# Personal Equipment

oronia base camp, Abkhazia

Appropriate clothing and equipment for a cave increases safety by increasing comfort and reducing your energy expenditure for any given trip. While the condition of the life support components of personal gear has an obvious effect on your well being and the rest of your gear is of less immediate importance, considerable care should still go into its selection.

## Clothing

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

### Undersuits

In caves colder than 15° C a one-piece undersuit of CoolMax, chlorofibre or polypropylene is ideal. Synthetic suits dry quickly, are reasonably comfortable when wet, are not too bulky to hinder movement and wash easily. One-piece fibrepile 'furry suits' are bulky and in all but the coldest caves are too hot when dry. Once wet a thick pile suit holds an enormous weight of water that is slow to drain and dry out. Clothing conducts heat away from your body much faster when it is wet. Fast drying, low bulk clothing is therefore better than wearing thicker but slow drying clothing if there is a high possibility of getting wet.

If you really feel the cold, multiple layers of light clothing are better than a single thick layer. You can augment any undersuit 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. Do not use cotton in any form in cold wet conditions. Once wet it dries slowly, feels uncomfortably damp and removes a lot of your valuable body heat.

In warmer caves, use light polypropylene underwear. It removes water from your skin rapidly, keeping you feeling dry and is more comfortable against bare skin than an oversuit. Take care when drying synthetics; too much heat will convert them into crunchy miniatures of the real thing.

Sew light neoprene or fibrepile patch-pads onto the knees and elbows of your undersuit to provide protection without appreciably restricting movement. Position the pads carefully by marking their position with your suit on and arm or knee bent. The pads end up a little lower than you may expect but in the correct position to protect you.

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'.

### Oversuits

Protection from cold is rarely enough, warm gear must stay dry and clean for it to be effective. It also needs a tough covering to keep it in one piece.

#### Waterproof

Brightly coloured plastic suits have been the mode in Europe's cold wet caves 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 armor' feel about it, especially at low temperatures and you must ask yourself whether the lack of flexibility and increased effort moving in a PVC suit is worth the extra protection. Its impermeability can cause a good deal of condensation to form if you wear it in warm caves or when working hard. Nevertheless they are unbeatable in cold, wet caves when the water is not too deep. Repairs are easy. Glue a patch on the inside with the PVC glue normally used for plastic plumbing or with contact adhesive.

#### Non-waterproof

Suits made of nylon with no waterproofing layer or even 'proofed' nylon or cordura are more comfortable to wear than impermeable plastic suits. They are light, flexible and breathe so that given the chance, they dry out. Unproofed suits 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.

## Something in between

There is also a range of oversuits made from woven nylon that are proofed with a heavy PVC layer on the inside. These suits as you would expect fill a mid-way niche between PVC suits and unproofed suits. They rarely have sealed seams and typically let in some water when new, and more water as the proofing wears out. The proofing layer also makes them a little warmer while you're moving and more subject to condensation. They are however still relatively lightweight and comfortable to wear. Meander makes a nice hybrid suit that has PVC from the waist down and cordura on the top half. It works well to protect your legs from splashes while allowing you to move your arms more freely and not overheat so badly.

## Extra clothing

For cold or slow trips (surveying, photography) a balaclava and undergloves make a world of difference. For colder conditions or for emergencies carry a thermal top in a waterproof bag until you need it.

## Wetsuits

Wetsuits are excellent for wet caves where you are 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 your limb movement considerably, making climbing difficult and adding to fatigue. A wetsuit is uncomfortable in a dry cave as it seals in sweat, keeping you constantly wet. After a long trip most cavers 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 you are forced to stop for some time it is easy to become dangerously cold. At the other extreme, 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 is the better alternative to a diver's wetsuit. This design accommodates all prusiking movements and allows you to reach both hands above your head. The neoprene should be double lined, no thicker than 5 mm and even thinner for warm caves.

A suit that is a slightly loose fit gives better freedom of movement and allows you to wear an undersuit for cold conditions. One-piece wetsuits are lighter and cheaper but less versatile than two piece suits. Female cavers find two-piece suits more comfortable while males can get by in any suit with a fly zip. A hood for diving sumps completes the suit.


*Wetsuits come in a wide variety of attractive colours and designs. You can also get ones like this.*

Contents Index

## Pontonniere


*Pontonniere in action*

The safest and most comfortable way to explore a cold cave is to stay dry. If you need to wade but not swim a 'ponto' is the way to keep your undersuit dry.

Pontonnieres are made of latex, polyurethane coated nylon or PVC. Latex versions are the most popular as they are made in one piece with no seams, feet included. Pontos keep you waterproof to the armpits with only minimal restriction of leg movement. A ponto weighs around 500 g and packs down small enough so you can carry it to the beginning of the wet section, then put it on over your undersuit but beneath your protective oversuit. Wear a pair of thin long socks and garters 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 that went straight to the feet, leaving me tolerably warm and 'dry'.

All pontos are delicate. Latex is tougher, more elastic 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, rinse your ponto in fresh water then dry it out of direct sunlight. When packing a latex ponto away, dust it inside and out with talcum powder to prevent it from sticking to itself.

## Footwear

The most popular cave footwear must be rubber 'gumboots' or 'wellies'. They offer good protection to your feet and lower leg, are robust, keep your 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. Wear the legs of your oversuit over your boot tops to keep out gravel and water. This works better if the boot tops maintain their shape. Rubber bands cut from car inner tubes are ideal for keeping your overalls from slipping down your wellies and restricting leg movement. They only keep your feet dry provided the water stays below 'welly-depth', once there is more than a little wading, the constant emptying is a nuisance and short lace-up boots are more practical.

If you don't like wellies, 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 you need to swim a lot, running shoes are suitable. Leather walking boots cope very badly with 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 your feet toasty warm and well padded—and wet. Wetsuit booties go well with wetsuits but if your feet aren't constantly being dunked in the water they quickly become uncomfortable. If you wear wellies, long wool or synthetic socks are ideal. Even after long trips it is possible to emerge with dry feet.

## Gloves

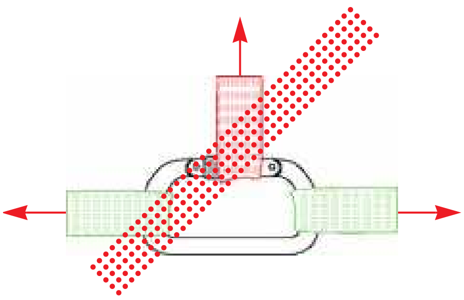
Perhaps on short trips into easy caves, you'll survive with bare hands. When caving day after day or on a long trip you can't afford to lose dexterity due to cold or damaged hands. Gloves are essential but good ones may be hard to find. Ideally a neat fitting pair of PVC industrial gloves with long gauntlet wrists are the best. Once you are used to the feel of gloves wear them as much as possible to keep your hands clean, dry and protected. The long gauntlets help keep water and dirt from getting in both the gloves and your sleeves. In really dirty caves you can put rubber bands or adhesive tape around oversuit or glove cuffs in an attempt to keep the cave out. If you can't find a good pair of gloves any gloves are 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:

- A harness must have at least two independent suspension points as a fail-safe. If one breaks there must be a back-up.
- A harness must be comfortable, you may have 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. Slack in a harness ultimately has an adverse effect on your prusiking efficiency.

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



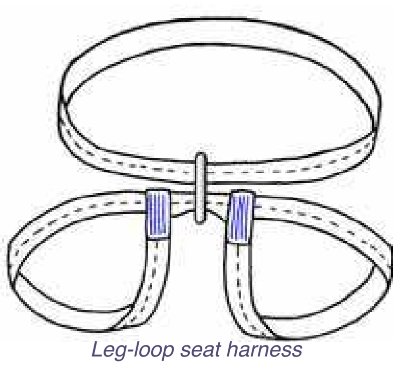
*3-way loaded karabiner*

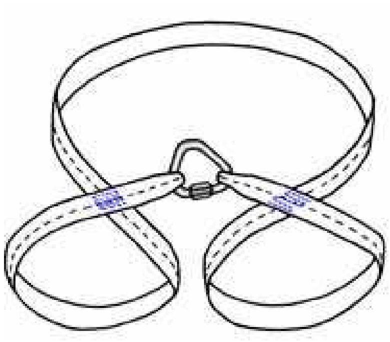
Always use a maillon rapide or Petzl Omni to hold your seat harness together at the front. Never use a karabiner, the 3 way loads that can occur at the harness attachment point make it dangerously weak. Use a 10 mm diameter maillon made of either steel or aluminium in a delta or half round shape. An 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. You can loosen a seat maillon that is jammed closed by wrapping a piece of clean tape around the gate or use the nose of your Petzl descender as a spanner. A steel maillon also works as an adjustable spanner, but may damage the maillon.

The 'seat maillon' can either sit flat against your abdomen like the 'European' style harness, or at right angles, as with 'Leg-loop' harnesses. Quite apart from comfort in squeezes and crawls the orientation of the seat maillon can have a significant effect on your prusik rig. Most cavers use a Petzl Croll as their chest-mounted ascender. The Croll has a preferred orientation so you must use a seat harness that complements the ascenders and prusik rig you use (See Chapter 7 on page 109).

Other features to be aware of are:

- Adjustment buckles —once set you will probably never need to touch them again but, if badly positioned they may dig into your hips or expose the tape to severe abrasion. In some cases turning the harness inside out can help.
- Harnesses specifically designed for caving often have patches or otherwise protected stitching. Be especially careful of exposed bar tacks that are strong when new, but can wear off very quickly.
- A good test of a harness is to prusik with it for at least 50 m. A test hang in a shop is better than nothing but only shows up a harness that **really** doesn't fit.
- On many people the legloops slip down and may need uplift straps at the back.
- Any harness can easily be modified at home if it is otherwise suitable.


Leg-loop seat harness

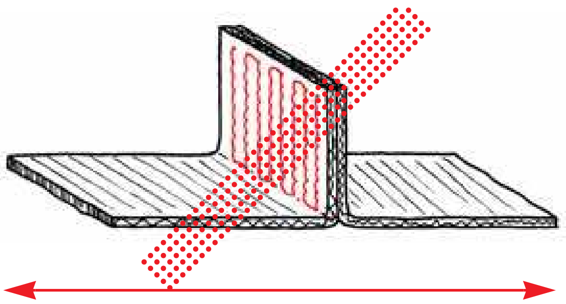

European style seat harness

## Home-sewn harness

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, leave off adjustment buckles and make the harness to measure. It will end up 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 that 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, sew a protecting patch over the surface. You can make a lighter but simpler protective patch by coating the stitches and tape with a layer of rubber glue. 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 or nylon thread (never use cotton as it rots).


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

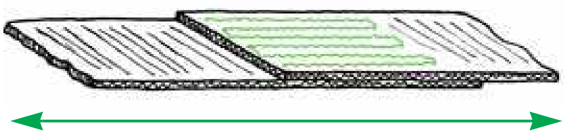
50 mm tape - 200 stitches

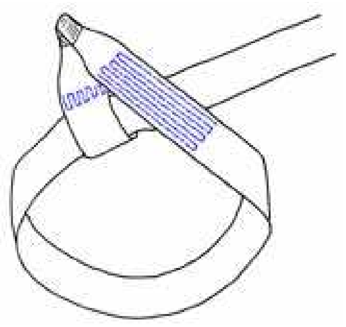
25 mm tape - 150 stitches

15 mm tape - 80 stitches

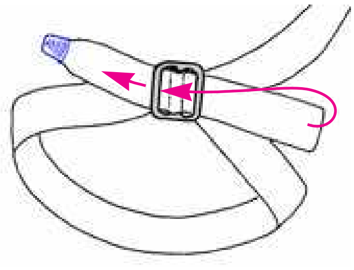
(At 5 stitches per centimetre and sufficient tension to pull the thread into the tape.)

Very few of us can sew to CE standard tough. If in doubt, just buy one.


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



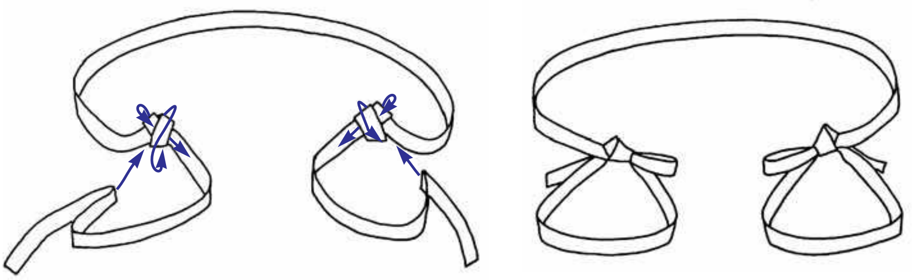
Sewn legloop



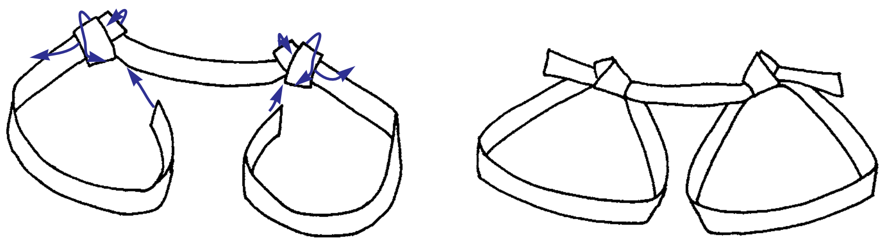
Buckled legloop

## Knotted harness

If you don't trust their own sewing or have no access to a suitable sewing machine you can replace stitched areas with buckles or knots using sewing for only those parts that are not 'life support'. Always thread tape back through buckles as illustrated. As an extra precaution, tack the tail on both buckles and knots with stitches or tape to keep it from sneaking back. The most suitable knots are tape and overhand knots that reduce the tape's strength by around 50%. Knots are less suitable than sewing for making a harness because their bulk can make them uncomfortable and wear badly. Knots have one advantage over sewing—you can tie a knotted harness quickly and easily, even in a cave.

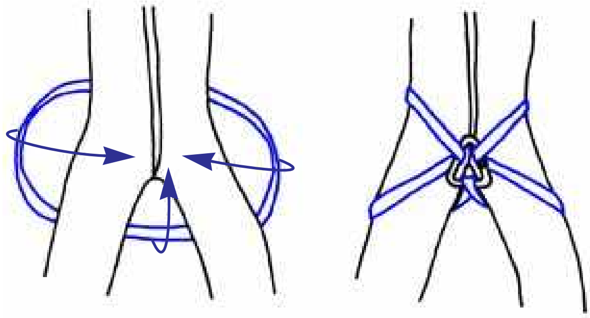


Tying a European style harness



Tying legloops

## Improvised seat harness



Nappy seat

To improvise an adequate harness 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.

With a longer sling you can be make a nappy seat that you can also clip 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. Replace your seat harness every few years, or more often if it is badly worn.

### Waist loop

A waistloop is simply several metres of tape wrapped around your waist and tied with a tape knot. As well as forming the second suspension point of some harnesses, you can use a waistloop as a handline or re-tie it to make a harness in times of need.

## Chest harnesses

Chest harnesses are not always 'life support' equipment. If not, they do not need to be heavy, overstrong or particularly well sewn. For this reason cavers often make their own, even though commercial models are readily available. Whatever chest harness you use, you'll normally wear it all the way through the cave just as you do a seat harness. It should therefore be comfortable, not slip off your shoulder or get in your way. A chest harness that you can hang things from is also useful when rigging.

The chest harness you use depends on your prusik system. If you may only need it to lift a chest ascender and support some of the weight of a pack, light tape is ideal. However, if you need it to keep your body upright and tightly against the rope it will need to be of wide, strong tape to spread the load. Some prusik systems do not even need a chest harness (See Chapter 7 on page 109).

### Neck loop

Neck loop

The simplest chest harness is a loop of shock cord (bungee cord) or tape threaded through the top of the chest ascender and put over your head.

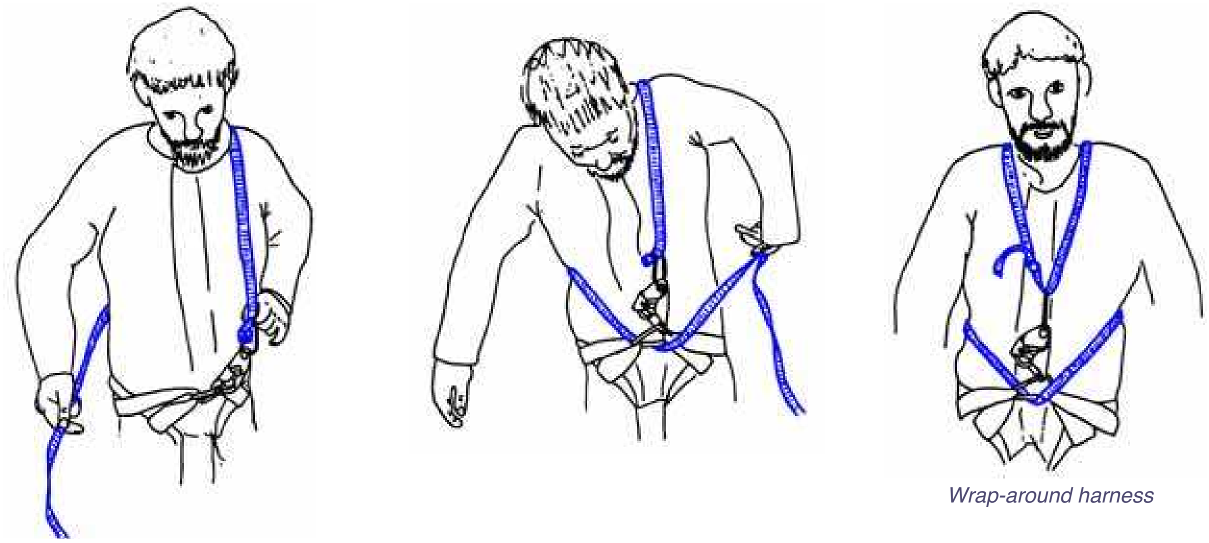
A neckloop works fine except when prusiking with a heavy pack or leaning back to rest. It is however, never especially comfortable. More sophisticated versions use a tape with a buckle or even a quick release buckle so that you can convert instantly from tight for prusiking to loose for walking.

### Sash

Sash

A tape over your shoulder like a bandolier gives you a convenient, light chest harness for short drops when not carrying heavy loads.

However the diagonal nature may give problems because it pulls your chest ascender to one side, which can affect its running. The chest ascender will probably run best with the harness over your right shoulder so the rope runs hard against the shell of your Croll rather than against its cam—but some prefer it over their left shoulder. For small pitches and emergencies, short chest ascenders also run adequately with their top eye clipped directly into a short carbide lamp sling, your top pocket, or velcro/zipper oversuit closure.



Wrap-around harness

## Wrap-around

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

Thread the tape through the eye at the top of the chest ascender so that the buckle is just to the right of the ascender. Alternatively, connect it to the top of the ascender with a small maillon or mini-krab. Throw the rest of the tape over your left shoulder, collect it from behind your back with your right hand, pass it under your right armpit and thread it under your seat maillon. Next, run it around under your left arm and across your back and over your right shoulder down to the buckle. It may sound complicated but once on it is an exceptionally comfortable harness even when carrying a cave pack.

In use, pull the harness as tight as possible without restricting your breathing. When walking between pitches, loosen the harness by feeding tape through the buckle, or releasing the mini-krab from the top of the ascender.

The biggest problem with a Wrap-around harness is that is that it has a tendency to slip off your shoulders when you wear it loose for descending the cave or moving between pitches.

## Figure-8

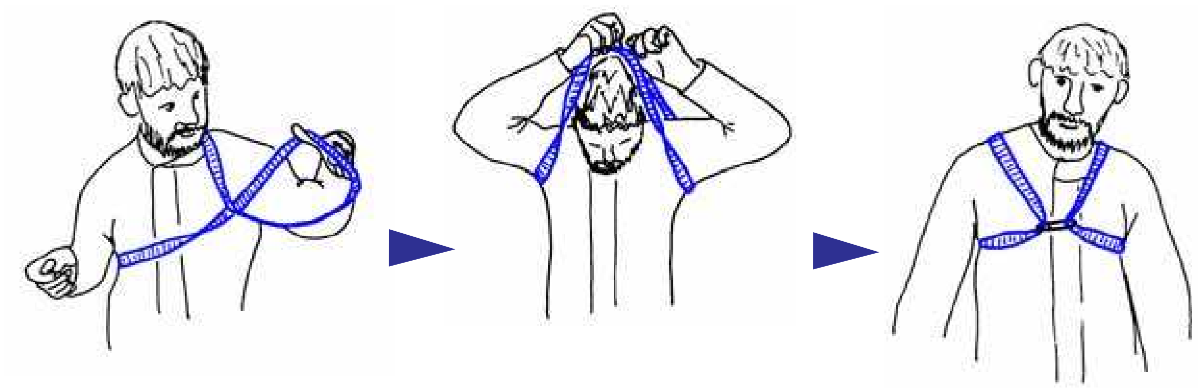


Figure-8 harness

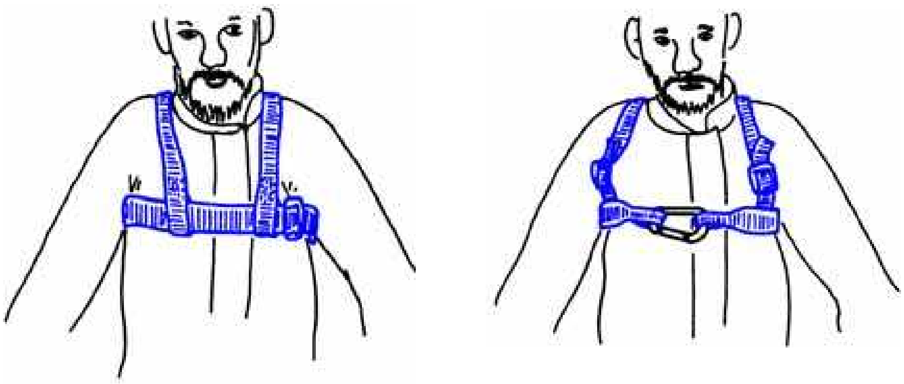
The Figure-8 chest harness is a simpler and popular alternative to the Wrap-around harness. All you need is a correctly sized pre-tied tape loop or bicycle inner tube and a karabiner.

Put one arm through the loop, then cross the loop in front of your body to make an '8'. Put your other arm through the other hole. Next, put the crossed part back over your head. Gather the two loops that sit in front of your shoulders and clip them at the front with a karabiner.

The harness should be a snug fit without being tight and you may have to experiment to get it just right. To ascend, simply bend over and clip the karabiner through the top of your chest ascender. The system works well, it is light, simple and will not slip off your shoulders, so you can comfortably wear it throughout the cave. It is not as comfortable as the wrap-around and can be quite uncomfortable when prusiking with a pack.

The chest harnesses so far described are most suited to prusik systems that require a chest ascender lifted rather than the harness holding you close to the rope (See Frog system on page 119).

## Climbing Chest Harness



*Climbing chest harnesses*

Most climbing chest harnesses have a wide adjustable band that goes around your chest just below your armpits and two lighter shoulder straps to hold it in place. Often a karabiner holds it together at the front. One ingenious variation on the climbing style chest harnesses the MTDE 'Garma'. It has a length of tape and quick release bicycle toe-strap buckle that allows you to tighten and adjust perfectly, or release your Croll very rapidly.

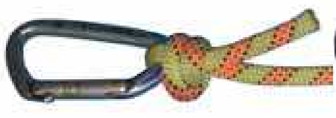
While they work with any prusik system, climbing chest harnesses can also hold your body close to the rope rather than just lift a chest ascender. As such they are a must for some Rope-walking systems and sometimes overkill for Sit/Stand prusik systems (See Ropewalk systems on page 121). For a climbing chest harnesses to be effective for ropewalking it must be tight, that may restrict your breathing, and comfortable, that means using wide tape (50 mm+), thus making it bulkier and heavier than simple lift harnesses.

*MTDE 'Garma' climbing chest harnesses*


*Sash chest harnesses*

## Cowstail

Double cowstails: rope, Petzl 'Spelegyca'



Cowstail to karabiner: barrel noose, Figure-8 and tyre tube

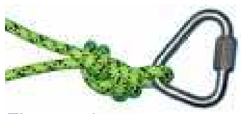


Figure-8 loop

Overhand loop

'Expé' Cowstail plate

Clove hitch

Cowstail to harness maillon

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 you could subject it to a Factor 2 fall so **anything less than 9 mm dynamic rope is unsafe** (See Properties on page 21). 'Dynamic' rope is very important for a cowstail. It must be able to absorb the shock of a fall without damaging you or the belay. There is nothing better than 9 mm to 10.5 mm dynamic rope tied with a Barrel noose to the karabiners. A dynamic rope cowstail is strong enough and shock absorbent enough that if you are foolish enough to clip an ascender just below a belay, then climb above the belay and fall off, there is a reasonable chance that nothing will break.

Low stretch fibres such as Dyneema, spectra and kevlar, either as rope or tape, are exceptionally dangerous. **Don't use them!**

25 mm (1 inch) tubular tape is almost as bad. In tests done by Long, Lyon & Lyon, 2001, 25 mm tube tape broke every time. It just doesn't have the shock absorption of a dynamic rope. Doubling it won't help either. It just increases the impact force.

Also to be avoided is the Petzl Spelegyca. It is not made as a shock absorbing device—but if you use it caving, you are potentially using it as one. The Spelegyca is made of low stretch tape stitched with 'burst stitching' that rips to absorb extreme shocks. Even so a Spelegyca will give you over twice the shock load of a good dynamic rope cowstail. Caving rope too has insufficient stretch for a good cowstail but is still better than **any** tape cowstail.

The classic double cowstail is made from 2.0 to 2.5 m of rope tied with figure-8 loops. The short length should be about long enough so that the attachment point reaches to your elbow with the karabiner held in the palm of your hand. The other measure is that your short cowstail should be just long enough to reach past your Croll and clip into the rebelay as you ascend. The long cowstail is about 50% longer. If you intend to use the long cowstail as a safety for an ascender it should reach from your seat maillon to your upstretched wrist when hanging on the rope, but never be so long that the ascender is out of reach (See Frog system on page 119). Experiment a little to get these lengths just right. A good starting point is:

- short 40 cm long
- long 55 cm long

The only reason to have a double cowstail is to use a minimum of rope and carry a minimum of bulk. Two separate cowstails allows you to replace them separately, and to put one on each side of your maillon.

You also have some choice over the attachment point. A figure 8 loop is most popular although some people use an overhand loop to reduce bulk. A clove hitch is another option. It uses less rope and theoretically at least, it will slide under a heavy load. At worst, a clove hitch is no weaker than an overhand loop. An attachment plate uses a minimum of rope and is very nice —if you can find one.

Should you feel that the normal cowstail is not strong enough, use 10 mm, 11 mm or even 11.5 mm multifall climbing rope, though of course it is bulkier and heavier. As will be explained in Rigging Equipment, strength is not all it seems to be, a very strong or doubled cowstail does survive more test falls than a single one in the same rope, but due to lower stretch, these falls also generate considerably higher shock loads that could in turn damage you, your harness or the belay.

The karabiners you use must be of the highest quality, you do after all hang everything off them. Snaplinks are the most commonly used as any sort of locking gate hinders efficient use. A steel karabiner on the long cowstail can double as a brake karabiner during descent (See Autostop bobbins on page 93), although dedicated karabiners are better for both the cowstail and the brake. The best cowstails karabiners have a small 'nose' so that they don't tend to get caught when you unclip them.


*Keylock detail*

A 'keylock' as on the Petzl 'Spirit' and others is ideal. For convenience, tie your cowstail to its karabiners with a barrel knot or fit them with a bar, clip or rubber bands to keep them oriented correctly for quick action.

Use a belt or chest harness loop to clip the cowstail's karabiners out of the way when you aren't using them.

Replace your cowstail regularly. While you normally load it gently, one slip could subject a cowstail to a severe shock load. Nine millimetre dynamic rope is only a minimum, 10 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.**

If you do take a more than F F 0.3 fall on your cowstail, you should replace it. If you can't replace it immediately, loosen the knots that took the fall and re-tie them as the knots themselves pay an important role in shock absorbtion, especially in shorter falls.

Cavers who never cross rebelays (or perhaps never used to cross them), often use a single ascender on a sling to give protection when needed. While this practice is popular in the USA, a shock load could damage the rope, sling (especially a tape sling), or the ascender, and cannot be recommended.

A single ascender with footloop can be very handy for crossing difficult rebelays or when carrying a load.

## Quick attachment safety (QAS)

The QAS is the IRT caver's answer to the cowstail. It is an arm's length sling tied to a handle ascender that you can easily and quickly use to attach yourself to the rope. A QAS is probably still a good option for IRT rigging where there may be nothing suitable to clip a cowstail karabiner to at a pitch head. The Mitchell system and Ropewalk systems need something more for resting and getting off a pitch head safely. For anyone using a Frog system, or Texas system a QAS only complicates your prusik rig. In both cases your top ascender is identical to a QAS anyway. Your Frog system by design uses a cowstail as a third point of attachment. For a Texas you will also need a cowstail or QAS for that third point.

If you make a QAS, use the same rules as those above for making a cowstail. Use dynamic rope tied with a Barrel noose to a linking karabiner or maillon. You can tie directly to ascenders like Jumars that have a large radius tie point, but Petzl Ascension ascenders are made of thinner metal and form a severe radius for the knot—use a small rapide or a karabiner. Never (never ever!) use 25 mm (1 inch) tape. The high impact force that you could generate with a fall onto tape is directly applied to you and your ascender-rope contact point. This greatly increases your chances of cutting the rope if your tape QAS doesn't break first. Ascenders are not made to catch falls. They are the weakest part of your caving rig. Don't use a QAS for traverse lines or anywhere they may be subjected to a shock load—get a cowstail, the karabiner on the end is made to catch falls. In the end, a QAS isn't near as quick as a cowstail, and often not as safe.

## Helmet

The functions of your helmet are to protect your head from falling rocks, blows from a fall, standing up when you shouldn't and to support your lamp.

CE[1] approved climbing helmets can withstand blows from all directions and have a strong chinstrap that if kept tight, keeps the helmet from falling off under all conditions. Any CE approved helmet is safe, though not all are ideal for caving. If you protect your head with a construction helmet to save money you are making a definite statement about the value of its contents.

*A good caving helmet*

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

- It should be CE 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 your head, be comfortable and have jugular straps that do not block side-vision.
- A quick action 'Fastex' type buckle that is far more convenient than a thread buckle but can be fitted after purchase.
- It should not fall off the back of your head, nor should the weight of a lamp drag it down at the front.
- Fit lamps so that the mounting screws, nuts or rivets do not project into its interior.

Moulded plastic helmets appear to survive the bumping and scraping of caving better than the fibreglass models that tend to crack. This may be largely cosmetic. Limited testing indicates that fibreglass helmets, even old ones, transmit less energy to the head below. Fibreglass helmets absorb the energy of a severe blow by delaminating while moulded plastic helmets rely mainly on the head cradle to absorb energy.

It is not reasonable to use a battered old helmet for caving when you would never consider it for climbing. Discard any helmet that becomes cracked, badly knocked about or receives a severe blow.

## Lighting

*One of many prototypes. A single central 'Luxeon' for spotting surrounded by 18 x 5 mm LEDs for normal use. Each set of LEDs is separately powered and switched to provide redundancy*

Caving lights have changed considerably over the past ten years. The only light seriously worth considering today is an LED light. The advantages leave every other type of light in the speleo museum. The only decision to make is which one? LEDs are experiencing rapid development with light output for energy used doubling every 18 months or so. What you read here is probably already out of date! The basic principles however remain the same.

1. The CE has standards for just about everything to do with safety. See CE certification on page 22 for further details.

## LED —light emitting diode

LEDs come in two basic types:

- 5 mm LEDs. You'll need 10 or more for a decent caving light.
- 'Luxeon' style LEDs. These come in 1 Watt, 3 Watt and 5 Watt. 3 W is the most suitable.

Contrary to popular belief, LEDs are not exceptionally efficient. Yes, they can give out light for a long time, but whether that light is particularly useful is quite another story. LEDs have a similar efficiency to halogen bulbs. The great advantage of LEDs is that they are efficient at low power whereas a halogen needs to burn at 50 Watts or so to be truly efficient. As cavers, low power is what we need. We have to carry the energy source for our lights with us. A single 3 Watt LED or an array of 5 mm LEDs running at 2 watts is more than you'll need for most caving and most of the time you'll be happy with much less.

## Power

There are two parts to powering a LED light: the batteries and the circuit.

### Batteries

*3 x D cell pack,*

*1 & 2 cell Lithium packs*

Alkaline or lithium disposable cells in AA size are convenient and carry easily on your helmet. They are fine for shorter trips, but for long trips or expedition use you'll use a lot of them. A longer duration alternative is a pack of D or C cells in a pack hanging from your waist of chest harness. These carry enough energy to last a very long time. My 3 x D cell pack lasts me a full month of expedition caving. Having such long lasting batteries may seem excessive, but it does have the advantage that you can just pick up your lamp and use it without ever being too concerned that it has enough power left.

Rechargeable lithium cells are currently the ideal solution. A 7 cm x 3.5 cm x 1.5 cm pack gives you light for up to 50 hours caving, depending on the light that you connect it to. Lithium cells are very fussy about how they are charged and discharged. Charging with the correct charger presents no problems. Lithium cells should never be completely discharged as it ruins them. A short circuit can cause them to overheat and destroy them—perhaps explosively. Any battery pack should therefore have a discharge protection circuit in it. This circuit disconnects the power if it is short circuited or the current drain is too high. It also switches off the connection if the battery voltage is too low. A lithium rechargeable may therefore suddenly stop as it runs down when the protection circuit cuts in.

NiMH (nickel metal hydride) are cheap, common robust rechargeables that you can directly substitute for AA alkaline cells.

Charging may be problematic in truly remote areas and may be solved with a 12 V charger and solar panel.

### Circuit

There are two basic families of circuits for LED lights: Regulated and unregulated. Each has its advantages and disadvantages.

**Regulated circuits** give a constant light output for the life of the battery—no more fading light as your batteries get old—then they die, or at best drop to an emergency mode that's enough light to find your spare batteries. A good circuit will suck every last joule of energy out of your battery and give you the maximum total quantity of light, but perhaps not maximum burn time, from your lamp. A convenient feature of regulated lights is that even though they are normally designed for a specific battery, they often accept a range of battery voltages. The biggest disadvantage of a regulated light is the complexity of the circuit. If the light malfunctions it is very difficult to figure out what has gone wrong and how to fix it. If the circuit gets wet it will probably fail.

**Unregulated circuits** have a simple resistor to control the maximum current through your LED(s). As the battery runs down and its voltage drops the light output also drops. The advantage is that as this happens, the light uses less power and will go for longer. With alkaline batteries it can be, in effect, a lamp that will never die. Unregulated lights are generally battery specific, but cheaper and more robust than regulated lights.

## Incandescent electrics

Some cast a strong more focused beam than a LED light can manage. This is useful for spotting up and down pitches and looking for leads in the roof and walls. Many diving lights are suitable as well as being waterproof and robust. Their disadvantages are expense, poor burn time to weight ratio and the consequent need to frequently recharge or replace used cells, especially on long trips.

## Lead-Acid lamps

If you still have a lead-acid miner’s light, put it beside your carbide light in your caving gear museum. They long ago priced themselves off the market, and are also heavy, leak acid onto caving gear too often, and troublesome to maintain.

## NiCad/NiMH lamps

‘Speleo Technics’ electrics with NiCd and NiMH batteries from Britain have effectively replaced lead acids for caving. Designed specifically for caving, their cells are sealed into a block of plastic while the headpiece is the traditional solid miner’s light. The older versions were a bit dim. Newer versions with LEDs give more light and are longer lasting. The battery packs are designed to unclip easily for charging and for longer trips an extra battery can be carried and just clipped on when the first one dies.

## Carbide lamps

*Premier, Fisma and Ariane carbide lamps*

Carbides still get some use, mainly on expeditions. However with LEDs now so good, carbides belong in museums, not caves. Carbide produces waste that must be disposed of and is often left in the cave. Even on the surface, waste carbide is a pollution hazard. And then there are the black stripes along the roof and above so many rebelays... Carbides don’t light instantly, don’t like spray or wind, take some practise to run and are banned for conservation reasons in many areas. They also lose on weight grounds. In Table 1:1. Lamps is the Ariane, the lightest carbide lamp available. A fully loaded Ariane will last you eight hours at best. For the same one kilo you can carry enough batteries to run even the heaviest LED light for over three days on a higher setting than you’ll want to. The carbide plus water reaction and the flame produce enough heat to be a valuable asset in emergency situations—so does a candle.

## What lamp to get?

For serious caving there is an ever increasing number of possibilities.

*Stenlight*

The Stenlight is from the USA (www.stenlight.com). It is a neat, compact and robust light that is designed to work with a dedicated lithium battery. It uses two 3 W Luxeon LEDs. One gives a wide beam while the other gives a narrow beam, but you can change them. It has several brightness levels. You cannot operate the two LEDs separately.

The Nova comes from the FX-2 people in the UK (www.speleo.co.uk). It has a single Luxeon LED in a robust waterproof case that's waterproof to 50 m. The Nova is powered by a range of Speleo Technics rechargeable batteries or by alkaline batteries.

LED caving lamps from Britain (www.ledcavinglamp.co.uk) makes a lithium powered traditional miners light body with LEDs instead of incandescent bulbs.

Less serious contenders include lights in the Petzl Duo range. These are made with the typical Petzl view to marketing and smooth looks but are somewhat lacking in durability and waterproofness. The general lack of a 'truly best' LED light at a reasonable price means that homebuilt light abound. LED lights typically don't have a built-in backup. In days gone by, the unreliability of carbide lamps meant that everybody had a backup electric mounted and ready to go. LED lights are more reliable, but perhaps harder to repair than carbide lamps. Electronics and caves don't mix so make sure you have a backup.

**Table 1:1 Lamps**

| Lamp | Weight (g) | | Duration (hrs)[a] | | | Comments |
|---|---|---|---|---|---|---|
| | Empty | Full | High | Normal | Low | |
| Prototype LED | 460<br>320 | 880[b]<br>320[c] | 30<br>12 | | 100<br>48 | Empty weights include the built-in backup light. Back-up battery = 80g |
| Stenlight | 125 | 275 | 4 | 7 24 | 72 | Normally run on 24 hr setting |
| NOVA 3<br>Speleo Technics | -<br>- | -<br>- | 15<br>10 | | 25[d]<br>22[e] | Lithium battery outputs a brighter light on high and therefore uses batteries faster. |
| Fixo Duo LED 14<br>Duo belt LED 14<br>Petzl | 180<br>270 | 280<br>550 | 3.5<br>10 | 10<br>24 | 63<br>125 | Duo LED 14 uses 4 AA cells<br>Duo belt has a separate 4 x C cell battery pack |
| NiCad FX-2<br>Speleo Technics | 1250 | 1250 | 8-10 | | | Virtually maintenance free<br>May be too dim |
| Ariane+Aceto Carbide<br>Petzl | 495 | 1000 | 8 | | 11 | 21 L or 14 L jet.<br>Uses 400g of carbide per fill/6-8 hrs light |
| Tikka<br>Petzl | 78 | 111 | 8 | | 20 | Good light for 8 hrs.<br>Usable light for about 20 hrs |
| Tec 40[f]<br>Princeton Tec | 180 | 280 | 5 | | | Robust<br>Good spotlight for its size |
| Weights and durations from manufacturers published data. | | | | | | |

a.Alkaline batteries unless noted otherwise
b.3 x D alkaline + empty weight includes battery holder
c.lithium rechargeable + empty weight includes battery holder
d.3 x AA alkaline batteries
e.lithium rechargeable battery
f.4xAA cells, halogen bulb

## Back-up lights

Many lights have more than one LED or bulb built-in and if caving in a group this is usually adequate, although you can still be left in the dark due to a failure in the battery or cable. Your backup light must be electrically independent of your main light. There is no shortage of small LED lights that are suitable for backup lights or for prospecting. A popular backup is a small one-piece headlight like Petzl's Tikka slung around your neck. It's almost ready to use and in an easy to reach position.

If your lamp does not incorporate a backup (and most don't), you can easily mount a simple backup by attaching two rubber rings to the side of your helmet to hold a robust 2 to 4 x AA light that you can remove when you don't need it. Cave divers mount one or two electrics on each side of their helmet using this type of fastening. A 1-5 LED torch is ideal as a backup. 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.

## Lamp problems

Lights that use a flat 4.5 V battery and mini-Mags may run an overrated bulb. ie, a 3.5 V bulb on a 4.5 V battery, to increase their light output. For this reason they burn out about every 20 hours or so. There is usually some warning as the bulb gets a shiny grey appearance when it is old. Reduce the possibility of failure by replacing grey bulbs before they fail, especially before you visit 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. LED electrics solve both of these problems.

Whether the lamp uses disposable dry cells or is rechargeable, you should keep track of how many hours it has been running so as to have some idea when it will run out. Unregulated LED lights fade slowly with alkaline cells, but be careful of NiMH and lithium cells as they can die very quickly. Perhaps the most 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 after the lamp has been wet.

If your regulated LED light gets wet inside, it may not work until you have dried it very well. You may need to wear it inside your clothing for a night, or pack it with a dessicant before it works well. If you will be caving in wet caves, use a waterproof lamp—'waterproof' to 1 m or even 5 m isn't waterproof...

## In general

When short of light, try and economise—stay near someone else with a light and make sure the person with the good light is coming out last. 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 you choose will depend on supply, ability to make one and the caves you want to take it in.

Features of a good cave pack are:

- Made of heavy PVC coated fabric that wears well, is waterproof and non-absorbent.
- Two shoulder straps of stiff tape that will not bunch up. You may not need both straps 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 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 a tight 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 you can carry it like a suitcase, and another on the bottom to hang it upside down and make it easier to handle in squeezes.
- Closed with a thin cord fastened by a cord grip or 5 mm cord through at least 6 eyelets and tied with a Reef knot.
- A lid flap to keep most of the water and dirt out and the contents in.
- Permanently attached knotted haul cord that hangs the pack just below your feet.

Many cavers also prefer a small personal pack to carry their lunch, spare batteries or who knows what that hangs from their waist or carried as a shoulder bag. Shoulder bags are a nuisance, try anything else and you'll soon change.

## Survival blanket

Do not even walk to the entrance without it! There are robust re-usable models or single use 'chocolate wrapper' ones that 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 your knees and elbows makes caving a lot more comfortable as well as reducing damage to these joints. Small patch-pads sewn to an undersuit or fitted into pockets on the knees and elbows should be adequate for all but the worst caves. For those worst caves, basketballer's knee and elbow pads are good but bulky. Diving shops sell neoprene pads that go quite well with wetsuits without the need to sew on permanent pads.

## Knife

A small Swiss army knife is useful in emergencies, makes a handy portable tool-kit and opens sardine tins more easily than a bolt-hammer.

## Whistle

Some cavers 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 (See Calls and signals on page 154).

Grotte Gounier, France

# 2

# Rigging Equipment

Sumidero Matarocas, Chile

## Ropes

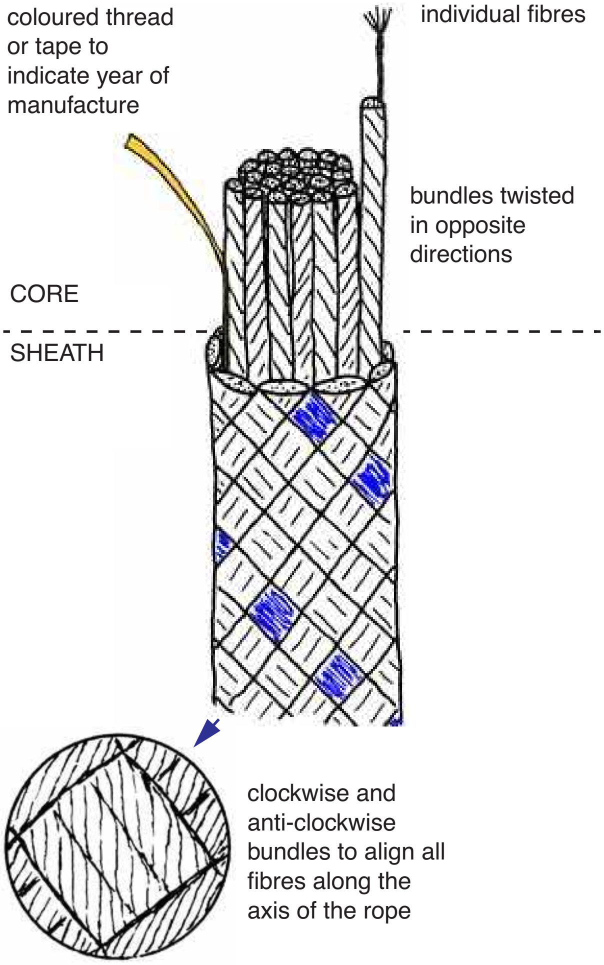
The rope is usually the weakest link in Single Rope Techniques and one that rarely has any back-up. For this reason alone, caving rope should be of the highest quality and treated with care. There is a dazzling range of ropes available but which one is the best has been a source of spirited debate for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

## Construction


*Kernmantle rope under construction (Beal factory/website)*

Caving ropes have a 'kernmantle' or core and sheath construction. The core is the load-bearing 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 countries, and unless the information is printed on the tape, you must contact the manufacturer to find out which colours they have used.

The core is protected by a sheath made of 16 or more bundles of fibre that 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.




*Kernmantle rope*

A loose sheath gives a soft rope that 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' that has formed. If this tail is excessive (more than 50 cm 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 dirt penetration, but makes the rope stiff and hard to handle. Fortunately most ropes lie between these two extremes.

The sheath is also the part of the rope to which ascenders and to a lesser extent descenders are attached. An excessively thin or loose sheath is dangerous because it may prove inadequate in protecting the core and 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 things such 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 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.

Avoid pure polyester (Terylene) ropes due to their exceptionally low shock resistance. Polypropylene and polyethylene are **NOT** suitable for SRT ropes but are good for canals and pools where a cheap floating rope 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.

'Super-fibres' such as Kevlar and Dyneema/Spectra don't yet make the grade, tempting as a 5 mm, 14 g/m rope may be. Their low stretch makes them dangerous under shock loads. Kevlar work-hardens and the sheath is so thin it can easily cut and slide down the core. Dyneema/Spectra has similar strength and stretch to Kevlar and also shares Kevlar's non-existent shock absorption. It does however have exceptional abrasion resistance, a sheath you could prusik on and doesn't suffer from work hardening as does Kevlar, is very slippery, but would melt on a hot descender.

## Properties

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

## CE certification

A, B & L classifications

CE certification covers just about everything you buy in Europe, especially when it comes to safety equipment. Without going into details, "If it's CE approved, it's safe to use" is a good way to look at any equipment. One effect of this is that there are two main classifications for CE 'semi-static' ropes. Type A is based on a 100 kg load, while type B is based on an 80 kg load. Type L is a special lightweight category specified by the French Speleological Federation (FFS). Type A is most suited to use by commercial riggers and heavy use/fixed rigging and rescue. Type B suits lightweight sports caving and expeditions, and type L is for experts only. 'Static' ropes now bounce more than they used to in order to absorb the higher loads. 80 kg is still a good practical load for caving rope testing.

**Table 2:1** **Summary of standard EN 1891**

| Type | A | B |
|---|---|---|
| Diameter | 9 to 16 mm | 9 to 16 mm |
| Static resistance | 2200 kg minimum | 1800 kg minimum |
| Static resistance with fig-8 knot | 1500 kg 3 minutes | 1200 kg 3 minutes |
| Number of falls | 5 falls factor 1 (100 kg) | 5 falls factor 1 (80 kg) |
| Impact force (Factor 0,3) | < 600 daN (~600 kg) | < 600 daN (~600 kg) |
| Extension between 50 & 150kg | <5% | <5% |
| Sheath slippage | 20 - 50 mm (Diam. Dependent) | 15 mm maximum (0.66%) |
| Shrinkage in water | No limit | No limit |
| From Beal website (www.bealplanet.com) | | |

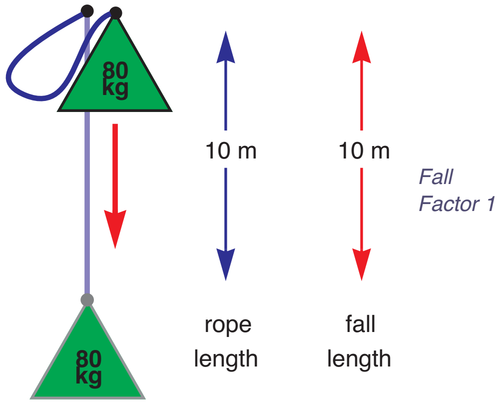
EN 1891 is a CE standard and doesn't apply outside Europe. Non-european rope may or may not comply with a similar standard. This in no way means that such ropes are inadequate or unsafe, just that it may be difficult to know exactly what you're buying.

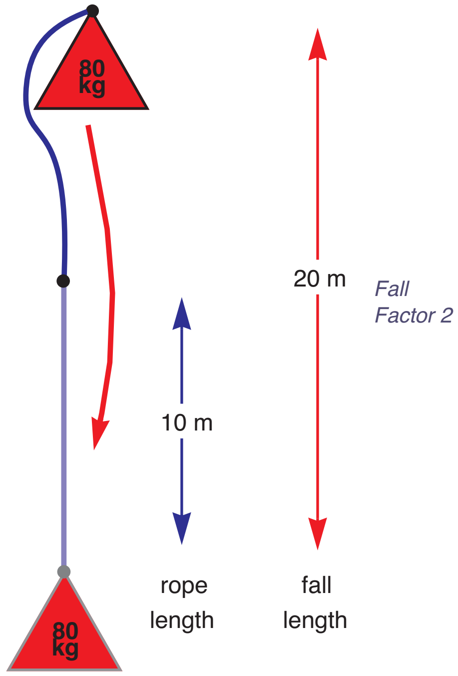
## Strength

The quoted "strength" of a rope is its Ultimate Tensile 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 little to do with the way a rope is loaded in a cave. A rope's strength is of 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 allows for the strength losses caused by knots, wetting and poor rigging and still leaves the rope with an adequate margin of safety, **provided** it also has sufficient shock resistance.

## Shock resistance




The most practical way of assessing a rope's strength is to subject it to a drop test. 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 100 kg weight for CE type A and 80 kg for CE type B. The Fall Factor is the ratio between the length of fall and length of rope, eg. If an 80 kg caver is tied onto 10 m 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. In caving, the rigging and how you use it should only ever risk a maximum FF 0.3 fall so FF1 test provide a good margin.

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 that 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 that effectively reduces the severity of falls under 1.5 m.

An 80 kg weight is a standard so that ropes can be compared, heavier weights cause more severe shocks in drop tests.

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 falls. ie. The first drop may generate a load that is 50% of the rope's breaking strength. The second 80%, the third 100% —until it breaks without an appreciable loss of 'strength'.

The shock resistance of a rope—its ability to survive falls—is largely a factor of its stretch, or more precisely its 'elongation under load'. As a rope catches a fall it stretches and absorbs the energy released by the fall. Greater stretch means more energy absorbed over a greater distance and less load applied to the anchor, rope and falling caver. People too have a limit as to how much force they can withstand. The absolute maximum for human shock resistance is 1200 kg for a fit individual in full-body harness. Anything over 600 kg may well injure you. That is, the rope must arrest a falling climber without the load ever reaching anywhere near 1200 kg. Caving falls of < FF1 are unlikely to generate this amount of force. However, the static properties of caving rope mean that the 1200 kg limit and possibly the breaking strength of the rope would be exceeded by a FF2 fall—the CE standard for climbing ropes. Indeed many caving ropes would not even survive a load of 1200 kg when tested under cave conditions!

**A new caving rope must be able to survive two or more FF1 falls**

Contents Index

The lack of shock resistance of caving ropes could well persuade you to use the strongest rope available but a very strong rope is not necessarily safe unless it can absorb FF1 falls without exceeding the 1200 kg limit.

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 (see page 57).

Take a worst case of two bolts rigged 15 cm apart at the same level with a 1 m stand-in loop between them —yes, they do exist! If the critical bolt fails when you are connected directly to it or perhaps just below it you 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 what is more important, your body and harness will absorb around 30% of the energy. There will also be some pendulum effect and no doubt you will fall outwards or crash into the wall and so absorb even more energy. Perhaps you 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 correctly with no more than 30 cm of rope between them and taking into account the mitigating factors would be unlikely to take a FF0.3 fall. This gives a good safety margin considering that FF0.3 is the maximum expected for well rigged ropes.

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 old design polyester ropes that have extremely low shock resistance compared with nylon ropes.

## Stretch

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

Insufficient stretch (less than 2%) is marvelous for prusiking, makes rigging easier, reduces abrasion problems caused by sawing but could make the rope dangerous if subjected to a shock load. A lack of stretch means a greater force will be generated in the event of a fall. For example—some polyester ropes 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 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 on page 27).

## Diameter and weight

The diameter of a rope will affect most of its other properties. Caving ropes range from 7 mm to 11.5 mm in diameter and those over 8 mm are all safe

**when rigged appropriately.**

When choosing a rope, consider the manner in which you will rig it, the weight of the rope and the space available to carry it. If weight and volume are no problem a thick rope is better; it will last longer and will 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 you cannot ignore the weight advantages of 8 mm or 9 mm ropes.

**Table 2:2** **Rope diameter and rigging style#**

| Rope (mm) | Rigging Style | | | | |
|---|---|---|---|---|---|
| | IRT | Alpine | Ultralight | Cord Technique | Climbing* |
| 11 | ideal | fixed rigging | too heavy | too heavy | ideal |
| 10 | marginal | general | too heavy | too heavy | CAUTION |
| 9 | DANGER | sport/ exploration | heavy | adequate | CAUTION |
| 8 | NO! | sport/ push rope | ideal | ideal | DANGER |
| 7 | NO! | NO! | Expert Alpine cavers only | | NO! |

* Dynamic rope only, 9 mm or thinner ropes must be used double
\# Rigging styles are discussed in Chapter 4.

Some cavers have taken the obvious weight reducing step and use 7 mm rope. To my knowledge no rope under 8 mm satisfies the minimum 1500 kg breaking strength requirement. However, if you find one sufficiently elastic to survive two or more FF1 falls, by all means use it **with extreme care**.

With thin rope there is no choice when rigging, it must be perfect Alpine style. Thin rope wears out more rapidly than thick rope and cost more in the long run because of its shorter life-span (see Table 2:4 on page 27).

## 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.

*In Mexico they call rope* "cable"*...*

Any rope will stiffen with use and lack of cleaning, and obviously a rope that is stiff when new will have a head start. A rope that 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/cost of the rope rather than one of safety.

When correctly rigged, Alpine style causes no immediate abrasion problem. IRT uses a thick rope that 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 and just plain accidents.

*"After prusiking some distance, the rope lost its bounce as if I was approaching a rebelay. I looked up to see if I could see it with my light. What I saw baffled me. Instead of the rebelay with the compulsory loop of rope to the side I saw the rope move quickly up and down on the wall, caught on a spike. I could see in the dimness that there were furry bits sticking out from the rope.*

*I stopped moving and braced my legs against the wall to try and get a better look. This enabled me to stand up straighter and I saw the rope come to a stop in its see sawing against the wall and it went 'twang'. I swung in a pendulum further to the left...*

*...Centimetres from my lead ascender, the 8 mm rope was shredded at one point to four very skinny threads, two of them rubbed and the sheath broken and completely in ribbons."*—Carol Layton in *Caves Australia* 170.

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 inevitably 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.

Some manufacturers have improved their rope's resistance to abrasion by increasing the tightness of the rope sheath and 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 you can do is to buy ropes 15% longer than the length needed and to make allowance when you rig 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 nylon rope is about 35% heavier than its dry counterpart and takes some days to dry out completely. 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.

**Table 2:3** **Rope strength when wet***

| 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 on 9 mm Bluewater II

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

### 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 energy to melt the entire rope. When abseiling fast on dry ropes it is possible to superficially glaze the rope sheath. Petzl Stops are very prone to this because the stainless steel lower pulley heats up very quickly. Fortunately, it also cools very quickly! Provided you don't remain in one spot with a hot descender this does little structural damage to the rope.

### Chemical deterioration

Nylon is a polyamide polymer. That is, it is made of long chains of molecules with the chains linked to each other less strongly. With time, these polymers slowly disintegrate to form simpler structures. Chlorine has adverse chemical effects on many polymers so never allow chlorine bleaches and washing powders that contain it to touch your ropes. Many substances commonly found in garages and car boots have 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, avoid drying ropes in direct sunlight, leaving entrance pitches permanently rigged, and always store ropes in the dark.

### Mechanical 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 its nylon.

Kevlar however, can lose 75% of its original strength after 100 descents! 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 twenty FF0.1 falls? Perhaps an avenue for investigation, in the meantime, cave gently.

### Dirt absorption

Dirt in the form of mud and tiny crystals slowly makes it's way into ropes, but exactly how far it gets and what harm it does is highly variable. Cut open an old rope, even a dirty one, and the core is usually quite clean. The sheath is a very effective filter. A lot of dirt in the sheath makes the rope stiff and unpleasant to handle. It probably also cuts some of the rope fibres and weakens the rope, but contributes more to wearing it out faster than it should rather than making it unsafe. The core rarely gets enough dirt in it to cause any real problem.

### 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. Take the pessimistic view and assume that within a year your rope will be only half as strong as when it was made. This may even have occurred by the time you buy it. It is interesting that while absolute strength deteriorates with age and/or use the percentage effect of knots and wetting diminishes with age. ie An old rope is almost as strong wet as it is dry, whereas the same rope when new is considerably weakened by wetting (see Table 2:3 and Table 2:4).

**Table 2:4** **Rope strength with age***

| 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 on dry 9 mm Bluewater II

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. Table 2:3 and Table 2:4

show how age and water can affect a rope, and these are an unavoidable part of using the rope in a cave. Even to perform the tests the rope strength had been reduced considerably by tying knots in each end of the rope.

**Table 2:5** **New rope comparison**

| Diameter | Av. Weight (g/m) Dry | Wet | 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 you must exercise much greater care when selecting and using 'thin' ropes instead of 'thick' ropes.

Strength loss is possibly connected with changes in other characteristics such as loss of handling properties and flexibility. Fibres don't move past each other as easily as when a rope is new and friction increases. Treat old stock as used rope and not as good as 'this year's model'. Treat rope left in a cave for long periods with extreme caution. Who knows how many falls it has taken or how much dirt is grinding around inside it. Relegate old ropes to the junk heap.

## Coatings and treatments

Many attempts have been made to improve handling properties and reduce water absorption using pre-treatment processes. 'Dry' sheath treatments have little effect on water absorption although the improvement in handling is noticeable. Dry 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. The major advantage is that 'dry' treatments involve a certain amount of pre-shrinking, thus reducing long term rope shrinkage to around 5%.

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 SRT rope

As you can see, rope properties interrelate and often conflict with each other. The perfect rope that 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. The CE standard for caving rope is at least a start, even if it isn't *really* designed for caving ropes.

Choose a caving rope to suit your pocket and rigging style so long as it fits the following set of minimum requirements:

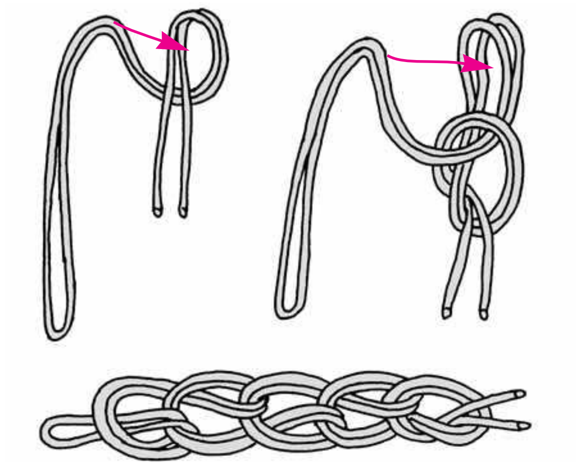
- Kernmantle construction
- Static strength in excess of 1500 kg
- Shock resistance of two or more FF1 falls
- Stretch of 1.5% to 4% with an 80 kg load
- Diameter of 7 mm to 11 mm
- Melting point in excess of 200° C

These are **minimum** requirements for a new rope and in most cases you will require more than minimum performance, 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.

## Care of ropes – new ropes

Wash or soak a new rope in water with a little detergent. This will remove the manufacturing lubricants and 'slow the rope down' so that you don't scare yourself silly on the first descent. Washing also shrinks the rope, increasing its abrasion resistance, and if you wash a rope before you use it, dirt is not trapped inside as it shrinks. If you intend to cut the rope to set lengths, make allowance for shrinkage.

## Washing ropes



*Chaining a rope*

Washing increases the rope life and helps keep it flexible and pleasant to handle. 'Chain' the rope and wash it in the biggest washing machine you can find using non-chlorine detergent and fabric softener in the rinse. Failing this, try scrubbing brushes or 'Scotchbrites' in the creek. Even a simple rinse is better than nothing. After washing, dry ropes out of direct sunlight and store them in a dark place. If drying is not possible, wet storage causes no damage to the nylon.

