SPELEOLOGY

From Sport to Science

An outdoor activity where cavers try to understand the formation of caves and contribute to the knowledge of a fragile environment.

Fédération française de spéléologie
www.ffspeleo.fr

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A fragile environment

Mankind has never frequented caves as much as during the last fifty years. But the underground environment, unchanging on a human time scale, keeps all traces left by visitors during thousands of years. The caving community has the responsibility to faithfully protect such a fragile environment.

A caver's boot print may last as long as the fascinating prehistoric footprints discovered in several caves in southern France. The environmental problems also include the quality of underground water and in some areas pollution by nitrates has reached disturbing levels. Caves with pit entrances are still frequently being used to dump garbage, which results in water pollution.

that needs to be protected

The French caving community has taken a long time to become fully aware of these problems, but now cavers often mark out a pathway in a newly discovered cave to avoid disturbing virgin surfaces. Many cavers are involved in projects to restore caves that have been damaged.

The fragility and richness of the natural underground environment should promote the development of cave research and exploration and the practice of sport caving which exercises proper respect for the cave environment.

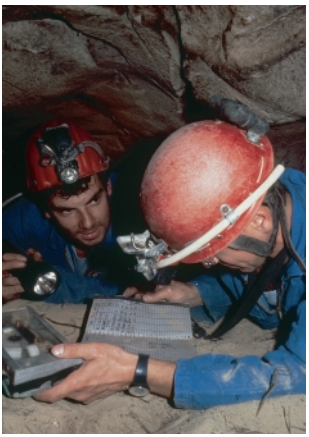
Lechuguilla Cave, New Mexico.

Unexplored places still remain on our planet

Exploration is the primary aim of speleology, which is regarded as a branch of geography.
In France there are approximately 12,000 cavers, organized in local clubs, which belong to the French Federation of Speleology. Many cavers are also members of the French Alpine Club. Whereas most cavers simply visit caves, motivated only by the sporting aspects, there are among these many cavers who are real explorers.

Cave exploration is still very active in France and other developed countries. However, the most spectacular finds have been made by cavers, mostly from northern hemisphere countries, working in distant lands, little known for their caves. These cavers are able to get to know caves very different from those they usually frequent. Recent major French expeditions have taken place on the islands of Chilean Patagonia, and in Papua New Guinea, China, and the Yucatan of Mexico.

Scientific exploration is the study of forms and phenomena in either virgin or well-known caves. This work is rich in future prospects, because our present knowledge and methods of operating far surpass those of the first explorers.



Every year cavers discover and map several kilometers of virgin passage.

Cave Exploration Techniques

Modern caving techniques, progressively improved regarding safety, efficiency, and comfort, were developed at the start of the 1970s and have contributed much to the progress of cave exploration. Today the equipment used by cavers is manufactured industrially according to very strict safety norms. In this regard, Fernand Petzl and the company he created have played a major innovative role not only in France but worldwide. These techniques have originated the development of a newly created professional activity involving the acrobatic work on the facades of high-rise buildings and cliffs.

Cave diving has made enormous progress, especially in the use of mixed gases, rebreathers (closed circuit systems). These techniques have considerably improved the ability to reach greater depths and distances in underwater passages while at the same time assuring greater safety.

Digging cave passages is often the only means of penetrating new caves or of opening up cave galleries obstructed by tight passages. Sometimes explosives are used, but their utilization is strictly controlled and official diplomas are required in France.

As in any outdoor sport, caving presents a few **risks**. The most frequent fatal accidents are due to falls and drowning. The French Federation of Speleology has created its own Cave Rescue Section (**Spéléo-Secours Français**), a volunteer and very efficient organization. Caving is not limited to the image often given by the media during cave accidents.

Karst

The term **karst** originated in Slovenia and designates all the forms linked to the solution of limestone and the regions where these forms develop. Besides caves and pits, the karst creates on the surface unusual karstic landscapes.

Landforms include ***closed depressions***. The size of ***dolines*** may vary from a few meters to several hundred meters and when their dimensions exceed a kilometer they are called closed basins. The rainwater that falls into these depressions must drain out by underground passages. A ***polje*** is a large closed depression subject to flooding because the surface drainage is limited, often by a narrow passage.

