DIDACTIC UNIT III

UNDERGROUND HERITAGE AND EUROPEAN TOURIST CAVES

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DIDACTIC UNIT III. UNDERGROUND HERITAGE AND EUROPEAN TOURIST CAVES

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CASE STUDIES:

- *Novohrad-Nograd UNESCO Global Geopark*
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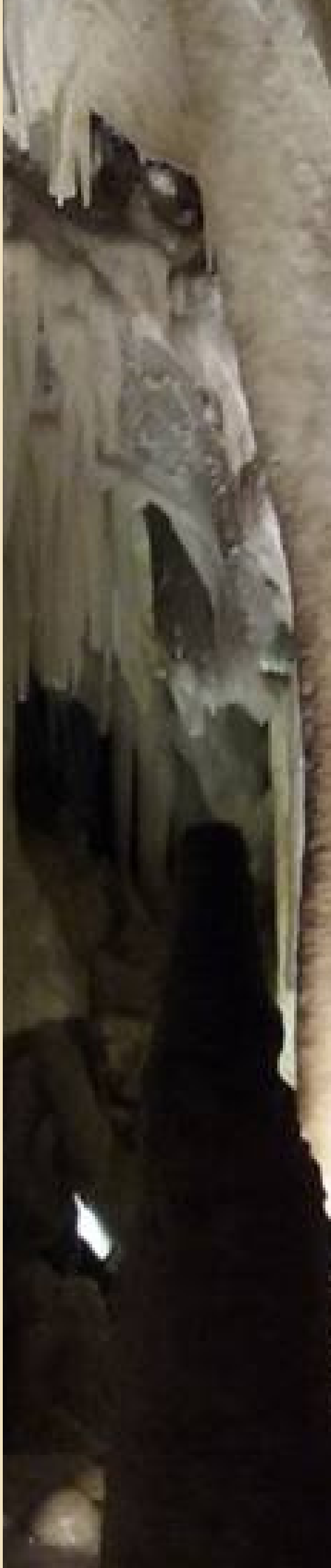
ANNEX I. European Touristic Caves



MODULE 1: Cave formation.

In this didactic unit, different points related to underground landscape will be taken into account, from rock formation basic concepts to karst modeling and cave formation, as well as, a selection of the main European tourist caves.

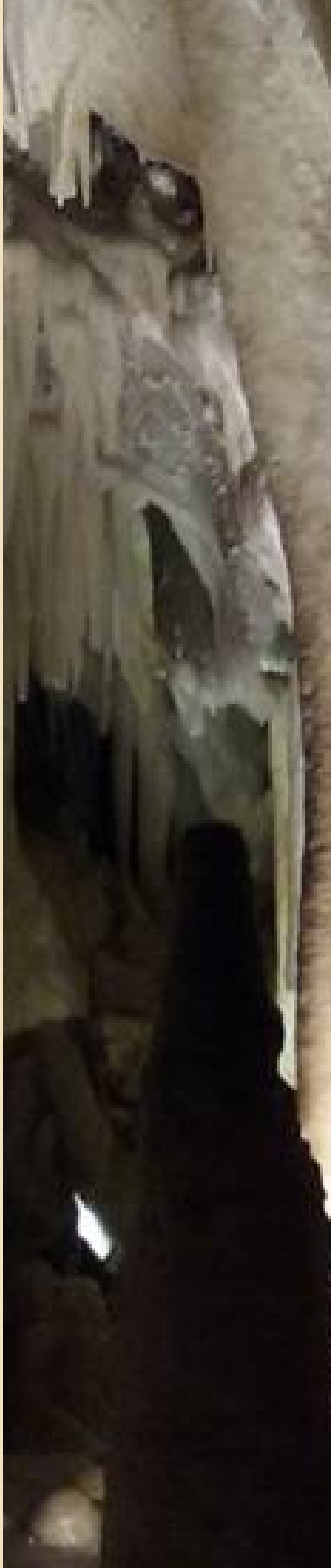
1.1. Introduction.

A cave can be defined as the empty space inside a rock due to erosion caused by water stream or the ice masses movement, or because of the limestone rock dissolution when it has been in contact with acid water or formed in volcanic rock, though it typically means caves formed by volcanic processes. Lava tubes are the most common and extensive kind of lava caves. Interest that caves arouse goes beyond strict scientific study because an antropologic vision is conserved which fuels, even more, the need of find the relationship between the cave and humans. Two uses are distinguished:

- Physical use. As a home, from Neanderthals and Cro-Magnons to hermits and ascetics, not forgetting shepherds and hunter´s refuge in times of conflict, as well as, religious worship place.

- Abstract use. At first, as a place of primitive artistic creation (cave paintings) and later, as a darkness dwelling place, inspiration of great philosophers, mythological creatures' domain, entrance to underworld, place of God´s manifestation, myths and legends source and, after all, part of the community culture.

Speleology, from Greek spelai on that means "cave, cavern" and logos "treaty", is the science which main purpose is the underground domain analyses. It takes into account the physical part of the cave, its formation, composition, structure and development, including speleothems (geological formations), being stalactites and stalagmites the most known.



Almost 90 % of large caves develop in carbonate rocks, mainly limestones and dolomites, because they enable water circulation.

1.2. Carbonate rocks.

Carbonate rocks are sedimentary rocks and have been formed by the precipitation of CO3Ca. Carbonate precipitation is usually linked to living organisms, which fix it to construct their skeletons (corals, sponges, calcareous organisms). One fifth of stratigraphic register of sedimentary rocks are carbonate rocks.

There are three carbonate rocks groups depending of the sea deepness where they were formed.

- **Oceanic.** Rocksformed in more or fewer deep seas are found in this group. Paleozoic, Cambrian, Devonian and Carboniferous rocks pertain to it.
- **Epicontinental.** Rocks formed in shallow epicontinental seas. Jurassic and Cretacic rocks are in this group.
- **Continental.** Rocks formed in large lagoons and swamps. They have fewer thickness so they don`t originate big caves. These are fine-grained calcareous rocks with organic remains.

Two components make up carbonate rocks.

1. Allochems. It refers to any type of carbonate particle with high organization and complexity.

2. Intergranular material. It is surrounded by the last ones. According to Anchurra (nd.) there are several matrix types.

a. Micrite. Carbonated matrix formed by aragonite or calcite crystals shorter than 4 µm. They are found in protect places where there is not agitation.

b. Bioclasts. Complete or fragmented skeleton remains of sea animals like equinoderms, corals, bryozoans and even mollusc. They are formed in marine or continental areas.

c. Added grains. Several particles bonded each other by micrite. They are usually found in intertidal or subtidal areas where the tidal circulation is low.

d. Peloids. They are made by faecal remains mix with micrite. They are found in protected areas without disturbing agents as lakes and tidal flats.

e. Intraclasts. Fragments with micrite matrix or other grains. They usually have a variable size, an anglular morphology and are formed where there is a huge activity of geological agents, within sedimentary basin.

f. Extraclasts. Carbonate rocks fragments eroded from other rocks, outside the sedimentary basin.

g. Oolites. Regular layers surround a nucleus, making up a spherical grain with maximun size of 2 mm. They originate in shallow areas.

h. Oncolihts. Due to algae activity, nucleus surrounding layers are not regular.

i. Other particles. Non-carbonated grains come from weathering of some rocks (quartz, feldespars, clays)

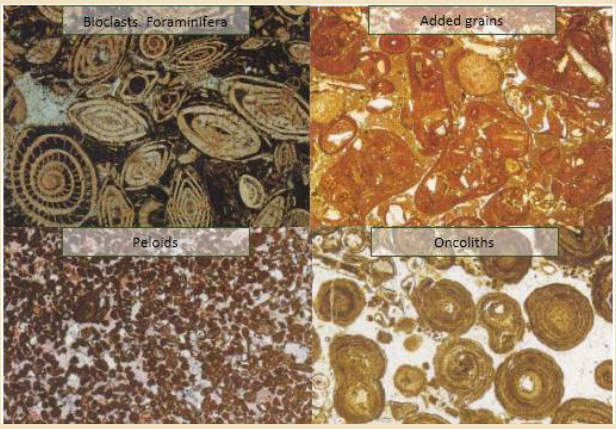


Fig. 3.1.Some types of intergranular materials (Achurra, nd).

Diagenes is the final stage of the sedimentary cycle in which chemical and physical changes take place, causing water exclusion of empty spaces due to compaction and subsequent filling with crystals. Temperature, light (the algae CO2 consume activates calcite formation) and water agitation will define the sedimentary nature, determining if the rock is more o fewer compact and more or fewer soluble. These factors are associated with karstification, where chemical (dissolution, hydration, ionic substitution and oxidation-reduction) and physical processes (mass transfer and diffusion) erode the carbonate rock surface.

Karst is the German name for the Slovenian region of Carso.

In the end, marine sedimentary rocks can emerge either by marine regression or by tectonic phenomena, being exposed at erosion and dissolution that will originate the karst landscape features.

1.3. Groundwater.

Limestone fractures determine their permeability grade, determining factor in the process of karstification. Those fractures form a branched drainage network inside the rocks, increasing the volume of water from up to bottom.

The micro-fissure network has a huge relevance not only because it is the main water source in the karst, but also for its role at the cave formation beginning.

Groundwater feeds mainly on rainfall and surface water courses that go across the subsoil, infiltrating throughout sinkholes and karst conducts, so that it is complex hydrological system with several inputs and outputs.

Fractures, rock type and terrain structure, determine the hydrogeological behaviour, setting up a groundwater circuit (drainage, fast flow, underground rivers, upwelling, etc.), where the water volume inside the rock mass is usually higher than on the surface.

1.4. First stages of karstification.

Karstification first stages begin with the dissolution in pure water, promoting the development of surface forms. To understand cave formation, molecular level needs to be taken into account, where next reactions take place, according to Martín et al. (2015). As a result of photosynthesis and flora decomposition, CO_2 is released, and reacts with rain water, forming carbonic acid (H_2CO_3).

