

Resolving dissolution...

Karst landscapes

Processes, forms and paleo-
environmental significance

Dr Alissa Flatley

ACNA4007 – Physical Landscape and the Geosphere



Prifysgol Cymru

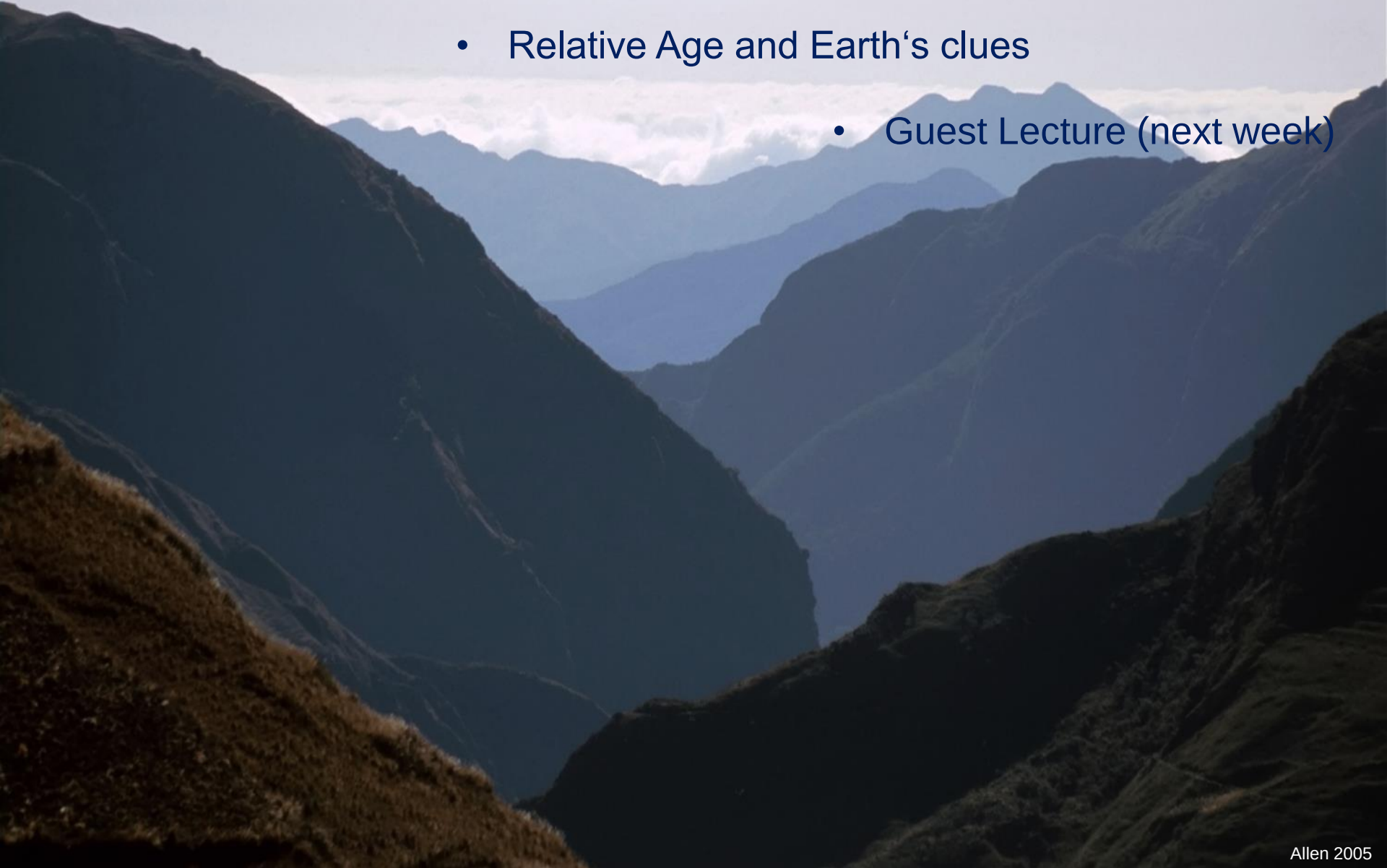
Y Drindod Dewi Sant

University of Wales

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Outline...

