Chapter 5

The karst relief

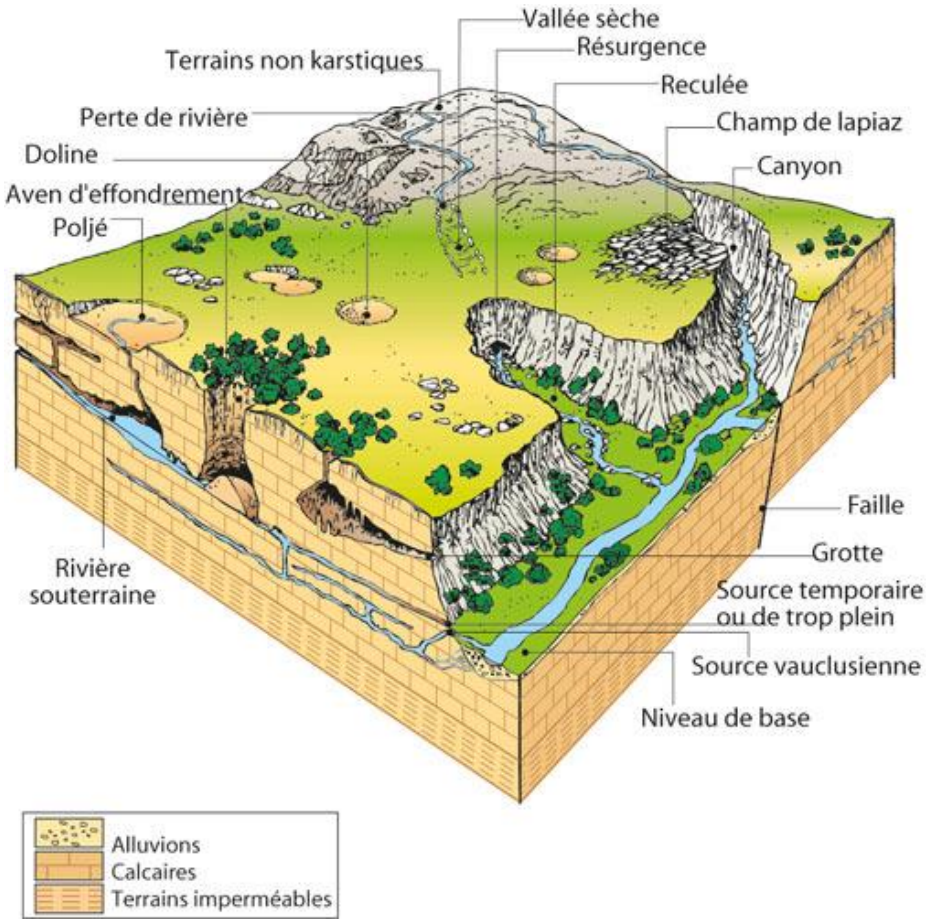
1/ Karst environment :

The formation of karst reliefs is mainly due to the corrosive and erosive action of water, which dissolves the calcium carbonate. Most current karsts result from the evolution of limestone plateaus (in Croatia, Greece, Italy, etc) under the tropical climate of the tertiary era. Most of the water circulates through complex networks, installed via faults, under the limestone plateaus. The waters that arise are aften loaded with limestone which precipitates upon reaching the surface (traventines, perfying spings)

Karst

The word karst designates a particular relief associated with limestone plateaus. Set of forms developed in a region where sedimentary rocks sensitive to dissolution predominate, primarily limestone. Karst results from particular underground flows which are gradually established in carbonate rocks (limestone and dolomites) and in saline rocks (gypsum and sometimes rock salt). Karst is therefore also an aquifer since groundwater and surface forms and underground flow conditions, which interact with each other.

Outside of the karst network, the voids in the rock are made up of cavities and by discontinuities in the rock (cracks, fractures and stratification planes more or less widened by dissolution) all these voids are poorly hydraulically connected to the conduits. This organization (karst network or drainage network) is done in the manner of that of rivers, depending on the general slope and the resistance opposed by the rock (permeability), it can be more or less linear and simple or very complex.



Représentation synthétique d'un système karstique

The main factors of karstification are water, the nature of the rock, CO2, the hydraulic gradient, which is the driving force behind underground circulation and which conditions the entire functioning of the karst.

