KARST TOPOGRAPHY

- KARST is a "Terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well developed secondary porosity".
- Although it is a geomorphic representation, however, it emphasises on PROCESS and STRUCTURAL CONTROL.
- Although the term has been used synonymous to Lst., however, others like Dolomite, Gyspsum, Salt and Snow also show karst landforms.

Essential conditions for formation of Karst

- Soluble (Pref. Lst) near the surface.
- Dense, highly jointed and preferably thinly bedded (should not be highly porous/ permeable as rain water will be absorbed enmasse through whole body and not through fractures).
- Abundant to moderate rainfall (Not semiarid to arid)

- Groundwater dissolves rock.
- This fact is key to understanding how caverns and sinkholes form.
- Because soluble rocks, especially limestone, underlie millions of square kilometers of Earth's surface, it is here that the groundwater carries on its important role as an erosional agent.
- Limestone is nearly insoluble in pure water but is quite easily dissolved by water containing small quantities of carbonic acid, and most groundwater contains this acid.

- It forms because rainwater readily dissolves carbon dioxide from the air and from decaying plants.

$$H_2O + Co_2 = H_2Co_3$$

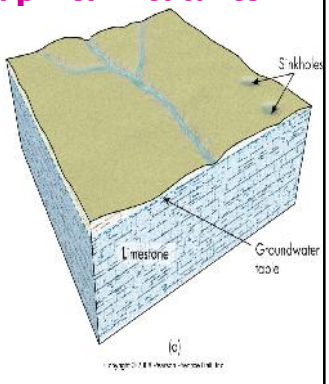
- Therefore, when groundwater comes in contact with limestone, the carbonic acid reacts with the calcite (calcium carbonate) in the rocks to form calcium bicarbonate, a soluble material that is then carried away in solution.

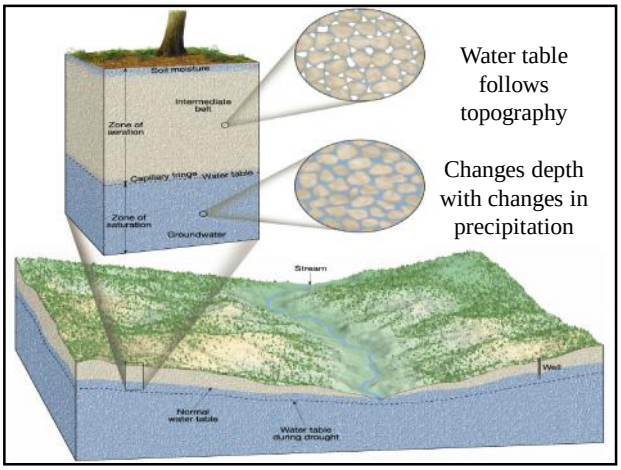
$$CaCo_3 + (H^+ + HCo_3^-) = Ca_2^+ + 2HCo_3^-$$

Calcite Carbonic acid Calcium ion Bicarbonate ion

Karst Topographical Features

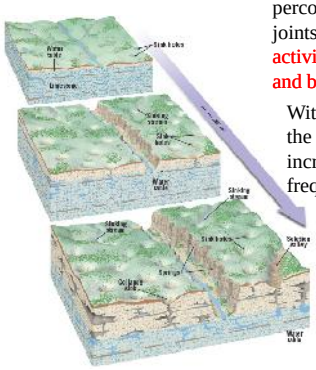
- **Rocks are dissolved by water: surface water or groundwater.**
  - **Carbonates, limestone, and dolostone are dissolved by acidic water.**
  - **Evaporites, rock salt, and gypsum are dissolved by water.**





Water table follows topography

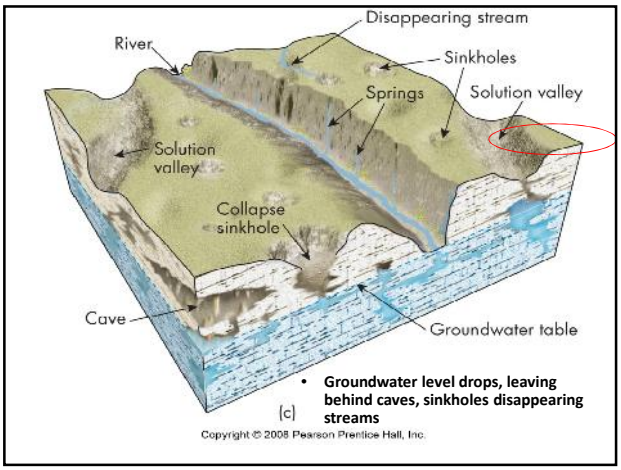
Changes depth with changes in precipitation



