Classification of Speleology in Wikipedia

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Abstract

The use of a low-frequency cave radio can also verify survey accuracy. A receiving unit on the surface can pinpoint the depth and location of a transmitter in a cave passage by measurement of the geometry of its radio waves. A survey over the surface from the receiver back to the cave entrance forms an artificial loop with the underground survey, whose loop-closure error can then be determined.

In the past, caves were reluctant to redraw complex cave maps after detecting survey errors. Today, computer cartography can automatically redraw cave maps after data has been corrected.

Keywords : speleology, low frequency, cave, geometry, loop closure error

I. Introduction

1. Definition

Speleology is the scientific study of caves and other karst features, their make-up, structure, physical properties, history, life forms, and the processes by which they form (speleogenesis) and change over time (speleo-morphology). The term speleology is also sometimes applied to the recreational activity of exploring caves, but this is more properly known as caving, spelunking or pot-holing. Speleology and caving are often connected, as the physical skills required for in situ study are the same.

Fig. 1. Grotte des Faux-Monnayeurs, Switzerland

Speleology is a cross-disciplinary field that combines the knowledge of chemistry, biology, geology, meteorology and

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cartography to develop portraits of caves as complex, evolving systems.

2. History

Prior to the mid-nineteenth century the scientific value of caves was considered only in its contribution to other branches of science, and cave studies were considered part of the larger disciplines of geography, geology or archaeology. Very little cave-specific study was undertaken prior to the work of Édouard-Alfred Martel (1859-1938), the 'father of modern speleology', who through his extensive and well-publiced cave explorations introduced the concept of speleology as a distinct area of study. In 1895 Martel founded the Société de Spéléologie, the first organization devoted to cave science in the world. The growth of speleology is directly linked with that of the sport of caving, both because of the stimulation of public interest and awareness, and the fact that most speleological field-work has been conducted by sport cavers.

II. Cave geology and hydrology

1. Geochemistry speleothems

A speleothem (from the Greek for "cave deposit") is a secondary mineral deposit formed in caves. It is the formal term for what is also known as a cave formation. Water seeping through cracks in a cave's surrounding bedrock may dissolve certain compounds, usually calcite and aragonite (both calcium carbonate), or gypsum (calcium sulfate). The rate depends on the amount of carbon dioxide held in solution, on temperature, and on other factors.

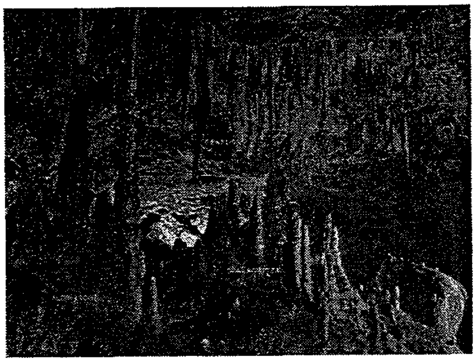


Fig. 2. Image showing the six most common speleothems with labels.

When the solution reaches an air-filled cave, a discharge of carbon dioxide may alter the water's ability to hold these minerals in solution, causing its solutes to precipitate. Over time, which may span tens of thousands of years, the accumulation of these precipitates may form speleothems.

Typical forms: Speleothems take various forms, depending on whether the water drips, seeps, condenses, flows, or ponds. Many speleothems are named for their resemblance to man-made or natural objects. Types of speleothems include: Dripstone is calcium carbonate in the form of stalactites or stalagmites. Stalactites are pointed pendants hanging from the cave ceiling, from which they grow; Soda straws are very thin but long stalactites having an elongated cylindrical shape rather than the usual more conical shape of stalactites; Helictites are stalactites that have a central canal with twig-like or spiral projections that appear to defy gravity; Chandeliers are complex clusters of ceiling decorations; Stalagmites are bluntly pointed mounds, often beneath stalactites; Columns result when stalactites and stalagmites meet or when stalactites reach the floor of the cave; Flowstone is sheetlike and found on cave floors and walls; Draperies or curtains are thin, wavy sheets of calcite hanging downward; Bacon is a drapery with variously colored bands within the sheet; Rimstone dams, or gours, occur at stream ripples and form barriers that may contain water; Stone waterfall formations simulate frozen cascades. Popcorn is small, knobby clusters of calcite; Cave pearls are the result of water dripping from high above, causing small "seed" crystals to turn over so often that they form into near-perfect spheres of calcium carbonate; Dogtooth spar are large calcite crystals often found near seasonal pools; Frostwork is needle-like growths of calcite or aragonite; Moonmilk is white and cheese-like; Snottites are colonies of speleobacteria and have the consistency of "snot", or mucous; and many more (Fig. 2).