- Karst Landforms and Processes
 - Relative Age and Earth's clues
 - Guest Lecture (next week)



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Guest Seminar
2024

**LANDSCAPE EVOLUTION OF
SOUTHWEST WALES: REVELATIONS
OF A DYNAMIC EARTH**

Caledonian Fold Belt

Brecon Beacons

Gower Peninsula

PROF. PETER KOKELAAR

About: Professor Peter Kokeelar was George Herdman Professor of Geology at Liverpool University. Primarily a field geologist, he has undertaken many seasons of research in Pembrokeshire, Snowdonia, the Lake District and Glencoe, as well as on numerous volcanoes worldwide. Prof. Peter Kokelaar will be presenting a talk on South Wales, as well as providing background on his new book 'All Our Own Water', that describes the exceptional landscape and physical features of the Gower peninsula. You can find more information about Peter here: <https://kokelaargower.com/>

Monday 18th March, 2024 **Architecture, Construction**
10AM in IQ Room 310 **and Environment**

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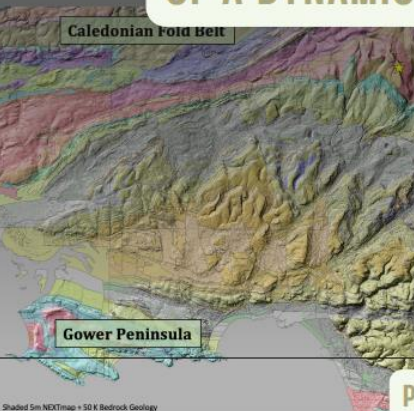
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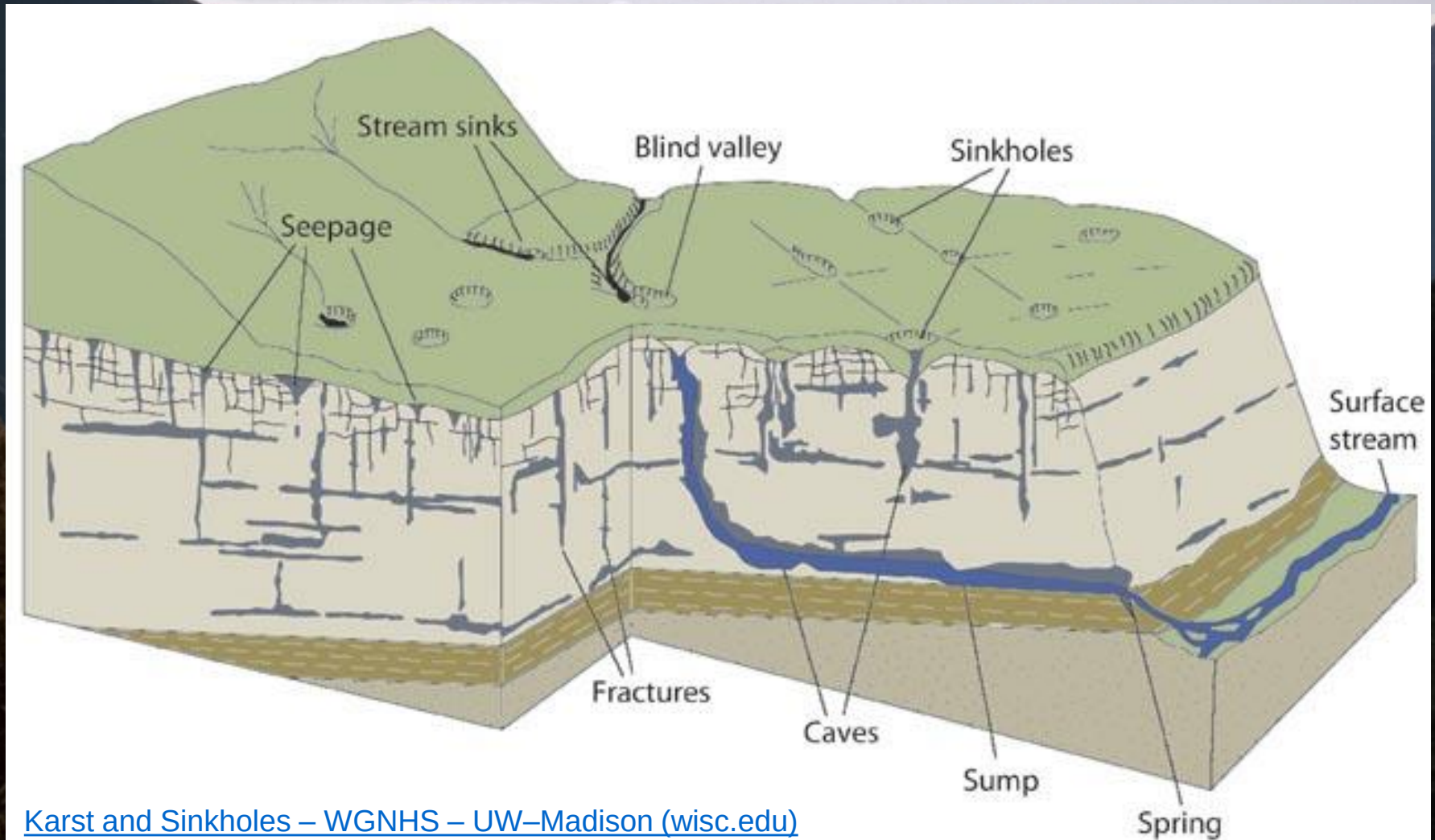
Architecture, Construction
and Environment

