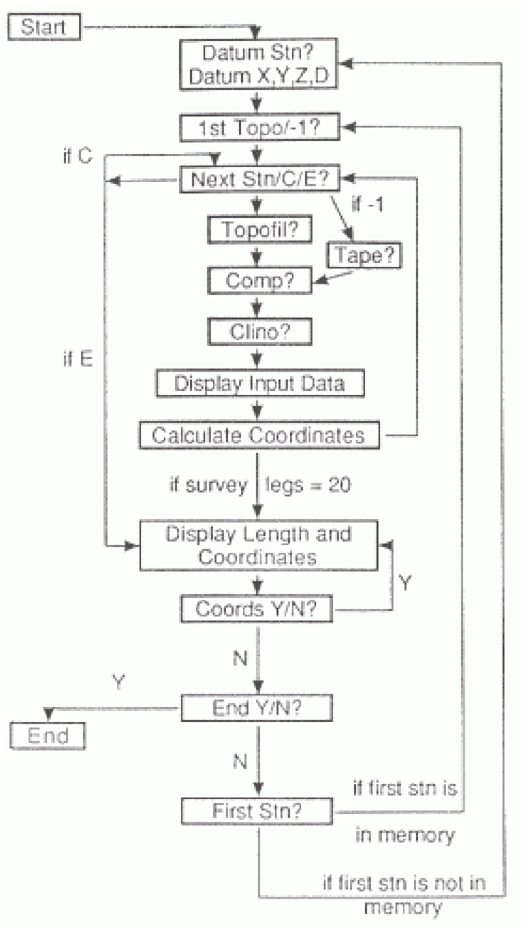
COMPUTING

Owing to the vast array of programmable calculators/personal computers on the market it is pointless to list programs for individual machines but rather the general features desirable in a field computer.

Even in the most remote location it is possible process raw survey data and have it back again as "X", "Y", "Z" and "D" coordinates within a few hours of exiting the cave.

"X" is the distance East of the starting point.
"Y" is the distance North of the starting point.
"Z" is the distance above the starting point.
"D" is an artificial ordinate achieved by accumulating the plan distances.

"TOPOTAPE.5" CAVE SURVEY REDUCTION PROGRAM



- *Original design by D. Martin*
- *Designed for a Casio PB-l00*
- *Results are displayed to the nearest 10 cm*
- *Topofil entries are 3 digits (instead of the usual 5) thus the topofil reads to the nearest 1 cm but shows the value rounded down to the nearest 10 cm. There is a maximum 10 cm error is on the first reading only.*

Such a program gives the survey stations as a series of ready to plot coordinates as in Table 10:2.

As a good field program it matches the format in which the data is taken down, is easy and foolproof to operate by us computer illiterates and has a safety read-back function so that data may be checked as or immediately after it has been entered. "Simple" computers which give only the X Y Z D data and keep no memory of the data as entered can lead to an entry error going undetected unless the data is recalculated or the resulting plot looks radically wrong.

Computers, which can give a printout, should be programmed to print both the input and output data so that it can be easily checked against the original. Even better for large surveys in remote areas are field computers, which can save data onto tape or disk (always keep a hard copy as well) and thus eliminate the task of re-entering it back home.

X Y Z D data calculated in the field is hand plotted as a plan, projected or developed section at a suitable scale (usually 1:1000) so that it can be used in further exploration of the cave. Once the data is brought home it can be reprocessed using a more sophisticated program on a mainframe or personal computer to get special features such as loop closures, plotting and 3D graphics.

