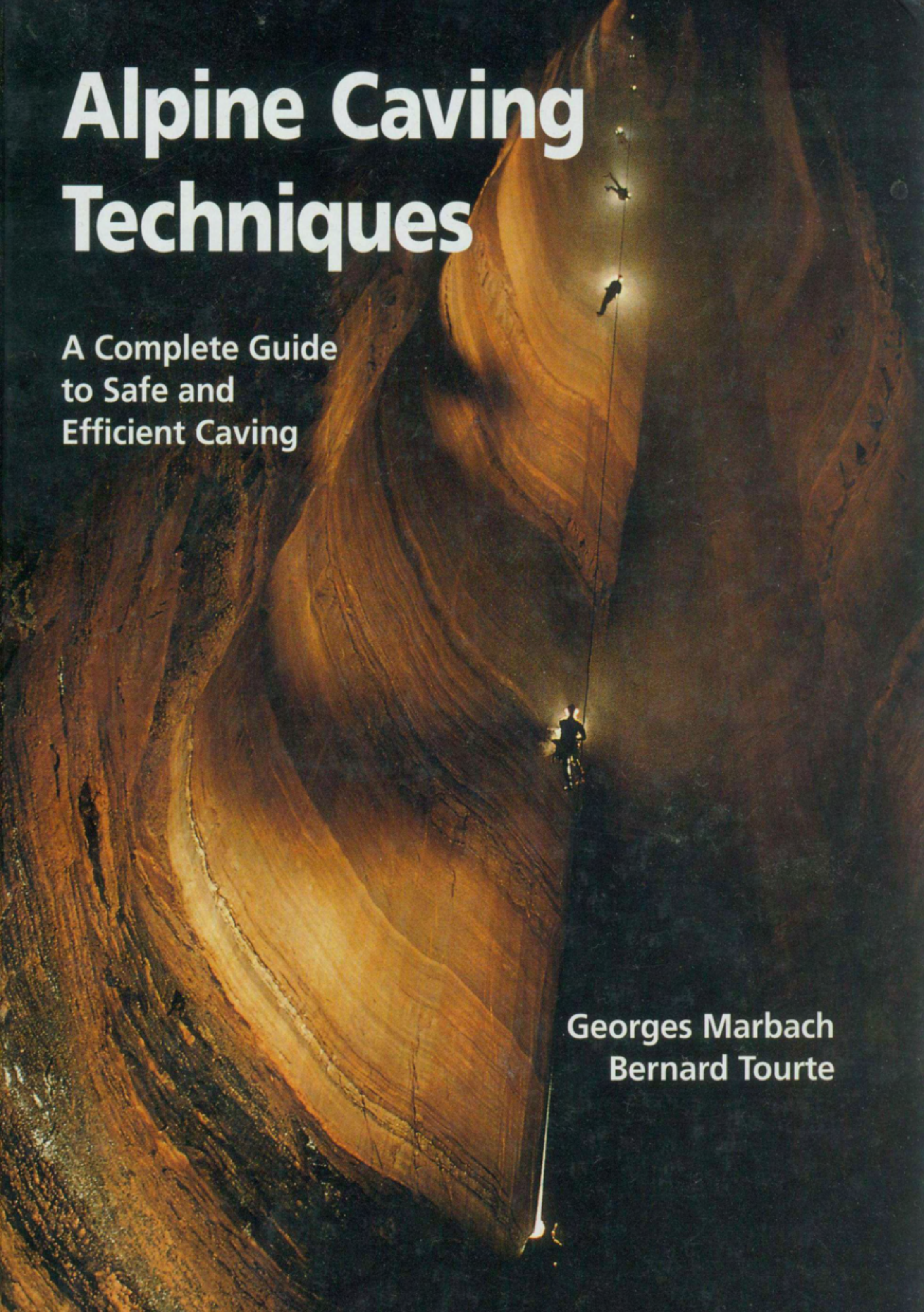
Alpine Caving Techniques

A Complete Guide
to Safe and
Efficient Caving



Georges Marbach
Bernard Tourte

Alpine Caving Techniques

WARNING !

CAVING IS DANGEROUS, and involves the risk of serious injury or death. A commitment to safe caving practices, a thorough understanding of the equipment used, and mastery of the techniques involved can greatly reduce, but will never eliminate, the risks inherent in the sport. It is the caver's responsibility to understand these risks and obtain qualified instruction from experienced cavers before entering the cave. The authors and publishers accept no responsibility for damage or injury resulting from use of the techniques or equipment described in this book.

Alpine Caving Techniques –
A Complete Guide to Safe and Efficient Caving
by Georges Marbach and Bernard Tourte
English Edition, 2002
Translated and adapted by Melanie Alspaugh

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Georges Marbach – Bernard Tourte

Alpine Caving Techniques

A Complete Guide to Safe and Efficient Caving

First English Edition
Translated and adapted from the 3rd French edition
by Melanie Alspaugh

Illustrations by
Jean-Yves Decottignies

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Photo P. Degouve

Georges Marbach has devoted his life to cave exploration, and even made it his profession. He founded the equipment company Expé in 1974, which he managed until 2001. For the past 23 years he has designed TSA caving products and in doing so developed a thorough knowledge of caving equipment. He has only rarely left his favorite caving arena, the Alps, to participate in expeditions to Papua New Guinea, Turkey, and Patagonia.

Georges Marbach headed the French Caving School (Ecole Française de Spéléologie), for which he remains an instructor.

From his first years caving with the Seine Spéléo-Club, he has had a passion for perfecting personal caving equipment, and was actively involved in developing French single rope techniques in the La Tronche Spéléo-Club near Grenoble. He began writing in 1973 with the first edition of *Techniques de la Spéléologie Alpine*. The present English edition is taken from the most recent third edition of the same book.

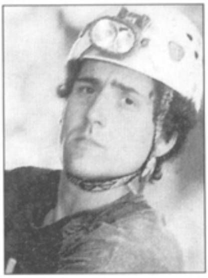

Photo DR

Bernard Tourte spends most of his professional life underground. He spends his weeks as a caving instructor, organizing and leading courses for the French Caving School and French Cave Rescue, and going as far as Spain, Lebanon and Bulgaria to teach classes. He spends his weekends exploring the caves of his native Pyrenees. He still finds time to teach in regular training sessions for Work at Heights. He spends his vacations travelling to the four corners of the Earth – from Mexico to Papua New Guinea, from Irian Jaya to Patagonia, from Malaysia to Austria and Thailand – searching for new caves and new adventures.

Bernard Tourte is a national instructor with a French certification in caving and canyoning. He is a technical advisor to the French Cave Rescue, as well as caving equipment designer for the Spanish company MTDE.

Through his participation in the third edition of this book, Bernard has been able to share his rich knowledge acquired from fifteen years of caving practice and many diverse experiences.

Acknowledgements to the 3rd French Edition

The authors wish to thank the following persons who contributed in various ways to the making of this book.

Daniel Chailloux, Marlène and Laurent Garnier, Fabien Hobléa and Eric Sanson who helped enrich the technical content by sharing their ideas.

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Translator's Note and Acknowledgements

Some readers will notice a lack of references to other caving manuals or articles. This point is not addressed in the original French edition(s), most likely because the French caving community is already familiar with the history and origin of this book and the background of its authors (see Foreword). There are only three references in the Third Edition bibliography; this is because *Techniques de la Spéléologie Alpine* IS the reference, at least in the French caving world. Perhaps this is why some call it "the Bible" of caving techniques manuals. Marbach and his co-authors and colleagues in the French Caving Federation and French Caving School helped invent and develop many of the techniques and standards described here, and they continue to do so today.

That said, there remained the challenge of translating a French caving manual into English, and ensuring that this "European" manual remains relevant to North American readers. Any caver who has caved in different regions or countries will agree that techniques and equipment differ around the world. This book presents horizontal and vertical caving techniques in detail, and particularly the single rope techniques developed in Europe. These are undoubtedly relevant – and often similar, if not identical – to the vertical techniques used by non-Europeans. However, there are a few exceptions. Working closely with Marbach, I have adapted some parts of the text in the hopes of making it as complete and relevant as possible to all readers. Those who are familiar with the 2000 edition will thus notice adaptations to the sections on descenders, racks and rack use, LEDs and seat harness pathology. Likewise, I have used footnotes throughout to provide complementary information on various points.

Non-European (and particularly American) readers will likely encounter techniques or ideas here that are not only new to them, but that may seem a bit shocking. They may even question the "accuracy" of a statement or the soundness of a technique. The techniques and standards presented here have been tried and tested (or used and abused) by competent cavers – underground and in the labs – and have proven safe and effective in practice. But the intent of this book is not to convince the reader of THE right technique; it is to share knowledge and hopefully widen the field of discourse. As Marbach often points out, it is ultimately up to the individual to decide what works best.

Another challenge relates to the diversity of the English language, and particularly the diversity of caving terminology. Churchill once said that we English-speakers are often separated by a common language. Though this rarely interferes with comprehension, there is a lot of variation between British, Australian and American use, and I've noticed this particularly in the field of caving. Correct terms for one group may be awkward or even "technically incorrect" for the other. Example: a vertical passage requiring a rope for progression may be called a *shaft*, a *pitch*, a *pit*, a *hole* or a *pot*, depending on where you live and cave. Likewise, the mechanical device we use for climbing up this vertical passage may be called an *ascender*, a *rope grab*, a *rope clamp*, a *jammer* or a *jumar*, and the act of going down this passage may be *rappelling, descending,* or *abseiling*. I hoped to make this edition as relevant and complete as possible for all English readers, and have tried to include all relevant terms when introducing them. Thereafter, I've tended to choose the American (or Texan) terms that I use most naturally.

This English edition would not be complete without the contributions of several helpful and enthusiastic persons. All proofed the text at various stages of its development and offered their suggestions on a multitude of technical, linguistic and content-related points. I am therefore eternally grateful to David Elliot, Yvonne Droms, Mark Tremblay, Rebecca Jones, Karlin Meyers and Robert Vocke for all their help. I also wish to thank Georges Marbach for the endless hours of attentive proofing and discussion, and for his thorough collaboration on every aspect of this English edition. Thanks also go to Alex Sproul for his input, Alan Warild, Hanna Barbara, Lea Guidon and Pascale Gisin for additional proofing, *On Rope* for permission to adapt additional rack drawings, and Jean-Yves Decottignies for additional line drawings.

Melanie Alspaugh,
Allschwil, 2002

The English edition of *Alpine Caving Techniques* is dedicated to the memory of Joe Ivy.

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Foreword

The original edition of this book, co-authored with Jean-Claude Dobrilla, first appeared in 1973. Twenty-six years ago...an entire generation! For the first time, it presented a comprehensive method for exploring vertical caves without cable ladders, though the book was certainly not meant to be exhaustive at the time. Jean-Claude is a man of action and conviction, so we hoped to stir things up and get people talking. We meant more to provoke than to demonstrate, which is why we included so many photos and illustrations for a text that we deliberately made brief. Hence a book of less than one hundred pages, compact and heretical, if not explosive... The choice of format of course meant that many points were left out, as we were describing methods that were still too new to have been tested thoroughly or subjected to all possible scenarios.

By the time we published an updated edition eight years later (in 1981) many things had already changed, beginning with cavers' opinions and habits – but many questions and criticisms remained. We had to take a more critical approach to the subject, launch new field tests, recast and develop the book further. Jean-Louis Rocourt was the perfect partner for accomplishing the task at hand: his demanding, rigorous nature contributed immensely to greater development in the second edition. The result was a 350-page book, but neither was this second attempt intended to be exhaustive...though we were getting closer. Left as such for nearly twenty years, the second edition seemed to have satisfied its readers since it required two additional print runs. But again it is out of print...

Objectively – if we can indeed be objective – the basis for both of these editions has hardly changed or lost its relevance. The fundamental principles set out in the first have not been called into question by use or experience, and new tests and technical developments outlined in the second remain relevant today. That important techniques have been refined and new materials have appeared on the market changes nothing about caving fundamentals, and a simple explanation of each would have been sufficient to present these. However, several considerations argued for a complete rewrite of the book, which is what we finally chose to undertake.

First of all, commercially available caving gear has developed markedly since 1981; devices that were hand-built by cavers fifteen years ago are now available in stores, and so many discussions in that domain have become superfluous. When talking about safety issues in this new edition, we will refer only to manufactured products since these are considered to be safe. The modern caver has largely lost the habit of building his own equipment and since his income – at least in many countries – has risen, this is no longer necessary. Besides, few would have the knowledge to do so nowadays, since modern materials have proliferated to such an extent that only specialists can understand all the specifications.

This brings up another problem: this book is not intended to be advertising for one brand or product over the next, and we tried not to single out specific brands too often. But this isn't always possible or desirable; it's sometimes easier to get the point across by referring to a specific product. For example, when a piece of equipment is unique, it would be strange not to use the product name. We've tried to maintain a balance here, sometimes citing specific brands or models but sticking to the generic terms as often as possible. We've tried to remain neutral without being vague, though we may not have succeeded entirely – we all have our preferences!

Another reason for replacing the 1981 edition was that the illustrations had become dated. This was particularly true of the photographs, which had been used throughout to represent complicated technical maneuvers. Because of shadows, extraneous details crowding the picture and the more or less relevant angle of view, photos are not as clear as drawings. We have therefore gone back to representing technical points with line drawings in the new edition. The reader will notice more of these in the second part of the book (devoted to exploration techniques) than in the first (covering equipment), where illustrations would be less useful. For example, drawings of manufactured products are not included, as illustrations are widely available in manufacturers' product guides and specialized equipment catalogs.

Another advantage of using line drawings is that it allows us to represent figures at angles that would not be possible in a photograph. For example, figures illustrating how to pass a rebelay can be viewed from the wall side, as if this were transparent. Techniques for travelling in crawlways can be viewed from above, and overall views can be clearly represented where a photograph would be ineffective because of distance, poor lighting, or lack of detail.

We have also removed numerous tables and numbers that are no longer necessary, either because the techniques they once justified are widely accepted now or because safety standards free today's caver from having to worry about the strength of his equipment. However, we in turn found it necessary to provide a more detailed description of these standards and the basis for them, and for each category of equipment they govern. The massive intrusion of these standards in the caving domain has far-reaching consequences, some of which we have yet to fully understand. They range from liability concerns when a piece of gear is loaned to a friend to reduced innovation (and increased cost) among manufacturers due to high testing and approval costs. They can also affect our potential inability to distinguish between quality and mediocrity among products, since all must conform to the CE (Confomité aux Éxigences) mark. This labeling is everywhere, guaranteeing safety and thus a peace of mind for the user that was once reserved for a limited number of manufacturers known for their quality and competence, and to which the client was ever loyal.

Of course, the regulatory nature of CE standards has no authority in countries outside the European Community, but we have nevertheless decided to retain CE descriptions in the English edition of the book for several reasons. Primarily, these standards are inarguably relevant to safety, having been established after close collaboration with industry experts and sports and recreation professionals in all relevant fields. Other international standards, namely those of the UIAA (Union Internationale des Associations d'Alpinisme), are nearly identical. In fact, the UIAA sits on the technical committee that develops and defines CE standards, so there isn't a single safety criteria that escapes its consideration. Each piece of equipment has a minimum safety specification that should be respected, especially among those who install rigging or who are responsible for club and collective equipment. These specifications also apply to anyone who constructs his own equipment or modifies any piece of equipment that already conforms to the standard. This is particularly the case with seat harnesses: in many countries, some of the more well-informed amateurs take to producing these themselves, but only after verifying the most important CE/UIAA safety specifications. On the same note, most local gear manufacturers in non-CE countries use these specifications in developing their own products.

CE norms are of course compulsory in Great Britain as well.

Like those before it, this edition is by no means exhaustive. For example, the subject of cave diving is not covered in any detail (despite its prodigious success and many promising developments), nor is the use of explosives in enlarging passages or entrances (though this has opened countless new caves). These activities involve specific risks and are more fully developed by specialists in numerous other works. Moreover, we will only touch briefly on the subject of cave mapping, which is now in the process of transformation. It would be more useful to deal with this subject in ten years, since developments in electronic technologies are now revolutionizing how we survey caves and draft maps. This applies not only to mapping and archiving software, but also to survey instruments: laser meters and electronic clinometers will soon relegate our dear old surveying tools to the museum. But why should we present this information again here when it is already available in other excellent sources?

Finally, we admit that the reader may still find some errors or misprints in the text as well as in the illustrations, despite careful proofing and revisions. Also, the techniques described in this book apply to an activity that we all know is potentially dangerous. It is the reader's responsibility to proceed with care and caution and to test the methods described in a safe setting where there is no risk of falling, before applying them underground.

Rewriting a book that is recognized as a "definitive source" is always a challenge: it has to be at least as good as the last, which doesn't come easy.

This new attempt has been made with a fresh accomplice. My long career betrays my advancing age. Though my profession has allowed me to maintain a thorough knowledge of the equipment and a passion for perfecting it, I no longer possess the same global knowledge as can be found in those caving circles where cutting-edge techniques are tried, tested and debated, and where today's explorers voice their aspirations and develop tomorrow's trends. For that, one would have to belong to the inner circle that drives today's caving in our country: the French Caving School (Ecole Française de Spéléologie) and the French Cave Rescue (Spéléo-Secours Français). By virtue of his activities in both of these organizations, Bernard Tourte was able to make a significant contribution to the present edition, which reflects our combined efforts.

This edition is of course only a snapshot of French techniques for exploring vertical caves in the year 2000. Like previous ones, it describes recent developments and presents innovative techniques, the fruits of our labor and that of our colleagues. But like the 1973 and 1981 editions, this too is destined to become outdated, and perhaps more quickly as caving grows in popularity. And so I welcome this eventuality, as I did in our conclusion of the 1973 edition. A new team may someday re-create a fourth edition – perhaps in an electronic version? In any case, I clearly will not be part of that new adventure… It is thus that each of us tries to share what he knows before passing the torch on to the next, a simple link in the chain of progress and knowledge!

Georges Marbach,
Choranche, August 1999

Neuenburger Cave, Sörenberg, Entlebuch, Switzerland. Photo Y. Weidmann / K. Downey

Equipment

A Basic Principles

In the text that follows, we will continually consider an important component of caving that affects nearly everything you do underground: energy. Cavers rarely talk about it and although the topic hardly seems compelling, keep in mind that when you enter the subterranean world you possess a precious store of "energy capital" that will diminish throughout the excursion. It is vital that you know how to manage this resource.

There is so much to do underground. Making observations, following leads, surveying, clearing obstacles, taking photos, sketching a geological cross section, or simply admiring the beauty of the cave environment...so many of these activities require concentration, willpower, physical effort, and a capacity for action. A body that is fatigued by or overly engaged in the simple problems of travel and movement (as would be the case with a beginner) will possess no reserves for action, particularly in the event of an unexpected problem or emergency. The key word is therefore "efficiency." The art of rigging and travelling through a cave lies in the parsimonious management of your precious "energy capital" in order to ensure a pleasant, effective and successful trip. This *savoir faire* supposes a thorough mastery of techniques that allow you to safely overcome obstacles without hesitation or wasted effort. It also relies on an informed and rigorous choice of equipment. These two considerations are of course the subject of this book, and even dictate its organization.

1. Criteria for Choosing Equipment

When choosing, using and maintaining your gear, always keep the following fundamentals in mind.

Safety

Safety is naturally fundamental to all our considerations since the risks involved in a fall in a 50-meter pit are not the same as those on a hiking trail. Failure of a piece of equipment can lead to serious consequences, even if this only involves a pack shoulder strap. Any problem will still result in added exertion and energy loss for the duration of the trip, thereby increasing fatigue and compromising your reflexes. All of this reduces your strength and ability to react in the event of any additional unanticipated difficulties.

A more serious and disabling problem could arise: the strap on a poorly maintained seat harness breaks, or a carelessly placed rope is severed...

The possibilities of failure are endless and, understandably, the fundamental requirement for safety cannot be covered in a few lines; it is a recurring theme throughout this book.

Weight

Weight is the enemy of every caver, especially in vertical caves. During the descent, everything is fine since gravity is helping you along. But then there is the climb out... Even in horizontal caves, you are faced with constrictions of all kinds (crawlways, meanders, belly-crawls, squeezes) that require you to take off your pack and carry it at arm's length or in strange, uncomfortable positions. These situations devour your energy; so, the lighter the pack, the less the fatigue!

The same goes for clothing: why skimp on gear if you turn around and wear heavy clothes that are unnecessarily thick or retain moisture? You will unconsciously carry this insidious weight throughout the cave as your body becomes progressively more fatigued.

Going light obviously has its limits: too light and you can no longer ensure a proper level of safety. If you are tempted to minimize – or miniaturize – material, you need good technical knowledge and experience to know where to draw the line. Not everyone has the necessary competence, which is why our lawmakers have decided to impose minimum standards. These guarantee user safety when the gear is used properly and for the correct activity or purpose. Where ropes are concerned, this is a particularly important point and we will discuss it at length in the following pages.

Functionality

We could also speak of *simplicity* here, which stems in part from the demand for lightness: any redundant tool or useless function should be eliminated since it compromises lightness. This also brings us back to the safety factor: when you start to feel fatigued, you are less likely to make a mistake if you use simple, straightforward gear that is readily accessible at the right moment. In case of an emergency, it is imperative that you be able to act promptly and without the slightest hesitation. This means both eliminating unnecessary gear and putting the gear on properly.

Strength and durability

Dressed in hard stone, the subterranean world is never gentle on your equipment. In constrictions, in meanders, on any slippery surface, you will exert considerable energy for even the simplest movements. If your caving suit, seat harness or pack gets caught, there may be a strong temptation to use brute force to wrench it loose rather than to back up and gently free it – but your gear will suffer in the end. Any resultant damage depends to some extent on the gear's sturdiness but once again, you must find the limit between strength and lightness.

Deciding among criteria

In the end, compromise is necessary when dealing with so many different factors. Lightness should not be achieved by sacrificing strength, which itself requires more material and therefore weight. Even if the old saying "it's better to have too much than not enough" is true, the wise caver evaluates his needs accurately to avoid an unnecessary equipment overload.

Naturally, the balance depends on each individual's ability – or inability – to use, carry, maintain and repair his or her equipment. Doing too little or too much will ultimately have consequences: "brutes" will need more robust therefore heavier and equipment, while the careless will need to repeatedly invest in new gear!

2. The Need for Proper Maintenance

Cleaning your equipment just to put it right back in the mud may seem a bit silly and, reinforced by our natural tendency toward laziness, this perspective leads many people to neglect their gear between uses. There may even be a bit of pride involved in nonchalantly emptying one's pack outside the cave in a dusty cloud of dried mud, then shaking out a caving suit stiffened with clay before putting it on. After all, isn't all this dirt proof of numerous challenging adventures, a gauge of competence and qualifications? Clearly, only rank beginners or losers would unpack spotless, new gear…

Wrong. Neglecting your gear can have serious consequences:

- Dirty equipment wears out quickly. Mud and clay stiffen straps, which in turn rub together with more friction. Cave mud contains microscopic calcite crystals that cut through fabric like mini-razors, working their way into seams and slowly cutting the threads of harnesses, packs and caving suits. These crystals are insidious and they penetrate into the rope, severing its fibers and diminishing its strength, not only on the surface but also at the core.
- Cleaning gear after a trip is the perfect opportunity to inspect its condition. It helps you find weaknesses before they worsen and compromise the strength and safety of the material. This is when you see the small crack in the carabiner gate, the tiny gash in the caving suit, the thread that is unraveling at the bottom of the cave pack, or the damaged gasket on the carbide generator.

  Make a habit of using this time to inspect the key elements of your equipment. While the specific elements depend on the gear being examined, these are the warning lights that will help you anticipate future failures that may be difficult to repair underground.

- Some metallic materials are sensitive to the combination of moisture and mud. This mixture leads to an acidic or oxidizing environment that attacks steel and even aluminum and its alloys. Care should thus be taken to store metallic materials in a well-ventilated, dry, cool (but not cold) place.
- Finally, a few words on comfort: your caving suit, undersuit and socks are much more comfortable and warm when they are soft and dry, rather than stiff with dirt and dried-out perspiration...

3. Reference to a Standard: the "CE" Mark

Standards and product labels are powerful agents of consumer safety and offer some guidance in a field that is often confusing for the non-specialist. Labels can aid you as a user in finding the product that is suited specifically to your need. They ensure that the product has been tested by professionals and is sanctioned by a governmental or European standards body (e.g., AFNOR: French national standards; or EN: European Norms). The European Community (EC) Headquarters in Brussels is now calling the shots by enacting directives that will be imposed throughout the EC , and extend to the rest of the world via trade agreements. In all the member states of the EC, national standards are now nothing more than transcriptions of a European Directive, "EN", into each country's respective language.

The directive that concerns us as cavers was issued in late 1989. It stipulates that no product used for personal protection (PPEs) in any of the member states may threaten the health of consumers.

More specifically, these PPEs must be classified into three categories, I to III, according to the significance of the risks involved in using the product. Thus, little is required of the manufacturers of Category I products (which are meant to protect against minimal risks) except to satisfy the general principle of the directive. Such products include, for example, sunglasses, swimming goggles, shin guards and sewing thimbles. Manufacturers guarantee the harmlessness of their product by marking their conformity to the directive with the label "CE" (Conformité aux Exigences) placed on each item. As luck would have it, the protective clothing worn for sports activities was removed as a category as long as it was for private personal use. If a manufacturer claims that its product provides a specific protection, then it must carry the appropriate label.

Category II is already more regulated. It includes products that protect against moderate risks; for example, cuts, impacts and burns. Gloves and helmets used for caving thus fall under this category, as do crampons and life jackets. In this category, compliance can be declared only after an independent lab, certified by the government as a "designated lab," has granted its CE approval. To begin this process, the manufacturer must submit a case file presenting the product specifications and supply samples that are then tested in the lab.

Category III includes all products that protect against life-threatening risks, such as electrical shock and falls from a height. Ropes and seat harnesses are among the Category III products used in cave exploration. They're not kidding around at this level. Approving a Category III article is a long and costly process. As with Category II products, the manufacturer must submit a set of specifications demonstrating performance levels that are at least equal to the standard requirements governing the specific sector. The product must be conceived, created and tested, technical specifications must be compiled, and then everything submitted to the designated laboratory responsible for testing every aspect of the product, point by point. Once certification is obtained, the product is marked "CE" along with the number of the designated lab that is charged with ensuring the quality follow-through compliance of the product. Finally, the product must come with instructions for use containing the necessary headings and required warnings, before finally being allowed on the market. Phew!

But it's not over yet. The manufacturer must also prove that it can maintain the same level of quality required by the standard for each piece it manufactures. To do so, it must do the following:

- either obtain certification for its quality assurance system from an authorized organization like the French AFAQ (Association Française pour l'Assurance Qualité), the German TÜV or the British Lloyds;

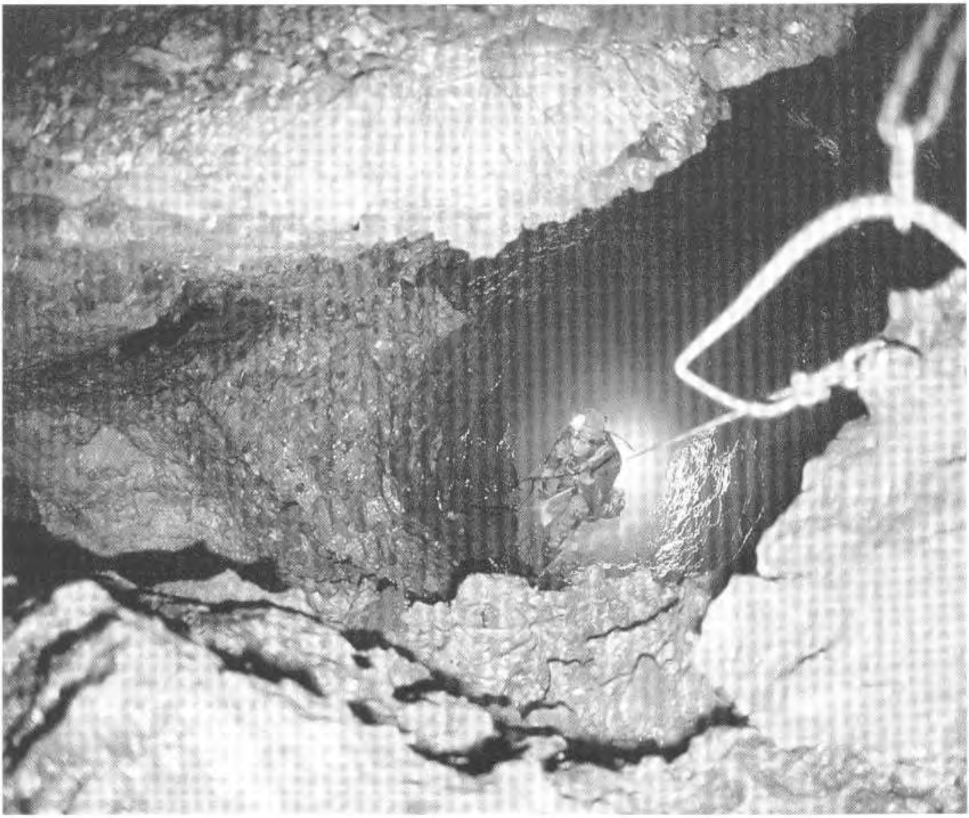
- or undergo annual inspections, in which a series of random samples are taken and subjected to a battery of tests at the designated laboratory, so as to verify and assure the uniformity of the product.

You can imagine that all of this must be quite expensive and it is of course the consumer who pays for it all in the end. But does safety really have a price? Undeniably, the CE Mark has one important advantage: it guarantees a minimum of safety. But a few exceptions have given rise to some aberrations, as with the standards for static caving ropes. This will be discussed later...

Seen purely from the viewpoint of industrial safety standards, ascenders (rope grabs) and descenders are presently considered only as accessories to anti-fall systems, and not as products for personal protection (PPEs). This classification is continually evolving and even if the standards presented in this book are current at the moment of its printing, they are unlikely to remain so for long.

The 1989 directive covers the following PPEs used in caving:

- In Category II:
  - helmets
  - gloves
- In Category III:
  - ropes, cords, webbing and slings
  - safety (seat) harnesses
  - connectors (carabiners and maillon rapides)
  - chocks (hexentrics, nuts, friends, etc.) and pitons
  - pulleys
- Not applicable:
  - descenders
  - ascenders (rope grabs)
  - belaying devices



22-m pitch in Théophile Cave, Alpe-d'Huez, France. Photo S. Caillault.

The complicated and rigid classification system of PPEs has of course resulted in some unintended negative consequences. In a specialized area such as caving, demand for goods is low and production runs are short, so manufacturers must think twice before introducing a new product. Just imagine: a harness manufacturer must notify the designated laboratory each time it makes the slightest design or colour change to the webbing used in its harnesses. With such rigorous regulation, why would anyone want to start manufacturing a product in Category III, even with a very good idea in mind? Potential technical advances have therefore been slowed and we are now faced with a problem: what happens when a new product with no pre-existing standard arrives on the market? Lawmakers have made provisions for this particular case with the option of a special CE approval whereby the manufacturer and designated laboratory work together directly. The manufacturer demonstrates to the lab that its product meets the safety requirements established by the directive, supporting its argument with a case file it has compiled. When the two parties are in agreement, the file is accepted and the product is then eligible for CE certification. Manufacturers with clever marketing strategies can sometimes benefit from this special procedure. For example, while descenders do not fall under the CE Mark, some manufacturers submit to these special certification procedures to obtain the well-known label anyway. They then market the product implying that the label is required, thereby misleading unsuspecting customers into thinking that they are the only manufacturers that have been able to obtain it! Welcome to the age of marketplace guerrilla warfare...

In the sections devoted to equipment descriptions, we will outline the regulatory standards required for each piece of gear. As nearly every country in the world has adopted the international system of measurements (SI, or metric system), none of the units used in these discussions should surprise the reader, aside from the *Newton*, which is a unit of force that has replaced the kilogram force (kgf, not to be confused with the kilogram, kg, a unit of mass) and the pound force (lbf). In deference to current legal, scientific and engineering practices, we will use the unit *Newton* to quantify force in this book. A *Newton* equals 102 grams-force (since the acceleration of gravity equals 9.81 m/s^2). As the forces we are concerned with are a thousand to ten thousand times larger than a *Newton*, we will use a multiple of this basic unit, the kilo-newton (kN), which equals 102 kgf or 225 lbf. For example, a maillon rapide must legally withstand 20 kN of tension along its length (long axis), which corresponds to 2040 kgf or 4500 lbf in the old units.

4. Rules of Conduct

As we mentioned earlier, fixed anchors (anchor sleeves, studs, eyebolts, rings, hanger plates), whether they are set by expansion plugs or by glue, do not fall under the directive as PPEs. They are instead considered to be collective equipment. This does not mean that their choice and placement should be left entirely to the imagination of the person setting them. Quite to the contrary, the person placing the anchors sets the level of difficulty needed to overcome the obstacle. His actions should therefore follow the rules of the art. He bears an obvious responsibility to all future users and could quite clearly be implicated in the event of a serious accident. In a society that is becoming ever more litigious, it is a risk that must be carefully weighed.

But this Sword of Damocles should not be our primary motivation for rigging carefully and correctly; the motivation should rather spring from a respect for others, from whom we expect reciprocal treatment. It is also out of a respect for nature that our rigging should alter the natural world as little as possible while assuring our safety. Poor rigging must inevitably be redone, which then multiplies anchor points and thus damages the rock. We have all seen and deplored the sight of multiple anchors sprinkled like stars in some constellation at the top of some pitches, reminders of the way some cavers perceive their relationship to our caves.

It is important here to recall the unwritten code of conduct that connects underground exploration with a natural respect for this magnificent playground. This respect is necessary for the survival of our sport.

But we'll come back to this later...

B Suiting up

In our daily lives as well as underground, our clothes serve as protection against the elements. In caves, however, we are exposed to scrapes, bumps, hits, shocks, cuts, water and cold. We need special protection to defend ourselves against this aggressive environment.

1. Undergarments

The primary role of our undergarments is to limit heat loss, and particularly in alpine caving. The body naturally releases heat as a by-product of its metabolic processes, constantly regulating these processes so as to maintain a constant core temperature of approximately 37°C (98.6°F), which is necessary for proper functioning. If the external environment is too cold, the body cannot do this alone, and clothing is essential in helping to protect against excessive heat loss. Heat can be lost through three processes, the effects of which are cumulative. These are convection, radiation, and conduction.

Convection only operates through a liquid or gaseous fluid; in caving, the primary concerns are with water and moist air. Heat always transfers from hot to cold, so when fluid molecules come into contact with a warm body, the heat moves to the cooler molecules. These become lighter and rise through the fluid, to be replaced by other cold molecules on the body's surface. You can limit convection heat loss by wearing undergarments that fit snug around the body, limiting the circulation of air and water near its surface. Loose clothing will allow small air currents to pass between it and the skin, every time you move. In addition to snug undergarments, gloves and a fully closed caving suit will also help limit limit heat loss. And of course you should always try to avoid getting wet.

Radiation is the emission of heat in the form of infrared waves and depends entirely on the temperature of the emitting body (in this case, yours !). Only a metallic barrier such as an aluminum-coated sheet can stop heat loss from radiation. This is why the rescue blanket is so effective in keeping you warm during an extended break in activity, and it should be an indispensable part of your personal gear.

Finally, conduction transfers heat by physical contact, further facilitated by the presence of moisture (an excellent conductor). Placed between our bodies and the external environment, our undergarments act as a physical barrier and thus an insulator, preventing conductive heat loss. But the best insulator (besides a vacuum) is dry air. Dry fibers are by their very nature insulating, largely because they trap the air in their mesh, making the air itself the insulator. As soon as the air begins to escape, convection transfer takes effect. When the air is dry, there is little difference in the performance characteristics of various types of fibers. Underground, however, the air is at about 100% humidity and wearing a PVC-coated caving suit prevents perspiration from evaporating away from the body's surface. Our undergarments then trap the moist air and this is precisely when the difference between one type of fiber and another becomes important.

In the caving environment, whether a fiber is hydrophilic (attracting or absorbing water) or hydrophobic (repelling water) will play a primary role in its effectiveness. Hydrophobic fabrics perform better because they repel water, particularly toward the cooler, external environment. This allows

Fig. 1 – Fleece undersuit.

your body and clothing to dry out quickly and you are more comfortable. On the other hand, hydrophilic fibers absorb and hold water. They remain wet and cold, allowing heat to escape through conduction.

Although we often prefer natural fibers in everyday life, these are hydrophilic and poorly suited to caving in a cold, humid environment. Cotton is the worst of all and you should even avoid wearing cotton underwear when caving. Wool is better but it becomes heavy when wet, making it somewhat inconvenient. Silk is light but also absorbs water.

Most synthetic fabrics are hydrophobic and therefore more appropriate to our needs. Leaving aside the more expensive fabrics, we are left with three synthetics: rhovyl, polyester and polypropylene. These fibers may also be manipulated to further enhance their performance. For example, some may be treated so as to channel water more quickly away from the body (Capilene), or ruffled up to trap more air inside (fleece). The thickness of the fabric also plays a role in its performance.

But it is not enough to be warm; comfort also depends on freedom of movement and therefore on the elasticity of the fabric. Better elasticity can be achieved either through better weaving techniques, or by adding rather expensive elastin fibers such as Lycra.

The one-piece undersuit

We favor undersuits because they stay in place, regardless of how much we twist and stretch them. The old combination of thermal tops and bottoms is ill-suited to your movements in the cave. When you raise your arms high over your head (during a climb, while climbing rope or in a tight crawlway), the bottom of the shirt comes up but, blocked by your harness belt, cannot go back down. Little by little, the top and bottom inch their way apart, your lower back becomes exposed to the chilly air and/or caving suit, and uncomfortable rolls of fabric start to bunch up above the belt.

The comfort and price of a thermal undersuit depends on its elasticity and whether this is multidirectional, unidirectional or nonexistent. The first is optimal since it allows more freedom of movement. This saves precious energy and results in a net gain by the end of the trip.

Choose the thickness of your suit according to your own metabolism; for example, whether you are warm- or cold- natured. If you have trouble deciding, go for more flexibility and choose the lighter model. You can always add another layer if necessary.

Key points:

- When choosing an undersuit, look for the following:
  - reinforced knees and elbows
  - a zipper with at least two if not three pulls
  - a high collar
  - wrist and ankle finishings: they should be comfortable and made of the same or similar material as the rest of the suit (soft and hydrophobic).
- Some models exist with longer zippers, which prove especially useful for women in "urgent" situations.

Tip:

Sew an extra square pocket over the knees, with a Velcro closure on the upper leg. Insert closed-cell foam padding into the pockets, and you have a set of comfortable kneepads that you will find very useful for those long, low crawlways. This is particularly helpful if you are using a lighter undersuit meant for warm caves. The problem with traditional kneepads is that they have a tendency to cut off circulation behind the legs when they are too tight, or twist and slide down the legs when they aren't tight enough!

Maintenance:

Wash your undersuit at a low temperature after each use to eliminate perspiration residue as well as clay and dirt particles. The latter tend to irritate the skin, especially at the cuffs where the wrists are always moving.

2. The Caving Suit

The caving suit is your armor against the elements. It needs to be comfortable, thin, light and flexible, yet also protective, durable...and therefore thick, heavy and stiff! These contradictory qualities are evidently incompatible, so you will have to make some compromises.

Cotton, polyester and nylon are the only materials used for caving suits. Because it soaks up so much water, cotton is only used for caving in countries with warm climates, in caves that are particularly dry or perhaps for specialized activities such as archeology.

Coating

Synthetic fibers, however, have one very annoying characteristic: they are smooth, whereas natural fibers are rough. To enhance their performance, woven synthetics must be coated to prevent them from losing their shape. Without this coating, the crossed threads would slide away from each other, becoming tight in some places and loose in others, until holes form in the fabric. Coatings help seal up the tiny holes between the weave, rendering the fabric resistant to water as well as airflow. That these caving suits are impermeable to water is a plus; that they don't "breathe" is a definite minus. Lighter coatings allow some air movement in the fabric, but also mean poor impermeability as well as durability in general, even when made up of the strongest threads.

Coatings in fact enhance the cohesion of the weave, making it more abrasion resistant. Stronger coatings produce a very solid, impermeable fabric which, on the other hand, turns into a portable steam bath as soon as the person wearing it becomes active.

The ideal balance between a durable coating and good breathability has yet to be acheived. Microporous coatings cannot withstand the harsh conditions encountered in caving. As for Gore-Tex, this would have to be laminated over Cordura to achieve the necessary strength; however, Cordura has a rough surface that easily picks up clay and dirt, which compromises the breathability already offered by this expensive material. Since few people are willing or able to pay upwards of $400 for a Gore-Tex-treated caving suit, most of us will have to wait for more effective and affordable possibilities. Some are already appearing on the market.

Coating a fabric involves pressing a paste into the weave using a series of rollers. The paste, made up of various compounds, is pressed into the inner side of the fabric or sometimes into both sides. Two types of material are generally used for caving purposes: PVC and polyurethane. PVC tends to harden in cold conditions and to become brittle with age, but it is very durable and relatively inexpensive. In addition, PVC coating can be fused together with high frequency welding, which reinforces and totally waterproofs the stitching. This is a definite advantage for anyone caving in wet systems. Finally, PVC is easy to repair with an adhesive such as Seamgrip or Aquaseal.

Polyurethane-coated materials are more expensive, but more comfortable because they are less rigid, especially at low temperatures. Some types can be fused together, but their seams don't hold up to the thrashing we give them underground. As a compensation, sewn seams in polyurethane suits do offer a bit more breathability. Some models attempt a compromise by using PVC only below the waist, where we are more often likely to get wet. This allows for more airflow around the upper body where we perspire and need it the most.

Once upon a time when cavers had to climb and descend right through waterfalls, the hood – folded up and stored in the collar of the suit – was crucial in protecting against the cold water. Now that the common approach is to rig away from waterfalls whenever possible, the hood has seen its importance diminish. However, it is still useful in providing insulation during prolonged periods of inactivity.

Choosing a caving suit

We have seen that there is no such thing as a universally adapted caving suit. You would need one of each. Because it is waterproof, the PVC model (such the Styx, fig. 2) would be used in active alpine caves. In drier caves, a polyurethane suit (such as the Helix or Sud, fig. 3) will suffice and is much more comfortable to wear, given its suppleness and breathability. If you can't have both, choose your suit according to the kind of caving you do most often.

Choosing the correct size is essential. Torso length should be well adjusted, especially if you rarely wear a seat harness. If the crotch falls too low, it will limit the breadth of your stride and will probably rip the first time you straddle a canyon or

Fig. 2 – PVC-coated caving suit.

Fig. 3 – Polyurethane-coated nylon caving suit.

take a wide step. It is best to try on the suit, making sure the crotch is where it should be, and simulate the kinds of movements you make when caving: with arms lifted high, you should be able to lean forward easily without restriction, take wide, straddling steps, etc.

Key points:

- Choose a smoother fabric that will be less likely to retain mud. Once it dries, the dirt will fall away easily rather than become enmeshed in the fabric.
- Choose a suit with a slippery internal coating. Your undersuit will be better able to slide against it, making it easier for you to move. If the caves in your area are mostly dry, choose a thinner coating.
- Make sure the flap of the outer pocket (if your suit has one) is as flat against the suit as possible. This will prevent snagging during those tight squeezes and crawls.
- The suit should have the least amount of exposed stitching as possible. The more outer stitches you have, the more quickly they will wear from abrasion. Then the Velcro comes apart, the bottom tears open, the patches reinforcing the knees turn into hanging flaps...You get the picture.
- Also avoid stitching near the armholes, since these areas are highly exposed to falling water (as when climbing in pits) and frequent scraping in meanders and crawlways.
- If you choose a suit with a reinforced rear, the second layer should be made of one continuous piece of fabric, without stitching down the center. This makes it more durable and resistant to wear. On models with stitching down the center, the stitches come undone quickly and the exposed material underneath, already worn by frequent rubbing, will tear more easily along the new thread holes when repaired.
- The diameter of the pant legs should be greater than that of your rubber boots, so that the suit can be worn over them.
- The Velcro closure on the torso should be at least 40 mm wide.

Tips:

- Use every possible occasion to air out your suit by allowing the warm, moist air accumulated inside to escape. This is just a matter of having the presence of mind to think of it, which comes naturally once you've developed more ease and efficiency in movement:
  - Open the Velcro in the chest area when travelling through spacious passages. If the suit isn't too mud-caked, turn both sides in from the neckline, making a "V" down the chest to the waist. In larger fossil systems, you can even remove the upper part of the suit if the length of the passage is long enough to justify doing so.
  - Create even more ventilation by opening the undersuit as well.
  - When moving through long walking passages that don't require the use of your hands, remove your gloves and place them against your chest, between your suit and undersuit.
- Be careful not to get mud on the Velcro closures or your suit will stay open for the rest of the trip!

- If you plan to carry your suit in your pack when you return from the cave, you can avoid getting it muddy by turning the suit inside out, folding the arms and legs into the torso area and closing it with the Velcro. This way, the mud stays in the suit and your pack stays relatively clean. You may even wish to put your muddy harness and vertical gear inside as well, but remember to take it out as soon as possible. If you don't, the metal parts will oxidize.
- More durable types of kneepads are usually worn outside the caving suit. Some cavers find it convenient to place the strap of their footloop between a kneepad and the suit, which allows them to keep the footloop on while moving from one pit to the next, without it catching on rock outcrops.

Maintenance:

- A wash with a hose is essential after each use. Failure to do this leads to more rapid wear on the stitching by microscopic calcite crystals present in the mud and clay. The seams will come apart sooner – much to the chagrin of the owner, who will undoubtedly complain that the maker of the suit can't even sew a decent seam. A tip for the lazy: a suit left submerged for an hour in a stream or river and weighted down by rocks will wash itself.
- Fine calcite crystals also cut the loops on the soft side of the Velcro closure, which reduces its holding power.
- Don't forget to let the suit dry completely if you want to avoid carrying some moisture-loving microscopic friends with you on your next trip.
- The time spent cleaning your suit is also the perfect opportunity to detect and repair any holes or tears in the fabric. Do this immediately and not "next time"; they will only get bigger and more difficult to repair.
- PVC is easy to repair using the appropriate glue and pieces of the same fabric, which can be procured from the manufacturer (ask for scraps). Glue the replacement piece inside out against the outside of the suit so that the strongest coatings come into contact with each other. For larger tears, add another piece to the inside of the suit as well.
- Polyurethane is a bit harder to glue. Neoprene sealant is acceptable, but one brand stands out above the rest: Seamgrip. This product contains Toluene (methylbenzine) and should be used in a well-ventilated area. With polyurethane, sew on the patch using a durable synthetic thread, then seal the seams with Seamgrip. This will protect it against abrasion and waterproof the seam. You can also use Seamgrip to plug small holes.
- For all repairs, regardless of the type of glue or patch used, always work with clean, dry material on a flat surface and respect the drying time recommended by the manufacturer.

3. Gloves

Gloves protect the hands from scrapes and cuts and help keep them clean for those times when cleanliness is especially desirable (surveying, photography). They also protect against the cold air, water and the walls of the cave. Gloves with longer cuffs are a plus, since they also protect the wrists.

PVC-coated gloves are commonly used in Europe since they are inexpensive and relatively sturdy. They are made by mounting a cotton lining on a mold and dipping it in a bath of PVC. The lining absorbs the sweat from your hands, but it unfortunately retains this moisture and hardly ever dries out underground.

The problem with PVC here is the same as with caving suits: it becomes stiff when cold, making it more difficult (and uncomfortable) to move. Synthetic rubber and thick latex gloves are durable and suppler, but difficult to find with longer cuffs.

No matter what kind of glove you use, you'll notice with frequent rope descents that your gloves wear out asymmetrically. The glove for your "rope hand" will wear out more quickly than its counterpart, especially at the junction between the thumb and palm, where you hold the rope for braking during descent.

Key points:

- Be sure the length of the fingers is correct: too short and your hand movement is restricted; too long and you compromise your grip.
- Gloves that are too big are easily lost, but gloves that are too small cause too much pressure and make your fingers cold.

Tips:

- We never know exactly what we should do with our gloves when they are caked with mud and we suddenly have to perform some precise or delicate operation. Solution: pierce a hole about 2 cm in diameter in each cuff. This will allow you to clip them onto a carabiner attached to your seat harness. Be sure you make a clean, round circle without any jagged edges; otherwise, it will snag and tear more easily on the carabiner.
- If they aren't too mud-caked, the best place to put your gloves is against your chest, between your undersuit and your caving suit (which should remain slightly open). Here, they will stay warm and might even dry out if they stay there long enough (as during a snack break, for example). You can also sit on them, in which case they will insulate you from the cold cave floor.
- When at the base of a wet pitch, bend your arms and raise your hands to avoid getting water inside your gloves. Use the same position when you descend a steep slope where loose dirt falls away under every step.

Maintenance:

- Rinsing with water is sufficient, but they must be completely dried out to prevent the progressive rotting of the cotton lining.
- Even with regular rinsing, dirt will eventually accumulate inside your gloves, rubbing painfully against your fingertips. So from time to time, turn the gloves completely inside out and scrub the lining. You can make the job easier by using a tub full of hot, soapy water. Machine washing is also effective, but remember to rinse the gloves and turn them at least partially inside out before throwing them in.

4. Boots

Rubber boots are waterproof, supple, gripping, insulating, and inexpensive, and they reign supreme on the feet of European cavers. Also known as "Wellies" to the British, they are only too warm to wear in more temperate zones (and the Americans steer clear of them, perhaps to distinguish themselves from the Old World). Note: rubber soles offer the best grip. The problem is that rubber wears down more quickly since, on a microscopic level, *traction* is the result of *attraction* between the contact surfaces. When the materials separate, the softer particles remain stuck to the harder ones and the sole imperceptibly erodes away. If our boots grip remarkably well on that clean, white flowstone, it's understandable that they will also leave their mark, which explains why we must sometimes move about in booties when we go through particularly pristine passages.

Choose non-lined boots, since the cotton lining holds water and perspiration; the boots then chill and soak the feet. Finding non-lined boots is sometimes difficult and is expected to be more so in the future. In France, the Workplace Regulation Authority (Réglementation du Travail) has declared non-lined boots to be "unhygienic," so all safety and work boots are now lined as required. A few non-lined models remain in the agricultural sector, where we tend to find more independent types than salaried government workers...and where the legislature interferes less. For smaller feet, these boots may even be more difficult to find and for years women with a shoe size smaller than 39 Eur (5 UK; 8 US) have had to fall back on PVC. These

Fig. 4 – Non-lined rubber caving boots.

may be more durable, but they are known to be very slippery. So, if some small-footed colleagues seem a bit uneasy in more treacherous situations, don't jump to any conclusions. The good news is that one manufacturer has recently come up with the excellent idea of extending its line of non-lined boots to women's sizes, which are now available in sizes of 39 Eur (3 1/2 UK; 5 US) and above. Are caving manufacturers finally beginning to notice that women go caving, too?

To be thorough, we should mention the recent appearance of shoes designed specifically for caving. These are made with neoprene and sturdy Cordura, and are waterproof and durable with excellent ankle support. A deeply treaded sole offers good traction. The sole is also more rigid, making them more comfortable in our footloops for those long rope climbs. They are better at holding our socks in place and, having neoprene insulation, are warmer than rubber boots. Even better, they don't fill with water in stream passages, and allow for moisture to escape from the leg openings of the cave suit. These specialized shoes only have one disadvantage: they cost three times more than rubber boots and are no more durable. That said, they also have a tendency to start taking in water in as little as ten centimeters depth.

So for the moment, the reign of our trusted Wellies isn't under serious threat...

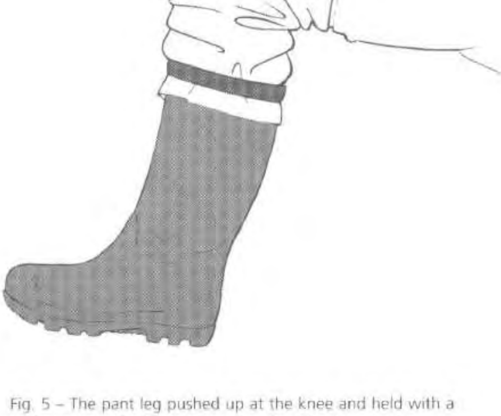


Fig. 5 – The pant leg pushed up at the knee and held with a rubber inner tube band makes bending the knee easier.

Key points:

- Look for a model with as much rigidity as possible in the bootleg. This will give more support for your ankles and help protect against sprains. Wearing a thin neoprene sock (see below) will add even more support.
- The soles should have deep, thick treads, especially at the heel. This serves both for shock absorption and better grip on slippery surfaces.

Tips:

- Cut two bands from a used tire inner tube (Tubeless tires are taking over, so stock up!). You can use these rubber bands to hold the legs of your caving suit over your boots, sealing them together. This will be useful for:
  - caving in cold systems, as it will help reduce heat loss.
  - lifting your knees (climbing rope and in steep terrain and boulder slopes); since your caving suit doesn't slide easily past the rubber bootleg, you will usually have to make an added effort to adjust your suit and lift your knees. This is a waste of precious energy that can be avoided. Simply pull the bottom of your pant legs up toward the top of your boots, puffing them up at the knee, and hold them in place with the rubber bands. This automatically allows more ease of movement at the knees.
  - moving quickly through shallow pools. If your suit doesn't have any holes in it, you can even step rapidly through pools and stream passage up to your thighs without getting wet.
- In easy horizontal passages, roll your suit up to just above your bootlegs to allow excess warmth to escape through the bottom of the suit. You can also fold the top of your boots down. Be careful not to leave the fold in the same place each time, or the rubber may eventually break at the fold. The same is true if you fold or roll the boots in the same manner every time you transport them, so avoid doing this.
- In river passages, rubber boots fill up and become heavy, and you will have to empty these "lead weights" often. To do so with the least amount of effort, remove the rubber band from around your pant leg, raise your leg up and press your boot heel against a wall. Better yet, use soled neoprene shoes instead of rubber boots when caving in stream caves. These hold only a thin layer of water that stays pleasantly warm

against your feet. Rubber boots with pierced drainage holes or with the tops cut off are only makeshift solutions and they keep your feet cold.

- Never tuck your pant legs into your boots. This is a perfect trap for pebbles, mud, sand and water.
- If you cave often, buy your boots a few months before you begin to use them and let them dry out in a cool, dark place. This will allow the rubber to harden a bit and will lengthen the life of the boot (it will also very slightly diminish its traction).
- Rubber boots can be very cold in snow. To keep your feet warm, slide a pocket toe warmer between your sock and boot. These function on the reaction between iron oxide and air. They don't work in water, but there are other varieties on the market that do.
- Shock absorbing insoles add extra warmth as well as padding.

Maintenance:

- Rinse your boots with a hose, being careful to remove all pebbles and clumps of mud that may be lodged in the grooves of the soles. Pebbles left wedged in your soles will wear them down more quickly, and mud will turn to dust when it dries and find its way into your equipment. Allow the boots to dry out completely.
- Aside from drying time, do not leave your boots in direct sunlight. This will eventually cook the rubber, causing it to crack and break.
- A torn or cut boot is nearly impossible to repair, so avoid walking over particularly sharp rocks or scraping them over jagged edges. You can repair smaller snags with tractor tire patches and vulcanizing glue.

Socks and booties

The feet and hands are the first parts of the body to get cold, so good socks are extremely important. They should have a thick loft, both for warmth and to cushion your step. As with all of your other clothes, they should be made of synthetic fibers.

Rubber boots have an annoying propensity for 'swallowing up' socks which, due to constant rubbing, tend to slip down under the heels and gather there in uncomfortable folds. You can hold your socks in place by wearing neoprene or quilted fabric booties over them. The latter are less expensive, but they quickly lose their shape and soak up water. The better choice is a jersey-lined (both sides) neoprene bootie, about 3.5 mm thick. Always wear inner socks or synthetic liners with these, since the neoprene can cause irritation, and perspiration will facilitate fungus growth. The neoprene will hold your socks perfectly in place and provide added cushioning for the feet.

Key points:

- What to look for when shopping for socks:
  - the loft of the small loops in the knit;
  - reinforced heels and toes;
  - elasticity, which will allow the sock to fit well and remain in place.

Tips:

- Bring an extra pair of dry socks on long explorations that follow a stream or river passage.
- Take the time to stop and wring out your wet socks. The minute spent will be worth hours of warmth to your feet!
- A pair of high quality, thick socks is better than two pairs of thin ones.
- In stream passages, use neoprene socks with a thickness that will provide proper insulation for your feet, and ankle-length inner socks rather than knee-highs: once they become soaked with water, the latter will most likely collapse around your ankles anyway.

Maintenance:

To preserve their shape, cushioning ability and elasticity, wash your socks in cool water after each use. Neoprene socks may simply be hand-washed in cool water, but can also be machine-washed at a low temperature. It is a good idea to turn booties inside out when possible, so that the inside of the booties get thoroughly washed. Hang them to dry out of direct sun, and never use a dryer.

5. Pontonniere and Cagoule[1]

The pontonniere is invaluable in long and relatively deep (no more than 1.5 m) stream passages or partially submerged crawlways. It saves a considerable amount of time when used in place of an inflatable boat since it makes it unnecessary to shuttle packs back and forth. It also eliminates the significant heat and energy loss that comes with prolonged submersion. It restricts your movements somewhat, but much less so than a neoprene wetsuit, which is much bulkier.

The pontonniere is a pair of one-piece waterproof overalls with feet, worn over your thermals or undersuit. It comes up to just under your armpits, and is held in place by suspender-like straps. Some models are made of fused PVC-coated nylon, much like the PVC caving suit except with lighter fabric. As with the caving suit, the inelasticity of PVC limits movement, especially at the knees. Fortunately, a more comfortable version exists in latex, which moves more easily with the body. This material is lighter but more delicate, so it should always be worn under a caving suit. A major disadvantage of the pontonniere is that it traps and condenses moisture inside, eventually saturating your socks and undergarments. For this reason, take it off as soon as you are out of the water to prevent overheating, excessive condensation and ultimately, chilling.[2]

The cagoule is a kind of waterproof anorak (often made of latex) that covers the upper body and most of the head and face. It fits tightly around the wrists and snuggly around the face to prevent water from seeping in. For climbing in waterfalls or crawling in low, water-filled passages, it is the ideal complement to the pontonniere. To seal the two against the influx of water, either roll the bottom of the cagoule (if it is long enough) and the top of the pontonniere together, or attach a large, wide rubber band (again from those useful inner tubes!) over the area where the two pieces overlap, like a belt. This combination will get you through some very wet situations in relative warmth and comfort.

Fig. 6 – Cagoule.

Fig. 7 – Latex Pontonniere.

Tips:

- Wear a second pair of regular or neoprene socks over the feet of the pontonniere to keep them in place inside your rubber boots. Otherwise, like your socks, they will tend to work their way down toward the bottom of your boots and get twisted around your feet.
- Neoprene socks also help protect the pontonniere from being torn and cut by small pebbles that may find their way into your boots.
- Because latex is delicate, never step on rocky ground when putting on or taking off the pontonniere. Instead, use an emptied, flattened cave pack or your caving suit as protection.
- When using the pontonniere without a cagoule in deep water, it's a good idea to have an elastic belt on hand, made from inner tube bands and linked together with girth hitches (lark's foot knots). Just before you enter a deep spot, fasten it around your chest with a carabiner to ensure a tight seal in case the water reaches above that level.

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[1] North Americans may use the term "waders" but the pontonniere is a much more specialized and refined form of "wader." The cagoule or latex hood is similar to a skintight anorak, covering the head, neck, shoulders, arms and torso, and is also called a balaclava.

[2] Good news! A pontonniere is being developed in France that is waterproof, breathable and elastic, making it far more comfortable and perfectly suited to our needs. It will likely appear on the French market in 2002 and be sold by Expé.

- When undressing after your submersion, be sure to wring out both socks and undergarments before continuing.

Maintenance:

- Because your waterproof garments are both expensive and fragile, consider paying special attention to their care. When properly cared for and stored in a cool, dry place, they can last you ten years or more.
- Rinse both pieces thoroughly – inside and out – with clean water and dry them in the shade, making sure to turn them so that both sides dry out thoroughly. Finally, dust both sides with talcum powder.
- Never leave them in direct sunlight; the latex will decompose and stick to itself, preventing further use.
- The latex combo is easy to repair with tire patches and rubber solution.

6. Wetsuits

Neoprene overalls ("farmer johns" or "long johns") rival the pontonniere in water-filled passages. In long and deep river passages, a complete wetsuit may replace the pontonniere and its cagoule altogether.

Be aware that the thickness and rigidity of a wetsuit will restrict your movement, especially if tighter passages require you to wear a cave suit over it for protection. The two layers don't slide easily against each other, making it hard to lift your legs and bend your elbows.

During longer trips and even in water, neoprene wetsuits may cause skin irritation behind the knees, in the armpits, and at the bend in the elbows. Being effectively waterproof, neoprene also prevents perspiration from escaping when you are out of the water...so don't even think of climbing a pit in one!

Another disadvantage is that wetsuits are heavy and cumbersome to carry; one suit can fill an entire pack by itself. For these reasons, they are only effective (and worth the trouble) in long, horizontal river passages that require prolonged immersion. At least then you won't need to be cautious about getting wet – jump right in and splash all you want!

Key points:

- Your wetsuit should be an exact fit. If it's too loose, water will circulate too easily, chilling you to the bone. If it's too tight, your movements will be even more restricted and you'll surely be miserable. At worst, it could also restrict circulation and lower body temperature. Consider having one custom made or making alterations to fit your body size.
- Choose the thickness of the neoprene according to the temperature of the water. There's no need to wear a heavy, cumbersome suit if you don't need it.

Maintenance:

- Wetsuits require relatively little maintenance and withstand both dampness as well as direct sunlight.
- They are also easy to repair using a neoprene or tire patch and neoprene glue, which you can find in any dive shop. Work on a hard, flat surface. Position the patch over the area to be repaired and cut both pieces at the same time using a sharp blade, then glue side to side.

Fig. 8 – Two-piece neoprene wetsuit.

C Lighting

1. The Helmet

The shell

It's hard to imagine a caver without a helmet. No matter where or why you go caving, the helmet is an invariable part of our equipment and fulfills two very essential functions: it protects the head from contact with the rock and rock falls, and it carries your light source, freeing both hands for use in moving through the cave.

A helmet has two parts: the shell and the cradle. The shell is bowl-shaped and generally rimless so as to reduce bulk and thus the possibility of it getting stuck in tight areas. It protects against the more benign bumps and shocks and is made of strong plastic compounds: ABS, nylon, polyethylene, and polycarbonate are the more common.

Climbing helmets already fall under European Community (EC) safety standards; all are now functionally identical aside from decorations and the number of ventilation holes. In accordance with the EC directive, all helmets in Europe must have ventilation holes. Under falling water, you'll have to resort to the hood of your caving suits (Petzl sells plastic plugs for the Ecrin Roc, allowing you to cover the holes or leave them open according to your needs). All shells are made of a hard plastic, and EC standards impose a minimum level of resistance to wear and aging. A helmet that conforms to these norms is stamped "CE" inside the shell, with the date of manufacture clearly marked. Helmets can last about five years or more, depending on the frequency of use. A helmet must be retired at the first appearance of cracks in the plastic, corroded rivets, deteriorated cradle webbing, or if the helmet sustains a violent shock due to a fall.

A note to those who are tempted by "industrial standard" construction helmets without holes. These differ from sport helmets in one important way: the chin strap on a sport helmet must withstand a force of .5 kN without opening, while on construction helmets it must open when subjected to under .15 kN force. With the latter, you thus risk losing the helmet in the event of a fall or an abrupt shock – and that's a risk you don't want to take.

The cradle

The cradle is designed to absorb the impact of a rock or other violent blows, and must be made of shock absorbing material. It usually consists of a network of webbing straps that adjust around the nape and chin but not over the skull area, so as to prevent any contact between the top of the head and the shell. This safeguard leaves the helmet perched a bit higher on the head, leaving some sideways play. You can compensate for this by tightening down on the nape and chin straps. Some models provide adequate shock absorption by adding a layer of expanded polystyrene foam to the inside of the helmet. This foam crushes when hit hard. These models should be avoided despite their lighter weight, since the foam traps heat and causes excess perspiration. Foam protections are also ill-suited to the adverse conditions of caves and tend to wear out quickly.

The nape and chin straps

Made of nylon webbing, these straps prevent the helmet from being knocked off the head in the event of a lateral impact, during a fall, or even when you bend forward. The chin strap should be V-shaped, framing the ears on each side, and the buckle below the chin should always be closed.

Safety standards require that the adjustment buckle below the chin be able to loosen or open automatically under a certain amount of pressure, to prevent the risk of strangulation. Quick-release buckles are especially convenient when you are stuck in a squeeze.

Key points:

- Choose the lightest helmet possible since all helmets comply with the same safety standards. But beware of polystyrene linings, which are hot as well as fragile.
- Not all helmets fit all head shapes; be sure you have a good fit before buying one. Some models have a very practical tension adjustment around the head, regulated by two side adjusters. But this doesn't allow width adjustment and so may not ensure a safe and correct fit for those with narrow heads. Again, we advise a careful and complete fitting.
- Be sure the cradle has a comfortable headband that will limit or prevent irritation to the forehead.
- Remember that adding holes to the outer shell will nullify the manufacturer's guarantee.

Tips:

- When mounting a headlamp (acetylene or electric) directly on the helmet, be careful not to drill the holes too large, too close together, or too close to the edge of the helmet. A carefully drilled circular hole will insure the best distribution of stress on the plastic.
- Be sure to tighten the head strap. It will tend to enlarge and loosen during the first few minutes it is worn due to heat from the head, so it should almost feel too tight when you put on the helmet, to prevent its bobbing about on your head during the rest of the trip.
- Keep a close eye on a helmet that has been set aside during a break with the acetylene lamp lit. The tube may twist and knock the helmet over, causing it to melt or catch fire, burning the straps and irreversibly damaging the shell.

Standard (EN 12492):

Caving helmets must conform to the same standards as climbing helmets but construction helmets do not, and should not be used.

- ventilation: the outer shell must contain holes covering a minimum specified surface area.

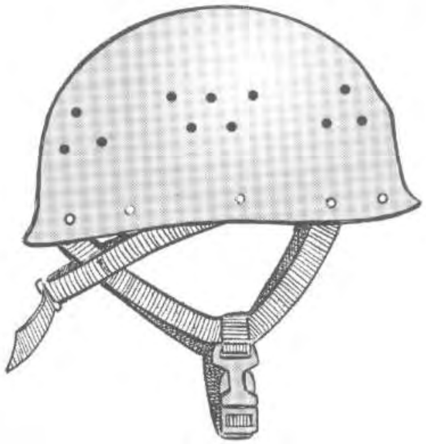

Fig. 9 – Protex caving helmet.

- shock absorbing capability: the helmet is placed on a standard dummy head and subjected to an impact. The force transmitted to the dummy must not exceed 10 kN in each of the following cases:
  - vertical impact of a hemispherical mass of 5 kg released from a height of 2 meters;
  - impact from the front, side or back of a spherical mass of 5 kg released from a height of .5 meter.
  - resistance to perforation: a conical mass of 1.5 kg must not make contact with the dummy when dropped vertically from a height of two meters.
  - the strength and effectiveness of the retaining system (chin and nape straps) are also tested.

Maintenance:

- Modern helmets are quite sturdy and only require a simple wash with water and a sponge or brush. The headband should be cleaned more thoroughly to remove sand and dirt, which can be especially irritating to the forehead. Allow the headband to dry completely.
- The helmet is not a do-it-yourself piece of equipment. Shell, cradle and chin strap are all extremely important for safety; if any part of the ensemble is damaged or altered, the entire helmet should be replaced.

2. The Acetylene Generator

Now that we no longer need to build our own equipment, we rarely end up doing emergency repairs while caving. The carbide lamp, however, still provides us with this opportunity. It remains one of the only devices that is capricious at the slightest change in treatment, much to the chagrin of its perplexed user.

Carbide

Acetylene has been used as a light source for over a century and remains the unparalleled preference of most European cavers. It is inexpensive, safe, and easy to transport, and it emits a strong, even, pleasing light. Carbide (calcium carbide) is synthesized in an electric furnace at 2000°C from a mixture of coke and calcium carbonate. Today in France, it is only manufactured by one company (Bellegarde), and would have likely disappeared in the 1970s if not for the energy crisis.[3]

When carbide reacts with water, it gives off acetylene gas, lime and a lot of heat, which we especially appreciate in cold caves. While most normal people are repulsed by the odor of acetylene gas (this comes from impurities; acetylene itself is odorless), cavers who are accustomed to its use often associate this scent with a powerful and evocative feeling of adventure. Acetylene combustion in the air is incomplete, forming carbon particles that are made incandescent by the flame's high temperature. It is these carbon particles that create such a bright and pleasing light.

To ensure the best possible carbon combustion – and thus the best lighting – the jet should spread the flame out in a kind of fishtail. The jet should be fanned right-to-left for a broader illumination in front, rather than front-to-back, which will instead light up the walls to either side. Faulty jets produce a high, cylindrical flame that flickers, glows a reddish color, and emits more soot. Barely able to see, you begin the ritual cursing and abuse of your generator, coming away looking like you just walked out of the Gulf War...

Classic generators

The reaction between water and carbide takes place in the generator, or "acetylene lamp." This is made up of two parts: the upper reservoir holds water and is filled through a screw cap. An adjustable valve allows water to drip into the lower reservoir, which is filled with carbide. Acetylene gas escapes through a tube leading to the burner tip on the headlamp. The increased pressure in the generator is only about one-tenth more than that found in the atmosphere, so you would really have to abuse your generator to make it explode. This is in fact a rare but potentially hazardous phenomenon. What is more likely to cause an explosion is the accidental opening of your spare carbide container in the cave pack and the resultant exposure to moisture that could lead to a sudden, massive production of acetylene. The caver's headlamp can ignite the gas as he opens the container. Fortunately, the explosion that follows is usually limited to the destruction of the pack, some crisped eyebrows and a temporary loss of hearing. Not critical, but annoying nevertheless.

Steel generators have been around since the beginning, but their monopoly has more recently been broken by more modern materials: the Fisma and Arras models have nearly disappeared from the market, replaced by one made of stainless steel, the Stella (fig. 11). Lighter materials are also available: the Ariane (fig. 10) and the Alp are both made of plastic. The Cascade comes from Moscow and is a gem of a generator in duraluminum, but it's unfortunately a rare find in the West. The Russians have also become the titanium specialists, having so much of this left over from the former military-industrial armament factories.

Special generators

Water is at times rare underground, and it always seems to be rarer on those occasions when we see it trickle out of our lamps in a crawlway. Some generators remedy this problem with a closed-circuit mechanism that prevents water from escaping. The plug and dropper valve are sealed by o-rings; a capillary tube crosses from the carbide compartment into the water reservoir, injecting gas into the upper portion of the water reservoir. The acetylene gas thus regulates the necessary pressure drop by drop. However, these generators can be unstable: as more water drips on the carbide, the pressure increases in both compartments,

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[3] Calcium carbide is still produced and used in the United States to make acetylene gas for welding, so is unlikely to disappear from the North American market anytime soon.

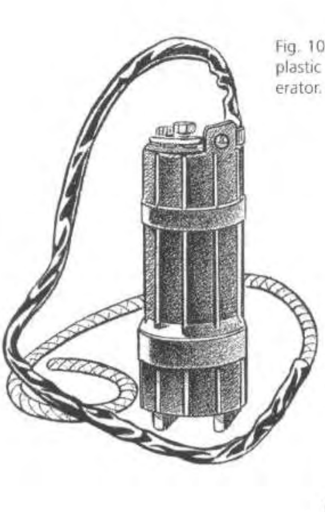

Fig. 10 – The Ariane plastic carbide generator.

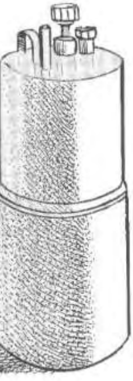

Fig. 11 – The stainless steel Stella works on either a closed or open circuit.

increasing the drip flow, and so on. The only solution to this problem is to open the water filler cap and release some of the acetylene gas build-up. Do not place your jet or any other flame near the filler hole during this maneuver! There is really only one stable rate for a given closed-circuit generator, corresponding to the specific flow of each drip valve. Determine the correct adjustment the first time you use the generator, and thereafter open the valve to the same setting while preparing to enter the cave. Do not touch the valve again, except to troubleshoot an eventual problem. Some of the more sophisticated models come with a pump that allows you to increase the internal pressure as you see fit. This refinement will (rarely) allow you to astound your colleagues upon entry into a larger gallery, and (more often) consume large quantities of carbide.

Disposing of spent carbide

Lime – known to us familiarly as spent carbide – is the solid by-product of the reaction between calcium carbide and water. Pure lime is a weak base, is non-toxic, does not chemically pollute the environment, and contains no dangerous impurities that can harm cave life. However, these gray-white deposits are an eyesore and tarnish the natural beauty of our caves. They remain indefinitely where they are dumped. Existing piles unfornately encourage others to repeat the offense, while the newcomers should instead denounce the carelessness of their predecessors. Even in flood zones, spent carbide tends to harden and is not completely flushed out by the water. Burying it in mud banks is a practice that will likely incur the disapproval of biologists: small particles of carbide residue continue to give off acetylene in the moist soil and by saturating it, the gas can ultimately affect the fauna.

The general rule is to "pack it out," which is of course not such a difficult task and in fact, it quickly becomes second nature. After all, spent carbide is hardly heavier than the carbide rocks we carry into the cave. Use a sturdy plastic sack for transport, large enough to allow you space to dump your carbide directly into it. Close it securely with a knot and store it at the bottom of your pack.

Carrying the generator

Whatever the model, the carbide generator is carried either on the hip, across the chest on a shoulder sling, or on the attachment point provided by some chest harnesses. Wearing it on a sling allows easy transfer of the generator when you're stuck in a squeeze, but also allows it to slide around every time you lean forward. Wearing it on the hip has the opposite advantages and disadvantages; moreover, the generator tends to pull the seat harness down and bruise the hip. A solution is to combine both methods: wear the generator on a sling, clipped to the side of the seat harness with an accessory carabiner to hold it in place. The carabiner should be one with a flat wire gate, like those once used for hanging water bottles from the belt. In a moment of need, such as when you become stuck in a squeeze, you just have to give it a good hard tug to deform the clip and release the generator. This is the only time when brute force rather than calculated finesse will help you out of a tight situation!

Key points:

- In caves as on the surface, do not dump your carbide; empty it into a plastic sack and pack it out to the nearest waste bin.
- When choosing a generator, be sure the water reservoir is sufficiently large (ideally, as large as the carbide reservoir); that the screw valve is long (to prevent you from losing it so often); that the filler cap cannot (theoretically) be lost; and that the joint between the two compartments does not stick out too much (this will reduce wear).
- Choosing a slender generator (Ariane, Stella) will result in fewer jams in tight passages – and fewer bruises on the hips!
- When weight is the primary consideration, plastic models are the top choice. Duraluminum and titanium generators are second best, then stainless steel and finally steel. Those who spend less time maintaining their equipment should be aware that the steel models rust if not cared for properly.
- If you want a generator that works smoothly without too many surprises, choose metal over plastic models. They are not only sturdier but are much less capricious. Specifically, the flexibility of the (otherwise sturdy) plastic can result in deformities caused by the occasional hard blows that occur during a trip. This can lead to problems with pressure variation, especially when carbide nearly spent and overall pressure in the lamp is low: the result is a flame that repeatedly goes out.

Tips:

- Make a scratch as a reference point for opening the valve screw; this will make it easier to regulate the lamp since this setting should remain unchanged, even with classic generators.
- Generators require a steady fine-tuning. A lower gas flow rate should not be compensated by a sudden, massive release of water. This will only lead to a sudden overproduction of gas, a hotter lamp and thus surplus water vapor in the lower compartment. This water vapor will then condense in the tube or burner jet, interrupting gas flow and resulting in an unstable flame that repeatedly goes out.
- A decrease in flow rate is usually caused by lime accumulating over unreacted carbide. Since water enters from above, lime forms on the carbide, making it more difficult for the water to reach unreacted portions. The solution for this is to shake the generator to make the lime fall between the solid pieces. To allow a steadier functioning of the generator, empty the spent carbide at least once between refills.
- An abrupt release of water on the carbide in a hurried attempt to light your lamp will lead to problems later. Think instead of opening the screw valve to its usual aperture about three minutes before going underground. A simple snap of the igniter as you step into the cave or grab the entrance rope will give life to a nice blue flame that will soon turn a brilliant yellow.
- Inside the generator, store the carbide in a nylon stocking or some other thin, porous fabric. This makes it easier to clean the lamp and prevents lime from plugging up the gas or valve openings. It also makes it easier to recuperate unused pieces of carbide.
- Carry unused carbide in a rubber "banana" fashioned from a car tire inner tube. It's free, waterproof, sturdy, supple, and lightweight.
- Treat the interior of the water reservoir on steel generators with an anti-rust product from time to time.
- Occasionally remove and clean the double air/water tube on the Ariane, which tends to plug up with use.
- Open a stuck generator by wrapping a piece of webbing (from a shoulder strap or chest harness strap) around the lower half. Have a friend hold the upper half to help twist it loose. The Ariane has two convenient holds on the carbide cap that can be used to grip the generator (with a descender, for example).
- Once the generator is open, never empty the carbide by banging the lower screwbase on a rock or wall; this will destroy the threads. With the Fisma, the entire screwbase could break off.

Maintenance:

- Close the screw valve a few minutes before leaving the cave and empty the water. Empty the carbide as soon as you are outside; otherwise, the spent carbide expands and hardens into a dense block that must be chiseled apart to be extracted. This swelling can also destroy the lower reservoirs of plastic lamps.
- Wash the generator with water and a non-metallic brush (especially with plastic models). If the

generator is metal, separate both parts and let them dry out completely to avoid rusting. Rust can attack the interior of the water reservoir in particular, and eventually eat through it. Also leave the plug and screw valve open when drying out the generator.

- Use a pointed tool from time to time to scrape out the lime deposits that accumulate between the threads on the screwbase, then lubricate this with a compact grease (or butter or cooking oil if you're in a remote area).
- When making repairs with a soldering or brazing iron, fill the water reservoir with water to help dissipate some of the heat, otherwise you'll end up seeing the valve stem, plug, or threads come apart!

The tube

The tube brings the acetylene formed in the generator up to the headlamp's jet.

Key points:

- Choose a tube that:
  - won't harden in the cold;
  - is supple, with the appropriate diameter for easy attachment to, and detachment from, the gas stem on the generator;
  - does not soften or melt when heated, since the metal stem from the lit burner jet can become quite hot;
  - won't crush easily when it gets jammed between your body and the cave, causing untimely blackouts.

Tips:

- A tube that hangs too far from the body gets hung up everywhere; the smallest rocky outcrop could compromise your rhythm, if not your balance, and this can be a nightmare in a tight squeeze! When the gas tube connects to the left side of the lamp, as with Laser and Duo headlamps, it is best to wear the generator on your right side. The tube then rises in front of the right armpit, passes over the shoulder and around the back of the helmet to join the headlamp at the jet. Make sure it is not twisted. When worn like this, the hose can be easily controlled and remains closer to the body, more or less following its contours. This is an effective and comfortable setup.

Cassowary Cave, Papua New Guinea. Photo L.H. Fage

- Cut off any excessive tube length so the tube rests in close contact with the body, without pulling tight against it: test this by turning your head completely to the right.

3. The Headlamp

Acetylene lamp

The acetylene headlamp is made up of an aluminum mounting plate, a pipe that connects to the gas tube, a jet held in a waterproof bezel by an o-ring, a piezo spark igniter, and a concave aluminum reflector to spread light forward. To function properly, the reflector should be kept clean and shiny. The major advantage of the piezo igniter is its ability to ignite without external energy: the impact of the hammer arm on a compressed quartz crystal is enough to trigger the necessary spark. The Petzl Acéto is the only model on the market with a piezo igniter. This model is compact and easily detachable, which is particularly useful for removing the lamp when prospecting with an electric headlamp alone, or when passing tight squeezes.

Tips:

- The incomparable old jets with two holes are unfortunately no longer available. Their alumina-based successors, having only one hole, give off an imperfect fishtail flame. Choose the 14-litre over the 21-litre jet model (these numbers correspond to the volume of acetylene given off by the jet in one hour). The 14-liter model allows less gas to pass and so consumes less while giving off a wide, luminous flame. Repeated sweeps with the wire jet cleaner will soon transform it into the 21-liter model.
- Extinguish the flame before cleaning the jet (have a friend shed some light on the subject): if the cleaning wire is heated until red, it will quickly soften and break, sometimes inside the jet!
- Be careful when leaning your head forward for prolonged periods of time: the reflector will become hot and eventually heat up and melt the plastic bracket that positions and holds the detachable headlamp. The same can occur if you lay the helmet down at an angle while the lamp is still lit. This will inevitably result in you having to rig some temporary contraption to hold the lamp in place or switch to electric, then replace the piece completely when you're out of the cave.

Maintenance:

Clean with a sponge and carefully polish the reflector with a dishtowel. The steel wire jet cleaner, included with the lamp, will permit a good brushing of crustier jets, whose tips will deform and enlarge as noted above. Cleaning with an old toothbrush is the best solution when possible.

Electric headlamps

In France, the Petzl Duo is the only commercially available electric headlamp that is ready for mounting on a helmet. Other models such as the Micro, Zoom, Enduro, and Solo can be altered for mounting. The Duo has the advantage of two light sources. The halogen bulb is an effective and bright light source, especially for viewing deeper shafts, high ceilings and chimneys. The dimmer incandescent bulb will give light longer since it consumes less energy. The Duo is relatively waterproof, even in waterfalls, but its oval shape can lead to problems when the lamp is submerged. It has a convenient storage spot behind the headpiece for extra bulbs and an acetylene jet. The beam direction is also adjustable.

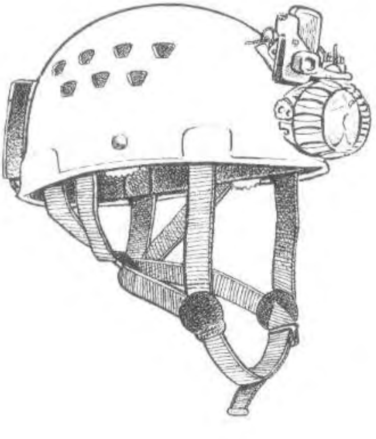

Fig. 12 – The Explorer helmet comes with pre-mounted electric and carbide lamps.

The Duo runs on four AA (R6), 1.5-volt batteries or on rechargeable batteries that can be charged from a wall socket or a car cigarette lighter. AA batteries can be found anywhere in the world, which is not the case for the flat battery used by some models.

Some cavers prefer to use an electric lamp with a waist-mounted battery pack. These lamps mostly come from Great Britain. They are dependable but less powerful, and have a colder, more directional beam. They are in fact as heavy as carbide generators. If they run on a lead-acid battery, you will need a polyester safety harness because the acid attacks nylon. In France, some sport cavers use these lamps because they find them less capricious than carbide lamps. For prospecting (ridgewalking), waist-mounted lamps have been largely replaced by the more convenient electric headlamps, which work well enough for these typically short trips.

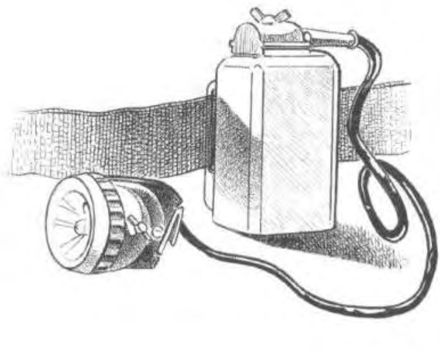

Fig. 13 – The FX2 headlamp uses a waist-mounted rechargeable Nickel-cadmium battery.

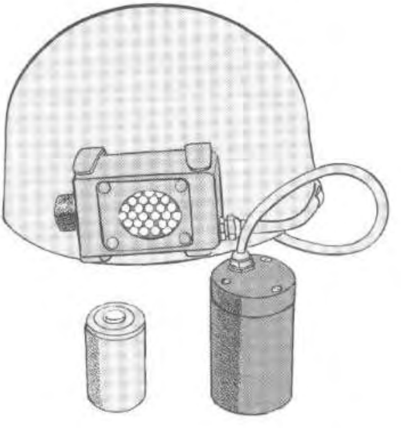

Fig. 14 – The HDS Action Light LED headlamp is available in either helmet- or waist-mounted systems.

With all electric lamps, rechargeable batteries – especially nickel-cadmium batteries – can replace regular batteries. Rechargeable batteries allow a more economic use of energy and are less harmful to the environment: regular batteries are stuffed with heavy metals that are difficult to recycle (recycling is required by law in some European countries). The primary precaution to take with rechargeables is to avoid total discharge. A nickel-cadmium battery normally delivers a constant voltage, but this falls off suddenly and rapidly at the end of its discharge cycle. When you detect an obvious yellowing of the light, turn the light off immediately. Otherwise, the weakest battery could end up with a reverse polarity: it will function inversely and be permanently altered.

The second weak point for nickel-cadmium batteries is the memory effect: a battery that is not discharged completely and is thus only partially recharged "remembers" this state: it will only discharge to its usual average level and not beyond. From then on, rechargeables will no longer hold a full charge. To avoid this memory effect, discharge the battery completely from time to time, without going to the point of total discharge. If the memory effect is already present, you will have to go through several charge/discharge cycles to "break the habit" to which the battery has so deplorably become accustomed.

LEDs

If we haven't seen much innovation in electric lighting systems from this side of the Atlantic, we are certainly seeing it happen in the United States, where the electric headlamp of the future is being perfected in the form of the Light Emitting Diode (LED). These little lamps are semiconductor-based electronic components, capable of converting electrical energy into light energy. They have several advantages: they consume very little energy (20 milliamperes at a few volts), give off a smooth light with a pre-focused beam, have an exceptionally long life (100,000 hours), and are very reliable since they have no filaments. Recently, new diodes were finally produced which emit a white light with a color temperature of 6,500°K.

Based on that breakthrough, Henry Schneiker came up with a clever device: an oval matrix of 24 high-luminosity white LEDs, set in a conductive resin, is powered via a high tension circuit by one 3-volt lithium battery weighing 250 grams. The Action Light headlamp that he commercialized is waterproof to 100 meters and provides an even, regular field of light that constitutes an excellent ambient light. It weights 400 grams, battery included, but this should be worn on a belt. A switch controls the choice between three light levels. On low, the battery supplies 300 hours of light. This corresponds roughly to the light needed in an underground camp, for example. The lamp automatically switches itself to low when the battery begins to weaken. The middle setting is intended for normal exploration activities, and supplies about 50 hours of light and excellent visual comfort. Finally, full power can be used to light up larger chambers, shafts and domes (avens) and supplies 12 hours of light.

For example, during a seven-day camp in the famous Lechuguilla Cave, where carbide is forbidden for environmental reasons, two batteries supplied enough light for all activities, about 90 hours total!

LED technology has developed rapidly in just the last year or two, and LEDs are becoming ever more available and affordable. To attempt to give an inventory of new products would soon prove useless; the market is evolving too rapidly. Suffice it to say that we can currently find a wide variety of lamp models using 3 to 24 bulbs, as well as 2 to 3 LED screw-on replacement bulbs for our traditional electric headlamps (4.5-volt or 6-volt with a dummy cell).

LEDs are changing the way many cavers use light underground and many have already made the switch from incandescent to LED. Some believe that LEDs may soon replace acetylene as well. However, there is one major advantage to using acetylene in cold caving conditions: the heat that it provides helps ward off hypothermia if ever we are immobilized for an extended period underground. In cold, wet caves, this is critical, so we aren't ready to put our old lamps up in the attic just yet.

Tips:

- As soon as you leave the cave, open the battery pack on any electric lamp to air out condensation and avoid corrosion of the contacts. On non-waterproof lamps, open the headpiece as well, and allow both to dry completely.
- Remove the batteries from the box prior to a long storage period.
- Do not handle halogen bulbs directly with fingers since the latter leave a fine film of dirt and grease that can migrate through the quartz and reduce the life of the bulb, or cause it to fail completely.

Maintenance:

- Wash with a wet sponge.
- The Duo, like other electric caving lamps, is compact and sturdy and requires little upkeep. Replace the lens when it becomes too scratched (it's made of plastic) or broken by an impact.

4. The Rescue Blanket[4]

Although it shines a brilliant silver or gold, this accessory has nothing to do with lighting. It appears in this section only because we traditionally store it in our helmets, where we leave it without further thought in hopes that we will rarely need to use it. The rescue blanket is a rectangular sheet of aluminum-coated plastic weighing about 60 grams. We use it underground when a more or less planned or prolonged wait is necessary: during an aid climb, in the event of an accident or exhaustion, or entrapment due to a flood or collapse. These situations will be treated in detail in the chapter "Emergencies and Rescue". Some prefer reinforced blankets, which are heavier (200 grams) and thicker but also much sturdier, easier to fold, and reusable. However, they don't fit in the helmet and so must be carried in a rubber boot or against the back under the caving suit (where they also protect against impacts). It is not a good idea to carry the blanket in the pack because it can be forgotten there, with negative consequences if the unexpected happens just when the pack is out of reach.

The rescue blanket is used in the turtle position: sit on the ground with something insulating the bottom from the cold rock or mud if possible, a pack or rope for example. Bring your knees up under your chin and lay your helmet – still lit – between your buttocks and heels, with the generator held between your thighs so as to warm the femoral arteries. Drape the sheet over your back and head to form a kind of bell to trap the warm air inside. Remember that aluminum reflects the infrared rays emitted by the body. Convection, conduction, and radiation heat loss are all thus effectively controlled and you will soon be bathed in sweet warmth. But be careful not to fall asleep! Slowly nodding off, you won't notice the thin sheet gradually approaching your carbide flame. If your teammate doesn't nudge you awake in time, your dreams of comforting warmth will soon go up in smoke. To avoid such a scenario and if there is enough space to do so, string a rope up across an area and place a few sheets over it to form a kind of group tent or shelter. This will limit condensation, heat loss...and fire hazards!

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[4] Also called "space blanket" and "survival sheet."

D Personal Gear

Even when suited up from head to toe, a caver is still limited to horizontal caving. As soon as the passage goes vertical, he will need additional equipment to face these obstacles and the risks of falling that they present.

1. The Harness

A harness is made from an ensemble of straps that encircle and hold a caver's body. Fastened with a connector, it attaches the user to a fixed point, a belay, or a caving rope.

A harness system is made up of various elements:

Seat harness

The seat harness (or sit harness) has, at the very least, a waist strap and two leg straps. It is the master unit of our entire personal safety system. Since it protects against fatal injury, the seat harness has of course been subjected to the legislator's magnifying glass: the CE Mark is now required on all seat harnesses sold in Europe. This guarantees that every harness meets all the safety requirements for its category. To secure a caver in all positions, the seat harness must fit as tightly as possible without cutting off circulation. To properly achieve this, all its straps must be adjustable.

The attachment points may include metal rings or they may be loop closures made from the harness webbing itself, reinforced with a sheath of tubular webbing. The former style of attachment is easier to close and leaves more space on the harness maillon. On the other hand, it doesn't hold the maillon as firmly in place, and tends to sit awkwardly against the body. The characteristics of the

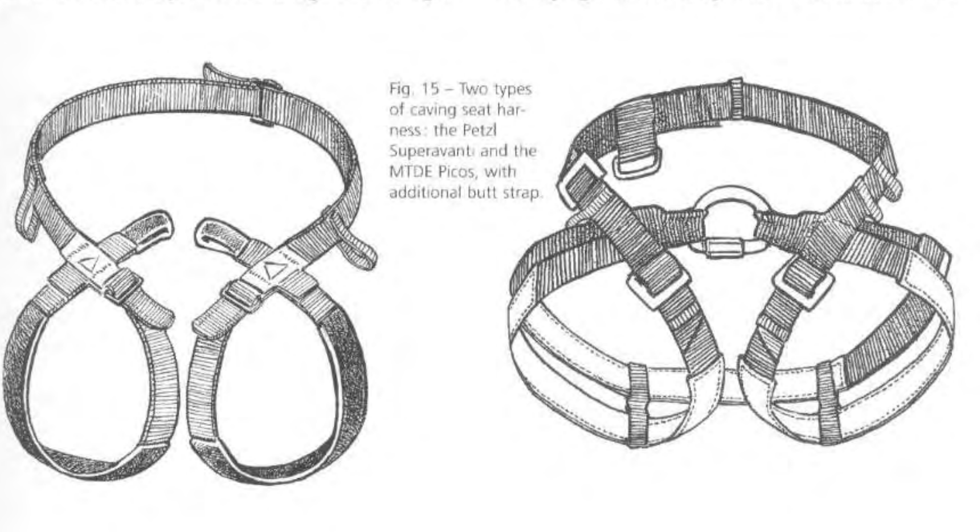

Fig. 15 – Two types of caving seat harness: the Petzl Superavanti and the MTDE Picos, with additional butt strap.

latter style are the opposite of the former, and it is also lighter. Again, it comes down to personal preference.

Even when moving through horizontal passages, the seat harness can be quite important. It keeps the caving suit well positioned against the body, in particular preventing the crotch from slipping down as you move. Such slippage can easily lead to tearing, since this part of the suit is constantly stressed to the extreme, especially during wide straddling moves. In high meanders, the harness also allows you to carry your pack below you on a tether.

Chest harness

The chest harness holds the chest ascender in place during rope climbs. In this capacity, it must fit rather tightly to ensure that the upper body is in vertical balance, thereby relieving the arms of unnecessary work. When you are not on rope, it can be removed or simply loosened, especially if the pitches are not far apart. It's best to only moderately tighten harnesses that have a horizontal strap around the chest, as this could compress the rib cage. In fact, the circumference of the rib cage automatically increases when the arms are raised to push the upper ascender into position. Breathing in, which you must logically do while climbing, also expands the chest area, and constricting the chest cavity in any way will prevent your lungs from filling to their proper capacity. This must be avoided because breathing supplies the body with oxygen, and you want as much oxygen as possible! Optimal chest harnesses for caving have straps attached to the rear of the harness that rise up the back and over the shoulders. They then descend back down over the chest as a continuous loop that is connected to the chest ascender. These help hold the seat harness up when tethering heavy packs.

Waist belt

The use of waist belts has fallen out of favor in recent years, as they are only useful in horizontal caves, and then only to hold the cave suit in place and carry the carbide generator (or battery pack). A better way to hold your suit in place (as discussed before) is to add a thin cord or strap that runs between your legs and forms a kind of harness.

Waist belts and chest harnesses are not considered safety devices, because they alone do not protect the body adequately in the event of a fall.

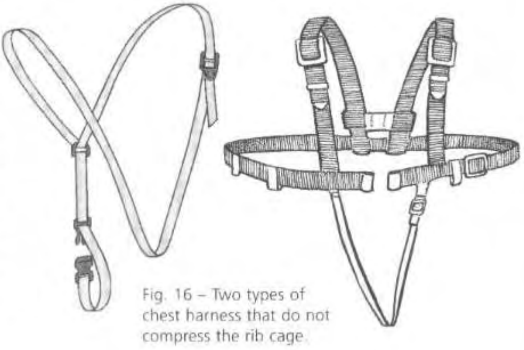

Fig. 16 – Two types of chest harness that do not compress the rib cage.

Key points:

- Choose a harness with separate leg loops; many people find this more comfortable. The bottom strap on models without separate leg loops compresses the hips and thighbones and tends to turn the knees inward so that they knock against each other.
- We recommend a minimum of two gear loops on the harness waist strap. These allow you to distribute gear more evenly on the harness, without having to clip carabiners directly onto the belt. Extra loops can be added but it is best to buy a harness with them already sewn in; such loops distort the waist belt less when loaded.
- The wider and more numerous the straps, the more comfortable the harness since these straps distribute the weight of the body over a larger surface. Unreinforced single straps that are less than 40 mm wide are uncomfortable (except for tiny people). For chest harnesses, a 28-mm wide strap is sufficient for comfort.
- The areas that wear out first on a seat harness are around the adjustment buckles. The better models are protected in these spots with extra webbing or plastic. Reinforcing the areas around buckles on the chest harness is not necessary.

Tips:

- The waist belt of the seat harness should be worn high on the back to maximize support; this also aids vertical balance when on rope.
- PVC strap reinforcements should be welded and not simply sewn on; this will prolong their life. Pieces of flexible plastic hose can also provide good, inexpensive protection.

- A well-made, well-adjusted harness doesn't need additional straps to hold up the back of the leg loops.
- Never use a chest harness made of elastic straps or bungee cord. In the event of a loss of consciousness, these straps will not support a caver's upper body and will allow the head to fall backwards.
- The simple act of hanging in a seat harness compresses the body, and leads to unnecessary play between the body and the harness straps. It is important to properly tighten down the chest harness before getting on rope. Inversely, when getting off rope, the chest will naturally want to move upward, but will be uncomfortably compressed by the harness. The need for such repetitive adjustment leads us to favor models with a quick-adjust buckle. Since the harness is constantly pulled tight and loosened by way of this buckle, the latter is in frequent use and should thus be chosen with great care.

Standard (EN12277):

To pass the European Directive's safety test, a seat harness is placed on a standard wooden dummy weighing 80 kg; it must withstand a force of 15 kN applied over three minutes without showing signs of deformation. It must also withstand a similar perpendicular force for three minutes; the adjustment buckle on the harness waist belt must not slip more than 25 mm during these loadings.

Maintenance:

- It is as important to clean a seat harness regularly as it is to clean our ropes: in both cases, microcrystals of calcite present in mud and clay will slowly cut the nylon fibers, diminishing harness strength little by little. Moreover, lack of care will also lead to swollen – and thus shortened – straps. A water hose and a nylon brush are sufficient for cleaning; both sides of the straps should be carefully scrubbed. Allow the harness to dry completely and store it in a cool place away from sunlight.
- As with ropes, don't use a high pressure water hose to clean the harness: instead of washing the calcite crystals away, the high water pressure will embed them deeper into the webbing.
- Only experienced professionals should repair damaged harnesses. Little by little, localized wear marks will appear at the more common rub points; the seat harness should be replaced before 30% of the material has disappeared from the most worn region. In addition, all harnesses undergo a natural and invisible aging process that results in the slow degradation of the fibers, so a seat harness should be replaced at least every five years, even if it shows no outward signs of damage.

2. The Seat Harness Maillon[5]

For its central closure and attachment point, the seat harness uses a special type of maillon rapide called the "harness maillon" (French *Maillon à Vis de Ceinture*). A maillon is used as the attachment point to a seat harness instead of a locking carabiner because once it is screwed close, its strength is the same for all directions of loading. This is not so for the locking carabiner, which shows a dramatic decrease in strength when loaded across the gate. The harness maillon usually comes in a half-moon shape and is made of 10-mm diameter galvanized steel, stainless steel, or zicral, an aluminum alloy (fig. 17). Some cavers prefer the triangular (Delta) form of harness maillon. The Delta leaves less space for gear when compared with the half-moon and is thus less practical. In addition, the Delta will reposition itself at times by turning abruptly when weighted, disconcerting its wearer even if there is no danger.

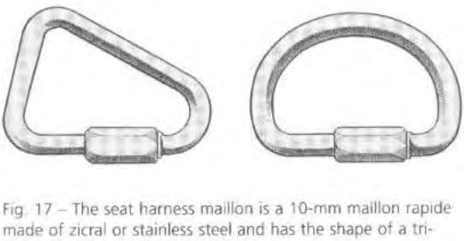

Fig. 17 – The seat harness maillon is a 10-mm maillon rapide made of zicral or stainless steel and has the shape of a triangle (Delta) or half-moon (D-ring).

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[5] Cavers around the world have different names for this link, depending on its shape and use. These include half-round, half-moon, D-ring, Delta, central maillon, and harness maillon. The term "harness maillon" will be used throughout.

Whatever its shape, the harness maillon has been known to unscrew itself during use if it has been incorrectly installed. This dangerous situation occurs when the maillon has been placed backwards on the harness and the caving rope or a footloop rubs against the sleeve during a climb. A correctly placed maillon must have its opening on the left side of the body (and towards the bottom), and NOT on the right. You must then screw down on the sleeve, and never up! The downward rubbing of the rope will thus tend to close the maillon further rather than open it. An open maillon is even more dangerous if the harness has metal attachment loops rather than web-loop closures because the former are more likely to slip out of the maillon.

The accidental unscrewing of the maillon is more likely to occur when either:

- the climbing rope is pulled taut by a foot ascender, a helpful teammate or the weight of the rope in a deep pit; or
- the harness is not properly adjusted, and therefore sits farther from the body.

Key points:

- A strong argument for the aluminum alloy (zicral) harness maillons can be made on the basis of weight savings (56 g for zicral versus 152 g for steel). To date, we have never seen an aluminum maillon rupture even though it is weaker than steel, which is the main reason some people hesitate between the two.
- Avoid using a zicral maillon on a harness with metal closure loops: these will cause accelerated wear on the maillon.

Tips:

- If the harness maillon can be easily positioned and closed, the harness needs to be tightened. It is usually necessary to crouch forward a bit in order to hook the harness loop or ring into the maillon (after having unscrewed it completely) and close it again.
- Some argue against using the half-moon maillon in steel because its radius of curvature is too wide for the material used, which consequently deforms easily, making it nearly impossible to screw and unscrew. Others argue that the zicral half-moon wears out more quickly (including the threads) and is dangerous if loaded accidentally when open.
- Never place a harness maillon upside down (with its opening on top) on a harness: the movement of the gear attached to it will cause the sleeve to unscrew and open at any time. In such a situation, the cowstail, chest ascender, or descender – depending on the circumstance – could detach immediately.
- To unscrew an especially tight harness maillon, use the two sideplates of a descender or the opening of another maillon to hold the sleeve like a wrench.

Standard:

The standard for harness maillons is the same as that which applies to all connectors. (see Chapter E).

Maintenance:

- Apply a bit of solid grease to the threads from time to time. If the maillon becomes difficult to screw and unscrew, scrape between the threads with a finely pointed object such as an awl.
- A slightly deformed steel maillon can be temporarily realigned with a bench vice, but the repair does not usually last long.
- After each trip, remove aluminum maillons from harnesses that have web-loop closures. An aluminum maillon will be slowly abraded and its diameter at the points of contact will decrease – and even more so if the harness has been badly cared for (again, see the effects of mud and calcite abrasions!). Replace the maillon when necessary.

3. Cowstails[6]

Cowstails ensure a caver's safety in exposed settings. They are indispensable on traverse lines, at pitch heads, and during changeovers while climbing or descending a rope.

When passing intermediate anchors on a traverse line, both cowstails must be used: the second is placed beyond the anchor on the continuing line before the first is removed from the previ-

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[6] Also called lanyards. The correct orthography for "cowstails" is "cows' tails"; the abridged version used here is a more convenient and widely accepted orthography.

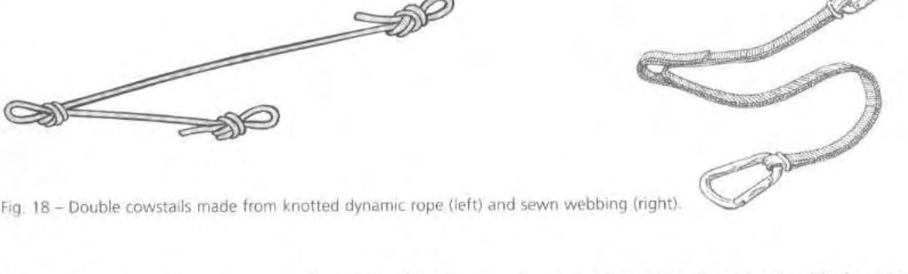


Fig. 18 – Double cowstails made from knotted dynamic rope (left) and sewn webbing (right).

ous section. Cowstails are generally made of 9- to 11-mm dynamic rope (though some are manufactured from webbing, weighing nearly 100 grams less; see fig. 18). To reduce bulk, we usually use a double cowstail made from a single length of rope, attached by an intermediate loop to the maillon. The loop can be made from a simple overhand knot and is placed directly in the harness maillon *to the left of the descender*. We do not recommend using a figure-eight knot here: it is bulkier, will wear more quickly and takes longer to tighten down to its final size. The cowstails must be of different lengths since you will use either the short or the long one according to circumstances. Each length ends in a loop, again made with an overhand knot and into which you place a non-locking zicral carabiner. Bent gate carabiners may appear to be more convenient, mainly because they have a larger opening. But in some cases – for example, sudden twisting on the rope, cowstails stiffened by dried mud, or a traverse with a sharp turn – a bent gate carabiner can actually be very dangerous. It can snap open under pressure from the rope, releasing the cowstail from the safety line. Safety should always come before convenience, so we recommend sticking to the classic straight gate carabiners. We also recommend the "keylock" variety of carabiners, which lack the notch of standard models where the nose meets the gate: the notchless gates make clipping and unclipping much easier because they don't snag on the rope (see section 7).

A word now about ice, ropes and cowstails. In winter, ice will cover and stiffen the traverse lines leading to entrance pits. These frozen lines can open cowstail carabiners with a simple twist. It is perhaps prudent in such a situation to use locking or screwgate carabiners on your cowstails.

With the increased use of foot ascenders, some cavers – particularly those who climb with this device on their left foot – now tend to use two separate cowstails rather than the doubled version with a single attachment loop. Although two attachment loops take up more space in the harness maillon, they help prevent the user from getting tangled up at rebelays. They also facilitate some rescue techniques.

Separate cowstails are also helpful when training beginners because they must learn the same sequence to pass any rebelay, no matter the length of the cowstail: ALWAYS pass the cowstail between the rope and the user.

The harness maillon is normally loaded from left to right (as seen by the user). For the double cowstail, the sequence is: cowstail, descender, Croll. For separate cowstails it is: short cowstail, descender, Croll, long cowstail. The last item may be attached directly to the right side attachment loop of the seat harness so as to leave more room in the maillon; however, with this arrangement, the user will hang a bit off to the side when suspended from it.

Some cavers use three cowstails, the third one being a single long one attached to the side opposite the double cowstails, either in the harness maillon or directly an attachment loop. This adds weight and bulk, but can be useful when getting off rope at the top of a pitch. Here the user can clip it into a traverse line. This allows the user to leave

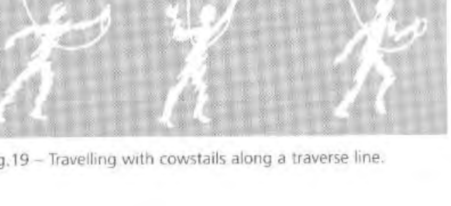


Fig.19 – Travelling with cowstails along a traverse line.

the other long cowstail attached to his ascender, thereby avoiding the risk of dropping the latter (quite an annoying situation, which happens!). It can also be useful at rebelays when one is using a foot ascender. In short, it's up to each individual to test the alternatives and then decide for himself. Novices, on the other hand, are strongly advised to begin training with either the classic doubled pair or the two separate cowstails.

Key points:

- Cowstails made from rope MUST be made from dynamic rope (please refer to the discussion on ropes, Chapter E1). Depending on your height, you may need between 2.2 to 2.5 meters of 9-mm rope or 2.5 to 3 meters of 11-mm rope to make a classic doubled pair cowstail. The latter will be more durable and psychologically reassuring, but will also be heavier and bulkier, exposing the knots to increased wear.
- A cowstail made from webbing must be made dynamic, and thus incorporate some energy-absorbing component. This is achieved by sewing the webbing together using special thread and stitching patterns that will progressively rip out under a shock load. But such a cowstail cannot be improvised at home: it should be purchased from a recognized caving equipment manufacturer.
- The long cowstail should be long enough to allow you to push your upper ascender up to your maximum preferred height. There is no need for it to be any longer (and therefore heavier). More importantly, it must never be longer than you can comfortably reach, as this would prevent you from getting hold of the carabiner while suspended from it (at a rebelay or attached to the upper ascender).
- The length of the short cowstail should be adjusted so that when the cowstail is loaded and your elbow is positioned over the harness maillon, the carabiner can easily be held in the palm of your hand.
- The attachment loop (or loops) placed in the harness maillon tends to wear rather quickly. Check this wear point regularly (as well as those at the other knots). To do this, always detach the cowstails from the harness maillon and carabiners when cleaning your gear.
- When clipping to wire or steel cables, always use steel carabiners.

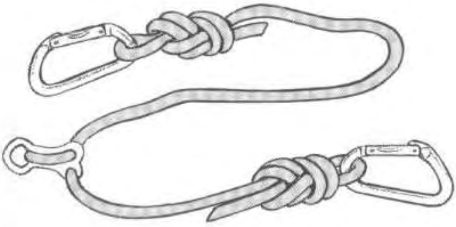


Fig. 20 – Cowstails mounted on a metal blocking plate.

Tips:

- When making knots, remember that they will tighten once weighted, thus lengthening the tails.
- It is sometimes useful to fix the orientation of the carabiner in its end loop, so that when you hold it, the gate opening is always at the extreme end of the cowstail. This can be done by wrapping a rubber band (again, from that handy inner tube) around the contact point between the carabiner and the knot. Some special cowstail carabiners are available equipped with a steel keeper bar that holds the rope loop on the correct side of the carabiner relative to the gate. However, this special characteristic limits the usefulness of the carabiner for any other purpose and can be bothersome during some maneuvers.

What NOT to do:

- Do not buy plastic keeper bars (one manufacturer still makes these in Europe) for use on a cowstail carabiner. If the end loop of the cowstail is too large, it could accidentally pass through the carabiner gate during use. The cowstail would then be fastened to the plastic bar rather than to the carabiner, presenting an immediate and possibly lethal danger: the caver would load this flimsy piece of plastic, resulting in a guaranteed free fall. This is not a hypothetical situation. One young caver found herself at a rebelay with just such a scenario unfolding before her and owes her salvation only to her very light weight – and perhaps some luck.
- Again: To avoid tangles when passing a rebelay on a climb, the cowstail should always be passed between the rope and the caver.

- Cowstails are subject to abrasion. On longer trips when it will not be needed, remove it if there is a risk of it being subjected to excessive scraping or rubbing (as in tight meanders or crawls). Store it in your cave pack.
- Some cowstails are sold attached to a metal plate that is connected to the harness maillon and replaces the central knot of the cowstail. It contains some holes that immobilize the rope while allowing you to adjust the relative length of the two tails, thus preventing the rope from wearing at the maillon.
- Most of us expect to use three carabiners on the sides of the seat harness for carrying gear: one on the left for the short cowstail, one on the right for the long cowstail, and another on the right for the carbide generator. This setup allows us to grab the correct cowstail even in total darkness.
- Don't allow the free ends of the cowstail knots to be too long. These can catch in the Croll during a climb. Ends that extend eight centimeters (3 in) beyond the knot are enough to ensure that the knot will not come undone.

Standard:

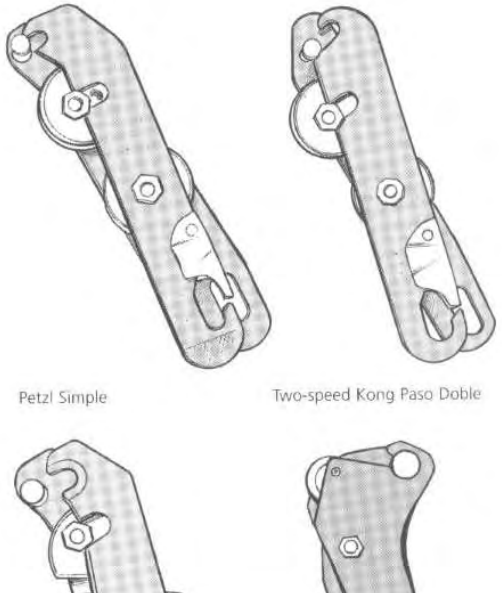
Caving cowstails do not fall under any safety standards.

Maintenance:

- A careful brushing under a stream of water is again essential for preventing microscopic calcite crystals from cutting the fibers and for preventing a loss of elasticity due to saturation of the rope by clay and mud. Another argument for a thorough cleaning: mud-encrusted cowstails become stiff and more difficult to handle.
- After each use, check for wear at the knots and inside the three end loops, as well as the condition of the carabiners and their gate springs.
- A cowstail that is worn from rubbing (usually at the knots or inside the loops) should be completely replaced. When? As soon as you begin to suspect its reliability, or at the latest, when the rope core at any point becomes visible through the worn sheath.

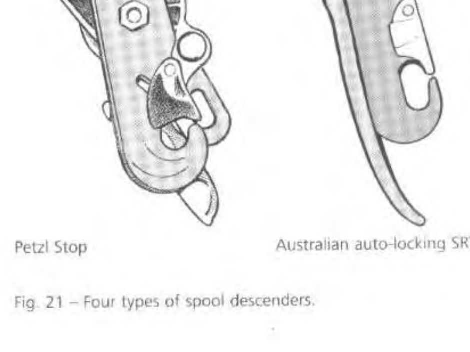
4. The Descender

Descenders allow us to slide down shafts on a single rope. The most common models used in Europe today are of the spool variety (fig. 21), based on a descender invented by Dressler in the early 1960s. Dressler had the brilliant idea of installing two fixed spools (also called bobbins or capstans, tr.) between parallel sideplates; the rope snakes around and between the spools in the form of an "S." The most popular model is the Petzl Simple ("Classic"). It is sturdy, free of useless complexity (simple), and it doesn't cause wear on ropes. A gated eye prevents the moveable sideplate from opening unexpectedly, but allows the rope to be loaded and unloaded



Petzl Simple

Two-speed Kong Paso Doble



Petzl Stop

Australian auto-locking SRT

Fig. 21 – Four types of spool descenders.

without removing the entire descender from the harness maillon. Braking is realized by tensioning the lower rope, which increases friction on the spools.

In Italy, the Kong Paso Doble is also quite popular. Its spools are offset, and by simply turning the device around, this descender can be adapted to different rope diameters. This can be useful when dealing with swollen, muddy ropes, or ropes whose loosened sheaths have gathered at the rebelay, usually in the deeper shafts.

Some descenders are auto-locking. The Petzl Stop is equipped with an eccentric lower spool, which is solidly connected to a handle and is moveable around its axis. Friction from the rope causes the spool to pivot, which then pinches and immobilizes the rope against the bottom of the upper spool. You need to squeeze the handle in order to prevent this automatic braking action from taking place and begin the rappel. This descender has certain advantages: when passing rebelays and during changeovers, it dispenses with the need to fully lock off the descender, thereby simplifying and accelerating these maneuvers. If necessary, it can also replace a lost Croll on a climb. In caving, it can be used as a belaying device during aid climbs and can protect the user from an uncontrolled rappel if he is suddenly struck unconscious while on rope.

But the Stop also has its disadvantages, the most serious of which is not directly attributable to the device itself but rather to how it is used. It is an "all or nothing" piece of equipment. That is to say that many careless or unknowing users will use the handle as a brake, which is NOT its purpose. By more or less squeezing on the handle, they adjust their speed with their left hand instead of using their right hand to control their rate of descent. By doing so, they crush the rope between the spools, which flattens the braids and accelerates its deterioration. Classic auto-lock descenders can also produce an uncontrolled rappel or freefall of a panicked novice, whose instinctive (yet in this case perilous) reflex in an emergency situation is to grab the descender instead of release it. It is only by releasing the descender that the auto-lock can function. During a rappel, the Stop requires a noticeable effort from the left hand to hold the handle down since it is too short to provide proper leverage. Finally, the Stop doesn't completely stop on new ropes or ropes whose diameter is smaller than 10 mm, or when carrying especially heavy loads. In these situations, the descender must be locked off in the conventional way.

In contrast to the Stop, the Australian SRT Stop offers stopping action at the end of the friction surface (top of the upper spool) rather than at the beginning, making for a softer, more effective brake. It allows a complete stop on all common rope diameters and the handle is longer and easier to hold down. Made mostly of stainless steel, it is nearly impervious to wear, but weighs almost 100 grams more than the Stop and costs twice as much.

Other panic-proof descending devices have recently appeared on the market. The most viable are the Kong Indy Double-Stop descender and the Slovenian Anthron Double-Action descender. The Indy is heavy, weighing almost 100 g more than the Stop (385 g), takes most rope sizes, and features a mechanical clamp that stops the device when released *or* squeezed. It costs just a little more than the Stop.

Like the Indy, the Anthron will stop when squeezed or when released, its descent position being in the middle. Unlike other auto-lock descenders, the Anthron cannot be accidentally opened by its connecting link because the sideplates are fixed in position: a bight of rope is inserted into the device to load the cam. Note, however, that this operation can be difficult with a stiff rope. The Anthron weighs less than the Indy (340 g), but costs about 25% more than the Stop.

SRT has also introduced a double-brake "stop" descender, but it weighs nearly twice as much as the Stop and costs over twice as much as any other double-brake descender. Australian SRT descenders are not as widely available as European models are.

