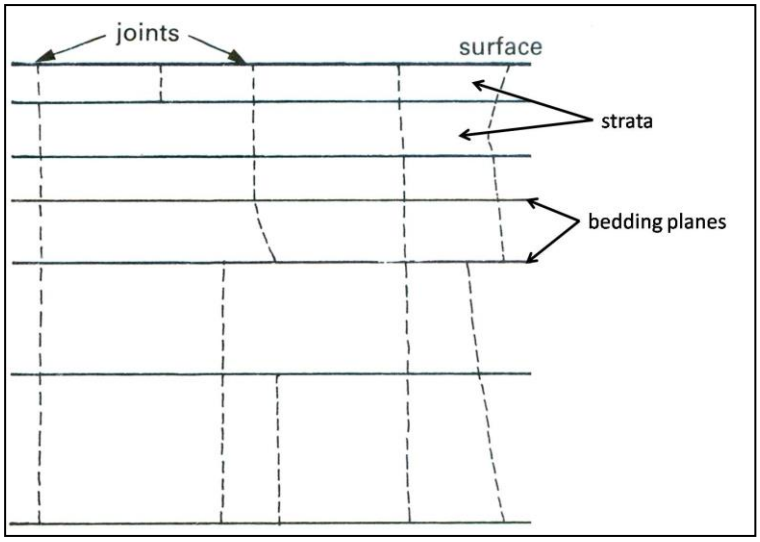
Higher 2 (9173)	Theme 1: Tropical Environments - Physical Processes in the Tropics	TMJC
C2 Lecture 7	*Karst Landscapes in Humid Tropics*	2025

I INTRODUCTION - LIMESTONE

1. Characteristics of limestone:

Characteristics	Limestone
Rock Type	Non-Clastic Sedimentary Rock
Chemical Composition	> 80% Calcium Carbonate
Texture	Coarse-grained crystalline rock
Structure	Rectangular jointing: Thick beds separated by almost horizontal bedding planes with vertical joints
Primary Permeability (Porosity)	No (Non-porous)
Secondary Permeability (Perviousness)	Yes (Pervious due to rectangular jointing)
Susceptibility to Chemical Weathering	Carbonation-Solution (Dissolution)



Limestone Structure

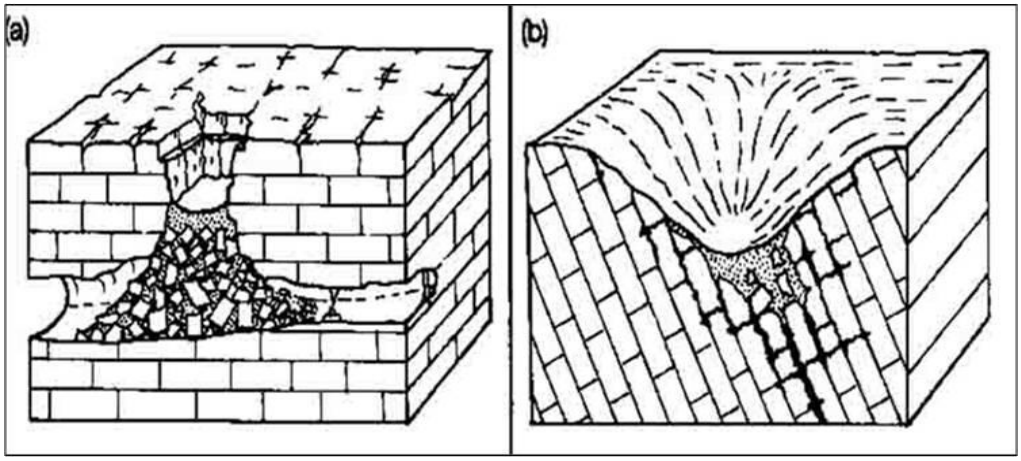
2. Limestone is a rock mainly made up of the mineral calcium carbonate. It is not porous (water cannot pass through the rock via pore spaces) but is pervious (water can pass along the bedding planes and down its joints). This allows water to penetrate the rock readily and allow chemical weathering to occur along the joints and bedding planes.

3. Limestone is susceptible to chemical weathering (processes of dissolution). This process occurs when limestone comes into contact with slightly **acidified rainwater** (containing dissolved carbon dioxide). The solid calcium carbonate reacts readily with the carbonic acid to form calcium bicarbonate, which is readily soluble in water. This reaction causes the limestone to "dissolve" and will widen existing cracks and joints in the rock.

4. The processes of dissolution and re-precipitation of calcium carbonate are critical in the formation of karst (distinct limestone) landscapes.