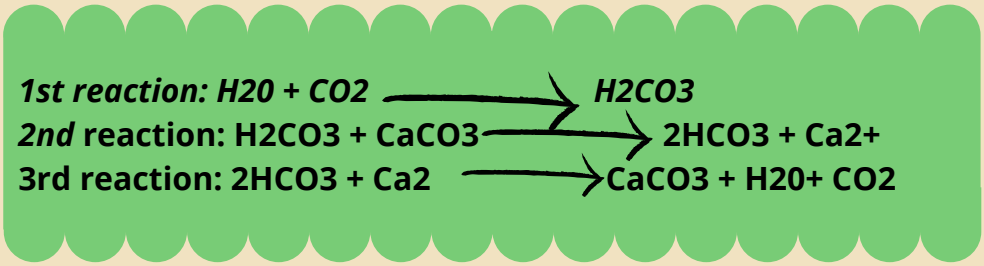


Fig. 3.2. Reactions that take place in both cave and speleothem formation.

This acid is able to dissolve some minerals like calcite and dolomite (2nd reaction).Pores and fractures that are formed due to weathering, at the end give place to marvellous caves that nowadays can be visited like Valporquero Cave, located in León (Spain).

Fig. 3.3.Valporquero Cave, León (Spain)

When the surface water seeps into the cave, it loses CO2 because inside caves that concentration is lower than outside, establishing a balance between both of them. When it happens, calcium carbonate precipitation (CaCO3) takes place (3rd reaction) (Martín et al., 2015).

Conducts only form in these rocks:

1. Soluble rocks to allow water percolation.
2. Pure so that insoluble residues, such as clays, do not hinder the dissolution of the rock.
3. Solid so that the spaces that are formed through them do not collapse.

Dolines, circular shaped depressions with sloping walls which can be originated by both erosion and land subsidence, are the main karst formations (Hernández, 2017).

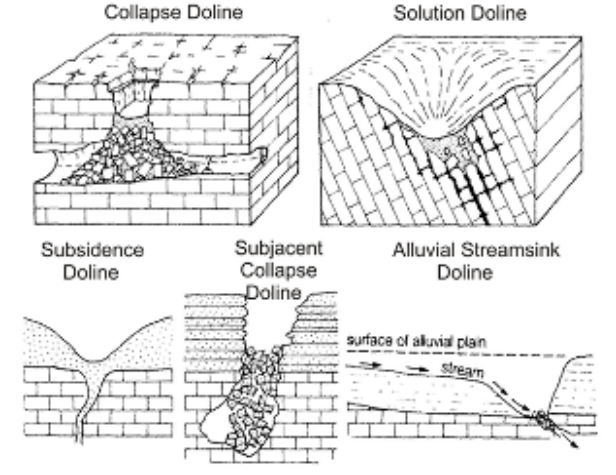


Fig. 3.4. Dolinedrawing.
http://www.kgs.ku.edu/SEISKARST/definitions.html

Depending on their physical features, dolines can get different terms but sometimes it is used sinkhole for all of them.

- ***Torcas***. They have very steep walls.
- ***Pit cave.*** Doline connected with an underground cave. They form when the cavern ceiling collapses.
- ***Cenote.*** Closed basins.
- ***Grapes***. Union of sinkholes in a certain region.
- ***Poljes.*** Several dolines joined making an elongated valley which can be flooded setting up a karst lake.

At times, the roof of the cavity can collapse and sink, thus creating a sinkhole of collapse or sinkhole.

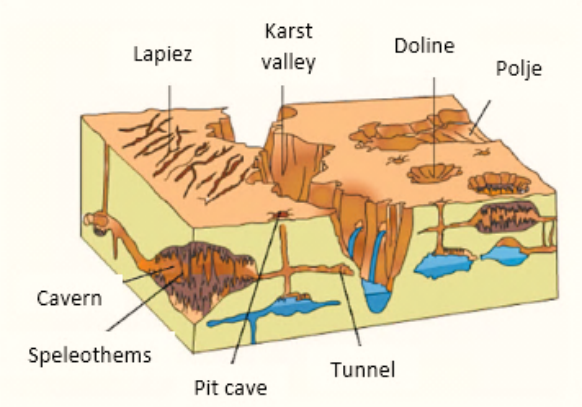


Fig. 3.5.Typical features of karst landscapes.

Limestone dissolution originates the development of karst landscape

1.5. Phreatic regimen and vadose regimen processes.

Hydrology determines the evolution and the development of karst systems, because water that goes through the rocks degrades some morphologies and enlarges other ones, connects endokarst and exokarst and changes water table (water upper level).

Karstification processes in phreatic regimen.

Both ducts and cavities under water table are permanently filled of water so rock dissolution occurs in the same way for all over the surface of them, developing water table tubes. These ones could show irregularities due to materials of the rock that may be different in its extension (Pinillos, 2015).

Karstification processes in vadose regimen.

After ducts development, a new drainage network is formed, changing water table to deeper areas, so that ducts are filled by air. This zone called vadose zone (Pinillos, 2015).

There are two vadose conduit types.

1- By nesting. They are formed following water table ducts, so that they are the first ones that turn up.

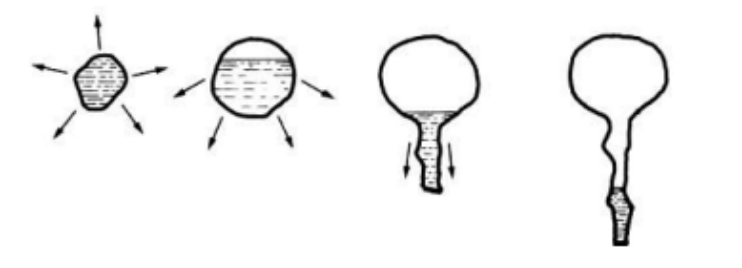


Fig. 3.6. Vadose duct formation by nesting (Pinillos, 2015).

2.- By encroachment. They are made up by watercourses without relation with ducts network, so they show slopes bigger than nesting ducts and haven´t got phreatic morphologies. The size can be large becoming like a hole one.

Karst is characterized by low surface runoff high infiltrations that circulate in a hierarchical way, so that caves are formed due to weathering and dissolution of karst ducts. Bit a bit, natural selection of bigger ones occurs, which will give place to caves in the future.

1.6. Cavities, caverns and galleries evolution.

Underground conduits are formed by widening of discontinuities (joints, fissures, layering plans, changes in porosity, etc.) variable in depth, length, plan layout and section plan.

Cavities are the result of complex evolution where collapse, sink and rock dissolution are combined so that it is complicated dating the age of a cave because traits and signs of previous phases have been lost. With dolines, their appearance determines the karst landscapes (Pinillos, 2015).

Caves evolution is characterized by:

- Quick development. Karst ducts have been made up for thousands of years, very short period taking into account geological scale. Karstification is a quick process so the same carbonate rock might have undergone several clogging and digging moments until it reached its current form.
- Energetic factor. Karts dissolution is a destructive process which uses large amounts of energy, mainly potential and chemical energy of water that erode rock mass. Three factors promote its development, depending of their strength.

- The relief.
- The biomass, which acts as a chemical energy factor, generating CO2.
- The pluviometry, acting as a potential and chemical factor.

Nonlinear evolution, because it depends on the weather and relief.

- Weather evolution may be quick and powerful. The best example is Quaternary glaciations, when dramatic climate changes occurred, conditioning times of activity and stop.
- Relief evolution is determined both by plate tectonics and erosion. Relief affects water courses which influence on weathering and rock dissolution.

1.7. Other processes of formation.

Travertines

Travertine is porous rock formed by calcium carbonate precipitation at the earth's surface. It will be developed in the point "2.2. Karst forms".

Duct fillers

Organic and inorganic materials storage on the surface of water table tubes that have been originated due to physical and chemical erosion of carbonate rock.

1.8. Pseudokarst cavities.

In water, some rocks will be more or fewer soluble, taking into account their solubility as well as water ionic concentration and water temperature. In this way, it might occur similar karst phenomena, so landscape would be called pseudokarst.

Evaporites

Forming by salt deposits on shallow basins where it has occurred intense evaporation. Halite and gypsum are the most common. Both have high solubility, so, cave formation is quite quick. Likewise, their ceiling usually collapses because it is less strong than carbonate rocks ceiling.

Quartzites

Its main materials are silicates. They are strong rocks resistant to weathering, so that fracture processes are more common than dissolution ones.

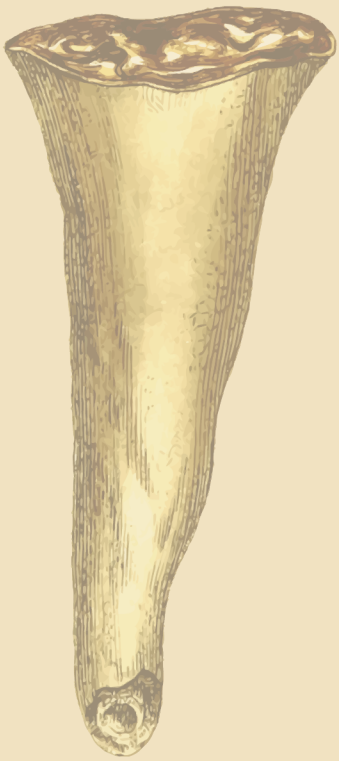
1.9. Karst landscapes evolution.

Bit a bit, water table tubes and vadose ducts are broadened, so that piezometric level falls until a balanced position is reached.

Water table or piezometric level: upper boundary of groundwater zone where pore water pressure is the same that atmospheric pressure.

As a result of tectonic plates movement or water level changes (sea level, lake level, etc.), a riverbed loses its balance. Then, the river erodes or deposits sediments trying to become stable again, to find its equilibrium profile. Likewise, karst ducts that where inactive, can put up with higher activity than before, widening due to rock dissolution. Finally, when these ducts are able to evacuate excess water, a new water table will be established. Over time, new ducts are produced, related to sequent phases when piezometric level is stable again (Pinillos, 2015).

Piezometric level stable position over time promotes the widening of water table ducts and vadose conduits.



MODULE 2: European Karst Landscape.

It is fundamental to understand factors that control the interaction between water and rock (see point 1.4.) to know and analyse both karst process and its result, karst landscape. (Andreu et al., 2016).