Given the above arguments, we tend to favor starting with the classic Simple descender. The experienced caver should only move to the auto-lock descender – if he wishes to do so – when he has mastered the necessary descent techniques and is resolved not to use the camming device to control his rappel speed. The transition to such a device will certainly save time on some maneuvers.

The problem of correctly placing the braking carabiner below the Simple descender deserves special attention here. This carabiner is practically indispensable for comfortably controlling your rappel speed, for effectively locking off, and for saving the right glove from excessive wear between the thumb and forefinger. Traditionally, this carabiner is placed in the harness maillon to the right of the descender. However, experience has shown that in this position, an abrupt loading of the lower rope – for example, when an anchor at a rebelay separating two climbers fails (fortunately, a rare event) – could cause the upper end of the descender to jam in the braking carabiner. It remains stuck there while the sideplates separate under the lower spool without, however, causing it to fail or to become significantly distorted. If the pull on the lower rope is the result of a temporary and somewhat less brutal loading and is quickly rectified, the top of the descender still remains stuck in the carabiner; reducing the braking action practically to nil, presenting the risk of an uncontrolled descent and a very hard landing below.

To avoid this possibility, some cavers prefers to pass the lower rope directly back through the carabiner connected to the descender, which obviously requires repeated screwing and unscrewing of the gate. If the caver is using an auto-locking carabiner, some of these actions are simplified. However, one must be careful that the direction in which the rope passes through the carabiner does not rotate the locking sleeve open by rubbing against it. There is another drawback to using this method, called the "Vertaco" method: if an anchor fails as described above, the sideplates on the descender could end up bending at right angles, possibly even breaking at the attachment hole… We therefore do not recommend this method.

Another group attaches the braking carabiner to the descender carabiner. The potential anchor rupture scenario does not result in any distortion or destruction of the descender, but effective braking will require the user to lift his right hand even higher, causing fatigue in the arm and more rapid wear on the right glove. We certainly do not recommend placing the carabiner in the hole of the descender's closure gate: the result is the same serious drawback of the second method, combined with the risk of losing the carabiner during the operation, which will then take longer to carry out.

Finally and for the record, there are those who intend to avoid all of the above mentioned risks by systematically leaving a free length of line between any two climbers. This non-solution to the problem will lengthen the time it takes to complete the climbs and interrupt communication between team members, and fortunately has little hope of becoming widely accepted.

Fig. 22 – The Handy braking carabiner.

So, how can we overcome this problem? There is in fact a solution: use the Italian (Raumer) braking carabiner called the Handy (fig. 22), attaching it directly to the harness maillon to the right of the descender. Since it is shorter and narrower than a normal carabiner, the top of the descender cannot get stuck in the Handy; there is no risk of distorting the descender and no risk of a resultant free fall. The problem is solved. Made of stainless steel, it is practically impervious to wear, and its V-shaped slot increases the braking effectiveness when the lower rope jams into it with a simple lift of the right hand. Finally, weighing only 106 grams, it is significantly lighter than a classic steel carabiner (170 grams).

Rack descenders (fig. 23) are effective for very deep, single-drop pits where the weight of rope on the descender is considerable (200 meters of 10-mm rope weighs 13 kg dry). These descenders have a long, open U-shaped frame and weave the rope in a zigzag pattern between the brake bars. The brake bars are usually made of a light aluminum alloy and are threaded onto the frame. Bars can be added one-by-one during the rappel, which compensates for the progressively diminishing rope weight below and makes for a comfortable

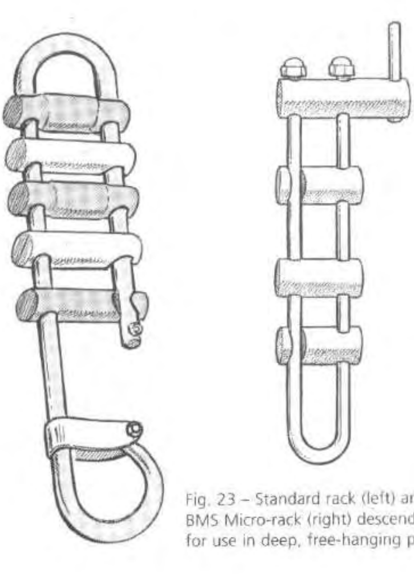


Fig. 23 – Standard rack (left) and BMS Micro-rack (right) descenders, for use in deep, free-hanging pitches.

descent. These advantages aside, rack descenders are by far heavier and bulkier than spool descenders.

A shorter, closed frame rack descender is widely available in North America, and gaining in popularity over the traditional, bulkier racks. Its "hyperbar" gives it the functionality of a traditional rack descender on longer drops, yet it is more compact and light. The standard BMS Micro-Rack costs and weighs about as much as the Stop.[7]

Key point:

Never allow a descender spool to wear down to the steel bolt (its axle) fixing it in place; the bolt threads will damage ropes.

Tips:

- To totally arrest a Stop that slips, use your right hand to take the rope from below the braking carabiner and bring it up and over the top of the descender. This is called a half-hitch or half-lock. Prolonged stops – when placing bolts or deviations, for example – require a full lock-off: pass a bight of the lower rope back through the descender's locking carabiner, then bring it back up and over the descender.
- Only moderately tighten the nut after changing the spool; tightening too much puts added pressure on the nut and can lead to breakage. Instead, put a drop of thread stopper (like Loctite) on the thread to immobilize the nut.

Standard:

Descenders for caving are not presently governed by any European norms. In industrial use, a standard exists (EN 341) for certain "descenders," which are actually rescue devices consisting of a descender and rope.

Maintenance:

- As with all mechanical equipment, clean the descender with a nylon brush and water and dry it thoroughly.
- The duraluminum spools will eventually wear down from friction and must be replaced. The closure clip may also twist or break, or the spring on the auto-locking descenders may eventually break off; these components can be replaced.

5. Ascenders[8]

An ascender is a device used on ropes that slides freely in one direction and locks when moved in the opposite. It is principally used for ascending ropes, as an accessory in some belay or haul systems, and even (at least in the past) as a moveable safety on a fixed line when climbing, for example, a cable ladder. Two basic types of ascenders are used in caving, and both operate by pinching the rope against a U-shaped channel, or gutter, formed in the housing of the ascender. The first type has a spring-loaded cam attached to the housing. The relative weakness of this spring requires that the point of contact between the cam and the rope have a rough surface that will help the cam engage the threads of the rope sheath. As soon as a braking action begins, it will continue automatically due to the shape of the cam, until the rope is squeezed and immobile in the channel.

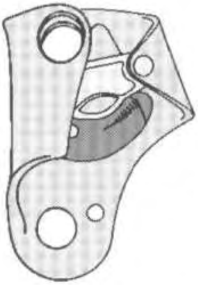


Fig. 24 – Petzl Basic ascender.

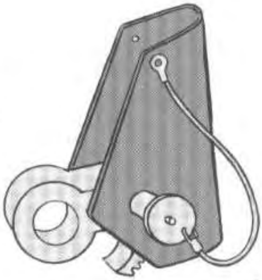


Fig. 25 – Gibbs lever ascender.

The second mechanism operates with a lever and thus requires no spring; the simple weight of a load on the lever creates the necessary pressure against the housing (fig. 25). Lever-based ascenders, such as the American Gibbs, are seldom used in Europe. They are less efficient on rope because the levering action takes place over a short but significant distance before it fully blocks the rope; we thus lose several centimeters of ascent with each stride up the rope. Their greatest advantage, however, is that they will work on any rope, no matter

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[7] Rack descenders of any kind are rarely, if ever, used in European caving.

[8] Other terms in English: "rope clamps," "grabs," "jumars," and "jammers." "Ascender" will be used throughout.

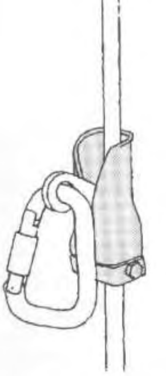

Fig. 26 – The Shunt is very effective on muddy ropes.

its condition. This is particularly useful with mud-caked ropes that leave other ascenders sliding (along with their users) unpleasantly downward with each stroke, even more so the higher one climbs! In these (fortunately rare) circumstances, a Shunt can also replace the classic upper ascender, providing incomparable relief to its user. In the United States and Australia, lever ascenders are sometimes used as components in haul systems. In the US, where it was once used widely in ropewalker systems, the popularity of Gibbs ascenders has seen a dramatic decline in recent years. It is gradually being replaced by spring-loaded cam ascenders in Ropewalker systems, or by the Frog system altogether.

Different types of ascenders have different uses.

The chest ascender

The chest ascender is used in a sit-stand (Frog) system and is mounted in front, between the harness maillon and the chest harness (fig. 27). Its specific role is to hold the body in place against the rope while an upper ascender with attached footloop is moved up the rope. The Petzl Croll and the Kong Cam Clean (effectively a Croll clone) carry out this function perfectly. Given the widespread use of the Croll, we will often use this name in the following pages to generically designate a chest ascender. The Croll lies flat against the body, which limits bulk when one is moving through tight pinches; it also holds a caver's body very close to the rope. The Croll, being a relatively short ascender, maximizes the effective length of travel each climbing step produces as a caver lifts himself on the upper ascender. Moreover, successive improvements in its design have made it easier to detach from a rope. It has also acquired a slotted cam for improved handling on muddy lines. Finally, the Croll is compact and light.

Fig. 27 – The Croll was the first ascender designed specifically for use on the chest.

Key points:

- For optimal performance, there should be no play between the chest harness and the chest ascender. No intermediate elements are allowed: the chest strap must go directly through the upper hole of the ascender. Any chest harness that requires the use of an additional maillon or a carabiner should not be used.
- The Croll should be worn low so that it doesn't ride up against the upper ascender (note however that the lower it is, the less vertical balance it provides). The footloop strap can also be made longer, though this requires the user to push the upper ascender higher, fatiguing the arms.
- The chest ascender should go to the right of the descender (as viewed by the wearer) on the harness maillon, leaving the cam free so that the rope can be easily attached if you need to change over to ascent during a rappel (for instance, if the rope is too short or you come to an impassable squeeze).

Tips:

- There are several ways to keep the Croll flat against your body when using a chest harness made wirh a single piece of webbing a quick-adjust buckle. Here is an efficient one that will not compress the rib cage: After threading the webbing through the upper hole of the Croll, twist the webbing on either side a half turn before bringing it over the shoulders and across the back. This twist will keep the Croll snug against your chest and prevent it from sitting perpendicular to your body during the climb. Fasten the chest harness somewhere on the front of your body after passing the free end back through the upper Croll hole, or better yet, through the harness maillon, as this will not compress your chest.
- When climbing past a rebelay that required a pendulum during the descent (or any offset rebelay), the rope will pull horizontally outwards from beneath the chest ascender when you switch over to the upper rope. You can solve this problem by either straddling the rope or stepping in the upper rebelay loop so as to pull the rope downward.

The upper ascender (handled ascender, Jumar, or jammer)

To step up in your footloops, you need a fixed point of support relative to the rope. A special ascender, connected to the footloops and placed on the rope above the chest ascender, provides this support. This ascender also provides another service: by always attaching the long cowstail to it, your system gains an essential safety backup in the event the chest ascender fails for any reason.

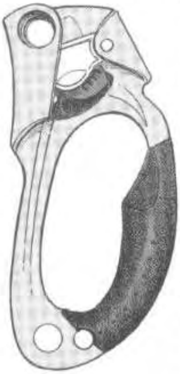
Fig. 28 – The Petzl Ascension handled ascender.

Because it is moved up with the hand, models with a handle, such as the Petzl Ascension or the Kong Lift, are more comfortable to use than those without handles. The Petzl and Kong are the most common models in use and have the advantage of being drawn easily along angled traverse lines and tyroleans without fatiguing the hand, which stays in a natural position.

The Swiss-made Jumar is a less ergonomically designed handled ascender; it is also a bit heavier and more sensitive to shock because it has a cast aluminum body. Ascender bodies stamped from sheet metal are preferable over cast models, because the heat treatment on the former gives the metal grains an internal structure that is stronger than the isotropic, non-directional internal structure of cast aluminum.

The Pump is another model of upper ascender. This ascender comes with a haul system that reduces (by one-third) the effort needed to step up with your legs. The footloop is integrated into the system and includes a bar at one end, which is wedged behind the upper hole of the Croll. This prevents unnecessary play while stepping up in the footloop. The length of each stride is reduced by a third, but the total energy spent to reach the top of a pitch remains the same as in a normal system (it is even augmented somewhat by the additional friction created by the two pulleys, as evidenced in their characteristic noise). As a result, the climb will be slower. Such a system should be reserved for de-rigging trips when climbers are hauling one or more heavy packs. Larger, heavier users will also find this system advantageous when learning to climb. Aside from these instances, the length of the footloop can be adjusted so as to neutralize the effect of the pulleys, so that the Pump can be used like a classic ascender. This still leaves the user with the extra weight (320 g versus 200 g) and the added bulk of a footloop that is more than double the normal length.


Fig. 29 – The Pump.

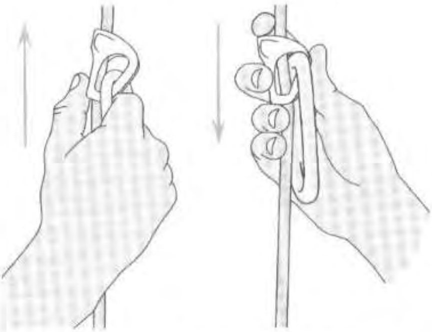
Fig. 30 – The Tibloc was designed for emergency use.

Some cavers prefer upper ascenders without a handle such as the Basic (fig. 24), which is lighter and more compact. Another advantage with the Basic is its shorter length; the top of the chest ascender is less likely to run into it as you step up in the footloops. Some cavers even use a Tibloc attached to a length of cord. Its lightness at 39 grams makes it quite attractive, but the Tibloc was conceived for occasional or emergency use and is not very practical for continuous use. For the sake of convenience, we will use the term "upper ascender" when discussing this category of rope grab.

Key points:

- The height of a vertical step is limited either by the length of one's maximum leg extension (i.e., the length of the femur) or maximum arm extension, depending on one's build. There is thus no universal rule for adjusting an ascending system. Someone with long arms, for example, might be better off using a Basic upper ascender rather than a handled ascender.

- The first adjustment to be made in the climbing system should be the length of the footloops. This is done while standing with the foot (or feet, depending on the type of loop) in the loop, Croll and upper ascender attached to the rope. When the footloop is stretched taut, the top of the Croll should reach the bottom of the upper ascender cam (the bottom of the handle, if this type of ascender is used, will be next to the Croll). Fine-tuning is done while on rope. Take the time to do this before going caving, as the efficiency of every climb depends on a well-adjusted climbing system.

Tips:

- In deep shafts, pulling down on the upper ascender will eventually fatigue your hand and arm. From time to time, alternate the position of the hands, placing both around and over the top of the ascender, like the position used with the Basic. Changing positions helps relax the hand and forearm (but this is obviously not a choice when using the Basic).
- When two pitches are separated by meanders, the ascender/footloop assembly can be cumbersome to carry. A solution is to leave the assembly intact and place it around the upper body as shown in figure 31.

Connecting the footloop, long cowstail and ascender

Joining these elements deserves some discussion. The most efficient system links the ascender and footloop with a compact locking carabiner. The cowstail carabiner is then clipped into the locking carabiner.

Advantages:

- When travelling horizontally and particularly during rappels, attach the ascender assembly to the side of the seat harness with the footloop's locking carabiner. The footloop is folded three times and held in the gutter of the ascender by the cam. If the long cowstail is needed, it can be easily detached while the ascender remains securely attached to the harness.
- During a rescue situation, this arrangement allows the footloop locking carabiner to be used in a counterweight system without compromising the availability of the long cowstail, which is needed for some maneuvers.

Fig. 31 – How to wear a "Frog" ascending system when travelling between pitches.

The foot ascender

When climbing rope, you need only to alternate between two attachment points: the chest ascender and upper ascender. So why increase your load with a third point of attachment when two is sufficient? In their natural search for lightness, cavers will rarely accept the weight and bulk of an additional device unless it is absolutely essential. But because the foot ascender is a highly effective and useful piece of equipment, even for experienced cavers, it has become a part of many cavers' equipment. This deserves some explanation.

The principle problem you will encounter when climbing rope is that of vertical balance. Every time you tip backward, you must compensate with your arms to bring your chest back up to the rope. This will cause the arms to fatigue much more rapidly than the legs, and you should do all you can to save your arms from this fatigue. Developing an efficient technique can already help, but it is not enough alone. This is where a foot ascender has its first advantage: the simple act of putting weight on a foot-mounted ascender will pull the rope taut above it. The Croll slides up when you step into the taut section of rope, and, pulling somewhat for-

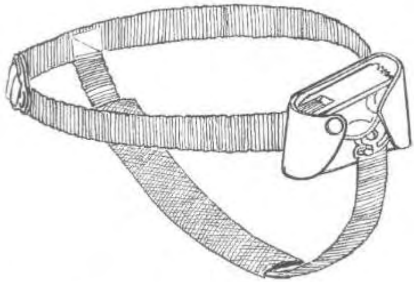

Fig. 32 – The Pantin can also be worn with low-cut caving boots or shoes, although it may cause the ankle to twist more.

ward, brings the upper body with it. But this is not the only positive feature. It also solves the problem of a Croll that "sticks" to the rope; for example, at the beginning of the climb when there is little weight below it. With a foot ascender, this problem is transferred from the Croll to this device, but since the latter has only a very weak spring, it has less tendency to stick than the Croll. It also takes up about half the loading that the Croll takes (at least when used simultaneously with the footloop, the other half of the load going to the footloop itself). In addition, it offers a convenient stepping point for getting past rebelays and pitch-heads, and likewise helps in tight vertical sections. We will consider all of these points in detail when we discuss basic vertical techniques.

There are two types of foot ascender: The Aphanicé was the first to appear. It is made of bent sheet metal folded at a right angle and comes with a foot strap to facilitate stepping. However, stepping up makes the ascender tip inward and the foot has a tendency to slip toward the outside of the strap, which the user can only counteract with a fatiguing tensing of the ankle. Using both feet solves this problem: the second foot slips into another strap built for just this purpose, and the stride is carried out more symmetrically. This eliminates the need for the normal footloop, but the device is more cumbersome when not in use; its bulkier frame hangs up everywhere. As for leaving it on the foot while travelling in horizontal passage, this is out of the question because the metal plate slips on rock and interferes with your footing.

The second model of foot ascender came later. It was first called the Economy and later the Pantin and it takes a different approach. This model sits above the ankle to prevent the foot from tipping outward. The foot remains straight since the ankle is no longer used. The foot strap is made of flexible, compact webbing. The simple abrasion resistantstrap goes under the instep of the boot. It thus does not affect the grip of your shoes or boots, and can be worn when not on rope. It cannot be used with two feet, however. This is a minor drawback in the deeper shafts when the rope and climber hang free (the other foot steps in its footloop), but it is a major advantage in climbs against the rock, when the free foot can use the wall for balance and support.

Tip:

To prevent the cam from knocking against the housing while walking, place a folded end of the upper ankle strap between the two parts.

Ascender standards and maintenance

Standard (EN 567):

Tests are carried out on four separate ascenders.

- Performance characteristics: permits manual slide control in one direction on the rope and blocks movement in the opposite direction.
- Action on the rope: manual testing to verify that the rope cannot be removed laterally.
- Strength: with the maximum rope diameter as specified by the manufacturer, the ascender must withstand a continuous force of 4 kN applied 5 times successively, without deforming. The same test is performed on the minimum rope diameter as specified by the manufacturer.
- Labelling: minimum and maximum rope diameters for use with the ascender are indicated on the ascender body.

This standard does not apply to the foot ascender, which is considered a climbing aid and not a personal safety device (PPE).

Maintenance:

- Because they have moving parts, ascenders should be cleaned with water and a brush to remove any mud or sand imbedded in the components. This debris will eventually cause wear around the cam pinhole, leading to more play in the cam. To prevent rusting, be sure to dry out your ascenders completely, and put an occasional drop of oil on the cam pin.

- The cam teeth will eventually wear down with use and the ascender will slowly lose its grip on the rope. The manufacturers can replace the cams and the device will work like new. Keep an eye out for wear on the attachment holes as well, especially the lower hole on the upper ascender.
- With greater use, friction caused by tension on the rope between the Croll and the foot ascender will slowly wear down the edge on the upper part of the Croll's outer housing. This can become razor-sharp, and depending on the condition of the rope and the weight of the pack below, can risk damaging the rope. Unfortunately, we can do little about the unceremonious demise of the Croll, aside from having the manufacturer place a stainles steel insert over the worn edge.

6. Footloops

During a climb, your footloop gives you the support necessary for lifting your body up the rope as you push with your legs. This component must therefore have no stretch, which is why it is made with static rope. It must also be flexible, light, and strong and abrasion resistant enough to withstand the tension created during some rescue maneuvers. The optimum material for this application is Spectra cord (or Dyneema), a rope made of specially extended chain polyethylene fibers, which is well suited to caving. It is so light that it floats on water; it is inelastic yet is stronger than steel, which allows us to use diameters as small as 5 mm. It is six times more abrasion resistant than nylon, and it is easy to melt the ends to prevent fraying. Always choose 100% Spectra cord (including the sheath) if possible, as it is the most abrasion resistant variety. It is completely white because Spectra cannot hold a dye; any cord having colored fibers indicates that it is a nylon blend. Kevlar is also an excellent fiber, although it is slightly inferior to Spectra: Kevlar is stiffer, melts only at a very high temperature, and needs a nylon sheath to protect it from abrasion. Like Spectra, Kevlar is expensive, but this shouldn't cause any problems because it doesn't take much cord to make a footloop. A nylon footloop, on the other hand, is less resistant to abrasion, more elastic, bulkier, and nearly twice as heavy!

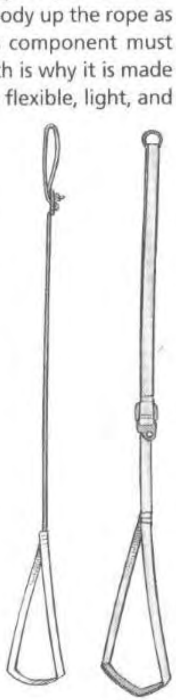

Fig. 33 – The footloop is made from either webbing or cord. Spectra cord is ideal.

Key points:

- Footloops made of webbing are easy to adjust, so they are preferable for club use. However, webbing footloops are not well suited for use in rescue situations because they have a larger contact surface area when passing over a carabiner, creating more friction and requiring more exertion. They also sometimes catch between the Croll cam and the rope during climbs.
- Which is better, a footloop with a single or a double loop? There are four different setups:
  1. One large single loop. The feet tend to crush against each other.
  2. With a double footloop, each foot has a cord with a separate loop, a somewhat bulkier arrangement.
  3. Making two separate loops at the end of a single cord is a possible compromise. Such a set-up can be used with either one foot or with both, but having both feet independent would no longer be possible.
  4. A single cord or strap with a single loop is the lightest and most compact assembly (fig. 33). It allows one foot to remain free for more maneuverability against a wall, and also allows both feet to be used for upward strides during longer climbs. In this case, place one foot over the top of the other at the edge of the loop. The single footloop is an ideal assembly if you are using a foot ascender.
- The length of the footloop assembly is critical. The bottom of the upper ascender cam should rest on top of the Croll when your legs are fully extended. Note that this is not the bottom of the handle on handled ascenders as such an adjustment would alter the ideal length by several centimeters. A rough adjustment can be made while standing on the ground, but fine-tuning must be performed while hanging on the rope. This is more easily achieved with the compact Basic ascender than with a handled ascender.

- The length of your upward step is limited either by your maximum leg extension (i.e., leg length), or by your arm length, depending on the way you are built. There is therefore no universal rule for adjusting the footloops. For example, someone with longer than average arms in relation to his leg length may prefer to use a Basic rather than a handled model.
- When you shorten a long footloop that has no adjustment buckle, don't place the knot in the middle of the strap, but at one of the ends. The knot will then not interfere with a release maneuver (pick-off) in the event of rescue situation.

Tips:

- When there is little horizontal progression between pitches, the upper ascender/footloop assembly can be worn as shown in figure 31.
- A small pulley fixed to the upper hole of the chest ascender and around the footloop is an effective way to pull the body up to the rope during a stride. While this greatly relieves the strain on the arms, it also requires that you disengage the mechanism at each rebelay. This can be done with a small accessory carabiner that will open easily under a load but remains attached to the pulley. The continuous back and forth motion of the footloop on the pulley makes it even more important to use Spectra cord in this situation to decrease friction and resist abrasion.
- To make the loop more comfortable with footloops made from cord, the loop can be made from a length of sturdy webbing. The webbing will also provide a wider instep. Twelve-mm Spectra-based straps are now available and these make excellent loops. Some cavers use a piece of plastic tubing to reinforce the lower loop(s).

Maintenance:

Nylon can become rough with wear, requiring more brushing with clean water to prevent it from stiffening. Less energetic cavers should opt for Spectra, which remains smooth and flexible, doesn't hold mud, and requires only a simple rinsing with water. Of course, a footloop that is swollen and abraded from excessive wear should be replaced.

7. Carabiners

Carabiners are used to connect two or more pieces of equipment: harness, ascenders, descender, pulley, etc. Most cavers need about six. Anytime safety is a factor, a locking carabiner must be used, except for the two cowstails carabiners. We are clipping and unclipping our cowstails so often that a locking mechanism interferes with their use, causing us to lose time and expend considerably more energy, particularly in more sporting passages. When security is not an issue, go for the simplest and lightest models. Two basic materials are used in making carabiners: steel and the light aluminum alloy zicral.

Steel deforms under an extreme force that is beyond its elastic limit, while zicral simply breaks. But the safety coefficient between the weight of the body on one hand (1 kN maximum) and a zicral carabiner's strength on the other (22 kN according to the required standard) means that even moun-

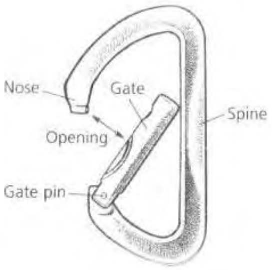

Fig. 34 – The parts of a carabiner.

Fig. 35 – HMS non-locking "D".

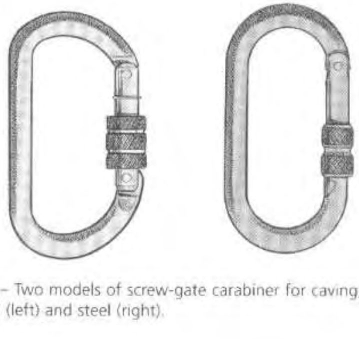

Fig. 36 – Two models of screw-gate carabiner for caving, in zicral (left) and steel (right).

taineering carabiners (all zicral) almost never break when shock loaded. Steel isonly worth using with the descender braking carabiner, where its abrasion resistance increases its longevity. Its density – twice that of zicral – and therefore weight disqualifies it for use anywhere else in our personal gear.

There are hundreds of models of carabiners, most of which fit into several more general categories according to their shapes. The strongest shape is the asymmetric "D" (fig. 34). The bends at the two ends tend to bring the load toward the spine, which is the strongest part of the carabiner. This is the preferred shape for safety carabiners. Note also the HMS variety, which is larger and pear-shaped (fig. 35). This carabiner is generally used with the Münter hitch (see fig. 70). There is also the classic oval-shaped, or symmetric "caving" model (fig. 36), which can easily be turned around in an anchor's hanger plate so that the rope knot hangs free of the wall. This shape also facilitates clipping in our cowstail during some maneuvers (we will discuss this in a later chapter). Oval carabiners are also indispensable when it comes to connecting pulleys and ascenders.

We recommend using an aluminum screwgate or auto-locking "D" carabiner to connect the descender to the harness maillon. If the safety mechanism consists of a screwgate with a locking sleeve, the carabiner should be placed with the gate facing the user, so that vibrations do not cause the sleeve to unscrew during the rappel and so that the gate is always visible to the user. Auto-locking carabiners can also be used. These have a quarter-turn, spring-loaded sleeve that rotates open when squeezed, making it easier to install and remove the descender from the maillon while insuring against accidental opening. Auto-locking models with a nylon sleeve are more robust than those with a zicral sleeve. For the descender's braking carabiner, choose a simple steel (abrasion resistant) carabiner, or better, a Handy (see section 4, fig. 22). Do not use an old retired aluminum carabiner for braking, since it cannot be used for any other load-bearing purpose in the event of an emergency. In that case, you will want a safer choice as a backup. The upper ascender can be connected to the foot-loop with a screwgate oval, and two carabiners – at least one of which is locking – should be reserved for emergency use on the harness side loops.

For a discussion of cowstail carabiners, refer to the previous section on cowstails.

Fig. 37 – Pear-shaped mini-carabiner used to attach the carbide generator to the harness. Not intended for life support.

This leaves us with two more non-locking carabiners. The first is used to carry the carbide generator on the harness, and the second attaches the pack tether to the harness. The latter should remain attached to the pack tether. When removing it from the harness, clip it directly to the pack closure to prevent it from dragging on the ground or becoming a projectile during transport.

Key points:

- The best type of gate latch is without a doubt the patented "key-lock" gate, which works just like a key in a lock. The nose and gate ends are both smooth and do not catch on cordage and webbing. Choose this gate style anytime there is risk of snagging. The hole in the gate end is slotted to allow for the removal of mud build-ups. Only Petzl and Kong carabiners have key-lock gates. However, with time the patent will fall into the public domain and we will surely see more manufacturers producing models with this feature.

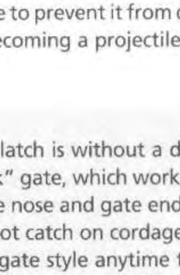

Fig. 38 – The key-lock gate closure

- The danger of a carabiner gate vibrating open during a rapid rappel is minimal in caving. Special high-strength springs on carabiners are therefore not a priority.
- However, always keep in mind that a carabiner's strength is severely reduced when its gate is open.
- In caving, avoid carabiners with a steel gate spring. The gate can twist relatively easily if levered and the rope can come out of the carabiner. Most importantly, never use these carabiners for the cowstails.

- Russian titanium carabiners have some serious defects that cannot be overlooked: flaking, a poorly set hinge pin, and excessive play. Numerous caving accidents occur every year in the Russian Republic and former Soviet states that can be attributed to such defects. These must be avoided; their low cost is still too high a price to pay for such poor quality.

Tips:

- Label carabiners by etching or stamping numbers only on the gate arm and not on the spine, which could compromise its strength. Or better yet, use colored tape to identify your carabiners.
- Once a carabiner has reached retirement age, it should be removed from your personal gear and not given some less noble function in the safety hierarchy (as on a pack tether, for example). Experience has shown that it will often end up again in a more critical role during an emergency, which common sense would otherwise proscribe. Similarly, non-load-bearing carabiners or those with unspecified strength specifications have no place in a serious caver's gear.
- Every carabiner should be carefully chosen according the specific function for which it will be used, and it should remain in that role throughout its life. This is the best way to avoid forgetting anything and to develop the correct habits in your technique. These habits will be important in certain critical situations such as the onset of exhaustion, when the right move at the right moment is absolutely essential and must be automatic.

Standard:

Standards for carabiners are covered in the section on all connectors, page 102.

Maintenance:

- Contrary to popular myth, zicral carabiners can be worn down, both mechanically and chemically. Clay, which is acidic in nature, can rapidly corrode and damage aluminum alloys, especially in the presence of high humidity. Carabiners should therefore be washed with clean water and a brush and left to dry completely as soon as possible after a trip.
- When cleaning them, also take the opportunity to check their condition. Look for small cracks in the body around the hinge pin (even if the pin is made of steel, it eventually wears down the gate), the quality of the spring itself, the sideways play on the gate, the residual diameter of the body, and any other corrosion cracks.

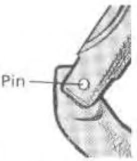

Fig. 39 – gate pin.

- An occasional drop of oil on the hinge pin, especially after a long trip underground, will ensure proper functioning of the gate.
- When left too long underground, carabiners can undergo electrochemical changes. A film of white alum gel forms on the surface, leading to further internal structural changes that are transmitted through the metal's micro-fissures. Fortunately, the process of oxidation is highly visible, and will even lead to the prompt disintegration of some carabiners left for extended periods in particularly wet, muddy conditions (as in river passages or waterfalls). With gear that is left permanently rigged, keep an eye on any wear caused by movement between anchor plates and the carabiners or maillons: this will also lead to eventual breakage!
- Mud can especially interfere with the proper functioning of some gates with cross-type latches, found only on steel carabiners. Packed mud prevents the gate from closing properly. Open gates inherently reduce the carabiner's strength and because of their shape, steel carabiners are actually not so strong (only 12 to 16 kN). Always scrape out any mud or dirt with a sharp object during cleaning.

A carabiner will wear out from surface abrasion, corrosion to the body, and excessive wear at the gate pinhole, all of which adversely affect its performance. Any suspect carabiner that is showing signs of age or wear should be replaced without hesitation.

E Material for Rigging the Cave

1. Ropes : the Basics

Though our lives literally hang from them, few people know much about caving ropes. Though it has taken nearly ten years, experience has finally taught us that we can trust them with our lives in almost any situation. That said, we must nonetheless understand their limits; to know how they are made and for what specific purposes they are meant to be used is another matter, but one that also deserves our attention.

1.1 Types of Ropes

We will consider two basic categories of rope: dynamic and static.

Dynamic ropes are made to protect against the consequences of shock loading after a fall, as when a leader falls while mountain climbing. They are elastic, a bit like a bungee cord. A dynamic rope's ability to stretch allows it to absorb the energy accumulated during a fall until the climber comes to a stop, like a coil spring that stretches from a suspended weight. They are always manufactured with a colored sheath; the contrasting lighter threads serve as abrasion indicators.

Conversely, **static ropes** have very little stretch and are used in activities where there is little or no danger of a significant fall, as when descending a pitch while caving. Their low stretch minimizes the unpleasant yo-yo effect we get when climbing with an ascending system. This feature also minimizes the rope's propensity for wear from abrasion, which is proportional to the speed and distance with which the rope moves against the rock at the point of contact, and thus to its elasticity. Therefore – and contrary to popular belief – the damage from abrasion on a dynamic rope is not less than that done to a static rope because it occurs over a longer section of rope. In fact, the static rope would probably sustain less damage. Note also that tyrolean traverses made with static ropes will sag less, making them easier to negotiate. Finally, static ropes are less expensive than dynamic ropes since their synthetic fibers are not subjected to the special heat treatment designed to increase their elastic response. Static ropes have a white sheath as well as contrasting (colored, in this case) indicator threads.

Fig. 40 – A static rope is composed of a core of many cabled fibers bundled inside a braided sheath that surrounds it and protects it from abrasion.

Modern ropes are made from synthetic fibers; nylon (polyamide) and polyester are the most common materials used. Natural fiber ropes made from cotton, hemp or sisal can rot and are extremely dangerous for use in caving. For specialized applications, aramide (Kevlar), polypropylene and high tenacity polyethylene (Spectra, Dyneema) may also be used.[9]

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[9] The brand names Kevlar and Spectra will be used throughout.

1.2 Construction

All modern ropes are kernmantel in construction, i.e., made up of two parts: a braided sheath (mantle) that surrounds and protects a core (kern) that may be either cabled or braided. The core is the load-bearing part of the rope and must never be directly exposed to wear (i.e., it should never be exposed!). This is why the sheath on caving ropes is thicker and more abrasion resistant than that on climbing ropes.

Braided cores have some advantages: the braiding is like a second rope within a rope, which remains strong and quite flexible. This latter advantage leads to some drawbacks, however: the flexibility of braided ropes makes them less resistant to abrasion since a greater surface area is effectively in contact with the rock. They also have another important weakness: they flatten when run through a descender, which clearly disqualifies them for use in caving. Cabled-core ropes, on the other hand, are quite abrasion and shock resistant. In European static caving ropes, the core consists of many small parallel cables, each composed of three twisted strands, which act like springs under a load (fig. 40).

In the old days, ropes under load tended to produce an unpleasant spin that, during a free rappel or ascent, would turn their users into spiraling tops. Rope manufacturers have overcome this problem by twisting one half of the core strands to the left and the other half to the right. These are the "S" and "Z" helixes. On high quality ropes, the sheath is also constructed with these two types of threading; the strands that make up the left helix are twisted again to the right and vice versa. This is not meant to reduce spin on the rope, but to better align the sheath fibers with the main axis of the rope, giving them more abrasion resistance: they work less against the sliding movement of the rope on the rock at the point of contact.

A rope has a rather complex structure, and the way it performs is no less complicated. In speaking of a rope's performance characteristics, we use several parameters:

1.3 Diameter and Mass per Meter

The diameter of a rope largely defines its breaking strength (or breaking load). Strength is therefore proportional to the quantity of material in a rope's cross-sectional area, or in other words, the square of its radius. The mass per meter is similarly proportional; this will determine how heavy your rope bag will be for a given length of rope (and of course how much you spend on the rope!). The choice of rope will usually rest on a preliminary compromise between lightness and strength.

1.4 Stretch

Rope stretch describes the distance the rope lengthens when loaded by the user. This value (expressed in percent) should not be too high as it would also increase bounce and the yo-yo effect during energetic climbs.

While there are other contributing factors, rope stretch is strongly correlated with the how the core is constructed, which was discussed earlier. The core may consist of small cabled, braided or straight bunched fibers. Cabled cores are twisted and elongate under tension, thus reducing the shock load transferred to the user. Most ropes have this type of core. Braided cores will also elongate considerably under light loads (1 kN); however, once they have reached their maximum extension, they tend to stop stretching suddenly, which contributes to higher shock loads after a fall. Stranded cores are constructed with unconnected parallel threads and so have a very low stretch.

Rope makers can modify the stretch and flexibility of their ropes by varying the composition of the core: by changing the number and size of cables within it, for example, or by mixing the kinds of internal components used.

The static elongation present when a rope breaks is equal to the maximum distance it will stretch before it breaks. Organic chemistry teaches us that synthetic fibers consist of macromolecules – that is, long chains of atoms connected to each other by very strong bonds having a certain angular elasticity. Between parallel chains, there is also the possibility of elastic behavior arising from the partially reversible gliding of one chain next to another. Finally, a special heat treatment applied during the production of the fibers can give them an additional "spring," similar to what we see in a strand of curly or crêped hair. The result is that under load, the fibers tend to stretch in the direction of the applied tension. By doing so, they absorb some of the energy being put into the system. When the rope can stretch no further and the tension continues to increase, the molecular structure is irreversibly transformed and begins to rupture. The rope's elastic limit has been exceeded. If the applied force continues beyond this point, the rope will soon break.

1.5 Shock Loads and Fall factors

Fall factors and the shock loads (impact force) transferred to a falling body may at first glance be a bit difficult to understand. But these notions follow naturally from what we have just discussed about rope stretch, and they can be better understood by taking an example: *your* falling body. When you fall on a rope to which you are belayed – while attempting to climb a dome, for example – what exactly happens? Your body falls, and by doing so, it simply obeys the laws of gravity. The rope, held by your watchful belay partner, takes up your weight and begins to stretch. Because it is somewhat elastic, it continues to stretch under the increasing shock load. As we have just seen, it is the lengthening of the rope that progressively absorbs the energy of your fall. However, if the rope is too weak (and let's hope that it isn't), it will reach its elastic limit and then break, leaving you to plunge to the bottom of the pitch. At this point, you might agree that a stronger rope with greater stretch is preferable. If this is the case, then in the above scenario the rope will continue to stretch, absorbing all of the energy of your fall. As your falling body comes to a stop, the stress on the rope is at its maximum: this is what we call the "maximum shock load" or "peak impact force." This notion is far from theoretical: it is the very force that is transferred to your body at the moment your fall is arrested.

Fig. 41

It is worth noting that if your rope is too static, your fall will be arrested very abruptly after a very short stretching distance. The effect on your body would be catastrophic: just imagine your spinal column as a loosely connected string of falling dominos, and you get the picture. Caving in a wheel chair remains a highly impracticable sport, so you may now be convinced of the merits of using dynamic rope when climbing domes or other obstacles on belay. But wait, the adventure isn't over yet: at the moment of maximum shock load, your rope will immediately release some of the energy it has just absorbed. You will then bounce until the absorbed energy is dissipated, the rope is brought back into equilibrium, and you eventually come to a complete stop. Your weight and the load on the rope now being one and the same, you will likely feel the lingering effects of a heavy adrenaline rush. But it all happened so quickly...

Here is the formula for the maximum shock load, which your falling body has just undergone:

$$F = (K \times H/L)$$

In this formula, the coefficient K is a function of your weight and the cross section and elasticity of the rope to which you are attached. H stands for the distance (height) fallen and L is the length of rope that absorbs the energy of the fall.

The ratio ***H/L*** in this formula represents the famous ***Fall Factor***.

Surprisingly, it is not just the distance that you fall that matters, but the ratio of the distance fallen to the length of rope that intercepts the fall. Thus, a fall of 50 meters intercepted by 25 meters of rope will give the same shock load as a fall of 5 meters intercepted by 2.5 meters of rope (of course, the consequences of possibly hitting a wall or ledge during a longer fall may make this equation quite academic...). In both cases, the fall factor (H/L) is the same: 50 divided by 25 equals 2; 5 divided by 2.5 equals 2. When we speak of fall factors, two is the maximum possible value for actively belayed climbing. While climbing, such a fall factor can be reached only if you have climbed above the last belay point held by a belay partner and fall before placing your first safety. You fall twice the length of the belay rope separating you from your belay partner, and you will find yourself hanging below him. Even in such a scenario, if your partner provides a dynamic belay by letting the rope slide some as you begin to load the rope, your fall factor can be appreciably reduced. Both European and UIAA standards require dynamic ropes to be tested for factor 2 falls. With these ropes, the shock load values typically measured in factor 2 falls are on the order of 7.5 to 9 kN on a single rope, and 5 to 6 kN on a double rope.

In caving and excluding situations where one is climbing belayed from below, a fall factor should *never* be greater than one. A fall factor greater than one could only happen if you fall after climbing above an anchor point, which should be absolutely prohibited, and which you will in fact rarely encountered in practice, except in the case of traverse lines. This is precisely why your cowstails must be made of dynamic rope. With a factor 1 fall on a static rope, you will realize a shock load of 6 to 10 kN, which is quite close to what you would experience in a factor 2 fall on a dynamic rope.

A typical example of a factor 1 fall can be found with bungee jumping. The jumper springs from a bridge into the void, held by his feet (and backed up around the waist) to a highly elastic rope (or, we could say, a very strong rubber band). This is attached at its opposite end to a fixed anchor on the bridge. The jumper doesn't realize that this band has become taut and begun to stretch; he only has the sensation of gradually slowing down until he comes to a stop when the band has absorbed all the energy acquired by the jumper's body during the fall (notwithstanding some internal friction). Since there is so much stretch, the shock load will be significantly reduced. The energy absorbed by the elastic band is then restored as the jumper bounces back upward, pulled by the taut rope. He will experience several high, successive oscillations – each one smaller than the previous – until he reaches equilibrium as he hangs by his feet at the end of the rope. Imagine the same jump on a solid, static chain; it would be difficult to think without a shiver of what happens to the jumper when the chain becomes taut...

A rope with an elasticity somewhere between that of a solid chain and a bungee cord will be able to absorb a number of shocks, intentional or not. This capacity for energy absorption will vary according to the rope's construction, which in turn depends on the uses for which it was made. This value is fundamental from a safety standpoint. It is measured in test conditions using a steel weight equivalent to the weight of the average user. The number of falls that a typical rope is able to withstand without breaking is counted, according to specifications for either factor 1 (for static ropes) or factor 2 (for dynamic). The higher the number of falls, the better the rope – at least in terms of energy absorption. On the other hand, stretch is a factor that contributes to abrasion. Again, manufacturing – and choosing – a rope involves a compromise between some rather contradictory factors.

But, you may ask, why does a rope that is subjected to successive shock loads eventually break, when these shock loads are significantly smaller than its breaking strength (which is often much more than 20 kN)? The answer is simple: with each shock load, the rope requires a certain amount of time to recover its initial stretching capacity. If the shocks come in close succession, as is the case in the requisite test conditions, the rope does not have time to recuperate and its shock absorption capacity is severely reduced. Sooner or later, it surpasses its limit of stretch and undergoes a permanent structural transformation that further reduces its elasticity and thus its ability to absorb subsequent shock loads. With each shock, the effects of the impact force increase until the rope breaks.

1.6 Flexibility at the Knot (Knotability)

The amount of flexibility (or lack thereof) where a knot has been placed is a good indication of whether a rope is stiff or soft. The nature of the core fibers and the compactness of the sheath threads both contribute to this quality. With ropes, everything is interrelated, all parts interact and nothing is simple. Manufacturer prowess lies entirely in the mix of these delicate subtleties that determine whether a rope is a well made masterpiece or a nightmare tangle of threads. Flexibility is a double-edged sword, with both advantages and drawbacks: a soft rope is easier to knot and untie, but a more rigid rope is more abrasion resistant as it tends to flatten less against a rock. Unfortunately, there is no such thing as a perfect rope!

1.7 Sheath Slippage

The rope sheath may slide back and forth against the rope core, and it is generally the use of a descender that causes this slipping. In passing around the lower spool (upper bar on a rack, or the body on a figure eight), the fibers opposite the contact point between the rope and spool are subjected to a high curving radius and are therefore stretched more than the fibers on the opposite side. On the second spool of a caving descender, the reverse happens. These localized, differential stresses add to the general stress caused by the weight of the user, and impact the sheath more directly than the core of the rope. Moreover, friction of the sheath with the spools pulls it somewhat downward in relation to the core. The sheath ends up slipping, leading to the infamous "sliding sock" effect, whereby a length of the sheathing extends beyond the core at the end of the rope. In a worst-case scenario, this could leave the caver hanging by a piece of sheath instead of the rope! But rest assured, rope makers are well aware of this phenomenon and the better static ropes now have zero relative slippage.

Canyoning ropes with a polypropylene core and nylon sheath always shrink with their first soak, but in this case it is the sheath that shrinks relative to the core rather than the inverse. This is the result of a different process: nylon absorbs more water than polypropylene, so the sheath shrinks more. This is a normal phenomenon and is easily corrected by cutting off the excess length of core sticking out of the sheath after several uses.

1.8 Factors Affecting Rope Strength

There are many factors, sometimes ignored or neglected, that affect rope strength. Some depend heavily on how and in what conditions the rope is used. Ropes developed specifically for use in caving, and which therefore directly concern us here, will be discussed in the section below on static ropes. Some other general factors apply to all types of ropes:

Knots

Demanding a comfortable margin of safety from our ropes makes a lot of sense when we know that a rope's labeled strength is only theoretical; it does not actually exist in practice, since we must always rig with at least one anchor knot. In the previous edition of this book, we emphasized this point because so many cavers seemed oblivious to its importance. This is no longer the case today, so we need only remind our readers that tying a knot in a rope effectively reduces its strength by 35 to 50%, depending on the knot. Moreover, the knot should be well made and dressed properly; tension should be well dispersed throughout the knot and there should never be extra overlapping parts. When this happens, the overlapping section will pinch the part beneath, preventing the knot from equalizing when weighted and subjecting the pinched underside to additional strain. It is at this point, just outside the knot, that the rope will eventually break, and at a much lower loading than its labeled breaking strength. A well-dressed knot is also more compact, less likely to rub against the cave wall, easier to manipulate, easier to untie, easier to inspect, and...prettier!

Physical aging

From its first use, a rope begins to deteriorate. As we have just seen, the simple act of running a rope through a descender stresses its fibers in different ways. Endurance tests have shown that after 1000 passages through a descender, a new rope's strength is reduced by half! Fortunately, the use of descenders on ropes is more erratic in reality than in test conditions; our ropes have the time to recuperate, and their fibers remain a bit stronger.

In mountaineering and climbing, a rope can become coated with dirt and sand, which are of course abrasive. In caving, our ropes absorb mud and clay, and the calcite crystals found in this clay penetrate deep into the sheath. These fine crystals are like tiny glass shards and are just as sharp, and they can slowly sever the rope fibers. That is why it is extremely important to wash caving ropes after every use.

Finally, rubbing against the rock can abrade the rope sheath, if not the core as well. This phenomenon deserves further discussion:

Abrasion from use

Some wear from abrasion is the result of normal use: the back and forth movement of carabiners, or the rubbing on the rock during maneuvers, for example. At first, this slight softening of the rope's feel is pleasant to the touch, but it still signals a slow deterioration in the rope fibers. Even if we are careful with our ropes, the sheath gradually absorbs microscopic impurities that abrade the fibers and cause it to stiffen. The rope runs less smoothly through our gear, the wear indicator threads become thinner and eventually abrade in places. This is a signal: it's time to retire the rope and relegate it to less noble tasks. It can be used to tow a vehicle, secure a tarp over that woodpile in the backyard, or maybe you can give it to that friendly landowner. Dipping it in a bucket of paint should give it some lively colors and prevent it from surreptitiously finding its way back into your pile of pit ropes.

While abrasion from normal use is unavoidable, you should nevertheless do all you can to prevent accidental abrasion. In rock climbing and on cliff rappels, this most often occurs because of poorly placed anchor points. In caving, it is bad rigging, which we will discuss further in the following section.

Chemical aging

Various chemical agents can cause a fiber's molecular chains to slowly break down. Ultraviolet radiation from the sun is one of these. A rope left in direct sunlight will do more than fade, and while discoloration is only a harmless indicator of the degradation of the dyes used on the threads, ultraviolet radiation damages the rope fibers themselves. This damage is invisible, yet it is very real and even cumulative. Ropes should always be stored in darkness and allowed to dry in the shade.

Acidic as well as alkaline (basic) chemicals are also enemies to our ropes. Acids are particularly damaging to nylon, while bases attack polyester. Some acids are even more insidious than battery acid, and these are spread throughout the atmosphere in the form of pollution: for example, sulfur from gasoline converts to sulfur dioxide, which when combined with water in the air, turns to trace amounts of sulfuric acid. This falls back to earth in the form of acid rain. Recent studies have shown that environmental pollution is even more harmful to our ropes than ultraviolet radiation: ropes exposed to the air pollution in larger cities wore out more quickly than those exposed under the same conditions in higher mountain or polar regions. So it seems we must protect our ropes from both air and sunlight. It is best to store them in closed drums rather than on racks.

Finally, over time, water also has a debilitating effect on ropes (see page 61).

And now back to our caving ropes…

2. Static Ropes

2.1 Size and Composition

Caving ropes are made of either polyester or nylon. While it is light, polypropylene cannot be used for caving ropes as it breaks down at a relatively low temperature – barely more than 100° Celsius [212° F]. We can reach this temperature by simply rappelling a bit fast on a descender and stopping suddenly. Neither can we use Kevlar or Spectra: though they are extremely strong fibers (about as strong as steel!), they are totally inelastic and have no capability for energy absorption. In the event of a sudden shock load, they lack the necessary "spring effect" and transfer the entire shock load to the anchor and to the body of the user who has just fallen. The potential physical consequences are considerable, since we are effectively talking about that steel chain mentioned above!

We generally prefer nylon to polyester. It is more elastic and produces ropes with a greater energy-absorbing capability, which is especially critical in the case of a failed anchor, for example. We will return to this in a moment.

Caving ropes in Europe are usually between 9 and 10.5 mm in diameter. Below 9 mm, we can no longer legally speak of them as "ropes" per se; in Europe, anything below this diameter is labeled a "cord" according to the safety standard. Once used primarily for smaller teams, 9-mm ropes are now the norm for most caving clubs, and are also used regularly in French Caving School (École Française de Spéléo) training sessions, and this is one organization that is serious about safety. A nine-millimeter rope can hold a static load of 19 to 24 kN at a cost in weight of about 55 grams per meter. At a diameter of 8 mm, this value drops to between 16 and 20 kN for roughly 45 g/m, and we are now in the category of light specialized cords, to be used with the utmost care and avoiding even the slightest risk of abrasion.

Ten-millimeter ropes can bear a static load between 24 and 26 kN for 65 g/m; for 10.5 mm, this increases to 26-27 kN for 70 g/m. These two diameters still make up the majority of our caving club ropes. Given the requirements of the new European standards and the improved performance of 10-mm ropes in recent years, we really have no need for 10.5-mm ropes today. Ten-millimeter rope is now effectively the maximum, even for use in rescue, and most clubs will find it best to rig with 9 mm (except in the case of heavily used permanent ropes). A nice opportunity to get your club's treasurer and equipment officers together!

Important differences can likewise be found in a rope's construction and depend on the competence of the manufacturer as well as differences in the labeled diameter from one model to the next. The commercial label of a rope's diameter may have little to do with its strength and falls under no standards: we can put a label of "10 mm" on ropes of 9.7 or 10.4 mm, for example. Some manufacturers take advantage of this, labeling their ropes up to 5/10 % greater than their actual diameter. By this simple subterfuge, their ropes seem lighter and less expensive than others at the "same" thickness. This makes for a great bargain, but in reality it is nothing more than an illusion. There can be up to a 13% difference in price and weight, and more than a few continue to fall for this trick!

2.2 Abrasion

As with all ropes and cords, static ropes are subject to the same wear factors discussed above and a few more as well. Among all the threats to our ropes, abrasion is the most insidious because it is often difficult for the first person down to detect it, depending on the pitch. It is also difficult to foresee the gravity of its effects. Abrasion breaks the rope's fibers one by one, literally tearing away the material. Abrasion is proportional to the intensity and extent of contact between rope and rock; the roughness of the rock and pressure at the contact point will both contribute to further abrasion, which can lead to complete destruction of the sheath. When the core is exposed, the situation has become critical because complete breakage is not far off: being less tightly woven than the sheath, the core threads are much less resistant to abrasion. All of this can happen relatively quickly, and the user may be quite oblivious to the problem. Assuming his safety and climbing the rope in peace, he is unaware that each stride cuts a little more into that last strand holding him in the void. Beware! This is not a theoretical hazard; very real (and unfortunately fatal) accidents have occurred that are proof of the danger. We should also not forget some of the less noticeable causes of abrasion, such as the use of a descender whose spools have worn down to the steel pin, or climbing on a chest or foot ascender that has been sharpened to a razor edge by overuse. In trying to put off spending a bit of money in the short term, one can end up wasting ten times more without even realizing it.

As soon as you notice a rub point, you should eliminate this by immediately altering the rigging (by changing the anchor point at the pitch head, placing a deviation or rebelay, etc.; see section K.2). Remember that the effects of abrasion are worse when the rope is softer, more flexible, or more elastic (page 58). In this respect, the standard requirement in drop tests has increased from 80 kg to 100 kg, which has led to an increase in the elasticity of static ropes. For cavers, this is completely absurd, but as they say, the road to hell is paved with good intentions...

2.3 Water Absorption

Since the cave environment is nearly always saturated (near 100% humidity), a rope rigged in a cave should always be viewed as a wet rope, even if the pitch is dry. Moisture reduces a nylon rope's performance; breaking strength, for example, is reduced by about 10%. Shock absorption capacity is reduced by much more: almost half. If a rope stays too long underground (i.e., several years), it can have serious effects on the rope, even resulting in breakage during normal use. We have already seen this with a dynamic climbing rope left in a cave for seven years. While it had only been used twice in those seven years, it broke on the third use under the weight of the second person to climb up that day. Beware that the effects of rope degradation are cumulative!

In a more immediate sense, water absorption translates into more weight, which we evidently want to reduce as much as possible. A rope can absorb water in two ways. The first is chemical and irreversible, resulting from the attraction between nylon and water molecules. This mutual attraction can be observed when a new rope is placed in water for the first time, as weak but irreversible hydrogen bonds are created. The rope swells slightly and so proportionally shrinks from two to five per cent or even more, since the total amount of material contained in the rope has not changed.

The second way a rope can absorb water is by simple physical saturation. This process is reversible and depends little on the type of rope involved; it is largely proportional to the cross-section and length of the rope, i.e., to its mass. Still, softer ropes will absorb even more water because there is more space between the threads. There is only one way to avoid saturation: treat the rope with a waterproofing agent that renders the fibers hydrophobic, and water will no longer be able to penetrate. Here, too, there are two kinds of treatment. One acts only on the rope's surface: by soaking the rope in the product. This method is not long lasting, but it is rather affordable. The second method is performed in an autoclave by pressurized infusion: the rope is completely impregnated with the waterproofing agent. This method is longer lasting, but expensive.

Besides water, ropes also absorb mud and clay. The more the rope wears on the surface, the more penetration of the mud is facilitated. This process is accelerated with time and can bring about renewed swelling, shrinking and loss of elasticity. The consequences of wear compound the problem and these also increase with age and time: the rope slowly loses its stretch and its ability to absorb shocks. In shrinking, some ropes can lose more than 10 % of their length by the time they are scrapped or recycled for dig projects! So we don't recommend you use nylon ropes to measure the depth of your pits...

Polyester ropes don't chemically absorb water and therefore shrink much less.

2.4 Freezing

During winter, moisture trapped in some entrance series ropes may freeze the ropes completely. This transforms them into heavy, stiff cables that are difficult to use. The ice is not in itself dangerous; in fact, if a frozen rope is subjected to a shock load, some of the energy released from this will melt the ice in the rope before transferring to the rope itself. A frozen rope is thus even stronger! But the basic risks are:

- in the event of streaming (alternate freezing and melting) on the rope surface, the build-up of ice on the rope can not only prevent the use of our vertical gear, but can also create a considerably heavier load on the rope that leads to breakage;
- the rope can become stuck by the ice to the cave wall, preventing its use;
- traverse lines can become stiff, which has an adverse effect on our cowstails, as discussed in section D3.

2.5 Field Tests on Static Ropes

In 1973, the first edition of this book discussed the new single rope techniques that would come to revolutionize vertical cave exploration. There was so much to cover on the subject that shock load tests were not discussed or even conducted. We mentioned this somewhat in the forward. At the time, our detractors seized on this omission, suggesting we were dangerous lunatics who had the audacity to throw out the use of our trusted cable ladders, symbols of the very practice of alpine caving. They hurled denouncements and went straight for the slaughter. Now we know what happened and which path history took. The second edition (1981) arrived on nearly conquered territory. The concept was the same, but it had time to circulate and tempers had calmed. We only needed to dispel the scattered doubts that remained in some minds. That second edition thus focused on a series of systematic tests on both new and used ropes. Putting forth our argument in this way paid off: what caver today crosses the lip of a pitch with more than the slightest worry that the rope will break before putting his life on it? Conversely, we will remind the most experienced and specialized cavers of the risks they are taking with beginners – who are without adequate experience and technical knowledge – if they insist on using smaller diameter cords that they hope to see legalized!

The widespread practice of single rope technique has proven that a sufficiently thick rope correctly rigged over a free drop is quite safe. Conformity to European safety standards for all products sold within the European Community has also helped do away with suspect ropes. We thus have no reason here to repeat the details of these studies, but only wish to outline them before mentioning a few more recent studies.

Performance tests on new ropes require no particular commentary here: all ropes with the CE label are obviously suitable for our use. On the other hand, a real danger lies in the "good buys" found and bought locally during summer expeditions to faraway places.

Tests performed on used ropes whose sheaths show no visible or tactile signs of localized wear have shown that five-year old ropes 9 mm or thicker can withstand the shock load of at least one factor 1 fall. This reduced strength relative to new ropes can be attributed to all of the wear factors previously discussed.

Five years is thus the acceptable life span of a healthy-looking rope, if we take into account that most shock loads rarely reach a fall factor of 1 in caving. A classic backed-up anchor with 20% slack between both fixed points will lead to a fall factor of about .3 in the event the primary anchor ruptures: a free fall and a pendulum swing follow. To reach a fall factor of 1, you would have to hoist yourself right up to the anchor, leaving the entire length of rope slack between your harness and the anchor, and fall without any horizontal travel whatsoever. Still, some shock absorption also takes place in the anchor knot, in the temporary stretch of your harness, and in the compression of your body's muscles. Real falls, taken by some rather fearless (or senseless?) guinea pigs, have shown that under these conditions, a reduction in the resulting shock load was about 30% more than the theoretical values. That is good news for the rope, the anchor, and the victim.

2.6 Falling on Climbing Gear after an Anchor Fails

While the standard for static ropes reassures us of their safety in the most common uses, it says nothing about falls that are taken on our various mechanical devices, which will of course happen in caving when an anchor fails. Some professionals also use ascenders and descenders on rope in some sectors of industry. However, rigorous procedures and reinforcement of the materials used make it highly unlikely for an industrial anchor to rupture. In caves, on the other hand, conditions are much less controlled. While bolt failure is rare it still occurs, either because of a weakness in the rock, incorrect placement, or a rigging error such as overtorquing the nut or screw. It is pertinent to consider what can happen in such a situation, when the falling caver is attached to the rope via the spools of his descender or the teeth of his ascenders, rather than by a knot (as is a climber).

When the primary anchor breaks

Let's first take a look at primary anchor failure in a pitch. In this case, only one caver is concerned. Possible fall factors of course remain below 1, but can be very close to it, especially as the caver gets closer to the problem anchor point and the distance between the two anchors (primary and backup) at the pitch head is reduced. On descent, the descender is not damaged and the caver is only left a bit shaken. Note that the risk of a ruptured bolt is one argument for using an auto-lock descender rather than a Simple: due to a surprise or an unexpected blow, the caver could lose his grip on the lower rope and be unable to get it back... until he reaches the ground. This risk is lower if we use a braking carabiner; it confines the rope to a smaller space where it is easier to grasp in the event of such an emergency.

When climbing, the danger lies in the teeth of the chest ascender and their contact with the rope.[10] Here again, their effect on the rope depends on the fall factor and shock load applied to the rope. This risk is elevated only if the failure occurs as the climber is approaching the anchor, a very possible scenario if we consider that the forces applied to the anchor increase as the eventual victim approaches it (yet he is still below the anchor, so the potential FF is less than one!). The result of this can be quite impressive, even leading to complete tearing of the rope sheath. Rest assured: the sheath will only slide down on the core, the latter still theoretically holding between half and two-thirds of the rope's strength intact. The sheath continues to slide down until the chest ascender comes slowly to a stop. If the long cowstail attached to the upper ascender becomes taut in the meantime, the stop may be a bit more abrupt. Nothing to be afraid of, but what fright in retrospect! From all this, you can deduce the following conduct: in every pitch, climb more and more fluidly as you approach the anchor. Fatigue, on the contrary, causes you to climb more fitfully and you will need to fight that tendency...

When a rebelay fails

Suppose the rebelay separating two cavers on rope breaks. During the descent, both are on their descenders. We have already discussed this case in the section on descenders (page 45), recommending the use of a braking carabiner such as the Handy, placed directly in the harness maillon.

On a climb, everyone is on ascenders. If the rebelay fails above the first climber, he alone is concerned. In terms of shock load, he finds himself in a similar, less dangerous scenario than that of a primary anchor failure because the entire length of rope separating the climber from the primary anchor helps to absorb the shock load. However, the rebelay was probably placed to avoid unnecessary contact between the rope and the cave wall (as is usually the case, except in deep pits to break up the climb). Now the rope is back against the wall... As we have already seen, stress on the anchor increases during a climb, so it is likely the rupture

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[10] Never use a toothed ascender as the primary climbing belay, and particularly when the fall factor can exceed one. The teeth can sever the rope under higher shock loads.

occurred as the climber approached the intermediate anchor. He must warn his team member below before continuing cautiously toward the faulty rebelay, moving as fluidly and gently as possible. After checking the condition of the rope and isolating any possible damage to the sheath with a butterfly knot or a figure eight, he should replace the anchor if he has the proper equipment and enough rope. Otherwise, he should take every step necessary to ensure that the subsequent climber's movements on the rope do not worsen the situation.

If a rebelay separating two climbers breaks, nothing serious will happen to the top climber, who will hardly even notice what has happened (unless he has just passed it). The bottom climber, on the other hand, will suddenly go flying, although the fall factor remains low since the length of rope rigging at the upper rebelay will give more shock absorbing distance. Depending on the placement and configuration of the rigging, he will experience something between a vertical fall and a more or less pronounced pendulum swing. The latter has an advantage, as the resulting shock load is reduced in proportion to the amplitude of the pendulum. It also has drawbacks: you risk hitting the wall – perhaps forcefully – and damaging the rope on a sharp outcrop (There is only a real risk of completely cutting the rope on a sharp piece of chert; avoid these like the plague when rigging, and back up your rebelays if you must rig near them). As for the primary anchor, it will only undergo a shock load of barely 5 kN, even in the most unfavorable conditions (as when our two guinea pigs are very close to their anchors). In cases where there is a wide pendulum, back up the rebelay.

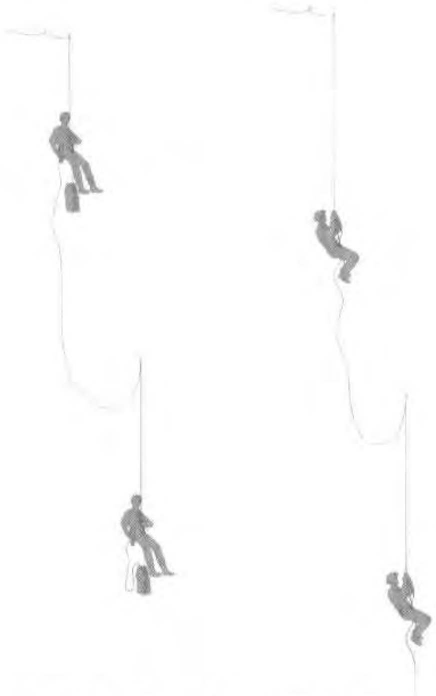


Fig. 42 – Sketch of situation during descent (left) and climb (right) before a main or rebelay anchor fails.

After this failure, the two climbers find themselves on the same stretch of rope, which poses no real danger. As the lower climber gathers his nerves, the upper teammate assesses the situation: as in the previous case, the failure of the rebelay has naturally brought the rope back to a rub point. At worst, the upper climber may have to climb back down to this point on a taut rope and position himself as a human deviation, with legs locked straight and feet set apart for greater stability. He waits there to be joined by his team mate, who comes across the remains of the faulty rebelay during his climb and treats them as if passing a knot (see the section on basic vertical techniques). The upper teammate can then begin climbing again. Once the rope is free, the second takes his turn.

Remember that if two anchors are placed at a rebelay, they should be placed level with one another. If the primary bolt is placed above the secondary and fails at the moment one is changing over on rappel, or when one is just reaching it on a climb, a fall of well between factor 1 and 2 will result. While this is of course intercepted by the second bolt, our gear was not designed for this. As for the risk of falling to the ground when a rebelay breaks near the bottom of a deep pitch, this is more theoretical than real: the last few meters of deep pits are generally quite spacious and it is rarely necessary to place rebelays here. The rope would also have to be rigged at the last anchor with excessive slack given its stretch, or rigged to the side as a pendulum with a breadth that would in any case call for a backup anchor.

So we see that whether climbing or rappelling, we are faced with little real danger as long as the cave has been rigged properly, except in some very rare cases. We repeat: ropes are safe, as long as we use them correctly.

2.7 Key Points and Criteria for Choosing Static Ropes

We cannot reduce a discussion of static ropes to merely a few key points, but let's nonetheless remember the most important precautions.

Key points:

- Choose the diameter according to the skill level of the teams using the rope and the frequency of its use.
- Retire any rope that has spent 3-4 years underground (2 to 3 years for 9 and 10 mm), unless it's passed a drop-test. Its strength can be reduced to levels that are difficult to determine.
- Avoid all contact with the rock, the flame of your carbide lamp, and any chemical (oil, gasoline, battery acid, etc.)
- Whether rappelling or climbing, always move with the utmost fluidity as you near the anchor.
- Wash your ropes often and check their condition at this time.
- Store your ropes in a dark place.
- Keep a thorough inventory of the your ropes and their condition.

Criteria for Choosing Ropes:

- The increase of the standard mass for determining shock load capacity from 80 kg to 100 kg has led rope manufacturers to make their ropes slightly more dynamic; don't hesitate to choose ropes with the least amount of stretch possible to help reduce the yo-yo effect.
- For the same reason, 9-mm ropes are now entirely suitable for club use: 10-mm is the maximum; 10.5-mm, being 10% heavier and more expensive, should be dismissed altogether.
- Choose stiffer ropes; as we have seen, they are more abrasion resistant. Wash them regularly to keep them from becoming too stiff.
- Some static ropes are now available with a "stretch reserve," a concept that seems promising. These ropes have a small number of special low stretch strands in their core: their behavior is therefore very static (1% stretch between 50 and 150 kg), which has two advantages:
  - they are more pleasant to climb, since the yo-yo effect is greatly reduced;
  - they are less sensitive to abrasion when rubbing does occur, since abrasion is proportional to the speed of movement between the rope and the rock (see page 61).

One would expect to see the reverse side of the coin as well: a higher impact force in the case of a shock load. No worries: these ropes remain as safe as their counterparts, because the low-stretch strands in the core will break in the event of a dangerous fall, limiting the shock load to about 5 kN. This makes it about equal to a classic semi-static rope (3% stretch between 50 and 150 kg). This change is of course irreversible, but very unlikely to occur since such high shock loads are quite rare. Even in such a case, the rope would remain perfectly usable. In this way, these ropes meet the standard while retaining their advantage as very static ropes.

Standard (EN 1891):

The birth of the European Standard for static ropes was a painful one and the story deserves to be told.

The standard covers "semi-static" ropes (a more suitable term than "static" since these ropes are not 100% static, as is Kevlar or Spectra for example), with diameters between 8.5 and 16-mm. Two types have been identified:

Type A: general purpose ropes used for all work at heights, for caving, and for rescue;

Type B: ropes having smaller diameters and less strength than Type A ropes, requiring greater care during use and intended for use in descent and rescue situations.

The characteristics of Type A and B ropes are listed in the table below. These specifications were set by the standardization process and deserve some commentary.

We have already outlined the regulations and procedures that are in place to protect the European consumer when he purchases his personal gear (PPEs). But it so happens that this great regulatory machine can slip up, which is exactly what happened in the case of static ropes. These have always been used widely in industry and public works, and specialists in these sectors were responsible for their standardization. These specialists thought of everything – except that semi-static ropes were also used for caving. In fact, it was cavers who invented these ropes, which were later used in industry. Everyone forgot about the recreational origins of our ropes, for economic reasons as well as lack of representation from the caving world. While the UIAA attended every meeting concerning the standardization of dynamic ropes,

Standards for semi-static ropes	**Type A**	**Type B**
Static breaking strength :	minimum 22 kN	minimum 18 kN
After one fall of 0.3 FF, must withstand :	5 falls of factor 1	5 falls of factor 1
on a weight of :	100 kg	80 kg
Minimum breaking strength with one figure 8 knot, force applied for 3 minutes:	15 kN	12 kN
Maximum Impact force:	6 kN	6KN
at a Fall Factor of (weight) :	0,3 (100 kg)	0,3 (80 kg)
Elongation with applied force of 50 to 150 kg :	< 5 %	< 5 %
Sheath slippage relative to core diameter, Ø :	< 20 mm + 10 x (Ø -9)	< 15 mm
Core as % of total mass :	between 30 and 50	between 30 and 50
Knot Flexibility (interior Ø of knot divided by nom. diameter of rope)	< 1.2	< 1.2
Labeling: a ribbon in the core is clearly marked with CE standard number, manufacture date, name of manufacturer and the material from which the rope is made.		

not a single caving organization was invited to participate in sessions involving semi-static ropes, for seven years, before 1997 – yet these ropes are our first concern. This absurdity is even more apparent when we consider that standards relating to recreational activities are within the remit of the Youth and Sports Ministry (in France) and the Technical Committee 136 (for European standards), while those relating to work depend on the Ministry for Industry and the Technical Committee 160. Of course, these committees don't communicate with each other…

Since Committee 160 was responsible for standards concerning semi-static ropes, standardization projects were enacted until 1997 without the input of cavers and in complete ignorance of their needs. In the work sector, safety standards are traditionally much higher than in the sports and recreation world.

So, while fall tests were performed on dynamic ropes with dummies weighing 80 kg, this weight was changed to 100 kg for static ropes – a heavy difference that required an increase in rope diameter to stay within the specifications, which, for caving purposes, are simply extravagant.

To add insult to injury, our brave standardizers from the industrial and climbing worlds decided to invent the stipulation that Type A ropes were required in caving use, though they knew nothing about caving whatsoever! What was going on here?

In response to the uproar in the caving community, led by the French Caving Federation (FFS), the Technical Committee 160 rectified the problem by extending the domain for semi-static rope applications. The standard now reads: "a rope that does not conform to the European standard may be used for the activities mentioned above" (these include caving). We now have the choice of using Type B ropes for climbing and descent, or ropes with a diameter of less than 8.5 mm, even for engineering new lighter ropes.

It is up to cavers themselves, and to their respective national organizations, to define which ropes may be used in our sport, regardless of the standard. A delicate task, indeed. Will they be able to listen to each other and come to an agreement, and will they be wise in determining these limits?

2.8 Limits on Light Ropes

Expedition cavers have the understandable temptation to use increasingly thinner ropes. This lightens the load, which is already significant in deep caves. With improved rigging techniques using ropes that have been proven safe and strong, experienced cavers have gone form 10.5 to 10 mm, from 10 to 9, 9 to 8… where will this end? Can we imagine someday climbing on a rope resembling the threads of a spider web? After all, at a corresponding diameter, silk is stronger than steel. Or perhaps another miracle fiber will come along…

Caving ropes certainly evolve with innovations in chemistry, methods of construction and technical use, and the European work groups recognized this point as mentioned above. This modification opened the door slightly and clearly indicated that ropes not classified as Type A or B could still be used in caving practice, though it did not stipulate minimum specifications or conditions for use. Their prudence is understandable since, even though present-day fibers are theoretically strong enough, one important point remains: when we reduce a rope's diameter by a factor of 2, we reduce the number of fibers used to construct the rope by a factor of 4. Where is the problem, you might ask? Here: wear from abrasion is directly proportional to the tension placed on the fibers in the rope. For a given weight, this tension is inversely proportional to the number of fibers in the rope... All other factors being equal, the sensitivity of a rope to abrasion – and the corresponding risk of failure – increases by the square of the diameter by which it is reduced. Who would dare to assume that, even with careful rigging, no abrasion whatsoever will occur, including that which results from a broken anchor. Considering abrasion alone, it is dangerous to seek too small a diameter.

Our caving federations should consider this argument when they assess the feasibility of a new type of rope, called "Type L lightweight caving rope." Rigging pitches, as we know, is never an exact science. There are too many variables in the rock itself and in the possibility of human error. Even if we leave technique aside, can we be sure that no club treasurer will ever choose a rope based purely on financial considerations and thus choose a type L rope, with its lower price (due to the reduced volume in material used)? Some margin of safety is necessary. Our cave diving colleagues reserve 2/3 of their air for the return trip, even when diving in known passages. This allows for the unexpected. Given the complexity of our practice, why should we do any different? Defining a limit of safety isn't easy, but one thing is certain: it is best to err on the side of prudence rather than recklessness.

In our opinion, 8 mm is a reasonable limit that should not be passed unless a new miracle fiber comes along. It would need to be extremely abrasion resistant, having a low coefficient of friction against the rock. This characteristic can only be achieved with fibers having low transitions points. But this inevitably makes them sensitive to the heat caused by the simple use of a descender. Trying to combine the advantages of nylon and Spectra would be like trying to crossbreed a fish and a rabbit, and we would then need to invent the appropriate mechanical devices. This leaves us far from a clear solution.

Still, some more specialized cavers – few of whom seem to practice at the average skill level – are putting pressure on the Federation (FFS) to allow the use of diameters below 8 mm. For now, the FFS defines Type L ropes as:

- having a minimum breaking strength of 16 kN for ropes with no knot, and 11 kN for ropes prepared with one figure eight knot at one end;
- able to withstand a minimum of two shock loads at fall factor 1 on an 80 kg weight, without the previous fall of factor 0.3 stipulated in the CE norm.

These specifications don't really address the true problem at hand, since it makes no reference at all to diameter, and therefore does not take into account the risks related to abrasion, the "Achilles' heel" of small diameter ropes.

And now for the latest development in this already long story. In October 1999 the General Assembly of Authorized European Laboratories refused to validate the provisional "CE" certificate given by an authorized French lab for an 8-mm rope made by a French manufacturer according to the Type L specifications defined by the FFS. The Federation found itself alone on the front line as it were, without the support of other European caving federations and disowned by rope safety professionals.

The authorization of cave ropes with diameters below 8-mm is a dream that can easily become a nightmare. That an elite few, having seriously taken into account the risks, wish to use more specialized equipment than the average user, is easy to understand – it is even a sign of progress. But for a caving federation to legalize the practice would inevitably make it more commonplace and even promote it – along with all the associated risks – among users who may not fully understand the conditions for use. In the end, it would be wiser to ignore the practice of a select few when creating standards that apply to everyone, rather than try to "cover" this elite by venturing onto shaky ground where the less experienced caver has more to lose than to gain. When the diameter is already small, the user stands to gain very little in terms of weight while taking significantly greater risks in terms of safety.

In the event of an accident, the temptation will be strong to brandish the official standards in calling for legal compensation. If we know that use of mechanical devices is limited by their manufacturers to ropes of 8 mm or more, we can easily imagine the rest in a courtroom. In a world that is becoming ever more litigious, such a risk shouldn't be taken lightly; well-informed, competent individuals certainly have the option, but it is hard to imagine our clubs doing so in their routine practices.

2.9 Rope Maintenance

Fig. 43 – Labeling on a 43-meter rope, belonging to SCR and put to use in 1999.

Cutting and labeling

Maintenance of our ropes begins from the moment of purchase, with a preliminary soak. This should last about 24 hours, preferable in running water (otherwise, change the water after 12 hours). The purpose of this soak is to eliminate residual lubricants left from manufacturing. These basically tend to enhance the "slipping sock" effect, facilitating relative slippage of the fibers when they are run through the descender. This preliminary bath permanently sets a certain amount of water in the rope fibers which, as we have mentioned, causes it to swell and shrink.

You can then cut and label the rope. Otherwise, the marked length will be incorrect even before its first use underground. Before cutting, let the rope dry in the shade, then stretch it out between two solid points and leave it to stabilize. Always shrink your rope before measuring.

We recommend using a measuring tape to measure rope lengths; cut the rope with a hot blade or melt the ends to prevent it from fraying. Labeling is important because the diversity of diameters doesn't allow for an easy visual determination when looking at the tangled mess later on. The labeling should at the very least include an "m" for meters (or "f" for feet), which will prevent any confusion between length and year (or between measurements in the case of joint international expeditions). Complete the labeling with the last two digits of the first year of use to will save you from having to peel the sheath away to read the core labeling later (see below). Marking the initials of the club or the owner of the rope is optional.

Your labeling should be clear, waterproof and not too thick.

A good way to label is with adhesive stencils. Place these over colored tape, which you may code to indicate the diameter of the rope and the purpose for which it is to be used. Protect both with a 5-7 cm sheath of transparent heat-shrink tubing. Then you just need a rope log to keep a record of the brand, diameter, lengths, dates of purchase, labeling and any modifications (usually a second cut of the rope following wear on the sheath), and the date of retirement. At the risk of seeming old fashioned, we will point out that an index card file kept at the caving club's building or room would likely be more useful to future members than a computer file that may be lost or inaccessible once the equipment chairperson leaves office. Be careful if you discover an unmarked rope or accept a donation from an outside party. In theory, you may be able to locate the year of manufacture in the color indicator thread in the rope's core (this still indicates little about its use, and only applies to European ropes). From 1982-1997, this thread has been, respectively: orange, purple, red, green, blue in 1986, black, yellow, pink, purple, red, blue again in 1992, orange, green, black, blue, and finally purple. Some years have double colors, so there may be some doubt: assume the earliest corresponding year just to be sure. Since 1997, the year is printed clearly on a ribbon in the core, to avoid any uncertainty as to the age of the rope.

Washing the rope

Washing ropes is a tedious task – and a chilly one in winter – but it is indispensable to a rope's preservation. The rope should be passed under running water – or at least left to soak in a sufficient volume of water – to remove clay, dirt and calcite. Leaving it to uncoil in a swiftly moving stream, with both ends attached to a rock or other anchor, is a good self-cleaning method. You only need to give it a final rinse. But this method isn't always available. A commercial rope washer has parallel brushes that wrap around the rope and slide along its length. This can be a time saver compared to using a conventional hand brush…

If none of these devices are available (as in the field, for example) you should at least soak the rope, running it back and forth between your gloved hands to help eliminate the larger mud deposits.

Some may be tempted to use a high-pressure hose for washing ropes – don't do it! High water pressure will literally embed the calcite crystals and other dirt particles into the rope core, where they will remain forever, slowly and insidiously cutting away at the tiny fibers… A kind of sly laziness may lead some to wash their ropes in an old washing machine (using the wife's brand new machine could lead to some unnecessary domestic troubles...). They will come out brilliant, but do not use detergent. If anything, a bit of mild soap will do, and always wash at a low temperature. Make sure to place the rope in loose and uncoiled.

Wash time is also the best time to check the condition of your rope. Since it must pass entirely through your hands, it will be easy to detect any alterations in the state of the sheath. Immediately place a knot at any damaged spot, and cut the rope there as soon as it has dried. Check the condition of the core by making consecutive bights of about 50 cm along lengths of the rope, held with both hands: the curving radius should always be regular. Any discontinuity in the curve indicates damage to the core. Again, cut the rope at this point. Change the labeling and stock file accordingly.

Coiling the rope

Properly coiling the rope is an important prerequisite for convenience later on, and it is easy to do. Start with the rope spread out in layered lengths on the ground. Standing next to the pile, hold the rope with left hand at about one meter from its end. Allow the long bit to run through the right hand while the left and right arms move in an arc in opposite directions in front of the body. When the arms are at their farthest point from each other, grip the rope with the right hand and bring the arms back together. Transfer the rope to the left hand, creating the first coil loop. Move the hands apart again, the right hand allowing the rope to slide through it, pulled by the left. The longer the rope, the longer the coil loops should be, limiting their number since the hand can only stretch so much. To lengthen each coil, simply begin with longer arcs between the arms. If the rope is too long, stop and undo two of the coils, place the already coiled section on the ground, and begin a new coil with the other end of the rope. The two can then be joined as one. This is known to some as a butterfly coil.

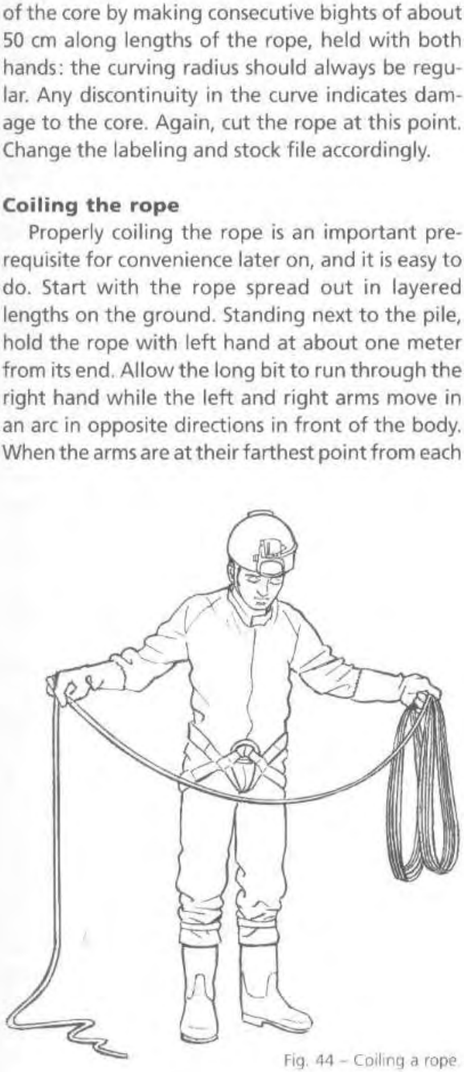


Fig. 44 – Coiling a rope

Fig. 45 – Topping off a butterfly coil.

Key points:

If you bring the rope to your left hand on the thumb side and bring it around to your small finger as you take it away (or vice versa), the rope will twist, especially if it's stiff. Always place the rope back on the same side of your hand as where it left, and invert it by twisting your wrist. The first loop enters and leaves your hand on the thumb side, the second loop enters and leaves on the opposite side, and so on (fig. 44). This should keep the rope from twisting. When you have about two or three meters of rope left to coil, stop. Holding the coiled rope with the left hand, use the right hand to bind it, wrapping a few turns of rope around the top quarter of the coil. If the coil is larger, wrap it a few more times. When you have only about a meter of rope left, finish it off by placing a bight in the loop made above the binding. Bring it over the loop and back down, and tighten it by pulling on the free end of the rope (fig. 45).

This way of coiling the rope makes it very easy to handle while at the same time preventing it from coming undone when held either by the top loop or the bottom strands. To undo the binding, just take out the bight and pull on the free end of the rope. The other end of the rope should hang about 30 to 40 cm beyond the loops. This will be useful in the event you need to throw the rope down a pitch later (though this is a rare practice since we generally pack our ropes in their rope bags). The end of the rope (along with its obligatory end knot) won't pass back through one of the loops as it falls, forming an accidental knot in the rope.

Coil dynamic rope (used double) the same way, except make two separately bound coils starting from the middle, working out to each end. At the end of the process, you are left with two identical coils linked by short bit of rope that acts as a convenient handle for carrying; it is also ready to be rigged for a rappel.

Shorter ropes (5-10 meters) can be wound about the elbow and the crux of the thumb, then finished off as above; with even shorter ropes, simply loop them a few times and tie a knot around their middle.

Storage

Ropes should be stored in a cool, dark place, as in a basement or in a closed drum or opaque rope packs. Caves are of course the prototypical cool, dark places, and you can store your ropes in them as well without fear of damage, as long as they don't stay there too long (see page 61) and are left well out of potential flood zones.

Rope life and drop tests

Ropes age and lose their strength gradually with time, regardless of whether they are subjected to any particular shock or wear – and even if they never leave their original packaging! This aging results from the slow degradation of the polymer chains that make up the fibers. But as mere amateurs, we can only guess as to the hidden mysteries of organic chemistry... In any case, this is why manufacturers specify an average life expectancy for their ropes, given normal use. As they surely don't want to be held responsible in the event of an accident, they tend to specify the minimum: from three to five years. These numbers are not so unrealistic: tests have shown that in five years, a new, unused 9-mm rope will lose 40% of its strength. For 8-mm ropes, the loss converts to 50% in only three years. Keep a close and constant eye on thinner ropes.

If you intend to continue using a rope in safety beyond its recommended life, it is absolutely imperative to know its real strength. There is only one way of knowing this: by performing a drop-test using an 80-kg metal weight, or "dummy." This represents the average caver in a factor 1 fall. While manufacturer tests use 100-kg weights according to the standard, 80 kg is sufficient for this kind of test since the weight is entirely inelastic. It is less shock absorbing than the human body, which will be held to the rope by a caving harness. The test doesn't require much technical skill, but it does require some work and must be performed with strict adherence to the guidelines.

Use a permanent anchor set in good, solid rock above an overhang. After soaking it in water, attach a section of rope measuring about one meter, not including the attachment knots at each end; expect to use about 1.5 meters total for each section tested. Use 10- to 12-mm oval maillons. Attach a doubled or quadrupled cord loop to the weight tied to the end of the auxiliary rope, which is arranged into a simple haul system, or passed through an upper pulley and pulled by a vehicle. Attach the weight to the lower loop of the rope being tested and then loosen tension on the auxiliary rope to check that the knots on the test rope are set (these are figure eight's for 9-mm or thicker rope and figure nine's for thinner). Leave at least two meters between the weight and the ground: stretch from the shock force can be significant. Tension the rope again and raise the weight straight up to the level of the lower anchor, avoiding any lateral displacement that will cause the weight to swing. Cut the cord loop using a knife or box-cutter attached to the end of a pole; this will result in a factor 1 fall (see fig. 46). Ropes considered to be sufficiently strong will withstand at least two successive factor-one falls before breaking. One fall is sufficient if the test is confirmed with a second section of the same rope being drop-tested.

A drop-test should be performed once a year after five years for 10-mm or thicker ropes, after four years for 9-mm ropes, and after three years for 8-mm ropes.

If you do not test your ropes, follow the manufacturer recommendations: attempting to prolong the life of your ropes could very well reduce your own.

Retiring your rope

Whether it is the result of age or wear, a rope must be retired permanently, leaving no confusion as to its eventual use as a lifeline. It should be physically removed from the caving ropes store and sent to the landfill, or moved to wherever you keep your digging ropes. In the latter case, dip it in some paint to avoid any confusion as to its use, before storing it in its new home. Use water-based paint to avoid further damage to the rope.

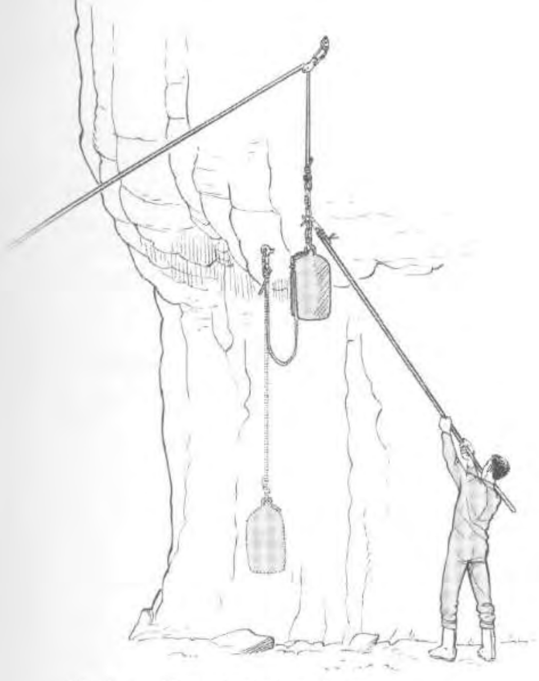


Fig. 46 – Installing a drop-test mechanism.

To start, let's go over a few terms:

A **bight** is a section of rope that almost forms a loop, but remains open; inversely, a **loop** is closed, basically a bight that has been turned over on itself. The same knot can often be tied in several different ways. Choose your favorite method, opting for the simplest and most easy to remember, which will also make it more habit-forming. In some cases, we can only make the knot by manipulating the free end (or slack end) little by little. Once the knot is made, the free end should be at least 10 cm long, to ensure that the knot does not come undone after tightening down or slipping.

Fig. 47 – Bight and loop.

3. Knots

Aside from doing pull-down traverses from one entrance to another (unfortunately rare for us), you cannot use a rope underground without using at least one attachment knot. As we have mentioned, simply placing a knot in the rope before loading it will reduce its strength and, apart from the case of localized damage, the rope will always break at the knot. This weakness varies from 30 to 50 %, according to the kind of knot used. In any case, these numbers are far from negligible, so the standards for static ropes include a minimal strength specification with a knot.

A good knot is versatile, easy to tie and untie, and does not severely reduce the rope's strength. This knot in fact exists: the figure eight, our most basic caving knot, which every caver should know how to tie perfectly with his eyes closed. It must also be dressed properly, which will make it more compact... and prettier! It can be tied for use in many situations, but it cannot be used to do everything, Sometimes caving requires additional, more specialized knots. Learning to tie knots requires a lot of hands-on practice, which can often be more amusing than tedious. Such practice sessions are indispensable and have the added advantage of letting the reader rest his eyes...

We classify our knots into the following categories:

3.1 Anchor Knots for Use on an Open Attachment Point

The loop above the knot is attached to carabiners, maillons, stalagmites, or boulders (choose only those that are strong, stable and fixed!).

3.1.1 Anchoring to a single point

This is the most common use. The simplest knots suffice.

- **Overhand loop**, or overhand on a bight: this is the most compact, but also harder to untie.

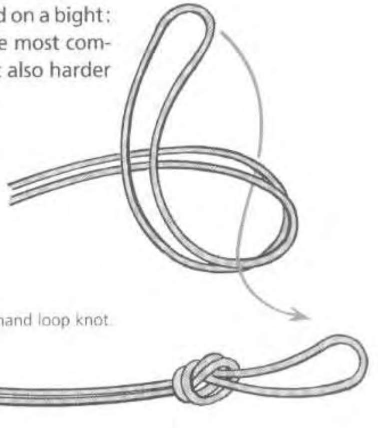


Fig. 48 – Overhand loop knot.

- **Figure eight** loop, the most basic knot used in caving, suitable for all rope diameters 9-mm and higher.

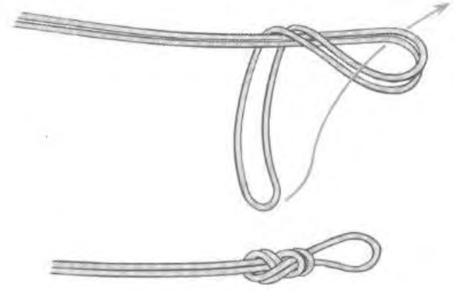


Fig. 49 – Figure eight loop.

- **Figure nine** loop: stronger than the figure eight, but this may not be an essential advantage. With a shock load, mechanical devices used to move on the rope will damage the sheath at a lower value (about 4 kN) than the residual strength of a knotted rope. The figure nine is also bulkier since it is made using an additional half-turn in the rope. To compensate, it is also a bit easier to untie on smaller rope diameters. As with the figure eight, always make sure the knot is compact and well dressed.

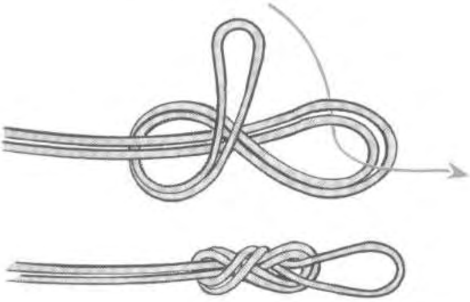


Fig. 50 – Figure nine loop.

- **Bowline**:
  1. Make a loop in the rope and pass a bight through it on the attached side.
  2. Place the free end in the loop.
  3. Retract the loop by pulling on the attached side, making the knot.
     The attached end should exit by the eye of the bight, the slack end should exit on the inside of the knot (otherwise, bring the slack end through the bight on the other side).
  4. Add a stopper knot for safety. Instead of a classic overhand knot (figure 51), use a double sliding knot (half-double fisherman's) which is more secure (fig. 63) or better yet, make a Yosemite bowline, which threads the rope back through the knot, leaving the bowline loop totally free (fig. 52).

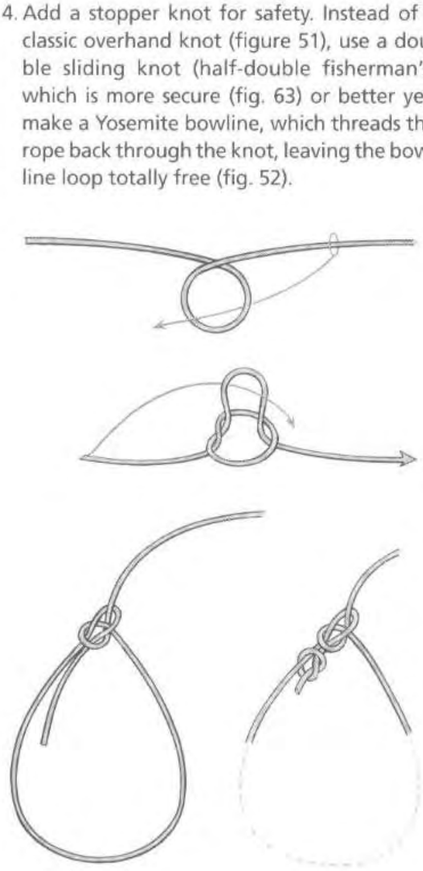


Fig. 51 – Bowline backed up with an overhand knot.

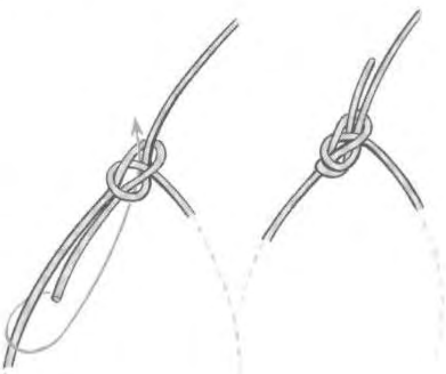


Fig. 52 – Yosemite Bowline.

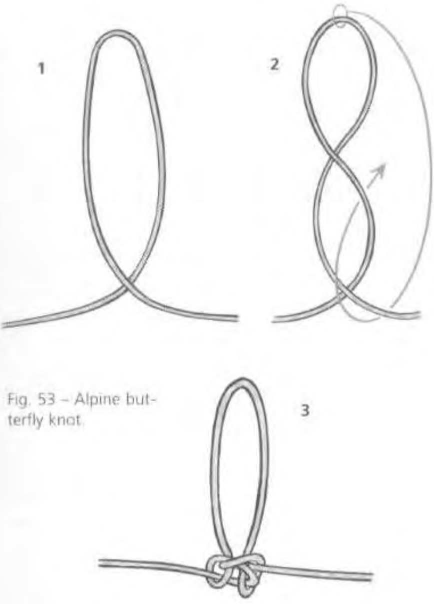


Fig. 53 – Alpine butterfly knot.

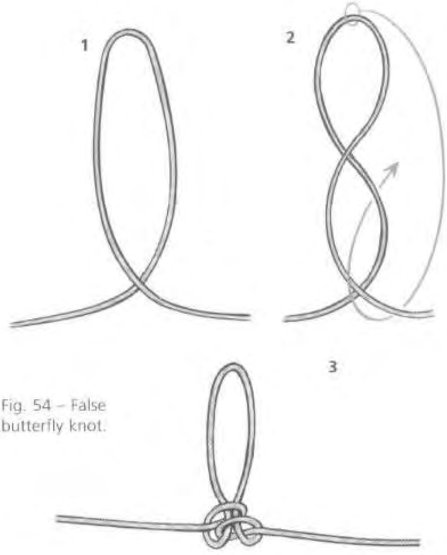


Fig. 54 – False butterfly knot.

- **Butterfly knot**: This allows you to make a perpendicular loop in the rope. It is perfect for traverse lines, some anchors, shortening a rope sling, and for isolating a damaged section of rope.

Key points:

Two kinds of butterfly knots exist: the true Alpine butterfly and the false butterfly. These should not be confused. The false butterfly is made when the same end is passed twice over the other end; the Alpine butterfly is made when each end passes once over the other end and once under it. (compare the second phase in figures 53 and 54). The false butterfly will slip much easier and it is recommended for different use: it is ideal as a shock absorbing knot.

The Alpine butterfly is really only useful as a midline knot.

- **Clove hitch** (fig. 72): this knot is also suitable for traverse lines but, while it makes it easier to regulate tension, this knot is hard to tighten down when used with stiff rope. In this case a butterfly is better.

All of these knots can be made in the middle of the rope as well as at the end, except the bowline, which must be doubled in the former case (fig. 59).

- **Polish knot**, or double lark's foot: This knot is rarely used but can be quite useful as a mid-rope knot, placed directly in a carabiner. Compared to a girth hitch, it has an extra bight around the carabiner, preventing any slippage under the weight of the user. This isn't the case with a single girth hitch, which should not be used. The Polish knot is particularly convenient at rebelays because it is easy to adjust the slack in the rope.

Fig. 55 – Polish Knot.

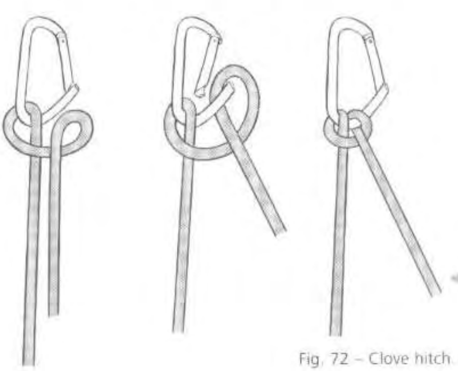


Fig. 72 – Clove hitch.

Fig. 56 – Double figure eight on a bight, or rabbit ear knot.

3.1.2 Anchoring to two or more points

We use Y-belays more and more, since they make it easier to rig free drops in meanders. Good load-sharing knots can be made with a **double figure eight on a bight** (a rabbit ear knot or a mickey knot; similar to a figure eight loop) or with a **double bowline on a bight**, made with a double rope and then finished off by bringing the rope over the two loops.

The double bowline on a bight is preferable to the double figure eight on a bight for four reasons. It is more compact, uses less rope, allows for easy adjustment between the two loops, and can be used for safety when passing a rebelay since it is easier to clip into both loops at the same time at the top of the knot.

Tips:

- When one of the two ears in the Y is much shorter than the other, you can save rope and make it easier to adjust the relative length of the ears by using a figure eight on the top anchor and a butterfly knot with an adjustable loop on the lower anchor.
- We rarely need to anchor to three fixed points, except in rescue situations (in which case, we use self-equalizing anchors). If you need to rig to three points, make a double bowline, with the original bight used as the third anchor loop.

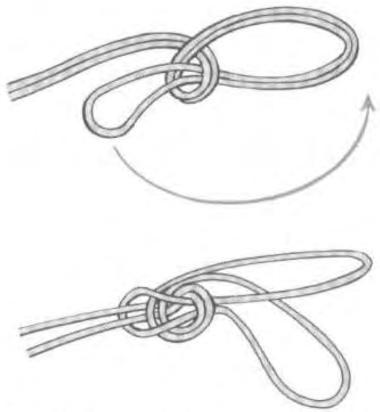


Fig. 57 – Double bowline on a bight.

3.2 Anchor Knots for Use on a Closed Attachment Point

We use these when attaching directly to anchor rings (such as the Star Fix, fig. 83) or natural anchors such as trees, flowstone columns, eyeholes, flakes and natural bridges.

3.2.1 End-line anchor knots

When the end of the rope is available, we can make all of the previous knots and then rethread the end through them. The best knots to use this way are either the rethreaded figure eight or rethreaded bowline; all other knots are more useful in boating and marine practice, and not optimal for caving.

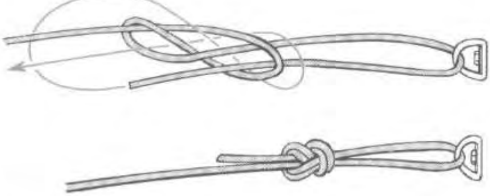


Fig. 58 – Rethreaded figure eight.

3.2.2 Mid-line anchor knots

On an anchor ring, a **double bowline on a bight** (fig. 57) or a **double figure eight on a bight** (fig. 56) are best. The first uses less rope and is easier to adjust.

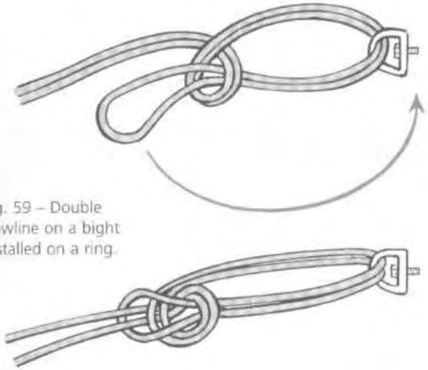


Fig. 59 – Double bowline on a bight installed on a ring.

A girth hitch alone (lark's foot; fig.60) should never be used, and backing it up with a figure eight is just a flimsy substitute for good rigging.

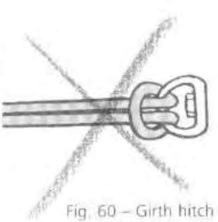


Fig. 60 – Girth hitch or lark's foot.

A **double bowline**, not to be confused with the double bowline on a bight, is perfect for rigging around a flowstone column or a tree – but it's only in the jungle that we encounter the need to rig to trees at mid-rope! If this knot is finished off with a Yosemite tie-off, we have a third loop that is aligned with the rope strands but opposite the two anchor loops. When using a Star Fix it is convenient to clip into this extra loop when passing the rebelay.

Fig. 61 – Double bowline.

3.3 Bends

3.3.1 Joining two ends

To join the ends of two ropes or make a closed loop, the most effective knot is the double fisherman's (or grapevine) knot. Easy to make and untie, it doesn't slip and it reduces rope strength less than any other knot. Only in the case of a pull-down rappel would you replace it with an overhand knot, which hangs up less on the rock when you are pulling the rope down.

Fig. 62 – Single Fisherman's knot.

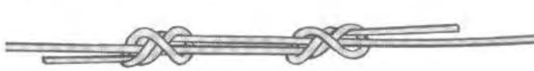


Fig. 63 – Double Fisherman's knot.

When you need to join two ropes in mid-pitch, a **triple figure eight** is best (fig. 65). Make a normal figure eight loop at the end of the top rope, and then make another figure eight by rethreading the upper end of the lower rope through this doubled knot.

Fig. 64 – Overhand knot installed on a pull-down rope.

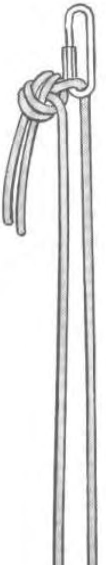


Fig. 65 – Triple figure eight.

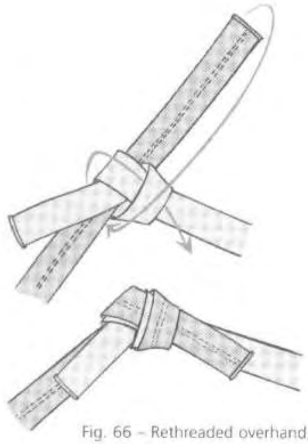


Fig. 66 – Rethreaded overhand, or tape knot.

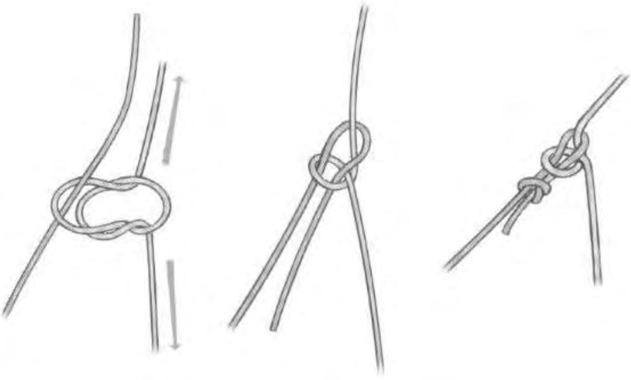


Fig. 67 – Sheet bend.

When joining webbing, the only really good knot is the simple rethreaded overhand, or **tape knot** (water knot, ring bend). Make a simple overhand knot at one end, then rethread the other end back through this knot, and set it by pulling all the elements taut.

3.3.2 Joining an end at mid-rope

This requires a **sheet bend** finished off with a simple stopper knot (fig. 67). When dressed, it resembles a bowline, and in fact is tied in much the same way, by drawing back on a loop. Likewise, it is finished with a barrel knot, or a Yosemite tie-off.

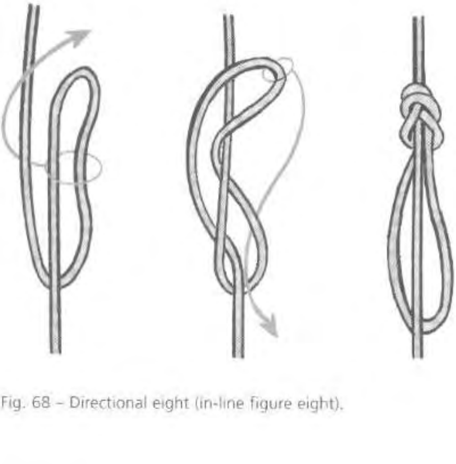


Fig. 68 – Directional eight (in-line figure eight).

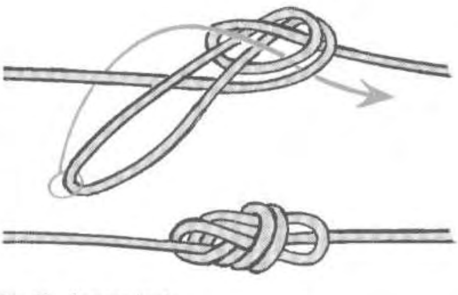


Fig. 69 – Romano knot.

3.4 Placing a Loop at Mid-rope

If you need to make a loop for use as a pulling point or for clipping in a cowstail, the **directional figure eight** (fig. 68) and the **Romano knot** (fig. 69) are useful (the latter is like the directional eight, but is a bit more complicated and begins with a half-hitch).

If you need to isolate a damaged section of rope, the best knot to use is the Alpine butterfly (fig. 53).

Note that none of these knots should be used to place a loop at a rebelay.

3.5 Belay and Self-belay Knots

3.5.1 Belaying on ascent or descent

To belay a climbing partner from above in such a way that he may go back down, use a Münter hitch (Italian hitch). When you take up the slack left by

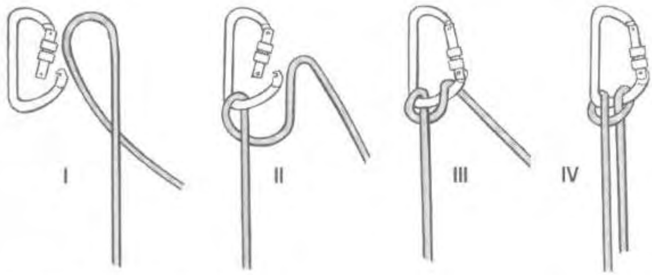


Fig. 70 – Italian or Münter hitch.

Fig. 71 – Italian hitch backed up with a mule knot.

your partner's progress, the hitch turns around the carabiner (phase IV, fig. 70). The left hand holds the two sections of rope against each other, and the right hand takes up the slack. If the climber falls, the hitch will return to its original configuration (phase III, fig. 70), and the left hand will increase pressure on the two ropes, temporarily stopping them. If necessary, you may also temporarily block the rope by placing a reversible mule knot under your left hand (fig. 71). This additional knot is easy to tie with one hand, the right in this case. It is an overhand on a bight; the bight may be secured with a carabiner if the mule knot must be left in place for a while.

When supervising novices, the Münter hitch also allows the instructor to safeguard a rappelling student from above, and to completely immobilize him if necessary using the mule knot.

3.5.2 Self-belay

For self-belay to a fixed point, when climbing for example, use a clove hitch (fig. 72). This is the knot that the lead climber makes as soon as he arrives at the first relay.

3.6 Pull-down (Remote Release) Knots

When de-rigging a climb from below, you need to pull down the rope after the last caver has rappelled. If this person does a classic rappel on a double rope, the rope used is twice the length of the pitch, or two ropes are tied together with an overhand knot. Be sure both ends are of equal length!

If the last person down descends on a single rope, he must be sure to distinguish between the descent side and the maneuvering side that will be used to pull down the rope.

There are several methods for pulling down the rope.

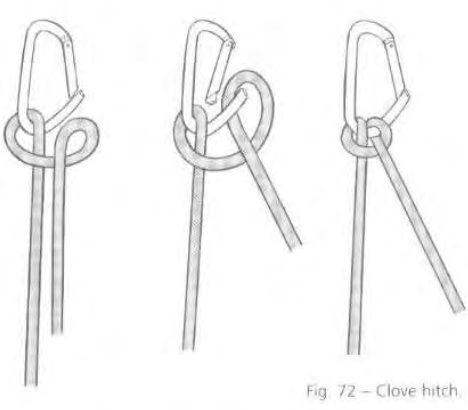


Fig. 72 – Clove hitch.

In the first, someone must belay from below, with a simple loop attached to his harness maillon. The other two methods allow the person de-rigging to remain autonomous. He ties the rope around a strong natural anchor (such as a sturdy stalagmite) using a **slipped bowline** (fig. 302) or a **daisy-chain slip knot** (trompe-la-mort; fig. 301). These can be undone by simply pulling on the maneuvering side once the last person is down. Of course, you still need a rope that is double the length of the pitch. If you plan to leave behind an entire bolt assembly complete with hanger and maillon, place an overhand knot just behind the maillon, where it will stay blocked (fig. 64). Once below, pull down the rope from the opposite side. In the latter method, the maneuvering side may be made with a smaller cord.

If you wish to leave a doubled cord in place for future access, see "cord techniques" in the section on rigging (page 215).

3.7 Belay/Blocking Knots

There are several knots that allow you to take up the slack on a loaded rope and then leave the rope blocked for some time. The **heart knot (noeud en coeur; garda hitch** in U.S.) is the easiest to tie. We first conceived and introduced this knot in 1972 while preparing the first edition of this book. The idea is quite simple: it consists of pinching the slack rope between two carabiners, underneath the loaded end to prevent slippage.

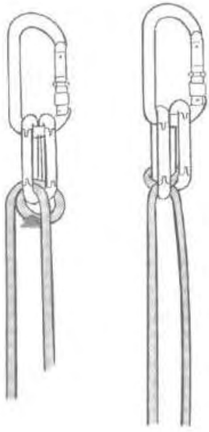
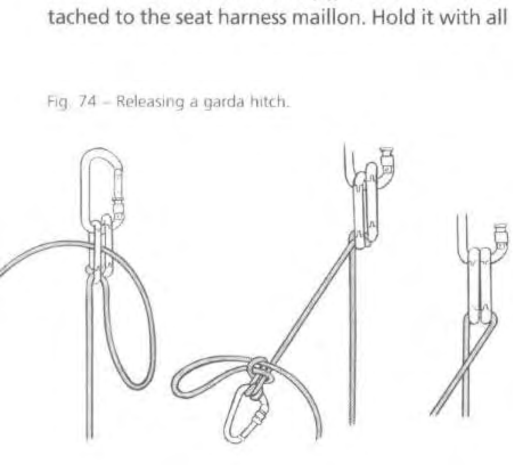


Fig. 73 – Garda hitch/ heart knot

The carabiners should be asymmetric (non-oval) and they should sit side-by-side in a third carabiner with their gate openings to the bottom. Pass the loaded end of the rope through both, then pass the rope again through the first carabiner only. Push the rope back (according to the arrow in fig. 73) so as to position it around the long axes of both carabiners.

To unblock this knot, pass the slack end back through the first carabiner (a). This is easier to do if the long arms of the carabiners have a triangular cross-section (like the Spirit) since there is more space between the two carabiners through which to pass the rope (B. Ballarin, pg. 77). Place a Münter (Italian) hitch backed up with a mule knot in the slack end (b), on a carabiner attached to the seat harness maillon. Hold it with all of your body weight, giving the necessary slack to the loaded side, and the heart knot will release itself (c). Undo the mule knot by pulling on the free end, then use a classic belay on the Italian hitch for the rest of the descent.

Fig. 74 – Releasing a garda hitch.



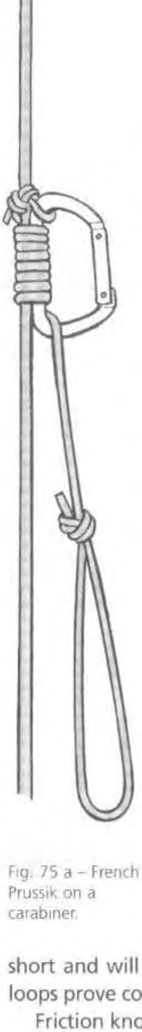


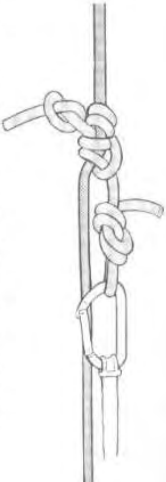
Fig. 75 a – French Prussik on a carabiner.

A similar mechanism can be achieved with an auto-lock descender.

3.8 Friction Knots

Friction (self-blocking) knots are used for climbing rope when we have lost or forgotten an ascender. The simplest is the **French prussik**, which can be tied directly with your footloop. Pass the upper end of the footloop into a carabiner, aligning the long arm with the rope before wrapping the footloop cord around the carabiner several times. The carabiner then serves as a handle and for balance. The long arm of the carabiner is held in the hand along with the rope and hitch. Since some of the length of the footloop is used to make this assembly, the footloop will end up short and will need to be readjusted. Adjustable loops prove convenient in this case.

Fig. 75 b – Blake knot.



Friction knots that do not use a carabiner rarely work well on a single rope. They tend to lock up under a load and are uncomfortable to hold and maneuver. All require some kind of additional cord with a diameter than is 1 to 2 mm smaller than that of the rope being used.

Let's also mention the **Blake knot** (or Blake's hitch), well-known among arborists, which has the advantage of working with the same diameter rope as the one it is wrapped around (and thus may be made from the latter if necessary), as well as with webbing. Also worth mentioning are the classic **prussik** and the **machard**: both are safe, but less effective since they are more difficult to untie.

More alternative climbing hitches and methods can be found in the section "Emergencies and Rescues." Some of these include:

- a **braid (plaited) hitch**, which can slide in both directions. Push it along with one hand, moving the bottom end toward the top to raise it and the top end downward to release it. It should not be used to climb down a taut rope: the only safe (albeit slow) way to do this is to down-climb on your ascenders;
- the maillon system, which is safe and effective, but which uses no knots and so has no place in the current discussion (see fig. 343, pg. 270).

Fig. 75 c – Braid knot.