## Length markings


*Rope length mark*

You can use codes of bars and stripes to mark rope length but it is better to use a band of pale electrical tape on the rope end and mark the length with a waterproof marking pen then cover it with clear heat-shrink plastic. For simplicity you only need to write the rope length, although clubs may find that the year of purchase and some positive identification markings are also useful. Distinguish rope within a group by having each person mark their rope with identifying colours.

## Rope pension plan

A well cared-for rope will appear to last for many years but the invisible loss of shock resistance could render it unsafe. Ideally two metres off the end of any rope over 5 years old should be shock tested with a FF1 test every two years and should survive **at least** one 80 kg 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 impossibly stiff, or has suffered a severe shock load.

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 that causes the rope to lose its normal flex requires cutting as does any section that becomes unusually hard, soft or lumpy.

## Cords

Use light accessory cord of 5 mm to 7 mm in much the same way as tape. It is cheaper than tape and adequate for most deviations.

Dyneema is a relatively new fibre made by Beal specially for caving. It comes in 5 mm white only and breaks at 1800 kg **static** load. It has exceptionally low stretch, so exceptionally low shock absorbance. It is excellent for natural anchors where once you may have used tape and risked it wearing through. Due to its poor shock absorbance it must be used so that it can never have a shock applied to it. Rig dyneema so that it is always under tension—Y belays for instance. Be especially careful rigging traverses and backup anchors with Dyneema.

For more critical uses such as belays, Dyneema is ideal. If you use light cord, use it double or triple to give adequate strength and abrasion resistance. Tie each loop separately so that if one thickness fails, the other one or two remain intact.

**Table 2:6 Cords**

| 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 slings when doubled, footloop cords. |
| 5.5 Kevlar | 22 | 2000 | Footloop cords, slings on climbing gear. Don’t use where shock absorbency is needed. |
| 5 Dyneema | 14 | 1800 | Footloop cords, slings on climbing gear, slings. Don’t use where shock absorbency is needed. |
| 5 | 15 | 500 | Deviations, pack closures. |
| 3 | 4 | 200 | Cord Technique, pack closures. |
| 2 | 2 | 100 | Cord Technique. |

Average values from manufacturers and suppliers catalogues

**Table 2:7 Tapes**

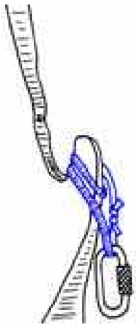
| Tape Width (mm) | Dry Weight (g/m) | Strength (kg) | Use |
|---|---|---|---|
| 50 | 50 | 2000 | Seat harness, chest harness. |
| 26 | 40 | 1500 | Rigging, deviations, light seat harness. |
| 20 | 30 | 1050 | Light rigging, footloops, chest harness |
| 15 | 20 | 780 | Deviations, chest harness |

Average values from manufacturers and suppliers catalogues

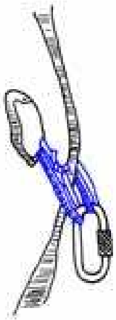
## Tapes

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. Take care with worn tape, while it is strong enough when new, it 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 never use tape under 25 mm wide in critical positions where it could be shock loaded (eg. belays, harnesses). Eight or 9 mm cord or the rope you are rigging pitches with usually makes safer slings than tape as you can easily see any sheath damage.

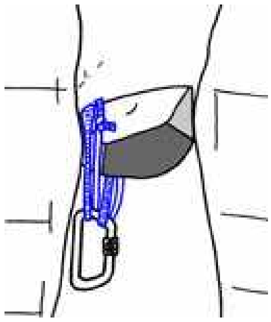
## Anchors – natural



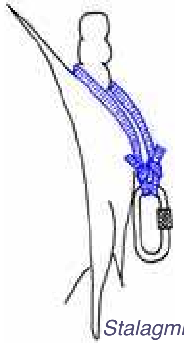
*Bollard*



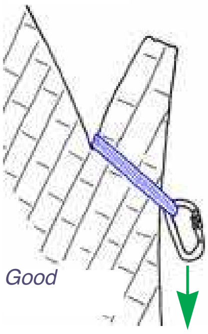
*Thread*



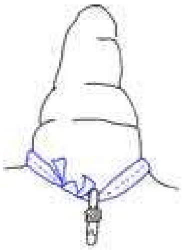
*Chockstone*



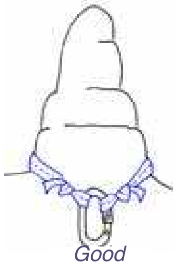
*Stalagmite*



*Good*

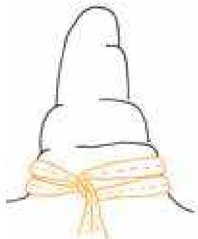


*Good*

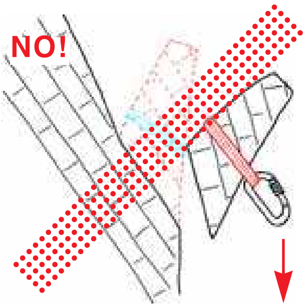


*Good*

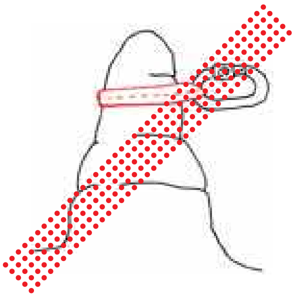
*Poor-too tight*



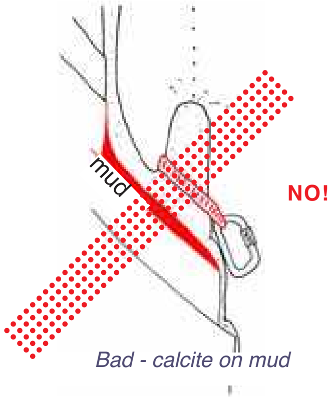
*Poor-Girth hitch can overload tape*




*Be careful of bedding or fracture planes*



*Bad - Too high*



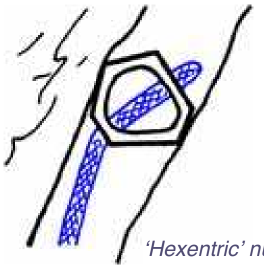

*Bad - calcite on mud*

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

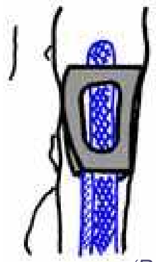
At many entrances, trees make obvious anchors and you require nothing more than common sense to choose one that is suitably tough and well anchored. If you can find a good natural anchor use it in preference to an artificial anchor as its use will cause minimal damage to the cave.

Naturals are not always as strong as they look—stalagmites can provide tempting and often adequate anchors but use them with care—their regular crystalline structure renders them surprisingly easy to snap. Always tie stalagmites 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. You can occasionally see fractures as thin lines in clean rock or infer them 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 you need it.

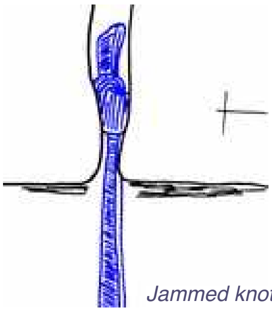
## Nuts



'Hexentric' nut



'Roc' (wedge) nut



Jammed knot

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 take care that they can't be lifted out sideways by a passing caver. Often a knotted tape or rope can work as well or better than a real nut. Tie a large or small knot to suit the size required and the soft nylon will often bite better than aluminium. A nylon 'nut' is not as durable as the genuine article and they are best reserved for one-off exploration use or low load applications like deviations.

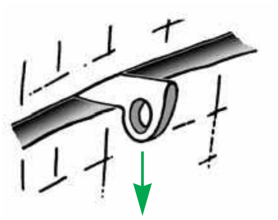
Nut placement takes some practise before it can be done safely. Always try to find a 'bombproof' placement in good rock. The wedging force exerted by a nut can be many times the load on the nut and can remove flakes and loosen jammed blocks.

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.

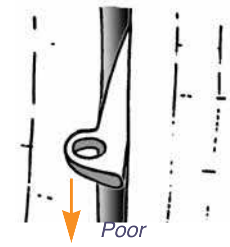
'Friends' and similar devices work well in caves but they are bulky and expensive, and the damp and dirt of caves damages them easily.

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

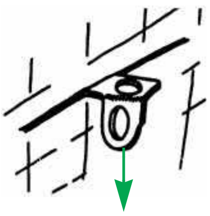
## Pitons



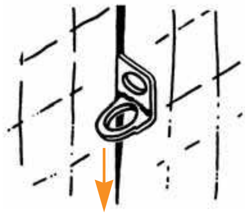
*Good*



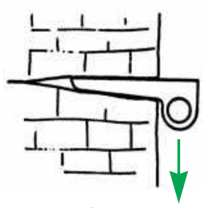
*Poor*



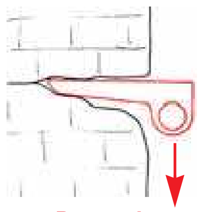
*Good*



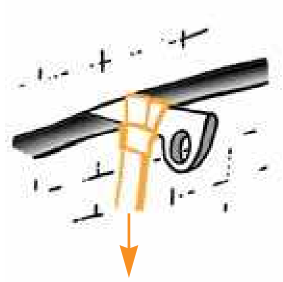
*Poor*



*Good*



**Danger!**



*Hero loop on a long piton*

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'. Pitons may be used to good effect in thinly bedded, soft or otherwise poor rock where other artificial anchors are often useless.

The security of pitons is often doubtful and even when you do find an ideal location the constant flexing caused by prusiking cavers can work them loose. Their main value comes as a fast anchor for prospecting or first descents, as easy back-up anchors (where they are not normally loaded and will not work loose) and most notably for deviations where the loads can be kept low and the consequences of failure not too severe.

Place pitons carefully. The ideal placement is one where the piton is loaded at 90° to the crack in which it is placed. eg. A horizontal crack for a downward load, a vertical crack for sideways load. Give thought to the load changing direction so that a securely placed piton does not suddenly become loaded badly if another anchor fails or as a caver passes it.

Fit the piton 1/2 to 2/3 of the way into the crack by hand then hammer it home firmly. If the eye hits before the piton is firm exchange it for a thicker version. Should the ringing sound of a piton you are hammering suddenly become dull the rock has probably fractured and you will need to try another placement.

Should the tip of a piton hit the bottom of a blind crack—a common case with solution widened joints—replace it with a thicker one. The piton should grip over its entire length or at worst its outer edge. One that grips only at its tip is prone to levering out or snapping. Tie off pitons that stick out too far from the rock with a 'hero loop', a short sling tied around the shaft to reduce leverage, rather than the piton eye.

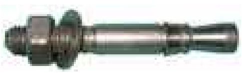
Once you've placed it, tap the head of the piton with a light sideways blow to check its security. Remove pitons by hitting them from side to side until they work loose.

## Bolts

*Self drill 'Spit'*

*Stainless 'Spit' (not self-drilling)*

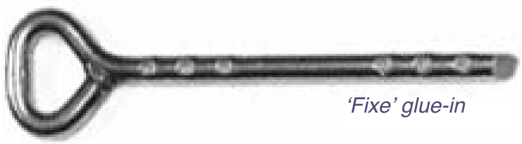
*Sleeve 'Dynabolt'*



*'Raumer' Collar stud*

*'Raumer' Collar stud—double expansion*

*'Starfix'*



*'Fixe' glue-in*

*'Fixe D' glue-in*

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

Bolts give you the ability to place an anchor virtually wherever you want it. Bolts are different from other anchors in that you don't remove them from the cave after use. Whenever you place a bolt the cave is permanently damaged by you drilling a hole and smoothing an area of rock around it. For this reason alone, always place bolts with discretion.

The international standard for cave exploration is 8 mm self-drilling anchors. Anything else may be of little use to the next person and should not be placed unless long life or large diameter permanent bolts with hangers or eyebolts are used (See Fixed rigging on page 88). The exception is in the USA where imperial measurement is still standard and 3/8 inch (or very rarely 1/4 inch for artificial climbing) collar studs (parabolts) are popular. If you intend to visit an area where the bolt sizes are in doubt, check first.

Expansion stud anchors have several advantages over self-drilling anchors:

- Studs require a smaller hole than an equivalent sized self-drilling anchor—an 8 mm spit requires a 12 mm hole; an 8 mm collar stud requires an 8 mm hole; an 8 mm sleeve stud requires a 10 mm hole.
- Hole depth is not critical, it must be of the correct depth or deeper. 5 mm to 10 mm overdrilled allows for dressing of the rock surface if necessary. A little deeper than the length of the stud allows you to tap the entire anchor below the rock surface once the bolt is no longer needed—useful for climbs although it would require a new line of bolts to repeat the climb. The 'Starfix' is an exception. The hole must be the correct depth so that the anchor's eye just becomes flush with the rock as the wedge fully expands and is not a good option.
- Studs are available in long lasting, low corrosion materials such as stainless steel.
- 8 mm studs are compatible with standard bolt hangers.
- Sleeve studs may be removable if you can extract the sleeve with pliers, and therefore replaceable if damaged.
- Long sleeve studs are probably the best expansion bolts for very soft rock, but are not as good as glue-in bolts.
- 'Double expansion' studs are available for softer rock, although double collars may not help.
- Studs expand by tightening the nut rather than being hammered against the bottom of the drill hole. They will 'set' in very bad rock—although they will not necessarily hold.
- Dirty studs are easier to clean.
- Normal hangers are usable by removing the hanger's captive bolt.

Studs also have disadvantages:

- Collar studs are fine for the occasional, but high loads of rockclimbing, but for the cyclic loads of prusiking they fail relative quickly because of the bending fatigue on the thread. CNS CAF, 2001. Sleeve studs may also suffer the same problem.
- Collar studs don't expand much and are only safe in hard rock.

- In anything but hard rock, the wedge on a collar stud can pull right through the collar, or the entire stud can just pull out. They often slowly eat their way to the surface. If they require periodic tightening it's a sure sign that they're on their way out.
- Holes for studs are difficult to drill by hand, hence the need for a hammer drill. Petzl have attempted to solve this with the 'Rockpecker', a hand drill for SDS bits. Unfortunately, they require a sharp bit and can be slow.
- You must carry a power drill.
- Once your battery dies you can go no further.
- The stud hangs out of the rock and once abandoned is more visible than a spit (perhaps an advantage for finding the anchor), but it creates an eyesore unless the hole is overdrilled and the stud can be tapped below the rock surface.
- Nuts are easily lost in the cave environment and a supply of spare nuts is valuable when placing or using stud anchors.
- All threaded anchors wear out the threads with constant use.

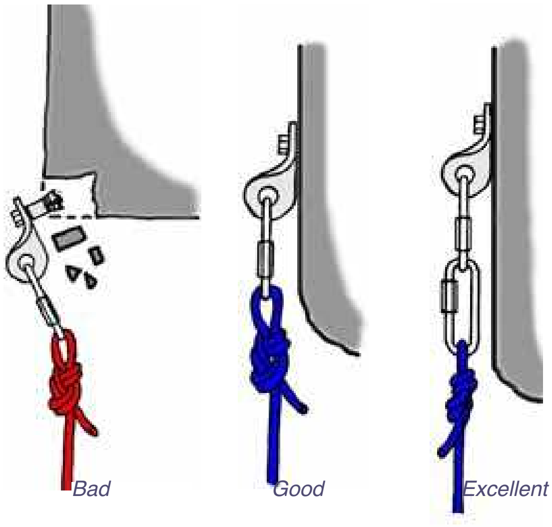
The only truly long lasting bolts are glue-in studs. They have a theoretical life of up to 200 years. They require a 12 mm dia. x 100 mm deep hole for a 10 mm stud, a lot of drilling and rock sculpting and a day or so for the glue to dry. Many UK caves have been rigged with 'P' or 'Eco' hangers much like the 'Fixe D' glue-in illustrated. An 8 mm stud requires a 14 mm hole, but have the advantage that you can replace a damaged one by drilling into the glue each side the stud, then twisting the stud out with a lever. Once you clean the hole out you can reuse it. Installation is slow and somewhat tedious. The hole must be dust and debris free and the glue mix must be correct (follow the instructions from someone like Hilti, not me!), and they're expensive. Their place is in popular caves and for fixed, heavy use rigging. See Fixed rigging on page 88.

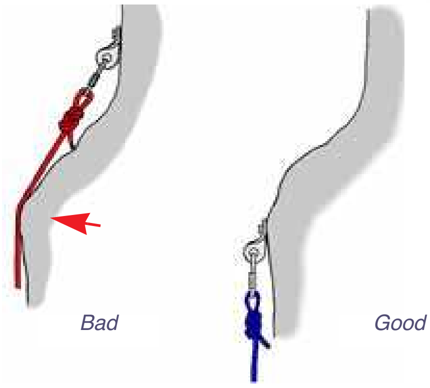
## Strength

A correctly placed spit in good rock will theoretically fail at or higher than 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 a different failure mechanism involved due to the brittle nature of the hi-tensile steel from which the bolt and anchor are made. Obviously, larger bolts are stronger. Nevertheless it is impossible to shock load a good bolt enough to break it—the rope or cowstail is the weak link. Expansion bolts, independent of type, tend to fail catastrophically. Glue-in anchors on the other hand fail slowly. They tend to become loose but remain strong long before they fall out. In practise, bolt anchors only fail in use when they are poorly placed or in bad rock.


Voronia, Abkhazia

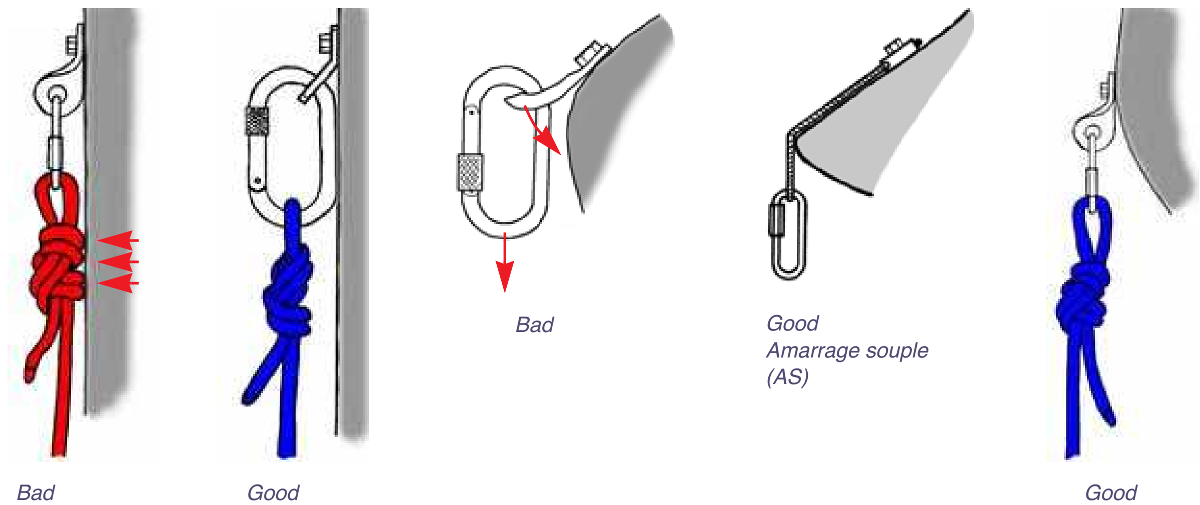
## Placement




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

*"Instead of delicately prusiking up the rope I was powering up at full speed to avoid a total soaking when the bolt burst out of the rock above me. I was dumped back onto the ledge under the waterfall as the rope pulled tight to Stefan who was almost at the top of the pitch."* — Australian Caver 120,(The bolt was in the top left 'Bad' category.)



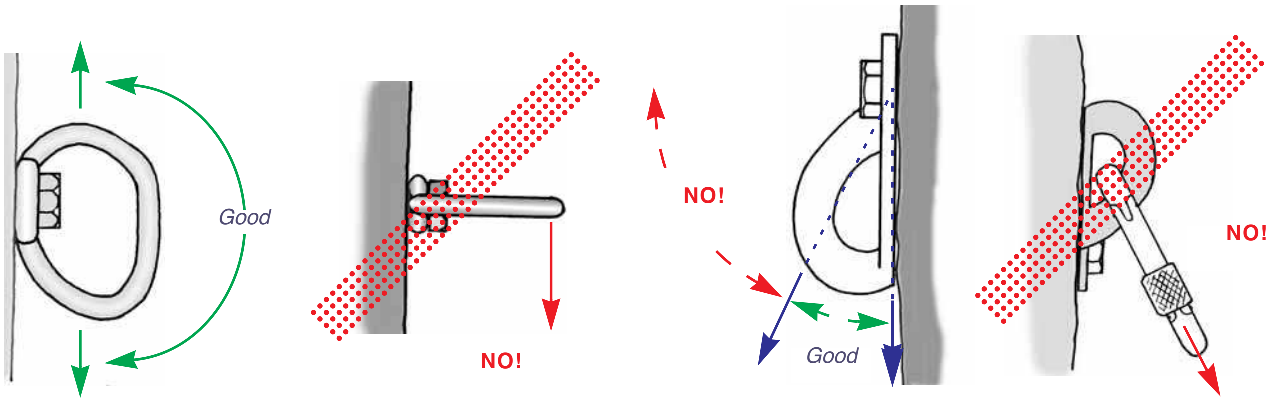
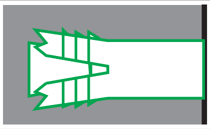
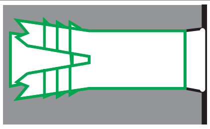
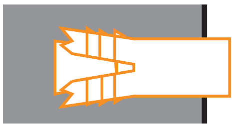
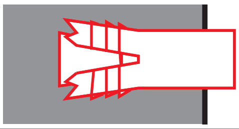
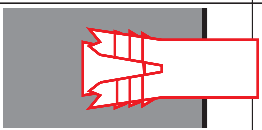
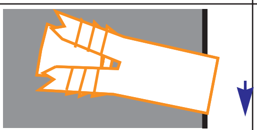
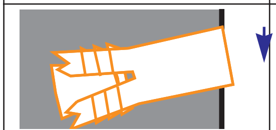
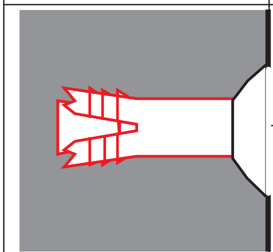
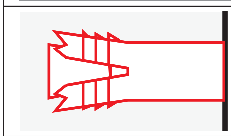
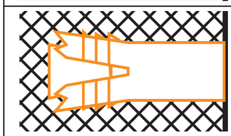



**Table 2:8** **Spit strengths - placement***

| 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 ideal placement in hard rock.
Less than 5 mm play between the hanger and rock has very little effect on the bolt or the anchor's static strength.

## Placing a Spit (self-drilling anchor)

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

*Smooth the surrounding rock*

*Wedge in, bolt ready to set*

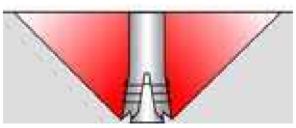
*Sideways pressure can cause the rock to crack*

*The finished product*

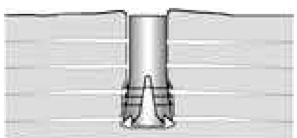
- Fully screw an anchor onto the driver, then begin the drillhole by tapping the driver lightly while rotating it clockwise until it begins to form a neat hole.
- Always keep the driver at 90° to the rock surface and be careful not to unscrew the anchor from the driver.
- Too much vigour in the early stages and sideways movement at any time may cause the hole to crater. Hard and brittle rock requires more care.
- Once you've started the hole - 4 mm to 5 mm will do - you can hit the driver 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 blow out all 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 you set the bolt, use the drill as a chisel or the pick of the hammer to gently sculpt the surrounding rock so that the hanger will sit well and deepen the hole if necessary.
- Make sure the hole and the drill are clear of debris, place the expansion cone into the end 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.
- Place a finger against the side of the driver but also touching the rock to let you feel the bolt as it moves inward. Over-hammering only risks fracturing the surrounding rock or the anchor itself.

Occasionally the driver will be stuck fast. You can remove it by tying a small sling to the driver with a Lark's Foot knot (see page 48). Put the pick of the hammer though the other end of the sling and wind it anti-clockwise around the driver until you can use the hammer 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 entire operation should take from 10 to 30 minutes, depending on the hardness of the rock, the awkwardness of the position and skill of the person bolting.



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



*Bolts in thinly bedded rock are always suspect*

Sumidero Matarocas, Chile

Cordless rotary hammers relieve much of the effort needed to place bolts by hand and replace it by the need to carry a heavy drill and battery through the cave. Depending on the cave this can be a huge time-saver or a false economy once you factor in the need to haul out and recharge the battery. Krubera- Voronia has been rigged largely with hand-driven spits simply to avoid the logistic problems. Considering the damage that bolts do to caves, the ability to place bolts relatively effortlessly has lead to an increase in their numbers and consequent damage to caves. A commensurate increase in safety will only result if the bolts are placed carefully.

Power drills also open us up to the vast array of industrial anchors available. Stud anchors allow you to drill a smaller diameter hole for the same sized bolt—an 8 mm or 10 mm hole instead of the 12 mm hole required for an 8 mm spit. Clearly this gives you more holes for your precious battery. Sleeve and collar bolts are the 'standard' here, but there are several other types also in use. So it can no longer be guaranteed that your hangers will fit the anchors in the cave. This is a very bad development for cave conservation and is leading to even worse bolt farms than before. **Make sure** that the bolt you put in will be usable by others that follow. If you remove your hanger, replace the nut, and try not to damage the stud that projects from the rock.

Placement of self-drilling anchors using a power drill is a similar procedure to hand drilling an anchor, with only minor modification:

- Use a good quality drill bit.
- Remove the drill from time to time to let the rock dust out. This allows the drill to run more freely and improves battery life.
- Drill the hole 3-5 mm short and finish the hole by hand. This is very fast because you're only flattening the bottom of the hole and not drilling much rock.
- The power drill hole has a conical bottom so the expansion cone will not be forced into the anchor far enough to set it adequately.
- Hole depth is critical, overdrilling may keep the anchor from setting correctly.

Collar and sleeve studs are very easy to place.

- Drill the correct diameter hole to the stud length or a little longer.
  Collar studs can usually tolerate a shallow hole, sleeve studs usually can't.
- Insert the stud with hanger already threaded.
- Crank it tight in the usual manner—until you feel resistance plus a 1/4 turn.
- If it just keeps tightening the rock is too soft. There's no point pulling the expansion wedge all the way to the surface. Either use it carefully, or put in another one.

Self-drilling anchors are popular because they are the lightest and most reliable method of placing bolts in caves. They are, however, not as durable as you may hope. (See Fixed rigging on page 88 & Conservation on page 154). If you use a power drill, your options are greater and you can choose the most suitable bolts for the job at hand, but in the end, you'll have to consider such things as speed of rigging, durability of the anchor, the amount of traffic the cave will take, price, availability, compatibility with other bolts in the cave and the hardness of the rock.

## Bolt hangers

*Plate hangers*
*Top row: karabiner hangs at 90˚ to the rock*
*Bottom row: karabiner hangs parallel to the rock*

A hanger is the usual means of attaching a rope to a bolt. 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 bolt used is an 8 mm diameter, 16 mm long, 8.8 (hi-tensile) metric set screw with a 13 mm hexagonal head. Use stainless steel screws and hangers if the hanger will be left for some time, especially in wet conditions. Allen headed bolts are useful for anti-theft applications. 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 some bent hangers specifically require an oval karabiner—the old Petzl (top centre, for example). Hangers that hang the karabiner parallel to the rock may cause the knot or loop of the rope to rub against the rock. Considerable effort has been put into designing hangers that hold the rope directly. No one has yet invented one that 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 Y belays direct attachment hangers can work well and save some weight.

*Direct attachment hangers*
*CAT AS old 'AS' hero loop rings*
*Clown*
*bolt and bent washer*

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 you've tied the rope to them. 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 the other hangers is that they are excellent for overhanging bolt placements where the rope is not hanging parallel to the rock.

The CAT (Cable Amarrage TSA) has now been completely and effectively superseded by the AS (Amarrage Souple). It is exactly the same as a CAT, but uses a length of Dyneema instead of steel cable. The Dyneema can be long or short depending on the application and is easy to tie to the rope. Take care though to never risk shock loading the Dyneema. A karabiner/maillon makes them much easier to pass on a rebelay, but you can use them without as well. They are excellent for poorly placed bolts where a plate hanger sits badly. The hero loop and bent washer are most useful when abandoning a climb.

Bolt hangers are generally overstrong, breaking at 1000 kg or better and instances of them failing are very rare. The only ones that may be suspect are those made of thin, brittle stainless steel or titanium, and permanently rigged aluminium ones due to corrosion. Simple hangers are easy to make in a small workshop, although you must be careful to find a suitable aluminium alloy. As a final check, test the hanger with a severe drop tested onto a low stretch rope. Five FF1 falls would be a minimum.

The interaction between the bolt (not the anchor) and the hanger deserves some consideration. If tightened too far, the bolt head could shear off when weighted but the risk of this happening is very low for 8 mm or larger bolts. There is however a real risk of shearing the head of an 8 mm hi-tensile bolt when you are tightening it. This risk is even greater with old, corroded and 'sticky' bolts. I have never heard of or experienced the problem with stainless bolts. Some cavers use a shortened spanner so that they can never apply enough torque to a bolt to overstress it. You can also just be careful. Tighten a bolt until it stops turning easily, then tighten it no more than an extra quarter turn. At the other extreme, you must get the hanger tight enough so that it will not work loose with sideways movements of the rope. At times you will find it impossible to tighten the bolt enough to keep it from being loosened. It is then preferable to use a direct attachment hanger such as an AS. Overhanging anchor placements may also cause plate hangers to load badly and try to lever the anchor out or overload the bolt head, especially if it is over-tightened. Again it is better to use a direct attachment or ring hanger.

## Rope to anchor links – maillon rapides

Apart from tying the rope directly, a maillon is the cheapest link for attaching a rope to an anchor. A 7 mm GO *(Grande Ouverture)* 'wide opening' maillon is the most suitable size. They open enough to take any rope, are of a big enough diameter so that the rope is not bent too severely through them and still allow space for a cowstail. 7 mm maillons are available in steel or, for twice the price, in aluminium. 7 mm aluminium maillons with twist hangers are easily the lightest, most versatile rope to hanger link available today. Maillons are also safe under three-way loads (unlike karabiners) and are suitable for linking the rope to traces and slings as well as to other anchors.

## 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 that are suitable for cave use and some manufacturers make a special speleo model that is oval to suit bent bolt hangers and has a mud resistant screw-gate.

Some karabiners distort so that if you lock the gate under load, it is difficult to undo once unloaded. The common result is that you are unable to remove your descender or a belay. You must reweight the karabiner in order to get it undone. Hang from the descender and loosen the karabiner gate and when derigging, loosen karabiner gates before unweighting them.

Even if you prefer maillons you'll need some non-locking karabiners for deviations and some locking karabiners for awkward belays. Strength and good handling are not especially important so the lightest, cheapest karabiners are fine. For rigging, karabiners have three major disadvantages—they are heavy, bulky and expensive.

**Table 2:9** **Karabiners and maillons**

| Type | Material | Weight (g) | Strength (kg) | Relative Cost | Use |
|---|---|---|---|---|---|
| Locking oval karabiner | aluminium | 60 | 1600 | 5 | General, some hangers |
| non-locking 'D' karabiner | aluminium | 60 | 2000 | 4 | Deviations, general |
| locking 'D' karabiner | aluminium | 60 | 2000 | 5 | General |
| mini krab | aluminium | 25 | 550 | 3 | Lightweight deviations |
| 7 mm GO maillon | steel | 60 | 2500 | 2 | General, fixed rigging |
| 7 mm GO maillon | aluminium | 20 | 1000 | 3 | Lightweight, general |
| 6 mm maillon | steel | 35 | 2000 | 1 | General, Cord Technique |
| 10 mm delta maillon | aluminium | 55 | 1750 | 7 | Seat maillon |
| 10 mm half-round maillon | aluminium | 55 | 2000 | 6 | Seat maillon |

Average values from manufacturers and suppliers catalogues

## Other equipment—rope protector

Wrap-around rope protector

When prospecting using alpine technique or for IRT it is usual for the rope to touch the rock. Use a rope protector or pad to reduce the chances of the rope being cut over a sharp edge or simply to reduce wear on the rope. In many cases an empty tackle bag is sufficient, if not, there are two alternatives worth considering. The best rope protector is about 15 cm wide with velcro along the edges so that you can close it to form a tube around the rope. A poor second is a flat pad about 30 cm wide by 50 cm long with a tie-on sling at the top. Both are ideally made of a double layer of heavy canvas fabric that unfortunately absorbs water and becomes even heavier when wet. Plasticised fabrics such as PVC cave pack fabric (as illustrated) are lighter and non-absorbent. Unfortunately the heating caused by the intense contact with moving rope melts them very quickly and they stop protecting (Long, Lyon & Lyon, 2001).

Protectors made of split garden hose or similar tubing are simply not worth having. Once they bend 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. If they do happen to stay in place they can cause more damage than the edge they are supposed to be protecting the rope from (Long, Lyon & Lyon, 2001). Nothing more than a heavy, bulky and potentially dangerous waste of time and effort.

## 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 has a 25 cm to 30 cm long handle.

## Wire trace

Traces are excellent for sharp natural belays that can eat into tape or rope very rapidly. Use traces with care as their lack of stretch makes them highly susceptible to shock failure. Take care also to not use traces unnecessarily, being much tougher than limestone they can leave ugly wire cuts in the rock. 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. Never use the C clips found on the ends of most ladder traces as they are not very strong.

Dyneema is better than stainless steel cable in almost all respects.

## Ladders

Wire ladder

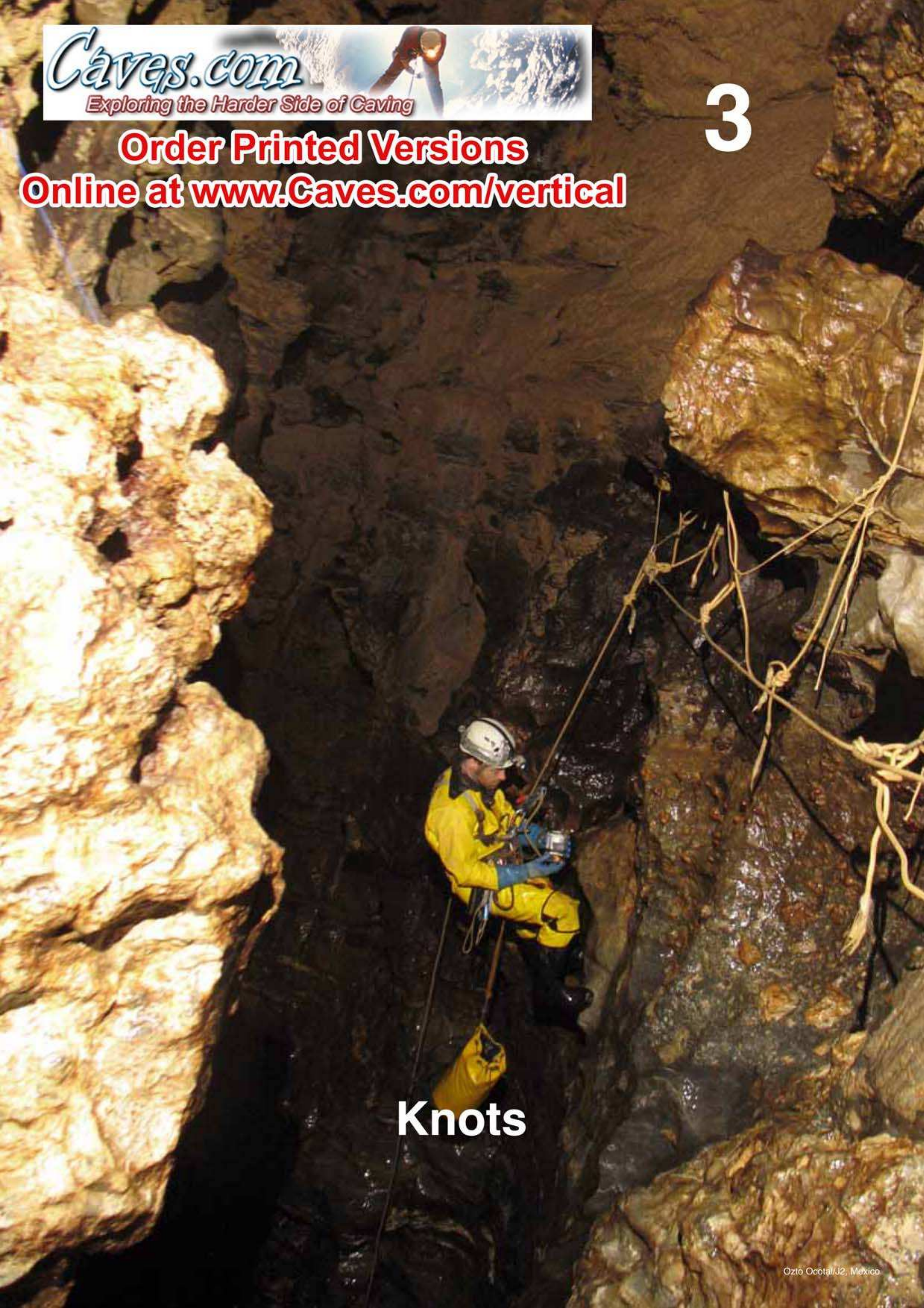
While generally out of fashion these days, ladders still have their uses. They are particularly good on isolated small pitches where it would otherwise be necessary to rig up your abseil/prusik gear. Ladders are often easier to use than ropes in vertical squeezes and in cases where there is a small up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

Most 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 parts suffer electrolysis between the cable and the rungs. This may be hard to detect but can cause catastrophic failure. Always treat ladders left in a cave for a long time with caution.

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 Single ascender/Self belays on page 128 and Belaying on page 88.

# 3

# Knots



Ozto Ocotal/J2, Mexico

A good knot has certain characteristics:

- Easy to tie
- Readily verified as correctly tied
- Secure once tied and no slip under load
- 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 that work best in as many situations as possible. This aids efficiency and safety as greater familiarity increases speed and reduces the probability of tying the knot incorrectly.

People generally assume 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 or at the minimum radius bend in the knot.

Nylon fibre fails when the stress concentration from pressure and tension on it is sufficiently high to soften it, in much the same way as you can melt snow into a snowball by squeezing it. The rope does not necessarily get much hotter, it softens at a lower temperature when under pressure. Inside the knot there is a combination of tension, pressure and higher temperature as the rope wraps around itself and the forces become 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 that has a maximum of 'active surface'; one that 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 you tie it 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. Once you have your knot tidy, pull it as tight as you can by hand so that it tightens up correctly when you fully load it.

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

## End loop knots

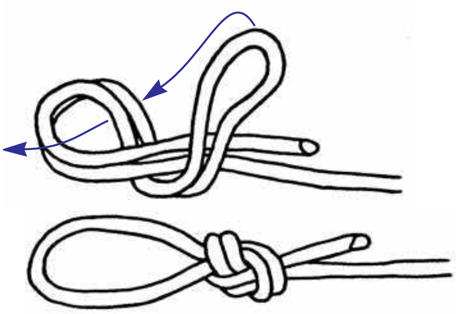


*Figure-8 loop, the most versatile and popular of loop knots*

If you had to learn just one knot for caving, that knot must be the Figure-8 in its various forms.

You need an end loop knot to attach one end of the rope to a belay. The most suitable knots are the **Figure-8** loop and the **Figure-9** loop for ropes of 9 mm or less because of its unequalled strength. You can use a Figure-9 for thick and/or stiff ropes but it will be difficult to tie and use a lot of rope. In either case, tie the loop then clip it to a maillon or karabiner, put the loop over a natural anchor, or tie a single knot, thread the rope end through and anchor, then thread the rope back through the knot.

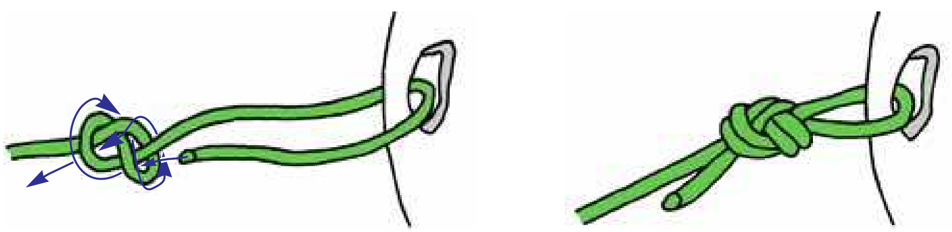
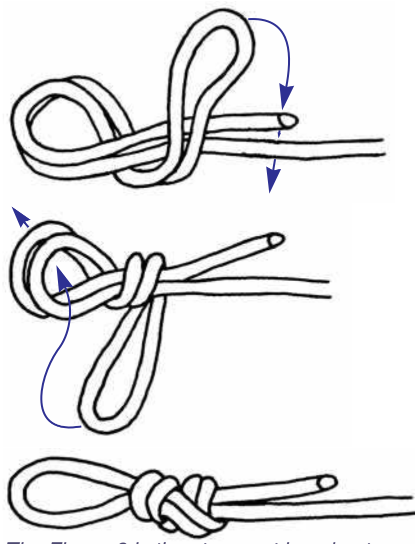
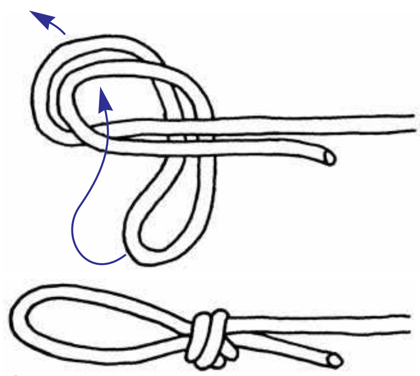


*Figure-8 threaded back on itself to tie through an eyehole*



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

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 easily when loaded wrongly. For these reasons alone, the Bowline is not recommended for any life support application. Anyone who still wishes to use a Bowline must 'lock' it with an extra Overhand knot or half a Double Fisherman's knot around the standing rope.



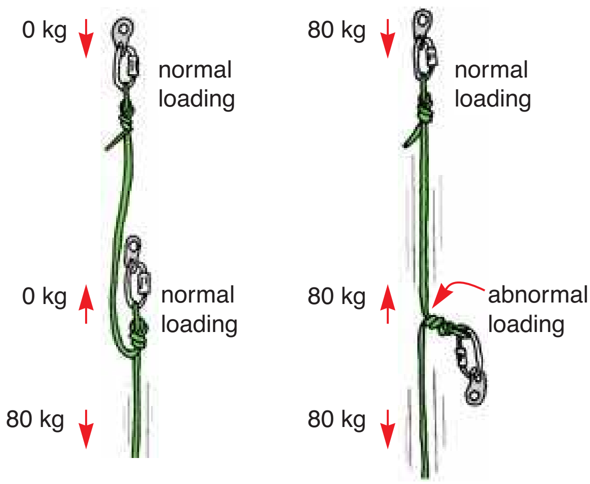
*Overhand loop knot, the simplest loop knot*

The simple **Overhand** loop has its uses. It is not so strong as the Figure-8 and Figure-9 loops, but is small and uses a minimum of rope. In very stiff rope it may be the only knot you can reasonably tie.

Tie all end of rope knots with ten or more centimetres of 'tail' hanging out of them so that as the knot tightens under load it does not come undone.

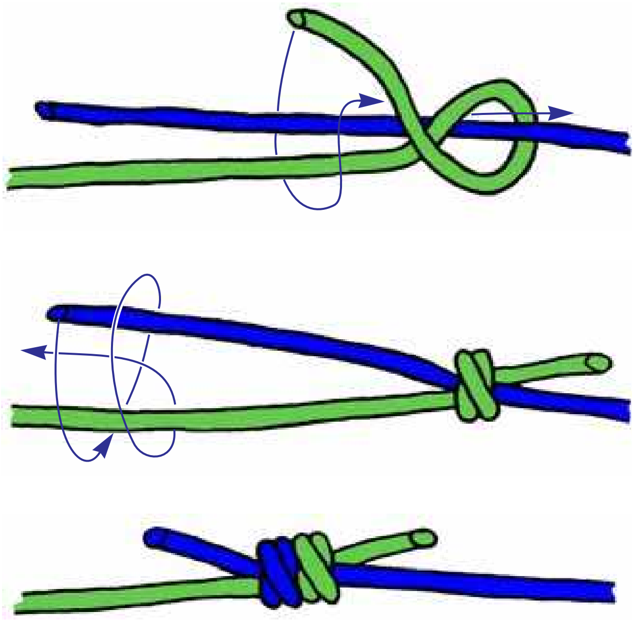
## Mid-rope knots

You will often need to tie a rope off somewhere along its length. Here the loading of the knot becomes more complicated. Take a rebelay for example. The knot acts as an end loop in normal use but if the belay fails the knot would be pulled apart (abnormal loading). The mid-rope loop must be good under these two distinct types of loading.

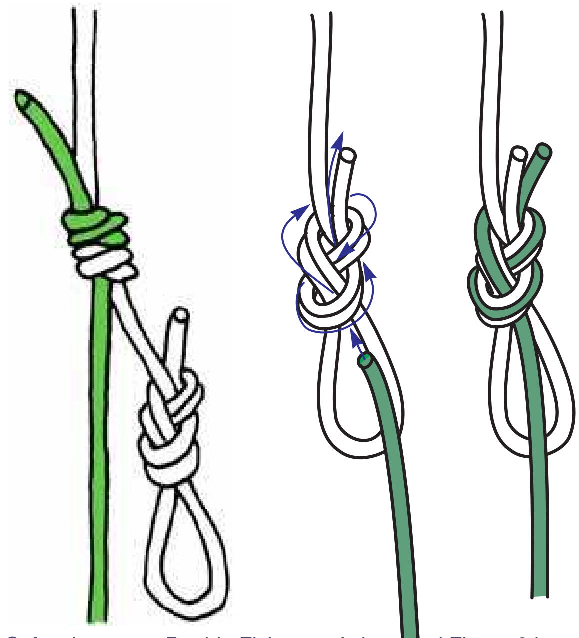



When the rope is rigged tight between anchors the Alpine Butterfly knot is popular because it looks right and uses very little rope. While the Alpine Butterfly performs well under abnormal loading, it is almost never loaded in this manner. Under normal loading it performs badly. Both the Alpine and standard 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 and Figure-8 knots still come out on top (see Table 3:1, Recommended rigging knots).

## Rope joining knots



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



Safety loop on a Double Fisherman's knot and Figure-8 knot

Two special considerations for rope joining knots are that they be short so that you can pass them easily and that they are relatively easy to untie after loading. Difficult to untie is a major problem with any rope joining knot.

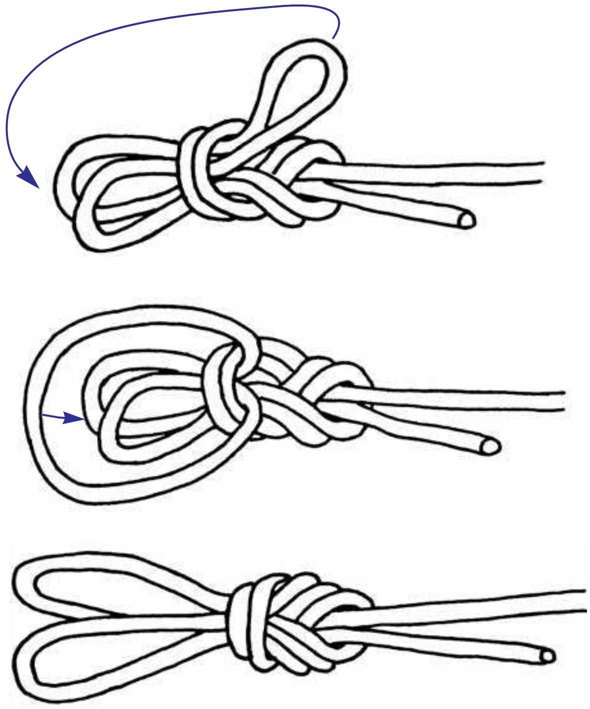
The **Double Fisherman's** knot is one of the best ways to tie ropes end to end. It is easy to tie, you can untie it and it works well on ropes of unequal diameters.

The other knot that you can use for joining ropes of equal diameters is the Figure-8, that some say is easier to untie than the Double Fisherman's. You could also use a Figure-9 in the same manner. It is more awkward to tie but has the advantage that it may be easier to untie after loading.

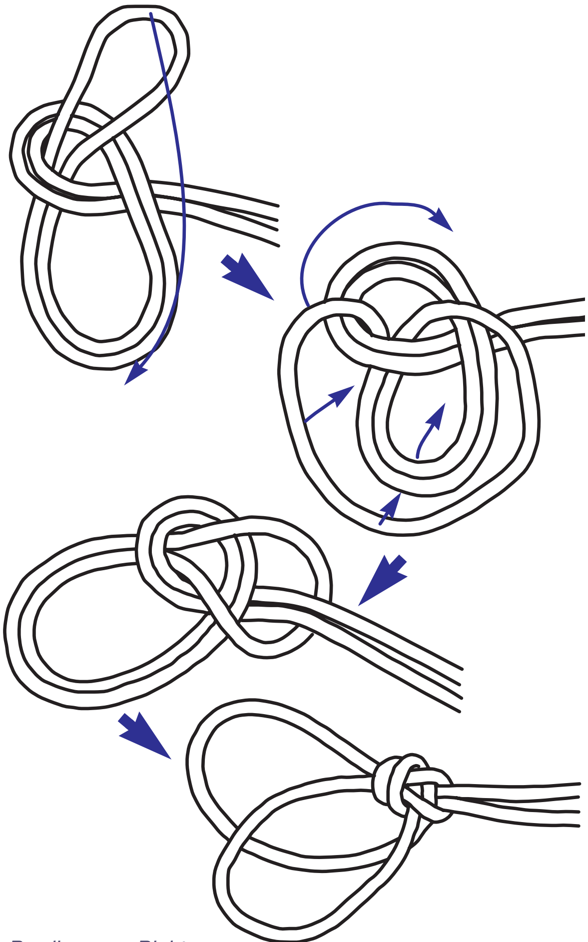
Whenever you join two ropes on a pitch you need a safety loop to clip your cowstail to when crossing the knot to avoid hanging on only one ascender. Tie a **Figure-8 loop** in the upper rope, then thread the lower rope back through it to make a rope join with a built-in safety loop. The resulting knot is bulky, but no longer than any other Figure-8 knot.

If you prefer a **Double Fisherman's**, hang a tail about a metre long out of the bottom of the knot so that you can put a **Figure-8 loop** in it. Be aware though, that the safety loop is never loaded unless someone falls on it, so will probably jiggle loose as the rope moves around.

## Other knots



Double Figure-8 knot

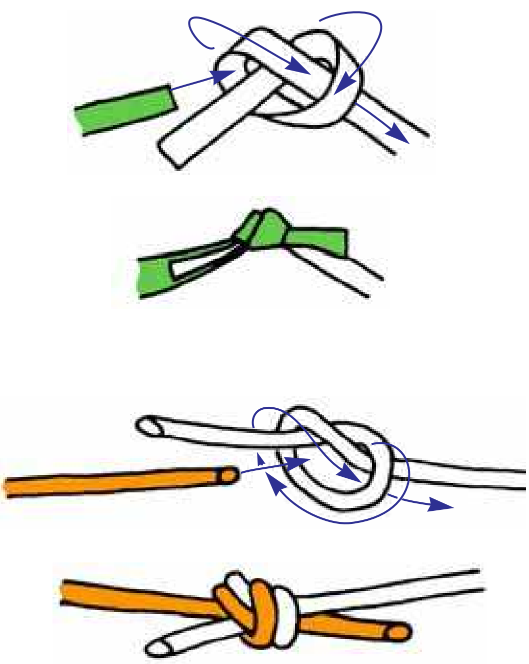


Bowline on a Bight

You can use the knots described so far to rig everything but there are a few other knots that are handy to know.

The **Double Figure-8** is good for Y belays and you can tie it as a mid or end loop knot. The two loops formed are easily adjustable and you can attach them to separate anchors, tie them to a ring hanger or use both on the same natural anchor to reduce the wear that would occur within a single loop. Use 'Double' loop knots with discretion. Should either loop be cut close to the knot—on a sharp natural belay for instance—there is the theoretical possibility that the cut end could slip back through the knot just like a short tail on any knot could do, and both loops fail. If only one loop is loaded it is perhaps possible for the other to slip back through the knot and the entire knot to undo. This is unlikely while the knot is loaded but could occur if the knot is loose when loaded and the loop is very short. Possible solutions are to clip something into each loop or if the anchor for one loop is 'weak', you can thread the 'strong' loop through it.

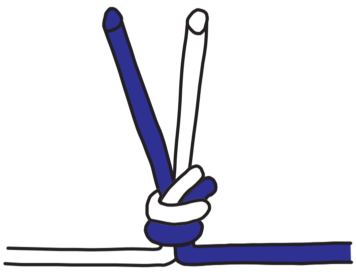
The **Bowline on a Bight** is a worthwhile alternative to the Double Figure-8. It is not as strong as the Double Figure-8, so like any Bowline, only use it on 10 mm or thicker ropes. It uses less rope, is easier to adjust and easier to tie—once you figure it out.



Tape knot (Round knot when tied in rope)

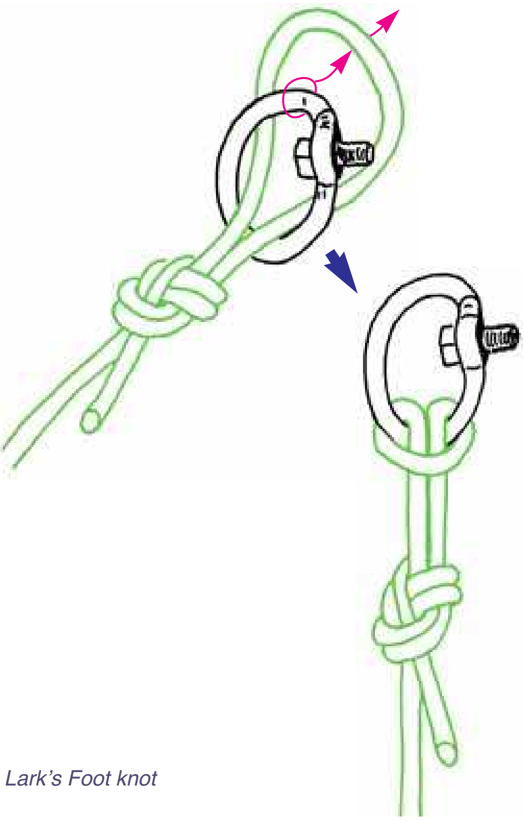
A **Tape** knot is **the** knot for tape. It is not very strong but other knots may not hold in tape. A **Round** knot is a tape knot tied in rope. It too is not very strong but makes a small neat knot that is most useful for the 'Cord technique'.

The **Overhand** knot is suitable for making an eye in the end of a tape, and as a stopper knot. It can also be useful for a rope-joining knot if you are pulling the rope down after you—a through trip for instance. An Overhand knot under abnormal load runs over edges very well as there is no knot-edge to catch on things. It is not especially strong, but this is not a problem if you're only descending on it and it's doubled. Use extra-long tails hanging out of the knot—30 cm or so, and as for any knot, pull the knot tight before you use it. Don't use a Figure-8 in the same way as the Figure-8 can invert and unroll its way off the end of the rope at low load.



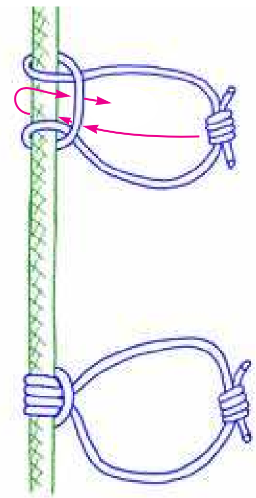
Overhand knot as rope-joining rock

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

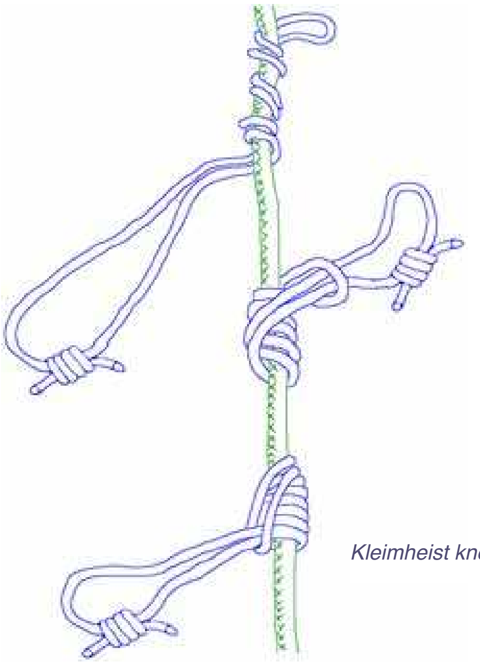


Lark's Foot knot

The **Prusik** and **Kleimheist** knots are two of a family of knots designed to slide along a rope when the body of the knot is held but grip when loaded through its sling. For many years it was the only means available for *prusiking* up a rope. Today they have been almost completely replaced by mechanical ascenders. However, They are still useful in emergency situations for replacing a damaged or lost ascender or for temporarily tying off a rope. Try to use cord that is 2 mm or more 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 you can use tape with less success. The knot illustrated is a Four Layer Prusik knot. An extra wraps on either knot can be used to give more grip if needed (see also No ascenders on page 135).

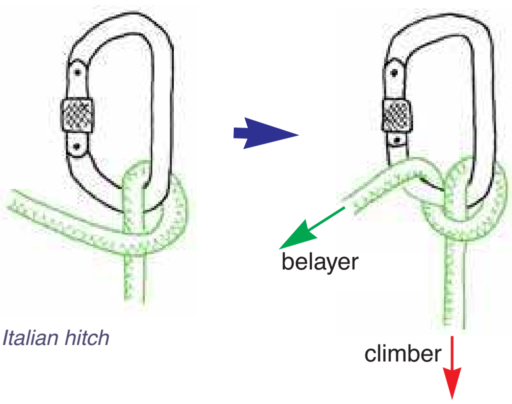


*Prusik knot*

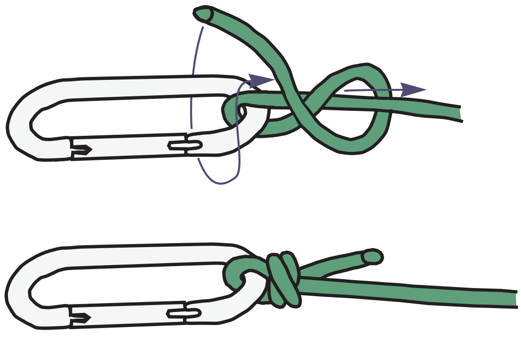


*Kleimheist knot*

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 Italian hitch is very effective and requires no more than a locking karabiner and a rope.




*Italian hitch*



*The Barrel noose*
*is the best for tying the karabiner to your cowstail*

The **Barrel**[1] **noose** is **the** knot to tie your karabiner to your cowstail. It has comparable strength to the popular Figure-8 loop, but more importantly, in drop tests it has a lower impact force than a Figure-8, and a much lower impact force than an Overhand Loop knot (Long, Lyon & Lyon, 2001). Add to this that is it smaller than either Figure-8 or Overhand and holds your cowstail around the right way ready for use—there is no reason not to use it.

## 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. When you are packing ropes for a cave tie a stopper knot in both ends of every rope and check them 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 you cannot push it off the end of the rope if you hit it 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 caver 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 supply a little bottom weight when you are prusiking the pitch.

## Comparing knots

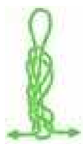
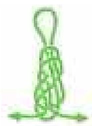
The results presented in Table 3:1, Table 3:2 and Table 3:3 give a general picture only. The performance of knots is variable as shown by the ranges of values and the generally higher figures given by Long, Lyon & Lyon, 2001 and depends on many factors including rope diameter (most samples 10 mm), wet or dry (most samples dry), knot packing and tightness, and to a lesser extent temperature.

What appears to be a clear advantage in favour of bulky knots such as the Figure-9 and Double Figure-8 knots is more obvious on 8 mm and 9 mm rope than 11 mm rope.

Ozto Ocotal/J2, Mexico

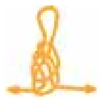
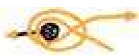
1. It doesn't really have a name... Also called a Double Overhand noose. I've also seen what may be described as a 'Triple Fisherman's Knot' called Barrel Knot.