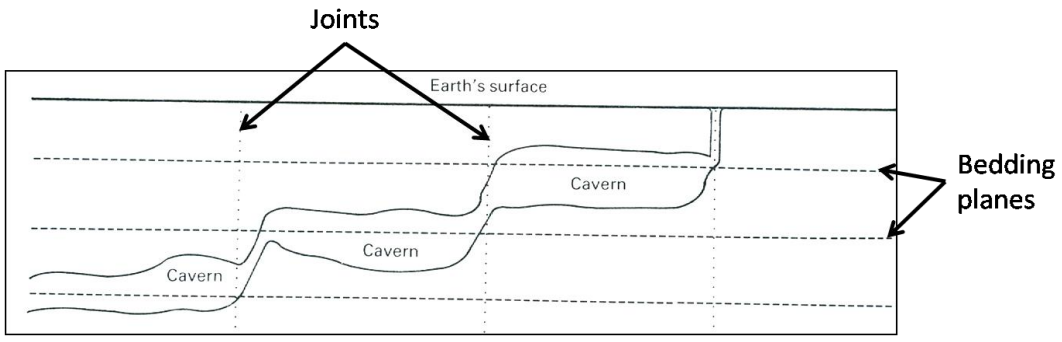
II LIMESTONE FEATURES FOUND IN TROPICAL AREAS

1. A **doline** (also known as a sinkhole) is a closed depression which may range in shape from bowl-shaped to cylindrical and in size up to 100m deep and 1km across. There are various types of doline.
    a. A *collapse doline* is formed when the roof of a cave falls to leave a steep-walled cavity.
    b. A *solution doline* is formed when there is concentrated carbonation-solution weathering occurring at the intersection of major joints in the limestone. This would result in the rock surface being lowered. The initial development of the depression leads to the capture of more surface drainage and this in turn promotes further doline enlargement.



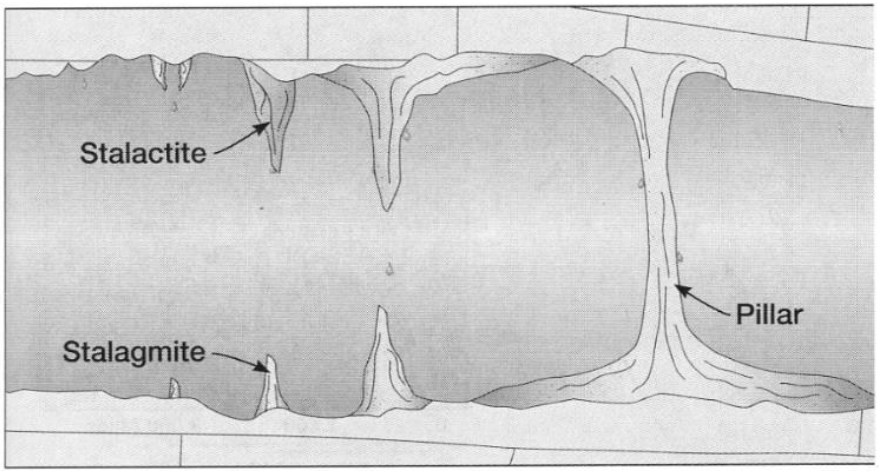
(a) Collapse doline (b) Solution Doline

2. Underground **caves** (caverns) may form where there is sufficient volume of water underground to form streams (consisting of mildly acidic water) that erode and dissolve **the surrounding limestone as they flow along joints and bedding planes** (Note: remember limestone is non-porous). This is assisted by heavy rainfall which quickly infiltrates downwards causing caves and linking passages to be filled with water. Rivers that are formed continuously make their way downwards to a lower level through joints and abandon the caves until they reach an underlying impermeable rock.



Cave System

3. **Speleothems:** When water which has percolated through the soil and limestone emerges into a cave, its dissolved carbon dioxide concentration will usually be much higher than that of the cave air. This will cause carbon dioxide to diffuse out into the cave atmosphere, supersaturating the water with calcium bicarbonate. Calcium carbonate crystals will then be precipitated.
    c. If the precipitation takes place on the roof of the cave, initially straw-like features will be formed which over a very long period of time may grow into icicle-shaped **stalactites**. These may grow about 7.5mm per year.
    d. When water drips onto the floor and precipitation occurs there, deposits of calcium carbonate form more rounded cone-shaped **stalagmites**.
    e. Over time, both the stalactites and stalagmites may join to form **pillars**.



Underground Depositional Features

How do Caves and Cavern form?