3.9 Shock Absorbing Knots

A shock absorbing knot is an additional knot placed on the rope just below the anchor loop that can partially come undone when shock loaded. By doing so, it absorbs some of the energy generated in a fall and provides added safety. It is useful in three situations in particular:

- when rigging with smaller diameter ropes (below 8 mm) during first explorations or in some rescue situations. Such a knot will not prevent static failure if the cord is simply too thin, but it can delay dynamic failure in the event of a shock load.
- in the case of weak or suspect anchors, for example when placing a bolt in soft or fractured rock. In the event of an overload, this knot can delay the anchor's coming away due to wear in the hole or fracturing of the rock. In the latter case, it is not a matter of protecting the rope, but of limiting the shock load being transmitted to the rock and anchor.
- when two rebelays are less than three meters apart. An energy-absorbing knot placed under the upper anchor will reduce the eventual shock load transmitted to it if the lower anchor breaks.

As you may have guessed, good energy-absorbing knots make very bad anchor knots and vice versa. The best energy absorber is the false butterfly

Photo S. Caillault

(fig. 54), followed by the overhand knot (fig. 48). At a rebelay, we place these just above the anchor in the upper rebelay loop that helps facilitate a changeover.

4. Dynamic Ropes

4.1 Various types

These ropes are made to intercept more significant falls, so they are much more elastic than semi-static ropes.

We can choose "single" ropes with diameters ranging from 9.4 to 11 mm, or "double" ropes with diameters between 8.1 and 9 mm. Double ropes are used for rappelling in mountain climbing. When climbing, the rope is also doubled and the climber is belayed from both half-ropes, each of which is anchored independently.

"Twin" ropes are finer than double ropes, but they are always used doubled (the two strands pass through each anchor point rather than alternatively in one or the other, as is the case with double ropes). Twin ropes are also more flexible.

If we leave aside the very specific case of cowstails, dynamic ropes are very rarely used in caving practice, except to assure a caver doing a lead climb. For this use, a single or double rope may be used (see chapter on climbing in caves). Its length will depend on the height the climber intends to reach in a single climbing session, which in turn depends on the gear being used to climb.

The sheath on dynamic ropes is manufactured on a rotating loom with spindles on which the future sheath threads are spooled. Continuous back and forth movement of the spindles against each other create the cross-stitching of the sheath threads over the already prepared core that runs through the main chamber of the loom where the sheath is woven at high speed.

Looms may have 32, 40, or 48 spindles. The more spindles, the more cross-stitching we find in the sheath. The sheath is thus finer, tighter, and more abrasion resistant. It lets fewer foreign elements penetrate into the core, and the rope is above all more fluid and slips more easily into carabiners. For lead climbing in caves, we thus prefer the 48-carrier sheath dynamic rope (alas, more expensive since it takes longer to manufacture). Stretch for these ropes is about 7 %, under a weight of 80 kg.

The standard only requires that the year of manufacture be clearly marked on the rope; French manufacturers use a color thread in the core, as was the practice for semi-static ropes until 1997.

They also use the same color coding, which ends in gray for 1998, pink for 1999, black for 2000. So that this book can remain current for at least a few more years, the colors to come are: brown, red, orange, yellow, green, blue, purple, gray, and again pink in...2009!

Of course, a clear labeling under a retractable sheath is more useful than peeling off the sheath to get at the core...

Standard (EN 892):

Three types of dynamic ropes are defined according to their ability to arrest a falling climber, by using:

- a single strand: single ropes;
- two strands: double ropes;
- parallel pairs: twin ropes.

These ropes must meet the following requirements:

Standards for dynamic ropes	Single	Double	Twin
Core as % of total mass:	>50%	>50%	>50%
Knot Flexibility*	<1.1	<1.1	<1.1
Sheath slippage:	<40 mm	<40 mm	<40 mm
Stretch/elongation:	<8% (1 strand)	<10% (1 strand)	<8% (2 strands)
Max. Shock Load:	12 kN (1 strand)	8kN (1 strand)	12 (2 strands)
Min. number of FF2 falls held:	5	5	12
Elongation, shock load and no. falls measured with applied force of:	80 kg	55 kg	80 kg

(interior Ø of standard knot divided by nominal diameter of rope)

Maintenance:

- Since the standard now requires static ropes to have a white background with colored indicator threads, it is much easier to distinguish them from dynamic ropes. Lengths are labeled in the same way for both types or rope.
- To have a better feel for the movements of the lead climber, the rope (not too elastic) should stay soft so that it runs more easily through the belay points. This is why the small amount of dynamic ropes kept by clubs should be particularly well maintained, and always free of mud and dirt. Washing them in a washing machine is not a bad idea. As with static ropes, they should not be used as primary lifelines beyond about five years: their use may be less frequent, but it is even more demanding than that of static ropes, and conditions underground are more difficult than in normal outdoor climbing practice.

5. Cords, Webbing and Accessories

5.1 Cords

These are quite useful for a variety of applications, which will correspond to preferred diameters:

2-3 mm: connector cords for hammers, bolt wrenches and small items, and for cord pull-downs.

4 mm: cords for moving inflatable boats back and forth, preferably made of polypropylene, which floats.

5.5-6 mm: deviations, etriers, and footloops (Spectra or Kevlar), pack tethers (also polypropylene to make it easier to fish out a pack that has fallen into a pool);

7 mm: climbing footloops (in pre-stretched material), etriers;

8 mm: auxiliary cords for use as hand-lines on smaller climbs.

For all of these uses, choose cords made with a core and sheath, rather than twisted marine-style cords.

Standard (EN 564):

Cords used for climbing meet the requirements of the following specifications guaranteeing minimum strength according to diameter:

Nominal diameter (mm):	4	5	6	7	8
Min. breaking load (kN):	3.2	5.0	7.2	9.8	12.8

5.2 Webbing

Webbing slings are used as safety belays when climbing and to fix rigging on natural anchors. They are more effective for this use than cords because they have more contact surface area, they hold better and slip less. Slings should be at least 75 cm when laid out flat (i.e., made with 1.5 meters of webbing not including the knot); depending on their use, slings may be as long as 1.5 meters.

We differentiate flat webbing from tubular webbing. The latter is more convenient to use; because it is more flexible and easily knotted and tied. Knots made in webbing often slip, so use tape knots when tying them together or making slings (see fig. 66). Leave at least 10 cm at the free end. When making an attachment loop use an overhand knot, which in fact functions like a tape knot.

Nylon webbing slings are seeing more competition from slings made from Spectra cord. For the same strength, the latter are lighter and more compact and have a core that retains 70% of its nominal breaking strength even when the sheath is cut or damaged in use.

Standards for Webbing (EN 565):

The minimum breaking strength for webbing is 5 kN. Because of the wide variety of fibers used in manufacturing webbing, it is difficult to know their strength based solely on their width or thickness. For this reason, all webbing conforming to the standards carries a set of threads that contrast with the background color of the webbing. In Europe, these are coded for breaking strength. Each strand accounts for 5 kN: webbing with a breaking strength of 15 kN will have three parallel strands. This is the case for nylon or polyester webbing with a width of about 25 mm.

Webbing that has no coding must never be used in load bearing situations. Eliminate them entirely from your personal and group gear, and buy only webbing coded with three (15 kN) or more strands.

Standard for Sewn Slings (EN 566):

The minimum breaking strength is at least 22 kN. Tests are made on five separate samples, all of which must conform to this specification.

5.3 Rope Protectors

Rope protectors are only a shortsighted solution to the problem of rope rub. The fine art of proper SRT rigging makes it rare that one should need these. In mid-pitch, they may be used by the first down to temporarily protect the rope at a rub point, but they make for awkward passage and often do not stay in place as well as they should. Placing a deviation is by far preferable. During reconnaissance trips, to avoid complex rigging at a pitch where continuation is doubtful, simply fix an empty cave pack between the rope and rock.

6. Ladders

How to make and use cable ladders filled entire pages in the caving manuals of yesterday. But we can no longer justify this since we can now buy them ready-made, and they are rarely used outside of training situations, under the supervision of experienced instructors. These trainers know that a safety rope is indispensable: beyond a load of 3 kN, a rung can slide on the wire cables holding it!

In caving clubs, these are rarely used, except for short climbs where they may facilitate passage: climbs in otherwise horizontal cave, difficult vertical squeezes that require us to become as flat as possible, and especially muddy, slippery passages where there are no good holds. There is no real need to buy anything beyond 5-meter ladders; these can be joined together on that rare occasion when you need something longer.

Key points:

There is only one: ladders made of galvanized steel break without warning. Given the need for only short ladders, buy stainless steel instead. This costs just a bit more, but it's worth it, considering an extra safety rope is not always available. An added advantage is that this material can stay underground a long time without risk of damage.

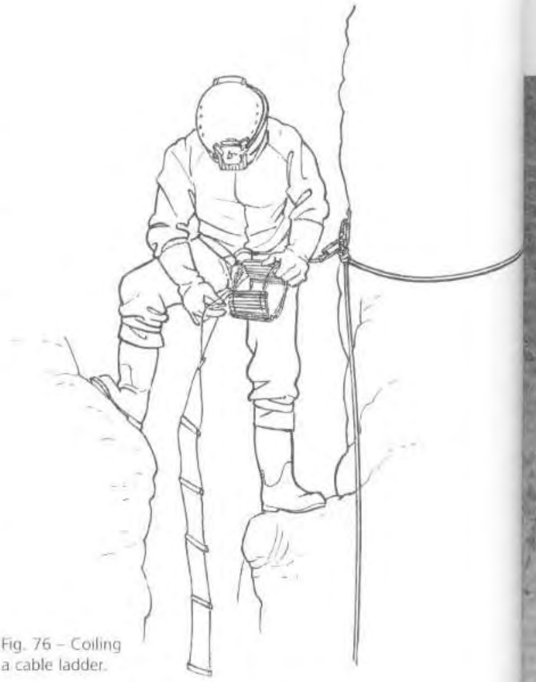
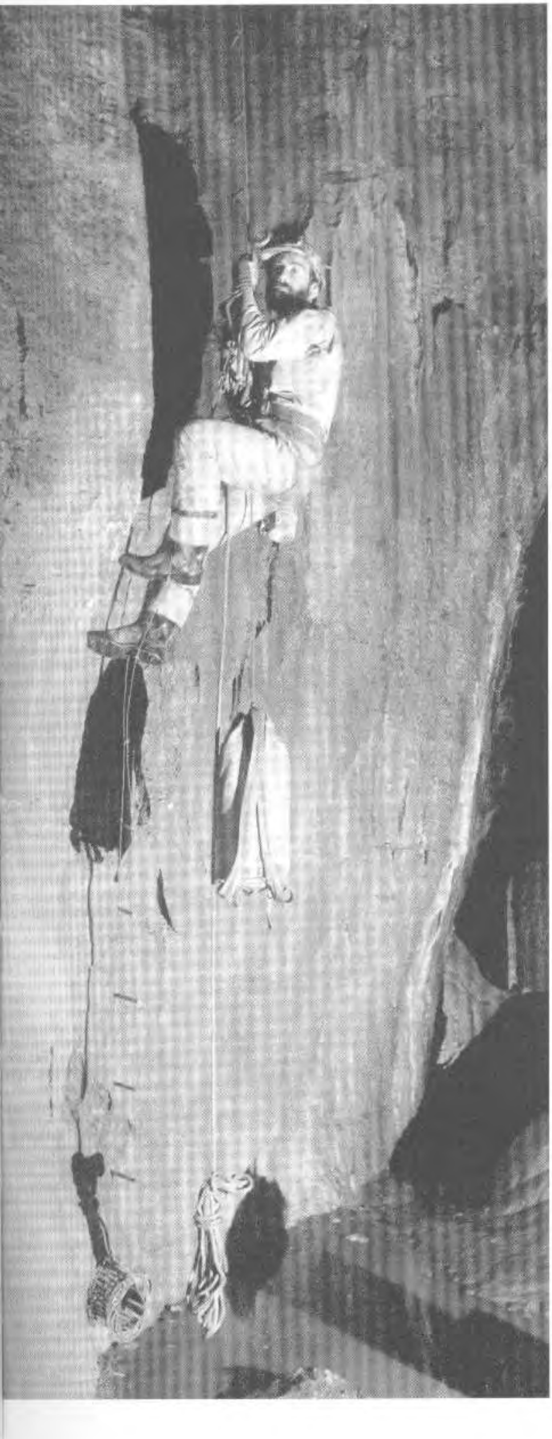


Fig. 76 – Coiling a cable ladder.

Tips:

- Proper technique for climbing a cable ladder is to step into the ladder rungs with the heel rather than the toes of the feet. Hold the ladder at face level, with the hands wrapped around the rungs on the opposite side of the ladder from the body. It is the climber's choice whether to climb with the same side hand and foot moving up, or by raising the opposite hand and foot at the same time. Look straight forward and not up, and breath in rhythm with your movements.
- We no longer use steel wires to connect ladders to natural anchors. Replace these with loops of webbing or rope. Rig with an oval carabiner connecting the two c-links at the end of the top rung.
- Coiling the ladder places less stress on the wire cables. Hold the end of the ladder with the left hand, the rest of it to be fed with the right hand. Coil the ladder about itself so that one complete circle uses two rungs. Keep the ends with their c-links (Italian rings) on the outside of the cables. When placing each rung, make sure to place the cables on the inside of the cables that have already been coiled. To do this correctly, you must twist the rung at an angle with the right hand and then place it over the already coiled bit held in the left. Place each rung in front of the last and inside the previous side cable. Finish by connecting the two c-links to each other at the end, inside the coiled ladder. Do the same with the c-links from the start of the ladder, linking them together outside the coiled ladder.



Sieben Hengste-Hohgant-System, Switzerland. Photo: U. Widmer

Maintenance:

Stainless steel only requires a rinse with high-pressure jet. If the rungs are caked with mud, use a brush. Stainless steel cable ladders can easily last ten years or more.

7. Hardware

Anything metallic used for rigging in a cave falls under this category.

7.1 Anchors: an Inventory

Since the 1960's, the remarkable qualities of 8-mm self-driving anchors (spits) have ensured a thirty-year reign in rigging practice (at least in France). Their effectiveness allowed us the comfort and security we needed before setting out on an exploration or visiting one of the great classics, since we were sure to find the cave rigged with our good old 8-mm anchors!

Well, times have changed somewhat, since motors and convenience have tended to take the place of biceps and hand drills. The equation is not as logical is it seems, considering the weight of battery powered drills and the risks of them breaking down...

Another problem has arisen with the wide variety of sizes, and therefore of wrenches, hangers and nuts needed to use with them, not to mention the incompatibility of some anchors with smaller carabiners and maillons. Will a caving tool kit soon become a "necessary evil" of caving? Of course, today's explorers have little to worry over, but what about their successors?

Aside from the occasional rigging difficulty, the anarchy that has begun to develop seems to favor redundancy: a caver who runs into an anchor that is incompatible with his own equipment will likely set his own anchors according to standard practice. Where, then, is the respect for the cave that we discussed in the foreword and first sections of this book, the minimum impact ethic that strictly limits our rigging to what is necessary for safety? If you wish to brush up on tour caving ethics, we suggest you refer to these sections.

There is another perverse effect related to our bolts: 8-mm self-driving anchors are made exclusively for caving. If the quantity sold lowers past the point of profitability, we risk losing our precious tool to the need for better profit margins...and what a loss!

So, it is past the time to act. From the beginning of this section, where we will review the range of anchors available today, we insist that bolting with 8-mm self-driving anchors should remain the rule for vertical rigging, and it is up to the individual's common sense and self-discipline to conform to these practices.

Other anchor devices should be reserved for very specific situations, where they will serve their purpose fully, without compromising the task of subsequent visitors or users.

Fig. 77 – Stainless steel caving hammer (left) and compact, light driver (right).

Exceptional use should be reserved for:

- bolt climbing: 6-mm bolts and 6-mm DBZ anchors (for progression; fig. 315) and 8-mm bolts for belays/runners
- permanently fixed rigging, which should remain an exceptional practice: 8-mm bolts with plate hangers, 8-mm Rainox expansion sleeves, and resin anchors. All hardware should be made of stainless steel.

7.2 Hammers and Drills

Hammers

The main role of the hammer is to set self-driving anchor sleeves. Caving hammers weigh about 600 grams and have a short handle made of either wood or steel with a rubber sheath. Hammers with wooden handles should not be left for long underground, as the wood absorbs moisture and rots easily. The head is made of steel; one end is pointed and used to clean the rock before setting the anchor. Some have a nose that acts as a lever for extracting pitons. The other end is square and used for hammering, as well as placing pitons. The head has an eyehole for attachment to a carabiner; this can be fixed to several carabiners when extracting pitons. The handle also has a hole for an attachment cord, and most steel models have a socket wrench at the end to fit 8-mm bolts. A mobile wristloop attached to the top of the handle provides more comfortable handling without the risk of dropping the hammer.

Drivers

The most common model has a metal body ending in an 8-mm threaded bolt, and fitted with a pivoting handle. This facilitates the rotation of the driver when drilling, even in the presence of clay. The driver is light (250 g), compact, and a favorite among cavers. Some users will prefer rubber-handled models with a wide rubber safeguard at the top end, to protect against those painfully misdirected hammer blows... If you are not confident in your agility when using the light model, wear your rubber glove on the hand holding the driver; this will reduce the risk of a nasty bruise. A wristloop also protects against loss of the driver. Some models come with a set of accessory bits for various uses: the installation of 10-mm anchors, drilling holes of various diameters for setting threaded bolts or compression pitons.

7.3 Self-driving Anchors

Cavers in Europe generally use only 8-mm self-driving (expansion bolt) anchors. Manufactured by Spit, a company located near Valence, these were first introduced in 1961 by the Valentinois Caving Group. Though its lost its capital "S," the term spit soon became synonymous with self-drilling anchors. For many years however, Spit advised against their use in caving, even declaring them hazardous on the box. It eventually gave up this stance in the wake of increased sales!

Fig. 78 – Self-driving anchor.

The self-drilling anchor consists of a hollow cylindrical sleeve made of hardened steel. One end has an interior thread that screws onto the bolt driver, and later takes the screw and hanger plate. The opposite end of the sleeve has a cutting surface with six teeth that act as a drill bit; this cuts the hole in the rock into which the sleeve and its cone will be placed (fig. 78). Here lies the advantage of the self-driving anchor, since a new drill bit is integral to each sleeve. When the hole is drilled, a cone-shaped metal wedge ("cone") is placed in the end of the anchor sleeve and the assembly is placed in the hole. When hammered in, the cone expands the sleeve in four sections inside the rock. Compression against the wall ensures an excellent hold in sound rock. A solid placement depends largely on the quality of the rock, and on that of the installation. If the rock crumbles under compression, (corroded limestone, for example), the hold will be uncertain: the sleeve will move about in the hole and eventually come out.

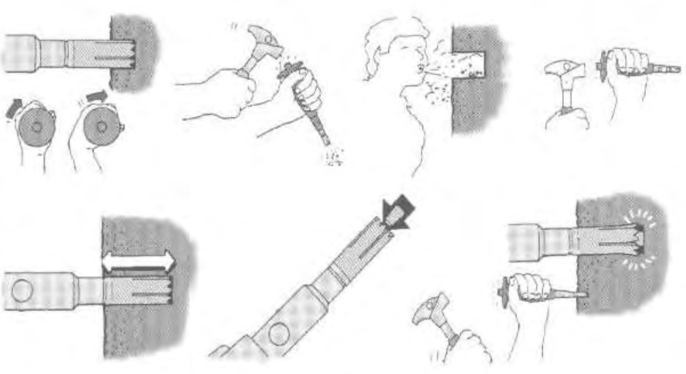


Fig. 79 – Steps for manually setting an anchor sleeve.

Hilti once sold a similar anchor but with use, its strength and durability proved much less satisfactory. These should not be used; more importantly, their cones should not be combined with other types of expansion sleeve, as they are different in shape and can lead to failure.

Placing an anchor by hand

Manually placing an anchor takes about ten minutes. Begin by choosing the correct placement: at the beginning of a traverse line, the backed up anchor point should provide easy and safe access to the drop; at the pitch head, the positioning of the rope must provide a perfectly free hang. Avoid anchoring to outcrops or irregular surfaces; look for rock that is part of a solid wall. Having chosen the location, use your hammer to check that the rock is sound and solid: hammering will render a high, clear tone. Clean the rock around the chosen area using the hammer point, removing a potentially loose top layer and any flakes or knobs that may come loose later. Make sure the surface is clean and flat before placing the sleeve.

Once you have verified that the rock is sound and solid, the strength and reliability of the anchor rests solely on its correct placement. Proper technique and attention to detail is absolutely essential. Inattention and improvisation have no place here.

Screw the sleeve completely onto the driver. Begin tapping gently so that the edges of the hole are not chipped; this provides maximum support for the anchor. The driver should remain perpendicular to the drilling surface: if the wall is vertical, the driver must remain horizontal at all times. After every two taps, turn the driver and sleeve clockwise about a quarter turn to multiply the points of impact, taking care to maintain the same perpendicular angle to the rock surface. Dust particles come away from the rock in the drill hole and accumulate there. Remove the sleeve frequently and blow out the rock dust from the hole. While the sleeve and driver are out of the hole, tap the driver two or three times to release the dust collected in the sleeve. Place the sleeve back in the hole and continue drilling. When the sleeve is drilled in about 5 mm, begin hammering harder, turning the driver more vigorously, but carefully holding the driver perpendicular to the rock surface: any alteration to the drilling axis will create an irregular hole that will provide a poor hold.

The sleeve will soon become flush with the hole; continue drilling about 2 mm into the hole. Blow out the hole one last time, then place the cone into the end of the sleeve and tap it lightly into place. Place the assembly into the hole and continue hammering so that the cone is pressed in between the hole and the sleeve, forcing the sleeve to expand over it. When the anchor is hammered in completely, it should be about flush with the rock. Unscrew the driver and screw the hanger plate into the anchor. If an irregularity in the rock prevents the plate from lying perfectly flat against the rock, this means the rock was not properly dressed. Do not try to smooth this down with the hammer! The rock is already weakened around the anchor and this could cause it to fracture. The best solution is to place another sleeve on the driver and use it like a miniature chisel: tap the driver lightly with the hammer at a 45-degree angle, removing the extra bit of rock. This meticulous operation takes some time, and it is better avoided with more careful dressing before the anchor placement.

An anchor placed correctly in sound rock has a static load bearing capacity of up to 18 kN in traction (loaded along the anchor axis, as a ring from a ceiling), and 16 kN in shear (loaded perpendicular to the bolt axis, as a plate hanger in a wall). These values can be reduced by a third if the placement is deficient, and fall significantly when the anchor is placed in bad rock.

Key points:

- Be sure to drill the anchor hole at a constant right angle to the rock face.
- Always turn the driver clockwise, otherwise the sleeve may partly unscrew, leaving the sleeve to sit incorrectly against the blocking nut on the driver. Blows from the hammer will irreversibly damage the thread on the driver stud.
- Drill to the correct depth. If the drill hole is too shallow, the anchor will not sit flush with the rock, placing much more stress on the anchor during use; this could result in it splitting along its length. A hole that is too deep will prevent the screw on the hanger plate from tightening down properly.
- Use the original manufacturer's cones that come with the anchor to ensure proper expansion.
- A sleeve that drills too easily or quickly into the rock indicates bad rock.
- Anchors placed in flowstone are less sound; their strength will depend entirely on the quality of the calcite. See previous point.

Tips:

- Try not to turn the driver a 1/6 or 1/3 turn, as the teeth will fall back into the holes cut by the previous tap. This leaves the spaces between undrilled and slows the overall operation.
- Blow the rock dust from the hole frequently, with eyes closed.
- Since you are trying to chip away at the rock rather than destroy it, tap with neat, sharp blows that are not too forceful.
- Don't place an anchor on a surface with running water. The pulverized rock forms a paste that cannot be removed from the drill hole and plugs the sleeve.
- Be sure to blow out the rock dust in the anchor sleeve frequently, otherwise the dust will become compacted inside the sleeve, requiring a wire tip cleaner for removal.

What NOT to do:

Do not over-tighten the hanger plate screw, as this could cause the screw head (and hanger) to snap off later when loaded.

Rendering an anchor unusable

If for any reason an anchor's strength or hold is in doubt, it must be made unusable for safety's sake. This is also the case with an anchor set in the wrong location: this will prevent less clear-sighted users from mistaking the right anchor for the wrong one.

There are several way of doing this, such as forcing a cone into the anchor hole, hammering down and destroying the outer threads, or filling the hole with clay. A more radical method would be to remove the anchor entirely. Unfortunately, we still lack the proper hardware to do this. This remains a challenge for the future.

Setting a self-driving anchor with a hammer drill

Bolting with a hammer drill also requires care and caution. The rock should be tested for soundness as when bolting manually (so you still need a hammer), and it must likewise be set at precisely the right depth. The drilling should be finished off with a manual driver so that the bottom of the hole is flat and the cone sits snugly against this, insuring proper expansion of the sleeve.

Stated differently: you must add the weight of the hammer drill to that of the hammer and driver! On the other hand, the Rainox Raumer expan-

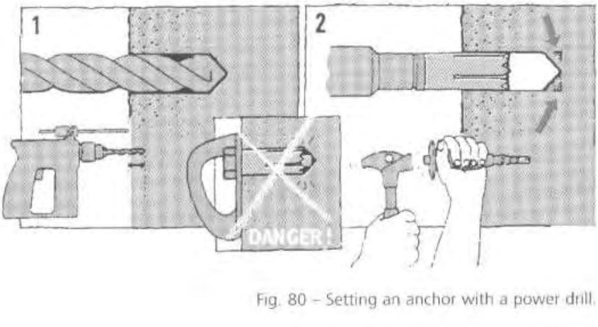


Fig. 80 – Setting an anchor with a power drill.

Photo Jürg Obendorf

sion bolt presents an interesting alternative. It is stainless steel and placed with a power drill, but does not require the final manual touch-up. The cone, which is captured in the sleeve, is manufactured to adapt to the configuration of the rock at the bottom of the drill hole.

7.4 Hammer Drills

Battery-powered models

When we have a number of anchors to set or holes of greater diameter or length to drill, using a manual driver can be very slow. This is especially true with aid climbs, in rescue operations, when setting eyebolts and when blasting. In these cases, a power drill is a precious luxury, but its use is justified. However, this still puts us a long way from using it in normal caving circumstances. Regardless of the influence of passing fads, keep in mind that a normal hammer and driver weigh only 800 grams, and you rarely lack the energy needed to use these. They are relatively inexpensive, very sturdy, compact and light, they do not break down, and water has no effect on their functioning. These are important advantages. On the other hand, the lightest available power drill weighs 2500 grams (remember to add 600 for the hammer you will need anyway to tap in the bolt). It is bulky, loses its charge rather rapidly, and requires special care in transport, including added protection and complete waterproofing. Finally, the first and most significant hole it makes will be the one in your pocket...

Power drills are available in 12, 24, and 36 volts. Avoid models that are not compatible with standard SDS+ drill bits, which largely dominate the market. Twenty-four and especially 36-volt drills are more powerful and the only ones we recommend for enlarging passages, where the holes to be drilled are much larger than anchor holes. On the best models, one fully charged battery of 2.5 ampere-hours (Ah) will give a total drilling capacity of about 180 cm for a 10-mm diameter hole. Twelve-volt 1.7 Ah models will generally only drill about 30 cm, or 40 cm for an 8-mm diameter hole. Such a marked difference is the result of several factors, the first being that effective drilling action naturally increases in proportion to the mass of the machine doing the drilling. If the machine's manufacturer wants to target users that can transport heavy loads, it won't hesitate to outfit the device with a suitably powerful battery, which sets it further apart from the smaller drills. But in bolt climbs, the notion of lightness prevails, as the idea is to drill as high as possible. Wearing the battery on a belt is advisable since the position is rather athletic, even with a 12-volt drill. Of course, the market is constantly evolving, and several models currently available seem well adapted to use in caving, such as: Hilti TE-6A 36-volt model, Bosch, Hilti TE5A and Spit 24-volt models, and finally the Hitachi and Metabo 12-volt models. The higher price of Hilti drill is justified by its pneumatic, rather than mechanical, drilling action. Drilling is more efficient and also wears less on the machine, thus extending its life.

Batteries

The same precautions apply here concerning nickel-cadmium batteries, which we discussed in the chapter on lighting (page 35). Many users complain about the rapid loss of charge, but this is because they use the battery to the very end, unaware that this also damages the battery. Only the most expensive models come with an automatic shut-off function that engages when the charge begins to drop. If you find yourself cut off without warning in the middle of an operation, at least you know that your battery has not been damaged. Fitting a shut-off mechanism to models that don't come with one is up to you and depends on your electronic competencies. But this could be an option in many clubs…

The cost of the original manufacturer's batteries is quite high, and then you still have to modify these for use on a waist belt or in a pack (although some top-of-the-line models have this option). From there, you also have the option of lead/acid gel batteries, which are less expensive and exist in many models. The use of a gel electrolyte reduces the risk of battery acid leaks.

Compared to nickel-cadmium, lead/acid has some drawbacks. It is heavier, but this is only a relative disadvantage, since you can divide up the load between several carriers. And since this battery is also worn on a waist belt, the added weight will not tire your arms during drilling. Lead/acid batteries don't have a flat discharge curve like nickel-cadmium batteries: the charge and power decrease steadily. To compensate, the final loss of charge is less abrupt, reducing the risk of inverting the battery's polarity. However, this does not cancel the possibility altogether. Again, there is nothing more detrimental to the life of the battery than draining it to the last drop; this is not a snifter of cognac. Lead batteries have a charge of 12 volts, but two may be connected in series if the machine demands it. Batteries with a 6.5 to 7 Ah capacity for under 2.5 kg are widely available; these are capable of drilling an 8-mm hole for about one meter (i.e., 20 bolts).

Finally, lead batteries must be charged slowly, with an intensity in amperes that remains below one-tenth of their capacity in ampere-hours.

Twelve-volt nickel-cadmium batteries can drill a dozen 8-mm bolt holes. The capacity of the same 24-volt batteries is double that, but so is the weight since the basic 1.5-volt elements are the same.

The better chargers can charge a battery in just one hour, and also allow rapid charge/discharge cycles to prevent the memory effect (see page 35).

Tips:

- Store your batteries in watertight containers fitted with a socket with triple contacts (to avoid plugging it in the wrong way) and a spring-loaded cover (to prevent mud from entering). Choose a model with a plug that is not compatible with 220-volt sockets, to avoid any possibility of ruining the battery.
- If the pitch being climbed is wet, use a waterproof protective sleeve with an opening at the bottom for the hand and fastened near the top of the drill with a rubber inner tube band close to the chuck.
- Modifying the drill to transfer the battery to a waist belt will nullify the guarantee. To avoid doing this, you have two options:
  - Make a dummy battery from a block of hard wood, fitted with contacts that are analogous to the original battery; solder the two conductors of a suitably sized cable to these contacts, leaving enough slack on the cable length to prevent any direct pull on the soldered points. Fit the opposite end of the cable with sturdy male connector that is easy to handle, for example those with a molded ring.
  - Find a dead battery, hollow it out, and fit it as described above.

Drill bits

To get the best possible performance from your power drill, choose good, effective bits. The price of bits can vary widely according to their quality. The price range for drill bits is directly related to their quality. A quality drill bit could be three times more than the cost of its counterpart in a normal hardware store. The type of steel, shape of the tip, length and number of flutes, angle of the twisted grooves, quality of the carbide plates or the grinding pattern for the cutting edge are important factors that will determine the total depth that can be drilled on one battery charge. The difference is important: you can drill up to 60% deeper with a top quality drill bit. Hilti twist drill bits with double helicoidal flutes and four cutting edges are the most expensive, but their performance surpasses that of any other drill bit. When you think of the cost of the twist drill, think also of the physical effort you will need just to reach the work area in the cave. Don't hesitate a second to choose the top of the line, especially for small and average diameters. A backup drill bit is also mandatory (in case of loss, a broken flute or carbide plate).

Fig. 81 – Double-fluted Hilti drill bit.

Fuel-powered models

Fuel-powered hammer drills are heavy and bulky, and should only be used when enlarging passage and placing permanent anchors. You can easily see the advantage of having a drilling capacity that is only limited to the amount of fuel you can carry below ground. Another advantage is that they can take either flat or pointed bits, which aids in clearing the surface after setting a charge. But beware! There's always a price to pay, and it can be high: these machines give off toxic gases carrying nitrogen oxide compounds, which are particularly harmful to breathe. While well-ventilated squeezes may exist here and there, most are confined.

Key points:

- Let's drive the nail in, so to speak: without exception, the use of fuel-powered drills is *strictly* limited to well-ventilated areas, and preferably where air is flowing into the cave. Otherwise, imagine the consequences: sudden loss of consciousness leading to an emergency rescue, followed by on-site intensive care and artificial resuscitation, and a prolonged hospital stay of a month or more – if you survive – involving painful headaches. Perhaps then you won't hesitate to go back to your trusty old hammer and chisel...
- Beware of potential explosions: when filling the fuel reservoir, all carbide lamps should obviously be extinguished!

Tips:

- Sawing off half the length of the carburetor intake can help protect this element from accidental bumps and blows, and make the machine more compact.
- Wash the starter cord with every use to remove the clay that gets imbedded inside, and replace this cord regularly. Having it break just when you want to drill can be a real pain!
- Gas motors can be very capricious. Bring along a small kit containing a spark plug wrench and the various tools you will need for on-site repairs.
- The fumes can be evacuated from the immediate area by replacing the exhaust pipe with a 20-cm copper tube attached to a few meters of hose. Evacuate to a well-ventilated area or toward a blowtorch that can reheat the gases. This modification will affect the performance of the motor slightly, but it will improve safety. Extreme care and caution is still imperative!

Handheld models

Hand drills are also available. Some models are self-contained, and others can be screwed onto a driver. Made of steel that is hardened dry, this tool is very brittle and should be handled with care and precision. Hammer neatly with sharp, regular blows straight on the axis, turning the driver each time. Don't hammer too hard; again, you only want to chip away at the rock, not obliterate it. Some models can be fitted directly with SDS + drill bits. These come from the United States, where the use of power drills is prohibited in the national parks. These bits should be carefully sharpened with a grinder before each use (a somewhat tedious operation). After purchase, grind down the carbide plate to about a 90-degree angle for better penetration.

Hand drills require practice to be used effectively; this is difficult to obtain if we are not bolting in caves on a regular basis.

7.5 Expansion Bolts

As soon as they hit the caving scene, expansion bolts were a remarkable success and their use underground coincides with the increased use of battery-powered drills. They cost less than self-driving anchors (hereafter, spits) and require little electrical energy to place since they have a smaller diameter. But the big craze over expansion bolts poses a problem with compatibility, as we have already mentioned.

Expansion bolts operate on a different principle than spits, since the spit shaft is female and the bolt is male. The bolt stem is solid rather than hollow, and thus threaded on the outside rather than the inside. Once in place, the hanger plate is placed directly on the stem sticking out of the wall and fastened with a nut. The hole is drilled to the diameter that corresponds to the bolt, but in this case the anchor does not rest at the back of the hole. Instead, an expansion clip with two opposing knobs helps block the bolt in the wall. This ring has a slit in one side, allowing it to move along the shaft between a stopper and the cone on the interior end of the bolt. In wet caves, use only stainless steel

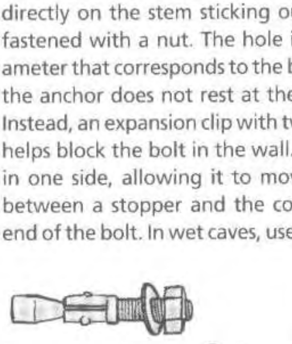


Fig. 82 – Classic expansion bolts, with a single clip for hard rock (top), and two clips for softer rock (bottom).

bolts. In drier caves, at least the clip should be made of stainless steel, since this alone guarantees the anchor's hold in the rock. Otherwise, it will quickly oxidize and break apart, causing the bolt to come out as soon as it's loaded. Unfortunately, many bolts have already been placed with steel rather than stainless clips, but we cannot tell the two apart. Don't trust a bolt that is already set without carefully inspecting and testing its hold first.

Placing the expansion bolt begins with drilling a hole that corresponds to its entire length. This may seem too long to some, but it in fact allows the bolt to be buried entirely in the rock if the bolt becomes dangerous (due to bad rock, corrosion, or incorrect placement), or ineffective (when permanent rigging is set later, for example).

Marking the correct drilling distance with paint or a stopper ring will save you from drilling too deep and wasting energy. The bolt is then placed in the hole, but since the expansion clip is a bit larger than the hole diameter, some hammering is required on the threaded outer end to get the bolt in the hole. Install the anchor plate, washer ring and nut (these may be assembled beforehand), and screw down the nut with a wrench. Doing this partially pulls out the bolt, but since the knobs hold it in place, the clip will expand over the end cone, locking down the assembly. The anchor is ready.

The same precautions are in order as when setting a spit:

- clean and dress the rock surface before bolting;
- drill at a right angle to the rock surface;
- drill the hole straight to avoid making an irregular hole;
- blow out the dust in the hole – eyes closed – when you finish drilling.

8-mm bolts are normally used in caving. In good rock, 50-mm lengths suffice for a holding strength of 10 kN. The minimum depth of the hole will thus be 40 mm (but 50 mm is better; see above). Note that the strength of a bolt is generally less than that of a spit (18 kN). A 10-mm bolt has a strength of up to 14 kN, depending on how it is set.

In softer rock, we use longer bolts for better anchoring in the rock. These bolts also have two expansion clips instead of one, which effectively doubles their holding strength. But even with these protections, the bolt is still not secure if placed in bad rock, and we can detect this when screwing the nut down on the bolt. More turns are required to tighten the nut and if the nut continues to screw down to the thread ends, then the placement is defective. Remove the anchor plate assembly and drive the bolt entirely into the rock to prevent accidental use by later visitors.

When climbing underground, you can alternate with two or three 6-mm, 35-mm long bolts for every 8-mm, 50-mm long bolt. In 25 MPA density concrete, the latter gives a 3.25 kN working load. Under the same conditions, 35-mm bolts alone have 1.4 kN pull out strength and 1.7 kN shear strength. This is again the *working* load and not the *breaking* load, which is five times higher.

Key points:

- Only use bolts having stainless steel expansion clips.
- Always test bolts that are already in place: partially unscrew the nut and tap the bolt lightly with a hammer, then replace the nut and screw it down. An oxidized steel clip will break during this operation. Take out the faulty bolt and replace it with a new one (with a stainless clip!). If the bolt won't come out of the rock, pound it in completely and drill a new hole.
- Drill deep enough so that the nut doesn't screw to the end of the threads before the cone finishes expanding.
- In stream passages, wet pitches, and when installing permanent rigging, always use stainless steel bolts.
- Since the expansion bolt tightens down against the walls of the drill hole, be careful to drill a hole that is consistent in diameter. To do this, hold the drill at a constant and correct angle.
- Choose bolts machined with rolled rather than cut threading; the former weakens the metal fibers less.
- Don't tighten down the nut too much. The risk of breakage is the same as that for the spit.
- Consider this performance test: after 30,000 cycles using a load of 2 kN – which corresponds to a typical climb on ascenders – a 10-mm stainless steel bolt and hanger will break, simply from fatigue. Its theoretical strength, however, is ten times higher. 30,000 test cycles correspond to only 200 climbs in a 100-meter pit, and in the well-traveled classics, such a number is easy to reach! By reducing the diameter to 8 mm, the stem shrinks from 8 to 6.5 mm, reducing its surface area and its strength by 34%.

Tips:

- When climbing, save time and reduce the risking of losing parts by assembling them beforehand. Install the washer, hanger plate, and nut on the bolt, in that order. The nut can be locked with a thread stopper or with some glue.
- You can place an extra washer between the plate and nut to prevent possible unscrewing.
- Always carry along extra replacement nuts.
- If you alternate between two bolt sizes (for fixed and belay points) when climbing, be sure to secure the corresponding drill bits so they don't fall to the bottom of the pitch. An easy way to do this is by inserting the cutting end of the bit into a piece of soft plastic tubing attached to a cord.

7.6 Wedge Bolts

Some anchors expand into the rock with direct hammering. Some bolts have a hollow body whose inside diameter becomes progressively smaller towards the inside of the rock. An attached stem is hammered in, forcing the body to expand. Choose only stainless since these bolts are intended for long-term installation (Wing Time, fig. 83).

The Star Fix can perhaps be placed in this category, though it is difficult to classify. It is in fact something between an eyebolt (resin anchor) and an expansion bolt. Its stem is fixed with a cone at the end, which works like that of a spit. The depth of the hole is thus critical. A power drill is used for drilling; a mark placed directly on the stem will serve as a depth gauge when drilling the hole.

The quality and strength of these anchors varies widely. Make sure to buy only anchors whose working load is much higher than your own weight! In terms of breaking strength, it should have a safety coefficient of at least five.

When placing compression bolts, follow the same ethical guidelines as those set out for eyebolts.

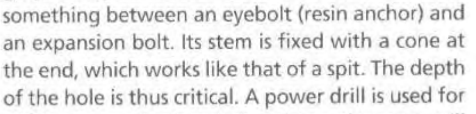


Fig. 83 – Compression bolts: Star Fix (left) and Wing Time (right).

7.7 Resin (Glue-in) Anchors

These have also seen their use increase along with that of the power drill. Installing a resin anchor also involves placing a metallic stem into a hole drilled in the rock, but in this case the anchor is fixed and sealed tight with cement/resin glue. Fixation occurs without placing any mechanical stress on the rock at the drill hole. These anchors can therefore be placed a bit closer to an edge, on bosses, or in softer rock (but don't go too far, use common sense).

Eyebolts

These are ideal for rigging in softer rock (provided the rock is sufficiently compact); here, they provide unparalleled strength. They are also recommended for use in especially wet areas (in waterfalls or riverways) since water cannot penetrate into the hole and corrode the stem, as well as long-term installations (such as traverses, for example). In the latter case especially, always choose stainless anchors.

Fig. 84 – Eyebolts: Collinox (top) and Superstar (bottom).

Eyebolts are either forged or welded. They are comprised of a stem that is destined to be buried in the rock, and a closed ring or eye (in rare cases, a hanger plate), which will sit right against the wall and serve as the anchor point. Forged anchors are more reliable – and more expensive – since they are made from a single piece of stainless steel. The less expensive variety is made from a metal stem that is bent into shape and then welded to itself. Some anchors have two stems, calling for two holes to be drilled in the rock. TIG-welded (under controlled atmosphere) eyebolts are best. The simplest resin anchors are made of cadmium or zinc plated steel that is then bichromate-treated to improve its durability. Since these anchors are generally for long-term fixtures, choose stainless (unfortunately twice as expensive!) whenever possible, even in relatively dry conditions.

The anchor alone has a strength of between 25 and 35 kN, but the cementing may limit this according to varying conditions. In general, the strength of a well-placed resin anchor should not be less than that of the anchor itself.

Since these anchors are meant for long term use, they require care and attention during installation. A badly placed anchor will permanently disfigure the surrounding rock so before placing the anchor, make sure you have chosen a solid location that insures a perfect positioning of the rigging.

For discussions concerning responsibility and respect for the cave environment, see chapters A and K.1.

Key points:

- Choose anchors with a rough stem surface (i.e., with grooves, threads, or scratches). This maximizes the surface area being cemented and improves their hold.
- Make sure the eyehole is large enough to take at least two normal carabiners.
- The eyehole on a resin anchor can work horizontally or vertically (if it is welded, the joint is placed on top in the latter case).
- In bad rock, install the bolt so that it takes only a shear load (the direction of pull is perpendicular to the bolt axis).

Tip:

You can place a permanent anchor using a stainless steel 10 x 200 mm screw, with the head retaining a stainless anchor plate (use the bent type, which holds the carabiner or maillon perpendicular to the wall).

Resin glues

All the resin glues we use have two components. Hardening is the result of a chemical reaction between these two liquid or pasty substances, which are mixed together before use. We use either cement glue such as Sika or small capsules containing a resin adhesive. Sika is not made for use underground, and requires about three days to harden at 20° C (68° F), or ten days at 10° C (50° F). During this time, the anchors must not be used (unless you intend to extract them!). Mixing the cement is a delicate operation: only mix the amount to be used immediately, using a palette and small container. These should be left behind – along with a note or other evidence of your activities – to ensure that the cement hardens completely before being used. Using cement glue only makes sense when you are placing a series of anchors, and is best performed with a glue gun fixed with a refillable reservoir.

We often use specialized resin glue capsules that are activated by hammering action. These glues set in just 20 minutes at 10 °C or higher, or 10 minutes at 20 °C or higher. A second advantage is that they come in individually prepared capsules. One glass or plastic capsule has two separate compartments: one side contains the reactants and some grains of quartz; the other contains the hardening agent. The capsule is inserted into the hole with the hardening agent side going last. The anchor is installed and hammered in, forcing the two agents to mix and react in the hole. Another kind of glue capsule contains the hardener in a small compartment inside the main one. This means you must crush the capsule in the hole with the anchor and rotate the rod to obtain a good mixture of the ingredients, one reason why this model has fallen from favor.

The strength of the resulting mortar is proportional to the amount of surface area that is saturated between the anchor and the wall. The glue mixture should fill the hole entirely until it overflows; you can then wipe off the excess glue. The hole should be drilled with precision according to the dimensions of the anchor, and a high quality glue should be used. Manufacturers normally specify drilling requirements and each diameter hole uses a corresponding capsule size.

First pitch of Rhino Rift, Somerset, Great Britain. Photo G. Newman

Nearly all of the resin anchors used in caving have a 10-mm diameter stem. A 12-mm hole is required to allow sufficient adhesive between the stem and the rock. Labeling on the glue packs corresponds to the anchor stem diameter, so in this case, M10. The packs remind us of the correct diameter to be drilled, since these are actually 10.5 mm wide and will not fit into a 10-mm hole – which would be the correct size for 8-mm stems.

Key points:

- Only install these anchors after a thorough assessment of the surrounding area.
- Choose glue capsules that are suitable for use in a humid environment (often having an epoxy base).
- Degrease the anchor stem beforehand with acetone or trichloroethylene.[12]
- Drilling at an angle, enlarge the hole opening with two opposing notches in the rock to help sink the base of the ring.
- Blow out the hole when drilling (eyes closed!): any dust will prevent proper saturation between the anchor and the wall. A wire brush, small blow tube or a toothbrush can be helpful.
- Sweep out the drill hole with a nylon brush or toothbrush and again blow it out.
- If you are not using a hammer-activated resin capsule, twist the anchor around at least ten times to thoroughly mix the adhesive.
- Do not load the anchor until the drying time is complete.
- An absence of glue overflow from the hole indicates a problem: the hole could be too deep or too large for the anchor, or the capsule may not have been set or broken correctly. In this case, take out the anchor, add another resin capsule, re-mix, and wipe off the excess glue.
- When using cement, leave highly visible signs at the site that an anchor was recently set; also leave a sign at the cave entrance that explicitly specifies the day and hour after which the anchors will be safe for use.
- Do not use hammer-activated resin capsule for placing ceiling anchors: the powdered hardening agent is at the top of the capsule and will fall, and the mixture tends to run out of the hole too quickly.

Tips:

- Transport resin capsules in a well-protected, rigid container and separate them carefully (with open-cell foam packing) to prevent them from being inadvertently smashed.
- Verify the expiration date on the resin capsule at the time of purchase and respect this indication, which varies according to the glue (one-year minimum).
- When placing ceiling anchors, block the anchor in the hole with a nail to prevent it from falling. To prevent the glue from running out of the hole, stop it with a rubber ring inner tube that can be made rigid by a washer cut from plastic. These can be removed when the glue has dried completely.

7.8 Screws

Screws make it possible to fix hanger plates onto their anchors, and usually come with commercial hangers, though not always. The type used depends on the anchor being used and why. It is therefore useful to know their characteristics to better separate them according to their use.

Material

There are an infinite number of steel types, and not all of them are appropriate for setting anchors in caves. Some types of steel can be too weak; others, dry tempered when plunged quickly into water to cool, are brittle (short). The European standard fortunately requires that the characteristics of the alloy be marked clearly on the head of the screw: 8.8 is the number required, and this alone. This corresponds to a steel alloy with a breaking strength of 80 kg per mm^2. All stainless steel screws have sufficient strength. These are identified by an "A" on the head.

An M8, 8 x 125 steel screw (the last number designates the thread size) with a specification of 8.8 has a shear strength of 18 kN, which corresponds well to the hanger strength. The best length is 16 mm. For rings, which are thicker than hanger plates, we recommend 20 mm: using a 16-mm screw in this case (as sometimes occurs with repairs) reduces the breaking strength to a quarter.

Good commercial hanger plate/screw assemblies are developed so that the screw will fasten

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[12] The latter is hazardous to health and the environment, and little used in North America since the late 1980's.

the hanger plate right down against the wall when the screw has been set properly. With homemade models – fortunately rarer these days – and depending on the exact form of the screw and thickness of the hanger, the screw can end up stopping at the end of the anchor thread, leaving the plate to rotate freely. Such plates can be hazardous and should never be left in place. When we climb past the rebelay, the hanger, pulled via the rope by a particularly tenacious Croll, could turn upside down. Weighted in the wrong direction, it will almost surely break as the following person climbs up. See the chapter on ropes to find out about the immediate consequences of such an incident.

Of course, the shape of the anchor sleeve will prevent the screw from running into the anchor cone.

Tightening the screw

You will need a 13-mm hex wrench to tighten down the screw. Be careful: it is entirely possible that with a simple commercial flat wrench, you could strip or break an 8.8 screw by applying too much force. Even if you don't completely break it, any excessive tightening will ultimately compromise the internal strength of the screw. You can limit the tendency to apply too much force by shortening the handle of the wrench to under 10 cm. The choice of an open- or closed-ended wrench is up to you. Open-ended wrenches have the advantage of allowing you to unscrew stuck 7-mm anchor maillons. It's a good idea to drill a small hole in the handle for an attachment cord. Warning: if the wrench is of high quality, this operation will ruin your drill bits! Some caving hammers come with a socket wrench on the handle end, which is quite convenient, except of course when you're dealing with ring hangers.

After several successive uses, screws can start to work loose. Make it a habit to always check these and to tighten them down if you find any play.

Aging and wear

As with bolts (see previous section), screws also fatigue from repeated loading and unloading. Moreover, the threads wear and will eventually become stripped. Change them at least once during the life of the hangers that they are holding. Stainless screws are the strongest, but they cost twice as much.

7.9 Hanger Plates and Rings

Hanger plates have two holes: one for the connector that will hold the rope, and one for the screw. These are only installed on sloping or vertical walls and never on overhangs or ceilings, unless the shape of the hanger hole is specially designed for such use. It this case, the shape and position of the hole require that the connector be positioned close to the anchor axis, preventing this from pulling on the anchor. Clown and Minox hanger plates allow for ceiling installation.

There are two basic hanger shapes: bent and twisted (fig. 85). Bent hangers are generally more useful. They position both the upper rope loop and the attachment knot parallel to the rock face, which limits the possibility of abrasion to the rope at these two sensitive points. On the other hand, twisted hangers position them perpendicular to the rock face, which you would rather avoid.

So why do twisted hangers sell almost twice as much as bent hangers? It is simply psychological: not only do bent hangers flex slightly when loaded, they also load the anchor in tension, while the twisted variety doesn't bend and works in shear. The fears associated with these facts are entirely unfounded. Hanger plate flex remains largely within its elastic limit and, under a heavy load, the connector will end up against the wall long before the anchor is seriously threatened by the elevated traction (3 kN is enough for this, while the anchor can withstand 19). So there is absolutely no risk involved in using a bent hanger.

The bent hanger has a second advantage: we sometimes need to place a Y-belay (or Y-hang) between two walls. These load the hanger at an angle that, if too wide, tends to bend it and consequently stress the bolt or screw in tension. Since the bent hanger is already angled away from the wall, it has a special advantage in this situation: it allows us to rig at up to a 45-degree angle from the wall, which permits lower rigging and consumes less rope.

Twisted hangers have no particular advantages worth mentioning, aside from that they allow the possibility of placing an anchor just above an overhang. But in this case, you could just as well set a bent hanger a few centimeters higher. We strongly argue for bent hangers, which we think have been unjustly abandoned. They deserve to replace twisted hangers, but old prejudices die hard. We have already pleaded the case for bent hangers in the

Fig. 85 – Minox (left) and Clown (right) hanger plates.

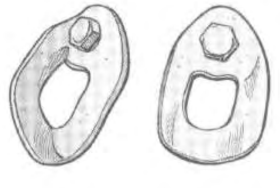

Fig. 86 – Twisted (left) and bent (right) hanger plates.

Fig. 87 – Bent plates hold the rope away from the wall and help reduce abrasion.

second edition of this book, nearly twenty years ago, but apparently to no avail! Such irrational fears will undoubtedly last into the twenty-first century...

Most hanger plates are manufactured from a light aluminum alloy (zicral), for obvious considerations of weight. These hangers should never be left for long in a moist environment. They will corrode as a result of an electrochemical reaction between two metals (with water acting as the electrolyte): the steel in the anchor, and the aluminum in the hanger. The aluminum oxidizes into alumina, a white powder that forms a translucent gel in the presence of water (this cannot occur under water due to the lack of oxygen). After a long period of disuse the hanger can corrode to the point of passing right over the head of the screw (and extracting) the moment it is loaded.

So in particularly humid caves, always use stainless steel hangers. Compact and relatively light models are available (54 g for the Minox, fig. 85, versus 30 g for an aluminum model). These are sometimes even less expensive than classic aluminum hangers.

The shape of the Clown hanger allows you to place a ceiling anchor and install the rope loop directly in the hanger without using a connector (fig. 88). This is the lightest anchor assembly on the market, but it unfortunately has some disadvantages. The Clown takes up a lot of space in the bolting kit. It is also easy to lose while de-rigging, is difficult to use with stiff rope, and requires a flat, even surface for anchoring.

Like Clown hangers, rings do not require a connector. Rings also have an eyehole into which the screw is placed (fig. 89). Recall that these must be installed with 20-mm screws, rather than the usual 16-mm screws for hanger plates. Ring anchors can be loaded in all directions; the only condition for their use is that they must never be loaded in shear. They are thus particularly useful for rigging on overhangs or ceilings.

Use only models manufactured specifically for use in caving. Rings designed for industrial use should not be used. Those with M8 threads are cast from a lower quality alloy, which harbors tiny imperfections that can ultimately cause them to break. Finally, their high leverage prevents them from being loaded in shear.

Hanger plates and rings can be used with expansion bolts as well as self-driving anchors. In the latter case, you will need a screw. To avoid losing this, it can be fitted with a simple rubber o-ring. Many manufacturers already provide these with the screw.

Key points:

- Remember not to tighten the screw too much when using an anchor sleeve, to avoid stripping the thread or breaking the head.
- Tightening down too hard on an expansion bolt will pull it out of poor rock.
- Classic rigging technique does not allow you to rig the rope directly into a hanger (except when using specific models such as the Clown). We will discuss this point later in the section on light rigging techniques.

Tip:

When leaving a full bolting kit for an extended period between explorations, store it in a watertight bag or container to limit the effects of corrosion between the steel and aluminum.

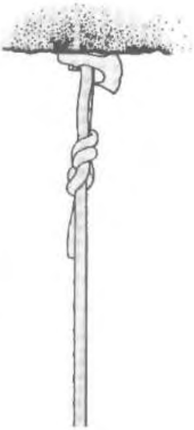

Fig. 88 – The Clown does not require a connector and can be used in a ceiling.

Fig. 89 – Hanger ring.

Standard:

Anchor assemblies are not considered PPEs and so do not require CE approval or labeling. However, they support the rigging in the same way as static ropes, which are subject to the standard. It's no use asking what kind of logic supports this doctrine...

There is, however, one standard (EN 959) that defines:

- minimal axial strength (pull along the axis of the bolt hole): 15 kN.
- minimal radial strength (shear loading along the radius of the bolt hole): 25 kN.

Maintenance:

- Label your hanger plates, using metal punches (stamps) in the center of the plate, away from the curving radius or edge.
- The only real enemy of plates and rings is corrosion. This relies on the presence of water and can be aggravated by mud, which is acidic. After washing and brushing these in clean water, store them in a dry place.
- Screws should be lightly greased on occasion, and their rubber o-rings replaced when broken. Replace screws that are rusty and those with damaged threads. If you follow these recommendations, the life of your hanger plates will be longer. They will only reach retirement age when the hole wears, after being accidentally bent during use...or after falling to the bottom of an impassable meander.

7.10 Pitons

Technology

Pitons are steel blades having various shapes and an eyehole, into which a carabiner is placed. They are hammered into fissures or cracks and used as quick belays or anchors. While pitons were once rather popular, their use has declined with the rise of bolt anchors. The reason for this is that they have two drawbacks: they can only be place in rock having some kind of fissure, and their hold is less certain. Despite all this, they can be very useful in some situations: in prospecting, as climbing aids, when pushing leads, and when setting deviations.

According to the alloy used to make them, there are three basic categories of pitons:

- soft steel pitons, which can bend to the shape of the cracks into which they are placed. They must be hammered back into shape after extraction;
- hard steel pitons, usually made of chrome-molybdene alloy, which retain their shape and stiffness as they are forced into the fissure. These can be identified by their darker color (soft pitons are lighter), and they are more durable than the previous models;
- semi-hard steel pitons, having intermediate characteristics, which have begun to take the place of soft pitons.

According to their shape, there are:

- Flat or vertical pitons, whose eyehole is on the same plane with the blade (Fig.90). These are used for very narrow cracks (less than 10 mm). Waved or double-bent pitons are a special type used only for larger fissures;

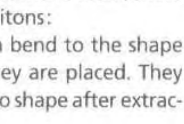

Fig. 90 – Flat piton.

- Horizontal pitons, with a lateral (L-piton) or central (T-piton) eyehole, both of which are perpendicular to the blade (fig. 91). These are also used for narrow cracks.

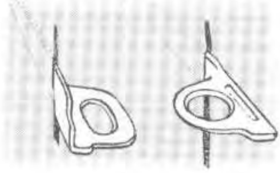

Fig. 91 – Horizontal pitons.

- U-pitons are special horizontal pitons with a lateral eyehole, and those in a V can be used like horizontal T-pitons (fig. 92). Both are used for larger fissures (more than 10 mm).
- Universal pitons have the eyehole at a 45-degree angle relative to the blade (fig. 93).

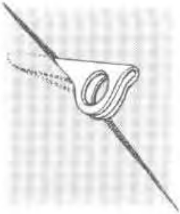

Fig. 92 – V-piton.

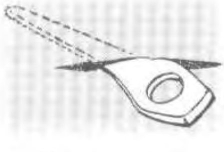

Fig. 93 – Universal piton.

Vertical, horizontal, and universal pitons are all "blade" pitons. These are the most frequently used models since they are the only possible aids for use in narrow cracks; pitons used for larger cracks have serious competition from chocks (mechanical or non-mechanical camming devices).

Ring pitons, which fit into the category of horizontal T-pitons, are not strong and are not used in caving activities. The rope should never be passed directly through the piton's eyehole; neither is it very convenient to thread them on a rope like a string of pearls!

Each shape has variable lengths and widths, chosen according to differing fissure configurations.

Placement and hold

You can ensure a proper hold in the following two ways:

- by applying direct pressure on the sides of the crack. This is only the case for a horizontal T-piton placed in a horizontal crack.
- more generally by making a twist that will jam the piton into the fissure and hold it there. The rule is simple: once the piton is in place, the plane of the eyehole should never be vertical, with one exception: you can place a horizontal piton with a lateral eye in a horizontal crack and it will hold quite well.

Remember that horizontal and universal pitons can fit into all cracks with one obvious exception: the universal piton cannot be placed in a sloping fissure with its eyehole sitting vertically. Vertical pitons, on the other hand, cannot be placed in vertical cracks. The table in fig. 94 illustrates these rules.

To summarize, carry horizontal pitons with a lateral eye since they can be placed anywhere, L-types for narrow cracks or U-types for larger cracks.

Once you have chosen the appropriate model, the piton is placed manually into the crack and then hammered in with successively harder blows. As it goes in, the free end of the shaft disappears and vibrates differently with each blow, creating a ring of increasingly higher pitch: this high ring indicates a correct placement. It will otherwise produce a lower, hollow ring if it is too narrow and not sufficiently gripped in the crack.

Removing the piton

When you de-rig a passage, you should attempt to recover the pitons as well. Extracting a well-set piton is no easy task; if you had a long, hard time setting it for a perfect hold, you'll likely spend at least as much effort getting the thing out. Hammering it alternately on both sides will often loosen it little by little. Be careful of knocking the piton out completely and losing it during the last blow – be aware of your own strength! Using a hammer with a notched extractor point will make it easier to remove the piton without fear of seeing it go flying into the depths below. You can also link the piton and hammer with a 7-mm x 30-cm long chain attached with two maillons or steel carabiners. Hammer in the opposite direction to which the piton was set. Be sure to use a hammer with a good wristloop, or you can say goodbye to the hammer, chain, and piton if the piton suddenly comes out.

Compression pitons

These require you to drill a hole using a specially adapted drill. They are also difficult to set, and have no particular advantages over normal pitons, so have fallen out of use. They work on the same principle of compression within the rock as do expansion bolts, but the latter are much easier to use.

Key points:

- A poorly placed piton will come away with no warning whatsoever. Do not settle for an approximate placement, unless the only thing you plan to hang on it is your caving suit during a camp.
- Before beginning the placement, mentally evaluate how you will set the piton and the kind of gripping action (twisting or direct pressure) you want to use.

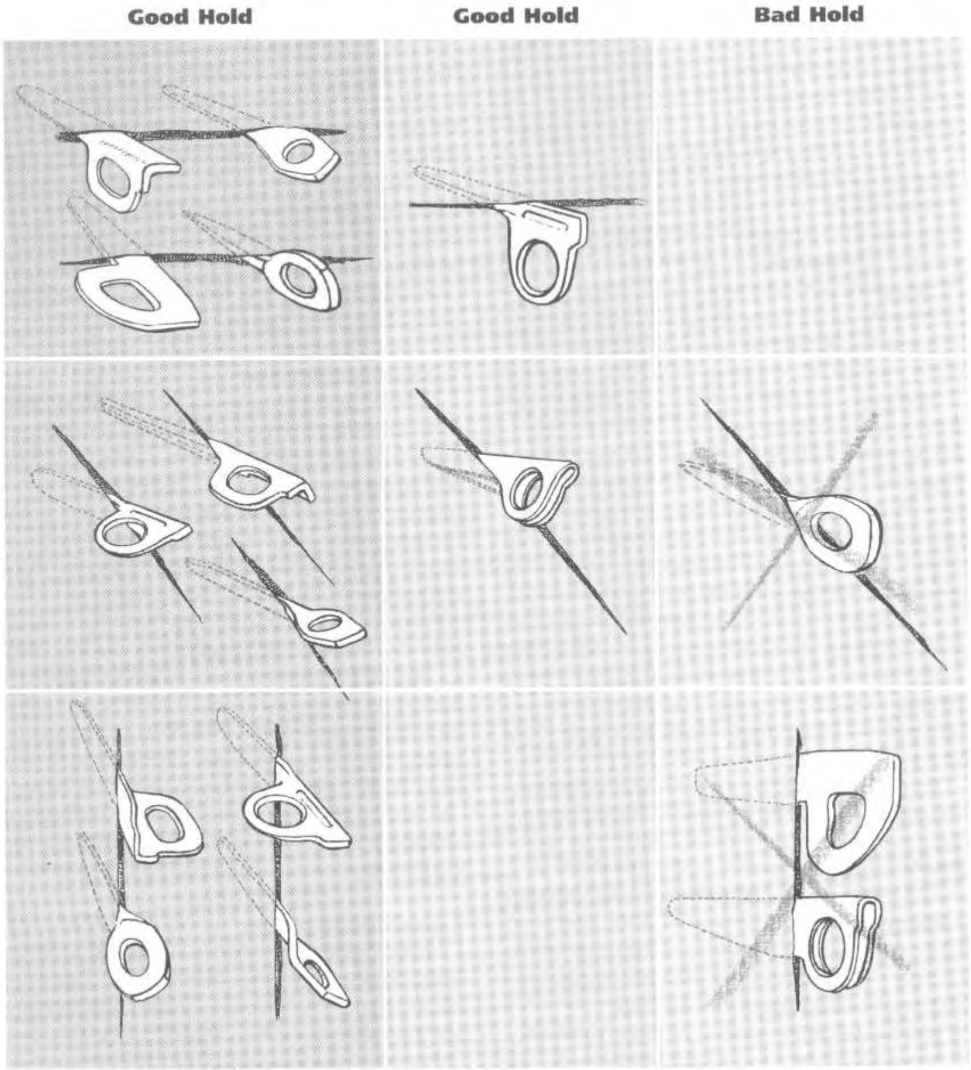

Fig. 94 – Effectiveness of piton holds in various kinds of fissure.

Tips:

- You can place two pitons side by side when you are dealing with a crack that is too large for just one.
- A soft steel piton that hasn't been completely driven into a slightly shallow crack can still hold perfectly if you bend it 90 degrees, which will bring the eyehole to sit against the rock. By increasing the twist, this maneuver makes for an even better hold. On the other hand, don't try bending a hard steel piton in this way. To use it in this situation, you must tie it off close to the rock by tightening a piece of cord around it with a girth hitch.
- Shallow cracks are quite common, either because they have closed on themselves or because they have filled with calcite. Consider taking along some shorter pitons.

Standard (EN 569):

Pitons are classified as PPEs because we remove them after use, while anchors are not classified as such because they remain in place! The logic is confounding...

We differentiate the following:

- safety pitons: these pitons have greater breaking strength, a minimum thickness of 3 mm, and a length of at least 90 mm. They are intended to protect against falls.
- progression pitons: these must have at least half the breaking strength of safety pitons and a thickness of at least 3 mm, but they have no minimal length requirement;
- suspension pitons: these are intended for use in aid climbing, and are not PPEs. They are not meant to protect against falls.

  All performance tests are carried out on 6 to 12 different samples each time, according to the shape of the piton (F1 corresponds to the load direction).
- Minimum static breaking strength:

	Normal	**Inverse**	**Transverse**
Direction of Load:	(downward)	(upward)	(perpendicular)
Safety Piton	25 kN	10 kN	15 kN
Prog. Piton	12.5 kN	5 kN	7.5 kN

- Labeling: safety pitons are engraved with "S"; progression pitons with "P." Both carry the CE label, the laboratory number, and the shaft length in cm. Suspension pitons must be labeled: "not load bearing."

Due to the high cost of CE testing, manufacturers have made major cuts in the variety of pitons they produce.

Maintenance:

- Soft steel pitons can be hammered back into shape using a flat rock or anvil. Successive straightening will naturally lead to eventual breakage.
- Lightly grease soft steel pitons. Hard steel models require no maintenance. Store them in a dry place.

7.11 Ice Screws

The use of ice screws in caving is limited to very specific circumstances: icy passages, glacier mills, or some icy entrance pitches in wintertime when ice flows cover the rock and anchors.

The strongest anchors are tubular. Chose the latest models, which have a cutting end with four teeth and a short thread (6 mm): they have the greater advantage of simply screwing down manually by turning the lever on the head.

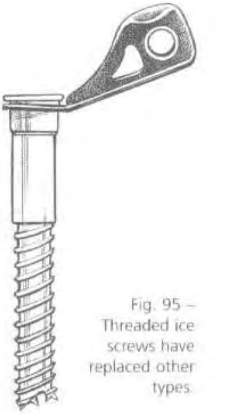

Fig. 95 – Threaded ice screws have replaced other types.

Standard (EN 568):

- Wear strength for hammered anchors: these must withstand 100 consecutive insertions.
- Screwing capacity: the rotation torque must increase 50% after 30 rounds.
- Breaking strength and holding power in the ice: they must withstand a radial force of 10 kN without breaking or extracting.

All tests are performed on three separate anchors each time.

7.12 Chocks[13]

Like pitons, chocks are also placed in fissures, and their advantage is that they do not require a hammer and are much easier to remove. A disadvantage is that placing them is a delicate operation and their hold can be uncertain. They are better used in cracks that are

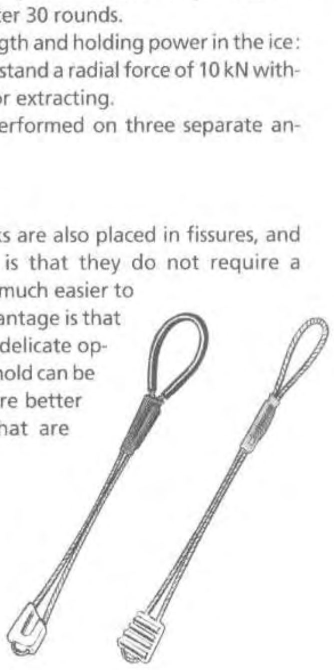

Fig. 96 – Two types of wired nut, one with a notched face for coupling with other nuts, the other with unequal faces for better choice of placement.

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[13] Short for "chockstone[s]," borrowed from the general term for a tightly wedged rock. This term here covers an array of mechanical and non-mechanical jamming devices that are used for temporary protection in aid climbing, including nuts, hexcentrics (hexes), friends, removable bolts.

Fig. 97 – Example of how a nut is wedged.

wider than those that take pitons. They are especially useful in climbing and prospecting, for setting deviations and even – in special circumstances – for rigging pitches.

Since cavers generally do not have a "chock culture," it is best that we abstain from using these devices as our main anchor points. Truly safe chock placement is a delicate, exacting maneuver, and those who know how to go about it have no need for the advice found here. All others should learn by spending quite a lot of time practicing with conditions and configurations that are similar to those found in caving. That said, we will therefore limit our discussion to a few generalities.

In caving, we hardly ever use anything but "nuts," which are light, compact, inexpensive, and generally have a better hold than larger pieces. Flexible models exist in lead or copper (copperheads) that can be hammered into cracks or hole and take on the shape of the crevice.

Key points:

- Do not use chocks as primary anchors unless you are very accustomed to placing them.
- Test for rock flakes before use: the chock could break them by acting as a wedge when weighted.
- Choose wired nuts (pre-fitted with a wire loop). These can be placed at arm's length since they are more rigid.
- Models with a notched face can be coupled to fit into larger cracks.
- Nuts with unequal and nonparallel faces offer greater choice in placement.

Tip:

In narrow cracks that have a sufficiently flared interior, you can fashion a do-it-yourself chock by making a knot in a rope or webbing and placing it in the opening. Whether the hold is excellent or uncertain naturally depends on how well you've set the protection!

Fig. 98 – Flexible chocks are hammered into cracks and fissures.

Standard (EN 12270):

Chocks are Type III PPEs.

For all types of placement indicated in the manufacturer's instructions, the minimum holding strength must be above 2 kN.

7.13 Skyhooks

Skyhooks are made of special steel and are very useful as direct aid in climbing, providing holds or temporary resting points. To use them, we link them to a cowstail or webbing sling. They can also be used to anchor an etrier on particularly small surface features in the rock.

Fig. 99 – Skyhook with webbing loop.

Skyhooks help you gain your equilibrium at the end of pendulums and give you some hold when setting anchors or deviations. But be aware that these hooks place more stress on the contact point. Soft rock, flakes, and flowstone rims don't always hold up! Some smaller hook radius models are available, but we recommend the larger shape with a wide radius hook. Carry these in your bolting kit.

7.14 Cables and Wires

A static support for your hands or feet can be useful when climbing past some obstacles such as bell-shaped pitch heads, waterfalls or deep pools. Here we often rig a steel cable or an iron wire. Such rigging should only be set in passages that are in frequent use since carrying and installing these aids is relatively time-consuming. Moreover, this kind of rigging is heavy and must be placed carefully and correctly so as not to damage the cave.

We generally use 5-mm wires or cables, which are strong yet not too heavy (under 100 g per meter), and easy to grip. Adjust the tension carefully, leaving adequate working slack that won't place too much stress on the anchors: these are more sensitive to shock due to the complete lack of elasticity in the wire or cable. Anchor sleeves may pull out or any part of the rigging could break if it is old and the tension is too high.

Steel cable permits very durable fixed rigging. This is easy to transport in a roll as it is more flexible. However, it is rather expensive since only stainless steel will do: galvanized steel oxidizes down to the core and will break without warning. Rigging it is also a more delicate operation, as this requires special cable clips and tighteners, and cutting it with a chisel can lead to dangerous unraveling upon subsequent loading (see below). Wear on cables also leads to rupture of the smaller wire strands, which turn into treacherous little spines. Even still, stainless steel cables are very durable.

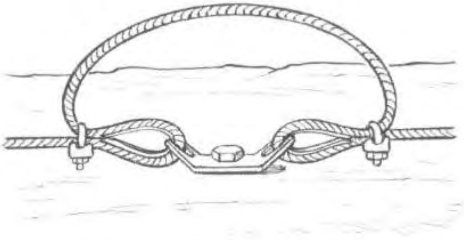


Fig. 100 – Anchor set along a wire cable traverse.

While it is much less expensive, iron wire comes in very stiff rolls that are difficult to carry and require straightening before being rigged. But it is also very sturdy and durable: special treatment during manufacturing makes it resistant to anything more than surface oxidation, even in stream passages. It wears without producing those annoying wire spines, but will break without much warning. It should therefore be checked carefully on a regular basis. This wire can be cut on site with a chisel and installed on hanger plates with 6-mm maillons, or directly on eyebolts. Simply twist it back around itself at the anchor over a distance of 20 cm at most, since the cowstail carabiner will be unable to slide along this section. Be careful of the free end, which can cause injury, stabbing your boot, glove...or bare hand. Fold the end back on itself and pinch it down with pliers to prevent the end from sticking out (fig. 101).

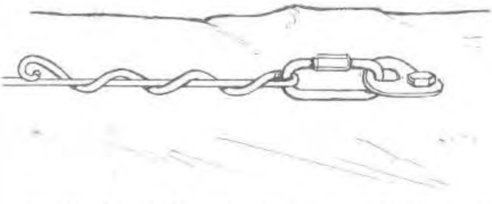


Fig. 101 – Twist the free end of the wire around the rigged end.

Key points:

- Rig a traverse line from different anchors where any failure in the rigging could lead to a fall and serious injury: at the pitch head, or where rigging is high above water, for example.
- For footholds in particular, rig short sections (even if this requires more anchor points) because they are much more stable.
- Do not use any wire or cable that oxidizes.
- Remove all cable from the cave that has been cut, altered, or rigged again after flood damage.
- Never connect cables or wires to rope.
- Install three cable fasteners of appropriate diameter at each extremity of the cable to insure good hold at the anchor.

Tips:

- To cut the proper cable length on site without allowing it to unravel, wrap the end to be cut thoroughly and tightly with industrial strength adhesive tape, and then cut it with a chisel. Place two cable fasteners on the end, one of which should be about 2 cm from the tip.
- Leave a slack loop between two contiguous cables to avoid having to cut them (see fig. 100).
- Remember that cable fasteners are installed with the base on the side of the strand to be weighted rather than the free strand.
- Use steel carabiners on your cowstails when travelling frequently on wires and cables.

Maintenance:

Check iron wires for wear on the anchor maillons and at all possible rub points, particularly in rivers where high floods can cause vibration : the wear can be inconspicuous but dangerous. Also check for splints formed from broken strands of cable.

8. Connectors

Carabiners connect the various elements in the chain of safety – hence the name "connector" in technical manuals and in the standards. This term also covers maillons (screwlinks or quicklinks) and other similar pieces of hardware. There are dozens of brands and hundreds of different models of carabiner, but these can be categorized under a few larger families, which we will discuss in the section on standards below.

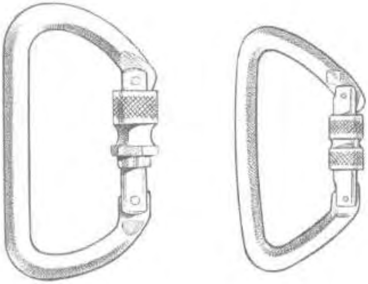


Fig. 102 – Two rigging carabiners, compact model on right.

8.1 Carabiners

We have already looked at carabiners used as part of our individual equipment. For collective purposes, we mainly use locking carabiners: carabiners used for rigging and anchoring and for placing pulleys, with or without an ascender (jammer). For the latter, only one shape should be used, the straight oval. Placed between the pulley and the ascender, it should be sized to rotate easily in both these devices.

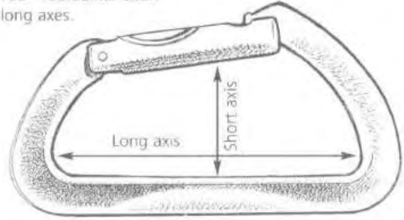


Fig. 103 – Carabiner short and long axes.

Fig. 104 – Strength specifications in kN, engraved on the carabiner spine.

There are two main schools of equal importance when it comes to rigging connectors. One stresses the use of locking (safety) carabiners, which are faster and easy to handle; the other uses maillons, which are more compact, more resistant to wear, and less expensive. The former school is gaining ground on the latter, proof that technical considerations have come to prevail over financial arguments. Indeed, it is easier to clip in to a carabiner than a maillon (except those that are pear-shaped) at the rebelay, and placing a carabiner is faster and doesn't require a wrench. Remember, however, that carabiners have a greater tendency to twist and jam in a poor direction in the hanger plate when pulled by the rope. This is something you should be aware of as you leave a rebelay when climbing.

There is little argument for using steel carabiners in caving (we are still speaking of collective use rather than, say, braking carabiners): steel is in fact weaker than zicral (16 to 20 kN versus 22 to 25 or more). The gate closure on these steel carabiners is often like a snake's tongue and can cut fingertips. It also helps collect and pack mud in the gate during the trip and this can ultimately compromise its strength. Finally, steel is three times heavier than zicral and requires more maintenance. Those who think it safer because of its almost total lack of casting flaws would do better to go rally around the maillons.

The light alloy wins the vote. Its only limitation is that it cannot be left rigged underground for long because it oxidizes (see the section on personal gear). It is also more sensitive to corrosion from mud and clay, which we can detect from the appearance of white marks on the aluminum. Those more negligent cavers have probably already noticed these.

Standard (EN 12275):

The carabiner body must be marked with the load bearing capacity of both its long axis (with gate open and closed), and its short axis (with gate closed). These values are given in kN and engraved on the long axis (fig. 104). For the strength of the long axis with a closed gate, the FFS follows the standard, but it is less demanding when it comes to the breaking strength of the short axis (5 kN) and the that of the long axis with an open gate (5 kN). However, their recommendations have no legal significance.

European Standard (EN 12275) for carabiners and maillons

code	Type	locking gate closure	Long axis gate open	Long axis gate closed	Short axis	Min. gate opening
B	General use	varies w/model	20 kN	7 kN	7 kN	15 mm
H	HMS*	obligatory	20 kN	6 kN	7 kN	15 mm
K	Via Ferrata	auto-lock	25 kN	–	7 kN	21 mm
A	Anchor	varies w/model	20 kN	7 kN	–	–
D	Directional	varies w/model	20 kN	7 kN	–	15 mm
Q	Maillon Rapide	varies w/model	25 kN	–	10 kN	–
X	Oval	varies w/model	16 kN	5 kN	7 kN	15 mm

* for active belaying on a Münter hitch.

8.2 Maillons Rapides (Screwlinks, Quicklinks)

These have the shape of a chain link that can be opened on one of its long sides with a hexagonal nut sleeve. Their primary use in caving is as the link between the hanger plate and the rope in vertical pitches. Only the "GO" (*grande ouverture* in French) series of maillons have a wide enough opening to allow easy placement of the rope inside. The best diameter is 7 mm: it has a breaking strength of 25 kN, the equivalent of a good carabiner. Though they are compact, sturdy, cheap, and resistant to oxidation, maillons do have some disadvantages. Using them is not as *rapide* as their name would suggest; it takes quite a while to twist the sleeve from a closed to an open position. And when they get stuck – which can happen often – we need an open-ended wrench to loosen them. Finally, its a bit harder to clip into a maillon than a carabiner.

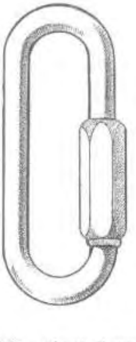


Fig. 105 – Classic 7-mm GO maillon rapide for anchors.

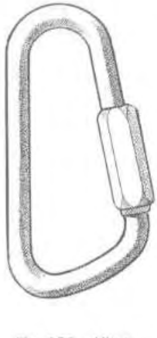


Fig. 106 – Ultra-rapide zicral Speedy.

Seven-millimeter GO maillons are available in several models. The most common is made of galvanized steel. It also exists in zicral, which only weighs 20 grams, but has a strength of only 10 kN. It also comes in stainless steel.

A new generation of ultra-*rapide* maillons has appeared: the upper end of the nut sleeve is not threaded, so these links only have one threaded end and can slide freely to its maximum aperture. Opening and closing is four times faster than with classic maillons, but unscrewing them when they become stuck still requires a wrench. Their long axis breaking strength is the same as that of classic maillons, but the short axis strength is less: 5 kN. They cannot serve as general purpose links, but two models can be used for rigging: the Speedy, a new generation of zicral maillon that is not only "ultra-rapide" but is relatively strong thanks to its shape: 15 kN for only 22 grams. The Presto is a new generation of steel maillon that is slightly pear-shaped and offers 27 kN breaking strength on its long axis; however, it's three times heavier than the Speedy (66 g). It's easy enough to clip into both of these models without getting stuck, even with the pit rope inside. Neither are CE approved (referring to standard 12275), but they meet the recommendations of the FFS.

Key points:

- **Carabiners whose long axis breaking strength falls between 15 and 20 kN satisfy the recommendations of the FFS for anchor connectors, but they cannot be used as general purpose carabiners, nor for bolt climbing in particular.**

- When leaving a pitch head or a rebelay, have a quick look behind you to be sure that all links are sitting correctly in their hangers, with the long axis resting vertically. This is particularly important in more difficult passages where the ropes are pulled in different directions, and so are the links connecting them to the anchors.
- When approaching a pitch head on descent, make sure that carabiners are positioned with the gate closure toward the bottom so that vibrations from the rope and gravity will keep it locked rather than twist it open. If the carabiner is not placed correctly, screw the carabiner closed and turn it to the proper orientation. Screw gates (on carabiners) and nut sleeves (on maillons) should always be placed facing away from the rock.
- For permanent rigging, zicral maillons and carabiners don't hold up very well (wear on the threads, oxidation, wear on the body from abrasion). Don't hesitate to check them often, turning them over to examine them completely.

Tips:

- Choose carabiners that can still open when loaded. Many asymmetrical models will do this, but this is rarely the case with oval carabiners.
- Reminder: engrave carabiners only on the gate and never on the body, since the latter will weaken it. Maillons should never be engraved; paint or label them with tape instead.
- If you don't have a wrench, you can unscrew a stuck maillon by wedging the sleeve into another partially opened maillon.

Standard:

Maillons are included in the category of screw-gate connectors, and must conform to Code Q of the general connectors table found on page 103.

Specific models that are CE certified are:

- steel 7-mm and 10-mm GO, 8- and 10-mm N
- stainless steel 7-mm and 7-mm GO
- steel 10-mm delta and half-moon maillons
- zicral 10-mm half-moons

Maintenance:

This is the same as maintenance for personal equipment links, discussed in chapter D (page 54).

9. Pulleys

When you need to move or lift a heavy load, pulling directly on a rope is not an effective option. You need return point for the rope in order to move the load more efficiently.

Pulling with the rope looped around a return carabiner is not very effective: you lose 50% of your effort to friction, and so must exert a force of 1 kN to lift a 50 kgf load. By doing so, you place that much more load on the carabiner. In such a situation, a pulley is necessary. A pulley has a rotating sheave and its diameter is much larger that that of a carabiner. Rope fibers are thus less stretched or compressed, and they work less against each other. Pulley sheaves are usually mounted on self-lubricating bronze axles, which reduce the friction opposing rotation. To lift the same 50 kgf load, 0.7 kN of traction is sufficient. If the load is really heavy, you can increase your efficiency by using a pulley fitted with ball bearings (which rotates more easily) or simply a larger diameter pulley (which reduces internal friction within the rope). In this case, 0.55 kN will suffice for lifting our 50 kgf load.

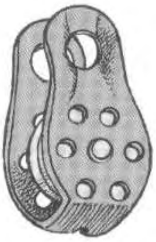


Fig. 107 – Fixed-sided pulley.

Several types of pulleys are used in caving. The simplest model is a plastic roller that is fitted on an oval carabiner. It is light (10 g) and compact, but not very efficient and it wears down quickly. It is not designed for regular use, and should be reserved for emergencies such as removing someone from the rope. Carry it on the draw cord inside your cave pack or on your acetylene lamp tube, so it is easily accessible in case you need it.

The most popular pulley is the fixed-sided model, particularly because it lends itself well to setting up a "pulley-ascender" hoist and thus for arranging haul systems. In this application, swing-sided pulleys with rotating side plates are much less effective since they do not stay in-line. A classic fixed sided pulley also has a stronger dural sheave: this will hold 22 kN as opposed to its swing-sided plastic sheave counterpart, which holds only 12 kN.

The Tandem is an example of a double fixed-sided inline pulley. It has excellent stability on tyrolean traverses and is ideal for use in several types of haul systems.

Fig. 108 – Mini Traxion pulley-ascender.

When digging, we must repetitively haul buckets, rocks and various sledges. If weight is not of particular importance, we would use a larger wide-diameter pulley (even going so far as to use gigantic mason's pulleys!).

In rescue, the load is significantly greater, and more energy is required over a longer period of time. Larger diameter (40 mm and above) ball-bearing pulleys are necessary. Under a heavy load, pulley-ascender systems must withstand significant pull from the rope when we resume traction. The ascender "pushes" on the carabiner that attaches it to the pulley, and the ensemble is off balance. Increased effort is needed to effectuate each pull. The Mini Traxion pulley-ascender will correct this problem.

Key points:

- Don't forget that the force of the load, and the force applied to the rope opposite the load to lift it, are combined at the pulley and thus to the point to which the pulley is fixed. This anchor point therefore takes at least double the force of the load being hauled.
- Rubbing and abrasion add still more to the load at the anchor. For these two reasons, it is essential during rescue operations to assemble haul systems and counterweights on three-point load distributors, with each point fixed to an independent anchor.

Tips:

A return pulley installed just above you will obviously facilitate pulling, but you cannot exert a force that is greater than your own weight. Without such a pulley, your own muscles are at work, and these can often exert a force greater than your weight.

Standard (EN 12278):

- Ease of rotation: the sheave must be able to rotate in both directions under a force of 2 kN without being damaged.
- Strength: the pulley must hold a load of 12 kN.
- Labeling: the maximum rope diameter to be used must be clearly labeled on one side plate.

10. Marking the Way

The size and complexity of some systems sometimes necessitate some kind of flagging, preferably of the non-permanent and discrete variety. The days of black carbide arrows have gone, a good indication of our evolution toward greater awareness of the fragility of our caves and our own sense of responsibility toward their conservation and protection. We are only the guests of Mother Nature and should behave as such, leaving behind us only the slightest traces of our passage. We already know that the cave will have a hard time erasing these traces alone, and in most cases it won't succeed in doing so. On the other hand, it seems useless to push the logic of conservation to the point of absurdity; this would leave us sitting on the surface so as not to disturb the cave! Complete avoidance only leaves us with an (albeit temporary) lack of knowledge, and can only be justified in some exceptional cases, when the value of the discovery (archeological, esthetic, or otherwise) dictates that we cease all activity out of respect for the cave and its future. Such situations rarely occur in the life of a cave explorer, but this does not clear us of the responsibility to act conscientiously in our usual caving practices. Each and every one of us should think of the many small precautions and gestures that will help lighten the impact of our passage.

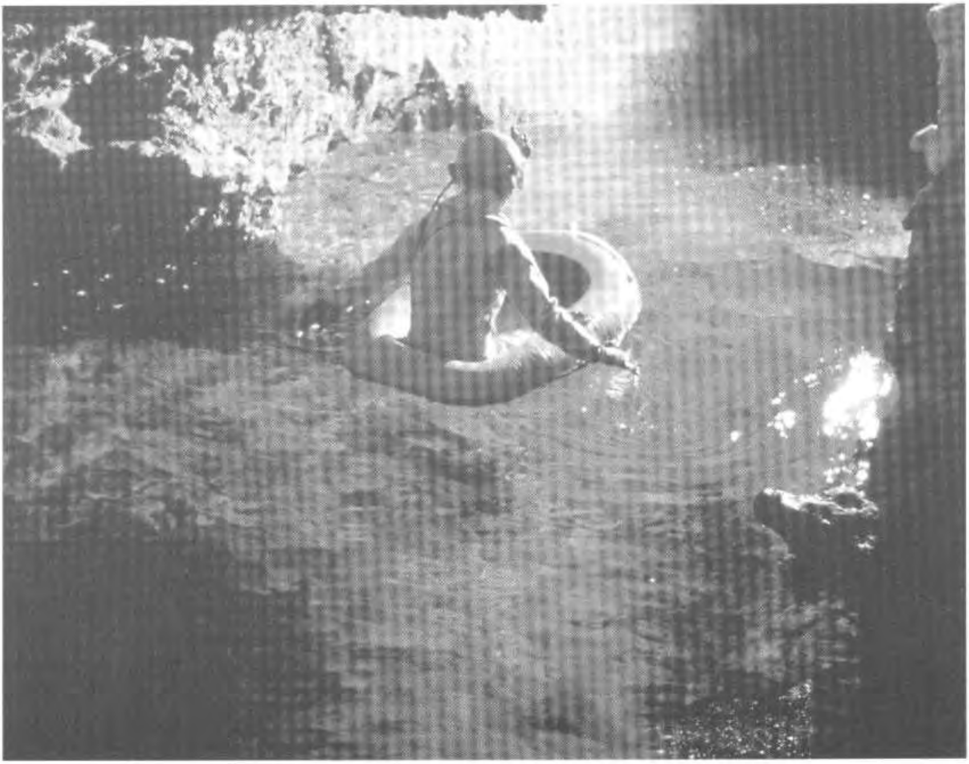
Flagging is one of these gestures. In primary exploration, you will rarely need to do this since your own footprints in the virgin passage will guide your return. You should limit yourself to flagging only strategic points (the way on through breakdown in a large chamber, for example) and your marks should be made from materials found in the cave. Cairns or arrows placed with pebbles or rocks can be easily taken apart once you no longer need them. During a cave's exploration, evidence of your passage can accumulate, including those of mistaken itineraries, and this calls for some proper signaling.

Here you can use pieces of 30-40 cm construction flagging tape, often red and white striped or bright orange, cut in half along its length with an arrow drawn in black permanent marker. Flagging tape can be carried in bundles held by a rubber band, and it is convenient to carry it on the body between the caving suit and undersuit, which saves time when placing the tape. The strip may be placed on the ground, a wall or on a boulder in the passage. Anchor it with a rock, pebbles, or sand; the arrow should always point in the direction of the exit since it is on the return that you generally risk losing your way.

In large chambers or galleries with a lot of breakdown over a large area, it may be necessary to flag the path between the confusion of boulders and rocks. Getting lost is a waste of time as well as energy. Small pieces of white reflective tape are very effective here. They reflect the light from our lamps and can be seen from dozens of meters away, yet they are very discrete: a two-cm square is largely sufficient. The only precaution needed here is being sure to avoid getting mud on the tape when placing it. Place the tape so that each square can be seen from the last, and they can be seen when travelling in both directions. This eliminates the need for arrows.

When exploration of a cave is finished, flagging no longer serves a purpose and it should be removed completely from the cave.

Similarly, when visiting one of the classics, respect existing flagging and leave it in place, taking care to remove any of your own markers when exiting the cave. Flagging is only useful to the person who sets it, since he is the only one who really knows its meaning: following another's itinerary may lead you where you don't want to go, but removing it could compromise the person who is counting on its presence. It is essential that we all respect these guidelines if we hope to avoid leaving excessively marked passages and losing control of the cave's preservation.



Gard, France. Photo P. Crochet

11. Aquatic Gear

Low water temperature in Alpine caves makes any submersion a trying experience, since this consumes our precious energy to the point of being dangerous. Wetsuits or pontonnieres are only practical when we are submerged for a long time. Otherwise, it is better to take a float.

The inflatable boat (dinghy)

The old sturdy neoprene-coated boats are no longer available. Since they didn't hold up to salt water, they couldn't be sold as beach crafts and were thus sacrificed on the altar of profitability. The best models today are made of latex-coated nylon, but they are expensive. Our only other options are models made of latex-coated cotton or PVC. The former are heavier and tend to rot if we leave them too long underground. Boats made of PVC are rather unreliable: they can tear when folded, wear out quickly, and stiffen when cold.

Single seat and double seat boats are available. The former are obviously lighter and more compact. Equipped with an attachment cord (choose one that floats), they help us through most watery situations.

A well-made inflatable boat should have a solid attachment point at both the front and back. A grab line around the outside makes for easier handling, but this can be fashioned from your own cord or webbing. A floorboard is heavy and doesn't really serve much purpose as long as you are careful when using the boat. For longer trips or when the water current is rather swift, short oars resembling ping-pong paddles can be useful. Be sure to choose the floating variety and place an attachment cord on each one. In calmer water or a short pool, your hands and long rubber gloves can also do the job. Be careful of advancing solely by using the cave walls; this requires some skill and practice, and the boat must never rub against the walls unless you want to wear it out quickly. Since you must constantly maintain perfect balance to avoid tipping over, this technique is not so easy.

The inflatable buoy

This is a large inflatable tube with triangular webbing in the middle for a seat, and two shoulder straps that help to hold it on the body when you are between two pools and the water is shallow. The buoy is used with a pontonniere or a wetsuit and doesn't need to be large to keep you afloat, thanks to Archimedes' Principle acting on the submerged parts of your body. We sometimes call it a "rubber ducky," in remembrance of our childhood beach craft, even if it lacks the head of this web-footed friend.

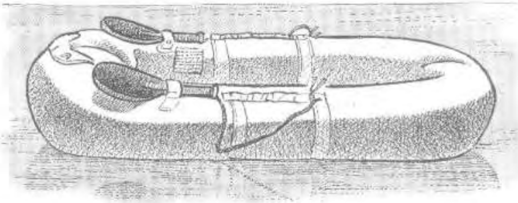


Fig. 109 – The inflatable boat, often made of latex-coated nylon.

There are several advantages to the rubber buoy. First, it allows you to maintain your autonomy since it is meant for individual use. This primarily saves time. Because of the body's good center of gravity when floating with the buoy, you maintain better balance when floating. The buoy is more compact, easier to inflate, allows you to divide up our gear among separate vessels, and doesn't pose any attachment or recovery problems in zigzagging or narrow waterways. It is easy to carry and doesn't require deflating when you walk between pools. Finally, you can't accidentally run aground since your feet serve as our underwater sonar, and you need not worry about flooding the vessel either. And what is lost in spectacle is gained in efficiency!

A very inexpensive buoy can be fashioned from a large truck tire inner tube (you will need about a 20-cm diameter for sufficient buoyancy). The seat and straps can be made from a length of webbing. The only problem with this homemade device is

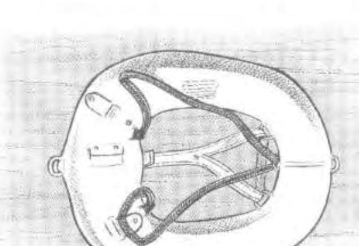


Fig. 110 – The inflatable buoy is very stable and allows easy progression with a pontonniere.

that it can be a bit heavier and inflating requires a pump, which is not so convenient to transport. These rustic vessels can be left in place during the duration of the cave exploration, which saves you having to inflate them so often.

When working on a lengthy exploration requiring repeated passages in a long, deep streamway, you can also make a raft from tubes of PVC closed by rubber inner tubes, cross-linked and bound together with cords. This can be made on site and then be left in place. Such a vessel is a bit heavy, but is strong and stable. Between uses, simply dock it on a bank, attached with a cord to prevent it from being carried away by a flood.

Key points:

- We recommend boats with two separate compartments. Otherwise, consider taking along a life jacket!
- Choose a self-inflating model. It makes it easier to re-inflate while afloat after a puncture.
- Always transport an inflatable boat underground inside a well-sized protective sack.
- Because they are less stable, don't bother with inflatable beach mattresses. Use a neoprene wetsuit for getting through water passages with low ceilings.

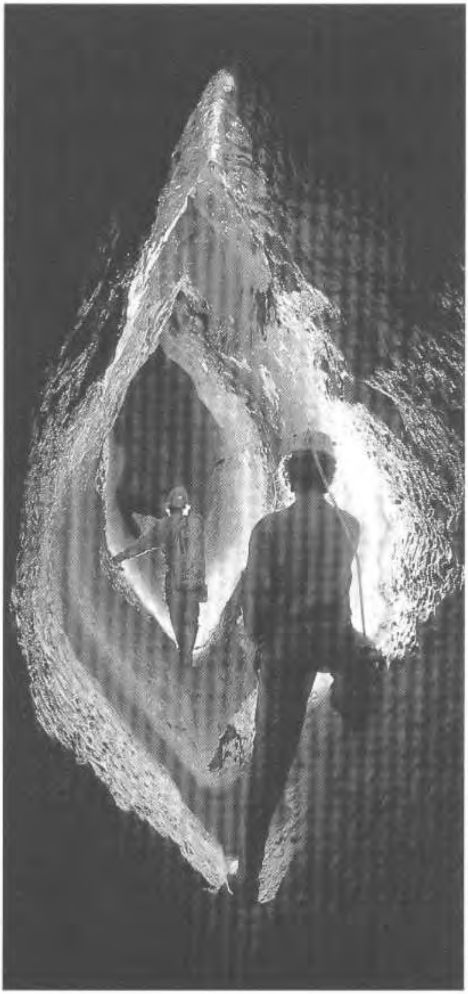
Tips:

- When deflating the vessel, get rid of all the air by rolling the tube over itself, starting from the side opposite the air valve. Close the valve and then unroll the boat. Roll it up again, opening the valve only at the very end, to eliminate the extra air trapped inside.
- If water gets inside the tube, throw a bit of carbide dust inside, then empty the leftover lime that has formed after about 24 hours. If this must be done underground, use your electric lamp to avoid any possibility of an explosion!
- If you have packs containing waterproof sacks or containers that will make them float, tether and pull them along behind your vessel; this leaves more space inside.

Maintenance:

- Remove mud and clay with a sponge and rinse the deflated boat (air valve closed) with running water. This will get rid of abrasive sand and grit. Dry in the shade, and store in a dry place, with the air valve left open.
- Immediately repair any slow leaks or punctures. Waiting until later will only make the problem worse.
- Latex boats can be repaired with rubber/latex patches and rubber solution. Talc the outside, and occasionally the inside as well.

The life of inflatable boats can vary considerably according to use, the care we take with them in the field, and maintenance after each use



Tempelgang, Hölloch, Switzerland. Photo U. Widmer

F Transporting Gear and Supplies

To survive the rugged, humid cave environment, our caving packs should be completely impermeable and resistant to rot. They should have a smooth, strong surface coating that isn't too heavy or stiff. PVC-coated polyester is the fabric of choice.

1. Cave Packs (Tackle Sacks)

They are abused, dragged, thrown, thrashed, beat up and sworn at. Our poor cave packs are the most mistreated of all our accessories underground... and then we expect them to hold up! The cave environment is so inhospitable that it is nearly impossible to carry our equipment – and there is usually quite a lot of it – without strong, adequate protection. Ropes, anchors, food, carbide, maps, survey, digging, photography and diving gear, camping supplies...suffice it to say that a pack's contents can vary widely. The French use the term "kit-bag" ("kit" for short) after the name for canvas military bags used by American GI's. These bags brought joy (and sometimes tears) to a generation of French cavers after World War II. They were made entirely of cotton canvass, from the cloth to the carrying straps, had a slender shape that fit well up ladder climbs and in restrictions, and a good price tag to boot. But their bottoms also broke open without warning, often emptying their motley contents down long drops. They tore easily on outcrops, their pressure clips popped off at the most unexpected times, they absorbed a clay shell that was impossible to remove, and their straps came undone in restrictions like a lizard losing its tail. Needless to say, we've seen nothing but progress since those days!

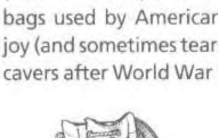


Fig. 111 – Standard cave pack.

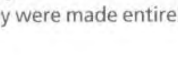


Fig. 112 – Personal cave pack.

To be really useful, a cave pack should have the following:

- two shoulder straps, preferably adjustable;
- a handle strap situated to the side (and out of the way when the pack is being carried on the back);
- a means of closure that can be easily manipulated while wearing gloves;
- a tether that is attached directly to the closure cord, to allow easy transport in pits, meanders and crawlways;
- a reinforced bottom with an additional protective band, ribbon or weld around its perimeter;
- a lid on the inside (to avoid hang-ups) to protect the contents of fully loaded packs and prevent mud from getting inside.

The pack seams should be welded or sewn solidly with strong rot resistant thread. They should ultimately be able to withstand the hysterical tugs of a caver whose pack is hung up in a zigzagging restriction, who refuses to back up at all costs for

Fig. 113 – Transport pack. As with standard packs, a side handle and tether are indispensable when carrying underground.

fear of getting more stuck. These specifications make our packs a bit more technical then we would suspect at first glance, and cheaper models will quickly prove to be a bad choice.

Cave packs come in many shapes and sizes, but they fall into two basic categories: larger expedition packs and personal packs. Expedition packs are about 60 cm tall and 25 cm in diameter; personal packs are a bit smaller in diameter (usually wide enough to hold a standard watertight container) and 40 to 50 cm tall. The latter can be used to carry carbide, extra batteries, food and water, spent carbide, rescue ropes and rescue blanket, and other equipment used in a day trip (such as photo or survey gear). Their volume can thus vary according to need, being quite small, for example, for shorter trips in a known cave. These can easily pass through restrictions.

Classic expedition packs are still the most widespread. Some have round or oval bottoms, and their advantages and disadvantages are inverse: oval bottoms carry better on the back but get jammed more easily when carried through meanders on a tether, since their bulk shifts when they turn sideways.

Transport packs

Transport packs, also known as "sherpas," are used to carry gear to the cave. These can also go underground when individual volume is substantial (for cave camps, diving or de-rigging trips) provided the cave is not too tight in some areas.

They need to be at least at strong and rugged as cave packs, with additional padding on the shoulder straps since they will carry more weight. They should be big enough to carry two 6-liter watertight drums side by side, or one 15-liter drum. They should have two closures, one on the outside equipped with a preferably metal buckle (plastic buckles rarely work for long underground), and one inside for additional protection.

Some models have a retractable interior skirting that can be adjusted according to the volume being carried. The fold-down closure is also adjustable along its outer strap. These packs should not be used at full volume underground because the height of the load can cause problems (scraping and knocking against walls, wear on the skirting, loss of balance, side handle lower than the center of gravity). With a normal load, the skirting assures an airtight closure and excellent protection of the contents.

✱ Key points:

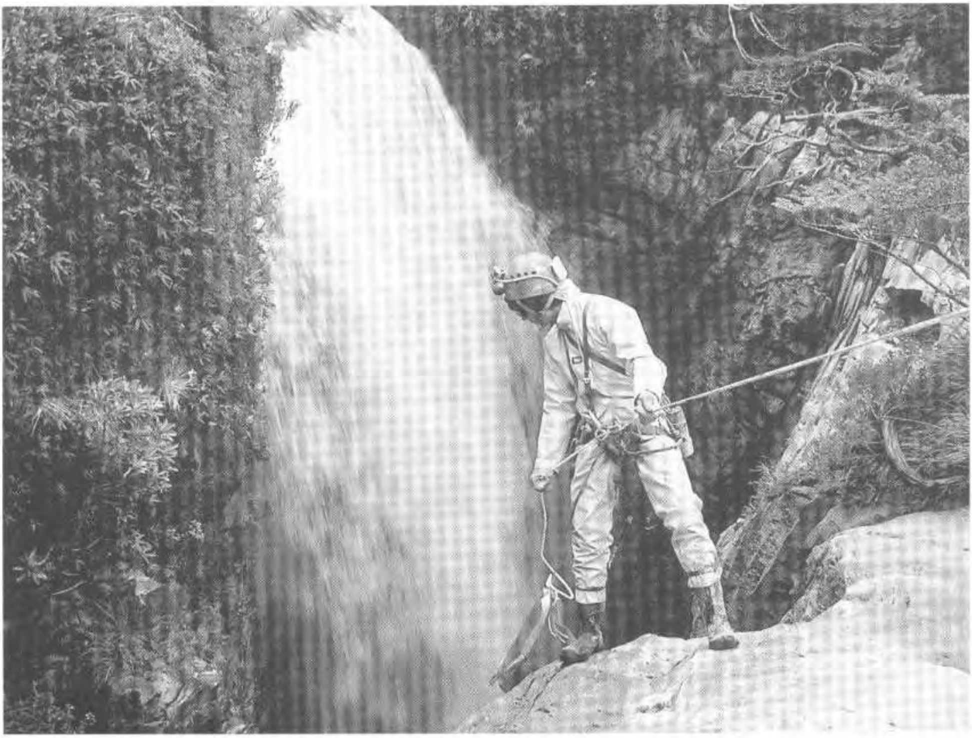
- Go for packs with welded bottoms: they are much more resistant to wear and, even if they cost more, it will be money well spent.
- It is almost always illusory to think you can unjam your pack by sheer force and brute strength. You will preserve both the integrity of the pack and your own energy by changing the position of the pack before yanking on it again.
- Make sure your pack tether is made of a material that floats in water. It will be easier to find if your pack falls into a pool.
- The pack handle should be positioned between the middle and upper third of the pack, preferably closer to the center, and not too flat against the side so it is easier to grab.
- The length of the pack tether should be adjusted so that the top of the pack hangs just under the sole of your boot when it's attached to your harness.
- Don't carry small objects loose in the pack. They will be harder to find just when you want them and are more likely to fall out while you're moving. Attach them to a tether made from a loop of cord or narrow webbing with a few intermediate knots. Fix this to the closure cord on the shoulder strap side (and of course inside the pack) with a girth hitch.
- On rope, the pack should never be carried on the back because it pulls the body backwards. Carrying it tethered to your seat harness, attached at the bottom of the harness maillon or linked to the leg straps by a length of cord or webbing.

Tips:

- A semi-rigid handle on the topside of a cave pack can be very convenient for carrying it through meanders.
- A cylindrical layer of closed cell foam padding placed inside the pack is excellent for preventing punctures in the fabric by hard objects inside the pack and sharp edges in the cave walls. This will prolong the life of the pack, protect its contents, keep your back warm in the colder caves, and can also be used as an insulating seat cushion or camp mattress.
- Shoulder straps that detach from the bottom of the pack can be hidden and protected inside it during crawls and squeezes.
- Make a few knots along the length of the pack tether. It can be a big help in narrow meanders when you may need to unjam the pack frequently.
- It is better to hoist the pack by its tether, which distributes tension through the eyelets in the closure (if the pack is closed correctly!), rather than use metal pull ring. Ideally, hoist the pack on opposite points on the closure: it will stay upright and get jammed less often.
- Don't use a sherpa pack for small loads: an empty pack will flop around and be harder to grab and pull along. For normal packs, placing a watertight drum inside can help solve this problem.
- In river passages, a pack that has an eyelet in the bottom will help empty the water from the pack. Or, use a very well worn pack that hasn't been repaired yet – it will empty itself automatically!

Maintenance:

- Proper care and treatment will help extend the life of these indispensable packs. Label or number them with a permanent marker as soon as you buy them, for easy identification before and during your trips. Labeling also helps you to keep track of a pack's condition throughout its long career.



Future Sink, Patagonia. Photo J.F. Pernette

- Packs require some care and attention. Wash with water and a brush, paying special attention to the straps to prevent wear on the seam threads by calcite crystals in the mud. Patch any tears as soon as they appear, using PVC glue and round patches of the same material. Protect and reinforce the seams on the straps with PVC glue as well.

2. Carriage Frames

Frames are made of a light metal alloy or plastic, with a waist belt and shoulder straps. They are very useful for transporting heavy, voluminous loads on the surface, which are strapped to the frame with webbing or bungee cords. With rigid frames, assemblies that screw together are the weakest. Those with riveted assemblies are a notch above, and argon welded frames are the sturdiest. But flexible plastic frames are actually better for our use because they have better shock absorption than the rigid frames, especially when it comes to putting the heavy load down on the ground. If the cave is large enough, these can also be used to transport dive tanks, but remember to protect the valves.

Fig. 114 – Carriage Frame.

3. Watertight Containers

Watertight "dry bags"

The hazards of underground transport make it difficult to guarantee that your material will remain dry in all circumstances, even in non-aquatic systems. Dry bags can be helpful in protecting gear that must stay dry, such as photography equipment, survey gear, clothes and food.

Fig. 115 – A simple plastic dry bag.

A dry bag should be made of a soft, waterproof material such as plastic, latex or PVC. It should be seamless (or have waterproof seams) and be able to close well enough to block out all moisture. The simplest type of closure can be achieved by folding the bag down three times from the top, each fold being a few centimeters wide, then folding it crossways three or four times like an accordion. The entire closure can then be held in place with a thick rubber band (taken once again from that handy inner tube). We can find commercialized dry bags with similar folding closures and a quicksnap buckle for quick opening. These bags should not remain submerged for too long since the water will eventually make its way inside.

The dry bag should be sturdy enough to resist tearing or breaking under the various pressures encountered during transport. PVC tends to harden in the cold. Latex dry bags are also available commercially and they fold and bend without getting damaged. You can also make small bags similar to your rubber carbide "banana" tube. Plastic trash bags are usually too fragile, even the if you double up; their seams give out if the cave pack gets compressed during transport.

Tips:

- Always squeeze excess air out of non-elastic dry bags before closing if they are going to be submerged. This will prevent pressure from forcing them open. This also applies to diving, as it aids equilibrium.
- Dry bags can also be used to fetch water (in camps, for example).
- If it is sturdy, a dry bag can be filled with air and used as a comfortable, insulating seat cushion during long waiting periods.

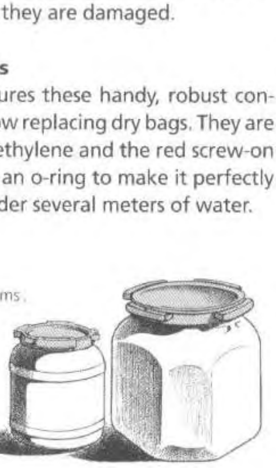
Maintenance:

- Rinse with clean water and allow the bag to dry inside out. Latex bags should be dried out away from direct sunlight and then dusted with talcum powder. They can be repaired with tire patches and rubber solution.
- PVC dry bags can be repaired with PVC fabric and PVC glue. Makeshift bags are obviously thrown away (in a trashcan, of course, not underground) once they are damaged.

Watertight drums

Curver manufactures these handy, robust containers, which are now replacing dry bags. They are made of white polyethylene and the red screw-on lid is equipped with an o-ring to make it perfectly watertight, even under several meters of water.

Fig. 116 – Watertight drums, 6 liters and 15 liters.



In fact, divers were first to introduce these receptacles to the caving world, before discovering a thousand and one other useful applications for them. They are very convenient: a large mouth makes their contents easily accessible and the lid is easy to handle in any circumstance, thanks to a wide screwbase and four large handholds.

The line has several shapes and sizes, some of which are well adapted for use in caving. The most popular is the 6-liter cylindrical drum, a perfect fit for cave packs (fig. 116). The smaller 3.5-liter model has the same diameter and is also quite practical since it allows you to separate your loads (fig. 117).

Fig. 117 – Small 3.5-liter watertight drum.

For larger volume or sherpa packs, we recommend the 15-liter square drum (although it isn't as watertight since it lacks the o-ring). Its width however prevents it from going through those smaller passages. Finally, the largest of them all is the 60-liter model (fig. 118). It can hold expedition gear and undergo all the hazards of transport without even flinching. Seal it with a length of colored cord, which doesn't necessarily prevent it from leaking but will at least prevent it from opening during transport. And in camp, they make a convenient seat! We also use them in our club headquarters to keep group carbide stocks dry: Metal bins bend out of shape, allowing moisture in, and the carbide eventually fuses together. So these containers are well worth the investment. In fact, all of these drums are extremely robust and very useful. And they have an added bonus: they make your cave pack float!

Fig. 118 – 60-liter expedition drum.

Tip:

Smaller drums can be expanded with air to pass a sump without being damaged, despite the pressure. To do this, attache a bicycle tire air valve to the lowest point on the lid. It will hold under ten meters of water, but remember that the drum will still cause problems with equilibrium.

Maintenance:

These containers are almost indestructible. Lubricate the seal from time to time with Vaseline.

Special packs

Between the cave pack and the watertight drum, you can transport just about anything underground. This is not the case, however, with most drills, which are too bulky even for a 15-liter drum. They require double protection, against water as well as impacts. A sturdy dry bag takes care of the first one; for the second, you can either use a smaller foam-lined pack or a small backpack, provided it is robust (preferably made of Cordura). A safety tether for the drill and a holster for the drill bits are also useful accessories.

4. Other Bags

The bolting kit (bolt bag)

A bolting kit allows you to carry everything you need for setting anchors. It includes:

- a driver (installing a sleeve on it will protect the end, but may rip out of the pouch)
- a supply of self-driving anchors and cones or expansion bolts
- corresponding hanger plates, screws, maillons and rings
- a caving hammer stored in a separate compartment, for easy access
- a skyhook for maintaining position during awkward placements.

Fig. 119 – Bolting kit.

These items are all quite heavy, so it's important to make as precise an estimation as possible as to how many will be needed for the trip, then increase it by 20 percent. When the links being used are carabiners and not maillons, carry these separately since they are bulkier. This is also true for maillons when you have a lot of them.

Hangers with their connectors attached can be held together on a loop of cord. This is better closed with a carabiner if you want to thread rings on this loop. Anchor sleeves can be screwed together with their hangers and screws. These are then threaded on a cord like a string of pearls, each separated by a knot to prevent them all from falling down a pitch all at once. The easily lost and damaged expansion cones can be pushed into holes in a rubber bracelet cut from our multi-purpose inner tube. This may be equipped with a carrying strap or attached to a carabiner by a hole at the end. Cones can also be carried between two strips of electric tape. Film canisters can also be used, but take care not to drop any cones when removing them over a pitch!

A bolting kit should of course have a carrying loop that can be attached to the seat harness belt or shoulder strap, the latter being more convenient for rummaging through while hanging in the air. The closure should have a clip that can't be pulled or snapped open easily, reinforced with a Velcro or other wraparound protector.

You may have noticed that a 13-mm wrench has not been mentioned for transport in the bolting kit. In fact, this should be carried with your personal gear, since everyone should be ready to tighten down hanger plates, and screw or unscrew maillons.

Let's consider this wrench now, since we didn't discuss it in the section on personal gear (where it might have seemed incongruous between the helmet and socks). Simple open-ended flat wrenches are the most convenient, since closed-end wrenches cannot be used with stuck maillons. Because there is a real risk of over-tightening and stripping the anchor nut, the wrench arm can be milled short. In light rigging technique, we often place backup anchors at rebelays, doubling the frequency of our wrench use. A ratchet wrench can be useful in this case, though it doesn't work well with rings. Facom has come out with an excellent time-saving flat wrench: you don't need to remove the end between turns. This is expensive but more efficient.

The wrench should have a 3-mm attachment loop or something similar to prevent it from disappearing down a pitch. When de-rigging, we've seen our share of scatterbrains who had to re-descend the pitch (or pitches) in search of their indispensable wrenches!

Finally, the wrench needs to be accessible: some cavers wear it on the wrist, held in place with two rubber bracelet bands, one of which serves as a wristloop; others wear it attached to the harness belt with a small carabiner.

Pouches

Various pouches allow us to separately protect, store, transport, and access specific equipment like surveying gear, camera gear, the pontonniere, and climbing gear. Some pouches can be worn on the harness belt for better accessibility, with a short skirt liner to protect their contents. A drawstring closure is the most convenient: Velcro and zipper closures quickly become caked in mud and rendered useless.

5. Carrying Food and Utensils

We will talk more about food intake in the next chapter, but before we can eat underground, we need to pack, carry and prepare the food effectively. As for transport, the method of choice is the watertight drum. The 3.5 and 6-litre models are perfect for such use.

Food should be appetizing yet relatively sturdy, well padded (for example, between slices of bread, or protected by an extra shirt wrapped in a plastic sack), and packed carefully in individual plastic containers, reinforced with a thick rubber band. These containers should also be separated from each other (with open cell foam padding for example).

In alpine caves, it's always nice to have something warm to eat and drink. The best stove is the Esbit: it's light, compact, inexpensive, and almost indestructible. It is basically a galvanized steel box that is flat, compact and sturdy, and folds down with two riveting half-lids.

When opened, the stove forms a burner onto which the cooking container is placed. When closed, it becomes the compartment that holds the solid fuel blocks. This kind of fuel has several advantages: it can't be spilled, doesn't leak, is not affected by blows or low temperatures, and keeps almost indefinitely. Of course, it doesn't have the higher heat energy of propane or gasoline, but it has enough for our use, i.e., boiling a cup of water for a warm drink or an instant meal.