NADA CAVE COORDINATES

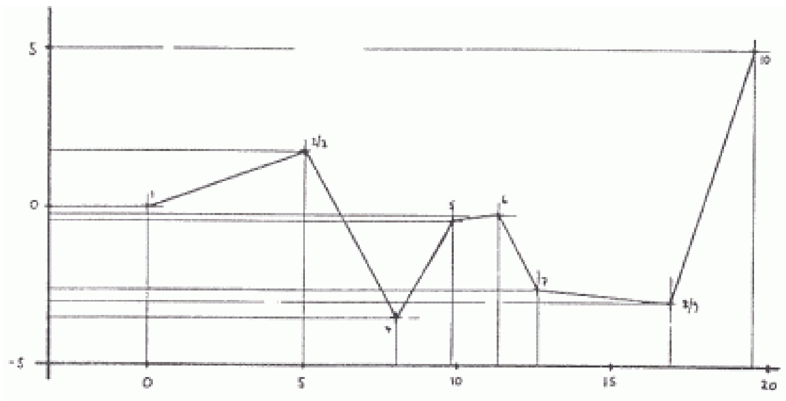
Table 10:2

Station	X	Y	Z	D
N2701	0.0	0.0	0.0	0.0
2	5.0	1.8	-2.0	5.3
3	5.0	1.8	-11.8	5.3
4	8.1	-3.5	-10.2	11.5
5	9.8	-0.4	-13.3	15.1
6	11.3	-0.2	-13.0	16.6
7	12.6	-2.6	-16.6	19.4
8	16.9	-2.6	-15.0	23.7
9	16.9	-2.6	-27.0	23.7
10	19.5	5.1	-26.0	31.9

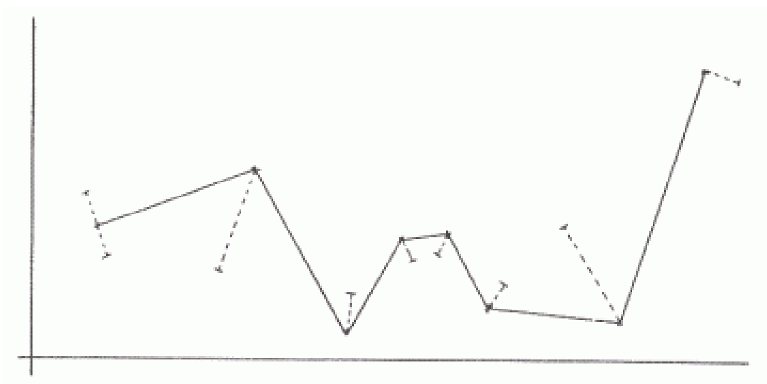
Traverse length = 57.5 m

PLOTTING THE SURVEY

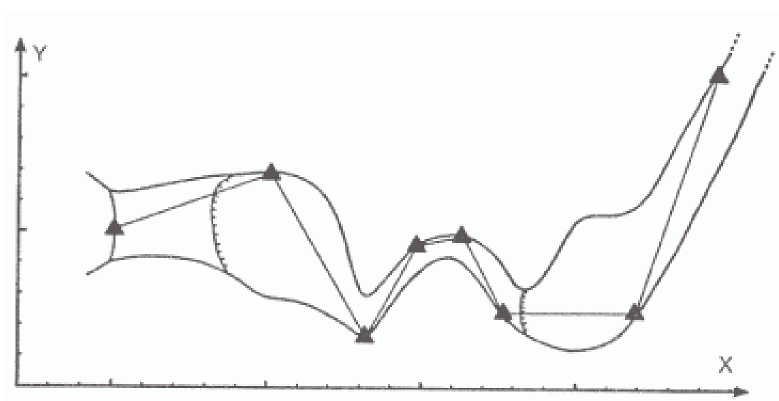
Before drawing up, a scale is settled on which either matches that of other caves in the area or allows the cave to comfortably fill the page it is being drawn on. A zero point is chosen which allows the cave fit on the page and scales drawn along the margins. Graph paper is best although a drawing board with tee and set squares can be used.



The plan is drawn by plotting the "X" (east) ordinate across the page against the "Y" (north) ordinate up the page. Each point is labeled with its station number and the dots are joined to produce the traverse. Unless the cave is relatively straight it is easiest to plot a few stations at a time, join the dots, then plot a few more so as not to become lost in a page of dots.