Fig 3.7. Karstslandscape: Vegacervera Sickles, León (España)

2.1. Dissolution and karst.

Karst is defined as that calcareous landscape with a hilly relief which has cracks and ridges, and it is subdued to chemical weathering.

Karst processes are intensified when soil acidity (related to CO2 concentration) and water movement through drainage network increase, so that some ducts are filled, and other ones are dropped.

It must taken into account that this process is reversible, that it's to say, dissolution processes continue with mineral precipitation where water evaporates, CO2 concentration is reduced and karst structure is formed due to minerals precipitation, mainly calcite and dolomite. (Pinillos, 2015).

2.1. Karst forms.

Karts forms can beexokarst and endokarst forms, and at the same time, destructive, constructive or a mix of both.

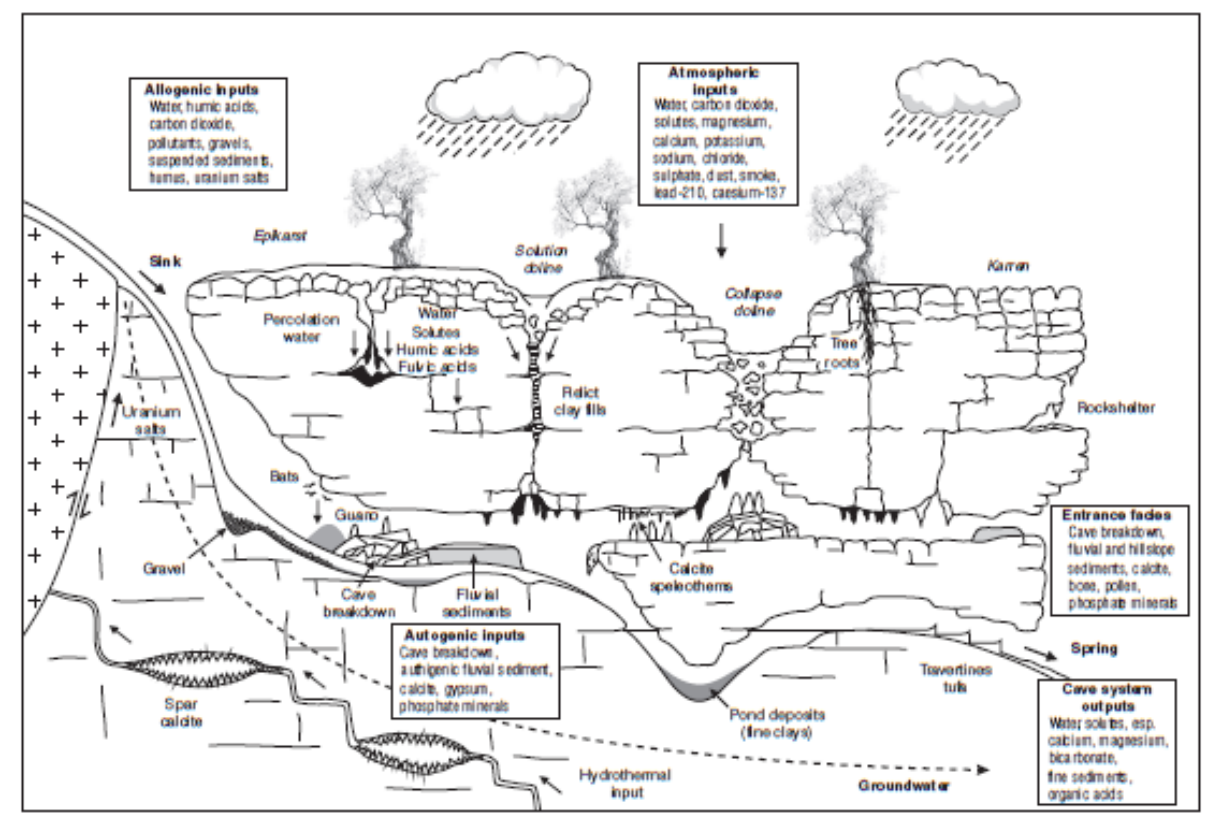


Fig. 3.8. Mediterranean karst system (Lewin y Woodward, 2009)

According to Pedraza (1996),destructive exokarst forms which can be found are: dolines, poljes, glaciokarst, karst valleys, mogotes, limestone pavements and pit caves. On the other hand, travertines and tobaceous platforms are constructive forms and the mixone's forms are decalcification trays.

Dolines

Dolines are closed soil depressions, which show circular base. There are different types depending of their origin, for example, pits and pit caves, dolines connected to underground galleries, can be formed from underground caves dissolution or collapse.

Usually, water goes towards them. Doline sinks essemble is called ponor and when a doline cannot soak up all water and as a result, the depression is sunk, it is called poljes which bottom is filled of insoluble sediments that close fissures.

Fig 3.9. San Pedro Pit cave, Toledo (Spain).

In karst, surface water circulation is sparse even absent, prevailing underground water flows. Upwellings are common on lower zones where water comes out.

Glaciokarst

Wide surfaces of naked rock on limestone rock grounds where water ice flow has formed huge canyons in high elevations and septentrional latitudes.

Fig 3.10.Greece karst landscape.

Karst valleys

Fluvial cracks on karst rock mass, with vertical walls, that come in handy as fluvial valley like canyons and sickles or remaining out of current stream, calling in that way dry or die valleys.

Mogotes

When most of rock has been dissolved because karst processes, sharp, conical and pyramid reliefs remain.

Fig. 3.11. Karst landscape with mogotes in Viñales Valley (Cuba).

Limestone pavements or karrens

They mean "field of stones" and they are minor forms of karst. They occur on naked surfaces or soil with vegetation, because runoff action originates blocks separate by channels or passages as a result soluble rock dissolution. First ones are produced by tectonic movements together with weathering as second ones are only the result of rock erosion. It usually takes place in high zones where limestone occurs.

Pit caves and pits

They are vertical ducts which connect both surface and underground water flows. Usually, they show a cylindrical shape and they have been formed because an exacerbated dissolution of a doline. Pit caves are deeper than pits.

Travertines and tobaceous platforms

Constructive exokarst forms originated by aerial carbonate calcium precipitation by means of chemical processes forming travertines or by organisms, both bacteria and plants, making this way tobas.

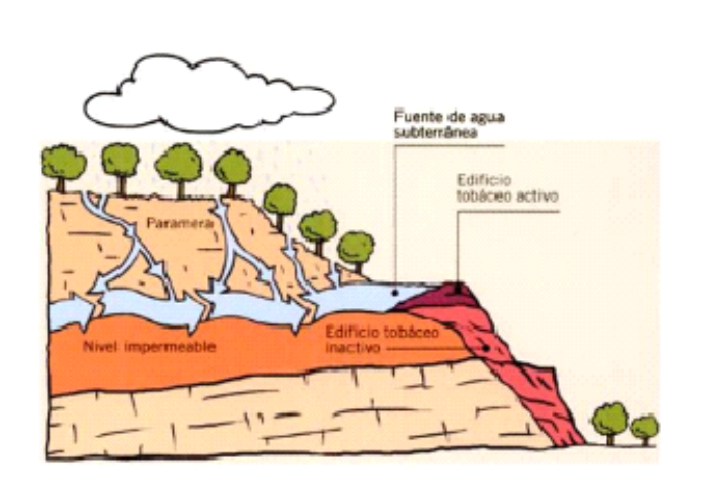


Fig. 3.12. Travertines formation.

Travertines appear to be like cascades or steps, because water flow saturated in minerals, such as calcite, came to rock surface (Carcavilla et al., 2008).

Decalcification trays

Mixedexokarst forms which show depression shapes filled with materials like, clays and iron oxides and hydroxides from karst bedrock erosion.
Both, Pedraza (1996) and Pinillos (2015) sort endokarst forms in destructive, caves, caverns and galleries and constructive, speleothems and duct filling.

Caves, caverns and galleries

They are underground conduits formed by the widening of some discontinuities (joints, fissures, bedding planes, porosity changes, etc.) and they are very changeable respect to depth, lenght and shape.

Speleothems

As a result of carbonate calcium precipitation as calcite or aragonite, it is formed structures inside caves and caverns. Depending on their morphology, they are classified as: stalactites, from ceiling caves, stalagmites, due to dropping of saturated water in carbonate calcium from the last ones and columns, from stalactite and stalagmite joining.

Fig. 3.13. Speleothems in Oñati-Arrikrutz Cave, Basque Country (Spain).

Ducts filling

Diverse materials like organic remains of both plants and animals or decalcification residues fill conduits.

Sinkholes, dolines and pit caves are the main forms that determine karst landscape, being closely related with dissolution, collapse and sinking. They are usually known as sinkholes. According to Pinillos (2015):

- Solution sinkholes. They are formed due to limestone dissolution with small collapses that occur near them. They are typical of karst land that have evolved over large periods of time.
- Collapse sinkholes. They are originated as a result of an imminent or progressive breakage and aftercave´s ceiling collapse. They are not common because carbonate rocks are so tough. However, collapses promote karst degradation and erosion on a small scale.
- Dropout sinkholes. They are formed both rock collapse and its roof because of water penetration through cracks and fissures of bedrock.
- Buried sinkholes. They are originated from remains deposit sinking that had been built over and old Sinkhole.
- Caprock sinkholes. Insoluble materials, that stay on karst surface, avert water penetration and its erosion, so that material could collapses over this surface or over an underneath karst cavity.
- Suffosion sinkholes. They turn up when the material, that is on the surface, is exposed to rainfall, which produces a gradual subsidence of the soil.