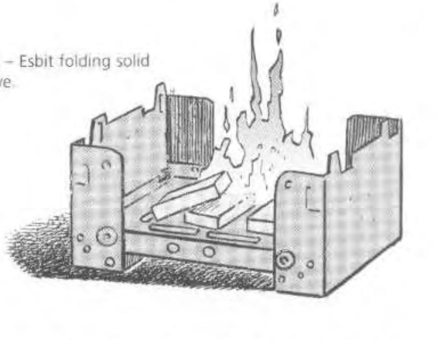
Fig. 120 – folding insulated cup.

There are two kinds of fuel that are available in solid form: the kind that comes with the stove is insensitive to humidity but toxic. Its competitor is sensitive to humidity but non-toxic, and it's best for the latter reason. You may not be able to completely avoid eventual contact between the fuel and your food during transport, but you can wrap the stove and fuel separately in a plastic bag with a semi-watertight closure, which should be replaced periodically. Place this near or inside the cook pot, which should be compact and light (made of aluminum rather than stainless steel) and should have a lid for faster heating. Your pot can also double as a bowl or plate, washed out with a bit of warm water between uses. For less abusive users, a small plastic cup might also be added.

Finally, a knife and spoon with shortened handles will complete the set.

A few words about the knife: its usefulness goes well beyond mealtime. It can in fact play a key role in many situations: to cut rubber bands from a piece of inner tube, to cut rope during an exploration or triangles of cord when practicing cord technique, to scrape out the screwbase on a carbide generator, etc. And the knife is essential for caver self-rescue or small party rescue techniques that require cutting the rope (see the chapter M).

Fig. 121 – Esbit folding solid fuel stove.



Don't store your caving knife with your food; it needs to be readily accessible for these uses at all times. Attach it to a 2-mm cord and wear it between the caving suit and under suit, or place it in the pocket of the caving suit if it has one. Choose the flattest, least bulky model with a tough, sturdy stainless steel blade. If it does not come with a cord hole, pierce one in the handle to attach a carrying cord.

Photo E. Sanson

Nare, Papua New Guinea. Photo D. Gill

Physical and Mental Aspects

If you want to get the most safety, efficiency, and satisfaction out of caving, it is not enough to have the best equipment, or even the most technical knowledge. These conditions are necessary, but insufficient in and of themselves. You must also be prepared both mentally and physically before going underground.

This is an important point, although cavers do not always give it the attention it deserves. In fact, human error is often the weak link in the chain of caving safety. Even when well-equipped and well-trained, some cavers risk venturing underground without possessing all the necessary means to do so; for example, you haven't eaten properly or lack the proper mental preparation required to face the harsh and often demanding conditions below. In essence, you have not "broken in" the machine with adequate training and preparation.

Before throwing the doors open to the world below and approaching the third section on caving techniques, recall some basic principles that everyone already knows to some degree, though we may not all master or practice them correctly. Far from focusing on dull, theoretical models, we will remain specific in our treatment of this essential aspect of caving preparation.

G

Physical Resources

Despite some (fortunately) unsuccessful attempts to the contrary, caving remains a non-competitive sport and cavers have managed to avoid some of the more unfortunate by-products of spectacle sports such as fraud, drug use and greed. At the same time, they find themselves sheltered from the glory and fame that would normally come with popular recognition of their achievements.

If we "compete" underground, it is usually neither against a stopwatch nor an adversary. We struggle with ourselves, not necessarily pushing our limits, but making our minds and bodies to work together in harmony. Caving requires only good physical and mental health, which implies an excellent knowledge of the self, the body and physical and mental limits, a balanced diet and steady training, and regular maintenance and care – just like a well-oiled machine!

And that is all. Caving requires neither an exceptional physique nor any greater physical ability than the average person might possess. You only need to follow a few basic rules in order to play your cards right. These rules become clearer when you remember how your muscles function.

1. Biochemical Mechanisms

The body must produce and use energy in order to maintain good muscle function and proper reaction to outside stimuli, and the source of this energy comes from the food we ingest. This food comes in the form of carbohydrates, fats, and proteins.

In general, the first two kinds of food provide the energy necessary for the body, and especially the muscles, to function properly. Proteins, along with mineral salts and vitamins, ensure tissue growth and maintenance. Everything is digested and put to work (metabolized) in the body through different physiological processes.

As with any mechanical system, a large part of the energy that is provided to the muscles is lost in its transfer. Only one quarter of the energy we consume is actually transferred into work (i.e., muscle contractions). The other three-quarters are lost as heat, a byproduct of the mechanical process that turns energy into work.

Mother Nature always has a plan. In order to feed the muscle tissue, she did not put all of her eggs in one basket. According to the type of effort required of the muscle – short or prolonged, normal or intense – four different processes may be used: two are aerobic and two are anaerobic. Each process has its own reaction, storage and replacement times.

To better define the practical rules for our conduct underground, we will look more closely at how the muscles function.

1.1 Endurance Work and Aerobic Energy Production

When we travel through a gallery at a moderate speed or do an easy climb, our muscles work at a moderate rate and are able to keep up this steady rhythm for a long time. This is called endurance work. In this situation, our body acts like an internal combustion engine that runs on simple fuels: carbohydrates (simple or complex) and fats (lipids) are consumed as fuel in the presence of the oxygen we breathe. Because oxygen plays a key role in this metabolic process, we call it "aerobic."

If there is a sufficient amount of fuel in the body (which is usually the case if we eat a balanced diet) the muscles' ability to produce energy will be defined by the capacity of the respiratory and cardiovascular systems to supply additional oxygen to the muscles. When the body can no longer supply additional oxygen, energy production becomes anaerobic. This transition point is called the VO^2 max, or aerobic threshold, and is mostly genetically determined. So when it comes to exercise, we are not all created equal! The aerobic threshold reaches its maximum around the age of twenty, and begins to drop off around age forty.

Two aerobic processes coexist in the body, one fuelled by fats and the other by carbohydrates.

Fat metabolism

Fat metabolism is an important source of energy, given the body's accumulation of fat reserves. Fat metabolism is a slow process, providing only 25% of the maximum muscle contraction intensity, but it can be sustained for a long period of time.

Aerobic glycolysis

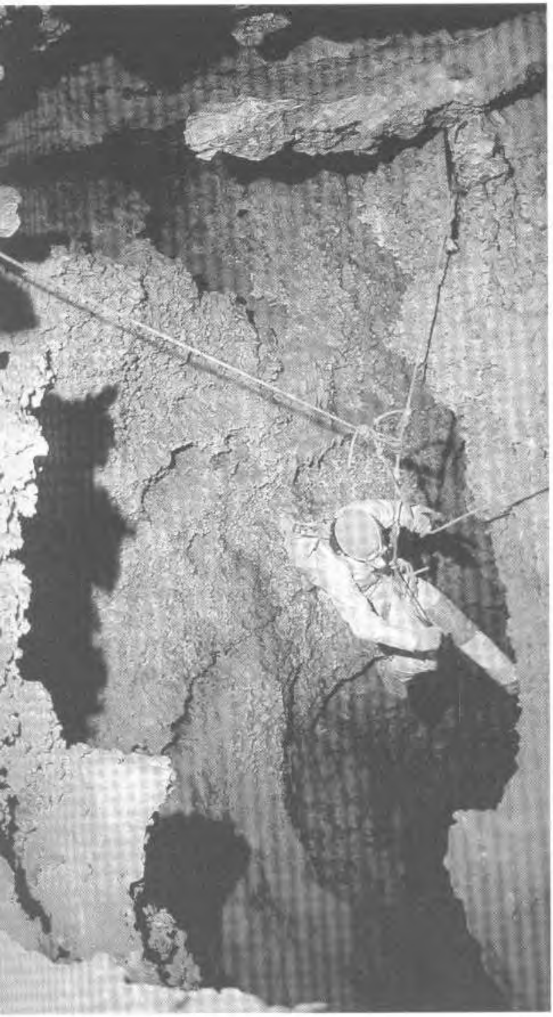
Glycogen is a complex carbohydrate (sugar) that is stored in the liver and muscles. Its consumption in the presence of oxygen, called aerobic glycolysis, is complete and releases a great deal of energy. This process is highly efficient as it operates on some dozen seconds of inertia and can be maintained for hours. However, it can only provide about 40% of the maximum muscle contraction intensity, so intense effort cannot follow from this process. Glycogen levels are replaced through the absorption of complex carbohydrates such as pasta and rice.

1.2 Strength-based Exercise and Anaerobic Energy Production

When the demand on the muscles becomes too high and the aerobic threshold limits oxygen transport, other methods of energy production take over. These processes doe not require oxygen and are thus called anaerobic. When muscle functions become anaerobic this effort corresponds to strength-based exercise. When caving, we encounter this level of effort when we negotiate a difficult crawlway or when we quickly climb a pitch. Here again, two distinct processes can intervene.

Anaerobic glycolysis

Glycogen can only be partially metabolized in the absence of oxygen, and only a third of the energy resulting from its combustion can be used, rendering this process less efficient. Anaerobic glycolysis also produces lactic acid (lactate) as a byproduct, which is responsible for muscle soreness.



Vercors, puits Martel, France. Photo S. Caillaut.

In exchange, anaerobic glycolysis allows the muscle to reach 60% of its maximum contraction intensity, and only requires a few seconds to be put to work. However, it can only be maintained continuously for a few minutes, depending on the level of glycogen reserves stored in the muscles. These levels also require several hours to be replaced.

Phosphate degradation

Phosphate compounds, such as creatine phosphate, exist in very small amounts in the muscles as a sort of specialty food. During a process called hydrolysis, the phosphate compound degrades, releasing energy. This energy is immediately available for use and allows 100% of the maximum intensity for muscle contraction. Once exhausted, however, phosphate restoration is slow, making it a privileged agent for short, intense energy output, which we encounter only rarely while caving.

1.3 Some Easy Guidelines

Endurance-based exercise ensures the best output by using the body's abundant energy reserves and it is this kind of work that we experience most while caving. On the other hand, strength-based exercise should be avoided as much as possible, as it has another drawback: in direct proportion to its higher fuel consumption, this process also releases much more heat to produce energy. The body uses perspiration as a means of regulating internal temperature, and this too has a negative side effect: because sweat is salty, a deficiency in sodium chloride develops, resulting in painful muscle cramps. Cramps are a warning sign that you should heed immediately by allowing the muscles to rest and the body to restore its depleted salt and water reserves.

You should reserve strength-based activity to the shorter, more physically demanding passages that you will inevitably encounter along the way. Size up these passages beforehand so as not to waste precious energy on failed or inefficient attempts at passing them – a classic error for beginners. If the passage is too physically challenging, it should be rigged to allow cavers to get through it under more "aerobic" conditions.

As you travel through the cave, you should be able to recognize the moment when you change from endurance-based to strength-based exercise. Fortunately, this is easy: breathlessness is an obvious and logical sign of the moment when pulmonary respiration reaches its maximum and when a lack of oxygen releases the mechanisms for strength-based work. The heart beats harder, trying to pump enough blood to carry essential oxygen to the muscles. As long as you are able to talk while moving through the cave, your body is still working aerobically, and all is well. If you are too breathless to talk, slow down to avoid pushing yourself into anaerobic mode. Naturally, the appearance of this signal in the less aerobically conditioned team member should signal the whole team to slow down.

2. Diet and Food

2.1 Water Needs

Water comprises 70% of our body mass, and it is present in our every cell. It serves as a means of transport for dissolved molecules, it helps in the elimination of waste products through urine and through evaporation of perspiration on the surface of the skin, which also helps regulate the body's core temperature during heat-generating exercise. Perspiration is therefore a natural and beneficial phenomenon that should be facilitated. Unfortunately, wearing a caving suit very clearly impedes this process: your undersuit soaks up all your sweat and you stay wet. This is why you should open your caving suit as soon and as often as possible while moving through the cave, and take the top off when you stop to rest. As soon as you start to feel a chill, either put the top back on or start moving again.

Just by perspiring, we can lose up to three-quarters of a liter of water per hour. Drink often to compensate for this water loss, as well as some salts (potassium and sodium) to compensate for their loss in the muscle tissues, as mentioned above. A nice, warm soup is thus not only pleasing but effective. If you do not drink you risk dehydration, sometimes without even realizing because your clothes stay damp. Dehydration can sneak up on you, and it is particularly dangerous because it reduces muscular output and produces cramps, dizziness, exhaustion, vomiting and – in the most serious cases – can lead to kidney blockage and failure of the urinary system.

If drinkable water cannot be found in the cave, you should carry it with you (about one and a half liters per person). It is nice to know the bottle will be empty – and lighter – for the climb out! In some caves, nearby pastures or water treatment plants could be a source of contamination to the underground water supply. There are two solutions to this problem: take in water from the outside, or gather the water in the cave and treat it (especially if there is a camp). The most effective method is treatment with chlorine solution or tablets. Respect treatment times before drinking the treated water.

2.2 Solid Foods: The Balancing Act

To perform properly, the body requires food in various forms. For building and maintaining tissue, it needs dietary protein (meats, eggs, cheese, dry legumes), mineral salts (sodium, potassium), water and vitamins. For energy it needs carbohydrates and fats. The latter can be found in animal fats and oils, while carbohydrates can be grouped into simple sugars (refined sugars such as cane or beet sugar, corn syrup, lactose, fructose, etc.) and complex carbohydrates (flour, potatoes, pasta, rice). Simple sugars are very small molecules that are easily and rapidly metabolized, while complex carbohydrates are larger molecules that carry a longer chain of sugar molecules and therefore take longer to metabolize.

These products should be present in your daily intake as approximately:

- 50 % carbohydrates
- 30 % fats
- 20 % proteins

To stray too far from these proportions may lead to various imbalances and to health problems. Rather than become a slave to calorie charts, you need only follow a few simple guidelines to maintain a balanced diet.

Breakfast in particular should be at least as substantial (and nutritious) as lunch, which is far from the norm for many of us: we start our days on an empty stomach and go to bed at night after a copious dinner with our stomachs full. We should in fact do the opposite: begin the day by giving our bodies more energy that can be used throughout the day when we are most active, and eat a light dinner.

A good breakfast would include milk (protein, fat), fruit juice (simple sugars, vitamins) and bread (complex carbohydrates) spread with butter (fat) and honey or jam (simple sugars). Cereal (complex carbohydrates) is another good choice, and/or some bacon or ham and eggs (protein).

Lunch could also be substantial, including a salad or raw vegetables (vitamins) and a portion of meat or fish (protein) and/or cooked legumes (fiber and carbohydrates) with a preferably uncooked fat, such as olive oil or butter. Finish with some cheese, yogurt or a dairy dessert (protein, fat).

Dinner should be lighter but just as balanced, and preferably meatless.

Avoid snacking in front of the television, as much for your mental as your physical well-being. And it is best to limit alcohol consumption – though they say a glass of red wine per day is good for cardiovascular health!

Overall, daily food intake should be proportional to your level of physical activity: too much food will lead to weight gain or obesity caused by an excess in dietary fat and sugars, stored as fat in the body when they are not metabolized.

Eating in the cave

If you eat a balanced diet on a daily basis, this is easy: a few infringements on the rules during a weekend of caving will be inconsequential. Plan on storing up some fats and complex carbohydrates during the day or two preceding the physical activity. On the morning of the outing, breakfast should be at least as copious as on normal days. When underground, stick to your normal lunchtime, so as not to upset the body's internal clock. In any case, such a break in activity is always welcome and rejuvenating, the perfect opportunity to heat up a warm cup of soup, which will replace important salts and fluids lost during the morning activities. You may want to add some cheese and cold cuts (in moderate amounts), bread, and a dessert. If your portions are a bit small, this should not have any negative side-effects since the body will begin drawing on its fat stores for the extra energy. The resulting weight loss should be compensated within a few days. Keep some dried fruits or energy bars in your pockets to ward off any sudden dips in energy level, as these simple sugars are rapidly assimilated.

However long your trip may be, your choice of foods should depend on your own preferences and common sense. Avoid soft or perishable foods such as fresh fruit and liquids, though the new watertight, durable containers now provide better protection for these products. Stay away from excess packaging, but don't throw out those good recipes! Choose products that are pre-cooked or that can be heated quickly. Avoid foods that contain a lot of water, as they add extra weight. Choose instead freeze-dried or dehydrated foods that can be reconstituted on site. Some of these products are found easily in stores in individual portions. Bringing your own food rather than sharing meals with your team members will allow you to eat what is more to your liking. Bring along some simple condiments and bread, preferably whole grain, finish with hot chocolate or tea, and set out again with a warm, satisfied stomach.

Avoid heavy meals since they take longer to digest. This is not conducive to increased physical activity because the body throws its energy into the digestive process, making you more lethargic. The longer the exploration, the lighter and more frequent the meals should be, providing steady and sustained fuel for prolonged efforts.

For longer underground camps, maintain normal dietary habits for the most part, with an additional intake of fats and carbohydrates as well as Vitamin C to compensate for increased physical activity. In camp, breakfast should be copious, with cereals, whole grain bread with butter and/or jam, cookies or pastries, biscuits, and hot chocolate or coffee with milk. Food intake during the day should be the same as with day trips, including a lunchtime meal and energy bars for a quick energy boost when necessary. In the evening, a pleasing dinner with soup and a hearty, high carbohydrate main course and dessert is the best way to end a long and satisfying day of caving. Finish with a hot herbal tea before slipping happily into your sleeping bag and...good night!

3. Signs of Fatigue

Even if you eat correctly and regulate your activity so as to stay within the parameters of aerobic-based exercise, there will inevitably come a time when glycogen stores in your muscles become depleted, blood sugar (glucose) levels fall, and acids start to accumulate in the muscle tissues, preventing proper muscle function. At this point, your body needs to stop all activity and rest in order to reconstitute its energy reserves. This is best accomplished during sleep. Fatigue must not be considered a sign of weakness to be overcome, but a normal and useful signal from your body that you *must not* ignore. Symptoms of fatigue include sleepiness, decreased mental faculties (esp., ability to evaluate a compromising or difficult situation), weakness and the inability to even briefly change to strength-based exercise (using muscle strength), and lack of motor coordination, which may outwardly resemble drunkenness. If these symptoms appear, it is time to STOP!

4. Exhaustion

If we do not listen to our bodies at this point, we risk exhaustion, a state of profound physiological distress that can lead to serious and irreversible consequences. These are the result of three processes:

4.1 Hypoglycemia

As we discussed above, the blood transports glucose from the liver to the muscles, where it is used as energy. If glucose reserves are exhausted, the blood glucose level drops, resulting in dizziness and blurred vision, and may lead to loss of consciousness.

4.2 Dehydration

As we noted above, dehydration is insidious because it is often difficult to detect while caving, since it can occur even when we are in an environment of 100% humidity, saturated in wet clothes. Lacking water internally, the body cannot eliminate waste through urine or regulate its internal temperature through perspiration (which then leads to hypothermia).

4.3 Hypothermia

A hot pan removed from its heat source eventually cools off. Likewise, the body, deprived of heat-generating energy, will eventually experience a decrease in its core temperature. To fight against this mortal threat, it stops sending warmth (blood) to the extremities: sensation is lost in the fingers and toes, and the victim becomes clumsy. The body will also begin to shiver uncontrollably, trying to generate precious heat. Shivering results in a further loss of dexterity. Once these last reserves are burned up, movement becomes impossible as the victim sinks into a deep lethargy and the will to live quickly fades. Once its temperature drops to 35° C (92° F), the body gives up, abandoning most of the organism to its fate in order to concentrate on feeding the brain with oxygen, despite a severe reduction in heart rate. The end is near if the medical team doesn't arrive in time to rehydrate, insulate and rewarm the victim.

4.4 Precautions

The consequences of exhaustion are so serious that you should never allow fatigue to get too close. There is absolutely no shame in turning back. To want to continue so as not to impede the team's progress could result in much more serious consequences than finishing the exploration at a later date. This is a risk you cannot afford to take even if you think you are helping the team. Remember also to pay close and discrete attention to the physical and mental state of your team members, to avoid any future accidents or incidents: confusion, breathlessness, bad temper or giddiness, paleness, shivering, and general lethargy are important early-warning signals that you should recognize *before* it is too late.

The onset of fatigue and exhaustion is even faster when the body is weak. Poor health, a sickness or injury, and antibiotic treatments should keep you from participating in longer or more involved trips, even if your colleagues depend on your participation for the success of the exploration. It would be better to wait for a later date, when your physical capacities are at their best and forced inactivity has intensified your motivation!

Photo F. Le Guen

H

Mental Aspects

For a caver worthy of the name, the cool darkness of a cave is seductive, and the simple idea of going underground unleashes a feeling of desire, excitement and expectation. This is certainly the first guarantee of a successful trip, both in terms of personal enjoyment and the end results. But there are times when we are lacking in motivation or confidence, and in such situations we must seek out the root of this apathy.

1. Lack of Confidence

We find this most often in the beginner who has not yet assimilated the fine art of cave exploration, and who can legitimately doubt his ability to overcome some of the difficulties of exploration. With time and experience, the caver will come to master the diversity of situations he encounters, and learn to react appropriately and positively to unexpected or exceptionally difficult circumstances. This experience is a strong factor in creating self-confidence, having a kind of snow-ball effect as it leads the cave explorer to progressively meet and overcome greater difficulties and to further improve his composure and confidence.

Even if he hesitates to fully participate in preparations before an outing, the beginner should nonetheless be ready to ask the advice of more experienced members of the group whom he trusts, and especially of the trip leader. He can then determine his own conduct according to their responses. He can be assured that those who encourage him to join them will be more ready to guide him in his technique and his progress underground. On the other hand, he shouldn't feel resentful toward those who discourage his participation in a group whose competencies are higher than his own. They are in fact doing him a favor by doing so, and it is in everyone's interest that he not be pushed beyond his limits. He'll eventually have his chance at more challenging trips, as long as he doesn't burn any bridges!

2. Illness or Lack of Motivation

Lack of interest in invitations to participate in weekend trip may reveal an as-yet unrecognized illness or psychological problem, perhaps one which only your subconscious has so far detected.

This latent dysfunction can only reduce your body's physical and mental capacity to function at an optimal level. If the goal of the trip is at all physically demanding, it is best to wait for a better time (which will undoubtedly come) or fall back on an easier trip, rather than force yourself in order to please a friend or prove something to yourself. Don't force nature; doing so could cause unnecessary pain or hardships.

While both physical and mental aspects clearly interact with one another, the ability of one to influence the other is limited. Physical mechanisms don't depend entirely on the mind, and the latter doesn't have the power – at least, in most situations – to make the body perform beyond its physical limits. In an exceptional environment like the one we find in caves, such a sublimation of our physical limits can be hazardous and the after effects painful, in both the short and long terms.

If you want to push your physical limits in a realistic and lasting way (through increased strength and endurance), you cannot do it by breaking the laws of nature. However, you *can* through proper training.

I Training

While you do not have to be a trained athlete to be a good caver, this sport is rather physically challenging. Since it requires the body to mold itself to the varying shapes of the rock, it particularly works some muscles groups that get little use in our normal daily activities. After a good, long belly crawl, for example, many cavers are sorely reminded of some muscles they did not even know they had! This brings us to the importance of preparation and regular training, especially if one is accustomed to a rather sedentary lifestyle, as is often the case for city-dwellers.

The benefits of training are twofold: increased endurance and improved strength.

1. Improving Physical Performance

1.1 Improving Endurance

Training conditions and strengthens the heart by increasing the rate and volume of blood that it pumps. As the heart increases in volume, its capacity to pump greater quantities of blood also increases and it can send more oxygen to other muscles. The aerobic threshold can be pushed back, allowing the body to remain longer in aerobic mode where it can use its energy reserves most efficiently.

Similarly, developing lung capacity also has beneficial effects, since an increase in pulmonary surface area allows the lungs to transfer more oxygen to the blood (per unit of time). Unfortunately, this isn't so helpful in those tight chest squeezes!

Training also significantly increases the amount of time the body can remain active at a given percentage of the aerobic threshold before fatigue and exhaustion set in. This is clearly advantageous, considering the long duration of many caving trips.

Another benefit affecting muscular efficiency: when the body works aerobically to supply the muscles with energy, regular training increases fat metabolism and proportionally decreases the process of glycolysis. Precious glycogen stores are then left intact, and fats – which are stored in greater quantities throughout the body – are burned instead.

1.2 Improving Strength

The heart is not the only muscle that benefits from training. Every muscle in the body is affected, each one growing in volume and developing better vascularization, two conditions that help increase muscle strength and improve performance. And with more strength, the muscles can hold up longer when pushed to their upper limits.

2. Optimizing Form

By following the movements and techniques that others have shown you, you can refine and optimize your own movements. This process is almost unconscious, less a result of the desire to improve than of an almost random series of attempts, mistakes, and fine-tuned corrections that will eventually improve your form.

We don't realize how much variability we possess in our movements, and the choice of gesture invariably affects our efficiency. However, these repeated movements become so refined and familiar that they are almost second nature. With improved form, you no longer have to pay attention to the accuracy of every move, and you exert less energy while moving efficiently through the cave. Once acquired, these automatic movements are only lost after a prolonged suspension of activity.

When you begin to feel the onset of fatigue, you will need to count on these automatic movements. This will allow you to concentrate on varying conditions in the cave – crucial for safety – without needing to think about technique.

3. Conditioning and Training

3.1 Aerobic conditioning in the city

There are many ways to train aerobically, even though modern life seems to have left many of us with fewer open, natural spaces in which to do so. But taking the stairs instead of the elevator is already a good start! In most cities, the local gym or fitness club, municipal swimming pool, and stadium are all possible training grounds. Choose any activity that lends itself to aerobic conditioning, such as race-walking, jogging, or swimming.

3.2 Aerobic conditioning outdoors

For most people, it is much more fun to exercise in a natural, outdoor setting. Cross-country running or skiing, hiking and mountain biking are some good examples of activities that allow you to condition your cardiovascular and pulmonary systems. Rock climbing is useful for developing technique, while practicing vertical caving techniques on a nearby cliff is an even better way to train for real caving situations. This also allows you to practice rigging techniques such as setting anchors, rebelays, and redirects. Once the "course" is set, you can practice moving up and down the rope.

3.3 Strength Training

Strength training is complementary to aerobic conditioning. Many sports use strength training, so you are not for lack of choices. However, one of the most effective activities for a caver is simply to climb a cable ladder over an extended period of time. At first, you may be tempted to practice climbing rope using an ascending system, but setting up a device that allows you to feed enough rope (through a rack or pulley) to climb a long distance is complex and requires outside assistance. Moreover, since the rope is not fixed, climbing movements are rather jerky and less rhythmic than they would be in a real caving situation.

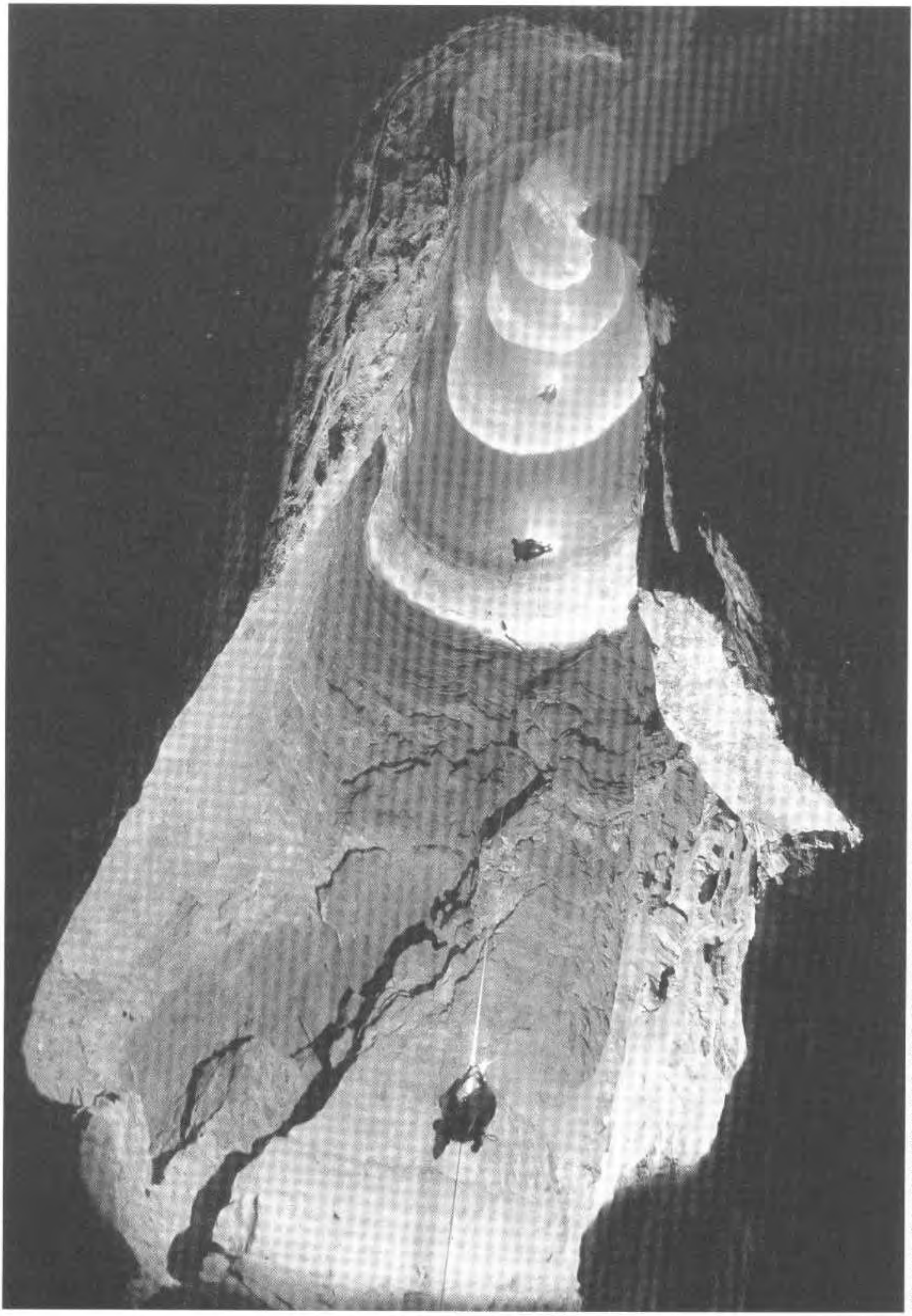
On the other hand, climbing a cable ladder rather than a rope is ultimately more effective and more physically demanding, not only because it allows more rapid and rhythmic vertical movement, but also because it is just as tiring to climb down as it is to climb up.

By simply installing a five-meter long ladder under an awning or a bridge, in a tree, a garage or a gymnasium, you can immediately have access to an excellent means of pushing your limits. On such a modest height, you don't need to attach a safety device. This will allow more rapid movement up and down the ladder. Breathing, arm and leg strength, balance and coordination are all used in this simple and effective exercise. Before an especially demanding exploration or just to shape up after a prolonged period of inactivity, this exercise will be even more useful if you regularly increase the number of repetitions. After one or two weeks, you will find yourself in excellent shape and able to confidently climb out of the most daunting series of underground pits.

3.4 Training in Caves

Do we even need to say it? The best, most natural way to train for caving is by going caving on a regular basis – every weekend, if possible. Thus, while the body is being conditioned and strengthened, you will also develop the experience that is indispensable for good technique, as well as your own safety and enjoyment underground. After confronting newer and more challenging situations, you will no longer need to think about your every move or the strength you will need to get through difficult passages. Once you are at the top of your form, you will be free to follow your passion, focusing your energy and attention on exploring the cave, in all its complexity.

Now that you and your equipment are ready, it its time to tackle the reality of the cave itself. Let's now step into this dark realm, with determination but also with respect, and learn what will be needed to overcome the various obstacles that lay ahead on this path of discovery.



154 meter deep OGH Pit in Köbelis Höhle, Switzerland. Photo S. Ballmann

Underground

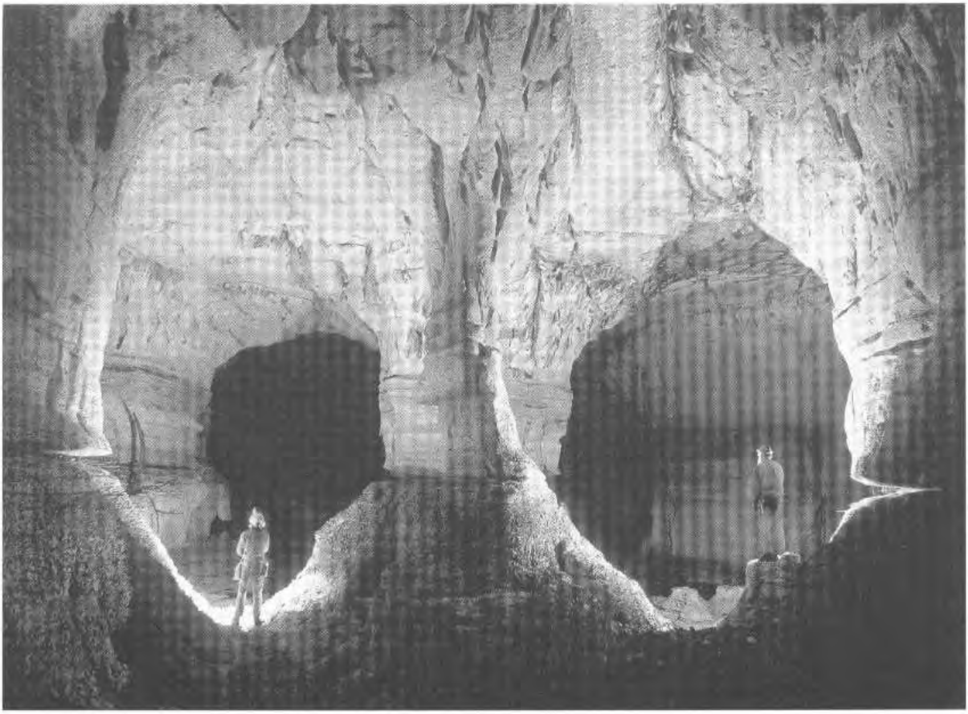
J Moving Through the Cave

How you travel through the cave and whether you need specific equipment to do so depends on the kinds of obstacles nature sets in your path. In horizontal caves and many large walking passages, effective use of your arms and legs, handholds and footholds, and balance will often allow you to get by without many cumbersome accessories. This accounts for a majority of the time you spend underground, and you can take advantage of these opportunities to improve efficiency whenever possible. You learn to move faster and better minimize your impact on the rock, and if you are conscientious, only your footprints and some minor scrape-marks should betray your passage. Unfortunately, broken formations, clay stains, black carbide inscriptions or piles of spent carbide are sometimes left behind as evidence that less responsible groups have been underground. At all times, each of us has a responsibility not only to act conscientiously, but also to be vigilant with others in protecting the cave against abuse and degradation. While we may not be the owners of these natural treasures, we are often their only true caretakers.

No matter how much you twist and contort your body, two types of situation will inevitably require additional equipment: vertical pitches and stream or river passages. Aside from short climbs (no more than the height of an average person), you can only rarely overcome a vertical passage safely without the help of a rope. Using one requires technical training and good physical condition. As for water passages, consider the potential risks inherent in these attractive yet hostile environments: rapid loss of body heat, the depth of the water and force of its current, and sudden changes in flow rate. We will consider specific scenarios in greater detail in the following pages, but let us first look at some general rules that apply to all situations.

First of all and in all circumstances, **think before you act.** Attacking any obstacle without some forethought will inevitably result in a waste of energy, failure, or even an accident. A quick analysis of the obstacle at hand and your capacity to manage it is indispensable. Fortunately, experience will teach you to decide quickly and correctly; based on past situations, you can more precisely evaluate the level of difficulty of a given passage and your ability to manage it without assistance. You can then act quickly with the most effective solution.

Rhythm is equally important. It should be regular, and your level of exertion such that the body remains in aerobic rather than anaerobic mode. We have just discussed this topic in the previous section; now we must put theory to practice. For those who were so impatient to get underground that they skipped the previous chapter, recall this simple sign: when you can no longer walk and talk at the same time, this is when you have moved out of aerobic mode. The team should generally maintain the rhythm of the person who is most quickly out of breath.



Sof Omar Cave, Ethiopia. Photo U. Widmer

1. Travelling Without Gear

1.1 Walking and Horizontal Passages

In relatively level horizontal passages, cavers usually carry their personal gear and supplies in a small caving pack. The simplest, most effective way to travel in walking passages with minimal impact on the cave is by following the same path left by previous parties or your fellow team members, carefully avoiding more sensitive areas (with flowstone, stalactites, stalagmites, rimstone dams, and mineral deposits, for example). By establishing a pathway at the outset – discrete yet recognizable to future visitors – others will be less likely to venture into pristine areas, thereby minimizing unnecessary degradation of the cave.

Walk with your arms dangling and hands down, following the most level path and avoiding needless elevation changes – even if this means taking a slightly longer route. This will help you conserve energy. Keep one eye on the path directly in front of you to help place your steps, and the other on the path further ahead to help determine your overall direction and itinerary. Since the ground is naturally uneven, pay attention to where and how you step, so as to maintain good rhythm and balance.

When a team member falls behind, the leader needs to slow down. If the slower team member continues to lag or falls even further behind, the leader should stop. In the latter case, the leader should not take off again as soon as the slow one catches up; this deprives him of the rest the other team members have been able to enjoy, and that he most likely needs.

Even when the team moves together at a steady pace, a brief pause from time to time is a welcome benefit to all. This allows your body temperature to adjust, as this tends to rise during exertion. To keep from overheating, the body releases perspiration that cools the skin upon evaporation. But, as we have already mentioned, the cave environment is humid and the caving suit traps perspiration, preventing the proper functioning of your body's natural cooling mechanism and leaving you soaking wet. To prevent this, open the upper part of your suit when travelling through dry walking passage, or remove it completely if the passage is long. Otherwise, take short, regular breaks, each time remembering to open your suit immediately to allow accumulated water vapor to escape. At the first shiver, close your suit or start moving again. If you remove your gloves and they aren't too muddy, place them between your caving suit and under suit, or sit on them. They will stay warmer, and putting them back on will be more pleasant – or, at least less unpleasant, depending on their condition!

Stooping passages and crawlways

Stooping positions include stooping, duck walking and hands and knees crawling. Depending on which one you take, you should carry your pack:

- on your back over one shoulder, so it can easily be removed if the pack begins to scrape too much against the ceiling (fig. 122);
- on a tether attached to your harness or belt, as long as the ground is not too rough;
- unattached and pushed or carried in front of you with the side handle as you advance (fig. 123);
- or unattached and carried by hand, with the forearm resting on the leg and following its movement.

You can minimize fatigue and sore muscles by varying your position as you move.

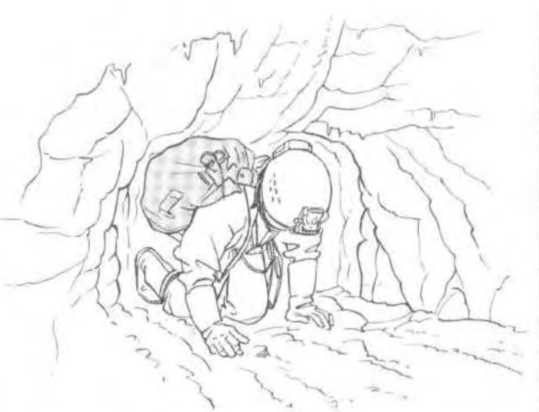


Fig. 122 – Travelling in a crawlway with the pack worn over one shoulder.

Fig. 123 – Pack carried or pushed in front while crawling.

Canyons and meanders

Canyon passages are high, narrow passages that sometimes require extra effort for travel. Except in extremely narrow or water-filled areas, you will usually move through these passages in upright position at ground level, with your pack on your back. If the passage narrows and you need to continue sideways, carry the pack with one strap over the shoulder (fig. 124), or by hand using the side handle or top closure and resting the pack on the front leg (fig. 125). Some packs have a handle at the top that is more ergonomic for the hands and wrists and easier to carry in these situations. If moving at ground level is not possible, you can some-

Photo P. Crochet

Fig. 124 – Moving through a meander with the pack worn on the rear shoulder.

Fig. 125 – Carrying the pack in front using the side handle with the arm resting as much as possible on the front thigh.

Fig. 126 – Pack tethered from the seat harness.

times find ledges that are wide enough to allow continuation in a walking position...or they may require you to move in opposition.

1.2 Opposition : Chimneys and Traverses

When the floor is inaccessible or impracticable, it's time to find a higher route, using footholds in the walls and a technique called opposition (or straddling). In this situation, the cave pack often hangs on a tether from the seat harness maillon (fig. 126). Its weight is thus transferred from your back to your legs. However, if you risk dragging the pack through water or jamming it into a crevice, you may have to carry it on your back or attach it to your belt with a shorter cord.

The simplest way to move in opposition through a meander – when the width allows it – is by facing forward with each foot and corresponding hand on opposite walls, straddling the empty space between. This is classic opposition. You will often find footholds in the unevenness of the rock to help you along (ridges, outcrops, nodules, hollows, etc.; fig. 127).

If the walls are smooth, you must rely on friction and the tension you create by pushing out firmly against both walls. Be especially careful of loose sediment or a thin layer of mud on the walls; these can make each step slippery and precarious. In such situations, only sheer pressure will create the friction you need to proceed, and this requires greater exertion.

When meanders are too narrow to allow frontal opposition, you will have to move sideways, with your back and bottom on one wall and your feet and hands against the opposite wall. Depending on the shape and width of the passage, press out on either feet or knees, always in opposition to your backside (fig. 128). As you move sideways, you should either have both hands on the wall behind you, or one hand on each wall. When you move up or down a narrow vertical passage using opposition technique, this is called "chimneying."

As a general rule, the pack is tethered to your harness in this kind of passage, but it may sometimes be thrown over one shoulder. You may want to remove some or all of your climbing gear and put it in the pack : this makes movement much easier and prevents wear on the gear.

If the passage narrows even more, you will have to look for the best way through. As in crawlways, travel becomes much more exerting, requiring you to move and climb in opposition through a narrow, confined space. If the meander is sinuous, attach your pack directly to the side of your harness belt to prevent it from hanging too low and getting stuck in crevices below you.

Wider meanders are less fatiguing, given they have plenty of footholds. Opposition is easier and more natural, with hands on one wall and feet on the other. If the meander widens even more or if – regardless of its width – the depth beneath you present a significant danger in the event of a fall, the passage should be rigged with a traverse line or as a vertical drop.

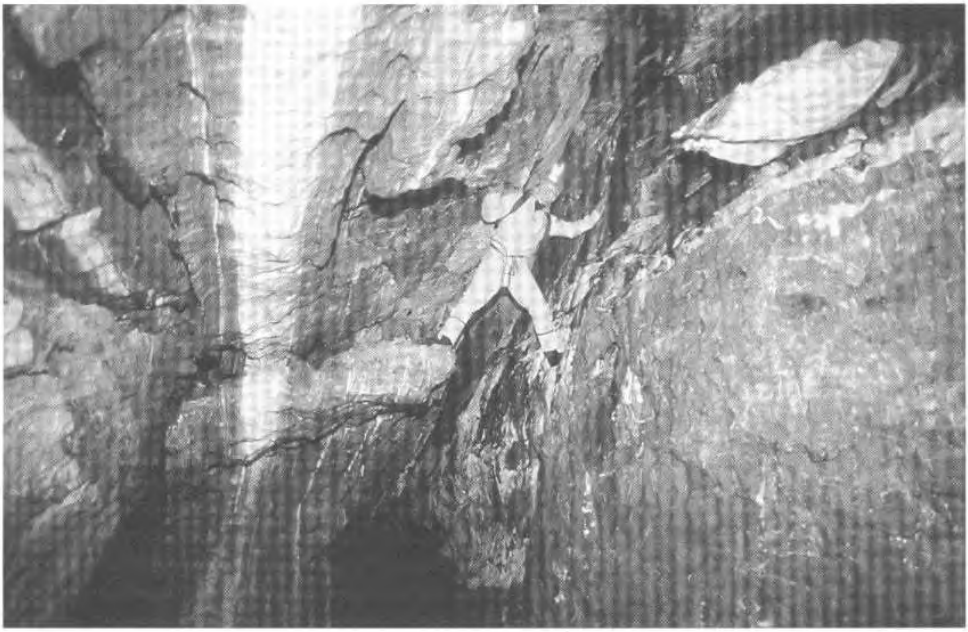
1.3 Free Climbing and Down-climbing

Free climbing without gear is an excellent time saver, but you should never compromise safety to save time. Remember that your risks are compounded by the cave environment; you must confront humidity, darkness, muddy walls and clay deposits that haven't been cleared off by the usual processes of erosion that occur on the surface. When climbing, there is one rule that should never be broken: always have at least three points of contact, in case you lose one. Any questionable holds should be carefully tested and if there is any doubt as to their reliability, they should be abandoned. If this is impossible and there are no other choices, these holds should be used with the utmost care and deliberation, and don't hesitate to rig a simple hand line. When climbing in either direction, if the climb can be cleared easily with a pack, this should be tethered to the harness (or carried on the back if it could get jammed somewhere), leaving the arms and hands free to negotiate the climb.

When down-climbing over steeper slopes, face the rock so that you can better see the holds. On less precipitous slopes, you can climb facing the slope – your back to the rock – with your pack tethered to your harness or carried on your back (fig. 129).

Fig. 127 – Moving in opposition through a meander.

Fig. 128 – Sideways opposition through a narrow meander.



Patagonia. Photo J.-F. Pernette

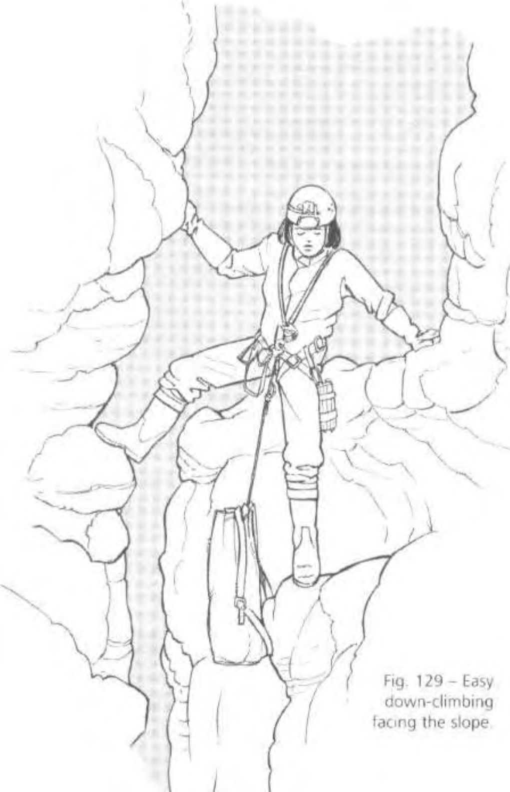


Fig. 129 – Easy down-climbing facing the slope.

Key points:

Never lean backwards when facing the slope as you down-climb. This is a common mistake and only gives a false sense of security. In this position, the feet can easily slip forward, leading to a more or less controlled slide or fall. If you feel more secure with your hands on the rock, you should instead bend your legs and lean forward on your hands.

1.4 Constrictions

Constrictions can be the most dreaded cave passages, not only because they are exhausting but also because confining the human body – especially the chest cavity – is unnatural and can lead to psychological discomfort or distress. Before a new or unfamiliar constriction, the group should call on the smallest or most motivated caver to attempt passage. The tighter the constriction, the more self-control you will need to move through it. It is important to control your breathing, keeping it calm and steady. To do so, move slowly, relaxing and resting as long as you need to before continuing.

Beginners in particular may panic, even at a constriction that was already passed on the way in! Try to reason with the "victim," speaking slowly

Fig. 130 – Duck walking in a low passage.

Fig. 131 – Belly crawling through a low crawlway, dragging the pack on its tether.

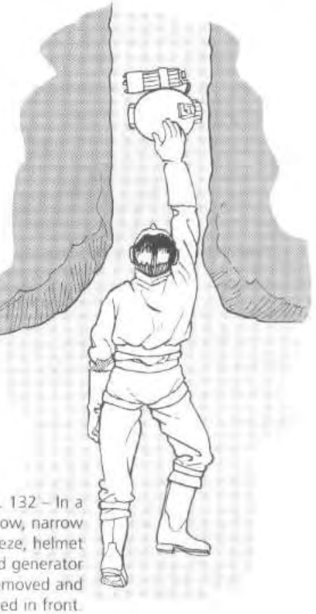


Fig. 132 – In a low, narrow squeeze, helmet and generator are removed and pushed in front.

and calmly, reminding him that he can back up if he needs to, take the time to rest, and then try again. In more serious situations, you will need an experienced, patient, and assuring caver to go ahead through the constriction, turn around to establish visual contact, and help guide and encourage the panicked person through the difficult spot, backing up as the latter moves forward.

Low crawlways

Low crawlways are horizontal passages that have particularly low ceilings. They may be long or short, wide or narrow, but they are always by definition low. You may sometimes be able to move through by duck walking in a stooped position (fig. 130) or by crawling on hands and knees. But most of these passages require a flat-out (literally) belly crawl: with elbows forward and out, head turned and legs flattened to the side, move forward by shimmying and sometimes slithering over the ground, lifting your body alternatively with hands, elbows, knees, and toes. Pushing and scraping through tighter areas is especially exhausting and will subject your caving suit to increased wear and tear. The cave pack is usually tethered and dragged between the legs; you can use your feet to help guide and release it from occasional jams.

Pinches

A pinch or squeeze is a punctual passage that is low and narrow, in which the body is more confined and can only advance with heavy scraping and more pushing or pulling. Remove your vertical gear and put it in your pack. Before proceeding, study the passage carefully and decide how best to fit into it. Extend one arm over your head and the other down against your body so as to flatten the shoulders. You may need to detach your generator from your harness and hold it in front of you with your lead hand, and you may have to remove your helmet, which you should also push in front of you (fig. 132). When moving your helmet be careful not to burn your hands: your gloves can only protect you so much, and melted PVC is no more pleasant than a hot flame!

Moving packs through difficult crawlways may require at least two people. Once out of the crawlway, the first person turns around, partially re-enters it and pull the packs out as the next person passes them forward one by one. Some teams attach the packs lengthwise to a tether and pull them through in all at once. If you know the passage well and it is not too long, drag your pack behind you on a tether. This works well enough for all but the last team member: if the pack gets seriously stuck

Fig. 133 – If the crawlway isn't too tight the pack can be pushed in front.

or a shoulder strap hangs up on a rock, there is no one behind to release it. In more sinuous passages, push or roll the pack in front of you; you can always back up and reposition it if it gets stuck.

Longer tube-like squeezes make travel even more difficult. If the passage if relatively comfortable you can drag your pack behind you on its tether, or push or roll it along in front of you (fig. 133).

If the passage is particularly narrow, move slowly, keep your breathing steady and stay calm so that you can think clearly about your movements. You may have to make more than one attempt, backing up and changing your position to find the right fit. It is best not to drag the pack on its tether in this case, as it could easily become stuck. Instead, attach your packs to each other lengthwise and haul them through on a section of rope.

Vertical or sloping constrictions

Tethered to your harness, your pack should be lowered down first when you are descending through a sloping constriction, and hauled up last when climbing out. Any severe or newly discovered constriction should naturally be attempted without the pack. When climbing, you can lengthen your tether by clipping it to a cowstail or your foot loops, so it remains on the ground while you negotiate the difficult passage. Moving through these areas may call for some turning, twisting and shimmying.

When descending, it can be very dangerous to proceed head-first; gravity makes it especially difficult to back up in a narrow space. Even on slopes that you consider less steep, tie a length of rope around your ankle and have the person behind you act as a belay. If you must back up, have them pull the rope taut, bend your knee and pull yourself backwards, wedge your body to avoid slipping and straighten your knee, bend your knee again, and so on.

On steeper inclines, proceed feet first, belayed at the waist by a team member and feeling around with the feet for continuing passage and footholds. If you get through without any surprises, you can use the rope as a hand line on the way back up, or add some loops and use it as an etrier. If the constriction is especially tight or doesn't go, install a haul system or counterweight to assist the first down in getting back up. If the constriction opens onto a pit, this rope can also be used to relay the equipment needed to rig the drop.

Constrictions in water

No matter how brief, a belly-crawl through a water-filled passage means soaking the chest and stomach and should be avoided. These are the last areas of the body you want to get wet since they hold a great deal of heat and are more sensitive to chilling. If your torso remains in prolonged contact with cold, wet clothing, you will lose additional energy and warmth. Draining the water is rarely an option (and impossible if you are moving upstream), as is digging a deeper channel (practically impossible if you arrive from upstream). The only other option is to avoid immersion as much as possible, lifting yourself gingerly on elbows and knees and carefully avoiding submerged areas. In many cases, this is easier said than done! The only sensible alternative is then to change into a pontonniere, and maybe even a cagoule. If the passage only has a trickling of water from above, you may be able to get by with a PVC suit.

To temporarily redirect or interrupt a flow from upstream, you can sometimes install a tarp, plastic sack, etc.

1.5 Travelling in Rivers and Streams

Without water the underground world would be forever silent and unchanging, and this is one reason why water is an obsession of cave explorers. Whether a babbling brook or a raging river, water draws us to it and holds us transfixed. Serpentine, erosive, cascading, corrosive, it runs its course, bewitching and captivating the delighted explorer. Following its path from confluence to confluence, every caver seeks the system's principle drain. Yet he knows the great adventure will almost inevitably end in the deep, green waters of a terminal sump or the mocking gurgle of water disappearing beneath some impassable obstacle. The water will continue its mysterious voyage alone, toward some unknown spring.

As beautiful and attractive as they may be, rivers are one of the principle dangers of the underground world and one of the most frequent causes behind cave rescues. Repeated submersions, exposure to waterfalls, low temperatures, increased exertion in attempts to stay dry – all help to accelerate exhaustion and hypothermia. A sudden rise in water due to an unexpected storm on the surface can turn trickling pit cascades into roaring waterfalls, and waterways that have risen several meters can become dangerous or impossible to pass. Surprise can turn to panic, increasing the likelihood of a fatal error. In the worst cases, this can result in hypothermia and its consequences, or drowning.

To limit these risks, you need to have an accurate weather forecast before venturing into underground waterways.

The pontonniere

As soon as the water level is above your Wellies and the cave walls are too far apart to permit a traverse in opposition, consider wearing a pontonniere. Since it is delicate, look for a spacious changing area to avoid scraping and tearing this against the cave walls or ground. Place an empty pack or plastic sack on the ground where you will change. The pontonniere is worn between the undersuit and caving suit, with socks or neoprene booties worn over the feet. Boots and belt or harness follow, but you'll have no need for the rubber bands that normally hold your suit against your boots. In fact, you will need a gap to periodically empty water from the boots. Since a liter of water weighs one kilogram, you'll soon feel like you're walking with lead weights. Rubber shoes or cut boots are most useful here. When moving, keep your unprotected arms up and out of the water. For deeper areas, use a buoy – a sort of small inflatable seat with straps that go between the legs – or add the watertight cagoule. This hooded top is tighter around the wrists, neck and face openings to prevent water from entering. Its lower section dou-

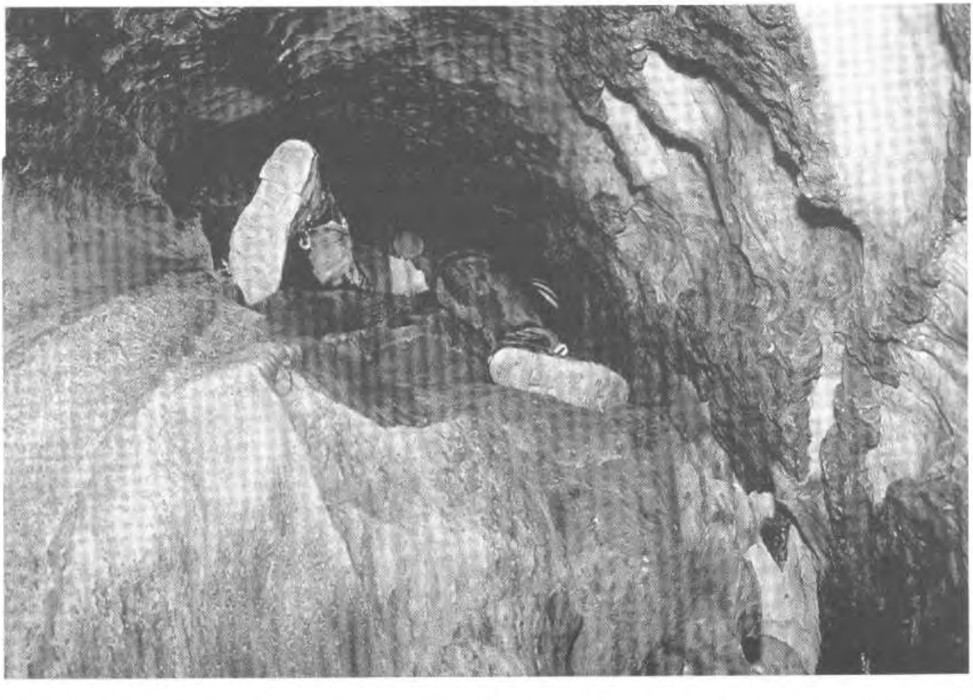


Photo M. Alspaugh

bles over the pontonniere, over which a rubber belt (made from a tire inner tube) is snugly worn. The entire ensemble is watertight, light, flexible, and even permits swimming for short distances.

Take a along a simple repair kit (rubber solution and patches), in case you have any catches or tears. Aside from major rips (irreparable in the field anyway), repairs should only take about twenty minutes, including undressing and suiting back up.

Place the contents of your cave pack in a waterproof sack. Tethered to your harness, the pack should float quietly behind. Carry it over your shoulders as soon as the water gets shallow again.

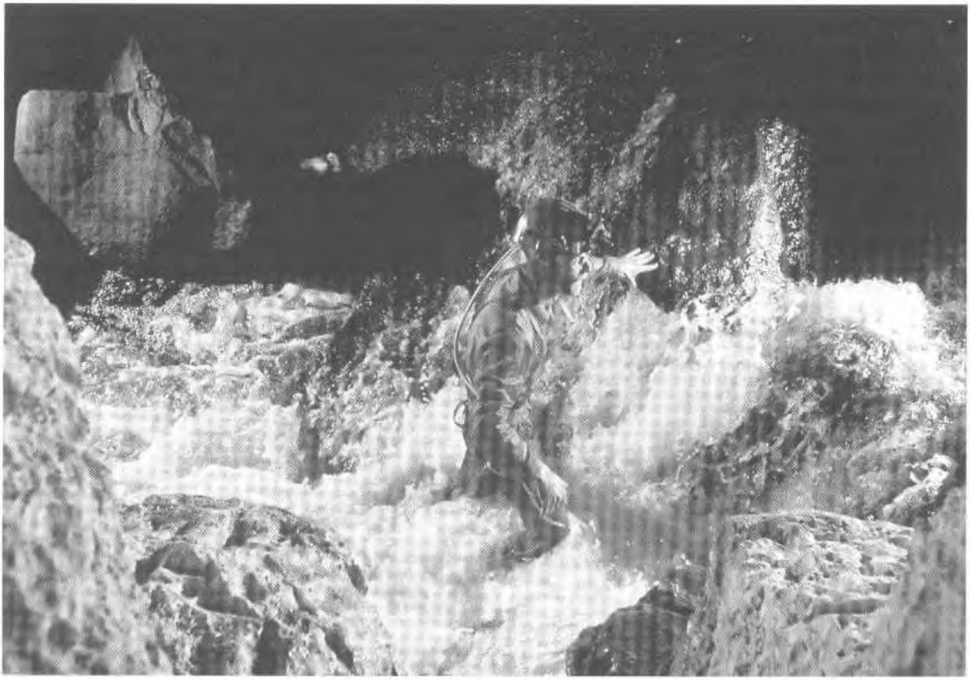
The classic pontonniere is not breathable and so prevents perspiration from escaping, and this soon condenses into water soaked up by your undergarments (see B5). This is okay as long as you are in the water because the moisture remains at body temperature. However, it chills as soon as you stop, so reduce pauses to a strict minimum, except to stop to undress and dry out a bit. As soon as you're beyond the wet section, change out of the pontonniere immediately, dry out as much as possible, suit up again and start moving before you become too cold. If you continue through dry passage in a pontonniere, you'll soon be marinating in your own perspiration.

Neoprene

The neoprene wetsuit is an alternative to the pontonniere, especially for longer immersions. Unlike the pontonniere, the wetsuit does not risk filling with water because it is already somewhat wet, yet it protects the body from exposure to the cold water. It is indispensable for longer deeper "swims" since it is both buoyant and insulating.

But the neoprene wetsuit has a few major drawbacks:

- You have to completely undress to change into it, which is not much fun in cold alpine caves.
- It is thick and cumbersome, limiting your movements and thus requiring extra effort. It can also irritate the skin, especially behind the knees and at the bend in the elbows.
- Water trapped between the skin and the wetsuit tends to soak the skin, preventing respiration of the cutaneous layer. This can lead quickly to fatigue.



Sof Omar Cave, Ethiopia. Photo U. Widmer

- Once you are out of the water, you need to remove the wetsuit immediately, for the same reasons as with the pontonniere. It is otherwise extremely cumbersome and can cause cramping at the first exertion, such as on a pitch climb.
- Finally, the wetsuit is bulky and heavy, and takes up considerable space in your pack.

2. Vertical Technique: General Principles

In horizontal caves or passages, you are often free to follow your fancy, to "do your own thing" depending on the circumstances. Vertical caving, however, leaves little room for improvisation, and the slightest mistake can be very unforgiving. This is where tried and tested vertical equipment and techniques enter the scene. The techniques that we will describe in the following pages are not the only possible choices nor the only ones used, even in France. But they have been so widely used and proven effective – in the field and in training situations – that they constitute an integrated system which will allow you to deal with any situation using standard equipment. They will help you progressively master the difficulties you encounter in vertical caving.

We recommend that the novice follow these techniques to the letter. Once he has practiced them thoroughly and completely mastered them, he will likely want to try out some variations and look for ways to improve and streamline them. He will do this either on his own, through contact with other cavers and clubs, or by referring back to sections of this book where we offer further suggestions. According to his personality, habits and preferences, he will eventually widen his field of experience and gain the technical skills and knowledge he will need to decide which techniques work best for him.

We are by no means suggesting here that an experienced caver should change his way of doing things to conform to the techniques described in this section. We only hope he is able to glean some information or insights that seems relevant to his own practice, and that he is tempted to try them out in comparison. He may want to adopt those variations that seem most useful, and keep the techniques he knows and trusts (provided they are safe). Aside from some basic principles, we present no theoretical dogma here.

The basic vertical techniques that we will now describe assume that all rigging is safe and has been installed by a competent person. A discussion on rigging can be found in Chapter K, Rigging the Cave. But it's no use knowing how to rig if you can't pass a rebelay, so let us continue our present discussion.

3. Rappelling (Descending/Abseiling) with a Descender

The heroic era of descent on cable ladders, (with or without belays), shoulder rappels and carabiner rappels is now past. We can find a variety of descenders on the market today, all conceived for different uses. The models used most in European caving can be broken down into the two types:

- The normal spool descender is the most widely used in Europe, and we especially recommend this model to the beginner. It presents one major risk, however: releasing the rope could result in an uncontrolled fall. During practice and training sessions, "newbies" should be belayed by their instructors.
- Auto-lock descenders are like normal descenders with an automatic stopping mechanism. This works by releasing the handle, while the descent is made by holding the handle down. This is counter-intuitive and can lead to significant injury (or worse) if a novice panics and automatically grabs hold of the descender and handle; auto-lock descenders should therefore be reserved for experienced vertical cavers. The experienced caver will rarely make such an error, but be aware that the stopping mechanism should not be used as a brake, as this wears down the rope. The handle should be held down completely during normal descent, and released only in case of difficulties. Slowing and stopping is carried out using tension on the slack rope below the braking hand. Only when you have learned and assimilated the proper use of auto-locks can you appreciate their comfort and effectiveness.

We will use the normal descender, or Simple, in our presentation of rappel techniques.

Fig. 134 – At a free drop, hang from the anchor on your short cowstail and use your knees for balance.

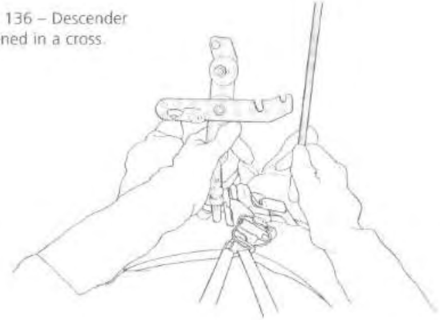


Fig. 136 – Descender opened in a cross.

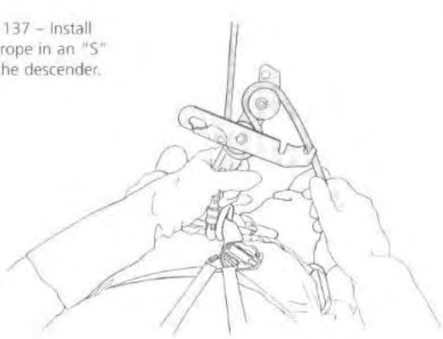


Fig. 137 – Install the rope in an "S" on the descender.

Fig. 138 – Pull the slack from above through descender.

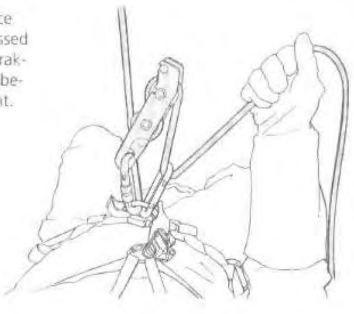


Fig. 139 – Once the rope is passed through the braking carabiner, begin the descent.

Fig. 135 – When there is a good ledge, the short cowstail is not loaded before the descent.

3.1 Approaching the Pitch Head

As soon as the first anchor of the traverse line appears, attach your cowstails for safety. At each point where the rope is anchored to the wall, place your unattached cowstail on the next length of rope before removing the first cowstail, and so on, until you arrive at the top of the pitch head. (Always have at least one point of attachment at all times). You will need both hands free to install the descender onto the rope. If sitting or standing on the ground is impossible or if you are already at the precipice, clip your short cowstail directly into the connector that is holding your descent rope and place all your weight on this cowstail. Balance yourself by making a triangle with your feet or knees against the wall. (fig. 134).

Even if you can stand comfortably on a ledge, you should still use a cowstail for safety. Clip it into the upper rope loop, where it will hang loose (fig. 135).

3.2 Installing the Descender

1. Attach the descender directly to your harness maillon with a locking carabiner and hold it with the left hand. Use your right hand to open the latch and release the sideplate, which you then position horizontally. Your descender is now open and in the shape of a cross (fig. 136).
2. Install the rope coming down from the anchor in an "S" formation through the descender, starting from the bottom left side. Holding the descender in the left hand and the rope in the right, place the rope on the left side underneath the horizontal sideplate. Pass it under the bottom spool, back between the two spools, and then out to the right over the top spool (fig. 137).
3. Close the descender, making sure the latch on the top sideplate has closed completely around the carabiner.
4. Pull the bottom of the rope up with the right hand to take up the slack (fig. 138). Then pull the rope down and place it in the braking carabiner (this is attached to your harness and adds extra friction for braking and stopping). Once your descender is engaged, hold the rope firmly in the right hand at all times (fig. 139). Never let go of it unless the descender is securely locked off (see 3.4 below).
5. Check that your descender is correctly installed and everything is in order.
6. Unclip your cowstail by stepping up against the wall (or using your footloops or the loop in the rope, if necessary). Once you have transferred your weight to your descender and established a comfortable, controlled position, begin rappelling.

3.3 Controlling Your Speed

You can control your speed by holding the rope with both hands (fig. 140), or with just one (fig. 141), below the braking carabiner, according to your pref-

Fig. 140 – Braking with both hands.

Fig. 141 – Braking with one hand.

erence. When the left hand is free, use it to hold the descender to help balance yourself on the rope. Novices tend to instead hold the rope above the descender, (mistakenly) thinking this will help them slow down. On the contrary, speed is only controlled with the rope below. As you pull upwards on this with the right hand, you create friction against the braking carabiner, slowing your descent. Try not to let the rope rub too much between your right thumb and forefinger, as this will rapidly wear a hole in your glove. Avoid this problem by using both hands to feed successive sections of rope through the descender.

In a free-hanging descent where your feet do not touch the wall, you should be in a half-sitting position with your chest parallel to the rope and your legs dangling freely. When rappelling against a wall, your legs are roughly perpendicular to your chest and slightly bent, intermittently pushing out on the wall so as to help guide your descent. Depending on the speed of your descent and the position of the wall relative to you and the rope, you either "walk" or "run" down the rope, slowing down if there is any danger of rock fall due to loose rocks in the walls. On faster rappels, look down below you to anticipate what will come next.

A smooth and controlled descent is important, both for the rope and for the anchor. Sudden jerks place added and unnecessary stress on these, especially when you are near the anchor. During a rappel, the descender gets hot from friction with the rope, especially when rappelling near the surface where the rope is dry, or at the end of a longer rappel. In these situations, avoid a sudden stop and remove the descender quickly from the rope, as it can melt the sheath.

On rapid rappels, control your speed with the right hand only, the arm extended downward. Don't get too carried away and burn your glove and possibly your hand. Your innate reflex is then to let go, resulting in an uncontrolled fall, unless you are the fortunate beginner who is being bottom-belayed by the instructor. It is important to maintain constant control of your speed. Once you're on rappel, you alone are master of your destiny.

As for the exhilaration of "free fall" rappels, this is off limits for beginners; it is reserved only for experienced cavers in pits that are sufficiently wide and deep with perfectly vertical hangs. An experienced caver will have mastered a finely-tuned technique: he leans back, head turned to down to the right, left hand around the rope without grasping it and right hand extended below, guiding the rope. He brakes slowly by making a wide half-circle with his right arm, stretching the rope out: if the calculation is perfect, the pack and then the feet will touch ground as he comes to the end of the stretch. A bit of slack at this precise moment with a subtle lowering of the right arm, and he is gracefully on his feet again. Pure finesse!

What NOT to do:

If you have long hair, be very careful not to let it feed into the descender. This can be excruciating, not to mention dangerous. Before going underground, pull all loose hair back and attach it under the helmet. This is the best precaution, although it probably won't save you from needing a good shampoo by the time you come out!

Photo F. Le Guen

3.4 Stopping on Rappel

The full (hard) lock is the safest way to completely stop and lock off the descender during rappel. This should only be done when the descender is fully loaded for descent. If it is not loaded, even a short fall could damage the descender if it is not positioned correctly in the locking carabiner connecting it to the maillon.

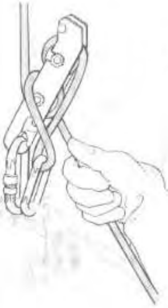


Fig. 142 – Start with a half-lock.

Fig. 143 – Finish with a full lock.

Fig. 144 – Only the full lock allows you to remove both hands safely.

1. Hold the descender firmly with the left hand.
2. Make a half-lock (soft lock) with the right hand (fig. 142).
3. Complete the half-lock with a full lock by pulling the rope through the descender/braking carabiners (fig. 143) and bring it up and over the descender (fig. 144). A half-lock is not enough; you must perform both maneuvers for a complete and safe lock. Your hands are then free.

If you are using an auto-lock descender, you only need to make a half-lock.

Now that you are securely locked off, both hands are free for your next maneuver: to clear loose rocks, set an anchor, rig a rope, or take a photo for example. You can undo the lock by performing the above actions in reverse, making sure always to hold the descender firmly with the left hand and the rope with the right.

3.5 Passing a Rebelay

If the person rigging notices an outcrop, edge, ridge or any part of the wall that will rub against the rope, he will redirect the rope with a rebelay (fixed anchor) or a deviation (also called a redirect, not load bearing). Passing a rebelay on rappel is relatively simple, but does require some technique:

1. Slow down and stop your rappel when you arrive at the level of the rebelay. Some slack should still be available below the descender.
2. Clip your short cowstail into the anchor (connector) with the carabiner gate facing you. With a normal descender, one hand is still holding the rope during this operation (fig. 145); here the advantage of the auto-lock descender is that it frees both hands without locking off the descender (fig. 146).
3. Continue descending until you have loaded your short cowstail. You can now remove your descender and install it on the next section of rope below the rebelay. Try to do this as close to the rebelay as possible, leaving a minimum of slack in the rope. Remember to pass the rope through the braking carabiner.
4. To unclip your cowstail, grab the rebelay knot and the bottom rope (just below the braking carabiner) with the right hand and unclip the cowstail with the left while standing up on a ledge or in the loop made by the top rope (fig. 147). You will then find yourself in maximum braking position, your right hand holding the rope high.

Fig. 145 – With a Simple descender, clip the short cowstail into the rebelay while holding the rope with your left hand.

Fig. 146 – With an auto-lock descender, the left hand remains free while clipping in.

5. Yell, "Off rope!" so that the person above can start down, then resume your descent.
   Never take your eyes off your descender or your right hand off the rope. This will help you position and load the descender correctly before your rappel.[14]

Key points:

- If there are no footholds at the rebelay, the upper rope should be rigged so that it hangs in a loop long enough to allow a person to stand in it and unclip the cowstail. Without this simple support, we have to compensate with our arms. The result is greater exertion, which should be avoided.
- If the rebelay is offset and requires a pendulum swing, rappel just a bit lower than the belay (fig. 148). If you do not have an auto-lock descender, locking off at this point will make it easier to swing over and clip in with your cowstail.
- Except in special situations (such as constrictions and other difficult take-offs or when carrying heavy packs, for example), we generally do not fully lock off below the bolt when beginning a descent. This usually serves no purpose and can be a waste of time.

What NOT to do:

Do not rappel all the way to the bottom of the loop in the upper rope.

3.6 Passing a Deviation (Redirectional)

1. Stop your rappel at the level of the deviation, locking off your descender if necessary.
2. If the opposite wall is within reach, push against it with your feet to create slack in the deviation.
3. While you do this, unclip the deviation carabiner with your free hand and place it above the descender.
4. Unlock your descender and continue the rappel.

To do:

To bypass a high angle deviation, clip your long cowstail into the deviation carabiner. This will prevent you from losing the deviation in case you happen to let go of it during the maneuver.

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[14] See footnote 17 on page 145 for an alternative technique.

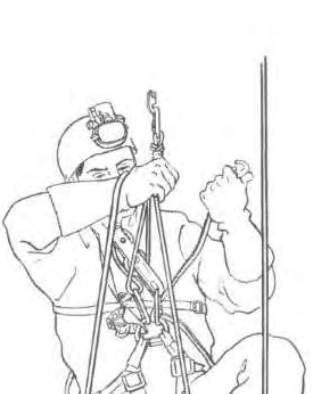

Fig. 147 – When there are no footholds, step up in the rebelay loop in order to unclip the cowstail.

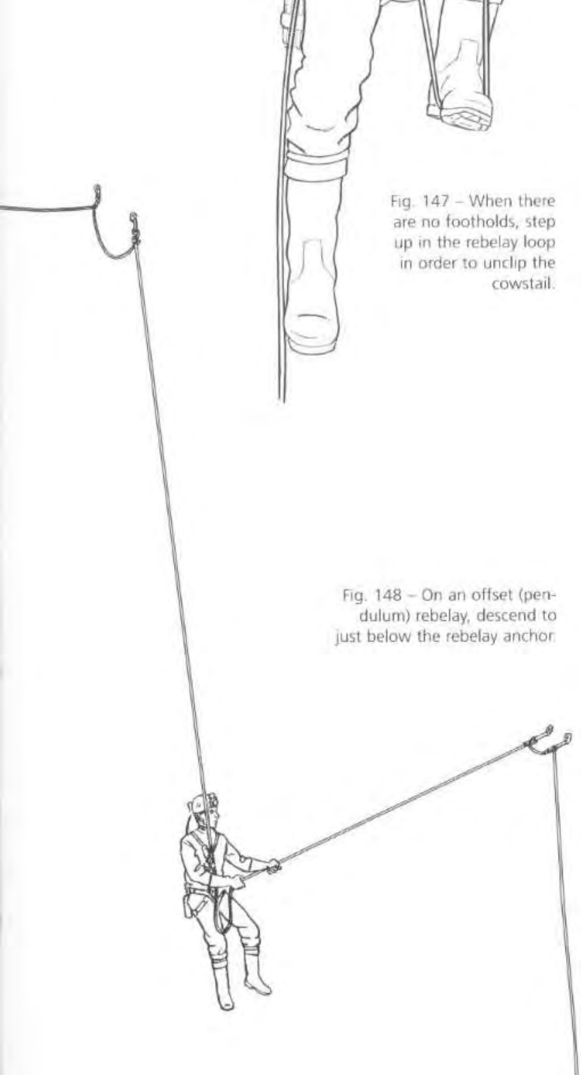

Fig. 148 – On an offset (pendulum) rebelay, descend to just below the rebelay anchor.

What NOT to do:

- Do not load the deviation with your cowstail while attempting to pass it. The gate of the deviation carabiner will be blocked by your weight, preventing you from removing the rope from the carabiner.
- Never remove your descender from the rope to pass a deviation.

3.7 At the Bottom of the Drop

If you land below on relatively flat ground, bend your knees to create the extra slack you'll need to quickly disengage your descender from the rope. Having a small amount of stretch, the rope will remain taut. If your next rappel immediately follows, clip a cowstail into the traverse line or directly into the connector for the next drop, before removing your descender from the previous rope. Remember to yell, "Off rope!"

3.8 Carrying the Pack

When you are on the rope, your cave pack hangs below you on a tether, attached to your seat harness maillon. In this position, the descender carries the weight, which is not the case when the pack hangs on the side of your harness.

To avoid twisting the pack around the descent rope, hold the latter off to the side of your right leg (fig. 149). Use your foot to direct the pack away from the rope if the pack has a tendency to pendulum.

Carrying the pack on your back while on rope pulls you backward and off-balance, and works your abdominal and arm muscles unnecessarily. Only do this when there is danger of rock fall (fig. 150) or if you are going to land in water. In the latter case, descend with the pack tethered until it brushes the surface of

Fig. 149 – Use your right foot to keep the rope from tangling with a tethered pack.

Fig. 150 – If the pack could cause rocks to fall below, carry it temporarily on one shoulder.

the water. Stop and throw it over your shoulder or attach it to your side.

3.9 Narrow Pits

During normal use, the descender is situated level with the sternum. This can be a problem in narrow pitches since it can get stuck between your chest and the cave wall. In this case, attach it to your short cowstail so it hangs at face level (fig. 151). In this position, make your brake by passing the rope through the descender's locking carabiner rather than the braking carabiner (Vertaco method).

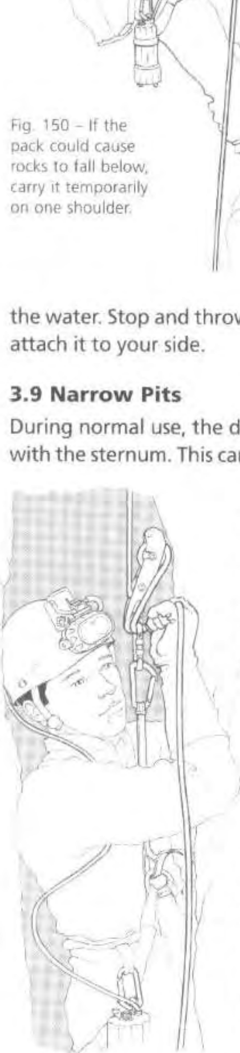

Fig. 151 – In narrow pitches, install the descender on a cowstail. Note the "Vertaco" braking technique.

3.10 Belays: Safeguarding the Descent

You can safeguard a beginner from the top or bottom of a any pit. When you are the only instructor present, you must check the correct placement and loading of the descender and so rappel after the student. You thus belay the student from above with an extra rope, using an Münter (Italian) hitch, letting out slack as the student descends. This is called a loop belay.

When two instructors are present, one descends first to bottom-belay the student, holding the rope firmly without pulling on it. If the student loses control of the rappel, the belayer can completely control this rappel from below by pulling the rope, thus regulating its tension. This is sometimes called a fireman's belay.

3.11 Descending Deep Pits

A wet rope can weigh as much as 50% more than normal. In very deep shafts, the increased weight of the rope can even make it difficult to install the descender. One solution is to attach your upper ascender upside down on your harness maillon (fig. 152). This leaves both hands free, which allows you to create the slack in the rope that you need to install the descender. Once the descender is installed, remove the upper ascender and begin the rappel. At the start, you will often have to pull up on the rope, at first with both hands and then with only one (the weight progressively diminishes as the rope passes above the descender), to help feed it through the descender. Eventually you can resume normal rappel techniques.

With an auto-lock descender, disable the locking mechanism with a carabiner so that you can have both hands free to pull on the rope.

Fig. 152 – The upper ascender can help hold a heavy rope in order to feed it through the descender.

What NOT to do:

Never load the descender in a "C" as described below for thick ropes. You could lose control of your speed toward the end of the rappel.

Using a rack descender

For those rare rappels over 200 meters without a rebelay, use a rack descender (fig. 153). By adding bars as you descend, you increase the braking action as the weight below you decreases.

Attach the rack to your seat harness with a locking carabiner.[15] Racks with a top "hyper-bar" are much easier to use. The closed-frame Micro-Rack comes with a hyper-bar (see fig. 23, right), and the top bar on larger open-frame rack can be replaced with a hyper-bar (as shown, fig. 154a). Otherwise, clip a carabiner into the frame of the rack between the top and second bars, and use this as you would a hyper-bar, for braking as well as locking off (fig. 154b).[16]

Be sure that the descender is installed so that the notch on the top bar faces *away* from you, or the top hyper-bar is on your *right*. This is crucial: if you install your descender backwards, you will then load it backwards, which will result in a free fall.

Attach the rope to the rack by weaving the rope over the top bar (or hyper-bar) of the rack (again, the notch of must face *away* from you). Clip the second bar to the frame (this notch should *face* you) and place the rope behind it, then bring the rope forward and over the next bar, and so on. Installation of the rope is similar with a Micro-rack, except the top and third bars are fixed to the frame.

What NOT to do:

Never install the rope by running the rope from *behind* the descender (as it is correctly installed, facing you; see fig. 153, right). You will then weave the rope inversely through the rack. As soon as you load this, your weight will cause the bars to pop of and you will become completely detached from the rope.[17]

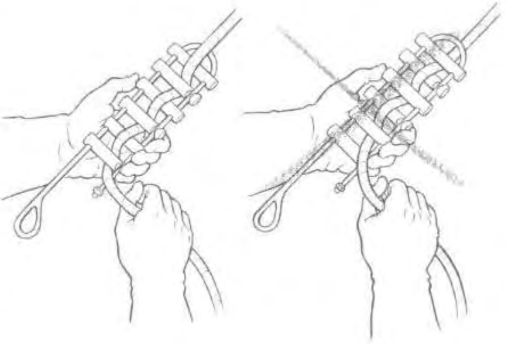

Fig. 153 – Left: Install the rope correctly by weaving it over the top bar and behind the first (already closed) notched bar. Right: Installing the rope backwards on a rack will cause the bars to pop off as soon as the rack is loaded, resulting in a free fall.

Braking

Regulate tension on the rope with the right hand by gripping it and pulling down. If all the bars are installed and you still need to reduce your speed, push up on the bottom bar with your left hand. If you still need more friction, bring the rope up over the hyper-bar and back down behind it, or clip it into the braking carabiner. Better braking action on a rack is effectuated by pulling down on the rope, rather than by pulling up, as with a spool descender and braking carabiner.

Stopping and locking off

To lock off a rack:

1. Bring the rope over the top of the rack and back down behind the upper rope and descender.

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[15] Some users prefer a long oval maillon in place of the locking carabiner.

[16] Ivy, Joe. "Rappelling 101: Using an Open Frame Rack." *The Texas Caver*, Sept.-Oct. 1999.

[17] It may be due to the graver consequences of user error with a rack that in the US, standard practice is to use both cowstails for safety when beginning a descent and passing a rebelay. The short cowstail is placed in the anchor or its connector, the long one is clipped into the rope loop as a backup. When the descender is installed on the lower rope, the short cowstail is removed to load the descender (long cowstail is still hanging slack in the loop). The long cowstail is only removed once the user has unlocked the descender and verified that it is loaded correctly. The long cowstail is removed and the descent continues.

After some accidents involving the use of two cowstails in these circumstances, many European cavers consider this technique to be more dangerous than the use of one cowstail, given the use of a spool descender (which does not detach from the rope when loaded incorrectly). However, the French Caving School does consider the use of two cowstails a viable choice when teaching beginners.

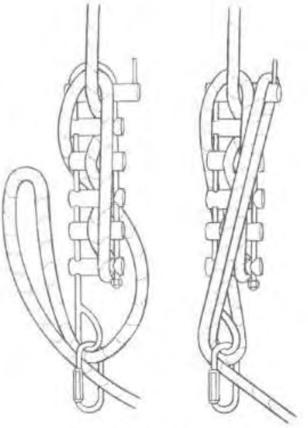


Fig. 154 a – Locking off using a hyper-bar.

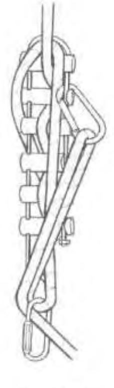


Fig. 154 b – Locking off a traditional rack.

2. Pass a bight of the down rope through the descender carabiner or maillon (fig. 154 a).
3. Bring the bight back up and hook it over the hyper-bar (fig. 154 b), or clip it into the braking carabiner (fig. 154 b).

   You are now securely locked-off.

An alternative using the hyper-bar is to 1.) hook the rope over the hyper-bar and bring it back down, 2.) pass a bight through the descender carabiner, 3.) then hook the rope over the hyper-bar a second time (not shown).

3.12 Rappelling on Thick Rope

When a particularly thick rope is placed over spools that are already worn by thinner ropes, the rope may become stuck in the descender, interfering with your rappel. This also happens with ropes swollen by mud.

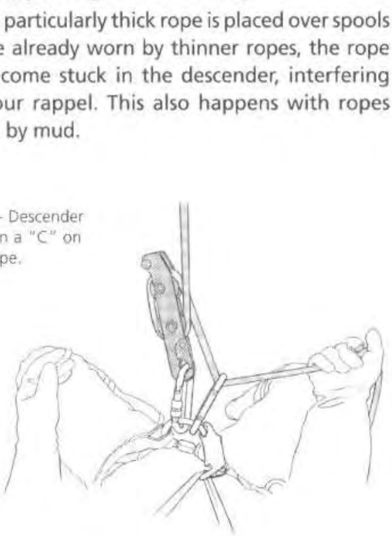


Fig. 155 – Descender installed in a "C" on thicker rope.

To do:

- Load the rope in a "C" instead of an "S" around the spools (this is also called a Zero). Don't forget to use your braking carabiner (fig. 155).
- When rappelling on a "C," be sure to leave one pitch completely free between two teammates to reduce shock in the event an intermediate anchor fails (see page 64).

What NOT to do:

Never belay an inexperienced caver on a "C" from below. The descender could twist and even break under the sudden tension on the rope.

3.13 Rappelling on Taut Rope

You may encounter a situation in which there is not enough slack in the rope to load the descender. This could result from the rope being twisted at the rebelay below or caught on a ledge or behind an outcrop in the wall, after a previous ascent. Once the rope is relieved of the weight of the unsuspecting caver (who is likely unaware of the problem), it will naturally become taut.

To do:

Down-climb on your ascenders (page 154), find and correct the problem.

What NOT to do:

Any other maneuver brilliantly improvised at the last minute or boasted about by another: if the rope suddenly unjams during such an improvisation, a free fall could result.

3.14 Slippery Ropes

When the rope is too small in diameter or covered in slippery mud, normal braking action could be ineffective. In this case, you have two solutions; one is good, the other is not.

To do:

Add another braking carabiner to the tense rope above the descender, placing the carabiner perpendicular to the descender with its opening facing up and out. Pass the rope below through this as well as the normal braking carabiner (fig. 156). In this configuration, braking action is improved by pulling down instead of up on the lower rope.

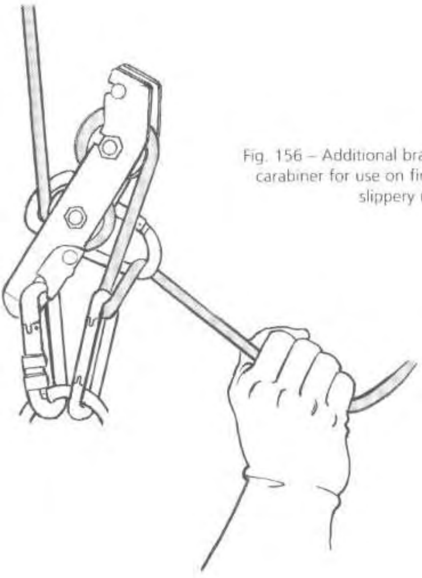


Fig. 156 – Additional braking carabiner for use on fine or slippery rope.

What NOT to do:

Do not add another loop to the braking carabiner, as this will badly twist the rope (fig. 157).

Fig. 157 – Wrapping the rope around the braking carabiner will severely twist the rope.

3.15 Using Auto-lock Descenders

An auto-lock descender has a moving mechanism that acts as an automatic brake on the rope unless the user intervenes by squeezing down with the left hand on the handle. Compared to the classic descender, this model has its pros and cons, and its overall effectiveness remains in dispute. Without wishing to change anyone's mind who has already established an opinion about the auto-lock, we will nevertheless present some information for consideration.

The major argument against the auto-lock is that the action of the handle is counter-intuitive to a beginner's spontaneous reflex, which is to grab hold of the handle rather than let it go. One solution to this problem has recently appeared: double-action stops that brake when the handle is both held down completely and let go completely (see Chapter D). However, we don't feel these are fully adapted yet to our use in caving, and we still suggest initial vertical training on Simple descenders.

Moreover, one careless move in a narrow passage, for example, could accidentally jam the handle, releasing the stopping mechanism and leading to an abrupt fall of several meters. Aside from the unpleasant surprise, the abrupt stop following the fall can damage or even tear the rope sheath.

The other problem with auto-locks is simply the result of bad technique: the stopping mechanism is not meant to be used as a brake, and should not be used as such. Controlling your speed by using pressure on the handle will flatten and wear down the rope. A braking carabiner should therefore still be used with auto-locks.

An eventual advantage of the auto-lock is that it provides added safety in the event of a sudden rock fall that could surprise or knock the rappeller unconscious (This is theoretical since we have never actually seen this occur yet).

But a major advantage of the auto-lock is that you need not make a half-lock before locking off fully. However, you should always lock the descender when stopping for a maneuver that will require your attention elsewhere. Engrossed in the maneuver at hand, your risk accidentally releasing the stopping mechanism as described above.

Key points:

You don't need to lock off before clipping in and coming to a stop at a rebelay (there is little rope left below to fall down). You can completely let go of the descender as well as the rope in this case, freeing both hands for the changeover. This is a great time-saver, especially in the case of pendulum rebelays.

What NOT to do:

With an auto-lock in particular, take care not to rappel with a jerking motion when you are approaching a belay: because the distance between the rope and the anchor is shorter, the anchor will have to absorb greater shock from these violent movements.

4. Climbing Rope on a Frog System

The development and use of the sit-stand system – known widely as the Frog system – has led to the gradual disappearance of caving ladders. During the era of cable ladders, it was already common to use a rope but only for descent, with the shoulder rappel techniques used in mountain climbing before the discovery of the figure eight descender. At the time, the belief was, "the faster you go, the less distance you will have to fall," and the short time spent away from the ladder troubled no one. But to do away with the ladder for climbing! It didn't seem like a safe bet...

Pierre Chevalier had already used "monkeys" – precursors to modern ascenders resembling the Gibbs – for climbing pitches in the Trou du Glaz (Dent de Crolles, Isère, France). But his technique was slow and tiring, and was only used by the first person to climb the pitch, who then rigged a ladder for the others. They had yet to discover a simple, efficient technique that the entire team could use. It was André Méozzi, ("Ded" to his friends, hence the French term for this method, the *Ded*), an active member of the Spéléo-Club de la Tronche (Isère, France), who first developed the modern technique. The members of his club adopted the method with enthusiasm, and it helped them make significant breakthroughs in their explorations. But the sit-stand method didn't catch on so quickly elsewhere, and many criticized it even before trying it themselves. It was only when the EFS (French Caving School) called on members of the La Tronche club to organize training sessions that the cause was won. Today, all of Europe – east as well as west – has adopted the Frog system. It has taken longer to catch on in some parts of the United States, but "the Frog" has seen a marked success there in recent years, and its use only seems to be growing.

4.1 Gear

A upper ascender attached to a footloop is linked to the long cowstail carabiner. A flat chest ascender, the Croll (invented by Fernand Petzl) is held snugly in place between the harness maillon and a chest harness. Five hundred grams of personal equipment thus spares us the weight of cable ladders, about 12.5 kilograms per 100 meters. We are left with the weight of the rope, only a third of the previous total weight. The revolution lies in this difference alone.

Who would even consider going back to the old days of rigging ladders? It nevertheless took a long time to convince the caving world of this safe and effective solution!

4.2 Technique

Open the cam of the chest ascender with a simple rotating movement of the thumb and place the rope inside. Use the same maneuver to position the rope in the upper ascender, at face level. Choose a single or double footloop according to the situation and to preference (see page 51). For the sake of simplicity, we will assume the use of a single loop. Place one foot (usually your lead foot) in the loop, and the other on top of the first to help push the body upward (except when using a foot ascender, which is worn on the right foot with the footloop on the left). To adjust the length of the footloop (once and for all), stand straight up holding the footloop assembly taut with feet on the ground and the foot in its loop. The chest harness should be tightened down and the chest ascender positioned on the rope. In this stance, the bottom

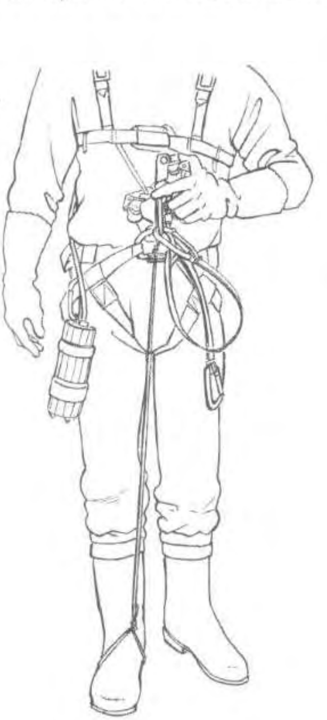


Fig. 158 – Adjusting the length of the footloop.

of the upper ascender cam should be about 2–3 cm above the chest ascender (fig. 158). Fine-tune this adjustment during a real rope climb.

To do:

If climbing with both feet in a loop adjusted for only one foot, lengthen the cord or strap if it is adjustable (quite convenient), or put an extra carabiner between the footloop and the upper ascender.

To avoid this adjustment altogether, simply place one foot in the loop and the other on top of it, and step up with both legs.

What NOT to do:

Do not use an elastic strap or cord in your footloop assembly. Instead, use 5mm Kevlar or Spectra (Dyneema): it has all the advantages of being light, flexible, compact and sturdy (see discussion on footloops, pages 51-52).

Key points:

- Do not allow any slack or play at the level of the chest ascender: your arms will have to compensate for the loss of balance when you step up in your footloop. Moreover, the chest ascender will trigger later, reducing the distance gained with each stride up the rope. Use a chest harness that will feed directly through the upper eyehole of the ascender.
- Fine-tune the adjustment of your footloop assembly. If this is too short, it will prevent the leg from extending completely and eventually lead to fatigue and discomfort. If it is too long, you will gain less distance with each step. If one stride gains an average of 55 to 65 cm, 5 cm lost with each stroke will result in a loss of about 5 meters per 50-meter climb.
- For comfort and efficiency, the upper ascender/footloop assembly should be detachable from the long cowstail when you are not climbing. During longer trips involving traverse lines, an upper ascender fixed to the cowstail is hardly useful, and you risk losing the ascender. For these kinds of passages, use the long cowstail alone and attach the footloop assembly to the side of your harness.

Climbing is carried out in two phases:

1. Push the upper ascender up as high as it can go. As you do so, lift your legs, bending your knees until your heels are just under the buttocks (fig. 159), positioning you for a vertical step upward. Placing one foot over the other (when you are using a single loop) helps push the lower foot backwards, improving your stride on the rope.
2. Keep your body and head straight while extending the leg downward and back (fig. 160), with the free foot placed on top of the other so as to share the work between both legs. At the same time, use your arms to help keep your upper body near and parallel to the rope. Avoid pulling yourself up with the arms; let your legs do the work. Since the arms have less muscle mass than the legs, using your arms is an unnecessary exertion that will tire you out more quickly. As soon as the legs are fully extended, take your weight off your legs by sitting down onto the chest ascender in your harness. This completes the cycle. Push your upper ascender up again, step up in the footloop, and so on (fig. 159).

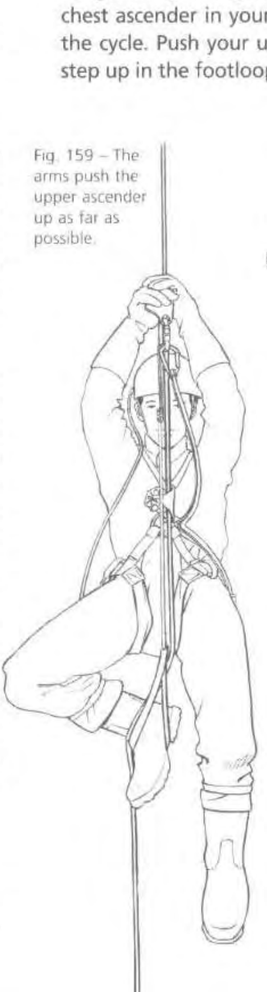


Fig. 159 – The arms push the upper ascender up as far as possible.


Fig. 160 – Stepping up in the footloop and straightening the legs brings the body up the rope.

During the first few meters of climbing, there is not enough rope weight below the chest ascender to pull the rope through it effectively. This is especially true of Crolls manufactured before 1998. The rope remains bunched up between the two ascenders, and you must pull it down with the right hand through the chest ascender, while holding yourself up against the rope with the left. This maneuver is fatiguing, and can be avoided by wedging the rope (fig. 161):

- either between both feet, which is more difficult with smaller diameter ropes;
- or between the footloop and your boot. While on the ground, pass the rope over the ankle and down toward the outside of the foot and behind the footloop.

Wedging the rope properly while climbing will require a little practice: as you are pushing up on the upper ascender, bend the knees slightly outward to prevent the rope from riding up and creating slack under the chest ascender. Bring the knees back to a vertical position before stepping up and extending the legs. This should wedge the rope.

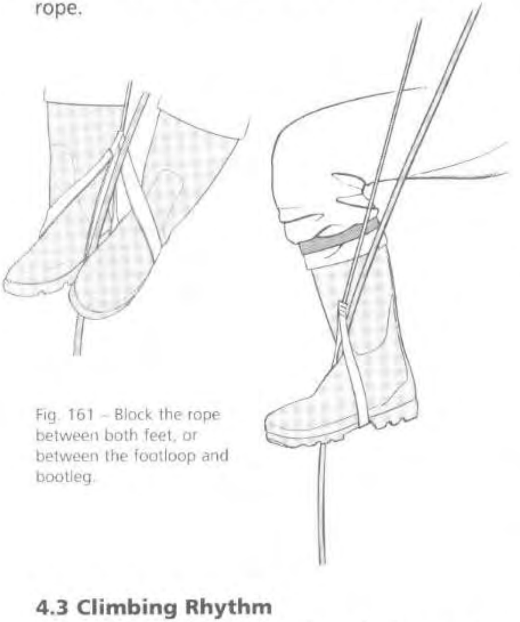


Fig. 161 – Block the rope between both feet, or between the footloop and bootleg.

4.3 Climbing Rhythm

Start off climbing slowly to allow the leg muscles to warm up, especially if you've been waiting awhile to climb. The muscles are cold after a long wait at the bottom of a pitch, and a bit of warming up before your climb is a good idea. Jumping jacks, running in place, or a friendly wrestle with a teammate could help. Set a regular pace when climbing, adjusted to your own rhythm and breathing and to the oscillations of the rope. In fact, since the rope is not entirely static, it will have a stretch of about 2-4 % depending on its constitution and the load it bears. The latter will of course change as you climb. It increases as you push yourself up with your legs and decreases when you sit back and push up on the upper ascender. As the rope bounces upward, extend the legs and stand in your footloops. When the rope moves downward again, apply your weight by sitting back on the chest ascender. Following this rhythm will make your climb more efficient, and requires a progressively faster pace as you near the top of the pitch since the frequency of the rope's oscillation increases as the length of rope above you decreases. You could also climb at half-tempo, still in sync with the rope bounce, but climbing against the rhythm of the bounce is more tiring.

Fig. 162 – To rest during a climb, let your body adopt the most comfortable position.

Remember that in addition to the factors already mentioned, hunger, fatigue and lack of training will adversely affect your efficiency. Stopping for a rest during your climb will allow you to catch your breath. Simply sit back in your harness and weight your chest ascender, with your arms hanging, your feet resting in your footloop, and your head and torso straight (fig. 162).

4.4 Carrying the Pack

The best way to carry your pack during a climb is by attaching its tether to your seat harness maillon, as during a rappel (see fig. 149). The weight is thus carried by the chest ascender during pauses, just as it is carried by the descender during rappels. The weight of the pack is balanced symmetrically and so are your efforts.

However, if the pack is light, it may be more troublesome to carry it this way because it is more affected by the increasing oscillations of the rope. This will ultimately disturb your climbing rhythm and the tether can become tangled with the rope (unless you are climbing with a foot ascender). To help reduce this problem, shorten the length of the tether by placing a carabiner through an intermediary knot tied in the tether. Better yet, simply clip the pack directly into the side of your harness (fig. 163).

Fig. 163 – A light pack can be attached directly to the side of the seat harness.

What NOT to do:

When climbing over a ledge where the rocks are *unstable, do not leave your pack dangling from its* tether. Instead, carry it on your back to prevent it from triggering a dangerous rock fall. This will save your fellow teammates below from having to run for cover from the shower of stones, cursing your name as they go!

4.5 Passing a Rebelay

Even without footholds, passing a rebelay during a climb is quite easy:

1. Stop your upper ascender about 2 or 3 cm under the knot (you will need this distance at point 5 in order to push up and disengage the cam from the rope) (fig. 164).
2. Clip your short cowstail into the anchor link with its opening facing away from the wall.
3. As you extend your legs for your last stride, disengage your chest ascender, and transfer your weight to the short cowstail. Doing so will save you from standing up twice in your footloops, and will permit you to comfortably complete the following maneuvers:
4. Load the upper length of rope into the chest ascender and pull the slack through until it is taut above the ascender.
5. Remove the upper ascender from the bottom rope and place it on the upper rope, above the chest ascender and at the level of the face (fig. 165).

Fig. 164 – Stop below the rebelay.

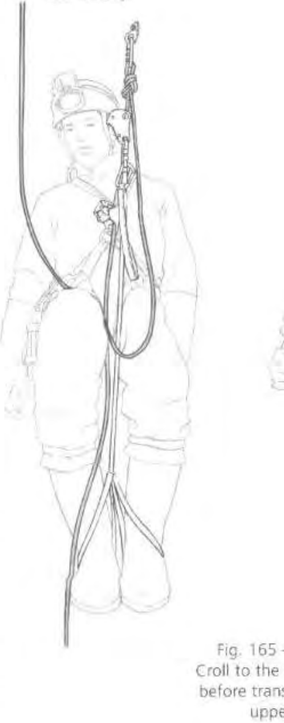


Fig. 165 – Move the Croll to the upper rope before transferring the upper ascender.

To do:

- If the upper rope is offset to the left of the rebelay (as is usually the case), pass it between your body and the cowstail before placing it in the Croll. If the upper rope is offset to the right, do not do this.
- Pass the upper ascender and long cowstail between yourself and the rope to avoid any tangling between the rope and footloop assembly.

6. Begin climbing by stepping up in your footloop (or in the upper rope loop) and pulling the rope down below the Croll.
7. After one or two strides, your short cowstail will slacken as your weight transfers to the Croll. Unclip it from the anchor (fig. 166). If the next anchor is offset to the side, a short pendulum swing will allow you the slack to unclip the cowstail.

Fig. 166 – Slack appears in the cowstail as you start climbing; you can now remove it from the anchor plate.

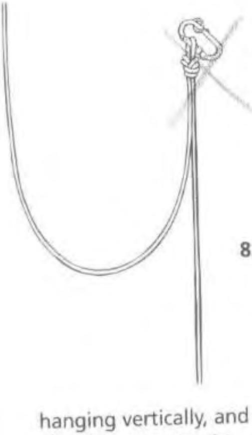


Fig. 167 – Check that the anchor carabiner is in correct position after you have left the rebelay. Loading a carabiner sideways could cause it to break.

8. Check that the rebelay is positioned correctly before moving on: the anchor plate is correctly in place, the carabiner or maillon is hanging vertically, and the rope hangs straight (fig. 167). Then let the others know that the rope is free, and continue your climb.

4.6 Passing a Deviation

1. As you approach the deviation, push the deviation carabiner up.
2. Stop at the level of the deviation anchor.
3. Swing in or push against the opposite wall toward the deviation, creating the slack you need to unclip the deviation carabiner from above the upper ascender and clip it back onto the rope below the chest ascender. Make sure the deviation stays free at all times; do not pass it between you and your footloop assembly unless you are climbing with the rope wedged in your footloop and the deviation is on the same side. If you are using a foot ascender, remove it before you reach the deviation and replace it once you are past the deviation.
4. Continue climbing.

4.7 Exiting the Pitch

Whether or not the exit from the pitch allows a place to stand or sit, treat this maneuver just as you do a rebelay (fig. 169). Once you are off your ascenders and your short cowstail is clipped into the traverse line, you will alternate cowstails until you are clear of the approach.

When there is a traverse directly off the pitch rope with no backup anchor, DO NOT use your cowstail as shown in figure 170. Use your upper ascender to move out. If the upper ascender is not on the rope, you are unprotected if a sudden fall causes the main anchor to come out. With this configuration, clip your short cowstail into the anchor and transfer your upper ascender to the traverse line.

Fig. 168 – Exit a free-hanging pitch as if passing a rebelay.

To do:

If the traverse leading off the pitch is sloping, install the upper ascender (still connected to the long cowstail) directly on the lead rope and clip the long cowstail carabiner itself over the same rope as well. Tow yourself upward using the ascender.

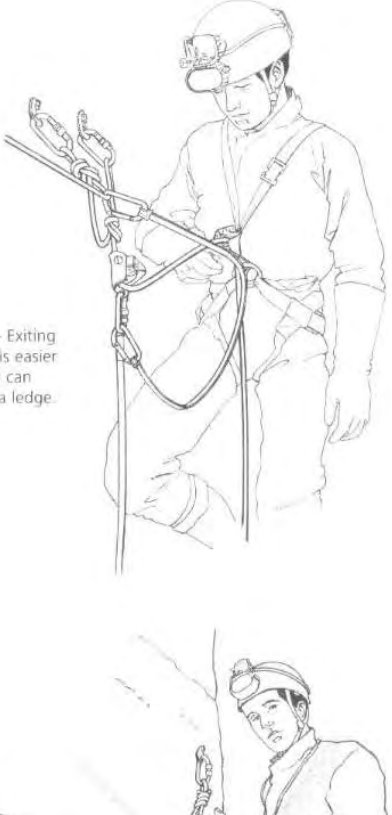


Fig. 169 – Exiting the pitch is easier when you can stand on a ledge.

Photo U. Widmer

Fig. 170 – To exit the pitch safely, place the upper ascender rather than the short cowstail on the traverse line, if the main pitch anchor is not doubled.

Fig. 171 – Down-climbing on ascenders. Moving the cam down allows the rope to slide through the ascender.

4.8 Down-climbing on Ascenders

This technique allows you to descend the rope if necessary. While stepping up in your footloop, you take your weight off the chest ascender. At this moment, press down on the cam with your right index finger. The cam will pivot downward, allowing the rope to move freely through the ascender housing (fig. 171 and 172). Bend your knees to move downward, then release the cam to reengage the ascender on the rope. Now that you are in resting position and your feet are free, perform the same action with the upper ascender, using your thumb to help move the cam down (fig. 173). Lower the upper ascender and again extend the legs. This technique is tiring but safe, since the safety catch prevents the rope from coming out of the ascender housing. This is a useful maneuver when you have climbed a few strides up and realize you've left your pack below, for example, or if you miss a less obvious continuation and find yourself suddenly stuck in a narrowing passage. It is also the only safe solution for descending a taut rope.

Key point:

Hold the cam all the way down, and lean your upper body slightly to the right of the rope while bending the knees to move down. This helps keep the rope in its housing. Likewise, lower the upper ascender while pulling sideways to the right (unless it is a left-handed ascender), still keep it vertical along the rope. If you do not perform these subtle maneuvers, the teeth of the cam will damage the rope's sheath.

Fig. 172 – Releasing the Croll cam.

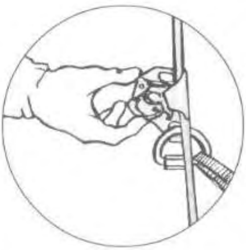


Fig. 173 – The upper ascender is released in the same way.

4.9 Training Methods for Beginners

Since the motions used in climbing are more complex than those used in rappelling, we think it useful to break down the elements of this technique in order to provide a better understanding. The following method is based on many years of experience:

1. With feet on the ground and your weight on the chest ascender, tighten down your chest harness so that it holds your torso close to the rope (fig. 174).

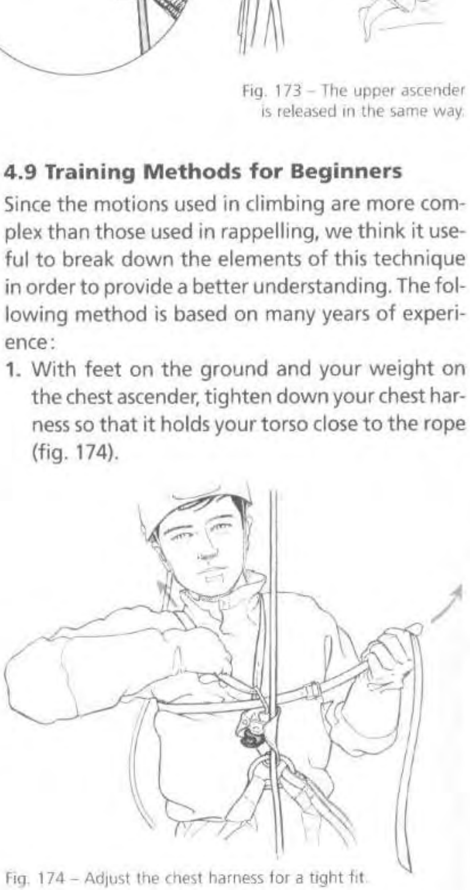


Fig. 174 – Adjust the chest harness for a tight fit.

2. Still standing beside the rope, remove the Croll briefly to verify that the harness is properly adjusted. Your chest is pulled forward by the harness and you should not be able to stand up straight (fig. 175).
3. With the Croll and upper ascender in place on the rope, check to see if the Croll moves up the rope when you extend your legs. Notice that a

Fig. 175 – A well-adjusted chest harness will prevent you from standing up straight when off rope.

Fig. 177 – Remove the chest ascender from the rope by standing up in your footloop.

Fig. 178 – Removing the chest ascender from the rope.

Fig. 176 – Pull down on the rope with the right hand when beginning a climb to prevent the Croll cam from catching the rope.

lack of weight below will usually prevent the cam from releasing, and the following maneuver will be necessary.

4. With one hand on the upper ascender and the other on the rope just below the Croll, step up in your footloop (fig. 176). As you extend your leg(s), the Croll will slide up the rope. At the end of the extension, open the cam on the Croll and remove it from the rope (fig. 177).
   This exercise allows the beginner to practice removing the Croll at the top of a pitch or at a rebelay.
5. Standing with the left foot on the ground and releasing the weight on your footloop, you can remove the upper ascender from the rope (fig. 178).
6. Reinstall your ascenders as before and climb a few strides up the rope, then practice downclimbing, alternating between Croll and upper ascender (fig. 172 and 173).

Once the impatient beginner has completely and correctly performed these exercises, he can then turn to refining his form. The logical next step in his training will be to learn the "changeover" from climbing to rappel, and then to pass deviations and rebelays.

4.10 Muddy Ropes

Sometimes mud may coat the rope and clog the cams in your ascenders, causing them to slip. It is not a nice feeling to know that at any moment you could suddenly lose traction and slip down the rope. In this situation, replace the upper ascender with a lever ascender such as the Shunt. Since the user's weight is directly applied to the lever, blocking action is effective no matter how slippery the rope may be (fig. 179). However, this apparatus is much slower and less efficient than the upper ascender since you must take apart your footloop and cowstail each time you remove the Shunt from the rope. This limits the Shunt's usefulness to this particular situation.

As for the chest ascender, there is really no good solution. The cams on the more recent models have small eyeholes to help push mud out. To help the teeth catch on the rope, push up on the bottom of the cam as you weight the Croll.

For really problematic situations, friction knots (page 78) are a possible solution. These could be used in addition to the ascenders to help intercept sudden slides. They can be improvised quickly and easily during a climb using your pack tether, for example.

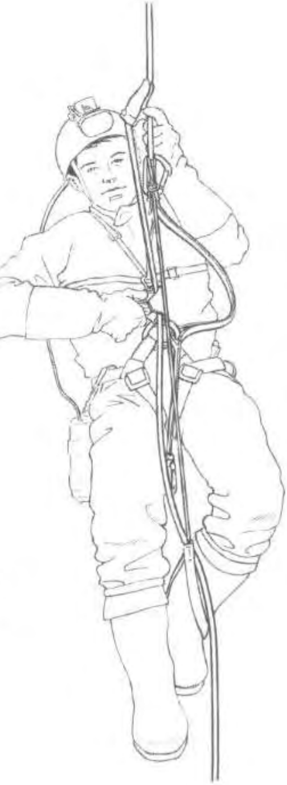


Fig. 179 – On muddy rope, push up on the Croll cam so that it catches the rope.

4.11 Pulleys

What NOT to do:

We do not recommend pulley mechanisms such as the one found on the Petzl Pump (see fig. 29) to reduce your workload, except if you are carrying an excessively heavy load up the pitch, as when derigging. Otherwise, a heavier caver may want to use it to limit overexertion from balancing his upper body against the rope. But as the effort exerted is reduced, the climbing speed is proportionally reduced. The total amount of energy spent is not reduced in the end; it is actually increased due to added friction between the rope and the pulley. Effort is merely spread over a longer duration, and therefore seems like less.

You will find similar limitations when using an Italian footloop (Mao system; see fig. 389). This system has a small pulley installed below the upper ascender. A longer footloop is fixed at the top of the Croll, then passed through the pulley and allowed to hang from there. This pulls the body forward and up with each step up in the footloop. However, since the leg's vertical distance is limited to about 60 cm with this configuration, the upper ascender can only be pushed up about 30 cm with each stroke, giving the impression that you are hardly moving. Climbing is twice as easy, but takes twice as long.

To do:

The only really effective pulley system for climbing consists of attaching a small ball pin pulley to the top of the chest ascender. The footloop then runs through the pulley so that with each step up in the footloop the chest is pulled toward the rope, saving the arms the extra effort of doing so. The advantage of this system is comparable to the use of a foot ascender, which also pulls the rope taut and the body forward. We will discuss the foot ascender shortly.

When using this pulley system, you must be able to quickly disengage the pulley from the chest harness (leaving it attached to the footloop) when you arrive at the top of the pitch. Attach this with a small "anti-panic" clip (used in sailing) that opens instantly when you pull the cord loop, even under tension.

5. Complimentary Use of the Foot Ascender

Foot ascenders began to appear among the components of the Frog system nearly ten years ago. As is often the case with caving equipment, the first models were homemade by some of the more industrious cavers, before they began to appear in manufacturers' catalogs. They are now in widespread use, having seduced cavers of all levels. The basic caver enjoys the greater comfort of this device, which improves his position on the rope and saves him from added upper body exertion. The more experienced and specialized caver finds his climbs go by in a flash, given a greater physical performance.

For a general description of the foot ascender, refer back to the first section (page 49).

5.1 Conditions for Use

This device is never used alone; it is meant to be a complement to the other two ascenders. Critics of the foot ascender see it as an additional and unnecessary weight, but these extra 125 grams are compensated by four substantial advantages:

1. When you step up, the foot ascender holds the rope taut below the chest ascender while at the same time improving vertical balance.
2. It provides a convenient "step" that helps you pass rebelays and exit the pitch at the end of climbs.
3. It helps the beginner learn to step vertically rather than at an angle.
4. At the beginning of a climb, it is an effortless solution to that annoying problem of the rope catching in the chest ascender – and we're all familiar with that one.