Pseudokarst

Is a form of weathering in non-carbonate rocks that results from physiochemical processes similar to karstification affecting limestones, pseudokarst is in fact a term which allows us to classify everything that is not karst in the strict sense (charbert et courbon 1997). They can correspond to scree caves, detachment cracks, and open in rocks such as granite or gneiss. They can also be sea caves, ice caves or even volcanic cavities.

Pseudokarst of mechanical origin essentially correspond to relaxation fractures or voids inside chaos of blocks (cave-scree). The evolution of the relaxation fractures continues with the complete separation and collapse of the rock section. The largest blocks which

accumulate at the foot of the wall can form a chaos of cyclopean blocks, in which penetrable and interconnected interstitial voids (talus cave) present a certain extent.

Hypokarst includes all processes and phenomena comparable to those of karst, such as glacier cavities or lava tubes.

Parakarst includes all processes similar to those of classical karst, but in soluble, non carbonate rocks, dissolution patterns develop in siliceous rocks, such as quartzites, sandstones, flysch, loess and marls, and evaporitic rocks, such as gypsum or salt. They give pseudo-lapies and ruiniform reliefs.

Cryokarst, also called glaciokarst or thermokarst, includes surfaces riddled with depressions due to the melting of lenses or pellets of ice.

2/ Karst and pseudo karst processes

The processes of karst formation =Karstification is rapid, an underground network is set up by wedged on the lowest level of limestone in the landscape, this is the base level where the spring appears. But flows can occur at levels lower than the source deep in the geological formation.

Empreintes de racine dans le calcaire par dissolution dans la zone de production de CO2

Thus, for karst to form, the following conditions must be met:

- The water most be able to dissolve the rocks, therefore contain an acid. The most common acid results from the dissolution of carbon dioxide (CO2) produced by vegetation in soils.
- Water most be able to flow within the rock, that is subsurface flow must occur, in preference to surface flow. As the voids in the rock (fissures, fractures and bench joints) initially have a very small width for the most part, the rock has low permeability, that is to say it offers a high resistance to underground flow. There must therefore be a sufficient head of groundwater, this condition is met when there is a well-defined relief, such as in the mountains or in regions of plateaus crossed by gorges.

Dissolution: solution and precipitation:

The dissolution of carbonate rocks (limestone and dolomite) is complex set of reactions involving three phases: solid (the rock CaCO3or CaMg(CO3)2), liquid (water and its substance in solution), and gaseous (the CO2 produced in the soil).

These are the reaction that occur between water and air (dissolution or escape of CO2) between water and rock (dissolution of carbonate minerals) and within the solution

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(combination of different ions with each other). Equation for dissolution of CO2 in water

$CO_2 + H_2O \quad H_2CO_3, \quad H_2CO_3 \longrightarrow H^+ + HCO_3^-$

Equation for dissolution of calcite $CaCO_3 + H_2O + CO_2 \longrightarrow Ca^{2+} + 2HCO_3^-$

The dissolution of rock occurs either on the surface or less at depth, depending on whether water circulates slowly or quickly.

Groundwater is often highly enriched in carbonic acid and other organic acids, notably humic acids produced by root activity as they percolate through the soil, CO2 dissolved in water hydrates and froms carbonic acid which dissociates into H+ and HCO3- ions, then into CO3- carbonate ion.

$CO_3^- + CaCO_3 + H_2O \longrightarrow 2HCO_3^- + Ca^{2+}$

The formation of concretions in the cavities is linked to the precipitation of carbonates, water circulating in the limestone rocks of the karst is charged with HCO3- and Ca2+ ions in solution. When these emerge in a cavity, they release a little CO2 into the atmosphere, this loss of CO2 shifts the equilibrium of the carbonate and results in a precipitate of CaCO3 (calcium carbonate) according to the chemical reaction:

$2HCO_3^- + Ca^{2+} \longrightarrow CO_2 + CaCO_3 + H_2O$ it is also often caused by living beings that build their shells or skeletons from calcium carbonate.

Evaporates:

Evaporates are formed by precipitation of ions in solution, in a supersaturated aqueous medium (brine) subject in principle to various thermal variations, causing for example more or less intense evaporation, or even cryogenization or significant ventilation with a drastic drying effect.

Silicate rocks:

The composition of the liquid phase represents the outcome of interactions between water and the solid mineral phases of rocks. The dissolution and precipitation of solid

phases play a decisive role, particularly for regulating the concentration of major elements such as calcium, carbonate, silicates.