**Table 3:1 Recommended rigging knots**

| Knot | Form | Static strength % of original | Falls[#] FF1 80 kg rated/10 | Use |
|---|---|---|---|---|
| Figure-9 loop |  | 70[M]<br>68-84[L] | 10 | General, thin rope |
| Figure-9 loop (abnormal) |  | 55[M] | 8 | Rebelay failure, Y-belay |
| Figure-8 loop |  | 55[M]<br>66-77[T] | 8 | General |
| Figure-8 loop (abnormal) |  | 40[M] | 5 | Rebelay failure, Y-belay |
| Double Figure-8 loop |  | 61-77[L] | 10 | Rebelay, Y-belay |
| Double Fisherman's |  | 55[M]<br>~70[L] | 10 | Rope join |
| Figure-8 join |  | 50[M] | - | Rope join |
| Overhand loop |  | 50[M]<br>58-68[L] | 5 | Tape knot<br>Stopper knot |
| Tape/Round |  | 45[M] | - | Tape join<br>Cord Technique |
| Barrel noose |  | 67-77[L] | - | Cowstail, semi-permanent attachment to a karabiner |

M From Marbach and Rocourt, 1980 and Courbis, 1984
[L] From Long, Lyon & Lyon, 2001
[#] Ratings for old rope. Mid-rope knots have a more pronounced effect on new rope

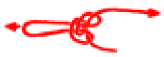
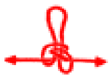
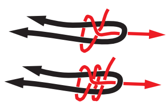
**Table 3:2** **Other rigging knots**

| Knot | Form | Static strength % of original | Falls[#] FF1 80 kg rated/10 | Use |
|---|---|---|---|---|
| Overhand loop (abnormal) |  | 45[M] | 7! | Rebelay failure, 'Shock absorbing' knot, rappel pull-down |
| Lasso Bowline |  | - | 5 | Natural belay |
| Bowline on a bight |  | 50 | 7 | Rebelay, Y-belay |
| Alpine Butterfly |  | 61-72[L] | 5 | Mid-rope tie-off Y-belay |
| Alpine Butterfly (abnormal) |  | - | 3 | Rebelay failure Y-belay |
| Clove hitch |  | ##[L] | 2 | Mid-rope tie-off, cowstail |

M From Marbach and Rocourt, 1980 and Courbis, 1984
[L] From Long, Lyon & Lyon, 2001
[#] Ratings for old rope. Mid-rope knots have a more pronounced effect on new rope
!Then again it may be 0 on a thin rope because of the highly variable performance of the knot
## Long, Lyon & Lyon, 2001 claim slippage at "widely varying forces" on static rope, and comparable with an overhand on dynamic rope

*Other rigging knots* are knots that work, and often used, but there are better knots around for the same purpose.

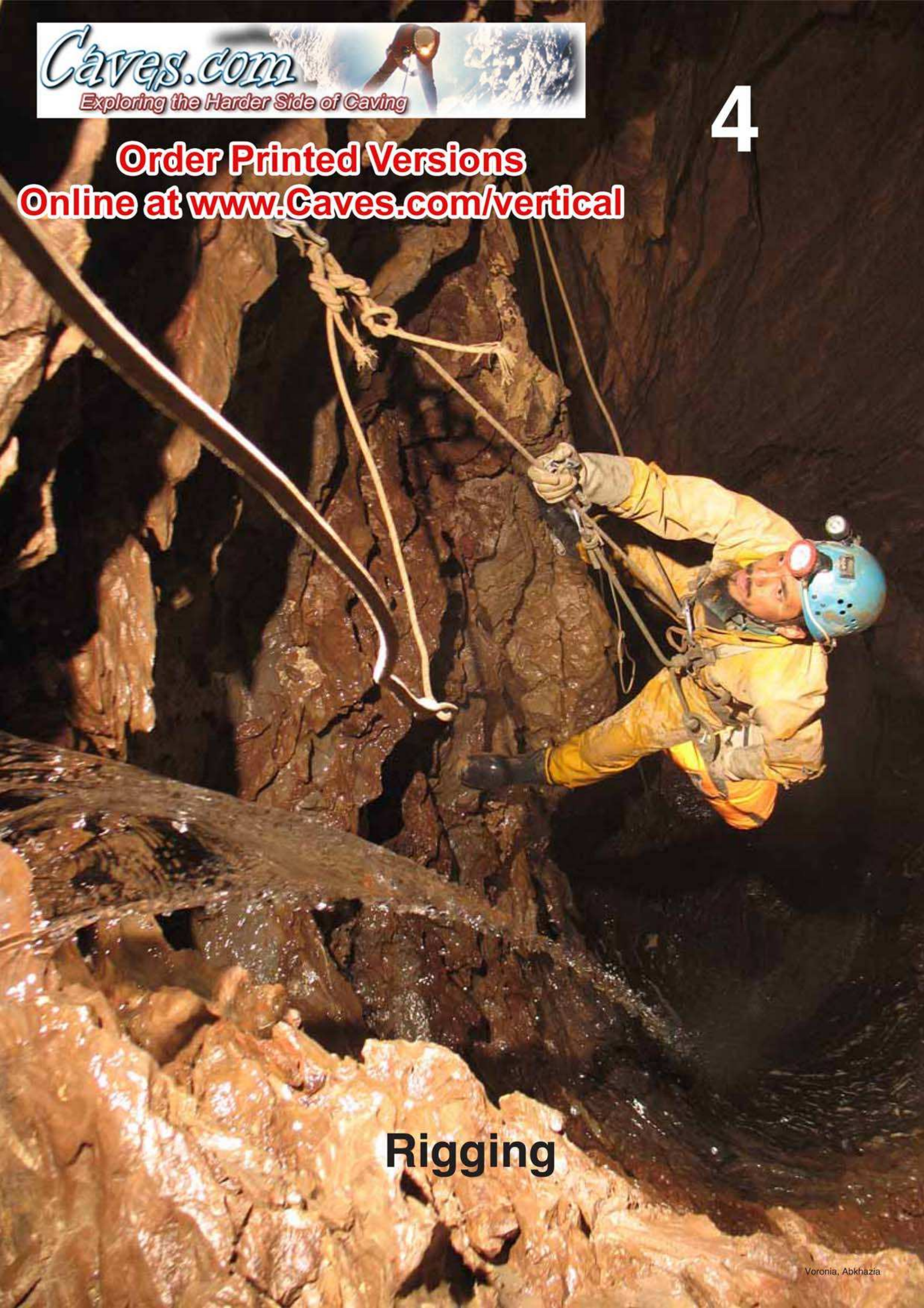
**Table 3:3** **Not recommended for rigging knots**

| Knot | Form | Static strength % of original | Falls[#] FF1 80 kg rated/10 | Use | Comments |
|---|---|---|---|---|---|
| Bowline |  | 50[M]<br>55-74[L] | 8 | General | Weak, insecure until loaded, insecure if you load the loop |
| Bowline on a bight (abnormal) |  | 40 | 5 | Mid-rope tie-off Y-belay | Weak |
| Butterfly |  | 45 | 5 | Mid-rope tie-off Y-belay | Weak, insecure, distorts easily |
| Butterfly (abnormal) |  | 47 | 5 | Rebelay failure Y-belay | Weak, insecure, distorts easily |
| Figure-9 stopper |  | - | 3** | Direct tie to bolt hanger | Rope may damage on hanger edge |
| Single fisherman's |  | 40 | - | Rope join | Creeps, may untie, weak |
| Reef |  | 10 | 0 | Not for rigging Pack closure | Very easy to untie. 10% value is the untie load. Unlikely to stay tied long enough to break. |
| Sheet bend & Double Sheet bend |  | — | — | Join dissimilar diameter ropes—Dyneema to rope. | Unties easily, weak. |

M From Marbach and Rocourt, 1980 and Courbis, 1984
L From Long, Lyon & Lyon, 2001
\# Ratings for old rope. Mid-rope knots have a more pronounced effect on new rope
** Only when used as shown

*Not recommended for rigging* knots are those that can be dangerous to use in rigging. Either because they are weak or because they loosen easily when in use.

Voronia, Abkhazia





# 4

# Rigging

Voronia, Abkhazia

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

1. Safety
2. Negotiable by the whole party
3. Conservation

There are two broad styles of rigging that I will call Alpine and Indestructible Rope Technique (IRT). Both styles have a lot in common—they are after all trying to accomplish the same thing. Nevertheless, practices that are acceptable in one style are often regarded as dangerous in the other. This is nowhere more evident than the concept of allowing rope to be hung in contact with the rock: taboo in Alpine rigging and the norm in IRT.

## 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

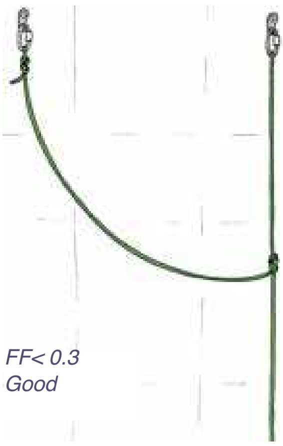
To obtain a free hang and have the rigging negotiable by the whole party usually demands extensive use of artificial anchors. To hang the rope just right often requires an anchor in a specific spot and there may not be a natural anchor there.

Most pitches require two anchors at the top so as to form a belay that has minimal risk of failure. Possibly one will be a little back from the edge and the other out where it will give a good hang. Below that, you may have to place other anchors as rebelays to keep the rope hanging free to the bottom.

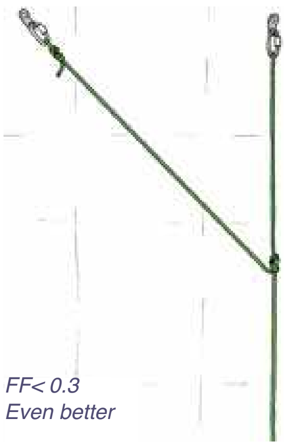
### Primary anchors

When a you clip onto the rope to descend a pitch there should be two or more anchors above you. The exact arrangement will depend on the pitch and who rigs it. You can connect two anchors so that both share the load (Y belay) or tie to each separately. Most often one anchor is in a position that gives a good hang and the other one where it is easier and safer to reach.

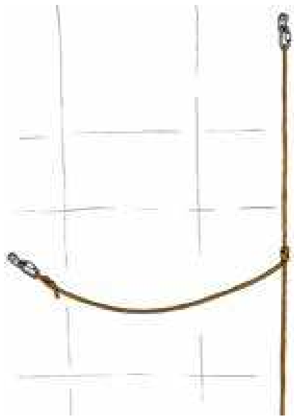
In any belay, keep slack rope to a minimum so as to reduce shock-loading in the event of anchor failure. Anchors placed close together can be particularly prone to this as it is difficult to tie two knots side by side with no slack between them.



FF< 0.3
Good

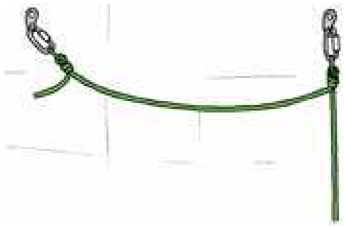


FF< 0.3
Even better

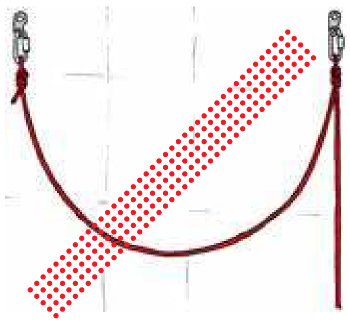


FF 0.3
Safe

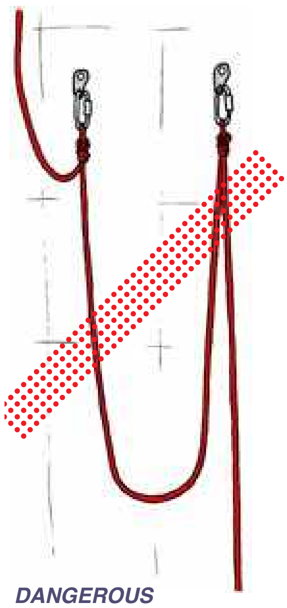
FF > 1
Lethal



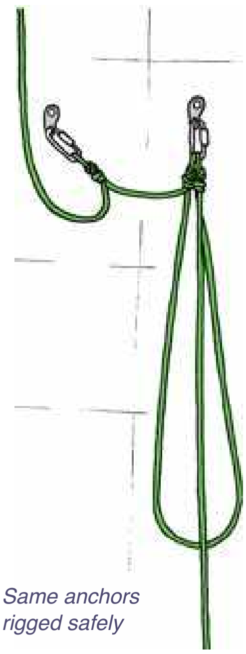
*Good*



**Danger!**



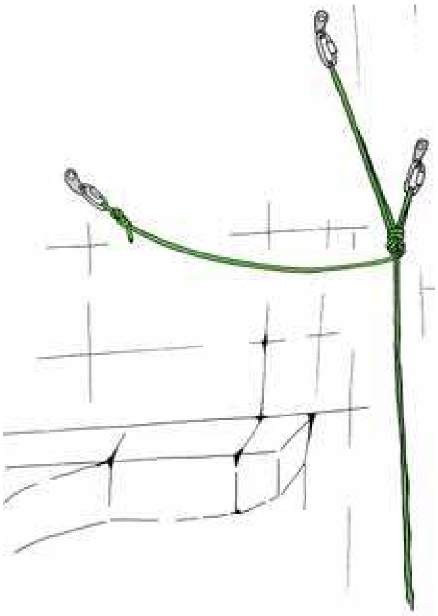
***DANGEROUS***
*stand-in loop*



*Same anchors rigged safely*

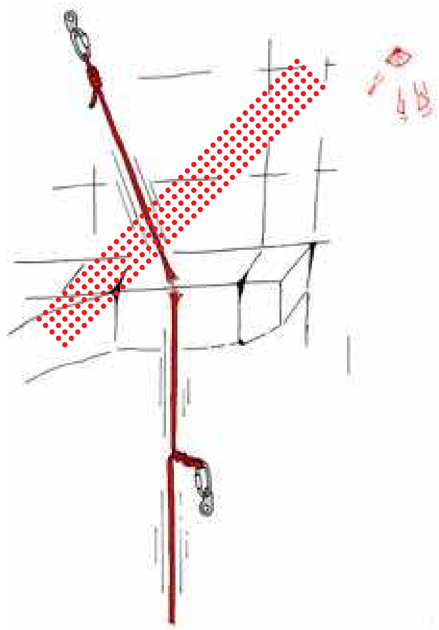
Place double bolts at least 30 cm apart to avoid any interaction between the stressed areas of rock caused by the bolts. Anchors more than 30 cm apart are also easier to rig with minimal slack.

Never rig two anchors that are side by side with a stand-in loop between them. A FF1 fall is possible should either anchor fail! They will be safer if you rig them with a tight sling between them or tie the rope tight and rig the stand-in loop from one or other anchor. In any double anchor belay the individual anchors must be totally independent.

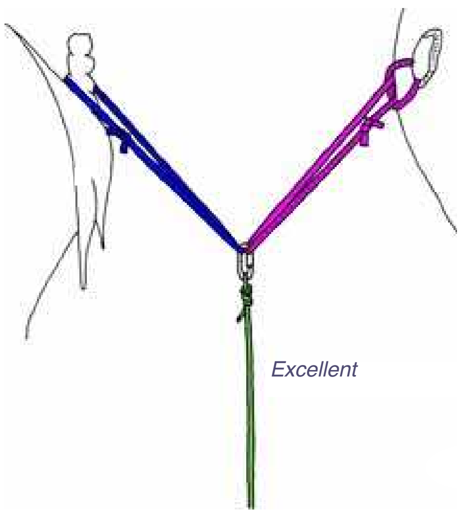


*The back-up line must* **always** *be protected from the possibility of failure*

At the same time you must protect the rope 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.

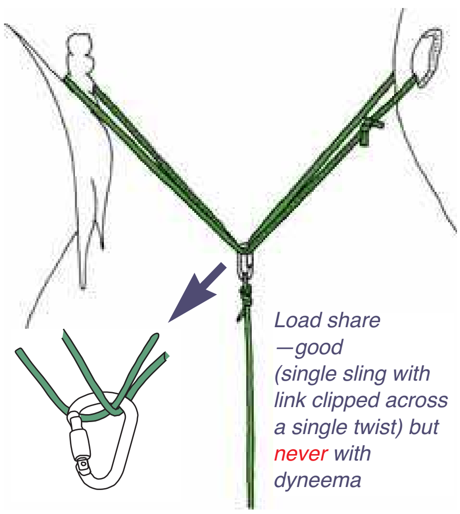


It would be disastrous if the failure of one anchor automatically led to the failure of the other. If you use dependant anchors like the *Lethal!* rig below, you must regard them as a single anchor. A single twist of the sling to form an '8', then clip hole to hole across the '8' turns this dangerous rigging into a good one.

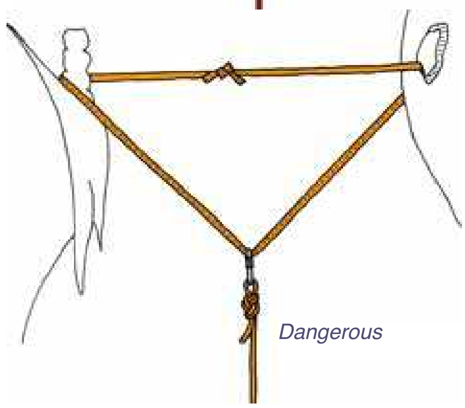


*Excellent*

**Lethal!**

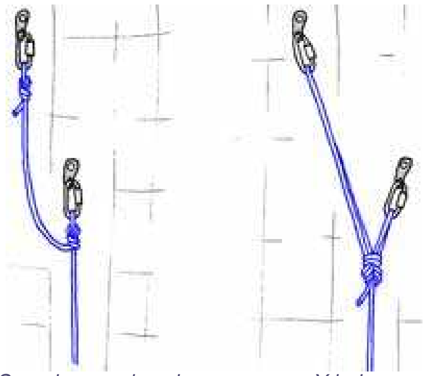


*Load share —good (single sling with link clipped across a single twist) but never with dyneema*



*Dangerous*

## Y belay

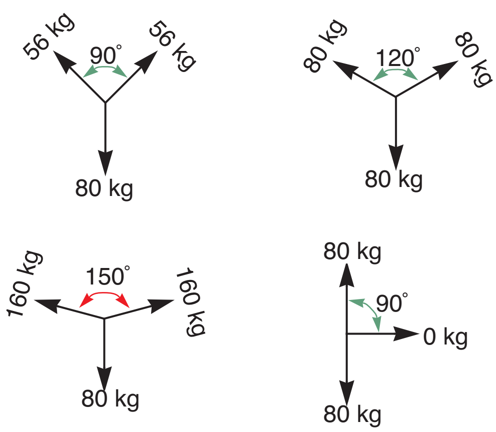


*Superimposed anchors* *Y belay*

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 (and your) chances of survival.

*'Classic' Y belay*

Sharing the load between two anchors does not divide it in half. Too great an angle between the arms of the 'Y' will only serve to overload both anchors simultaneously. Keep the angle below 90° and 120° is certainly the upper limit. Keep in mind also that most plate type bolt hangers should not be loaded at more than 45° out from the wall and use ring hangers if this is a problem.

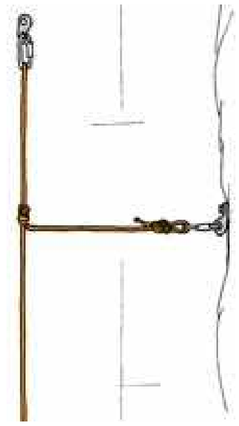



*Y belay anchor loads*

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. Sharing the load between two or more anchors – as well as backing them up well and having minimum slack in the system – is advisable when the anchors are of dubious quality.

Y belays are versatile, you can use them whenever there are two anchors at about the same level. Like anything though, don't get carried away with it—use what is appropriate to the situation. Just because a belay is mechanically safe it shouldn't be awkward to pass or use excessive rope or anchors.

## Asymmetric Y belay



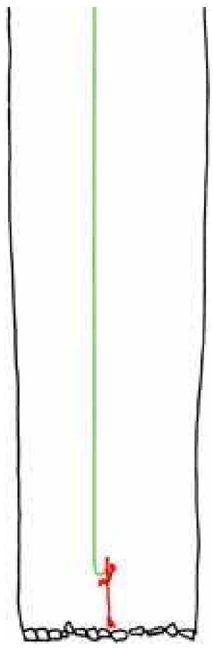
*Only just a Y belay*

You can vary the position of the arms of the 'Y' to the extreme that one of them approaches the horizontal. Do not exceeded this though, as once the knot at the centre of the 'Y' is above either anchor a greater than FF1 fall is possible. A ring hanger is necessary if the lower anchor is a bolt that 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. Often the easiest to tie and adjust is a separate sling. When no sling is available, you can use the rope, though this is less economical on gear. Most often a double end loop knot is used, the Double Figure-8 knot being the most adequate although the Bowline on a Bight is easier to adjust and uses a little less rope if you are using a rope of 10 mm or more.

## Back-up anchors

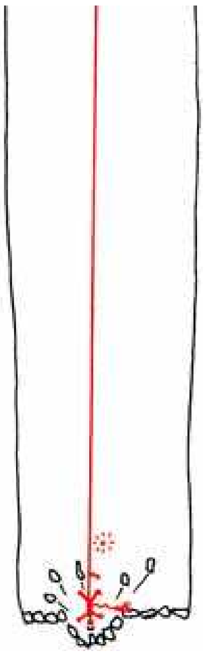


As often as not the primary anchor will be in a position that is not safe to reach without a safety line. You must 'back it up' to another anchor in a less ideal position but is safe to reach.

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, you can clip a cowstail to the line for safety while moving out to the descent rope.

When pitches come one after another you can use the rope from the previous pitch as the back-up for the next pitch. So long as you make sure that if the lower anchor does fail the back-up will take up before you hit bottom.

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



## Rebelays

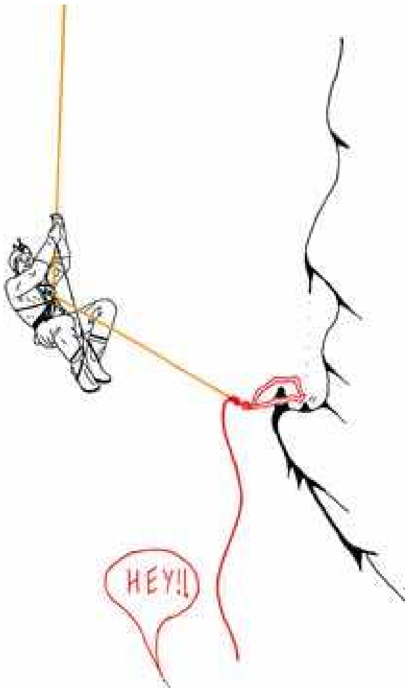
If the rope hangs from the primary belay to the bottom without hitting the wall or being hit by water then the pitch is rigged. If the rope touches rock or there is water on the pitch you may need a rebelay (intermediate anchor) to keep the rope hanging free or allow you to swing sideways. The usual rule is to place the rebelay in a position where the rope will hang as far as possible before it touches the rock. 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 hangs away from it. Choose a suitable anchor position by dropping a small rock or hanging some rope down the pitch and putting it against the wall in likely spots to see how well it really does hang. On long drops use rebelays to keep the pitch length less than 40 m, which is a good maximum for a heavily used pitch.

When tying the rope to the rebelay anchor, allow only just enough slack to unclip a descender when the upper rope is not loaded—no more than one metre.
There are several reasons to get this correct:

- minimum slack means minimum shock load should the anchor fail
- too short makes it difficult to remove your descender and pass the rebelay
- too long reduces the effectiveness of the backup
- too long may make it difficult to use the loop as a stand-in loop to help cross the rebelay
- too long uses more rope than necessary.

Accurately allowing for stretch can be difficult on long drops. There are two ways to ensure the correct amount of slack:

- clip your short cowstail to the rebelay and abseil onto it, feed through the right amount of slack. Without uncliping your descender tie a loop knot in the rope below you and clip it to the belay. Finish crossing the rebelay as normal and continue your descent.
- Alternatively, abseil onto the belay as above, then feed through enough slack for the loop and the knot and clip that into the belay. Without ever removing your descender from the rope, undo your cowstail and continue your descent.



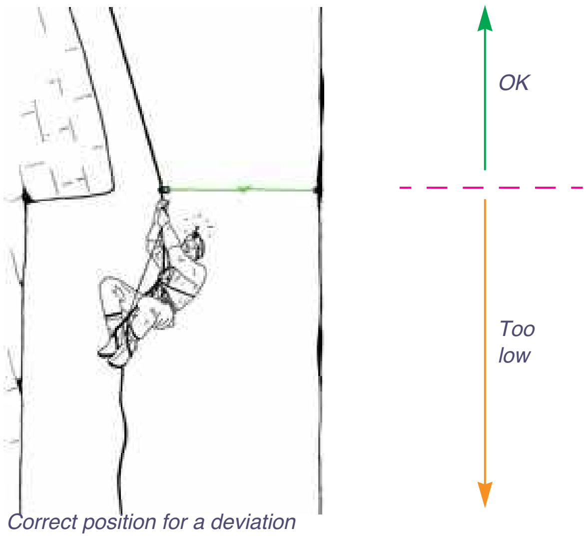
*Some belays must be tied down!*

Either way, the belay must have a karabiner, sling or a bolt hanger with a large enough hole to take your cowstail karabiner and the anchor karabiner/maillon. Do not clip your cowstail into a maillon during this maneuver as it will deform if opened under load. While the second method is faster, you do risk a longer fall if the anchor should fail while you have maximum slack out. **Never** clip to the anchor, then undo your descender without first clipping the rope into the anchor. That is, don't put all your trust in one anchor—stay attached to the rope as a backup.

A single anchor is normally sufficient for a rebelay. It is always backed up to an anchor above and its greatest chance of failure occurs when you are at it. Once lower, the rope between you 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. Consider a double anchor when a single anchor failure would risk the rope being cut on a sharp edge, cause a dangerous pendulum, or if the rock or anchor is of such poor quality that its integrity is in doubt.

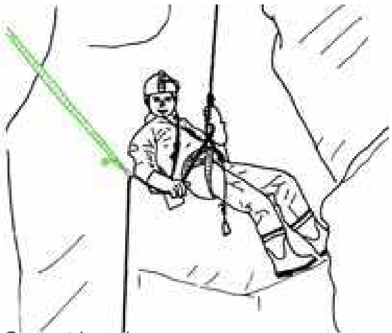
When you use a natural anchor for a rebelay take care to rig it so that a passing caver cannot lift the sling, nut, etc. out of position on the way past. It is best to rig as fool proof as possible by tying down the rebelay or using a long sling so that it cannot escape.

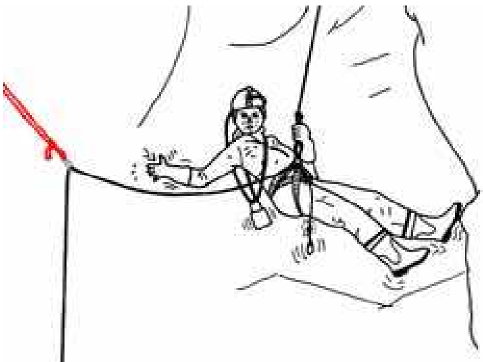
## Deviations (redirections)



Correct position for a deviation

You can often place a deviation as an alternative to a rebelay. Deviations are faster to rig than rebelays and in most cases are nothing more than 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 the correct length to deviate the rope from its natural path and take it away from the rub point.

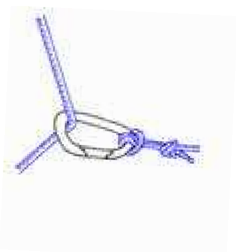

Correct length - easy

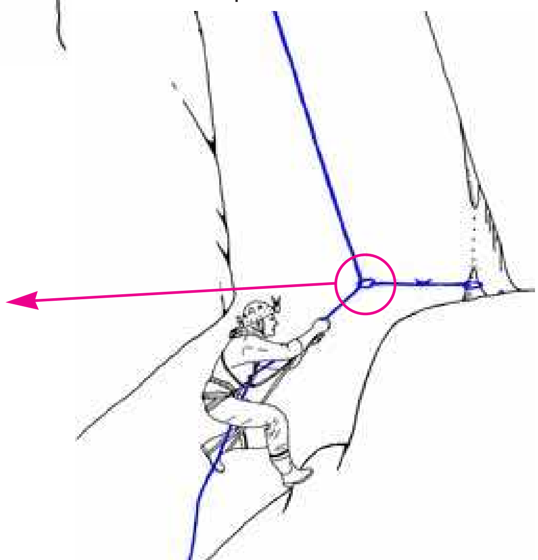

Too short - difficult

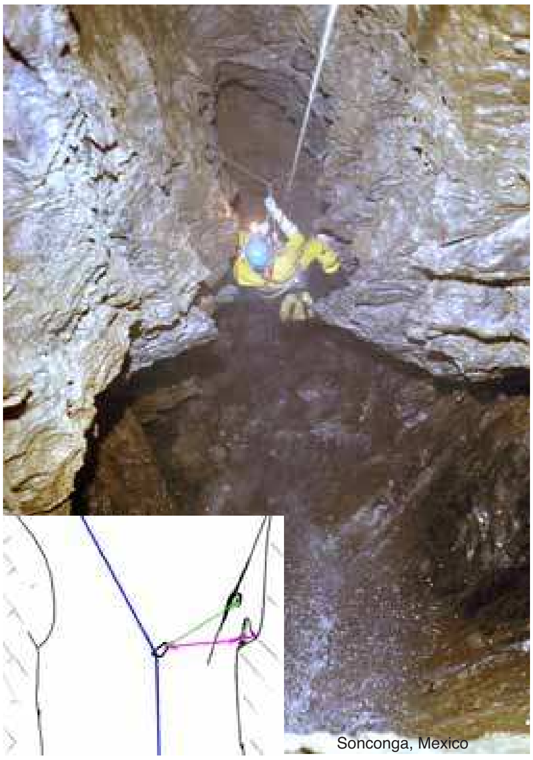
To be effective and easy to pass, you must set up a deviation properly. Use an anchor as near as possible to the same level or a little above the rub point and in such a position that it pulls the rope away from the rub point. The rope only has to avoid touching, not miss the rock by metres. The sling you use should be long enough so that you can easily reach it with your 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 when ascending.

Avoid using extremely short deviations such as one or two karabiners on a bolt hanger – they have so little movement that they are difficult to pass. Avoid severe deviations. The forces on them work similarly to Y belays and it is possible to overload the deviation anchor as well as making it difficult to pass.


The karabiner should be a snaplink rather than a locking karabiner, and tied to keep it in place


A deviation can also be placed in the ‘floor’



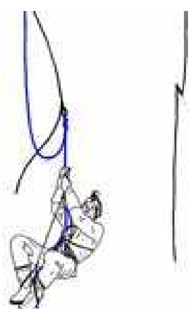

*Double deviation*

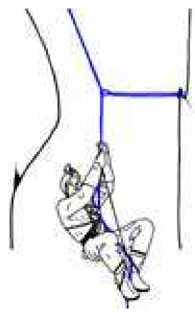
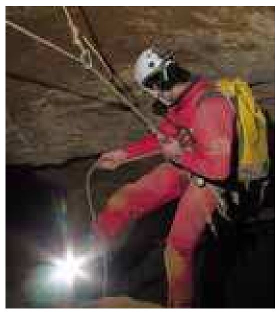
The anchor you use for a deviation never receives full body weight, nor can it be shock loaded as can a rebelay. It therefore does not need to be as strong. In most cases a rock spike or jammed knot that is nowhere near strong enough for a rebelay is fine. The sling and anchor need not be of the highest quality either, cheap 5 mm cord and a mini-krab are strong enough and save weight. In those rare cases where there is no natural anchor you can use a bolt and because the loads are low some cavers half drill the hole to save effort. While this is strong enough it is better to take the time to drill **all** bolts properly so that the next caver down does not place a 'good' bolt beside it. The quality of the hanger and its load angle is unimportant as any 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 require a minimum of time to rig and use less rope than rebelays.

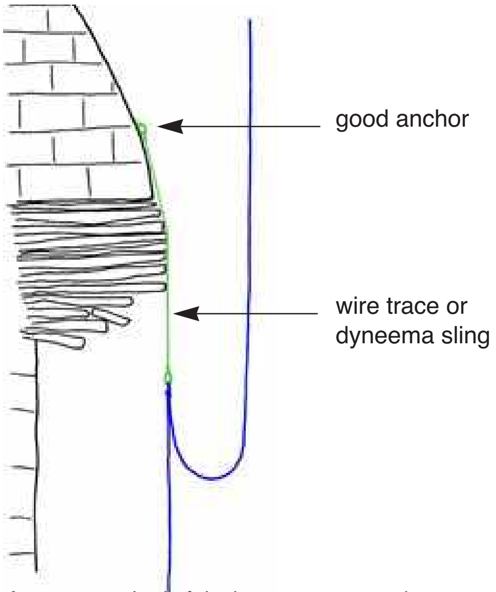
Deviations do not break pitches into shorter units. While a deviation is faster in the short term (exploration or sport trips for instance) a rebelay may be better if many people are going to use the pitch as may happen on a 'trade route'.

At times you must constrain the descent rope precisely. To achieve this, use two slings on opposite walls and clip them to the same karabiner in order to hang the rope in exactly the right spot.

| Rebelay? | |
|---|---|
|  |  |
| + | - |
| secure—rope less able to move around | slow to rig and pass |
| more cavers can climb at once | rockfall danger increased |
| easier to climb (less rope bounce) | needs more gear |
| | ascenders/descender must be detached from the rope |

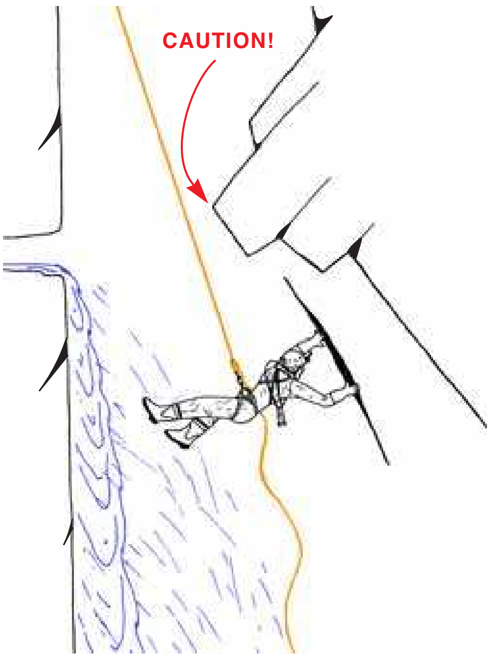
| Deviation? | |
|---|---|
|  |  |
| + | - |
| fast to rig and pass | rope less constrained |
| reduced rockfall danger | only one caver can climb at a time |
| uses minimal gear | awkward at times (more rope bounce) |
| ascenders/descender always attached to the rope | |

## Rotten rock

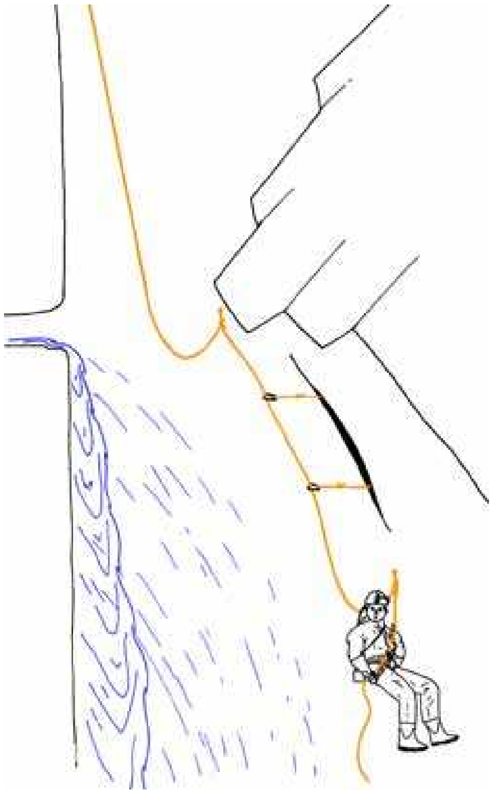



*A secure method of rigging past rotten rock*

If the rock is bad it may be difficult to place a secure rebelay. Often a deviation will work or perhaps a rebelay higher up, if not you may be able to use a wire trace. 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 you do not have a trace, a dyneema sling, well padded rope or tape (possibly doubled or tripled) can serve the same purpose.




*Pendulum to avoid water*



*Several small swings are easier than one big one*

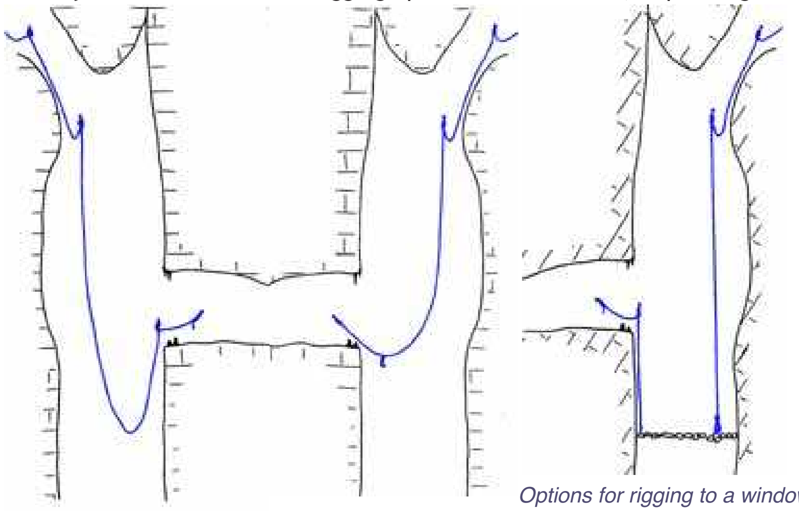
## Pendulums

You often need to swing sideways on wet pitches, if there is a deep pool at the bottom, or there is a danger of falling rock. Occasionally a you will encounter a drop where the passage continues through a window partway down.

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

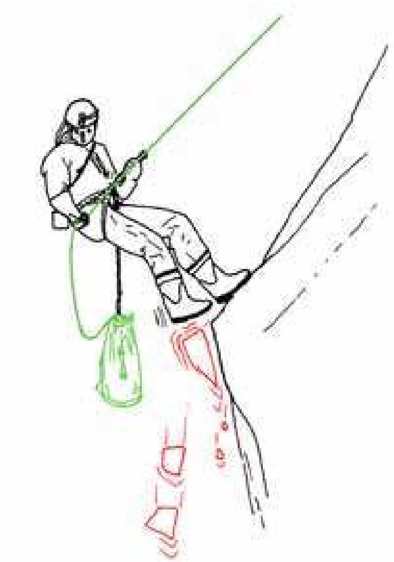
On long wet pitches one solution is to make a series of small pendulums rather than one large one. In any case place the anchor you swing from so that the rope does not grind as it swings sideways. You may have to place a second anchor or deviation to achieve this.

Once across a pendulum, anchor the rope and leave enough slack so that the next caver can cross. Tie a loop knot in the rope to indicate when to stop descending and when to start swinging. The amount of slack rope in the pendulum could mean that double anchors are necessary before descending the next part of the pitch. 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.

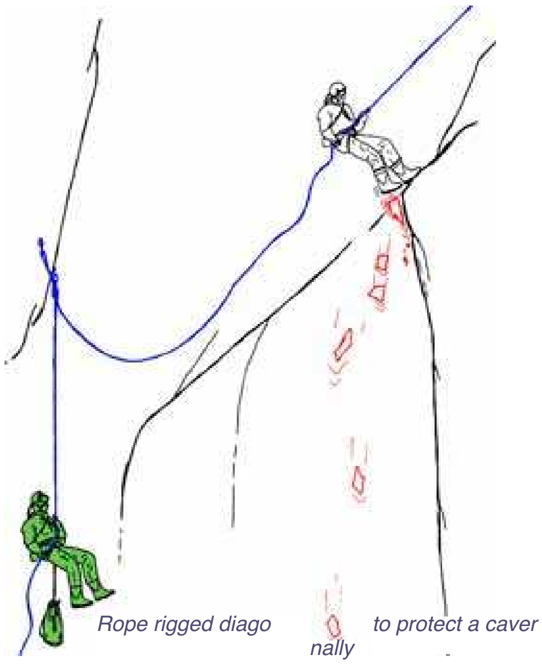


*Options for rigging to a window*

## Gardening



*Rope is best carried in a pack on loose pitches*



*Rope rigged diagonally to protect a caver*

Many caves contain an abundance of loose rock. The first caver down must clear or 'garden' the pitch head of loose rock **before** lowering the rope and starting down. While descending he should try to rig away from loose areas and continue to clean as he goes.

When rigging loose pitches, make a conscious effort to move sideways between anchors. This will allow any rocks dislodged by cavers on the upper rope to fall past any cavers below instead of onto them. If rocks are dropped while the rope is rigged and there is any chance of them cutting the rope, eg. if the rope lies against the wall and a falling rock hits in its vicinity, it may be prudent to check the rope before anyone ascends it.

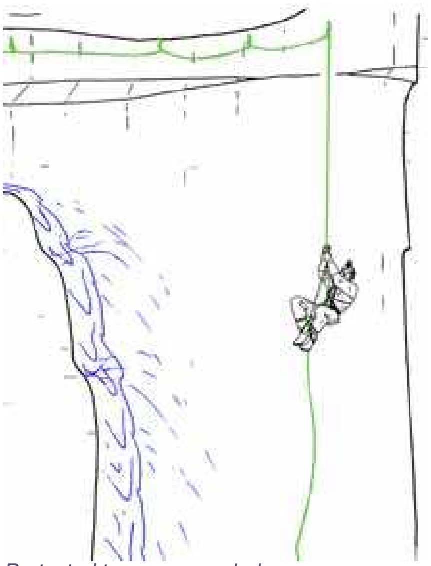
## Handlines

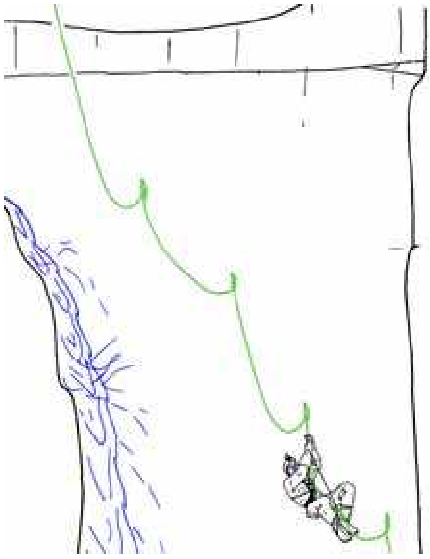

Tonio-Cañuela, Spain

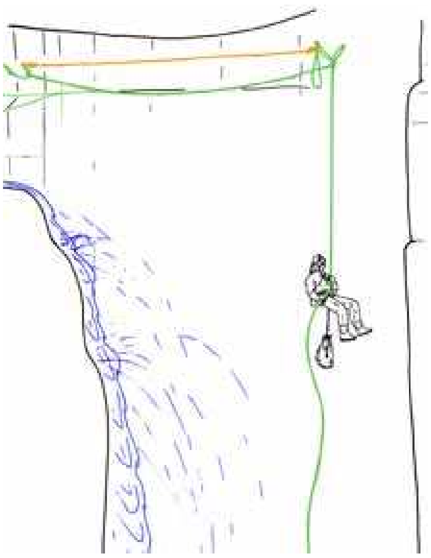
A handline gives security at a pitch heads, and can also be rigged to avoid the risk of falling down rifts or holes. You do not normally weight the line, simply clip in a cowstail and slide it across with you. Double cowstails make it a simple procedure to pass belays in the line without detaching yourself from it. Rig the rope as tight as you comfortably can without tensioning it. The anchors and rope should be 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

Occasionally you will have to rig a handline to give direct aid to cavers climbing out to the descent rope. More often you will rig a traverse to protect cavers climbing along a deep rift or 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 rare.

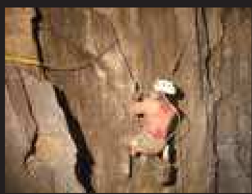

*Protected traverse on a ledge*


*Small pendulums*


*Tyrolean without a ledge*


*Bolt traverse*

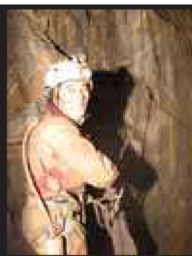


Pass a rope rigged to a line of anchors about a metre apart and tied in to each one by swinging ape-like from one rope span to the next:

- clip both cowstails to the first span (gate outwards as always)
- slide across as far as you can
- remove your long cowstail and clip it to the next span
- lean back and release your short cowstail and reclip it to the second span beside your long cowstail
- repeat until you reach the end of the traverse!

Such traverses are rarely necessary and if you really need one, always try to follow above a ledge or series of footholds to make life easier for everyone. You may be able to rig a rope that needs to go sideways 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. You can also rig a Tyrolean traverse.

*Simple, really!*

## Tyrolean traverses

Ozto Ocotal/J2, Mexico

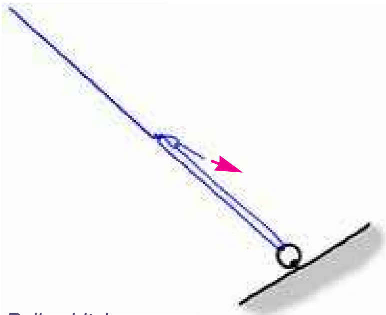
Tyroleans may look good in photos, however they usually require a lot of energy to pass. A slightly sloping line is easy one way and just plain hard work the other. Any sag in the rope means that you end up in the middle and have to struggle up the other side. Especially difficult are tyroleans across space—even a smooth wall to 'walk' across is better than flailing in space.

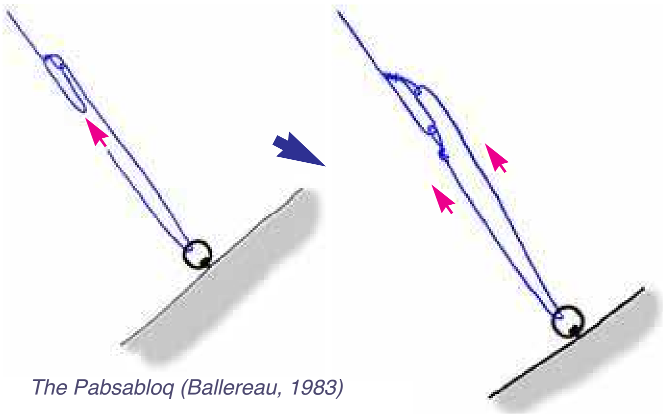
## Tyrolean - horizontal


Caballos-Valle, Spain

A Tyrolean traverse across a pitch or pool 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, rig one tight and an optional loose rope, 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 so much that you will slide down it, use the loose rope to abseil/prusik on as well.

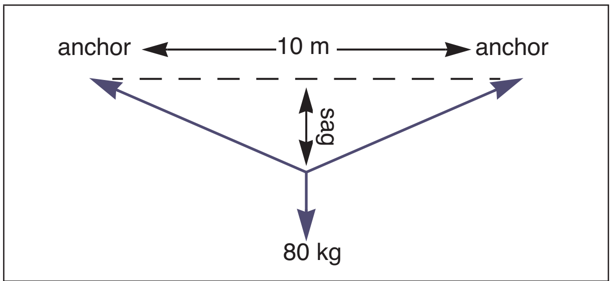
Use the least stretchy rope available for the tight rope—heavy fencing wire or wire cable is great, but who carries that? A length of dyneema is a more sensible alternative. If you use a low stretch line like steel or dyneema you must use a separate safety rope and everyone crossing should have a steel karabiner, or plenty of disposable aluminium ones. A simple block and tackle, pulley hitch or Pabsabloq is helpful for tensioning normal rope. While illustrated with rope loops, you can use karabiners to increase efficiency. Don't use external tensioning for wire cable or Dyneema, which is best tied as tightly as you can to avoid enormous anchor loads. 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 you hit the water anyway.


*Pulley hitch*


*The Pabsabloq (Ballereau, 1983)*

The tighter you can pull the tight line, 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 you reach the middle of the rope.

**Table 4:1** **Tyrolean anchor loads***




| 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 taken as 0 kg.

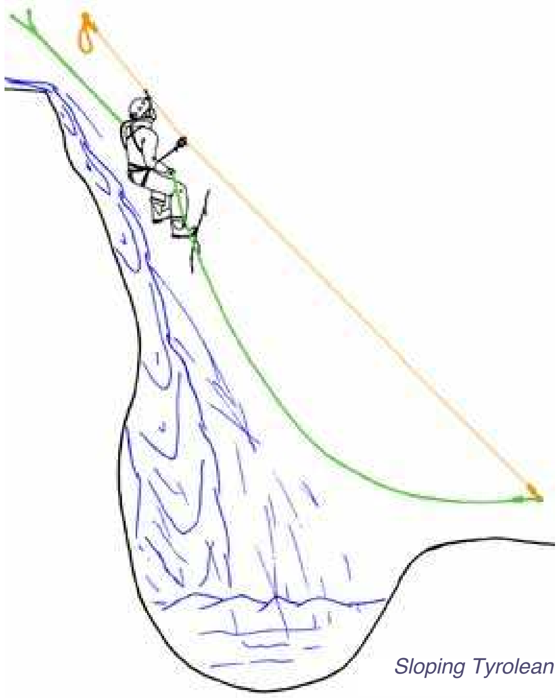
Caving ropes have enough stretch that even when rigged as tight as possible, without using a mechanical advantage to tension them, it is not possible to generate dangerous loads. However, take care when using low stretch line such as wire cable or dyneema.

Do not run Tyroleans around corners. The loaded rope undergoing side to side abrasion wears through very quickly. Wherever the rope touches rock place an intermediate anchor and preferably fit a stand-in loop to make it easier to pass.

### Tyrolean - sloping (guided descent)

If you are faced with a long stretch of rotten rock that overhangs at the bottom or a cascade that ends in a pool, try a diagonal tyrolean.

Initially, descend straight down, protecting the rope with pads if necessary. When you reach the bottom set up a belay away from the base of the pitch. Rig the least stretchy rope you have from a separate belay and pull it as tight as possible—the gentler the slope the tighter the rope needs to be. Those following descend on a separate rope with a cowstail clipped to the Tyrolean and as they descend, the tight line pulls them to one side.



*Sloping Tyrolean*

Ozto Ocotal/J2, Mexico

## Water

Avoid water on pitches. Most stream caves have a clean-washed zone that you can regard as the flood risk level. Depending on the likelihood of a flood and the water temperature, rig pitches a safe distance from the water. In extreme cases this may require a traverse to the far side of the pitch to descend in safety.

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

When there is no choice but to rig in or close to the water, hang the rope as far from the walls as possible to avoid the rope being thrashed against the rock. At the same time keep the rigging 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, pull the rope away from the water and rock and tie it so that it cannot touch the rock no matter how high the water becomes.

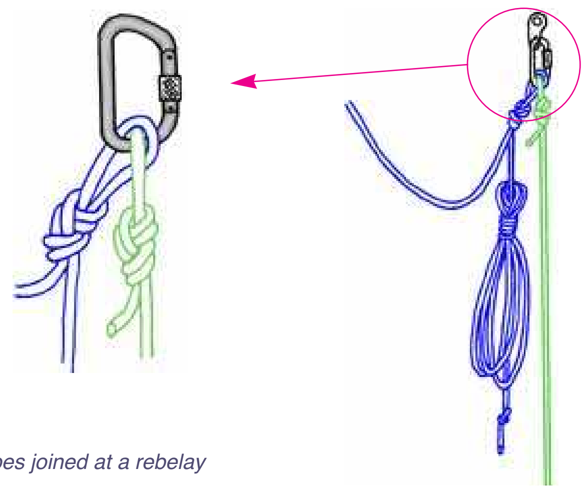
If you are leaving the cave rigged the last person should haul the rope up on the way out and coil it at or above the belay to keep it out of danger.

## ‘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 you 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 you can use small inflatable boats but they are heavy and bulky to carry and you may have 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 you **must** swim, stay buoyant: a partly inflated garbage bag or wine cask liner inside your oversuit works wonders. The same goes for packs: a well loaded pack will fill with water and sink like a stone, and take you with it if you don’t let go! Make the pack buoyant or leave it behind and haul it across with a rope once you’ve crossed the pool. 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. In that worst case, the divers who come in to rescue you will have something to follow through the brown floodwaters.

## Short ropes



*Ropes joined at a rebelay*

If it looks as if the rope will not be long enough tie on extra rope before you start the descent, you can always remove it at the bottom if you do not need it. Knots are always a nuisance to cross. Wherever possible arrange a knot so that there is a ledge to swing onto to pass it and never put a knot near falling water. Even a smooth wall to balance against makes crossing easier than free space and psychologically it is easier for many cavers to cross a knot closer to the ground.

It is better to join ropes at a belay even if it means wasting some rope. Do this by tying two end loops linked through each other and then clipping the down loop (or both) to the anchor. Use any excess rope to make a stand-in loop or bundle it at the anchor and **tie a stopper knot** so it’s still safe even if someone descends it accidentally.

## IRT rigging

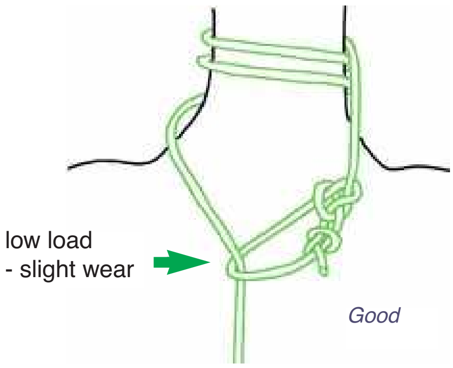
*The "Bad old days" – thick polyester rope rubbing all the way down, and in the water.*

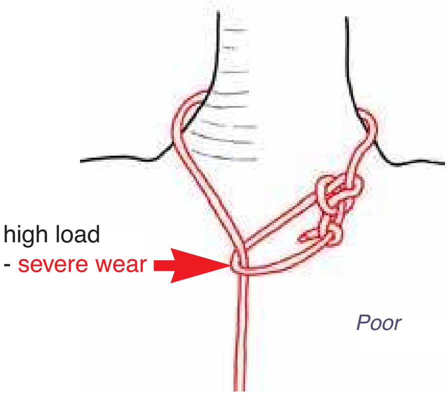
IRT (Indestructible Rope Technique) is where it all began. Take a rope, throw it over, slide on down, then climb back up it. Fairly soon cavers began to run into problems. For a start, limestone is harder than nylon. In France the solution was obvious—rig the rope so that it didn't touch that nasty limestone. Away to the west, the answer was just as obvious—get tougher rope.

Instead of relying on complex rigging and abundant hardware to keep the rope intact, IRT requires a tough heavy rope that can withstand some abrasion. Rigging is considerably easier when you're not too concerned about whether the rope touches rock or not. Without doubt the strong point of IRT is its simplicity.

## Anchors

IRT avoids hanging the rope in contact with the 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.



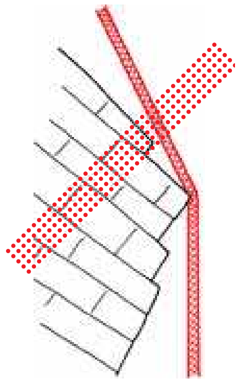

A popular knot for the natural belays normally employed is the 'Lasso' Bowline that tightens securely onto the anchor. You can also use Figure-8 knot tied in the same manner for improved security. Separate slings are considered unnecessary as they can weaken the system and are extra gear to carry.

Should the only good anchor be at floor level it may be difficult to exit the pitch on the way up. I have seen cavers hook the rope over or wrap it around a knob near the edge to lift it up a little. If the rope slips off or the knob fails a large shock load would occur. The danger to the rope is usually not 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 IRT are rare.

IRT rigging rarely breaks pitches into short sections. An effort is made to make them as long as possible to take advantage of the fast but unmanoeuvrable prusik systems usually employed and to avoid having to clip past artificial obstacles on the pitch. The pitch is only ended when you reach a big ledge or the bottom—even to the extent of crossing ledges and turning corners on the way.

## Rope protection

*Slight*



*Use a protector*

Despite attempts to make tougher and tougher ropes, a truly indestructible rope that you can still carry into a cave has not yet been invented.

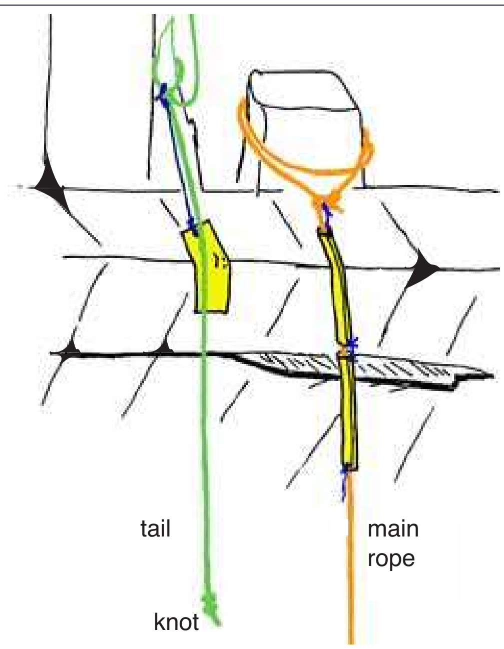
IRT rigged ropes are often in contact with the rock, making rope protection of paramount importance. The trend has been to tougher ropes that are better able to withstand the wear and tear, even so it is often necessary to pad pitch edges.

Once below the edge of a pitch the rope moves around too much and pads become ineffective, so you're forced to resort to wrap around pads. In most cases the worst abrasion occurs 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 worthwhile lower down the pitch.

In practise I have found all rope protectors unreliable unless you can place them above the point where you clip on the rope. Protection on the main lip works tolerably provided everybody is careful to replace the rope and pad in the right place, which is not always the case! Even then, protectors are ineffective once the rope eats a hole in them. Once more than five metres down a rope, you should expect all protectors to fail at least 50% of the time for various reasons—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 or replaced in the wrong place.

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 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. See also Other equipment—rope protector on page 42.

## Pitch Edges




*Tail to negotiate an otherwise dangerous edge*

Negotiating pitch edges is often the most difficult part of an IRT rigged cave. The rope is forced into contact with the rock and passing the edge 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 bends through, making the edge easier to pass as well as reducing rope wear.

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

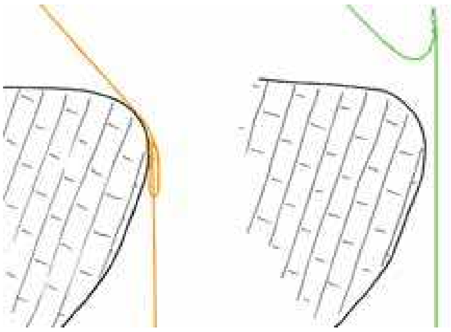
Another device that has gained some popularity is to hang a 'tail' over a difficult edge or on one which requires excessive padding. The idea is to descend the tail past the lip, then change over to the main rope below the padding. Rope pads stay in place and there is no problem with rope weight. Unfortunately, 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 on page 64.

## Compromise

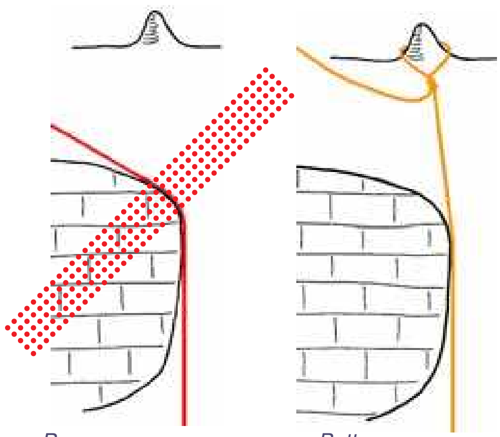
IRT can be terrifying for Alpine cavers who cannot afford to tolerate the slightest rope abrasion. IRT riggers find Alpine style far too light, flimsy and complex to be at all safe.

Despite a general lack of understanding between cavers on different continents some uses of one 'pure' technique, be it Alpine or IRT, 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, IRT cavers could use some Alpine techniques to keep them away from water, make their ropes last longer, get a group through the cave faster.

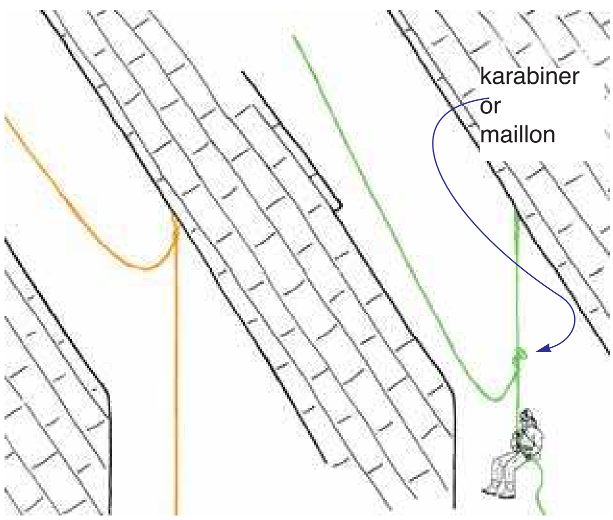
## Rigging for comfort



*Poor* *Best*



*Poor* *Better*

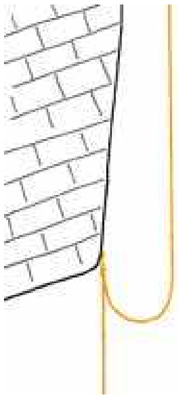



*Safe* *Safe and easier*

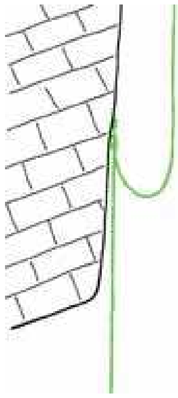
During exploration, prospecting or one-off sport trips you can tolerate some difficult rigging. However, when you are rigging a cave for a large group or heavy usage rig it for ease of travel, so long as you never compromise safety. Comfort considerations are a collection of small, often subtle features that you usually learn by experiencing uncomfortable rigging.