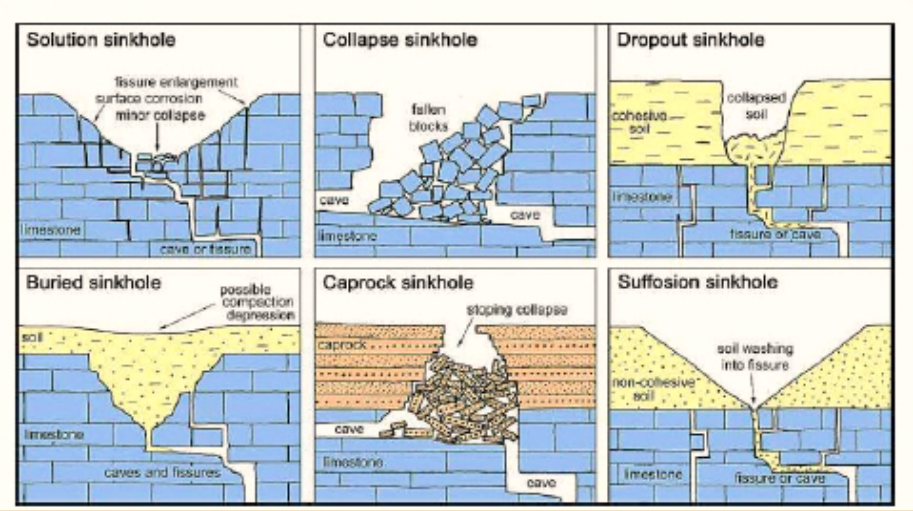


Figure 3.14. Sinkholes types (Waltham y Fookes, 2003)

2.3. karst and weather

Weather is an essential factor for karst processes, in as much as it exerts its influence through water availability and temperature.

- Earth rainfall climatology. Dissolution and weathering processes are heightened when water volume that passes through the rock is increased. Hydrologic network will deep into karst rock mass, degrading some morphologies and widening other ones. Likewise, outside (exokarst) and inside (endokarst) forms will be connected, changing piezometric level as it was mentioned before (Pinillos, 2015).

- Temperature. Cold water erodes carbonate rock better than that of higher temperature, since cold water catches CO2 more easily. Thus, glacial water or these that come from snow break have a higher concentration of dissolved CO2 to carry out limestone weathering.

- Vegetation. It is determined by climate conditions and its density plays an essential role in karst and caves development. On one hand, vegetation prevents from erosion, but on the other hand, due to fermentative and photosynthetic processes high amounts of CO2 releases. If CO2 is catched by water, acid water will speed massively rocks dissolution. It is usually that in karst zones with copious vegetation caves are formed.

Not only weather must be taken into account, but also tectonic processes that condition structure and promote rock fragmentation. Fracture discontinuities let surface water pass through the rock, leading to different types of cave morphologies.

Water movement inside these discontinuities is mainly induced by gravity. The presence of ducts and fractures accelerates the water flow. Points were two or more fractures join are more susceptible to karst processes. Sinkholes and dolines usually come along with small lagoons. Main tectonic discontinuities control principal direction of Karst morphologies (Pinillos, 2015).

Other main factor is relief. Effective underground drainage is needed for karst landscape to develop, since carbonate rocks have variable proportions of insoluble minerals which need to be separated and pulled by water streams. This only takes place when relief has slope.

Depending on climate, three karst types can be distinguished, according to Pinillos (2015):

- Tropical. As a result of hight temperatures and humidity, there is a huge biological activity on the ground, factor that increases soil acidity. Moreover, high dissolution take place due to the combination of abundant rainfall and high temperatures.

- Cold. Due to low water temperatures, CO2 dissolution is high, so these waters are quite aggressive with the rocks, promoting mainly destructive phenomena. They develop in high altitudes and latitudes where karst processes are associated with glaciers.

- Warm. Mixture of the other types, where variable saturation levels and intermediate water aggressiveness lead to, both, exokarst and endokarst forms. They develop in dry zones where the lack of water, due to seasonality, ¿makes karst more evident?.

2.4. Europe karst panorama.

All areas with notable rainfall and tropical or similar weathers are prone to karstification, as long as a carbonate massif is found. In Europe, without taking into account Russia, there are 1337635 km2 of limestone karst outcrops, which means 21,8 % of the European surface (Pinillos 2015) (fig. 3.15.).

In figure 3.16. all limestone outcrops in 2005 are shown, which it represented the 12% of earth surface (Goldscheider, 2005).

Fig. 3.15. Limestone upwellings in Europe are shown in grey (Goldscheider, 2005).

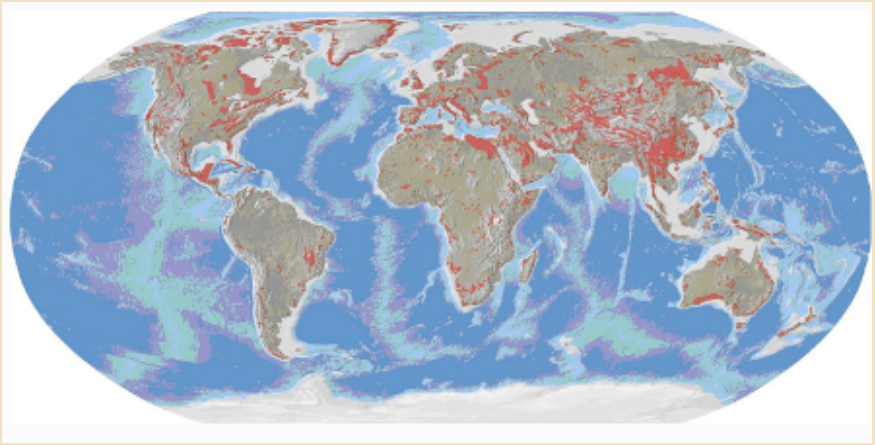


Fig. 3.16. In red, earth´s limestone upwellings.

According Jakucs (1977in Lewin and Woodward) there is an altitudinal variation that conditions the existence of four different karst sceneries, as it is shown in figure 3.17. The range in altitude and relief across the Mediterranean basin is believed to have a very strong effect on karstic processes, as well as landscape development (Lewin y Woodward, 2009)., as it is shown in figures 3.18. and 3.19.

- **A: Areas with altitudes above 3000 m**. In them, the intensity of karstification, as well as the depth of erosion and therefore the formation of caves are not very noticeable. However, U-shaped valleys do appear due to erosion caused by the accumulation of ice and snow.

- **B: Areas below 2000 m**. The erosion of the limestone rock together with the formation of furrows are the main characteristics found at this altitude. Likewise, there is a medium-low intensity of karstification. A small calcareous deposition and formation of sinkholes also appear.

- **C: Areas located at an altitude of 1000 m**. The rock surface presents a vegetal cover, which increases the intensity of the karstification processes.

- **D: Areas less than 1000 m**. The calcareous deposition increases notably, as well as the formation of caves and sinkholes. The depth of erosion is substantially reduced, as well as the formation of furrows.

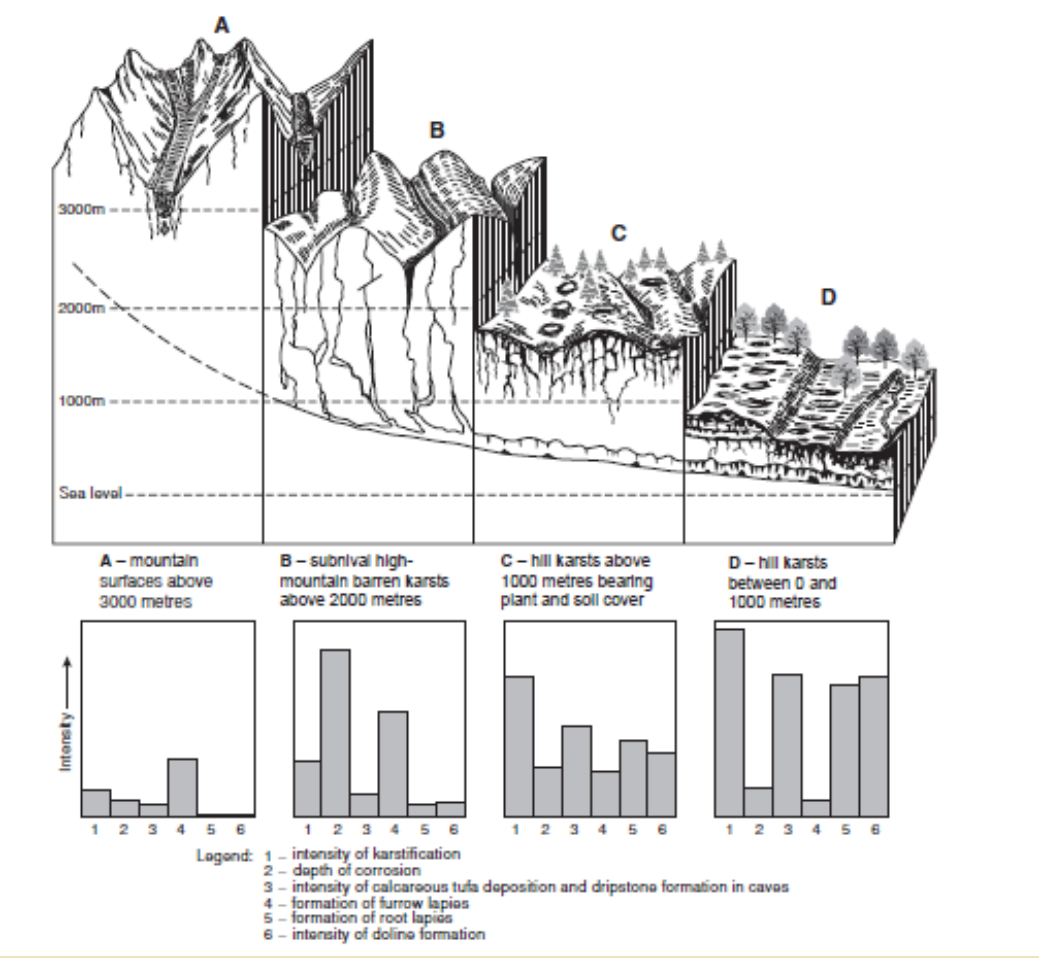


Fig. 3.17. Mediterranean karst sceneries (Lewin y Woodward, 2009).

Fig. 3.18. Karst landscape in Picos de Europa National Park, north of the Iberian Peninsula (Spain)

Fig. 3.19. Karst Galbenain Apuseni (Romania).

MODULE 3: The inside of the Karst.

