Further Reading


CAVES

Various kinds of cavities occur widely beneath the Earth’s surface, both natural and artificial (created by humans). The term “cave” is commonly applied to natural openings, usually in rocks, that are large enough for human entry. This definition is clearly anthropocentric, relies on the ambiguous criterion of accessibility by man, has no genetic meaning, and is therefore non-scientific. It also implies that a cavity is connected to the surface through entrances. Caves can be distinguished from surface landforms by morphometric criteria: caves are forms in which the long dimension (length or depth) is greater than the cross-sectional dimensions at the entrance. The anthropocentrism of the above definition of a cave implies that it is largely air-filled, but advances in underwater cave exploration during the second half of the 20th century have dramatically relaxed this limitation. The concept of a cave is, rather, an exploration notion.

Caves are formed by different processes in many rock types and unconsolidated sediments. They can be classified according to their origin and the lithology of host rock or the type of sediment. However, speleogenetic processes differ greatly and many of them do not depend strongly on host rock composition. Numerous attempts have been made to develop genetic classifications that would encompass all caves and relate them to host rocks (e.g. White, 1988; Dubljansky & Andrejchuk, 1989) but none of them appear to be quite harmonious in grouping the processes and genetic types of caves. Instead, some kind of heuristic approach, only partly genetic, is commonly used in distinguishing the most significant classes of caves. The great majority of natural caves, including the largest ones (see Figure), are solution (or karst) caves, that is, caves that have been created principally by the dissolution of bedrock by water circulating through initial openings such as fissures and pores. Solution caves are the most important to cave and karst scientists and so are the principal focus of this Encyclopedia; they are also most important in terms of their interference with human activities. Caves produced by processes other than solution occur in many types
Caves: An example of a large abandoned trunk passage, Beimo Dong, in the Bama karst of Guangxi, China. (Photo by Jerry Wooldridge)

of rocks and are sometimes referred to as pseudokarst or karst-like features (see Pseudokarst entry).

Solution caves occur widely in limestone and gypsum, and, less commonly, in salt, quartzite, and elastic rocks cemented by soluble material (e.g. some sandstones and conglomerates). Although dissolution is the dominant process, other processes such as erosion and gravitational breakdown may take part in their development, particularly at later stages. The lower limit of the size of a conduit (the precursor to a cave) is accepted to be about 5–15 mm. This range encompasses the important thresholds which permit turbulent flow through initial openings under common hydraulic gradients and temperatures, switch calcite dissolution kinetics to boost up the growth rate, and trigger effective sediment transport (Ford, 1988; Palmer, 1991; White, 1977; 1988; see also entry on Speleogenesis). It therefore allows conduits to be distinguished from proto-conduits, and from pores that form during diagenesis of sediments. Speleogenetic consideration implies that conduits can be partly or entirely filled by water, air, and sediments during various stages of their development.

Volcanic caves are formed in several ways (see Volcanic Caves entry), of which the most important is the evacuation of fluid lava from a cooling lava flow. The process operates mainly in pahoehoe basalt flows and is responsible for some very large cave
systems, such as the 65.5 km long and 1101 m deep Kazumura Cave in Hawaii. Caves of this type are also termed lava tube caves.

**Glacier caves** are formed by melting of the ice of glaciers (see Glacier Caves and Glacier Pseudokarst). They form along crevices in the ice and along its contact with bedrock, through the action of invading water usually derived from ice melting on the surface of the glacier. Glacier caves tend to be ephemeral, but some form quite large integrated systems, e.g. Paradise Ice Caves (Washington State, United States) which extend for over 24 km.

**Crevice caves** may form in any massive rock by disjunction due to various forces (see Crevice Caves). This group includes true tectonic caves, whose openings were formed by tectonic tension forces, and dilatancy/gravity caves usually formed along cliffs and steep slopes due to the combined effect of unloading and gravitational mass movement.

**Littoral caves** (or sea caves) may form in many types of rock at sea cliffs, due to wave action that involves abrasion (see Littoral Caves). They are abundant in many coastal areas around the world; the most famous cave of this type is Fingal’s Cave in basalts of the Hebrides Islands, Scotland.

**Piping caves** (or suffosion caves) develop in fine-grained, poorly consolidated sediments such as peat, loams, clays, and particularly loess, by removal of tiny clasts suspended in water (see Piping Caves). The process may involve dissolution to facilitate decomposition of the bedrock material but most of the mass transport is mechanical. Piping caves rarely attain a length of more than 100 m.

**Erosion caves** (or stream-cut caves) form in soft rocks such as shales by mechanical action of water streams. They are numerous in cliffs, being commonly shelters rather than caves. Erosion caves develop best where some resistant bed overlies a weaker bed, though large high-gradient streams may also produce erosion caves in solid rock. Illustrative of the conditional character of the process-based classification of caves is the fact that mechanical erosion plays a considerable part in the formation of many solution caves and it may become the dominant process in mature stages of their development if the caves carry large streams. Some other processes, such as aeolian deflation, hydration, crystallization and contraction, and underground pyrolysis, can also form non-solutional caves, although they are small and rare.