22	18/03/ 24	Guest Lecture: Prof. Peter Kokelaar: Landscape Evolution of Southwest Wales				
	25/03/ 24	EASTER BREAK				
	01/04/ 24					
	08/04/ 24					
23	15/04/ 24	Stratigraphy, hydrogeology and pollen Assemblages (2hrs) Cwm Ivy				
24	22/04/ 24	Absolute Dating and future geomorphology (1hr)				
Wee k	W/C Date	Topic	Lectu rer	Pre-Lecture preparation	Post Lecture work	Assessment
		Course Recap (1				

What is karst?...

What is karst?

- “Karst” is a landscape created when water dissolves rocks.



[Karst and Sinkholes – WGNHS – UW–Madison \(wisc.edu\)](http://wisc.edu)

Rock Dissolution...

- Transition of a mineral into aqueous solution (needs water), special case carbonate (needs carbonic acid)

= Dissolution

Reversible !!

Calcite + Carbonic acid → Calcium Hydrogen Carbonate

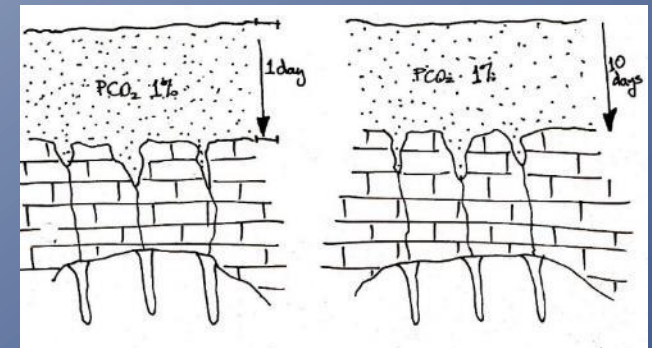
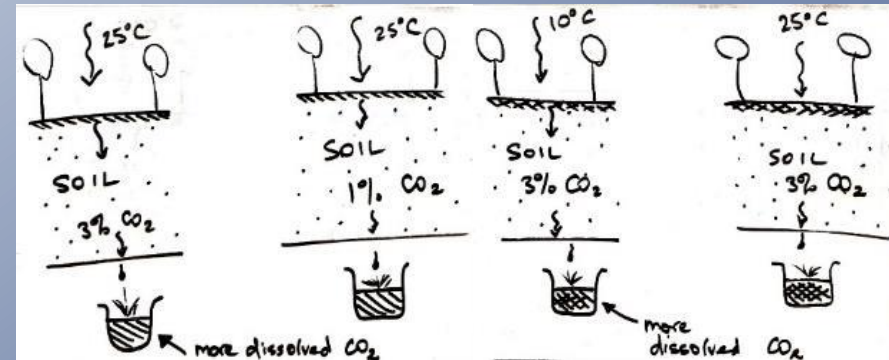