3.1. The zoning of karstic systems.

Depending on the hydrogeological dynamics, several zones inside and outside karstic rock mass can be distinguished:

a. Absorption or infiltration zone. It is found in the superficial zone and it is also known as epikarst. Very intense dissolution processes take place, which depends on external conditions, climate, rainfall and tectonics. In addition, the presence of vegetation will act on rock erosion, where highest CO2 concentration is found. The joints (rock fracture without relative displacement) further water infiltration promoting cave ´s formation.

b. Vadose passage. It is defined by underground network of fissures, holes and pit caves. The kinetic energy of water acts as a mechanical agent, eroding the rock so that there are collapses and silts, which can connect holes and pit caves.

c. Horizontal passage. There are galleries and rooms where calcium carbonate precipitates, forming several speleothems and all kind of concretions such as stalactites and stalagmites. Likewise, underground rivers, chimneys, siphons, etc, may appear.

It is said that caves and galleries are active when water goes through them and formation and development processes take place. Stalactites dripping reveals that the cave is alive because of these processes.

However, dead caves or galleries are those in which there are not formation or development processes, so walls are dry and there is not limestone breaking up.

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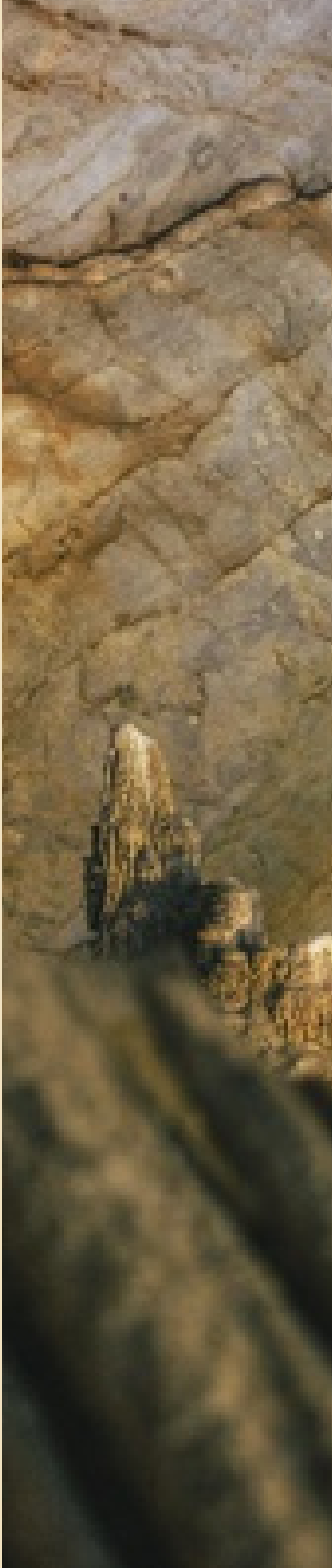

d. Deep core. It is associated with the karstification limit zone. Although it cannot be said that there is a definite true limit, because inside the bedrock there are changes that could favour deep karst development, starting from this area. However, Bosnia Herzegovina, the base of the karstification zone is found at a depth of 250 m in the Dinaric Alps regionalthough it depends on the type of rock and external factors as it was mentioned. (Pinillos 2015). Generally, it delimits with the water table, with permanent circulation of water, which corresponds to aquifers and with the exit of the water, giving rise to springs.

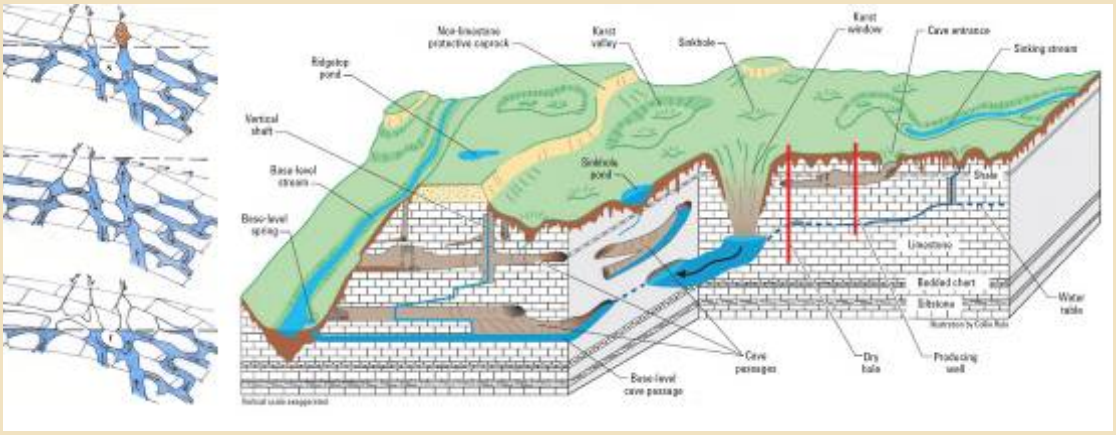

Fig. 3.20. Karstic system zones.

Water from aquifers is one of the main sources of fresh water to all population, being 50 % of whole water used in some European countries. Thus, is important taking into consideration the aquifers´ vulnerability due to pollutants which go through soil fissures. For it, COST 620 Action has been established whitin the European framework, with the purpose of conserving European karstic aquifers (Goldscheider 2005).

3.2 Speleothems.

Speleothems are developed due to chemical precipitation of several minerals from carbonate rocks.

When CO2 rich water has circulated through fissured dissolving carbonate rocks, it leaves the rocks slowly, so CO2 releases and calcium carbonate precipitates, originating speleothems (figure 3.21.).

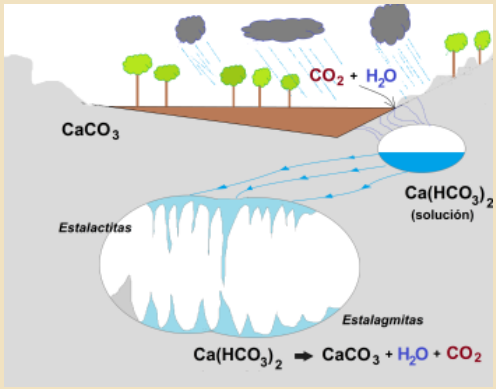

Fig. 3.20. Calcium carbonate (CaCO3) precipitation.

Their formation and development depend on water fluidity and CO2 concentration. Because of that, their growth is not constant, there are changes in the evolution of their length and thickness. They grow more in winter than in summer because water temperature is lower during the first season. Speleothems formations is reduced when there are air streams which reduce the time that one drop stays at the surface, for example on a stalactite.

Fig. 3.21. Calcium carbonate saturated drop on a stalactite.

Speleothems length growth is opposite to their thickness growth. For example, a stalactite, with 2 m length and with a diameter of 40 cm, has been formed about 150000 years.

Speleothems keep important information in their growth layers, like that on past climates and on their absolute age. Most of them are fragile, so they shouldn't be even touched. Generally, they can break due to underground vibrations, for examples seismic movements. Next, the most characteristic speleothems are shown according to Martín et al. (2015).

Stalactites.

Cylindrical or conical forms that grow from cave´s ceiling by dripping. When water arrives at the cave and loses CO2 ,calcite or aragonite precipitation take place, originating a thin deposit around the stalactite´s drop. Water moves inside the tube, forming new crystals which give place to tubular stalactites, long and thin, called soda straws. Likewise, that water can move outside the stalactite, making mineral layers around this speleothem. They are formed when water flows outside and inside the soda straws, promoting their thickness and length growth.

Stalagmites.

Cylindrical forms with rounded end, that have been formed by an extended dripping from a stalactite or from cave´s ceiling. They have not got central tube, so they have grown by means of layering.

Columns or stalagnates.

They are formed when both stalactite and stalagmite ends are joined.

Draperies.

Sheet like speleothems suspended from cavities ceiling. They have been developed from calcium carbonate deposits over sloping cave´s ceiling when drops slipped., an then fell.

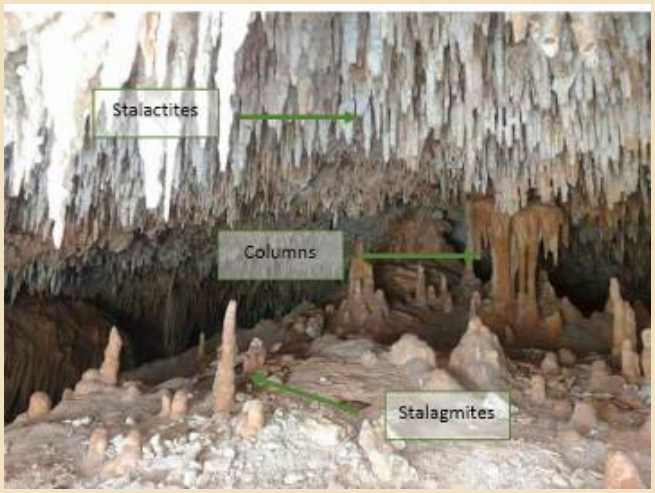

Fig. 3.22. Main speleothems in a cave.

Flowstone.

Calcium carbonate deposits with mantle morphology due to layers superposition along a large surface. They are formed in zones where water is rich in minerals.

Platelets.

Thin calcite plates formed over small lakes surface. They are on the surface until they are too heavy, and then sink.

Fibrous formations.

- **Pompons.** Acicular morphologies arranged from central point which have a length between 1 mm and 5 cm.
- **Garlands**. Pompon groups.

Other formations

- Pisolitas o cave pearls. Formed in small deposits or water regularly stirred by dripping. The pearl core is a fragment around which layers of calcium carbonate grow.
- Coralloid structures. Small accumulations formed by spheres arranged next to each other. They are formed because of slow water flows.
- Helictites. Multidirectional growth speleothems. They have a central channel through which water runs.
- Moonmilk. Accumulations of matte white microscopic crystals.
- Scabs. They cover the red clays on the floor and on the walls. They are compact structures formed by several successive layers of several minerals.

