Karst landscape

Where do caves form?

A large number of factors influence the formation of cave systems: chemical factors and climate control the dissolving capacity of water; geological factors control the type of rock, the geological structure and the characteristics of fracturing and jointing, which in their turn control underground water circulation and the development and trend of the cave zone; topographic factors such as altitudes gradient and the presence of deep valleys control the prevalently vertical or horizontal development of karst systems.
Caves therefore show different characteristics depending on the conditions and the environment in which they were formed.

Tropical caves

In tropical environments, all caves have similar characteristics. They are often arranged in vast underground systems, generally with a prevalently horizontal development, often drained by veritable underground rivers, and cave passages are very large and rich with speleothemes. Thanks to high temperatures, dissolution reaction is fast: since water filtering underground is very aggressive due to the presence of CO_2 and organic acids deriving from the dense plant overgrowth, it rapidly dissolves large quantities of limestone near the surface, soon becoming saturated or oversaturated, thus forming large quantities of speleothemes, which are a peculiar features of tropical karst.

High mountain caves

On the extreme opposite hand, caves in high mountain areas have a prevalently vertical trend due to the energetic potential created because of the large differences in altitudes and a geological structure that is generally complex, with big shafts, which are often very deep (at times over 600 m). Due to the slower dissolution speed as a result of low temperatures, circulating water may remain aggressive even at deeper levels, thus creating deep and vertical systems. Because of low temperatures, speleothemes are on the contrary very rare. On the surface, vertical shafts and sinkholes are often peculiar features. Their formation is often due to the conjoined action of karst processes and corrosion processes controlled by the presence of ice and snow.

Surface karst landscape

Karst landscapes have two peculiar characteristics which make them immediately identifiable even where rocks are covered by soil and vegetation: particular forms of dissolution on the surface and the practically total absence of watercourses on the surface, as all the water or most of it, rapidly is swallowed into the depths.
This characteristic makes the work of speleologists particularly important, because karst zones are generally characterized by water supply problems: the identification of underground water reserves, their localization and the study of the possibility of exploiting them are a very important contribution to the wellbeing of local populations, specially in the arid zones of developing countries.
Among the most particular karst forms, besides the afore mentioned karren or lapiez, which are forms on a small scale, dolines are surely the most well known and striking. These can be of different origins, but for cavers the most interesting ones are surely those formed by collapse, which often allow access to cave systems. Dolines formed by collapse, often are shafts and their cross-section is often sub-circular. At times they are very deep (like the famous sòtanos in Mexico, of which the Sotano de las Golondrinas, 370 m deep, is the most well-known representative) . At times forms of this type allow direct access to flooded systems: as in the case of the cenotes (those in Yucatan are the most famous, but there are many in most coast areas in tropical zones).
More complex and larger forms are polja (singular: polje), large flat bottom depressions characterised by caves, the ponores, that act alternatively as sinkholes during dry season or as springs during rainy season, when the water flowing within the karst system exceeds the drainage capacity of the system. Water rises up the sinkoles from which it flows out, often forming temporary lakes (for example the polja in the karst area of Postojna, in Slovenia).
Tropical zones are characterized by particular karst landscapes, such as cone karst and tower karst (famous tower karst can be found in Southern China or Thailand).

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The formation of underground drainage systems often brings about the swallowing of surface water through sinkholes, leaving valleys “dry”. Thus dry valleys are formed with water courses in which water no longer flows; in blind valleys, water courses disappear underground, often sinking into large entrances. Pocket valleys are on the contrary valleys suddently closed upstream, where waters comes out a spring, often at the base of a wall, or beginning at big karst springs (for example the famous Fontaine de Vaucluse, in France).

Underground landscape

Observing a vertical cross section of a karst system it is possible to point out different zones, depending on the presence of water and on how water moves within.