- The process of forming caves in soluble rock is very slow. If you link the process to carbonation-solution as discussed, we know that the process would begin with rain. As rain falls through the atmosphere, it absorbs a small amount of carbon dioxide. It gathers additional carbon dioxide as it moves through the soil. Water mixed with carbon dioxide forms weak carbonic acid solution. As this solution of water and carbon dioxide seeps through the cracks and crevices, it dissolves the soluble carbonate minerals in the rock and forms cavities and channels as it moves downwards vertically and laterally. After many years of carbonation-solution, underground caverns and chambers are formed due to the enlargement and collapse of the joints and bedding planes
    - **Quiet water solution** - Sometimes water moves very slowly underground, rather than rushing along underground streams. Many of the caves formed this way are mazes of passages with many interconnections.
    - **Vertical shafts** (also known as **domes and pits** or **dome-pits** in the US) can be formed by vertical carbonation-solution. Water flowing vertically down cracks can develop passages almost like elevator shafts, except that the passages are circular or oval.
- In many caves, **underground streams** have been very important, and we know that these underground streams are due to surface water entering the cave system through the above mentioned **swallow holes** resulting in **disappearing streams**, as well as **sinkholes/dolines**. These streams then travel underground and may exit at a spring (See large picture)

How do Speleotherms form?

- Speleothems are cave features created in underground chambers/caves and caverns. They are a result of slow-moving water containing **calcium carbonate,** which has been dissolved from the limestone where the cave was formed.

- As mentioned earlier, when this solution of calcium carbonate (calcium bicarbonate) enters the cave, due to differences in atmospheric conditions (e.g. changes in pressure, temperature, humidity), a chemical change can occur, leading to the precipitation of calcium carbonate from solution and the creation of **speleothems**. This happens due to the **reversibility** of the carbonation reaction.

- **Stalactites** are icicle-shaped accumulations of dripstone hanging from a cave roof. They are formed from the dripping water and eventual precipitation and deposition of calcium carbonate. **Stalagmites** are posts of dripstone extending upwards from a cave floor which develops when water containing calcium carbonate drips onto the cave floor, and builds up as calcium carbonate precipitates. Over time, **pillar/columns** may develop when stalactites and stalagmites join.

IV LIMESTONE LANDFORMS (Surface)

1. There are two unique types of limestone features which can only be found in tropical limestone landscapes: cockpit karst and tower karst.

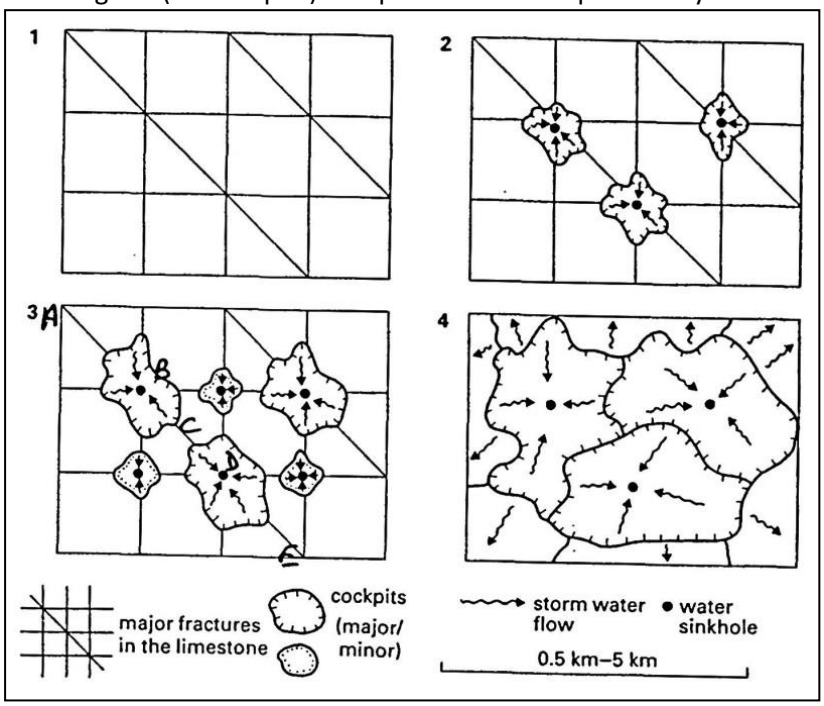
2. These two features are able to form in tropical areas due to the climatic conditions that are present: a) high torrential rainfall and b) high temperature. Both of these conditions allow a greater rate of chemical weathering as well as enabling water to flow on the surface of limestone rocks.

3. **Cone and cockpit karst** (also known as *fengcong***)** consists of clusters of hills separated by irregular star-shaped depressions. Individual hills may vary in height, with the maximum height being around 500m.