Caves are characterized by their shape and size, the latter being measured by various dimensions considered in the entry on Morphometry of Caves. While most caves do not exceed 1 km in length and 100 m in depth, hundreds are much larger. The longest cave is the 563 km long Mammoth Cave System in Kentucky, United States, the deepest is Gouffre Mirolda (−1733 m) in the Chamonix Alps, France, and the largest underground chamber, by both area and volume, is Sarawak Chamber in Malaysia (respectively 160000 m² and 12 million m³). The shape of caves, or their morphology, is extremely variable and can be described in several scales. Micro-morphology characterizes minor forms that constitute relief of the host rock surface within passages. Meso-morphology expresses the geometry of the main elements of a cave, that is, of passages (elongated segments in which the length is considerably greater than width or height) and chambers (cave elements in which the width or height is larger compared with adjacent passages). Passages can be linear, angulate, or sinuous, and be horizontal, inclined, or vertical. Vertical passages are termed pits or shafts. (For more details of micro- and meso-morphology features, see Morphology of Caves.) The simplest caves consist of single
elements but most are assemblages of passages and chambers with various relationships to each other. Macro-morphology of caves is expressed by cave patterns, overall orientation relative to the gravity field, and tier structure. Several distinctive types of cave patterns are recognized: single-conduit caves, single-void caves, branchwork caves, and maze caves (the latter are further subdivided into network, anastomotic, ramiform, and spongework mazes). Patterns of solution caves are controlled mainly by hydrogeologic factors, by the recharge mode and type of flow in particular (Palmer, 1991, 2000; see also Patterns of Caves). These and other important controls change in regular ways throughout the evolution of karst aquifers, giving rise to the changes of karst/speleogenetic settings and respective karst types (Klimchouk & Ford, 2000). Several settings are recognized that generate distinct styles of solution cave development (see entries on Speleogenesis). The above evolution may result in the presence of different cave patterns in the same region or in their combination in the same cave system.

Caves are sometimes classified according to their orientation relative to the gravity field into horizontal, inclined, and vertical caves, although large systems commonly have elements of various orientations. Vertical caves are dominant in mountain regions where thickness of karstified rocks and the vadose zone is great. Although there are many truly vertical caves that consist of single-drop shafts (up to 640 m deep, as is the Vrtiglavica shaft in the Kanin massif in the Julian Alps, Slovenia), most vertical caves are actually composed of shafts interspersed with inclined passages and have a stair-step profile. In many caves passages are stacked in tiers or levels, often superimposed and interconnected to form complex 3-D cave systems. A number of other approaches have been suggested to further classify solution caves as the most diverse, abundant, and scientifically and practically important category. They are overviewed in Ford & Williams (1989, pp.243–48). Some genetically based classifications are outlined in the entry on Speleogenesis.

Tens of thousands of caves have been explored so far but this is still a small proportion of the underground world represented by explorable cave passages. Caves constitute a particular environment with their specific 3-D morphology, hydrology (see Hydraulics of Caves), sediments, and minerals (see entries on Sediments, Minerals in Caves, and Speleothems), climate (see Climate of Caves) and biota (see entries on Biology of Caves and on Micro-organisms in Caves), and so they can be regarded as special complex natural systems. During long time spans in some distant past many caves functioned as traps for animals that lived at that time (see Paleontology: Animal Remains in Caves) while others served as shelters and dwellings for ancient man who left there many marks of his activity. Being well protected from destructive processes operating on the surface, caves are unique repositories of various forms of information about the past, imprinted in their morphology and contents. This justifies the exceptional scientific value of caves, recognition of which has dramatically increased during recent decades. For the above reasons, and due to the fact that caves offer spectacular scenery with striking natural marvels, beautiful mineral formations, and other unique features, a number of them have been recognized under the UNESCO World Heritage Convention and instituted as protected sites or areas on the national level (see World Heritage Sites).

See also Pseudokarst

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Works Cited

Dubljansky, V.N. & Andrejchuk, V.N. 1989. Speleologia (terminologia, svyazi s drugimi naukami, klassificatziya polostey) [Speleology (terminology, relations with other sciences, classification of cavities)]. Kungur, Russia: Gorny Institute of the Ural Division of the Academy of Sciences of the USSR.


Further Reading


CAVES IN FICTION

For as long as humans have walked the Earth we have wondered at and feared what might lie within the dark reaches of caves. For some, the mere mention of caves brings on claustrophobic nightmares, and reading about them is as close as they want to get. Thankfully, there are hundreds of books that take readers to the farthest depths of the Earth from the comfort of their favourite chair. Many of the early stories associated with caves and the underworld invoke images of a dark and mysterious place, inhabited by gods and demons, and of course the final resting-place for the souls of the dead. The