The catchment zone

The catchment zone is the one closest to the surface where surface water and meteoric water sink and seep deep underground. Catchment may take place through a large number of fractures, thus being diffuse, or through concentrated sinking input points, such as dolines, where surface water can collect and concentrate: in this way the corrosive action of water concentrates on a small number of fractures that are then widened preferentially, thus leading rapidly to the creation of underground karst galleries. At times the entrance of surface water into the deeper layers is characterized by spectacular forms. When water courses flowing on impermeable rocks that cannot be karstified come into contact with karstifiable rocks, such as limestones and dolomite, they are literally swallowed underground, at times with small losses, that gradually dry up the flow of the river, till it disappears, leaving a dry valley, at times with spectacular sinkholes that capture the flow of the water totally. This is the so called allogenic recharge. A particularly impressive example is the sinking of the Reka river in Slovenia. Through the San Canziano caves the river is swallowed and disappears, to reappear 40 km downstream, from a resurgence near Trieste, with the new name of Timavo.

The transfer or vadose zone

Below the catchment zone, the vadose zone of vertical transfer develops, where water mainly flows downwards and caves have a prevalently vertical trend. Due to the progressive union and concentration of underground water flows, from the vertical transfer zone water gradually passes to the horizontal transfer zone where veritable underground water courses exist, Just like surface water courses, they entrench and erode canyons, gorges, meanders, characterized by a series of erosion forms similar to potholes and cauldrons at the base of shafts. Here water generally has a strong energy and a high speed, so that erosion phenomena prevail over corrosion.

This entire zone belongs to the so called vadose zone, a term that indicates the presence of voids filled with both air and water, where water flow is free. In the vertical transfer zone, it is quite rare to find completely flooded galleries or conduits, while in the horizontal transfer zone underground lakes may form, where obstacles to the outflow may cause the formation of small basins, which may often be temporary. At times the water level can rise above the ceiling of the gallery, in which case the lake is turned to a siphon, i.e. a part of a gallery completely flooded, where the ceiling sinks below the water surface. Normally in the zone of horizontal flow , after passing a siphon it is possible to continue explorations of the sub-aerial zone. Siphons of this type generally are not very deep. One of the main causes of the formation of lakes or siphons is the presence of depressions whose bottom is impermeable due to clay deposits. Furthermore, the water level in lakes and siphons may vary remarkably, depending on external input (rainfalls). In very rainy periods, galleries that are normally dry can be completely flooded and vice versa. In some karst systems, water level is known to rise over 100 m, in particularly rainy periods, thus obviously flooding all the galleries below this level.

The phreatic zone

Below the vadose zone of horizontal flow , is the phreatic zone, i.e. in this zone, all cave passages, conduits, galleries, rooms, shafts,fractures, voids of any shape and size are completely flooded. This zone draws the attention of cave-divers. The top of the phreatic zone, also called the water table, is found at sea level, in karst close to coastline, while far from the sea it is at the same level as the main valley floors, close to the so-called base-level, i.e. the level below which all voids are completely full of water.

Base level

The peculiarity of the base level is that it is not a fixed unchanging level, but it varies in (geological) time. It generally tends to lower progressively, as valleys deepen getting more and more entrenched. When a valley cuts the phreatic zone of a karst system the cave conduits that were previuosly filled with water get empty, letting water drain out. Thus karst springs are formed. These are normally found close to the base level, on valley floors – at times directly feeding water courses, at times creating pocket valleys.
A subsequent deepening of valleys leads to the formation of springs at a lower level and to the fossilization of the oldest springs, which remain perched over the valley floor, and above the new base level. During exceptional flooding events, when springs at the base level are unable to take away the large discharge of water flowing through them, the karst water table inside caves may rise, invading the upper galleries, which are normally inactive, thus temporarily flowing out of the ancient springs: these are known as overflow springs. Also in this case, a good knowledge of the behaviour of the karst systems and the geological structure are very important in order to be able to foresee possible hydro-geological problems. The new activation of ancient galleries and springs, in fact, is often sudden and difficult to foresee, if one does not know the structure and the behaviour of the karst systems.