Speleothems made of pure calcium carbonate are a translucent white color, but often speleothems are colored by minerals such as iron, copper or manganese, or may be brown because of mud and silt particulate inclusions.

2. Chemistry

Many factors impact the shape and color of speleothem formations including the rate and direction of water seepage, the amount of acid in the water, the temperature and humidity content of a cave, air currents, the above ground climate, the amount of annual rainfall and the density of the plant cover. Most cave chemistry revolves around calcite; $CaCO_3$, the primary mineral in limestone. It is a slightly soluble mineral whose solubility increases with the introduction of carbon dioxide, CO_2. It is paradoxical in that its solubility decreases as the temperature increases, unlike the vast majority of dissolved solids. This decrease is due to interactions with the carbon dioxide, whose solubility is diminished by elevated temperatures; as the carbon dioxide is released, the calcium carbonate is precipitated. Most other solution caves that are not composed of limestone or dolostone are composed of gypsum (calcium sulfate), the solubility of which is positively correlated with temperature.

3. As climate proxies

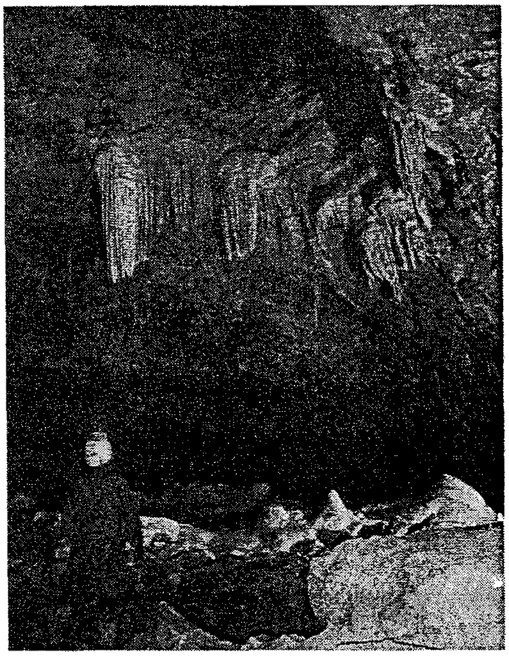
Samples can be taken from speleothems to be used like ice cores as a proxy record of past climate changes. A particular strength of speleothems in this regard is their unique ability to be accurately dated over much of the late Quaternary period using the uranium-thorium dating technique. Stalagmites are particularly useful for palaeoclimate applications because of their relatively simple geometry and because they contain several different climate records, such as oxygen and carbon isotopes and trace cations. These can provide clues to past precipitation, temperature, and vegetation changes over the last ~ 500,000 years.

4. Absolute dating

Another dating method using electron spin resonance (ESR) — also known as electron paramagnetic resonance (EPR) — is based on the measurement of electron-hole centers accumulated with time in the crystal lattice of CaCO3 exposed to natural radiations. In principle, in the more favorable cases, and assuming some simplifying hypotheses, the age of a speleothem could be derived from the total radiation dose cumulated by the sample and the annual dose rate to which it was exposed. Unfortunately, not all the samples are suited for ESR dating: indeed, the presence of cationic impurities such as Mn2+, Fe2+, or Fe3+, humic acids (organic matter), can mask the signal of interest, or interfere with it. Moreover, the radiation centers must be stable on geologic time, i.e., to have a very large lifetime, to make dating possible. Many other artifacts, such as, e.g., surface defects induced by the grinding of the sample can also preclude a correct dating. Only a few percents of the samples tested are in fact suitable for dating. This makes the technique often disappointing for the experimentalists. One of the main challenge of the technique is the correct identification of the radiation-induced centers and their great variety related to the nature and the variable concentration of the impurities present in the crystal lattice of the sample. ESR dating can be tricky and must be applied with discernment. It can never be used alone: "One date only is No date", or in other words, "multiple lines of evidence and multiple lines of reasoning are necessary in absolute dating". However, "good samples" might be found if all the selection criteria are met.