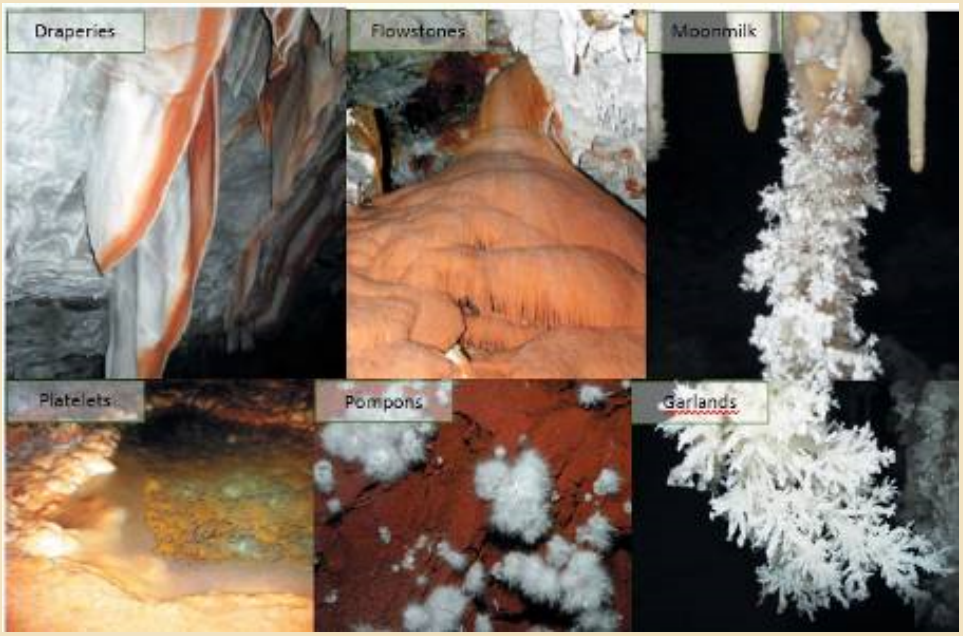

Fig. 3.23. Speleothems (Martín et al., 2015).

Mineral	Formula	Origin	Speleothems	Picture
Aragonite	$CaCO_3$	It is formed when there is a high Mg^{2+}concentration in the water.	Stalactites, stalagmites, columns, flowstones, draperies, helictites, coralloids, pompons, garland sand scabs.	
Calcite	$CaCO_3$	It is usually formed by aragonite transformation.	Stalactites, stalagmites, columns, flowstones and draperies.	
389/Dolomite	$CaMg(CO_3)_2$	It is usually formed by aragonite transformation.	Pompons, moonmilk and scabs.	
Magnesite	$MgCO_3$	Direct precipitation?	Moonmilk and scabs.	
Gypsum	$CaSO_4 \cdot 2H_2O$	Direct precipitation?	Scabs	

Table 3.1.Main minerals in speleothems (Martín et al., 2015).

3.3. The extraordinarian troglofauna.

During last 2000 years, humanity thought that caves were lifeless places in which only living beings inhabited them temporarily and accidentally and finally, they would die. The reason for this belief was that there was not light so photosynthesis could not take place. In fact,inside caves there are detritivorous, root and predatory underground animals, that are studied by Biospeleology.

Biospeleology is the branch of Biology dedicated tothe study of cave organisms, called troglofaunal

Troglofaunal species are evolved species with differences in their evolution grade, which found refuge inside caves due to adverse weather, so that they did not appear in caves. Furthermore, they are called living fossils because they keep ancestral features that have disappeared from epigeo because their ancestror have been extinct.

Fig 3.24 Hydraphaenops vasconicus, endemic beetle from Basque Country.

On one hand, there are troglophiles which can inhabit out if conditions are suitable and on the other hand, trogloxenes, that sometimes they are established inside caves due to adverse conditions but they have not got any cavern feature (Galan, 2006).

Underground animals associated with water are called stygofauna. There are three types considering their habitat´s depth:

a. Stigobites. Complete their whole life cycle in deep aquatic environments.
b. Stygophiles. Inhabit both surface and subterranean aquatic environments.
c. Stigoxenes. Trawling fauna.

Underground colonization is a result of active colonization carried out trough slow adaptative process due to refuge search when adverse weather arrived in, for example, during Quaternary glaciation. After colonization, adaptation to new conditions takes place, which involves an evolutionary process associated with several changes such as: body and appendicular elongation, physical and ethological changes, low metabolism, and longevity, etc. Moreover, structural reductions like depigmentation, ocular atrophy, or wing loss are common. Then, founder populations speciation occurs as consequence of genetic isolation due to physical barriers. There have been several microevolution phenomena with the appearance of endemic species, which, for example, represent 81 % Basque Country (Spain) cave species. (Galan, 2006).

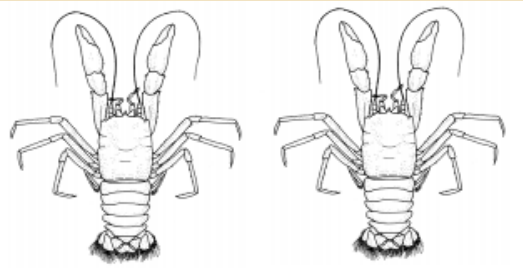

Fig. 3.25. Munidopsispolymorpha (left), squash lobsterandCyclopodia (right), copepoda, cavern´s endemisms from Canary Islands and Basque Country (Spain), respectively (Galán 1993).

Endemism is referred to that taxon which has a limited and unique distribution in the planet.

3.4. Climate change and its relationship with karst systems.

During the Pleistocene and Holocene, the Mediterranean karst morphology was affected as a consequence of successive climatic stages of cold-heat and humidity-drought. The limestone zones suffered intense weathering, appearing cliffs that are still preserved today.

Nowadays, karst landscapes represent tourism attractions, as well as reserves for life development and water supplies. As previously was said, aquifers protection is sought because they are really threatened by contamination (Lewin y Woodward, 2009).

MODULE 4: Cavities in Volcanic Materials.

4.1. Introduction.

Volcanoes are part of a highly dynamic morphogenetic phenomenon due to both geomorphological back was hess it implies
and reorganizing capacity of the ground on the area in which they are developed. In addition, they are related with natural heritage (geoheritage), taking into account three prospects (Dóniz, 2009b).

a. Biodiversity. Variety of life´s forms. It involves geodiversity and hydro diversity.
b. Geodiversity. Variety of earth materials, forms and processes which originate unique geological and geomorphological formations.
c. Hydrodiversity. Water plays an essential role in most ecosystems.

Fig. 3.26. Biodiversity, geodiversity and hydro diversity.

Regarding to geological ways, earth´s volcanoes depend on magmatic activity, mainly extrusive. They are associated with volcanism zones in which there are island arcs and rifts. Every volcano activity starts with crust rupture followed by magma (molten rocks) rise with volcanic ash (tephra) and gases from a magma chamber.

Volcanoes are classified taking into account their magma, molten rocks generated by geotermal energy and expelled through crust´s fractures. There are explosive and effusive eruptions. The eruptions in which lava fluids flow slowly (effusive eruptions) are able to form lava tubes, interesting from a touristic point of view.

Molten rocks emerged to the Earth´s surface.

Fig. 3.27. Lava flows at the Hawaii Volcanoes National Park.

4.2. Igneous rocks. Basic concepts.

Igneous or magmatic rocks are originated as a consequence of magma´s cooling and solidification. Magma rises and when it is cooled (outside or below the surface) it crystallizes and solidifies, originating the igneous rocks.

Intrusive or plutons	Extrusive or volcanic	Hypabyssal
They are formed from magma that cools and solidifies slowly inside the planet crust. As a result of this slowly cooling, the rocks are coarse-grained. Granite, diorite, gabbro and peridotite.	They are formed from magma that cools and solidifies quickly after eruption, so they have not got crystals but show gas bubbles. Basalt, rhyolite, trachyte and phonolite.	They have intermediate grain size between plutons and volcanic rocks and are emplaced at medium shallow depths. Pegmatite, diabase and diorite.
 Granite	 Trachyte	 Diabase

Table 3.2. Igneous rocks types taking into account their formation(SGM: Mexican Geological Service)

4.3. Lavatubes. Description and origin.

Igneous rocks are formed by insoluble minerals, so lava tubes, which have volcanic origin, do not involve dissolution process as karst caves otherwise lava flows cooling. This cooling causes sinking and drains which formed volcanic ducts, with hydrological interest as karstic ones (Guerrero, 2012).

Fig. 3.28. The Los Verde´s Cave is a lava tube in Lanzarote, Canary Islands (Spain)

4.4. Other volcanic cavities.

The difference in the type of terrain, the composition of the magma and the variation in the slope give rise to different patterns- (Guerrero, 2012).

- Drainage Lobes or surface Tubes.
- Lava channels. Volcanic tubes in which the roof did not form.
- Volcanic chimneys. Vertical ducts through which lava flowed to the surface and subsequently retracted, leaving the mempty. They usually arise from volcanic cones.
- Pit-Crater. They are formed as a consequence of the drainage of magma, leaving in its path a sinking in the surface. Large well switch steep walls similar to those modelled by dissolution processes originate.
- Volcanic joints. They occur in areas where situations caused by volcanic movements occur as a consequence of plate tectonics. When the lava flows back in a liquid state, it empties, leaving a well similar to that of a volcanic chimney.
- Molds of lava. They originate when the lava flows around dead trees or animals, therefore forming cavities with an organic nucleus that are time disintegrates, leaving the hole in the shape of the individual.