- Rig high. Look for anchors that you reach 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 freehang with no immediate need for another anchor.
- Rig difficult traverses high enough to allow cavers to weight the rope rather than forcing everyone to climb unaided all the way.
- It is often necessary to make long reaches and acrobatic moves but once the rope is installed there is rarely a need for the whole party to suffer the same inconvenience. Attach a sling or long rope loop to a distant anchor so that those following can pull the belay toward them 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, clip a karabiner or maillon 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.

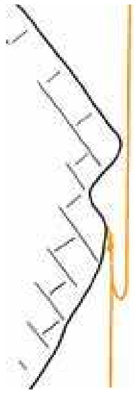
Contents Index



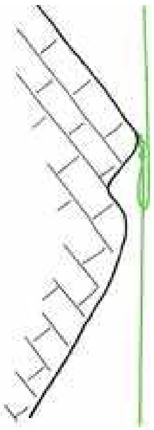
*Safe*



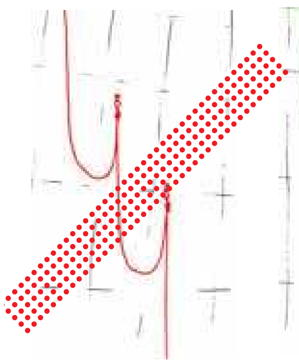
*Easier*



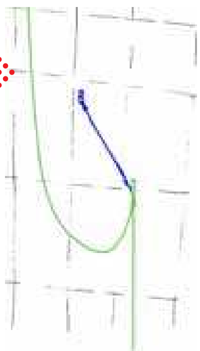
*Difficult*



*Easier*



**Dangerous**

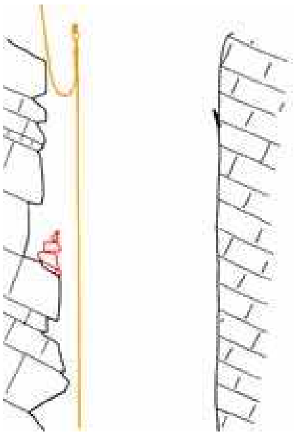


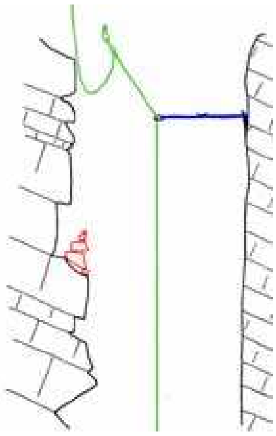
*Safe and easier*

- Do not insist on a freehang 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 that gives a free drop.

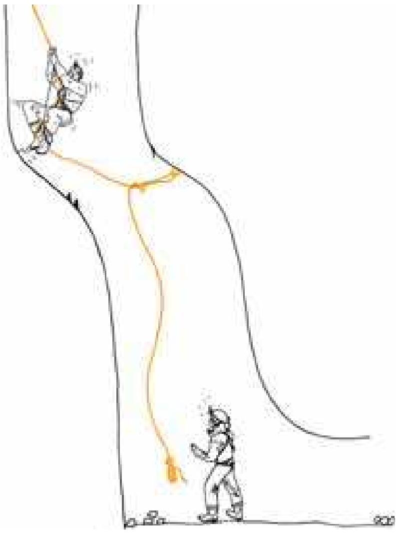
- When a swing after a pendulum is extreme, a stand-in loop may be useful.
- Keep aerial rebelays to a minimum. Place rebelays where there is a landing platform or at least footholds to aid crossing over.
- Make a special effort to make awkward rebelays easily passable. Save direct attachment bolt hangers and tight loops for tiebacks and anchors that do not need to be crossed – they do not easily take cowstails.
- Avoid rigging deviations with no footholds.
- Make deviations as gentle as possible.
- Avoid rigging deviations with very short slings that reduce their manoeuvrability.
- Rig double anchor rebelays so that it is only necessary to cross one rebelay.
- A rope is easy to climb when it is hanging just off a smooth wall so that your feet touch lightly when prusiking, but there is no need to fend off.
- Do not be tempted by bolt farms or an abundance of natural anchors to use more anchors than you need. A complicated lacing together of several anchors can be confusing for all but the person who rigs it.

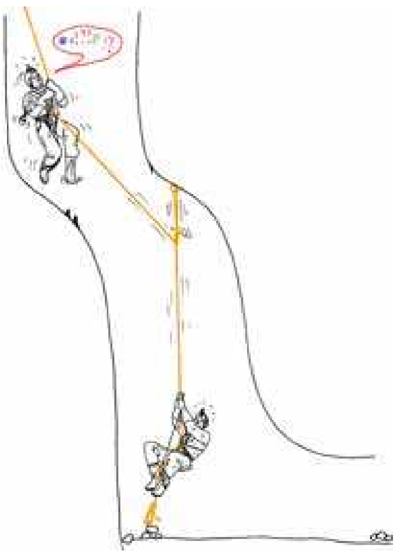

*Simple(?) rigging*


Messy

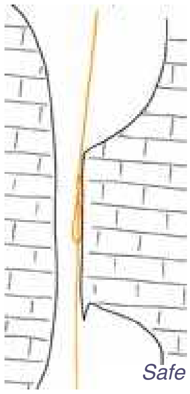

Safe and easier

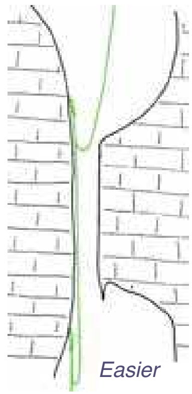
- You only need to rig a rope so that it is free when in use, not as far from the rock as possible. It is often acceptable to have the rope lying against the rock so long as it pulls free when you are on it.
- Rig rope clear of spiky walls that can make prusiking difficult.
- Rig away from loose rock. Failing to do so may mean that it is only safe to have one person on a pitch at a time – or that it is dangerous for all who use the rigging.



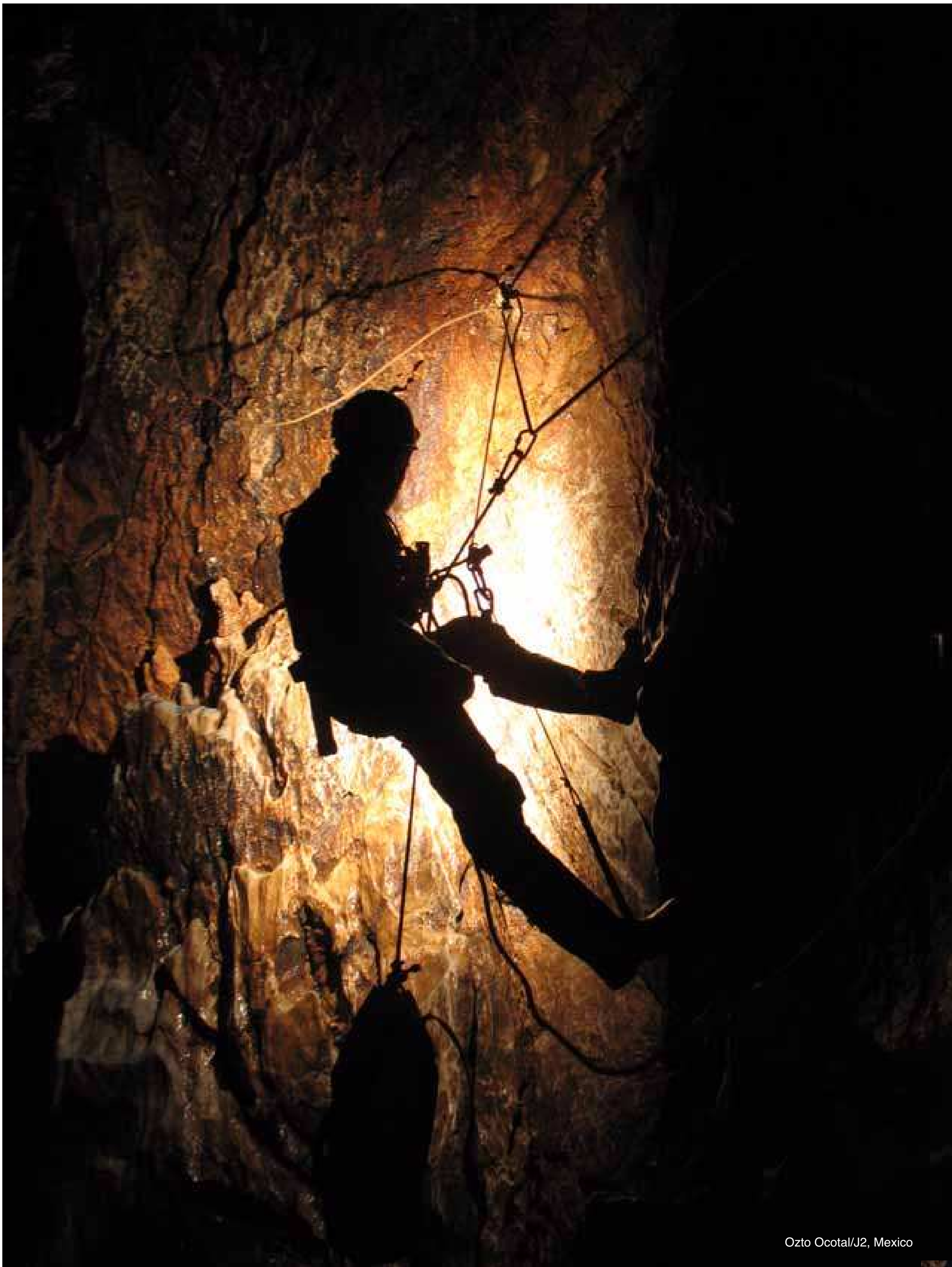


- Rig clean. A rope or caver not covered in mud is much easier to handle than a dirty one.
- If there is a ledge to stand on during the changeover, it is possible to arrange no slack in the upper rope. This may be worthwhile if the anchor is of poor quality but if there is insufficient slack it will be impossible for two people to be climbing (one either side of the rebelay) at the same time.
- Avoid placing rebelays or deviations in narrow sections. One above and a second below a constriction are easier to pass.


Safe


Easier

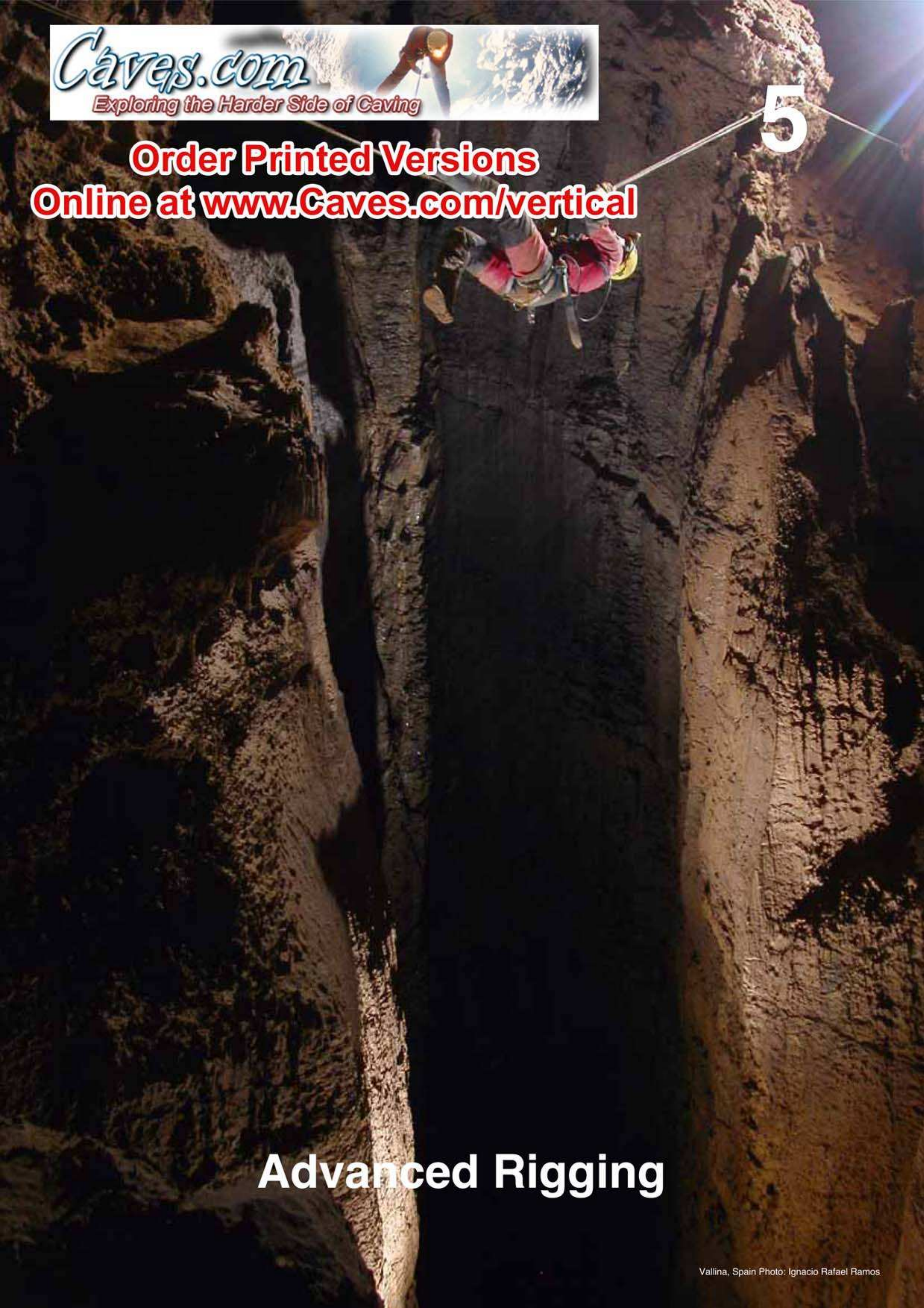
- Do not regard all these hints as compulsory. Indeed some are contradictory! Ultimately each pitch has its own rigging requirements.



Ozto Ocotal/J2, Mexico

# 5

# Advanced Rigging



Vallina, Spain Photo: Ignacio Rafael Ramos

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

## Ultralight rigging

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

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 hangers (aluminium with rounded attachment hole only please) will also save weight. Leave pitons and nuts at home and use jammed knots and slings instead.

The greatest risk in Ultralight 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. Rig ropes to avoid this by using tight backups and Y belays. This also keeps the chances of shock loading of the rope to an absolute minimum. Seven millimetre ropes made specifically for caving are rare and even when found, cannot be guaranteed safe. Take extreme care in choosing one, even to the point of shock testing prospective ropes until you find a good one.

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

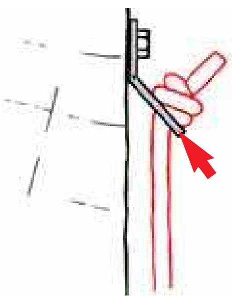
## Cord technique

*La Technique Cordelette* or Cord Technique takes lightweight one step further. Instead of fixing rope down the entire cave, you retrieve the rope from each pitch and leave behind a double length of string so that you can replace the rope on your way out. It is a technique to use only when nothing else is possible—it is frustratingly slow, fiddly and demandingly precise but is also the lightest rigging style yet devised.

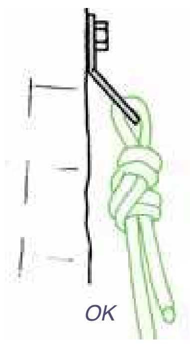
Poor judgement could leave you trapped below your mistake. Practise Cord Technique on the surface and in easy caves before taking the more committing step of using it in a deep cave.

It is rarely worth considering Cord Technique 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 600 m or more down is a different proposition. The upper length limit for a Cord Technique pitch is 40 m to 50 m. You will either need to rig long pitches Ultralight or break them into smaller pitches, and this is not always possible. On longer pitches it is feasible to rig a fixed rope to within 50 m of the bottom and retrieve the last length using Cord Technique. In virtually all caves you will need to carry a certain amount of fixed rope for pitches that are just too messy for Cord as well as some shorter lengths for tiebacks and pitch-head handlines.



*Risk of rope damage*



*OK*

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 rig 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.

## Equipment

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

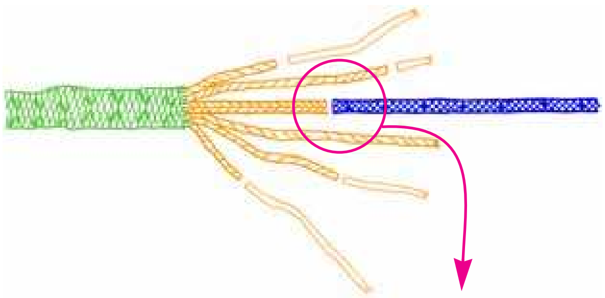
Cord Technique requires the normal range of Alpine caving slings, bolt hangers, etc, as well as one 6 mm steel maillon for each pitch. These open just enough to take a 9 mm rope, wear well and are strong enough. Seven millimetre aluminium maillons are also adequate but while lighter, they wear quickly when 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 is usually 3 mm nylon 'venetian blind' cord although you can use 2 mm cord for small drops when the loads are low. Despite a considerable weight advantage, 2 mm cord tangles easily and makes a lumpy knot that pulls through maillons badly. Stuff the cord 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. Close the top with a drawstring and cordgrip. The only other equipment you need are a few 7 mm aluminium maillons as links where knots are not suitable.

## The rope

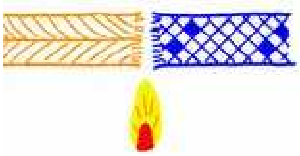
A 50 m rope on a 5 m pitch usually involves a tangle. In most caves you will find it convenient to use two ropes with specially prepared 'tails'. I normally take a long and a short one so that there is no need to handle a long rope on short pitches. The rope should be 8 mm and of a flexible design so that it runs through the rigging easily. Remember that you will be using the same rope over and over again, it will wear out faster than rope that is fixed and used once.

### Preparation



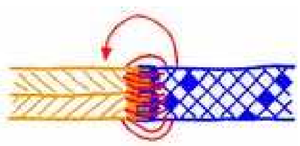
The rope must taper smoothly from 8 mm down to a 3 mm diameter, 30 cm long tail.

1 Push the sheath back to expose 30 cm of the core.

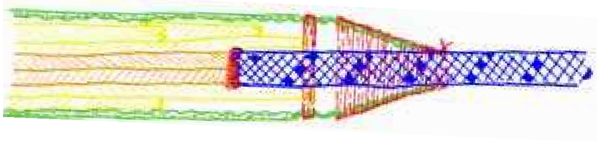


2 Select two central bundles of core and trim 15 cm off them.

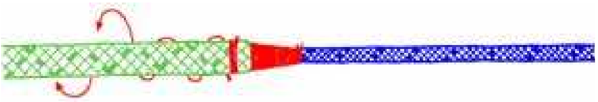
3 Fuse the trimmed bundles and the end of the 3 mm tail end-to-end over a small flame or 'hot knife'.



4 Reinforce the fused joint with stitching.



5 Trim the rest of the core bundles to give a gradual taper over a length of 15 cm.

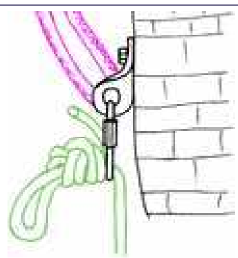


6 Pull the sheath back over the join and tie a 3 mm long whipping around it 5 cm from its end.

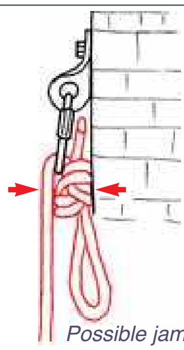
7 Trim out four strands of sheath to increase flexibility then start a tapered whipping 5 mm along from the first whipping. Once started, unravel the remaining sheath and progressively trim it to give a conical whipping no longer than 15 mm so as to keep the area flexible. A small amount of rubber glue will help hold the whipping in place as it is being tied and a coating of glue will protect the thread.

8 Stitch through the rope to further lock the tail in place, being careful to not stiffen the rope with too many stitches.

## Rigging cord technique



*Good*



*Possible jam—poor*

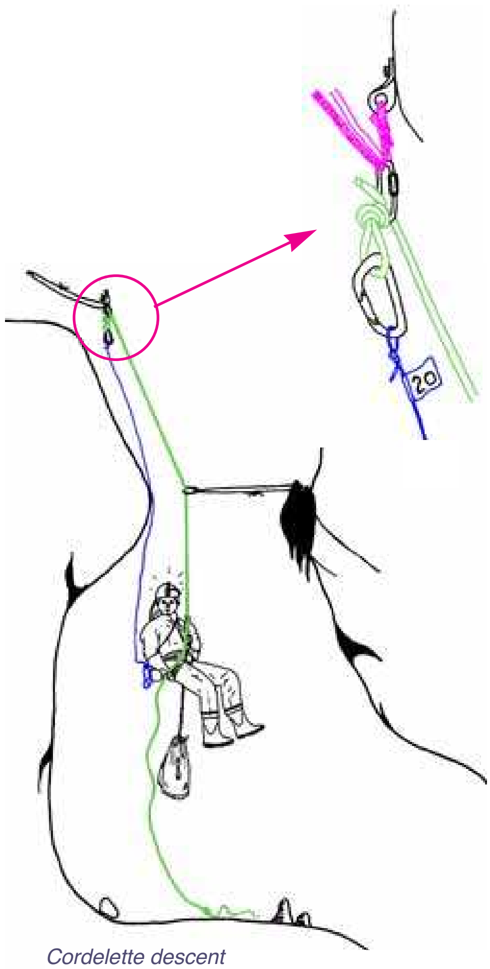
Rig pitch heads as for Ultralight technique with double anchors and handlines to exposed anchors. This will require several 4 m to 5 m long ropes as well as shorter slings to tie between the easier to reach anchors.

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 means that the maillon is very close to the rock. If so, 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. Hang the maillon itself with its gate uppermost so as to allow a maximum of space for the rope to pass at the bottom. Push the tieback to the top of the maillon and tuck any loose ends out of the way. For a rig that will run better, attach a short tail or sling to hang the final maillon in space.

On pitch heads that round over it is better to fix a rope at the top down to an anchor that gives a freehang. Lower down, avoid rebelays, which you must treat as separate pitches, and replace them with deviations wherever possible. Arrange deviations so that you can pull the rope 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

*Cordelette descent*
*– with the cord running well clear of the descender*



*Cordelette descent*

Initially pack the cord in bulk with joins tied by Round or overhand knots and the end tied to the tag at the bottom of the sack. On the first trip, cut the cord to suit as you rig each pitch. After the trip you can measure the cut lengths and tag them with small flags of adhesive tape at one end. On future trips, select appropriate lengths of cord just as you would choose ropes for any other trip. When exact lengths of cord are not available, tie several cords end-to-end with Round or overhand knots. The knots and the tape flags cause no problems sliding through the maillons.

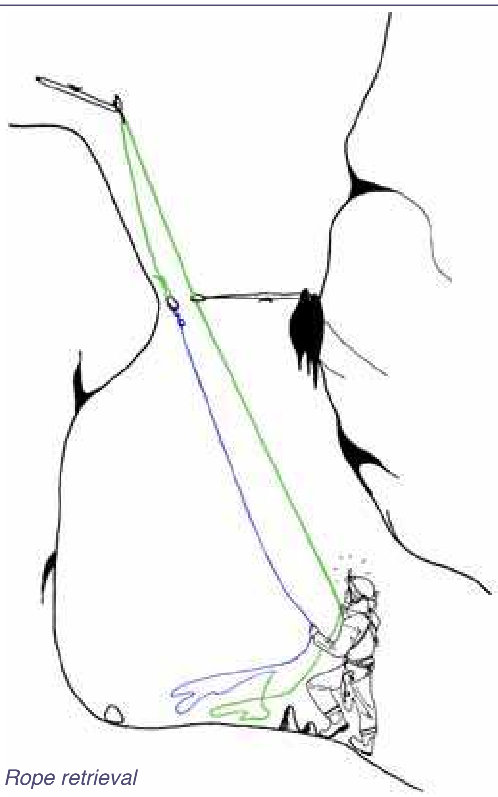
To descend, jam the rope in place with a Figure-9 loop that is far too large to fit through the maillon. Clip a karabiner to this loop in order to attach the pull-cord. Allow this cord to run freely from its sack as you descend taking care not to spin and twist the cord around the rope. If you have the cord packed in bulk, it is simplest to use a separate pull-cord. At the bottom remove the end of the cord from its sack and tie it onto the tail with a Round or overhand knot.

Retrieve the rope by pulling on the cord until all the rope is on the bottom and is replaced with a double length of cord. Cut the cord and code the ends by tying an overhand loop in the ‘pull’ end and attaching the end you’ve just 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.

Separate the knotted strands of cord and lightly anchor them with rocks or tie them to spikes to prevent tangling due to air or water movements. You are now free to move on, having left a minimum of equipment.

Ascent is simply the reverse of the descent procedure. Tie the rope tail to the end of the cord with a Round knot and the pull it back up until the Figure-9 loop is once again jammed against the maillon. As you pull the rope through it begins to move by itself and when the pitch is long or its walls are jagged, clip the free end of the cord to the Figure-9 loop so that you can ease the rope into place or retrieve it should it snag on the way up. Once the knot has jammed in place against the maillon, the rope is ready for you to ascend. Untie the string from the end of the tail before you leave the ground and progressively stuff the cord into its sack on your way up.

## Organisation

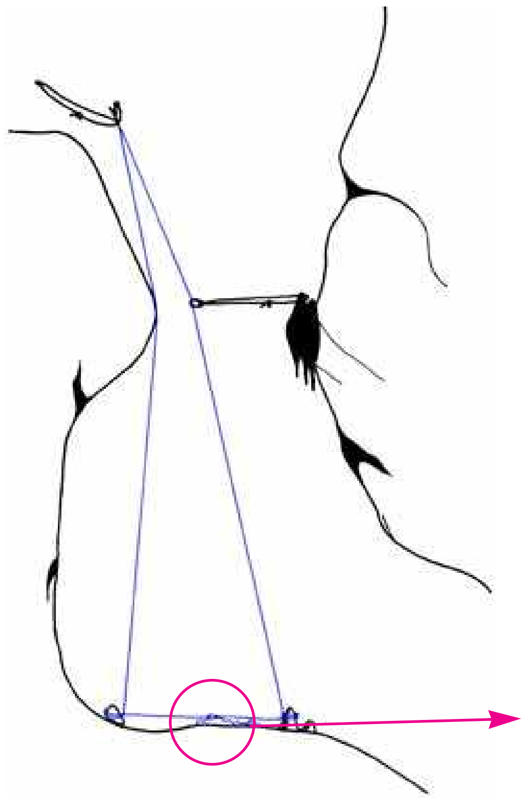


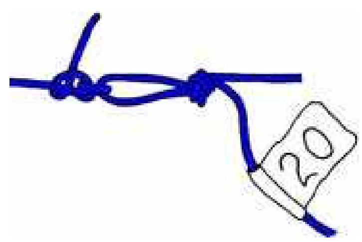
*Rope retrieval*

Draw up a detailed tackle list for both rope and cord (see Tackle lists on page 146). In the cave, stuff the rope 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.

I can't over emphasize the need for care. The Cord Technique demands an attention to detail and neatness not necessary in any other rigging style. The string is especially prone to tangling or winding around itself. Should this happen on the way up and it becomes impossible to rectify, you will be unable to rerig your rope. At **best** you will suffer a long uncomfortable wait for your rescuers.






*String coded...* *...and ready to go*

## Rigging styles compared

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

Issues such as safety, conservation, speed and enjoyment lead into pointless arguments that ultimately come back to the competence of the cavers concerned. A clear comparison that can be made is that of relative weight.

To this end, let us compare the loads required for Khazad Dûm, an Australian vertical classic - a cold, wet cave around 300 metres deep. It has a total of 170 m of pitches with several bolts.

Bear 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 Dûm would have a hard time carrying their IRT 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 is pushed in favour of the lighter styles.

**Table 5:1** **Weight comparison for Khazad Dûm**

| Equipment | Style | | | |
|---|---|---|---|---|
| | IRT | Alpine | Ultralight | Cord Technique |
| **Rope** (mm)<br>Length (m) | 11<br>250 | 9<br>210 | 8<br>210 | 8   3#<br>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**<br>**Links***| — | 5<br>16 | 5<br>16 | 5<br>$3^{Al}$   $9^{St}$ |
| 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$^{Al}$ and 6 mm steel$^{St}$ maillons for Cord technique.

# 3 mm blind cord

## Figures in brackets indicate actual 25 L sackfuls. Alpine style may need an extra sack for food, spare clothing and batteries while all others should be able to fit this into the left over space in the sacks.
IRT would not necessarily require the rope to be in sacks but would need at least one for extra items.

## Shock absorbent rigging

Caving ropes are often exposed to the risk of shock loading. What is required is a static rope and rigging that will survive shock loads and safely absorb their energy. Attempts have been made to solve the problem. One attempt was '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 dynamic rope, stretch a lot and absorb the rest of the energy. During the fall the rope would lose its static properties forever and become bouncy, an indication that it was time to throw it away.

Another possibility is to use shock absorbing slings—lengths of tape that 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 been thoroughly 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 use in caves would be uncertain.

## Shock absorbing knots

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

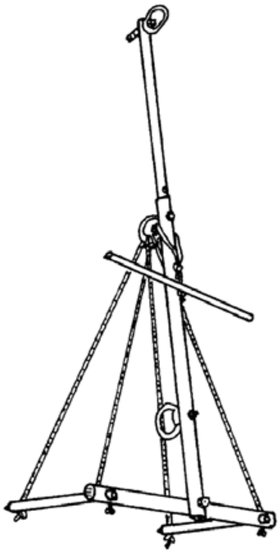
Shock absorbing knots have some chance of working in a new rope that normally fails within two FF1 80 kg falls (ie. 7 mm or some 8 mm ropes). Their performance however is so variable as to make them more dangerous than no shock absorbing knot. The only possible advantage a shock absorbing knot may give is that the extra 'end effect' created by another knot tightening may dampen the shock of the first fall and reduce the chances of your 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!

**Table 5:2** **Shock absorbing? knots**

| 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 = Bluewater II
8 = Bluewater accessory cord
7 = Beal accessory cord
In only one test (the 8 mm) out of thirteen did a Shock Absorbing Knot give a clear improvement. The 7 mm rope results are especially frightening. See also Marbach and Tourte, 2000, for a positive appraisal of Shock Absorbing Knots.

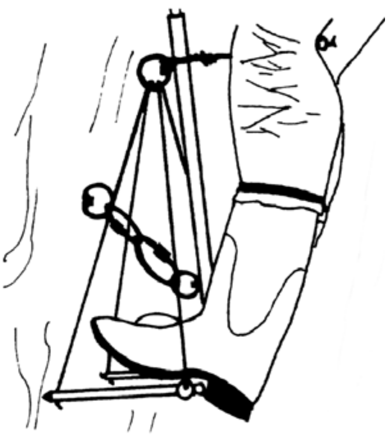
## Climbing



Climbing platform

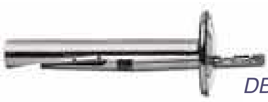
It occasionally becomes necessary to climb a pitch or wall to reach a continuation passage in a cave or for that matter an 'up' cave has to be climbed all the way. Most caving climbers use standard rockclimbing techniques and underground climbing should not be attempted without first gaining competence above ground.

Underground, climbers make extensive use of artificial aid—place more emphasis on security and less on good climbing style and ethics. The idea is not to put up a new route but rather to gain access to cave that you cannot otherwise reach. When aid climbing, make maximum use of quick anchors such as slings, nuts and pitons that may not be bombproof but will support body weight 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'. This was traditionally done by hand drilling and has been limited by the strength of the average caver's bolting arm that is only good for five to ten bolts per session. The appearance of portable battery-powered hammer drills that can place more than twenty 8 mm anchors on one battery has changed bolting tactics considerably.



In order to reduce time and battery power, half drill spits to hold body weight only and place a full depth one every fourth bolt for safety. Smaller bolts allow you to place more bolts for the same amount of energy. Six millimetre self drilling anchors are adequate if you are drilling by hand.

DBZ and concrete screw anchors can both use 6 mm holes and are fast to insert. For DBZs you'll need keyhole hangers to avoid abandoning your hangers and place a more solid anchor from time to time. Concrete screws are easy to remove, very strong, and you can remove and reuse them when you are finished. You can save further time on good rock by drilling shallow down-angled holes and using a skyhook in them to gain extra reach or for a move or two between good anchors if you are brave.



DBZ anchor

Concrete screw

## Climbing platform

For long lines of bolts a you can construct a bolting platform from aluminium tubing (Marbach and Rocourt, 1980). Such compact, collapsible platforms weigh only 1.5 kg and make it possible to stand higher than with etriers and reach 1.5 m between bolts.

## 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 height range of around 10 m under good conditions, often making a climb feasible in one hit. In narrow pitches the pole can be hauled up to the high point and used again.

Scaling poles are heavy and bulky and therefore unsuitable for use in difficult, very deep or tight caves or when a large team is not available to carry the pieces and help support the pole while the climber is ascending. It probably won't be possible to use an independent belay so the pole cannot be allowed to fail. Also consider the conservation aspect: four or five 1.5 m long aluminium pipes and their fittings can make quite a mess of a cave. Grey aluminium scrapes don't clean off easily and a large metal bar is hardly a good thing to have in a delicate cave.

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

## Mini-climbing pole

Mini-climbing pole

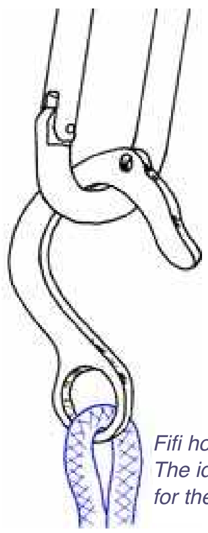
A mini-climbing pole as sold by Raumer (*Allonge Stick-up*) is an 80 cm length of aluminium tube with attachment holes at the top and bottom and a hole about 1/3 of the way along.

Attach oval karabiners to the top and bottom and preferably a fifi hook, or karabiner, to the centre hole. Hook the centre into the highest anchor and two etriers to the bottom, then climb the etriers as high as possible while using the top point for your cowstail, short chain of karabiners or tension from below. You can use the mini-climbing pole up either way—to give a little extra reach and good stability or 50 cm extra reach at the expense of some stability. What you can't do is take your weight off your etriers and sit back on you seat harness. If you try, the pole will invert.

The main advantage of the mini-climbing pole is its compactness—a few hundred grammes of pole 80 cm long is the only extra equipment you need.

Platforms and especially scaling poles, give valuable increases in reach on vertical or near vertical walls, but become unstable on overhangs. They also involve a considerable amount of extra paraphernalia that must be brought into the cave, assembled and organised and later removed. Before using one, also consider the danger of being injured in a fall while attached to a big hunk of metal.

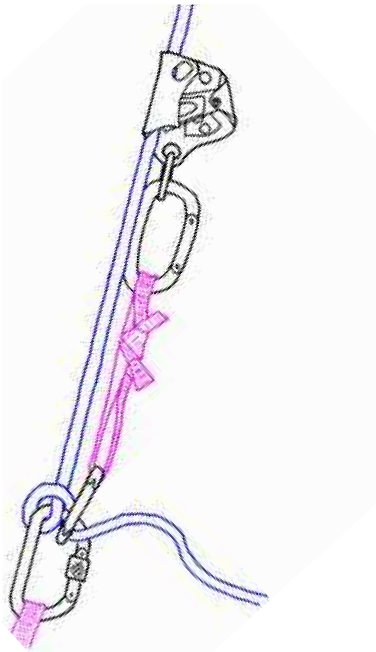
## Aid climbing


Fifi hook
The ideal attachment for the top of an etrier

On an expedition or for a short climb, slings or etriers will gain you around a metre between aid points.

A handy device for aid climbing is a 'cheat stick'. In its simplest form, this is any light stick with a rubber band or hook on the top that you can use to place a sling or skyhook onto a hold that is out of reach. Aluminium tent pole wands and ski stocks both make great cheat sticks.

The technique for aid climbing with etriers is simple but strenuous. Double ropes clipped into each anchor give much greater safety than a single rope or even a double rope clipped to alternate anchors, as they continuously provide a belay that has as little slack as possible plus a backup rope.



Belay rope locked off with an ascender

Begin by placing an anchor as high as possible and fitting it with a karabiner. Then hook an etrier and **one** rope into the karabiner and climb up until you are able to clip in a cowstail as well. Move up the other etrier to the top karabiner to provide one for each foot, then climb as high up the etriers as possible and clip yourself to the anchor with a karabiner, chain of karabiners or short cowstail, depending on the angle of the wall. Only now do you clip your second rope to the upper anchor—any earlier would have introduced excess slack into the system at the same time as you're about to weight the untested anchor for the first time. Once standing in the top of your etriers you can once again place an anchor as high as possible. When climbing with a single rope, clip it as for the second rope.

The ideal etriers are made of the lightest 25 mm tape available with four or five steps 30 cm apart at the bottom, reducing to 15 cm apart at the top. A stiffener bar keeps the steps open so you can insert your feet, and a fifi hook with haul cord allows you to easily hook and unhook the etrier by tugging the cord from the anchor above. Etriers are normally used in pairs but on difficult climbs and overhangs, a third can be handy.

Placing a bolt at arm's length above your 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 you have a number of them to place. 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.

Avoid using the belay rope for direct support. Tension from the belayer can double the loading on the top anchor, increasing its risk of failure.

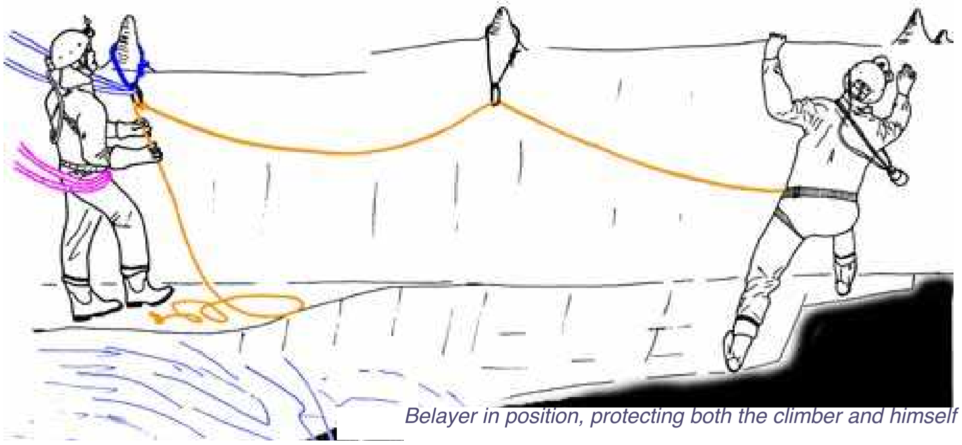
## Desperate measures

At times more desperate measures are called for. You 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 you never know exactly what you have caught until you get up there —or you pull it down!

Moving up from a jammed knot, you can use a grappling hook for getting a line across a fast flowing river or up a small pitch. Use three equally spaced small replaceable ice axe picks bolted to the end of a short handle twice the length of the picks in order for the hook to obtain a positive grip. Grappling hooks get good grip in rotten rock and have a tendency to become snagged wherever they hit, so a spare may be necessary.

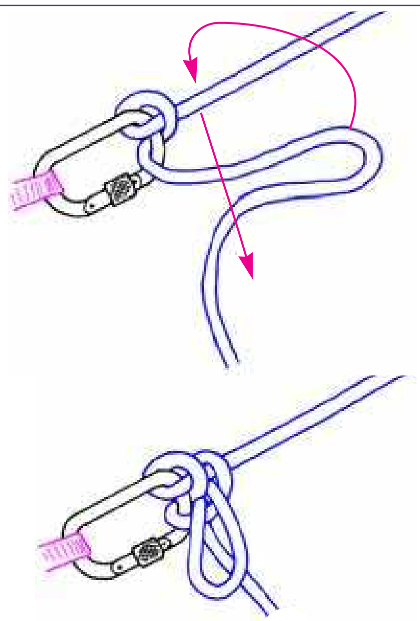
When climbing a rope whose anchors are dubious always use a separate rope with a dynamic belay and runners. Climbing with a static rope as a belay is dangerous and not recommended.

**All climbing should be done with a good belay using a proper climbing rope.**



Belayer in position, protecting both the climber and himself

## Belaying



*Locking off an Italian hitch*

Some rig points are in such precarious positions that you need a belay to place them. The chance of holding a fall using **any** body friction belay is negligible and in the fall both belayer and climber would probably be injured. **Always** belay using a well anchored Italian hitch on a locking karabiner or a Sticht plate, ATC, or similar belay device. If using double ropes, tie separate Italian hitches on separate karabiners for each, or a double Sticht plate.

When belaying anchor yourself separately from the climbing rope in a comfortable position to one side of the anchor. This allows you to escape from the belay and aid the climber in the event of a fall. Seek a position that is sheltered from both falling water and rock yet still provides a view of the climber.

Pay out the rope straight towards the climber or first runner so that in the event of a fall the rope will not be whipped sideways out of your hands.

Another approach is to tie on with no slack and to attach the belay device directly to your seat harness. This has the advantages that your body will absorb some of the shock and reducing the possibility of you losing the rope should the climber fall. It should however be weighed against the greater risk it exposes you to and the difficulty of escaping from a belay that is loaded by a fallen climber (always keep a prusik sling or ascender and sling handy).

You must wear gloves and **never** let go of the slack end of the rope unless you tie it off or the climber calls "safe". Should the climber fall and not be able to regain the rock, you must tie-off the rope or lock it with an ascender before going to his aid.

Most rockclimbing manuals contain a more detailed treatment of belaying but take care to avoid out of date books that describe body belays. Any prospective belayer is well advised to take a practise session on a drop test rig before trying the real thing.

Increase safety by using runners, a high belay and having the belay set up well back from the pitch edge. Anything that reduces the possible fall length is a help. In any case never allow the Fall Factor to approach FF1 unless a you are using a good climbing rope. If the rope is not new and less than 10 mm, use it doubled.

Using a descender as a self belay for rigging is popular and acceptable if you do it correctly. Never use an ascender to give a self belay when you are rigging – the shock load you could generate from even a short fall would be dangerous (see Strength of descenders on page 99 and Strength on page 114).

## 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 summons up enough enthusiasm to remove it.

Ropes can wear dangerously with repeated usage and floods, yet the damage may not be apparent until you use the rope. Even rigging that receives no apparent wear in the course of normal usage is suspect after five years due to the ageing of the rope, tape and anchors. 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. Don't rely on an unknown caver who may not understand what he is doing to replace a deviation or rope protector.

Back up all fixed rigging exceptionally well and make it totally abrasion free, even when using 11 mm rope. Protect potential rub points, notably those on traverse lines, with unsplit plastic hose threaded onto the rope. In popular caves use wire or steel cable for traverse lines to reduced wear.

On low-level traverses across pools it may be acceptable for a caver to cross wires attaching himself only by a steel karabiner (aluminium wears rapidly).

When the consequences of failure are more serious than a dunking in cold water belay the first person 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. Always leave one rigged for this purpose.

Bolts have their own particular problems. Self-drilling anchors were originally designed for single usage rather than the repeated use they get in popular caves. After several years the thread degrades with corrosion or wear to the point where it no longer holds and the bolt pops from the anchor under the weight of a caver. Anchors may also suffer from misuse such as cross-threading and over-tightening that can leave the anchor plugged with a sheared-off bolt stub. It is 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. Should the bolt/nut screw in very easily or with a lot of play the anchor is definitely suspect. Use it with a tight backup or not at all. If the bolt/nut jumps its threads on tightening it definitely should not be used. Greasing the anchor helps reduce corrosion on fixed anchors and bolts. The bolt (as opposed to the spit anchor) threads also wear out. Inspect them regularly for wear and damage and replace them with 8 mm, stainless steel set screws if necessary.


*12 mm Loxin with angle iron hanger*

Heavily trafficked caves can and have been equipped with heavy duty bolts and even metal bars for belays. While perhaps a little unsightly, heavy bolts are infinitely better than the 8 mm bolt farm that may otherwise appear. There are several long term possibilities: 10 mm+ self drilling anchors with stainless steel set screws and hangers, 10 mm+ stud anchors with stainless steel, angle iron or for larger studs, welded eyebolt hangers or Petzl 'longlife' anchors and hangers or double expansion stainless bolt by Fixe or Raumer. Some have the advantage that you can remove the anchor for inspection and replacement thus making the bolt last 'forever'.

The best by far are glue-in anchors. They require a 12 mm dia. x 100 mm deep hole and special epoxy. They are expensive, but very long lasting and strong, even in poor rock. More important for conservation reasons, they are easily replaced. Just heat them with a blowtorch, then put a lever through the eye and twist them out. You can then drill the glue out of the hole and glue in a new one. For more information on glue-in and other long lasting bolts, visit: www.climbinganchors.com. See also Bolts on page 34.

Never leave equipment in a cave without careful thought. Fixed equipment may 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 that is neither dangerous to others nor junk that 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 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 ropes it may become necessary to break the ice crust off a rope before being able to use it.

## Pull-down rigging

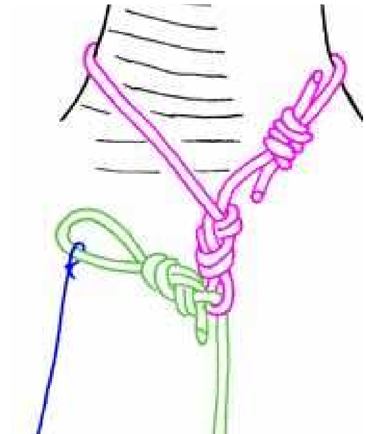
Through trips done *en rappel,* or derigging a rope from a climb to leave behind a minimum of gear are special cases in vertical caving. A through trip is easier if the cave has already been rigged with eyebolts or steel rings. If not, you can leave double ring hangers or backed-up slings on natural anchors. To rig 'on the cheap', tie light cord or tape hero loops to 2 cm long bolts (no hangers). You will usually need slings for pull-downs from natural anchors so as to reduce friction.

Try to use a thicker rope than usual on through trips. You need far less rope than for a normal trip but it will get considerably more wear with the repeated use. The rope must be twice as long as the longest pitch and you can knot two equal lengths rather than carry a double length rope. For safety it is a good idea to carry extra rope or cord so that if the rope becomes stuck you can continue your descent. Once you've pulled that first rope there is no turning back!

Observe standard rigging safety precautions such as double anchors and avoiding abrasion points, although you can tolerate slight abrasion for a single descent. Rig so that you can pull the rope down with little risk of it jamming as it falls down the pitch and 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 pulling it down and be sure to pull on the correct rope! Never climb a jammed rope as it may suddenly unjam with a climber on it.

Most bobbins only work on single rope (see Descenders — bobbins on page 92). Use a rack or double bobbin for double rope descents. Figure-8 descenders can also be used but they may twist the rope and make the pull-down difficult.

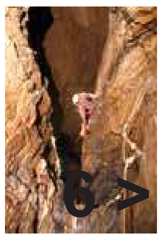
## Cordelette style


*'Double roping', Cordelette style*

Fix a single rope with a jammed knot at the top just as you would do for the Cord Technique. Retrieve the rope using 3 mm cord or a collection of shorter ropes and slings. There is no need for a special Cord Technique tail on the rope unless you intend leaving a string in place but you still need some means of jamming the knot at the top. 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.

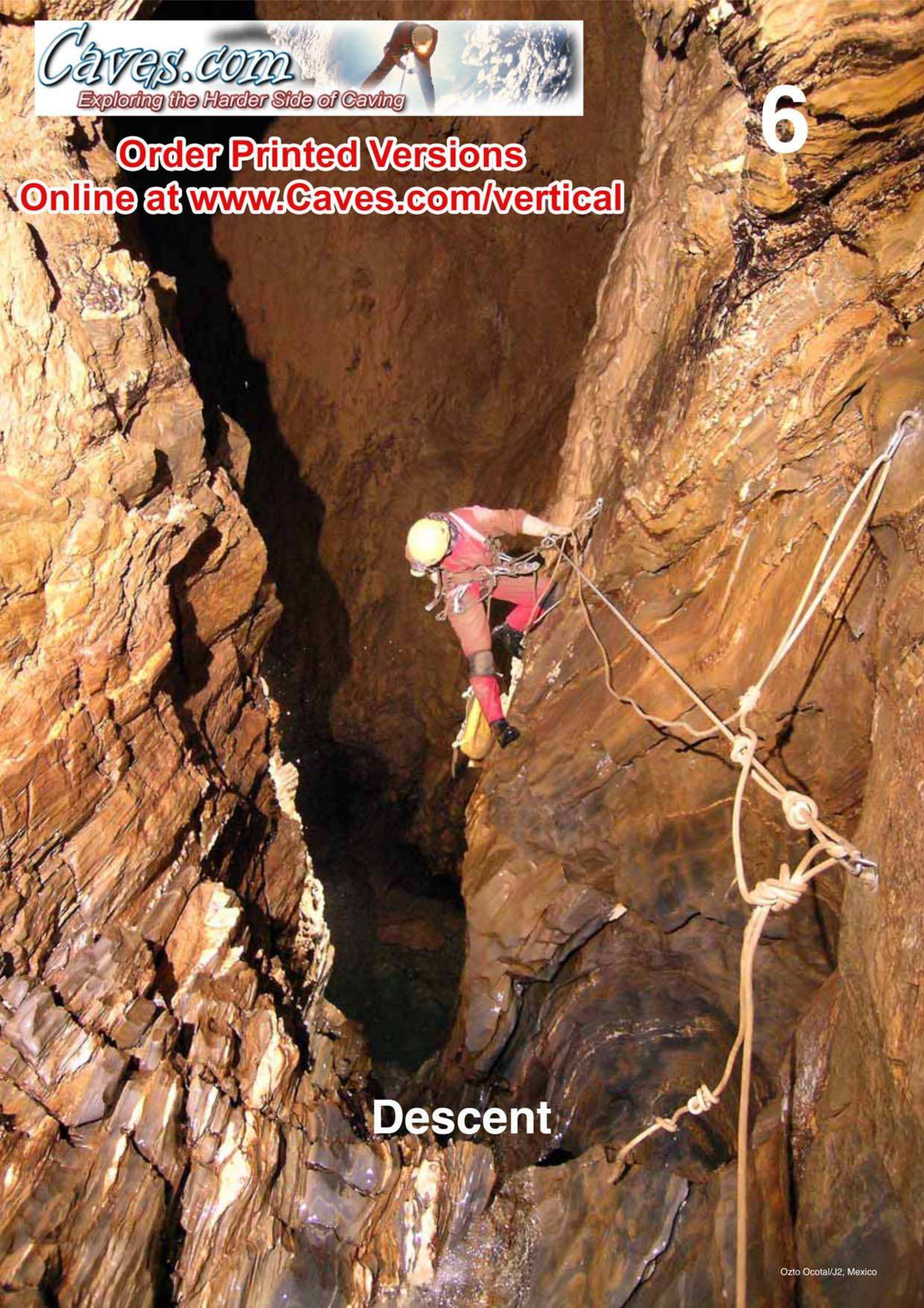
Decrocheurs are mechanical devices that allow you to unhook the descent rope from the belay once you have reached the bottom of the pitch. None of them offer any advantages over a cordelette style pull-down.


*Single rope descender (Petzl Stop) on one strand of a 'double' rope held in place by a stopper knot.*

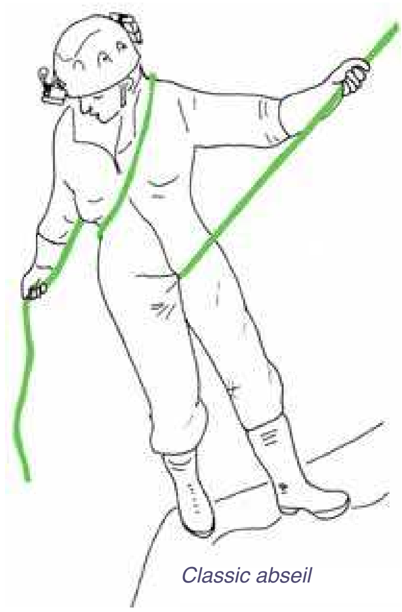


# 6

# Descent



Ozto Ocotal/J2, Mexico



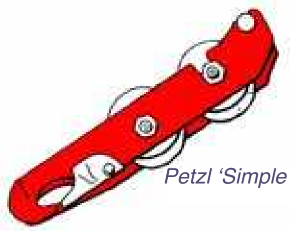
Classic abseil

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

A more comfortable classic abseil runs the rope straight across your 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.

Shoulder abseil

## Descenders — bobbins



Petzl 'Simple'

Petzl 'Stop'

SRTE descender

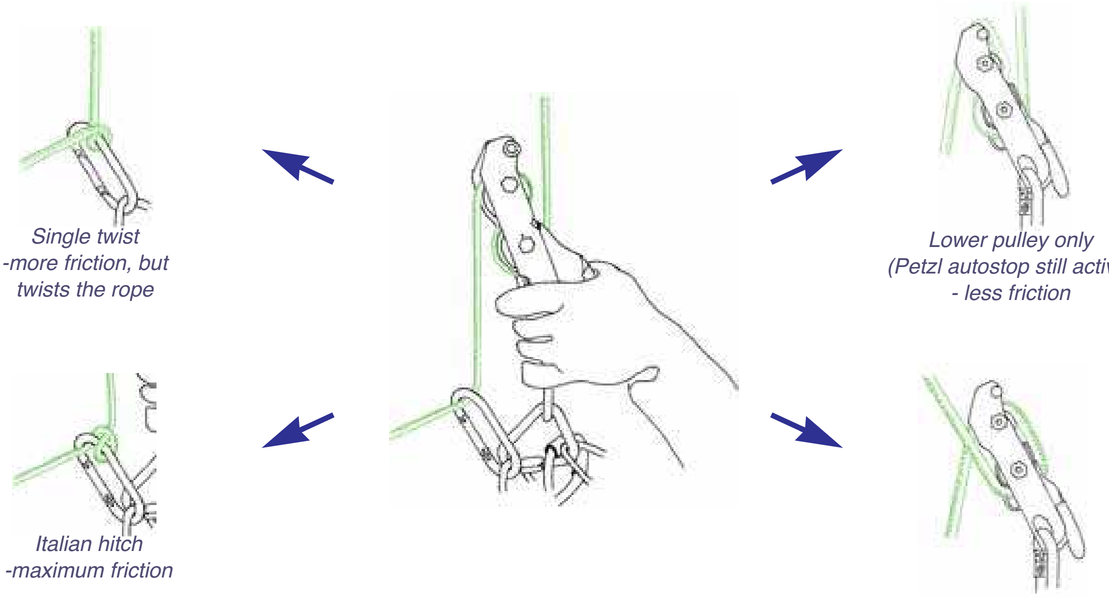
All bobbins work on the same principle. Open the descender by rotating a moveable plate (like operating a pair of scissors). Thread the rope under the bottom pulley, through a tight 'S' bend between two pulleys fixed to a plate and exit at the top of the device on the other side. The rear plate has the pulleys bolted to it and an oval hole to attach the bobbin to your seat maillon with a locking karabiner. The front (moveable) plate has a spring loaded gate that allows the bobbin to be opened quickly with no risk of dropping it. Once the top plate is closed again the rope cannot escape. The pulleys are made of either aluminium or stainless steel.

Control your descent by varying the tension on the rope on the lower side of the bobbin. Use a Brake karabiner attached to your seat maillon and clipped onto the rope below the descender to add extra friction and allow you to hold the rope at a more comfortable angle. Control your descent rate by lifting or lowering the rope to change its bend through the brake karabiner. This gives much better control than squeezing the rope or passing it over your hip.

Should the rope be too fast, use an Italian hitch, or the first turn of one, on the brake karabiner. Should the bobbin run too slowly, only engage the lower pulley or thread the rope backwards in a 'C'. Depending on the descender, reduced friction configurations may disable the autostop ability of the descender. Some models allow you to pull a flexible rope backwards through the descender, a handy feature when crossing rebelays and for rigging.

Bobbins are not variable friction devices but they do work well over a wide range of ropes and rope weights, being best on ropes 10 mm or less and pitches shorter than 50 m (though you can safely use one on any pitch). At first a bobbin may seem fast and uncontrollable but with practice you can go fast or slow with ease without adjusting the device.

**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, and the softer the rope, the faster this happens.



*Single twist -more friction, but twists the rope*

*Lower pulley only (Petzl autostop still active) - less friction*

*Italian hitch -maximum friction*

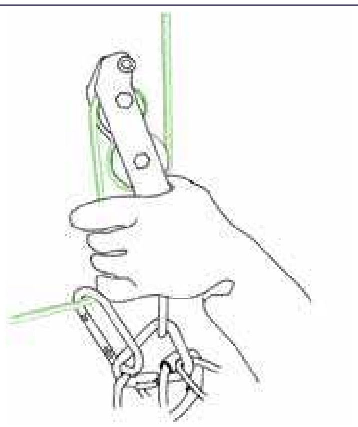
*'C' threaded bobbin (autostop inactive) - minimum friction*

*Extra friction*

*Reduced friction*

## Simple bobbin

A simple bobbin is just that – simple. Two fixed aluminium pulleys bolted between aluminium plates.



*Simple bobbin – without a brake handle you can hold it so that it stops with a single squeeze*

## Autostop bobbins

Take the essentials of a simple bobbin and add a camming action to pinch the rope and a handle to control it and you have the best descender so far invented. To 'go', squeeze the handle and control the rope as for a simple bobbin. If you release the handle you stop automatically. The 'stop' handle is just that. Use it as a stop or go lever while maintaining control with your 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. You can use an autostop that allows you to pull the rope backwards through it as a tolerable ascender. Another desirable feature is some means of disabling the stop action. This typically takes the form of an eye through which you can clip a karabiner.

If you intend to hang around 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.

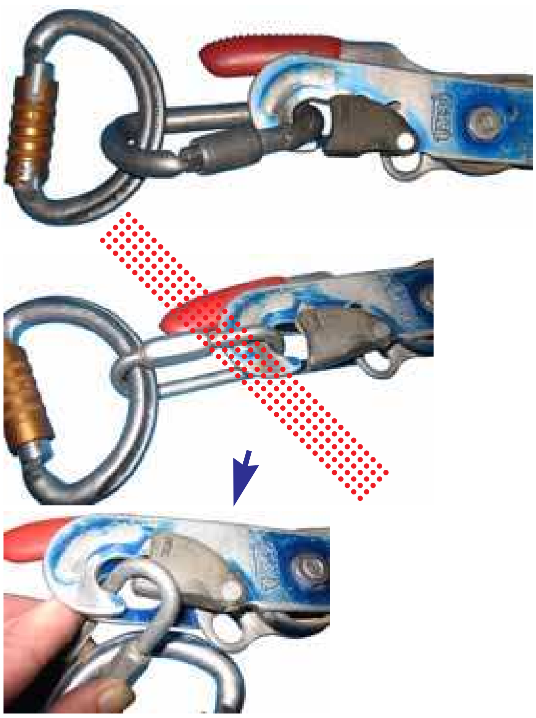
Once you've seriously used an autostop it is difficult to settle for another descender. Safety at pitch tops and rebelays is vastly superior to **any** other descender and the ability to stop easily, exactly where you need to, is a tremendous aid when rigging.

## Brake karabiner

It doesn't matter what type of bobbin you use, you also need a brake krab. Any karabiner will work, but steel lasts longer. You can save a little weight and use titanium or a little more weight and use aluminium, but expect to have to replace it often. You may occasionally use your brake krab for life support functions—I leave mine clipped in for crossing rebelays—so make sure it's a good one. It can be difficult to find a steel karabiner that doesn't have a nasty claw on the gate, Kong makes one. A non-locking karabiner is better although French cavers are very attached to their steel oval Simond locking karabiners.

The Raumer Handy is a specialised stainless steel brake karabiner. It is narrow enough to stop it getting caught over the end of your bobbin (See Top of bobbin in brake krab on page 106). The tapered shape is designed to offer extra friction for 8 mm to 11 mm ropes, and while this works, it also makes for a jerky descent at times. They are expensive but just one is likely to last you forever.

