Studying caves

Exploring caves

There are many different reasons that drive some men and women towards speleology: for some it is the sporting or technical aspect, for others it is the urge for adventure and ‘strong’ emotions or the curiosity to know ‘what lies beyond’, or even scientific research. Often it is a mixture of all these put together or yet some other reason. In any case, the aim of a speleologist is rarely just visiting an underground environment, be it sub-aerial or flooded, (we call him/her a caver), but it is the exploration of new conduits and galleries and the conjunction of the caves, to be able to reconstruct one large karst system, that is vaster and deeper, to be able to understand how these caves formed and evolved and to discover the potential of the system and how much vaster and deeper it may become (we call him/her a caver),. Man, however, is not suited to the cave environment, so in order to explore it he must be aware of certain specific techniques and equip himself adequately. Since we are unable to move about in the dark, at least two sources of light are necessary, the main one usually being an acetylene lamp. It is essential to protect oneself from cold and mud by wearing clothing made of pile and appropriate jump-suits. At times the use of a wet suit is required to cover parts that are very wet without risking hypothermia. Generally, boots or mountain climbing boots are the required footwear, while rubber gloves must be worn to protect one’s hands from rock and rope abrasion. To cope with the vertical parts, static ropes with a 10 or 9 mm diameter are used, along with a climbing harness (similar, with some modifications, to those used for climbing) and suitable equipment for climbing up and descending ropes.

Many dangers are present when exploring a cave, but actually all can be foreseen and overcome with a correct technical preparation and the right equipment: you cannot stand in as a caver!

Contrary to what is usually thought, no caver has ever died trapped in a narrow passage or under a collapsed cave roof (which, on the contrary, might happen in a mine, where the hollow is man-made, and is therefore unstable): the main risks are falling stones (always caused by the passing of explorers) and water. Since flood propagation in a karst system can be very rapid at times, it is possible that, in conjunction with an external rain event, galleries that are normally dry might get flooded, even completely: this is one of the most frequent causes of entrapment inside caves of imprudent cavers (often with a limited knowledge of the underground system),which requires the intervention of a rescue team of cave divers and adds another, at times, gruesome anecdote to the literature on this subject even though, fortunately, the majority have a happy ending. An example is the incident in the French cave of Vittarelle, where some cavers were trapped for days on board a small inflatable boat, in a chamber that was rapidly turning into a lake: the rise of the waters stopped when the boat was just a few metres from the roof…). In caves, however, water leaves unmistakable and evident traces, so that those who normally visit this type of caves know its behaviour and can foresee it easily: it is unnecessary to underline that before venturing into complex cave systems, especially if they are close to the springs, it is essential to collect information from the local caving groups.

Tracers and dyes

At times, the fact that a cave and a spring belong to the same system can be perceived immediately, especially in the case of the so-called hydrogeological tunnels, where the course of the underground waters can be followed physically by cavers from the sinkholes to the spring. Other times, on the contrary, the relationship between caves and karst springs is not obvious; it may happen that the closest springs, that rationally seem to be the most likely to be connected to a karst system, do not in fact belong to it. One must not forget that, while on the surface topographic morphology makes the identification of the divide between different hydrographic basins quite easy, underground, the dependence of karst systems on the geological structure can create dividers that are difficult to identify externally unless the geology of the area is well-known.

The easiest and safest method to establish the connection between caves and springs is water tracing. The technique is very simple: a tracer, mostly a dye, is put in the water, in any part of the system, either at the entrance or at a deep internal point, and then its presence is verified at the spring. Finding the tracers at the spring is an unmistakable proof of the connection between the input point and the check point. Moreover: the analysis of the time the tracer takes to reach

and the dilution it has undergone when correlated to the discharge at the spring and to a chemical analysis of the water, enable the extrapolation of important information regarding the karst aquifer, its water reserves, the water flow rate and also the depth of the saturated zone and the presence of big underground drainage conduits.
The most commonly used tracers are dyes such as Fluorescein (that gives a green colouring) or optical bleachers such as Tinopal (the substance that makes our washing 'whiter than white'). These substances not only have very low toxicity, even on the most delicate organisms, but have the advantage of being identified with simple methods even at low concentrations invisible to the naked eye, which makes it possible to use only modest quantities.
In the past, different substances were used, among which some really curious ones that are now part of the literature on this subject, such as the legendary eels used to 'trace' the waters of the Timavo river, rather than straw, sawdust, spores, radioactive elements and kitchen salt. At times the colouring has been totally involuntary as in the case of the overturning of a road tanker full of Pernod in the South of France that brought about the discovery of the connection between a small stream on the side of the road and an important karst system close by, to the joy of the cavers present in the cave when the 'tracer' flowed past… However simple in theory, tracing operations need, as a matter of fact, a series of precautions so as to avoid pollution and incorrect results and they must be carried out by specialists…to avoid accidents that can be tragicomical at times. Some examples are the big green patch that mysteriously appeared in front of Nesso, on Lake Como, in the Eighties or the tens of km2 of fluorescent rice fields in the Philippines caused by an Italian expedition, whose members were subsequently forced to drink the water to prove to the infuriated inhabitants, lead by some old beheaders, that the substance was not toxic…the side effects connected to a glass of water from a rice field are certainly greater than the toxic effect of the fluorescein used…