- Soil is the major CO_2 source in dissolution - transfer of CO_2 from soil air to soil water is proportional to its concentration in the soil air but is inversely proportional to temperature:

Dissolution rates depend on...

- CO_2 concentration**
- Temperature**
- Time** and equilibrium (percolation)
- Flow type
- ... and ?

- Limestone can dissolve in pure water, but it is more soluble in natural waters which contain weak acids
- CO_2 from atmosphere as catalyst



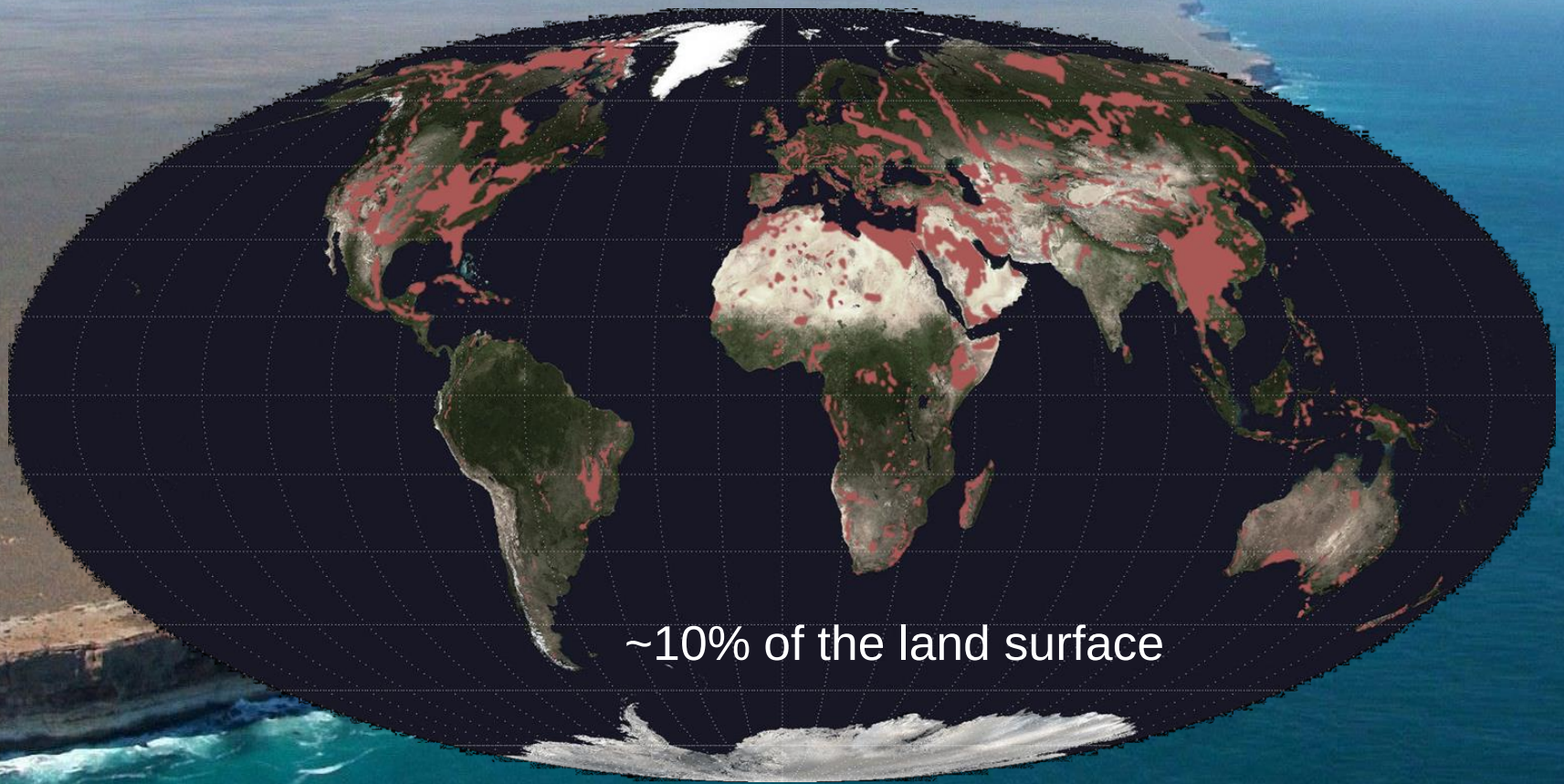
Karstification

There are three **preconditions** for karst landscape formation (karstification)

1. Soluble rock (e.g. limestone, dolomite, gypsum...)
2. Water
3. Secondary porosity (e.g. bedding planes, fractures, faults)