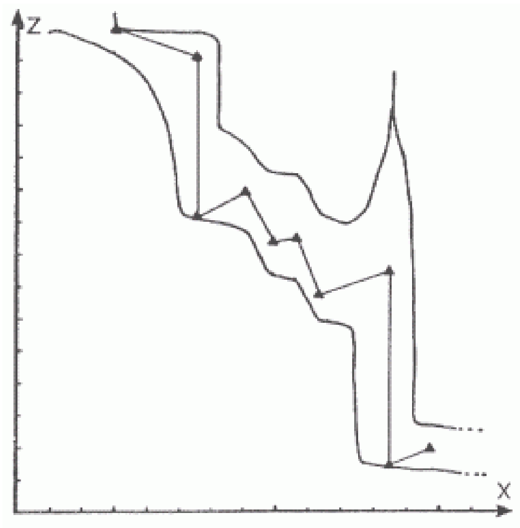
The left and right estimates are lightly marked.



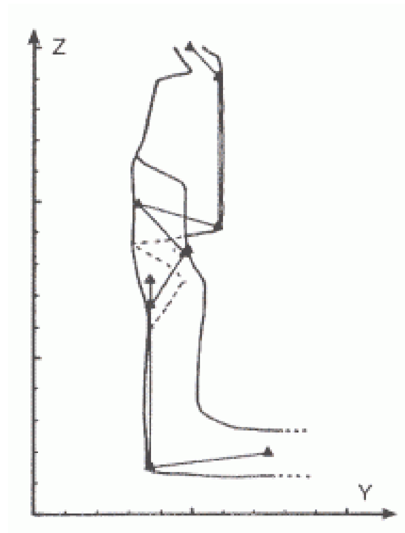
The sketch taken in the cave is copied so that the walls fit the traverse, then the details are filled in.

Sections (elevations, profiles) are drawn in the same manner as the plan but using different coordinates, depending on the nature of the cave and the effect desired.

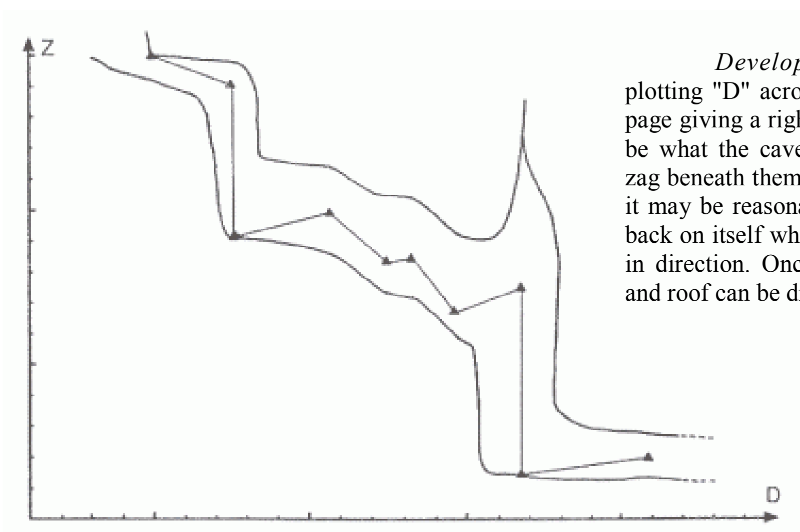
Projected sections compress any part of the cave, which does not run parallel to the projection plane and can make a vertical cave appear much steeper and shorter than it really is.



Projected Section, East-West plane. "X" ordinates are plotted across the page against "Z" down the page and the walls added with the aid of LRUD data and the plan.