## Attachment & orientation



*Use a real karabiner, preferably a thick one.*
*It is surprisingly easy to undo a bobbin with a thin attachment link*

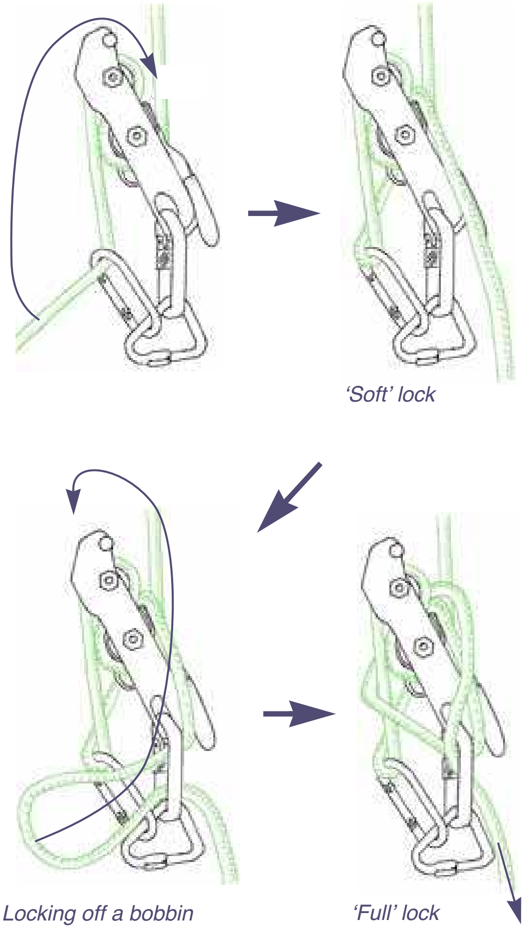
Attach a bobbin to your seat maillon by a locking karabiner so that it sits with the moveable plate upwards. This allows you to easily clip it on or off the rope. Use a locking karabiner made of about 12 mm rod—thicker than usual. A karabiner such as the Petzl Attache is ideal. The thicker karabiner avoids the possibility of un-clipping the bobbin's gate by twisting the karabiner against it. I doubt that this has ever actually happened, but it is a theoretical possibility that you can easily avoid. It is surprisingly easy to do with a 7 mm maillon. Remember also that like your seat maillon, this karabiner as no backup.

The rope enters on the top right and exits on the lower left (if you are left handed, you may find it easier to have the moveable plate facing down and control with you left hand).

## Wear

Replace the solid aluminium pulley when it wears down to its securing bolt. On simple bobbins you can invert the pulleys when one side wears out but on autostops the pulleys are asymmetric and you must discard them when worn. An aluminium pulley that has been deeply grooved with an 8 mm rope may jam with a thicker rope. Stainless steel pulleys are hard-wearing. The lower one on a Petzl Stop usually outlives four or five top pulleys but can last as long as nine aluminium top pulleys. They fail 'gently with a small hole appearing at the bottom where the smooth curve become flat. On extended trips or expeditions it is worth taking along one or two spare aluminium pulleys to leave in camp until you need one.

## Locking off



*'Soft' lock*

*Locking off a bobbin*

*'Full' lock*

It often becomes necessary to 'lock' a bobbin so as to safely free your hands for other manoeuvres. Once you release the handle of your autostop descender it is locked-off —but not always convincingly. Bump or lean against the handle on an awkward move and you're on your way again. For simple things like reaching for a deviation or clipping a rebelay, the autostop action is fine. For anything more complex, some type of lock is necessary.

### Soft lock

- Lift the free end of the rope below your brake karabiner and drop it over the top of your descender. This adds a little more security for an autostop, but is inadequate for a simple bobbin and will drop off either descender if you stand up on a ledge.

### Full lock

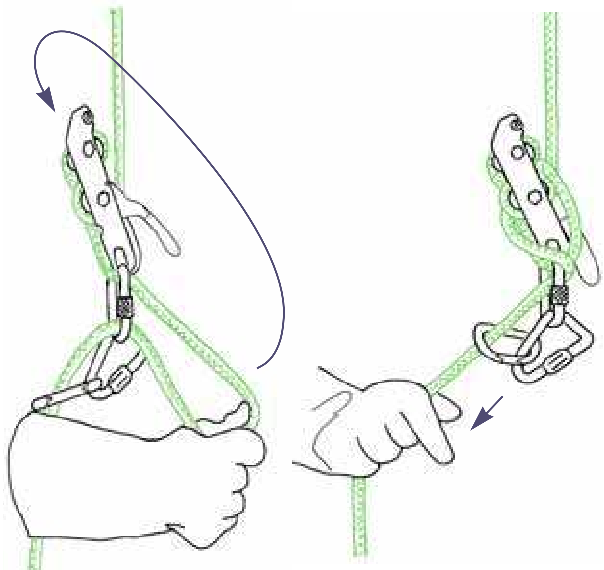
- From the soft lock position, pass a loop of rope through the linking karabiner that attaches your bobbin.
- Take a loop of rope from between the bobbin and the brake karabiner and pass it through the descender's linking karabiner.
- Loop the rope over the top of the descender and pull down tight to provide a firm lock that has no tendency to come undone.

### Unlock

- Loosen the loop around the descender and take it back over the top of the descender
- Clasp the bobbin and rope to keep the soft lock secure.
- Pop off the soft lock and continue.

### Autostop lock

- An autostop has an inherent soft lock so you can dispense with making a soft lock and pass the rope loop directly through the attachment karabiner to give just as good a full lock. You can also do this on a simple bobbin but holding the rope while making the lock is more difficult.

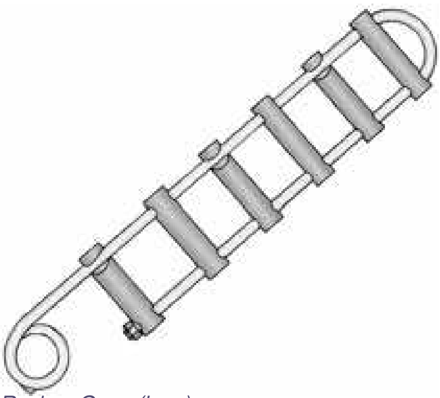


*Locking off an autostop bobbin*

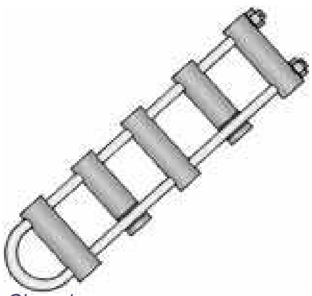
### Unlock

- Pull up a little slack from below and take the loop back over the top of the descender.
- If you're using a simple bobbin or the rope is excessively slippery, clasp your left hand tightly around the bobbin and down rope.
- Pull the slack out of the system and continue.

## Racks



Racks - Open (long)



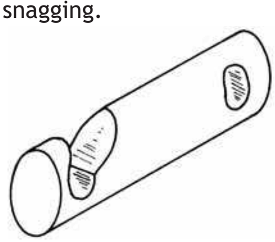
Closed

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 best on long uncomplicated drops. The price paid for versatility is that of a bulky, heavy device that is clumsy and slow to get 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 guaranteed to remove your kneecaps!

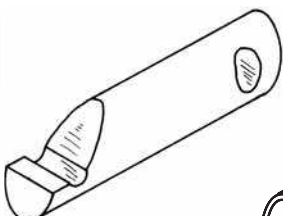
Load a rack by weaving the rope between a series of bars, usually five, some or all of which hinge open to allow you to insert the rope. Vary friction by threading the rope between different numbers of bars, and sliding the bars up or down the rack. Pushing the bars up the rack increases the bend in the rope and the amount of bar/rope contact to increase friction, while spreading bars down the rack decreases friction. When descending heavy ropes you can use as few as three bars spread the full length of the rack, thus giving the rope only a slight bend. During the descent 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 solid aluminium or steel tube. Either type wear rapidly on dirty rope so be sure suitably sized replacement bars are available when buying a rack. Bars are easy to make in a home workshop.

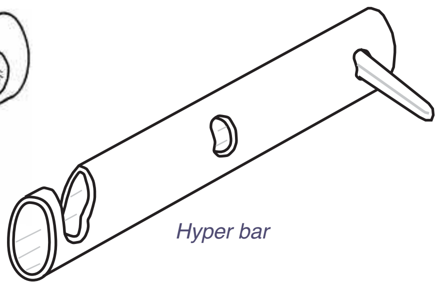
A hyper bar is normally a non-opening top bar nearly twice as long as a normal bar with the extra hanging out to one side—usually to the right. It has an upward pointing pin towards the outer end. The idea is that you can quickly pop the rope over it to provide extra friction and/or as a simple soft lock. It also makes the rack somewhat more ungainly and prone to snagging.



Rack bars - Clip closed



Safety



Hyper bar

## Open-ended rack

The standard rack is a long inverted 'U' of 10 mm (3/8 inch) stainless steel rod with an attachment eye bent into one end of the 'U' and the other end left open to allow you to insert the rope. The frame is springy with the bars 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 angled 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 you are not using it.

You can thread rack bars onto either the long or short arm of the rack. Using the long arm, you can drop the bottom bar 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 (and lose).

When you are loading the rope into a rack take care not to load it backwards. Your body weight, will force the bars open leaving the rack (and you) 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. Always wear the rack the same way to get into the habit of loading it correctly each time.

### Closed rack

A closed rack is 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 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 opening.

Load a closed rack by passing a rope loop between bars one and three and then closing the second bar through the loop. When you need more friction, you can also load bar four in the same manner. Their design allows them to be lighter and smaller than an open rack but this is at the expense of frictional variability that is not as good as for an open rack. While it is possible to remove a bar during descent it is much more difficult to add one – the opposite of what you normally require!

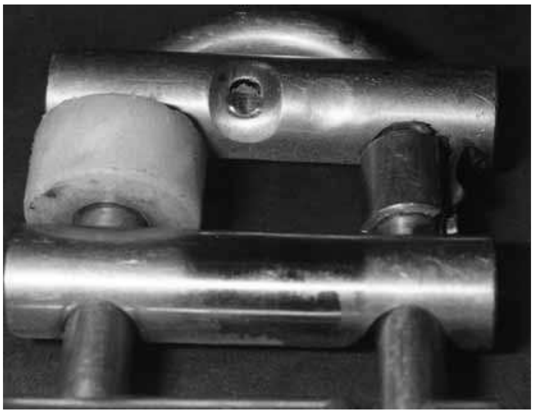
The homemade 'SupeRack' is specifically for long pitches. This extra long closed rack has heavy, square, heat-sink aluminium bars and virtually all its control is obtained by jamming the bars together or moving them apart to suit. Control at the bottom of pitches is very difficult.

Because racks are easy to make in a home workshop there is a huge variety available.

### Attachment & orientation

The orientation of a rack is a matter of personal preference. An open rack is easier to load when the open side is on the right for right-handed cavers. A link between the rack and your seat maillon makes the rack manoeuvrable although a long rack may then reach above head high and so increase the risk of catching your hair or beard in it (if you're wearing one). For this reason and to stop them from swinging about so much, many cavers clip their rack directly to their seat maillon. This is inconvenient if not painful in crawls and awkward passages between pitches so many rack users use an attachment karabiner or maillon. The karabiner is easier and faster but may turn sideways and load the gate while a 7 mm to 10 mm maillon is usually regarded as more secure, if not so convenient.

### Wear



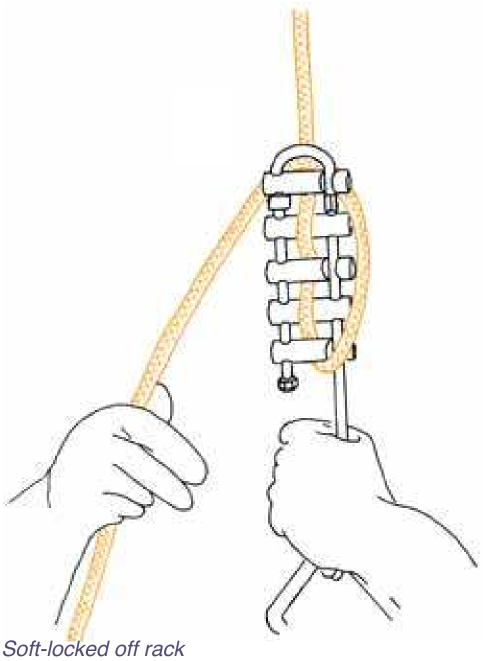
*Rack spacer and worn hollow brake bar*

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 mounting holes and slots and will not damage the rack frame. To keep the rope centred use 'trainer' bars or file a small groove in the top two bars. Steel bars need a wide spacer between the top two bars to give the same result as you cannot effectively groove them. 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.

Replace solid bars when they begin to pinch the rope and stop it running well – about a third to half worn through. Replace hollow bars when the rope groove wears a hole through the wall of the bar. Before this happens swap the bars 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 you may need spare bars plus a spanner to change them for a descent of a deep muddy cave.

## Locking off



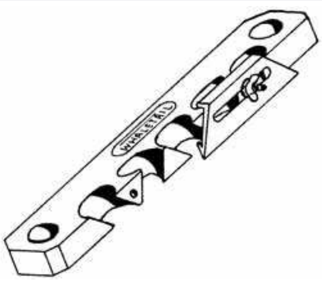
Soft-locked off rack

Make a soft lock 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 you remove the tension from the rack by standing on a ledge or crossing a rebelay etc. the rope will drop off. To obtain a more secure lock for open racks, push up all but the bottom bar, put the rope over the top of the rack and then clip it in place using the free bottom bar. Another alternative is to put the rope over the top 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.

*"When they made us stop using wire cables and use nylon rope instead, I tried a bobbin, but I didn't like it, so I went back to the rack."* — Ilia Zharkov


6 mm steel cable —where only a rack will do

## Whaletail




Other - Spelean whaletail

A whaletail is a cast or machined block of aluminium with a series of overlapping wedge-shaped pegs down one edge that give the descender its name. The rope weaves between the pegs so that the whale's tails hold it in place with a sliding gate at the top for security. Vary friction 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 the block of aluminium provides. 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. Considering their disadvantages (weight, ease of reverse loading, non-replaceable wear surfaces, lack of versatility), I'm amazed that anyone still uses them, but apparently some rescue groups still use them for lowering.

## Figure-8

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 you to load and unload the descender without unclipping it. 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.

**Table 6:1** **Some common descenders**

| 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 |
| **SRTE** single<br>double | 460<br>525 | 23<br>23 | yes<br>yes | 9 to 12<br>9 to 12 | <50<br><50 |
| **Bluewater** Rack (long)<br>(short) | 700<br>600 | 35<br>30 | yes<br>yes | 7 to 13<br>7 to 13 | >50<br>10 to 100 |
| **Petzl** Rack | 475 | 30.5 | yes | 7 to 10 | 10 to 100 |
| Closed Rack | 280 to 500 | 20+ | usually | 10 to 13 | <50 (small models) |
| **Spelean** Whaletail | 550 | 30 | no but can change ends | 10 to 13 | <100 |
| Figure-8 | 100 to 300 | 14+ | no | 10 to 13 | <50 |

## 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 mean that under FF1 tests, neither descender nor rope is normally damaged.

When locked-off or jammed hard against a stopper knot, autostops are as strong as any other bobbin. However, if allowed to slide uncontrolled for two or more metres from an anchor then stopped suddenly by releasing the handle they will probably damage the rope by partially cutting or lightly melting the sheath. Autostops that jam the rope at the top of the upper pulley (SRTE, Bonaiti) instead of between the two pulleys (Petzl, Dad) are less brutal on the rope. It is, however, 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, cutting the rope with an autostop has never happened as far as I know.

Some open ended racks begin to unwind their attachment eye at surprisingly low loads (as low as 250 kg!) and even locked-off you could not rely on one to survive a shock load. Racks with welded eyes are obviously better. Closed racks are much stronger, some models testing in excess of 2000 kg. Descenders are very useful as self belays when rigging. Do so with safety in mind by keeping your 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 your potential fall factor low. Provided you never climb 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 is unlikely to harm the descender but the consequences for you may not be as good. On long or difficult traverses it is better to set up a real belay using runners and save the descender for descending (see Belaying on page 88).

While generally safe against breaking, you can damage most descenders by using them 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. It is easy to badly bend the fixed plate on most bobbins if you weight the descender while its moveable plate is open. This is most likely to happen when you're trying to unclip from a tight diagonal rope.

## Shunts

Shunts were originally conceived as 'deadman' safety devices for abseiling. Attach one to your seat maillon with an arm's length or shorter sling. You must hold it open to descend. If you release the shunt it will hold and allow you to hang there for rigging or save you from falling should you 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 is not much use 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. A shunt provides a little extra safety at rebelays if you cross the shunt first and then don't grip it until you are safely hanging from your descender again.

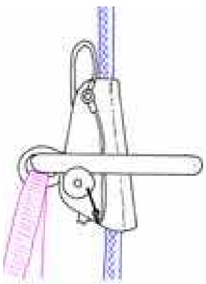
The potential safety advantages of using a shunt can be weighted against the potential danger of triggering your shunt in an awkward or dangerous situation such as a squeeze amongst water, and being unable to easily release it.

For the price of extra weight and loss of usability, Bonaiti, Petzl, SRT Equipment (Aust) and Gemlok (UK) make autostop descenders that apply the brakes when you squeeze the 'go' lever too hard, as well as when you let go.

### Petzl shunt

The Petzl Shunt works on single or 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 you hold it open to descend and thus it would be almost impossible to release in an emergency. The Petzl Shunt is still popular amongst some groups of cavers who train beginners to use one at all times while descending in what I believe is a mistaken belief that a Stop is dangerous and should only be used by experts.

### Spelean (Gibbs) shunt



You can arrange a Gibbs ascender and a large karabiner or specially fabricated bar and pin to make a shunt for single rope. It has the advantage that you can rig it with a short sling to your seat harness through a chest harness. The shunt sits on top of your descender and slides down the rope by itself. You trigger it by leaning back instead of letting go. However it only works comfortably with long descenders such as racks or whaletails and only then if you remember to lean back at the right time. It is slow and fiddly to set up and as such is usable on the occasional simple pitch but is not useful for multipitch alpine caving.

### Prusik knot shunt

Tie a prusik knot on a sling above your descender when you need a psychological shunt. A good knot will hold well under static and shock loads but if you load it while the you're moving or holding it, the knot can slip and melt the prusik sling. Once loaded it may be impossible to unload a tight prusik knot without a separate stand-in loop. A variation is the 'French Wrap'. It uses a prusik or similar knot on a very short sling tied below your descender and attached to a specially sewn eye on the legloop of your seat harness. Unlike a shunt, it puts enough tension on the rope to stop your descender and you can restart easily. The prospect of untieing and retieing your French Wrap everytime you pass a rebelay makes it unfeasible for any serious Alpine-rigged cave.

## The descent

In caving, abseiling is a means of descending a pitch, and should be done carefully and in complete control. Going too fast risks you smashing into walls and projections, puts melt marks on the rope and causes a shock load when you stop suddenly. When abseiling in a cave, keep a cowstail ready and prusik gear attached to you ready for use.

## At the top

Before clipping on check the rigging, no matter who rigged it – gurus can make mistakes too! Make sure the rope is in good condition, all slings and nuts are in place, bolt hangers tight and pegs are firm.

Pitches with insecure starts must have a back-tie or traverse line installed so you can clip in with a cowstail while still safely back from the edge. When attaching any descender to the rope, clip in too much friction, then release an appropriate amount when you're ready to start down. On difficult, awkward or swing-out starts it is also advisable to lock-off non-autostop descenders. When you are all connected and checked, **ease** onto the rope to avoid a shock load close to the anchors, and start down.

## On the way down—deviations (redirections)

The ideal deviation is one where you unload the sling by putting your feet on the wall and pushing out slightly.

Passing is then simple:

- Descend right to the deviation karabiner, perhaps pushing it down a little.
- Undo the deviation and clip it above your descender.
- You will usually do this operation with one hand so that there is no need to lock-off your descender.

Occasionally you must pass a deviation in space with no wall close enough to push off from. In this case descend until your descender is about 30 cm below the level of the deviation karabiner if its sling had remained horizontal. Lock-off your descender to allow you to spring out and grab the sling with one hand and clip the karabiner past with the other.

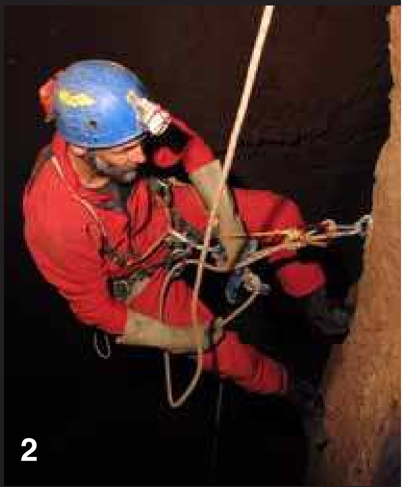
If a deviation is extra difficult clip it with a cowstail so as not to drop it or swing away.

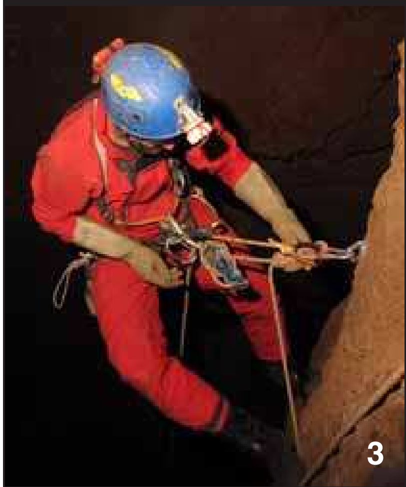
**Never cross a deviation as a rebelay.**

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

Ozto Ocotal/J2, Mexico

## Rebelays





With practise, crossing a rebelay becomes easy and fast.

1. Descend until you are level with the anchor and clip your short cowstail, to its karabiner (or maillon) in front of the rope.

- Descend **gently** until your cowstail takes up.

- Release the rope from your descender, but not your brake karabiner.

2. Still keeping your descender behind your cowstail, put the released rope to one side and thread your descender as high as possible onto the downward rope.

- Unclip your brake karabiner from the upper rope and clip it to the down rope.

3. Lock your descender (optional for autostop).

- Check your descender.

**If your descender is not attached correctly the next step could leave you COMPLETELY unattached**

4. Stand up on a ledge or put your foot or knee in the loop of rope from above and unclip your cowstail.

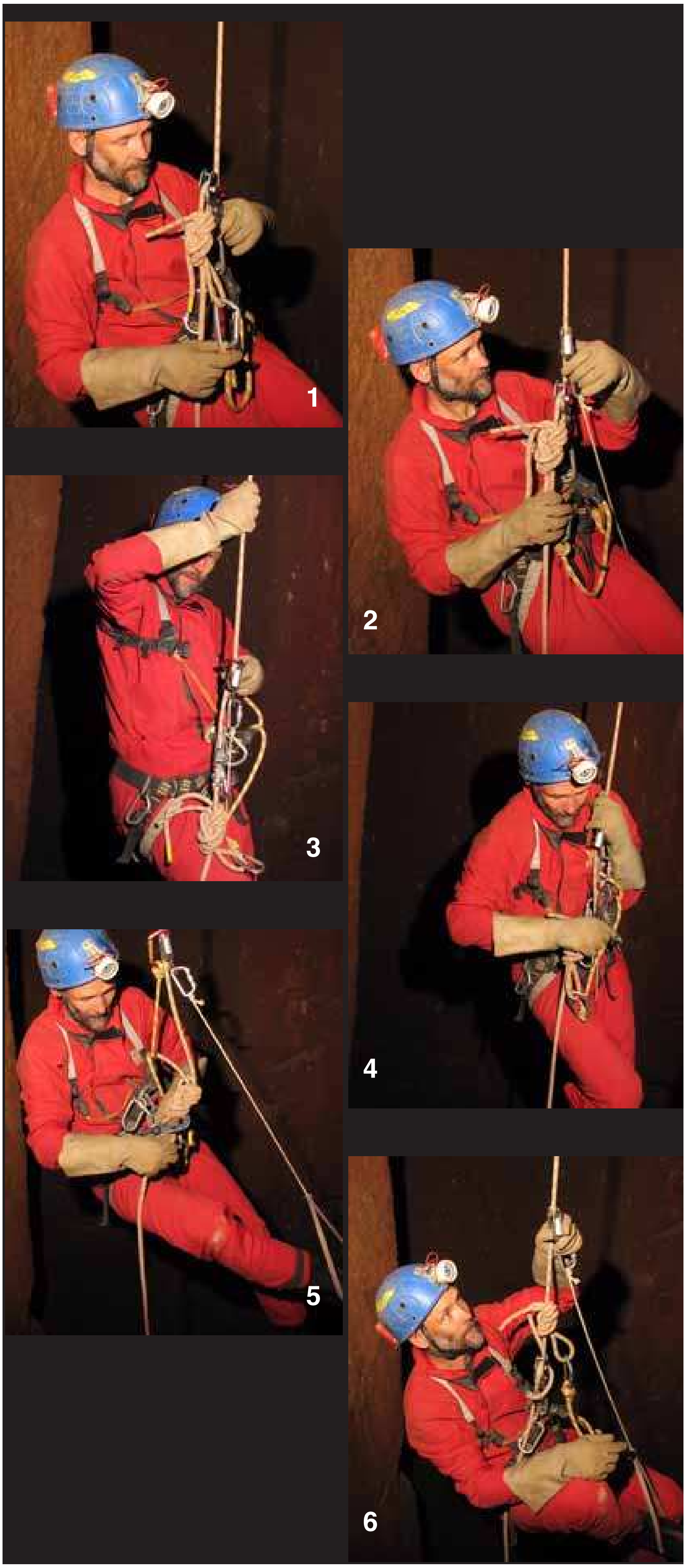
    - An alternative here is to attach your foot ascender to the down rope as high as possible below the knot immediately after you attach your short cowstail. Change your descender as normal. Use your footloop as a stand-in (especially useful with a heavy load), and sit back onto your descender. Remove your ascender only when you are secure and ready to continue.

5. Sit back on your descender, unlock.

6. Continue your descent.

If the loop is too long, reposition the rebelay knot or tie a Figure-9 loop to shorten it. When the rebelay involves a pendulum to reach it, descend to just below the level of the anchor, lock your descender (optional for autostop), to free both hands, then swing across and clip in (see Rebelays on page 60).

## Knots




On a pitch where a single rope is too short, 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. You will need a long leg-loop to an upper ascender (see Frog system on page 119 or *Mitchell system on page 123*), and a cowstail.

1. Descend until the knot is about 5 cm below your descender.

- Clip your long cowstail to the Figure-8 eye that is **always** hanging out of the knot (see page 46).

2. Attach your ascender just above your descender so that when you stand in the long leg-loop you unweight your descender.
3. Stand and clip your short cowstail to the rope above your ascender.
4. Still standing, undo your descender from the rope.
5. Sit back onto your short cowstail and at your leisure reattach your descender as close below the knot as possible. If the descender is not an autostop lock it off.

- Stand in your leg-loop and unclip your short cowstail.

6. Sit onto your descender and unclip your ascender.

- Remove your long cowstail.
- Descend to the next knot.

It is easier to have no safety cord attached to your 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 to release the rope from of the descender.

Many cavers are not so strong and to reduce the effort required you can pass a knot with both ascenders:

- Attach both ascenders to the rope close above your descender.
- Release your descender
- Re-attach your descender as high as possible below the knot and lock it off
- Move your descenders down to just above the knot
- Remove your Croll
- Sit back onto your descender
- Remove your upper ascender
- Continue your descent.

While the movements are no more strenuous than prusiking this second method is slower and more complex than the first.

Prusik systems that do not allow you to weight a high ascender with a long leg-loop (Texas system on page 120, *3 Gibbs ropewalker on page 121*) make crossing knots almost impossible. The difficulty lies in **un**weighting your top ascender so that you can **re**weight your descender. The easiest escape is to carry a spare ascender with a long stand-in sling for crossing knots. 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, 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. If you use a bobbin you will have to haul yourself down the rope with both hands for a large part of the way and disable your autostop in order to use both hands. Reduce friction by not using a brake karabiner but have it ready to clip in before you need it.

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 you must be extra careful, spread the bars slowly until you begin 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 stay in control.

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

Alpine technique treats it as a normal pitch except that perhaps you will use a double anchor 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 IRT 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 ascender and replace it above him. The reverse of this is done on the way up.
- Rig a tail with a knot in its end over the edge from separate anchors beside the main rope (see Pitch Edges on page 72 for details). Descending cavers drop over the edge on the short rope and change over to the main rope for the descent. Taking the idea a step further you can use a tail 50 m to 100 m long. This allows cavers to swap ropes in 'mid-flight', allowing two cavers to descend simultaneously.

Rope protection must be infallible on long drops. The best solution is to rig so that you need none but if you can't, use rope transport sacks, possibly with a foam pad inside them.

The longest **free** pitch found in a cave to date is 333 m into El Sótano de las Golondrinas and cavers regularly descend it using normal caving techniques, as have all the deep pits in Velebit.

Ultra-specialised equipment such as '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 your 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 you spit on it, slow down, but do not stop. Be careful not to catch your 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. Remember that there will be several metres of stretch at the bottom of 150+ m of rope. The first person down should be careful that the end of the rope does not recoil out of reach once it is unweighted. Always give inexperienced or nervous cavers a 'bottom belay' provided you can arrange it safely.

## Rope protectors

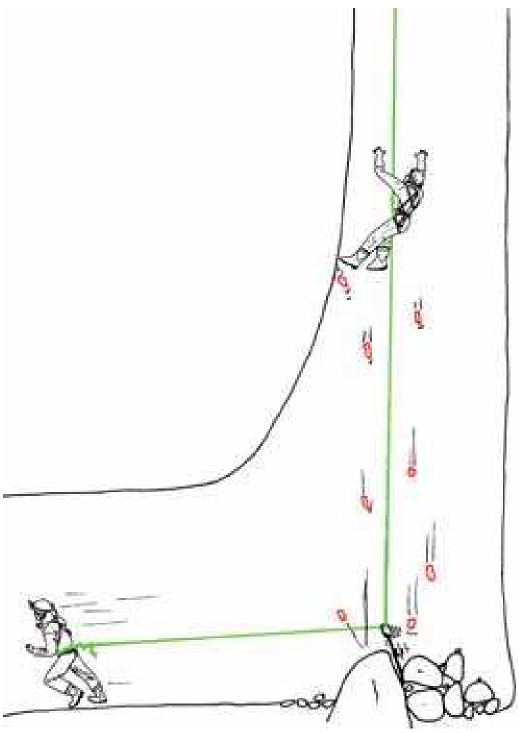
Flat rope pads are easy to pass. They rarely need to be tied to the rope and it is a simple matter of making sure that the rope is replaced after you pass them. It is an even simpler matter to create sideways movement and displace the rope off the pad once you pass one.

Cross Wrap-around rope protectors by descending to just above the protector, locking-off, removing the protector completely from the rope and putting it back on the rope above. Continue to just below the rub point, sliding the protector down with one hand on the way. After locking-off again tie the protector in place being careful to replace it correctly.

Often the protector will be so near to the anchor that you can remove or push it up enough to clip on below it without having to remove it completely.

It is a good habit to check the rope whenever you encounter a protector as they are never 100% reliable.

## Bottom belays



Bottom belay

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. Bottom belay cavers lacking confidence or experience by stationing someone at the bottom who hauls on the rope and thus stops the person above if the need arises. This works fine 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 rig a pulley or karabiner on a sling 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.

## 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 an unprepared caver may become stuck in a loop of tight rope. To avoid this, unclip your 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.

## Narrow pitches

With gravity to help, narrow pitches are rarely a problem on descent but at times they can be so tight that there is not enough room for you and your descender to fit at the same time. One solution to the problem is to clip your descender to the end of a cowstail and let it ride above head level. Disable your autostop and adjust its friction so that the descender will run without further adjustment while you are negotiating the squeeze.

## Pitch edges

Pitches that 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 your feet against the wall. Most bad edges are primarily due to bad rigging – go back to 4 Rigging!

## At the bottom

Is it really the bottom or just a ledge? Tie all the ropes in your sack end to end to avoid tying knots while you're hanging in space. Before leaving, look back up to make sure the rope is not caught behind a flake or knob. Check that the stopper knot is still intact and the rope end is bundled off the ground (page 129), then call "rope free" and move away – or move clear first if there is risk of loose rock above.

## Descent problems – lack of control

Wrap the rope once or twice around one leg to add friction. If this gives the required security, continue. Otherwise, with the rope securely around your leg, tie an Italian hitch on your brake karabiner – this will give sufficient friction with any descender. Use a Soft lock on page 95 to maintain control while you're tying the hitch. It is still necessary to maintain a hold on the rope but such a lock provides enough quick friction to stop and tie an Italian hitch. An Italian hitch will twist your rope badly.

## Autostop doesn't

Few autostop descenders are 100% effective on all ropes. You must always 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. Forcing the stop handle may work but the stop achieved is tenuous at best. Sometimes all you need is a new top pulley. Even when an autostop does not work perfectly it still gives some 'autobrake' action and at worst will function as a normal descender.

## Top of bobbin in brake krab

If you severely weight the down-rope below your bobbin it can invert and catch in your brake karabiner. This can result in an unexpected and dangerous loss of friction from your brake krab. Every time that you move up to remove your cowstail when you cross a rebelay your bobbin has a tendency to invert, as it may also do when you use any of the friction hitches in Extra friction. The horizontal bobbin is more alarming than dangerous—it can look like you're hanging on that tiny plastic gate.

There are several possible solutions to this:

- Use a Stop.
  It may still get caught, but the Stop action still works, just stand up again to free it.
- Use a Raumer Handy.
  It is too narrow to allow the end of your bobbin to enter, but expect a jerkier ride as the rope grabs in the Handy's V-notch
- Clip your brake krab into your bobbin's attachment krab instead of your seat maillon.
  As the bobbin and the brake krab are now clipped to the same point there is no bobbin pivoting action possible, but you can wear a groove in the side plate of your bobbin.

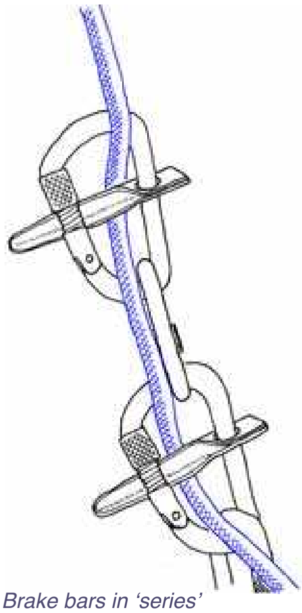
Midnight Hole, Australia

- Use a Petzl Freino to attach your bobbin.
  It has a built-in brake but may also wear your bobbin's side plate and being made of aluminium, won't last many gritty caves, and they're way to expensive to throw away too often.

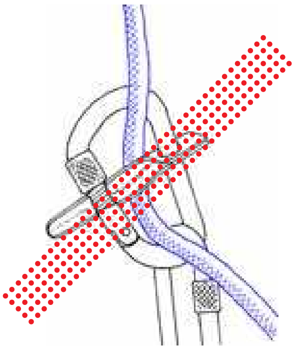
## No descender

You can descend a rope without a specialist descender. Karabiners arranged as descenders do not work as well as the real thing and wear out rapidly but are considerably safer than classic abseiling.

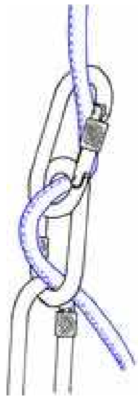
'Crossed krabs', using one or more karabiners or angle pitons as brake bars work fine on thick ropes but on single thin rope they can be too fast to control. Two brake bar units in 'series' are more controllable than single units and give a back-up should one of the karabiner gates fail or open due to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



*Brake bars in 'series'*



*Single brake bar - insufficient friction on most single ropes*



*Bicephale*

*Descending a double rope on 'Crossed-krabs' – the Stop is not very useful here*

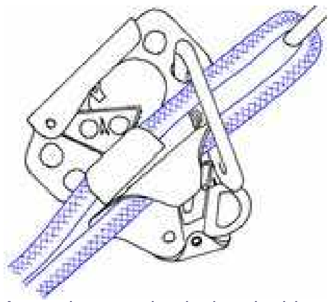
The 'Bicephale' is a variation on crossed krabs, it gives more friction than the standard set-up although the descent may not be as smooth. A careless bump or poor karabiner match quickly turns a bicephale into a single crossed krab setup. Try it out **very** close to the ground first. With considerably less equipment you can abseil on an Italian hitch, it is easy and fast to tie and the control is excellent. Either crossed krabs or an Italian hitch will ruin aluminium karabiners very quickly on a muddy rope, while a locking steel karabiner will last indefinitely. Locking karabiners are preferable for the critical karabiner in any of these methods. If none is available stack two non-locking karabiners with their gates on opposite sides.

## Long hair

Long descenders such as racks and whaletails are ideal for catching long hair and beards. Loose clothing such as scarfs and long chin-straps are also at risk. If something gets caught, stop descending immediately and try ripping the offending item from the descender. If it is too well trapped 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 use a knife to very **carefully** cut your hair or trapped item free, 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, jewelry, chinstrap or dangling item in range of a descender or ascender.

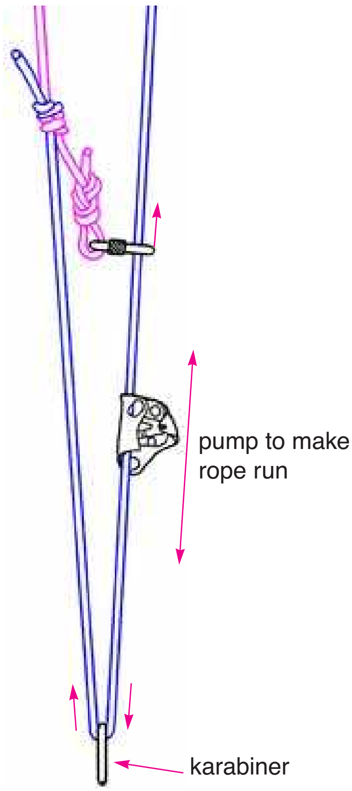
## Rope too short



*Ascenders used to lock a double rope*

The most immediate concern when descending a short rope is to not slide off the end due to lack of a stopper knot. When you rig correctly in the first instance the problem is no more serious than having to change over to prusik and ascend. However if you are using IRT and the intention is to have the last caver down place the protectors, the situation could be far more serious. The first caver down a rope must always carry prusik gear ready for use and place protectors, deviations and rebelays as he goes. The rigger must be able to turn back at any time, especially in difficult or wet caves (see Descent to ascent on page 133).

In the event of descending a double rope that 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, an assistant using two ascenders can lock the ropes at the top. The descending caver can then tie an extra rope to either strand and finish his descent.




*Running karabiner*

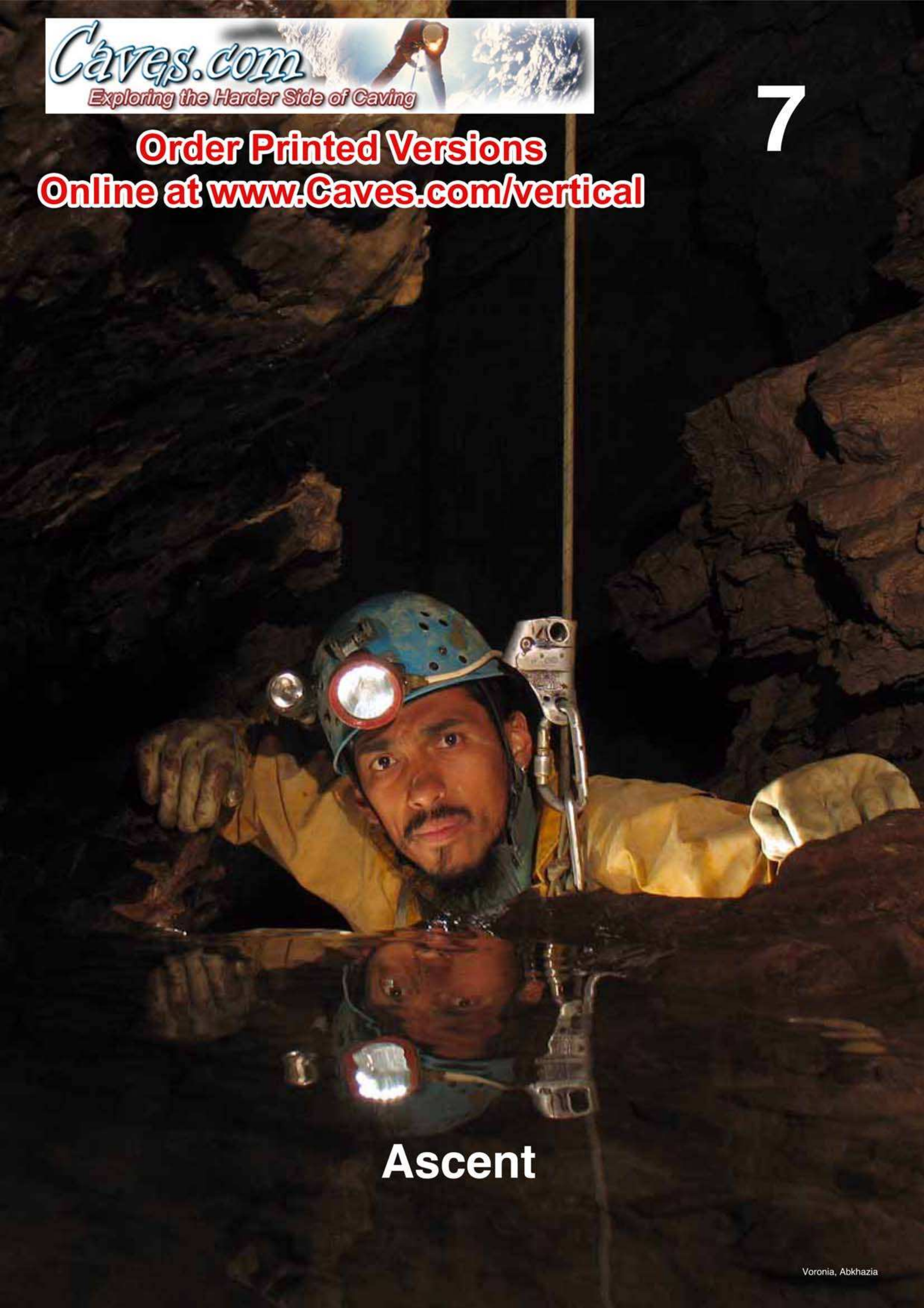
If you have no spare rope available and nobody at the pitch head to help, lock the rope using a *Mousqueton Coulant* or 'Running karabiner' (Frachon, 1980), then climb with caution.

- 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 your 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 your descender with your other hand.
- Allow the rope to slide until you are hanging from your seat maillon karabiner.
- Clip the safety loop from the knot to the other strand of rope using a karabiner **above** your 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.

The friction produced as the full length of the abseil rope is dragged through a sling under load could easily cut it. In this case there is little choice but to prusik up the double rope using prusik knots.

# 7

# Ascent



Voronia, Abkhazia

Climbing a long thin rope is a hard way to get out of a cave so it makes sense to do it as efficiently as possible. The traditional method of using a pair of Prusik knots made of a thinner cord 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!

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

**Sit/Stand** systems where you climb with a frog-like sit/stand motion.

**Ropewalking**, where you use a more natural walking motion to climb the rope.

## Mechanical ascenders

Mechanical ascenders work by means of a cam that jams the rope so that the ascender slides 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 holds more strongly as the load increases, so a strong spring is not necessary. Only Gibbs 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. Choose ascenders on the basis of suitability for a prusik system. As will be explained later, the relative strength of ascenders is of minor concern.

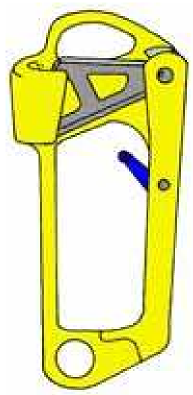
## Desirable features

- Single-handed loading or lock-open cam that releases with one hand 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.
- Better than 400 kg breaking strain. Most ascenders cut the rope before they fail structurally. Attachment eyes must be strong enough to allow for wear.
- Robust —the cam and body should be hard enough that they will not wear out quickly.

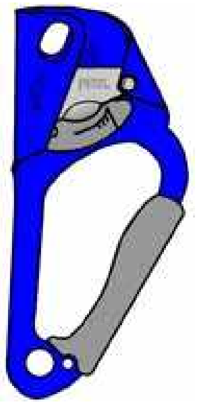

Mortero de Astrana, Spain

## Handle ascenders

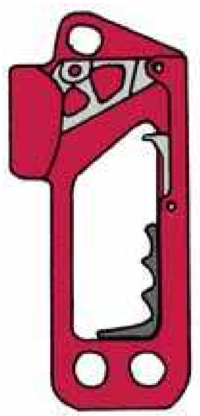
Many ascenders incorporate an integral handle in left and right versions to allow you to use them comfortably in either hand. While the handle may add to ease and comfort when using the ascender, especially on sloping pitches, it also adds to the weight and bulk of the device. A handle ascender is cumbersome when you are not using it in your hand, and while the handle is sometimes nice for a top ascender it is by no means essential.



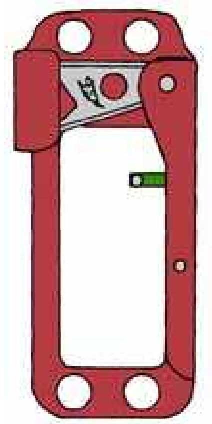
*Jumar*



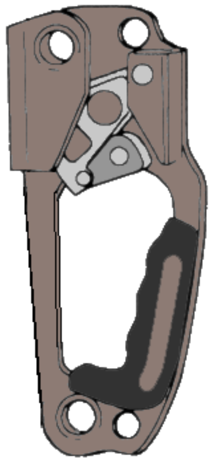
*Petzl 'Ascension'*



*CMI 'Ultrascender'*



*SRTE 'Standard'*



*SRTE 'Explorer'*

### Table 7:1 Common handle ascenders

| Ascender | Weight (g) | Length (cm) | One hand | | Cam open | Comfort*/ Ease | Durability* |
|---|---|---|---|---|---|---|---|
| | | | On | Off | | | |
| Petzl Ascension | 195 | 19 | yes | yes | yes | 1 | 3 |
| Jumar | 270 | 18 | yes | yes | yes | 2 | 2 |
| CMI Expedition | 275 | 20.3 | yes | yes (just) | no | 3 | 1 |
| CMI Ultrascender | 270 | 19 | yes | yes (just) | yes | 5 | 1 |
| SRTE Standard | 339 | 19.7 | yes | yes | yes | 3 | 1 |
| Kong Lift | 225 | 19.3 | yes | yes (just) | yes | 2 | 3 |

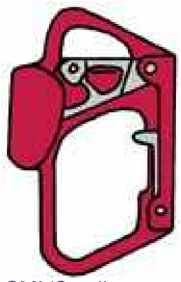
* Ratings 1 = best 5 = worst
It is not possible to show all available ascenders. Use this as a guide to other ascenders that in many cases are variations or copies of those described here.

## Non-handle ascenders

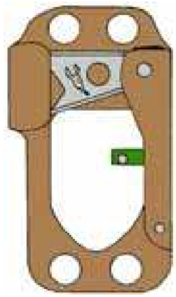
Short, compact ascenders are useful for virtually any application. Some are especially designed as chest mounted ascenders and as such work exceptionally well. Others are less specific and you can mount them anywhere on a prusik rig, but they may not be as good as a specifically designed device.

*Petzl 'Basic'*

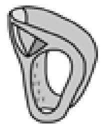
*Petzl 'Croll'*



*CMI 'Small Ultracender'*



*SRTE 'Short Standard'*



*Petzl 'Tibloc'*

### Table 7:2 Common non-handle ascenders

| Ascender | Weight (g) | Length (cm) | One hand On | One hand Off | Cam open | Comfort*/ Ease | Durability* |
|---|---|---|---|---|---|---|---|
| Prusik knots | 60 | - | no | no | no | 9 | 6 |
| Petzl Tibloc | 39 | 5 | no | yes[+] | no | 5 | 3 |
| Petzl Basic | 140 | 10 | yes | yes | yes | 2 | 3 |
| Petzl Croll | 140 | 12 | yes | yes | yes | 1 (chest only) | 4 |
| Kong Cam Clean[#] | 150 | 11.5 | yes | yes | yes | 1 (chest only) | 3.5 |
| CMI Small Ultrascender | 180 | 13 | yes | yes | yes | 3 | 2 |
| SRTE short Standard | 221 | 13.5 | yes | yes | yes | 3 | 2 |
| Petzl Pantin | 112[@] | 5 | yes | no hands | no | 2 | 1 |
| Gibbs | 175 | 10 | no[&] | yes | no | 6 | 1 |

[*] Ratings 1 = best 6 = worst

[#] A copy of the Croll but slightly rougher and with no rivet to help it survive FF1 falls.

[&] Not even close! Unbelievers would say that it requires 3 hands.

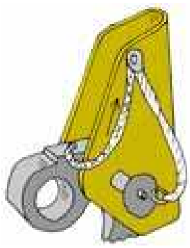
[@] Weight includes attachment tape.

[+] But use an attachment string or you'll drop it.

It is not possible to show all available ascenders. Use this as a guide to other ascenders that in many cases are variations or copies of those described here.

## Foot ascenders

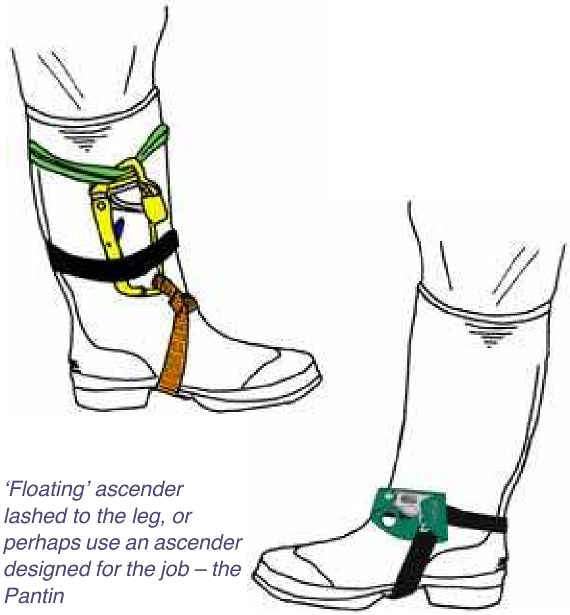
Petzl 'Pantin'



Gibbs

These ascenders are specifically suited for foot mounting. There are only two in common usage at the moment. The Pantin, that is a 'cut down' Petzl Basic or Croll with a weakened spring to reduce rope drag and no safety catch so that it is easy to remove from the rope (and impossible to keep on for the uninitiated!), and the Gibbs.

Gibbs ascenders are most suited to Ropewalk rigs and 7/16th inch (11 mm) rope where they work better than any other ascender. They are probably the surest ascenders on muddy or iced ropes but for anything else they are not worth the trouble – they need to be dismantled to get them on and off the rope and on 8 mm and 9 mm ropes they do not always grip immediately, making it difficult to maintain a good ropewalking rhythm.



'Floating' ascender lashed to the leg, or perhaps use an ascender designed for the job – the Pantin

## Attachment

Connect chest mounted ascenders directly to your seat maillon or by a short link such as a 6 mm maillon. A tape or rope loop works, but is hard to tie short and can wear dangerously fast. The exact configuration you use depends on your harness, ascender and prusik rig. For example, Croll ascenders are shaped to sit flat against your chest when connected directly to a seat maillon that is also flat. When connected directly to a harness that has the seat maillon at 90° to your 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 a little high for an efficient Frog system.

Attach your hand ascender with your long cowstail. If your rig calls for a permanent attachment, tie cords and tapes to the ascender directly to the eyeholes at the top and bottom or by using small maillons as intermediate links. Use light tape to cover 5 mm to 8 mm static cord and reinforce it at the ascender connection to make it last longer.

Use 8 mm or 9 mm dynamic rope for 'life support' safety cords and tie them to the bottom of the ascender separately from other attachments.

Ideal | Good (but high) | Bad | Bad

*Chest ascender orientation*

## Wear

*Worn Croll*

Your Croll will wear out long before any of your other ascenders. The top edge immediately in front of the cam usually wears to a razor-sharp edge. Not much good for either the rope or your fingers. This wear is usually exacerbated if you use a Pantin or other foot ascender as you tend to lean back against the rope that's tightened but the foot ascender as you move up.

Your hand ascender should last a lot longer. Mine wears out every five or six Crolls by wearing the bottom edge, just below the cam. I wear out handle ascenders faster than basic ascenders because I move them up holding the handle and twist them a little and that causes more wear on the lower edge.

Old spring ascenders begin to slip when their teeth become excessively worn or their springs become too weak. This usually becomes apparent when you're climbing muddy or clay covered ropes where the already blunt teeth become clogged. While it is possible to buy replacement cams and springs for most ascenders, the frame will probably also be sufficiently worn that it's better just to throw away the ascender and buy a new one. Ascenders require very little other maintenance apart from the obvious need to clean and oil them occasionally.

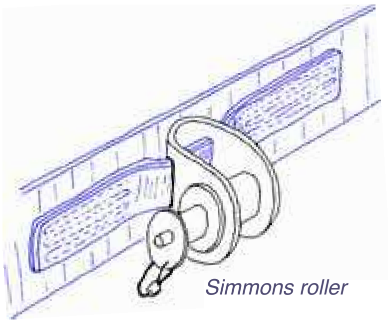
*Mark wears out the bottom edge of his Croll. I wear out the top. On one expedition we were running short of Crolls and thought that it would be a good idea to trade Crolls to scratch out a bit of extra life from them. It didn't take long to realise that, having worn out one edge of the Croll, wearing out the other edge would leave....nothing.*

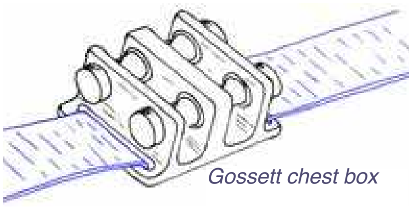
## Strength

The connection point 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. In tests, 'Strong' ascenders typically fail by chopping the rope or sheath and sliding. Under FF1 shock-load tests 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. In many tests however, the ascender has simply cut the rope in two. Thick ropes do not perform much better than thin ones in this respect. Many ascenders, or the rope you connect them to, begin to fail at loads as low as 450 kg, hardly a marvellous safety factor.

There is no mechanical ascender you can rely on to withstand a FF1, 80 kg shock load. Those that stand the best chance are prusik knots tied in 6 mm or thicker cord on 10 mm or thicker rope if they don't slip enough to melt. Petzl ascenders stop the cam from closing all the way that helps (but doesn't guarantee) to stop the rope from being cut completely. The obvious solution is to avoid shock loading ascenders. Don't climb above a belay point while your ascender is attached below and **NEVER** use ascenders as belay devices when rigging or climbing.

## Chest box


*Simmons roller*


*Gossett chest box*

Chest boxes and rollers are not ascenders but guides to hold you 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 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 that is made even heavier when you add on the heavy chest harness they require.


Selangane, Papua New Guinea

## Footloops

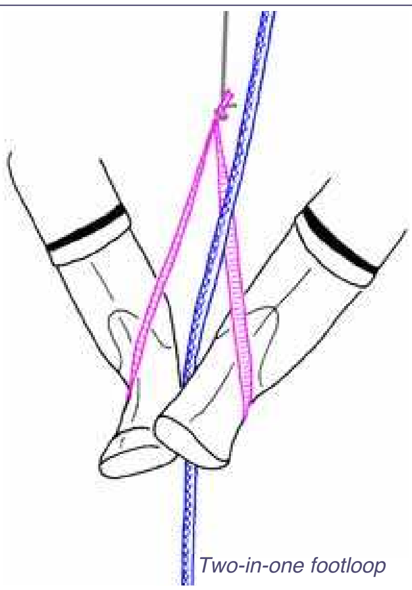
Footloops:
MTDE 'Siam doble' modified as a two-in-one
30 cm quickdraw – just too small for two feet + dyneema
MTDE 'Colectivo' adjustable

You can connect an ascender to one or both feet in a variety of ways. The main need is to provide a secure foothold in the right place. Any footloop is better if it's made from a low stretch cord. Dyneema is ideal—almost no stretch, long wearing and compact. Kevlar isn't bad except that the sheath will eventually wear through. 25 mm tape stretches, is bulky and heavy when wet. Don't even bother with thin accessory cord! You can make the entire footloop out of a single piece of cord, or make the loop at the bottom from a piece of spectra tape and use a length of dyneema cord to attach that to your ascender. Don't use tape, especially thin tape, on a Frog system. It slips into a chest ascender very easily, then you prusik up your own footloop, then you're stuck...

Tie your footloops tied in a fixed length that you determine by a personal fitting. If you need adjustability attach the footloops by tying an 8 mm rope tail to the ascender and attaching the footloop with a prusik knot, or buy one of the various adjustable footloops available. Adjustable footloops are not necessary unless you use a convertible prusik rig or it must fit different sized people.

For a Frog rig, tie a loop in the top of your footloop and clip it to your upper ascender with a small karabiner. This easily removable footloop can be very handy for passing a difficult rebelay in either direction—just unclip it from your ascender and clip it to the rebelay for a quick stand-in loop.

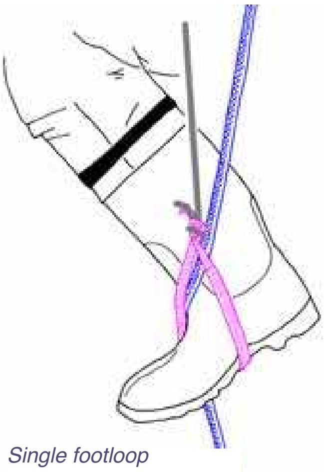
## Two-in-one



Two-in-one footloop

By far the best footloop for sit/stand prusik rigs is a single loop about 90 cm in circumference into which you can slip one, both or no feet as required. Its size allows you to kick it off or put it on easily and with only a little practice it stays on while you are prusiking. Its biggest advantage over other footloops is that by placing the rope between your feet after you put them in the footloop you can give yourself 'bottom-weight'. It is only a matter of separating both feet slightly as you lift them, then allowing them to clamp the rope during the stand cycle.

## Single loop

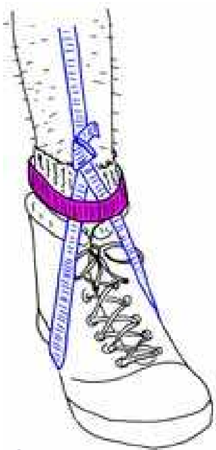

Single footloop

Rope walkers, lightweight fanatics or cavers who frequent tight caves with small pitches 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 even incorporate an etrier step underfoot and completely lose any weight and bulk advantage gained by a single loop. For sit/stand systems it uses a minimum of cord and you can still use both feet by doubling your 'spare' foot on top of the instep of the other. While light, a single loop lacks comfort on long drops and makes it is difficult to give yourself bottom-weight.

## Separate single loops

Separate small loops can be tied for each foot and connected independently to the ascender. The only advantage in sit/stand systems is some independence for your feet. An extension of single loops is to use small loops of tape or 'Foot Loops' that stay attached to your 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. Almost nobody uses separate foot loops anymore.

## Chicken loop


Chicken loop

A chicken loop is a loop of car tyre tube or tape tied around your ankle. Before putting on a single foot loop thread it through the chicken loop then over your foot so as to firmly tie the loop in place. A tape chicken loop is 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 that makes your footloops slow to get on and off. If you have trouble with your feet falling out of your footloops, practise coordinating moving your ascender up with lifting your foot, or use a smaller loop that doesn't fall off you foot so easily.

## Prusik systems

You can arrange two or three ascenders in an endless variety of configurations, many of which provide an efficient means of climbing a rope, but as well as actually climbing the rope you must also consider how well a prusik system performs crossing knots, rebelays, angled ropes, getting on and off the rope, and all the varied obstacles that you may encounter in a vertical cave—even obstacles away from the rope like narrow passages.

I divide prusik systems into three groups:

- Sit/Stand,
- Ropewalking and
- Convertible Systems.

Each has its strong and weak points. Sit/Stand systems are light, simple, easy to use on complex rigging and relatively 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 one or both feet and one ascender while sitting in a seat harness then standing to bring up the other ascender. Sitting back and lifting your feet completes the cycle. All lose a little height in the sitting back but are very powerful because both legs work together —especially useful when hauling a heavy sack or at the end of a long trip.

## 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.

To set up a Frog system, attach a chest ascender to your seat harness maillon low on your chest and hold it up with a chest harness. Attach your other ascender to the rope above your chest ascender with a footloop long enough so that when you are standing your chest ascender is 2 cm to 3 cm below the top one.

Run a safety cord from the top ascender to your seat maillon. Preferably use a long cowstail clipped into the bottom of the ascender or use a separate cord. The safety cord should be of such a length that the top ascender can never be out of reach. Make it just long enough so that it doesn't restrict the upward push in the 'sit' part of your sit/stand cycle.

The final choice of ascenders and trimmings is up to you 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 your 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 for the entire cave.

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

Stand up with your feet tucked beneath you for maximum efficiency, and your chest ascender moves up automatically provided there is sufficient bottom weight on the rope.

If not, run the rope over your right foot and pull through with one hand, usually your left one, as you stand. This is not very efficient so only use it for short distances.