Two additional benefits of the foot ascender:

- It prevents the rope from tangling up with your pack tether during the climb;
- It can be used as an emergency replacement for the chest or upper ascender, arranging a haul system, or as a second ascender in a counterweight system (see page 296).

However, use of the foot ascender does not facilitate passing a deviation. Remove it from the rope as you approach the deviation and reinstall it again once you've passed it.

5.2 Choosing and Adjusting the Foot Ascender

If the model allows a choice, you may wonder whether to place the ascender on the left or the right foot. This is a matter of preference. Those who insist on the merits of the right foot have two arguments, the first being that if your right foot is your lead foot (which is usually the case) it is also stronger and more effective in pulling the chest ascender into the rope. The second argument is a bit less obvious, but the result is the same regardless of which foot you favor: most cavers who rig are right-handed, and difficult pitch heads are most often rigged on the left wall (going down). On the climb out, we exit the pitch to the left, and a right foot ascender is more useful since we need to step up more on the right foot.

Promoters of the left foot ascender argue that when we leave a rebelay, we usually need to step up one or two times in our footloop before we can install the foot ascender: we may as well use our stronger foot, usually the right. In this case, we are accustomed to having our right foot in the footloop. Why change this habit and upset our well-established rhythm?

In the end, it is up to each individual to choose. In fact, the authors of this book each have an opposing preference, and each stands by his choice. If you choose to use a Petzl Pantin, you will not have to make a decision since it is only made for the right foot. In this chapter's illustrations, the foot ascender has been shown on the left foot (in the line drawings) as well as on the right foot (in the shadowbox drawings).

The foot ascender is attached over the boot or shoe on the inside of the foot, with the straps tightened down snugly. Adjust the side strap so that the contact between the rope and the ascender is above the heel, along its vertical axis. The strap for the instep is also adjustable, allowing you to change the height of the ascender relative to the heel. The higher you place it, the less it will tend to twist sideways, and this makes it more comfortable. However, this will also slightly reduce the height of your stride, especially if you tend to raise the feet rather than the knees, which is improper form: the leg gains less vertical distance in this position. In short, the best position is one that places the contact between the rope and the ascender at about 5 cm above the heel.

5.3 Technique

The foot ascender can be used four ways. But regardless of the technique, some factors remain constant:

Key points:

- The beginner may have problems tangling the footloop and long cowstail in the rope when using this ascender. To avoid this, practice on the surface beforehand (on cliffs, in a gym, etc.). During this training, reproduce the same obstacles found on a vertical climb (over a shorter distance), including rebelay and exit. In practice, you'll find that with a left foot ascender, it is helpful to exchange the double cowstail for two separate ones. The short cowstail is worn on the left side of the harness maillon as usual, but the long cowstail will be attached on the right side (i.e., the footloop side) of the harness maillon. With a right foot ascender, the cowstails remain on the left as usual.
  One might wonder why the placement of the cowstails is different in each case. This results from the fact that there is no left-handed version of the chest ascender so, no matter which foot ascender is used, the rope much be engaged and disengaged from the right.
- The foot ascender cam best engages with the rope if you push the foot slightly forward as you finish lifting it for a stride, so as to position the rope correctly in the ascender gutter. This will keep the rope from sitting on the upper part of the cam and opening it. Then the foot can be brought up under the buttocks before pushing off in a vertical stroke.

To do:

Some foot ascenders have a catch that prevents the rope from automatically detaching, but this accessory can be disengaged. The advantage of doing so is that it allows you to quickly detach the ascender from the rope at a rebelay or at the pitch head without having to bend down; you simply kick your leg back with the knee bent (fig. 180). The problem for beginners is that they often accidentally kick the foot ascender off the rope while climbing the deeper pitches (over 30 meters), because the rope weighs more against the cam. This poses no risks but it interferes with the climber's rhythm. Avoid the problem altogether by learning to climb correctly: the foot and knee must come up as straight as possible and the ankle should not be allowed to move off sideways. The foot should also move up with a slightly forward movement, then come back under your body before pushing off – almost as if you were pedaling backwards on a bicycle!

Fig. 180 – The absence of a safety catch allows you to remove the ascender from the rope by simply kicking back with a bent knee.

Do not disengage that catch on the foot ascender (if there is one) until you have mastered the correct climbing form and it has become second nature.

What NOT to do:

- It should go without saying that you must NEVER remove the corresponding safety catch on a handle or chest ascender. This would compromise the proper functioning of the device and your safety. This is not the case with a foot ascender since this device is an accessory and not a PPE item.
- Don't look up while climbing the rope, but straight ahead; this will facilitate breathing.

Frogging with a foot ascender

This is the most widely used method for climbing with a foot ascender since it is the same as the classic Frog / sit-stand technique. We generally learn to use the foot ascender with this method. One foot is placed in the footloop and the other in the foot ascender strap (fig. 181 and 182). Both feet remain at the same level and push down simultaneously. This is the method used for average climbs or when you are hauling an especially heavy load. It will likely soon become the new standard in France, maybe we'll call it the "New French Method" (fig. 183).

Alternate steps

With this movement, we push down with one leg at a time rather than both, like "stepping" up the rope. Since humans are bipedal, this movement is natural, and it was from this general idea that the most efficient American climbing methods were developed (see below).

Symmetric and asymmetric stepping methods are derived from the classic sit-stand method, but they are both clearly more strenuous than frogging. They require extra practice and perfect coordination of breathing and movement.

Fig. 181 – Bend the knees and raise the upper ascender.

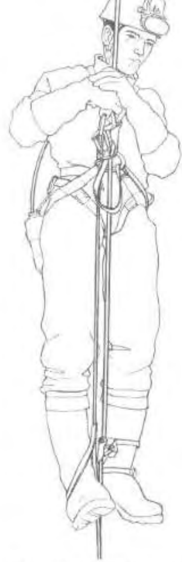


Fig. 182 – Raise the body by extending the legs.

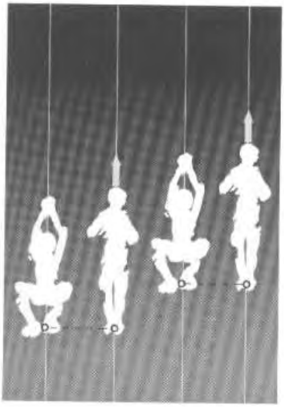


Fig. 183 – Basic sit-stand movements.

Asymmetric Stepping

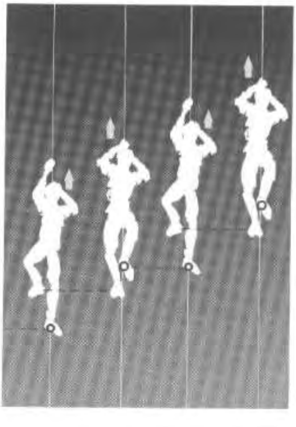


Fig. 186 – Upper ascender is raised as the left foot steps in the foot ascender (right foot level with opposite knee).

1. In asymmetric stepping, the ascender foot pushes from a higher point than the other foot (fig. 184). Both hands may be placed on the upper ascender, but it's best to have them at slightly different heights. There is no resting phase when the climber sits back in the harness (fig. 185 and 186). This method is effective in that it is very rapid, but it has two limitations:
   - Since stretch in the rope thwarts a good rhythm of movement, this fast pace cannot be maintained on long climbs (thirty meters or more), unless one is climbing a very static rope or against a wall, where balance is easier to maintain.
   - Since it is more exerting, this method is not suitable for climbing with a loaded cave pack. The tension on the chest harness must also be loosened for this type of climbing; the chest ascender sits lower so as not to limit the height of the arm strokes.

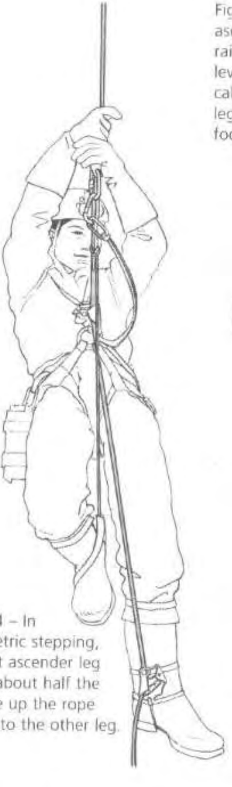
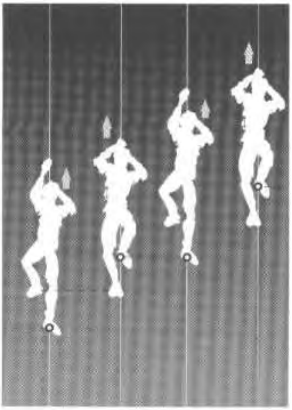


Fig. 184 – In asymmetric stepping, the foot ascender leg moves about half the distance up the rope relative to the other leg.

Fig. 185 – Foot ascender is raised to the level of opposite calf as the other leg steps in the footloop.

Symmetric Stepping

Fig. 187 – In symmetric stepping, both feet move approximately the same distance up the rope.



2. Symmetric stepping is the fastest method, but also the most strenuous (fig. 188 and 189). It is best suited for short climbs when one is not carrying a pack. Both legs step from the same height. If the foot ascender is worn on the right foot, the right hand holds the upper ascender (and vice versa). The left hand is placed higher up on the rope to ensure proper balance (fig. 187).

Key points:

Especially when beginning, try not to make strides that are too long as these are particularly exerting on the thigh muscles.

To do:

Lengthen the footloop the distance of one carabiner.

5.4 Recent Trends

Increased use of the foot ascender has influenced the way we rig pitches. The current trend is to rig as often as possible against the wall and to reduce the distance between consecutive rebelays. There are two advantages to doing this:

- The body automatically finds its equilibrium when we can use the wall for support. This also relieves the arms of some work.
- It is easier to coordinate climbing rhythm and the bounce on the rope caused by the yo-yo effect. This advantage is more obvious if the rope is thinner; smaller diameters need greater elasticity to withstand the number of falls allowed by the standard.

Fig. 188 – Step in the footloop and raise the foot ascender (level with the opposite knee).

Fig. 189 – Step in the foot ascender and raise the upper ascender (right foot level with opposite knee).

6. Other Climbing Methods

6.1 The Two Schools

There are basically two schools for descending and climbing a single rope on ascenders, and these correspond to two techniques for rigging caves: the French method and the American method. The latter evolved in the United State in the late 1960's, at roughly the same time as the French method.

The French method corresponds to Single Rope Technique (SRT), a method of rigging that places the rope away from walls or rub points, so as to protect it – and consequently the caver – as much as possible. This technique leads to shorter but more numerous vertical sections because rebelays are more frequent. On rappel, this technique is well suited for spool descenders. For climbing, you must be able to change your ascenders from one section of rope to another (i.e., install and remove them) quickly and efficiently, since you must do so several times in the same shaft. Spring loaded cam ascenders are perfect for this, and the Frog system is adapted for use with these ascenders.

The American method is rooted in a clearly Anglo-Saxon philosophy (though it also developed in a different geological context than Alpine SRT, in the large open-air pits of the Southeastern and Central US). At least in theory, this practice seems to favor protection of the cave more than that of the rope (but in reality, rub marks on the cave from the body and a thicker rope render this laudable conservation ethic a bit suspect). It also favors natural rig points to artificial anchors, since the latter are thought to compromise the integrity of the rock. Rub points are acceptable, which requires thicker diameter rope to ensure safety, and there are fewer or no rebelays. Some call this "Indestructible Rope Technique," and it has several important consequences: rope weight increases by the square of the rope diameter, so cave packs are also heavier. Rope protectors are used more often to reduce the effects of inevitable friction, and rack descenders are the preferred choice since the weight of the rope below is also increased (at least for long free-hanging drops with thicker rope).

On the climb, it is less important to be able to move quickly through a rebelay since there are fewer of these. Though many have already switched to spring loaded ascenders, some people still use lever ascenders such as the Gibbs (fig. 190 a), which have the unique advantage of working well on muddy rope. The lever takes longer to engage the rope completely, causing the climber to slip back down several centimeters with each stride upward. Installing a lever ascender on the rope is also tedious work, requiring the user to align three independent parts in the device: the cam, the housing, and the pin that holds these together. The pin can be removed by squeezing down with the thumb on the pinhead, which engages a piston inside the pin.

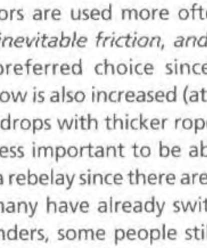


Fig. 190 a – The Gibbs lever ascender.

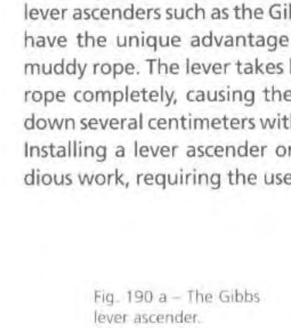


Fig. 190 b – The chest roller or "chest-box" is mounted on the horizontal webbing of the chest harness.

6.2 American Techniques

Every technique belonging to the American school takes longer to carry out. While these techniques may sometimes be faster when it comes to pure climbing speed, their overall performance during caving soon reminds us of the moral of the fable "The Tortoise and the Hare."[18]

What is even more interesting is that these climbing techniques are generally viewed as less physically exerting; perhaps this in fact occurs once one has become habituated to the movements. But each system requires more gear and thus more weight than the Frog system (sometimes up to three times more than the 500 grams needed for the latter). Several techniques require the user to run the rope, and sometimes even the footloop, through a chest pulley (the "chest roller" or "chest box"), so as to pull the upper body up to the rope. A roller is made of two metal side plates on a housing, through which a special chest harness strap is placed, and a roller pin that holds the rope in place (fig. 190 b). This pin can be disengaged at any moment, with the same type of ball pin found on the Gibbs. Once the pin is disengaged from the housing, it remains attached by a short wire cable (also like the Gibbs). Since the roller must sit as close to the body as possible to be effective, the chest harness must be tightened right down, which can constrain the rib cage from fully expanding and interferes with proper breathing. This is hardly a plus.

While American techniques have been abandoned for the most part in the UK, they are still practiced in some areas of the United States, particularly in the Southeast and Midwest. In the last decade, however, the Frog method has gained significant ground in the US, likely due to its simplicity, versatility and relatively low cost. In Australia, some cavers continue to use the Mitchell system, but others have also moved to the Frog system.

The purpose of this book is not to discuss every American technique in minute detail; others have

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[18] Similar findings can be found in a general comparison of climbing systems in *On Rope*, 1996 (NSS), by Bruce Smith and Brian Padgett, p. 164.

already done this, and their authors were quite knowledgeable of the subject. Our perspective is more or less that of an outsider, but it is interesting nonetheless for us to have some understanding of these techniques. There are at least three systems, aside from the Frog, which we will here list in descending order of popularity:

- the Ropewalker system (very fast on the rope and not too tiring, but complicated; requires a significant amount of preparation time and a chest roller)
- the Mitchell system (fast on the rope and not too tiring, but long in preparing; requires a chest roller to bring the body in line with the rope)
- the Texas system (slow and quite tiring)

If no single system has actually succeeded in replacing the others completely, this is doubtless for lack of a clear advantage of one over the others. This diversity can certainly be seen as a source of richness, but it nonetheless complicates the process of training and practice, and even more so since each system has its own internal variations.

We illustrate here the most widespread of American systems, the Ropewalker, in its most evolved form: the double bungee (fig. 191). A bungee cord links the foot ascender to a leg ascender worn on the opposite leg (usually the left), via a small pulley attached to the bottom of the chest harness/roller. These ascenders may either be spring-loaded cam models (Basic or Croll type), or lever ascenders, and they are alternatively pulled upward by the pulley. A third upper ascender is attached to a cowstail for safety and pushed up the rope with the hand.

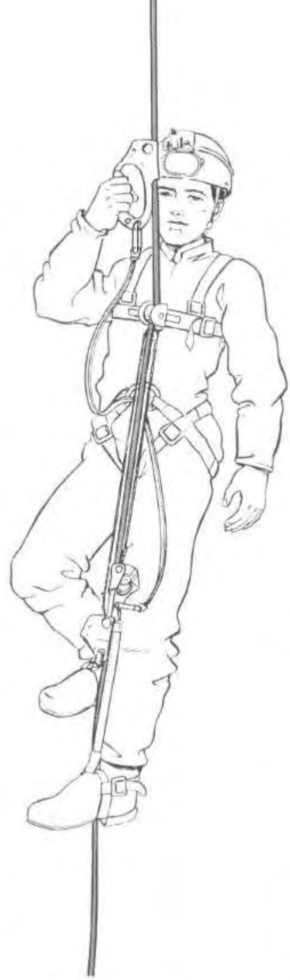


Fig. 191. – The double bungee system. The chest roller is mounted on a horizontal metal plate incorporated into the chest harness to minimize chest compression.

6.3 The Jumar System

Finally, let's mention the ancestor of all of these systems, the Jumar system. This technique employs two upper ascenders (Jumars, see Chapter D.5), each maneuvered with the corresponding hand and each attached to a footloop. The American systems originated from this setup. Its principle drawback is that it does not allow the user to sit down and rest, but its claim to fame remains that it ushered in a new era in vertical cave exploration at the end of the 1950s. Thus we still hear the expression, "climbing on Jumars," which continues to be used generically when people talk of climbing with ascenders. As is the privilege of our forerunners, the Jumar has become part of that exclusive club where we also find the Fridge, Kleenex, the Thermos and, let's not forget, the Spit – all products whose use has so permeated our lives that their brand names have become "household" words.

6.4 The Stair-Climbing Method: A Compromise?

If we stop to think about it, both the American and French techniques have their strong points. The former makes use of simple, natural leg movements that resemble a swift hike up a steep slope. It is also fast and less tiring on the arms. The latter is lighter and much faster to prepare and install on the rope. Its attachment and suspension point is also closer to the body's center of gravity, which provides stability. This is at the heart of its versatility. So why not find a compromise?

In fact, the first step toward such a compromise has already been made. We only needed to introduce the foot ascender – the quintessential component of the American system – into the French outfit. For 125 additional grams of weight, the French school can now achieve a climbing speed approaching that of our overseas colleagues. Symmetric stepping thus seems at first glance to be the realization of that long-sought compromise. But it is still a bit too athletic to be a realistic solution for everyone.

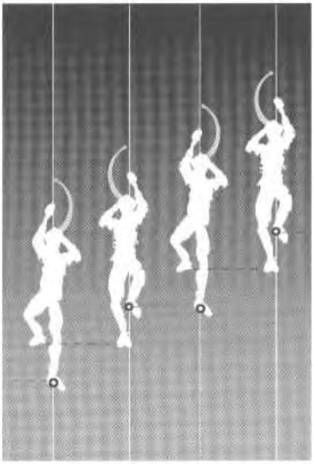


Fig. 192 – The stair-climbing method.

Let us suggest an alternative technique derived from the symmetric stepping method and one step closer to the American school: welcome to "stair-climbing" technique. Like stepping, this is an efficient and ergonomic alternative, yet it is easier to learn and less fatiguing because the upper ascender is transformed into a leg ascender like that found on the Ropewalker, which moves up by itself. The hands are entirely independent and free to make even strokes up the rope. This allows both the arms and legs to truly work in even, alternating strides on the rope (fig. 192, 193).

Above the Croll, you can hold the rope as you like, moving your arms up in synchronicity with each stride, your hands alternating at the level of your chest and face or, otherwise, placed high on the rope bringing you closer to it. Since you grasp the rope directly with your hands, you should wear gloves, and preferably the rubber variety: it grips the rope better than PVC and helps save your hands and arms from fatigue.

A major advantage to the Stair-climbing technique is that it is entirely compatible with the Frog (plus foot ascender) system.

To move from this system to Stair-climbing, place the foot ascender in its usual position on the right foot. Two slight modifications follow:

1. Make a simple loop in the footloop cord at about 30 cm above the instep in order to shorten the length of the footloop, via a small accessory carabiner, and to allow the placement of the upper ascender as a leg ascender (weight: 20 g);

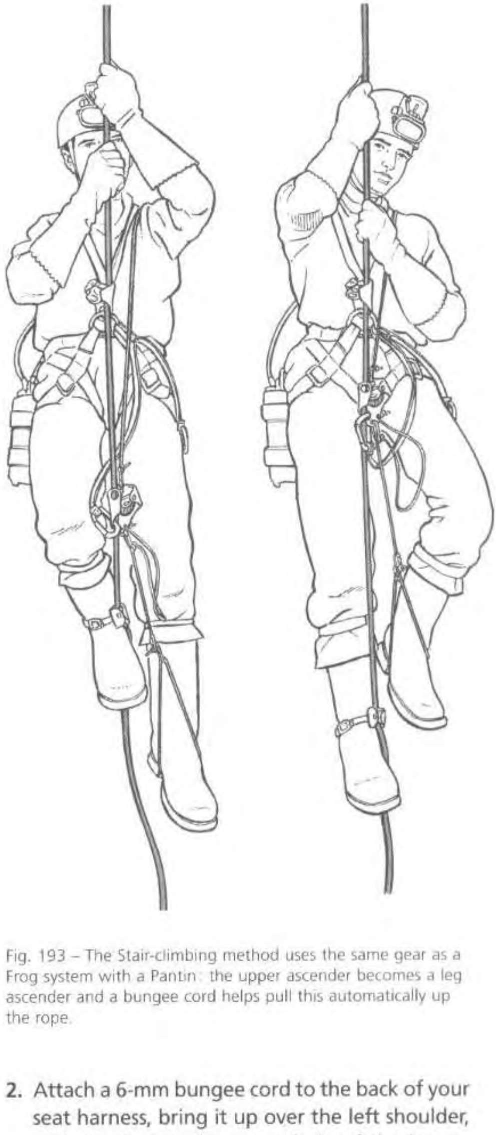


Fig. 193 – The Stair-climbing method uses the same gear as a Frog system with a Pantin: the upper ascender becomes a leg ascender and a bungee cord helps pull this automatically up the rope.

2. Attach a 6-mm bungee cord to the back of your seat harness, bring it up over the left shoulder, and attach it to the upper hole of the leg ascender. This creates the tension you need to pull the leg ascender up automatically when your left leg bends (weight: 30 g).

The long cowstail remains attached to the leg ascender as usual, and the intermediate footloop carabiner is clipped into the leg ascender carabiner (or into the additional hole next to the large lower hole on the ascender).

Inversely, you can switch back to the traditional Frog method, even in the middle of a climb. Just sit back in the seat harness (on the Croll), remove the intermediate footloop carabiner from the leg ascender –restoring the footloop to its original length – and place the upper (leg) ascender back in its original position above the Croll. By switching between the two techniques, you work different muscles alternately and will tire less quickly. This technique is especially effective when your are climbing against a wall because the hands do not have to help balance the body. You can let go of the rope completely; and can even let them hang freely during the climb (as when climbing on a Ropewalker), which saves energy.

To pass rebelays using the stair-climbing technique:

1. Stop under the anchor knot and sit back on the Croll, as usual.
2. Clip your short cowstail into the anchor maillon or the anchor plate itself, with the carabiner gate facing you.
3. As you step up in the foot ascender/footloop, remove the Croll from the rope and sit back in your harness, i.e., the short cowstail.
4. Place the upper rope in the Croll and take up the slack.
5. Remove the leg ascender from the lower rope and place it on the upper rope (the bungee cord should not affect this maneuver).
6. Begin the climb by stepping in the footloop and unclip the short cowstail from the anchor once it has some slack.
7. Transfer the foot ascender from the bottom to the top rope.

This maneuver is thus identical to the classic rebelay changeover discussed on page 151, except for point 5. The primary advantage is that at point 6, stepping in the footloop via the leg ascender automatically pulls the rope through the Croll, which saves us the trouble of pulling it through ourselves as we leave the rebelay.

An American-style chest roller could be added to aid vertical balance on the rope, which would leave the hands completely free, even for climbing free drops (averages an additional 90 g). It's best to wear this on a v-shaped chest harness rather than one that goes around the rib cage, to avoid compressing the chest. We have perfected such a device, which allows us to climb without using the arms, even on free drops (the Ropewalker does not have the help of the Croll to anchor a V-style harness). But if the climber feels energetic enough to alternately pull up on the rope with the hands at face level, this will increase his climbing speed. Even without the chest roller, the stair-climbing system thus offers the choice of speeding up a climb.

When used with a chest roller, stair climbing indeed looks like a hybrid between the American and French methods!

Only time will tell. If it ever happens that one climbing method comes to reign supreme, it will likely be a similar compromise between the two principle techniques. Like the Anglo-Saxons we are equally concerned with putting cave protection and conservation to the forefront of our considerations, but we don't want to sacrifice safety in doing so. A stronger conservation ethic could well have prevented the abuse of some of our great classics and we should be committed to restoring and protecting them from further degradation as much as possible, by getting rid of redundant anchors, for example. We should above all try to leave these caves in the same or better condition than that in which we found them.

7. Various Rope Maneuvers

7.1 Changing from a Rappel to a Climb

Any number of circumstances can force us to interrupt a rappel and return up the rope. A fallen rock could cut the rope below, a sudden waterfall could inundate a pitch, the rope could run short of the bottom...and we have no choice but to turn around. The "changeover" is therefore a maneuver that every vertical caver should know:

1. Come to a stop and lock off the descender.
2. Place the upper ascender and footloop on the rope at about face level.
3. Step up in the footloop and place the Croll on the rope between the upper ascender and descender, then sit in the harness to load the Croll.
4. Remove the descender from the rope and begin climbing.

7.2 Changing from a Climb to a Rappel

The climb to rappel changeover is of course the inverse. This may be needed to go fetch that 13-mm wrench that just fell down the drop:

1. Install the descender on the rope as close to the bottom of the Croll as possible and lock it off.
2. Remove the Croll from the rope by stepping up in the footloop.
3. Sit down; your weight should transfer to the descender.
4. Remove the upper ascender from the rope.
5. Unlock the descender and begin the rappel.

You may also act as if you are passing a knot on rappel, with the short cowstail also clipped to the upper ascender (see 7.3.2 below). The advantage is that the descender is easier to install because the Croll is already removed and no longer in the way, so the rope is more accessible. Since you are hanging under static tension from the short cowstail on the upper ascender with the long cowstail as a backup, this is not a problem for safety.

Key point:

Be sure the descender is positioned correctly in its attachment carabiner; loading the carabiner sideways could damage it.

7.3 Passing a Knot on Rappel

We find knots on the rope when one rope is too short and two ropes must be tied together (pages 75-76), or when we need to isolate a damaged section of the rope (page 73). We then have to get around them.

Fig. 194 – Descend onto the knot.

7.3.1 Passing the knot using your ascenders

1. Rappel onto the knot (after having taken the rope out of the braking carabiner; fig. 194).
2. Place the upper ascender (attached to its cowstail) on the rope at face level.
3. Step up in the footloop, place the Croll on the rope between the upper ascender and descender, and sit back on the Croll.
4. Remove the descender and reposition it on the rope just below the knot (locking off is optional).
5. Down-climb as close to the knot as possible on the ascenders.
6. Remove the Croll from the rope. This should transfer your weight back to the descender; be sure it is positioned properly in its carabiner before loading it.
7. Remove the upper ascender from the rope and continue the rappel.

7.3.2 Passing the knot with the short cowstail in the upper ascender

1. Rappel onto the knot as described above.
2. Place the upper ascender on the rope above the descender, about 10 cm above the point where the short cowstail carabiner would sit when the cowstail is pulled up taut (fig. 195).

Fig. 195 – Pull the short cowstail up ward and position the upper ascender on the rope about 10 cm above the end of it.

3. Remove the long cowstail from the upper ascender and place it in the knot loop (fig. 196). If there is no loop or if the loop is not usable, leave it in the ascender until just before removing the short cowstail (during a later phase in the operation, see point 7).

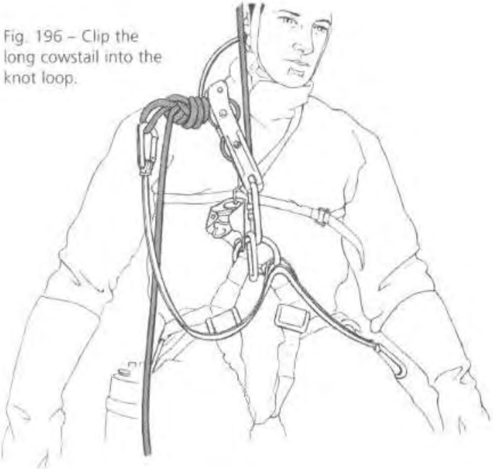


Fig. 196 – Clip the long cowstail into the knot loop.

Fig. 197 – Clip the short cowstail around the rope above the upper ascender.

4. While stepping in the footloop, place the short cowstail carabiner directly on the rope above the upper ascender (fig. 197).
5. Sit back down; the short cowstail should now be weighted.
6. The descender should now be slack; remove it from the rope and reinstall it below and as close as possible to the knot (again, locking off is optional; fig. 198).
7. Step up again in the footloops and remove the short cowstail (the long cowstail would also be removed here if it is still attached). Make sure the descender is properly positioned on its attachment carabiner before transferring your weight back to the descender (fig. 199).
8. Remove the upper ascender from the rope and the long cowstail from the knot.
9. Continue the rappel.

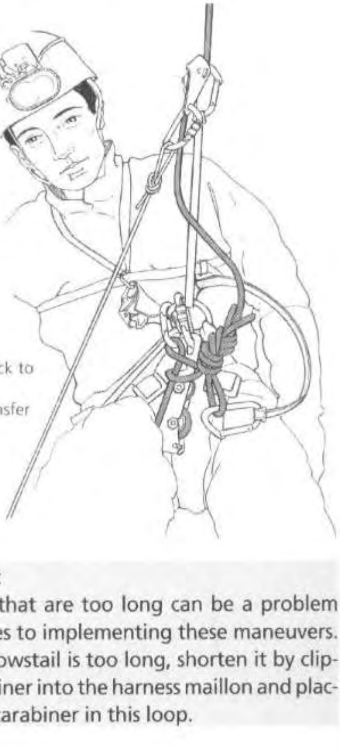


Fig. 198 – Sit back to load the short cowstail and transfer the descender.

For both of these methods, it is not necessary to clip your cowstail into the knot loop as an added safety (especially if the knot was made to isolate a damaged section!). This saves time since you perform fewer maneuvers.

Key point:

Cowstails that are too long can be a problem when it comes to implementing these maneuvers. If the short cowstail is too long, shorten it by clipping its carabiner into the harness maillon and placing another carabiner in this loop.

Fig. 199 – Retrieve the short cowstail, putting your weight on the descender.

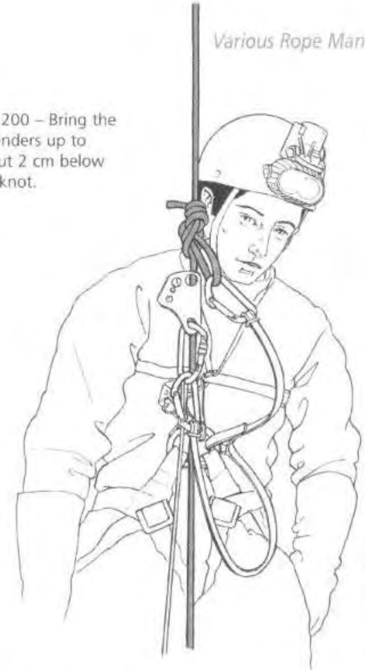


Fig. 200 – Bring the ascenders up to about 2 cm below the knot.

Fig. 201 – Transfer the upper ascender high enough above the knot to allow space for the Croll.

Fig. 202 – Transfer the Croll above the knot.

7.4 Passing a Knot While Climbing

If we passed a knot on the way down, we will sooner or later have to pass it on the way up! But this is fast and easy to do:

1. Bring the upper ascender to about two or three centimeters under the knot; raise the Croll as high as it will go (fig. 200).
2. Remove the upper ascender from the rope and place it above the knot, high enough to allow space for the Croll.
3. Step up in the footloop and transfer the Croll to the rope just above the knot (fig. 202).
4. Continue climbing.

As on rappel, clipping into the knot loop with the short cowstail is optional.

8. The Rope and Energy Absorption

When you hang motionless on a rope, the tension on the rope is simply equal to your weight. But as soon as you begin moving, you generate more or less abrupt jolts on the rope, depending on how well you have mastered your vertical technique. Learning how to move fluidly takes time but it is very important. Caving ropes are basically semi-static; their low stretch helps to limit the "yo-yo" effect and yet absorbs enough energy from jolts and possible falls to avoid transferring a greater load to the anchor. The static stretch on caving ropes varies from 3% for thick diameters to 6% for thinner ropes, under a load that increases from 50 kg to 150 kg (only "stretch reserve" ropes have a 1% stretch, see Section E, 2.7). As you climb, the length of rope separating you and the anchor from which you hang shortens, and thus has less shock absorbing capability (see Section E).

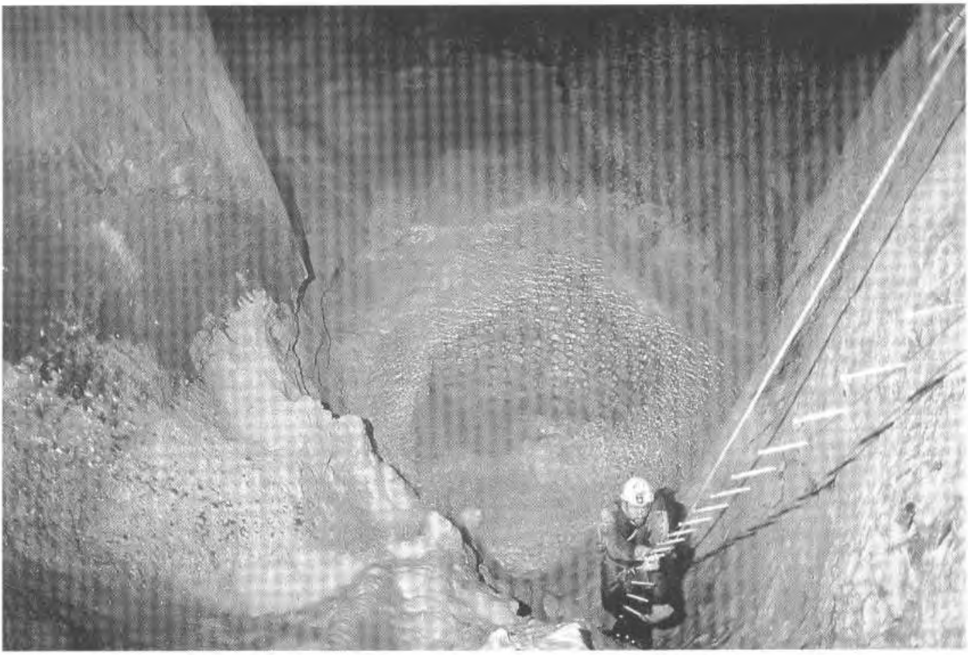
8.1 Impact Force During a Climb

In test situations, the shock load transmitted to an anchor by an average semi-static rope was measured during a climb by an 80-kg caver. As we just mentioned, this force increases as the distance between the anchor and the caver decreases; but the impact force generated on the rope also depends on the way the climber moves up the rope. If his movement is fitful and jerky, the force transferred to the anchor goes from 90 newtons at 20 meters to 180 newtons at two meters, and 200 newtons at one-half meter from the anchor. If the climb is fluid, these figures diminish respectively to 85, 100, and 110. At 0.5 meter the value is nearly halved!

Try to climb as fluidly as possible, and more so when climbing on thinner rope, approaching an anchor, or when the quality of the rock is suspect.

8.2 Impact Force During a Rappel

Energy generated on the rope during a rappel is less than that generated during a climb and has little to do with one's distance from the anchor. During a bouncy rappel, the shock load transferred to the anchor is about 150 newtons. If the rappel is smooth, this figure reduces to half. Be careful with auto-lock descenders: a bouncy descent of three or four meters followed by an abrupt stop can damage the sheath on thin ropes.



Grotte de Coufin. Photo S. Caillault

8.3 Tandem Climbing

In tandem climbing, two people climb up the same rope at one time. This technique is used for climbing out of especially deep shafts, as in Mexico for example; it is still not used much in Europe, more for reasons of comfort rather than safety. Rope with a diameter of 9 mm or more are strong enough for use with this technique, but the climbers may find it difficult to coordinate their movements so that the oscillations made by the first do not interfere with the second climber's rhythm. Moreover, the taut rope under the top climber may sometimes interfere with the Croll grabbing the rope; the foot ascender cam will also disengage systematically if it does not have a safety catch. We therefore relegate this technique to emergency situations (such as sudden flooding or a rescue), or to particularly deep shafts or slow climbs that would otherwise entail a long wait below.

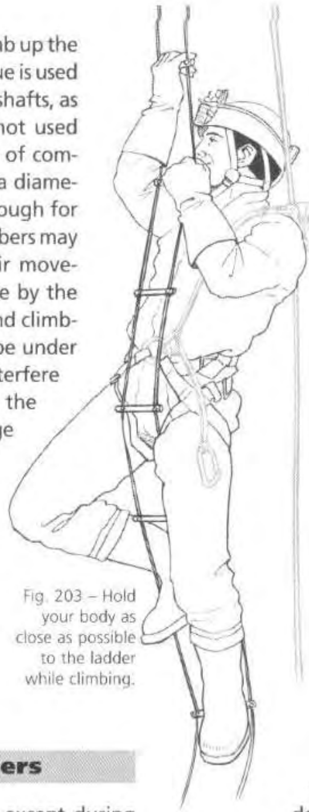


Fig. 203 – Hold your body as close as possible to the ladder while climbing.

9. Climbing Ladders

We rarely see cable ladders today except during initiations and trainings. For the beginner, the cable ladder provides a more intuitive and assuring climb than the rope alone. For training purposes at least, we will now present an overview discussion on this climbing technique. We need not treat the finer points of rigging them in difficult situations, since we do not encounter such scenarios.

For cave exploration, the ladder is useful for rigging in vertical passages that lack maneuverability or handholds, as in squeezes, narrow tubes, muddy climbs or climbs with loose, unstable rocks.

Since our wire caving ladders have limited strength (about 3 kN), and because there is the ever-present possibility of human error, a safety line should always be used. This can be placed either:

- as a fixed self-belay rope rigged alongside the ladder;
- or as a belay rope held by a teammate at the pitch head.

We no longer belay from below as we once did, with a rope doubled and run through a pulley. *Normal practice today has an experienced* caver climb first and then belay his novice teammates from above. Another experienced teammate remains below to oversee each student's technique for tying onto rope and for climbing.

9.1 Climbing

After checking that the ladder is not twisted over itself and that the safety rope is not tangled in it, grab two consecutive rungs from behind with each hand, at about face level. The outer wire cable on each side should be held between the thumb and forefinger. If the left hand is lower, the first foot to step up should also be the left, so that thereafter the right leg and left arm move up simultaneously. Then the left leg and right arm move up together, and so on (fig. 203). This method ensures the best vertical balance for the body against the ladder. Like the arms, the legs also wrap around the ladder, holding the body in close to the rope. You thus step onto each rung from the back, with your heels rather than your toes. On the other hand, when climbing against a wall, it is easier to step with your toes first, since you can hold your balance more naturally along the wall. For easier movement, place a knee on the rock to provide some space between the ladder and the wall. As with climbing on rope, look straight ahead rather than up; this limits strain on your neck and aids in breathing, which should follow the rhythm of each arm stroke.

9.2 Resting

Contrary to popular belief, climbing a caving ladder requires more effort than climbing on ascenders. Always try to conserve energy. Whether self-belaying or not, you can stop for a rest by simply clipping a cowstail into one of the side cables and sitting back in your harness with your arms hanging down (fig. 204). Because of stretch in the rope, this method is better than hanging from the rope alone. Doing this causes you to lose some vertical distance (fig. 205). If you are not self-belaying, be sure to forewarn your belayer of your intentions.

What NOT to do:
Clipping directly into a rung on the ladder for safety (as opposed to the side cable) can bend the rung.

Fig. 204 – Clip into the ladder with the short cowstail to rest, with arms hanging down.

Fig. 205 – Hanging from the safety line will cause you to lose height due to stretch in the rope.

9.3 Self-belay Technique

This technique allows the climber to safeguard himself on the rope without the aid of his teammates. He should have mastered vertical self-rescue techniques before using a self-belay technique; if the ladder breaks or its anchor ruptures, he must be fully capable of getting off the rope unaided.

Two techniques are commonly used:

1. Attach the harness belt to the rope via an upper ascender (or a Shunt or Tibloc), connected by a locking carabiner to the device's upper hole (fig. 206). Pass the carabiner directly (or via another carabiner) into your seat harness waist belt, on the side so it can't get caught in the ladder.
2. Attach to the rope using an upper ascender and cowstail. Use a locking carabiner to connect the ascender to the long cowstail through the ascender's upper hole. Place the ascender at face level on the rope (fig. 207). The arm should pass between the rope and the cowstail to help pull the ascender automatically up the rope. The rope is thus at your back, and the ascender sits over your shoulder.

Fig. 206 – Self-belay to the harness belt using a carabiner.

Fig. 207 – Self-belay using the cowstail.

The second technique is the most convenient. When you arrive at the pitch head, it allows more freedom of movement to step out of the pitch before removing the safety. In the event the ladder breaks, hanging from the harness maillon is also more balanced and comfortable than hanging from the waist belt.

9.4 Rope Self-rescue

If the ladder breaks and you are not outfitted with all your ascending gear, you will find yourself hanging by a side ascender or by the cowstail ascender. The only way off the rope is down:

1. Clip the descender into your short cowstail and put it on the rope under the ascender, then fully locked off (fig. 208).
2. Make an emergency footloop on the rope with a clove hitch around one foot (fig. 209).
3. Holding the rope with one hand and the ascender with the other, step up to remove the cowstail or carabiner connecting the ascender. Then disengage the cam and remove the ascender from the rope (fig. 210).

Fig. 208 – Install and lock off the descender.

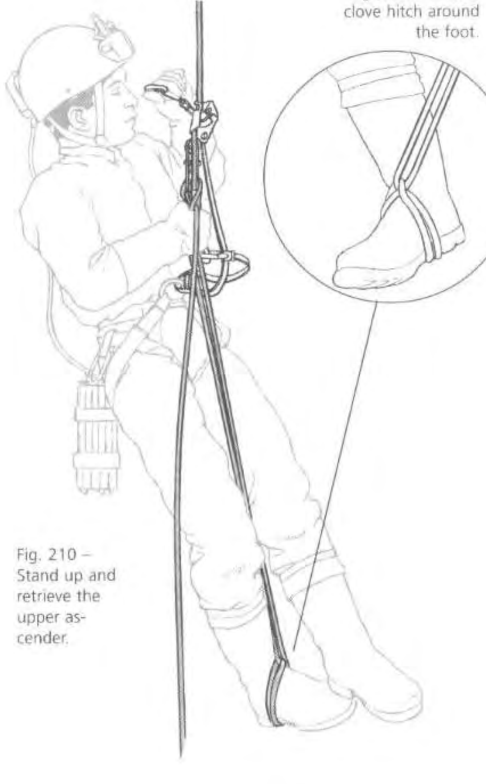


Fig. 209 – Place a clove hitch around the foot.

Fig. 210 – Stand up and retrieve the upper ascender.

4. Bending the leg to transfer your weight to the descender, check to verify the correct position of the descender and attachment carabiner on the rope.
5. Unlock the descender and begin the rappel (fig. 211).

Fig. 211 – Unlock the descender.

What NOT to do:

Linking the descender directly to the attachment carabiner and harness maillon (as usual) will prevent you from fully extending your leg when removing the ascender.

9.5 Belaying from Above

Three devices can be used:

- a Münter hitch, as described in fig. 70; this is the most adaptable.
- An ascender, either alone (fig. 212) or used with a pulley (fig. 213), or integrated mechanism such as the Petzl Mini Traxion or Traxion (see fig. 108). The belayer brings up the slack in the rope below the ascender as the teammate climbs.
- A Tibloc linked to a carabiner.

Fig. 212. – Belaying from above with an ascender.

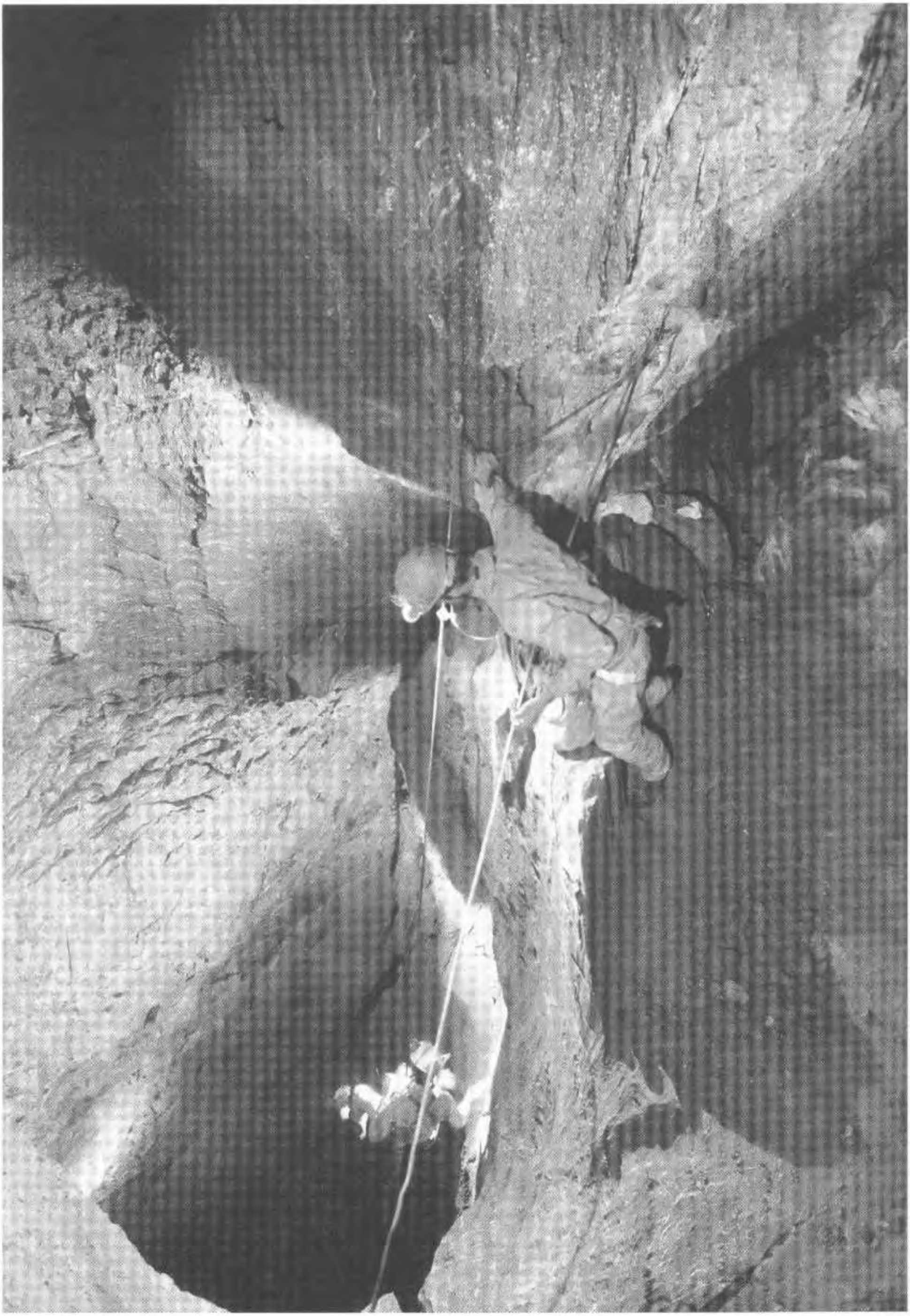
Fig. 213 – Belaying from above with a pulley-ascender device.

If the ladder breaks, the victim is completely dependent on his belay partner, who should be perfectly familiar with rope rescue techniques. The belayer must be able to raise a heavy load using a haul system (shown here in its simplest form, fig. 214) or a counterweight (see M.8) and must also know how to lower that load using a braking system such as a counterweight with a descender (fig. 215) or the Münter hitch. The preferred method will be chosen according to each situation, particularly based on the distance between the site of the incident and the top of the pitch.

Fig. 214 – Raising a load using a haul system.

Fig. 215 – Lowering a load using the counterweight method on a descender.

Chlausenschlot, Hölloch, Switzerland. Photo P. Berg



40 meter pit in K2, Sieben Hengste-Hohgant-System, Switzerland. Photo W. Janz

K Rigging the Cave

1. Basic Principles

Now begins the most exciting part of this book. We travel through known caves by simply applying our individual techniques to the rigging already in place. Rigging past an obstacle, on the other hand, is an act that projects the caver into the very heart of exploration, and this is the essence of caving. But rigging is not an easy matter since it also implies altering the cave.

The joy of discovery is difficult to temper: standing above a gaping shaft that disappears into darkness, in virgin passage, before a raging underground river or a chamber full of splendid formations, cavers naturally tend toward action. But before opening the bolting kit or delving into the unknown wonderland ahead, stop a moment and consider the possible consequences of your acts. Your intrusion into this unexplored realm will inevitably impact its environment, until now untouched and unprepared for your sudden arrival. When speaking of respect for the cave environment, everyone agrees it is important. But unfortunately, the concept means different things to different people.

Most cavers know that from the moment of discovery you should move slowly and carefully through a gallery packed with pristine formations. This could require removing your boots, walking single-file on a designated path, using the utmost care with every movement, and flagging the path so as to leave the least impact as possible. These are simple and effective measures that cavers have begun to practice more often and with better success in recent years.

In the case of archeological discoveries, greater caution is even more important: you must stop at the very moment of discovery, even though it may already be too late. Such discoveries are so rare that many of us are little prepared to react appropriately. Is this simply a piece of flint? You may not realize its true significance until you've already picked up the object and unintentionally (and without much forethought) taken it from its original resting place. Visiting the Grotte Chauvet, it is impressive to learn of its discoverers' remarkable self-discipline when they came upon their extraordinary find. From the outset, they tempered their excitement and subordinated their explorers' instincts to the protection of the cave. We can all learn from their example.

In these special situations the need for rigorous protection is well understood and usually well respected. But in a less remarkable cave the explorer may not be as conscientious of the influence that his choice of rigging will have on the cave's integrity.

Rigging an obstacle in a cave makes it accessible to humans; it also affects the natural state of the site, modifying it in some way and often irreversibly. There's no need to talk of more extreme methods here, explosive or otherwise. Drilling in the rock to place an anchor, using a stalagmite as a handhold, or stepping on the edge of a rimstone pool all represent permanent alterations to the cave environment. The intervention not only modifies the cave but it also directs the way in which future visitors will move through it.

Take the time to think before you act!

We are usually aware of the need for both safety and convenience when rigging past an obstacle, but we are unfortunately less inclined to think of protection. With time, the mere movement of cavers through the cave will create a recognizable pathway, but it will also degrade the passage. Do your best to limit this deterioration from the outset. At pitch heads, moving an anchor placement just one meter to the side could save a pristine white flowstone column from muddy handprints or black boot scuffs. In stream passages, raising a hand line 50 cm could prevent your turning a beautiful fossil into a foothold...until it breaks!

While nothing about rigging is without some consequence for the cave, you at least have some choice in how you rig that can help limit your impact. Responsible decision-making rests entirely on the head of the caver who is rigging. Will he make the right choice? The cave and its future visitors depend on it. If it's a bad choice, not only will it lead to irreversible degradation to the cave and/or difficult travel through it, but this will be good reason for a more enlightened caver to come along some day and question the rigging. He will then have to decide between the lesser of two evils: damage the cave more to rectify the problem, or leave the faulty rigging in place, even though it may already compromise the natural state of the cave or the safety of its visitors?

Rigging is a demanding activity that no one should undertake without the proper training and a full understanding of the responsibilities involved. Both of these prerequisites call for willingness and reflection. Even an experienced caver would do well to share his thoughts and fears with his teammates when perplexed by a difficult rigging situation. We are generally more intelligent when we put our heads together to solve a problem, at least until we reach that critical mass of too many people with too many opinions!

Good rigging ensures the safety of the user with the least possible impact on the cave environment. Repeating this tenet may fix the idea in some minds, but putting belief into practice is easier said than done. Who is to say where the truth lies? Here as elsewhere, hell (as Sartre put it) is indeed other people: the person who is rigging may have a tendency to rig the obstacle according to his own abilities or preferences.

You obviously don't need to transform a narrow crawlway into a boulevard under the pretext that you are a bit large around the middle, or change a short climb into a staircase to ensure the safety of those who can't climb. Fortunately, overweight people can lose weight, and beginners can improve their skills with practice. Once again, aim for an average skill level and try to rig with a minimalist style; it's easier to add an extra support later than to remove one that's in place, without leaving the obvious trace of redundant rigging.

Key point:

So this is the golden rule: *Rig first with your brain, then use your hands.* In the end, it's not so hard to do. Anyone with a solid conservation ethic and a good sense of awareness can add the pleasure of good rigging to the joy of discovering new cave.

2. Rigging Vertical Pitches

2.1 Fundamentals

In the case of an incident or accident, pits obviously pose the greatest risk of serious or fatal injury. Special care should be taken when rigging any vertical pitch, and consideration should be given to the following basic principles:

- *Good rigging is ergonomic and easy to use*, requiring the minimum amount of effort and thus less energy (given, of course, a normal physical condition and skill level). In caving, the accumulation of wasted effort will inevitably lead to exhaustion, the weakest person being the first to suffer.
- *Rig safely* so that if an anchor fails, it will result in neither a dangerous fall for the user, nor prevent him or her from continuing to descend or climb the rope.
- *Good rigging ensures the integrity of the rope*, on which everyone's life depends. Protect the rope from all possible abrasion from rubbing and contact with the rock by using deviations and rebelays. Be sure that the rope always hangs free of the rock.
- *Your rigging should be beyond reproach from the outset.* Saving an eventual improvement for the next trip is not only inefficient but dangerous: the desire to "go further" could send your good intentions flying...
- *Rigging should be simple, clear and straightforward*, making the means of travel obvious and understandable. If a rope is too long, its excess length should be tied off and coiled—and a knot always placed at its end—to avoid confusion with the trailing rope.
- *Beware of unstable rock*, especially in virgin cave passages: loose breakdown or dubious boulder chokes, rocks suspended in dangerous places of passage... Always correct or avoid these problems while rigging before moving on.

- *Always rig outside of potential flood zones,* far enough from water flows to allow an emergency exit even in unusually high flood conditions.
- *Good rigging conforms to basic principle of respect for the cave environment,* as explained in the above section.

All that remains is putting principle to practice... But, you might say, that seems like a lot of conditions! Yet they are all very important, especially the one that stresses perfect rigging from the very first descent. In exploration, we tend to rig "light" in order to see whether the cave continues, telling ourselves that if it doesn't, we won't have needed all those backup anchors. If it does, we have more equipment left to go further. This reasoning confuses speed with haste and doesn't hold up well: multiplying all of these little risks increases the potential for a major accident; the immunity that we've enjoyed up to now is no guarantee for future safety.

Perfect rigging does not necessarily imply definitive rigging. Nothing prevents you from descending into virgin passage on a chock backed up with a sling around a natural anchor. But if the shaft continues, the rigging should be changed. Though it is sufficiently safe for two or three people, it isn't safe for repeated use.

2.2 Dividing up Responsibilities

In the traditional two-person team, rigging is left to the lead person while the second acts as assistant. The secondary role is much less exciting and, since this caver is less active, it can be hard to stay warm. One solution is to switch roles from time to time, as long as both teammates have the same skill level. A homogenous pair is more efficient since partners can switch roles; a team having just one member with the adequate skill level means that if the leader is too challenged, it's time to turn back.

Some suggest splitting the task of setting anchors between the two: the first sets one of the two anchors needed for the pitch, the second sets the other. This seems an attractive proposition at first glance: it helps both teammates stay active and warm, and it saves time. However, it doesn't really ensure proper safety: the leader does not have the safety of both anchors at the pitch head, nor those that he would need for a safe descent (in case of a pendulum, for example). Yet he will take the most risks in this first descent. There are so many potential hazards in virgin passage: the rope could get stuck on a rock blade, a natural anchor could fail, a rockfall could occur, a bolt could come loose... In general, the lead person should finish rigging each step before moving on to the next.

That being the case, the activity of the second teammate is limited to:

- setting the backup anchor at the beginning of the traverse line leading to the pitch head while the lead person sets an anchor at the drop, whether this double maneuver can be safely performed without a belay or with self-belay;
- modifying the original rigging if the lead person sees the need for it as he descends. The most typical situation that arises is when the first person down sees an unexpected rub point once he has descended past it on the rope. He then leaves the necessary slack in the rope for the second to follow and place an intermediate anchor, while he himself is setting another below if necessary. The second then has the opportunity to warm up while correcting the rigging.

3. Preparation and Approaching the Pitch Head

3.1 Choosing Rope Lengths

If your club keeps good documentation of caves and cave surveys, you should be able to find the right rigging information for the next trip to a known cave. This of course doesn't apply if you have a new or continuing exploration to look forward to. In the latter case, you need some knowledge of the mountain or karst area concerned, and particularly the morphology of the known caves it contains. This will help you determine the amount of rope you should take. Quantity will depend on the size of your team and the projected duration of the exploration. Rope size will depend on the technical level of the team and the expected frequency of use.

3.2 Preliminary Check

The condition of all ropes should be checked again before or when they are packed into their packs. During this last examination, each rope should be uncoiled and checked both visually and manually for any possible damage to the sheath, or variation in diameter or softness that would indicate an alteration in the core. Performing this last check is important, even if the ropes were already checked when they were washed after their last use. We have in fact seen incidents when improperly stored ropes had undergone an alteration, or even served as dinner for the local rodents!

3.3 Knotting the End

This is more serious than it first seems. Despite all the precautions taken, serious and even fatal falls have occurred, and still occur, because a safety "stopper" knot was not placed in the end of a rope that was too short to reach the bottom of the pitch. This hazard has been somewhat facilitated by the traditional practice of leaving the rope in its pack during the first descent. If the rope is too short, there is little time to stop since the end comes out of the pack at the very last moment. Slow reflexes at this point could mean a guaranteed free fall, *unless* there is a stopper knot in the end of the rope.

The knot can be a simple figure eight, not too tightly dressed, placed about a meter from the rope end. If another rope is to be joined to this, make an end-to-end knot by threading the second rope back through this first figure eight.

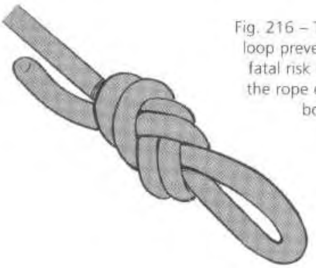


Fig. 216 – The end-line safety loop prevents the potentially fatal risk of a free fall when the rope does not reach the bottom of the pitch.

Make a figure eight loop instead of a normal figure eight. This is your "end-line safety loop." During rescue operations, this is how we distinguish the end of the progression rope (end-line safety loop) from the stretcher's haul line (safety loop preceded by an overhand knot) and from the belay line (safety loop preceded by two overhand knots).

Get in the habit of using these simple and effective codes. Another advantage of the safety loop: if the rope is too short, a triple figure eight can be made by rethreading the second rope through the first knot. A changeover loop is then available for clipping into when passing the knot on rappel.

The end-line safety loop is perfectly safe: the worst that can happen is that your descender will come down and jam on it. This knot has only one flaw: if you can't see it, you may have forgotten to tie it, and still think you did! So always remove it from the pack and check it before the first rappel. This also calls for a small precaution when packing rope: don't forget to check for the safety loop, your life depends on it.

3.4 Packing the Rope

When visiting the classics, you will know your rope lengths and can pack the ropes length-by-length in consecutive packs in the order in which they will be used, the first rope being at the top of the first pack.

In exploration, pack the longest ropes by lengths and place shorter ropes folded in small coils on top. When approaching a deeper drop, transfer the coils to another pack for easier access to the longer rope.

In both cases, packing a rope involves first placing a safety knot in the end and leaving this to hang on the outside of the pack. Then stuff the rest of the rope inside, either length by length (fig. 217) or by handfuls (fig. 218). It is best not to make loops in the rope as you pack it (fig. 219) because they can get twisted and cause the rope to tangle as it is removed from its pack. For optimal use of space, pack down the rope by bouncing it a few times on the ground.

Key point:

Once the rope is packed completely, the lower end with the safety loop should be placed inside on top of the packed rope. It will lie next to the upper end that is to be rigged at the top of the pitch. Run this free end through the safety loop (or tie it with a half-hitch/slip knot), so that you can find it easily when you need it by simply grabbing the safety loop.

If enough space is left, place another rope on top to be used for the preceding pitch.

When opening the rope pack, expect to find the safety loop end of the rope that is to be used and if it is not there, make one. The safety loop must be brought out of the pack first, and with it you will have the upper end as well. Leave the safety loop to hang visibly just outside the pack, and you know you're safe in case the rope is too short.

Fig. 217 – Packing the rope length-by-length.

Fig. 218 – Packing the rope by handfuls.

Fig. 219 – Packing the rope in coils will cause it to tangle.

☺ To do:

- When packing long ropes, pass the rope through a carabiner installed directly above the rope pack. This can be attached with webbing to a tree branch, a section of wall, a rock outcrop, or even a colleague, who can stand over the pack and hold it open at the same time (fig. 220). This is a fast, easy way to pack the rope.
- Throw some water on stiff ropes before packing them; this softens them and makes them easier to pack, though it also adds some weight to the pack.

A normal sized rope sack can hold 100 meters of 9-mm rope. Naturally, there is much more to carry than just rope. The lead person will set off with the rope, a bolting kit and some slings, chocks and pitons; the second will carry extra carbide, batteries, food, extra hardware, and a reserve hand driver and hammer. If two packs aren't enough, you will need three, but this isn't too bothersome as long as the pitches are close. Besides, the first pack will soon be empty.

Fig. 220 – Use a return carabiner or pulley when packing long ropes.

3.5 Approaching the Pitch Head

Let's go underground now and apply some of the things we've learned. Turning the corner of a meander, the floor suddenly drops and the cave walls fall away into a promising darkness... It's time to rig! This would also be the case for climbs that aren't so deep but still present a risk of falling. Suitably belayed, the lead person will check the pitch. He should not only rig the pitch, but make the approach safe, taking into account fatigue, heavy loads, and the possibility that lighting will not be as good on the way out.

3.6 Clearing the Site

Safety requires that we clear the pitch head of any objects that could eventually come loose and fall down the pitch later: wedged or loose rocks or accumulated mud should be pushed down the drop. This is also a great opportunity for a preliminary sounding. If you are standing on flowstone, test it with a few hard kicks; the surface crust is sometimes thin and may come away under your weight.

3.7 Checking Pitch Depth

Back in the day of cable ladders, which were only available in standard five- to ten-meter lengths, we had to know the exact depth of the pitch. We rigged these by unraveling successive ladders and connecting them together as we moved downward. If too much length was used, it would accumulate at the bottom and we either rolled up the excess length or changed the last ladder length. Such complications are now rare. It is easy to stop during a rappel and add length to a short rope or have a teammate change the rope for one that is better suited to the pitch. And it isn't a problem to change over from rappel to climbing if you think you need to go back up the rope. So knowing precise depths are perhaps not so important nowadays, and you can be content with an approximate guess. At less than 25 meters, the beam of an electric headlamp will suffice for estimating the depth. Beyond that, you will need to let a stone fall (it should not be thrown) and then count the seconds until you hear it first hit. Any ricochet will alter the measurement. We use the formula $D = 35 + 25\,(T-3)$, where T stands for the time counted until the first contact, and is viable between 25 and 100 meters, which applies to most situations. Let's just take three numbers to get an idea of sounding depths: three seconds corresponds to 35 meters, four to 60 meters, and five to 85 meters.

4. Natural Anchors

Since they are already in place, natural anchors save us a lot of time during exploration. These should of course be solid and secure, and situated to ensure a good hang for the rope. They are often better for use with traverse lines (less demanding positioning) than with pitch heads since Mother Nature didn't exactly consider cavers when She made the caves!

4.1 Precautions

Check every natural anchor first with a hammer; it should not sound empty or hollow when hit. Once you know it's solid, you may want to smooth out the surface a bit (with the hammer) if it has any sharp ridges.

Depending on its shape, one carefully tested natural anchor is often enough, though it should still be rigged with a backup as well (webbing plus rope, or two slings of webbing, etc.). To prevent wear when rigging at mid-rope, install the rope first on the natural anchor, then make a rebelay on the same anchor using an additional sling (figs. 221-222). Natural anchors such as bosses or projections should be rigged to avoid all possibility of the sling

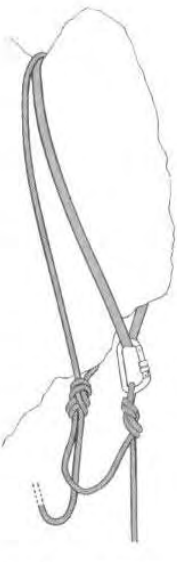


Fig. 221 – Double anchor on a natural projection.

Fig. 222 – Double anchor on a natural bridge.

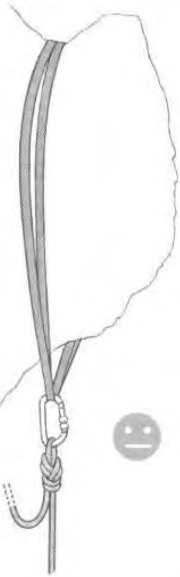


Fig. 223 – If the direction of pull on the rope changes, the sling could slip off.

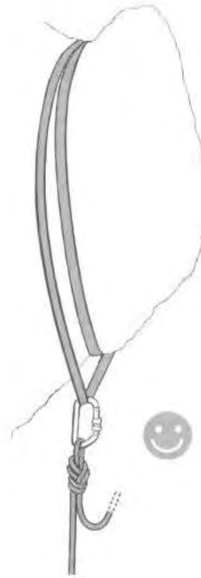


Fig. 224 – A self-tightening rebelay loop made with webbing.

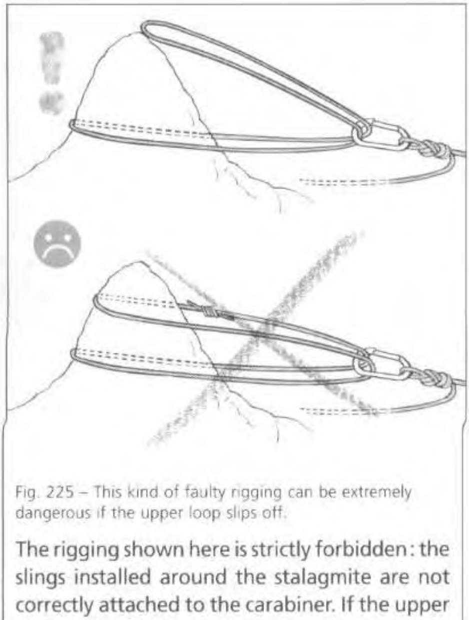


Fig. 225 – This kind of faulty rigging can be extremely dangerous if the upper loop slips off.

The rigging shown here is strictly forbidden: the slings installed around the stalagmite are not correctly attached to the carabiner. If the upper sling pulls off the anchor point, the carabiner will come away and a fall will result.

coming off if a sudden movement somehow changes the direction of pull on the anchor. This could happen with the rigging shown in fig. 223.

Don't leave the rope fastened loosely around the anchor point; instead, either rig the rope with a self-tightening double loop (fig. 224) or a girth hitch (see section 4.5), though this knot weakens the sling by about 20%.

4.2 Trees

When we find them in the right place, trees are great anchors for entrance drops. As long as they are still alive, mature and well rooted in the ground, they are generally very solid. A good, solid tree can be used alone as a double anchor: attach one sling with a carabiner to the down rope taking its tension, and rig the upper end of the rope (free of tension) as a secondary anchor (fig. 226).

Fig. 226 – Rigging to a tree.

4.3 Formations

Stalagmites are tempting anchor points but they must be carefully tested before use. Some may have formed over a sub-layer of clay, from which they can detach without warning under relatively little tension. Others are less solid and will break up under pressure from the rope. *Formations should be* girdled as close as possible to their bases to avoid any risk of rupture from overloading.

4.4 Rock Outcrops and Flakes

Flakes are particularly sturdy when they are an extension of the bedrock. However, they sometimes have sharp angles that you should soften before rigging. Do this with a hammer but be discrete – you don't need to remodel the entire wall, just try

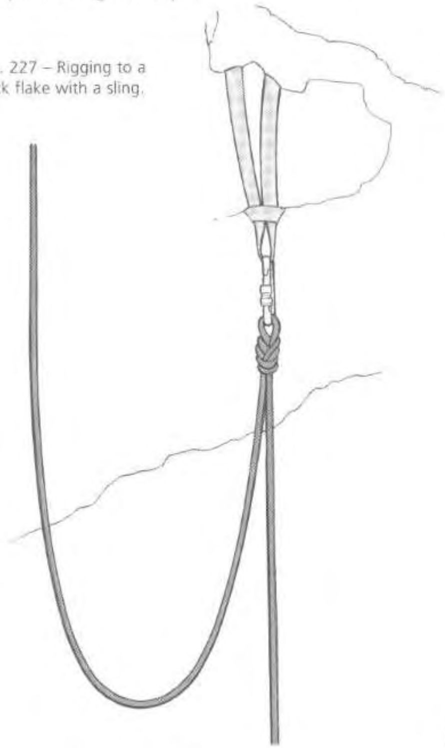


Fig. 227 – Rigging to a rock flake with a sling.

to reduce possible damage to the rope (see page 180). When rigging around this, use a sling or an auxiliary length of rope to protect the primary rope from abrasion (fig. 227).

4.5 Eyeholes and Jughandles

The frequency and strength of eyeholes depends largely on the nature of the rock. We often find these in river passages since they are the result of an active process of corrosion. If they are strong enough for use, they are very practical. They also require auxiliary webbing or rope (figs. 228 and 229).

4.6 Rocks and Chockstones

Large rocks or boulders on the ground are a good departure point for hand lines. Always check their base. If this is in clay or loose rocks or pebbles, the rock isn't likely to withstand the traction placed on

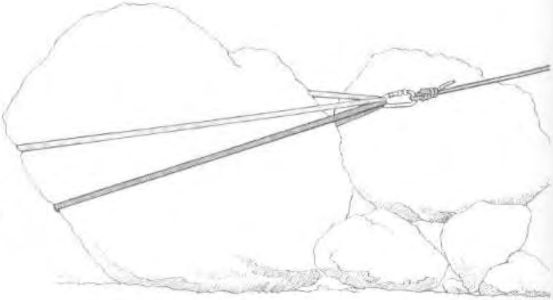


Fig. 230 – Rigging around a boulder with a double sling.

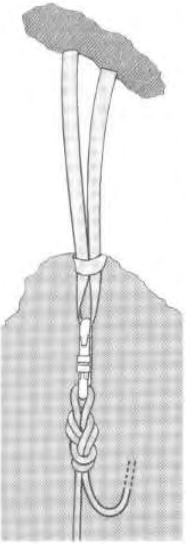


Fig. 228 – Eyehole rigged with webbing on a girth hitch.

Fig. 229 – Jughandle rigged with a webbing sling.

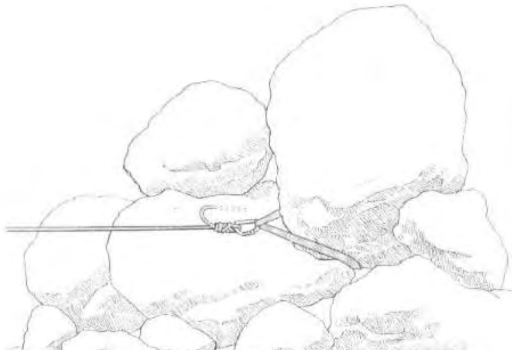
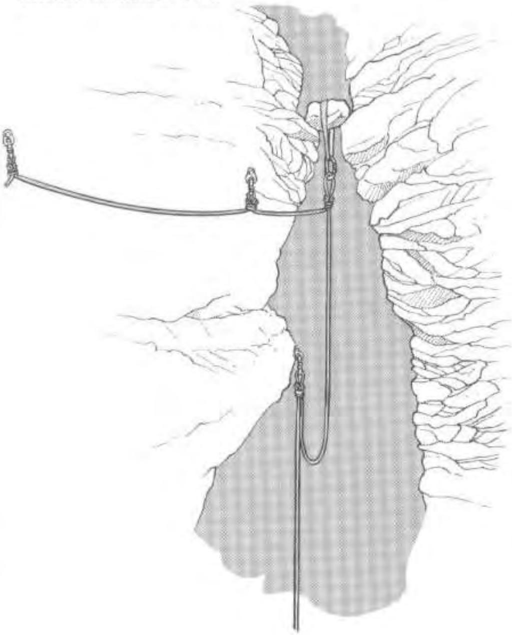


Fig. 231 – If the rope is rigged with only one sling, it must be backed up at a second anchor point, shown here as the fading rope end.

Fig. 232 – Anchoring on a chockstone jammed between the walls of a rift.



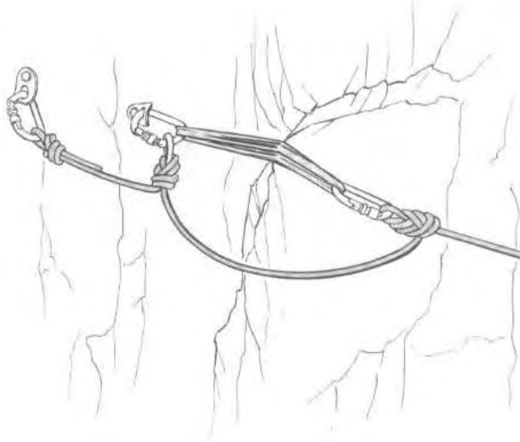


Fig. 233 – At the start of a traverse, rig a protective webbing sling over a rub point and back it up with the rope.

it. A chockstone wedged firmly between two walls is stable, but it could come loose if you try to place a bolt in it (unless it's a large boulder). Rig it with a sling, which should be doubled if the rock is the only anchor (fig. 230 and 231). Make sure the rock cannot turn on the axis that joins its two points of contact with the walls. In narrow meanders, wedged rocks (they should be very tightly wedged) are convenient when there is not enough space to place a bolt in the wall (fig. 232).

4.7 Using Slings

When we rig on natural anchors, we generally use slings made of rope or more often webbing. Since there is generally some abrasion between the anchor point and the slings, they wear out fast. Check them systematically and change them often. Installing a length of webbing at the beginning of a traverse line or a pitch requires a backup for safety. You can make this secondary anchor by simply backing up the webbing attachment with the rope (fig. 233). At a rebelay you consider to be solid and safe, there is no need to backup an anchor rigged with webbing: the attachment point of the previous rope length provides the safety (fig. 234).

A sling made from rope is somewhat safer than one made from webbing. In fact, a rope sling has some shock absorbing capability while webbing is inelastic. Rope is also stronger: even if its sheath is completely abraded, the rope still retains 70 % of its initial strength. Abrasion on webbing is more difficult to detect and tends to spread more easily, and faster. Depending on the type of weave used in making the webbing, total rupture can occur quite rapidly.

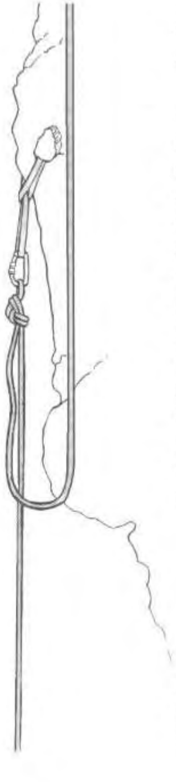


Fig. 234 – If the jughandle at a rebelay is considered safe, the upper rope suffices as the backup.

5. Placing a Backup Anchor at the Pitch Head

5.1 General Principle

You can never totally exclude the possibility that an anchor will fail. There are a thousand possible causes for this: bad rock, forgetting to place a cone in the sleeve, a rock overhang coming away, or a broken screw head are just a few examples. If the anchor holding you comes out and it is the only one rigged, you will find yourself taking flight without the proper gear or training to make an emergency landing. Never take this risk, no matter how deep the pitch may be.

Don't be tempted to minimize the risks involved in passing a lesser pitch, and remember that greater stress is transferred to the anchor as you approach it. You can just as easily kill yourself in a five-meter fall as you can in a 50-meter fall; the only difference lies in how you will look when they find you. With a backup (or doubled) anchor at the pitch head, the likelihood of a fall resulting from two anchor failures is almost nil, at least if you've allowed the minimum distance of separation between the two.

Rigging begins with cleaning and securing the approach. Then you must find the ideal line of descent that will prevent all contact between the rock and the rope (and thus abrasion to the latter), as well as possible exposure to a waterfall in the event of a sudden flood pulse. Looking for this often requires you to lean out over the pitch or climb in opposition to a point just above it, which should only be done if you are belayed by your partner. The primary anchor should be placed at the point where this ideal axis intersects the rock. Check its trajectory by dropping a rock or dangling the rope from this point.

Important: your comfort while bolting should not affect the placement of the primary anchor. Even if it's a bit difficult to hold your position, it only takes a few minutes to perform the operation. What a pain to find those bolts placed in comfort without regard for the rope's trajectory at the start of a meander or a corkscrew, which then requires a rebelay or deviation just three meters down! There are several solutions to this problem.

- Choosing the best anchor placement requires you to account for both the configuration of the approach and the best use of your gear.

Surprise River Cave, Papua New Guinea. Photo U. Widmer

- If it is possible to place two anchors and the second allows you to avoid a further rebelay during the descent, opt for this. Then decide on the most logical location for the backup anchor.

✵ Key points:

Once all this is done, ask yourself the two questions that will either confirm or invalidate your choice of placement:

1. What will happen to the rope if the primary anchor fails?
   a. If the new position of the rope still allows you to safely continue down to solid ground or to the summit of the drop (albeit with greater care), then the rigging is safe.
   b. If the rope risks rubbing dangerously against the wall or a ledge once it is held by the secondary anchor, it will prevent safe progression in either direction on the rope and the rigging is thus faulty.
2. What will happen to YOU if the primary anchor fails?
   a. If a pendulum swing brings you safely to rest below the secondary anchor, then the rigging is good.
   b. If this pendulum has a dangerously high angle or risks hurling you violently into some obstruction, then the rigging is faulty.

Of course, your choice of rigging is satisfactory only if conditions 1a and 2a are *both* satisfied.

While there are an infinite number of rigging configurations, the possibilities for correctly placing two anchors next to each other are rather limited. We will illustrate these here, with P representing the primary anchor, and S representing the secondary anchor.

5.2 Primary and Secondary Anchors Offset Vertically

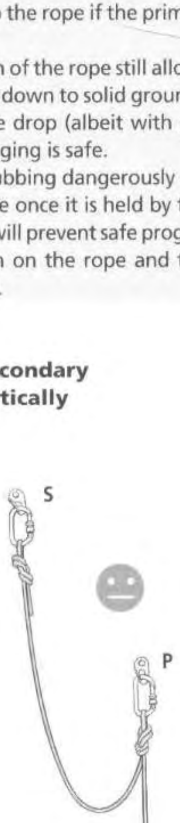


Fig. 235 – Some slack is acceptable here, but you will feel an unpleasant shock if the primary fails.

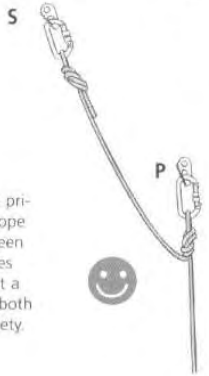


Fig. 236 – If the primary fails, the rope in tension between the **P** and **S** takes the load without a shock, insuring both comfort and safety.

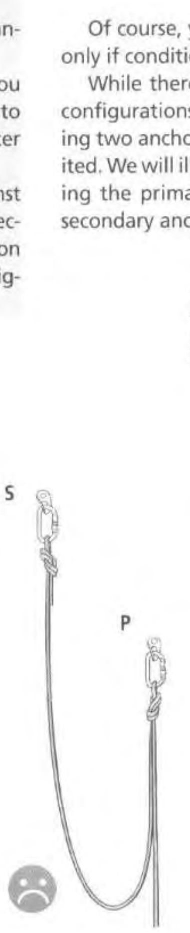


Fig. 237 – There is no need for slack between **S** and **P**. If P fails, it increases the fall distance and therefore the shock load, even if the fall factor remains below one and does not reach a dangerous level. Another disadvantage: this configuration wastes a lot of rope.

Fig. 238 – This rigging exposes the rope and the caver to a fall factor approaching 2. Inadmissible.

Fig. 239 – In this "false factor 2" configuration, placing a knot on the primary anchor rope at the level of the secondary reduces the potential fall to a much lower value.

5.3 Anchors Placed Side-by-side

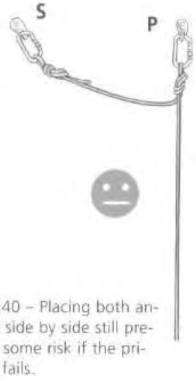


Fig. 240 – Placing both anchors side by side still presents some risk if the primary fails.

Fig. 241 – The slack between **S** and **P** is unnecessary and dangerous. In case of failure, it raises the fall distance and thus the shock force, though the fall factor remains below danger level. Again, another disadvantage is the useless waste of rope.

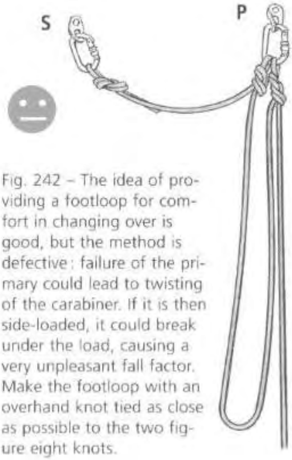


Fig. 242 – The idea of providing a footloop for comfort in changing over is good, but the method is defective: failure of the primary could lead to twisting of the carabiner. If it is then side-loaded, it could break under the load, causing a very unpleasant fall factor. Make the footloop with an overhand knot tied as close as possible to the two figure eight knots.

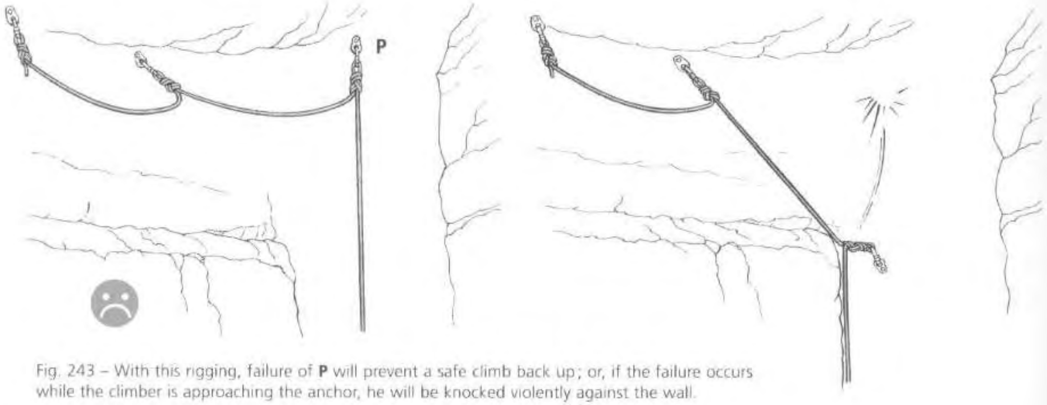


Fig. 243 – With this rigging, failure of **P** will prevent a safe climb back up; or, if the failure occurs while the climber is approaching the anchor, he will be knocked violently against the wall.

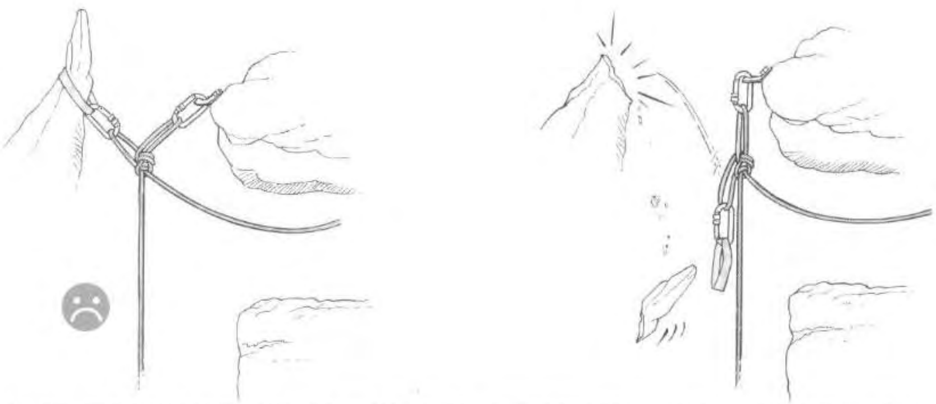


Fig. 244 – With this rigging, the anchor plate could break under the shock load following the failure of the backup anchor.

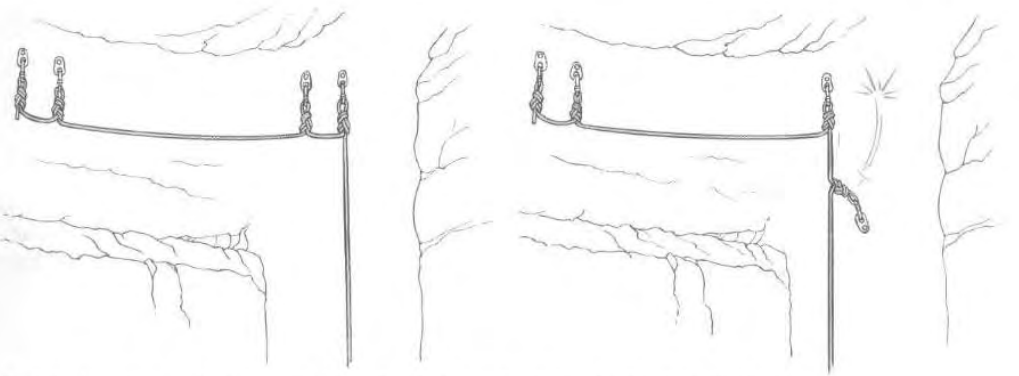


Fig. 245 – In any case, it is best to rig with two anchors backed up to a traverse line that is also backed up.

5.4 Y-Belay (Y-hang, Y-rig)

This arrangement divides the load between two anchor points. The axis of the pit rope follows to neither anchor directly. Y-belays are especially useful in the following three cases:

- in meanders (anchors on opposite walls), where it helps prevent abrasion to the rope;
- when the walls have no overhang, as in a funnel pitch or when there is a bank or outcrop just below the pitch head. Only Y-belays and deviations will provide a free hang;
- when rigging light (see pages 205 and beyond), this best rigging divides the load between two anchors, avoiding a shock load in case one fails.

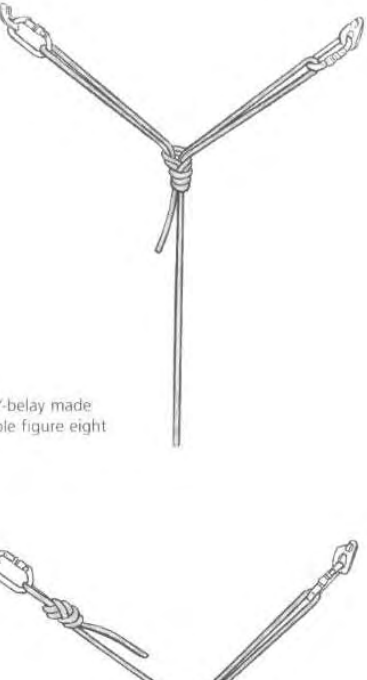


Fig. 246 – Y-belay made with a double figure eight on a bight.

Knots used for Y-belays are described on pages 74-75. The most common are the double bowline on a bight (see fig. 57) and the double figure eight on a bight (fig. 246). We can also connect to the far anchor with a simple loop in the rope, joining this to the near anchor with an intermediate loop knot (fig. 247). This method saves the most rope.

Key point:

- Never place your climbing equipment above the center knot, since this area is not protected by a backup anchor.
- We once feared that a greater angle between the two anchors of a Y-belay would considerably increase the load on each anchor. In fact, we have found that this angle cannot go beyond 120 degrees in practice because the knots tighten and the rope, being somewhat elastic, begins to stretch. So, there is no great danger in this respect.

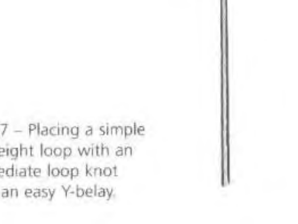


Fig. 247 – Placing a simple figure eight loop with an intermediate loop knot makes an easy Y-belay.

- If one of the two anchors in the Y-belay fails, there is no appreciable shock or pendulum since the secondary is already under tension, so there is no resulting fall. The smaller the angle between the two anchors and the smaller the length of rope separating them, the smaller the resulting pendulum.

To do:

There are four ways to clip into a Y-belay with your cowstails:

1. Clip into one of the two arms formed by the double bowline on a bight or double figure eight on a bight, taking care to only place the carabiner through one strand of the loop and NOT over both.
2. Clip into the loop on EACH of the two arms.
3. Permanently place a safety carabiner in the loop of each of the two arms, and clip into this.
4. Make a butterfly knot under the Y.

The second and third options are easier to do when the Y-belay has been made with a bowline on a bight rather than a figure eight on a bight.

What NOT to do:

- Never place an anchor plate so that it will not sit in alignment with the rope's line of descent if the primary anchor fails (fig. 244, page 186).
- Never clip around *both* strands of *one* arm on a Y-belay.
- Never place the central knot higher than the secondary anchor (fig. 249).

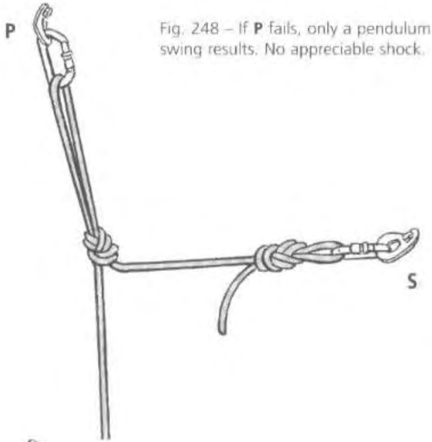


Fig. 248 – If **P** fails, only a pendulum swing results. No appreciable shock.

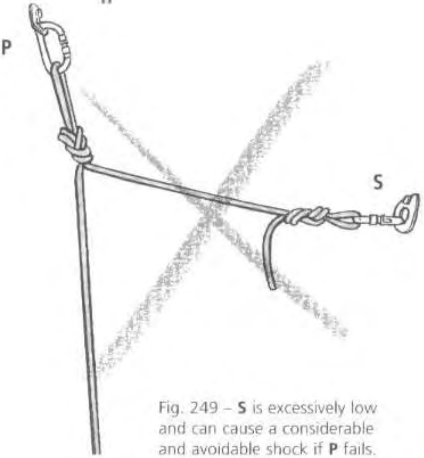


Fig. 249 – **S** is excessively low and can cause a considerable and avoidable shock if **P** fails.

Papua New Guinea. Photo J.P. Sounier

6. Traverse Lines and Tyroleans

Since you must rig so the rope hangs free, approaching the anchor at the pitch head often means being exposed to a possible fall. You need to secure the approach with specific rigging.

Even if the approach seems easy (wide turn, easy chimney, good hand holds), danger still exists and one wrong move or loss of balance due to a heavy load could lead to a fall. You need to fix a traverse line. Secure both ends to reliable anchors, and safeguard your passage by clipping in with one or both cowstails. Alternate with both cowstails if the traverse has intermediate belays.

☺ To do: Install the traverse line high. A fall will place less stress on the anchors (fig. 250).

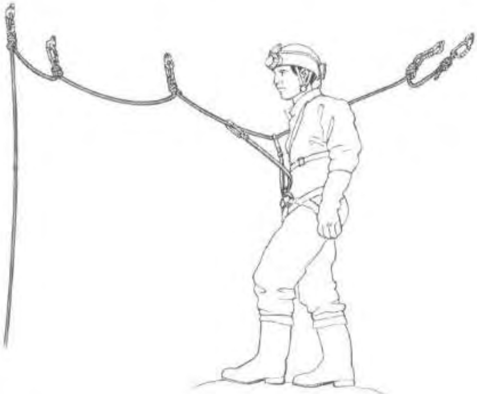
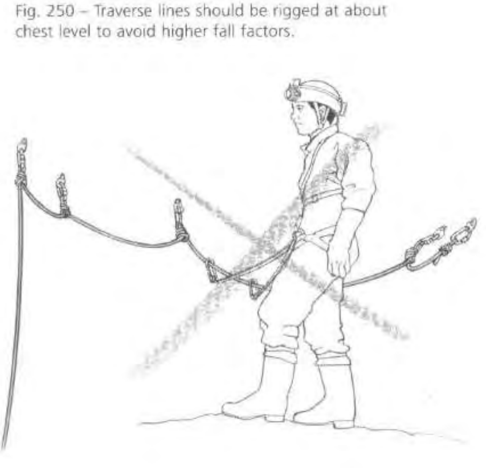


Fig. 250 – Traverse lines should be rigged at about chest level to avoid higher fall factors.



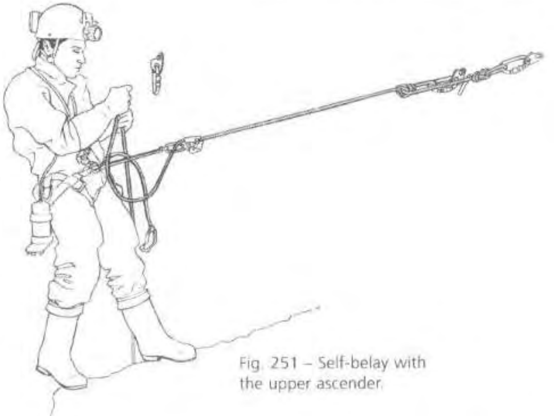


Fig. 251 – Self-belay with the upper ascender.

Fig. 252 – Self-belay with the descender.

Once you have secured the first anchor, you can belay yourself two ways:

- with the upper ascender attached to a cowstail. During progression, lower the ascender as if down climbing, releasing the cam by pressing down with the thumb or fingertip (the safety catch remains closed; fig. 251).
- with the descender. Place an overhand knot as safety on the lower rope. Stopping on this allows you to free both hands. You can lock off the descender, making sure that the upper rope remains in constant tension (fig. 252). In both cases, the rope should be carried in its pack, attached to your harness with a carabiner or on a tether, and fed out as you progress. Once the first bolt of the primary anchor is in place at the pitch head, belay the traverse line to this. The descender will unfortunately produce some slack when you remove it from the rope, so you will need to take out the excess slack in the traverse line before attaching it.

Future Sink, Patagonia. Photo L.H. Fage.

Photo S. Muir

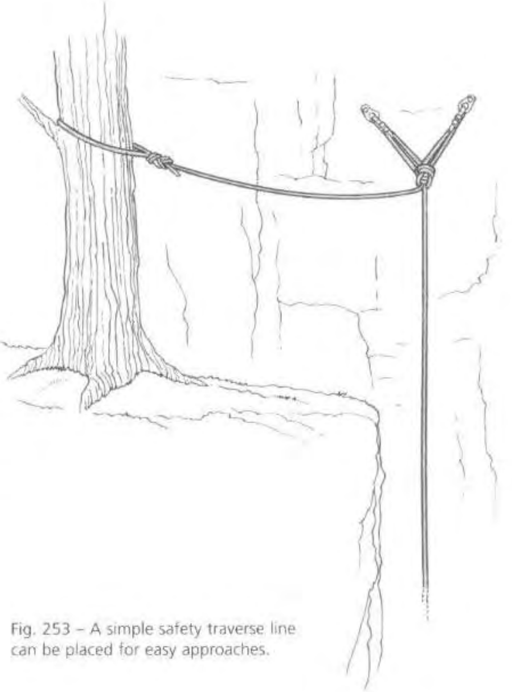


Fig. 253 – A simple safety traverse line can be placed for easy approaches.

6.1 Safety Traverses

These are rigged for safety only when the approach is judged very easy (fig. 253). A solid natural anchor doesn't require a backup since you won't load the rope with your cowstail unless you slip. You can fasten the rope for the backup belay directly around the natural anchor since abrasion will only occur in the event of a fall.

6.2 Traverse lines for Travelling

When the approach is exposed or more difficult (fig. 254), you need the traverse for safety and balance, placing all your weight on it with your short cowstail, arms, or otherwise. You must therefore install an additional backup anchor above the primary, and rig both anchors to avoid possible abrasion to the rope. At the lower end of the traverse, both anchors at the pitch head are rigged in the same way, but the anchor plate holding the traverse line must be on a suitable axis with it when the traverse is loaded.

By their very nature, traverse lines are difficult and athletic to rig. When you rig to avoid waterfalls for example, the rock is often smooth and perhaps even overhanging. If you are rigging, have your partner belay you (and depending on the circumstances,

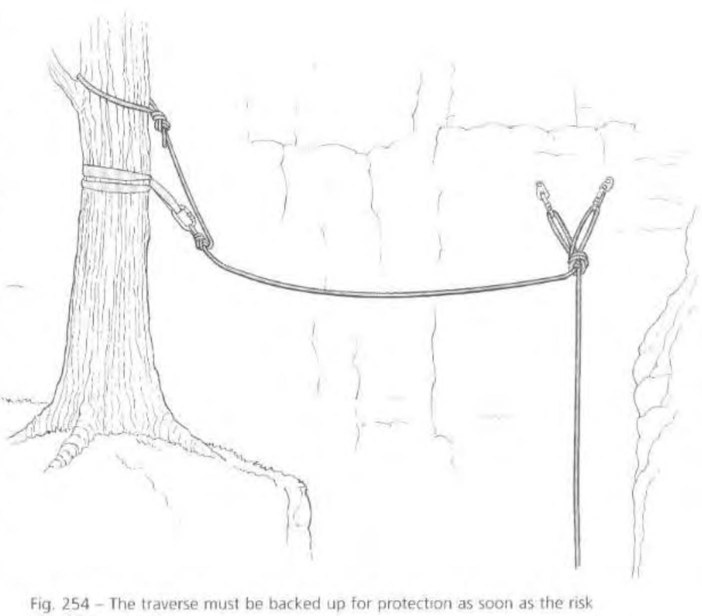


Fig. 254 – The traverse must be backed up for protection as soon as the risk of a fall is present.

Fig. 255 – Progressing on self-belay while rigging a traverse line.

may need to leave your pack behind). You have three possibilities for continuing:

1. Hanging from the previous anchor point, or simply clipped in if this is nearby, move to the next point using the appropriate safety (descender, ascender; fig. 255).
2. Free climb the traverse (figs. 256, 257). If more difficult passage presents a risk of falling, you should be belayed on dynamic rope.
3. Use aid climbing techniques (see K.12).

Once you have reached your goal and while still on belay, steady yourself firmly (using a sling, piton, chock, or in opposition, etc.) before installing the first bolt. Clipped to this, set the primary.

The rope can be rigged two ways.

1. If the same rope is being used for both the traverse line and the pitch, clip into the anchors you have just installed, check for the stopper knot in the rope end, and begin lowering the rope down the pitch. Tie the appropriate anchor knots and adjust the tension.
2. If the traverse line is separate from the pit rope, clip into the anchors you installed and get off the traverse rope. Rig the end of this to both anchors at the pitch head. Your partner adjusts the tension on the traverse anchors, coils and ties the excess length, and hangs it from the backup. He joins you, tying the knots on the traverse as he goes

With frequent use, traverse lines are highly solicited and can wear more quickly from abrasion, particularly when rigged against convex walls and at localized contact points. You can minimize this contact by placing more rebelays in the line as necessary.

Key point:

Avoid rigging long, unbelayed traverse lines as much as possible, because:

- an unbelayed line will produce more sag in the rope when loaded, which pushes the upper body away from the wall and requires us to compensate with our arms. We also have to expend more energy to climb back up the rope when we reach the end.
- the line is farther from the wall at the middle if it crosses a concave wall, which requires us to adopt a bridging position or even treat it as a tyrolean.
- when returning to the cave after a long absence, it is difficult to judge the condition of the rope and rigging from a distance.

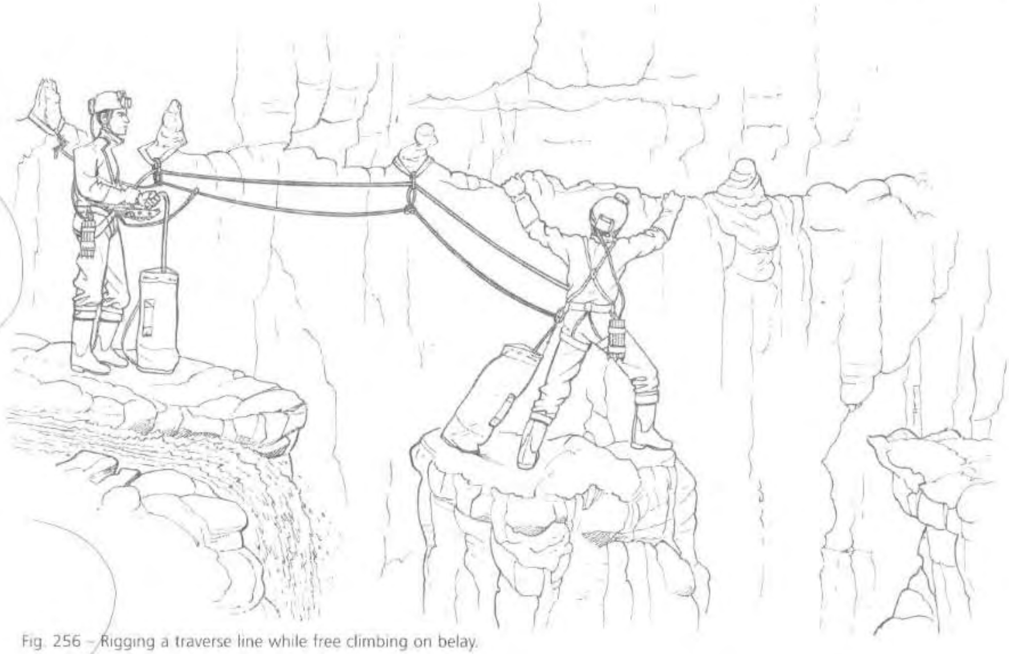
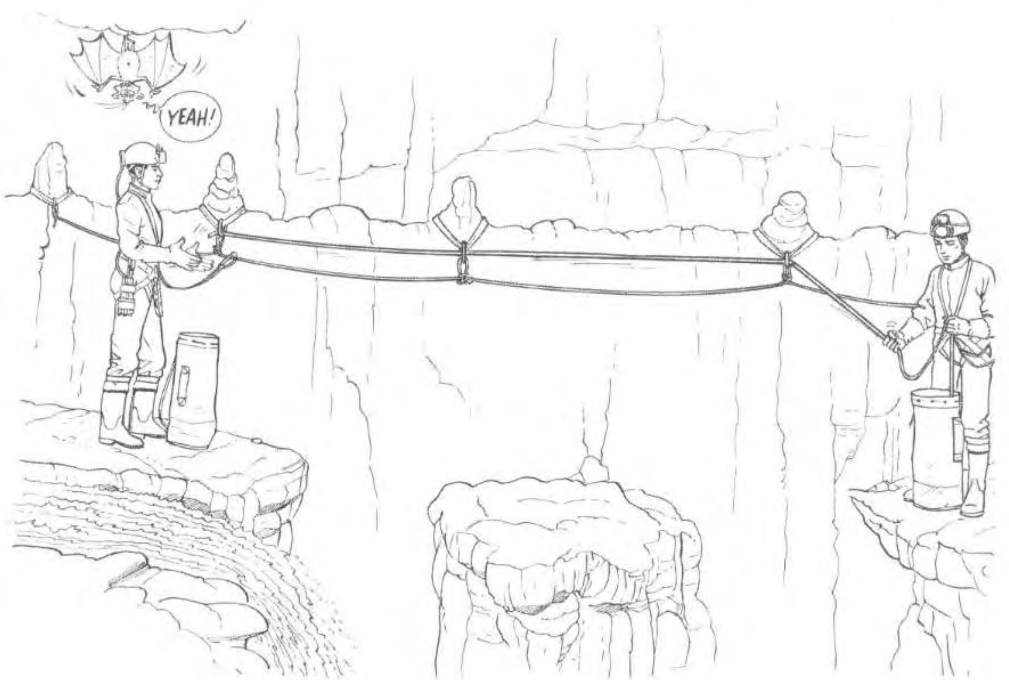


Fig. 256 – Rigging a traverse line while free climbing on belay.

Fig. 257 – Once the exposed passage is safely rigged, retrieve the belay rope.



To do:

- Keep the line on the same wall. This helps you avoid more difficult opposition maneuvers to get past (fig. 258). If this is unavoidable, rig high to allow passage underneath the line (fig. 259): having to step over it often requires an unstable balancing act that could end with someone hanging upside down!
- For difficult traverses, it is helpful to rig a line or cable for the feet. This improves balance and reduces sag in the rope and wear to it, so you ultimately use less energy in passing. If footholds are lacking in particular areas, rig etriers or footloops (fig. 260).

What NOT to do:

Never leave excess slack in a traverse line.

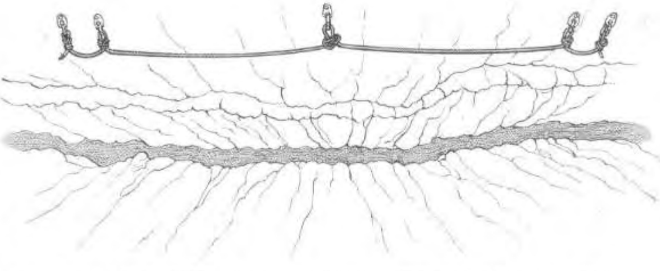


Fig. 258 – Classic rigging for a canyon traverse: the rope remains on the same wall for easier progression.

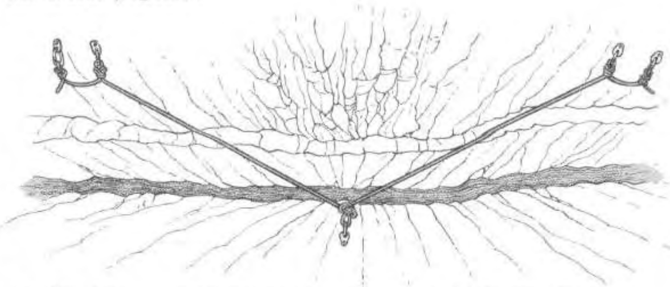


Fig. 259 – Another scenario: where the rock is fractured or disintegrated, the anchor is moved to the opposite wall and placed higher to allow easier passage.

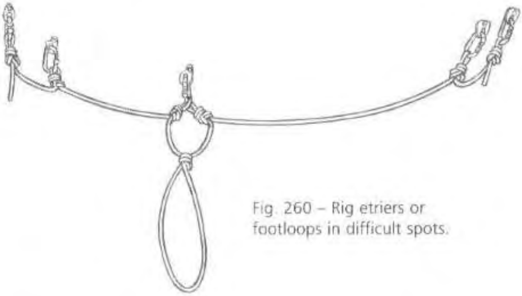


Fig. 260 – Rig etriers or footloops in difficult spots.

Fig. 261 – Sloping traverse line: any point where there is the risk of a fall is backed up.

6.3 Sloping Traverses

These progression traverses require a double anchor at the first rig point. They are easier to rig when you are secured on a descender. Depending on the passage shape, the following pitch may or may not require a backup anchor. Decide this by starting with the same questions as above: what would happen if the anchor fails here, for the rope and for me? If there is a potential hazard, back it up (fig. 261).

Once rigged, the slope will determine whether you descend on cowstails – braking with your hands – or on a descender. When climbing, use your upper ascender attached to the long cowstail.

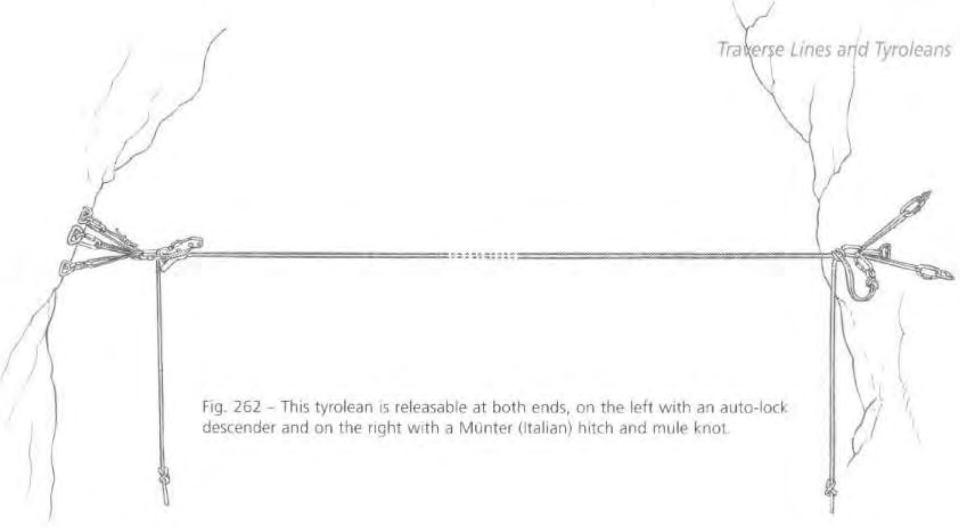


Fig. 262 – This tyrolean is releasable at both ends, on the left with an auto-lock descender and on the right with a Münter (Italian) hitch and mule knot.

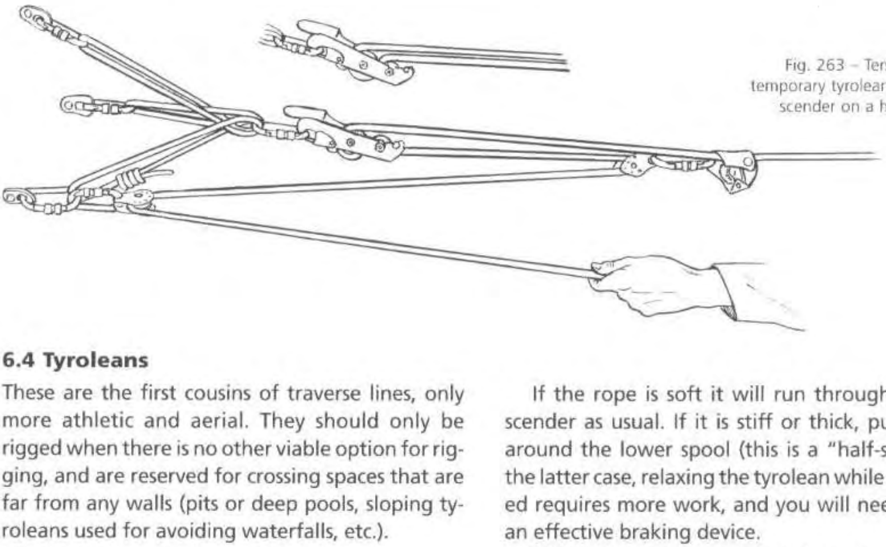


Fig. 263 – Tensioning the temporary tyrolean with a descender on a haul system.

6.4 Tyroleans

These are the first cousins of traverse lines, only more athletic and aerial. They should only be rigged when there is no other viable option for rigging, and are reserved for crossing spaces that are far from any walls (pits or deep pools, sloping tyroleans used for avoiding waterfalls, etc.).

Rigging

Each end of the rope is anchored to three points with a load-sharing anchor. This method allows equal sharing of the static load between all three anchor points. The connection between the multiple anchor and the line is made with either an auto-lock descender or a Münter (Italian) hitch backed up by a mule knot (fig. 262).

Tensioning

If a temporary tyrolean is to be de-rigged after use, as in a rescue for example, tension the rope with an auto-lock descender backed up by a pulley-ascender hoist (fig. 263).

If the rope is soft it will run through the descender as usual. If it is stiff or thick, put it only around the lower spool (this is a "half-stop"). In the latter case, relaxing the tyrolean while it is loaded requires more work, and you will need to use an effective braking device.

When the rope is tensioned as you want it, fix the system by locking off the descender completely (fig. 264), and then disassemble the haul system.

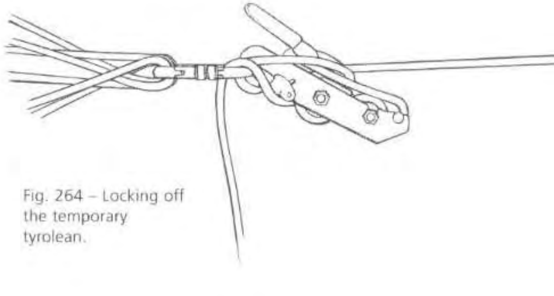


Fig. 264 – Locking off the temporary tyrolean.

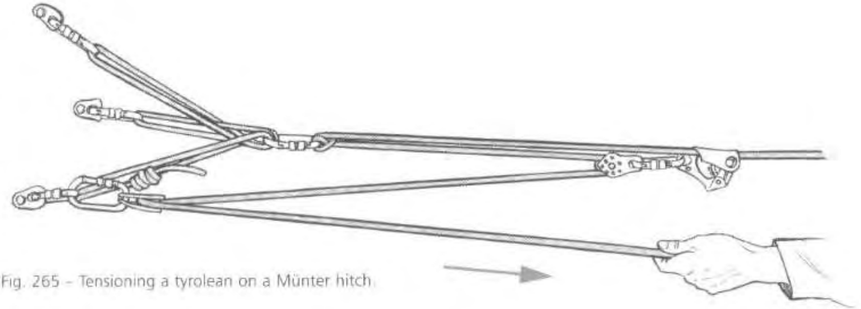


Fig. 265 – Tensioning a tyrolean on a Münter hitch.

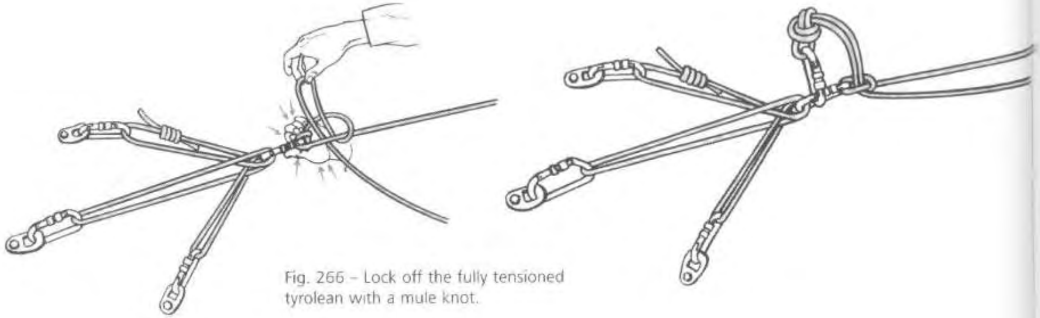


Fig. 266 – Lock off the fully tensioned tyrolean with a mule knot.

In normal rigging situations, don't leave the descender in place; replace it with an Italian (Münter) hitch (fig. 265). It can be rather difficult to hold the tension while locking this off with a mule knot (fig. 266). Have a team mate help ease the tension by bracing himself with his upper ascender attached to a cowstail, or make an Obendorf half-hoist (see page 294) with an extra rope.

When tensioning a tyrolean, the force placed on each end can approach 6 kN before the line is fixed. This is not far from the value at which the sheath will tear on a new ascender's cam teeth (7 kN). Due to some unavoidable slippage, tension reduces to 2 kN on an auto-lock descender, and to 1.2 kN on an Italian hitch. When the rope is loaded with the weight of the person using it, this tension increases by 80 to 120 percent. A typical 80-kg caver hanging in the middle of a tyrolean initially pulled to 1.2 kN will increase the force applied to the anchors to 2.2 kN. These values were obtained in tests using lengths under six meters; we don't really reach these numbers underground but they are acceptable for single 9-mm ropes, provided there is no contact with the rock.

To do:

- To avoid problems when relaxing the tyrolean, use a normal descender instead of an auto-lock and control the tension on the line with an Obendorf hoist. If the line is loaded beyond 4.5 kN (if two people are hanging on it, for example), you must use this method since releasing the auto-lock descender becomes very difficult.
- If there is any risk of damage to the line from abrasion, exposure to rock falls, etc., you should add a second rope.
- If you have enough rope ("if" because this rig consumes a lot of it), install a Passabloc, which makes the tension especially easy to regulate. To obtain maximum tension on the tyrolean, modify the operation of the classic Passabloc in two steps: instead of finishing it off with a simple loop in the central carabiner, make an Italian hitch tightened down as much as possible and locking it off with a mule knot (fig. 267). Tension the line by pulling on the Passabloc's two mobile strands.