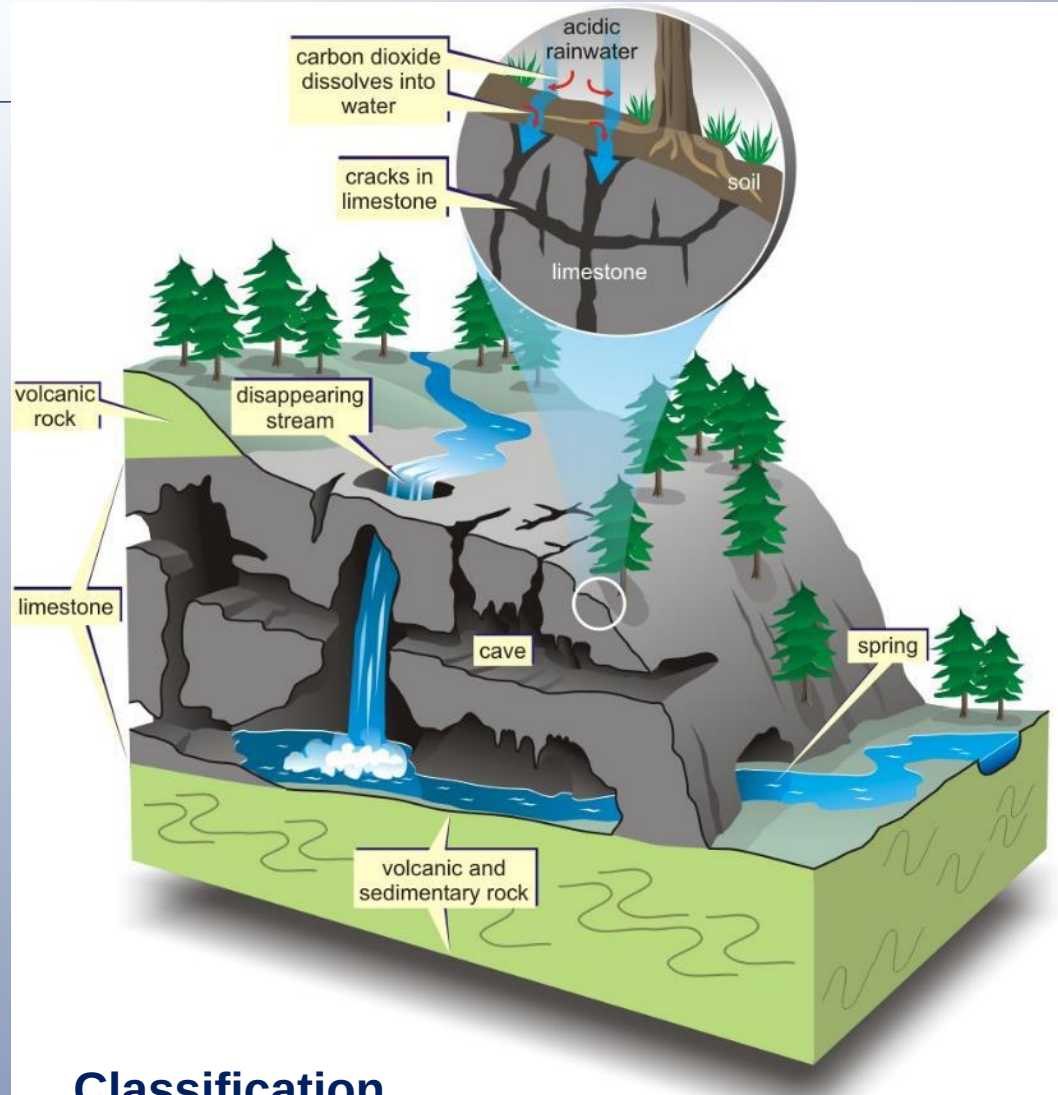
Karst Landscapes



“Karst” is the term used to describe a special style of landscape containing caves and extensive underground water systems that is **developed on especially soluble rocks** such as limestone, marble and gypsum (Ford and Williams, 2007)

Karst Landscapes

- Most of drainage underground (often leading to relatively dry environments at surface)
- Surface drainage is chaotic and 'disorganised'
- Underground drainage is highly integrated
- An elaborate subterranean geomorphology develops
- Hydrographic limits $\neq$ hydrogeological limits
- Catchment boundaries are often impossible to delineate



Classification

- Underground (endo-), surface (exokarst)
- Cover – covered and uncovered karst
- Activity – active or fossil (past) karst
- Size and Morphology...