A ***dry valley*** is often found at the downstream portion of a surface drainage where the water has been captured in the underlying limestone. A canyon is a steep-sided valley. A *reculée* is a canyon resulting from the retreat of a discharge of underground waters in a limestone massif.

Cone karst consists of conical hills with nearly identical shapes. In certain tropical countries it covers extensive areas and is not unusual in temperate zones.

Dolomite pinnacle karst, as found at Montpellier-le-Vieux in the Aveyron, is a grouping of vertical rock formations up to 10 meters high exhibiting tortured shapes in the form of arches, towers, and mushrooms.

Karren *results from surface solution of the rock - Pierre Saint Martin, French Pyrenees*

Underground Water

Underground water circulation is ruled by unusual mechanisms. Tectonic movement of the earth's crust occurring in the vicinity of fractures or at the meeting of strata creates spaces, which the water uses, selecting the route that allows the best flow. The selective widening of certain tectonic spaces results in a two-stage circulation of water. A ***system of cracks*** is dissolved, but its dimensions do not allow the passage of cavers. Then a ***system of passages*** is developed, starting downstream, as with the surface streams. Now partly penetrable, this is the realm of cavers.

Underground rivers have very variable flow rates. In flood state, the water level rises in the conduits, due to its inability to spread out, as would a surface stream. As the speed of the water increases the amount of suspended sediments augments. The essential erosion of the conduits takes place during those few days or weeks of yearly flooding.

Underground water is the most precious resource that caves provide for mankind. The city of Paris is partly dependent on cave waters and the Quercy region of central France is almost totally dependent.

The **discharge** where the water resurges drains the limestone massif continually. Other discharge points, higher in elevation, only function at flood periods. The study of floodwater at the discharge level allows an estimation of the reserves of water in the **groundwater aquifer**, which drain out through the fractures and conduits.

Bordes de Crue Spring - Ariege, France.

How caves are formed

Caves are formed in **sedimentary rocks**, principally ***limestone*** (calcium carbonate) and ***gypsum*** (hydrous calcium sulfate), that can be dissolved in water and that have sufficient structural resistance to support ceilings with large spans. In limestone this process is essentially due to chemical corrosion causing the solution of calcium carbonate by water together with carbon dioxide generated through contact with the air in the soil cover which is rich in carbonic acid. In gypsum, the chemical corrosion acts together with mechanical erosion, but the physical solution also takes place. Extensive caves are also formed within glaciers, developed due to melting of the ice.

A Geological Phenomenon

Excepting a few special circumstances, the formation of a limestone cave large enough to be entered by man takes at least a several hundred thousand years. Many caves are several million years old (Cottonwood Cave, New Mexico, is 12 million years old) and some are even hundreds of millions years old.

The formation of a cave can be deduced from the visible cave forms : the *passage layout, pits,* and *rooms*, whose general organization can be very complex. The *sections of conduits* and the *wall scallops* can be very varied.

When caves are refilled

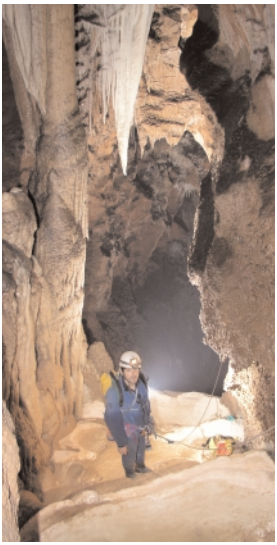
Remarkable sediment traps, caves are also protected from various eroding agents, making them a remarkably preservative environment. The sediments near the entrances provide a wealth of data on recent climatic evolution, while the deep zones of caves also constitute a formidable reserve of information.

Stalactites and **stalagmites**, or more generally speaking what are called **speleothems** (an American term), result from the deposition of calcium carbonate carried in solution by the water after the carbon dioxide has been released, an opposite process to that of corrosion. The stalagmites of the Aven Armand in the Lozere and those of the Aven d'Orgnac in the Ardeche are known the world over. Speleothems can also allow very accurate dating.

Clastic sediments consisting of either clay, sand, pebbles, or blocks, nearly always cover the cave bedrock floor, sometimes up to several meters in depth. They primarily indicate the direction of the water flow and the original source of the water in the conduits where there is no longer any flow.