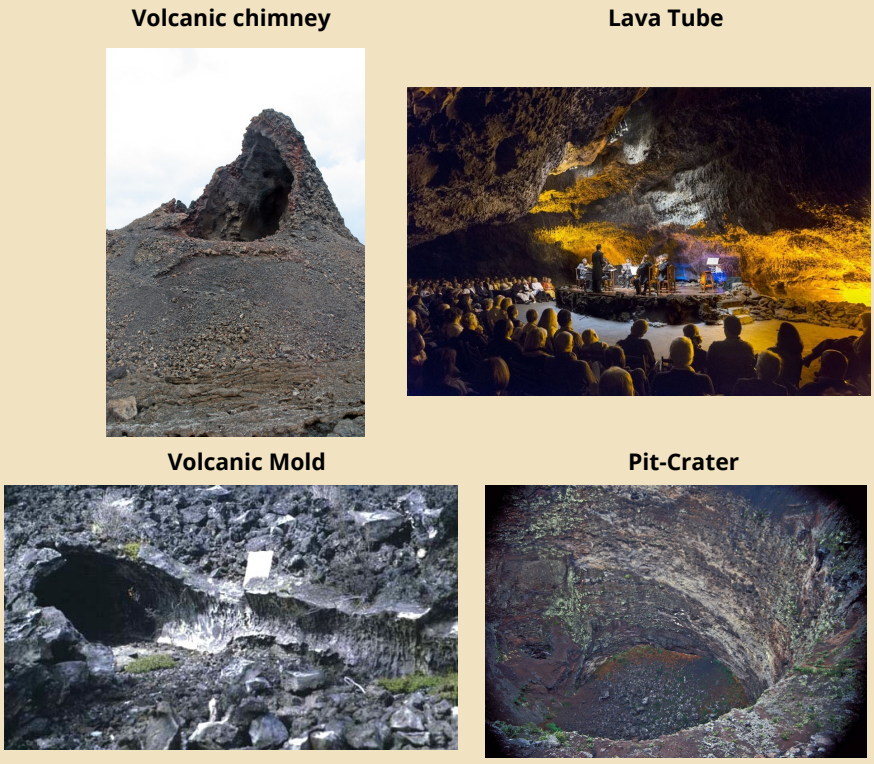

Fig. 3.29. Examples of the different volcanic cavities.

4.5. Volcanic cavities in Europe.

In volcanic terrains the presence of volcanic cavities is quite common. Within the European territory there are several examples such as: the volcanic tubes of the Canary Islands (Spain), the Azores Geopark (Portugal) or the Vesuvius volcano (Italy).

Canary Islands (Spain).

Due to the volcanic origin of the Canary Islands, there is a large number of examples of volcanic tubes. Here are some of them. (Naranjo et al., 2016).

- Aslobas Cave. With an age of almost 14 million years, this volcanic tube is one of the best preserved on the islands. The cave is divided into two galleries, in which a large number of invertebrates, of geobiological interest, resides, thanks to the high level of humidity it treasures.

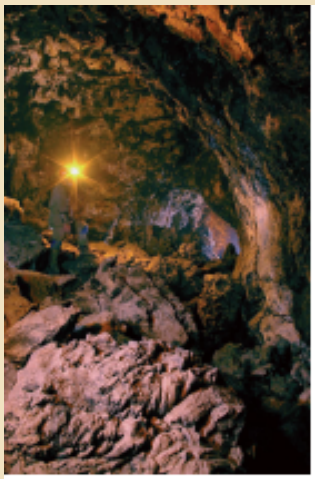

Fig. 3.30. Aslobas Cave, Canary Islands

- La Luna Cave. It is oneof the best-known volcanic tubes on the island given the width of its access mouth.

- Los Bucios de Los Marteles. Volcanic tube of great dimensions, up to 44 m in length. It presents an interior space included by a powerful sedimentary filling with several detached blocks.

- Los Verdes Cave. Tunnel formed by the Corona volcano 5000 years ago. It is located north of the island of Lanzarote. It has one of the longest volcanic tubes in Europe, reaching an extension of 6 km, connecting the crater with the sea.

Fig. 3.31. Los Verdes Cave, Canary Islands (Spain).

Azores Islands (Portugal).

The Azores Islands Geopark is unique in the world as it treasures 121 diversified Geosites between the nine islands and the surrounding marine area. In the subsoil almost three hundred volcanic cavities have been discovered in the form of caves, caves or cracks.

Fig. 3.32. Volcanic Cave of Carvao, Azores Islands (Portugal).

Vesuvius Volcano (Italy).

Mount Vesuvius is a volcano, still active, located near Naples. World famous for the eruption that took place in AD 79, in which the city of Pompeii and a part of Herculaneum were buried. Currently, It is the most densely populated volcanic area on the planet, with a population of three million people.

Fig. 3.33. Pompeiiunder Mount Vesuvius (Italy).

Fig. 3.34. Plaster casts of the victims of the Mount Vesuvius's eruption in 79 AD in Pompeii (Italy)

The Case Study on European touristic caves management of NN Geopark

A) MAIN CHARACTERISTICS OF THE GEOPARK CAVES:

The Novohrad-Nograd Geopark in the lack of extended carbonate rocks in its built up is not a cave Geopark, although some internal cementation discrepancies in the rocks gave way to the development of cavities, pseudokarst caves.

There are 77 caves (43 on the Slovak and 34 on the Hungarian side) within the Geopark, 4 of them are endogenous and 73 exogenous in origin.

The main 26 nonkarst caves have been developed in sedimentary and volcanic formations.

8 caves have been listed in different sandstones. For example erosion produced the Kőlyuk of Kishartyán formed in glauconitic sandstone, which got later expanded by human
activity during the Middle-Ages.

18 caves are enlisted in and at the boundaries of volcanic rocks. For example the Mucsiny Cave (Slovak part) is a 12 m long tree mould cave in rhyolite tuff, at the Paris-gorge (Hungarian part) 3 smaller tree mould caves were formed in younger formations.

The bubble cave of Sámsonháza (3 m) is a simple gas bubble of regular shape. Caves formed by gas and steam explosions are also known to exist: the Kiskő Cave near the town of Salgótarján (30 m), the basalt cavity of Baglyaskő (13 m) and the Függőkő Cave at Mátraszőlős (3 m).

Movement along fault lines and incision created the caves of Szilváskő-Rift (Hungarian side) in the basalt of the Medves Plateau (with several caves of 20-50 m in a 300 m long, 5-10 m deep open rift). Some such caves are above former underground mining operations.

Pseudo-caves created by the displacement of blocks, boulders falling on each other are considered consequence caves, the extension of fracture woolsack caves are resulted by the removal of saprolite among blocks.

The enlisted fourteen artificial cavities which are considered as caves by the local population have been carved in loose rock.

A.1. Indicate if there is cartography of the caves and if are all explored.

The catalogued caves have been mapped and explored but only partly studied or excavated.

A.2. Indicate the most important geological characteristics of the caves in the area: karst formations, volcanic formations, cave paintings, etc ...

In Hungary caves are ex lege protected and are defined as natural underground spaces formed in rocks, which are big enough for a human to enter and which extend at least 2 m, underground.

The Case Study on European touristic caves management of NN Geopark

A.3. Are there protected fauna and flora associated with the caves in the area? Are the caves inside of any protected natural area?

Beside the ex lege protected status most of these caves are within protected landscape areas.

Due to special climate conditions the deeper, not show-caves host protected biota.

B) DESCRIPTION OF THE ACTIVITIES IN THE CAVES OF THE GEOPARK:

B.1. Indicate the number of caves that can be visited in the Geopark: is there the possibility of guided tours? Are there limited in the number of people who can visit the caves?

Due to the geopark's non-karstic cave features most of the caves are small and narrow cavities, they are not show-caves and mostly cannot be entered. By their entrance they are interpreted and organized guided tours or individuals can visit them, ifthe terrain is not difficult up to 40 people can do this at the same time.

The show-cave of the Kőlyuk-cave of Kishartyán , which functioned as a refuge hide-out during dangerous times of the Middle-Ages can be reached only by steep stairs carved intro marine sandstone cliff and can be entered, but less than 10 people can attend such a program at the same time.

Fig. 3.35. Kőlyuk cave of Kishartyán

The Case Study on European touristic caves management of NN Geopark

B.2. Indicate the tourist, cultural or sports activities currently taking place in the caves of the geopark (speleogy, sports activities, geotourism, etc.)

The non-karstic caves of geoturistic potentials are enlisted geosites within the Geopark, but due to their limited inner space almost all of the activities can take part only outside, around their entrance by the forms of mainly guided tours.

B.3. Are there routes around the caves of the Geopark? Indicate the name and the length.

There are plenty of 0, 7-4 km long trails leading to the caves, or to paths, where cave entrances represent one stop along the trail, such as the Mucsiny-cave, which can be reached by organized thematic tours either from Slovakia or Hungary (Ipolytarnoc Fossils) or the Szilváskő trail.

B.4. Are there active tourism companies that carry out activities within the caves of the Geopark? Indicate the name and type of activities carried out.

There are some private entrepreneurs who organize guided tours to the caves, but not inside the caves.

C) ACCESSIBILITY AND EQUIPMENT OF THE GEOPARK CAVES:

C.1. Describe the equipment and infrastructures associated with the caves of the Geopark: signage, visitor center, etc.

There are interpretation panels and publications available about the caves. The GUIDE @ HAND Bükki National Park Directorate is a smart phone, mobile application that lets visitor's offline discover the caves.

C.2. Indicate if have been carried out conservation, restoration and conditioning activities in the caves or if there are future plans for their implementation.

Some cave entrances got safety blocked, along the Szilváskő-rift fissures got encircled and trails mended.

C.3. Are the caves accessible to the disabled public? Are there accessibility plans available for the future?

No

The Case Study on European touristic caves management of NN Geopark

C.4. Is it necessary any special permit for the development of active tourism activities within or near of the caves? Say which ones.

Yes, active tourism in groups is controlled, permission is needed to obtain from the authority of environmental protection.

C.5. Is it possible to arrive to the caves by public or private transport? Is there an adequate transport network in the zone?

The non-karstic caves of the Geopark are within 1-5 km walking distance away from parking plots or stops of public transport.

D) EDUCATION AND RESEARCH:

D.1. Are open the caves for educational activities? List the most important ones.

Schools can visit the cave entrances and educational material about the caves is available for the public. Sometimes conferences are organized, like in the case of the Szilváskő-rift caves studies' 100 years anniversary in 2017.

D.2. Are there publications and / or scientific studies associated with the caves in the area? Indicate which ones.

Yes, details of it just above.

D.3. Are the caves integrated into a national and/or international network? Have the caves any national or international recognition / award? Indicate which ones.