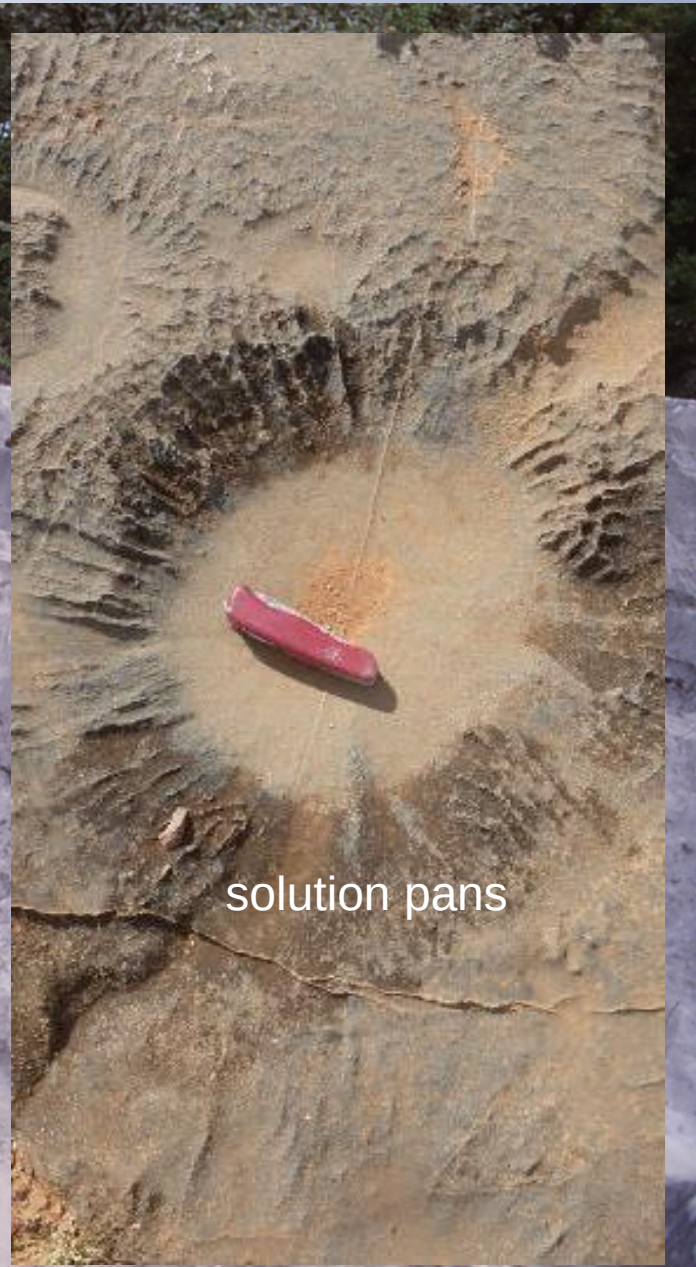
Karst Landforms 1



- Is rain water aggressive to limestone? YES
- 'Karren' - general term for the suite of surface solution features: simple and composite forms (Rillenkarren, Rinnenkarren)
- Form varies according to bedrock grain-size characteristics, rock surface slope, vegetation cover, hydrodynamics