The age of caves

Chemical deposits in caves offer extraordinary research possibilities to those who are engaged in reconstructing the geological history of the past.
These can, in fact, be easily dated with a method based on the decadence of certain isotopes of the radioactive 'family' of ^{238}U.
The latter, in fact, decays into a series of elements: ^{234}Th, ^{234}Pa, ^{234}U, ^{230}Th, up to ^{206}Pb, which is stable.
Cave speleothemes contain uranium, which substitutes calcium in the crystalline network of calcite, but they do not contain thorium. From the moment the speleotheme is formed, ^{238}U starts decaying, changing into ^{230}Th. The measure of the concentration of ^{230}Th in the calcite is therefore a measure of the time elapsed from its formation. Hence, by measuring the ratio $^{230}Th/^{234}U$ and $^{234}U/^{238}U$ (^{234}U is another descendent of ^{238}U) it is possible to obtain the age of a calcite speleotheme.
The U/Th method of dating is very efficient, but only allows the dating of very young calcite, not older than 350,000 years. Using the 234U/238U ratio it is possible to extend this limit to 1.5 million years.
Recently it has been discovered that most speleothemes are much older than 1.5 million years and hence other methods are being studied currently, such as the U/Pb method (that works well on very old deposits) or paleomagnetic methods.
As far as the study of sediments that contain pebbles brought from the outside is concerned, experiments are being carried out with the so-called cosmogenic isotope method. Cosmic ray radiation (which gives the method its name) produces 10Be, 26Al and other isotopes in addition to the better known ^{14}C in the network of certain minerals (for example, quartz) when they are exposed on the surface .
When sediments are buried beyond the effect of the cosmic rays (for example, in caves deeper than 30 m), the cosmogenic isotopes begin to decay and it is possible to determine, in a way similar to the U/Th method, the moment of burial, i.e. the age of the deposit, for dates varying between 100,000 to 5 million years.

Caves remember the past

Caves are formed progressively in relatively long geological periods and evolve continuously: their history depends on many factors, among which the amount of water (depending mainly on climate), the way in which the latter enters the system, the variations of the base level and of the surface topography. Modifications in the topography can change the hydraulic supply of a cave causing, for example, the transfer of phreatic conduits to vadose zones, or bring about variations in position and functioning of springs, and much more: every modification in the cave surroundings, such as tectonic movements, climatic variations or topographical changes result in modifications within the karst system which tend towards a new equilibrium in the new situation. Hence, caves are not stable and unchanging in time and space and one must always keep in mind that they were formed in topographi and climatic conditions very different from the present ones (for example, caves in the Lombard Prealps started forming a little less than 30 million years ago when the valley presently occupied by Lake Como did not exist and there was a tropical climate with a dense rain forest covering the entire area). Any variation is promptly registered within a cave both as karst features that originated in conditions different from the present ones and as deposits of minerals and sediments that vary depending on the amount of water or on the climate (for example, in many caves in Northern Italy it is possible to find sediments related to the advance of the great glaciers that, during the last 2 million years, have repeatedly scoured the valleys from the Alps). Since on the surface erosion often results in the disappearance of all traces of the geological history of a region, caves, being on the contrary a very conservative environment, are often an important archive of precious geological data. Cavers, who are the only visitors in this environment, are often asked to unearth these data. Hence it is important that cavers should have some geological knowledge to be able to recognise the main karst features and collaborate effectively with speleologists who are engaged in researches in this field.