Cockpit Karst

a. While the hills are the dominant visual feature, it is the deep, irregularly-shaped closed depressions (cockpits) that are the dynamic features of the landscape.
    i. Cave formation and dolines form as a result of preferential dissolution in densely jointed limestone.
    ii. The torrential nature of the rainfall in the humid tropics allows water to flow over the surface of the ground for brief periods during storms.

iii. Surface gullies[1] are cut leading to a depression being formed and a swallow hole at the lowest point of the developing cockpit.
iv. As the gullies extend headwards they merge with other depressions that have been formed around them.
v. This forms irregular (star shaped) cockpits which are separated by residual hills.



Cockpit Karst Formation Diagram (bird eye view)

b. Vertical carbonation-solution and erosion is dominant in the formation of cockpit karst. Examples of cone karst include Chocolate Hills of Bohol Islands in the Philippines

4. **Tower karst** (also known as *fenglin***)** refers to isolated towers rising above flat plains. These towers are steep-sided and may range from just a few metres to over 150 metres in height.
a. Tower karsts are formed when water is no longer able to percolate downwards (due to either reaching the water table or an impermeable rock), resulting in lateral carbonation-solution and erosion being dominant both underground and on the surface. This will cause the walls of hills becoming steep-sided while at the same time forming flat plains.
b. Lateral carbonation-solution and erosion is dominant in the formation of cockpit karst.

Tower Karst

[1] Gullies refer to deep channels caused by erosion of water flowing on the surface of the ground

5. Bearing in mind the different dominant processes responsible for the formation of both cockpit karst (vertical carbonation-solution and erosion) and tower karst (horizontal carbonation-solution and erosion), there are 3 conditions which are necessary in order to facilitate the formation of tower karsts:

    a. **High level of water table**: Water will continue to weather the limestone as far down as the water table. Once the water table is reached, water will flow laterally rather than vertically, hence creating a flat plain. In this instance, horizontal carbonation-solution and erosion will become dominant. A higher water table would also enable surface streams to develop and laterally erode the surroundings.

    b. **Minimal rates of uplift**: In the areas where uplift has been greatest, cockpit karst has developed and where uplift has been less, tower karst has developed. This is because uplift will affect the level of water table: where the uplift is greater, the water table is lowered, making vertical carbonation-solution and erosion more dominant and increasing the likelihood of cone karst being formed instead of tower karst.

    c. **Presence of impermeable rock beneath the limestone**: The presence of impermeable rock beneath the limestone would prevent water from moving downwards but instead move sideways. As a result, horizontal carbonation-solution and erosion will become dominant, leading to the formation of tower karsts.

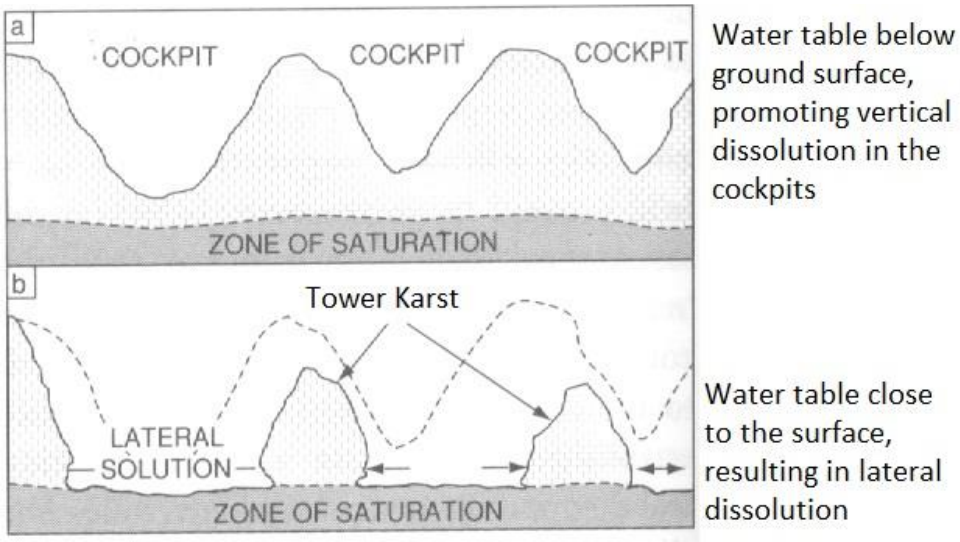


Diagram showing transition of cockpit karst into tower karst

Examples of tower karsts include those found in Ha Long Bay, Vietnam and Guilin, Guangxi, China.

What are the factors affecting Karst Landscapes formation?

1. Climate

2. Geology

3. Vegetation

4. Tectonic Uplift (which could affect height of water table)

5. Time

6. Human activities