5. Other speleothems

Speleothems may also occur in lava tubes. Although sometimes similar in appearance to speleothems in solutional caves, these are formed by the cooling of residual lava within the lava tube. Speleothems formed from salt, sulphur and other minerals are also known. Formations within caves that are created from the removal of bedrock (rather than as secondary deposits) are called speleogens. These include pillars, scallops, boneyard and boxwork (Figure 3, 4, 5, 6).



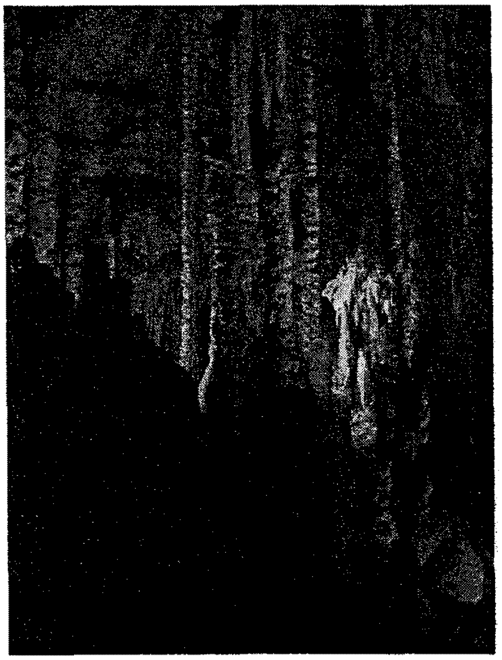


Fig. 3. Various formations in the Hall of

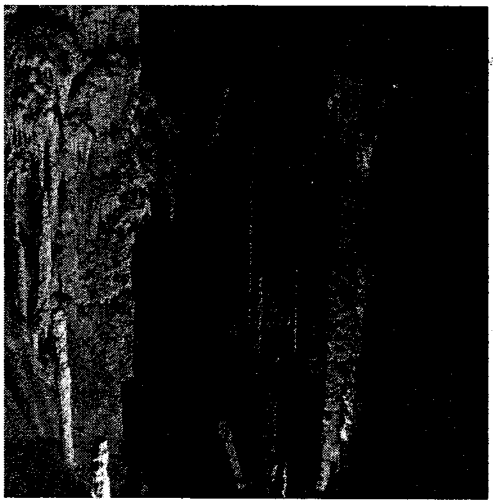
Fig. 4. Stalactites and columns in Natural the Mountain Kings, Ogof Craig a Ffynnon,South Wales, Great Britain.

Bridge Caverns, Texas, U.S..

6. Cave cartography

The creation of an accurate, detailed map is one of the most common technical activities undertaken within a cave. Cave maps, called surveys, can be used to compare caves to each other by length, depth and volume, may reveal clues on speleogenesis, provide a spatial reference for further scientific study, and assist visitors with route-finding.

A survey team begins at a fixed point (such as the cave entrance) and measures a series of consecutive line-of-sight measurements between stations. These measurements include direction (azimuth) taken with a compass, inclination from horizontal (dip) taken with a clinometer, and distance measured with a low-stretch tape or laser range-finder.



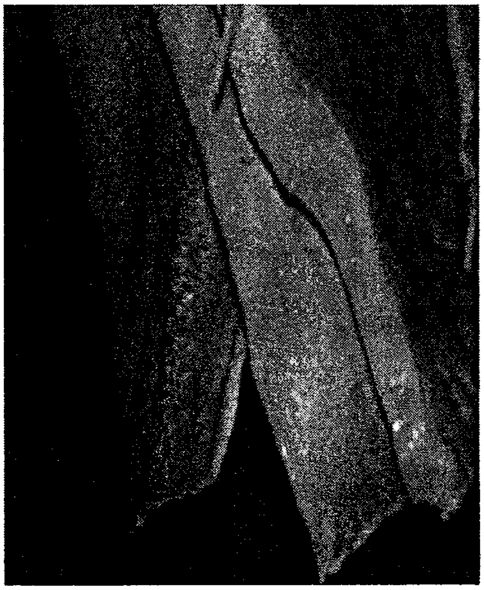


Fig. 5. Stalactites and columns in Natural Fig. 6. Cave curtain formation in the Bridge Caverns, Texas, U.S.. MarbleArch Caves, County Fermanagh, Northern Ireland.