The solubility of the corresponding minerals then determines the possible dissolved elements concentrations in the water. Silicate rocks are not completely soluble without water, they are differentially altered.

If we take the most common of the crustal silicates, plagioclase, we can summarize the balance of its alteration as follows: $2AL2CaSi2O8 + 4CO2 + 6H2O \longrightarrow 2Ca+2 + 4HCO3- + Si4O10Al4(OH)8$

Al2CaSi2O8 being the calcium pole of calcium plagioclases (anorthite) and Si4O10Al4(OH)8 the simples of clays, kaolinite.

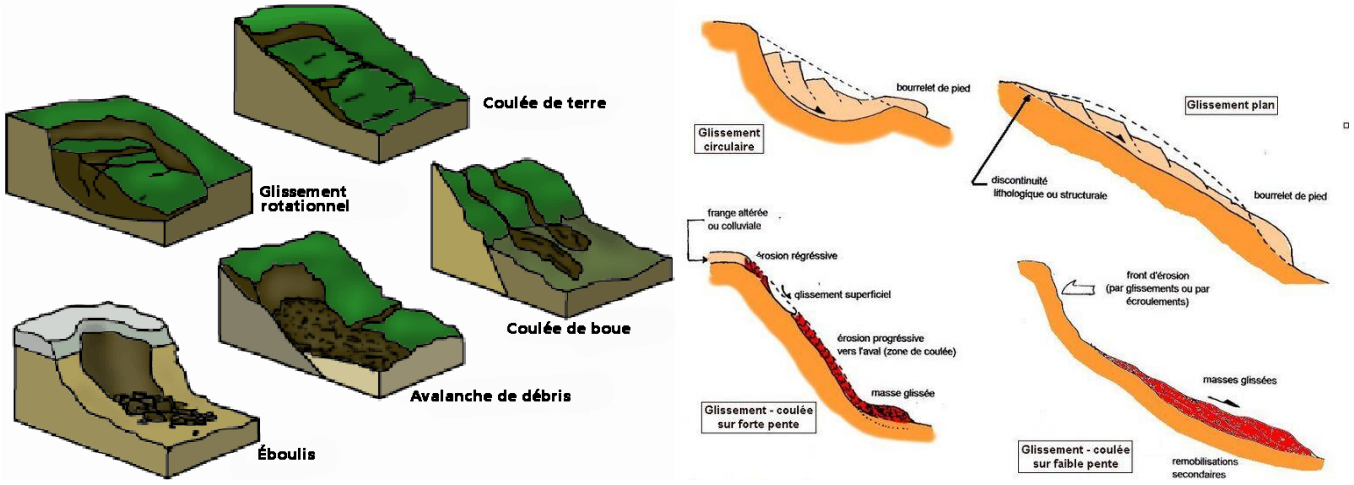
3/ Slow movements

Ground movements bring together a set of movements, more or less brutal of the soil or subsoil. The volumes involved range from a few cubic meters to several million cubic meters. It depends on the nature and arrangement of the geological layers, it is due to slow processes of dissolution or erosion favored by the action of water and man.

Land movements appear during the natural or artificial conjunction of factors topographical (land slopes, reliefs), geological (nature of the soil),hydrological and climatic (significant precipitation)

Land movements most often manifest themselves through falls of stones, blocks and landslides in cliffs and ramparts, landslides, bank erosion, mud flows and debris flows, collapse of tunnels, lava and finally soil erosion.

Landslides they generally occur in situations of high water saturation of the soil they can mobilize considerable volumes of land, which move along a slope.



Collapse:

A collapse or collapse is a sudden and brutal separation of a natural (cliff) or artificial (wall, building) structure with falling materials. When this collapse concerns coherent rocks, we can also speak of a rock slide. The result of this fall, namely the piling up of earth, rocks or construction materials on the ground, is called landslide.

Evolution collapses of natural (dissolution of gypsum) or artificial (quarries and underground works outside mines, marl pits) underground cavities can lead to the collapse of the roof of the cavity and cause a depression on the surface that is generally circular in shape. Muddy and torrential flows are characterized by the transport of materials in more or less fluid form. Mud flows occur on slopes, by degeneration of certain landslides with

influx of water, torrential flows occur in the torrent bed at the time of flooding in the flood section.