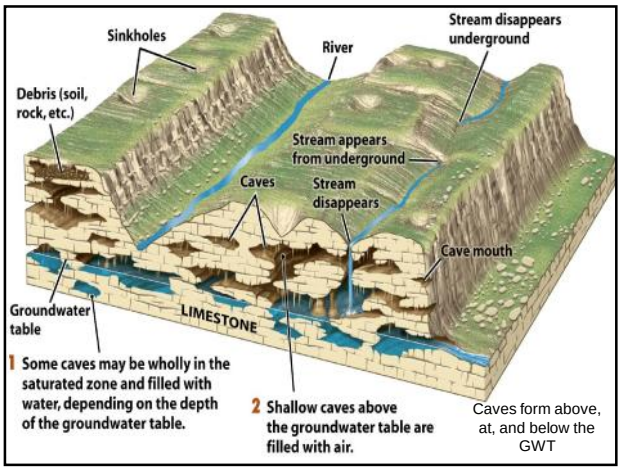
During early stages, groundwater percolates through limestone along joints and bedding planes. Solution activity creates and enlarges caverns at and below the water table.

With time, caverns grow larger and the number and size of sinkholes increase. Surface drainage is frequently funnelled below ground.

Collapse of caverns and coalescence of sinkholes form larger, flat- floored depressions. Eventually solution activity may remove most of the limestone from the area, leaving isolated remnants



- Groundwater level drops, leaving behind caves, sinkholes disappearing streams



- $H_2O + Co_2 \rightleftharpoons H_2Co_3 \rightleftharpoons H^+ + HCo_3^-$ (Carbonic Acid)
- $CaCo_3 + Co_2 + H_2O \rightleftharpoons Ca^{++} + 2\ HCo_3^-$ (Bicarbonate Ions)
- $CaCo_3 + H^+ + HCo_3^- \rightleftharpoons Ca^{++} + 2\ HCo_3^-$

If more Co_2 is added in the system– more and more calcite is dissolved (Reaction moves to the right).

If Co_2 is removed from the system, the saturated bicarbonate system tends to move to left (and combines with Ca^{++} to form precipitated $CaCo_3$.

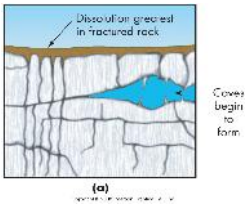
Thus in carbonate rocks, the solubility is controlled by the addition or loss of Co_2

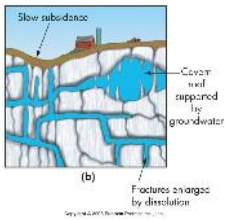
- **Karst topography**
  - Landscapes that have been shaped by the dissolving power of groundwater on limestone
  - Some common features include
    - Irregular terrain
    - Dolines: Sinkholes or sinks (formed by groundwater slowly dissolving the bedrock
      - often accompanied by collapse
    - Disappearing (sinking) streams

- Early stage – lapiés = Small limestone ridges and pool structures which have developed as a result of the solution of rock by running or standing water.
- Collapsed caverns numerous create sinkholes on the surface – doline = deep, steep-walled funnel-like sinkholes.
- In places, sinkholes, or dolines, have coalesced to make open, flat-floored valleys termed poljes.
- The limestone has largely been reduced, as has local relief. Surface streams flow and the soil may be suitable for agriculture.

Sinkholes

- Groundwater dissolves soluble rock, creating fractures and caves.
- Dissolving continues to form larger caves and fractures.