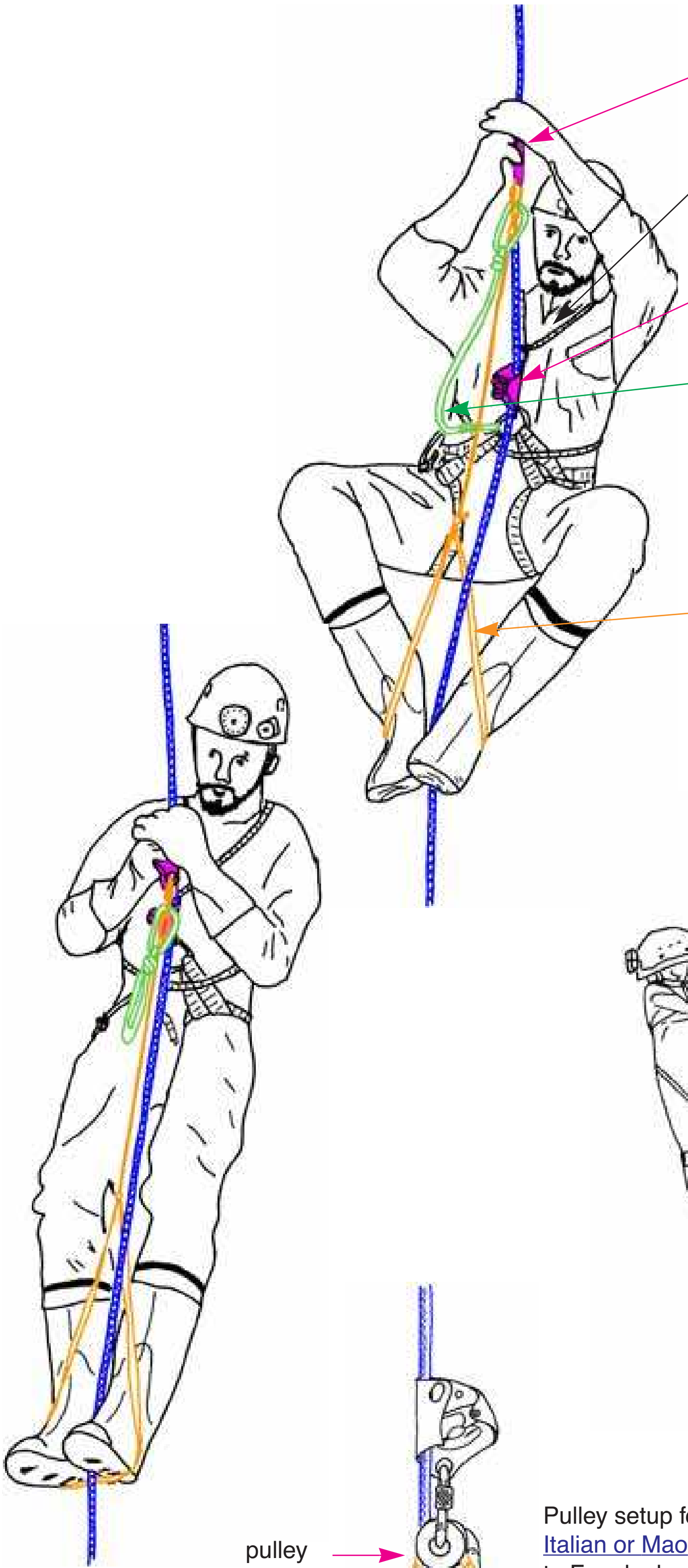
Running the rope between your feet with a 'Two-in-one' foot loop not only provides bottom-weight but also helps maintain your body and legs in an efficient prusik position. In the 'stand' part of the cycle your feet are tucked under you to reduce arm strain and your body moves up with no wasteful sideways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

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

A useful variation to the standard Frog is the Italian or Mao technique. Mount a pulley on the bottom of your top ascender with a cord footloop 50% longer than normal running through it. Tie a normal foot loop in one end, and attach the other end to the top of your chest ascender or seat maillon. This length is critical so set it by trial and error until you are satisfied with it.

Use a sit/stand motion as usual but as you move your hands up, your feet move up twice as far. During the stand motion your feet move downwards and help pull your body up. 'Stands' are only half the height as Frog stands and your feet slide annoyingly against walls but the mechanical advantage makes it possible to haul loads that would be very strenuous by other means.

## Frog system



**Foot ascender –** Petzl Basic, SRTE short, Petzl Pantin

**Chest harness –** Neck loop, Sash, Wrap-around, Figure-8, Climbing Chest Harness

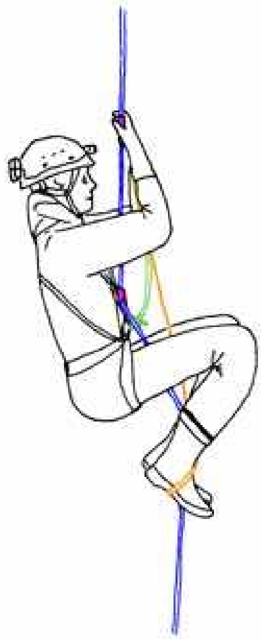
**Chest ascender –** Petzl Croll, Kong Cam Clean#

**Long cowstail –** Cowstail
or

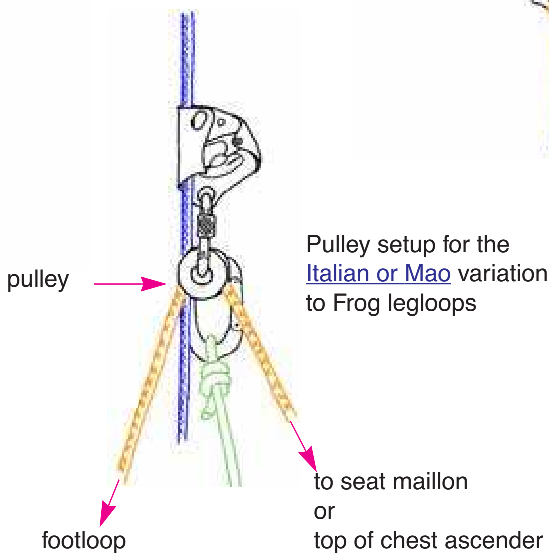
**Safety cord –** 1.5 - 2 m of 8 mm cord attached directly to the foot ascender

**Footloop –** Two-in-one, Single loop

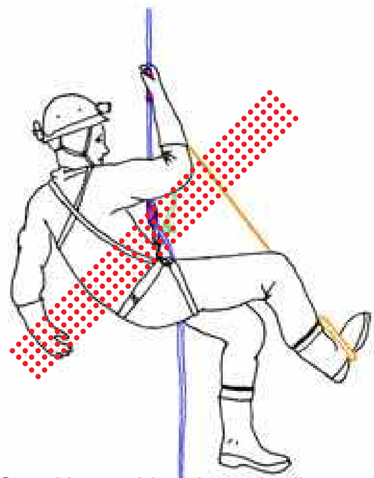
See How I do it on page 139 for details of how I put my Frog system together.



Keep both feet underneath in a squatting position rather than a sitting position

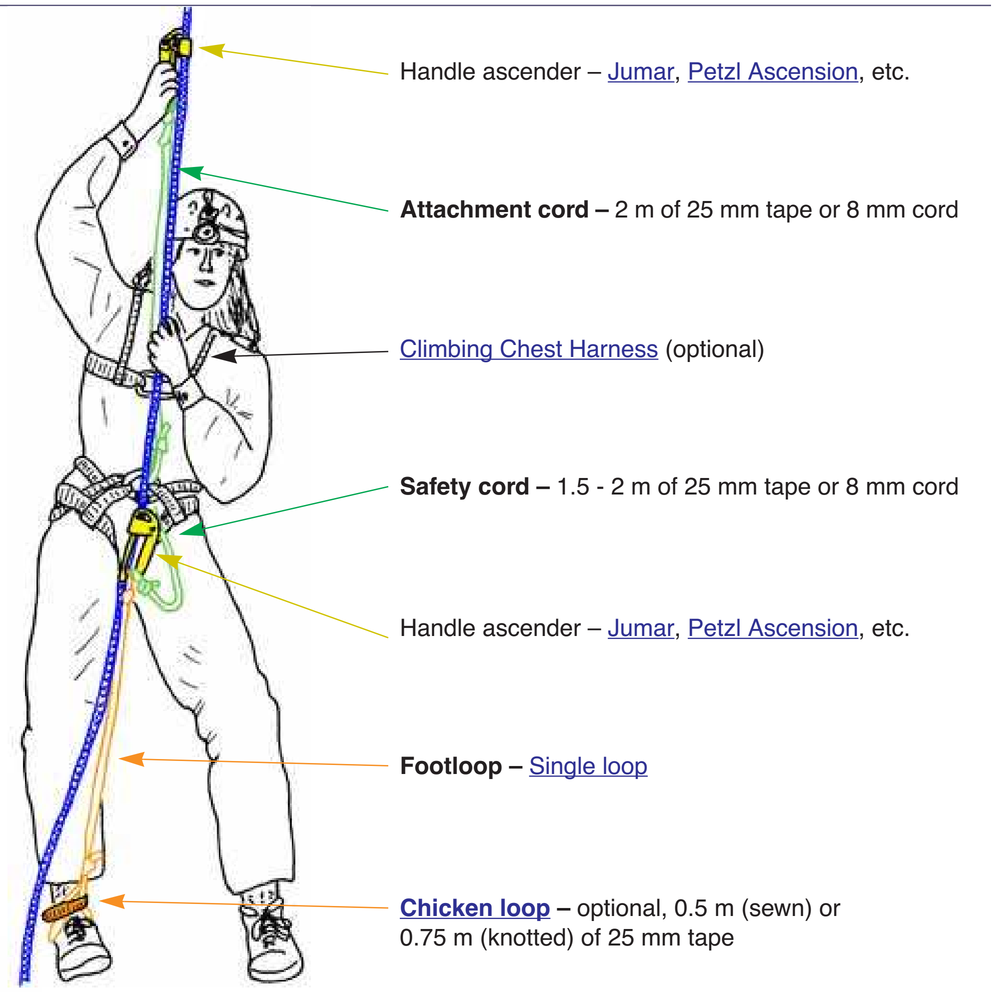


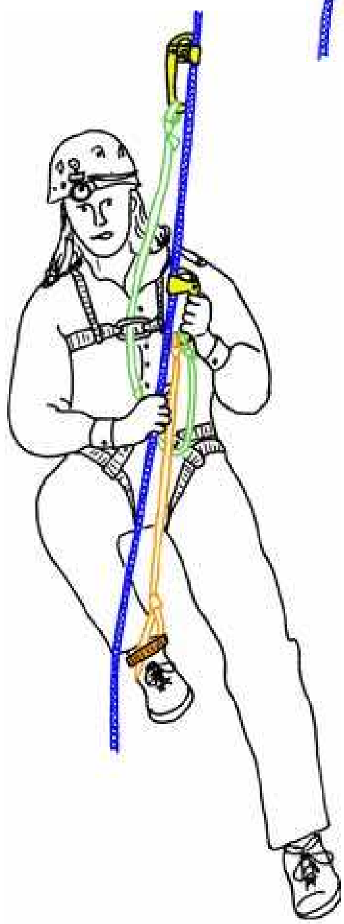

Pulley setup for the Italian or Mao variation to Frog legloops



Stand by pushing down the line of the rope, not outwards. Tired arms are a sign that they are working too hard

## Texas system



The Texas system is almost an inverted Frog system. Attach an upper ascender on an arm's length sling to your seat maillon and the other ascender on a short footloop to one or both feet (usually one) such that when you stand, the ascender reaches to thigh level and is still within reach. Link the lower ascender to your seat maillon with a short safety sling.

To climb, push up your top ascender and stand simultaneously then sit back to rest and move up your lower ascender. When necessary, provide bottom weight with one hand while moving up the lower ascender with the other. 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.

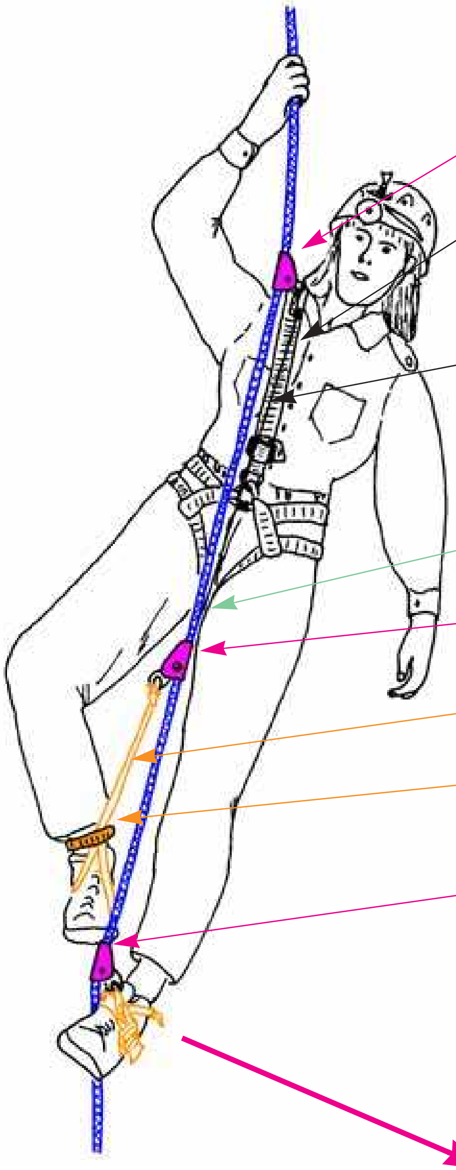
Texas is simple, light and versatile being good on sloping broken drops when used with one foot. Its popularity is probably due to the way it converts readily to a Mitchell system giving it the boost required for free drops—and force of habit. Proponents claim that it a superior system for sloping pitches. Opponents feel that it is so bad on freehanging pitches that it just feels like it's good on sloping pitches. It is also the best system for prusik knots.

A variation of the Texas system mounts a top chest ascender as in Frog and the leg ascender as a normal Texas. While this perhaps makes climbing less strenuous and faster, it makes changeovers and other on-rope manoeuvres problematic without an extra ascender (as with any system without a long legloop), and offers no convertibility to the Mitchell system.

## Ropewalk systems

Ropewalk systems attach a separate ascender to each foot so that each leg moves independently, allowing you to 'walk' up the rope. As opposed to the Sit/Stand systems, the seat harness is hardly used, however the chest harness must be treated as a life support component. Their chief advantage is speed up the rope. Compared to Sit/Stand systems they are fast but complex and heavy.

## 3 Gibbs ropewalker



**Shoulder Gibbs — ** sewn* to Butt strap

**Butt strap — ** 2- 3 m of 50 mm tape, 2 buckles and 'D' ring
or

Chest box on
Climbing Chest Harness (not shown)

**Shock cord — ** 1 - 2 m of 8 mm shock cord and micro-krab, runs from knee Gibbs shell to shoulder Gibbs attachment point

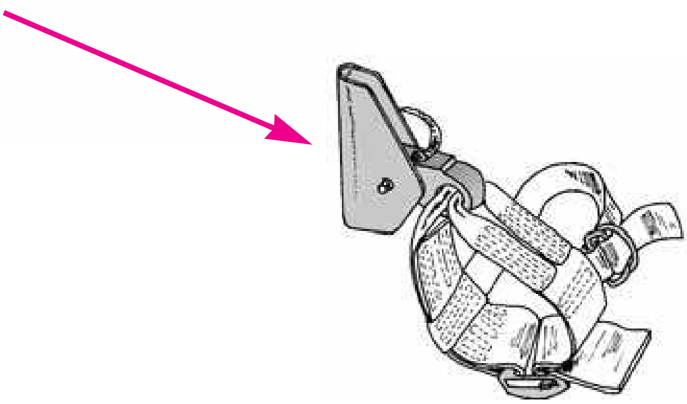
**Safety cord — ** (knee Gibbs to seat, not shown) 1.5-2 m of 25 mm tape or 8 mm cord

Knee Gibbs

**Footloop — ** 2 m of 25 mm tape

**Chicken loop — ** optional, 0.5 m (sewn) or 0.75 m (knotted) of 25 mm tape

**Foot Gibbs — ** sewn* to footloop, 0.7 m of 50 mm tape, buckle, 0.5 m of 25 mm tape, buckle or 'D' ring



*Foot mounted Gibbs*

*Sewn Gibbs fixtures require 0.5 m of 25 mm tape

The 'genuine' Ropewalker employs three Gibbs ascenders that have extremely low rope drag allowing maximum speed up the rope.

Instead of a chest harness, run an adjustable 'Butt-Strap' from your seat maillon up over your right shoulder and down to a fixture on the back of your seat harness at belt level. Sew the upper Gibbs to this strap at the point of your shoulder. Connect the other two ascenders one to each foot. One should float at thigh level with a shock-cord running from its shell to just below the shoulder Gibbs – a small clip will allow you to disengage it for walking. Fit a safety sling between this Gibbs and the seat maillon. Sew the bottom ascender to a foot loop and ankle strap and mount it on your 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 pop the Butt Strap off your shoulder to allow you to lean back from the rope. When starting, arrange bottom weight by passing the tail of the rope under the foot that has the lower Gibbs and holding it in one hand. This is only necessary for the first few metres and only possible if there is 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 you 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 (QAS) for difficult pitch heads and sometimes even a spare Texas rig for short pitches or complex rigging.

## Mitchell system

Fit an upper ascender with a long footloop so that it reaches to high chest level immediately above your chest box when you are standing upright. A safety cord should also run between this ascender and your seat maillon but many people do not bother. The half measure of tying a stopper knot in the long footloop below your chest box can be dangerous as the footloop wears where it passes through the box. A failure here or of the chest harness or box with no safety cord attached to the top ascender could leave the you hanging upside-down by your feet! Mount the other ascender as for Texas on a short footloop to reach high thigh level when you are standing and fit it with a safety cord.

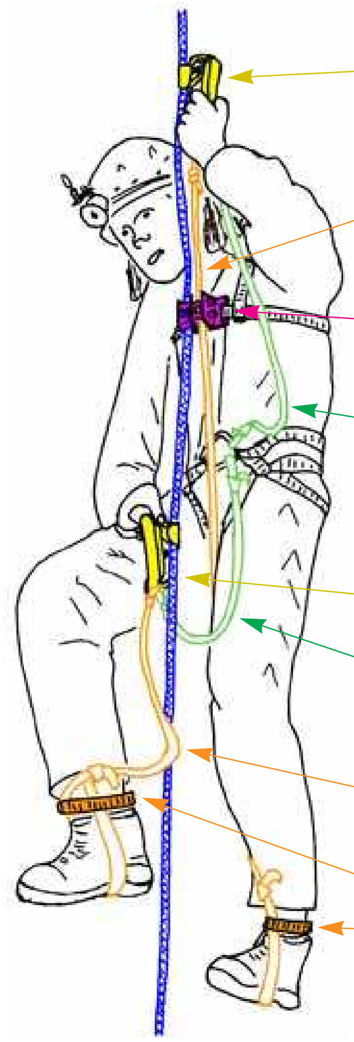
The chest box is to keep your body upright and ease arm strain. Run the rope in one channel and your long footloop in the other. Connect a single channel chest box to the rope only.

Climbing is a matter of walking up the rope with one hand on each ascender and moving your right hand up in time with your right foot and left hand with your 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 you can climb very quickly. On slopes loosen your chest harness or undo your chest box and climb with your body vertical even though the rope is not.

The main drawback of the Mitchell system is that both your 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.

When starting, you need bottom weight to make the lower ascender run properly. When there is none, you need one hand on the lower ascender, another to pull the rope through for the first few metres and a third to operate the top ascender. With practise though, you can alleviate this by 'thumbing' open the cam on the lower ascender to make it run easier. The chest box is cumbersome in narrow passages, is slow to get on and off the rope and can be difficult to get onto the rope while you are on the pitch—you may be able to hang off your top ascender to do it, but not always.

## Mitchell system



Handle ascender — Jumar, Petzl Ascension, etc.

Long footloop - 3 m of 8 mm cord
or 2 m of 8 mm cord and 1 m of 26 mm tape footloop

Chest box on Climbing Chest Harness

**Safety cord** - optional 2.5 m of 25 mm tape or 8 mm cord (or stopper knot in the long footloop below the chest box)

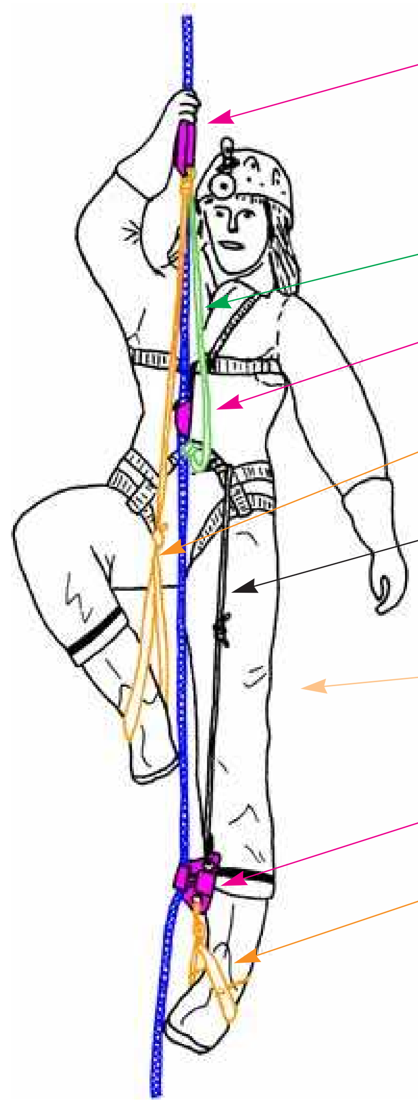
Handle ascender — Jumar, Petzl Ascension, etc.

**Short safety cord** - 2 m of 25 mm tape or 8 mm cord

**Short footloop** - 2 m of 25 mm tape

**Chicken loops (2)** - 0.5 m (sewn) or 0.75 m (knotted) of 25 mm tape (each)

## A floating cam system



Handle ascender – Jumar, Petzl Ascension, etc

Safety cord - 2.5 m of 25 mm tape or 8 mm cord

or

Cowstail

Chest ascender (Petzl Croll), Chest box or roller on Climbing Chest Harness

**Footloop –** Single loop or Two-in-one

**Shock cord** - 1.5 - 2.5 m of 8 mm shock cord doubled from foot ascender to waist. Not necessary with a Pantin or other ascender firmly attached to your foot.

**Chicken loop —** (optional, not shown)

**Foot ascender** - Petzl Basic or Petzl Pantin*, CMI Small Ultrascender, Petzl Croll, Gibbs

**Footloop** - 0.5 m (sewn) or 0.75 m (knotted) of 25 mm tape, mini-krab or matching ‘C’ links
or
ascender permanently attached and mini-krab at other end of shockcord.

Held on with 0.3 m of shock cord or tape and buckle ankle strap

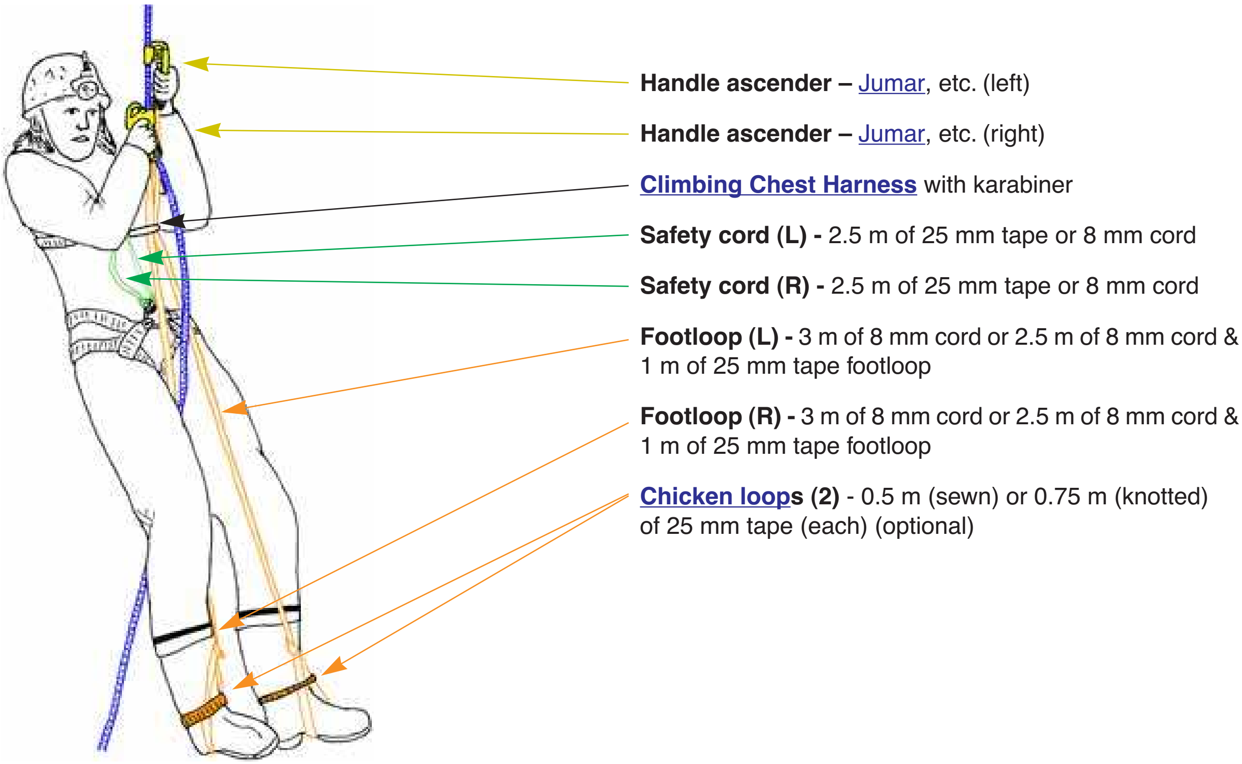
* A Pantin only works on your right foot.

## Floating cam system

You can overcome some of the problems of the Mitchell system by making the lower ascender move up automatically or ‘float’. Do this by running a length of shock-cord from the top of the lower ascender to your chest or seat harness or by the more complicated means of mounting a small pulley on your seat maillon or below the chest box. Run a shock-cord from the top of your lower ascender up through the pulley and down to your 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 your calf using an adjustable strap or large rubber band, though it takes a peculiar leg action to make it run well (see page 113).

If you use a chest ascender instead of a chest box, the floating cam ascender is not a life support ascender so you can safely modify it to make it easier to use or run better. Unwind the spring on a sprung ascender a turn or two or replace it by a weaker spring so that the cam touches the rope lightly and therefore drags on the rope as little as possible. A Gibbs ascender cam can be mounted on a stud on one side of the shell and the other side cut away so the ascender no longer needs to be disassembled to get it on and off the rope. You can also mount a Pantin on your right foot and the long foot loop on your left foot.

## Jumar system




### Jumar system

Jumars started it all and 'jumaring' is synonymous with prusiking even though many cavers have never even seen a Jumar. The ascent system as outlined on Jumar pamphlets works - but only just and few cavers seriously consider it for caving use. Connect a right ascender with a long footloop to your right foot so that it is about face level when you are standing. Mount a left ascender similarly so that it is just above the right one. To stay upright run the leg loops 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 your head and there is no resting position.

## Convertible systems

Variation is the essence of evolution. There is a myriad of minor changes and adjustments you can make 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.

### Mitchell-Texas

A Mitchell system with safety cords is a Texas system once you disengage the chest box and release your foot from the long leg loop. 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. You can remove or leave the chest box behind for a series of small, sloping or tight pitches.

### Frog-Floating cam system

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. Set up the Frog system to climb one-legged. Attach the floating cam to your other leg and with all three ascenders on the rope ascend with either a walking or a sit/stand action. To convert to a true Frog system disengage the floating cam.

While the system works well enough, in order to stay as upright as possible mount the chest ascender high on your 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 you need an adjustable footloop or one with two loops at different heights to overcome the problem. For efficient ropewalking use a climbing chest harness to stay close to the rope.

In the 90s, this system was 'discovered' in France and made popular by the release of the Pantin. The Pantin has become so popular that many, perhaps most, european cavers now use one. The Pantin is a simple and light addition to the standard Frog system and has all the advantages and disadvantages associated with the Frog-Floating Cam system described as well as a few of its own.

The Pantin is very neat and light. It won't weigh you down much and 'forces' you to carry a spare ascender that works well, unlike a Tibloc or knots. Many proponents prefer the freedom of separate leg movement, especially against walls. On freehangs, you either move your feet up simultaneously as for normal Frog, or quickly one after the other, followed by a normal stand motion. With the optimal low Croll attachment, very few cavers 'walk' with a Pantin, it's just too strenuous.

A Pantin requires very little bottom weight so one or two up moves pulling the rope through by hand is enough before you can attach one— still enough to be annoying when you have a lot of rebelays. On the down side, it is an annoying piece of metal attached to your foot when you are walking and climbing and is adept at clipping onto your pack haul cord in crawls. They also only work on you right foot while many of us prefer a foot ascender on our left. Possibly their biggest disadvantage is that by standing up against a rope tensioned by the Pantin (or floating cam) below, your Croll will wear out faster.

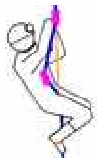
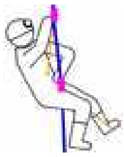
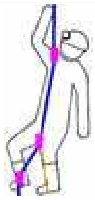
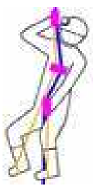
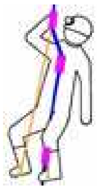
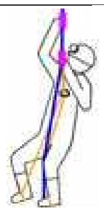
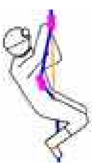
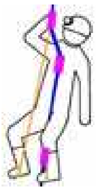
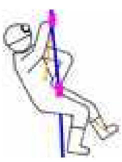
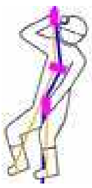
Strangely, Frog's original proponents are dabbling with ropewalking (of a sort) as fast as Americans have been abandoning their heavy rigs and moving to Frog.

Any convertibility to ropewalking adds to the complexity and weight of the basic Frog system and somewhere you must decide if it is worthwhile.

*Long before the Pantin, I used a convertible floating cam system when I first went caving with Jean-Paul and his simple Frog system in New Zealand. At the end of the trip I threw out what seemed like a kilo of tapes, cords and ascender— other cavers were amazed that I could climb a rope with so little gear. Meanwhile, J-P took the Frog-Floating cam back to France and his friends were amazed at how fast he got up the rope...*

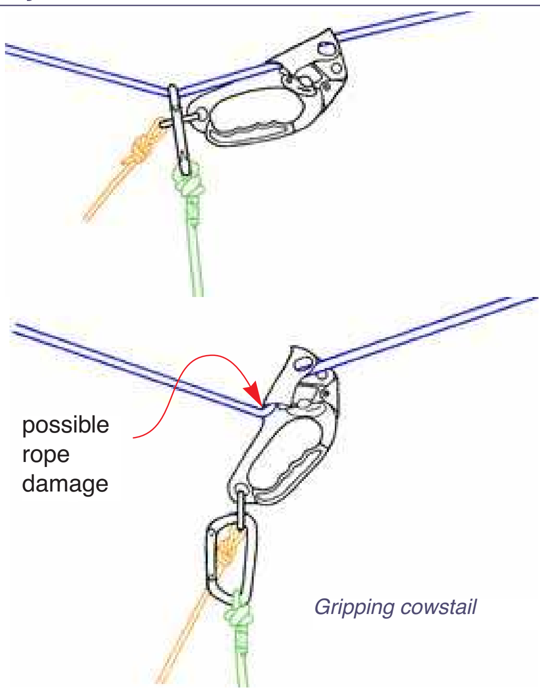
Harwood Hole, New Zealand

**Table 7:3 Ascent systems**

| System | Ascenders | Extras | Weight* (g) | Advantages | Disadvantages |
|---|---|---|---|---|---|
|  Frog | 2 | cowstail | 500 | simple, light, easy to use, copes with any manoeuvre, fast on-off time | slow climb rate |
|  Texas | 2 | ascender on sling | 800 | simple, light, easy to use | slow climb rate, some manoeuvres may be difficult, strenuous |
|  3 Gibbs Ropewalk | 3 Gibbs | ascender on sling | 1100 | fastest climb rate (up to 50 m/min.), both hands free | extremely slow on-off time, midrope manoeuvres very difficult, complex |
|  Mitchell | 2 + box | ascender on 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 on sling | 800 | fast up rope, versatile, copes well with midrope manoeuvres, light (if using chest ascender) | slow on-off time, complex |
|  Jumar | 2 | ascender on sling | 1100 | | strenuous, both hands busy above head, copes poorly with all manoeuvres, poor safety |
|   Frog/ Floating Cam | 3 | cowstail | 800 | light, fast up rope, versatile, copes well with all manoeuvres | convertibility not always useful, neither conversion works as well as its single use version |
|   Texas/ Mitchell | 2 + box | ascender on 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 a double cowstail and 350 g for ascender on sling/QAS.

## Single ascender/Self belays




*Gripping cowstail*

One ascender on a cowstail is often enough to help you climb short slopes and steps where the consequences of a fall are minimal. For traverses, a karabiner linked into the bottom of an ascender or an ascender attached to a long cowstail gives a 'gripping cowstail' that can be useful for angled lines should you 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 provide a convenient portable handhold it also introduces a lot of slack into the system that could result in a shock load in the event of a fall.

When climbing a ladder, use a spring loaded ascender 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. The ascender has a tendency to catch on ladder but is adequate for the occasional use that an SRT caver would have. For more serious self belaying mount the ascender to one side so that it does not catch on the ladder.

A prerequisite for using a self belay is that you must be able to get 'unhung' if the ladder breaks or you 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 you need to get down safely:

- Attach your descender to your seat maillon, then to the rope as high as possible below your ascender and lock it off.
- Take a Footlock high on the rope and stand.
- Your bobbin will invert and your ascender be unweighted enough for you to release it.
- A non-bobbin may not allow enough movement unless you connect it by a chain of karabiners.
- A prusik knot or ascender on a sling above your chest ascender to stand up in is easier to use than a footlock.

## Safety

You must protect yourself from failure or accidental disengagement of an ascender. Back up any prusik system with safety cords so that if any one ascender in the system is undone or otherwise fails you will hang in a sitting position. This requires.......

**at least two points of contact
with the rope at all times**

........and that you use a cowstail to maintain these points during mid-rope manoeuvres.

Risking a heel-hang or worse is simple stupidity! The failure of the chest harness or box in Ropewalk systems will result in a heel-hang if you have no safety cords. Worse still, a Frog system with no safety to the top ascender puts you at risk of complete disengagement from the rope should your chest ascender fail or you remove it as you cross a rebelay.

## The ascent - at the bottom

*Rope bundled at the bottom*

Do not start in a hole. Start climbing from the top of a rock or ledge so that you can save at least a few metres of prusiking. 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 you have both ascenders on the rope before gently swinging out. Ascenders are easier to attach while standing rather than hanging and it is not safe to swing into a void on only one ascender.

Arrange some help with bottom weight 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 your weight may be out of reach once the rope is unweighted. If you are really desperate for bottom weight, tie a **small** rock to the rope. Never pull the rope tight and tie it off or it will be difficult to descend next time with no slack to clip a descender into. When waiting for someone to ascend the rope above, stay under cover as much as possible until you are called up or the pitch is clear.

## 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 you and the anchor decreases.

### Crossing a rebelay (Frog system)


• Stop a centimetre or two below the knot. Most ascenders require a slight upward movement to release them and if crashed into a knot can be hard to undo.

1. Stand and clip your short cowstail to the belay. In the same stand movement undo your chest ascender.
2. Sit back onto your cowstail and reclip your chest ascender at your leisure (there **should** be enough slack rope above). If you are in balance or there is not enough slack rope above, reclip your chest ascender to the up rope before sitting back.
3. Change your leg ascender to the up rope.
4. Prusik until your cowstail is unloaded enough so you can retrieve it.

When there is insufficient slack in the up rope it is necessary to proceed as normal but change your foot ascender first and pull down enough slack (or stand up enough) to connect your chest ascender. If the up rope has a lot of stretch you will have to work a bit to pull the rope tight enough to allow you to unweight your chest ascender. In the worst case it is entirely feasible that you will have both ascenders equally weighted and unable to remove either.

There are three (at least!) ways out of this circumstance:

- Temporarily remove your footloop from your ascender and clip it to the rebelay, then stand in the footloop to unweight your Croll. You can only do this if you attach your footloop to your ascender with a karabiner rather than direct tie or maillon.
- Stand up on your Pantin to unweight your Croll.
- Tie/clip a sling to the anchor and stand in that to unweight your Croll.

Remember that the loose footloop, Pantin and sling are not secure, life support attachment points. Attach your cowstail before you attempt any method.

### 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 your 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 place a deviation that is exceptionally difficult to pass on the way up. Typically, you can't reach a wall or suitable footholds to unload the deviation. The bend in the rope should have been rigged gentle enough for you 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, clip a cowstail into it for safety. Never try clipping your ascenders past a deviation. Once you have been strung up with one ascender each side of a deviation you will never try it again!

### Crossing knots

Passing a knot on ascent is a simple matter. Clip a cowstail into the safety loop that hangs out of the knot, then move each ascender past in turn. Once you have two ascenders past, undo your cowstail and continue. On ascent it isn't worth swinging onto a ledge to cross a knot.

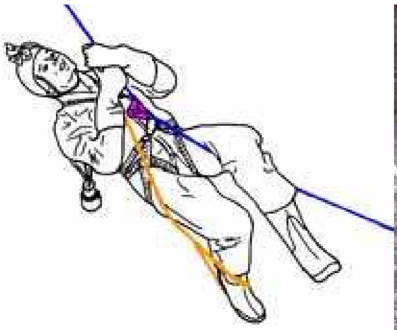
### Rope protectors

Crossing flat rope pads is no problem, it is only a matter of making sure you leave the rope 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 the last person to cross it got it wrong and the protector is doing nothing. To reduce this possibility, only place rope protectors on unmistakable rub points and preferably where there is no need to cross them.

### Grinding up

Some ascenders open more easily than others. What for some is a plus in the 'ease of use' columns in Table 7:1 on page 111 and Table 7:2 on page 112 may also be a negative when the ascender opens when you don't want it to. Climb with the open side of your hand ascender facing you and don't grind the open side over rocks or edges or it may open. Clearly, good rigging will avoid most situations where this could happen, but sometimes your ascender will touch rock. Make sure it is the back and not the front of the ascender that takes the beating and always use two attachment points. Be especially aware of this when you are negotiating an on-rope squeeze where you could conceivably lock your body, then accidentally unclip everything... The Pantin ascender doesn't even have a safety catch. It is not designed to be a life support ascender—don't use it as one. It does have a hole below the cam for a karabiner that you can both clip to and use to secure the cam. Use this attachment point in an emergency.

## Diagonals



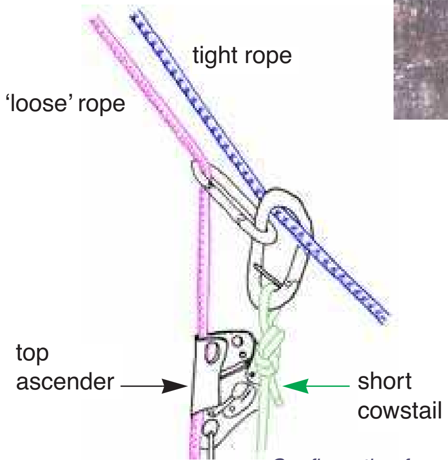
*Prusiking a diagonal rope*

Ozto Ocotal/J2, Mexico
Photo: Enrique Ogando

Ascending a diagonal rope such as a pendulum or tyrolean is 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. High mounted chest ascenders do not run well as they are a long way from your body's centre of gravity. Depending on the angle and tension in the rope, try one, or all of:

- Prusik one-legged with your free leg hooked over the rope so that your body runs parallel with the rope.
- Clip a karabiner or two between your seat maillon and the rope to give a straight run through your chest ascender and allow it to run more smoothly.
- Climb a tyrolean rigged with two ropes by clipping a cowstail to the tight rope and prusiking on the other. This manoeuvre is easier if you pass the prusik rope through a guide karabiner on the cowstail karabiner above your top ascender.

Take extra care 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.




*Configuration for ascending a steep tyrolean*

## Muddy rope

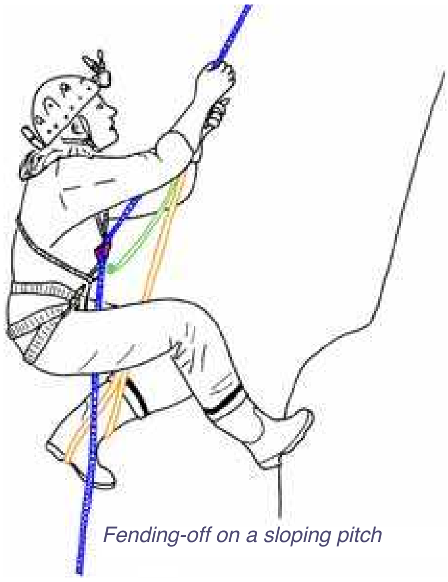

*Ascender rigged for a muddy rope*

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. Wash your ascender cams and as much as possible of your boots, hands and clothing before ascending a muddy rope.

If ascenders do slip, try:

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

## Sloping pitch



*Fending-off on a sloping pitch*

When a pitch is not vertical the problem of fending off the wall while pushing up your ascenders may arise. Too bad if your 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 your chest attachment to maintain an upright stance even though the rope is sloping.

Using a Frog and Texas rig you can tackle just off vertical slopes by pushing-off with one hand while moving your feet and other ascender up. On more pronounced slopes it is better to release one foot to fend-off with and prusik one-legged with the other. Two separate legloops make sloping pitches easier and a Pantin can help even more.

## Tight pitch

Ropewalkers should have no special problems. The independent leg action is ideal and the lack of a chest ascender makes you 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 or with a Pantin. On extremely tight pitches a low, flat-mounted chest ascender will cause little problem as it pushes into your stomach whereas a high-mounted one could jam painfully against your rib-cage or make you too thick to fit through. For really tight pitches, remove your chest ascender and try just the leg ascender and jam your body between stand strokes, or use a Pantin or remount the ascender on your other foot using the now obsolete chest harness and ropewalk up. Keep in mind though, that while a 'hands free' ropewalk rig gets you through squeezes well, it may be impossible to reach your knee or foot-mounted ascender in order to release it or down prusik. Rearrange yourself before becoming jammed into the tight spot as it can be difficult to down-prusik and even easily kicked-off footloops may not be so easy to remove with no room to move.

## Tandem prusiking

Two people climbing simultaneously can halve the total prusik time on big pitches. This may be the case for slow prusikers or cavers who like plenty of rests on the way up but those who climb quickly will 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 that the upper caver may dislodge.

Tandem climbing places more than twice the usual loads on a rope and so use only a good, well rigged 11 mm rope. As part of that rigging, a tail or rebelay will make life easier when the upper climber reaches the top of the pitch.

## Down prusiking

You can make a slow descent of a rope by reversing the usual ascent movements; releasing each ascender with a slight upward push then holding the cam open for the move down. Take care to manipulate just the cam and not the safety latch or you may detach the ascender from the rope. It is easiest to take several small steps rather than few large ones. Remove excess ascenders 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

A changeover from ascent to descent while on the rope is a similar manoeuvre to crossing Knots on descent. There is little problem with prusik systems that use a long footloop (Frog, Mitchell) but others (Texas, Ropewalk) do best with a spare ascender or prusik knot with a long sling to stand in.

While you are in a resting position, clip your descender to your seat maillon and onto the rope as high as possible and lock it off. Release any foot-mounted ascenders. Position your top ascender as low as possible but still high enough to stand in and release your chest ascender/box. Once you've released your chest ascender it is only a matter of sitting back onto your descender and releasing your top ascender.

If you normally attach your descender directly to your seat maillon it will either already be attached or if not, use a karabiner just this once.

**Don't even think about undoing your seat maillon while hanging on it!**

If you don't have a long leg loop to stand in, it may be possible to stand on a foot ascender attached below your descender and have enough slack in your descender attachment to release your chest ascender/box, however in less than ideal conditions you may also get stuck—practise in a safe place first.

## Descent to ascent

Clip your top ascender high on the rope and then stand up in its footloop. Clip your chest ascender to the rope and remove your descender. If you use a long descender or foot-mounted ascenders you may find it necessary to hang from your top ascender and pull some slack through your descender so that you can clip on your lower ascender above it. Once you have two attachment points on the rope remove your descender.

You should always wear your prusik gear ready, or almost ready for use all the way down the cave. If you don't, make sure that it is always clipped onto your harness and never in a pack that you could leave behind, swap by accident or drop. If you do need to attach ascenders and/or safety cords, connect them to your seat maillon with your brake or a spare karabiner and strap on other ascenders as well as possible. You can arrange your prusik rig properly on safe ground.

**Don't even think about undoing your seat maillon while hanging on it!**

But do remember to check it occasionally-they do like to undo by themselves.

## Gear sacks

On sloping pitches carry your sack on your back where it will not snag or drag against the rock. Anything but an empty sack on a your back for vertical pitches will move your centre of gravity back enough to tire your arms rapidly. Climbing is much easier if you connect your pack by its haul cord to one side of your seat maillon or by rigging a short 'V' of tape from your harness attachment points to hang it from. The pack's haul cord should be long enough so that the pack does not foul against your feet but still hangs within tiptoe reach so that you can free it 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 running the haul cord over your leg or putting more weight in the sack! On wet pitches the open top of a sack may act as a funnel and fill the pack with water, unnecessarily slowing you down in a place where you want to move fast. Try suspending the pack upside down to put the biggest hole at the bottom and save needlessly hauling a sack of water up a pitch. After a swim, remember to drain your sack before starting up a pitch.

## At the top

On arrival at the top of a pitch your first move is always to clip a cowstail to the tieback rope, anchor or knot loop. You are then free to get off the pitch in complete safety.

- Next, release your foot mounted ascender or one foot from a Sit/Stand rig and stand on your other foot and release your chest ascender.
- Step onto the lip and release your foot (top) ascender.
- If your cowstail is clipped to a tieback rope, walk away from the pitch and unclip it.
- If your cowstail is clipped directly to the belay or similar you must first attach your other cowstail or an ascender on a sling to the tieback and then unclip your first cowstail from the belay.

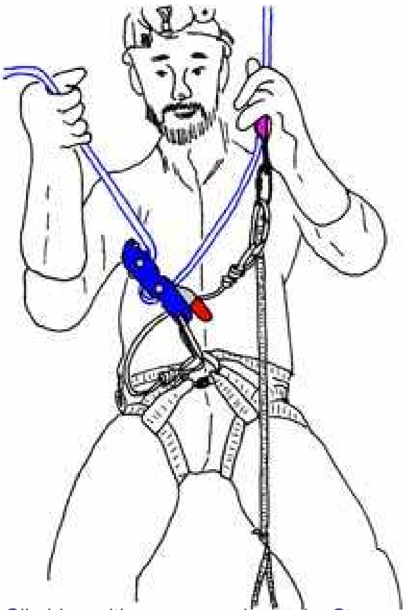
Swing-out pitch heads can be more difficult.

- Clip your short cowstail to the knot loop, rigging link or anchor, but not the tieback rope.
- Release restrictive foot and chest ascenders, hang back on the cowstail and transfer your long footloop ascender to the tieback rope so that you can use it as a handhold.
- Pull across to the lip.
- Once across and safely clipped in, lean back and release your long cowstail.

Generally you will negotiate a pitch head like a rebelay, always remembering to undo your chest ascender before attempting to leave the line of the rope.

Before you leave the pitch head, look back down the pitch or to the last rebelay and check that the rope hangs correctly and is not caught behind a flake or spike, give a call and move on. Take extra care when the pitch involves sideways movement or loose rock. If the next pitch is close, just walk those few steps with your ascenders in your hand. If it's any further, tidy everything up. Be careful to **always** close your Croll and other Petzl ascenders. The safety catch is fragile and if you catch it on something, you may damage it, and a Croll with no safety catch isn't worth much. Fold your legloop a couple of times and clip your ascender to it. Clip your cowstails to your chest or seat harness and get on your way.

## Ascent problems - one ascender

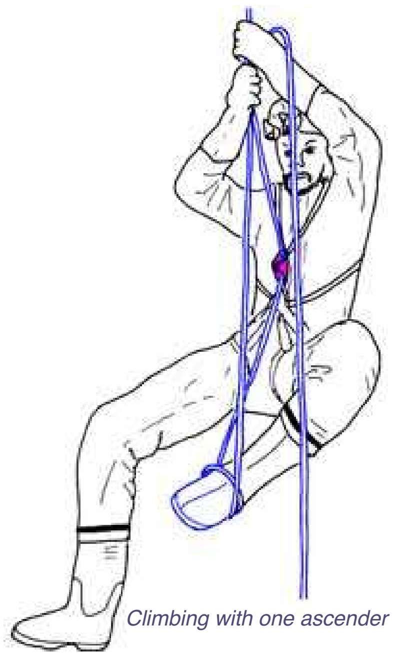


Climbing with one ascender and a Stop

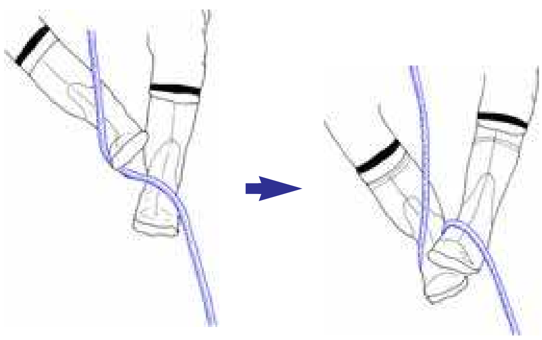
The situation is not too critical provided you still have one ascender. Connect your bobbin descender to your seat maillon as for descent and pull the rope backwards through it to make it act as a chest ascender. Use your one good ascender as a leg ascender for a Frog system with footloops fashioned from whatever is at hand —the end of the rope, pack haul cord or spare clothing. With a Texas system connect the bobbin to your feet and the real ascender to your chest. Pulling your rope through a bobbin descender only works for suitable descenders (Petzl, some Kong) and soft, supple rope. An ordinary bobbin slides back down unless you hold it well, so clearly, an autostop bobbin is preferable.

Without a bobbin, mount your ascender on your chest and use a prusik knot for a leg ascender in a Frog or Texas rig. To tie an effective prusik knot you need a length of cord that is thinner than the rope to be climbed and this may not be easy for 7 mm or 8 mm rope!

With nothing that will work as a prusik knot it is possible to climb 'Inchworm' style with a chest mounted ascender and footlocks for your feet but it isn't easy.



Climbing with one ascender



Footlock

## No ascenders

If you have a bobbin, use it as described above but use a prusik loop instead of a leg ascender.

With no ascenders or autostop the only choice is to construct a prusik rig using knots. Texas is easier than Frog as both hands are free to manipulate the bottom knot. The main problem is finding cord for the prusik knots that is both strong and will grip. Some imagination may be required – a carbide lamp sling, pack cords, sheath or core stripped off the bottom of the rope. Should the situation be desperate enough for you to try 3 mm cord or boot laces for prusik loops, arrange a self belay 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 replace the knot every few metres you climb. 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. You could also avoid the whole problem by always carrying a Tibloc wherever you go.

## Footloop caught in chest ascender

With a Frog and similar systems it is possible to catch both the rope and the long footloop in your chest ascender. In the next stand move the chest ascender climbs the rope and footloop *et voila*! Stuck! Dangling knot tails and thin tape are the most likely offenders. To escape, the chest ascender must move up a little before you can release it and inclined cam teeth make this more difficult.

When you are jammed as high as possible you can gain extra height by tying a knot in your 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 be possible using a separate stand-in sling to unweight the entire prusik rig or to carefully cut the offending footloop free and attach another. Avoid such incidents by using brightly coloured footloops and safety cords that 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 your prusik style causes them to rub against your chest ascender.

Caballos-Valle, Spain


Ozto Ocotal/J2, Mexico




8 >

# Organisation

Caballos-Valle, Spain

No matter how well equipped you are, you won't get far unless that gear and you are organised. The level of organisation you require depends on the cave and your group, but in general the more serious the trip the better organised you'll have 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 you must first decide how you intend to rig caves and then attach other units that fit.

Alpine rigging goes with thin rope, Frog prusik rigs, cowstails, bobbin descenders, bolts, staying dry at all costs and rope packs. IRT 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 you cannot choose caving methods and equipment 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 your 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 your personal limits, whether physical or psychological.

Before starting down a cave, everything should be pre-arranged ready for use. Wear your prusik gear ready for action with footloops rolled up out of the way so they will not snag, or pack it into a small but secure sack and hang it from your belt. Never carry prusik gear 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 you should keep your descender on you in case you must redescend a pitch. Arrange personal equipment neatly. The more odds and ends hanging off the more they will get hung up.

Your seat maillon is the focal point that connects you to your 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
- Cowstail
- Croll
- Descender on a locking karabiner
- Brake karabiner

The **pack haul karabiner** is easy to undo and its cord hangs against the left harness leg loop instead of more delicate objects. A pack haul karabiner also works well clipped into the left attachment eye of your harness.

The **Croll** moves up to the top of the seat 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 you can remove it 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 across your Croll on ascent it conflicts with the Croll. As best of a bad lot, it is better to have your cowstail push against the left of the Croll, than the right.

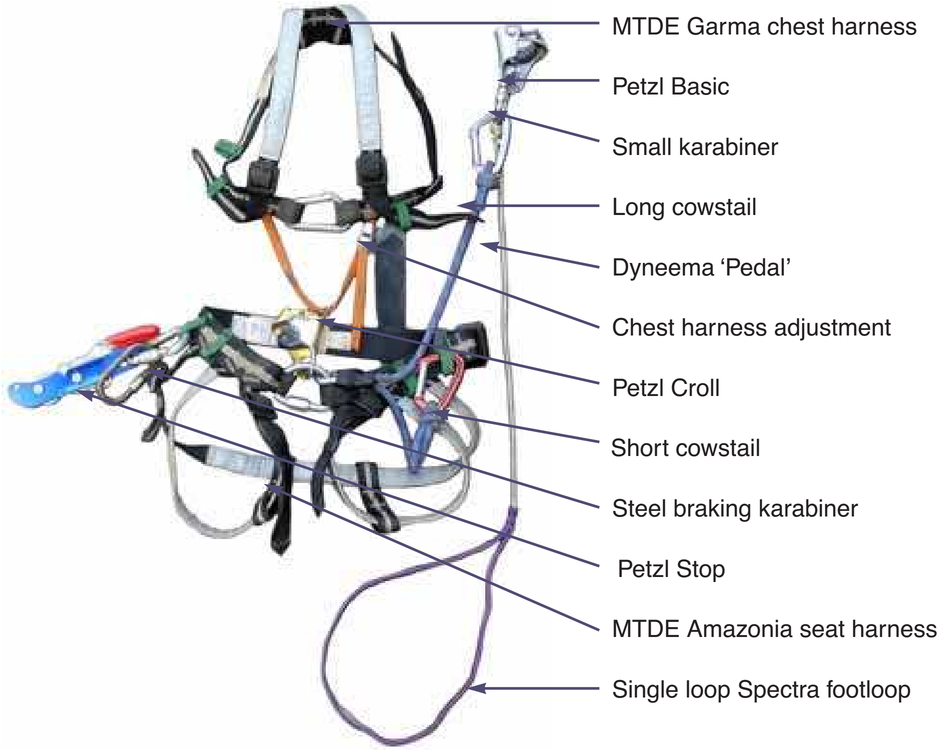
The **ascender safety cord** (if you wear one) is as far out of the way as possible on your extreme left. Don't clip it to the bottom of your seat maillon—if you weight it, the maillon will capsize and make other items difficult to reach.

It is rarely necessary to wear everything at once.

## How I do it

I have all the gear. I have a cave rigged and ready to go. This is what I use to get down and back up.

The emphasis of my rig is simplicity and light weight, usability, efficiency and safety. It's not a rig for absolute speed up any one rope, however in a deep cave, simple, light, usable and efficient wins every time by saving me energy on the climbs and time passing obstacles. This in it's way improves my safety. There's a straight forward method for just about any rigging obstacle and I don't need to resort to gorilla acts to make up for shortcomings in my SRT rig.




## Seat harness

I use an MTDE Amazonia. It's light, exceptionally comfortable and has a very low attachment point. Harnesses like the Petzl Superavanti are also good —just not as comfortable or as low. No doubt there are other nice harnesses out there. Provided the harness holds your main maillon flat against your abdomen, your rig will work, you'll just stand to lose efficiency and comfort. Whatever harness you get, wear it as tight as you can comfortably get it.

*Garma: cranked-down tight*

*Quick release*

*Free to move*

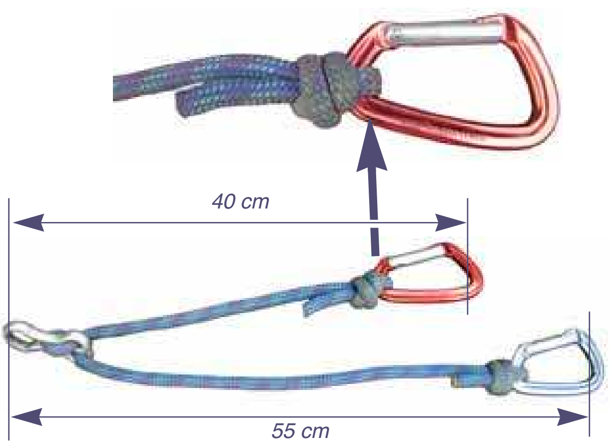
## Chest harness

I use an MTDE Garma. It's a traditional Climbing Chest Harness with one important difference: it supports my Croll with an ingenious tape and bicycle toe-strap buckle arrangement. It's faster and easier to adjust than any other chest harness —by a long way. It also has handy attachment loops to hang your goodies from. Of course for the money and weight, you still can't beat a figure-8 harness with a fairly easy to release karabiner on the Croll.

## Ascenders

A Petzl Croll on my chest is best. The Kong copy is almost as good, possibly wears better, but isn't quite as smooth to release or handle. For a hand ascender, I use a Petzl Basic for several reasons. It's small, compact, light, versatile and lasts well. I haven't used a handle ascender for years. They're much bigger and a little heavier. The handle is useless when climbing a vertical rope—but nice on slopes and handlines. When I push a handle ascender up the rope I tend to push the handle slightly to one side and this wears out the lower edge of the ascender's running surface. Looking at other people's handle ascenders from time to time, I don't think I'm alone with this action.

## Cowstails – material



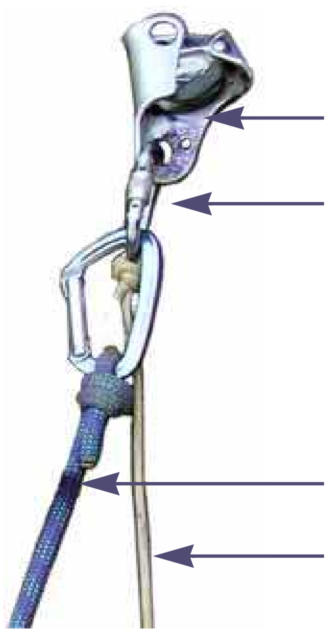

Made of 9 mm dynamic rope. I use a double one with a metal eye that I got from Expe at the bottom. It locks the rope without a knot so I don't have a bulky knot at my main maillon, or a knot that gets abraded. But the rope itself still gets abraded, which is one reason why I use rope instead of tape. When the sheath wears out I change it. With tape I just can't tell when it's worn out. Tape isn't dynamic either and easily catches in ascenders. At the other end I attach my cowstail karabiners. I use good quality, straight gated non-locking D's—Petzl Spirit is good. Kong are even better: I can get them in red and blue so I can put a different colour on each cowstail. I attach the rope with a Barrel noose—half a double fisherman's knot (that's a half a double fisherman's knot, not a single fisherman's!). They're strong, neat and tighten onto the karabiner so I don't have to mess around with rubber bands or little metal bits to keep my cowstail tied to the correct end of it's krab.

## Cowstails – lengths

My long cowstail also doubles as my safety for my hand ascender. It's long enough so that when I push up that hand ascender, I have just enough rope, but no spare—if I'm hanging from it, I still need to be able to reach it. My short cowstail has grown a little over recent years as rigging styles have changed. It's just long enough so that I can use it for crossing rebelays on the way up, while not too long to cross them on the way down. So, when I climb up to a rebelay and have both my ascenders as high as they'll go without jamming them into the knot, I can just clip my short cowstail into the rebelay karabiner. All that works out to an inside top of karabiner to maillon attachment eye distance of 55 cm for the long one and 40 cm for the short one.

I should point out here that it's the cowstails that hold the whole thing together and provide much of the safety for my SRT rig. I've long ago got rid of the extra safety cord to my top ascender—it only got in the way, got tangled around things and was more weight and bulk to carry. Whenever I used it, my long cowstail was just hanging there doing nothing anyway, so I replaced it with a 'removable' safety aka. long cowstail. This of course means that I have to take care to always use it and not unclip it at the wrong time or trust my Croll as my only attachment point. Yes, it is physically possible to prusik the rope with no cowstail and my top ascender not attached to me at all. Would I do or recommend it, even for a little pitch - no! Get in the habit of always doing it right. Treat every pitch as a 100 m pitch.