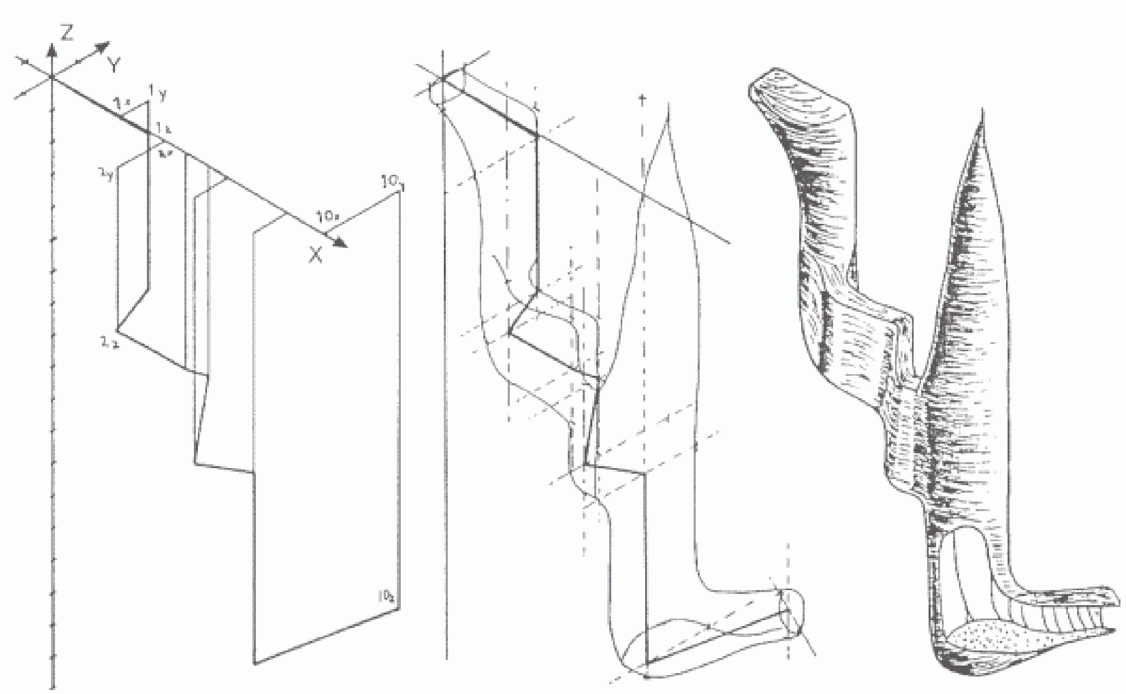


Projected Section, North-South plane. "Y" ordinates are plotted across the page against "Z" down the page.



Developed sections are drawn by plotting "D" across the page against "Z" down the page giving a right trending plot, which may indeed be what the cave does. Often however caves zig-zag beneath themselves and by referring to the plan it may be reasonable to fold the developed section back on itself when the cave makes a major change in direction. Once the traverse is drawn the floor and roof can be drawn on as before.

"ISOMETRIC PERSPECTIVE"



Under construction *Finished*

An "Isometric Perspective" can be drawn to show "X", "Y" and "Z" coordinates on the same diagram and give a 3D image of the cave. The data are plotted on three isometric axes by systematically plotting the "X" ordinate of a station along the "X" axis, then its "Y" ordinate parallel to the "Y" axis and from there, its "Z" ordinate parallel to the "Z" axis. Different views of the cave can be obtained by rotating the "X" and "Y" axes and their positive and negative directions. i.e. To give a W-E section instead of an E-W section.

Once the traverse is plotted the LRUD data can be plotted with reference to the axes and the walls drawn to suit. To successfully draw an isometric of even a simple cave, a drawing board, tee square, 30°/60° set square and some artistic ability are indispensable.