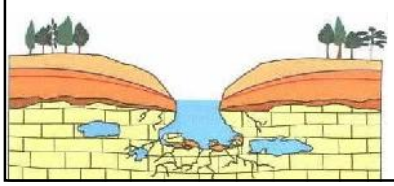


Winter Park sinkhole, USA (1981)

- 100 m across
- One day
- Due to water table lowering
- Now an urban lake.

Cenotes

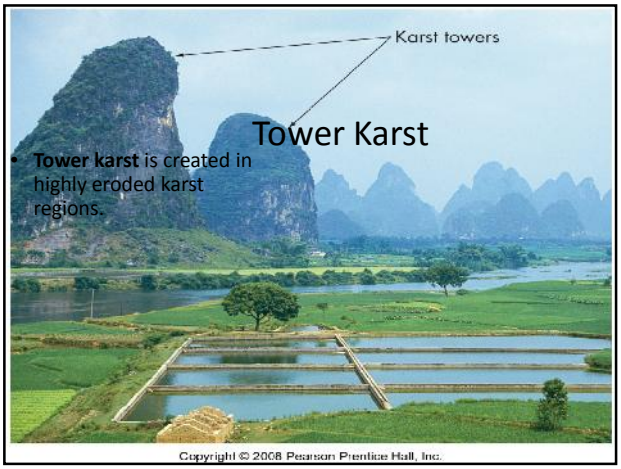
- Flooded and dissolved during interglacial time
- Broke during glaciations

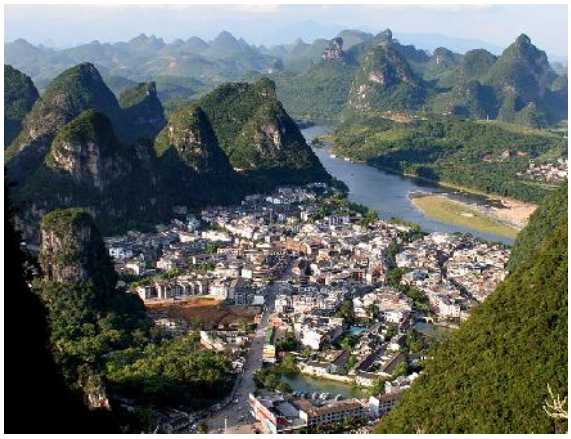


As the sea level dropped during active glaciation, the water table also dropped, leading to the drainage of caverns that were previously filled with water. This caused the ceilings of the caves to collapse

Karst Landscapes --Cockpit karst

- Cockpit Karst is a form of karst in which the residual hills are chiefly hemispheroidal and surround closed, lobed, depressions known as dolines or "cockpits" each of which is drained to the aquifer by one or more sinkholes.





Karren : These are the micro-solutional features that form on exposed Limestone surfaces favoured by pure, homogenous Limestone with low permeability and well developed widely spaced joints

Disappearing Streams

Polje

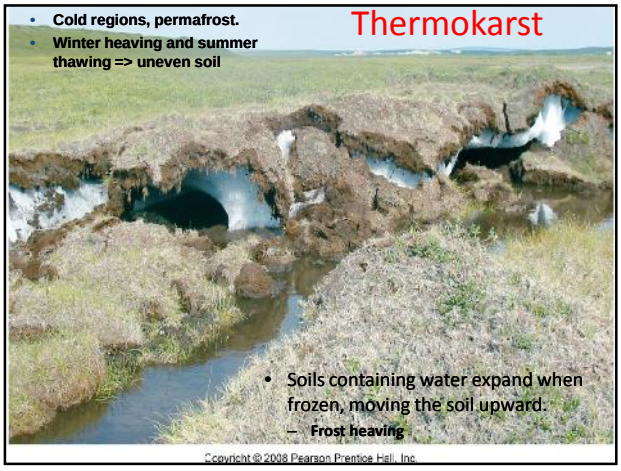
- A polje is a large flat plain in karst territory, often structurally controlled

Clint and Grike

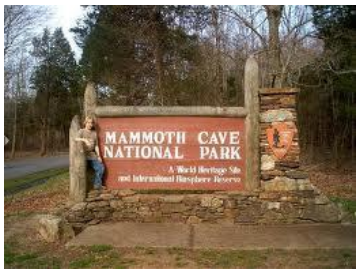
Corrosive drainage along joints and cracks in the limestone can produce slabs called "clints" isolated by deep fissures called "grikes".