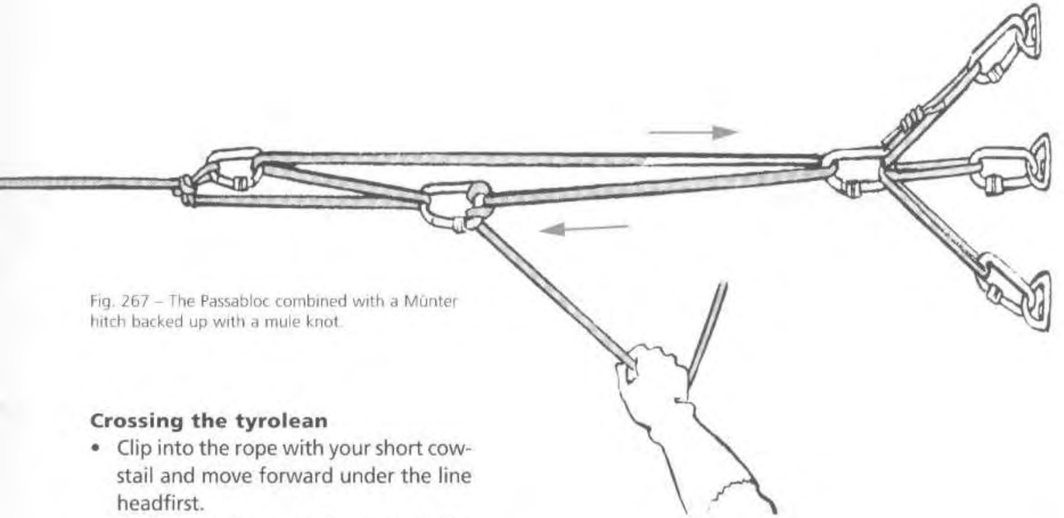


Fig. 267 – The Passabloc combined with a Münter hitch backed up with a mule knot.

Crossing the tyrolean

- Clip into the rope with your short cowstail and move forward under the line headfirst.
- Swing one leg over the rope at the bend in the knee, or bring both legs up and cross them at the heel and calf. The arms will do the pulling.
- If the tyrolean is long, use two carabiners attached in a chain to your harness maillon.
- Clip in with your short cowstail (or carabiner chain) and then get into place under the rope.
- With a strong heave, pull your mid-section up to the rope and clip in the end carabiner (do the same in reverse when leaving the line).

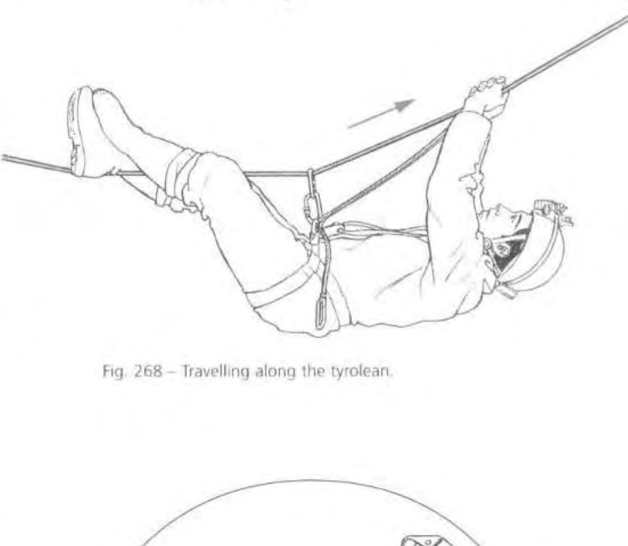


Fig. 268 – Travelling along the tyrolean.

Using the carabiner chain will bring your body closer to the line and provide more support; the weight of your pack (tethered to your harness maillon) is also neutralized.

- When you reach the ascending side of the tyrolean, it is easier to move up the rope using your upper ascender attached to its cowstail (fig. 268). This should of course be installed in the right direction on the rope in order to work properly (fig. 269). If the ascending side is steep, prepare your chest ascender for use on the line as well, which will give your arms a welcomed rest. The carabiners are still attached to the rope for added safety.

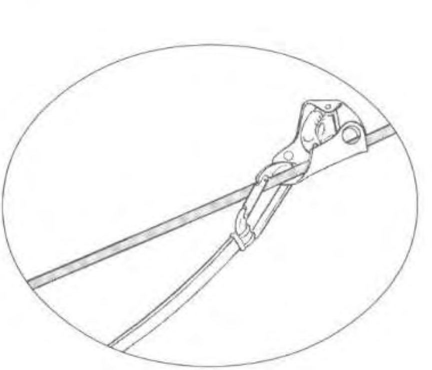
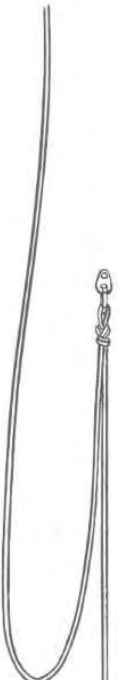


Fig. 269 – Installation of the upper ascender and cowstail carabiner on the rope.

7. Placing Rebelays

7.1 Why Use Rebelays ?



Even when you rig correctly at the pitch head and the rope hangs free, it may end up touching the rock somewhere down below. You need to place a new anchor to prevent this potentially dangerous rub point (fig. 270). You will naturally ask yourself the same questions as before concerning the consequences of anchor failure on the rope and your own safety. Your response in each situation will dictate whether you double the new anchor.

Aside from guaranteeing our safety, rebelays have a second advantage: they help speed up the team's movement on the rope, since for every length of rope with a separate anchor, another caver can travel through the same pitch.

Fig. 270 – A rebelay with working slack in the upper loop.

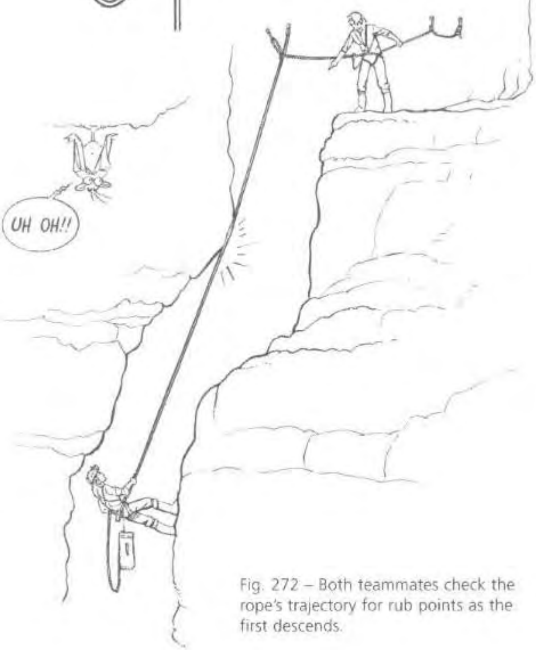
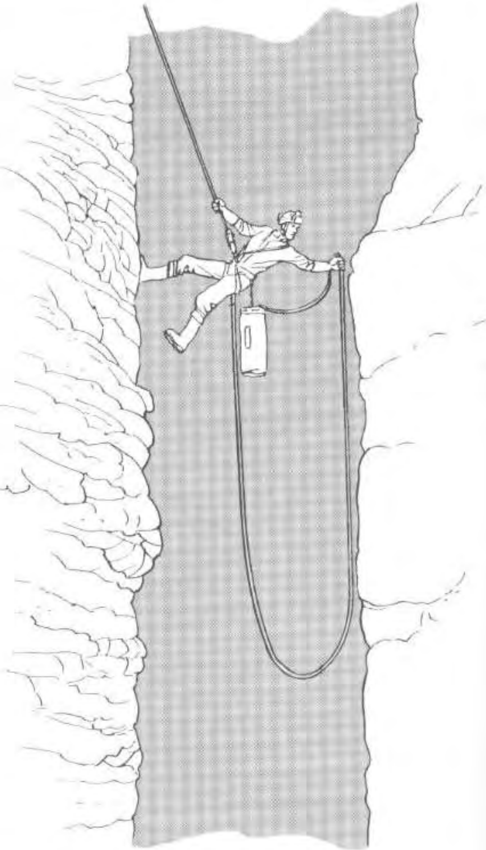


Fig. 272 – Both teammates check the rope's trajectory for rub points as the first descends.

Fig. 271- Looking for a good rebelay anchor point requires constant care and attention.



7.2 Identifying Rub Points

Whatever the shape of the drop, the rope must never come into contact with the cave walls. The lead person (rigger) and his assistant will combine their efforts to detect potential rub points, since they each have a complimentary view of the rigging as it is taking place. The rigger will of course try to anticipate possible contact points while descending (fig. 271). But in some cases, his partner up above will have a better view of the situation. For example, if the rigger moves sideways during his descent, his partner can follow changes in the rope's position from above, and alert the first of an imminent rub point (fig. 272).

Using an electric headlamp during this operation will allow you to better visualize the rope's line of descent. While you (as the rigger) descend, clear the passage of loose rocks or larger stones and clay deposits that could be hazardous if they fall, or completely avoid any area with too much unstable breakdown.

7.3 Installing the Rebelay

Before installing the rebelay, you need to come to a stop and have both hands free. If you are using a normal descender, lock it off completely so you are free to swing around using your hands to guide you as necessary. If there are no footholds where you want to set the rebelay, a skyhook will come in handy. Attached to a cowstail, it will usually help you get a hold on some surface feature. Other climbing aids can also help, like a chock placed in a crack or a sling thrown around a small formation.

Once the anchor is set, you need to calculate how much slack should be left in the upper rope loop before you fix the rope. On subsequent rappels, the caver will come to this point and clip into the anchor, loading the short cowstail. He will need enough slack in the rope to remove the descender from it. Trying to save rope by reducing the slack too much will always lead to problems with passing the rebelay, which will call for an alteration to the rigging anyway. If there are two or more rebelays in the pitch in question, this will require adjustment at all subsequent belays since lengthening an upper section will shorten the section below.

When the rebelay follows a short drop

Stretch in the rope is minimal and so easier to gauge. Place your attachment knot in the rope at the appropriate estimated distance below the descender, accounting for the length taken up by the descender and its lock, and for the working slack. You can adjust the slack by feeding some rope through the knot as long as you haven't tightened it yet by weighting the rope below the knot.

When the rebelay follows a long drop

The amount of stretch in the rope is harder to gauge and you will need to take your weight off the rope completely in order to correctly adjust the slack.

Key point:

- Be generous with the slack, especially if there is a wide pendulum swing to the rebelay or if the rope is new (it will shrink after the first few passages). During climbs, this will prevent lateral stress on the belay anchor plate; with these movements, the plate will eventually get turned around, which can cause it to break when the next climber mounts the rope under the rebelay.
- Well-calculated slack in the upper loop also provides a convenient foothold for use in passing the rebelay while climbing.

Normal situations

1. Clip your short cowstail into the anchor carabiner if the latter can still open when loaded (asymmetrical carabiner), or directly into the eyehole of the hanger plate (fig. 273) on top of the carabiner (all modern hanger plates allow this). If the rebelay has been placed around a natural anchor with a sling or attached to a ring with a carabiner, you can clip directly into the sling (fig. 274);

Fig. 273 – Clipping the cowstail carabiner directly into a rebelay anchor plate.

Fig. 274 – Clipping the cowstail carabiner into a rebelay sling.

2. Without letting go of the lower rope that is still in the braking carabiner, let the rope run up through the descender, transferring your weight from the descender to the anchor. You can then gather the length of rope you need for the upper loop and for making the attachment knot.
3. Make a loop in the rope with an overhand knot, which serves as a stopper knot in the rope below the descender (fig. 275). Now that you are secure, let go of the lower rope, adjust the working slack, and tie the attachment loop, which you then place in the anchor carabiner before screwing it shut.

To do:

Instead of placing a safety knot in the rope below the descender, you can safeguard yourself on the upper rope with your upper ascender attached to its long cowstail (NOT your Croll).

What NOT to do:

- Don't lock off your descender in lieu of making a safety knot (fig. 276). If the rebelay anchor fails, falling on the locked descender can damage it; the safety knot will not.
- Don't use a clown hanger at a rebelay that follows a long drop: adjusting the length of the

Fig. 275 – Place a stopper knot below the descender when installing the rebelay loop.

Fig. 276 – Locking off the descender while rigging the rebelay can be hazardous if the anchor fails.

slack is impossible since the rope is fixed between the hanger and wall. If you absolutely must use this type hanger, overestimate the slack needed and then tie off the excess with a loop knot placed beside the hanger.

Installing a ring hanger

There is a specific procedure for installing a ring hanger used alone (without a carabiner):

1. Estimate the slack you will need.
2. Place the attachment knot in the ring (double bowline on a bight or double figure eight on a bight) before screwing it into the anchor.
3. Screw down the ring and then clip in and hang from it with your short cowstail.
4. Remove the descender from the rope.
5. Adjust the slack.

7.4 Getting the Slack Right

The working slack for the rebelay loop should be sufficient, but not excessive. Too much slack is a waste of rope and, in the event of anchor failure, it increases your fall factor. Note, however, that you can never reach a dangerous fall factor here, as the following calculations will demonstrate.

Let's say you've descended 5 meters and have 2 meters of slack at the rebelay loop (which is plenty). If the anchor fails while you're at the rebelay, the fall factor is only 2/7 = .29, which is quite low. If, with the same amount of slack, the preceding drop length is 15 meters, the fall factor goes down to .1, and down to .05 for a 30-meter drop. The longer the previous drop, the lower the fall factor. This doesn't mean we should leave excessively long slack in such conditions because this will increase your risk of colliding headlong into a wall, or even into the floor! In fact, let's imagine a rebelay set at 4 meters above the bottom of a 50-meter pitch, due to some outcrop. If only one anchor has been set and this fails, you are guaranteed to go crashing into the floor. While the likelihood that this scenario will happen is low, you should nonetheless double that anchor.

On a shorter preceding drop length, excessive slack in the loop raises the potential fall factor: If the upper rebelay loop descends 2.5 meters lower than the rebelay point following a 5-meter drop, the fall factor increases to 5/10 = .5. That's at least enough to be quite uselessly shaken.

7.5 Joining Ropes at a Rebelay

Crossing a knot in mid-air takes time and energy. If the cave configuration allows it, always try to place a rebelay where your rope runs out or just before.

- The first length of rope is placed in the rebelay carabiner with a figure eight loop, leaving the usual necessary slack.
- The attachment loop for the down rope goes in the rebelay carabiner but it must also be linked to the upper rope's attachment loop, in case the carabiner breaks for any reason (corrosion, following a sideways placement, when weighted incorrectly). This is done by rethreading a figure eight with the lower rope into the attachment loop of the upper rope (fig. 277).

What NOT to do:

Never let any excess length from the upper rope hang freely, even if it's only a few meters and even if you've placed a stopper knot in the end. This increases the risk of confusing this end with the

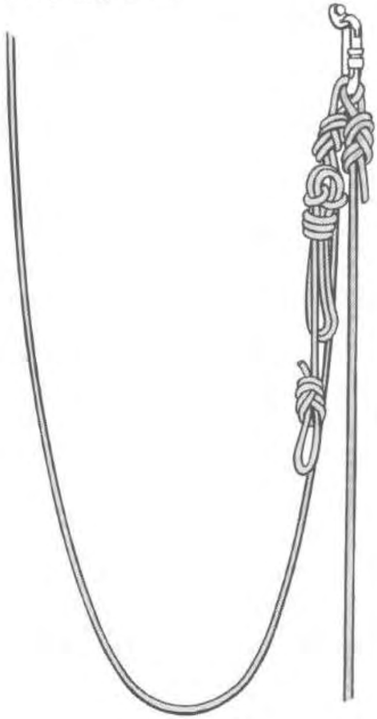


Fig. 277 – Never allow excess length to hang freely; tie it off.

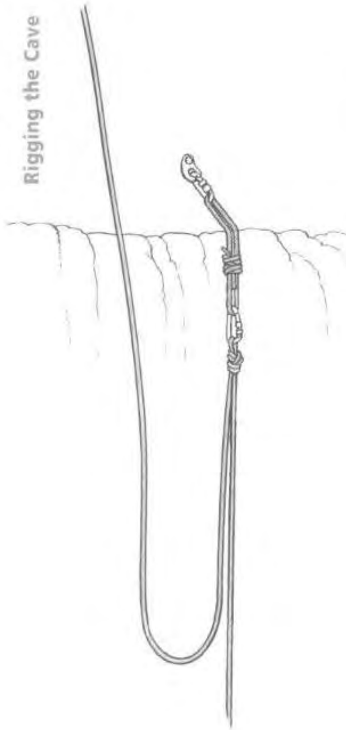


Fig. 278 – Rigging a rub loop at the pitch head.

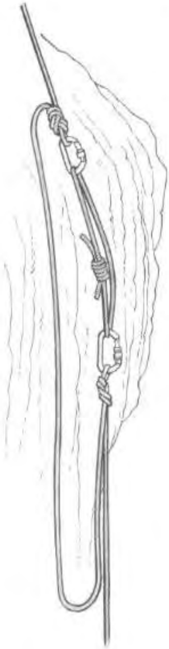


Fig. 279 – In mid-pitch the position and length of the rub loop must account for rope stretch.

lower rope. Coil the excess rope and tie it off instead. At a free-hanging rebelay, tie out the excess rope with a loop knot that can be used as a foot hold or other aid and secure it to the side (You still need to place a stopper knot in any extra rope that is left).

7.6 Unavoidable Rub Points

Real life is not often like the storybooks, and sometimes the shape of the passage prevents us from being able to set an anchor for a free hang. A clay or flowstone outcrop, a fractured or detached section of rock... many unexpected obstacles can get in the way of a rigger's best-laid plans. Sticking to the no-rub rule isn't always feasible, so you may need to rig a "rub loop," which you will expect to wear down from abrasion (fig. 278 and 279). But these obstacles may have another solution: the deviation.

8. Deviations

8.1 Basics

Like rebelays, deviations keep the rope away from possible rub points. The difference is that deviations do not anchor the rope with an attachment loop. The rope is simply placed in a carabiner and sling attached to a wall opposite the rub point, redirecting the rope away from the rock. The stress placed on the sling depends on the angle at which the rope is redirected (fig. 280). This angle is usually low and the sling takes only a fraction of the load; this load diminishes when the angle at the deviation approaches a flat angle (180°).

The sling cord may be thin (5-6 mm) and the anchor doesn't need to be as bombproof as a rebelay. Natural anchors are an easy solution.

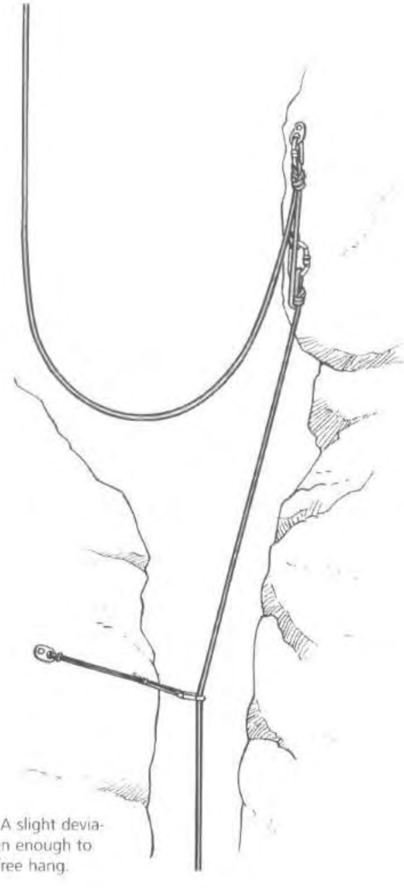


Fig. 280 – A slight deviation is often enough to provide a free hang.

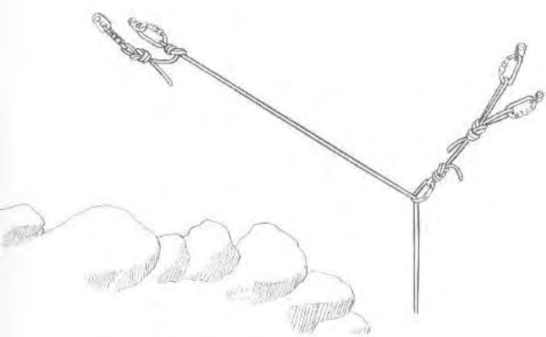


Fig. 281 – A high-angle deviation.

Redirecting the rope at a 15°-angle is common; the force on the sling then equals one quarter the weight of the user. This value increases to one half for a 30°-angle.

Sometimes, however, the angle at the deviation is higher. When this reaches 60°, the deviation sling is subjected to a force equal to that carried by the main anchor, which corresponds to the weight of the user (fig. 281).

We rarely go beyond this angle: at that point the deviation anchor must be at least as strong a normal rope anchor. The rig point must be equally secure and strong, and the sling used to redirect the rope must have at least 10 kN load bearing capacity, and be doubled.

8.2 Equipment and Installation

All you will need is a length of cord and a non-locking carabiner. Assemble this in advance with single sections of 6-mm nylon rope, one meter and two meters long once they are looped. Five-millimeter Spectra is more expensive but better since it is has multiple uses: you can install any kind of deviation, no matter the angle, as well as natural anchors. The lengths you will need depend on the kinds of caves you will explore. If one meter proves too long upon installation, tie a loop to shorten the sling. If two meters is too short, link two slings with a girth hitch or untie one sling and use it as a single line. If you are installing a high-angle deviation, double up your slings for added strength. This will prevent you needing to use several sizes of cord.

Depending on the passage and the strength you need, the deviation can be fixed to the wall via a natural anchor, a chock, knot or piton gripped into a crack, or a bolt. For lower angles, loads are also lower and you can simply attach the cord to a hanger with a girth hitch, which saves you using a carabiner.

Key point:

- Placing a deviation where there is a possible foothold makes passing it much easier, especially if it has a high angle.
- Rig so that if the deviation fails the person on rope is not exposed to any immediate danger, such as drowning in a waterfall, swinging into unstable breakdown, cutting the rope on a sharp blade, or falling into a narrow fissure. This is more likely to occur when there is a high angle of deviation.

8.3 Advantages

- Compared to rebelays, deviations are easier to install and easier to pass, in both directions.
- Deviations use less rope since no slack is needed.
- In the general case of lower angle deviations, the gear and anchor only need to be of moderate strength.
- Even if a deviation fails, it will only result in a swing, without the risk of a dangerous fall.

8.4 Drawbacks

- Two cavers cannot move along the two lengths of rope separated by a deviation, since these do not have independent anchors. For faster movement on rope, rebelays are thus advisable for longer drops and larger teams.
- At angles above 30 degrees passing a deviation can be more difficult, especially with a heavy load. A foothold in this situation is essential.
- Installing a deviation may seem simple, but if adequate thought has not been given to its placement, passing one can quickly turn into a nightmare.

In sum, rebelays and deviations are complementary. When a slight redirection of the rope is enough to avoid a rub point or a shower, or when your team is small, a deviation seems the best choice. This is also true in prospecting, when you must descend several entrance pitches in hopes of finally reaching the one that really "goes." Besides being more time-consuming, placing bolts in this situation is rather disrespectful of the environment.

9. The Various Shapes of Pits and Pitches

9.1 Very Narrow Pitches

Whatever you use for rigging, if you have to squeeze through a really narrow passage, the rope is likely to rub against the rock since it will be stuck between the rock and your body. The best way to rig here is to place a rebelay just above the narrow spot. This limits the yo-yo effect and thus abrasion to the rope (see section on static ropes, page 56). When you arrive below the pinch, place a double rebelay to ensure a perfectly safe descent.

9.2 Sloping (or Funnel) Pitch Heads

This shape of pitch tends to collect rubble and you will often find the slope covered with more or less loose breakdown. From the outset, you need to thoroughly clear the slope and its surrounding area of this potential hazard. Be even more cautious if the rope ends up lying against the slope once it is rigged, since it is then more exposed to falling rocks.

In the rather likely event that the slope is covered with a calcite flow, remember that this rock isn't particularly good for placing solid anchors: hollowed-out anchor holes and weak natural anchors are risks to consider when rigging.

The rope pulls at an angle on sloping pitches, so anchors at the pitch head should be placed as high as possible to avoid (or at least delay) having to belay the rope at some point along the descending slope. When you reach the lip of the pitch itself, rig a double anchor to help protect the rope (and you) against rock falls, which may still occur despite a careful clearing of the slope.

To do:

While backing down the slope, check the position of the rope behind you frequently to avoid stepping on it as you progress.

9.3 Deep Pits

We often see their walls littered with constellations of bolts, proof that they are sufficiently impressive! Of course, this redundant rigging is completely illogical...but logic rarely works well in the presence of fear. Remember that the rules for rigging a pitch are the same whether it is 10 meters deep or 150 meters deep. We have already covered these rules, so there's no need to go back over them now.

With a well adjusted, effective climbing system, climbing a deep pit is not such a big deal, and there's no reason to fear it more than any other vertical obstacle, even when you are carrying a pack. Climb at your own rhythm and a regular pace, coordinating your movements and breathing. But no matter how fast or efficiently you do this, the height of the climb remains the same. If the team is large, waiting time at the bottom increases, along with the possibility of becoming cold. We suggest placing some rebelays at regular intervals in deeper drops, even when the rope hangs free for its entire length. A group will spend four times less time climbing out of a 100-meter pit with four rebelays than it will spend in one with none. Of course, the pitch needs to have the right shape for this: no matter how well you rig, you can't place rebelays in bell-shaped pits, even if its single drop is on the order of 340 meters, like Mexico's famous Sotano de las Golondrinas.

9.4 Pendulums

Basics

Pendulums help us reach passages leading off from the pitch, rebelay points, or parallel passages that would otherwise be inaccessible. It's simple: just swing on the rope in wider and wider oscillations until you can reach your goal. A pendulum is just like a big swing, so to start it moving you need to:

- push off the wall or other feature with your feet or hands;
- get the help of a teammate below, who will pull on the rope to start it moving; or
- get the help of a teammate at the pitch head. Braced against a wall, he will push the rope sideways with his feet.

In the latter two cases, the "swinger" should try to push or pull in synchronicity with the rope's movements, as on a swing.

Though they seem like play and may remind us of our childhood, pendulums do have some risks.

Limits and risks

First of all, you must overcome the backforce exerted on your body, which increases with the amplitude of the pendulum. If it is too great – that is, if the point you are trying to reach is too far off to the side, given the length of rope you are hanging from – then the maneuver isn't feasible, and can even be dangerous. If you try to go further by pulling yourself to the side using features in the rock, you could lose your hold and possibly go crashing into the opposite wall.

There is also the risk that the rope on which you are hanging will rub against the rock as you swing. If the rock is rough, the rope could be seriously damaged. A teammate above should watch your movements and those of the rope. At the slightest point of contact, climb back up and install a deviation on the opposite wall. Doing so won't make your work any easier, since this will shorten the length of the pendulum and thus the length you are able to move sideways.

Tip:

Use a skyhook to help you get a hold. This can be very helpful.

What NOT to do:

Do not pendulum with a heavy pack tethered below you. This will lead to opposing oscillations between the primary pendulum (you) and a secondary pendulum created by the pack and tether. You will reach your objective only to find yourself being pulled back into the void by your pack. Leave your pack behind for this maneuver , or attach it directly to your harness.

Placing the rope

Key point:

The horizontal distance to your objective should be much shorter than the length of rope will use to pendulum. In general, the limit should be 25 %: five meters of horizontal travel requires 20 meters of rope above you; to reach a point ten meters away, you will need forty. If the rope is too short, you may have to cheat:

- by moving the anchor point at the pitch head closer to the vertical axis of the pendulum, or by placing more deviations along the descent. But this latter has a major drawback in that it reduces the length of the pendulum;
- by moving along the wall using surface features, eventually installing a traverse line here;
- by throwing a grappling hook. This is a delicate maneuver because even if the hook reaches its target, its hold isn't certain. There's always the risk that it will come loose just as you are nearing your objective, suddenly releasing you to go flying backwards into the opposite wall.

To do:

- Once you have a stance, try throwing a sling around a projection to help hold yourself to the rock.
- Pendulum on your descender, not your ascenders. Your descender allows you to regulate the slack more easily when calculating your height during the swing. Begin the approach a little high since it's not so easy to climb back up on a non-auto-locking descender. Upon your arrival, quickly feed in some slack to lower yourself onto your feet before the rope pulls you backwards.

Your descender should be fully locked off before you begin swinging. Place an overhand knot loop in the rope about one meter below the descender: this will ensure your safety, by protecting you from a possible fall when you land, unlock, and start feeding out slack in the rope.

Securing the landing

Once you have reached your objective and checked that the passage continues, you'll need to rig the landing.

- If the landing is easy, it suffices to fix the end of the rope next to the continuing passage to prevent it from falling down the pitch and out of reach.
- If the pendulum is wider and the landing more difficult but the line more or less follows the near wall, install a traverse line at the exit. It will help save time during later trips through the passage.
- If the pendulum is extremely wide and must be carried out over an open drop, you will need to rig a sloping tyrolean. On rappel, you can very easily reach your target by rappelling on the slack line, with your cowstail clipped into the tyrolean (fig. 282).

Tip:

Don't clip into the tyrolean while climbing, unless its purpose is to keep you out of a waterfall (see 13.5.2). Instead, place your ascenders as usual on the slack rope and then install your descender on the rope where it is rigged at the landing point, as if you were going to descend into the loop forming the pendulum. Slowly release the slack through the descender as you climb the rope until you reach your vertical hang. Here you can remove the descender and continue climbing as usual.

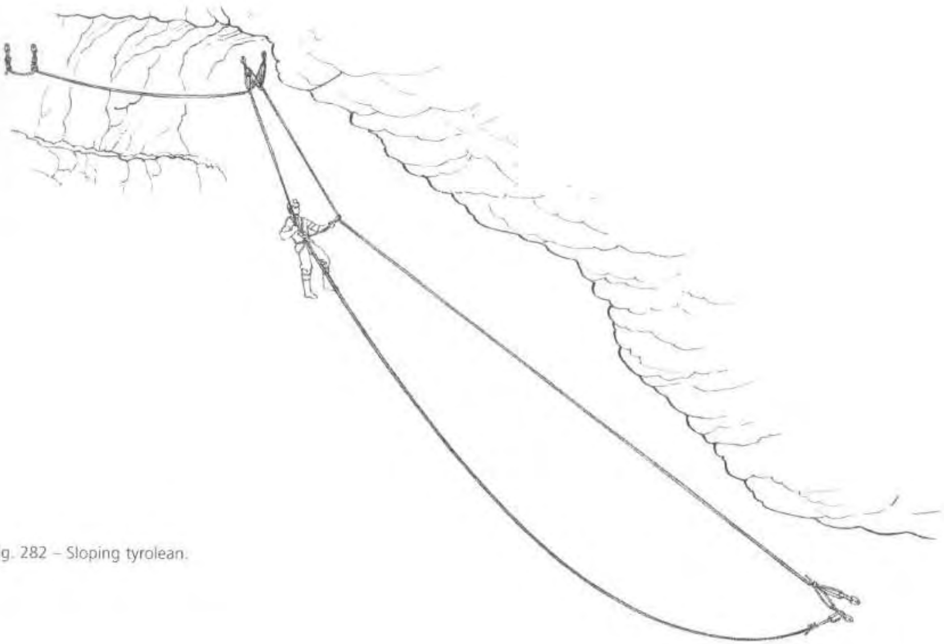


Fig. 282 – Sloping tyrolean.

10. Light Rigging Techniques

10.1 A Word of Warning

The expression "rigging light" may frighten anyone who thinks we are talking about compromising safety. But this is not at all the case, at least when it comes to choosing our gear and the precautions we take in rigging it. In fact, "light techniques" originated from the challenges involved in carrying out particularly deep explorations or expeditions to remote places. In these circumstances weight is always a critical factor, and it must be minimized as much as possible and wherever possible. Whatever the skill level of your team, standard gear should also be as light as possible. This applies to personal equipment, food, camp gear, and rigging equipment. This chapter, however, takes the meaning of "light" to another level.

Light rigging is one strategy for dealing with the problem of weight, as it applies to rigging in particular. It involves overlooking some standards, which would seem suicidal or even criminal if this were not carried out through a rigorously controlled process. Dismissing these standards is no small matter, since their very purpose is to set minimum safety guidelines based on practical experience and the knowledge and competence of recognized professionals. Disobeying them would seem rather unreasonable and even a bit insane; if we do so, we must be ready to justify ourselves.

In a book that addresses a diverse public, treating the subject of light rigging may be controversial, but we refuse to avoid the subject altogether; to do so is a bit like passing judgement on the practice, and avoiding an awkward subject doesn't make it go away. Since light rigging techniques exist, we should account for them. Their practice makes perfect sense in a specific context, as long as we remain strictly within its limits.

Having made that disclaimer (it won't be the last!), let's move on...

A closer analysis of the standards governing ropes and connectors demonstrates that official safety factors are rather elevated. Given the 0.8 kN (80 kg) load of a typical caver, we are faced with an 18 kN minimum load bearing requirement for type B semi-static ropes and a 20 kN minimum for anchor connectors. These numbers are a far cry from the mere 9.6 kN per person minimum (based on a safety factor of 12) that applies to the elevators in our apartment buildings! Of course, conditions are well defined and professionals guarantee steady maintenance in these buildings. In caving, however, those who created the standards had to account for (as they should) a whole set of factors that could come into play – wear, the margin for human error, the quality of the rock, lack of maintenance, an equipment flaw, shock loads, rock falls, etc.

Some of these factors are impossible to control, so the minimum safety standards account for them – and this applies to *all* cavers, no matter the skill level. But other factors can be discounted, on the sole condition that we avoid *any* situation in which they could come into play. If – *and only if* – we can control these factors, we can admit that some of the standards are inflated, and we may subtract from the weight (and thus the strength) of our equipment without compromising safety. But remember that for the average caver, this logic doesn't apply. It was developed by and for the most specialized, experienced and efficient vertical cavers, and is only legitimate in the context of their activities.

There are many prerequisites to rigging light, including:

- technical competence (limiting the possibility of errors in rigging and progression);
- a thorough knowledge of the cave environment (limiting miscalculations as to cave behavior in general);
- small and efficient teams (less wear on the equipment);
- precision maintenance of the equipment;
- and removing or replacing questionable gear without hesitation. Material that is weaker when new will evidently reach its wear limit more quickly.

Only a strong team with a proven level of stamina and technical ability is qualified for light rigging practice. Those who are not qualified should not engage in this practice; simply be aware that the techniques exist, and may later be used when each participant has thoroughly mastered them.

10.2 Conditions for Use

When visiting one of the known classics, light rigging allows a small team to significantly reduce the amount of gear to be transported. This results in faster progress and less fatigue, two paramount factors in safety.

The same applies to exploration. The weight saved allows a team to carry more gear further and deeper into the cave while expending a comparable amount of energy.

10.3 Potential Advantages

We can illustrate the advantages gained by rigging light with a simple table comparing the weight of two packs, each containing 150 meters of rope and the corresponding anchors (five items each; see figure 283).

We save 4.5 kg, over 40% less weight! Of course, the rope accounts for most of this weight, but the anchors also save 675 grams, 15% of the total weight saved. As for mini-hanger plates, the more compact models are best; for example, those that will only take one carabiner, like the old bent (Coudée) and twisted (Vrillée) models – but these aren't easy to find these days! In ceilings, you can use compact threaded eyebolts, on the sole condition that you know their strength and origin. In

Fig. 283 – Comparison of light versus classic techniques for rigging 150 meters of rope.

Light Technique			
Equipment	*Weight/unit*	*No.*	*Wt.(g)*
7- to 8- mm ropes	32 to 38 g/m	150	5250
Light non-locking 'biners	35 to 40 g	5	187
Zicral anchor maillons	20 to 22 g	5	105
Mini hanger plates	22 to 25 g	5	117
Light rings	33 g	5	165
Spectra cord and webbing	15 to 17 g/m	5	80
		Total	5904 g

Classic Technique			
Equipment	*Weight/unit*	*No.*	*Wt.(g)*
9- to 10.5- mm ropes	51 to 70 g/m	150	9075
Locking anchor carabiners	68 to 70 g	5	345
Steel anchor maillons	60 g	5	300
Classic Dural hangers	30 g	5	150
Steel rings	68 to 76 g	5	360
Nylon webbing	24 to 45 g/m	5	172
		Total	10402 g

this domain quality ranges from the worst to the best, but specs are not engraved on the items themselves. These should only work on a direct pull, i.e., along their main axis, and should never be shear loaded (perpendicular to the axis), as they are rather weak in this respect.

For the sake of consistency, we apply the same weight-saving principles to our entire caving load:

- Personal gear (multiply weight saved by the number of team members): a lightweight harness saves about 300 g, a nylon caving suit weighs 450 g less than PVC, and a pair of caving/canyoning shoes instead of our boots weighs...a whole kilo less than caving boots! Even if we don't really "feel" the weight of our clothes, it doesn't mean the weight isn't there...
- Food: calculate precise daily energy requirements, choose dehydrated or freeze-dried, solid fuel (over 400 g lighter than liquid fuel stoves), use a strict minimum of containers and utensils, and eliminate all excess packaging.
- Camp gear: use hammocks instead of inflatable pads; ultralight, compressible sleeping bags, and carefully select (and limit) your change of clothes.

10.4 Protecting the Rope

A rope must never rub, and a thin rope should rub even less! With thin ropes, the potential risks are even more critical, and both the lead rigger and his second must be particularly vigilant when checking for potential rub points during the first's descent. Strong (especially halogen or krypton) electric headlamps facilitate inspection. If a rub point appears, the usual procedure applies: the second modifies the rigging since the leader will only damage the rope more by climbing back up it.

Key point:

Try to stay as close to a zero fall factor as possible by favoring Y-belays. Install these with care: if one arm of the Y fails, the knot on the other arm must not come into contact with the rock, and the remaining hanger plate should not be loaded outside its normal specifications. To place the widest Y-belay possible with the least amount of rope, make a figure eight on a shorter loop for the high anchor, and a figure eight on a longer loop for the lower side.

On 8-mm rope, the fall factor in the event of anchor failure should always remain below .5 (and below .3 for thinner ropes, if you want to risk using these).

We can argue for figure nine rather than figure eight anchor knots when using thinner ropes. They weaken the rope less, but they *must* be tied and dressed correctly. Here is proof: some 8-mm ropes pass the safety tests that apply to knot failure when tied in a figure nine – and fail the same tests with a figure eight. But a knot's breaking strength is not actually the limiting factor in caving: it is more the strength of the rope/ascender connection or even the quality of the rock surrounding the anchor, that can cause problems. Since figure nines use more rope and are bulkier and more likely to rub on the wall, the pro's and con's seem to balance out: you can decide according to the situation.

10.5 Backing up Primary Anchors

For every primary anchor point, including traverse lines, the load should be shared between two anchors. This also applies to sharp changes of direction, which could result in hazardous rub points in the event one side of the anchor fails. Again, consider rigging a Y-belay (fig. 284).

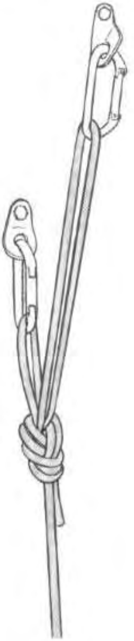


Fig. 284 – Y-belay on compact hangers and non-locking carabiners.

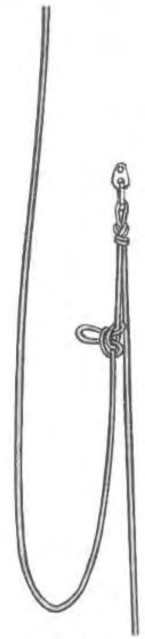


Fig. 285 – Rebelay tied with a shock absorbing knot.

10.6 Rebelays

We always double these, except those that are installed for convenience rather than to avoid rope contact. Rebelays are installed every 30 meters or so to facilitate more effective, comfortable climbing when there is more stretch in the rope – as is the case with thin ropes.

Recall that a potential danger exists when two rebelays are placed five meters or less apart. The potential fall factor approaches .3: if you fall 2 times the distance to the bend in the rope (i.e., 2 meters) and are arrested by 5 + 2 meters of rope, your fall factor is .29. This would be .4 for 3 meters of separation between rebelays. In these situations, you need to place a shock absorbing knot (fig. 285) on any rope that is under 8 mm; we recommend the same for 8-mm ropes as well. Reduce all slack in the rope to a strict minimum.

When visiting a known cave using light rigging, we often find rebelay points without backup anchors. You can use 5-mm spectra cord for backing up these anchors to nearby points (fig. 286). Spectra is five times more abrasion resistant than nylon and has a higher breaking load than the rope itself (16 kN!).

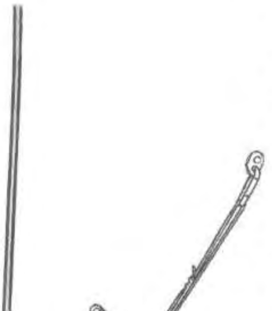


Fig. 286 – Rebelay backed up with a Spectra sling on a girth hitch (lark's foot).

10.7 Shock Absorbing Knots

These help make semi-static rope a bit more dynamic in the event of a shock load: under strong traction, they will slip and absorb some of the energy created by the fall, reducing the shock load. It is important to use these knots with thin ropes, especially where rebelays are close together (see above). Tie a loop using a false butterfly or an overhand knot near the point you wish to protect.

10.8 Pendulums

With pendulums or widely offset rebelays, the anchor is stressed laterally when we pull on the rope – while rappelling, when we come to the anchor, and when we leave it on climbing. This is especially true when there is insufficient slack left in the rebelay loop. Use a light maillon rapide to rig instead of a carabiner; carabiner strength is cut in half if it rotates and is loaded sideways.

10.9 Deviations

Deviations have two advantages over rebelays:

- they present low fall factors in case of failure;
- they save rope.

However, no deviation should present a risk in the event some part of the 'chain' fails. In particular, we should limit ourselves to a single deviation between two rebelays, since failure above could lead to potentially dangerous modifications to the rope's trajectory. For the same reason, never place a deviation under a convenience rebelay that hasn't been backed up.

10.10 Spectra Slings

This miracle fiber is perfect for use in light rigging. Five-mm Spectra slings can be used to rig around a natural anchor, back up a bolt, or place deviations. Tie them off with a double fisherman's knot.

To do:

At the pitch head, install a Y-belay and replace one of the arms with a Spectra sling on a Prussik or Blake knot and link it to the anchor.

What NOT to do:

Even in light rigging, it would be pure insanity to use 5-mm Spectra cord as your pit rope, and this applies to all pitches, short as well as long. Spectra is as static as a steel cable; in the event of an anchor failure, the resulting shock load could be critical. Even if you can rig with a zero fall factor, don't forget that ascenders will slip on such a small diameter (at 100 kg load), and descenders do not brake or stop.

10.11 AS Flexible Anchors

Fig. 287 – AS Flexible anchor.

Fig. 288

Fig. 289

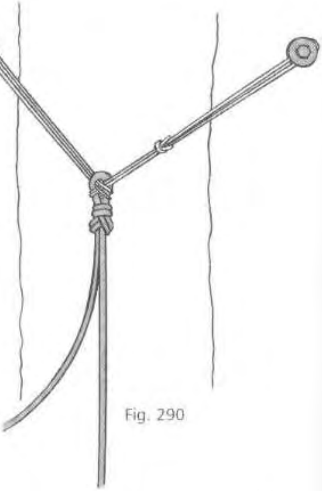


Fig. 290

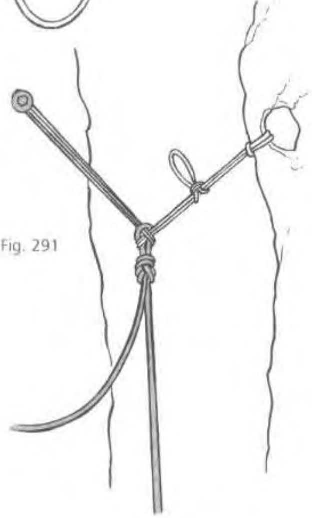


Fig. 291

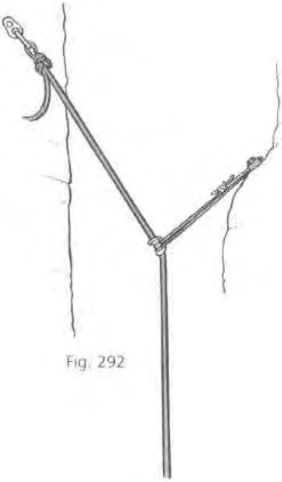


Fig. 292

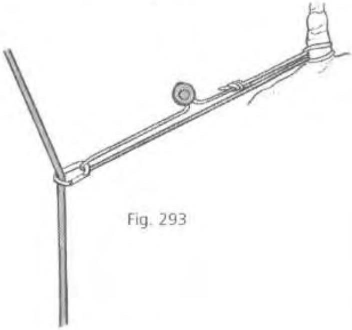


Fig. 293

These French flexible anchors (*amarrages souples*, hence AS) have an aluminum head pierced with two parallel holes through which the cord is passed. Perpendicular to these is the 8-mm bolt hole (fig. 287). Here, 5-mm Spectra cord has yet another use: we can place the ensemble directly on a self-drilling anchor. AS anchors can be used without a carabiner to place normal anchors, Y-belays, deviations, ceiling anchors or for belting natural anchors. Both their tension and shear loading is 11 kN.

Some drawings illustrate their many uses (figs. 288 – 296).

The length of the sling can be adjusted with a sheet bend, a stopper knot or butterfly knot depending on the situation. Since Spectra is very slip-

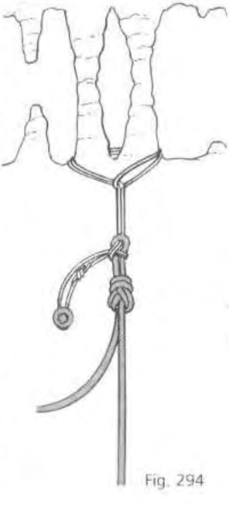


Fig. 294

Fig. 295

Fig. 296

Fig. 297 – Optimized rigging on an AS flexible anchor.

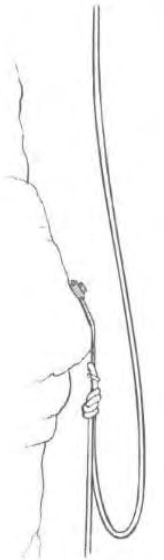


Fig. 298 – Using a flexible anchor on a localized rub point.

pery, these knots are still easy to untie. On Y-belays, you can achieve a straight vertical hang away from the walls by simply moving the anchor to the side. By removing the cord from the AS anchor and tying a stopper knot, you can double its effective range (fig. 297).

One unique characteristic of AS anchors is that they allow you to place the cord directly on a rub point and even over a ledge. Because Spectra is totally inelastic, the cord sits on the contact point without moving about and rubbing on it (see page 56), so there is practically no wear (fig. 298).

10.12 Connecting Ropes

The only knot we recommend for tying ropes together is the triple figure eight: it is relatively easy to untie, it provides a loop to clip into, and works with different diameter ropes.

10.13 Removing Carabiners

The faint at heart can now skip to the next paragraph! Here's a suggestion that will sound a bit insane: we can save even more weight by getting rid of our anchor carabiners altogether and passing the rope directly through the hanger plate. Using ring anchors instead is out of the question: they weigh two to three times more than normal hanger assemblies and are thus disqualified from use in light techniques. Similarly, the Clown hanger weights 30 % more than a normal model and its bulk can make it bothersome to carry. Using hangers without carabiners can potentially make our bolting kit 400 g lighter (this includes removing carabiners and replacing rings with hanger plates)! But is all this still within the bounds of reason, and is it safe?

When you think about it, yes. In fact, where exactly is the weak link in our chain of safety? We find it in our ascenders and not the rope: the standards only require a 4 kN load before an ascender distorts, but they require 20 kN for a link and 12 kN for a type B rope tied with a figure eight knot. The FFS only reduces its standard to 11 kN for type L ropes. And when it is placed directly in the hanger plate, the rope is loaded on both sides: it always breaks where it leaves the knot and never in the loop. But isn't there some risk of shearing the rope on the edges of the plate hole? The answer is no, on the following condition:

To do:

Use only light alloy plates with rounded eyehole edges – no sharp edges are allowed! Fortunately, this is what we find for most of the recent models. Most manufacturers resolutely oppose using their hangers in such a way in their product instructions, for one simple reason: self-protection. They don't want to be held liable if ever there is an accident...

Once we've made the mental jump, how do we make this not-so-crazy idea operational? At the beginning of the traverse line, just make rethreaded knots. In the middle of the traverse, tie a double bowline, or thread the hanger plates on the rope beforehand and tie these to the loop of a figure eight.

At rebelays, there are two methods:

- Rig as if you are installing a ring anchor, pass a bight through the hanger – easy, since you are using a thinner rope – and then tie a double bowline rather than a double figure eight. The former renders a more open loop once the knot is tightened and set, so clipping in is easier. Screw down the hanger plate. This method has two drawbacks: it is more difficult to adjust the slack in the rebelay loop, and a double bowline on a bight uses much more rope than the double figure eight on a bight.

- Thread your hangers onto the upper end of your packed rope. Since the rope is thinner, the hangers slide easily down as the rope feeds out while you descend. If you need to place a rebelay, make a bight with the hanger in the middle and tie it with a figure nine. Screw down the plate. Adjusting the slack in the upper loop is easy by pulling the rope section by section through the knot. You can also make a Y-belay: you of course need two consecutive hangers, tied into a double bowline or figure eight on a bight.

To do:

- Use bent rather than twisted hanger plates; they hold the rope knot farther away from the wall.
- While making the knot, be sure to separate the two hangers on the rope so that each sits on its own loop once the knot is finished (see figs. 56 and 57).

When making a Y-belay with uneven sides, use a figure nine knot for the high anchor and a butterfly for the low one.

Once again, carefully adjusting the length on each arm of the Y and the slack in the rope can be time-consuming.

10.14 Travelling Techniques Specific to Light Rigging

Let's come back to a more comfortable topic.

Using your cowstails

Since carabiners used in light techniques are not as strong, it is best to clip directly into the anchor loop above the knot (this offers some dynamic safety). If you prefer to clip into the carabiner, check it for proper placement and closure before doing so. Clip in closest to the spine (long axis) of the carabiner since this is the strongest point. To do this, clip your cowstail carabiner between the anchor loop and the spine of the anchor carabiner (fig. 299).

In either case, when descending past a free hanging rebelay with no footholds, you will have to deal with your cowstail carabiner becoming pinched in the loop as soon as you transfer your weight to your descender on the lower rope, which makes it harder to remove.

Braking

Controlling your speed can be a problem on thinner ropes. It is important to use a braking carabiner here, and you may even want to wrap the lower rope once around your leg to provide more friction. You can also use a second braking carabiner placed directly on the rope above the descender. But your braking problems are solved if you use a Handy: its side slit is particularly effective for braking, so we will forgive its extra 100 grams, especially since it is the lightest of all the steel braking carabiners. It is also the safest in the event of an anchor failure (see page 45).

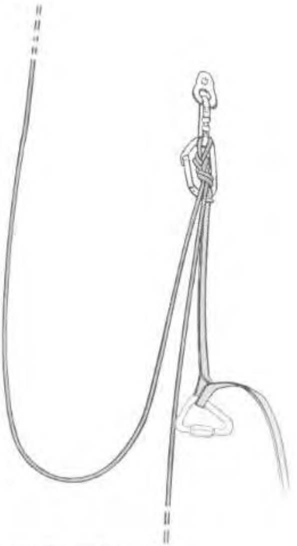


Fig. 299 – How to clip into the anchor using light rigging technique.

As another tactic for saving weight, some extremists do not use the braking carabiner at all. Why don't they just cut off the legs of their boots while they're at it, too? This would save even more weight...at this point, we're approaching a whole new dogma! Without a braking carabiner, you need to increase the amount of rope that passes through the descender pulleys to improve braking action. Several methods exist for doing this, though the drawback is that it requires nearly a half meter more slack at each rebelay (unless you use the Vertaco method, which has other drawbacks; see Chapter J.). After five rebelays, you have already gained back those hard-won 100 grams, and you begin losing ground from there! We won't go into the details of these methods, but note that "S" and "half-O" rappels involve the peculiar practice of passing the rope twice in opposite directions under the bottom pulley – an excellent way to increase abrasion and wear out your precious rope more quickly!

What NOT to do:

Never control your speed using the handle brake on an auto-lock descender, no matter what size rope you are using and even if it tends to slide. See page 147 for proper braking methods.

10.15 Checking and Maintaining Gear

We cannot avoid the fact that lighter gear is also more fragile. Thin ropes must be examined meticulously before and after each and every use, and they must always be cleaned after de-rigging. Every team member should check the anchor knot on both sides for signs of abrasion or weakness. Finally, the life of your thinner ropes should be limited to three years, regardless how much they have been used.

Light carabiners also require special attention. Wash them to remove any mud that gets inside the gate, and dry and lubricate the hinges. Light carabiners also wear more quickly and reach retirement age earlier; do not hesitate to replace them.

10.16 Can we go Any Further?

Can we rig even lighter than this? The answer is yes, but the techniques for doing so have no relevance in this manual since they have not yet undergone sufficient testing or proved safe enough in the long run. Every specialist has a trick, and we will leave this higher level of research to develop its theory and practice in its own time. In a few years, it will surely be time to talk about it again!

10.17 Conclusions

Let's recall some useful numbers concerning thin ropes:

Diameter	Strength	Maximum FF with a knot
10 mm	19.9 kN	1
9 mm	16 kN	1
8 mm	11.4 kN	0.5
7 mm	8 kN	0.3

And again:

Key points:

Do not use light rigging unless you are caving in the specific context that we defined at the beginning of this section. We will recall that it includes

- a small team
- a high level of experience and technical skill for every member of the team
- perfectly maintained equipment
- impeccable rigging.

Failure to respect even one of these conditions can lead to unnecessary risk, and danger of injury or even death.

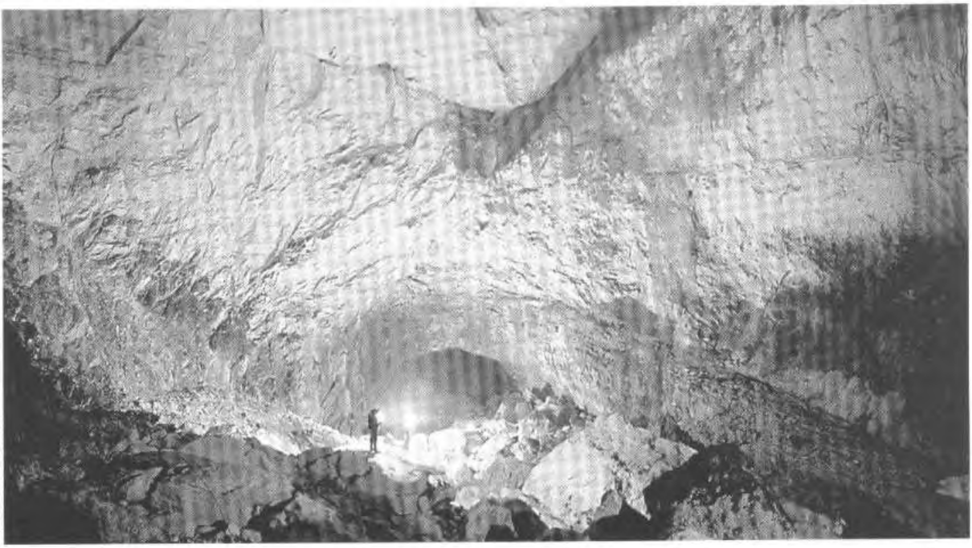


Photo J.P. Sounier

11. Pull-down Techniques

11.1 General Principles

We generally apply these when traversing a system from one entrance to another, which is the context in which we will discuss them here. However, we also use them for de-rigging climbs and in systems that ascend from entrance level, as well as for canyoning.

We should specify now that a purely academic knowledge of these techniques is insufficient for their safe practice during a traverse. Once the first rope has been pulled down after a rappel, there is no turning back: the only way out is down. Perfect autonomy is a must and the team should have a thorough understanding of the system. Insufficient carbide or batteries, lack of knowledge about the cave and its routes, a stuck rope on a pull-down, an unexpected flood, an unclear or incomplete topographical map...these are problems that could turn a fun trip into a nightmare, and an avoidable use of rescue resources.

A pull-down traverse therefore requires meticulous preparation; nothing is left to chance. Each team member must know exactly what he or she is carrying and essential gear such as ropes and carbide, must be divided evenly among participants, to avoid immobilizing the entire group in case a pack is accidentally lost.

The acceptable margin of error is reduced in pull-down traverses. For example, if you accidentally rappel a pitch that is not on the itinerary and then pull down the rope, you're trapped! Bring along an extra single rope and a pull-down cord, both the length of the longest drop on the itinerary. The team can still get out if the main rope gets hopelessly stuck or if the pack containing it is lost down a deep pit or narrow fissure. Another advantage of this emergency maneuver is that if the team is large, you can alternate between the two sets of rigging; the first group that arrives at the bottom has the autonomy to advance to the next pitch and begin rigging.

Finally, remember that traverses take time, especially if the team is only using one set of rigging – and every delay accumulates. We cannot turn around, as we can in normal caving practice, if we find that time has slipped by too quickly. We must continue onward. Give a wider estimation of your time underground to avoid triggering an unnecessary rescue.

11.2 Pulling Down on a Double Line

Your rope length must naturally be double that of your longest rappel. Install the rope by running one end through the link at the anchor (usually a maillon), place a classic safety knot at both ends of the rope and then make both sides even, or tie both ends together. You usually descend on the double rope with a figure eight descender. However, this device wears quickly underground since the rope is more abrasive compared to a normal climbing rope. Figure eight's must sometimes be thrown out completely after just one long traverse! It is therefore advisable to rappel on a single line with your usual bobbin descender. Tie a loop knot and set it against the pull-down maillon, secured with a carabiner clipped to the anchor point. The last person down will remove the knot and retrieve the carabiner, then rappel alone using the double rope. She could also simply remove the carabiner and rappel down on the correct descent rope, the knot still in place against the maillon. Leaving a loop knot in place when pulling down the rope can sometimes cause the rope to get stuck somewhere along its trajectory; do not leave a knot when flakes, ridges, fissures, stalagmites or other such projections are present. In this case, the last person can be belayed as a counterweight from below, and descend on the single line. Keep in mind that this method places twice the load on anchor points.

The same chances of getting the rope stuck exist when you tie two ropes together.

You should of course remove your end-line safety knot before retrieving the rope...otherwise, you will need your rescue ascenders!

11.3 Pulling Down on a Single Line

Here we use a single rope that is as long as the deepest drop. It is packed with its usual end-line safety loop, and its upper end is threaded through the pull-down maillon and blocked behind it with a figure eight. Before the last person descends, a cord the length of the pitch is attached to

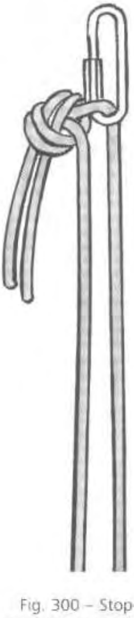


Fig. 300 – Stopper knot connecting two ropes at the pitch head.

the loop in the stopper knot via a locking carabiner. After removing the lower safety knot, pull on this cord to retrieve the rope from below. Figure 300 illustrates another possibility.

11.4 Self-releasing Pull-downs

These methods are rarely used, so we only mention them briefly here. They save you having to pull down the rope, bringing it down on top of you all at once, but they don't guarantee that the rope won't get caught up during the operation. We do not recommend using a mechanical device such as a remote-release hook or Shunt, as this could be damaged when it falls or injure someone below before it lands.

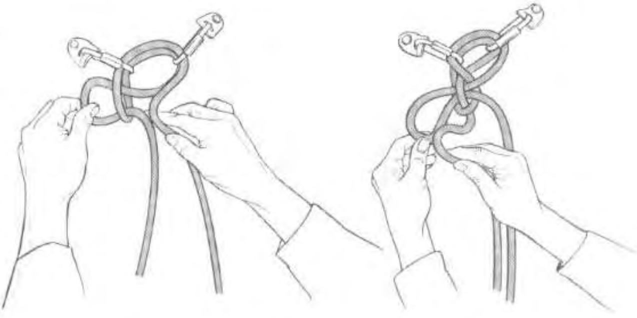


Fig. 301 – Tying a daisy-chain slip knot.

Daisy-chain slip knot (trompe-la-mort)

Tie this directly on the rope, with one side for use on the descent and the other for retrieving the rope (fig. 301).

Releasable pull-down

This configuration is useful when there is no anchor in place for installing the pull-down rope. It is used mostly for de-rigging an ascending passage or a climb rather than for through-trips.

It is made with an anchor sling made from rope on which the pull-down rope is installed. The anchor sling is tied so that it releases when pulled from below. There are two versions:

- descending on a single strand of rope, with a separate auxiliary rope that forms the anchor sling and hangs down to the pitch bottom. This is used for retrieving the rope.
- descending on a doubled rope, using an anchor sling made from a short length of auxiliary rope (fig. 302). This sling is formed with a slipped bowline, the release end of which is tied with a sheet bend to the pull-down strand of the main rope. Pulling down on this will release the entire configuration.

Fig. 302 – Releasable pull-down using an auxiliary length of rope as the anchor sling.

11.5 Cord Technique

11.5.1 Basic principles and conditions for use

With this method, you can use the same rope in several consecutive pitches by leaving a doubled cord in place at each drop. This technique allows you to re-rig the pitch from below and climb up, and it is useful for several applications.

First, it allows you to visit even very deep caves with a significant reduction in the weight and volume of your equipment – whether this concerns a tour of a classic or checking a potential lead in the farther reaches of a system. For 500 meters of vertical passage, you only need one rope that is as long as the deepest drop (3 kg. for 50 meters of 9-mm rope), plus about 1,100 meters of 3-mm cord (6.5 kg). Total weight: 9.5 kg. Using traditional rigging techniques, the weight would be 21 kg. for 8-mm rope, 26 kg. for 9-mm, or 32 kg. for 10-mm!

Cord technique is also useful for traverses when you are unsure of the itinerary at some point and want to keep an optional "escape route." It is also used in canyoning to ensure an alternate way out, as with high water, high water conditions or a sump zone, or when locating new routes.

Since nothing is ever perfect, there is of course one major counterpoint to the lightness of cord technique: the time it takes to install and use. Not only does installing the cord on rappel require special care and time, but so does placing the rope again on the way up. To top it all off, team members have to wait at each drop when descending as well as climbing. You are thus projected back to the age before self-belay techniques, and the hours of waiting associated with it. Alone or in a pair, the loss of time is tolerable; with three or more, you are beyond the functional limit.

In any case, this technique is confined to specific applications and in no way constitutes the future of cave exploration. It allows for deviations but not rebelays. Even worse, as soon as you need to work repeatedly in a system or in teams of two or more, this technique is no longer practicable. We should nonetheless stop a moment to discuss it, since improvisation has no place in its application, which requires skill and precision.

11.5.2 Choosing and preparing the rope

This method uses a rope that has undergone a special preparation to progressively reduce its diameter until is matches that of the cord. Since this requires good flexibility, it is best to use a new rope.

Proper functioning of this technique depends on the weight the rope. A 3-mm cord cannot support too heavy a load, and its elasticity prevents you from accurately feeling what is really happening with the rope and cord above while you are pulling down on the cord. Nine millimeters is our minimum diameter, since the rope is to withstand frequent passages, and a length of 60 meters is the maximum. Forty meters is more reasonable if you account for deviations that will make it harder to pull the rope.

Gather some strong nylon thread and a heavy duty needle, electrical tape, scissors, a clothespin, two meters of 3-mm accessory cord having a core/sheath construction, and an old tennis or rubber ball pierced across its diameter.

1. Take one end of the rope and begin unraveling its core braids, pushing back the sheath over about one meter; then hold it in place with the clothespin (fig. 303, steps 1 and 2).
   Shorten the braids by about 10 cm. Then separate the core and sheath of the cord. To do so, cut an opening in the sheath about 5 cm from the end and pass the whole core through this (step 1).
2. All our modern ropes have parallel strands in the core. Choose two from the center of the rope and tie one to the core and the other to the sheath of the 3-mm cord, using fisherman's knots and offsetting the tie-off points (fig. 303, step 3).
   Tie a third core strand around the cord using a Blake knot. Equalize the lengths so that the three connection points share the tension equally. Cut off the excess length on the knotted strands. Bring the other core strands down along the cord, then cut these also in tapered fashion, with the exterior strands being shorter and those toward the center gradually becoming longer (fig. 303, step 4).
3. Slide the sheath back into place. Stretch it out well by squeezing and pulling it several times in the same direction. Now the most difficult part is over.
4. Sew the core and sheath together over the meter joining the rope and cord. Sew forward on one plane and back on a perpendicular plane to this. Leave the last five centimeters of the sheath end unsewn (fig. 303, step 5).
5. Carefully wrap the nylon thread around the unsewn section of sheath and cord, binding them tightly together, then wrap the whole with electrical tape.

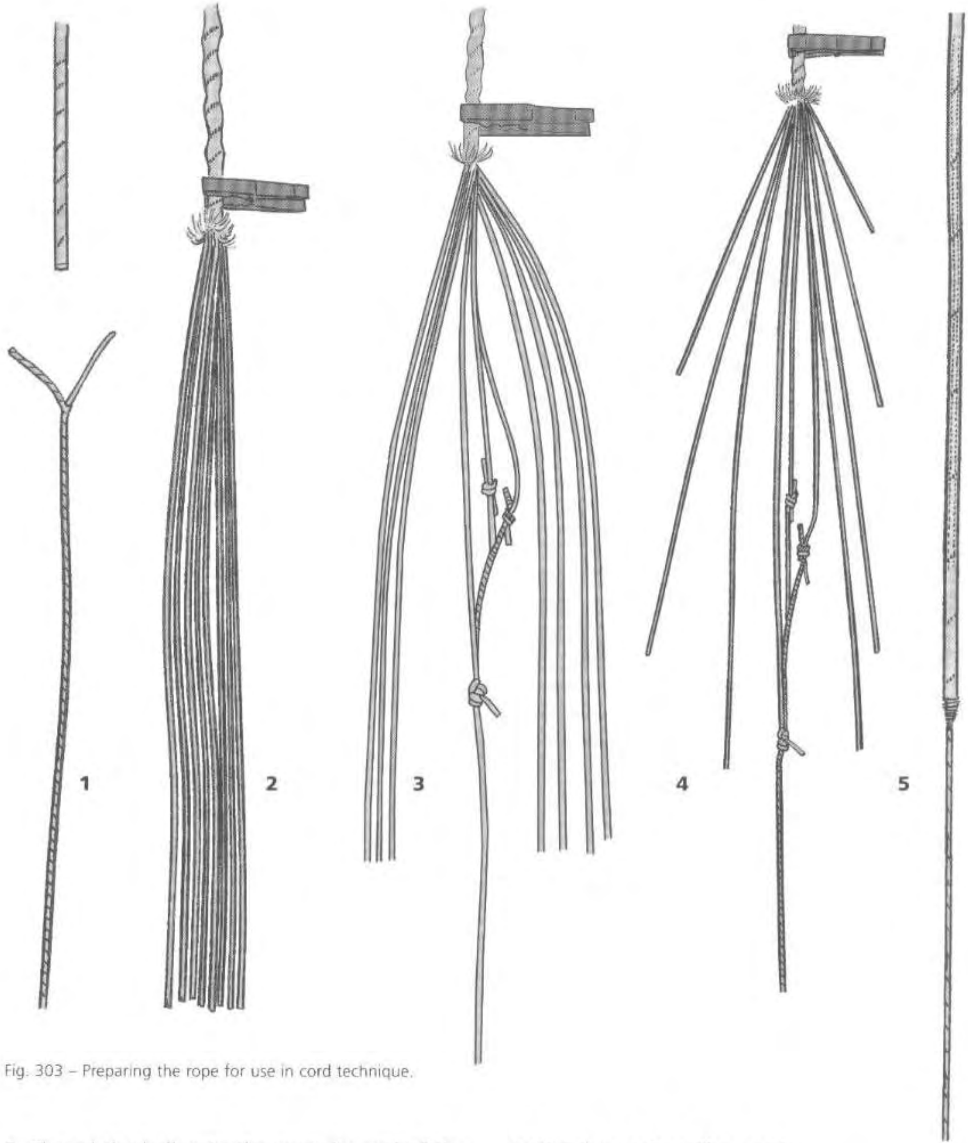


Fig. 303 – Preparing the rope for use in cord technique.

6. Thread the ball onto the opposite end of the rope and tie a loop in the end with a figure eight knot. We will call this the "ball loop." The free strand should be about 20 cm long. Push the ball against the ball loop.

The rope is now ready for packing. Pack the cord end first, remembering to tie a safety knot in this end as well. The loop and ball should be on top in the pack.

11.5.3 Preparing the cord

Your 3-mm cord should have the tightest possible sheath weave to protect against abrasion. Pack it the same way you pack your rope, in a pouch that will hold 200-300 meters. Depending on how much you are carrying you can prepare several of these pouches. They will be used to place the rigging cord installed in a triangle in each pitch.

In another pouch, pack a cord that is equal to the length of the rope. This is the pull-down cord:

attached on the ball end, and it will help you pull down the rope and replace this with the rigging cord. The pull-down cord also ends in a loop.

To do:

Secure the end of each rigging cord to its respective pouch, so that the cord doesn't run out unexpectedly when the pouch empties. You will need to connect this end to the cord in the next pouch using an overhand knot.

11.5.4 Deviations

Deviations are acceptable with cord technique, although they lead to notable rubbing in the carabiners and you must pull harder to reinstall the rope on the climb up. They are really only useful with cord technique if the angle of deviation remains low, and it is better to have several low-angle deviations than one high angle. Moreover, when the rope is being placed for the climb, it may pull backward on the deviation, causing it to come away from its fixture. Be aware of this risk when installing the deviation on the descent.

Of course, you have a deviation because there would have been rope rub without it. On rappel, you cannot place the pull down cord in the deviation carabiner to protect from this abrasion because the ball will get stuck there. So, only one of the two sides of the rigging cord triangle will pass through the deviation carabiner(s). This side will then be the side that pulls the rope on the return. For this reason, you must be careful to distinguish between the two sides once you are below, which calls for some essential precautions when placing the cord. To illustrate these, we will describe the cord installation as it is performed with deviations. The reader can simplify this in situations where no deviations are needed.

11.5.5 Approaching the pitch head

Since your team is by definition smaller and highly skilled, cord technique is naturally carried out using light rigging (except with regard to the tapered rope diameter). Traverse lines are thus made of thinner diameter rope and your anchors are light. At each pitch head, the return maillon should be 7-mm zicral with a wide opening, and it must hang freely above the drop, for example, placed on a Y-belay.

To do:

- Keep the return maillon from moving around on its anchor point by fastening it to the anchor with an inner tube band.
- If the return maillon is near the wall and parallel to it, insert a second maillon between the the anchor and the return maillon. This will allow the rope to hang more freely and prevent possible rubbing.

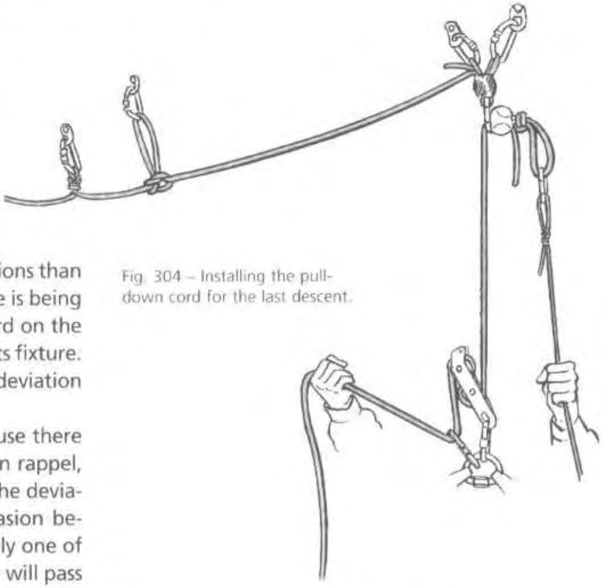


Fig. 304 – Installing the pull-down cord for the last descent.

Fig. 305 – The cord forms a large triangle with its base at the bottom of the pitch.

11.5.6 Rappelling

- The leader places the rope in the return maillon and rappels, feeding out the rope as he goes; the second attaches the end of the pull-down cord to the ball loop with a locking carabiner and attaches the rigging pouch to his harness belt.
- While descending, the leader installs the necessary deviations and places the rope in them, remembering that during the climb up they will be pulled upward and could come away from their attachment points. He adjusts the rigging to avoid this risk.
- His second feeds out the pull-down cord while descending (fig. 304), but does not place this in the deviation carabiners. At the same time, the leader connects the rigging cord to the cord at the tapered end of the rope with an overhand knot. This knot will slide more easily through the return maillon.
- After the second has reached the floor, he retrieves the pull-down cord, progressively lowering the ball loop of the rope. The rigging cord, guided by the leader along the rope's path, gradually replaces the rope, deviations included.
- When the tapered end of the rope lands below, the rigging cord attached to it is then tied with two reference loops. These indicate the side to be pulled during the climb: it is best to use the same coding procedures as that used in rescue operations for the hauling rope. The second clips his cowstail into one of the two reference loops and detaches the cord from the rope. The first takes more cord from the rigging pouch, the length that corresponds to the estimated width of the pitch base. We will see why now.
- The end of cord with the marker loops is tied to this pouch cord with an overhand knot. The cord that has just come out of the pouch is then cut with a lighter or a knife so that the rigging cord now forms a large closed loop. This procedure prevents us from accidentally losing either end of the cord, which we have just placed.
- The two vertical sides of the rigging cord loop are separated as much as possible from each other and each is temporarily hung to a some feature on the wall, held with a rock or attached to a fixed point with two rubber bands tied in a girth hitch. The cord will thus form a large triangle with its base at the bottom of the pitch (fig. 305).

Key points:

This triangular shape is the best way to prevent the two down lines of cord from twisting together.

- The leader packs the rope again into its pack, while the second does the same with the pull-down cord and pouch.
- Both continue to the next pitch head, where they repeat the operation.

11.5.7 Climbing back up

The pull-down cord has no use on the climb. The procedure for packing the tapered rope is simply the reverse: this time, the ball end is packed first.

- At the base of the first climb, the two team members go to each side of the triangle and detach the rigging cord from its respective fixtures. One caver clips his cowstail into one of the reference loops; the other ties a loop near the triangle closure knot in the other strand of cord and clips into this. Each is thus attached to opposite ends of the cord, preventing it from escaping when the closure knot on the triangle is untied.
- The tapered end of the rope is tied with an overhand knot to the end of the rigging cord with the two reference loops. The other end of the cord is tied to the ball end loop. If the ball gets stuck while the rope is being placed, this configuration will help release it by simply pulling on the other strand.
- Both cavers unclip their cowstails and untie the three loop knots.
- As the cord is pulled down, the tapered end of the rope goes up, passes through the return maillon and comes back down, passing through any deviations along the way (fig. 306). As the ball comes up against the return maillon, the rope is blocked in place. Correct installation is checked with a hard tug on the rope.
- While the first climbs, the second gathers the used rigging cord.
- The second then climbs up.
- After arriving at the top, both repack the rope.
- They continue to the base of the next pitch, and so on.

Using AS anchors

An AS is made with a Spectra sling and a light alloy head bolt installed on a self-driving anchor sleeve, without carabiners (see section 10.11; fig. 287). By placing one or two stopper knots behind

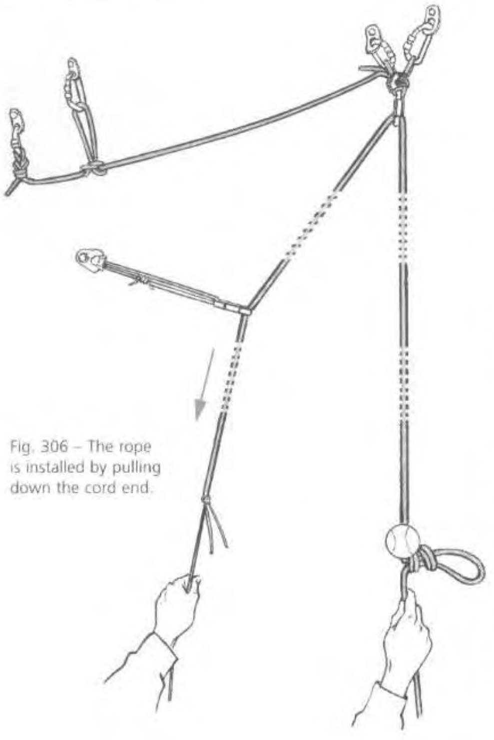


Fig. 306 – The rope is installed by pulling down the cord end.

the head (depending on whether you knot the cord strands together or separately) on the side opposite the attachment loop, you can reduce this loop to a minimum. This will help hold the return maillon in place against the ball loop, which saves you from placing a rubber band as a holder. The backup anchor can be made with a second AS anchor connected to the first with a tensioned Spectra cord, and its length adjusted with a butterfly knot. Use the false and not the true butterfly: it can slip and act as a shock absorber in case the first anchor fails.

You can also place a backup anchor using a Spectra sling around a natural anchor (fig. 307a), or a classic bolt configuration (fig. 307b).

Conclusion

We can see that cord technique has its limitations, which rest on the more or less favorable configuration of the pitch and on the time-consuming and rigorous nature of the maneuvers. In addition to these, it has two more drawbacks:

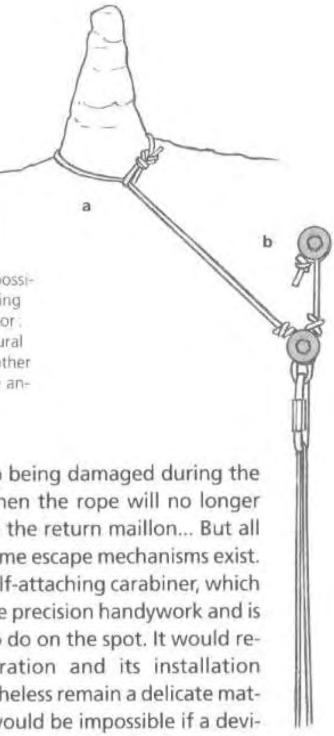


Fig. 307 – Two possibilities for doubling the flexible anchor: one uses an natural anchor (a), the other a second flexible anchor (b).

The first is the relative weakness of the tapered end of the rope, and all this laborious sailor's work could end up being damaged during the operation. Then the rope will no longer pass through the return maillon... But all is not lost: some escape mechanisms exist. Forget the self-attaching carabiner, which requires some precision handywork and is impossible to do on the spot. It would require preparation and its installation would nonetheless remain a delicate matter – and it would be impossible if a deviation were necessary. Consider instead the possibility of replacing the faulty rope/cord knot with a braid hitch (fig. 75 c), after having cut off the now defunct tapered end of the rope. Hold the pull-down cord at about 50 cm from one end and wrap a tight plait around the end of the rope. Start at about six centimeters from the rope end and wrap the cord very tightly over about five centimeters, leaving one centimeter of the rope end free. Then tie the plait off closely with a bowline knot. The rope is thus solidly connected to the pull-down cord, of which about 20 cm remains free at the end. Use this free end to close the cord triangle with a classic overhand knot, and then continue as you would with the usual technique.

The second drawback of cord technique is its admittedly unpredictable side. Whatever precautions you have taken, there is still the realistic possibility that the cord will get stuck or break: we've already had a close call at –600 in a cave in the Chartreuse Mountains! Such an incident would have likely resulted in a long wait under rescue blankets, telling each other jokes to pass the time or wrestling to stay warm. And of course, preparing ourselves for the big smiling faces of the rescue team, relieved to find us unhurt and ready to give us hell about our misadventure...

12. Climbing Underground

When it doesn't "go" anymore at ground level, it's time to start looking up. Over time, the course of subterranean waters leaves abandoned passages in its path, perched high above. These fossil galleries are often the key to vast systems. They can provide you with alternative routes and lead you further into the active level through shafts that may or may not be part of the present-day tributaries.

Some of these leads may be easy to reach, but systematically locating high leads often demands an organized search. You will soon see the limited capacity of normal headlamps and may resort to more high-powered flashlights, dive lights, or even searchlights. Halogen or krypton bulbs and high-tech lenses make for more powerful light sources that are effective in illuminating higher domes. Working from available topographical, geological and hydrological data, concentrate your search efforts in key sectors. In meanders, you can sometimes find a detour around a blocked or narrow pitch by following an original fossil gallery in the ceiling: bypassing the pitch, this gallery may lead to an older and perhaps larger pitch beyond. Just as faraway galaxies show us how they appeared billions of years ago, these fossil galleries tell us about the cave system as it existed hundreds of thousands of years ago. Both give us with an opportunity to travel back in time...

When evaluating each lead, try to make your observations as precise as possible: the height to be overcome, weak points to attack, potential complications, the quality of the rock. These observations will determine what equipment you will need, what techniques you will use, and what your chances for success will be once you act. Prioritize these leads according to your evaluation and the inherent interest that each has in relation to your objectives.

12.2 Safety Measures

The rope

Just like rock climbing on the surface and for the same reasons, climbing underground requires the use of dynamic rope: it must be able to safely intercept the lead climber's fall. Since the leader always moves upward from the last fixed anchor point (also called a "runner" or "protection" in climbing), there is an ever-present risk of a factor one or greater fall at the moment he is placing the second next anchor. The climber could fall nearly to the bottom of the pitch; if he was senseless enough to try climbing more than two times higher than the height his first runner, he will simply smack right into the ground. Note that falling before you set your first runner is strictly prohibited, just as it is at the beginning of any climb!

A new, dry semi-static rope can of course support a factor one fall. But if it is wet, its shock absorption is cut almost in half, which precludes us entirely from using semi-static rope. We may only use double or single dynamic rope. It is not obligatory to use double rope, as in mountain or rock climbing, since we don't need to descend by placing rappels. At first glance, you may be tempted to use a single rope since this requires only half the amount of rope in comparison to double roping. The lightest 8.1-mm diameter double ropes now weigh 42 grams per meter. Thanks to technical innovations, their single rope counterparts are only 9.4 mm and weigh 58 grams per meter. When you do the math, you'll find you save 30% more weight – 780 grams for 30 meters – by using single rope. And using single rope is easier, since you don't need to distinguish between the two strands during your maneuvers.

On the other hand, double roping has its advantages. It creates less friction on the anchor carabiners, and it is also the safest technique since the two ropes are significantly more shock absorbing if an anchor fails. This is especially important since each rope only passes through every other runner, and you should remember this in the presence of bad rock.

Double roping requires better coordination between the climber and his belay partner, and requires more participation from the belayer. This is not a bad thing, since it will help keep the belayer warm and more alert! But the belayer must have a thorough knowledge of all the maneuvers involved.

We will discuss both methods and leave the reader to learn and test both and choose which one is best, according to his tastes and also to the specific conditions of each climb. If the climb is far from the entrance (in length or depth) or if you intend to try free climbing, you would likely choose a single line. But if the climb involves a difficult horizontal traverse or several direction changes, use a double rope.

No matter which method is used, the deliberate pull of the belayer aiding the lead climber (via an

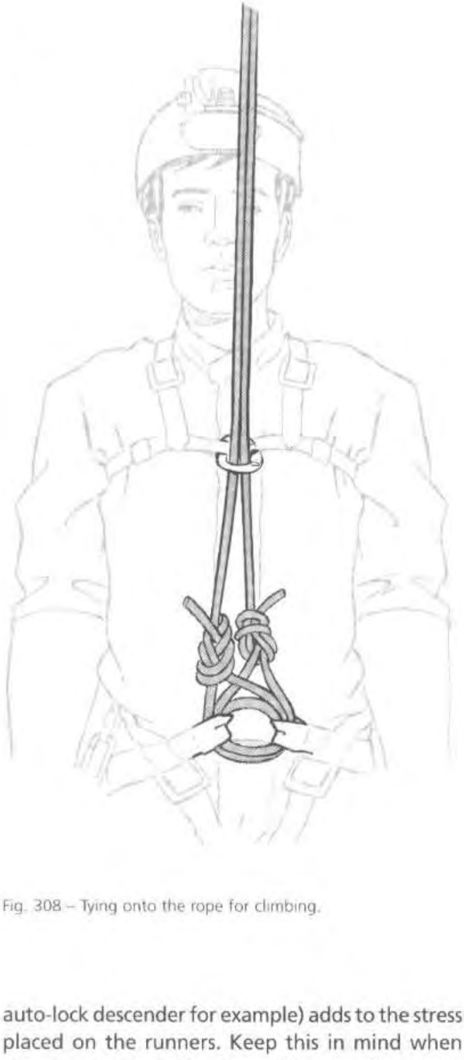


Fig. 308 – Tying onto the rope for climbing.

auto-lock descender for example) adds to the stress placed on the runners. Keep this in mind when choosing and installing these. You can also bypass an anchor you think is unsafe by using your cowstails and asking the belayer not to pull on the rope.

Roping up

Tying on to the rope is done in the same way, whether you are using a double or single line. The rope passes directly through both harness attachment loops rather than the harness maillon (fig. 308). To do this, tie a rethreaded figure eight (or two knots when climbing on a double rope) as close as possible to your body.

We have two strong arguments for using a chest harness, and the first is reason enough to make it compulsory:

- It prevents you from turning upside down in the event of a fall. In the event of a loss of consciousness or injury, turning upside down increases the already grave risks related to seat harness pathology (see Chapter M, section 2). The chest harness should be strong and solid, like those used in climbing. It is linked to the to the rope itself and acts as a full body harness.
- Correctly fitted, it provides a comfortable, upright hang and good support for carrying the many tools and accessories you will need for the climb.

Belaying

You can belay using some of the favorite tools of "real" climbers: the figure eight descender, Stitch plate, gri-gri, climbing ascenders, etc....But why weigh yourself down with all this special gear, when you can belay with the your plain old caving gear? All you really need is your descender installed in a "zero" or a Münter hitch. We no longer practice body (or shoulder) belays. If you have an autolock descender, the best method is to install this in the "half stop" configuration on the belayer's harness maillon, passing the rope over the lower spool only (see fig. 263, top drawing).

The belayer will "pay out" the rope by operating the handle with one hand and feeding the rope above the descender with the other. Take up the slack by pulling on the free end.

The lead climber is obviously much more active, and therefore warmer, than his belay partner. It is advisable to switch roles from time to time so that both partners can stay warm. If there are three in the team, the third can relieve the belayer periodically, while the climber continues up.

Like the pit rope, the climbing rope is kept in a pack and fed out as the climber ascends. This saves it from an accidental trampling, falling rocks, and mud: clay in particular will make it slippery and compromise an effective belay.

The skyhook

This accessory has its true purpose in aid climbing, and it should be a part of every bolting kit. Link it to your seat harness with a carabiner or to one of your cowstails, then hook it onto a feature in the rock and carefully test its hold before transferring more of your weight or balance onto it. This allows you to free your hands, rest your legs and thus relax your back muscles. This welcome rest helps you place your anchor in more comfort and stability.

12.3. Free Climbing

This is the simplest and fastest method of all whenever possible, and this is the case more often than we think. Aid climbing with a drill isn't necessarily more difficult, but it is more time consuming. Even when aid climbing, if you come upon a passage that lends itself to free climbing, leave your tools behind and become "one" with the rock. But always remember to minimize your risks, and don't take chances: this is no practice session, and a false move could be critical.

Our boots grip pretty well on clean rock, even when it's wet, but in some places you better forget scaling the wall. When the passage allows, opt for opposition climbing, or chimneying, technique. While chimneying often seems to repel rock climbers and mountaineers, it allows us to overcome many obstacles underground, and cavers excel at it. Of course, the subterranean rock climber isn't burdened with the "correct form" concerns of the rock climbing purist: whether you use a knee or an elbow or place a sling to substitute for an etrier is of little importance, because in this case the end justifies the means. And though a fantastic climb might be a source of pleasure underground as on the surface, the caver's joy doesn't end at the top of the climb. On the contrary, it's in fact at the end of this hard-fought challenge when his heart starts to pound in expectation...Will his efforts be rewarded with this newly discovered passage, will it lead to still more new cave, and farther into the unknown?

Along with the cave diver and the cave digger, the subterranean climber holds the key to many of the discoveries to come in this limestone land where it seems so much has already been explored.

12.4 Aid Climbing

In the absence of sufficient natural holds that would permit a free climb, you can still resort to placing temporary anchors, or aids, as you climb.

Equipment

The gear to be used is divided into two categories. The first includes gear that is essential and common to all climbing methods used; the second comprises gear that is specific to the chosen technique, and will be described in detail below, with each technique.

Essential gear for all methods includes:

1. One or two etriers (depending on the method), each equipped with a fifi hook and a retrieval cord that is attached to the climber. This automatically releases the etrier from the anchor point as the climber leaves it.

To do:

For better maneuverability, attach the two etriers on both sides of the seat harness belt or chest harness, rather than on the harness maillon. Use three-step or, preferably, four-step etriers.

2. Equipment for setting anchors (runners), which will vary in type according to the nature of the route and the quality of the rock. This may include hand and/or power drill, hammer, self-drilling anchors, pitons, removable bolts, copper heads, quick slings, webbing loops/slings, etc. Power drills are slowly replacing manual drills in aid climbing, especially if the climb is high, since it saves an appreciable amount of time and energy for the climber, which justifies its extra weight. Modifications for limiting its weight when in use were discussed in Chapter E, section 7.4.
   All this heavy equipment can be divided up and carried on the seat and chest harnesses if these have gear loops, or they can be carried on one or two slings of webbing worn as a bandolier.
3. A single or double rope, depending on the method you choose, which should in turn depends on the climbing terrain. Rope maneuvers will differ according to which type of rope you use, but not according to the climbing method used, whether this is with etriers, a Raumer bar, or a bolting platform. For a more practical discussion, we will describe these various rope maneuvers, taking the technique of climbing with etriers as our example.

To do:

Install a haul line between the lead climber and belay partner for use in resupplying drill bits, equipment, water, etc. This also allows the climber to get rid of some of his equipment if he sees the opportunity for a free climb, for example.

12.4.1 Aid climbing with etriers on a single rope

Alternating between two etriers allows you to place successively higher anchors, moving from one to the other on the etriers (fig. 309). This method makes it possible to set the anchors at about 85 cm-1 m apart, maximum.

1. Roped up and wearing all the necessary personal and bolting gear, climb up and set the first anchor.

Key point:

The first three runners should be bombproof, placed to prevent you from falling all the way to the ground if you lose a hold.

2. Fit the ring or plate on the runner with a quickdraw sling (a short stitched piece of webbing with a carabiner attached in a loop at each end). The fifi hook of the first etrier is placed in the quickdraw carabiner that is attached to the runner (we will call this the runner carabiner), while the rope clips into the carabiner at the other end (we'll call this the rope carabiner). This reduces the drag on the rope.
3. Climb as high as possible on the etrier and clip in as short as possible to the runner carabiner. If your short cowstail is too long, shorten it or replace it with two linked carabiners. The belayer holds the rope firmly.

Key point:

With legs stretched and knees locked, you may be able to stand with your upper body above the runner by leaning out in opposition to your tensioned cowstail. This stance achieves the most distance for placing the next runner.

If the wall is even slightly overhung, you cannot use this stance; it is unstable, and it's impossible to raise your seat harness above your present runner. You must instead clip in as close as possible with a single carabiner.

4. Holding your position, set the next runner and place a new quickdraw on it.
5. The belayer, in the meantime, pays out the rope needed to place it in the upper rope carabiner.
6. The climber clips the second etrier into the runner carabiner. While transferring your weight from the first to the second etrier, remove your short cowstail from the lower runner and im-

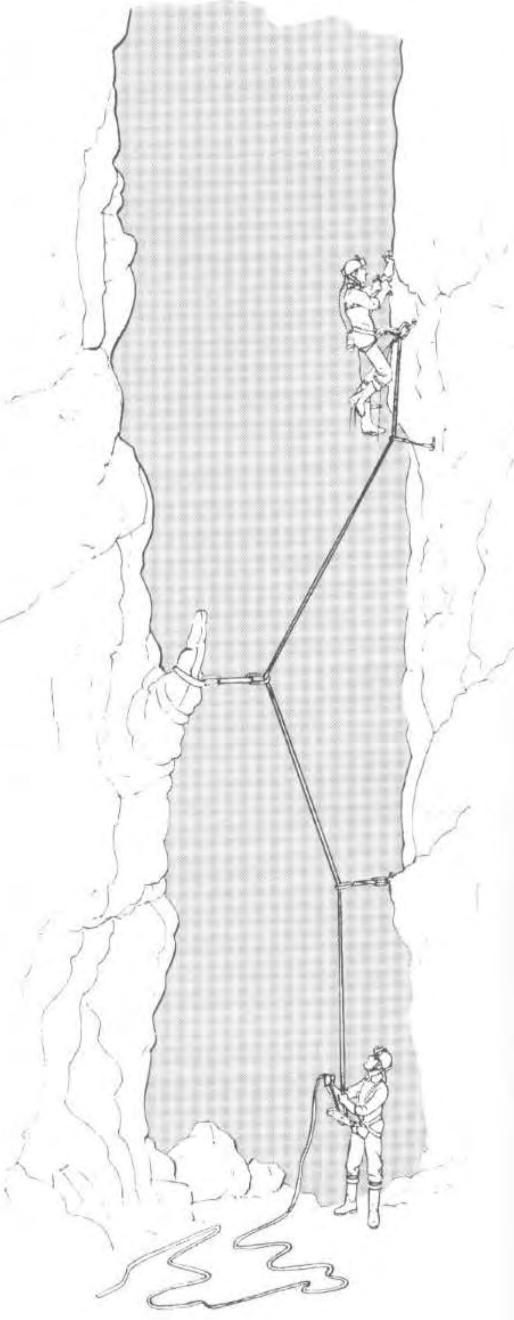


Fig. 309 – Aid climbing on a single rope.

mediately place it in the upper runner's rope carabiner. During this rather sporting maneuver – which should be as brief as possible – the belayer helps by increasing tension on the belay rope, while the climber stabilizes himself by holding the quickdraw with one hand, clips the cowstail into it, and then sits back on it.

7. Now you can prepare to set the next runner, repeating steps 3-6.

☺ To do:

While setting your anchor you can use both etriers, one for each foot. This position provides more stability because it allows you to stand with legs apart. If your etriers are made of webbing, you effectively have no choice since it's difficult and rather tiring to stand with two feet in one webbing loop.

12.4.2 Aid climbing with etriers on a double rope

Double roping saves you from maneuvering with your cowstails. Before standing up in the etrier, run one rope through the rope carabiner. The belayer maintains tension on this rope while paying out the other, following your every movement as you are transferring your weight from the lower to the next runner (fig. 310).

Compared to belaying on a single rope, your instructions to the belayer are different. You must refer to the specific strand of rope (usually by color) instead of simply calling, "tension" (N.Am.) or "take-in" (Br.) to take up slack in the rope, or "slack" to pay out the rope.

12.4.3 Other aid climbing techniques

All other aid climbing methods are based on the same principle: place a straight aluminum bar against or near the wall, and attach it to the last runner so as to position its upper end as high as possible above this last runner. The climber gains additional distance by clipping in to the upper end of the bar.

You can also use a simple tube with a hole pieced halfway along its length. This point is linked to the anchor and its lower end is stabilized either with a rope pulled taut from below, or by simply applying the climber's weight. The upper end, attached to the harness, helps elevate the hips above the belay point. The Raumer bar belongs to this family of

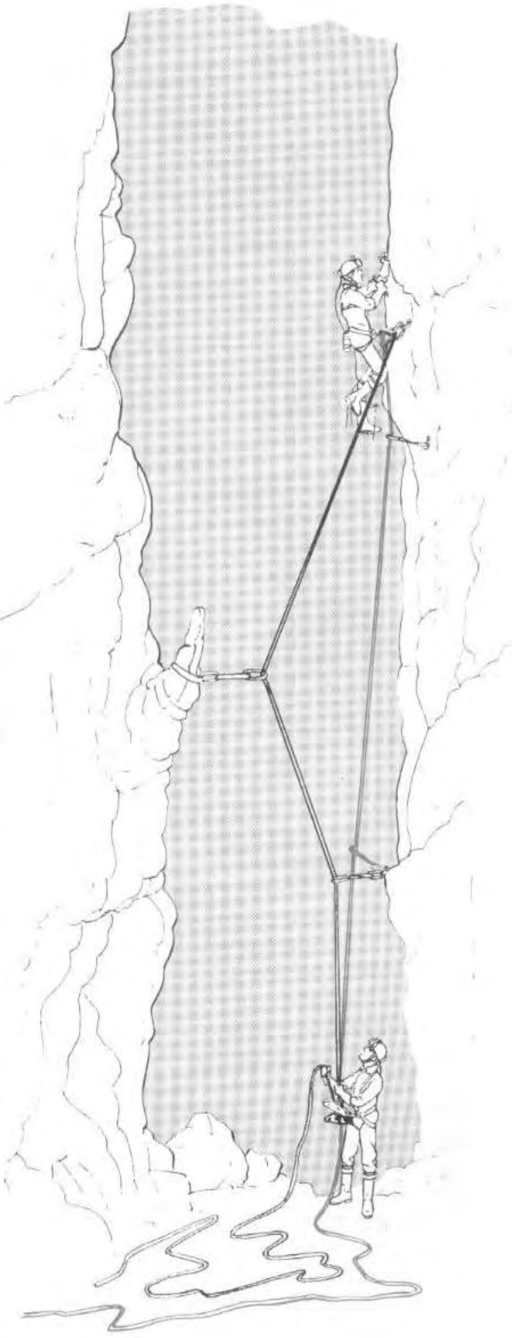


Fig. 310 – Aid climbing on a double rope.

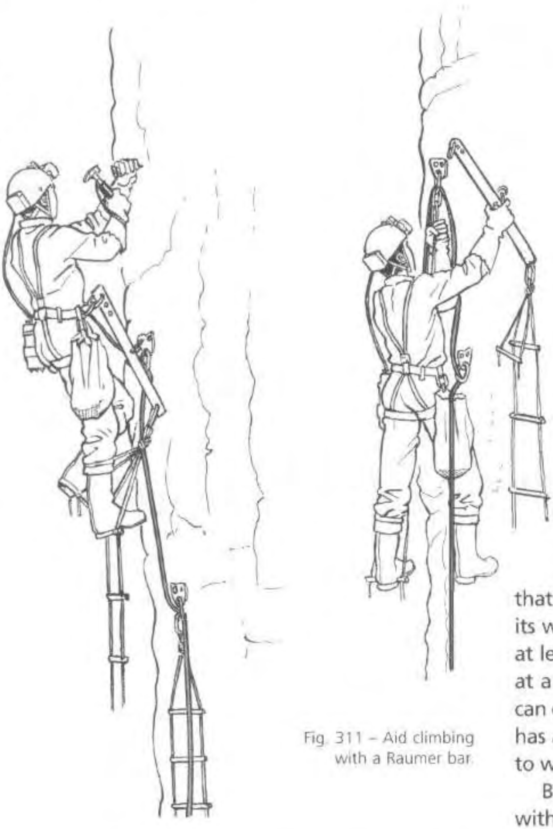


Fig. 311 – Aid climbing with a Raumer bar.

climbing aids (fig. 311). You can also construct a kind of bipod platform that can be stabilized once it is attached to the anchor. There are several kinds of bipods and tripods having a vertical section that attaches to the wall: these also fall into the category of bolting platforms.

12.4.4 The Raumer bar

This compact, lightweight bar (350 g) is highly effective and easy to install. It requires two-holed anchor plates that can withstand pull-out traction, and a special kind of etrier that you can fashion yourself. With each runner – and for the same effort – the Raumer bar can help you gain an extra 30 cm height and thus a considerable amount of time, compared to traditional etrier climbing (see fig. 311).

You normally use a single rope belay, but double roping is also possible. Be careful where the route moves off to the side: if you place too much of your weight on the top of the bar while trying to move sideways, you risk rotating the bar to the side. This could cause the anchor plate carabiner to break or damage the bar itself.

12.4.5 Bolting (scaling) platforms and Spiders

The bolting platform is the ideal tool for long climbs since it allows you to place much higher anchors (about 1.5 meters); it is also quick to install and relatively light. A normal platform pulls on the anchor at less than a 45-degree angle. This makes it possible to use other anchors besides self-driving sleeves and expansion bolts, and to use lighter plates. On the other hand, normal platforms cannot be used where there is the slightest overhang. The Spider platform (from the french *Araignée*) has the advantage of allowing a higher reach (1.85 – 2 m), and it saves time. The drawbacks are that it is more difficult to carry, install and use, and its weight can soon become an important factor: at least 1500 grams. When in use, the spider pulls at a 45-degree angle, a direct pull-out load, so it can only be installed on a ring or anchor plate that has an acceptable pull-out strength. This allows it to work on slight overhangs (fig. 312).

Both kinds of platform operate the same way, with either a single or double rope:

1. A quickdraw is placed in the ring (Spider) or hanger plate (normal) of each new anchor, and the platform is attached by its fifi hook to the hanger carabiner.
2. The upper etrier which is used to access the platform is linked to the same carabiner by its fifi.
3. Standing on the lower etrier, the climber is belayed by the two strands of double rope, each passing through the rope carabiners of both quickdraws. There is thus a "high line" and a "low line" that should be distinguished by their different colors when calling out instructions to the belayer.
4. With tension on the belay, the climber steps into the upper etrier and then raises himself cautiously onto the platform. With a normal platform, he stands in profile with one shoulder leaning against the wall; this position provides the most stability. With a Spider, he faces the wall and can even, in favorable conditions, balance himself from the top of the device, clipped in with a carabiner (fig. 312).

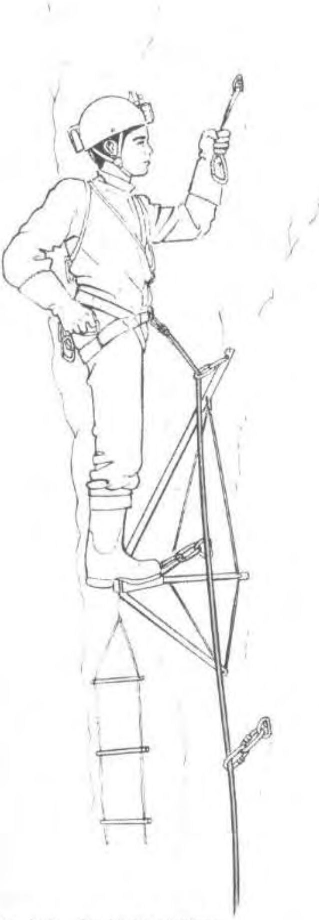


Fig. 312 – The Spider platform.

Fig. 313 – Stepping up onto the bolting platform.

Fig. 314 – Installing an etrier at the next anchor point.

5. The lower etrier is recovered using its retrieval cord.
6. The cycle is complete when the next anchor is installed, and steps are repeated (figs. 313, 314).

12.4.6 Removable anchors for aid climbing

There are two basic categories of removable anchors: those that exploit the existing surface features of the rock, and those that require a drill hole.

The first type are of course preferable since they can be completely removed, leaving the rock in its original state. Another advantage is that they are faster to place.

The second type can be placed anywhere and guarantee a better hold in the rock. However, they still leave part of the bolt permanently in the rock.

Removable anchors take advantage of the natural features in the rock (stalagmites and flowstone columns included), namely fissures. They include:

- chocks, which come in many shapes and sizes: nuts, hexcentrics, Friends, and other mechanical jamming devices, and cord knots. These can be placed without additional accessories, but often require a tool, such as a small metal hook, to be removed from the rock;
- pitons of all shapes and sizes, each adapted for the various types of joints and fissures in which they are placed;
- maleable anchors: copperheads and their lead counterparts, which are hammered directly into holes or fissures and conform to their shape. These are not used much in caving;
- Slings and etriers, for tying in and around various configurations.

All of these devices have been discussed in the first part of this book.

12.4.7 Drill Anchors : DBZ bolts

You can of course use expansion bolts, compression pitons, and self-drilling anchors, and you already know about these. Let's introduce another anchor: the DBZ bolt.

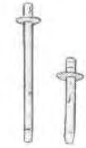


Fig. 315 – Two types of DBZ bolt.

The main advantage of this anchor is it strength-to-diameter ratio, which allows the use of a 6-mm type. Drilling a small diameter hole allows you to drill more holes on a single battery: at the same depth, you get twice as many as with 8-mm bolts! The DBZ comes in two lengths: 45 or 110 mm, which can be chosen according to the quality of the rock. The length of the drill hole is not critical, since the bottom of the hole has no effect on the bolt's expansion action.

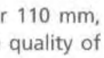


Fig. 316 – The spur must be positioned vertically (as shown on right).

For 6-mm diameter the pull-out strength is 4 kN, and so its safety factor is five. For shear loading, its strength depends on the orientation of the spur, which must be positioned vertically. This provides 10 kN strength, as opposed to 6 kN if the spur is positioned horizontally (fig. 316).

The second advantage of the DBZ is its quick installation. Once it's in the hole, a few whacks with the hammer are enough to expand the anchor.

There are no commercially available hanger plates that are designed for use with the most recent of these anchors, so we must modify the existing models. Twisted hanger plates are perfect for this.

To do:

Link the anchor and carabiner eyeholes together on the hanger by making a 7-mm wide slit between them (fig. 317).

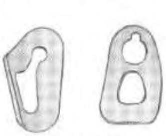


Fig. 317 – Classic hangers need to be modified for use with DBZ bolts.

Hold the plate and bolt together with some adhesive tape before placing them in the hole. Link the hanger to its quickdraw beforehand as well, to reduce the time it takes to install the anchor (fig. 318)

Fig. 318 – Hangers placed on DBZs. The quickdraw and lower carabiner are not shown.

The DBZ costs a bit less than other anchors, and that can make a difference for those long climbs.

Finally, we should mention that this anchor must be left in place. Although its impact on the cave is minimal, its one centimeter-wide head remains visible. The hanger plate can be removed by simply pulling up on it once the runner carabiner is removed.

12.5 The Scaling Pole

The scaling pole was the first device used to conquer domes or walls that could not be free-climbed. Stopping at nothing, Norbert Casteret used sections of steel heating tube fastened together before climbing up them like a kid up a flagpole. The technique has since been refined and improved: a flexible ladder is now attached to the top end of the pole and the steel has been replaced with lighter aluminum alloy. Tensioned cable stays have also been added to provide structural support and prevent buckling: when loaded, a non-reinforced pole will compress and bend until it eventually breaks.

We rarely or never use scaling poles nowadays, so our discussion of them is limited here. They are heavy, cumbersome, and fragile at their sleeve ends, they take time to assemble, and are rather difficult to raise for higher climbs. They have largely been replaced by the methods we just discussed. However, there are two situations in which scaling poles are virtually irreplaceable: when the rock is too soft or rotten for placing any protection, as in the presence of shale or dissolved limestone, and when the passage opens in the ceiling (unless you are willing to carry out a long ceiling climb).

A scaling pole consists of 8-10 cm diameter aluminum tubing sections, clamped together at the ends, with a cross at mid-height. Four cables are attached, passing through holes at the ends of the cross that act as stays. A scaling pole of this type construction may be up to 12 meters long. Attached to it is a flexible ladder, two support ropes for holding the pole in place, and a double belay rope, which sits in the carabiner that links the ladder and pole. It is erected so that its head sits lodged in the intended opening. Each support rope is held by a helper, forming a wide (as possible) "V" that will immobilize the top of the pole. Each side can be secured with either an ascender attached to the seat harness, or with a shoulder belay or Italian hitch. The climber, bottom belayed on the double rope, climbs the ladder. The most difficult moment is when he must leave the pole, but he remains safely belayed until he has set a viable anchor.

12.6 De-rigging the Route

Definitively

When the climb pays off, we place fixed rigging to allow easier access for subsequent explorations. The climbing protection is retrieved once the permanent rigging is in place. Anchors are hammered into the rock and covered with clay, as we do with any unusable anchors, leaving the site as "clean" as possible. As we've seen, the DBZs stay behind.

But the climber's efforts aren't always so well rewarded, and the desired objective ends before it even begins! In this case, we de-rig in the same trip, and the equipment is retrieved as described above. The last person descends using a pull-down method (see page 214) on one backed-up anchor, which will be abandoned. The team, in no way disheartened but rather enlightened by this new experience, concentrates on a new objective. It that one didn't go, the next one will. Hope is often our greatest motivator.

Temporarily

After an exploration, you can de-rig a climb and still reserve the possibility of coming back to it. To do this, rig a triangle as you would using cord technique (see page 218). However, you will need to fix the two lower angles to more solid anchors.

After each trip

It could happen that the climbing route turns into a waterfall during the wet season or during flood pulses. In such cases, fixed rigging should be installed out of the path of the waterfall if possible; if it's not, you will have to de-rig and rig the route again with each visit. Of course, you most likely didn't use stainless steel hardware during your first climb. Any steel anchors left in flowing water will rust and weaken rapidly, so you should re-rig the route and replace your anchors with stainless. Again, bury your original anchors as described above. For the new rigging, use Rainox anchors, which require a drill. These stainless self-drilling anchors are expensive, but they are virtually indestructible. They resemble spits and, like them, have the advantage of sitting flush with the wall. This minimizes their visual effect and prevents damage to the anchor from rockfall or impact from passing rocks during high floods. They make it easy to re-climb the wall each time, belayed from below, of course!

Another option is to seal in some stainless resin (eyebolt) anchors every two meters or so (excluding the first three anchors). In fact, you can increase your stretch in this case with the help of a piece of aluminum tubing. The fifi hook of an etrier, equipped with its retrieval cord, is strung to the end of this with some cord. With this, you can reach up and carefully hook the next eyebolt with the fifi. An old ski pole, cut down to a length that fits conveniently into a cave pack, is perfect for this use.

13. Aquatic or Active Systems

13.1 Prevention: Knowing the Weather

Underground, water is our muse: aside from the air that we cannot see, it's the only "living" element in this mineral world. But water can also kill, and it plays with a poker face. In wet caves, we have to play all our cards right, and our ace is knowing the local weather forecast.

Thanks to super-computers, which have the capacity to process a seemingly infinite amount of ever-changing data, weather forecasts in general have improved and refined considerably in recent years. The accuracy of short-term forecasts is quite good, and 5-day forecasts can even provide us with valuable information. In developed countries, you can obtain accurate and updated local weather reports by calling a toll number of the national weather service. The internet is also becoming a more reliable and convenient source for accurate weather information.

Of course, a forecast remains an estimation of a future event; the weather service unfortunately cannot always guess everything right because pure certainty doesn't exist in this domain. Storms in particular are too erratic and localized to allow us to predict exactly where they will break out. But the forecast can at least tell us if the risks are high on a given day, in a given locality. Depending on the objective we wish to reach, we'll attempt the adventure or not with the knowledge we have at our disposal.

13.2 Rigging in Stream Passages

Whether we are using cables or ropes, all hardware used in rigging should be resistant to corrosion and to wear caused by the endless oscillations of the rigging in the current during high water. Stainless steel is your only choice here.

Wire cables

We already spoke of these on page 100. Wire cable is permanent rigging that is only installed on traverses and over rivers that are frequently travelled. When crossing deep water in your pontonniere, it helps you keep your balance on the traverse and keeps you out of the water. In the latter case, the cable is fixed a few dozen centimeters above water level. Since zicral wears quickly on steel, use an intermediate steel carabiner on your cowstails when traversing cables. On short climbs, steep slopes, or above deep pools, you can use one cable for the feet, holding onto another traverse line that is rigged at about face level. To maintain good stability, the distance between consecutive anchor points should be short. As soon as the risk of a significant fall exists, any cable being used as a traverse line must be backed up with a rope: only the rope can absorb the energy of an eventual fall. Remember that the cable will also thrash about under water during floods: this will subject its anchors to similarly strong loads since it lacks any stretch or shock absorbing capacity, and thus it is never 100% safe.

Rope traverses

Rope traverses play a role like that of wire cables, but they are never left rigged unless they are placed out of flood range or above water that we are certain will not rise, even during floods. If we are mistaken about this, we'll know it when we find a frayed mess of strands in the place of our ropes! In new exploration, we generally use ropes where we would otherwise rig cables – it's all we have on hand. If the rope must hold the entire weight of their user, it is rigged just like a pitch head traverse; its ends in particular are backed up with a double anchor. This precaution isn't necessary if the line is placed near water level to hold us while crossing deep water. Buoyancy is at work, so the line takes less of a load.

No matter the situation, the traverse is always rigged so that the continuation is easily discernible. At each passage, the first person across can thus check that the rope and rigging are in good condition and rectify any problems if necessary.

On fixed lines, you can protect all anchor knots from abrasion using appropriately sized bands of – yes, you guessed it – rubber inner tube. This is an effective precaution not only against wear on the equipment from the constantly moving water, but also wear on all rigging that undergoes repeated use, even in dry passage.

13.3 Nautical Equipment

Inflatable Boats

This accessory is rather heavy and cumbersome, so we only use it for long trips through deep water, or to avoid using a pontonniere to get past the occasional lake.

Given the number of soakings we've seen accompanied by the cheers of onlookers, getting into a boat isn't so easy. It's not a very stable vessel, and it must not touch the bottom or the sides of the passage as you try to climb aboard. The best way we know to perform this delicate maneuver is as follows:

Once the boat is in the water, first put your pack in. Then you have two choices:

1. If the water isn't deep, take advantage of your waterproof boots and maybe some submerged stones to step over to the boat. Let's say you're holding it on your left side, with your right hand on the right side toward the bow. Straddle the right side of the craft, putting your left leg inside and against the left rear side. The left hand goes to the left bow side, opposite the right hand. Balancing (more or less) on these three contact points with the boat, and staying low to maintain your center of gravity, push off and board the craft, placing your right leg in the right rear (fig. 319).

Fig. 319 – Getting in

Key point:
Center yourself with each knee sitting against opposite sides of the boat, sit back on your heels, sit up and release your hands. If you leave your knees together, your weight distribution is too narrow and you will soon be off-balance, guaranteeing a somersault and a good soak as soon as you extend an arm out sideways.

2. If you board in deep water, you need to bring the boat to the bank and pull yourself up sideways or backwards. Keep both hands on the wall hold and bring each leg up and over the sides. Brace your knees on opposite sides, sit back on your heels, and let go of the bank.

If there are two passengers, it gets a bit more complicated. Once in the boat, the first person sits as far to the front as possible, with both cave packs sitting on top of each other between his spread knees. The second repeats the same operation as the first, getting into position with knees spread and placing his pack between them. Sails at nine!

Navigation is rather simple: your center of gravity must remain within your area of weight distribution, which is delineated by the points of the navigator's feet and spread knees. This area is thus smaller than the craft itself. Paddle forward using your hands if you are wearing long gloves. Use the walls to pull or push yourself along, but reach only with the arms; do not lean your chest out sideways as this may offset your balance. If you are sailing in a pair, don't lean to the same side!

Getting out is easier, but also has its method. Just do each maneuver backwards, according to whichever situation is present (deep or shallow water; fig. 320).

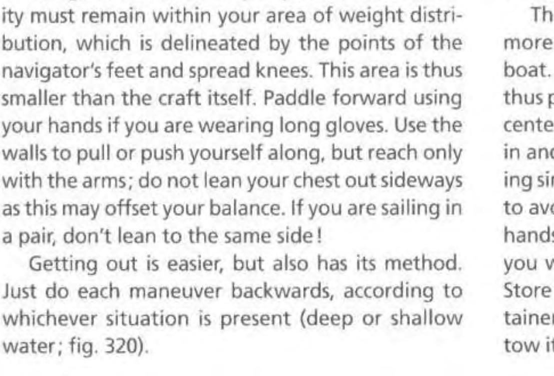


Fig. 320 – Getting out.

If the team is too large to fit in the boat, you need to run transport shuttles as necessary. Pulling the boat on a line saves some time, but be careful of zigzagging passage. Use a cord that floats and is twice the length of passage to be crossed, each end tied to an end of the boat. This creates a loop that can be linked to each end of the pool and allowed to slide through a carabiner. We recommend this system especially when several teams are travelling back and forth through the cave: wherever the boat is in relation to those who need it, it is easy to retrieve. The transport line helps to change the direction of the boat if it becomes stuck on something in the middle of the pool.

Key point:
If you are not using a looped cord, you can prevent the floating line from getting tangled at each end by leaving it to float on the surface instead of coiling it. This saves you both time and the frustration of untangling the mess. But don't let the end get away from you!

Buoys

The inflatable buoy (see page 107) is lighter, more compact, and quicker to inflate than the boat. This must be used with a pontonniere, and thus poses no problems for balance: the swimmer's center of gravity stays below water level. Getting in and out doesn't need explanation, and navigating simply requires that you keep your hands raised to avoid getting your arms wet. Paddling with the hands is a bit more difficult than with the boat if you want to avoid filling your gloves with water. Store the contents of your pack in a watertight container to keep them dry and to make it easier to tow it on the water on its tether. You can walk between two pools as long as they are not too far apart and you don't touch the cave walls: the buoy is not very resistant to abrasion.

Finally, you can also retrieve a buoy on a transport line, as described for the boat.

13.4 Rivers with Strong Currents

In temperate climates we rarely find a river powerful enough to sweep away the person who dares to cross it. The exception is of course flood pulses, but the golden rule in this case is to "wait it out" until the water returns to its normal level. In tropical caves, however, strong rivers abound in the presence of very high precipitation; fortunately, their higher water temperature is more forgiving. In any event, techniques exist for dealing with these subterranean rivers.