The **forms of sediments** and especially their sequence come under the study of stratigraphy.

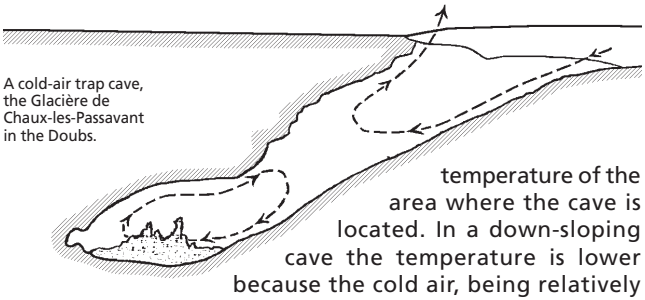
Erosion and refilling of caves are frequently interdependent. The shapes in the walls and ceilings testify to the action of ancient refilling. Sediments are carved and incised by the renewal of erosion. Clastic material is often brought underground by water and remains trapped there, while it has completely disappeared on the surface, such is the case of the halloysite, an unusual white clay found in the Grotte de Clamouse in the Herault.



Cave Climate

The climate in caves is attenuated in its variations compared to the exterior climate conditions. Since the cave air is nearly always saturated with humidity, any variation in temperature results in evaporation or condensation that engenders enough energy to reduce the variations in temperature. This phenomenon is even more noticeable in hot and humid regions.

The **air temperature** is less and less variable as one gets further from the entrance, becoming approximately the mean annual



A cold-air trap cave, the Glacière de Chaux-les-Passavant in the Doubs.

temperature of the area where the cave is located. In a down-sloping cave the temperature is lower because the cold air, being relatively heavier, can enter the cave in winter, whereas in the summer, the warm air does not enter. This cold-air trap phenomenon explains why some natural ice caves (*glacieres*) have been measured well below 0°C.

The **composition of the air** is different from the outside air. During the deposition of calcite and the formation of speleothems, carbon dioxide is released, and its proportion becomes higher than it is outside the cave and is compensated by a reduction of oxygen. Cavers sometimes suffer from heavy breathing, but the only danger arises in cases of exceptionally deep accumulations of gas.

The level of the radioactive gas, ***radon***, is also superior. Here again, the dangerous levels for a caver or people working in caves are only attained in areas near volcanoes, even extinct volcanoes.

Regarding **air movements** generated in caves, the most important are the air currents between two entrances at high elevations or entrances with different orientations. The barometric variations induce movements of air to compensate between the cave and the exterior.

Evolution of Caves

Mountain uplifts lead to a reorganization of underground water circulation. **The evolution of world climate** is another important factor where, during cold weather, the chemical reactions are decreased and the cave development and speleothems growth are greatly reduced. In warm periods, the exact opposite occurs.

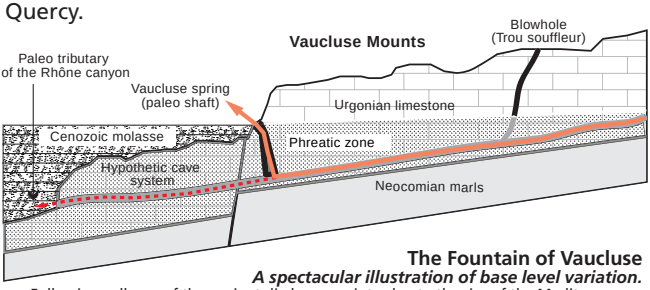
Base level variations of the principal valleys result due to mountain uplift as well as climatic variations. During the last glaciation, some 20,000 years ago, the sea level all over the world was 100 meters lower than today, and this brought about the deepening of valleys.

In turn the ***lowering of the base level*** causes a lowering of the erosion process of the system of conduits.

A ***rising of the base level***, due to the filling of valleys by alluvial sediments, causes the flooding of the system of conduits during a long period.

On the surface the **stream piracy** disrupts the circulation of water that drains into caves. Within the limestone massif other sinkholes and depressions concentrate this circulation toward a unique discharge point. The discharge springs in limestone terrains are far more powerful than those in other types of rock.

The progressive enlargement of conduits provoke **collapses**, some of which reach the surface, thus creating the formation of cave pits like the Gouffre de Padirac in the karst deserts of Quercy.