Collapses and falling blocks:

The evolution of cliffs and rocky slopes cause's rocks falls (volume less than 1dm3) block falls (volume greater than 1dm3) or mass collapses (volume which can reach several million m3), isolated blocks bounce or roll down the slope, while in the case of mass collapses, the materials flow at high speed over a very long distance.

River processes

A fluvial system relates to watercourses, especially rivers also tributaries and confluences such as rivers. Fluvial processes sculpt the landscape, eroding landforms, transporting sediment and depositing it to create new landforms.

Fluvial processes are involved in geomorphology with the formation of river valleys and channels: erosion (vertical end lateral), weathering and mass movement, transport and deposition and factors affecting these processes, the entire river system characterizes a hydrographic basin. The fluvial environment is closely linked to the activity of the river and also to the alluvial plain.

A river system is made up of three parts:

1- Headwater streams flow quickly down steep mountain slopes and cut deep V shaped valleys.

2- Transfer zone, low altitude watercourses merge to descend gentle slopes. The valleys widen as the rivers begin to meander.
3- Depositional zone, at the lowest elevations, a river meanders through a wide, almost flat valley forming a floodplain. At the mouth of a river, it can divide into separate channels as it crosses a delta (case of the coastal river) which extends to the sea, the coastal plain and the delta are made up of fluvial sediments

Hydrothermals:

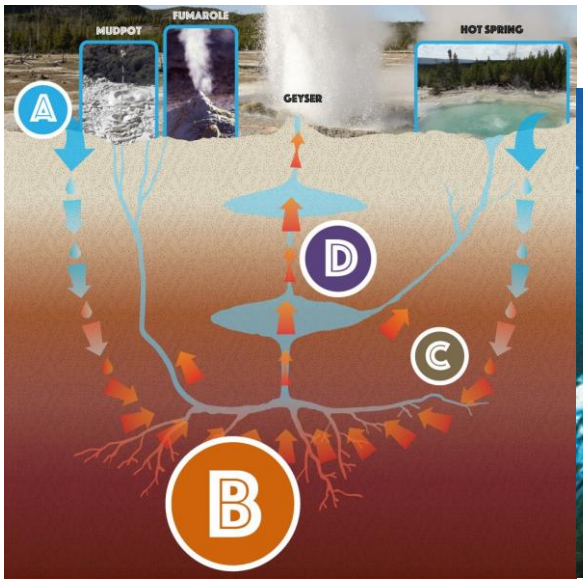
A hydrothermal source relates to the underground circulation of hot fluids, or designates the action of heated water in the earth`s crust. Hydrothermalism refers to the underground circulation of hot water, loaded with dissolved minerals. This circulation, favored by a heat source, often takes place in veins in a volcanic zone, not far from a magma chamber or in a plutonic zone.

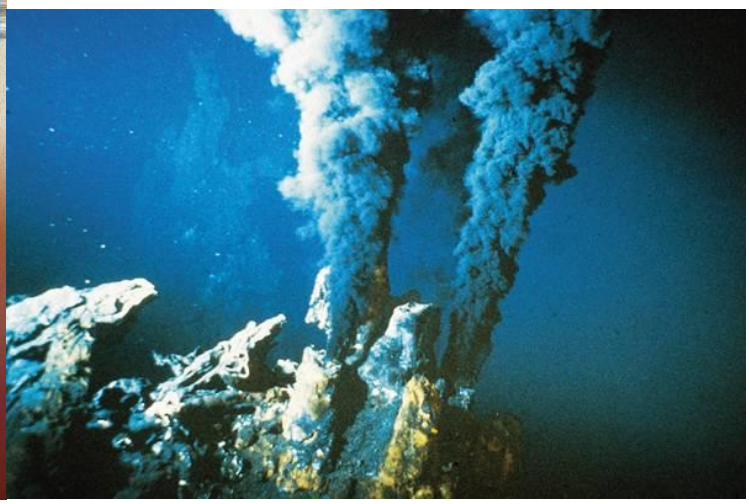
This circulation dissolves the minerals present in the rocks crossed, this is the origin of many types of ores.

Hydrothermal veins correspond to fractures filled following the differentiation of magma, during its ascent, the magma undergoes fractional crystallization which leads to an enrichment of the residual silicate liquid in volatile mineralizing elements and in metals extracted from the earth`s crust. The open fractures are first filled by the residual silicate liquid (crystallization of pegmatite, aplite) then by aqueous fluids rich in dissolved elements. As the brine rises closer to the surface, the water cools and loses its dissolving

power. Other metal ions (cold, silver, zinc) precipitate in the form of sulphides , carbonates, oxides or more rarely in the form of native elements to from veins.