Travelling along the bank

High water with strong currents should compel us to travel out of the water, if at all possible, for several good reasons. The most obvious is the risk of being swept away and drowning if you are caught in an undertow or between boulders, etc. High water volumes also fluctuate considerably and rapidly according to surface rainfall, which may occur daily. The danger obviously increases as you travel downstream. Even if you are not carried off, rising water could prevent a safe return. Place some markers in key passages for help in referencing changes in water level on the return. Another risk comes from the noise created by the sheer volume of water, which swallows the sound of oncoming rapids or waterfalls. You risk being pulled into these without warning if you are travelling in the current. Finally, even if the water isn't cold, the swiftly moving water sucks away our warmth and energy more quickly than a normal current, given the same amount of time in the water. If you immerse yourself completely, your body will soon be tapping its reserves.

The general rule is therefore to stay out of the water as long as possible.

Crossing the current

When the bank you've been traversing comes to a sudden end while the opposite side continues, it's time to cross. You have several possibilities:

- Swim. This requires lifejacket and a safety belay, and usually a wetsuit. A belayer (or even two) takes a position downstream at a distance that at least equals the width of the river, and with enough rope to be prepared for any possible problems. The swimmer is attached by a clove hitch around the wrist (fig. 321). He tries crossing, without attempting to swim upstream against the current, and must be a strong and fast swimmer. If he can't make it, the belayer hauls him back to the bank.
- Stay out of the water. You can sometimes cross on boulders for part or all of the traverse. Belaying is still the rule, and it could be necessary to place some anchors along the way.
- Throw a grappling hook. Fix it securely to the rope and spin it around a few times above your head before throwing it with all your force toward the opposite bank. Assuming it reaches its destination, it still needs to catch firmly on something...this often requires several attempts. Once it's hooked onto a solid hold that has been duly tested, you have two possibilities. If it's necessary to cross in the water, the guideline is tensioned at an angle across the river with the hook end downstream (fig. 322). The current thus helps pull the swimmers across. If you can manage to rig a tyrolean traverse, the support rope is tensioned as short as possible, perpendicular to the river's flow, to reduce sag in the line (fig. 323).

In both situations, the person who volunteers to rig the traverse should be outfitted with a wetsuit and lifejacket and belayed at the wrist with his belayer downstream, as described above. He clips

Fig. 321 – Crossing the current on a safety belay

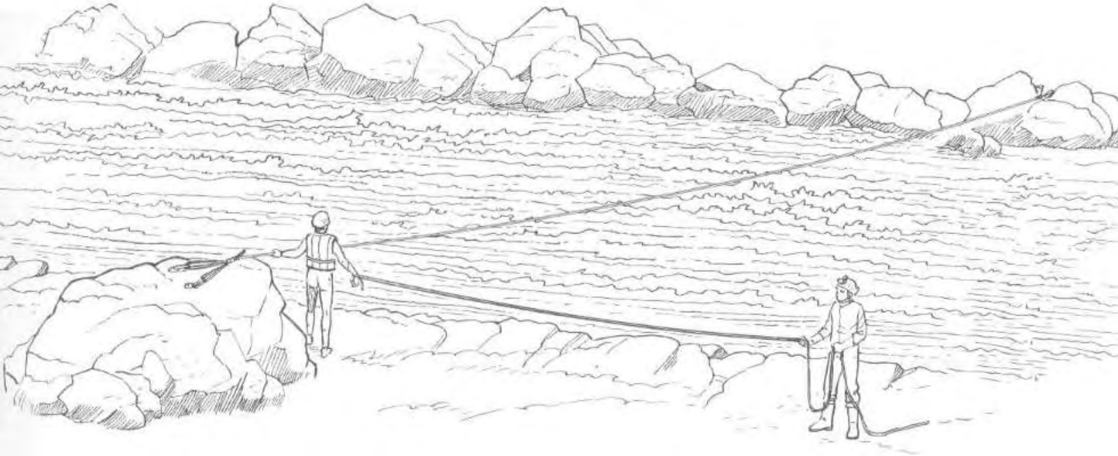


Fig. 322 – Crossing the current using a guideline.

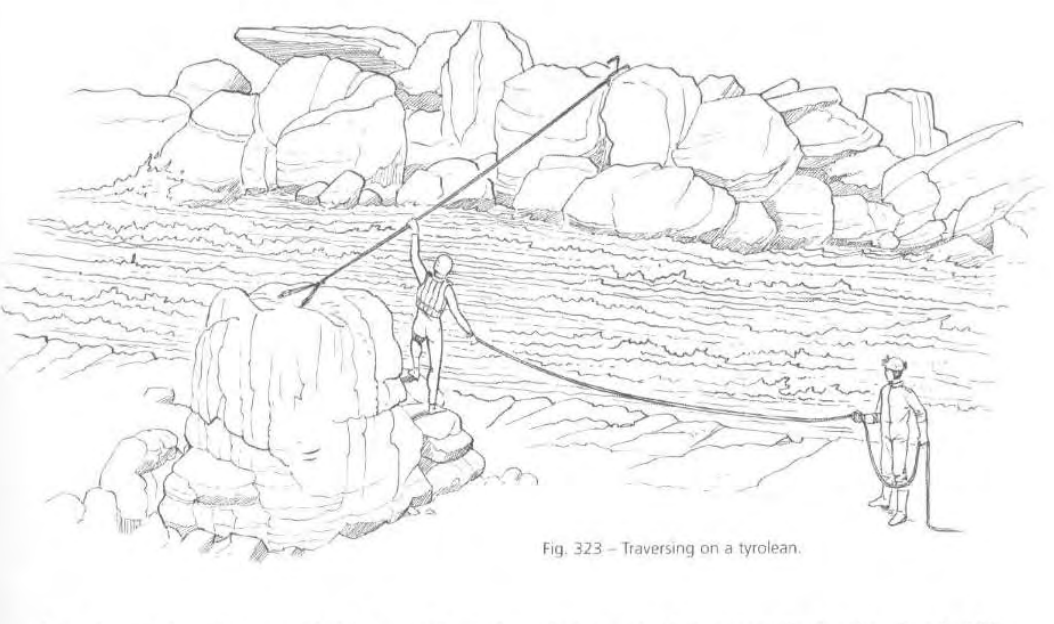
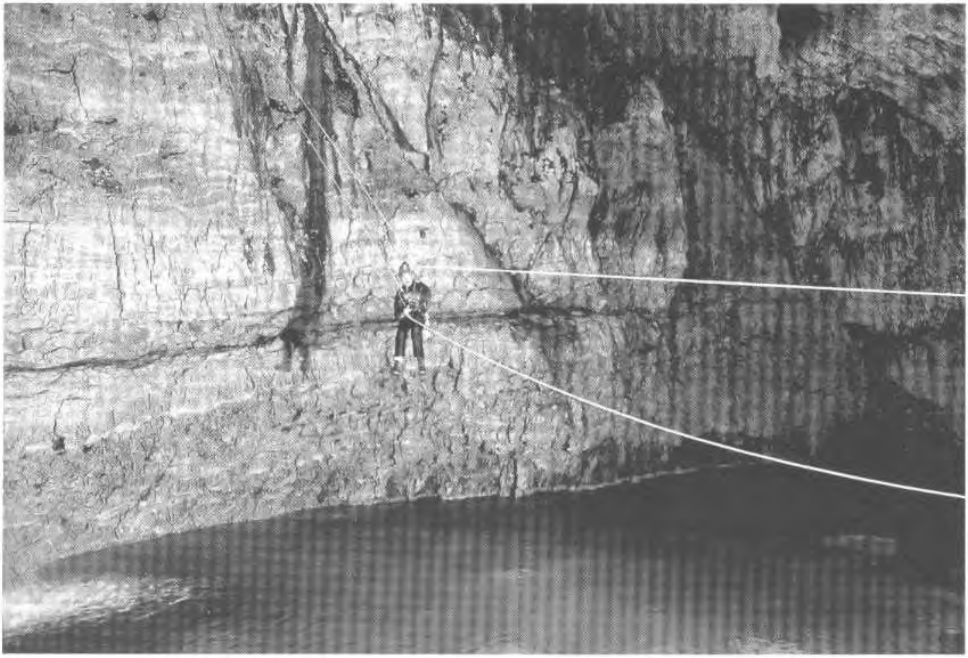


Fig. 323 – Traversing on a tyrolean.

into the tensioned rope with his cowstails and launches into the traverse, pulling himself along on the rope or with help of his ascenders.

Climbing

If both banks are steep or vertical, free or aid climbing may be necessary. It could take much time and equipment to rig such passages, and the thundering water below complicates the already difficult maneuvers: you may need to use hand gestures to communicate. Using pendulums or redirections, fissures, throwing the rope into the water... all of these solutions can work to your advantage. An additional hazard is often soft or shattered rock, which calls for extra care when traversing and rigging these sections.



Muruk Hul, Papua New Guinea. Photo J.P. Sounier

13.5 Wet Pitches

A pitch may be wet permanently or only during periods of high water. The latter case is more dangerous if the heedless explorer is not cautious when he arrives during a dry period. In fact, there is always some indication left by the water: clean walls that have been polished by pebbles, sand and clay carried in the water. Larger rocks not carried away are left clean and smooth. Beware! Even if it is dry at the moment, the pitch should be rigged as if it were wet, with the rope as far as possible from the supposed path of water. If you have had the opportunity to climb in a waterfall up a pitch that was dry just a few hours earlier, you'll remember the force of water on your shoulders, lashing around your face, and getting into your suit to eventually find its way down into your boots. You won't get caught again in the same situation. During high water, waiting below partially sheltered from the icy air and the roar of the spray, you'll have plenty of time to consider how best to re-rig this accursed pitch, which you just never got around to doing before... Anticipate high water when you rig the first time and overestimate its eventual flow and possible flood trajectory. Consider the preceding gallery and how flood waters may enter the pitch. Look at the pitch configuration for possible rope and rebelay placements. Sometimes the pitch simply offers no alternate "dry" rigging. We will discuss this situation later.

If the pitch is wide, it's no use trying to redirect the path of falling water; the only logical choice is to stay out of it. Several possibilities exist for rigging out of the water. These depend on the configuration of the pitch, how you see the path of water and how you anticipate its trajectory during high flow.

13.5.1 Traverse lines

At the lip of the drop, continue rigging out horizontally from the column of water. If there is a ledge along the wall, use it (fig. 324). If not, you will have to use aid climbing techniques to rig. If there are no footholds, placing a footloop at each anchor point will make them easier to pass. Even if there is little or no water at the moment, you may often choose to rig a traverse, just to be safe. Again, try to anticipate the potential flood, taking into account the winds and spray that will accompany it.

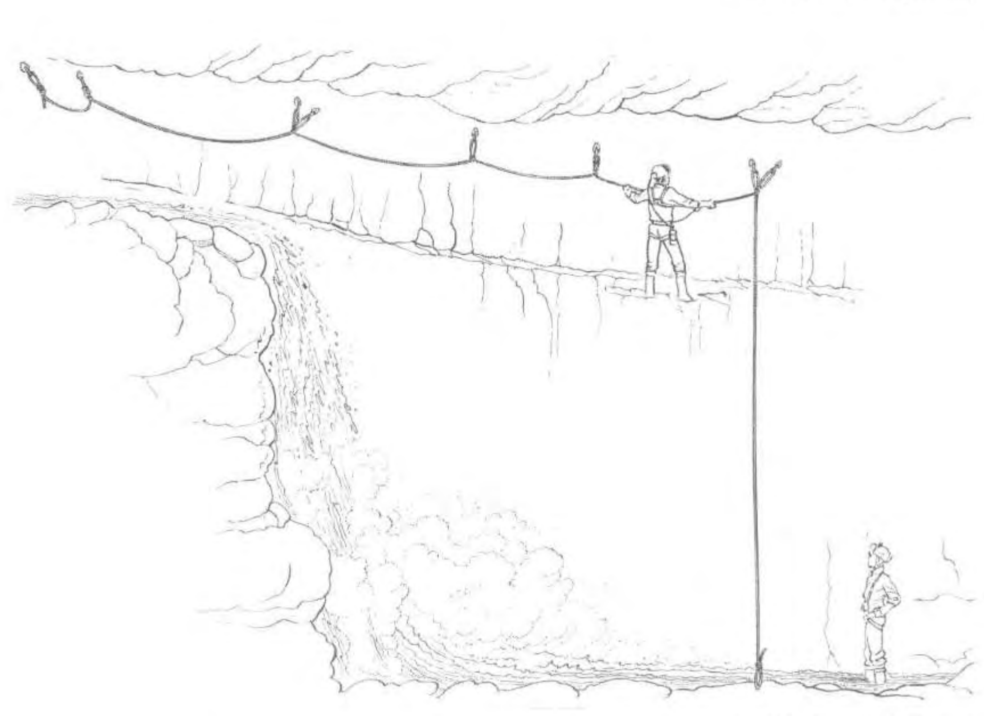


Fig. 324 – Traversing to the pitch head using a natural ledge.

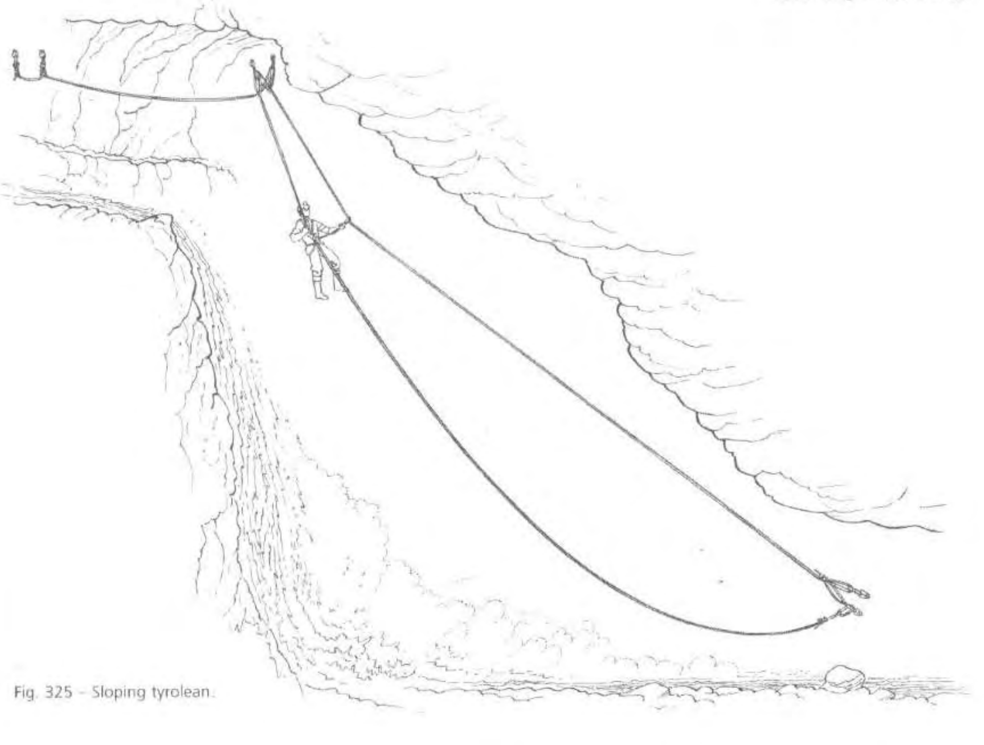


Fig. 325 – Sloping tyrolean.

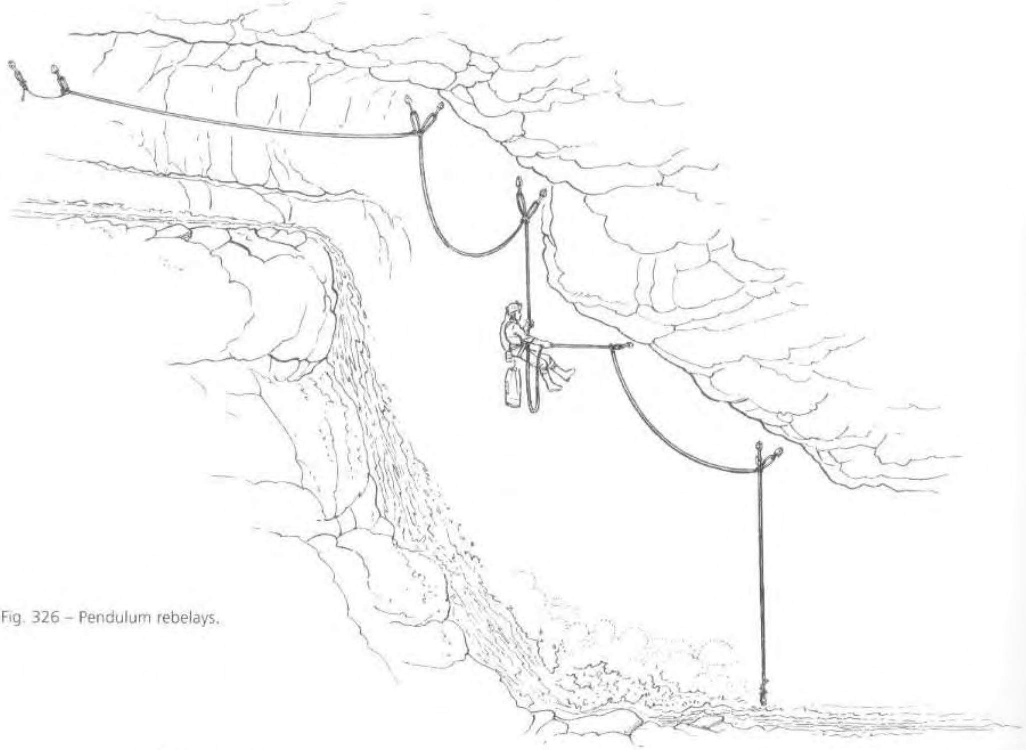


Fig. 326 – Pendulum rebelays.

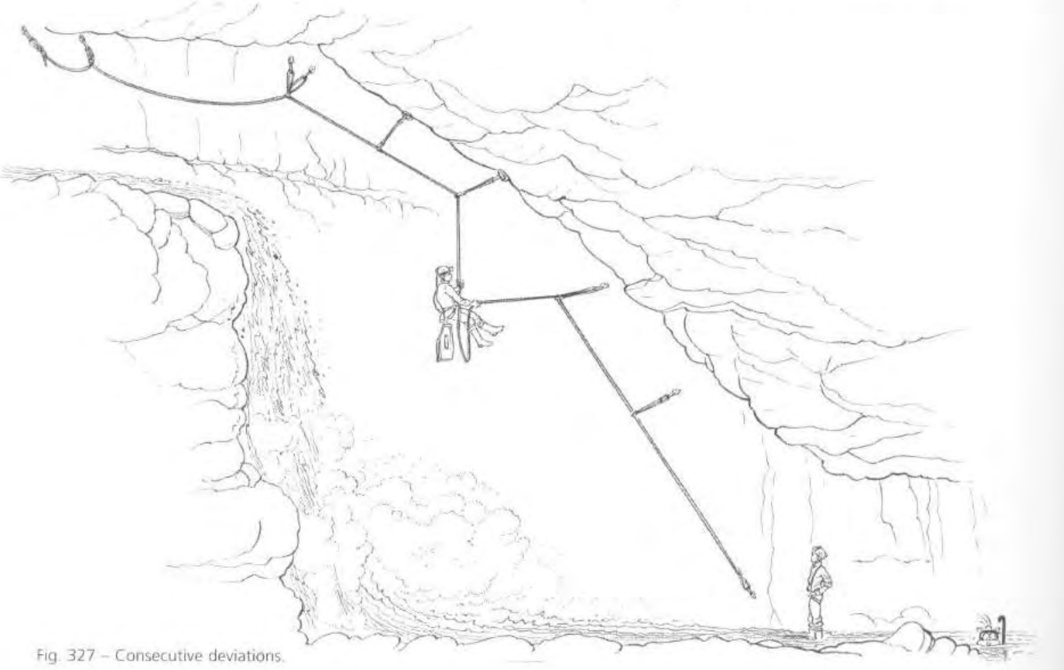


Fig. 327 – Consecutive deviations.

Fig. 328 – Channeling the water with a plastic sheet.

13.5.2 Sloping tyrolean

An auxiliary rope is tensioned at an angle in the pitch. When descending and climbing – which takes place on the primary slack rope – clip your short cowstail into the tensioned line, which holds you out of the spray (fig. 325). The slack line should be kept out of the water as much as possible or it will wear rapidly. On rappel, the last person down should pull it over and attach it to the tensioned auxiliary rope. On the return, the last to climb should coil and attach it at the pitch head, where it will await the next group.

13.5.3 Pendulum rebelay

You may choose instead to rig a pendulum to stay out of the spray (fig. 326). A skyhook can help you keep your stance while placing the first anchor. Though swinging back and forth in a dry pitch may be harmless, doing so under strong water is entirely another matter. When the pendulum is wide, always back up the anchors: rock that is exposed to frequent spray is often weaker.

13.5.4 Consecutive deviations

You can also install deviations as necessary to hold the traveler out of the line of water and its surrounding spray. If good anchor points in the wall are abundant, rigging deviations is faster than a traverse line, though progress may be a bit more sporting, depending on the angles of the deviations. Remember also that travel time for larger teams is longer than with rebelays since only one person at a time can travel the rope.

The rope must be anchored at the bottom of the pitch (away from the water) so that the user can pull on the rope while passing each deviation (fig. 327).

13.5.5 Water-filled pitches

When water fills the pitch, you only have three choices:

1. If the flow is weak, make use of the (supposed) good condition of your caving attire and its relative impermeability. Those who carefully repair each tear in their caving suits will see their efforts rewarded here. The caving suit hood, long PVC or rubber gloves, a rubber band on each boot, and a wide Velcro closure on your suit will keep you relatively dry for the task.
2. If the flow is stronger, wear a pontonniere and latex cagoule under your caving suit. This is an effective accessory but it takes time to put on and take off, and should only be used to carry out a preliminary reconnaissance of the passage and its continuation below. The brave volunteer will descend with his ascending system in place. Every five meters, he stops long enough to determine whether the growing force of the falling water on his head and shoulders might endanger his climb, in which case he changes over and begins climbing as quickly as possible.
3. If "it goes" you are now faced with deviating or channeling the flow of water. This is only possible for flows under five or six liters per second, otherwise the force of water is too strong and nothing will hold for long. We channel the water by hanging a large plastic sheet at the waterfall; the water will tend to follow this, which will minimize its spray (fig. 328). You can also

place a piece of waterproof canvass tarp (or similar material) anchored with stones to contain the water between it and the wall. Such a device is difficult to adjust and should only remain in place the time it takes the team to descend, explore and climb back up the pitch. It will be torn to shreds if left in place for long.

Key Point:

Never underestimate the strength of the waterfall during your rappel, and never attempt to climb in a waterfall during high water. The consequences can be and have been fatal.

14. Enlarging a Cave Passage

When a passage is too narrow to allow the explorers to pass, it may be time to enlarge it. We have thousands of examples where enlarging tiny constrictions has given access to immense systems. The main clue is often a strong airflow through the break in the rock, which may (or may not!) indicate the presence of another entrance or large chambers beyond. This is why we often put so much effort into digging open these constrictions. Some "digs" even deserve to be called construction sites: here, you will find shovels, picks, crowbars, tracks, trolleys, and even generator-powered tools.

There are many cavers out there having more years and bigger bellies who have specialized in this domain, and could write volumes on the subject! In alpine caving, we won't deal with such colossal works, but will remain in the domain of digs that do not require the extensive use of explosives or power tools. We will leave out the former because it is a subject for specialists; we will leave out the latter because we rarely consider transporting so much equipment to remote mountain caves. Besides, alpine karren fields often provide a more pleasant alternative when we are faced with impossible constrictions: ah, the call of new, unexplored entrances...

When you begin enlarging a constriction, whether this consists of removing breakdown or getting through solid rock, keep in mind that we are going to alter the site. Constrictions that play a role in speleogenesis (or karstogenesis) can be useful for specialists and so require a preliminary site evaluation accompanied by photo documentation.

14.1 Digging Manually

Rock hammer

The rock hammer helps us through a lot of work, like removing thin flowstone layers, breaking up stones and boulders, taking out rimstones, formations or other features that chock the passage. An effective hammer weighs about a kilogram. Below this weight, it doesn't carry enough force to back up a good blow, and we need this since we are usually working in a relatively confined space and have little room for a good swing. Above this weight, it is too heavy to handle effectively in positions that are often a bit awkward. The best model has a composite handle, which is light, waterproof, shock absorbing and doesn't come off.

Chisel, pick and crowbar

The chisel and pick extend the effective use of the hammer and help in reaching holes and fissures. They are perfect for use in fractured or flaked rock, as long as their user has a minimum of skill. Don't dismiss a rubber hand guard: a good solid blow of the hammer is painful and disabling. The crowbar helps you move and extract what the other tools shatter and break apart. Choose a model that is short enough to fit inside your cave pack.

To avoid losing these tools, attach them to a cord tether with a rubber inner tube ring in the middle.

To do:

Carry the chisel, pick and crowbar in a large rubber inner tube, closed at both ends with a rubber band. This will prevent them from piercing the pack when it bangs against hard rock. Attach their tether to the pack tether or closure cord to prevent any possibility for these heavy, blunt objects to escape the pack.

Rock wedges (plug and feathers, rock poppers)

This is a flat wedging device that is hammered between two counter-wedges in a hole. It causes the rock to compress in the sides of the hole, then fracture along the fissures in the rock. For greater effectiveness, use at least two sets of wedges placed in nearby holes and hammer alternately on each. The holes, which are drilled, are about 16-18 mm in diameter and 150 mm deep. Rock wedges are quite effective in hard rock, especially if you can place them along the same fracture. They aren't as spectacular as dynamite, but they don't create harmful gases or shock waves, and they have no purchasing restrictions...

Expansion cement

This cement expands as it hardens using a mixture of two reactants. We recommend it for use in areas that are more sensitive to shock waves, as near breakdown and fragile formations. But it requires descending holes to be drilled, into which the mixture is introduced and sits to harden. This product is rarely used because it is expensive and slow to show its results: complete expansion takes about 24 hours.

14.2 Use of Explosives

Because they are highly effective in the more difficult situations, and particularly in the case of compact rock, we often prefer using explosives to any other means. However, their constraints are numerous. Their sale, storage, transport and use is strictly controlled and if you intend to work with them legally, you must be ready to go through some long and complicated permit procedures.

Moreover, explosives are clearly hazardous outside their precise protocols for handling and use. The dangers are twofold:

- the shock waves that are capable of breaking rock can much more easily break eardrums and body parts.
- they give off fumes that can asphyxiate an amateur like a fox in its hole. Such a risk (also fatal) exists immediately after an explosion and can persist for days and even weeks if the area is not well ventilated.

What NOT to do:

Never use a fuel-powered drill for drilling underground unless the area is very well ventilated. These machines emit very hazardous fumes that have sent their careless users to the hospital for weeks.

All of these hazards and constraints mean that one should never improvise or build homemade explosives. In Europe, anyone who wants to work with explosives must complete a formal training program, with a specialization in underground use. Such training programs are organized regularly and completion is awarded with a diploma. In France, cavers are welcomed to participate in them, especially if they are introduced by a Technical Advisor of the local cave rescue section, which can sometimes tap into subsidies to help pay for the certification.

Finally, we must recognize that any use of explosives in a cave results in damage to its environment. To avoid widespread damage, explosives should be kept to a strict minimum, limited only to the immediate passage to be enlarged.

Nail gun charges

We will mention these as a preventative measure since the method may seem relatively simple and safe.

Some explosive are available on the market in small quantities, an example being nail gun clips, also know as fixing guns. These guns should not be used underground, but their cartridges may be used for smaller projects, particularly for breaking up large rocks or boulders. You need a special hand driver that can set off one or several charges placed in a previously drilled hole when hit with a hammer.

Though this method is accessible to anyone, it can still be dangerous. The driver must be made according to very precise guidelines, and the method requires rigorous implementation and effective protection (safety glasses, gloves, rubber protector on and around the drill hole) since we remain only a short distance from the explosion site. Drivers have been launched like rockets into space before dumbfounded amateurs who were fortunate enough to escape serious harm. Even with such small charges, persons without experience should not use these explosives; find a specialist.

14.3 Moving Large Boulders

You will sometimes find a large boulder blocking a pitch head or narrow passage. Gird this with a piece of rope or webbing, or place an anchor in it, attached to a hauling ring. Then extract the rock using a manual cable winch such as the Tirfor, or a rope haul system.

You can divide the weight to be pulled by two by lifting the load with a pulley attached to a fixed point on one end and pulled vertically from the other end. It is best to add an ascender so you can hold the load while resting (fig. 329 A and B). In reality, we save 40% rather then 50% due to friction. If the shape of the passage requires us to pull at an angle, our mechanical advantage is considerably reduced. In this case, add another pulley on top so that the two strands of rope directly supporting the load are parallel.

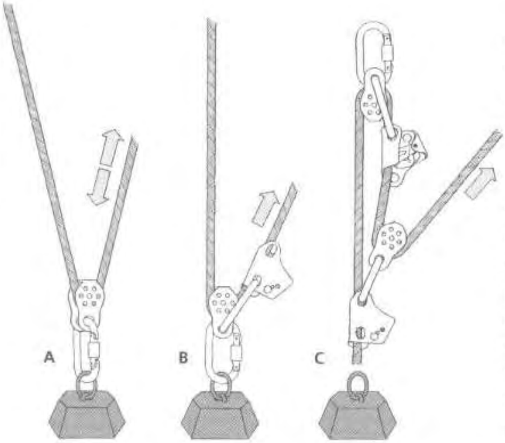


Fig. 329 – Various ways to raise a load.

The classic twin pulley-ascender system (3:1 haul system; fig. 329 C) theoretically reduces the load to be hauled by one third, given it is pulled in the same direction as the load being hauled. In reality, we hardly reach more than half. You can improve your advantage by using pulleys with ball bearings, and decrease the necessary force with each additional pulley. As for the two pulleys in question, the Petzl Tandem allows you to quickly install an effective haul system. "All-in-one" self-jamming pulleys such as the Mini Traxion and Traxion (see fig. 108, page 105) are convenient and easy to use, and have an anti-return cam that acts directly on the rope to the right of the pulley. This prevents any slip in the rope and makes it easy to release the load again for hauling.

What NOT to do:

Never leave your hands near the stone being hauled, as it can sometimes pivot without warning. As an example, two explorers were struggling with a boulder that was jammed at a pitch head, blocking a passage that echoed loudly with a strong air current. They worked together, one pushing with his feet, the other with his hands. Finally the boulder turned on itself and then disappeared into the darkness below, smashing loudly to the bottom and sending up a strong odor of pulverized rock. The passage was open! But the first caver's excitement was cut off when he saw his friend's pale-white expression. When it pivoted, the boulder had crushed one of his thumbs, which was swelling with excruciating pain. For the victim, the adventure ended in the emergency room after a lethargic two hours' hike.

14.4 Excavating Vertical Entrances

"Digging out" a vertical cave entrance from the surface involves similar techniques to those just described. In addition to all other equipment, you will need a loading tripod or gallows that can support the haul pulley, and a container to hold the material that has been excavated. Working on the surface, we can use heavier tools and machinery than we could normally use underground. In particular, it make it possible to use a generator to power an electric winch. This saves a great deal of time and permits a much larger excavation, such as we would never even consider undertaking in the cave.

To do:

Filled surface pits often contain archeological and paleontological remains: proceed with caution. In case of discovery, you should stop the dig immediately and notify the appropriate authorities. Specialists will know how to evaluate the potential significance of the find and of the site. It is better to bother them for what turns out to be nothing than to upset an entire deposit layer that will consequently lose most of its significance.

14.5 Excavating in Breakdown

A pile of rocks accumulated below a pitch or fracture could completely obstruct a passage, but excavating in breakdown from below can be difficult and dangerous work. Compare it to taking apart a wall from the bottom up! It is important to first approach the beast from a distance, using a crowbar attached to a rope. Place the bar carefully in between the rocks and then work it like a lever by pulling from a good distance. Destabilized, the breakdown will come falling down until it finds a new place of rest, which will depend on some complex factors: the size and shape of the rocks, height of the blockage, the distance between the rocks, etc. With each new collapse, remove the rocks that do not touch the breakdown pile, and begin the maneuver again.

If you lack adequate distance, a specialist could trigger some explosives from a safe place, but it could happen that nothing even budges. Beware! It is safest not to touch anything, and leave the breakdown some time to settle if it is going to do so. In the meantime, check elsewhere for possible ways around the obstacle, and come back on a later trip to check the situation.

14.6 Gravel and Clay

Digging out gravel and clay is relatively easy (unless the clay is very moist). All you need is your hands, a pick-axe and a collapsible shovel.

Again, remember that your "dig" could yield some interesting paleoclimatic information, or microforms that could be of interest to specialists (drip-tube pits, mud stalagmites, varves). Don't hesitate to seek advice when in doubt. Also, choose a clean site for depositing your rubble.

This accumulated rubble could eventually become a problem: after being dug out and decompressed, it always takes up more space.

If after a preliminary evaluation – with serious thought to the ins and outs of the situation – you decide to go for it, don't hesitate to "think big." Try to work comfortably or you won't be efficient. To evacuate to an area behind your dig site, shuttle the material in a cart made from a large plastic container cut in half, or a plastic sled, pulled back and forth on a rope attached to it. This method is simple and convenient.

To do:

Dig along one wall to prevent the finer particles from sliding constantly down.

When doing this kind of work, it is best to work in relay teams to keep up motivation and stamina. Decide on a set time or number of rounds that you plan to work, and stick to it; it's no use getting too obsessive about it. Some plugs never give way!

14.7 Draining Sumps (Siphons)

Many cave passages end in a sump, or siphon, that has a small in-feeder or none at all, and geologic indicators often convince us to seek a possible continuation. Diving (see below) sometimes brings us to our desired extensions. In other instances, the pool may shrink during drier periods, leaving a strong air current to ripple its surface – proof enough that the cave doesn't end there! It's time to consider draining the sump to allow further ex-

Trou de l'Aygue. Photo S. Caillault

ploration beyond. If this pool is small with little water, you could just use a boot, but this method definitely has its limits. At the other extreme, some larger reservoirs, whether they are fed by an obvious stream or not, require strong generator-powered pumps connected to large hoses. We won't go into detail about these techniques, since they are closer to civil engineering than to our more homemade solutions.

Though they are quite simple, manual drainage techniques are not so well known among cavers, and rarely used, so we will stop here for an explanation.

The explorer's first tendency is often toward using explosives if possible; that is, if the edge of the sump is rather vertical and not too thick, or if the ceiling seems to be rather a flake of hanging rock. However, this solution shows little respect for the integrity of the cave, and it can permanently modify the air pressure and circulation in the cavity since the ceiling will never touch water again. It will also result in some ugly damage to the rock: what was once a beautiful rimstone dam has now become a sharply mangled crest. It's a poor situation when the ethics that we should be defending find no place in our own acts. Cavers do not have to destroy caves under the pretext of exploration; they have a responsibility to protect rather than abuse them.

And there is in fact a better solution: draining a sump is an entirely reversible technique, unless there is absolutely no water – not a drop or a trickle – feeding into the pool. This is practically impossible since the pool would have evaporated long before. Draining protects the cave's integrity, and is operational in a wider variety of situations than blasting: rim shapes are no problem, even if these are several meters thick or high.

Basics

The basic principle is well known: a hose is placed in the pool and rolled out over its rim and to some point lower than water level, creating an inverse sump with the help of gravity. Once the draining begins, if the rate of drainage is greater than the rate of supply, the sump will inevitably drain.

The force that drains the pool is equal to the weight (W) of water contained in the hose between the water level in the sump (S) and the lower drain end of the hose (D) (fig. 330). This force can therefore only diminish during drainage. At all times, the higher the (W) value, the more rapidly the water drains. This is an important point, either to help us cut down on our waiting time or to help deal with an excessive supply, as after a flood for example. To evacuate the water more quickly, use a larger hose (or place more hoses), and/or increase the height (h) by lowering the drain end (D), if the configuration of the passage allows it.

When the water level in the sump (S) reaches the level of the drain end of the hose (D), water stops flowing out because (h) and (W) both equal zero. The former sump may have now completely drained, unless the lower extremity (D) is not lower than the bottom of the sump. Depending on the available space between the lower water level and the ceiling, this partial drainage may still be enough

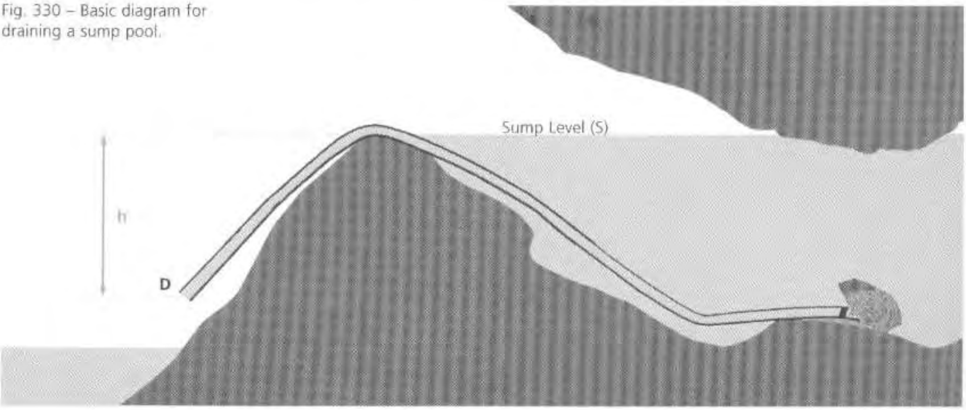


Fig. 330 – Basic diagram for draining a sump pool.

Fig. 331 – Backflow begins when a drop forms at the mouth of the hose.

to pass the sump, though at the cost of a cold dip in water.

Either way, we've now solved that problem, but we find it has triggered another one: when the water stops flowing in the drain hose, it cannot remain in equilibrium above the air it hangs over at (D). A drop forms, water starts to stream back down, the hose "backs up" and empties (fig. 331). Since flow from the hose diminishes as (h) diminishes, this backflow starts to occur before (S) reaches the level of (D): drainage is incomplete, and more so as the diameter of the hose increases.

There is an annoying consequence to all this: if the sump begins receiving water soon after, for example after a sudden storm or during a wet season, the level (S) goes back up and the sump soon returns to its original state. Time to start over!

You need a more effective tool if you want to avoid breaking your neck emptying the refilled sump the following weekend, or camping out in the cave to wait for it to slowly drain... or getting trapped behind the sump that has filled back up while you were off exploring!

Feasibility

Of course, draining the sump isn't always a possibility.

The first limitation arises from the atmospheric pressure in the cave. This corresponds to the weight of the air filling the space above us, which equals that of a column of water about ten meters high. If the rim of the sump to be drained is more than ten meters above the water level, backflow in the hose will begin automatically. The only alternative is to use a generator-powered vacuum pump.

The second limitation is that you need a place to put the water that is being drained; this should be relatively close to the drainage site, situated below the sump, and large enough to hold the water being evacuated (these conditions also apply to using explosives). The last problem concerns the amount of water that needs to be drained when the sump has an in-feeder: the hose must empty the sump faster than its natural supply can refill it. In this case, you can start by using larger piping. Rigid 100-mm PVC sectional piping can still be transported (but with care since it can break, especially when cold). Prepare the end clamps beforehand (straight or bent) and glue them in place. With this, you can easily drain more than a liter per second, which will open up many watery gates. Another option is to set up several hoses in parallel.

Installation

Aside from instances of high flow, you will generally use soft hose, flexible enough to be carried in a roll and take the necessary shape when being placed. It should, however, be rigid enough to not to bend and fold when placed over the rim. It should be free of any leak hole, however small, to prevent the dreaded backup effect. Plymouth hoses are well suited to our needs, especially since they can be fitted with watertight seals for extending the length.

On site, the upper (sump) end of the hose is held down with a rock, fixed to it with a nylon cord using a prussik knot.

What NOT to do:

It is tiring and useless to try starting the draining action by sucking in from the lower end.

The more efficient solution is to fill the hose completely by gradually submerging its length in the sump, holding the upper end under water. When the hose is full, close both ends with some cork plugs designed for this purpose and fixed to the hose with prussiks. These cords should be tensioned well because pressure from the water in the hose will "push" on them quite a lot during the subsequent installation. No air bubbles should be allowed in while you are filling the hose, which can be difficult if the sump is narrow and the hose is rigid.

If this is the case, unroll the hose on a continuous slope, without any high point where air can accumulate, and then plug its lower end tightly. Its upper end is brought toward the sump, to a point below it. Use a small auxiliary hose having a smaller diameter than the main hose, which allows the smaller to fit inside the main hose. Start draining as described above, placing the hose underwater and then plugging both ends. When it is in place on the rim, unplug its upper end (which is of course under water), and then the lower end. When the inverse sump begins draining, put the lower end of the auxiliary hose into the upper end of the main hose, and leave it to fill.

When this is complete, plug the main hose at its upper end, then pull it to its destination in the sump. Tie its upper end down with a rock and submerge it.

Whatever method you use to fill the hose, if the height between the upper and lower ends is significant, the lower hose plug may quickly come out. You then need to bring up the lower end to diminish the pressure in the hose.

On the high end, unplug the hose underwater and move it to the deepest part of the sump. Estimate the depth at which you wish to stop draining, for example 80 cm. Once you reach this depth, the upper end of the hose must remain below the new water level; otherwise, the hose will back up and the sump will refill. It is better to underestimate the depth of the water being drained and risk having to return at a later date to finish job, after moving the hose forward and deeper into the sump.

Back at the lower end of the hose, raise this so as the position the cork upwards, then remove it. A stream of water will erupt, indicating that the sump is beginning to drain. Slowly raise the lower end of the hose until the water stops running out of it: you are now level with the water in the sump. Mark this level and then lower the hose end the desired 80 cm to adjust the level where you wish the water to stabilize when drainage is complete. Using yet another prussik knot, attach the hose end at this level to a nearby wall.

The tool is now installed. Starting from upstream, the first half of the hose now forms a reverse sump (inverted U-shape) and the second half of the hose forms a normal sump (U-shape) towards the receiving pool. When water in the sump reaches the desired level, it will stop draining.

Key Point:
With the hose opening held higher, this remains full of water, so there is no spontaneous backup and no partial drainage!

This technique works for all situations. It matters little if the rim of the pool is vertical (gours, perched basins) or horizontal (sloping leads). Whether the hose is soft or rigid changes nothing, nor does the amount of water feeding the sump. If a flood pulse or the wet season arrives, there's no problem: the contraption will sink until the next dry spell, begin draining the sump automatically, and patiently await the arrival of the explorers... The only condition is that both ends of the hose must be fixed solidly enough to prevent them moving about in the sometimes turbulent water.

When access is from upstream

Without explicitly saying it, the preceding discussion assumed arrival at the sump from its downstream end, and this is by far the more convenient situation. In fact, we approach the sump on the side where drainage is possible.

Arriving at the upstream end, we are not so fortunate. We might be lucky enough to come upon a lowered sump during an exceptional dry period and rig the passage for future explorations. One alpine cave had us dispatching bucket, trowel, quick drying cement, 100-mm PVC hose, attachments, fixing wire, etc. to secure passage through a sump that only emptied during especially long, dry periods, and filled with the first rainfall.

We may also send in divers to check the lead, if the sump is large enough and if it seems worth the work. Otherwise, it's useless to expect miracles, since they don't happen often!

A nice succession of pits led some explorers one day to –300 m, into a vast breakdown chamber. At the end of this a little stream trickled and led, with a mocking gurgle, to a final shallow pool that put an end to the explorers' hopes. Some angered kicks with their boots did nothing but soak their socks and loosen some clouds of clay into the mirror of water. When they returned to de-rig, the craziest among them had come up with the extravagant idea to poke around in the water with a ski pole. He probed with determination, under the mocking regard of his companions, when a vortex suddenly began, accompanied by a sucking sound. Before the eyes of the excited actor and his dumbfounded spectators, huge bubbles broke on the water surface as it began sinking, and suddenly the pool emptied out, replace by a strong air flow. After two enthusiastic digging trips, they popped out into a borehole that led them to –700...

Proof that where there's nothing ventured, there's nothing gained!

15. Cave Diving

There are two basic categories of cave divers: those who see their activity as an end, and those who see it as a means.

In the former group, we are dealing with divers who specialize in long and deep dives, who defend it as a separate activity altogether, and who would be almost disappointed to break the mirrored ceiling at the end of a sump!

For the latter group, diving is in the interest of caving: its purpose is to do one's best to get past this obstacle, just like any other, to reach the dry passage beyond and continue the exploration. This kind of cave diving has helped us discover incredibly vast systems, or continue the exploration of deep alpine caves. In some regions, it has even become illusory to expect to find new cave without diving at some point.

This categorization is naturally somewhat caricatured since some cave divers happily practice both kinds of diving. Whatever the case may be, cave diving requires sophisticated gear and highly specialized techniques, all of which is put to use in an unforgiving environment where the slightest human or mechanical error could well be fatal. It goes without saying that we are dealing with an extremely high-risk activity. This discipline is strictly reserve for specialists and therefore a discussion of cave diving techniques has no place in this manual. We do not consider cave (sump) diving to be a part of alpine caving techniques.

So if you encounter one of these walls of water during the course of your explorations, seek the help of an experienced cave diver to get an idea of what you're dealing with. He may come dripping back to inform you that it's an easy dive followed by vast extensions of dry cave, but he could only explore the first few hundred meters since he had no gear. Divided between admiration and envy, you may be tempted to go there yourself and explore the new cave. Anyway, you deserve the triumph, after all the hell you've been through in this system...

In this case – and if the draining techniques that we've just discussed do not apply – we have only one piece of advice: go join a club whose competence in cave diving is known and respected. Take the classes and get some practice before pursuing your lead. Any attempts at "independent learning" can only result – in the best case scenario and without mentioning the worst – in cruel disillusion.

Papua New Guinea. Photo J.P. Sounier

L Exploration

Once you have mastered the techniques described in the previous chapter, a new world of explora tion is within your grasp. But it would be naive to believe that good caving technique is enough in itself to guarantee a successful exploration. You still need to know how to organize and prepare for it... You have to obtain access, gather information on the geologic or hydrologic characteristics of the system or the area to be explored, and decide how many people and how much equipment you will need to explore the cave.

You obviously don't prepare for a "push trip" into a vertical cave the same way you prepare to visit a known classic. Of course, some factors remain the same for both, and even well-known caves still retain some aspect of mystery and discovery (which is what makes caving so challenging and enjoyable). Topographical maps don't always tell all, and water flows can vary considerably according to the season and the weather. The cave topography can even change after a particularly severe flood: cave fills are rearranged, new pools or obstructions may appear and breakdown areas can wash away. Still, trip preparation will vary according to whether the destination is new cave or not: in a new cave, you can't take advantage of previous knowledge or information.

But first things first. What could drive you to go exploring deep dark holes more than the chance to discover new cave?

1. Organizing an Exploration

1.1 Prospecting (Ridgewalking)

Before you can explore a new cave, you have to discover it. In countries where caving has a long history, it can be quite difficult to find new cave by simply gathering information from the local inhabitants, although this is one common method in "new" countries. Information gathered from people who walk the path less travelled, so to speak, can be very useful. Hunters, rangers, foresters, herders, mushroom and berry pickers—these are the people who know the terrain intimately. They are most likely to notice a solitary column of fog arising from nowhere on an icy morning, that unusual stream of water appearing after a heavy rain, or the sudden appearance of a hole under an uprooted pine tree or during the construction of a forest road.

Without outside help or pure luck, cavers usually only find new cave by digging open a promising entrance, diving in a resurgence or sink, or by prospecting.

1.1.1 Choosing the prospecting zone

When the end of an exploration phase is in sight, you and your caving group must turn your attention to new objectives. There are several resources you can use to seek out a new prospect. You may already have a something in mind thanks to an interesting tip, a previous reconnaissance, or even a lucky discovery made during a Sunday hike. Cavers always travel through limestone terrain with one eye on promising shadows, holes, sinks, and overhangs.

There may be the opportunity to take over a zone that others have abandoned, either because a group has disbanded or simply lost interest over the years.

A bit of library research can also shed some light on the subject – useful information, unanswered questions, or some possibility that was never fully explored or that lacks detail in the literature. These areas are almost certainly far from the well-travelled routes, so expect a good long hike to the entrance!

Another possibility is that more recent discoveries in the cave direct your interest toward new zones where you think the cave may extend. Hopes for a connection or better understanding of a drainage basin are strong reasons to begin prospecting. Confirm your suspicions by studying 1/25,000 topo maps and the geology of the area, an inventory of its resurgences and of caves already mapped. After making sure you're not stepping on anyone's toes, you're ready for action.

1.1.2 The team

It's best to prospect in pairs: this avoids having more than one person waiting around while the other checks the newly discovered cave. If the team has four people or more, divide them up into smaller groups.

Prospecting alone is not a good idea. It is difficult for one person to follow a surface bearing, and if the slightest incident were to occur underground that prevents a lone explorer from leaving the cave under his own power, the wait is going to be very long! It would be wisest to locate and mark the entrances and come back later with others.

1.1.3 Combing the terrain

For effective ridgewalking, the surface area to be inspected is divided into smaller zones which are then systematically walked, one after the other. Use noticeable surface features and changes in the terrain to define the boundary of each zone: ridges, crests, trails, rock banks, logging areas, enclosures, cabins, creeks, etc. Each zone is designated with a letter A, B, C and so forth, or with two letters taken from the local topography (for example, CV for Carta Valley, GG for Gaping Ghyll, etc.). Each cave is then numbered starting at 1 in each zone: CA2 is thus the second cave found in the Col d'Arp zone. Within each zone, comb the land systematically, beginning from one boundary. One of the best methods is to follow the terrain contours. This keeps you roughly at the same elevation and saves you from repeatedly climbing and descending, which can be exhausting. If the slope is steep, it's best to start on top and climb down, since your points of interest are easier to locate from above. The width of the strip that each person covers varies according to the nature of the vegetation and on the local relief. Each person should be able to see everything in his strip without deviating from his line, except to check a possibility. The person walking adjacent to the strip that hasn't been covered will be responsible for the first part of the next strip. That person will look back periodically and flag the route for orientation; when the team reaches the end of the first strip, this end person turns and walks in the opposite direction along the boundary of the new strip, while the other(s) leapfrog to the inside strips.

1.1.4 Equipment

Let's be realistic: the chances of finding a new and extensive cave are not so great and you'll be carrying your equipment all day. It's best to go light.

In our neighborhood, we usually wear a thermal top and bottoms and carry a light caving suit to put on before exploring new holes. Shoes should be comfortable and more adapted to backcountry hiking than descending pits. Personal equipment should consist of a lightweight harness, vertical gear and of course a helmet, but with only its electric lamp (it's lighter, more compact and easier to carry than carbide). Bring a backup headlamp, which may also be handy for a late return. Each person should carry his own equipment. Group gear should include two 30-meter ropes (depending of course on the type of caves you intend to find), a small bolting bag, and light anchors to be used as often as possible on natural points: these will leave the site clean when you go. Besides, it's a waste of time to set bolts above pitches that will most likely go nowhere. Slings, chocks, lightweight carabiners and rope protectors are about all you need, along with one surveying set for each group: map, sketch book, compass, altimeter, tape and a GPS if you have one. "Gadget freaks" will also bring along their cell phones for communicating between groups – that is, if the area has coverage. Some may instead use two-way radios (walkie-talkies). And finally the most important component: food and drink, including a liter and a half of water per person minimum. All this starts to get heavy, so carry a comfortable rucksack with a large, padded waist belt and good back supports.

1.1.5 Exploring the cave

Once you've located a cave entrance, both cavers get back together and one begins gearing up while the second prepares the rigging material for the first pitch, given it's a vertical entrance. The second also tags the entrance (see above) using a paint marker, if the cave seems worth marking. The letters should be small and the tag discreet, though the paint must be bright if you want to find the tag again later. Choose a spot that is sheltered from the elements and scrub it first with a wire brush, so you're guaranteed to find the tag even years later. As soon as you are back up the rope, sketch a plan and profile view of the cave from memory. You will usually be dealing with small, vertical cavities for which our rope estimations are quite sufficient. A more precise topo can be made later for those rare caves that deserve one. The sketch is accompanied by other various details, either geological (strike direction, jointing, lithology) or speleological (obstruction causing the cave to end, air flow, other entrance, snow firn (névé) that might melt later, recommendation for a return or otherwise).

Once you've repacked everything, your search continues.

1.1.6 Positioning entrance locations

Roughly fix the location of your cave entrances in relation to surface features. Those with most potential or interest should be plotted on the surface map, which demands more precise coordinates. This task can be left to the teammate on the surface, who does this while waiting for his colleague to return. There are several methods for obtaining these coordinates.

Traditional methods

The most common method is compass triangulation, aiming at visible landmarks that are well spread out over a 360° radius. If these landmarks are too far away, the orientation is less precise. Use features that are close to you and visible on the surface topo (paths, rock outcrops, the base of a cliff, a pass, a hut, etc.). If you have a measuring tape, you can also map directly from a feature on the surface map.

GPS (Global Positioning System)

This device allows you to triangulate without any nearby landmarks, even in foggy conditions, using satellite reception technology. At least three of 24 satellites circling the Earth must be visible from your location (fog does not interfere) and in a suitable position (i.e., spread out evenly like the terrestrial landmarks in traditional triangulation). You also need an open view of the sky for higher precision: if you are under dense forest, at the base of a cliff, or blocked by a nearby summit, your reading may not be as precise, so this method isn't perfect for all occasions.

With three well-positioned satellites, you can obtain your XY-coordinates from your GPS location using the coordinate system of your choice. All GPS models give both UTM (Universal Mercator Transverse) and geographical (latitude and longitude in relation to the Greenwich meridian, expressed in degrees or grad coordinates. In France, both types of coordinates are marked on 1/25,000 scale IGN (Institut Géographique National) maps, but beware: longitude values are oriented according to Paris Mean Time instead of Greenwich Mean Time – always a French exception to the rule. Anyone using French maps must therefore correct for the geographical coordinates, though not UTM. Some models also provide Lambert coordinates. UTM and Lambert are the most convenient systems for use with French maps.

If you have exposure to four satellites, you can also receive an altitude coordinate, Z, though this is generally not very precise. Don't worry, you can get the altitude from your altimeter or plot the X-Y coordinates on the topographical map to reveal it.

Until recently, the accuracy of our GPS coordinates varied between 10 m and 300 m and sometimes more, due to U.S. strategic control over these satellites. However, in May 2000 the Pentagon relaxed its satellite controls, improving the GPS accuracy dramatically. It is now around 10 meters with a standard receiver and better with high-end models. GPS accuracy is now at least as good as that obtained with careful triangulation using the best available topographic maps in a given zone. We therefore recommend using GPS for plotting cave entrances.

The altimeter

An altimeter is a device that reflects variations in atmospheric pressure. Since this pressure lowers with altitude, the latter can be calculated using mechanical or electronic means. But atmospheric (measured as barometric) pressure also varies according to other factors such as weather, which can be more difficult to control. Left in a fixed place, an altimeter will detect and display an elevated altitude if bad weather is approaching, since atmospheric pressure is lower. If a change from bad to good weather is taking place, the inverse occurs.

The second major factor affecting altimeter readings is variations in air temperature, since altimeters use a "standard atmosphere," in which the temperature is fixed at 15 ° C at sea level and lowers by .65 ° C with each 100-meter gain in altitude. It goes without saying that Mother Nature doesn't always hold to this standard and that temperatures can vary considerably according the season, wind, the time of day, latitude, tree cover, exposure to sunlight, and so many other factors. Let's add that measuring the 'true' temperature in hopes of correcting for a false altimeter reading would require you to take a reading in shadow with no wind, using a precise thermometer and by taking the reading after 30 minutes stabilization time...

The only practicable solution is to recalibrate the altimeter regularly by comparing its readings to spot elevations on the map, noting the separation between the two, and correcting for the values by interpolation, according to the time of reading. By taking these steps (which few people ever go to the trouble to take), you get an accuracy of ten meters at best, even if the manufacturer claims that its device only has an error of one meter. It's best to count on a 20- to 50-meter accuracy and no more, and remember to specify that Z was measured with an altimeter when you publish the cave coordinates!

1.2 Weekend Trips

Once you've discovered an interesting hole while prospecting, the little rope you have usually runs out and you have to return for a more thorough exploration. Local caving groups have the advantage of being nearby and can carry out trips as often as necessary during the dry season.

1.2.1 Risk prevention

When planning the trip, be sure that the weather forecast is suitable for the objective. We've already discussed this in the section on active caves and wet pitches (page 229), and will return to it again in the section on rescue situations. If the weather is uncertain or risks turning bad, change your objective.

It is extremely important to advise family or friends of the cave location and expected duration of the trip (see below). This will facilitate a rescue in case there is an accident or someone becomes trapped in the cave.

1.2.2 Teams

"Who's going caving this weekend?" Theoretically, it's easier to decide on an objective once the team has already been chosen, but this isn't always the way it works out. We often form our teams around the chosen objective and a team leader or organizer. When access is easy (horizontal cave, the beginning of a vertical exploration), the team can welcome anyone who is interested in going. But as explorations becoming deeper and more difficult, the organizer has to choose team members according to the skill level and competence required for the objective. At this point, the leader has three choices:

- change the objective completely;
- retain it, but make it less ambitious;
- or divide the group into two homogenous teams having different roles. The stronger team will do the harder trip. Good leadership skills and psychology will allow the leader to form teams without making anyone feel unimportant or left out.

Once in the cave, there is almost always a leader, whether he or she is explicitly designated as such, or this occurs simply by virtue of that person's skill or experience. The leader is very often the "rigger." However, each individual is responsible for his safety *as well as that of the group*, and should be alert to signs of abnormal fatigue or weakness among other teammates. The team should always travel at the rhythm of its slowest member, and should not leave him behind for the sake of speed, unless he himself gives the signal to do so. Whatever the chosen objective may be, it can be changed at any time according to the conditions encountered in the cave (especially in the case of higher water flows), and according to the condition of each team member.

Horizontal caves

Since they require less group equipment, horizontal caves can usually take larger groups, unless they have a more fragile environment or passages that make travel more difficult (pools to be crossed with a inflatable boat, tight crawlways or squeezes, a sump to be drained). In the latter case, the group is divided into smaller teams that set out at different times.

Vertical caves

Teams should be limited to two or three persons for exploration in vertical caves. With two people, there is plenty for both to do: while one rigs, the other belays, organizes the gear, sets backup anchors, or warms up some soup. On the climb out, these two become the survey team, each having had a turn at the lead. This system is preferable to the one in which the fastest caver(s) get the glory of discovering new cave, while those who follow are left with the work of mapping. Though a two-person team is ideal in terms of efficiency, it has two drawbacks:

- It is limited in the amount of equipment that can be carried.
- If there is a serious accident with one of the two members, carrying out or signaling a rescue can become problematic.

With three, the leader can rig while the remaining two map as they go. Once the team decides to turn around, the survey is already complete and it is easier to determine the time needed to de-rig and exit the cave.

At more than three, it is more effective to split the group into smaller teams, each responsible for a different task or objective. Some projects (diving, digging, sump draining) call for support teams. These can be made up of small teams of two or three who enter the cave at different intervals so as not to create bottlenecks at the rigged sections, on the descent as well as the return.

1.2.3 Preparing and dividing up equipment and supplies

Equipment and supplies are prepared according to the kind of cave you plan to explore (average pitch height, wet passages requiring watertight packaging, tight meanders requiring small packs, etc.). These are then divided up among the team members – this includes carbide – so that a lost or forgotten pack will not interfere with the team's safe return to the surface. With large teams, a pack can be forgotten in this way if each member is not carrying one.

1.2.4 Trip duration

Estimating the duration of a caving trip is not so easy, especially if you are only familiar with part of the cave. After all, you are carrying out an exploration! Many factors can come into play:

- The time the team actually enters the cave, which in turn depends on the length or difficulty of the approach.
- The time it takes to reach the previous limit of exploration, generally easy to determine since the route to the lead is pretty well known.
- The duration of the push – by definition unknown. You could be stopped by lack of rope, an unexpected obstacle, or lack of time.
- Incidental hazards or unexpected developments related to difficult passages, changes in water levels, physical condition of team members, the load being carried, fatigue, equipment problems (pierced inflatable boat, damaged thread on the bolt driver, a lost hammer, etc.).
- The return time, which may be slowed by a fatigued team member, loss of some climbing gear, mistaking the route, slower surveying/mapping, weak lamps.
- The return from the cave to the vehicles (darkness, fog, snow, etc.).

After evaluating these factors as thoroughly as possible, set a strict deadline to stop exploration and begin exiting the cave. Overestimate the total time you actually need to return home, and leave this time for your friends or family. Beyond this time, they are to raise the rescue alarm.

1.2.5 Hazards related to the approach

There are three dangers related to hiking to and from the cave, which should be controlled as much as possible:

1. **Getting lost**, usually greater on the return. In unknown terrain, simply mark the route on the way to the cave, and return as a group. The bright, sunny hike to the cave could turn into a nighttime return through rain or dense fog. Fatigue can increase your chances for error and losing your way, especially if you are returning alone.
2. **Snow.** Snow cover can drastically alter your perception of terrain contours and features. Be sure to place markers high up (on trees or boulders). On steeper slopes, there is a risk of avalanches that may increase even while you are underground. The usual rules for mountaineering and backcountry skiing apply here: spread out while crossing exposed areas; avoid crossing steep slopes or windy ridges where unstable snow banks accumulate; carry an avalanche transceiv-

er; avoid warm periods (i.e., leave early and return late, when the cold air acts to stabilize the snow pack).

3. **Exposure to heights.** Access to some alpine caves requires a traverse along exposed ledges, slippery slopes, or unstable rock slides, all of which are even more hazardous if you are fatigued. Don't hesitate to use a belay rope as soon as anyone in the group needs it, and preferably before they have to ask! Place two more experienced team members on either side of the person being belayed. He'll be grateful for the support, and all the more so if his pride is still intact...

1.2.6 General rules for safety

Rule 1:

Respect the scheduled curfew and leave alert instructions with a friend or family member in the event you do not return within the prearranged time.

Rule 2:

Always take sufficient carbide and food, divided up among several packs. In dry caves, be sure to carry water in a flexible plastic container. There are many light, sturdy containers available for this purpose. If there is water in the cave but it risks being polluted by livestock on the surface, treat it before drinking (see page 120).

Should you also take along a first aid kit? The answer rests with each individual. A collective first aid kit has every chance of lacking precisely the item you need in a given situation. It is each person's responsibility to know what predisposition may require specific care (tendency toward sprains, stomach problems, migraines, etc.), and to take into account any ailments that require special medication or attention (diabetics or asthmatics, for example).

Rule 3:

Avoid travelling alone. The smallest incident (light failure, getting lost, a sprain) could lead to significant delays and can have potentially serious consequences.

1.2.7 De-rigging

After all those exciting trips filled with passage after virgin passage, it is finally time for the thoroughly explored and surveyed cave to be de-rigged. This inevitable task is far from interesting, but it can be made easier if teams operate in the same manner as the initial exploration: successive teams of two carry out one or two packs. Each person can thus climb out at a rhythm that corresponds to his own fitness level and the obstacles in the cave. Those exhausting trips in which you each drag out mountains of equipment leave such bad memories that you find your volunteers have all disappeared by the time the next de-rigging trip comes around...

1.3 Organizing Longer Explorations and Expeditions

1.3.1 "Push trips" without a camp

With progressive exploration of a cave, trips inevitably become longer and longer. You'll soon find you are going beyond twelve hours for each trip, and on weekends your time is limited. An all-out "assault" can save on time and the load to be carried in the cave. Such long, sustained explorations are reserved for experienced cavers only; it is the responsibility of each individual to balance his or her present physical capacity against the objectives to be reached, the duration of the survey trips, and the resulting fatigue. You should of course try to rig as light as possible. Rigging must be based on a precise estimate of the equipment needed, though no skimping is allowed when it comes to carbide and food.

It is best to start out at dawn when carrying out this kind of trip, so as to stay in synch with the normal day/night rhythm; otherwise, you will find enthusiasm waning as your body realizes it should be sleeping. Take a short break every two to three hours to allow the body to rest without breaking the rhythm, and eat at regular intervals. It is best to load up on complex carbohydrates the day before the trip. In colder caves, a compact stove will allow you to have hot food and drink, a psychological and calorie boost well worth having.

Also carry a dry change of thermals to keep you warm and comfortable during periods of inactivity.

1.3.2 Bivouacs and cave camps

When trips become so long that they require some more serious rest, it's time to set up a camp, given the cave is not subject to flooding.

If necessary, you can improvise a quick bivouac before or during a return, to provide a few hours of sleep and allow you to "recharge your battery." Get close together with your teammates, insulate yourselves from the ground using packs and ropes, and create a makeshift shelter by throwing your rescue blankets over a cord or rope strung as a rooftop. If space is limited, sit curled up with your chin resting on your knees. Keep your acetylene lamps close to act as heaters. Now all you need is to start dozing off...without setting fire to the rescue blankets!

Now no cheating here: snatching a quick nap like this in a cave provides a limited amount of real rest, comfort and warmth. When this is possible, its only advantage is that it requires no extra equipment, but it is no substitute for the real thing: for a good night's sleep, you need to set up a camp.

Foam pad

If you're lucky enough to find campsite with flat, dry ground, the foam pad is an excellent option: it is light, insulates you well from the ground, and allows you to sleep on your side. Choose only closed cell foam pads: they won't absorb water when submerged en route, or from the humidity of the saturated cave environment. Carry the pad wrapped around the inside of your pack between the shell and its contents. This protects your gear from damage and insulates your back from the cold.

Hammock

The uneven nature of the cave floor often makes the hammock a better choice than the ground for sleeping in a cave. Unfortunately, we can usually only find traditional netted hammocks with two attachment points. These are totally uncomfortable, turning the would-be sleeper into a sausage bound up within the netting, arms and shoulders compressed and back rounded in a curve...not a very favorable position for a good night's sleep!

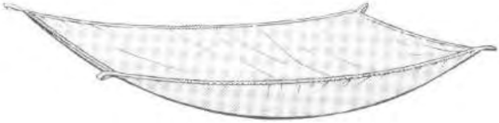


Fig. 332 – Hammock with four attachment points.

To do:

you must take apart the ends of the hammock and rebuild them into four attachment points. This will make the hammock flatter and much more comfortable. To do this, undo the outer cord that reinforces the sides of the hammock, and discard the thimbles, making a square. Weave the previously mentioned cord around all four sides of the hammock. Make an attachment at each corners with this cord using overhand knots, and, tie off the cord with a fisherman's knot For an even flatter hang, replace the original cord with some 20-mm wide nylon webbing, which is less elastic.

A more comfortable but more complicated option is to fashion your own four-point hammock from a strong nylon sheet with edges made of webbing.

You will need to set four anchors on opposing walls to hang the hammock, but only six points to hang two hammocks, and eight for three. Set ring hangers (if you have them) less than a meter and a half from the cave floor, to make it easier to get in and out of the hammocks. Spread the anchors further apart as the distance between the opposing walls increases. A meter apart is the minimum when these walls are close together; otherwise, the sides will be too close and the hammock will hang too low.

Tension the hammock at either end with a Münter hitch, fastened tightly and tied off with a mule knot. Along the length of the hammock, hang a rescue blanket over a cord fastened above the hammock. This reflects the body's heat and thus insulates; it also provides shelter from water drops. Leave about 30-40 cm between the blanket and your sleeping bag (once you're in it) to avoid condensation. Those who sleep on their backs can use an inflatable travel pillow for neck support.

Use a mummy-shaped sleeping bag with synthetic fill (better in moisture and humidity than down). It should be rated at about +5° C, which corresponds to about 900 grams weight for a quality bag. Transport the sleeping bag in a 6-liter watertight container.

A four-corner hammock has just one drawback: left relatively exposed to the cold, humid cave air, your back tends also to get cold. There are two solutions to this problem:

To do:

- Insulate the back with a 50 x 100-cm, 1-cm thick section of closed-cell foam padding, carried in the cave pack as described above.
- Use a hammock with a double aluminized bottom. This is the heated hammock.

The heated hammock

In particularly cold caves, you can achieve greater comfort by adding another source of warmth: hang a heater under a hammock with a double aluminized bottom designed to trap the heat. The heater can burn liquid paraffin or alcohol (fig. 333A), which work well but give off an unpleasant odor. Perfectionists can close the bottom to create a heat chamber under the hammock.

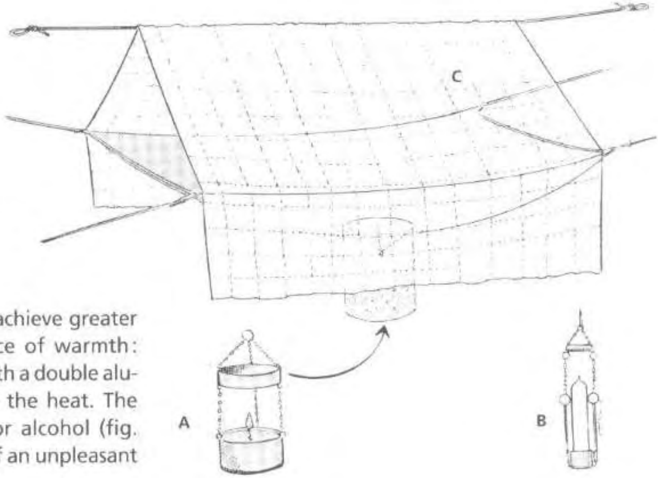


Fig. 333 – Heated Hammock.

Camp 17 in the High-system of Hölloch, Switzerland. Photo U. Widmer

Those who are less inclined to building a homemade heater can settle for a simple candle lantern (fig. 333B). Some are quite light (100 g) and come with protective glass and a spring that pushes the candle upward to ensure a constant flame and complete combustion.

In a heated hammock you can sleep underground in temperatures approaching 0° C (32°F), as in caves at higher altitudes. The heated hammock is still effective at more forgiving temperatures, since it allows you to carry a lighter and less insulating sleeping bag.

To do:

Hang your rescue blanket over a cord strung above the hammock: it still insulates and protects you from dripping water and air currents (fig. 333C).

Organizing camp

The site and organization of a cave camp will depend on the cave being explored. The cmap should be set near the unexplored zones in a moderately sized, dry passage or room. The area should have enough airflow (but not too much!) to allow clothes and equipment to dry, and be removed from the noise of flowing water, but not too far since you will frequently need to haul some of this to camp (fig. 334).

Key Point:

Hygiene is your number one problem. Please excuse the explicitness of the details to follow, but a proper camp depends directly on this information. Look for a site a couple hundred meters from the camp where the ground is soft and dry, in which to dig your latrine. Bury your waste and leave a piece a toilet paper on the site to mark its location. If the ground is rocky everywhere, relieve yourself into plastic bags, which you will later carry to the surface. Even when a soft dirt floor is available, this is the best solution for the cave environment.

It goes without saying that all trash should be picked up and carried out of the cave as well. The campsite should be kept clean and tidy. Division of "household" chores is usually not a problem since cooking and eating utensils are minimal – but that's no reason to put off cleaning them!

Spend your time in camp in your thermal underwear or undersuit; those who tend to feel the cold can wear an extra fleece. This allows your undersuit to dry out on your body. It will create less moisture in the sleeping bag, where it will dry out as you sleep. In the meantime, string your caving suits out to dry. Fold down the legs of your caving boots so your socks can dry out as well; socks will also finish drying inside or on top of your sleeping bag while you sleep in a clean, warm pair.

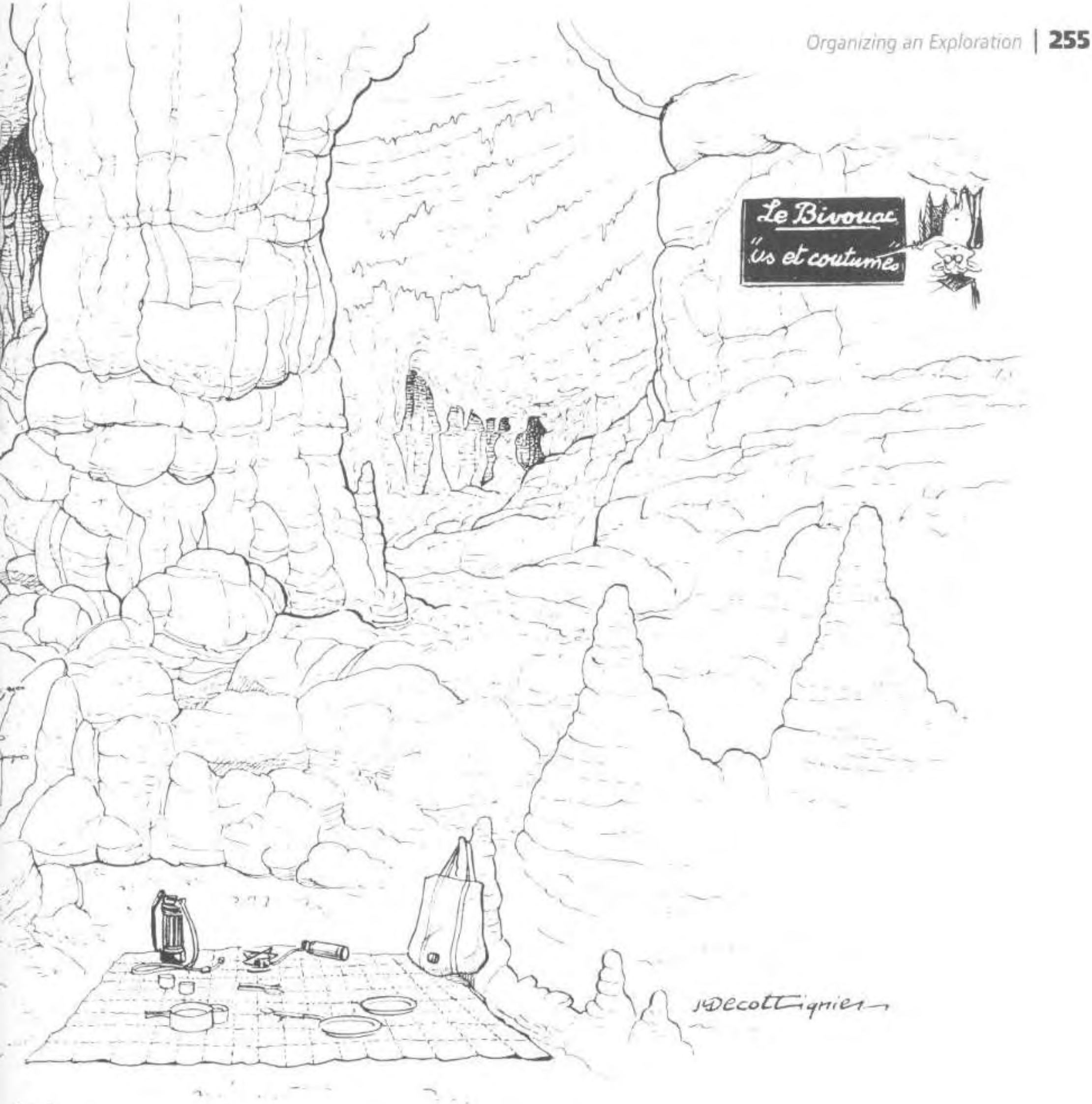
To do:

Wear a balaclava around camp to keep your neck and ears warm and provide some protection for the head, which your now-removed helmet no longer does.

Fig. 334 – Setting up a cave camp. The water filter is just one option for treating water.

Fig. 335 – Organizing an underground camp.

Type of exploration and cave	Time spent underground	Camp location	Team organization
Weekend exploration in a long (> 6 km) and deep (-700m) cave	2 days	5 km, -500 m from entrance	**Day 1:** Descent to bottom, exploration and return to camp (15 hrs) to sleep. **Day 2:** Return to the surface (8 hrs).
Summer expedition, frequent team rotation in a -1000 m cave that is technical and cold.	3 days	No. 1: -600 m No. 2: -1000 m	**Day 1:** Descent to Camp II in 12 hrs. **Day 2:** Descent to bottom, exploration and return to Camp I (15 hrs). **Day 3:** Return to surface (10 hrs).
Scientific expedition in a long river cave (10 km)	6 days	8 km from entrance	**Day 1:** Travel to and set up camp. **Days 2-5:** Exploration and research **Day 6:** Return to surface.



In systems that are being actively explored over a longer period of time, the camp remains in place to reduce the amount of gear you need to carry for each trip. Only the sleeping bags should be brought out to the surface on a regular basis for cleaning. In the interim, these are each stored in a separate plastic bag along with a piece of carbide to absorb the moisture. The number of sleeping bags left in camp will depend on the size of the teams going down.

With each trip down, restock the camp with food stored in airtight plastic containers, and plenty of carbide reserves.

To illustrate how different cave camps function, let's take three typical examples, which are outlined in the table below (fig. 335).

In each case, the location of the camp or camps depends on the duration of the exploration. They are set up in keeping with the explorers' sleeping/waking cycles. In the first type, the camp still allows the participants to return early on Sunday in readiness for a productive workday on Monday.

In the second example, note that a separate team may use camp 2 as early as the second night, while the first team sleeps at camp 1 before exiting. The two teams will theoretically cross paths between the two camps, which permits an exchange of information as one leaves and the other begins. On the other hand, contact with the surface is offset by a day, which will cause delays in the event of the unexpected (if, for example, a blocked passage requires specific equipment to be brought down). However, new ground communication devices (such as the Nicola system) now make it possible to communicate directly with the surface. These devices have a promising future.

The third type of camp is to be set up for longer explorations (those requiring extensive digging or scientific sampling) where the target site is far from the entrance, in a cave that allows only a limited period in which to carry out the work (in a drought, for example).

1.3.3 Summer expeditions

For those especially dedicated cave explorers, vacation time is the prime time for attacking more ambitious projects, whether they are nearby, far away, or off in some exotic land. Underground camps are organized in the same manner, according to specific objectives. The problem lies more in external logistics: camp preparations, budget considerations, organizing carriers, supplies and supply lines, balancing the menu, division of tasks, sharing the lead, determining rest periods, maintaining a daily rhythm that doesn't interfere with sleep cycles, cleanliness, comfort, etc. In short, it is essential to maintain health and hygiene, to ensure peak performance as well as a positive atmosphere in general, both of which determine the success of a summer camp.

It goes without saying that good physical conditioning and preparation are equally important for each and every participant. This will curtail exhaustion and the technical errors that result from it during long or deep trips.

2. Continuing an Exploration or Visiting a Known Cave

Though nothing can replace the excitement of discovering new cave, there are some that are so impressive in size or beauty that they deserve a visit. By leaving your usual caving area and its sometimes ungratifying work for a while, you can become a speleo-tourist. There's no reason to be ashamed of having a little fun. Quite the contrary: speleo-tourism is an enriching experience and adds to you as a caver.

A second reason for visiting a known cave is if, after pouring over old surveys and making recent discoveries, you suspect that there just might be a lead that escaped the attention of previous explorers. In that case, you'll have to go and see for yourself.

We won't repeat the common points between exploring leads in a known cave and exploring new caves, but will instead consider specific points related to visiting a classic. This is particularly about gathering information, which will help in planning and organizing the outing.

2.1 The Cave Map

The cave map ("topo map" or "survey") is fundamental: this gives you an idea of the shape and size of the cave, obstacles that you will come upon, risks of possible flooding, areas where a possible lead could be hidden, etc. If an article on the cave has already been published, a little research will lead you to the map. Otherwise, tapping the underground grapevine will usually help you find the necessary information from previous explorers.

The plan and profile views are complementary. The profile shows vertical obstacles (pits, climbs, etc.) and how the various levels of the cave are situated in relation to geological levels. The plan view gives information on the shape of the passages, horizontal development, water flows and how they relate to each other, meanders and squeezes, and how the various passages join.

These views combine to help you visualize the spatial organization of the cave system within the mountain. If you wish to recommence research in a cave, it is also a good idea to gather maps of neighboring caves as well as any geologic and hydrologic data that is available on the area in question.

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[19] Rigging charts do not exist as such in the UK or N. America. For this reason, the original French notations have been retained and a translation provided to the side (for those who intend to visit French caves). Notations could then be adapted to English. For example: 1AN(arbre)‡1NA(tree); 1AN(frac)‡1NA(reb), 1G8‡1XB8, 1B‡ 1EB, 1S‡1SDA, etc.
In the US, rope lengths and rigging information are indicated to the side of the map or in the survey notes, though this information is rarely published with the cave map. In the UK, the information is depicted in simple schematic diagrams of the vertical sections of the cave ("rigging topos"; see Elliot and Lawson, *SRT Rigging Guide*, Lizard: N. Yorks, UK, 1987.).

2.2 The Description

The cave description complements the topo map by describing important details that will help in travel and avoiding errors (route, landmarks, special points of interest, key passages, various risks...). The description will help you determine whether an inflatable boat or a pontonniere or wetsuit is best to use in a particular stream passage. It will indicate that a muddy zone can be bypassed through a ceiling passage, or whether a pit will require several deviations due to the risk of sudden flooding. It will also warn you that the way into or out of a given gallery is narrow and hidden by a boulder, or that a low passage can fill with water during rainy periods.

2.3 The Rigging Chart[19]

The rigging chart helps us prepare the equipment for vertical passages, and pack it in the correct order. This is a coded list in which the vertical obstacles and the rigging needed to overcome them appear in a condensed table format, as follows:

P	Pitch
[ ]	Optional Rigging
CP	Corde Précédente (previous rope)
E	Escalade (free-climb)
1AN	1 Natural Anchor
1AN (arbre)	1 natural anchor (around tree)
1S	1 spit/self-drilling anchor (SDA)
1S (!)	1 mono-spit (danger, requires backup)
2S en y	Y-belay on 2 spits/SDAs
1AN +1S en y	Y-belay on 1 natural anchor and 1 SDA
1P	1 piton
1G 8	1 8-mm expansion bolt
1B	1 eyebolt
1S (frac)	Rebelay on 1 spit/SDA
1AN (frac)	Rebelay on natural anchor
1AN (dev)	Deviation on natural anchor
1S (dev)	Deviation on 1 spit
→	Horizontal traverse line
↑	Ascent or climb-up
↗	Ascending traverse
↘	Descending traverse
↓	Descent or climb-down

All arrows can have a specified length, as:

↓7	7-m descent

As an example, let's take the beginning of the rigging chart for the Scialet de la Bulle, as it appears in *Spéléo dans le Vercors* (volume 2), S. Caillault, D. Haffner, T. Krattinger, J.-J. Delannoy, Édisud, 1999, the work from which the chart abbreviations were taken:

Scialet de la Bulle *[Additional explanations are provided in bracketed italics.Tr.]*

Rigging Chart 373 m rope, 54 anchors (September 1997)

Obstacle	Rope	Anchors	Observations
P20	30 m	1S + 1S ↘ 2S en y, ↓	
			[y-belay on 2S at pitch head, backed up to 2S on descending traverse]
P4 + P20	35 m	1AN (bloc) + 1S, ↓4, 1S ↘2S en y,↓	
P15	22 m	1AN (bloc) → 2S en y, ↓	
			[y-belay on 2S at pitch head, backed up to NA around boulder]
Barraminien Meandre			
P8	11 m	2S en y, ↓	
P21	28 m	2S en y, ↘ 2S en y, ↓	
P22	30 m	1AN (bloc) → 1S + 1S, ↓6	
		1S (frac en plafond), ↓7	
		1S (frac en plafond), ↓4	Do not descend to bottom of 22-m pitch. At bottom of third (4m) drop, follow a meander that goes up from left bank.
			[P22 : 1 NA around boulder backs up double anchor on 2S at pitch head; 6m descent to 1S rebelay in ceiling, then 7m descent to 1S rebelay in ceiling, followed by 4m descent]
E7	[11 m]	[↑, AN possibles, 2S à planter]	Optional but recommended
			[climb-up, may be rigged using NAs, and 2S to be drilled] etc...
P6	45 m	1AN + 1S en y, ↓6	
P16	—	1S ↘ 1AN, ↓4, 1S (frac), ↓12	
P9	—	1AN + 1S en y, ↓9	
etc...			

Muruk Cave, Papua New Guinea. Photo J.P. Sounier

Though it may be carefully researched, a rigging chart is only intended to be indicative and depends on the skill of its creator(s) and their familiarity with rigging.

2.4 Preparing the Equipment

Organize your equipment using the rigging chart or, if there is no chart, by studying the plan and profile views of the cave map to help you estimate what gear you will need. Overestimate rope lengths and the number of anchors you need, in case any unexpected configurations come up, and because some charts tend to minimize the gear that will be needed.

Spread out the equipment on the ground in the order that it will be used in the cave, down to the last pitch or handline. After a final safety inspection, begin packing the rope for the last pitch at the bottom of the pack, then the ropes for the next to last pitch on top, and so on. Uncoil each rope and tie a safety knot at its bottom end and then pack the rope as described on page 178, chapter K. When one pack is full, top it off with the anchors that correspond with the ropes inside the pack, and move on to the next pack. The first rope you need ends up on top of the last pack you fill, or rather, the first pack you'll use. Divide carbide and food and distribute them among the various packs, so that there are no serious consequences if one pack is lost or left underground. As we noted at the beginning of the book, packs should be numbered in some way as soon as they are purchased. In the series of packs you are using, use the smaller number first, the subsequent packs increasing in numbering as you use them in the cave. Some pack models have a clear plastic pocket on the lid in which you can place a polyester card that specifies the pack's intended destination. Assign each pack to a team member, the higher numbered packs corresponding to increasingly stronger participants, the strongest member taking the pack containing the equipment that goes the deepest or farthest in the cave. This order can be reversed for the climb out, but the division of packs depends largely on the circumstances of each trip and the judgement of its participants.

3. Winter Explorations

In many regions, caving continues all year round, including winter. But like in mountaineering, conditions can become extreme in some areas. We are particularly concerned here with wintertime expeditions at high altitude, when the specific conditions related to alpine terrain make access to the cave and its entrance areas more complicated. Snow, ice, and sub-zero temperatures become key factors.

Ice makes travel more difficult and the cold eats away at our energy reserves. You will normally only confront these conditions for specific safety reasons related to an exploration: in high altitude alpine caves, snow melt begins in spring and may last throughout the summer. With the capriciousness of uncertain weather, snow melt can increase water flow to a dangerous level, especially in pits. Winter is thus the only safe time for downstream exploration, since all precipitation falls as snow or ice and low temperatures prevent the snow pack from melting.

Organizing a winter exploration can be complicated and, in order to pay off, it is usually planned for several days with an underground camp, depending on the cave being explored.

3.1 Getting to the Cave

In extreme conditions, never improvise a caving trip. Travel to and from the cave is a serious obstacle in itself, rendered even more difficult by a heavy load. Even if you are not going for several days (which is rare), you must carry more food (and don't forget warm drinks), more clothing (gloves, cap, thermals, rain pants), and travel with special equipment (skis with skins, snowshoes, poles, crampons, ice axe). This equipment alone requires special shoes that are heavier for more insulation and more rigid to support the ankle and foot. Movement is thus slower and more difficult...and carrying a heavier pack doesn't help!

Snow also changes the contour of the terrain and often covers familiar landmarks. Carefully mark your route with flagging placed higher up in trees or on boulders. Flagging should be removable so you leave no trace once the exploration is finished. One easy method is to use strips of brightly colored cloth, which will be even more visible in windy conditions. Flag at close intervals so that each consecutive marker can be seen from the previous, in both directions and even in fog.

3.2 Tagging the Entrance

A narrow entrance covered by snow is nearly impossible to find, unless it is blowing enough warm air to stay open. Locate the entrance during the summer months and stick a painted pole in the ground next to it as a marker. This should stand well above the eventual snow depth at its deepest point. When the time comes, dig out the entrance using a snow shovel...even more weight for your pack! It may be helpful to build a trap door over the hole. This will prevent snow from plugging the entrance and keep the interior walls free of ice, since the air inside the cave is warmer than the air outside.

If the entrance is large but vertical, the approach must be rigged and secured, as snow can be treacherous. It may form an unstable cornice that can collapse under a person's weight, freeze to make a dangerous slide, or completely transform the normal route, even in the time between your entering and exiting the cave.

3.3 Special Precautions for Equipment

Equipment must be carried dry, or it will freeze hard: this includes the caving suit, cowstails and harnesses, as well as cave packs and ropes. Thermals worn during the approach become soaked with perspiration and also risk freezing as you prepare to enter the cave. Change into warm, dry underclothes at the entrance, before the first set starts to freeze and stiffen. It's also a good idea to take along another change of clothes for when you exit the cave. Changing clothes is more comfortable if you bring along a plastic trash bag to stand on while changing. Remove the snow from your snowshoes, boots and crampons, and don't forget to shake out the adjustment straps as well. Water brought to the cave for carbide lamps should be treated with a small amount of antifreeze. Once you are suited up for caving, any equipment remaining at the surface should be placed in a pack and left at the entrance. It's a good idea to put this in that same plastic trash bag, since snow powder tends to get inside everything when it blows around.

3.4 Rigging in Ice

Anchors

It is of course preferable to set your anchors in solid rock if you can still find it. Beware of the effects of frost-heave, which destabilizes the surface layer of the ground. Pay special attention to where you place your hand and foot holds, as soil, snow and ice are all unstable, and relatively long hand lines are often required.

When there is a greater build-up of snow, it may be hard to find viable anchor points for a completely safe departure. In this case, use a 'dead-man' anchor. Make this with some of the gear to be left on the surface (ski pole, ice pick, snow shovel, snowshoe, or even backpack), and attach the rope to it. Bury the "anchor" in a hole that you have dug out with the snow shovel, and then pack it in with snow. Pay attention to the kind of snow being used: powder snow does not stick well and requires you to dig a deeper hole.

Rock walls may sometimes be covered in a layer of transparent ice. Use an ice axe to dig out bolts that you can see underneath the ice and then unplug the threads using the flame from your lamp. The best method is to leave the hangers in place before winter, with a colored piece of cord attached to help you find them.

When the ice layer is thick and consistent, ice screws must be used. Use only tubular ice screws with short threads, which are easy to screw down by hand or with a crank after they have been tapped in with a hammer. Once below the surface area, be careful of the quality of the ice layer before setting an ice screw and test it vigorously if you do set one. Ice deposits in the underground entrance areas of a cave are mainly the result of cold outside air being sucked into the cave (e.g., a 'middle' entrance in a high altitude cave system) and freezing any streaming water inside. The rock in this zone is not as cold as that outside and once the shell of ice is in place, it acts as an insulator against the cold air and streams eventually begin flowing again underneath the ice layer. Separated from the rock, the ice sheet can have a very dubious hold.

If vertical sections require double ice screws, these should be spaced out at least 30 cm apart and connected with a load sharing sling.

Installing the rope

Avoid all contact between ice and the rope. We know that a weighted wire anchored at both ends and placed over a block of ice will eventually sink into the ice until it has gone right through it. A rope left to hang against an icy wall and loaded with the weight of its users also melts the outer layer of ice and digs a gutter into which melting ice automatically flows. When the rope is unloaded, this water re-freezes and will literally glue the rope to the wall. If the ice layer thickens the rope will eventually become enveloped in the ice, sometimes over long distances.

It may happen that the rope doesn't touch the wall while someone is climbing on it, but ends up touching when it is unloaded. If the slightest trickle of water (from daily thaw and freeze cycle) flows over this contact point, the rope will eventually absorb some. Since the rope is hanging in cold air, the water inside it will freeze, progressively forming a sleeve of ice that can eventually reach several centimeters of thickness over several meters. On the return up, you're in for a nice surprise! So, on the way down, always check that the rope is not touching the wall (otherwise, place a deviation), and consider placing Y-belays. If the entrance pitch is rebelayed, you can place a piece of rubber tire tubing above the bend in the slack part of the rope using a girth hitch. This will cause any water trickles to flow off the rope at this point, instead of accumulating and forming a sleeve of ice at the bend.

Despite these precautions, the surface of the rope could still freeze. Ascenders are useless when this happens, and you must remove the icy layer from at least the surface of the rope to allow the cam teeth to engage. This is only possible if the layer is thin: use your descender as an ice scraper, passing the rope between the top pulley and the stainless steel pin at the top, then slide the descender up and down the rope while turning it sideways to allow the edges of the descender to scrape the ice. This is slow, tedious work!

For these reasons and because there is the risk of large ice blocks falling when they begin to melt, always de-rig the entrance series where ropes could freeze between explorations. Store the ropes inside a plastic garbage sack, closed tightly and placed upside-down so that snow and water cannot get inside. But this of course doesn't prevent the rope from freeze during your exploration.

Remember that frost and ice do not alter the strength of caving ropes under shock loads; in fact, they tend to improve it since the ice fused into the rope absorbs some of the energy of an eventual shock load.

3.5 Dangers from Melting Ice and Snow

When caving in winter or at altitude, a major risk comes from melting snow and ice on the surface. At high altitudes and during the coldest part of winter, this is not a problem, but depending on the altitude of the cave entrance, the date and the weather, the temperature could rise above the freezing mark during the daytime at a higher altitude than that of the cave entrance. This translates into a cyclical change in the daily rate of underground water flow, and the difference increases progressively with depth. If you are exploring from an underground camp, time your activities in accordance with the lowest flow, while you allow the water to rage below as you sleep warm and comfy in your hammocks. This will provide the excitement of safely moving about in passages where the water is still streaming from the previous daily flood. If the trip is only going to last a day, it should be timed during a cold enough period to prevent you from engaging in such a game of Russian roulette.

3.6 Scheduling

However long the trip is going to be, it is important to accurately plan a schedule that allows you to exit the cave and return down the mountain during the daytime. In fact, the climatic conditions at high altitudes (ice, dense fog, snow, cold) leave little room for error. Considering the consequences of a forced bivouac on exhausted bodies left exposed to the cold in wet clothing, you should never risk being caught out.

Nare, Papua New Guinea. Photo D. Gill

M Emergencies and Rescue

Training, experience, exchange of ideas and regular practice: these conditions will help you build your skills and prepare you to handle the various situations you will encounter underground. But some times the unexpected can happen. This may only be a minor incident: a descender is lost down a narrow rift or your carbide lamp breaks. You will have to improvise using the limited means available to you; you can't get out of the cave by snapping your fingers or give up and go wait on the roadside for the sag wagon to pick you up. There are some tricks for dealing with these problems, though these are not always obvious.

Aside from miscellaneous equipment problems, much more dangerous situations can occur. A sudden flood pulse, an exhausted or collapsed teammate – such situations can quickly become a matter of life and death and the circumstances leave no room for error, ignorance or haste. You need to possess the proper reflexes and know certain maneuvers beforehand. Improvisation is rarely the best response when stress is high and time is critical.

In truly dangerous situations, there are those who are able to keep a level head and act quickly and effectively, and there are those who panic and become paralyzed. Experience and a thorough knowledge of the available choices and appropriate maneuvers are key to giving you the self-confidence to act with calm and precision.

Ask yourself regularly how you would respond to the unexpected. What would I do if the pit rope I'm descending comes to an end four meters from the floor? What if I notice an unstable rock collapse just after I step over it? And if my footloop gets stuck between the rope and my Croll, would I know how to get out of the mess alone? If John above me gets jammed in a narrow vertical crack, how could I help him out of it?

As long as the problem is hypothetical, you can usually reason around it calmly and objectively and find a solution. If you can't come up with an answer in this way, why not ask your teammates in the car on the way home? Many lively discussions have followed from this kind of reflection. This is how you can begin to familiarize yourself with exceptional situations and acquire the mental armor you will need to react if a real problem occurs.

Responding to adverse situations is easier said than done and you need a minimum of understanding to confront them effectively. So let's review some of the field repairs, special maneuvers, and more complex interventions you may encounter while caving. This will help you adapt your responses to real-life situations when they arise.

1. Lost, Forgotten, or Broken Personal Equipment

1.1 Harness

Harness maillon

Any locking carabiner that is in good condition can replace the harness maillon. Like the maillon, it should be placed with the gate closure downward, and check that rope rub during a climb doesn't unscrew the lock. Also, make sure it doesn't turn and load sideways on its short axis (i.e., the gate).

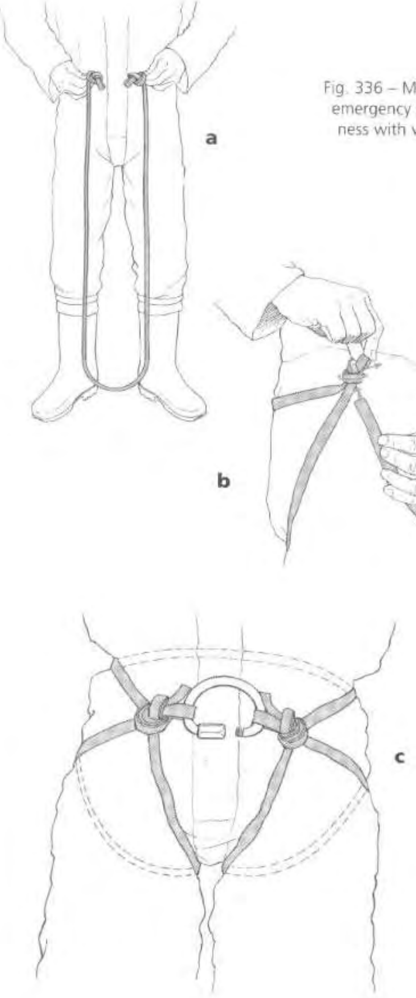

Fig. 336 – Making an emergency seat harness with webbing.

Seat harness

A simple length of rope or (preferably) webbing can replace the harness. It certainly won't be as comfortable as the original and you will remember this throughout the rest of the trip...but it's a good lesson in precaution for the next time!

To make an emergency harness, position the middle of the piece of webbing around your back. Make a loose overhand loop knot on each side, which will be placed inside the harness maillon (fig. 336). Pass both ends of webbing between the thighs and around the back of each leg before rethreading each end through its corresponding knot. Adjust the harness for a snug fit and then tighten down the knots.

Chest harness

Use a rope or webbing sling twisted to form a figure eight. Bring this over your head, place it around your back and bring your arms through the loops. Place the two loops that come out at your chest into a carabiner (fig. 337), which will then attach to the upper eyehole of the Croll with a small carabiner. The strap should of course be adjusted tightly so that there is no play in it before it is attached to the Croll.

1.2 Headlamp

Acetylene headlamp

If you lose the small metal tip ring, you will have to place the tip directly in the hose that links the generator to the headlamp. Since tips are now made of ceramic rather than brass, they are slower to heat up the hose. The latter takes longer to soften and will eventually melt, at which time you must cut the end and begin the operation again.

Tubes

Tubes can get holes in them. If the hole is near either end, just shorten the tube by cutting off the end at the problem spot. If you must cut off a lot of length, you can attach the generator higher up, on the chest harness. If the hole is right in the middle of the tube, don't cut it: plug it up by tying a piece of rubber inner tube band a few times around the affected area.

Acetylene generator

Our lamps have several components, each as capricious as the next. Losing the drip valve screw will

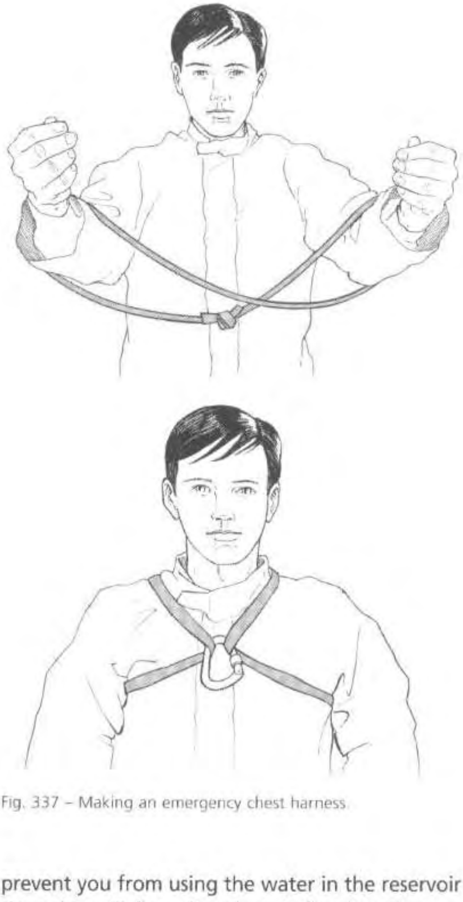

Fig. 337 – Making an emergency chest harness.

prevent you from using the water in the reservoir since this will flow directly out, flooding the carbide. Instead, wet the pad covering the carbide directly and regularly – any other piece of fabric will work for this as well. You can easily replace a lost reservoir plug with 5 cm of rope, a candy bar wrapper, a balled-up piece of survey paper, etc.... It all depends on what you have in your pack. A lost gasket (ring) can also be replaced with a rubber tire tube band, a true savior for the broken-down caver! Ditto for damaged threading that separates the water and carbide reservoirs. Cut a 10-cm band from your rubber carbide pouch and hold it in place with two thinner bands, one at each end.

When a welding contact comes apart or is pierced (gas connecting tube, valve screw, base), the repair gets trickier. You might try improvising by melting a piece of plastic or burnt rope end, but the hold is uncertain. But at least you can say you tried...

At worst, transform your rubber carbide pouch into a generator by placing a piece of fabric in one end and wetting it regularly. The gas tube is placed snugly in the opposite end and held...with another inner tube band, of course (If we haven't already cursed the inventor of the tubeless tire, we'll do so now). Don't expect this contraption to work well, but at least it will allow you to see better than an electric lamp whose batteries will quickly run low, especially if the return is long.

Total breakdown

Though this is rare, it could happen: you run out of carbide completely, or burn out your last bulb... When nothing works at all, you'll have to rely on the light of your teammates' lamps to continue on. In horizontal passage this can be done but on rope, you're on your own, and it's time to resort to survival tactics. You have two solutions. The first is to use a chemical light source such as Cyalume ("glowsticks"), which gives off a weak, diffuse light that will allow you to just barely get by – carefully – in the dark for a few hours. It is enough for climbing a rope, but it's best to have someone wait at the top to light your movements as you exit the pitch. Check the expiration date on your sticks: they are only good for a few years.

The second solution is to use an emergency white diode (LED) light that runs on a lithium button battery. These are commercialized as key ring lights and weigh all of five grams. They are truly effective: hung about the chest on a cord, they light up enough of your perimeter to allow you to see your next step or maneuver, and even enough to distinguish objects over five meters away. These little lights run for ten hours and last ten years, which makes them perfect emergency backup lights.

1.3 Equipment and Hardware

Descender

Remember that you can ask a teammate to leave his descender on the rope once he is below and then retrieve it by pulling up the rope, as long as there are no deviations or rebelays between you. These are limiting, and using a borrowed descender is only possible for the odd isolated pitch; otherwise, the delay from waiting for the second person adds up.

We have two emergency solutions: the first is the Münter hitch (see fig. 70), which is usually used as a braking device for belaying, tensioning tyroleans, or lowering heavy loads. This is installed on a carabiner clipped directly into the seat harness maillon and it makes for an effective rappelling device (fig. 338).

This hitch allows you to stop and let go of the rope: just place a keeper (mule) knot behind the hitch. Fasten this with a cowstail carabiner placed in the knot loop, since the trailing line tends to pull and undo the loop.

To reduce arm fatigue, hold the lower rope just below the hitch with the left hand at face level and feed slack through using the right arm.

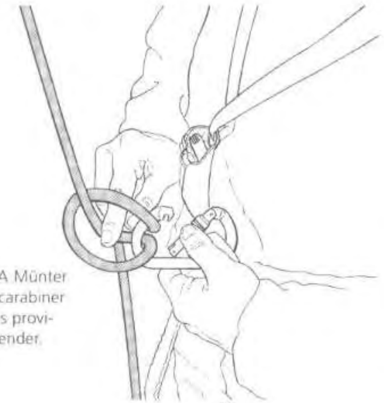

Fig. 338 – A Münter hitch on a carabiner can serve as provisional descender.

Fig. 339 – Holding the rope up vertically prevents it from tangling.

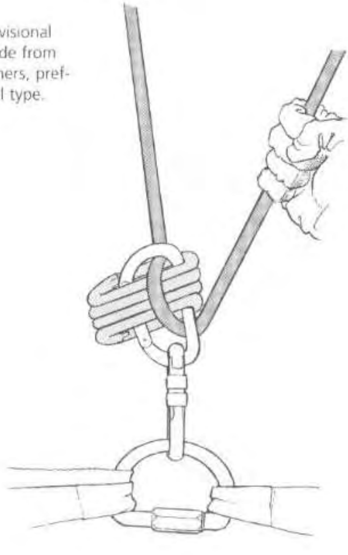

Fig. 340 – Provisional descender made from several carabiners, preferably the oval type.

Key Point:

Hold the slack end high to prevent spin on the rope (fig. 339).

The second emergency device can be made with an oval locking carabiner crossed with several other carabiners as necessary (two to four) for a comfortable rappel (fig. 340). On large diameter ropes, this is more effective than the Münter hitch and allows you to free your hands by adding a keeper knot. It also allows you to control your descent more easily in deep pits (over 50 m).

Some teach the "two-headed" descender method, which uses two safety carabiners through which the rope is passed in a very specific way. But we will refrain from describing this method because there is a risk of twisting the upper carabiner, which leads to a rapid descent.

Ascenders

With the increased use of the foot ascender, it is now rare for us one is not available somewhere in the team. The simplest, fastest and most effective solution in this case is to convert a foot ascender into a chest or upper ascender.

If there is no such device available, another option is to borrow a teammate's ascender, as with a lost descender. If there is no intermediate anchor or deviation, a teammate above can lower his.

To do:

Once the first person is up, the second holds up the end of the rope below to form a bend at about one meter from the ground. He then steps away from the line of trajectory: 200 grams of metal arriving at terminal velocity can damage a headlamp, or a shoulder... The ascender slides down the rope on a carabiner and comes to a stop in the rope bend.

Here again, the first person must wait at the top for the second to climb before moving on to the next pitch. You lose even more time than on a descent since climbing takes longer, so this solution isn't very effective when there are numerous drops in the cave.

You can choose from among a few other emergency devices, which differ according to the kind of ascender that is lacking.

Upper ascender

In the absence of a foot ascender, we recommend the Tibloc, Ropeman or another similar device. This solution has some drawbacks, however. First of all, the device is quite small (though this is also an advantage) and so easily lost. Some models snag the sheath or flatten the rope. But most of all, it is simply another piece of equipment to carry that will only be used in exceptional circumstances.

Auto-blocking friction knots (described on page 78) are an even better option.

The most versatile of these is the Blake knot (fig. 75b, page 78) and the braid hitch, the latter being the best if you have an extra webbing sling, and the former being best if you need to climb using a cord or piece of rope (fig. 341). With the braid hitch, the number of wraps you place over the rope will depend on the relative diameter between the rope and the auxiliary cord as well as the rigidity of the latter. In general, this varies between three and six wraps. In practice, just work by trial and error; getting it right doesn't take long. For more efficiency, place a stopper knot using an overhand knot at the bottom of the last wrap (fig. 341 b).

The French prussik on a carabiner (page 78) is also a good replacement for a missing ascender. The footloop works directly to tighten down on the pit rope. Since the footloop is shortened so much, it is best to use quick-adjusting models.

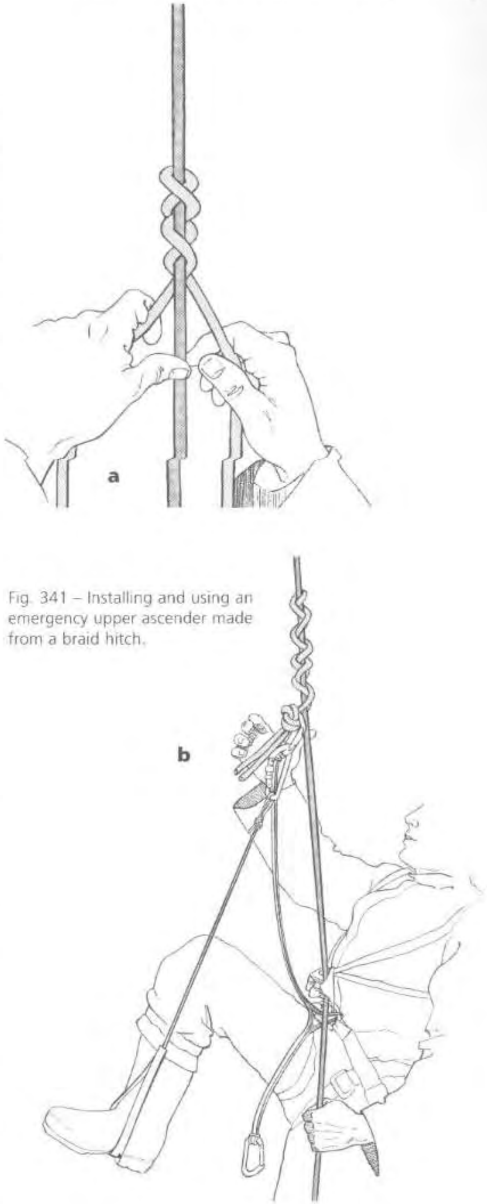

Fig. 341 – Installing and using an emergency upper ascender made from a braid hitch.

Chest ascender

The best replacement for a missing chest ascender is a foot ascender (the best system is to replace the upper ascender with the foot ascender and use the upper as the chest ascender).

To do:

If you have no foot ascender and no deviations to pass, share a chest ascender with a preceding teammate, unless you have numerous pitches.

Otherwise you'll have to fall back on an emergency device. Unfortunately, you need to take up slack in the rope by pulling down on it during each step up. The most efficient method is to pass the slack end back up through the upper ascender's carabiner so the slack is pulled from the bottom rather than from the top.

In order of preference, we recommend the following emergency climbing devices:

1. **An auto-locking descender** installed on half-lock (fig. 342). This works well on any rope diameter.
2. **The "maillon system,"** which is simple and effective, especially on softer rope since it slides better. Make this with an oval maillon and a locking carabiner, which is then linked to the harness maillon (fig. 343).
3. **The garda hitch** (heart knot) is another option (fig. 344). This one only requires two identical carabiners.

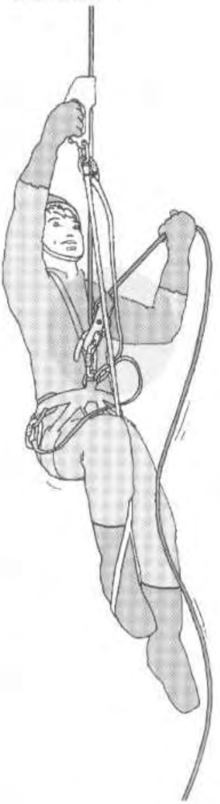

Fig. 342 – An auto-locking descender can be used as a chest ascender.

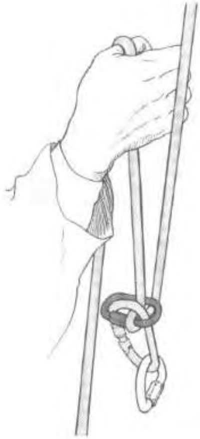

Fig. 343 – The maillon system.

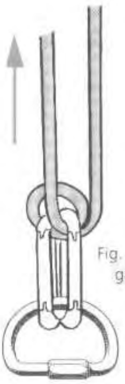

Fig. 344 – The garda hitch.

Cave pack

It could happen that your cave pack falls down a fissure or into a deep pool. If it's out of the question to leave it there, you'll have to start fishing. Your hook will be a carabiner held open with a rubber band (like the one around your bootleg); the fishing line is the rope. Of course, Murphy's Law would dictate that the desired rope is lying in the runaway pack... You'll have to manage with your cowstails, footloops, and harness strung end to end. The goal is to hook a strap and pull hard, especially if the crack is tight or sinuous. Well-equipped packs will have a floating tether that will rise toward the surface if the pack falls into water. That makes it easier to hook.

Hex wrench

Losing your wrench while you're de-rigging can be very annoying. Remember first of all that many caving hammers have a spanner incorporated into their handles. If no one else in the team has an extra one (which should be a part of every caver's personal rig), you canimprovise by using the opening on a maillon, which you screw down around the nut. This works well when rigging, but tighten down the screw again with a wrench on the next descent. When de-rigging, the maillon only works to loosen the nut if the latter has been only moderately tightened.

1.4 Clothing

Remember that in colder, active caves it's not easy to cave without a caving suit. You are unprotected and get wet quickly even in caves that don't seem particularly humid, and your clothes usually get shredded from contact with the rough cave walls and floor. The problem is not as critical for other articles of clothing: by digging through your teammates' packs, you can usually manage to find a suitable replacement. It may be less comfortable, but that's the least of your worries.

You could find yourself with two gloves of the same hand, usually two lefties since the bend between the thumb and hand wears down from rope rub while rappelling. Just turn one inside out!

2. Small Party Self-Rescue[20]: Evacuating an Injured Person from the Cave

2.1 Fundamental Principles

Whether or not we know the person we are helping, coming to someone's rescue is a spontaneous act that we perform simply because we are human. The need to help can arise before anyone while underground, requiring a quick decision on what to do and how to react. Carrying out a rescue is not as easy in a cave as it is in everyday life – it's not like coming to the aid of a grandmother who has fallen down some stairs or comforting a child who has fallen off his bike. You may be faced with the difficulty of intervening while on rope or in a narrow, confined passage. On the other hand, the average caver is fit enough to get himself out of most difficult situations. Rescuing a teammate thus implies a level of difficulty and urgency that allows little time for procrastination. This could lead to dramatic physical or moral consequences, for both the victim and the rescuer.

Rescue techniques are difficult and complex, but the novice caver can begin learning them as soon as he can manage basic vertical maneuvers. He can then build upon and practice these techniques in regular training sessions, and be better prepared to use them effectively if circumstances require it.

Rescuing someone requires experience, clear thinking, good technique – and total self-control. At the beginning of this chapter, we discussed how best to prepare mentally for emergency situations.

Key Point:
Remaining calm goes along way to assuring a successful rescue.

1. **Before you act,** it is extremely important to decide on the most effective (or the only feasible) method to use, given the particular circumstances at hand. Below we will specify the criteria to be used in reacting to various situations you may encounter.

2. **Once the choice is made**, be sure you have the necessary equipment to carry out the task.
   - If the problem occurs on rope, ask yourself:
     - Do I have all of my personal climbing gear in good operating condition?
     - Do I need to carry extra equipment with me?
   - If the problem occurs in a tight space, ask yourself:
     - What nonessential equipment can I leave behind in order to move more easily and effectively?
   - If the problem occurs in an aquatic area, ask:
     - What type of floating or waterproof equipment do I need (container, dry bag)?
     - Is a safety rope available for me to use?
     - Do I need one?

3. **The rescue maneuver** is not simply a question of methodology. Any number of factors, subjective or objective, may complicate it: high water, a panicked victim, damaged equipment or risk of damage, equipment lost in the accident, wounds, etc. All of these parameters must be taken into account and prioritized so that you can decide on the intervention to be used and plan it out.

Now we will describe various techniques, putting you in the rescuer's shoes. This approach will help clarify these complex procedures and prepare you for what may someday – perhaps even tomorrow – occur, and certainly under more trying circumstances.

2.2 Now I Can Act:

- **Secure my own safety above all** (another accident would be catastrophic):
  - By strictly adhering to the usual belay and safety methods;
  - By maintaining a reassuring attitude and control over the situation (which can calm a panicked victim for example, preventing rash gestures that could have serious consequences);
- **As soon as I have joined the victim, I must do whatever necessary to:**
  - secure the site and protect the victim from any immediate dangers;
  - avoid aggravating his condition;
  - locate any obvious wounds;
  - make the victim as comfortable as possible before continuing with the rescue operation.

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[20] Rescue by the partner or team with which the victim has been caving, as opposed to signalling a fully equipped external rescue.

To do:

If the victim is conscious, my presence alone can be a significant source of comfort. I will use this positive effect to our advantage, since it can make the difference between life and death in the most serious cases. I will speak as much as possible to the victim, using a calm reassuring voice, even if I am saying things that may not be important. I question the victim frequently to determine his level of consciousness and/or shock, the condition of his wounds, and any information that he should give me to pass on to medical personnel.

- **To protect the victim from any immediate danger, I must:**
  - begin moving the victim very slowly, looking for possible wounds, and so as to slowly reestablish blood circulation;
  - try to get the victim positioned as upright as possible if he is hanging on the rope;
  - evacuate the victim using my chosen method.
- **Set the victim down carefully in a safe, comfortable place:**
  - far from falling rocks, steep slopes or vertical pitches, and out of water (otherwise, I must belay him to a safety line accordingly);
  - under a makeshift rescue heater, if the wait is expected to be long. This can be fashioned from rescue blankets and carbide lamps.
- **If necessary, dispatch the fastest team member to seek reinforcements or signal a rescue.**
  - If I remain with the victim, I will have to wait with him and will need to keep us both as warm as possible.