## Footloop/Legloop/Pedal




Perhaps the French/Spanish 'pedal' is a better word for this thing. Mine is made of 5.5 mm Dyneema (also goes by the name 'Spectra'. Get it from MTDE or Expe), and is made specially for caving by Beal. It doesn't take a dye, so you buy it white and it becomes dirty white in no time. It's real advantage is that it wears and stretches like wire cable—that is, not at all. The lack of stretch makes for a more efficient stand motion. The lack of water absorption and bulk are unbeatable. Unlike wire cable though, it's soft to touch, flexible and light. For the footloop itself I prefer a single large loop about 40 cm in circumference so I can get both feet in to hold the rope, and pop one or the other foot out easily. Get a spectra sling of the length you like and tie an overhand loop around it with the end of the Dyneema. If you've got tough feet, just tie a loop in the end of the dyneema, or you can buy ready made pedals. Don't get an adjustable one, except perhaps for training people, just experiment a bit to get the length right.

At the top of the pedal, I use a Barrel noose to attach it to a small, locking, life support karabiner. My usual routine is to clip my pedal to the bottom of my hand ascender on the way down when I want to remove it easily and lock it to my harness for travelling. On the way up I normally clip my cowstail to my ascender, then my pedal to my cowstail karabiner. This way I can use the ascender and pedal together (normal use) or as separate items on traverses and slopes where I may not want the pedal getting in the way. If I meet a really difficult rebelay on my way down or up, I can clip just my pedal into the anchor and stand in it to pass.

### Pedal length

*Basic reaches to here when I'm standing on the ground*

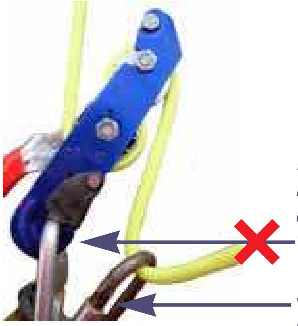
*and*

*here when I'm hanging on the rope*

My pedal is surprisingly short – 106 cm from the bottom of the footloop to the eye of my ascender. When I put both feet in the loop and stand up straight, the ascender barely makes it to the bottom of my Croll. However, once I'm hanging on a rope, my pedal is short enough that when I push my hand ascender up as far as I can reach, my feet can't come up any further anyway, and my cowstail is just about to pull tight. If I take out one foot, I can step higher and reach higher, but have less power climbing with one leg. When I stand as high as I can with both feet in the loop of the pedal my Croll almost hits my Basic. The bodies of the ascenders do overlap, but the wrap around sections don't actually hit. To get the your pedal length right, just shorten it bit by bit until your ascenders hit, then lengthen it a little.

Pedal length isn't critical. Mine has two lengths some 5 cm different depending on how I clip my pedal to my ascender.

## Descender



*I don't clip my brake karabiner in here. The rope doesn't run as well and would wear the body of my Stop*

*Steel brake karabiner with a pin & slot or keylock 'smooth' gate clipped into the seat maillon. It only locks because I couldn't find a non-locker. In fact, it's long since jammed unlocked.*

Petzl Stop. Zipping down a rope on a non-stop descender is like riding a bicycle without brakes... I attach my descender with a locking karabiner. No need for any fancy twist-lock, rapid on off mechanisms. I also always use a steel braking karabiner. Sure steel's heavy, but anything else wears out rapidly, even Russian titanium karabiners. I picked up two really nice steel ovals with smooth pin & slot latches on the gate, that makes them really user-friendly. Most steel krabs - if you can get them - have really nasty claw latches and there's just so much you can do with a file. If you can't get steel, or titanium, or have enough aluminium karabiners to grind to dust, try to find a Raumer 'Handy', a special stainless karabiner-like 'brake-krab' that should last you forever. Very positive braking, a bit too positive at times. A karabiner is nicer and if it's a good one I can occasionally use it for something more serious like a tyrolean when I don't want to wear out a precious cowstail karabiner. As a rule my Stop is either on my seat maillon for descending or on my belt/harness loop in an easy to get position when I'm ascending. Just as my 'up' gear goes down a cave on me and ready to go, my Stop is always handy when I'm climbing and never in a pack that may get left behind or carried-off by someone else.

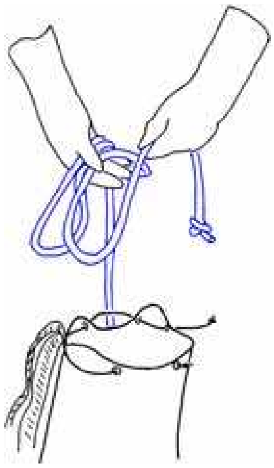
## Foot ascenders/Pantin

Euro cavers have discovered the foot ascender. Ask any French caver and they'll tell you that the Pantin is "zee best". A Pantin pulls the rope tight for your Croll so you can effectively prusik up a tight rope and use a walking motion on slopes or on freehangs if you're a gorilla. It may also save you some energy and certainly makes you feel like you're climbing better, but there's a price. Your Croll will wear out perhaps twice as fast, and you have a third ascender to attach to the rope, that you usually have to put on a few metres up as they don't necessarily run right from the bottom. No need to wear your Pantin all the way down the cave. You don't 'need' it to climb.

This is how SRT works for me. Everyone is a different height, has different proportions and different flexibility, and so needs to set up their equipment slightly differently.

Voronia, Abkhazia

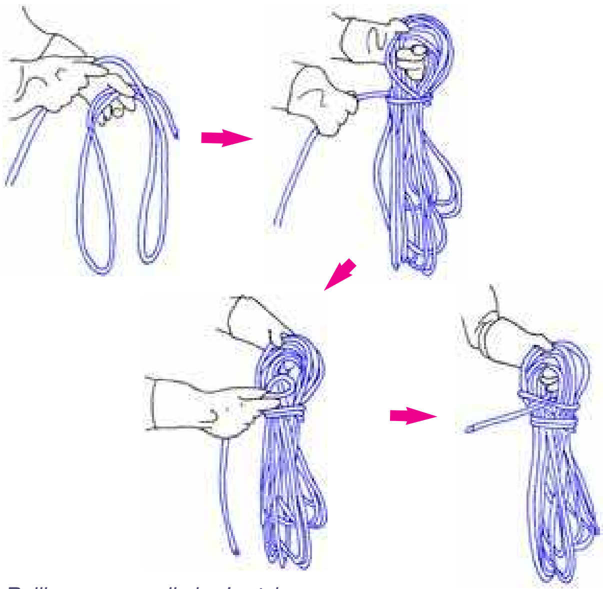
## Gear management – rope



Stuffing a rope pack

Cavers spend a lot of time handling ropes and most would agree that the only place to carry one is in a rope sack.

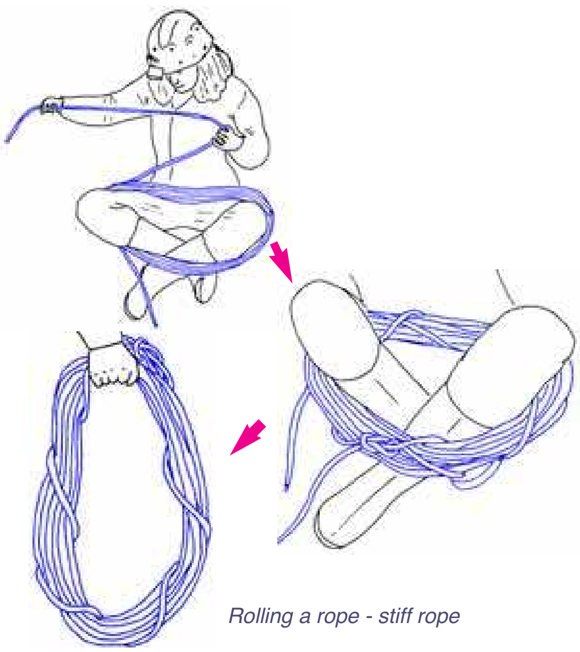
When you know the cave or cut a long rope to fit a pitch tie a stopper knot in the end and stuff the rope into the sack, ideally in handfuls that do not twist the rope. Tie consecutive ropes to each other either loosely if the pitches are not continuous or with a knot and safety loop ready to cross so that you won't have to do it while hanging in space. Descend pitches with the rope pulling out of a sack to reduce the danger of a falling rock damaging it or the rope becoming tangled as often happens when it is thrown down. I prefer to pull out a few metres of rope at a time, descend a little, then repeat the process. This way I can see that I still have rope. Even though you 'know' that the rope has a knot in the end, if for some reason it doesn't the end will be out of the pack and through your descender before you know it.



Rolling a rope - climber's style

When you don't know the cave, choose a suitable rope as you encounter each new pitch. Carry these as a selection of ropes, each rolled up separately, with the longest one stuffed into the bottom of your sack. The specific selection you carry depends on what you know about the cave or other caves in the area. As you empty a rope sack split the load more evenly between the party or leave the bag hanging from a belay for refilling on the way out.

Stiff thick ropes don't easily fit into rope sacks but you can roll them around your knees and tie them into 'wagon wheels' that you wear over your shoulder, hanging below on pitches or rolled along ahead of you in narrow passages.



Rolling a rope - stiff rope

Occasionally the rigging of a pitch requires delicate climbing that would be difficult with a heavy pack dangling below you. Instead, 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.

While the bulk of your load will be rope there are several other items that you will need.

## Anchors

Pre-clip bolt hangers to their karabiner or maillon and link them in chains of ten for convenience. When you split the chains between rope sacks to spread the load clip them to the drawcord or rope so they cannot be lost. While you are rigging pitches it is a simple matter to hang one chain of karabiners or maillons with hangers, and another without, from your belt ready for use. In dirty caves keep the hangers in a small sack to keep the bolt threads clean.

Avoid carrying hangers or small metal items loose in a cave sack, as they are adept at finding their way to the side or bottom and eating their way out. Pegs and nuts carry well on metal peg rings or short lengths of knotted cord. Knot slings loosely to make them easier to handle and clip a number to a karabiner to keep them together. Wind wire traces into a 15 cm diameter ring and join the two ends with a maillon to keep them from unraveling.

When you know the cave well or have a good tackle list attach the rigging gear for each pitch to the top of its rope. This avoids the need to rummage in a tackle bag at each belay point and saves time.

## Bolt kit


Bolt kit

Pack everything you need for bolting into a pouch that doubles as a hammer holster that can hang at your 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 your gear sack. Tie the hammer and cone pocket to the pouch with cords and fit the driver with a wrist loop if it does not already have one. You can also throw in a sky hook to help keep you in position when placing difficult bolts.

Before packing the anchors check their threads and only take a few more than you think you will need on the trip or they will only become wet, dirty and difficult to thread next time around.

Many cavers regard a spanner as a necessary piece of personal gear. The ideal is a 13 mm spanner for spits or a size that suits your bolts, with a ring spanner at one end and open at the other. Carry it separately from the bolt kit as you may need one for rigging to existing bolts or adjusting rigging during exploration. Attach it to a string and mini-karabiner and hang it from your harness or put it on a car tyre tube armband. When you are derigging without a spanner, use the oval attachment eye on Petzl bobbins as a spanner to save abandoning a hanger.

When exploring previously bolted caves add an anchor cleaning tool made from a sharpened wire.

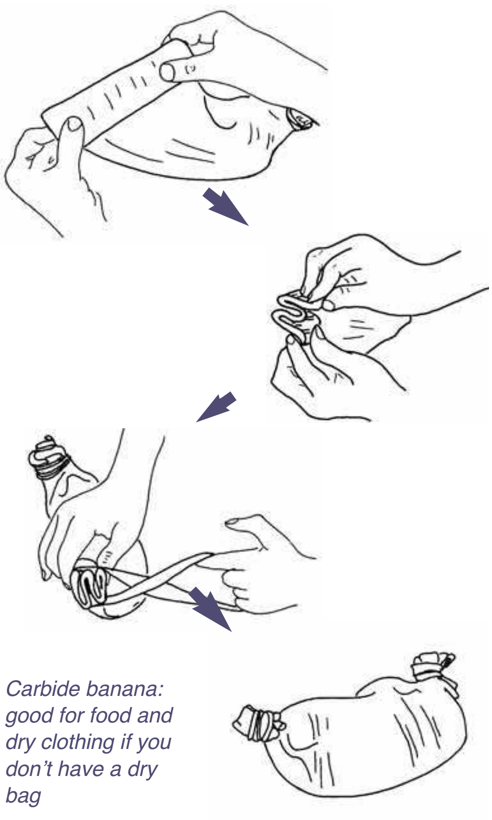
## Spare clothing

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

## Spare batteries

For short trips, the batteries in your main light and backup light should be adequate. For longer trips take spare batteries in a robust, waterproof container. With your food or spare clothing works well. With such a wide variety of LED lights now available either carry your own spares, or take care that group batteries suit everyone’s light.

## Carbide



Carbide banana: good for food and dry clothing if you don't have a dry bag

Carry larger chunks and quantities of carbide in lengths of small diameter car tyre tubes with the ends closed by rubber 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 the maximum anyone would want to carry and it is usually more convenient to take several smaller ones rather than one big one for longer trips. Don't carry waste carbide in a banana. The waste usually continues producing acetylene and the banana will inflate until it bursts. Carry carbide waste in an unsealed plastic bag protected in a nylon sack. Often the carbide hasn't completely reacted and will produce a lot more acetylene if it gets wet. Take care in swims and especially in tight, wet sections where a gas leak can produce an impressive explosion.

Calculate the quantity of carbide you carry 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 you can cut down on the spare third for most trips.

## Gear sacks

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

Pack hard items such as hammers and karabiners in the centre of the sack to keep them from damaging the sack fabric or your back. Carry odd items like food or rigging gear in a light nylon sack within the gear sack so that you can easily remove them to get at the rope below. If you know the cave, prepack every item in the reverse order of when you will need it.

A pack that looks reasonable on the surface could become an impossible monster underground. Anything heavier that 15 kg and larger than 35 L is too big for most people. Carry more smaller packs rather than fewer large ones, you'll have a better chance of not injuring yourself.

## Tackle lists

When planning a trip down a known cave 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. Encase a copy of each in 'contact' plastic or a clear plastic bag and carry them through the cave for ready reference.

**Table 8:1** **Creek Cave - tackle list**

| Pitch | Length (m) | Rope (m) | Rope taken | Anchors |
|---|---|---|---|---|
| 1 | 12 | 20 | 30 | nat + b, b-6 |
| 2 | 3 | 6 | 15 | pr + b |
| 3 | 90 | 100 | 120 | 2nat, nat-20, b-30, ledge b-50, 2b-60, b-70 |
| 4 | 20 | 25 | 28 | nat + b |
| 5 | 30 | 35 | 40 | b, b-5 |
| 6 | 30 | 30 | 32 | nat + b |
| 7 | 45 | 50 | 50 | b + nat, nat-15 |
| 8 | 2C | 6 | 8 | climb up/ ladder |
| 9 | 30 | 35 | 37 | nat, r-5, r-20 |

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

If a tackle list is not available you can usually draw one 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 calculate them 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 make extra allowance for long tiebacks, traverses, stepwise pitches or large natural belays, all of which require more rope. If in doubt take too much and pack a few five to ten metre ropes 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 that 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 on the list, then stuff them into the rope sacks in order from the bottom of the cave up.

Split rigging gear between the sacks so that there is an appropriate amount to rig each load of rope or concentrate it to make one small but heavy rig pack. Put food, carbide and spare clothing into the packs that are lighter to even up the loads and later transfer it to the first empty sack so it will not have to be unpacked each time you need a rope. When there are a large number of sacks it may be worth marking each one with a number or tag so as not to get them confused.

## New caves - prospecting

When surface prospecting it is best to walk the area first with minimal gear, perhaps a torch and short handline at the most. Once you find some reasonable holes you 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, take a GPS fix and take notes as to what each numbered cave is like.

## Depth estimation

Before descending any shaft it is useful to know how deep it is. Estimate small pitches by shining a spot light down them to 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.

Drop a solid, fist-sized rock down the pitch taking care to give it no initial downward velocity, although a light outwards toss may be necessary to make it fall down the centre of the shaft. Count fall time to the nearest half second using a watch. Use this to calculate a rough estimate with the formula:

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

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

ie. A three second drop would give:

**5 x 9 = 45** metres

In most cases this will give an exaggerated figure that at least encourages you to take too much rope rather than too little.

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 anyone wishing to write it on the lid of their cave pack.

**Table 8:2** **Depth estimates**

| Time (sec) | Rough depth $5 \times T^2$ (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 $D = 340 \times T + 11784(1-\sqrt{1 + 0.0577 \times T})$ (Hoffman, 1985)

## What to take

In most karst areas the majority of surface shafts are blind, so make your initial descent 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 IRT rigging will save a lot of time and effort if there are a number of holes to look at, but on the balance side, you have to carry more rope up the hill. Confirmed Alpine cavers or those who only have thin rope 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 you can rig the rope roughly and quickly, though always safely, just to see if the hole 'goes'. Make heavy use of natural anchors and don't fuss too much about comfort or ease. Should the cave go, it is not much trouble to rerig one pitch and if it doesn't go, you will save time and effort. A slight exception is for bolts. If you are forced to spend the time placing one, 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 rig it 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 you carry underground varies with what you 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 100 m to 200 m of rope and place up to ten bolts by hand—more with a power drill, in a days' exploration of a cave that goes with no major complications. When you carry a selection of different length ropes there is a good chance that 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 works best with small groups. Parties from one up to four are reasonable, depending on experience. Beyond four it is preferable to split into sub-groups that 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. The deriggers can arrive after the riggers leave the bottom and immediately begin the derig.

## Trip duration

While you can estimate the 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 duration.

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 serious. 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, the right attitude and acceptance of the extra risk, go for longer – thirty, forty or more hours without sleeping.

Once a trip goes overnight, you must make allowance for your body's slowing down during normal sleeping hours and the increased accident risk that it entails. The turn around time for most cavers is about 10.00 pm to midnight, and anyone still working their way into a cave in the early hours of the morning should not take it lightly. Reduce or avoid the problem entirely by getting an early start so that you do as much caving as possible 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

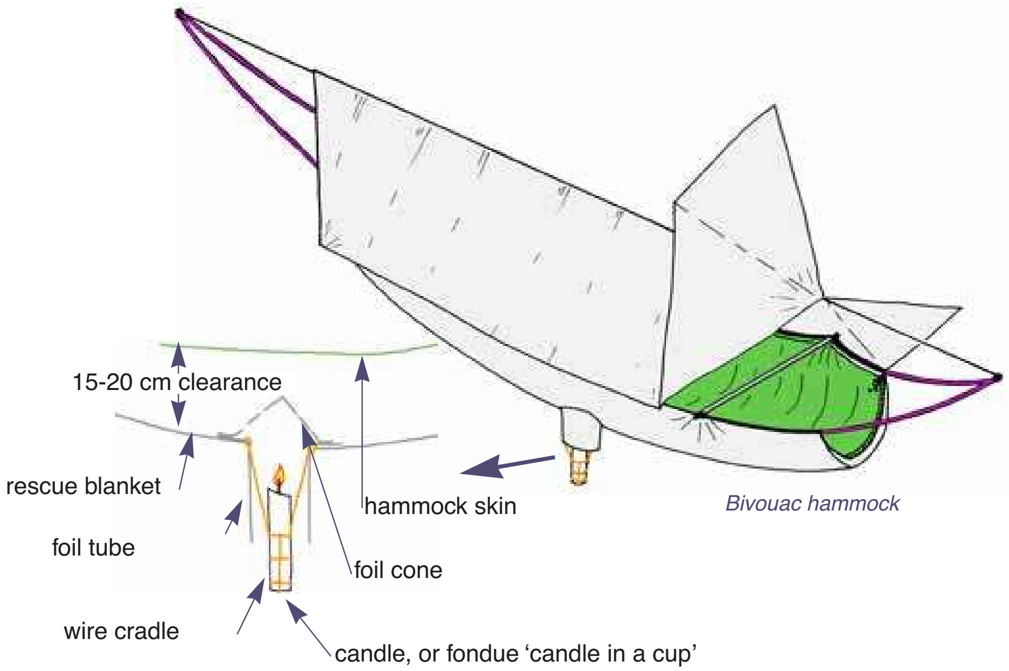
The need to place an underground camp or not is often a matter of caving style rather than an absolute "It-is-not-possible-to-go-further-without-a-camp". Many cave camps are a waste of time and effort. The same result may well be achievable from the surface with less expenditure of time and manpower. The effort involved in carrying in camping equipment, food and extra clothing often ties up several people for a few days when the same effort could be put toward exploring the cave. Granted, camps may be set up by those who take on a support team role, so that other 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 that 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.

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. Cut everything to a minimum. Specifically designed gear helps 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. Pack everything as small as possible and take a minimum in hard containers that pack badly and once you've used the contents, be it food or carbide, they still take up the same volume empty as they did full.

## Hammocks

Light, heated hammocks cut weight even further as they provide a bed and shelter and do not require a sleeping bag in warmer caves and a less bulky bag than would otherwise be needed in a cold cave. Hammocks also allow you to camp in truly inhospitable locations where there is no flat ground or water below. The heat source is a solid fuel burner, long burning candle or carbide lamp. Bivouac hammocks are commercially available but you can improvise using a light nylon hammock, three rescue blankets or light plastic sheeting and adhesive tape. Your heated hammocks will be much more comfortable if you run a stove under it to dry it out and warm it before you go to bed. The candle then keeps the hammock relatively warm and dry. Hammocks are best reserved for short, hard bivouacs when you can arrange nothing better.




*Bivouac hammock*

## Camps


Ozto Ocotal/J2, Mexico

For longer camps in better campsites a lightweight tent to trap your body and cooking heat makes a huge difference. A traditional 'A' tent with short walls made of the lightest possible synthetic fabric is ideal. A 2 m by 3 m tent holds 6 cavers in comfort and weighs around 500 g if you choose the correct fabric, and saves everybody carrying the extra clothing they'd need to survive 'outside' in the cold. They heat trap effect is even more noticeable if the cave has a breeze. In caves where the roof leaks it may be necessary to add a roof from light plastic sheeting.

## Camp food

The key to efficiency is to plan everything. For a one or two night bivouac it's easy to plan each meal and carry the precise amount of fuel to cook it. Longer trips require considerably more planning and the planning task gets even bigger once there are cavers moving between camps.

**Table 8:3** **Ten cave/day theoretical food pack**

| Food | Amount | kJ | ...reality |
|---|---|---|---|
| rice/pasta/couscous/instant potato/etc. | 2.5 kg | 40 000 |  |
| porridge | 500 g | 7500 | |
| cheese | 1 kg | 20 000 | |
| salami | 1 kg | 20 000 | |
| bacon/jerky/dried meat | 500 g | 10 000 | |
| chocolate/bars | 1 kg | 20 000 | |
| sugar | 400 g | 6 400 | |
| tea | 30 bags | - | |
| olive oil | 200 mL | 6000 | |
| nuts | 500 g | 12000 | |
| dried fruit | 500 g | 5 000 | |
| powdered milk | 300 g | 6500 | |
| candles | 2 | | |
| lighter | 1 | | |
| toilet paper | 1 roll | | |
| flavourings (chilli, tomato paste, garlic, salt) | | | |
| stove fuel | 1L | | |
| **~10 kg pack** | **~1kg/person/day** | **~16 000 kJ/person/day** |  Photo: Enrique Ogando |

An approach that works is to make 10 caver/day packs that contain the food and fuel. With waterproofing in a drybag and padded with thin foam it should fit into a 30-35 L sack and weigh 10-12 kg, with just enough room on top for a little personal gear—your spare batteries and dry top. Everything is communal, the tent, plastic floor, sleeping bags, mats (that came down padding the food), and cooking gear so when you move between camps you are not already half loaded with clothes and camp gear.

Neither list has freeze dried food on it. If you read the nutritional information on a freeze dried packet you will see that they contain very little energy in such a bulky packet. On an energy for cost basis, they are even worse, and I won't even consider the question as to whether they are food or not.

Take the lightest available liquid fuel, canned gas or solid fuel stove. The best stove depends on the type of camp: liquid fuel for longer stays and heavy usage and to avoid carrying out a lot of cans and expense; canned gas for convenience and lighter, cheaper stoves for short stays, and solid fuel for lightest weight bivouacs.

Once you have installed and inhabited the camp use it as efficiently as possible and waste it on nothing other than its intended purpose – to explore the cave.

## Communications

*Nicola cave 'radio'*


*'Michie Phone' single wire phone*

Communications are hardly a problem for shorter trips. The worst that can happen is that you have to wait until one team emerges before the next team knows what to take in. Once you have more than one group working or living in the cave the confusion increases exponentially. Sending messages usually results in a speleo version of a game of 'Chinese Whispers'. Even written messages are often out of date by the time they reach the surface. At some point you may just have to take the plunge and set up an in-cave communications system. They are of two basic types:

- Wireless. Like the Nicola system as used by French Cave rescue
- Wire telephones. Preferably purpose-built single wire phones

Each has advantages and disadvantages. A Nicola fits in a lunchbox sized Pelican case plus antenna. You set up the antenna, preferably in a damp spot, then call the base. On the downside, the battery consumption is high enough that you can't just leave a Nicola running and wait for a call, the two stations are best more or less one above the other and within 700 m, and they are expensive.

A single wire 'Michie' phone is a mobile phone sized handset that can talk to any other handset on the line. A Michie phone runs for at least a month on a single small battery, and they are cheap. They have a range of 30 or more km. Unfortunately, they require you to lay a phone line down the cave. This is neither trivial or cheap.

With good communications between anywhere in the cave and the surface, the next team entering can know exactly what they need to bring and start down the cave much earlier. For caves where there is a chance of becoming trapped by flooding, complex logistics, or in an emergency, good communications become more important.

## 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. As last person up you begin pulling the ropes. As you ascend you should dismantle belays and undo knots and loops so as to reduce the chances of a rope snagging when you pull it up. Any knot left in the rope will also grind against the rock on its way up and cause unnecessary rope wear. On long pitches with ledges you may find it necessary to haul the rope up to each ledge and re-stack it so that when you haul it up the next section it pulls from the top of the pile.

When a pack is full, either take it to the surface or pass it on to someone who does. Anyone with a full load gets priority so as to get the gear moving as fast as possible. 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. A group derigging a cave from the top should organise themselves so that each person descends to a pre-determined point and hauls out a sackfull of rope. Stagger your entry times such that as you fill your sack and begin to head out, the next person arrives to take over without waiting.

If you intend to leave a cave rigged from one season to the next it may be desirable to 'stage derig', especially in flood prone caves. All this means is that you pull up the ropes and stack them every few hundred metres in a safe dry location to save them from being destroyed. Derigging whereby cavers haul sacks part of the way out and then leave them for a later derig trip while they exit 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 and will not work at all with rebelays. The biggest risk however, is of the rope not being replaced correctly after the haul—a rope snagged because it wasn't thrown down correctly can easily trap a party below. Makes for good campfire stories, but it's not much fun at the time. Flying foxes (ziplines) and pulley lifts are a thing of the past, any caver who needs them should rethink their approach to **lightweight** caving.

The most efficient way to move gear is for each caver to carry their 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. Rarely will there be a section of cave that 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. You should only consider it in very difficult passages or when you have a lot of bags to move. 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 of 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 danger areas before the rain begins.

In alpine areas the worst times are during snowmelt or when there is heavy rain on a light snowcover, and far less predictably from thunder storms. After waiting out bad weather it may not be wise to start 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 pre-mixed 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 you feel well nourished, which is half the battle. Numerous light snacks, such as sweets in your pocket so you can nibble them while waiting for rope free calls or during a short stop provide a constant supply of quick energy and a valuable psychological boost. Most cavers on extended trips soon tire of a diet of sweets and more traditional meals like sandwiches are often appreciated so long as you keep them intact.

Carry your food in plastic bags and on rough trips in wet caves it will probably get wet. Wide mouthed plastic bottles and lunch boxes keep food in better shape and keep it dry. In wet caves you can keep food dry in plastic bags inside tyre tubes like you would use for carbide or use a dry bag.

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

Cavers in cold caves often carry stoves to make cups of tea and soup 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. Snacks instead of meals help keep cavers from becoming cold and avoids the lethargy most of us usually feel after a good meal. The only time you need a stove 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 you eat in the cave is what you eat before the trip. As in other endurance sports, eat as much complex carbohydrate, especially pasta, as you can tolerate before the trip so that you enter the cave with a maximum of energy reserves already in your body. 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 you expect 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 you 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 you 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

Some cavers fuss 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 belayer and climber had to communicate up and down pitches. 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 left the top or bottom of a pitch or has passed a rebelay. If you carry a whistle, keep it simple:

**1** blast - going down

**2** blasts - going up

**3** blasts - rope free

**Long**, urgent blasts HELP!

If there is loose rock, water or some other reason why the next person should not follow close behind, withhold the call, preferably by pre-arrangement, 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 that may never come. Similarly, in Alpine rigging, it is usually possible to see the rig point ahead but this is no reason to not call because you think your companion has seen you pass it.

When you knock a rock 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. Always remove it from the cave system and then dispose of it 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. Hopefully the advent of LED lights won't result in little piles of AA cells appearing in out caves.

Throwaway rigging is another irresponsible 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. eg. 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! This unfortunately, is no isolated case. 20 years on and you can visit the deepest caves in Mexico and find ropes left there because "the project is not finished", even though there is no plan to return.

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 you find them in vast numbers.

At least rubbish is removable with a little effort. 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 leads 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, then there is a bolt farm with most of the bolts safely back from the edge where they are useless and perhaps one or two well located so they are useful.

When doing a known cave it is worth being a bit tolerant of weird rigging provided it is safe. Save time and the cave by taking along something to clean out clogged bolts rather than just putting in new ones beside the old. A small piece of stiff wire with a curved point at one end is light, simple and cheap. With some work you can make rusty 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 may only serve to compound pollution problems. When a bolt is no good disable it **neatly** with a wooden or plastic plug, leave it alone or better still, remove it.

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 will remove many loose, half drilled or otherwise bad bolts provided they have usable threads.

Some bolts can be difficult to locate. This is both good and bad. A bolt that you cannot find is effectively not there but also increases the chance of a superfluous bolt being placed. Mark obscure bolts with flagging or 'Scotchlite' tape, or leave hangers on them, but not giant carbide arrows and spray paint. Bolt caps made of nylon pegs help keep the anchor clean in dirty conditions, while marker tags and a thread or fishing line set in with the anchor so they are not lost make the bolts easy to find and stops them 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 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. Try to be fit 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. Train on cliffs or in trees until you are completely familiar with vertical gear and rigging that in turn will lead to increased confidence underground. Even so, no amount of simulated practice can replace the training gained from caving itself. On expeditions one or two 'acclimatisation' trips can be worthwhile to get familiar with the cave before doing more committing trips.

Madre de Dios, Chile

Madre de Dios, Chile




Caves.com
Exploring the Harder Side of Caving
Order Printed Versions
Online at www.Caves.com/vertical
9
Disasters
СПАСАТЕЛЬ

Caving is not a dangerous sport in itself, but the harsh environment of caves can turn even a minor accident into a tragedy. Accidents happen to anyone, so First Aid and rescue cannot be left to one person. How well you cope with adverse conditions is as much a measure of competence as how well you cope 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 Ambulance courses. A basic grounding in First Aid will help you assess the condition of a victim and thus make a decision that could save their life.

A First Aid kit should always be available on the surface. What the kit contains depends on where you are 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.

## 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 weak or injured cavers and when there are swims and wet pitches.

The only treatment available to cavers is to rewarm the patient. Once hypothermia has set in the victim will be incapable of rewarming themself. The best external heat source is another caver or two jammed into the same sleeping bag or 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

Xongo Dwi Ñi, Mexico

... five minutes later

Active caves are often 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 you 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 flood pulse down the cave and avoid flowing water as much as possible.

If a rope is hanging in floodwater and you will be hit by a lot of water on the way up or down, it is much safer to sit and wait. Once you are 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 you truly appreciate the need for rigging ropes clear of the water.

Should you become trapped in a safe zone the best choice is 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 you can put the oversuit back on. Make a seat from a sack or ropes and sit in a foetal position under a rescue 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 rescue blanket to provide extra heat. When you have a choice 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 rescue blanket over to let any condensation dry off. Ration what food and carbide you have so that it will last as long as the expected stay allowing enough to get out when the time comes.

## Exhaustion

Learn your limits. One caver '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 perhaps hard to admit that a trip is too difficult but this will certainly be better than having to be rescued. It may be the trip leader's duty to 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. Badly rigged ropes or pitches rigged wetter than they need to be also tire people out. Never start up a pitch if there is any serious doubt of having enough energy to reach the top.

## Trapped on rope—harness hang syndrome

Humans are not designed to stay still in a vertical position and any circumstance that keeps you immobile and with your feet substantially lower than your body is dangerous. It's what causes people to feint after standing too long. Falling over of course returns them to horizontal and they recover. If you are on a rope and feint, you stay right where you are. If you must stop for a long time on rope, move to a ledge where you can move about a little. If you are really stuck, at least move your legs—pushing against a wall is better than just swinging them in space—and don't try to sleep while you're waiting.

The problem is that if your legs are immobile and below you, your blood start to pool in them. Much of the pumping force required to return blood to your heart is supplied by muscle action. Blood isn't just pushed by your heart. If you remain still you will experience extreme discomfort within 30 minutes or less. By then it may be too late. There is a fair chance that you'll pass out. It gets worse. Once you have been immobile on rope for as few as ten minutes you are in grave danger. Even if someone can pick you off the rope and bring you to the ground, you have a high risk of dying as blood pooled in your legs rushes back to your heart.

Seddon, 2001 makes particularly scary reading. He describes cases of people losing consciousness just pretending to be victims and even just waiting to pretend. In several simulations' subjects acknowledged they wanted to be lowered to the ground, but lost consciousness before it could be done. In even more cases, mainly of climbers, victims often died once they were rescued from the rope.

**If someone is incapacitated on a rope it is imperative that you reach them quickly and at least get them into a sitting position by attaching their chest harness to the rope, and foot stirrups to keep their legs horizontal and take some off the large blood vessels in their thighs.**

Once on the ground, DON'T lay the victim horizontal. Put them in a sitting position, with their legs outstretched in front of them. Slowly lay them down over the space of 30-40 minutes.

## Cave accidents


*Immediately after a self rescue from -450 m.*

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, you can avoid both 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.

*"At first we didn't understand what had happened. But when we heard shouts we realized what had happened and immediately started looking for the fallen caver...I was ascending the rope and as I was moving up, the wall was covered with blood. Finally I reached Sasha. His leg was twisted at 120 degrees. It looked like he had a compound fracture. I climbed higher so that I could see his face. His eyes were half closed. He was unconscious."* [he had just fallen 30 m onto a rebelay loop attached only by his brake karabiner]– Bernard Tourte in the documentary 'Voronia 2003'

## What to do

Every rescue situation is different and there is no formula to decide exactly what must be done. As a rescuer, your response must be based on two main factors – the severity of the injury and the availability of outside rescue.

Assess the accident victim's condition in the first instance and render First Aid. Only then if it is necessary, move the victim to a location where both they 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 you can do so safely, start the rescue immediately. 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, despatch someone immediately 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 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. Depending on the country, the best 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 skills. Those interested in cave rescue should 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.

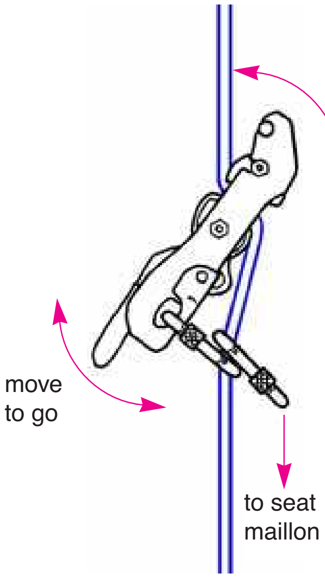
If you must move the victim to a safer area to await a complete rescue it is much easier to go down rather than up even if this means moving further into the cave. Lowering a victim takes no specialist equipment and little effort whereas any lift system requires at least two pulleys to work efficiently. Few cavers make a habit of carrying rescue pulleys with them but all caving groups 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 they are on the rope are rare. However, I will assume the worst possible case of an incapacitated victim hanging on the rope, 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. All of the techniques described below give a basic outline only.

For clarity I have simplified the rescue techniques that I have described but in a real or simulated rescue things are rarely so simple. Practise all rescue techniques before you need them so that in the event of an accident you can take the appropriate action as quickly as possible. Practise will also make it blatantly obvious that a single rescuer stands no chance of getting an incapacitated caver out of a deep cave.

## Getting to the victim




*'Abseiling' a taut rope*

There is no real choice if the victim is trapped above. You must prusik up the same rope to the victim before you can take any other action. If the victim is below and you are not carrying a separate rope to descend to the victim and work from, you face the problem of descending a taut rope. The surest way is to prusik down but it is slow (see Down prusiking on page 132). For longer descents use a bobbin on as shown in "Abseiling a taut rope" or use a rack similarly with two bars (Michel, 1982)—practise first with a belay!

'Abseiling' a taut rope is a delicate procedure. Should the victim somehow unload the rope by climbing onto a ledge you will immediately start to freefall. With such dire consequences you should only use this form of descent with the utmost caution so as to avoid having two victims. Any form of shunt will provide some security provided you can activate it at the first sign of movement from the victim. Unless you are totally confident and have practised this previously, take more time, prusik down, and avoid a double rescue.

## Lowering

The easiest and safest way to lower an incapacitated victim is to abseil with them hanging below you like a heavy sack. In this way you can fend them off rocks and keep in close contact during the descent. On arrival at the bottom you are there immediately to keep the victim from drowning in a pool or move them to a safer area. Whenever descending with a load as heavy as a person, rig your descender with extra friction such as an Italian hitch on the brake krab (see Extra friction on page 93).

## Victim on ascenders

You 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 (see Ascent to descent on page 133).

### Heavy victim

In most cases you will be unable to lift the victim in order to release his ascenders or change from ascent to descent.

- For security, clip a short cowstail to the victim's short cowstail.

- Release the victim’s ascenders until only his chest ascender remains attached.
- Connect a footloop or 1.5 m long sling to the victim’s seat maillon then thread it through a karabiner or pulley on your top ascender then down to your own seat maillon.
- Push your top ascender up to pull the footloop tight.
- Clip a descender to the victim’s seat maillon and attach it to the rope as high as possible. Add extra friction and lock-off the descender.
- Unclip your chest ascender and sit back to counterbalance the victim’s weight against yours. Push the victim up with your arms and legs to unweight them enough for you to release their Croll.
- Sneak the victim’s descender further up the rope as far as you can before lowering them onto it.
- Remove the counterbalance footloop.
- Prusik down and attach yourself as directly as possible to the victim’s seat maillon —a chain of two karabiners is ideal.
- Prusik down until you are also weighting the descender already attached to the victim.
- You are now ready to remove your ascenders and descend in tandem with the victim.

## Cutting the rope

This is what you would do if you had a separate rope:

- Descend on a separately rigged rope until you are just slightly higher than the victim.
- Use your arms and legs to lift them up and transfer as much weight to you as possible.
- Clip into their seat maillon with a chain of two karabiners.
- Add extra friction to your descender.
- Cut the **correct** rope and continue.

## But if you’re on the same rope?

(after Marbach and Tourte, 2000)

- Descend or climb up until your Croll is just below that of the victim.
- Attach your short cowstail to their seat maillon.
- Remove your foot ascender.
- Remove the victim’s long cowstail (or separate safety cord) from their foot ascender.
- Attach the end of the rope to the bottom of their foot ascender. If you’ve just ascended the pitch, you could have brought the end with you. If the rope is tied below, take in slack from just below the victim and attach that to their foot ascender.
- Make sure that the victim’s ascenders are about 30 cm apart.
- Clip a descender to the victim’s seat maillon and attach it to the rope as high as possible below where it attaches to their foot ascender, add extra friction and lock it off.
- Stand in the victim’s foot loop and remove your Croll. In the same movement, attach your foot ascender above that of the victim and sit back on it.
- Tie an end rope stopper knot just below their Croll – the rope will zip through and be gone once you cut it.
- Cut the rope just above the victim’s Croll.
- Stand in the victim’s footloop and remove your foot ascender. As you sit back, attach yourself to their seat maillon with a chain of two karabiners.
- Remove your short cowstail.
- Continue on down.

The important advantage of this second method is that you don’t have to lift the victim. Also, the victim’s Croll may be jammed tight if there has been any fall involved.

### Victim on autostop

Using any other descender the victim would probably already be on the bottom! You can approach the victim from above or below.

- Tie an Italian hitch on the victim's brake krab and lock-off their descender.
- Clip as directly as possible to the victim's seat maillon and prusik down until all your weight is on the victim's descender.
- Release your own ascenders and descend using the victim's descender.

### Rebelay

(Marbach and Tourte, 2000)

Fortunately, you have two descenders, your own and the victim's.

- Descend until you are just above the rebelay.
- Attach the second descender parallel to the first with its own karabiner on your seat maillon, then attach it to the rope below the rebelay. Lock it off.
- Descend until the load takes up on the second descender. Be very careful to stay on the same side of the rope as the victim.
- Remove the top ascender and continue.

Simple! Except that if there isn't enough slack in the rebelay you may end up with each rope partly loaded. Remember that the load is double and so is the stretch in the rope. If in doubt, sneak some extra rope through the knot from below. If you then allow too much, tie a Figure-8 loop above the rebelay to use up the slack before you move off. Of course, do this a few times and you won't have enough rope left to reach the bottom...

Larger groups with enough rope will find it easier to lower the victim on a separate rope threaded through a descender anchored to a backed-up belay at the top of the pitch. One person should abseil with the victim to keep them clear of rocks and call stop/go signals to the top.

Attach the lowering rope to the victim, then detach them from their own rope as described above. Next, descend with them until the lowering rope takes up.

If you have enough manpower or pulleys you can attach a lowering rope to the victim's rope at the belay above them, lift a little to release the belay then lower the victim and rope to the bottom. Keep the lowering rope attached through a descender at all times to avoid dropping the victim and use a totally separate belay rope and belayer for extra safety if these are available.

Organisation takes time and the victim may only have a few minutes. Getting to an unconscious victim quickly and putting a chest harness on them and lifting their legs is far more important than the comfort of the rescuers.

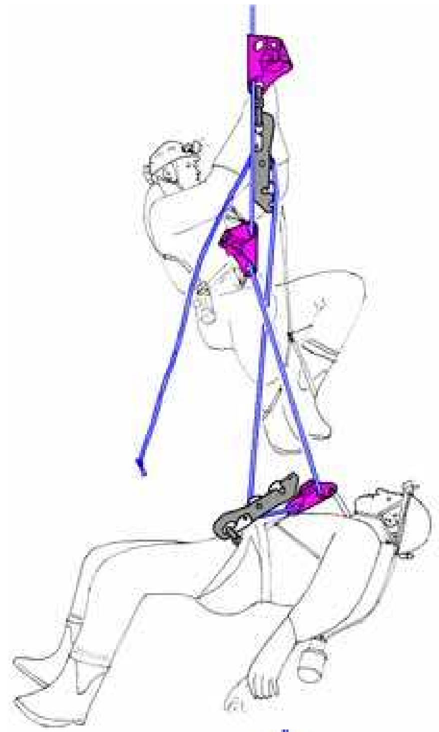
## Lifting

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.

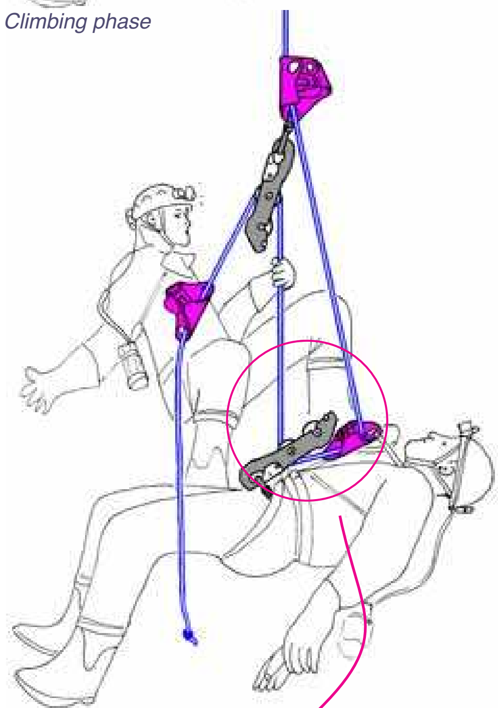
### Direct lift

Clipping the victim onto the end of a cowstail and prusiking with them towing along behind will only work for suitably strong cavers and then only for short distances but may be possible and worthwhile to remove them from immediate danger quickly.

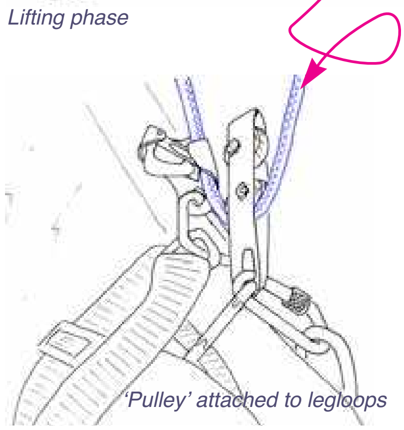
## Counterbalance lift



Climbing phase



Lifting phase



'Pulley' attached to legloops

(Frog system, Gutierrez and Lopez, 1985)

You must be on ascenders above and the victim arranged with only their chest ascender attached to the rope.

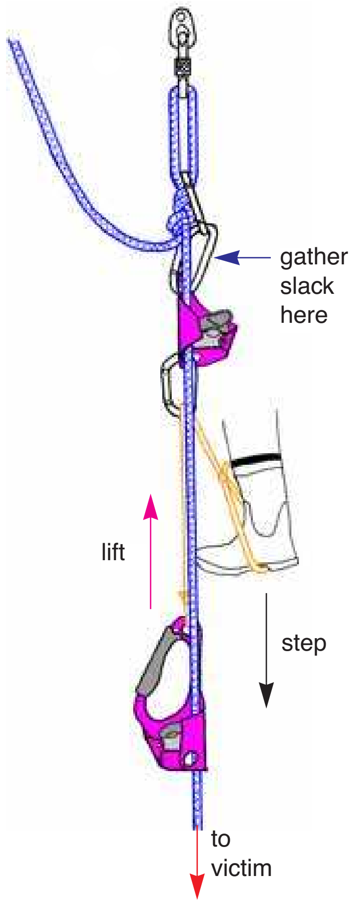
- Fix a pulley on the victim's seat maillon so that the rope comes out of the bottom of his ascender and then through the pulley.
- When the victim's chest ascender is mounted high on their chest, fix the pulley to their seat harness attachment loops parallel to the seat maillon. This is the best arrangement to use when you are starting from a ledge or the ground.
- On a mid-rope rescue, clip the victim's cowstail karabiners (or two spares) to their harness legloops and attach the pulley to them.
- Run the rope up from the victim's chest ascender and through a pulley that is hanging from the bottom of your top ascender.
- To lift, prusik up a few metres above the victim or as far as the rope will allow.
- Remove your chest ascender from the main rope and attach it to the rope coming down from your pulley.
- With a normal sit/stand prusik motion, lift the victim up countering your own bodyweight against the victim's whose chest ascender will lock in position after each stroke.
- When the victim reaches you, change back to the main rope and ascend again.

### Rebelays

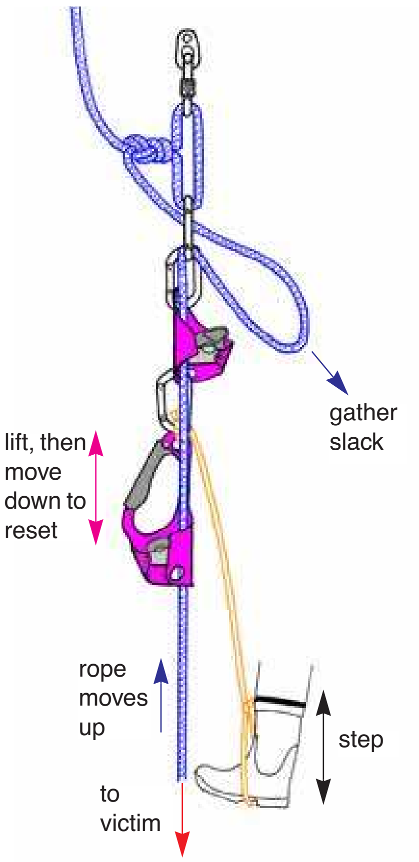
- Without removing the counterbalance setup, cross the rebelay yourself.
- Suspend the victim from their cowstail attached to the rebelay anchor. You'll have to thumb their Croll cam to ease them back onto their cowstail.
- Undo the rebelay and feed the rope through ready to go again.

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 their cowstail to a tight handline and slide them 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




*Getting slack into the system*




*Lifting*

(Marbach and Rocourt, 1980)

This method only works 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.

- Clip your cowstail to the rope anchor.
- **Invert** your chest ascender and clip it onto the rope just below the knot then attach it by a karabiner through its bottom eye to the knot loop.
- Attach a pulley or karabiner to the ascender's top (now lower) eye.
- Invert your footloop ascender, attach it lower down the rope and put its footloop through the pulley.
- Lift by standing in the footloop while simultaneously pulling up on the ascender. Push the slack gained through the chest ascender.
- When you have enough slack feed it through the chest ascender, then through the ascender's anchoring karabiner so you can pull it through with one hand while lifting with the other and standing in the footloop.
- Push the foot ascender down between strokes and continue the procedure until you can clip the victim's cowstail 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.

To arrange the lowering and lift systems described so far you require nothing more than what a vertical caver normally carries. Real pulleys, even those light nylon rings that clip directly to a karabiner, make lifting much more efficient than using bobbin pulleys, but few cavers carry them. One suggestion is to thread one onto the haul cord of every cave pack where it will always be handy but never in the way. Others carry one threaded on their carbide tube/power cable.

## Heavy lift systems

### Counterbalance lift

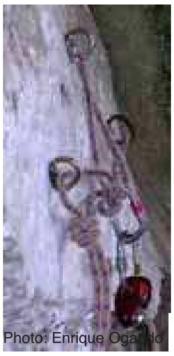
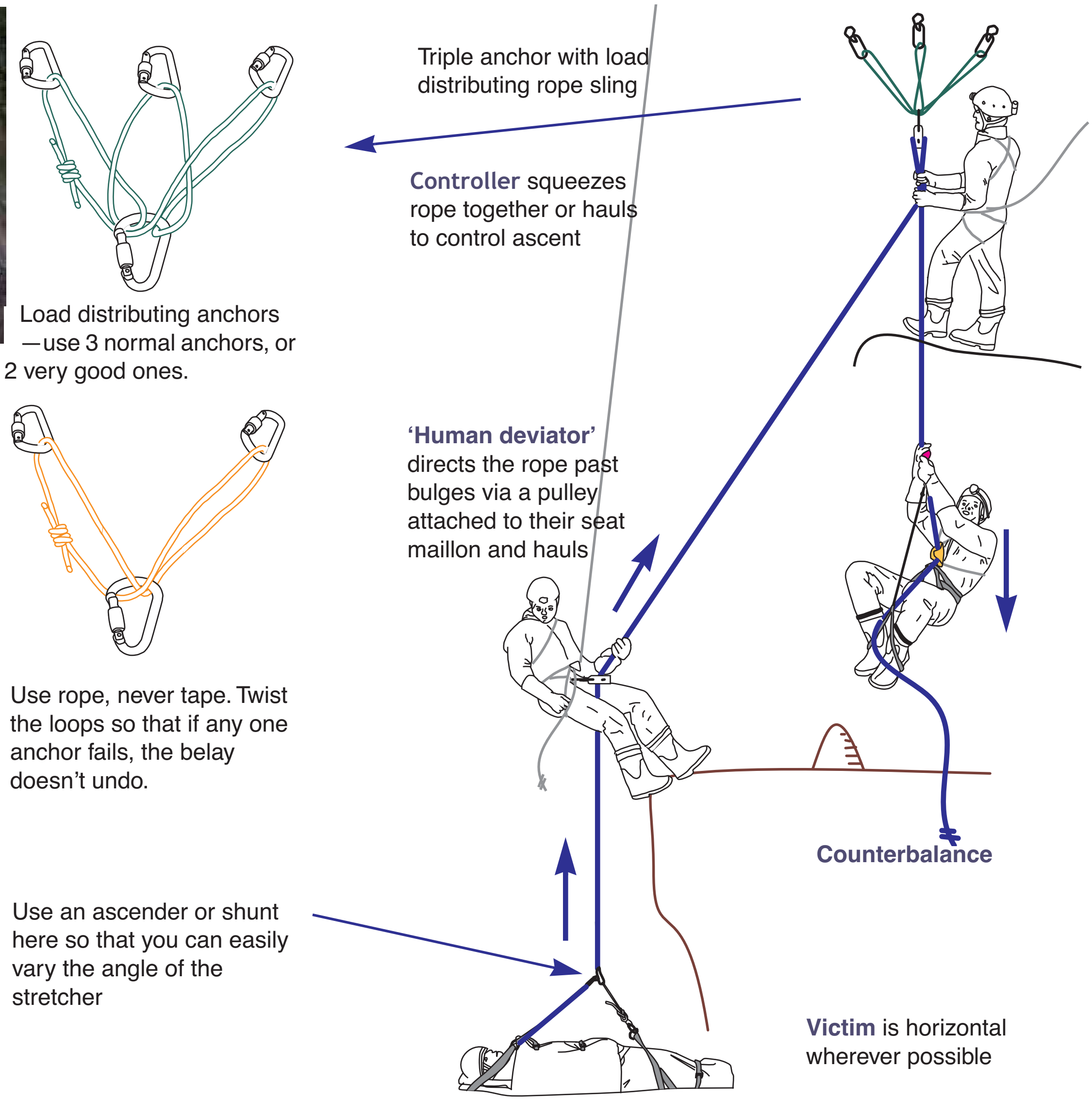


Photo: Enrique Ogando




*The counterbalance method*

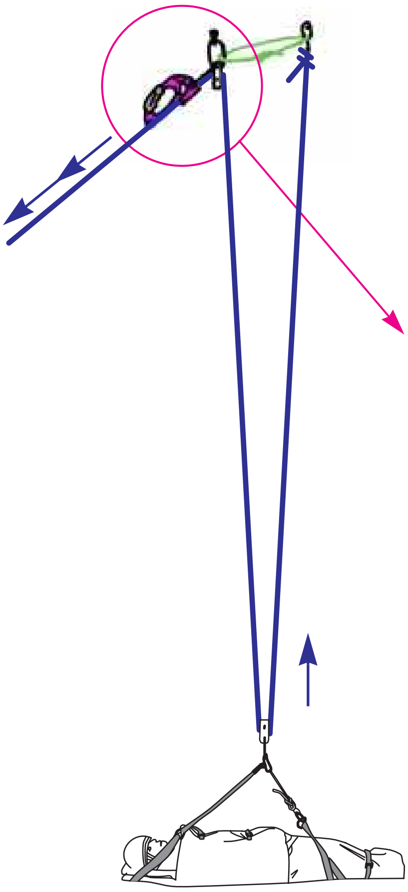
The preferred method is to mount a large pulley at the top of the pitch and run a rope up from the victim and through the pulley to a caver who can act as counterweight (Martinez 1979). Ideally, the counterweight caver prusiks near a ledge or comfortable safe area near the pulley. Place a controller at the pulley to control the rope.

On bigger pitches, a third caver prusiks on a separate rope beside the victim to fend off and un-snag the victim as necessary. Small, simple pitches are best managed with rescuers at the top and bottom with perhaps a guide line from below. It is better to not attach a separate lift or belay rope as this easily leads to tangles with the counterbalance rope.

Counterbalance lifts benefit from making a pitch as long as possible. Rig deviations with pulleys. Rig 'reverse' deviations where the rope would run over a bulge with 'human' deviations. That is, a caver stands on rope on the edge with a pulley attached to their seat maillon and directs the rope around the edge and helps pull the rope through to compensate for the drag in the pulley.

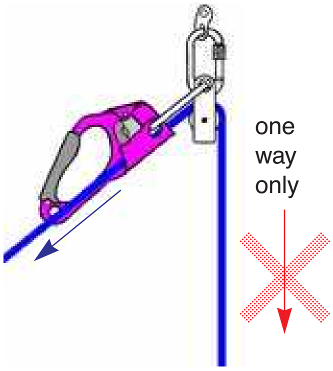
Pitch-head anchors should be doubled or tripled and fitted with load-sharing slings.

## 2:1 lift

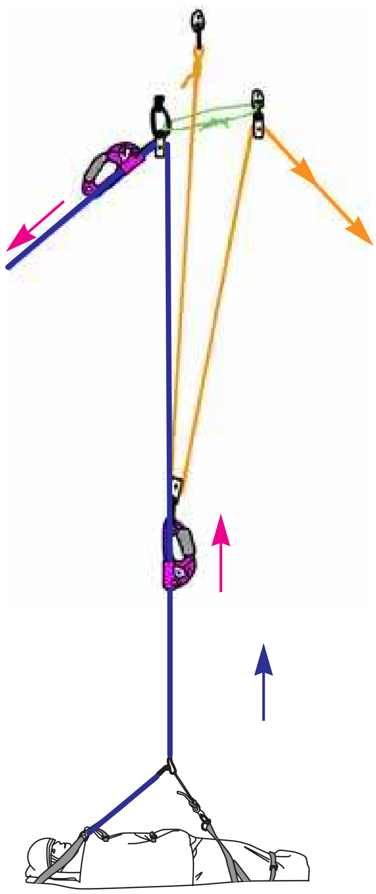


A simple 2:1 lift

As an alternative you can fit the victim with a single pulley and attach the rope at the top of the pitch so that it runs down to the victim, through their pulley and back up to the top. There it runs through another pulley and ascender so that it cannot slide back. This method has no advantages over the counterbalance unless the victim is much heavier than the rescuers. Even so it may be better to have the controller use their weight to help the augment that of the conterbalancer.

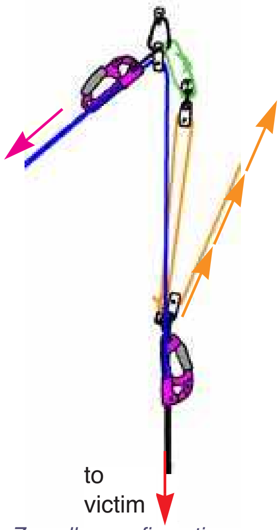



Using the same number of pulleys, but concentrating them at the top as a 'Moveable 2:1 lift' it is feasible to lift the victim on a single rope – perhaps the rope used to rig the pitch if none other is available. A Moveable 2:1 system lifts a metre or so of rope, then is reset to lift again.



Moveable 2:1 lift

A 'Z-pulley' configuration is similar to the Moveable 2:1 lift but gives a 3:1 advantage. This advantage however is countered by the need to pull upward instead of down so that a rescuer cannot use his body weight to counterbalance the load without an extra pulley at the top.




Z - pulley configuration

Heavy lift systems take time to set up and while it may 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 the faster, lighter techniques – at least in the short term until they are out of immediate danger.