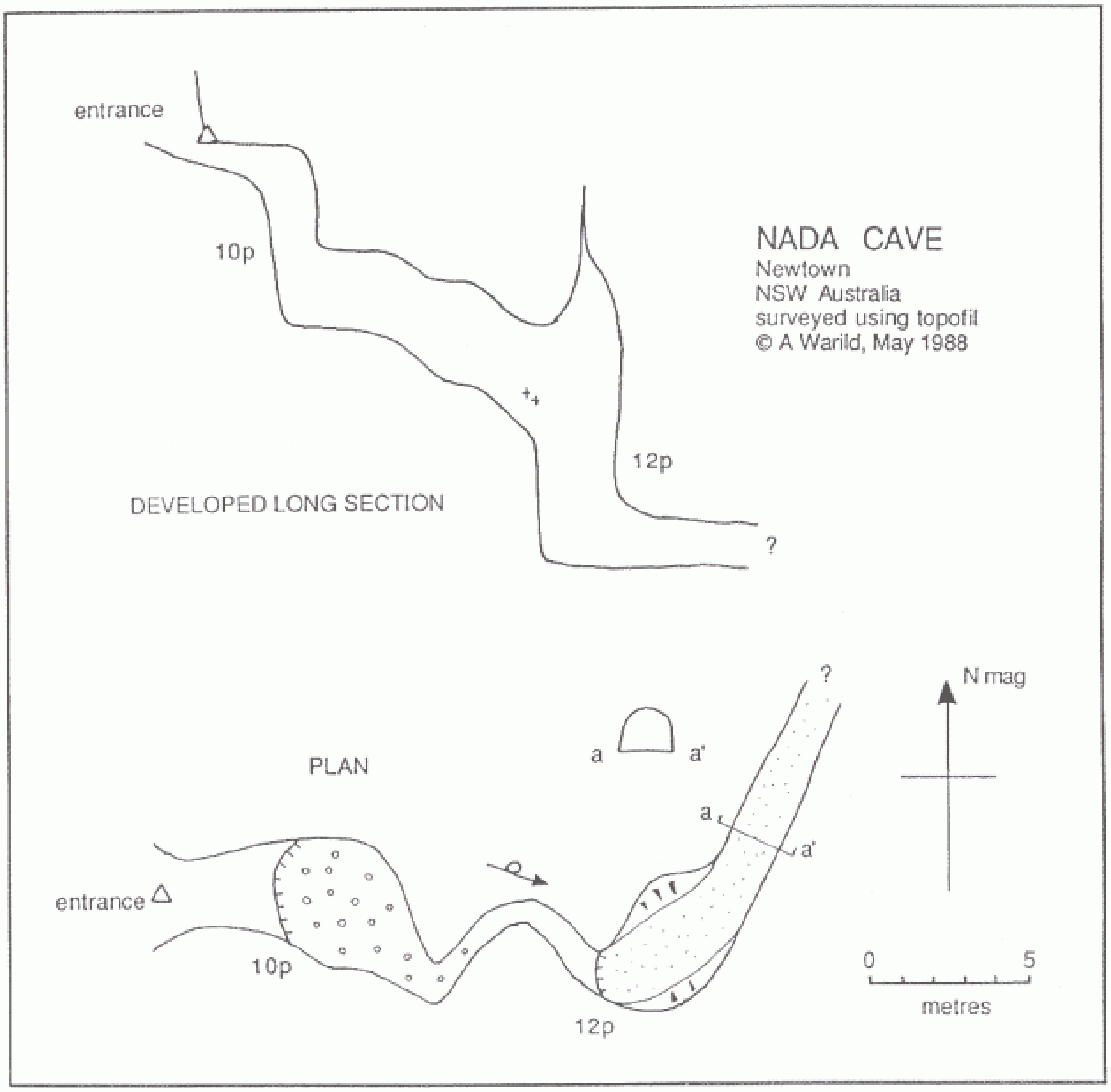
THE FINAL PRODUCT

Pencil maps on graph paper are the most that is needed in the field. Once the map reaches this stage it is traced onto tracing film or art paper for the final presentation.

The ultimate product of a cave survey should be a high quality map, which is rich in information and self explanatory. It should be accompanied by a tackle description or equipment list as well as a cave description if the cave is complex or the information cannot be clearly shown otherwise.

The map can be a projected section and plan if it is of a system and passage relationships need to be shown. A developed long section gives a better representation as to what the cave is really like. It "straightens out" the cave by showing the true length and inclination for each survey leg. However passage relationships are difficult to depict as developed sections only show true displacement between two consecutive points. The plan can be used to show the actual horizontal extent of the cave.

The final scale of the drawing depends on the extent of the cave and the sheet of paper it must fit on for publication. Preferably the scale should he some simple multiple such as 1:200, 1:500, 1:1000 and be represented as a bar scale so that the map may be reduced or enlarged without losing it. Information such as cave name, surveyors, north arrow, date, survey instruments used (survey grades such as M5.4 will be meaningless in another country) and scale can be placed for balance or shown as an information block.