Hydrothermal vents are the result of seawater percolating through cracks in the oceanic crust near spreading centers or subduction zones.





4/ Surface and internal karst forms:

Caves:

A sea cave also called a coastal cave, is a natural cavity in the coastel rock structure, the formation of which essentially results from erosion by the action of sea waves. These caves can be submerged or semi-submerged and are subject to the tide.

The active force of water and waves is the driving force behind the development of sea caves. These weathering agents are such that the water pressure of the waves can reach several tens of tonnes/m2 depending on the importance of the waves.

In addition to the hydraulic force of the waves, there is the abrasive effect of sand and other suspended rock particles, of the vibration phenomenon induced by waves, most sea cave walls have an irregular surface. However, some caves have parts where the walls have rounded and polished surfaces. Chemical weathering, a secondary driving force, acts mainly through atmospheric precipitation which, by infiltrating subjects the walls to

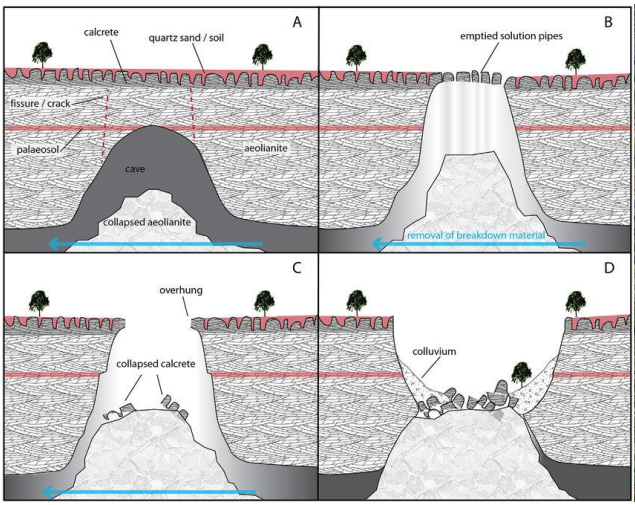
leaching. Coastal caves are found in a wide variety of horst rocks, of sedimentary, metamorphic or igneous origin. Those formed in igneous rocks tend to be larger due to the greather strength of the bedrock.

Sinkholes:

These are more or less rounded depressions in the surface in which limestone has been dissolved by rainwater, causing the subsoil to subside. Sinkholes circular or elliptical in shape, can be from a few dozen to a few hundred meters in diameter and a depth of between 2 and 200m, some have a funnel shape, others a tub.

The slopes of the sinkholes are gentle and converge towards the center of the depression. Sinkholes are very often aligned along a main fracturing or along the route of an underground watercourse.

Decalcification clays (residues from the chemical dissolution of limestone) accumulate at the bottom of these sinkholes, retaining water and making these surfaces fertile and cultivable. If the bottom of the sinkhole continues to deepen, when several sinkholes come together, we speak of an ouvala.



The ouvalas

The ouvalas are depressions with a sinuous outline, resulting from the coalescence of several sinkholes, many ouvalas are present in the Grands Causses.

Lap up

There are more or less parallel dissolution channels, traced on limestone soils by the action of water (ronuff) or by alternations of freezing and thawing.

The rock is as if jagged, The rock is as if jagged, with sharp asperities sometimes holes, crevices, grooves, the lapiates are forms of corrosion of the surface of the rocks in the open air or under the ground, on a millimetric scale or several meters.

When clays resulting from decarbonation (decalcification clays) accumulate in the hollows of the lapiaz, vegetation can settle there, otherwise, lapiaz is completely sterile.

The poljes:

The poljes are closed plains, from a few hundred meters to several tens of kilometers long and few kilometers wide at most. The bottom of the poljes, lined with loose deposits, the flat bottom of the poljes is due to clogging by decalcification residues and lake alluvium.

In fact, the clayey residues of the limestones remain on site and line the bottom of the depressions, making them fertile, this bottom being impermeable it can form a temporary lake as in many poljes in Croatia, they can even be transformed into a permanent lake. The polje is sometimes uneven with hillocks with steep sides rising like rocky islets. The water which is lost in these poljes is absorbed by chasms, the ponors, at certain times, can on the contrary reject water and more or less completely flood the plain.