The Fountain of Vaucluse
A spectacular illustration of base level variation.
Following collapse of the ancient discharge points, due to the rise of the Mediterranean sea level, the water of this cave system was only able to find an exit through a preexisting conduit which the waters of this vauclusian spring climbed along its entire length for over 300 meters. The base of this conduit is situated at 224 meters below the present sea level.

Scientific Speleology

Speleology became a science at the end of the 19th century. The French speleologists played a major role, especially, **Edouard Alfred Martel**, who from 1888 to 1936 was the originator of the scientific study of speleology. **Norbert Casteret** popularized cave exploration all over the world and **Pierre Chevalier** improved the equipment and techniques of sport caving.

The present organization in France centers around the **French Federation of Speleology** (FFS), which is attached to the Ministry of Sports. Its scientific commission organizes training programs. The October Conference (*Rencontre d'Octobre*), an annual scientific conference of French speleologists, has been organized since 1991 by the Speleo Club de Paris. The **French Association of Karstology** (AFK) co-edits with the FFS a scientific revue, *Karstologia*, which disseminates findings in karst research worldwide.

Since 1953, the **International Union of Speleology** (UIS) organizes a congress every four years. Numerous national and international sessions are held on specialized themes : karst hydrology, volcanospeleology, glaciospeleology, speleotherapy, biospeleology, and more. Some 5000 annual speleological publications and books are catalogued regularly in *Speleological Abstracts*.

Caves as Natural Laboratories

Laboratories have been installed in caves, first of all to study cave animals and also physical phenomena, such as, earth tides, earthquakes, and recent tectonic movements. Caves have been used for long confinement, **Beyond Time experiments**, conducted by Michel Siffre, showing that the sleep-wakefulness rhythm is longer when someone is deprived of a time reference.

Over 100 **show caves** in France play an important cultural role for the six million people that visit them annually. Most of the managers of these caves are very concerned about cave conservation and proper presentation by the guides who must undergo training programs. Associations bring together the owners and managers of tourist show caves. Scientific measurement equipment can be installed in these caves for long periods of time, as in the Grotte de Han-sur-Lesse in Belgium.

Generally speaking, the study of karst, surface and underground features, is well developed in France. More than one hundred university papers and theses have been completed at the Moulis Laboratory in Ariege and at the universities of Montpellier, Bordeaux, and Aix-en-Provence. A karst research team of the CNRS is associated with the University of Savoy at Chambery. Today cavers who choose to do further studies in geology and geography are active promoters of the scientific study of caves.

Tools used by working speleologists

The **observation of cave genesis and the refilling processes** is a necessary part of the study of any cave and constitutes the main occupation of a speleologist. In order to carry out this research the speleologist uses several tools.

Surveying - Specialized software has been developed by cavers to represent the three-dimensional spaces of an underground cave. The examination of a well-made cave map is sufficient for imagining the speleogenetic origins of a cave. Today the GPS helps situate cave entrances on the map.

Photography is used to capture images of erosion forms, such as conduit sections or scalloped walls, which are difficult to measure or draw.

Dye tracing is a means of detecting underground water circulation to determine the discharge point of water or the time the water takes to travel to the discharge. The most frequently used tracer is fluorescein.

The variations of cave water levels can be recorded automatically with a *luirograph*, an instrument that measures, over a long period of immersion, pressures attaining up to several dozen bars. In the Grotte de la Luire in the Vercors, for which this instrument was first conceived, the water level can rise over 450 meters.

Cavers can measure the levels of carbon dioxide in the cave with a *Drager gas detector*.

Specialized laboratories can establish *absolute dating* by measuring the proportion of stable isotopes in sediments and water.

Life in caves

Biospeleology studies the **cave fauna;** animals which spend their entire live cycle underground and are totally adapted to the cave environment, essentially invertebrates, such as, insects, spiders, and crustaceans but also salamanders and fish. Their main characteristics are lack of pigmentation and a marked regression of their ocular system leading to a total disappearance of the eyes. Their reduced metabolism rate is often accompanied by an augmented life span.