Finished product

CAVING GEAR SUPPLIERS

Caving shops seem to specialise in mail order and are often a good way of getting equipment, which is not available locally.

Bob & Bob
P.G. Box 441, Lewisburg, WV 24901 USA ph (304) 772-5049
Equipment retailers.

Caving Supplies
19 London Rd, Buxton, Derbyshire SK 17 9PA, UK ph (0298) 5040
Equipment retailers and wholesalers.

Expé (TSA, Marbach)
B.P. 5, 38680 Pont-en-Royans, France. ph 76.36.02.67
Manufacturers of software and retailers of everything.

Lyon Equipment
Rise Hill Mill - Dent, Sedbergh. Cumbria LA 10 5QL. UK (19.44) 5875.370
Equipment importers and retailers.

PMI (Pigeon Mountain lndustries Ltd.)
P.O. Box 803, Lafayette, Georgia 30728, USA. (404) 638-2181
Manufacturers of rope and some hardware.

Prospectors Supplies
lA Garden Ave Wahroonga ph (02) 487 3477 (P.G. Box 76 Wahroonga 2076 Aust)
Survey instruments.

Spelemat
85 Rue Cuvier, 102 Rue Boileau, 69006 Lyon, France. ph 78 24 34 01
Equipment retailers.

SRT (Single Rope Techniques Equipment)
54 Blackshaw Ave Mortdale, 2223 Aust. ph (02) 57 6420
Manufacturers of ascenders and descenders and equipment retailers.

Wildsports (ex Caving Equipment)
327 Sussex St Sydney (P.O. Box Q302, Queen Victoria Building, Sydney 2000. ph (02) 264 2095)
Manufacturers and retailers.

BIBLIOGRAPHY

AUTHORS

COLISHAW, M., 1981 Choosing a rope for SRT. *Proceedings of the 8th Congress of the IUS* : pp 108-109.

COURBIS, R., 1980 Feuille de presentation du rapport d'etude sur cordes utilizes en speleologie en 1980. FFS Commission Etude du Material. unpub.

GUERIN, P., 1951 *Speleologie - Manuel Technique.* Vigot Freres Paris.

GENUITE, P., 1984 L'amarrage AS. *L 'Aven,No 44* (Bulletin du Speleo Club de la Seine): pp 186-189.

ISENHART, K., 1981 Development of relevant testing procedures leading towards establishing standards for caving and static loaded rescue rope. *Proceedings of the 8th Congress of the IUS* : pp 179-180.

LARSON, L. and LARSON, P., 1982 *Caving.* Sierra Club Books.

LOMBARD, P. and QUIVY, D., 1978. *Exploration Souterraine, La Technique Cordelette.*

PADGETT, A and SMITH, B, 1987. *ON ROPE.* NSS.

RAMSDEN, P., 1983 Rescue techniques for the small SRT party. *Cave Science 10 No 1* : pp 9-20.

THRUN, R., 1981 A comparison of expected survey errors with closure adjustment. *Proceedings of the 8th Congress of IUS* : pp 648-649.

PERIODICALS

AUSTRALIAN CAVER, (ex ASF Newsletter) Australian Speleological Federation

CAVE SCIENCE, 1982 Vol 9, No 4 Transactions of the British Cave Research Association (BCRA). (Techniques and Equipment special)

CAVES and CAVING, Bulletin of the BCRA

CAVING INTERNATIONAL MAGAZINE, Stalactite Press.

NSS News, monthly magazine of the National Speleological Society (NSS), USA.

NYLON HIGHWAY, periodical magazine of the NSS Vertical Section.

SPELUNCA, Publication trimestrielle de la Federation Française de Speleologie (FPS).

REFERENCES

ANDERSON, E., 1978 Cave survey and map standards. *ASF Newsletter 79*

BRINDLE, D. and SMITH, R.A., 1983 Strength of rock anchors. *Caves and Caving 20* : pp 22-27.