Caves have a shape

Cave morphology is often complex and difficult to describe, however there are few elementary shapes : galleries, shafts, meandering channels, or canyons, rooms.
The trend of galleries is prevalently horizontal or slightly inclined, and generally galleries are large (if the size is small they are often called "passages", but this definition is purely speleological and not geologic. From the point of view of the origin, there is no difference between a "passage" and a gallery). The diameters of the galleries can be impressive. The largest gallery in the world is in Deer Cave in Sarawak – its average diameter is over 80 m.
Underground meanders, or canyons, are horizontal tracts characterized by a very high and narrow channeling. Meanders is an improper term because these are real underground canyons that are perfectly similar to the entrenched canyons on the surface, eroded by flowing water. Often these are the most difficult passages to explore, because they are frequently very narrow at the base and have water courses flowing on the bottom that can even be quite violent, therefore they must be explored at a mid-height, progressing delicately and painstakingly.
Shafts have a vertical trend: they can be perfectly cylindrical tubes, with smooth vertical walls (as in the case of the shafts formed in the phreatic zone, or at high mountain altitudes, due to the presence of snow or ice, or they may develop in ledges, or steps with erosion potholes on the bottom, as in the case of the vertical shafts originated from water courses on the surface, which recede due to the erosion of a water fall. Shafts can be of incredible heights, an example is the Vritiglavica (Slovenia) shaft that is over 643 m deep and has an absolute vertical drop of 500 m.
Rooms form due to collapses where shafts and galleries meet. The size of an underground room may at times be immense. The largest chamber in the world is the Sarawak Chamber, in the Lubang Nasib Bagus cave, in the Gunung Mulu karst area in Sarawak. It is 700 x 430 m in size, with a height of 120 m. It is still a mystery how a similar void underground can exist without breaking down.

Different zones, different forms

Cave morphologies are controlled by the zones in which they have been formed : in the vadose zone mechanical erosion features prevail (such as canyons, gorges, meanders and vertical shafts) and collapses, such as rooms; while in the phreatic zone corrosion features prevail.
Finding typical phreatic zone features in a vadose zone (or more rarely vice versa) is a precious clue in order to reconstruct the evolution and the geological history of a cave. Most underground caves form in the phreatic zone, in particular at its top (near to what is called the water table, or, less correct, the piezometric surface), where galleries are permanently flooded, but where there is a certain mixing of water and a merging with meteoric water, which periodically renews the corrosive capacity. Therefore caves are not formed starting from the surface but from inside, because flowing water must be concentrated in order to give rise to galleries and conduits of a certain size.

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The shapes of galleries and conduits in the phreatic zone are peculiar. Water occupying uniformly the entire section of a gallery leads to corrosion over the entire surface, thus giving origin to conduits with a circular cross section (both vertical and horizontal). If the rock contain portions that are easier to corrode or to erode, such as bedding planes or layers where the rock is particularly frail, fractures, etc, cross sections will elongate along these layers and elliptical or more complex galleries will form. Galleries of this type are known as phreatic galleries, and form in the first phases of the birth and evolution of a cave. If the water flow is very slow, on the bottom of the conduits fine sediments that “protect” the rock may accumulate. In this case dissolution only takes place on the ceiling, and galleries, known as paragenetic galleries, are formed, usually characterized by a flat roof.
Together with large-scale phreatic morphology, small-scale corrosion forms may be present, and when these are found they are precious evidence in the reconstruction of the history of a cave. For example it is possible to see ceiling half tubes or anastomoses (remains of the most ancient conduits of a karst system, which can be seen winding on the ceilings of larger galleries), dissolution pockets and boneyards where water mixes (at the confluence of conduits, where the chemical composition of water is transformed by mixing), or scallops. The latter are small asymmetric scoops, with an elongated tip indicating the direction of flow, formed by the presence of eddies in non laminar water flow.
At times these may be seen also in inactive caves and can be examined by speleologists. They are extremely precious clues regarding water flow in the past. In fact is it possible to recognize the direction of flow and in addition the scallops size can help evaluating the speed of flow in flooded conditions. In fact scallops sizes are inversely proportional to the speed of flow. Small, tightly packed forms indicate a rapid flow, large well separated forms indicate slow flows.