The Aphaenops is *an authentic troglobite, totally adapted to the cave environment.*

Trichomycterus chaberti, *a troglobitic fish from Bolivia.*

Occasionally cavers bring back from their explorations new species unknown to science. The **paleontologist** also benefits from discoveries made by cavers. Fossil bones of large extinct mammals, especially the cave bear, have been found in cave deposits, sometimes quite far from the entrance, as in the Balme à Collomb in the Savoy.

In Europe, the **bats** that inhabit caves are insectivorous and the massive use of insecticides has brought about a decrease in their numbers. Important populations of bats may still be found in tropical regions. An estimated twenty million bats are estimated to roost in the Bracken Bat Cave of Texas.

In certain tropical countries, the inhalation of cave dust containing fungus spores can transmit the serious, sometimes fatal disease of **histoplasmosis**, which has symptoms similar to tuberculosis.

Caves around the world

Most caves are formed in limestone or in a related rock, dolomite. In certain regions like Ukraine, caves frequently form in gypsum. So the distribution of caves depends directly on the geology.

In **France**, the published departmental cave lists have inventoried over 70,000 natural caves. The majority are located in the Jura mountains, the lower French Alps, the Causses plateaus, the Languedoc region, and the Pyrenees mountains.

In **Europe**, caves are more numerous in the central and southern countries. The density of caves is particularly high in Slovenia. In **Africa**, the northwestern portion (Maghreb) and South Africa both contain numerous natural caves. In **North and South America**, notably, the United States, Mexico, the West Indies, and Brazil are especially rich in caves. Venezuela has some exceptionally large pits developed in quartzite. In **Asia** the most important known caves are located in the southeastern part of the continent in China, Vietnam, Thailand, Malaysia, and Indonesia. Several major caves are found in Papua New Guinea and in southern Australia.

Volcanic islands, like Hawaii, the Canaries, and the Azores, have many **lava tube caves** that were formed under the lava flows. The upper part of the lava flow solidifies on contact with the air while the molten interior continues to flow. These types of cave are also found on the continents in Kenya, Korea, and northwestern United States.

Various records give an idea of cave phenomena

Over 579 km of cave passages have been surveyed in the **Mammoth Cave System** in Kentucky.
The depth of 1000 meters was reached in 1956 in the **Gouffre Berger**, France and the depth of 2000 meters was reached in October 2004 in the **Krubera (or Voronya) Cave** in the Caucasian Mountains of Abkhazia.
The **Sarawak Chamber** in Borneo in the largest known cave room with a length of 700 m, an average width of 300 m, and a height of 70 m.
Xe-Bang-Fai Cave in Laos drains a closed basin of 1300 square kilometers and its average discharge rate is 65 cubic meters/second and, in flood time, an estimated 600 cubic meters/second.

For further information

The best references are :
- *Spelunca* (magazine of the French Federation of Speleology).
- *Karstologia* (magazine of the French Federation of Speleology and of the French Association of Karstology).
- *Speleological Abstracts* (annual).
- *Spéléo* (indépendent magazine of caving news)

Recent publications are on sale at Spelunca-Librairie (FFS bookstore). Catalog on request.

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In memory of Jacques Choppy (1926-2004)

Photos and drawings : *Cover photo :* Lake Como seen from the bucone di Tremezzo, Italy, Photo Jean-Yves Bigot ; *p.2-3 :* Photo Daniel Chailloux ; *p.4* : Cave mapping in Grottes de Coquibus, Essonne (JYB) ; *p.5* : Aven de la Plaine des Gras, Vallon-Pont-d'Arc, Ardèche (JYB) ; *p.6* : Photo Francis Guichard ; *p.7* : Photo Eric Ollivier ; *p.8* : Main passage in Grotte de Sakany, Quié, Ariège (JYB) ; *p.9* : Aven Despeysse, Bidon, Ardèche (JYB) ; *p.10* : Drawing by Jean Taisne from Trouillet ; *p.11* : Drawing by Eric Gilli ; *p.12* : Grotte de Saint-Eucher, Beaumont-de-Pertuis, Vaucluse (JYB) ; *p.14* : Aphaenops cerberus Dieck, Gouffre de Peillot, Cazavet, Ariège (EO) ; Drawing by J.-P. Durand ; Horseshoe bat, Rhinolophus ferrum equinum, Gouffre de Peillot. (JYB).

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