Yes, the caves are integrated into the national network, but represent not unique ones with universal significance.

The Case Study on European touristic caves management of Sierras Subbéticas Geopark

A) MAIN CHARACTERISTICS OF THE GEOPARK CAVES:

There are around 900 catalogued caves, sinkholes and cavities in Sierras Subbéticas UGGp. Some of the most important are: Murciélagos, Encantada, Macarrones, Talillas, Los Tocinos, or Mármoles caves, the Cabra sinkhole and the Nava ponor. They are about 250 caves properly named. The rest, i.e., the smallest ones, are listed with an alphanumeric code.

A.1. Indicate if there is cartography of the caves and if are all explored.

Around 750 of the catalogued caves have been explored and conveniently mapped.

A.2. Indicate the most important geological characteristics of the caves in the area: karst formations, volcanic formations, cave paintings, etc ...

The geological substrate of the geopark consist of a very thick pile of Jurassic limestones, sandwiched by Triasic clays/evaporates and Cretaceous marls. When these rocks were folded and thrusted, a very large volume of limestones were exposed at surface. This, the suitable climatic conditions and a long exposure time resulted in the development of a very intense karst system. All the caves in the geopark are related to this karstification process.

A.3. Are there protected fauna and flora associated with the caves in the area? Are the caves inside of any protected natural area?

There are threatened fauna under protection into several Subbética caves, specifically chiroptera and troglofauna, including here an endemic species of millipede reported in the Murciélagos Cave. The current figures of protection are diverse. As a general rule, all the caves in the geopark are protected by the figure of Natural Park. In addition, the existence of archaeological vestiges in numerous caves provide them an additional protection figure under the denomination of Site of Cultural Interest. An extra-figure of protection was given to the Murciélagos Cave when it was also declared Natural Monument in 2001.

The Case Study on European touristic caves management of Sierras Subbéticas Geopark

B) DESCRIPTION OF THE ACTIVITIES IN THE CAVES OF THE GEOPARK:

B.1. Indicate the number of caves that can be visited in the Geopark: is there the possibility of guided tours? Are there limited in the number of people who can visit the caves?

There are two caves in Sierras Subbéticas UGGp that can be visited by non-speleologists, the Murciélagos and Encantada caves. Both are currently visited with guidance support. Apart from the visiting activities developed in these two caves, access to the non-touristic visitors is regulated by the geopark management body in coordination with the Andalusian Federation of Speleology.

B.2. Indicate the tourist, cultural or sports activities currently taking place in the caves of the geopark (speleogy, sports activities, geotourism, etc.)

The Murciélagos Cave is the most visited Geosite in the Geopark and one of the most renowned and visited Natural Monument in southern Spain. Developed from a fault system and with almost 1000 m high it offers a circuit of about 2 km showing a rich plethora of speleothems of enormous beauty. It is also well recognized all along Europe as one of the most important caves for Neolithic and especially for Upper Palaeolithic archaeological remains.

The other visiting cave is named the Encantada. Into the walls of this 40m long cave, several Neolithic and Chalcolithic paintings from neighbouring and more inaccessible caves are reproduced, thus giving to visitors the possibility to contemplate them in a more favourable point of view. Although the cave is open to all visitors, there are activities specially designed for primary and secondary schools.

Other caves are currently under investigation for archaeological vestiges. Some of them are even planned to be open to visit to the general public by a tourist enterprise, obviously with restrictions and under regulation.

The sport activity is currently restricted to expertise speleologist groups that count with enough technical and physical competences to entering the caves.

B.3. Are there routes around the caves of the Geopark? Indicate the name and the length.

The two caves open to visit are located in the northern part of the Geopark. There, different routes and geosites are also accessible to visitors, most of them equally in relation to the intense karstification process, but showing different manifestations.

The Case Study on European touristic caves management of Sierras Subbéticas Geopark

The closest signposted trails are the Bailón River trail, with 11.8 km long and the Buitreras trail, with 17.4 km. There is also a circular route connecting Zuheros and Luque, that enable visitors to accede to the two caves currently open to public, the Murciélagos Cave in Zuheros and the Encantada Cave in Luque.

B.4. Are there active tourism companies that carry out activities within the caves of the Geopark? Indicate the name and type of activities carried out.

The Murciélagos and Encantada caves are managed by the Zuheros and Luque councils, respectively. The activities regularly developed in both cases are touristic an educational. The possibility an area of the Murciélagos Cave for speleo-turistic activities is currently under evaluation.

C) ACCESSIBILITY AND EQUIPMENT OF THE GEOPARK CAVES:

C.1. Describe the equipment and infrastructures associated with the caves of the Geopark: signage, visitor center, etc.

The Murciélagos Cave has an interpretation centre close to the main entrance, called Ecomuseum, with information about technical aspects of the cave as well as about the highly relevant Neolithic and Palaeolithic remains on it. The Ecomuseum also offers booklets, leaflets and diverse merchandising. In the path connecting the Ecomuseum and the Cave there is a viewpoint equipped with interpretive panels that offers a splendid view of another geosite of the Geopark, the Subbetic thrust front.

It should be noted that the Zuheros Council, that manages the Murciélagos Cave, offers touristic packages that include, together with the visit to the Cave and Ecomuseum, a visit to the Archaeological Museum to see the monographic exhibition of prehistoric and historical objects from the cave.

At the other hand, the Encantada Cave have no interpretation centre, but the guides offer very enthusiastically to visitors, booklets, leaflets, and simple lamp recreations.

There are signed caves other than the two aforementioned ones, as for example the Cabra sinkhole, renowned for being cited in the legendary Cervantes's novel Don Quixote.

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C.2. Indicate if have been carried out conservation, restoration and conditioning activities in the caves or if there are future plans for their implementation.

Since the discovery of the Murciélagos Cave in 1938, in modern times, many research projects have been developed in the cave providing critical information about the Palaeolotic and Neolithic of southern Europe. The abundant archaeological remains have offered details on the life style of inhabitants, their tools and their diet. In coordination with this research activity, different campaigns of restoration and conditioning have been also taken into account to facilitate and accommodate visiting activities.

The Encantada Cave was restored and conditioned for visiting activities in 2004. As stated above, many Neolithic and Chalcolithic painting discovered in adjacent and more inaccessible caves were reproduced there, a task entailing important archaeological research and plastic works.

Other caves with archaeological remains have been also studied, while some other are currently being conditioned to be open for visiting.

C.3. Are the caves accessible to the disabled public? Are there accessibility plans available for the future?

The Encantada cave is accessible to disabled people while the Murcialagos Cave is not due to its vertical and complex orography.

There was recently a study to implement a pulley system to facilitate the entrance of disabled people to the Cabra sinkhole. However, the idea was refused due to the complexity, risk and the potential conservation problems.

C.4. Is it necessary any special permit for the development of active tourism activities within or near of the caves? Say which ones.

Yes, active turism in caves and cavities is only allowed to accredited active tourism companies. They must request a licence from the managing body of the Geopark to carry out these activities. To obtain the licence the companies must have rescue plans for possible emergencies and all the monitors accompanying the groups must have specialized technical training.

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C.5. Is it possible to arrive to the caves by public or private transport? Is there an adequate transport network in the zone?

The Encantada Cave is located into the village of Luque, so that, it is very accessible by public and private transport. The Murciélagos Cave, located 4 km from Zuheros, is accessible by road, with private transport, or just walking.

D) EDUCATION AND RESEARCH:

D.1. Are open the caves for educational activities? List the most important ones.

The two caves mentioned above are regularly open to educational visits. Their archaeological remains and paintings are excellent for understanding the Palaeolithic, Neolithic and Calcolitic life and art in the territory. A vast number of schools, mostly primary schools, come from many other localities of Andalusia to visit both caves. Some secondary schools and occasionally students from different Universities also visit the caves.

D.2. Are there publications and / or scientific studies associated with the caves in the area? Indicate which ones.

The different archaeological excavations carried out since the sixties in the Murciélagos Cave has resulted in an important number publications. These suggest that humans have occupied the cave since the middle Palaeolithic (35.000 years ago) until roman times, leaving important manifestations of middle Palaeolitic, Neolithic and Bronze art, including vessels, necklaces, bracelets and specially paining of horned animals, eyes and humans. On the basis of this art expressions, as well as the food remains, seeds, tools and bones recovered, researchers have reconstructed the live of the ancient occupants of the cave, have provided valued information about ancient commercial routes and have documented one of the oldest evidences of opium poppy cultivation in Europe.

D.3. Are the caves integrated into a national and/or international network? Have the caves any national or international recognition / award? Indicate which ones.

The Murciélagos Cave forms part of the Spanish Association of Tourist Caves, which in turn is integrated into the International Association of Tourist Caves. Regarding the second question, the Murciélagos Cave was declared Natural Monument in 2001, as stated above, due to the enormous importance of the middle Palaeolithic and Neolithic archaeological remains.

ANNEX I. MODULE 5. European Touristic Caves

The speleo-tourism is the activity of visiting underground cavities for recreation; being different from speleology, a concept that implies the scientific study of these cavities.

It is one of the tourist modalities with more years and tradition such as the wine-tourism, active tourism or bicycle touring. The caves tourism is based on the choice of destinations motivated by the taste for caves, either in its aspect of visit, or in its closes aspect to speleology.

Caves were the first and, for a long period, the single geologic item for tourism. In the last few tens of years, with the creation of "Geo-Parks", new geomorphological items started to become touristic targets. Anyway, show caves are still now by far the most important geologic tourist at attraction from the economic point of view and, in the last 20 years, their interest grew very rapidly.

Some 250 major tourism caves with over 25.000visitor/year exist in the Europe and over 75 million visitors pay yearly a ticket to visit them. If all the activities related to the existence of a cave (transportation, lodging, etc.) are considered, some50 million people stake, directly or indirectly, their income from tourism caves: these figures may be at least doubled taking into consideration surficial and deep karst within geoparks. It is therefore evident that show caves are presently the most important geotouristic target all over the world and they represent an important economic resource for many of the still developing countries.

Annex 3.1 List of the most important tourist caves in countries of the European Union.

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