*...and as always: practise*


Yes, they are logs in the photo:

*"The flood*

*- phase 1: a loud drumming sound*

*-phase 2: 10 seconds later, a sudden increase in air pressure, ears popped, eyes stung and breathing strange*

*-phase 3: the wave... the flow changed instantaneously from 10 L/s to several cumecs. The accuracy of the measurement may be a little out due to the lack of objectivity of the observers.*

*-phase 4: 10 minutes later the altimeter bottomed out, and the pressure began to rise. Are we between two sumps?*

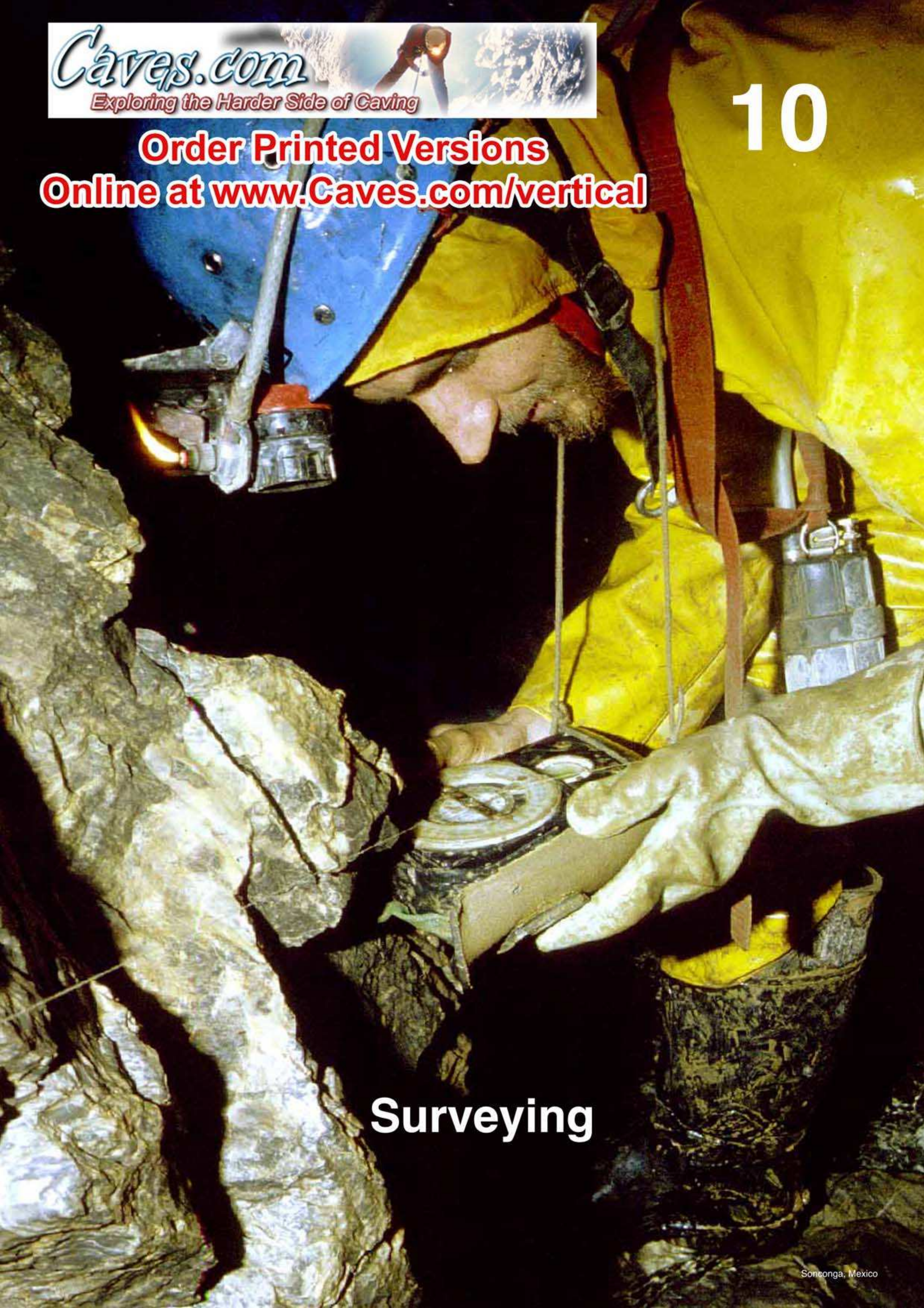
*-phase 5: after about 15 minutes the altimeter returned to its initial position, to our relief.*

*-phase 6: 2 hours waiting and the flow is back to 200 L/s. We stop the observations and get out of this horrible place!*

*The exploration of the most promising cave on the plateau was stopped because we only had equipment to rig to -500 m...and the passage continued 4 m wide and 5 m high..."*

from the expedition report (Sounier, 1991)





# 10

# Surveying

Sonconga, Mexico

A survey is the only way you can find out how deep your cave is and where it is going. It is a guide that indicates where to look for a continuation or passages that 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 simple. 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 and total stations 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 you to take sights 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 that sometimes 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. You can reduce the risk of condensation by warming instruments to or above the cave temperature before you use them – carry them in an inside pocket. Limited waterproofing has been achieved by covering all joints in the instruments with epoxy resin. They then leak more slowly.

After each day's surveying, bring the Suuntos out of the cave and dry them in the sun, 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 that you can remove to simplify drying. Other compasses such as the Silva 54NL and a similar Suunto KB-77 model have a direct sighting lens on top of the instrument that cannot mist up, making them far superior to the KB-14. Complimentary clinometers are also available.

Suunto kit

Suuntos are easy and fast to read in the full light of day, but once underground you need a good light to see the face of the dial clearly. In most cases it is necessary to externally light the face of the instrument. A removable back-up or hand held electric is ideal for this as it is safer and easier than removing your helmet for each reading.

Cavers often place a light 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 and magnetic switches in the lamp will affect the compass. Carbide lamps too, may have enough steel pieces to upset a compass. Keep any lamps, battery packs or generators a safe distance away.

Always read the left side of a Suunto clinometer – the right is a percentage scale. Also remember that the scale on the compass is backwards (right to left). Read sighting compasses with one eye only to avoid the possibility of a 3° or more parallax error.

Most compasses only work well in a horizontal plane, or close to it. When you're 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, avoid steep down-sights.

Use 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.

## Laser distance measurers

Hilti PD-32

Tapes are rapidly being replaced by laser distance measurers. They are very accurate, fast, sufficiently robust (although, clearly, not as robust as a tape!), and very expensive. The original is the Leica 'Disto'. As time goes on, more and more copies and new versions with more features are appearing, such as the Hilti illustrated. It is small, fast so that you don't have to hold it on target for long and has an excellent optical sight for use in sunlight where the laser spot is often impossible to see. As I write, Leica has released the 'A8' with a built-in clinometer. It's not cheap and still has no compass. Like anything, you must use them correctly. You can measure a distance to almost anything, so be careful that you are actually taking a distance to the station. The survey notebook makes a good target. Lasers require extra care as they can damage your eyes. The target holder should close their eyes or look away, while the instrument man should avoid shining the laser at people's faces. They are probably more dangerous while they are actually measuring rather than when they are only 'pointing'.

## Topofil

Topofil kit

In its simplest form a topofil consists of a small box that contains a roll of thread and distance counter. A topofil offers some advantages over a tape:

- It is lighter.
- No distance limit between stations, which is ideal for big pitches.
- The thread is sighted along, increasing the accuracy of high angle compass shots.

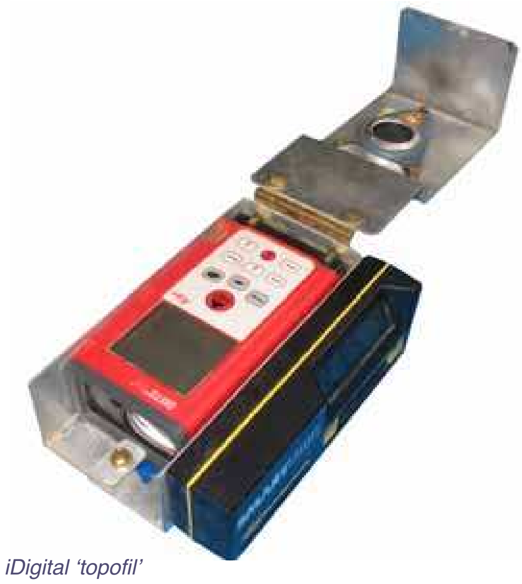
More advanced topofils use a compass and clinometer adapted to read along the thread laid from one station to the next. These are a separate unit or mounted in the topofil box provided it contains no magnetic components. Commercially available topofils specifically for caving use are restricted to the Vulcain. The Vulcain model is a complete unit with detachable compass, however they are only sporadically available from the Club Vulcain in Lyon, France and as such are hard to get. This rarity and design limitations make constructing one a reasonable alternative.

Unlike Suuntos, topofils have no optical sighting, therefore there is never a problem with them misting up or the need to put your 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 have more working parts than tape and require a light touch to run well. If you use it roughly the thread can break or snag as it pays out and you need to open the instrument to insert a new roll of cotton when the old one runs out.

Topofils leave a thread line throughout the cave that you must collect on your way out. Use cotton thread so that if you accidentally leave any behind it will eventually rot.

## Electronic instruments



*iDigital 'topofil'*

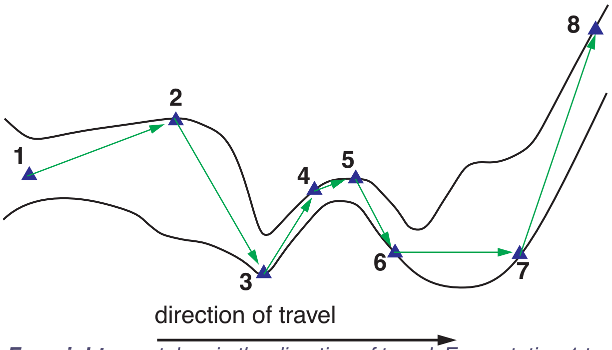
*TopoScan*

As an experiment, I have mounted an electronic clinometer and electronic compass onto a Disto. The unit is something like a 'digital topofil', without the thread. Once calibrated, the clino and compass 'sight' along the laser beam. Shine the laser at the target, press the hold button on the clino, then the hold on the compass, then take the distance. You can now read off the instruments at your leisure rather than at some awkward angle. The procedure is simpler than Suuntos, and not as easy as a topofil, but you don't have to look after a thread. You also still risk the possibility of a transcribing error between the instruments and the book. Hopefully you'll make fewer errors transcribing the digital readouts than you would for analogue instruments.

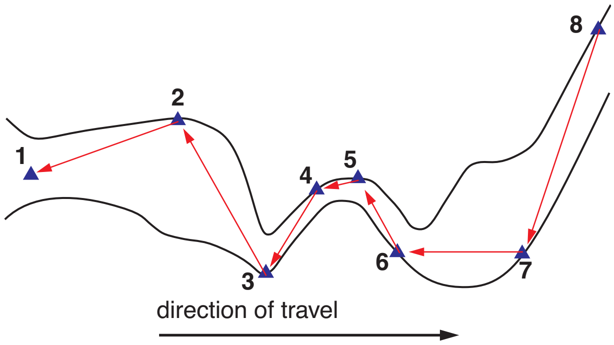
The ultimate cave surveying instrument is the much more sophisticated and even more experimental. 'Toposcan' is made by a French/Quebec group. It combines the three instruments into a single unit. A single press of button sends the distance-compass-clino reading directly to your Palm PDA—no more transcribing errors. With a Toposcan it should at last be possible to survey at a reasonable speed, if you can find one.

## Tactics and procedure

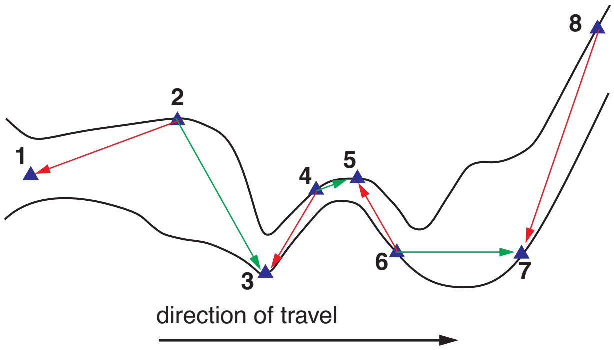
'Survey what you explore' is a good rule and one that has caused many an argument when broken. A reasonable compromise is to have one or two cavers rigging and a survey team following along behind them. On the next trip the two teams can swap places.



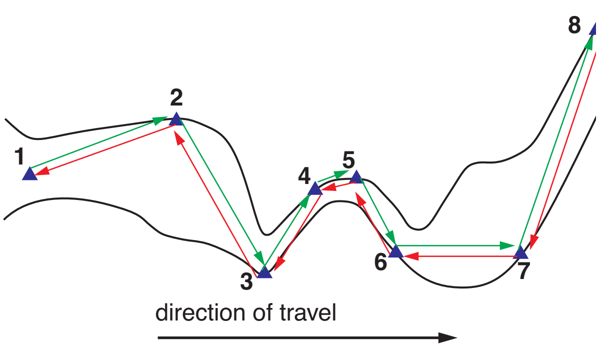

***Foresights*** *are taken in the direction of travel. From station 1 to 2, then 2 to 3, 3 to 4, etc. It is the simplest, least confusing method of gathering data, especially when using tape and compass.*




***Backsights*** *are taken facing opposite to the direction of travel. From station 2 to 1, then 3 to 2, 4 to 3, etc. This is the preferred method for topofils.*




***Leapfrog*** *is taken in both directions alternately. From station 2 to 1, then 2 to 3, 4 to 3, then 4 to 5, etc It gives the maximum survey speed for tape and compass and minimises systematic errors.*

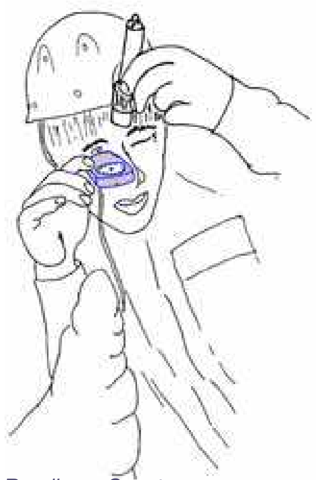



***Fore*** *and* ***Backsights*** *are taken in both directions from each station. From station 1 to 2, the 2 to 1, 2 to 3, 3 to 2, 3 to 4, 4 to 3, etc. For maximum accuracy.*

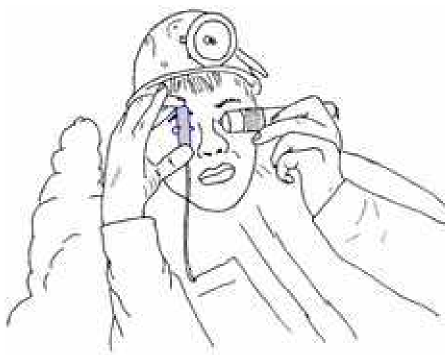
For ease of understanding the data and its later reduction, it is best to maintain the survey direction. If you begin the survey at the entrance of a cave you should continue down the cave, starting each new day's surveying at the end point of the day before or some other known point along the way. Surveying 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 that you have to tack together or reverse to calculate the total displacement from the starting point. It's not that the data is 'wrong', just that easier to understand data means fewer problems later outside the cave.

The data you collect will be easier to understand and therefore mistakes are less likely if you take all survey sights 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. If you're 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, when something looks wrong.

### Tape and compass



*Reading a Suunto compass*



*Reading a Suunto clinometer*

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. If you use a Disto instead of a tape, the instrument reader can also use the Disto and the ideal team becomes two.

The note-taker is the 'boss' and in easy passage the survey will move only as fast as the sketcher 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 usually done as a series of forward sights. In essentially 'down' caves however, it is far better to survey facing uphill, taking 'backsights' so you can read the compass more easily.

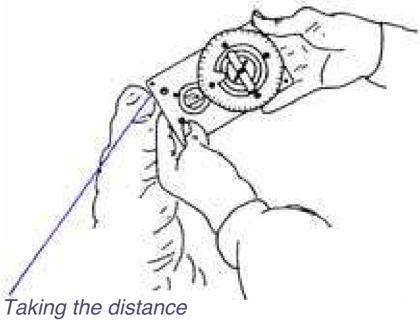
Begin the survey at a cave tag or marked point at the entrance. The tape reader waits at the entrance while the instrument reader runs the tape down the cave and finds a 'station' from which the tape reader is visible as well as providing a good view toward the next station.

Measure the distance and perhaps move the forward station a few centimetres so as to coincide with a full decimetre on the tape. The tape reader calls out the measurement to the note-taker who repeats it.

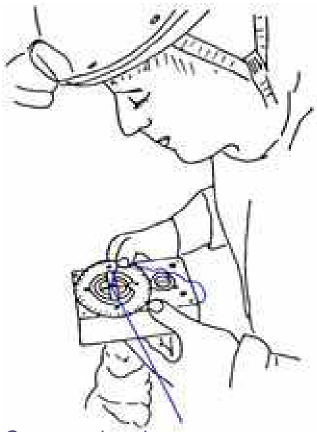
The tape reader 'lights' the station by holding a light on or behind it or by putting a finger on it and lighting that. While lighting the station they call out 'left', 'right', 'up' and 'down' estimates and rewinds the tape. Meanwhile, the instrument reader sights the compass and calls the figure to the note-taker, who repeats it, then the same for the clinometer. Before moving on they make sure that the note-taker knows where the station is so that they can include it on the sketch. The instrument reader then moves to the next station where the tape reader points out the station's precise location, leaves 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.

## Using a topofil

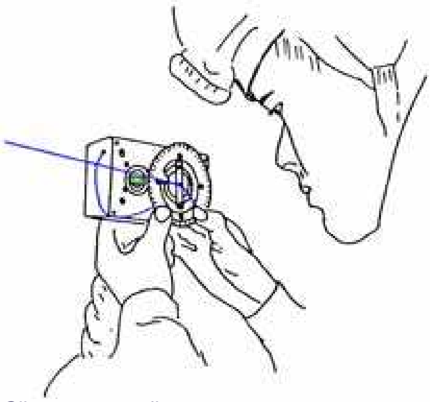
### Topofil



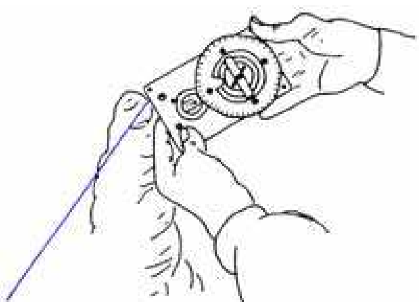
*Taking the distance*



*Compass bearing*



*Clinometer reading*



*Finding the correct position on the thread*

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 you can do a topofil survey alone with no loss of accuracy although it will be slower.

Topofil surveys run easily down a cave taking a series of backsights and leaving a trail of thread behind. If the thread breaks on a pitch or difficult passage you can leave that one sight for the return trip rather than having to do the pitch an extra time.

The instrument reader begins by pulling out enough thread to tie off to the entrance station then calls out a 'first topo' to the note-taker, who repeats it, then runs out a straight line of thread to the next station. Preferably choose a small projection you can later wrap the thread around, that also has a view forward. After calling out the distance, hold the topofil above the station or in line between the stations and take a compass reading and call it to the note-taker. Next, hold the instrument beside or in line with the station and take the inclination. The note-taker repeats all readings. Be careful to ensure that the thread is not snagged between stations and do not allow it to sag while taking clinometer readings.

After you have taken the readings, wrap the thread around the station two or three times by pulling sufficient thread as stretch from the leg that you've just measured.

Find the exact point on the thread 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, anchor it with a rock or ask the note-taker to hold it.

## New ways of surveying

New faster surveying instruments are shifting the balance so that the sketcher doesn't have a hope of keeping up. If you want a really detailed sketch you don't have much choice but to travel at the speed of your team artist. One option is to just neglect the sketch and use the left, right, up and down data to computer generate the map. For large caves that will be drawn at scales larger than 1:1000, this may well be adequate. Another approach is to enter your data directly into a Palm PDA using Auriga software and plot as you go. All you record on paper is the sketch and the Auriga plot helps a lot with that. With practise, this could save you some time in the cave, and considerable time in the drawing up phase. If you have time and resources you can take the data and mark the stations on one trip, then return with a print of the line plot and sketch-in the details.

*Thirty minutes later, against the same wall, as the instrument man and I fade off into the calm world of hypothermia-induced sleep, we begin to dream of rainbows, lollipops, and the cave collapsing on the sketcher. When we finally awake, another 30 minutes has gone by and the sketcher has at last caught up with the survey. Disappointed by the lack of sweets, happiness, and dead sketchers, we carry on to the next station.* —Brandon Kowallis, NSS News, August 2006.

## Survey stations

Choose stations that give as long a sight as possible in each direction as well as being easy and comfortable to reach while taking the sight. Don't, however, exceed 30 m and for accuracy, try to stay below 20 m. 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, systematise the station labels or names so that each survey is readily identifiable. Do this by assigning a unique alphanumeric label for each station.

Eg. 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 of the expedition 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 you survey more than 100 stations in one day change the date numerals. ie. The station after N2799 could be NB700 or N2800. All this information is not needed for each station in the field. What is required is that you mark each page of data clearly with the appropriate letter and number. In simple or isolated caves it is sufficient to assign station numbers only. Other labelling schemes that provide unique station numbers also work. One thing to avoid is to split a series and use the same series of labels in two distinct sections of caves. This easy leads to confusion as it is quite natural to assume that like numbered items will be near each other.

Mark some stations such as those at junctions and the end of a day's surveying. Do so in some semi-permanent manner such as a strip of note paper or flagging tape 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 you label a station write the complete station number so as to make it readily identifiable should another survey connect to it.

Before entering a cave to continue a survey, note down the tie-in station and the correct series of station labels you will use that day.

## Surface surveys

At the cave entrance, 'tie' the survey to a permanent station whether it be a tag, painted number or point chipped into the rock. Later you can locate the exact position of the cave entrance by surveying to some known point such as another cave tag, local bench mark, trig point, corner of a building marked on a topographic map of the area or fix the point using GPS.

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.

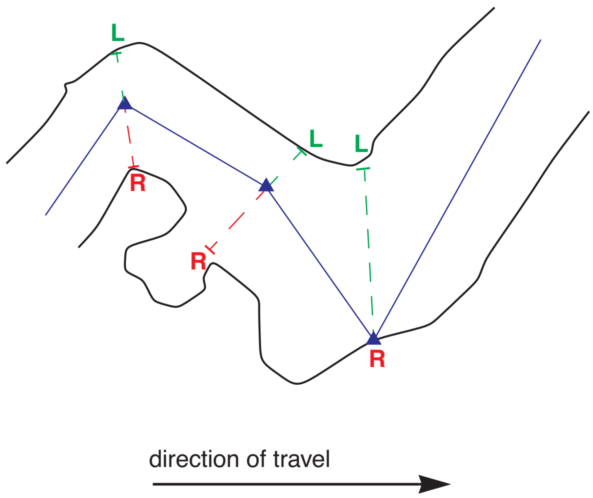
Use Suuntos or more accurate instruments for surface survey and only use topofils to measure the distance component. Even a light crosswind will displace a topofil thread enough to give a compass error of several degrees.

In open country it may be difficult to use fixed stations that are not on the ground. Rather than lay on the ground for each leg, sight to a vertical stick with a bright mark on it at the same height off the ground as the instrument reader's eye level. Take length measurements with a tape, topofil or rangefinder. Laser distance measurers can be difficult to see in bright sunshine. For accuracy avoid the temptation to use long sights—keep survey legs to a maximum of 30 m.

## Data collection

The notes and sketches that a surveyor makes should be of such a standard that someone can draw up the map with no prior knowledge of the cave. To this end, note your data systematically and consistently. A reliable method is to use a small pad with removable sheets of waterproof paper 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 you must collect in the cave is station number, distance, bearing and inclination. To these, add estimates of left, right, up and down (LRUD) distances to the walls, roof and floor. There is no recognised convention for these. However it is most reasonable to take LRUD data while facing in the direction the survey is travelling. Remember, they are estimates that reflect the general passage form and should be the average distance to the walls, roof and floor from the station.




*Left and right data convention*

Another convention you must decide on is the exact direction of left and right. The option that involves minimal notes and gives a good representation is to take the left and right data in the direction that bisects the angle between the two sights. Up and down are best left as true verticals.

LRUD data are essential for good computer graphics and give scale to the sketches, making drawing up of the final map easier than relying on sketches for information that is difficult to show. eg. If the surveyor is sketching a plan as he goes, the up and down data automatically give a passage height.

## Survey data sheets

CAVE Nada Cave DATE 15/5/88
SERIES N2701 – 10 SHEET 1/1
SURVEY BY A.W.

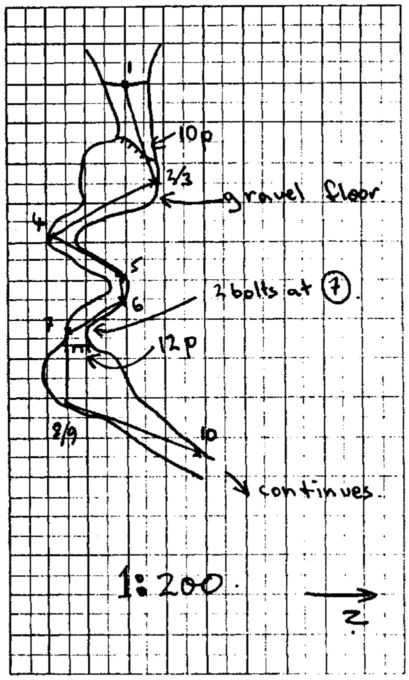
| STN | TOPO | COMP | CLINO | ← | → | ↑ | ↓ |
|---|---|---|---|---|---|---|---|
| N2701 | 062 | — | — | 1·2 | 1 | 0 | 1·5 |
| 2 | 119 | 250 | 20 | 0 | 4 | 1·5 | 10 |
| 3 | 217 | 0 | 90 | 0 | 4 | 11·5 | 0 |
| 4 | 281 | 330 | -15 | 1·4 | 0 | 3 | 2·5 |
| 5 | 328 | 208 | 41 | 0 | 0·8 | 4 | 2 |
| 6 | 344 | 262 | -8 | 0 | 0·8 | 4 | 2·5 |
| 7 | 389 | 332 | 52 | 1 | 0 | 5 | 1·5 |
| 8 | 435 | 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 Backsights

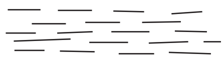
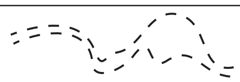
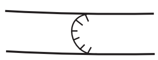
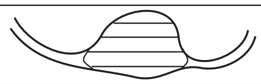
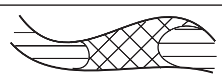
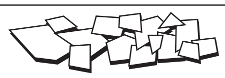
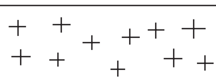
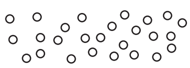
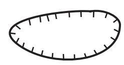
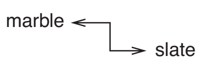
| STATION | ~~TOPOFIL~~ TAPE | COMPASS | CLINO ± | ← | → | ↑ | ↓ |
|---|---|---|---|---|---|---|---|
| N2701 | | | | 1·2 | 1 | 0 | 1·5 |
| | 5·7 | 250 | 20 | | | | |
| 2 | | | | 0 | 4 | 1·5 | 10 |
| | 9·8 | 0 | 90 | | | | |
| 3 | | | | 0 | 4 | 11·5 | 0 |
| | 6·4 | 330 | -15 | | | | |
| 4 | | | | 1·4 | 0 | 3 | 2·5 |
| | 4·7 | 208 | 41 | | | | |
| 5 | | | | 0 | 0·8 | 4 | 2 |
| | 1·6 | 262 | -8 | | | | |
| 6 | | | | 0 | 0·8 | 4 | 2·5 |
| | 4·5 | 332 | 52 | | | | |
| 7 | | | | 1 | 0 | 5 | 1·5 |
| | 4·6 | 270 | -20 | | | | |
| 8 | | | | 3·5 | 0 | 10 | 12 |
| | 12·0 | 0 | 90 | | | | |
| 9 | | | | 3·5 | 0 | 22 | 0 |
| | 8·2 | 198 | -7 | | | | |
| 10 | | | | 0 | 1·2 | 1·5 | 1·2 |

*Suunto*




*Sketch*

**Table 10:1** **Cave map symbols**

| | | | |
|---|---|---|---|
|  | marked survey station |  | mud |
| sketch / topofil | change of survey grade |  | flowstone |
| a a' | 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. For official international symbols, see: www.carto.net/neumann/caving/cave-symbols/

Draw sketches of the cave passage as a series of small plans or occasionally sections, with all stations and pitches marked to simplify the drawing up. As a check, keep the plans to scale and orientation so that you will notice a wrong figure from the instrument reader in the first instance. Draw cross-sections, perhaps at a larger scale, to show passage shape or help explain a complex piece of passage. Note a provisional tackle list along with the sketch.

Take down sketches and data with a soft mechanical or self-sharpening pencil. Carry the pad, pencil, spare pencil, marking pen and flagging tape in a pouch that hangs around your neck.

If you make a mistake during note taking, cross it out neatly and rewrite it. 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 you do not erase errors.

At the end of each days surveying remove the used data pages from the pad so as not to risk losing them in the cave on a later survey trip and transcribe the numerical data into a master data book or computer so as to give a duplicate copy.

Be sure to include information such as members of the survey party, full name of the cave, date and instruments used on the first page of any series of data or attached as a separate title page.

Plot a traverse line as soon as possible and have the person who took the original notes draw on the wall detail. Mark pitches, climbs and squeezes and write up an accompanying tackle description or note the information beside each pitch. The original note taker should do as much as possible 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. Use a few written words and an arrow to indicate where and save the pretty symbols 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 a 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 you are surveying **carefully**.

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 you can estimate. 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 that are supposed to be the same. This difference is the 'misclose' and is rarely zero. A loop that closes within acceptable limits is probably alright, one that is outside the limit suffers from one or more gross errors.

## Estimating survey accuracy

You can estimate the theoretical accuracy of a survey using Random error curves for Suunto and topofil surveys on page 181. These give an expression of the possible accuracy that the instrument and survey can produce given certain parameters but cannot 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.

Use the curves to estimate the expected accuracy of an open survey as well as to check if the misclose in a loop is within acceptable limits.

You can expect a perfectly executed survey 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 are still regarded as acceptable even though they are obviously affected by some gross error(s). 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.

You can eliminate most of the potential gross errors in a survey by taking back-bearings on each leg with a separate compass and clinometer as a check on misread instruments.

## Altimeter

In most vertical caves it is not possible to survey a loop that takes in the extremities of the cave, though minor loops will at least indicate if the surveying is generally up to standard. Use an altimeter as a control to take a series of readings at known stations on the way down and back up the cave and if possible leave a second altimeter on the surface to record pressure variations caused by weather changes. A good altimeter 'survey' should give readings that are within ±25 m of a good survey.

There are several variables to take into account when you do an altimeter survey. The pressure difference either side of a strongly blowing squeeze can give altimeter errors up to 100 m. Fortunately, this is a local phenomenon and reading quickly return to normal as you move away from the disturbance. One thing to specially take note of is the temperature adjustment that any altimeter requires—even a temperature compensated altimeter. An altimeter can only read the weight of air pushing on it. It 'knows' the altitude it is at based on a standard column of air that has a standard temperature gradient. As you climb a mountain the temperature often drops tens of degrees. As you climb up cave, it's temperature may drop two or three degrees.

**Table 10:2** **Standard temperatures**

| Altitude (m) | Temperature (˚C) |
|---|---|
| 0 | 15.0 |
| 200 | 13.7 |
| 400 | 12.4 |
| 600 | 11.1 |
| 800 | 9.8 |
| 1000 | 8.5 |
| 1200 | 7.2 |
| 1400 | 5.9 |
| 1600 | 4.6 |
| 1800 | 3.3 |
| 2000 | 2.0 |
| 2400 | -0.6 |
| 2800 | -3.2 |
| 3000 | -4.5 |

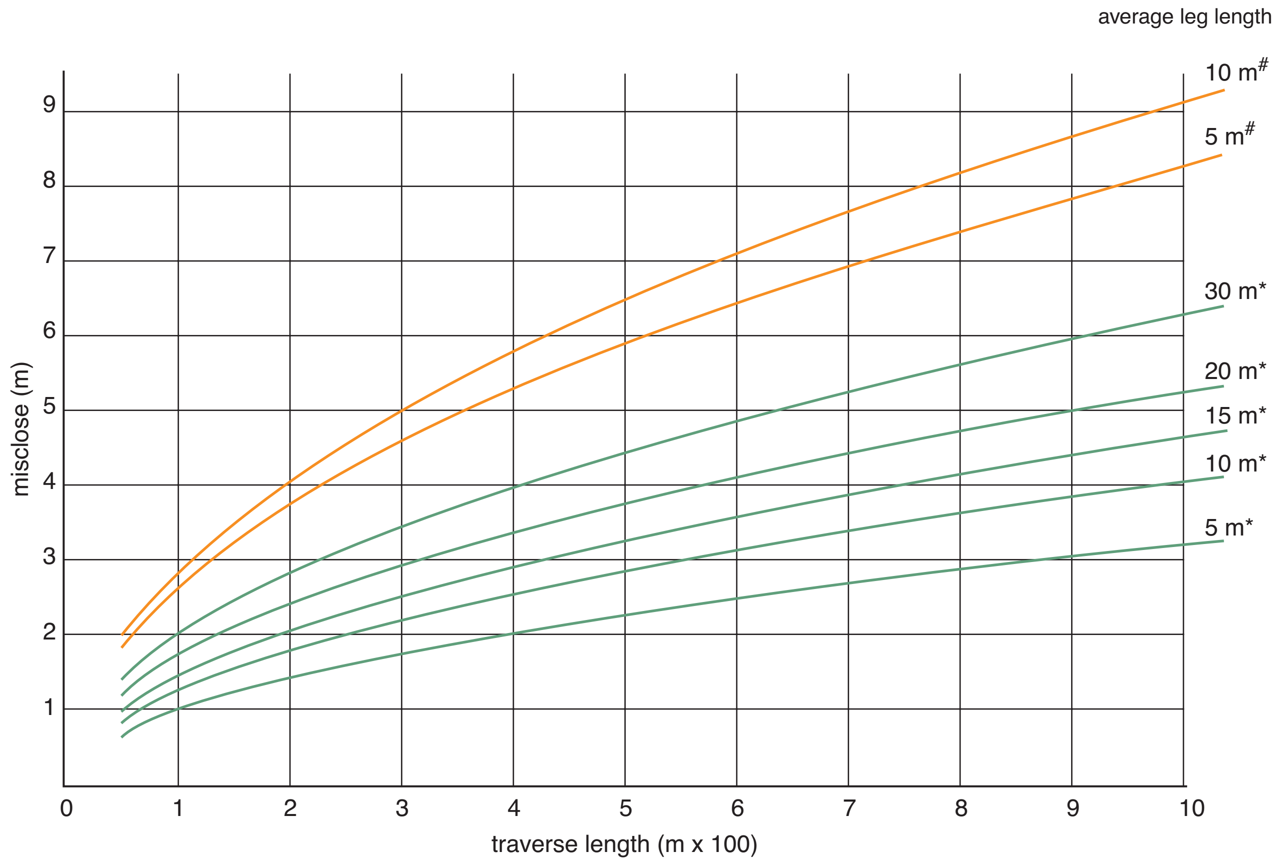
If the sum of the temperature offsets from the normal temperatures (from Table 10:2) at two different altitudes is 1 ˚C, the altitude difference calculated by your altimeter is 0.2% off the real altitude difference (Suunto, 2003).

To temperature compensate altimeter depth readings:
- Calculate offset between the normal and measured temperature for each point
- Add the two differences
- Altitude error = sum of offsets x measured altitude difference x 0.002.

For example, the figures below are from a recent trip with a surface control:
entrance alt= 2232, temp = 20: offset = 19.5
camp 2a alt = 1377, temp = 13: offset = 6.9
so, 26.4 x 855 x 0.002 = 45
855 + 45 = 900 m (surveyed depth is 901 m)

While I can't advocate mapping a cave with an altimeter alone, if you encounter a discrepancy between the altimeter and traditional mapping, you can narrow down the location of the problem and check the survey.

## Random error curves for Suunto and topofil surveys




*Good survey:*
*station error ± 5 cm, distance error ± 5 cm, compass/clinometer error ± 1°.*

*# Rough survey:*
*station error ± 20cm, distance error ± 20cm, compass/clinometer error ± 2°.*

## Systematic errors

Systematic errors are those inherent in the design or calibration of the instruments as well as the way you read them. 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 or smaller than it really is. A poorly calibrated compass will give a constant error that 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 you survey the entire cave 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. Surveying a test loop will not easily detect these systematic errors. Comparison with a standard is the best way.

Systematically misreading instruments can also accumulate errors. A surveyor sighting with a Suunto to the light of an assistant of the same height adds 15 cm to the vertical difference between the two stations and this accumulates for the length of the survey. A 200 m leg survey would be 30 m out from this error alone!

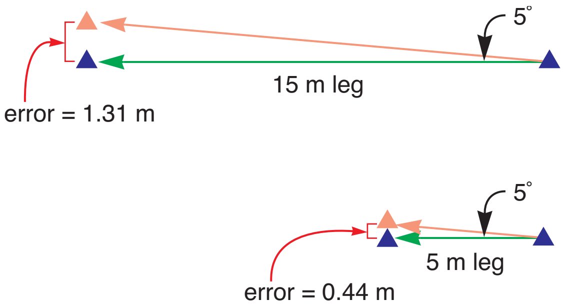
Check your instruments before a surveying project and periodically during it to ensure that they really do point north, horizontal and measure distance correctly. Test compasses against each other. Check clinometers quickly by putting them on a flat surface, taking a reading, turning them through 180° and taking a reciprocal reading. Test surveyors and instruments by surveying a known non-horizontal test triangle in both directions.

Note any errors in the instruments and correct them if possible. Otherwise, clearly mark the original notes and allow for the deviation by adding or subtracting it as a zero error when you calculate the data.

## 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 you should ignore random errors. There are several procedures you can follow in order to minimise both random and systematic errors.

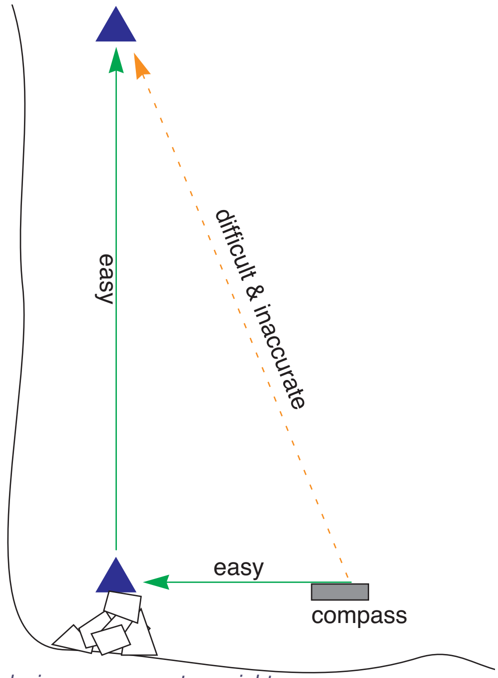
## Leg length




*Comparative error in short and long survey legs*

Long leg length magnifies compass and clinometer errors and gives less accurate final displacement than a series of short sights. If you're 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 (see Random error curves for Suunto and topofil surveys on page 181). 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.

## High angle readings

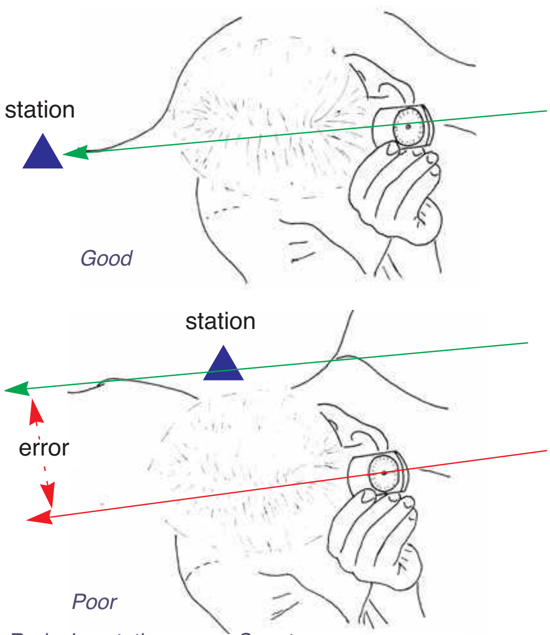



*Reducing error on a steep sight*

Compasses become increasingly difficult to read accurately as the angle of the sight leaves the horizontal. On high angle legs, improve accuracy by taking a vertical then a low angle sight rather than one high angle sight. On up sights droop the tape between the stations after you take the length and sight the compass to the tape. Most topofils do this automatically. Another possibility is to dangle the clinometer from its string as a plumbob at arm's length to line up the survey station with a spot on the wall at the same level as the surveyor. Sight the compass to the spot or the plumb line.

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 low angle clinometer readings).

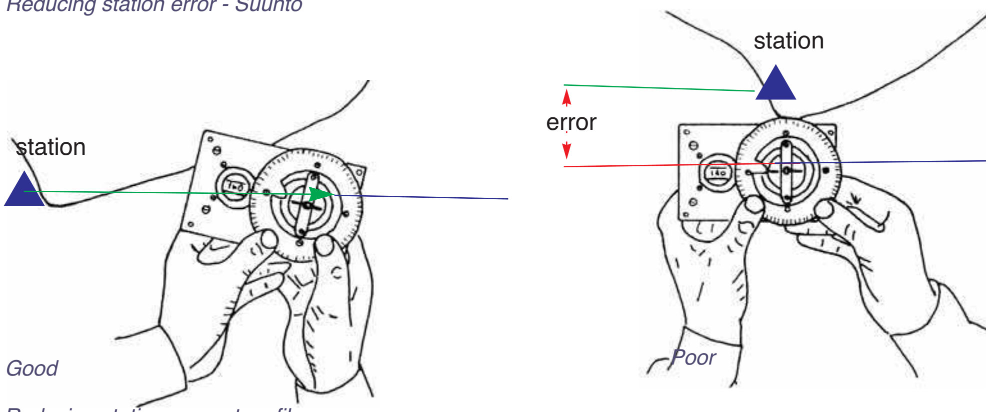
## Station error




*Reducing station error - Suunto*

Avoid ‘floating’ stations such as sighting to the light of someone standing in mid-passage. The person holding the other end of the survey can never faithfully relocate them. When sighting it is often better to hold the instrument in line between the two stations rather than as close to the station 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.




*Reducing station error - topofil*

## Transcribing errors

Transcribing errors are common in cave surveying and once a reading is taken wrongly, it is difficult to identify as wrong and in need of checking. At least one survey program (Compass) attempts to find transcribing errors using statistical analysis of closed loops. Do not remember readings, note them down as the instrument reader calls them out. A roughly oriented sketch will help you pick up badly wrong compass readings. Have the note taker call back all readings including the sign of clinometer angle for confirmation. Short leg length aids communication. Do not mentally reverse readings while in the cave. Note the reading as given and indicate beside it whether it is a back or fore sight if it is different from the others. Direct entry into a PDA using Auriga reduces the problem. TopoScan will solve it.

## Magnetic errors

Keep anything electrical or magnetic well away from compasses. Be especially careful of holding a hand torch and anything with a magnetic switch too close when lighting the compass dial. The bigger the piece of steel the worse the problem.

## 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.

## Computing

Even in the most remote location it is possible to process raw survey data and have it back as an on-screen plot within a few hours of exiting the cave.

It is easiest to calculate data on a purpose designed program such as Compass, Survex or Walls. Most cave survey reduction software can be downloaded for free. Most have been written to solve a specific cave surveying problem, then improved. Download a few, try them out and see that one suits your needs. Whatever software you use, proof read the data you enter as soon as possible in order to pick up any errors in both the data itself and its organisation.

If you're forced to a more basic level by the lack of a computer, calculate X, Y, Z, D data on any calculator that has trigonometric functions by using four simple formulae:

| | | |
|---|---|---|
| p | = d cos c | p=plan distance |
| ΔX | = p sin b | c=compass |
| ΔY | = p cos b | d=distance |
| ΔZ | = d sin c | b=bearing |
| D | = sum of p | ΔX=change in X |
| | | ΔY= change in Y |
| | | ΔZ = change in Z |

**Table 10:3** **Nada Cave coordinates**

| 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

Carefully list the results, then make a cumulative list made of these relative coordinates (ie. relative to the previous point) to give coordinates relative to the starting point.

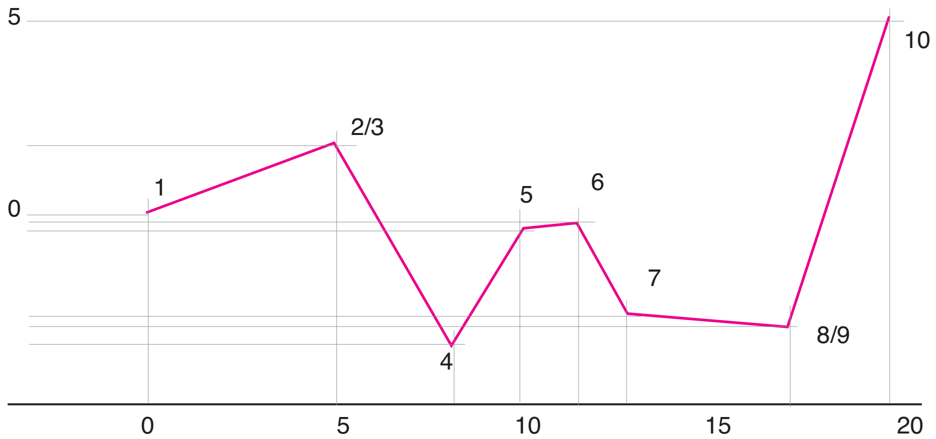
Hand plot the X Y Z D data you've calculated in the field as a plan and projected or developed section at a suitable scale (usually 1:1000) so that it can be used in further exploration of the cave. Once you get the data home you can reprocess it using a more sophisticated program on a bigger computer to get special features such as loop closures and 3-D graphics.

## Plotting the survey

Before drawing up settle on a scale that either matches that of other caves in the area or allows the cave to fill the page you are drawing it on. How much hand drawing you have to do depends on the software that you choose. Chances are, you'll have a line plot perhaps with left and right (or up and down points), marked to match your sketch too.

For hand plotting, choose a zero point that allows the cave to fit on the page and draw scales along the margins. Graph paper is better than trying to scale off distances with a ruler.

### Traverse line



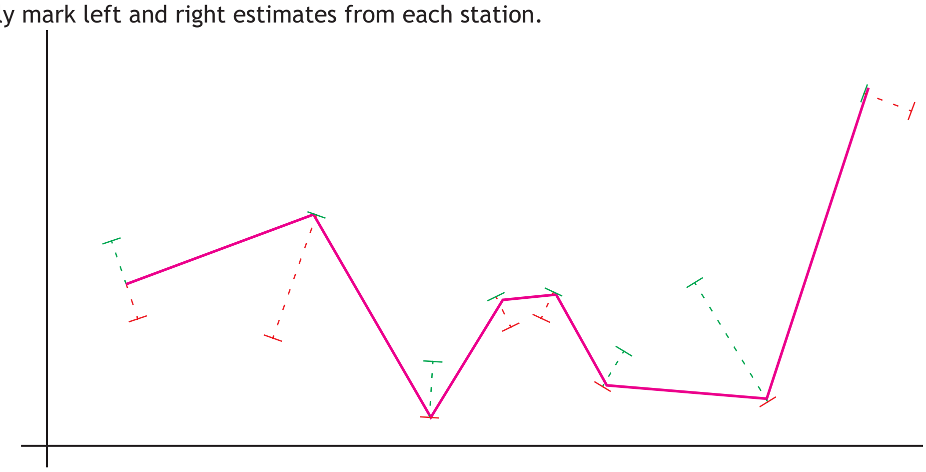

Plot the X (east) ordinate across the page against the Y (north) ordinate up the page.

Label each point with its station number and join the dots 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.

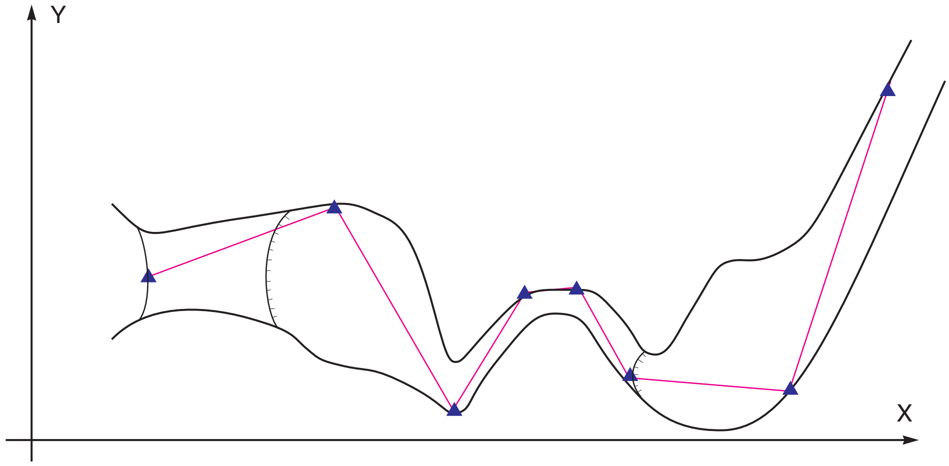
### Mark left and right

Lightly mark left and right estimates from each station.



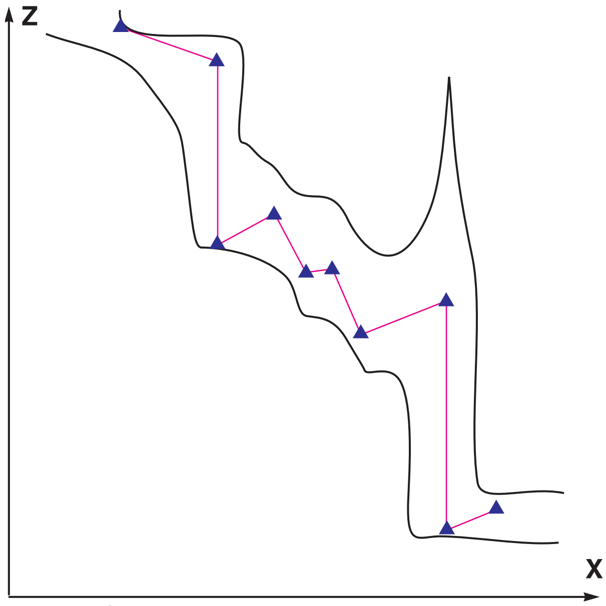
## Sketch

Copy the sketch taken in the cave so that it fits the traverse, then fill in the details.




Draw sections (elevations, profiles) in the same manner as the plan but use different coordinates, depending on the nature of the cave and the effect you desire.

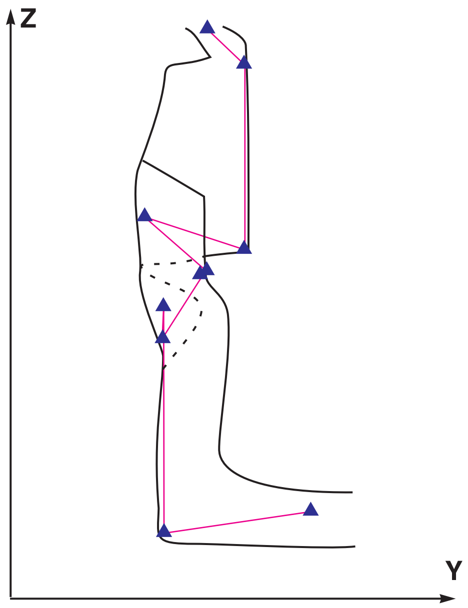
Projected sections compress any part of the cave that does not run parallel to the projection plane and make a vertical cave appear much steeper and shorter than it really is.



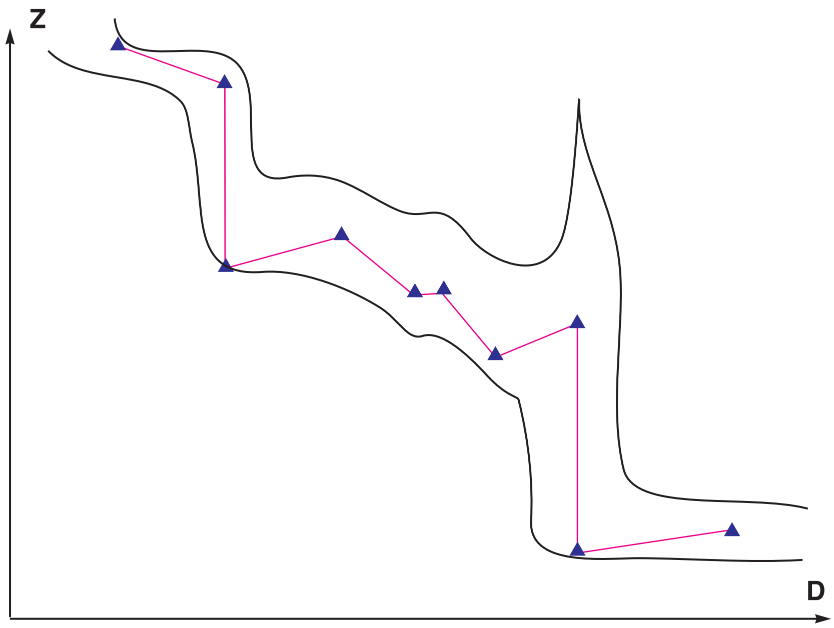

*Projected Section, East-West plane*

Plot X ordinates across the page against Z down the page and add the walls with the aid of LRUD data and the plan.

Plot Y ordinates across the page against Z down the page.



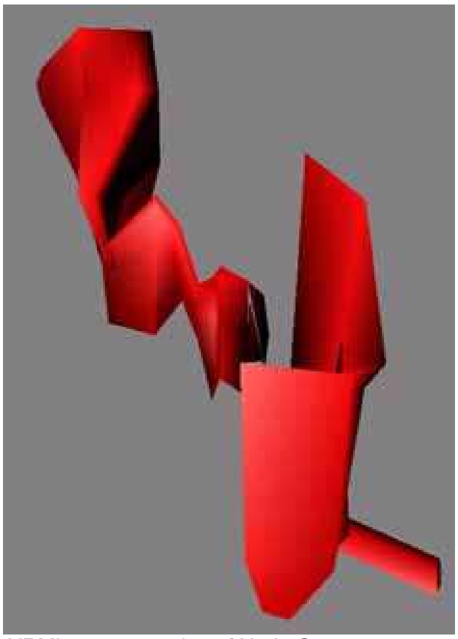

*Projected Section, North-South plane*




*Projected Section, East-West plane*

Plot D across the page against Z down the page to give a right trending plot, that may indeed be what the cave does. Often however caves zig-zag beneath themselves and by referring to the plan you may wish to fold the developed section back on itself when the cave makes a major change in direction. Once you plot the traverse, draw the floor and roof on as before.

## '3D' view



VRML representation of Nada Cave

Provided you supply LRUD data along with the traverse data, some survey reduction programs can plot a 3D representation of your cave in seconds for on-screen viewing using VRML. Unfortunately, this usually doesn't translate very well to printed images. Such images usually work better for big, complex systems by making the relationships between the various passages more evident. Small caves tend to look blocky and stylized, while long, straight caves show most of the cave 'too far away' to be especially useful.

On a small scale (10 stations), Nada Cave on the following page looks too stylised but you could use it to provide the basis for a hand drawn map. However on a larger scale—the 3D of Dead Dog Cave has 700 stations —with hidden lines removed, the plot gives a better idea of what the cave is like than a conventional map. By plotting the same data twice, at viewing angles a few degrees apart, you can generate stereo pairs of the cave.

Ozto Ocotal/J2, Mexico. Photo: Enrique Ogando

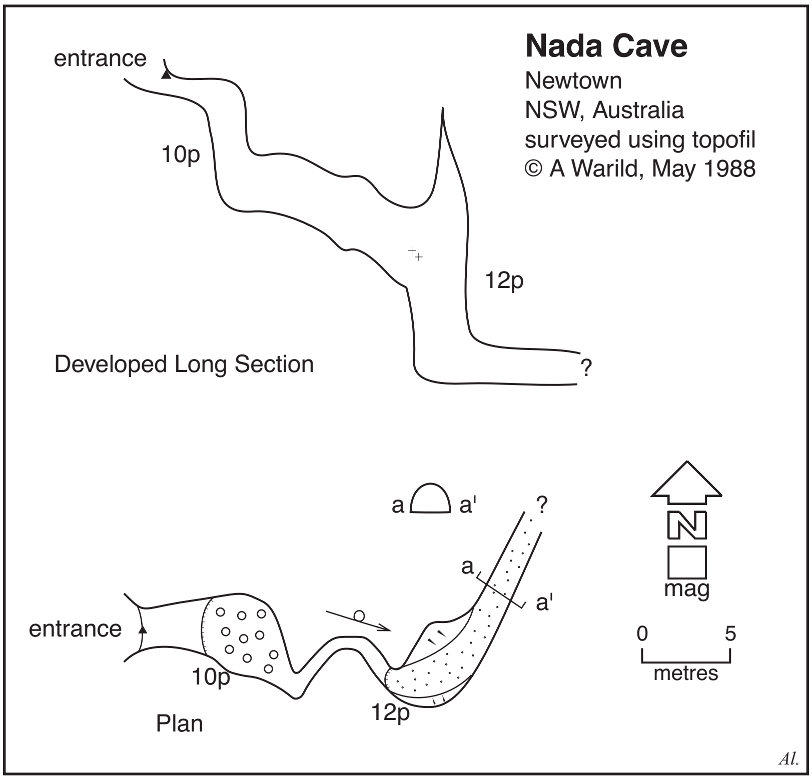
## The final product

A line plot on screen or graph paper is all you need in the field. Once the map reaches this stage you can superimpose the line plot over the sketch and trace and adjust it for the final presentation.

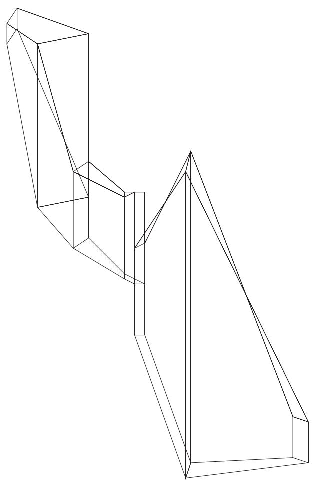
The ultimate product of a cave survey should be a high quality map that is rich in information and self explanatory. It should be accompanied by a tackle description or equipment list as well as a cave description if the cave is complex or the information cannot be clearly shown otherwise.

The map can be a projected section and plan if it is of a system and interpassage 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 leg of the survey. However interpassage relationships are difficult to depict as developed sections only show true displacement between any two consecutive points. A developed section needs an accompanying plan to show the actual horizontal extent of the cave.

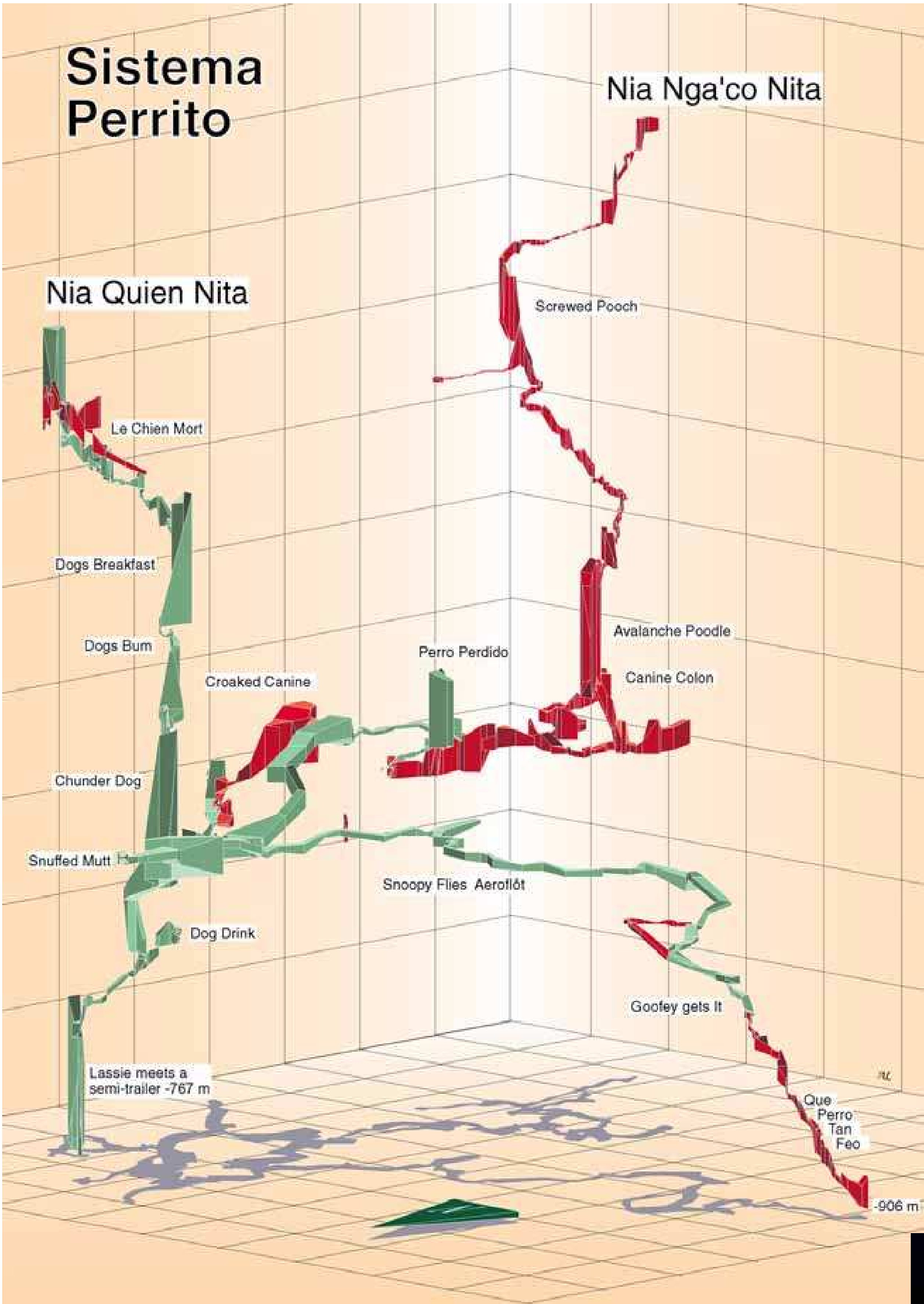
The final scale of the drawing depends on the extent of the cave and the sheet of paper it must fit on for publication. Preferably the scale should be some simple multiple such as 1:200, 1:500, 1:1000 and be represented as a bar scale so that the map may be reduced or enlarged without losing it. Information such as cave name, surveyors, north arrow, date, survey instruments used (survey grades such as M5.4 may be meaningless in another country) and scale can be placed for balance or shown as an information block.




Finished product – traditional



3D skeleton




*3D representation of Dead Dog Cave*