BALLEREAU, A., 1983 Le pabsabloq. *Spelunca 11* : p 40.

CLOSS, L., 1987 Ascenders. *Wild 24* : p 83.

COURBIS, R., 1976 Utilisation d'un mat en escalade souterraine. *Spelunca 2* : pp 81-82.

COURBIS, R., 1982A Tests material: Cordes et descendeurs autobloquants. *Spelunca 5* : pp 41-44.

CQURBIS, R., 1982B Essai sur les plaquettes textiles et leur vis support. *Spelunca 6* : pp 45-47.

COURBIS, R., 1984 Essais de noeuds en position anormale. *Spelunca 15* : pp 42-44.

DELPY, A., 1981 Les casques de montagne. *Spelunca 1* : pp 5-12.

ELLlOT, D. and MROCZKOWSKI, D., 1984 Knot tests. *Caves and Caving 23* : pp 16-19.

ELLlOT, D., 1985 Experiments on harnesses. *Caves and Caving 27* : p 35. (from *Chaplain 39*: May 1984).

EXPÉ (TSA) *Catalogue*, 1987.

FRACHON, J.-C., 1980 Technique du «Mousqueton Coulant». *Spelunca 3* : p 125.

GANTER, J., 1986 The Speleo Technics FX-2 lamp. *NSS News Feb, 1986* : pp 43-45.

GUTIERREZ, J. and LOPEZ, M., 1985 Técnica de autosocorro. *SIL 3* : pp 17-20.

HOFFMAN, J., 1985 Traite sur le sondage des puits par objets contondants. *Lumiere et Noire 1* : p 7. Bulletin Speleo D'Ille-de-France

IRWIN, D. J. and STENNER, R. D., 1975 Accuracy and closure of traverses in cave surveying. *BCRA trans. Vol 2 No 4* : pp 151-166.

MAGNUSSEN, C., 1975 How strong is a stitched splice in nylon webbing? *ASF Newsletter 68* : pp 7-10. (Reprinted from *Off Belay Oct.1972*).

MARBACH, G. and ROCOURT, J.-L., 1980 *Techniques de la Speleologie Alpine. Techniques Sportives Appliquees*, Choranche.

MARBACH, G., 1982 Cordes statiques et securitie. *Spelunca 7* : pp 40-41.

MARTIN, D.J. and BONWICK, M.H., 1987 A user friendly survey data reduction program for a hand held micro computer. *Descent Yearbook 1987.*

MARTINEZ, D., 1979 Secours en methode balancier. *Spelunca 3* : pp 125-126.

MICHEL, Y., 1982 Descente sur corde verticale tendue. *Speleologie Dossiers 16* : p 60. CDS du Rhone.

MIZERY, R., 1982 Pour la remontee aux bloqueurs. *Spelunca 5* : p 45.

MONTGOMERY, N., 1977 *Single Rope Techniques* Sydney Speleological Society Occasional Paper No 7.

MONTGOMERY, N. and MROCZKOWSKI, D., 1981 The new Jumar. *Caving International 10* : pp 42-46.

PETZL *Brochure, 1986.*

PETZL *Brochure, 1988.*

POLLACK, J., 1979 Static loads on tyrolean traverses. *Caving International 3* : pp 37-38.

ROCOURT, J.-L., 1974 La plate-forme d'escalade artificielle Rocourt. *Spelunca 1* : pp 24-25.

SMITH, B.J., 1980 Rope review. *Caving International 6+7* : pp 71-75.

SPELEMAT *Catalogue, hiver 1986/87.*

STIBRANYI, G., 1986 Tests and practical experiences with Czechoslovak climbing ropes, used in speleology. *Communications of the 9th Congress of IUS, Barcelona 2* : pp 324-328.

TOOMER, P. and WELCH, B., 1977 The Spelean shunt technique. *ASF Newsletter 77* : p 15.

WEBB, J., 1978 The Spelean shunt: A discussion. *ASF Newsletter 82* : p 6.

WILDSPORTS *Catalogue, May 1987.*

INDEX