Cave evolution

Generally, the evolution of karst systems is similar to that of the mountain massif in which they are found. The general tendency is a gradual deepening of the cave systems as a consequence of the deepening of the base level of the valleys. But this is not always the case: the base level can also rise, bringing about the flooding of galleries that previously were fossilized. This has taken place, for example, in all the caves of coastal areas where, in the course of the last 2 million years, continental glaciations determined fluctuations in the sea level. The formation of big continental glaciers, in fact, causes the entrapment of enormous quantities of water on lands above sea level: this implies that during each ice age the expansion of glaciers provoked the lowering of the average sea level, and hence the lowering of the base level by about 100-120 m. This led to the formation of continental caves at altitudes presently below sea level. During warm interglacial periods, on the contrary, waters freed by the ice melt caused the sea level to rise and brought about the flooding of the ‘terrestrial’ caves that had been formed previously. As a result of the last Ice Age, during the last 10,000 years the average level of the Mediterranean has risen by about 100-120 m, while 125,000 years ago, not long before the last Ice Age, it was 8 m higher than today (as can be deduced from ancient nips and remains of sea caves). Naturally, it is not always that simple: variations in the sea level can also be a consequence of other causes among which, for example, tectonic activity that can raise or sink lands, and isostasy raising areas formerly covered by the weight of thick ice sheets, as is happening in Scandinavia. These variations can amplify or thwart the eustatic variations of the sea level, producing different effects from one place to another. In general, however, the result is that the majority of the sea caves does not actually have a marine origin but is the result of the flooding of continental caves with sea water. Confirmation of this is given by the study of the morphologies that are typical of continental karst caves but not of marine ones. The finding of speleothemes, in particular, is the proof of this fact and is a very precious element in the reconstruction of the history of the caves and of climatic evolution. Speleothemes can in fact be dated and the study of their morphology and of the minerals they are made of at times allows surprisingly detailed reconstructions. By studying the stalagmites formed at a depth of 20-30 m in sea caves, in Southern Italy, it has been possible to observe, for example, consecutive deposits of minerals of a continental environment and those of marine organisms, at times even with the holes of stone-boring mussels, with a cyclical alternation showing the advance and retreat of the continental glaciers. Cave-divers are a precious allies for geologists! Fluctuations in the sea level, particularly the rise of the last 10,000 years, have created vast systems of flooded caves: the most beautiful examples are the cenotes in Yukatan, entrances to ancient systems of sub-aerial caves that have been flooded by the rise in the water table to a depth of just a few metres or the blue holes of the Bahamas or Belize, where a very old karst plain, pitted with karst systems, has been completely flooded by the rising sea level.

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Caves and climate in the past

A study of sediments transported within caves, their characteristics, their composition and their content in fossils allows the reconstruction of the variations of the environment on the surface and of the climate: in particular, remains of soil formed in tropical climates can be interesting, as well as sediments related to cold climates, such as material deriving from glacial or periglacial deposits. Speleothemes, on the other hand, are formed prevalently in warm climates and are therefore very important climate markers.
In a way similar to that of ice cores, the isotopic analysis of the ratio 16O/18O enables us to determine air temperature when the calcite of which spleothemes are made of was deposited. The overlapping laminated structure and the possibility of dating calcite allow a reconstruction of the temperatures in the past that can be very detailed at times. The curve of past climatic fluctuations plotted with data from the analysis of cave speleothemes fits very well with paleo-climatic data obtained from other sources, such as the isotopic analysis of foraminifers (marine organisms with a calcareous shell) or pollen analysis.

An example close by

Even caves close to the big prealpine lakes (Maggiore, Como and Garda) have experienced a similar evolution: Lake Como, for example, is set in a deep canyon whose formation dates back more than 5 million years and hence is not of glacial origin (like its fellow-lakes, Lake Maggiore, Lake Iseo and Lake Garda). At present, Lake Como is over 400 m deep, which means that its bed is 200 m below sea level, but the bottom of the canyon, filled with sediments, is 700 m deeper. Considering that it is surrounded by highly karstifiable rocks, it is most probable that complex, highly developed karst systems are present in the depths, in equilibrium with the old base level at the bottom of the canyon. Successively, a little over 2 million years ago, the sea flooded the border of the Lombard Prealps, as ancient valleys filled by clays containing fossils of marine organisms testify. Hence, even deep caves at the bottom of the canyon were flooded, filled with sediments and colonized by marine organisms. The sea then withdrew, emptying the caves once again, and the canyon filled up with alluvial sediments, first of marine and then of glacial and fluvio-glacial origin, when the big Adda Glacier advanced repeatedly down the valley now occupied by the lake. Along the steep submerged walls of the lake, big flooded galleries must therefore exist. The proof of this is given by the springs of the most important karst systems of Pian del Tivano and of the Grigna Settentrionale. The springs that are visible on the surface are only overflow springs, whose discharge is very poor with respect to the great amounts of water that enter the system in the catchmente zone. The main springs must therefore be below lake level, but they have not been found yet. All this simply means that the origin of caves is usually very ancient and that their evolution is often complex and closely controlled by geographical events in the area. Speleologists and cave-divers have on hand the keys to open the important archives of geological data contained in the darkness of the caves. And these data can, in turn, give important suggestions for new explorations!