In fact, there is no hard and fast rule here; everything depends on the specific circumstance and one's own judgement. If you are near the entrance, for example, it may be best to leave the cave to raise the alert rather than wait hours for a rescue to be called by your family or friends. Outside of this specific case, we should only leave the victim alone in the cave if his condition does not risk worsening and if he is psychologically prepared to remain there alone.

3. Removing a Victim from an Unrigged Passage

The most serious situations usually occur when someone is stuck in a meander, fissure or other tight crawlway. The compression of the body – and especially the chest – can be one of the most uncomfortable experiences imaginable and can rapidly lead to breathlessness, panic and even suffocation.

3.1 Meander or Rift

The latter situation is particularly frightening if it is vertical, when there are no footholds and gravity pulls the victim insidiously downward each time he exhales and his lungs slowly constrict.

In this situation, I must first of all comfort and calm the victim to prevent him from panicking. Panic will lead to hyperventilation and cause further slipping and further panic. We will likely be in a known passage; otherwise the victim would not have entered without a belay. But he has somehow been separated from the more open passageway and I must help get him back to it.

If I am below him, I will climb up as close as possible to him and try to guide his feet to a foothold, or supply a hold for him myself with a shoulder, hand, head, knee or cave pack. When we've arrested his descent, I'll raise morale by shouting victory and continue to encourage him. I'll instruct him not to try moving until he has calmed down and caught his breath. Then he can begin extracting himself with my help and suggestions.

If I am above him, I can only help by lowering a rope with a loop tied in the end, which I need to lower to his feet. He could also use it to as a hold to prevent him slipping further, until he can get his foot into the loop. Now that the rope is taut and his foot solidly in the loop, I instruct the victim to bend his leg as much as possible (which usually isn't much), while I hold the rope in place. The stuck caver should be able to push down against the footloop little by little, until he manages to extract himself. With each straightening of the knee, he must wedge himself against the walls to prevent slipping back down.

We must take occasional rests during this operation since it can be exhausting for the victim. The maneuver is of course easier if there is another teammate below the trapped caver.

3.2 Narrow Crawlway

In horizontal passage, gravity fortunately has less effect; the situation is not as critical but the feeling of compression remains a source of psychological distress.

Again, it is very important to maintain constant contact with the victim.

If I am behind him, I will approach and remove his pack if he has one, cutting the tether if necessary. I will them help him move forward by blocking myself against one or both of his feet so as to provide a solid hold. If necessary, I will ask him to try to retreat, then place a rope or pack tether around his foot, and pull on it as hard as possible. It is then up to the victim to bend his knee and slowly back out.

If I am in front of the victim, I will exit the narrow crawlway, turn around, and re-enter it so that I am face to face with my teammate. Now I can comfort and counsel him, and at least help take off his helmet, gloves or other accessible gear that may cause discomfort. I will then retreat as he advances or, again, use my body as a support against which he can push to move backwards.

Again, having one teammate in on either side of the victim is more effective.

4. Removing a Victim from a Wet Passage

Every caver should of course know how to swim. But doing this with boots, pack, caving suit, and helmet assembly can complicate matters. If someone falls into deep or swift-moving water and can't get out alone, I must reach out an arm or a leg for him to seize. If he is too far away, I will throw out a rope or a tethered pack if this can act as a flotation device (if it contains a watertight container or waterproof bag, for example), and instruct him to detach himself from his pack (unless it floats!). If the current isn't strong, I can swim to his aide, but only if I am myself attached to a lifeline that ensures my safe return to shore.

Warning! People who are drowning will sink their rescuer by grabbing and clinging to them in panic. I must be especially careful of this, and will not hesitate to dunk the victim myself in order to diminish his strength before dragging him to the shore. The ends justifies the means, as they say...

If the victim is swept into a strong current, the situation is extremely serious and perhaps hopeless.

What NOT to do:

It is useless to leap into turbulent waters in an attempt to retrieve a drowning victim: one drowning is still better than two. From above, I will try to guide him to a place where he can seize a hold. If necessary and if the situation allows, I will try to accompany him downstream with the help of traverse lines, going as fast as possible but always observing the rule of using two cowstails for safety, and only as long as the maneuver is safe.

5. Removing a Victim from the Rope

Removing a victim from a rope in a pitch (also called a pickoff) is truly a challenge. It is already difficult to move an inanimate body about on the ground; doing so while you are both hanging on a rope is even more complicated...and more urgent.

5.1 The Situation is Critical !

First and foremost, be aware that a person who has lost consciousness on rope will hang backward, chest horizontal, arms and legs dangling. This position can lead to rapid physiological pathology that can be fatal. The phenomenon, called "harness induced pathology" or "harness hang syndrome" is little understood, but we know that it occurs when circulation is cut off by the harness and blood is compressed or compartmentalized. Studies have shown that after 10-20 minutes, a healthy person hanging conscious but motionless on rope will suddenly lose consciousness. This process seems to be accelerated if the person is already injured or unconsciousness, and death can occur in just minutes if the victim is not removed from the rope.[21] So time is critical: you must not only reach the victim but also get off the rope and onto solid ground as quickly as possible. If the pitch is even slightly wet,

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[21] see http://www.cancaver.ca/int/mexico/zotz/harness-death.htm for more information on this phenomenon.

the situation is even more urgent because the victim is losing energy more quickly and hypothermia is a constant threat.

If the victim is unconscious, it is imperative that you raise his head up using whatever means you can find (on yourself or on the victim), and as quickly as possible. Adjust his chest harness to bring his upper body closest to the rope and then secure him to the rope with a carabiner clipped into his chest harness and the rope.

To do:

Once the carabiner is clipped into the two straps of the chest harness, twist it around once before clipping it to the rope. This will prevent it from falling down toward the Croll.

If the victim was rappelling, he may not have been wearing a chest harness, in which case you must improvise one on site.

5.2 What to Consider When Choosing a Method

What are the criteria for choosing the best pickoff method? Since we rarely have to carry out such a maneuver, the method first of all needs to be **simple**; it is unrealistic to expect to remember a complex procedure, especially under the emotionally stressful conditions of a real emergency. Considering the diversity of possible circumstances, the method should also be **universal**, or almost. In particular, it must work even if the lower end of the rope is anchored to a rebelay. And if we want it to be as operational for a small young lady as for a fully padded old-timer, it needs to **require minimal physical strength**. In addition, there must be **no need for intervention** from a third party. And of course, only a method that requires **no additional equipment** besides what is already on our personal rigs will allow us to operate in any situation.

Finally, as we have said, the condition of a person hanging immobile on rope will quickly deteriorate: the method must be as **rapid** as possible.

Integrating all six of these criteria into one method isn't so easy, which is perhaps why so many methods have been proposed yet so many remain insufficient.

So let's throw out all methods that require an additional rescue rope: this would lead you to believe you have the problem solved. If by chance you happen to have one available, don't hesitate to use this godsend. It would save precious time and make your work much easier. But whoever can do more can also do less, so we will leave this possibility in the realm of the hypothetical since we want you to be prepared for any difficult situation below...

5.3 Lower or Raise the Victim?

It is clearly easier to have gravity working in your favor when you are moving a load as heavy as a human body that may even be inanimate. It is better to lower the victim, except in special circumstances such as when the victim is immobilized nearer to the pitch head, the bottom of the pitch is exposed to water spray or the passage shape does not allow you to set the victim down in a comfortable position. There may also be a narrowing of the passage just below the victim or a similar complication. We can hardly set out a complete list of all the possible scenarios; it is up to the rescuer to consider the situation calmly and rationally before deciding on a plan of action.

When raising the victim, you must reduce the amount of effort you spend and this requires you to use your own body as a counterweight. When lowering, you will evidently carry out the operation using a descender. It is advisable for the rescuer to arrive below before the victim in order to ensure a comfortable landing for the victim. The descender used to rappel will therefore be that of the victim.

Key Point:

You must attach yourself as close as possible to the victim's descender using two linked carabiners (rather than the short cowstail) linked to the victim's harness maillon. This will help you to better control the descender.

To do:

When the technique calls for two persons to rappel on the same descender, it is imperative that you use a braking carabiner (preferably a Handy) to effectively control the rappel.

5.4 Joining the Victim

Rest assured that loading the rope with the static weight of two people, as is required in this pickoff maneuver, is perfectly safe. Remember that we frequently climb in tandem in the deeper pits. You will not have a choice about whether your departure point is from below or above, but there is only one really safe way to join the victim without an extra rope: by using your ascenders.

5.4.1 Climbing from below

Nothing changes here from your usual climbing technique, except that the rope will oscillate more slowly due to the weight of the person above. Be careful not to climb too fast: you don't want to arrive exhausted.

5.4.2 Down-climbing on your ascenders from above

When you must join the victim from above, it gets more complicated (unless you have an auxiliary rope!). You cannot use a descender because the added tension on the rope will not allow you to install it as usual. There are two methods for reaching the victim in this case.

The only really practicable method involves using your ascenders to down-climb the rope: just climb in reverse. We described this technique on page 154, but we will repeat the maneuver here. With each stride,

- begin by stepping in your footloops to take your weight off the chest ascender;
- push down on the cam with your thumb until it touches the housing (this disengages the teeth from the rope), then bend the legs and move down the rope;
- release your thumb from the cam and transfer your weight back to the Croll;
- take your weight off your footloops and lower the upper ascender by similarly releasing the cam;
- repeat the procedure.

Movement is slow with this technique but it is perfectly safe, and we highly recommend you use it. The only other practicable technique for descending the rope would be to use a braid hitch with an auxiliary piece of rope (see fig. 75c).

5.4.3 Rappelling on a descender from above

Beware! Using techniques for rappelling on a tensioned rope with a descender vary according to the kind of descender being used (auto-locking or Simple), and they require special modifications for each model (brand) and according to the wear on the spools at time of use. We only rarely need to put these techniques into practice, and the extensive variations and the delicate modifications needed for this particular method leave more room for error and thus diminished safety. For these reasons, we have decided not to discuss these methods.

5.5 Which Method to Choose?

You've analyzed the problem and taken into account the principle considerations and the options that logically result from them. Now you only need to make your decision and put them to practice... but it's easier said than done.

Many methods already exist and this indicates the complexity of the problem. Some newer techniques have arisen from canyoning that are simpler and faster, and involve cutting the rope. These are still rarely practiced and could use some perfecting; we also propose a newer version that can be used from above as well as below.

We find it useful to put these techniques into some sort of perspective, to better highlight each one's strong and weak points.

We will present four pickoff techniques that vary according to the rescuer's departure point and whether he decides to lower or raise the victim.

Key Points:

- The methods discussed below all require the rescuer to check the link between the victim's footloop and upper ascender (hereafter called "the footloop assembly"). These must be linked with a carabiner, into which the victim's long cowstail carabiner is clipped (rather than having the footloops clipped into the cowstail carabiner). We recommended this assembly on page 49. In fact, the victim's footloop carabiner will be used as the return on the counterweight, or as the descending rope's attachment point if the rope is to be cut. This point will therefore be loaded when you have to remove the victim's long cowstail carabiner.
- During all pickoff maneuvers, use your body to lever the victim into an upright position (i.e., put your knees on top of the victim's thighs). This will create more free space to a maneuver the equipment and save you valuable time and energy.

6. Victim on Ascenders: Lowering the Victim from Below

We invite the reader once again to step into the boots of the rescuer...

When the victim has started climbing the rope above me, the easiest solution would be to lower him back down to the bottom of the pitch, unless he is very near the pitch head. If this is the case, I may choose either direction for evacuation according to the circumstances: the shape of the pitch and summit, whether there is a convenient, sheltered area to place the victim, etc.

Here are four techniques for lowering the victim.

6.1 Footloop/Croll Method

1. I climb up as close as possible to the victim and take his foot out of his footloop but leave it attached to the rope (I will need it for a foothold in step 5).
2. I clip my short cowstail into the bottom of my partner's harness maillon for safety, with its carabiner gate facing me. *This is **always** how you should clip a cowstail carabiner into a harness maillon. This prevents the gate from coming open as it presses against the body during a maneuver.*
3. I remove my upper ascender from the rope. I will no longer need this ascender, though I will need my footloop (fig. 345).
4. I remove my footloop and its carabiner from my upper ascender and clip the carabiner into the top eyehole of the victim's Croll. I run my footloop through the carabiner linking the victim's footloop assembly (fig. 346). I should have about 10 cm between the knot on my footloop at the victim's Croll and the carabiner at his upper ascender, when I transfer my weight to it in step 7 (otherwise, I can adjust victim's upper ascender as necessary).

Fig. 345 – The footloop/Croll method, the counterweight on long cowstail and the Croll-to-Croll, step 3.

Fig. 346 – Footloop/Croll method, step 4.

5. I place the victim's footloop on the outside of his leg and step up in it in order to take weight off of my Croll, keeping my heels below my buttocks for better balance. In the same movement, I remove my Croll from the rope and place it on my footloop near the bottom loop knot at the height of the victim's harness maillon. I then step back out of the victim's footloop.

Fig. 348 – Footloop/ Croll method, step 7.

Fig. 347 – Footloop/Croll method, step 6.

6. (Fig. 347) I attach the descender to the victim's harness maillon with the latch facing me, and attach the obligatory braking carabiner as well. I then install the pit rope on the descender just below the victim's Croll, and fully lock it off (unless the descender is an auto-lock).
7. (Fig. 348) Since my weight is now on my chest ascender and footloop, I can act as a counterweight. The victim is now ready to be lifted as I sit. I begin the maneuver by pushing the victim's buttocks up with my hands and knees (under the circumstances, efficiency is of course more important than propriety!).

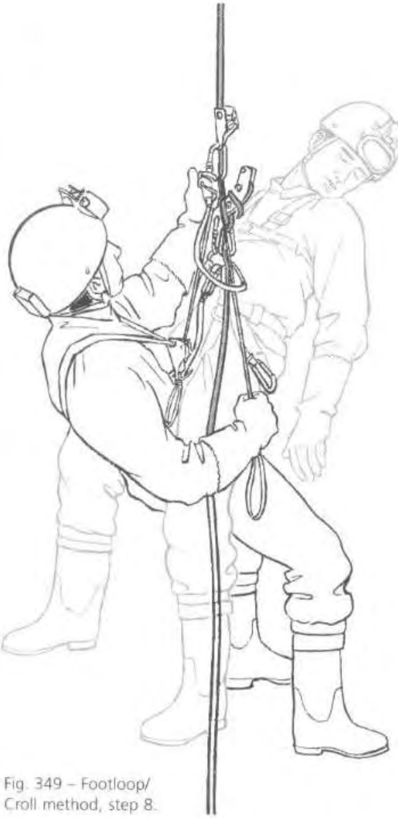


Fig. 349 – Footloop/ Croll method, step 8.

Fig. 350 – Footloop/Croll method, step 10.

8. I unlock the descender (unless it's an auto-lock), take up the available slack, and redo the full lock.

   I then remove the victim's Croll from the rope and his long cowstail from his footloop assembly (fig. 349).
9. Once again stepping up in his footloop, I take my weight off my Croll: the counterweight effect works inversely and the victim's weight transfers to the descender.
10. At the same time, I remove my Croll from my footloop and retrieve this cord. I then attach myself as close as possible to the victim using two linked (preferably locking) carabiners, one attached to my harness maillon, the other to the victim's (fig. 350).

    I now unlock the victim's descender and lower him down. Since I arrive at the floor just before him, I can be sure he lands gently and comfortably (fig. 351).

Fig. 351 – Footloop/Croll method, end of step 10.

Fig. 352 – Counterweight on long cowstail, step 5.

Fig. 353 – Counterweight on long cowstail, step 6.

6.2 Counterweight Method on Long Cowstail

1. I climb up as close as possible to the victim and take his foot out of his footloop (I will need to step up in it later).
2. I clip my short cowstail into his harness maillon with the carabiner gate facing me.
3. I remove my upper ascender from the rope, since I no longer need it (fig. 345, page 274).
4. I clip my long cowstail carabiner into the upper eyehole of the victim's chest ascender.
5. I should leave about 10 cm between the knot on my long cowstail (where it sits near the victim's Croll) and the victim's footloop carabiner, once I've transferred my weight to my cowstail in step 7 (otherwise I must raise the victim's upper ascender a bit; fig. 352).
6. I move the victim's footloop to the outside of his leg and step up into it, and remove my Croll from the rope. I then pass my long cowstail through the victim's footloop carabiner (fig. 353).

Fig. 354 – Counterweight on long cowstail, step 7.

Fig. 355 – Counterweight on long cowstail, step 8.

Fig. 356 – Counterweight on long cowstail, step 10.

Fig. 357 – Counterweight on long cowstail, step 11.

7. I transfer my weight back to my long cowstail, triggering a counterweight effect and lifting the victim. If my weight is less than that of the victim, I can again push up on the victim's bottom with my hands and knees. I then remove his Croll from the rope (fig. 354).
8. I install a descender on the victim's harness maillon with the latch facing me, and attach the obligatory braking carabiner. I install the pit rope on the descender and carabiner, take up the extra slack, and lock it off completely. I unclip the victim's long cowstail from his footloop assembly carabiner (fig. 355).
9. Once again stepping up in the victim's footloop, I can take my weight off my long cowstail. The counterweight effect causes the victim's weight to transfer to the descender. I remove my long cowstail from the victim's upper ascender carabiner.
10. During the same maneuver, I link our harness maillons together with two attached carabiners and transfer my weight to the victim's maillon (fig. 356).
11. I unlock the descender and lower the victim and myself to the floor. Arriving just before the victim, I can be sure he lands gently (fig. 357).

6.3 Croll-to-Croll Method

The maneuver begins in the same way as the previous maneuver:

1. I climb up as close as possible to the victim and take his foot out of his footloop.
2. I clip my short cowstail into his harness maillon with the carabiner gate facing me.
3. I remove my upper ascender from the rope, since I no longer need it (fig. 345, page 274).
4. I step up in the victim's footloop (preferably on the outside of his leg) in order to bring my Croll just up underneath his (hence the name of the maneuver, fig. 358).
5. I install a descender on the victim's harness maillon with the latch facing me, and attach the obligatory braking carabiner. I install the pit rope on the descender and carabiner, take up the extra slack, and lock it off completely.
6. I remove the victim's long cowstail from his upper ascender, which remains on the rope.

Now the maneuvers begin to differ:

7. I loosen my chest harness (see step 9) and position myself directly opposite the victim. I spread his legs and place my own legs between them, under his bottom. This will make it easier to lift him in a minute.
8. I hold the victim's Croll with my right hand, and get ready to open this with my left (fig. 359).


Fig. 358 – Croll-to-Croll, step 4.


Fig. 359 – Croll-to-Croll, step 8.

9. I swing back with my stomach muscles tight and push my knees up to raise the victim. At the same time, I use my right hand to push up on his Croll. His weight comes off the Croll, allowing me to open and remove it from the rope.
10. I try to hold the victim as I accompany him to rest on the descender (fig. 360).
11. Stepping back up in his footloop, I remove my Croll from the rope.
12. At this point, I link our two harnesses with the two carabiners. I then lower myself, transferring my weight to the victim's harness maillon (fig. 361).
13. I unlock the descender and lower us to the floor. Arriving just before the victim, I can insure a gentle landing (fig. 362).

This technique is more exerting but it has the advantage of being faster than the others, which may count for a lot since time is of the essence. However, if the rescuer is lighter than the victim or if the rescuer is not so strong, the maneuver in step 9 could be too difficult. In this case, either of the other two methods would be preferable.


Fig. 361 – Croll-to-Croll, step 12.


Fig. 360 – Croll-to-Croll, step 10.


Fig. 362 – Croll-to-Croll, step 13.

6.4 Cutting the Rope

The most time consuming and difficult part of doing a pickoff is removing the victim's Croll from the rope. We can avoid this step altogether and save precious time with one simple maneuver: cut the rope. Of course, if there's one thing a caver is loath to do, it's this! How could we cut the rope, our link to the surface, our indispensable companion, the object of our greatest care and attention and source of so many rebelays and deviations... Sacrilege!

There are however times when you should not hesitate to do this, and some pickoff techniques demand it be done, so get used to the idea!

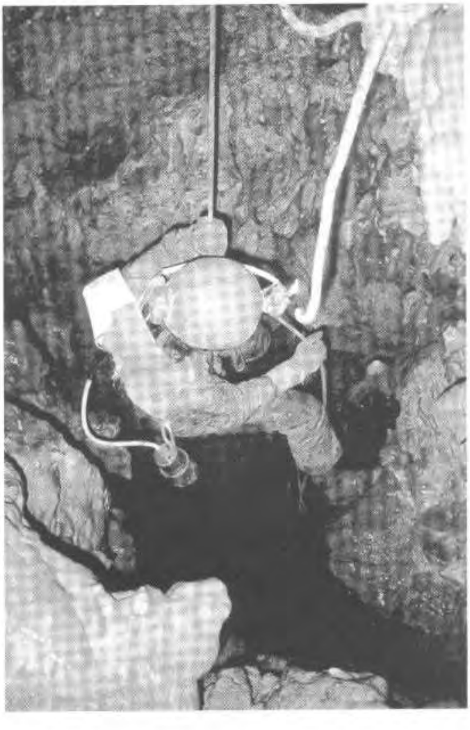
6.4.1 How to cut the rope

Well, with a knife of course, assuming you have the one we advised you carry at all times (see page 115).

Those who arrive in a rescue situation without this indispensable tool are victims of their own negligence, and will have to get by with what's available. There are two other solution which are slower, but you may not have a choice...

- Use the flame of your carbide lamp. Contrary to what one might think, the operation isn't difficult and doesn't take too long on a wet rope, as the fibers are taut under the weight on the rope: about ten seconds will usually suffice. You will have to remove your helmet during the procedure and the gas tube may get in the way as you try to get the flame to its contact point. And of course, this method will not work in the presence of a waterfall!
- Rub the rope against itself or another cord (5 mm or larger) such as a footloop, unless it is made from spectra: its melting temperature is too low. Sitting opposite the victim with your knees resting on the victim's thighs for support, place the cord just above and against the top of the victim's chest ascender. Holding both ends of the cord tightly, begin sawing this rapidly back and forth against the rope, pulling constantly toward you. Since the same spot of rope is being heated and abraded by friction, this will eventually break before the cord does, regardless of the difference in diameter.

You can practice these three maneuvers safely outside using a length of old rope (moistened beforehand), hanging about a meter off the ground.



Puech Nègre. Photo L.H. Fage

But It goes without saying that using a knife is by far the easiest, most effective means of cutting the rope.

To do:

It should go without saying that you must cut *away* from the victim and yourself, to avoid accidental injuries (which have occurred!).

6.4.2 The maneuver

Whether I arrive at the victim from below or above, the method will be the same:

1. I join the victim using my ascenders by either climbing or down-climbing, and position my Croll right below the victim's. If necessary, I pull or lever the victim up to the rope as discussed earlier.
2. I clip my short cowstail into his harness maillon, gate facing me.
3. I remove my upper ascender and my footloop from the rope.
4. I unclip the victim's long cowstail from his footloop assembly, leaving the footloop in place.

Fig. 363 – Cutting the rope, step 5a.

Fig. 364 – Cutting the rope, step 8.

5a. If I have climbed from below, I have made sure to bring the end of the rope up with me, which is tied with a figure eight loop. I clip this into the victim's footloop assembly (fig. 363).

5b. If I have down-climbed from above, I will make the loop using the rope that is available below the victim. Even if the lower end of the rope is attached to an anchor, the 160 kg load being applied during these maneuvers will produce more than two meters of slack along 30 meters or rope, in addition to the working slack normally left in the rope. This is more than I will need (if this isn't the case, that means the victim is near the pitch head, and I should be hauling him up rather than lowering him). I then clip the knot loop into the victim's footloop assembly as in 5a.

6. I check that there is at least 30 cm of rope between the victim's two ascenders, and raise his upper ascender if necessary.

7. I place the victim's descender on his harness maillon and install the bottom part of the rope. I carefully take up the extra slack above the descender, clip the rope into the braking carabiner, and lock off the descender.

8. I raise the victim's upper ascender as high as possible, putting some tension on the descender (fig. 364).

9. Stepping into the victim's footloop, I remove my chest ascender from the rope. At the same time, I retrieve my upper ascender (still attached to my long cowstail), install it on the pit rope about 20-30 cm above that of the victim, and transfer my weight (fig. 365).

Fig. 365 – Cutting the rope, step 9.

Fig. 366 – Cutting the rope, step 10.

Fig. 367 – Cutting the rope, step 11.

If the landing point where I intend to set down the victim is in any way exposed (top of a pitch, rebelay point, etc.), I will make an end rope loop knot just below the victim's Croll, where the future rope end will be.

10. I cut the rope just above the victim's Croll. Since I have removed the slack above the descender, this will cause very little shock loading as our weight transfers to the descender (fig. 366).

11. I retrieve my upper ascender by stepping into the victim's footloops, and simultaneously attach my harness maillon to the victim's maillon with a chain of two linked carabiners, lower myself, and transfer my weight to the victim's harness maillon (fig. 367).

12. I begin descending to the bottom of the pitch, arriving before the victim and insuring as comfortable landing as possible for him (fig. 368).

Fig. 368 – Cutting the rope, step 12.

Key Points:

- At step 5b, try to reduce the amount of rope that will be lost after the cut to a minimum. You need enough rope to be able to set the victim down below. If you arrive from above and if the rope is not anchored somewhere below, there's little to indicate if the rope end reaches the floor. However, the rope will stretch more from the double load as you descend. There is little risk that you will not have enough rope below.
- If you are able to join the victim on an auxiliary rope from above, the rope-cutting maneuver is extremely rapid if you are going to lower him down. You, the rescuer, come to a stop just above the victim and attach your harness maillon to his with the carabiner link. Retrieve his upper ascender and cut the main rope. The only possible drawback of this very effective method is that the victim will land on the floor before you do.

6.4.3 Safety

Other rope-cutting techniques exist, and these techniques raise some concerns and risks.

One concern is that the victim's ascender will slip down when the rope is cut just below it. This is unfounded. The true risk lies in cutting the wrong rope... This has occurred in training sessions, causing both participants to fall to the ground.

The method described here resolves both of these problems. when the rope is being cut, the rescuer's upper ascender works as a backup safety, and cutting the wrong rope would not lead to any danger of fall. Moreover, it is practically impossible for the rescuer to cut the rope above his own upper ascender since he can only reach this by stepping up in the victim's footloop.

This method has an added advantage: when the rope is cut, only the weight of the victim transfers from one rope to the other, limiting shock load.

6.5 Problems Encountered on Descent

Additional problems can come about while you are lowering the victim. These complications are even rarer than the need for pickoff maneuvers, but they could nonetheless occur.

6.5.1 Passing a rebelay

A rebelay below could limit the available slack in the rope when I need to install the victim's descender and lock it off. The additional lengthening of the rope caused by the double load should compensate for this.

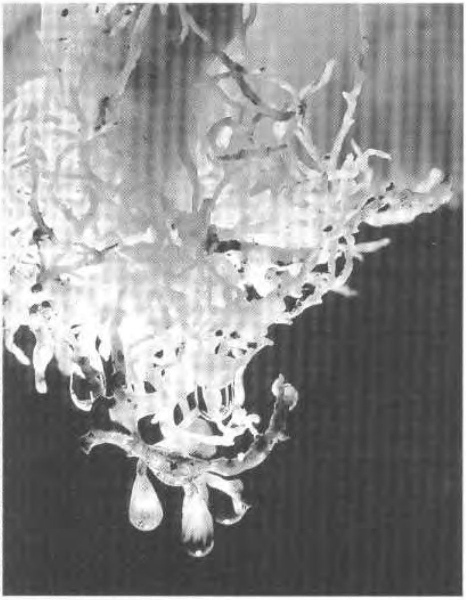
I remain with the victim, attached to the upper rope on his descender. I must then install a second descender on the lower rope to pass the rebelay, transferring our weight from the first to the second.

To do:

If I know that the upper rebelay loop is particularly short, I will need some extra length to facilitate the maneuver. I will procure this during the initial pickoff by installing the victim's descender on the end of his short cowstail rather than directly on his harness maillon. The victim is thus attached to his descender via his harness maillon (normal rebelay loop length) or his short cowstail (shorter loop). I am hanging from his harness maillon via the carabiner links.

Fig. 369 – Passing a rebelay on descent, step 1.

Fig. 370 – Passing a rebelay on descent, step 2.



Grotte Théophile. Photo S. Caillault

1. Arriving at the rebelay, I arrest our descent when the victim's harness maillon is level with the rebelay and lock off his descender (fig. 369).

Key Point:

The rebelay loop must not come between the two of us on the rope, or the next descent will be impossible. Push the rope loop against the wall.

2. I clip the second descender into the victim's maillon, next to the first. I install the lower rope, taken just below the anchor and with the least amount of slack possible. I lock off the second descender (fig. 370).

Key Point:

I check again that I haven't crossed the upper and lower ropes while installing the descender.

3. I unlocked the upper rope descender and transfer our weight to the lower descender.

Fig. 371 – Passing a rebelay on descent, step 3.

4. When I've removed the first descender from the upper rope, I unlock the second and continue the descent (fig. 371).

What NOT to do:

I must NOT clip myself or the victim into the rebelay because I risk not being able to take our weight off the cowstail to remove it and continue the descent.

6.5.2 Passing a knot

Here the circumstances aren't really in my favor, but I've already weighed the pros and cons of the situation and excluded the option of hauling the victim up, and I should know what to expect...

1. I stop two meters above the knot and lock off the descender. If the type of knot in the rope has no belay loop or protects a damaged spot, I can tie another loop knot directly below it (fig. 372).
2. **I install an upper ascender on the taut rope,** above and as near as possible to the loaded descender (fig. 373).
3. I clip the loop knot into the upper ascender with a carabiner.

Key Point:

Again, the slack loop of the rope should not come between us, as it will prevent our continuation down the rope.

4. I clip the second descender into the victim's maillon, next to the first. I install the rope, taking this from just below the knot loop that is attached to the upper ascender, and leaving minimal slack. I lock off the second descender.
5. I push the upper ascender up to put more tension on the second descender (fig. 374).
6. I unlock the first descender and transfer our weight to the second.
7. Once I've removed the first descender from the upper rope, I unlock the second and continue the descent (fig. 375).
8. We've passed the knot, but I had to abandon an upper ascender on the rope above.

Fig. 372 – Passing a knot on descent, step 1.

Fig. 373 – Passing a knot on descent, step 2.

Fig. 374 – Passing a knot on descent, step 5.

Fig. 375 – Passing a knot on descent, step 7.

6.5.3 Deviation

Passing a deviation is a delicate and strenuous maneuver. Getting rid of it is in some cases an option, but if it plays a major role in protecting the rope or caver (significant rub point, waterfall deviation), doing so could compromise the subsequent climb out. If the deviation has to stay, here's what to do:

1. I stop level with the deviation and lock off the descender.
2. Pushing against the opposite wall, I clip into the deviation *anchor* or I clip my short cowstail to my upper ascender and install this on the deviation cord or webbing, and I pull on it.
3. I remove the deviation carabiner from the rope and reinstall it above the descender, adding a carabiner or two if necessary to lengthen the deviation.
4. With a final pull, I retrieve my gear (cowstail, upper ascender), unlock the descender, and continue the descent.

What NOT to do:

As with the rebelay, I must not clip myself or the victim into the deviation carabiner.

7. Victim on Ascenders: Lowering the Victim from Above

As previously mentioned, in most cases it is more convenient and often safer to lower the victim down the pitch rather than haul him up it. For example, the pitch head may involve some difficult or particularly complicated maneuvering (squeeze, incline, complex traverse). Evacuating the victim from above and then lowering him down implies that you must climb down to him on a tensioned rope.

Once you have down-climbed to the victim (once again, this is by far the safest method), you must climb past him and position yourself directly below him. Do this by clipping your short cowstail into the bottom of the victim's harness maillon. Now you can choose from among the four rescue methods we have just described.

8. Victim on Ascenders: Raising the Victim from Above

This method is most advisable if the victim is conscious and in the appropriate state, and as long as the pitch head provides a comfortable resting area. It is also best if the pitch head is very near, if the bottom of the pitch is wet but the top is not, if the space below the victim is too narrow, if the emergency occurs in an entrance zone and you hope to evacuate the victim without outside help, etc.

8.1 The Spanish Pendulum

This is in fact a counterweight technique, but common use has given us this name, so we will keep it. Its great advantage lies in its simplicity, but the initial phase requires some effort. The technique can only be used if the rope is free below. If it is attached to a rebelay, the rescuer must first join the victim by down-climbing and cut the rope below him before climbing back up to create the Spanish Pendulum.

1. I clip my long cowstail into the anchor at the pitch head. If I am beginning from a rebelay, I remain at the rebelay level on the upper rope.
2. I hang a chain of safety carabiners from the anchor.
3. I clip the last carabiner in the chain onto the down rope. This carabiner will be called the "pendulum carabiner" (fig, 376).

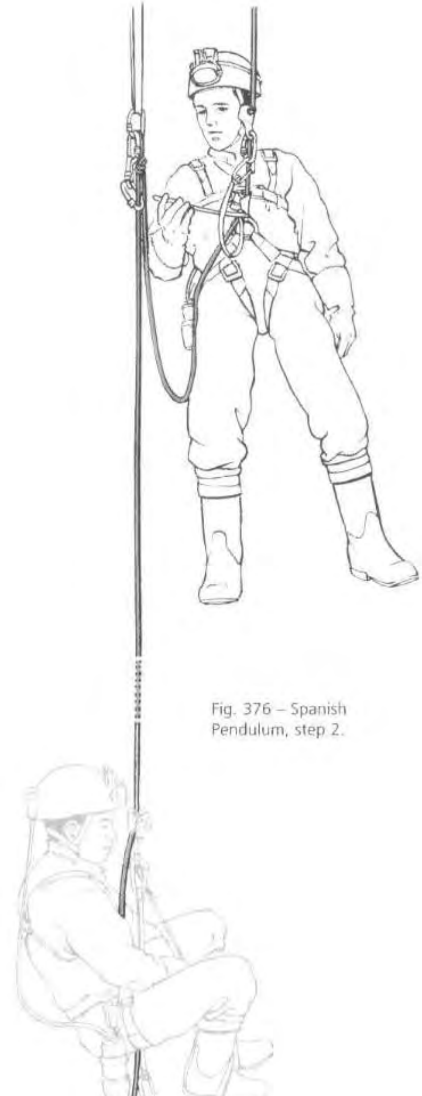


Fig. 376 – Spanish Pendulum, step 2.

4. I clip my short cowstail onto the down rope between the anchor knot and the pendulum carabiner.
5. I sit down and load my short cowstail. The pendulum is in place.

What NOT to do:

From this point on, the victim's weight must never come off the rope (pay special attention during training exercises when participants are less vigilant). If the victim's weight comes off the rope, the rescuer will fall to the ground if he is not clipped in at the pitch head.

Fig. 377 – Spanish Pendulum, step 6: setting the counterweight in motion.

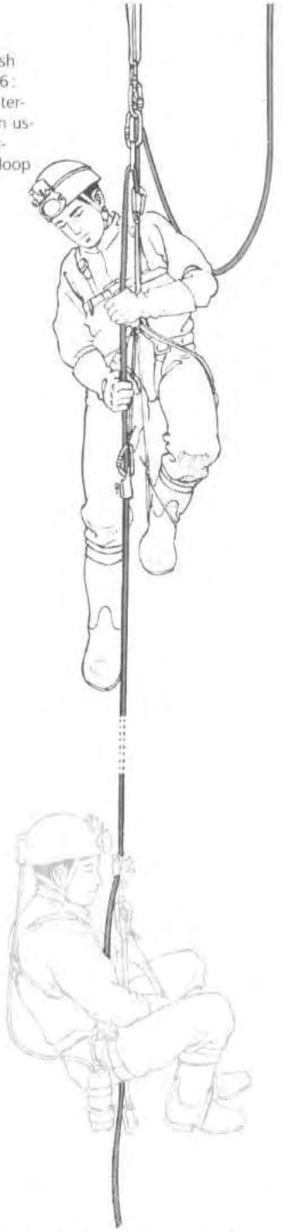


Fig. 378 – Spanish Pendulum, step 6: setting the counterweight in motion using the upper ascender and footloop as an aid.

6. I pull on the rope below that is attached to the victim, using my upper ascender attached to my long cowstail if necessary. This is usually enough to start the victim moving upward as I move down (fig. 377). If it is not, I install my upper ascender and footloop upside down on the rope below (making sure not to let it fall right down), lower than my harness maillon. I then pass my footloop through the lower part of my maillon and step down in the loop with my feet, thus adding my weight and leg strength to the task (fig. 378).

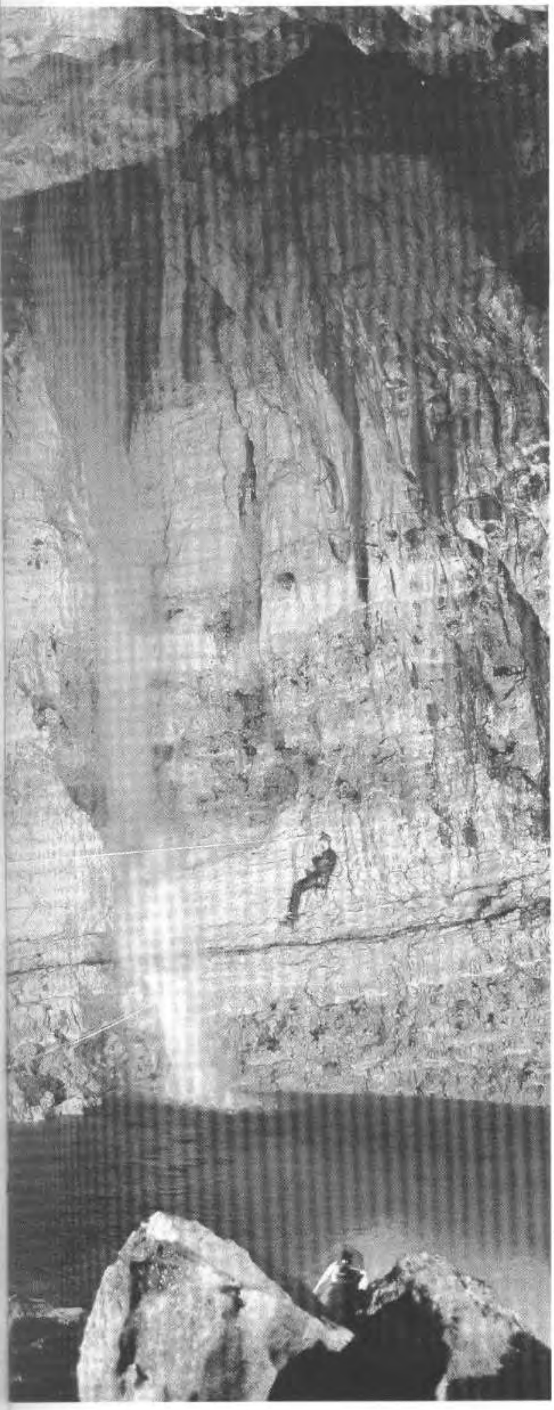
I may be tempted to continue in this way, but there is considerable friction between my short cowstail carabiner and the return rope leaving the

Fig. 379 – Spanish Pendulum, step 7.

Fig. 380 – Spanish Pendulum, step 8. My Croll arrives at the bottom of the loop.

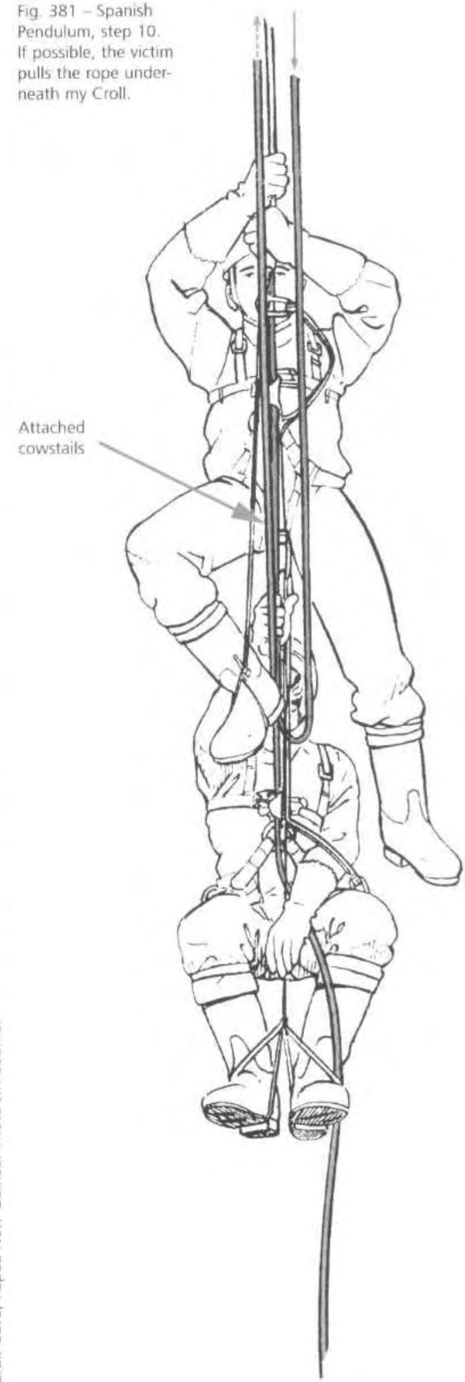
pendulum carabiner. It is better to change to ascenders:

7. Once I have descended about 50 cm below the pendulum carabiner, I place my entire footloop assembly on the return rope, where it comes out of the pendulum carabiner. I then install my Croll as close as possible below the upper ascender (fig. 379).
8. I raise the victim until my Croll reaches the bottom of the rope loop (fig. 380).
9. I climb on my ascenders until they reach the pendulum carabiner and begin the maneuver again, and so on.
10. If the drop is long, I will link the victim's long cowstail to my short cowstail when I arrive at the victim. If he can do so, the victim should hold on to the rope under my Croll (fig. 381). If I have a pulley, I will of course use this instead of the pendulum carabiner at step 3, unless I have a much lower weight ratio to that of the victim.



Muruk Cave, Papua New Guinea. Photo J.P. Sounier

Fig. 381 – Spanish Pendulum, step 10. If possible, the victim pulls the rope underneath my Croll.



8.2 Haul System on a Taut Rope

Compared to the Spanish Pendulum, installing a haul system is only a better choice if at least three persons are available to haul the rope. A typical application for this is to help haul an exhausted caver from the last few pitches before the exit.

Here is how to install a haul line on a taut rope:

1. Install a pulley-ascender assembly (see page 172, fig. 213) upside down on the rope about 20 cm from the anchor.

Tip:

Make sure it doesn't slide down the rope before you secure it. Clip your long cowstail underneath it on the rope, for example.

2. Place a carabiner at the anchor point; this will hold the pulley-ascender assembly.
3. Install a second ascender and footloop assembly under the first, also upside down. Pass the footloop back up through the anchor carabiner to make a hauling stirrup (fig. 382).

Fig. 382 – Haul system on a taut rope, step 3.

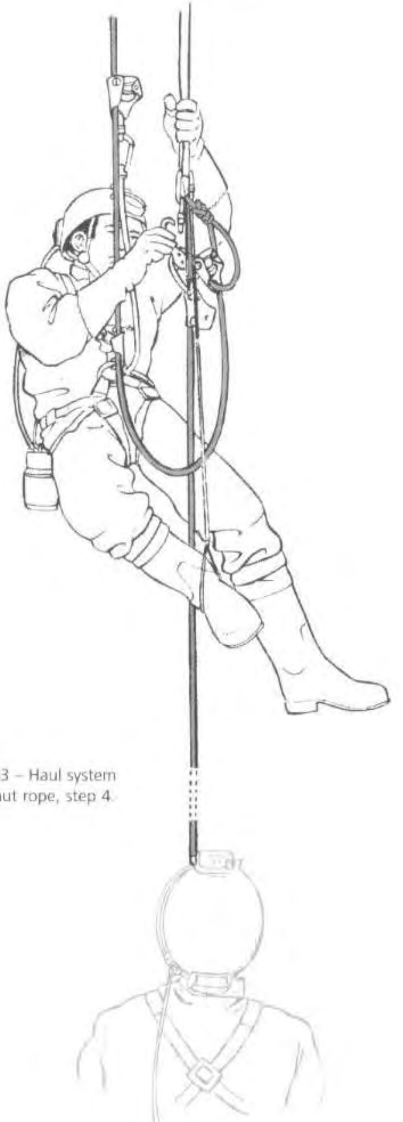


Fig. 383 – Haul system on a taut rope, step 4.

Fig. 384 – Haul system on a taut rope, step 5.

Fig. 385 – Haul system on a taut rope, step 6.

4. Step up in the stirrup while pulling on the taut line to pull extra slack through. This will make it possible to install the pulley-ascender assembly on the anchor carabiner mentioned in step 2 (fig. 383).
5. Pull more rope through by starting a Spanish Pendulum as you hang on your short cowstail from the slack side that you wish to lengthen (fig. 384).
6. Once you have enough slack, install the second pulley-ascender assembly upside down on the rope (fig. 385).

Installation is similar and much easier with a Mini-Traxion assembly.

Though this system theoretically gives a 3:1 mechanical advantage (dividing the victim's weight by three) you must still account for friction and the angle of the hauling side in relation to the vertical. In practice, you realistically get no more than 2:1 advantage.

Tip:

Pull on the haul line with an ascender to capture the rope and prevent downward slip.

8.3 Obendorf Hoist

This requires an additional rope, taken for example from one of your packs or a nearby traverse line.

Key Point:

The Obendorf hoist is faster and requires less strength to install, but requires as many people to operate and also uses two pulleys and two ascenders.

To install:

1. Place an ascender upside down on the rope below the anchor and connected to it via a carabiner. Be careful not to let it slide down the rope before securing it (as above, step 1).
2. Fix a spare rope to the anchor point and pass it through a pulley that is also clipped into the anchor (or nearby point) with a carabiner. Install a pulley linked to an ascender hanging upside down between the first pulley and the anchor point for the spare rope. Then place the ascender upside down on the main rope underneath the first ascender.
3. Pull on the auxiliary rope and take up the slack in the pit rope through the first ascender (fig. 386).

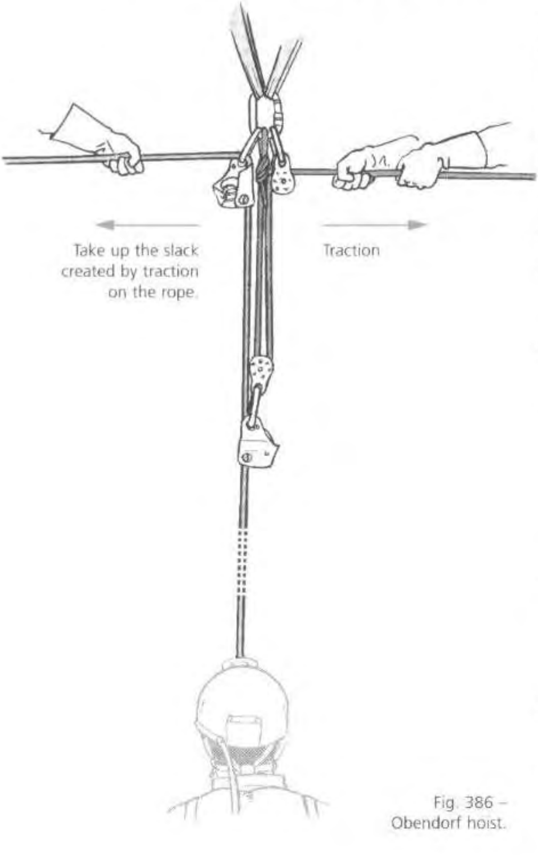


Fig. 386 – Obendorf hoist.

Recall that to lift a load the Obendorf hoist requires traction on the auxiliary rope from below or from the side; a classic haul system requires traction on the main rope from above (unless there is an additional support line – carabiner or pulley – which can be placed on both systems).

8.4 Passing Obstacles While Raising the Victim

8.4.1 Passing a knot

Spanish Pendulum

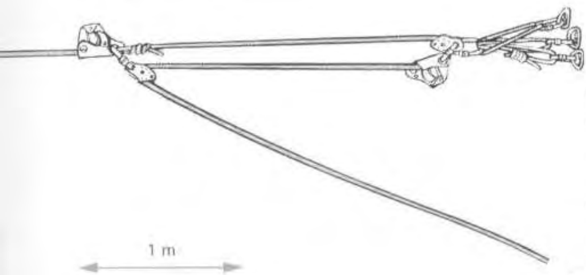
Let's step briefly back into the rescuer's boots…

When the knot and loop appear at the end of the carabiner chain, I secure the rope using an ascender placed upside down 20 cm under the knot above the victim, and clipped to the anchor. Taking my weight off the line, I lengthen the carabiner chain so that the knot passes the pendulum carabiner. I reapply my weight, remove the auxiliary ascender and continue.

Simple haul system

1. When the knot arrives at the lower pulley-ascender assembly, I remove the latter and replace it below the knot (fig. 387a).
2. Pulling continues until the knot comes up against the upper pulley-ascender assembly.
3. I prepare an additional cowstail/sling with an attachment carabiner at both ends, using the end of the rope, for example. I attach the upper end to the anchor and position the lower end to about one meter above the lower pulley-ascender assembly (fig. 387).
4. By hauling on the line, I can attach the end of the auxiliary cowstail to the lower ascender, and then let some slack into the haul line. The cowstail will tension, leaving a meter of slack in the rope below the knot (fig. 387c).
5. I remove the upper pulley-ascender and reposition it below the knot (fig. 387d).
6. I begin hauling on the line until the knot arrives at the lower pulley-ascender. I remove this and reposition it below the knot (fig. 387e).

Fig. 387 a – Passing a knot on a haul system, step 1.



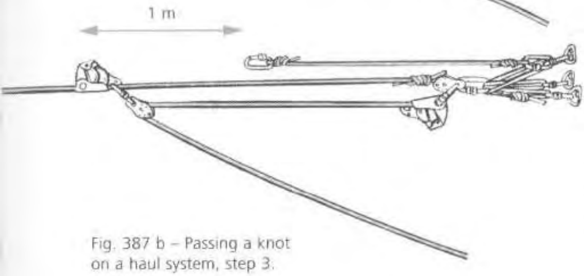


Fig. 387 b – Passing a knot on a haul system, step 3.

7. I have passed the knot and can now continue hauling.

8.4.2 Passing a rebelay

Passing a rebelay is impossible with all three of these methods if you are carrying out the rescue alone, unless you have an additional rope on ascent.

In the presence of a rebelay, and assuming you are still hauling the victim from above, you would escort the victim as a counterweight (see section 9.2), after having down-climbed and passed the victim on the taut rope.

8.4.3 Passing a deviation

It is not possible to pass a deviation with an unconscious victim in any of the three methods. However, we have recommended the Spanish Pendulum only for hauling a conscious victim (pg. 292). The victim is thus capable of releasing and repositioning the deviation when he reaches it.

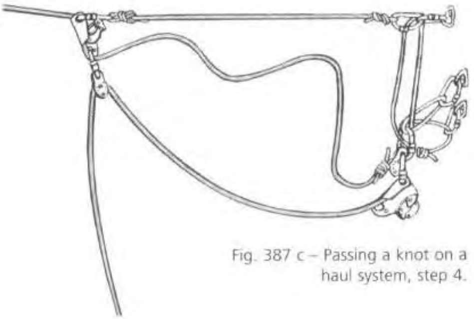


Fig. 387 c – Passing a knot on a haul system, step 4.

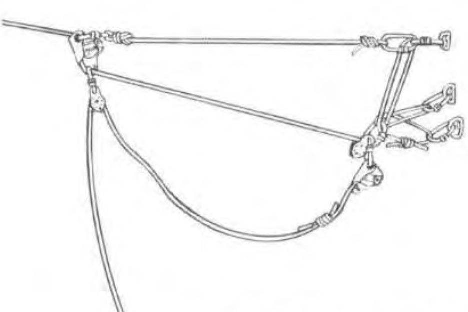
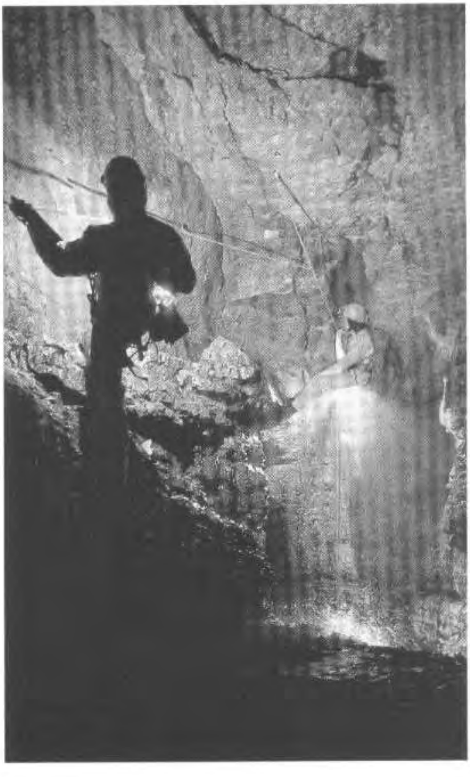


Fig. 387 d – Passing a knot on a haul system, step 5.



Rouge Eau Cave, Switzerland. Photo O. Trueb

9. Victim on Ascenders: Raising the Victim from Below

Like the previous, this kind of pickoff can be used when a conscious victim is immobilized relatively close to the pitch head, when there is a better resting area above, when there is an obstacle below the victim that would interfere with his rescue, etc. The three methods previously discussed are also practicable, particularly the Spanish Pendulum, which is faster when we approach the victim from below since it only requires one rescuer. Prior to intervening, the rescuer must free the rope end below if necessary, then climb up to the victim and pass him. In doing so, he should take the time to check the victim's condition, rectify his position relative to the rope, and calm and comfort him.

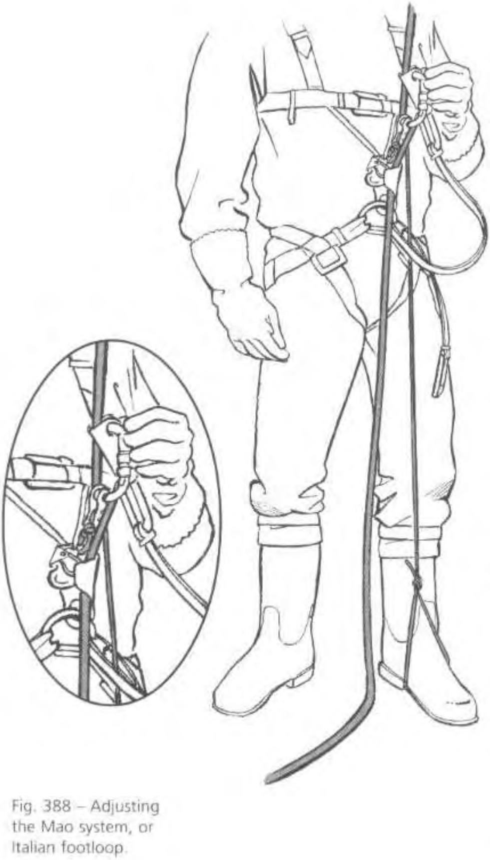


Fig. 388 – Adjusting the Mao system, or Italian footloop.

Fig. 389 – Lifting a child using the Mao system.

9.1 Italian Footloop (Mao System)

(This method is also possible if you arrive from above the victim.)

If the rescuer is significantly heavier than the victim or if the distance over which the victim is hauled is limited to only a few meters, we recommend this method (see 4.11, page 156). Its great advantage is its rapidity, since you only need to pass the victim, clip both of your short cowstails together and continue climbing, pulling him directly below you...like a pack (fig. 388 and 389).

However, this system is far from useful in many situations. The new method that follows has some added advantages.

9.2 Counterweight

This technique is very easy and gives me a 2:1 (theoretical) mechanical advantage, reducing the effective weight of the victim by half, which is not the case for the Spanish Pendulum. This method is thus less exerting and allows me to remain in constant contact with my injured colleague, or climb in one stretch if enough rope is available:

1. I climb up to and pass the victim on my ascenders, carrying the end of the rope with me (I have cut the rope if it was attached somewhere below). I reposition the victim against the rope if necessary and check his chest harness adjustment.
2. I stop just above the victim's Croll and install a simple haul system. To do this, I undo the safety loop and thread the rope end through the victim's harness maillon (without opening the latter!) so that the rope comes back out between his Croll and cowstails. I retie a loop knot in the end and attach this to my own harness, then begin pulling all the extra rope through the victim's harness maillon. This maillon is going to act as a lower pulley in my haul system (fig. 390). I remember to retrieve the victim's upper ascender from the rope.
3. I climb up as far as the slack in the rope between us will allow (unless the victim's condition requires me to stay in closer proximity). I then place the victim's upper ascender on the rope. I attach a locking carabiner to the ascender's lower eyehole, and place the rope that I am pulling up from the victim's maillon into the carabiner. We will call this assembly the "ascender anchor." I pull all extra slack through this carabiner. The haul line is ready and will be especially easy to operate thanks to the load reduction provided by the maillon "pulley" in step 2.
4. I place my ascenders on the loose end of the rope coming down from the ascender anchor and begin hauling the victim. I can move back down to the level of the victim if necessary, to escort him, prevent him from turning around, or to comfort him (fig. 391).
5. I raise the victim up until he reaches the fixed ascender anchor.


Fig. 390 – Raising the victim with a counterweight, step 2.


Fig. 391 – Raising the victim with a counterweight, step 4.

6. At this point, I should change over to the main rope: the victim's weight then shifts to his Croll. I raise the victim's ascender anchor up the rope as high as possible (fig. 392).

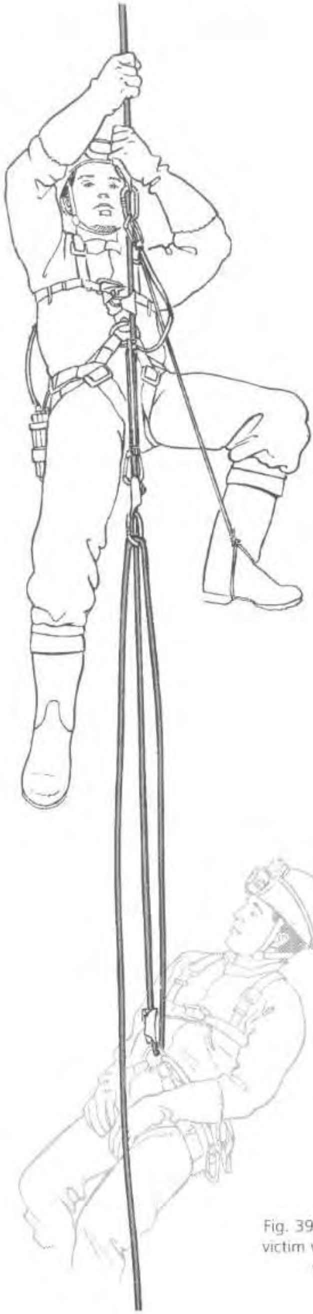


Fig. 392 – Raising the victim with a counterweight, step 6.

7. This brings me back to step 4. I change back over to the hauling end of the rope and recommence hauling.

This technique allows the rescuer to stay in close proximity to the victim, which is preferable from a psychological point of view.

Key Point:

At step 2, it is essential that the rope comes back out of the victim's maillon on the *right* side of his Croll (*as viewed by the rescuer*) and not on the left. Otherwise, the rope can escape from the Croll during the following maneuvers.

9.2.1 Passing a rebelay

1. I transfer the victim's weight to the rebelay anchor using his short cowstail, and take up the extra 5-10 cm of slack above his Croll once it has been unloaded, but not removed from the rope.
2. I transfer the upper ascender anchor to the upper rope.
3. I tie off the slack end of the haul system by tying a loop knot in it and fastening it to the carabiner below the ascender anchor.
4. Since the victim is now belayed at two points, I can remove the rebelay loop from its anchor plate and untie the knot in the rope.
5. I untie the knot I made on the haul anchor in step 3 and take up the available slack.
6. Once the haul line is tensioned I can begin hauling again, and remove the victim's short cowstail from the anchor as his weight transfers.

9.2.2 Passing a knot

Climbing past a knot with this technique is possible, but much more difficult than with the Spanish Pendulum. If a mid-line knot exists, choose the latter technique to evacuate the victim.

9.2.3 Passing a deviation

In this scenario, the rescuer arrives at the deviation first with the victim below him in the rope loop. Here again the rescuer will have to remove and replace the deviation carabiner. Some deviations will be easier to pass by simply pushing against an opposite wall; others are more difficult, even if you use your upper ascender to pull on the deviation cord. In the worst case, cut the deviation. The rope will rub until the victim arrives at the deviation point, but this very temporary rubbing is admissible under the circumstance.

10. Victim on Ascenders: The Final Choice

We now come to the end of our inventory of practicable pickoff methods. Recommending some above others is difficult, considering the number of possible scenarios: a critical analysis by the rescuer is evidently essential, and this will lead to the appropriate decision.

Having considered the alternatives though, some methods stand out. Due to their speed, efficiency, easy installation, or overall performance capacity, they deserve preference.

In the most difficult situations, such as when there is no spare rope or when the rescuer is lighter than the victim, we recommend the following:

- lowering from above: the cut rope method;
- lowering from below: the cut rope method;
- hauling from above: the Spanish Pendulum;
- hauling from below: the counterweight method.

11. Removing a Victim on a Descender from the Rope

It is extremely rare that we find ourselves in this kind of situation. In fact, a person can only get stuck while rappelling if:

- he rappels onto a knot with anything other than an auto-lock descender and cannot extract himself alone. The rescuer must then use one of the lowering pickoff methods described above.
- he is injured by a falling rocks while rappelling and the following two cases apply:
  - the victim has managed to arrest his descent by locking off his descender, but cannot continue the rappel (rare!);
  - the victim is rappelling on an auto-lock descender and is suddenly knocked unconscious.

If a person loses consciousness while rappelling on a normal non-locking descender and is unable to arrest his rappel, the problem – strictly speaking – is solved: the victim will fall to the ground or the next rebelay. This may of course lead to injury and/or seriously aggravate those already incurred.

If the victim was able to arrest his descent or is using an auto-lock descender, the maneuver is rather simple and fast since the victim's descender is already on the rope.

To lower the victim:

1. I join the victim using my ascenders (from above or below).
2. If the victim is unconscious, I adjust his chest harness to bring his chest as close as possible to the rope.
3. I position myself under the victim, at least 20 cm from his backup carabiner. I check (but am not alarmed by) the more or less abnormal position of his descender, which is mainly due to my added weight below it.
4. I clip my short cowstail to the bottom of the victim's maillon.
5. I install my upper ascender above the victim's descender and step into my footloop, take my weight off my Croll and remove it from the rope. From now on, I must not let go of the down rope, unless I have locked off the descender completely.
6. I clip myself to the victim's maillon using the double carabiner chain and transfer my weight, then remove my upper ascender.
7. I begin the descent using the victim's descender, which should be equipped with a good braking carabiner.

What NOT to do:

During step 5 (if I come from below) I must remember not to push my upper ascender right up against the victim's descender: I will be unable to remove it from the rope at step 6 when the descender returns to its normal position after I take my weight off it.

12. Removing a Victim from a Traverse Line

The easiest option when dealing with a traverse line is to move the victim along little by little using a mini-footloop counterweight system. This is installed on the rope with an upper ascender and pushed forward as you advance. The footloop is passed through your Croll at one end and attached to the victim's short cowstail at the other end. Before moving the ascender on the line, place an additional ascender behind the victim's short cowstail to prevent it from slipping backwards. If the traverse has no footholds, use the victim's footloop, which is attached to the extra ascender.

13. Removing a Victim from a Tyrolean

Without the aid of a spare rope, removing a victim from a tyrolean can be difficult. However, the technique is easier if the victim has been using a pulley to move across the line: this method is becoming more popular, but is still not widespread.

What NOT to do:

In the absence of a pulley, don't try to pull directly on the victim's short cowstail carabiner: it will turn on its side and cause too much friction on the rope.

Instead, you will have to place a second carabiner or a pulley between the cowstail carabiner and the rope. To achieve this, install a temporary mini-counterweight with a footloop attached to the victim's harness maillon, passed through a return carabiner clipped into the tyrolean and finally passed through your Croll.

The following description assumes that you are working with a pulley and not a carabiner, installed before or after the incident and linking the victim's short cowstail to the rope.

Although ascenders will operate horizontally on the rope, we will continue to use their vertical positioning to refer to the "top" and "bottom" of each ascender and the placement of its eyeholes, etc.

Let's again step into the boots of the rescuer:

First, I must decide to which end of the line I will evacuate the victim, taking into account where I will set him down and the various obstacles I will encounter in either direction. Thereafter, "in front" and "behind" will correspond to my chosen direction.

1. I join the victim and position myself in front of him with both my cowstails on the line.
2. I install the victim's upper ascender on the rope between us, with the top of the ascender toward me so that it slides in the direction of the evacuation. The lower eyehole is thus facing the victim and the cam sits below the rope.
3. I clip a double carabiner chain through the lower eyehole of the ascender and the end of the victim's short cowstail that is attached to the pulley (The carabiner attachment on the pulley should be identical to that of a pulley-ascender assembly.).

Fig. 393 a – Removing a victim from a tyrolean, step 7: the counterweight effect.

Fig. 393 b – Removing a victim from a tyrolean, step 8: pulling the ascender forward.

4. I place my own upper ascender on the rope in front of my cowstails, about 50 cm in front of the victim's ascender so that it slides in the same direction, but its cam should sit on top of the rope. I clip my long cowstail into my ascender's double upper eyehole and around the rope. I then clip the return carabiner into my ascender's lower eyehole, and also around the rope.
5. I hang the victim's footloop, shortened by about 20 cm with an overhand knot, from his pulley carabiner (as shown, fig. 393b) or short cowstail carabiner. This will be a foothold for me when I pull my upper ascender forward.
6. I clip a hauling carabiner into the double upper eyehole of the victim's upper ascender and attach the top loop of my footloop to this. I then pass my footloop through the carabiner of my front ascender assembly and back down through my Croll. I can now use this as a horizontal hauling footloop.
7. I remove my short cowstail from the tyrolean and apply my weight to the hauling footloop. A counterweight effect will pull the victim toward me. Since he is held by his upper ascender, he cannot slide backward (fig. 393a).
8. I now step into the victim's shortened footloop and pull myself forward on the rope with my arms so as to move my upper ascender as far forward along the rope as possible (fig. 393b).
9. And I continue on, repeating steps 7 and 8.

To do:

- To obtain the maximum distance with each stride of my front ascender, my Croll and footloop assembly should be positioned so that my long cowstail is just barely tensioned when the victim comes to a stop against the counterweight carabiner (fig. 393a).
- This maneuver is much easier if a spare rope is available. I attach the end of this rope to the pulley that is clipped to the end of the victim's long cowstail, and then install the counterweight mechanism on the top anchor of the tyrolean. I will create a counterweight by climbing directly on the vertical return of the auxiliary rope, using my ascenders. I must take care to attach the anchor pulley of the counterweight on the highest anchor of the tyrolean. This will enable me to raise the victim more easily to remove his cowstails from the line when he arrives near the anchor.

14. Once the Victim is off the Rope

14.1 Waiting to Exit the Cave or for Help to Arrive

Once the victim is out of immediate danger, it's time to decide whether or not to call for outside help. The main factors affecting this decision are the apparent state of the victim and the nature of the obstacles between the victim and the cave entrance.

If you decide – with your injured colleague's assent – to leave the cave under your own force, you should rig each pitch so as not to strain the victim or worsen his condition.

If the situation is more critical, do not hesitate to signal, or "call out" a rescue: without prior medical training, you lack the knowledge to accurately determine the risks on the injured party of performing a self-rescue.

The long wait begins. It corresponds to the time it takes for the designated party to exit the cave, reach a vehicle and telephone, and contact the necessary authorities, and then the time for them to contact collaborators and dispatch the first teams. This waiting period is rarely brief, it could last anywhere between two and twelve hours, and sometimes more!

If you are alone with the injured party, you will likely choose to stay with him. The time it takes for family or friends to become worried and to call out a rescue will be at least as long, if not quite a bit longer.

In any event, your priority will be to ensure the most comfortable conditions possible for the victim while waiting for help to arrive. Make sure he is sheltered from falling water or spray, strong airflow, darkness, noise, and move him as little as possible to avoid aggravating his condition. After taking off his harness, carefully close his caving suit and put on his gloves (preferably dry). The best position for maintaining vital functions is the recovery position (fig. 394).

Set up a makeshift shelter, and closed as possible, using your rescue blankets and a length of rope. The simplest would be the kind resembling a scout tent. Place an acetylene headlamp at each end to warm the interior and protect against the cold and humidity on the exterior (fig. 395).

If the victim is able to swallow, heat up a warm drink.

To best prepare him for the long evacuation that will soon begin, make sure the victim receives the following:

- Rest
- Food
- Comfort
- Liquids
- Warmth

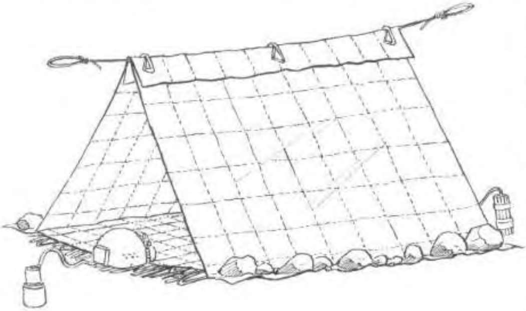
14.2 Calling out a Rescue

Whenever possible, a direct witness to the accident should be charged with triggering the alert. Before leaving or while exiting the cave, he should write down or memorize all of the answers that he will be expected to give during the subsequent telephone call(s).

These are as follows:

- Medical:
  - Is the injured able to respond to questions?
  - Can the injured move all of his/her limbs?
  - Is his breathing normal?
  - Is his pulse normal?
  - Does he have any obvious injuries/wounds?
  - Is he becoming weaker?

Fig. 395 – Emergency shelter for the victim.



- Logistics:
  - At what time did the accident occur?
  - What happened exactly?
  - How long will it take to join the victim?
  - How many people are now with the victim?
- Topography (if the cave is not well known):
  - What is the route to the cave entrance?
  - What are any particular obstacle to be aware of in the cave?

Signaling a rescue involves:

- A first call to the cave rescue authority of the area in which the accident took place. This person will usually gather all the information from the caller that is needed to organize the rescue.
- A second phone call should be made to the local police headquarters or to the fire department. In most cases, these services are able to alert the appropriate authorities.[24]

If you do not know the number to the local cave rescue authorities, you can evidently only make the second call. You will likely lose a considerable amount of time passing through administrative red tape before reaching anyone competent enough to act appropriately on the matter, and this could have serous consequences if time is critical. If you are caving in your own area or country, there is no excuse for not having the appropriate emergency numbers in your immediate reach. In France, each department distributes a list of useful numbers every year, and some even produce stickers.

When making these calls, the witness must also be able to give the telephone number from which he is calling. He must not leave that site until he has been authorized to do so by the Technical Advisor responsible for the rescue. He may need to provide additional information before the first rescue team arrives at the cave; he is thus the sole contact until that time.

Fig. 394 – Victim in recovery position.

15. Floods

15.1 Prevention

15.1.1 Gathering information

Floods are a major risk in caves and we must do everything we possibly can to avoid them. The best way to do this is by acquiring a thorough understanding of the hydrology of the area where you are caving. However, such knowledge only comes from the gathering of data, experiments, and sometimes...getting caught in one. When we are beginning to study a new cave, these details are unknown to us, though it is sometimes possible to gather information about resurgences, microclimatic changes and weather conditions from the local community. This is in fact valuable information that helps us to predict the possible effects of precipitation according to the water level of the cave. This information can complement other data gathered from previous explorations, if any exist.

15.1.2 Weather data

We've already talked about the weather in our section on rigging underground rivers, but let's hammer the nail in a bit. The weather forecast is an essential element of safety, it is easy to obtain, and it becoming increasingly reliable. There is no excuse for overlooking it. When specific risks are under consideration, we can also obtain more precise information from the local weather station. This provides us with firsthand and much more reliable information. Pay special attention to the risk of sudden storms, the precise location of which remains difficult to pinpoint. Depending on what we know of the surface catchment area, the recent pattern of precipitation, and the size and shape of the cave galleries, we will either continue with our trip as planned or go to Plan B. Periods of snowmelt or persistent rain usually involve greater risks.

15.1.3 Precautions

Preventing a problem is always easier than repairing it later. You must take every precaution to avoid any number of possible situations, some of which could take you by surprise.

If the cave presents particular flood hazards, such as low ceilings and crawlways, installing a telephone line could prove useful for keeping up with the weather on the surface, for example when doing an extended exploration. In caves that present particular risks, it is generally advisable to store extra carbide, food and rescue blankets at some strategic points in the cave, or carry them with you during the trip. You never know...

When there is the risk of a sudden release of water from a hydroelectric installation, try to get information from the facility concerned. If the releases are automatic, which is almost always the case, there is little you can do. At least you'll be more aware of the risks.

15.1.4 Hydraulic processes in caves

Why are floods so sudden and dramatic? The answer is linked to several factors. They include the average slope of the conduits relative to surface waterways; the weakness of recharge areas when they are under precipitation simultaneously; the scarcity of flat banks where water can spread out; whether there is more soil to absorb the water, slowing the process.

Careful observation of cave passages during exploration will allow you to determine the height attained by water in previous floods, and what level it will likely reach in the next. Leaves, twigs, and branches (not to mention whole trunks in the more spectacular cases) are often carried quite far underground. They may follow the main galleries or come from in-feeders or secondary systems, but they are always very telling indicators: you can sometimes find them jammed into cracks in the ceiling at impressive heights!

Clean, "scoured" passages with floors carved with potholes or strung with smooth, rounded pebbles signal semi-active cave where very strong water flows circulate. On the other hand, accumulations of clay indicate settling zones where water is calmer, but where flooding can still be significant.

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[24] Procedures for signalling a cave rescue differ across countries and often across regions. In the US, a cave rescue may be activated through a local or regional hotline or through the national emergency hotline, 911, depending on the region. On public lands such as the National Park Service, the park manager is the responsible agent. In the UK, activation is generally through the police using the national emergency number 999, and the call is routed from there. In Mexico, on the other hand, the most direct cave rescue contact is the Red Cross. Again, it is the responsibility of individual cavers and caving groups to be familiar with the appropriate (and most efficient) procedure for calling out a rescue in the projected caving area.

During floods, foam coating the cave walls can remain for days. When you encounter it, this is an indication that the water level actually rose higher, so proceed with special caution.

15.2 Types of Flooding

15.2.1 Flash floods

Floods that follow sudden storms are violent and often deadly. Limestone karsts have little or no soil cover to absorb water, so most precipitation rushes directly underground toward catchment areas where it collects. The arrival of floodwaters in normally dry passages can be especially dramatic. Inconsistency in underground soils will slow the first trickles, but higher flows will swell and catch the smaller streams. A great surge of water arrives without warning, especially when lower catchments that have accumulated water suddenly overflow. Water volume can instantly rise from zero to maximum flow. This huge wall of water displaces the air, chasing it down the cave passages and producing the sound of explosions that signal its imminent arrival. As soon as you hear such a sound, drop everything and run for higher ground.

In active systems, muddy floodwaters chase water collected in basins in front of them: the front of the flood surge arrives clear, followed by debris-filled floodwater.

Most summer floodwaters are absorbed quickly, unless there is persistent rain or the system is blocked somewhere below.

15.2.2 Flooding from snowmelt

In the mountains, springtime warmth brings with it a massive melting of the snow mantel, though low nighttime temperatures suspend this process. We see significant variations in underground water levels that correspond to this shift in surface temperature, and also depend on the structure and development of the cave system. Peak daytime flow may arrive in late afternoon, evening, or at night. Outside of this peak period, flow can remain quite high. Set your exploration schedule according to these cycles to better limit your risks.

Floods from snowmelt will continue even after the snow has disappeared from the surface, since rifts and fissures still harbor large quantities of it. These hidden volumes of snow lay protected from the heat of the sun, so it is harder to predict the level and suddenness of peak flows with the onset of summer.

15.2.3 High water floods

The ground and drainage areas become saturated during periods of persistent rain (in Europe, late autumn and early winter), and water flows tend to remain consistently elevated. Caves "respond" by flooding with each new rain; the water level can rise dramatically but water levels drop slowly. It is during such periods that we risk being trapped for longer periods. The most dangerous situations arise when steady rains, accompanied by a warming period, melts a layer of snow left on the mountain.

15.3 Here it Comes!

So what do you do now? Keep calm, assemble the team, decide what to do and act on that decision quickly (without confusing speed and blind haste), and remember to be safe: another emergency is the last thing you need now.

Move to higher (or more open) ground as soon as you notice the first signs: the sudden appearance of a stream where before there was none, surge in an existing flow, sudden change in air pressure or flow, explosion-like sounds, the appearance of a waterfall from an inlet. Flooding in vertical shafts requires you to seek refuge in lower areas of the cave: attempting to climb out would be like playing double or quits, and the stakes are your life. The sheer force of falling water (one cubic meter weights one ton!) can become a factor at any moment during the climb, and the icy flow will drain your body of all its warmth and energy: hypothermia soon follows. If you are considering climbing up, you must be very close to the pitch head and certain that the rigging there is not submerged.

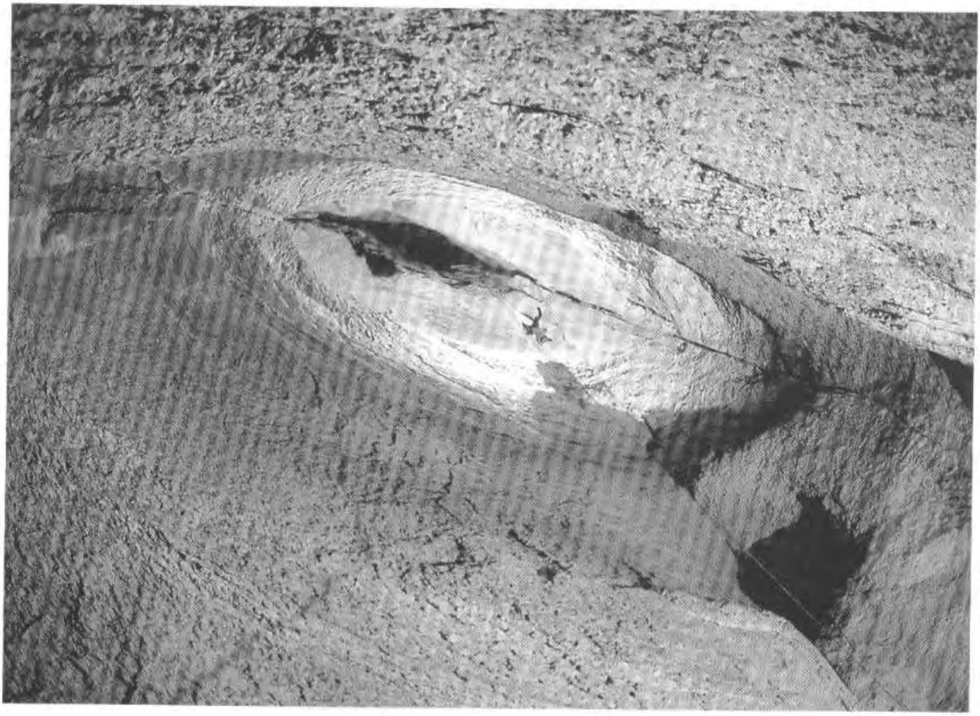
If you become stuck in mid-climb and are unable to either descend or climb, the situation is critical: waiting, suspended in your harness, can become uncomfortable and dangerous. You need to put together a makeshift seat "swing," using whatever you have on hand: an emptied pack or coiled rope, for example. This will help reduce muscle compression caused by your seat harness and improve blood circulation. You must force yourself to keep moving (by climbing and down-climbing a few meters of rope, for example) and to move the straps on your harness around to alternate compression zones in your legs.

When a team is suddenly caught in a flood, everyone should stay together whenever possible. This approach saves some members from worrying about the safety of others, provides warmth if necessary, helps keep morale up, saves carbide, and makes it easier for members to look out for each other. Of course, this recommendation is harder to follow in vertical zones.

If you have enough space, keep warm by gathering your rescue blankets together and making a tent. Otherwise, each person sits on a cave pack to isolate himself from the floor and curl up with knees under the chin, rescue blanket draped over the head and body and carbide headlamp held between the legs to warm the body. This position warms the femoral arteries, which circulate blood down to the feet. These are often left most exposed to the cold as the lay outside the makeshift shelter. If you are only able to climb or chimney up above the water, you need to find some kind of ledge where you can manage a safer stance. Belay yourself to the rock if possible, using whatever extra gear you can find in your pack. At the first lull, seek a less exposed area where you can "hold out" a bit longer.

Once you and your team have found a safe place to wait, you need to find a way to monitor changes in water level. If you can reach a bank, you can mark the water level on rocks at regular intervals. This is easier to do if the sides aren't steep. Ration and distribute food and supplies. When the water has gone down to a safer level, you can begin exiting the cave, unless the condition of any ropes to be climbed is uncertain. In that case, it is better to wait for a rescue from the surface than to risk a potentially serious accident caused by a rigging failure.

In any event, it is always best to wait in a safe place for the waters to calm down than attempt to brave their fury. If the high water continues, a rescue will eventually start to organize on the surface, with access to accurate, updated weather forecasts. You may as well wait for them, since they will know best when it's possible to "get through" safely. You can in fact survive a week or even two underground, with only water to drink and no food, as long as you can find a shelter where you can lie down to sleep, even if you only do so in shifts. No one has ever died of starvation in these circumstances while awaiting the rescuers. So why risk your life trying to make a hasty escape?



Gros aven de Canjuers, puits Martel. Photo S. Caillault

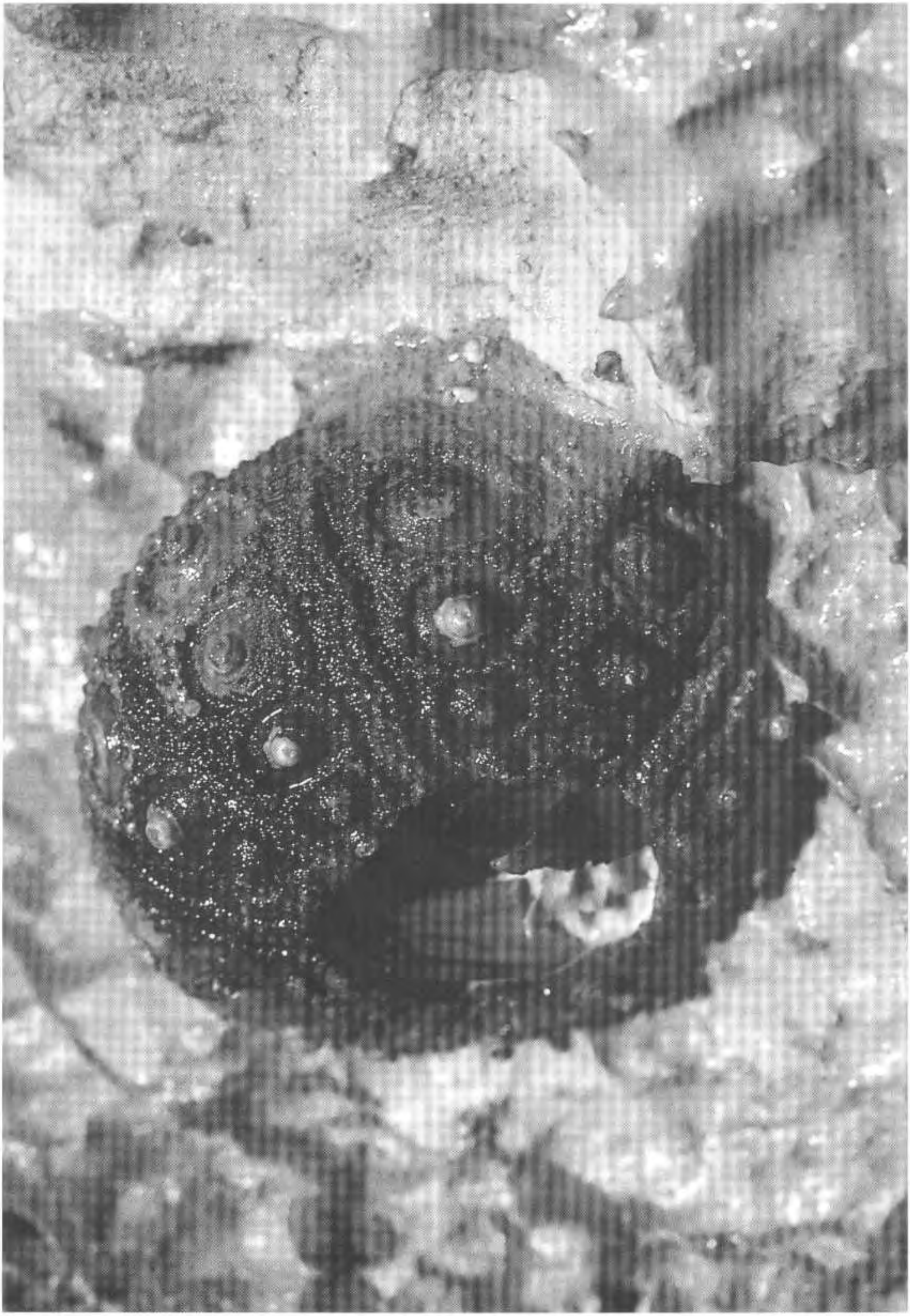


Photo U. Widmer

N Observing and Documenting the Cave

Recall that the purpose of this book is to introduce the art of exploring caves rather than to describe in detail how to document what we find in them. We warned the reader from the outset! Our subject is already extensive, as you can see from the thickness of this book. The amount of space we've left for the present chapter is therefore in no way representative of the importance of documenting what we observe while caving. That is not the focus of this book, and many other works, published on a regular basis by recognized specialists, address these topics more specifically (mapping, photography, geology, biospeleology, archeology...).

On the other hand, we can't remain entirely silent on the subject because the cave explorer is often the only person who is capable of bringing back this information, due to the remoteness of some areas and the difficulties involved in reaching them. Therefore, we want to convince him of his responsibility as a discoverer and make him aware of his duty to observe and report on what he encounters, particularly by publishing the results. The following pages will be limited to this purpose, but they only provide a point of departure: it is up to the reader to dig in deeper by consulting other sources...

There are three steps in the process of gathering and distributing information: observing and collecting data underground, classifying and validating it, and finally archiving and making it available through the appropriate medium.

1. To Look is Not to See

The capacity for observation is above all a state of mind, a manifestation of our intellectual curiosity about the world around us. Curiosity can be both a gift and a curse: a curse when it leads us to pry into the private lives of others, and a gift when it leads to the path of discovery.

Both underground and above, a curious mind reveals a desire to understand and to make sense of what we see. And what do we need to observe in caves? Everything!

Observe everything that seems new, intriguing, surprising, original, or worthy of interest in its rareness or size. Look for anything that could contribute to knowledge, beginning with yours as the observer, even if you learn later that what you thought was remarkable was in fact commonplace. At least you will have learned something... And of course, observe everything that indicates a continuation to the cave or may contribute to your understanding of the system or its history. Geology is often king in this domain. Obstructions, fossils, passage shapes, stratigraphy, air flow, water temperature, etc., are all subjects worth observing and studying!

As an explorer, you need to ferret about, look up and around you, be aware of the cave's traps, take note of every clue, ask relevant questions and seek the answers. If you don't find them alone, ask your teammates, friends in the club and other colleagues who are knowledgeable in the relevant domain. Little by little, you will find the pieces to the puzzle as you deepen your knowledge, making perfect use of the combination of sport and science that is the essence of caving. The quality and interest of your explorations will evolve with your activity and experiences. Observations that were strictly related to caving in the beginning will often become more scientific, leading to trips with more specific objectives: measuring water flow, taking samples and cross sections, collecting specimens, dye tracing, and so on.

It is clearly impossible to make good observations if you are exhausted or if the mere act of traveling through the cave occupies all your attention. Here lies your primary interest in mastering the techniques and getting into shape: only then will your attention be free to turn toward more glorious tasks.

Seeing is not so easy. Think of how many generations of cave visitors – including cavers – walked right past prehistoric paintings or engravings without even noticing them! But remember that any archeological discovery should put an immediate stop to exploration (see page 175) and should be reported as soon as possible to the appropriate agency or authorities that oversee archeological finds in the area. In fact, continuing the exploration – even with the utmost care – would almost certainly destroy many important (albeit subtle) vestiges, some of which could be essential for understanding the site and which only specialists could recognize as such (charcoal, hearths, ground deposits, imprints, bone splinters, pollens, etc.).

There's no better way to practice observing underground than to take along a pencil and notebook and to play the role of sketcher during a survey trip. After all, the sketcher's purpose is to document the cave as accurately as possible, noting details and making a kind of inventory.

1.2 Making a Survey

Any new cave discovery must be mapped from the outset: plan and profile views provide essential information about the cave that can then be distributed to teams working on various projects or seeking potential leads.

Every caver should be capable of contributing to a cave survey and the importance of this operation requires that we consider it in some detail. Making a survey is like creating a model of the cave. You will draw a series of straight line segments that will be like a framework for the cave sketch. This is the line plot. As you progress through the cave you record each segment, as well as its inclination (or dip) in relation to the horizontal plane (slope), and its orientation in relation to the magnetic north (azimuth or bearing). Back at home, you reduce the data with the help of calculus used in special mapping software: by projecting the line plot on a horizontal plane, you obtain the plan view; projecting it on a vertical plane, you obtain the profile based on the plan. But a profile obtained in this way isn't very useful; you can make a developed profile view by projecting each segment of the line plot onto the vertical plane to which it corresponds, and then bring the whole into line. In this way, the length of each shot is preserved.

1.2.1 Surveying instruments

Measuring length

You have three choices of instrument:

- a measuring tape that comes mounted on a reel. These have a fiberglass base to prevent stretch and are easy to use, except in really muddy situations when they become difficult to read and to rewind.
- A Topofil: this is a semi-waterproof box containing a measuring thread that revolves on a counter spool. It works well even when covered with thick mud and isn't susceptible to positioning errors when you are setting stations. Unfortunately, its spool/counter mechanism is delicate and not well suited to the rigors of caves.
- Laser distance meters that use either a laser beam or an infrared beam coupled with an ultrasound beam. The former is a bit pricey, but will likely become the tool of the future. The latter is less expensive but unfortunately quite sensitive to changes in air temperature and humidity, so it is less reliable in entrance areas and stream passages. Since laser meters require no additional tools, they are particularly nice to use.

To do:

If the length between stations is measured from the front of the belt of each of the two surveyors, then add 20-25 cm to each shot (plus the length of a carabiner, if used) to correct for a centering error at each station.

Measuring azimuth (compass bearing)

Rather than a standard compass with a needle that moves around above a graduated circle, we use a compass with a magnetized disk that turns on a pivot and is also graduated. You can take your readings through the transparent glass. The disk sits in a shock absorbing liquid that helps stabilize the disk so you can take a reading more easily by aligning the fixed marker with our target. These compasses are graduated in either degrees (which are most common) or in gradients. Either kind can be used for cave surveying, but remember to note which unit of measurement you are using at the beginning of the survey.

Measuring slope

The two devices for measuring slope are:

- the optic inclinometer. This has a weighted vertical drum whose gradations are read by aligning them with the target by means of a prism mechanism.
- The electronic display inclinometer. This model is not as easy to find for a low price, but you can make your own from an electronic level, coupled with a laser pointer. It takes a few hours to make, but provides an easier and more precise reading than traditional optic inclinometers, for nearly the same price.

Sistema Río Encantado, Puerto Rico. Photo U. Widmer / K. Downey

The survey (sketch) book

We use the survey book for taking our notes and drawing our maps in typically adverse underground conditions, so it must be both compact and sturdy. Choose survey paper with grid lines and polyester film coating, which makes it waterproof and harder to tear. When used with a polyester-based pen (or pencil), what is written cannot be erased, which allows you to rinse off caked mud with water. Whatever kind of pen or pencil you use, attach it to the survey book with a string or cord, and keep a backup wooden graphite pencil in a safe place (along with a sharpener), just in case.

The best size for a survey book is A5 or A6 (approx. 5x7"). The booklet is held sideways instead of upright. Sketch the cave passage on the upper page; this drawing will later be used to "dress up" the line plot for the final map. Record data on the lower page, which usually consists of nine columns:

1. number of the shot
2. length of shot
3. azimuth bearing
4. slope (including plus or minus sign)
5. distance from the station to the right wall
6. distance from the station to the left wall
7. distance from the station to the ceiling
8. distance from the station to the floor
9. observations

When either one of the two pages is full, move on to the next double page.

Some people prefer to use survey books with thicker pages that can be erased and reused. Since this method destroys the original sketches, you may not be able to correct an error found later, because it makes it impossible to refer to previous books to locate the exact position of connection points between surveys. Even photocopying the pages is not foolproof: mud-smeared areas can come out black on the photocopy and hide an important number.

1.2.2 Surveying technique

Surveying a cave requires skill and care; the precision and accuracy of the final map depends on it.

The sketcher must be observant, able to make a detailed drawing, and have clear handwriting. For better legibility, he should use the standard symbols recommended by the International Union of Speleology (see http://www.karto.ethz.ch/neumann-cgi/cave_symbol.pl). In a two-person team, he will act as sketcher as well as "point" or "lead tape," while his partner is the "operator" or "instrument reader." In a three-person team, the sketcher only needs to keep book.

At the beginning of the session, the sketcher writes down the name of the cave and the names of each person on the team, the date, and the units of measurement to be used. He will also note the departure point for the present survey, the direction of travel (away from or towards the surface), and the direction or the shots, which are usually foresights (i.e., in the direction of travel) but may sometimes be backsights. Finally, he notes the difference in height between the operator's eye and the flame of the point person's headlamp. If the flame is not exactly on station, failing to note the difference could lead to a systematic error in the data.

The survey begins and the operator positions himself at the first (zero) station. The point person chooses the next station and is responsible for reading the tape measurements. The operator takes the instrument readings, always in the same order (usually direction and then slope), before estimating the heights and widths of the passage in relation to the station. He calls out the nature of the shot followed by each number: "Azimuth: 110...Incline (or Dip): plus 7," for example. The sketcher repeats these values to ensure accuracy before noting them in their respective columns. While the point person and operator are moving to the next station and setting up the next shot, the sketcher fills in the sketch based on the readings and his observations of the cave.

1.2.3 Mistakes and errors

A map is not an exact representation of reality, and there are many kinds of errors that can affect the accuracy of the survey. In the past, the process of drafting the survey also produced errors and graphical misrepresentations, but since we now use computers to draft our maps, this is no longer a problem.

One kind of error comes from incorrect measurement, due to either instrument or user error. You may have to interpolate between two gradation marks, sometimes estimating higher and sometimes lower. In addition, you can never hit the exact point of the next station: there's always a slight movement that will put you a bit to the right or left. These errors are random and unpredictable and they partially cancel each other out statistically, once there is a certain amount of data. However, you need a rather high number of shots to achieve a less noticeable error rate, which more sinuous passages will provide. Contrary to what one would think, you will achieve less accurate readings (though you will save some time) in larger passages if you try to take the longest possible shots: it is actually better to take more short shots – without, of course, falling into the other extreme.

Systematic errors are caused by faulty instruments. For example, the perimeter of the Topofil drum, which is usually 10 cm, may be too short or long; the gradations on the compass wheel may be slightly offset in relation to true magnetic north. These defects lead to inaccurate readings but you can find them when you calibrate your instruments (by comparing your readings with those of other instruments), and then you can correct your data.

Finally, there are problems that result from human error, which you cannot really correct, except in two cases and only after the fact:

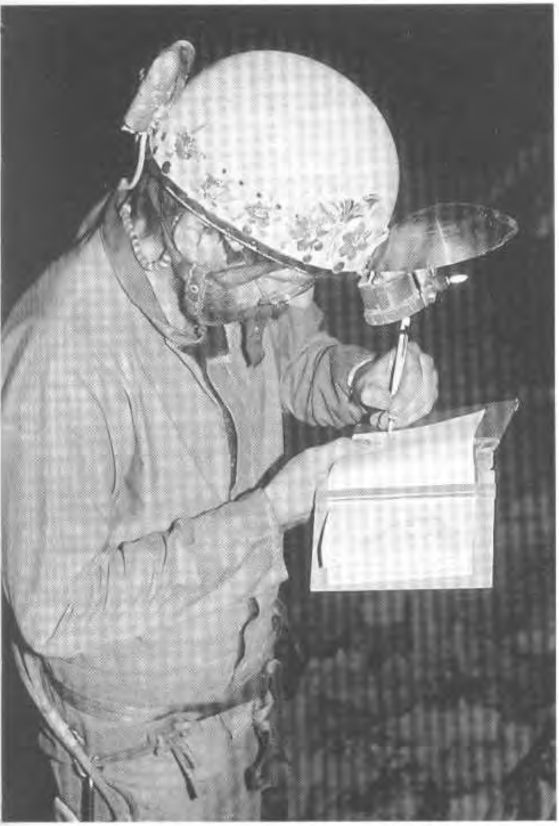
- You notice an obvious inconsistency between the sketch and the line plot calculated from the data. In this case, we go back to the original notes and look for a possible transcription error (often a number that was not written clearly). If nothing can be found, then the questionable shots will have to be retaken.
- If you happen to close a loop (connecting one passage back into itself or another part of the cave), the map will likely show some error at the closure, which should be no greater than the statistical error calculated by the software. If the error is greater, this is due either to faulty instruments (recalibrate them and correct for the error) or to human error. In the latter case, you have no choice but to resurvey; not a happy thought, but it will give you the incentive to be more careful the next time around!

If you need a truly precise survey in order to determine if it makes sense to dig or the likelihood of a connection exists, survey in both directions (entering and leaving the cave). This will automatically give you a loop, although the survey trip will be twice as long.

1.2.4 Frequent errors

Remember the causes of some common errors to better prevent them in the future. These include:

- magnetic objects that influence the accuracy of the compass bearing (carbide headlamp, steel carabiners, electric headlamp)



Proyecto Cerro Rabón, Oaxaca, Mexico. Photo U. Widmer

- error in the positive and negative value when shooting a weak slope
- error in the compass reading when shooting a steep slope
- miscalculation when correcting the values taken as backsights for convenience
- forgetting to correct for height differences between instrument readers
- reading error, particularly when interpolating values (139 instead of 141, for example)
- forgetting to calibrate the instruments
- inaccuracy in placing stations
- writing numbers down illegibly
- faulty positioning of the compass plate, which will "stick" and not turn freely when not held horizontally
- confusing between degrees and gradients
- placing the values in the wrong columns on the data sheet
- faulty positioning of the stations connecting the present survey to a previous or later survey
- forgetting to correct for changes in the Earth's magnetic field when linking the survey to a much older one
- typing error when entering the data into a computer

...and the list goes on!

Recall that for this as well as the other topics presented in this chapter, our purpose is not to give a complete course on these subjects, but rather to make the reader aware of the importance and complexity of cave surveying.

2. Classifying and Archiving Cave Data

Within the setting of a club or caving organization, it is essential to preserve the maps and data that have been collected and processed trip after trip and year after year. Doing so will allow the club to locate and reproduce any or all of the group's work since its inception.

At the risk of sounding a bit old-fashioned, we will mention that using a computer hard drive as the sole archive of a club's activities is not always a reliable method for filing and storing data. Using a computer is convenient and even inevitable, but backup hardcopies should be produced systematically and kept in a safe place. Electronic files can easily be lost or destroyed, especially since the computer or software usually does not belong to the club but to one of its members. This can be problematic when there is frequent turnover in membership and leadership, as it often the case with caving clubs. And then there are the possibilities of faulty commands, lost diskettes, hard drive malfunctions and incompatibility between systems and programs...

Some official databases – usually belonging to universities – provide safe, long-term digital archiving. The University of Zurich, Switzerland has one such cave database which gathers cave surveys created with the mapping software Toporobot (http://www.geo.unizh.ch/~heller/toporobot).

Still, paper records have proven indispensable for the last five thousands years, and will likely continue to be so for some time to come!

2.1 Plan and Profile Maps of Explored Caves

Once you've collected the survey data underground, you need to translate the information into the form of a map. The time of rulers and protractors is long gone, and we now have sophisticated (and free!) software that has made this step a simple formality, as long as you don't mind typing in the data. Among the most common are in France are Visual Topo for PC users, and Toporobot for Macintosh fans.[25] By using a plotter or a printer, you can obtain plan and profile views, various perspectives revolving around a specified axis, statistical error calculations, positioning of several caves on the same plane, etc. These documents are useful for carrying out further research and for publishing a final report in a specialized journal.

2.2 Rigging Chart

The rigging chart inventories the equipment needed for exploring a cave (see page 257 for more detail). This inventory can be conveniently produced while de-rigging the cave after its first exploration (or, if it will not be de-rigged for some time, during the survey trip). In fact, this is an ideal time since you still have the details of how each obstacle was rigged (number and type of anchors, traverses), and the packs that are brought out of the cave will contain exactly what was needed for rigging. Ropes should be left with their anchor knots and end coils intact, and measured before they are disassembled and washed. This method allows you to obtain the exact length needed to rig each pitch or succession of pitches, taking into account traverses, backup anchors and rebelay loops. The rigging chart, usually concise and in tabled form, should nevertheless contain any visual information that is necessary for locating – while descending, but before it is too late – the anchor points for rebelays and deviations. You will then specify that a deviation anchor sits behind a thin rock blade, or that a rebelay is offset three meters to the right (always facing the wall to be rigged). You should also note potential risks (unstable breakdown, anchors to be backed up, risk of falling rocks, flood conditions...) as well as useful visual indicators when the continuation is unclear or hard to find (passage between boulders, high lead situated behind a rock outcrop, etc.).

2.3 History of an Exploration

Every club should have a trip log or some similar source containing reports on all club trips, which remains on site at the club. It plays the role of the club memoir, and it should be well-bound since it will be constantly leafed through over the years. Note all of the club's activities in chronological order, including the date, objective of the trip, participants, time spent underground, special remarks, results, and work left to continue. The trip leader is usually responsible for clearly and concisely noting this information during the next reunion, so that all can benefit from it later.

This register is a treasure of valuable information that can be particularly useful in two kinds of situations:

- when the club is lacking inspiration for the next trip, here is where to find ideas;
- when you are preparing to publish a report: some explorations can go on for months or years and the club log supplies valuable dates and details for failing memories.

This log of course does not prevent any club member who so desires from keeping his own personal notebook at home. In there, depending on his personal interests, he can add photos and illustrations as well as record his own observations, anecdotes, comments, work to be done, and future trip plans.

3. Disseminating Information

3.1 The Importance of Reporting

As with any human endeavor, an underground exploration that is not eventually recorded in a durable medium and made accessible to others is useless to the community at large; its entire purpose remains limited to the fleeting pleasure of its participants. It will need to be redone if any worthwhile lessons are to be gained from it, be it from a tourist, scientific, or human point of view. It is important to report on and share your activities with the rest of the caving community; otherwise, what's the point?

Since we draw our knowledge from information that has been patiently gathered by generations

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[25] For more information on various surveying software (for PC, Mac, Unix) from North America and Europe, go to: http:/ /www.karst.net/Software/softwar_e.htm

of driven, hardworking cavers who came before us, it is our duty (and in our own interest) to contribute back to this treasure of information. The richer it is, the more we can gain from it, for ourselves, our clubs, and our successors. We can also use it to prove the relevance of our work to outsiders and politicians who are inclined to see our activity as a selfish and marginal hobby that only produces expensive rescue operations to be paid for with public monies.

3.2 Communicating What You Find

What you report should be durable and accessible (in other words, oral and confidential reports do not count), and may be either:

- written, in the form of a club newsletter, monograph, bulletin, magazine or journal article, or book; or
- audio-visual, in the form of photographs, films, videos, CD-roms, or internet sites.

3.3 Written Documents

Use information that is dated, reliable, and supported with figures if you wish to remain objective in your reports. Anecdotal trip reports, usually reserved for a small circle of exploration participants, can certainly provide added amusement when oral accounts are given at weekly club meetings, and they may even find a place in the club's newsletter. But unless the author is a true literary talent, these kinds of reports are rarely worthy of wider diffusion.

Monographs

"Serious" reports, which require more development, appear in the form of articles. These are often presented as cave monographs and include the following components:

- topographic information: description, plan, profile, and expanded views;
- the rigging chart;
- a historical account describing the various stages of the cave's exploration and mentioning the names of its original discoverers;
- scientific information, including paragraphs devoted to hydrology, geology, biology, etc.

Bulletins

These are usually compiled for separate areas by one or several clubs or explorers. They are rather technical in nature and provide a wealth of information for later explorations in the area. They usually contain a detailed bibliography and are extremely useful for more thorough or specific research.

Scientific reports

Scientific reports are clearly the domain of specialists, though these are not always the stereotypical bookworms or mad scientists you may expect to find. There are many accomplished cave explorers who are willing to dedicate themselves to studying a particular field of research in depth, thereby creating a perfect union between the physical, technical challenge of caving and the intellectual fulfillment derived from working in their chosen field.

3.4 Audio-visual Documents

The choice to use an unwritten medium assumes some technical knowledge as well as a certain measure of artistic talent in that field, at least if you wish to go beyond the category of simple 'souvenirs.' Creating these works isn't for everyone.

Audio-visual media are particularly important for educating the general public about your activities. From a simple slide show to a professional quality film, they are an excellent means of informing others about the true nature of the underground world, which they will soon discover is amazing, grand, and beautiful, worth knowing, and very different from their preconceived notions and prejudices. These media directly serve to present a positive image of the caving community, and indirectly help bring much-needed financial support to clubs through sponsorship by public and private organisms in associated domains.

Internet sites have begun to multiply dramatically, and some providers offers free web space and personal web pages to their customers. This is an excellent opportunity for clubs to present themselves and promote their activities, exchange information, highlight their successes, and even recruit new members. There seems to be no lack of young aficionados of the World Wide Web who are ready to begin programming in HTML. Here again, a minimum of talent and skill is required to create an attractive site that others can enjoy surfing with ease.

Conclusion

This brings us to the end of our Alpine Caving Techniques. Two years have passed since we first decided to publish a new edition. A long gestation period nonetheless allowed us to develop new techniques and account for new equipment, such as the foot ascender and light rigging respectively, and to fine-tune a new method for climbing and to improve techniques for removing a victim from the rope.

Before closing, it would be useful to take a step back and ask ourselves about the fundamental principles upon which our activities as modern-day cave explorers are based. What behaviors and actions will ensure the success of our activity and its continued contribution to the advancement of human knowledge?

Respect for the Environment

When cavers bring up the topic of pollution in caves, they often place the blame for contamination on external sources: fertilizers, pesticides, industrial waste, hydrocarbons, various other kinds of run-off. Yet they often avoid addressing the degradation for which they are themselves responsible! These may not be as detrimental to the ecosystem, but their impact remains real enough, even if it may be only visual. We should tend to our own garden first...

Rather than devote an entire chapter to this topic, we decided to bring up the point throughout the book wherever it applied specifically to our activities and our behavior underground. It was a deliberate choice to do so: protecting our caves should be an ever-present concern; we felt it more pertinent to make continual reference to environmental concerns, rather than sweep the topic into the corner with a single isolated paragraph.

That said, is it really useful to come back to it yet again? Yes, because here is where we can put it all into perspective.

Generally speaking, our behavior underground must constantly moderate between conflicting demands: those of the explorer of course, those related to our safety, and finally those that insure the cave's protection and integrity. From the first discovery, we must take care to thoroughly observe the landscape and record the initial state of the cave, to highlight any points that are of special interest, and to make an inventory using notes and photos of anything that risks being destroyed. And we must do all this while leaving as little evidence as possible of our passing.

"Take nothing but pictures, Leave nothing but footprints..." It's a nice motto, but a bit unrealistic nevertheless. Whatever precautions we take, many marks will remain after we have gone. We only need to look at the average evolution of one of our known caves to see how the traces left with each passage can accumulate over time: worn-out anchors that have been replaced three times, progressive erosion of the main pathways, footholds scuffed with black boot marks, and even the slow wearing down of tighter passages where so many bodies have traveled. Our caves slowly erode like country streams, but underground there are no external factors that continuously reshape the soil surface, and all damage is permanent! Even placing a cave under full protection would not heal the wounds we've already inflicted upon it...

Our impact is real and irreversible. Since we cannot prevent it entirely, we have a responsibility at least to minimize it. We have the good fortune to be the last explorers in this Earth; we should be deserving of the privilege. It is up to us to account for and inventory the underground world, and to do so with awareness and respect. Even if caves often seem strong, they are in fact fragile in many ways. We should try to give them the treatment and respect they deserve.

Preserving the Future

We are responsible not only for our underground world, but also for that of future generations. Our first task is to avoid creating more damage or further complicating matters for those who will follow us. We are neither the keepers nor the only users of these caves and the karst terrain, and our first responsibility (and primary interest) is to respect what belongs to others. We should introduce ourselves to the farmers and ranchers whose land we use, explain our interests and our objectives to them, and seek their consent and approval. We should respect the crops and the fences, park our cars so as to leave room for farm vehicles and forestry machines to pass, report on the results of our explorations, and buy local products. These are just some of the things we can do to improve our relations and leave a positive mark on the local community once our research has led us to other horizons. Our successors will benefit from our behavior when they approach the community in turn, to begin a new exploration or visit a known cave.

We should also make ourselves known to official bodies. These include the water authority, agricultural administrations, university Earth science laboratories specializing in water-resource management, the forestry administration to obtain permits to pass through certain sectors or open a cave entrance, regional and national parks when we are interested in working in a protected area, environmental and waste-management authorities to report pollution, etc. In short, we need to know how to communicate with others to be understood, appreciated, and respected. Any insolence or underhanded act is out of the question: even if you personally escape the negative consequences of your acts, such behavior will ultimately reflect on the caving community at large.

To respect our successors is also to respect our caves, and our subterranean heritage may be vast but it isn't infinite. In developed countries, caves are being explored and mapped more and more. There will continue to be new finds but these are becoming rarer and more difficult to reach. What little bits of unknown territory and crumbs of underground beauty will we leave our successors? Will we have to create virtual reproductions of our best classics, as has been done for the recently discovered prehistoric caves (Lascaux, Chauvet)? What a sad future for the adventure seeker!

If we don't feel any ethical reason to leave some exploration for future generations, we still have the imperative duty to pass on to them a preserved legacy. The progressive degradation of our caves will force future cavers to impose greater restrictions tomorrow than those that we fail to respect today; a little bit of care now will save us greater sacrifices later. Is it too much to ask today's caver to consider the future and to act more responsibly? The future of our caves depends on it.

In Pursuit of Discovery

Einstein once said that the world will always be amazing, but man too often forgets how to be amazed. You may expect cavers to be exempt from such a lack of interest in exploration and adventure; however, more and more of them seem to limit themselves to visiting only known caves. Far be it from us to criticize this activity, but we believe that it is every caver's task to expand this extraordinary playground and to build on our common heritage. We find joy, excitement and fulfillment in doing this, and soon realize it has become a need, that our passion for caving deepens rather than diminishes with each new discovery. We only need to take that first step...so how is it that so many among us are not tempted to take it?

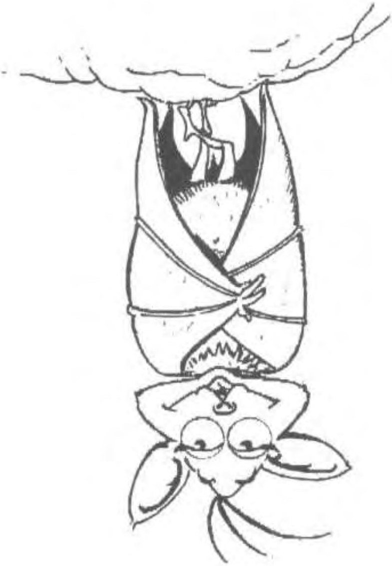
That unexplored caves and systems are increasingly hard to come by doesn't explain it all. We could point our fingers at the modern day tendency to live vicariously off our TVs. The media follows danger and the unknown everywhere, feverishly seeking to blame those responsible for the smallest accident or incident that occurs in the outdoors, to the extent that the very concept of accepting personal risk is questioned. Yet this acceptance was the key factor that allowed adventure sports to thrive. Given today's flabby, padded, overprotected and over-insured societies, who will be prepared to leap out into the great unknown tomorrow? Let's hope that cavers are still resistant to the couch-potato tendencies of a civilization that will soon be made up of only consumers and spectators. Our feeling of belonging to a small clan, little known and less understood, makes it easier for us to free ourselves from the conformist tendencies around us.

Of course, we only know a part of the underground world; better yet, we don't even know the location or the extent of what remains to be discovered. What luck, and what a magnificent opportunity! The doorway to the last unknown spaces on the planet lies unlocked before each of us... We only need to open this door to share the joy of those who passionately and resolutely carry the flame of exploration ever further. The quest continues, and along with it all our successes and failures, rebounds, struggles, risks, intense emotions, accomplishments, and shared happiness.

Our greatest wish is that these Alpine Caving Techniques will serve more in the interest of discovery than simple athletic performance and its eventual by-products. We encourage the reader to make his or her own concoction from the information presented here and to use it to make a positive contribution, no matter how big or small, to the study of karst and caves. Here as elsewhere, the smallest of streams can together create raging rivers.

The reader should remember that technique is only a means and not an end in itself. The pursuit of Knowledge should be the goal: knowledge of yourself, knowledge of others, of the underground world, this mysterious and engrossing "sixth continent." As with all great human adventures, our search belongs to history, and each of us in turn has the chance to hold the flame before passing it on. Explorers come and go, but the work itself continues on.

A cave is immutable and yet constantly changing. She is sometimes violent and sometimes serene, but she is always proud, wild and beautiful. We court this lady but we can never command her and her mystery, her magic spell, will forever lure us on. In this endless quest where danger so often mixes with beauty and exaltation, our safety certainly depends on our technique. But technique is nothing more than a humble servant to Knowledge.



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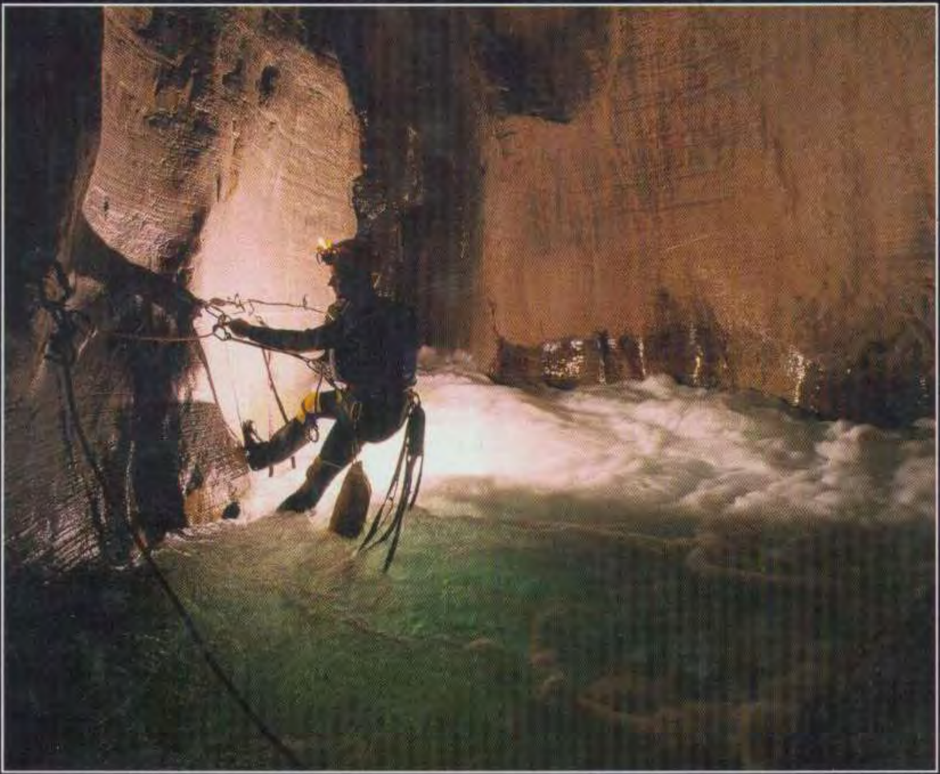
Alpine Caving Techniques

by George Marbach and Bernard Tourte

The long-awaited English edition of this classic manual, the definitive source for caving techniques among French speakers, is now translated and updated from the third French edition (2000). While it emphasizes vertical caving and rigging practices, it also presents new and thorough discussions on many other aspects of cave exploration, such as:

- equipment specifications and use
- training, diet and mental well-being
- travelling efficiently through the cave, on and off rope
- systematic prospection methods
- emergency self-and small party-rescue.

Whether you cave in the high mountains or in the equatorial jungle, as a speleo-tourist or a hardcore explorer, this manual provides essential information on how to optimize your efficiency and ensure your ultimate safety in the challenging environment of vertical caves.



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