Coincident with recording straight-line data, details of passage dimensions, shape, gradual or sudden changes in elevation, the presence or absence of still or flowing water, and material on the floor are recorded. Later, the cartographer presents the technical measurements as a line-plot, then draws details around the line-plot for a completed cave survey. Cave surveys drawn on paper are often presented in two-dimensional plan or profile views, while computer surveys may simulate three dimensions. Although primarily designed to be functional, some cavers consider cave surveys as an art form.

The accuracy, or grade, of a cave survey is dependent on the methodology of measurement. A common survey grading system is that created by the British Cave Research Association in the 1960s, which ranges from Grade One (a simple sketch based on memory) to Grade Six (use of tripod-mounted instruments and a temperature-calibrated steel tape), with the most common grade being Five. A BCRA Grade 5 survey utilizes hand held instruments taking measurements within one degree accuracy or better and a tape measure accurate to ten centimeters or better, per station.

The equipment used to undertake a cave survey continues to improve. The use of computers, inertia systems, and electronic distance finders has been proposed, but no practical underground applications have evolved at present.

7. Survey error detection

Faulty instruments, imprecise measurements, recording errors or other factors may result in an inaccurate survey, although these errors are often difficult to detect. Some cave surveyors measure each station twice, recording a back-sight to the previous station but in the opposite direction. A back-sight compass reading that is different by 180 degrees and a clinometer reading that is the same value but with the reverse direction (positive rather than negative, for example) indicates that the original measurement was accurate.

When a loop within a cave is surveyed back to its starting point, the resulting line-plot should also form a closed loop. Any gap between the first and last stations is called a loop-closure error. If no single error is apparent, one may assume the loop-closure error is due to cumulative inaccuracies, and cave survey software can 'close the loop' by averaging errors throughout the loop stations. Loops to test survey accuracy may also be made by surveying across the surface between entrances to the same cave.

The use of a low-frequency cave radio can also verify survey accuracy. A receiving unit on the surface can pinpoint the depth and location of a transmitter in a cave passage by measurement of the geometry of its radio waves. A survey over the surface from the receiver back to the cave entrance forms an artificial loop with the underground survey, whose loop-closure error can then be determined.

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8. Cave biology

Caves provide a home for many unique biota. Cave ecologies are very diverse, and not sharply distinct from surface habitats. Generally however, the deeper the cave becomes, the more rarefied the ecology. Cave environments fall into three general categories:

Endogean: the parts of caves that are in communication with surface soils through cracks and rock seams, groundwater seepage, and root protrusion.

Parahypogean: the threshold regions near cave mouths that extend to the last penetration of sunlight.

Hypogean: or "true" cave environments. These can be in regular contact with the surface via wind and underground rivers, or the migration of animals, or can be almost entirely isolated. Deep hypogean environments can host autonomous ecologies whose primary source of energy is not sunlight, but chemical energy liberated from limestone and other minerals by chemoautotrophic bacteria.

Cave organisms fall into three basic classes:

Troglobites ("cave dwellers") are obligatory cavernicoles, specialized for cave life. Some can leave caves for short periods, and may complete parts of their life cycles above ground, but cannot live their entire lives outside of a cave environment. Examples include chemotrophic bacteria, some species of flatworms, collembola, and Blindfish.

Troglophiles ("cave lovers") can live part or all of their lives in caves, but can also complete a life cycle in appropriate environments on the surface. Examples include cave crickets, millipedes, pseudoscorpions and spiders.

Trogloxenes ("cave guests"): Frequents caves, and may require caves for a portion of its life cycle, but must return to the surface (or a parahypogean zone) for at least some portion of its life. Hibernating reptiles and mammals are the most widely recognized examples.

There are also so-called accidental trogloxenes which are surface organisms that enter caves for no survival reason. Some may even be troglophobes ("cave haters"), which cannot survive in caves for any extended period. Examples include deer which fell through a sinkhole, frogs swept into a cave by a flash flood, etc.

The two factors that limit cave ecologies are generally energy and nutrients. To some degree moisture is always available in actively-forming Karst caves. Cut off from the sunlight and steady deposition of plant detritus, caves are poor habitats in comparison with wet areas on the surface. The majority of energy in cave environments comes from the surplus of the ecosystems outside. One major source of energy and nutrients in caves is dung from trogloxenes, the majority of which is deposited by bats. Other sources are mentioned above.

Cave ecosystems are very fragile. Because of their rarity and position in the ecosystem they are threatened by a large number of human activities. Dam construction, limestone quarrying, water pollution and logging are just some of the disasters that can devastate or destroy underground biological communities.

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