Thermokarst

- **Cold regions, permafrost.**
- **Winter heaving and summer thawing => uneven soil**



- Soils containing water expand when frozen, moving the soil upward:
  - **Frost heaving**



Mammoth Cave National Park is a U.S. National Park in central Kentucky, USA encompassing portions of Mammoth Cave, the longest cave system known in the world.

Precipitation and Formation of Speleothems

When water table drops below the level of a cave, it becomes an open space filled with air. Acidic calcite containing water then emerges from the rock above the cave and drips/ trickles from the ceiling down the walls.

As it renters the air it evaporates and releases some of the dissolved Co_2 as a result $CaCo_3$ precipitates out of the water forming drip stones.

- Speleothems take various forms, depending on whether the water
- Drips
- Seeps
- Condenses
- Flows or
- Ponds.
- Many speleothems are named for their resemblance to man-made or natural objects.
- Types of speleothems include

- **Dripstone** is calcium carbonate precipitated in the form of
  - **Stalactites**
  - **Stalagmites**

Draperies or curtains

These are thin, wavy sheets of calcite hanging downward

Chandeliers are complex clusters of ceiling decorations.

Soda straws

These are very thin but long stalactites having an elongated cylindrical shape rather than the usual more conical shape of stalactites.

A **helictite** is a speleothem that changes its axis from the vertical at one or more stages during its growth. They have a curving or angular form that looks as if they were grown in zero gravity.

- They are most likely the result of capillary forces acting on tiny water droplets, a force often strong enough at this scale to defy gravity.
- They typically have radial symmetry. They can be easily crushed or broken by the slightest touch.
- Helictites are, perhaps, the most delicate of cave formations. They are usually made of needle-form calcite and aragonite.

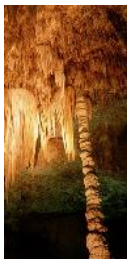
- Forms of helictites have been described in several types: ribbon helictites, saws, rods, butterflies, "hands", curly-fries, and "clumps of worms

Stalagmites are the "ground-up" counterparts of stalactites, often blunt mounds.

Broomstick stalagmites are very tall and spindly

Totem pole stalagmites

These are also tall and shaped like their namesakes



Fried egg stalagmites

These are small, typically wider than they are tall

Columns result when stalactites and stalagmites meet or when stalactites reach the floor of the cave.

Use of Spelothems: As climate proxies

Samples can be taken from speleothems to be used like ice cores as a proxy record of past climate changes.

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

Connection between isotopes and temperature/ weather

- The $^{18}O/^{16}O$ ratio provides a record of ancient water temperature.
- ^{18}O is two neutrons heavier than ^{16}O and causes the water molecule in which it occurs to be heavier by that amount. The addition of more energy is required to vaporize $H_2{}^{18}O$ than $H_2{}^{16}O$, and $H_2{}^{18}O$ liberates more energy when it condenses. In addition, $H_2{}^{16}O$ tends to diffuse more rapidly.

- The ratio of ^{18}O to ^{16}O in ice, atmosphere, precipitation and deep sea is temperature dependent, and can be used as a proxy measure for reconstructing climate change.
- During colder periods of the Earth's history (glacials) such as during the ice ages, ^{16}O is preferentially evaporated from the colder oceans, leaving the slightly heavier and more sluggish ^{18}O behind.

- When ocean water is warm, there is higher evaporation of ^{18}O.
- When ocean water is cold evaporation of ^{18}O is less. Thus water vapours (and rainfall) will have higher $^{18}O/ ^{16}O$ ratio during warmer phase and low $^{18}O/ ^{16}O$ ratio during colder times.
- Spelothems, therefore incorporate the temperature-dependent ^{18}O to ^{16}O ratio and preserve a record of global climate change through much of the Quaternary.

- Similarly, ice cores on land are enriched in the heavier ^{18}O relative to ^{16}O during warmer climatic phases (interglacials) as more energy is available for the evaporation of the heavier ^{18}O isotope. The oxygen isotope record preserved in the ice cores is therefore a `mirror` of the record contained in ocean sediments.