Karst Landforms 1



Karst Landforms 1

Tsingy de Ankarana, Madagascar



Karst Landforms 1

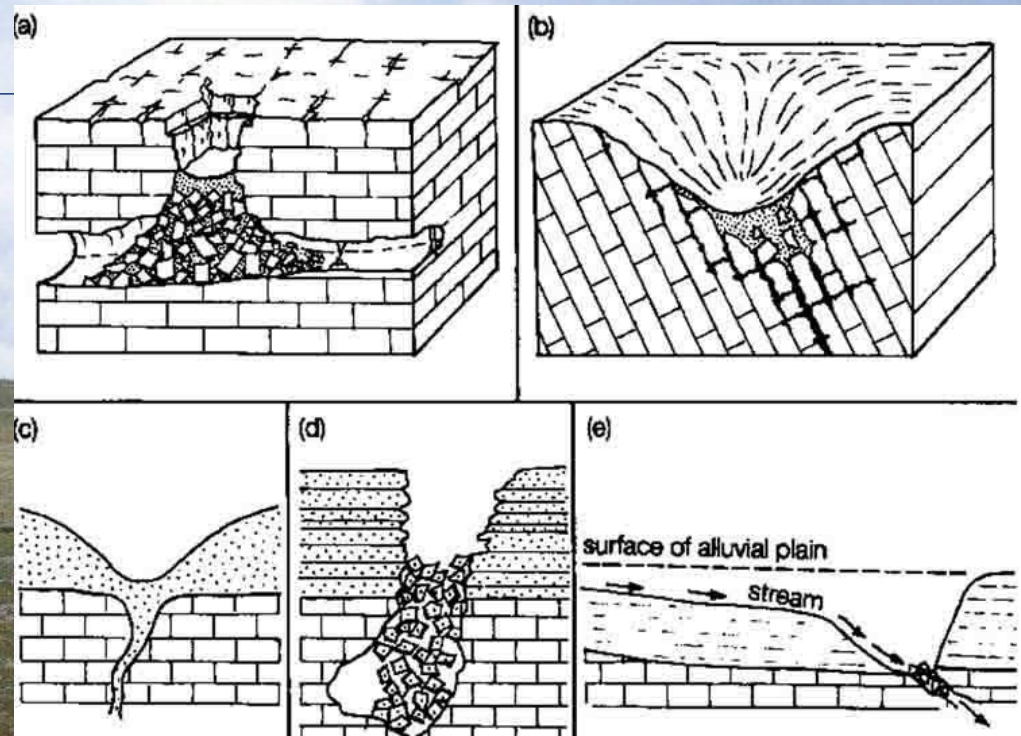
Tsingy de Bemaraha, , Madagascar



Karst Landforms 2

- Dolines ('sinkholes'), genetic types

- (a) Collapse
- (b) Solution
- (c) Suffosion
- (d) Subjacent
- (e) Streamsink



Isolated individual features or clusters

Network of collapse and streamsink dolines, Nullarbor Plain

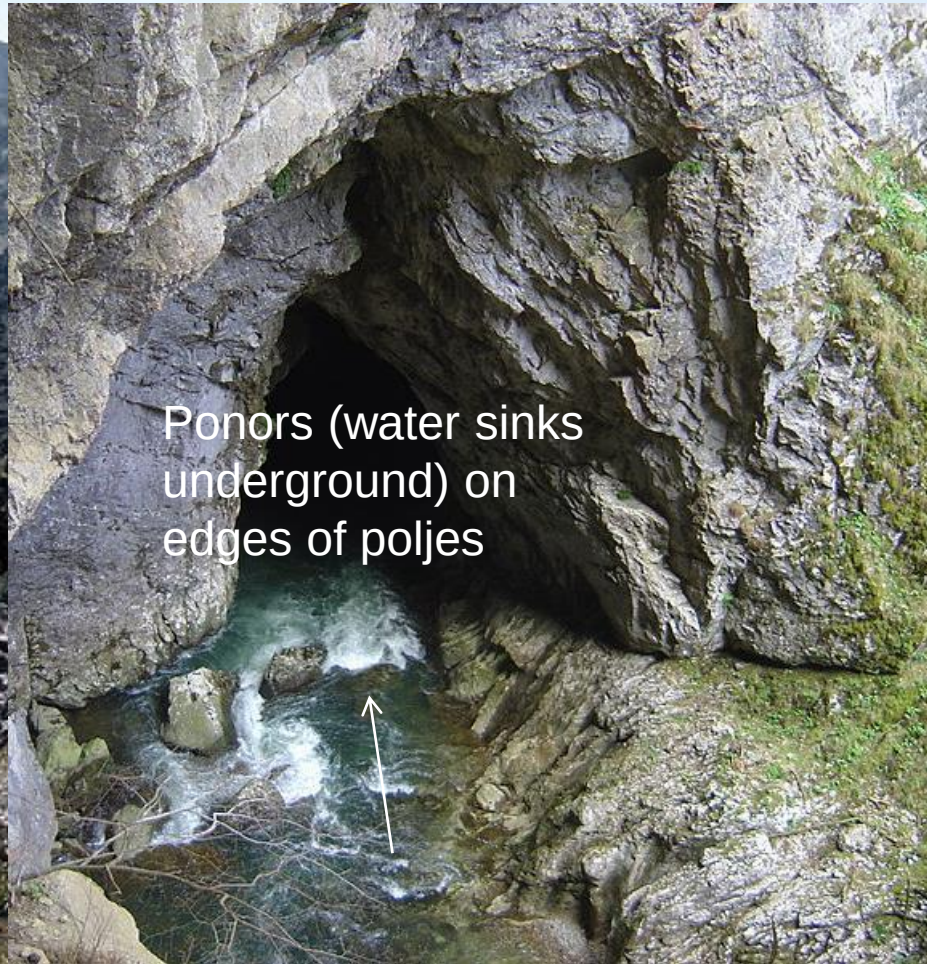
Karst Landforms 2



Bravsko plains, Bosnia

Karst Landforms 3

- Polje - Large-scale closed depressions with steep slopes, flat bottom with alluvial cover



Sierra de Libar, Andalucia

Karst Landforms 4

- Cockpit-, tower- and conical karst in tropics

Residual topography



- Karst is most rapidly developed in wet, CO₂-rich regions (tropics, middle latitudes)
- Perennial and higher soil CO₂ production in tropics (vs temperature)
- Seasonally decreased soil activity in mid-latitudes

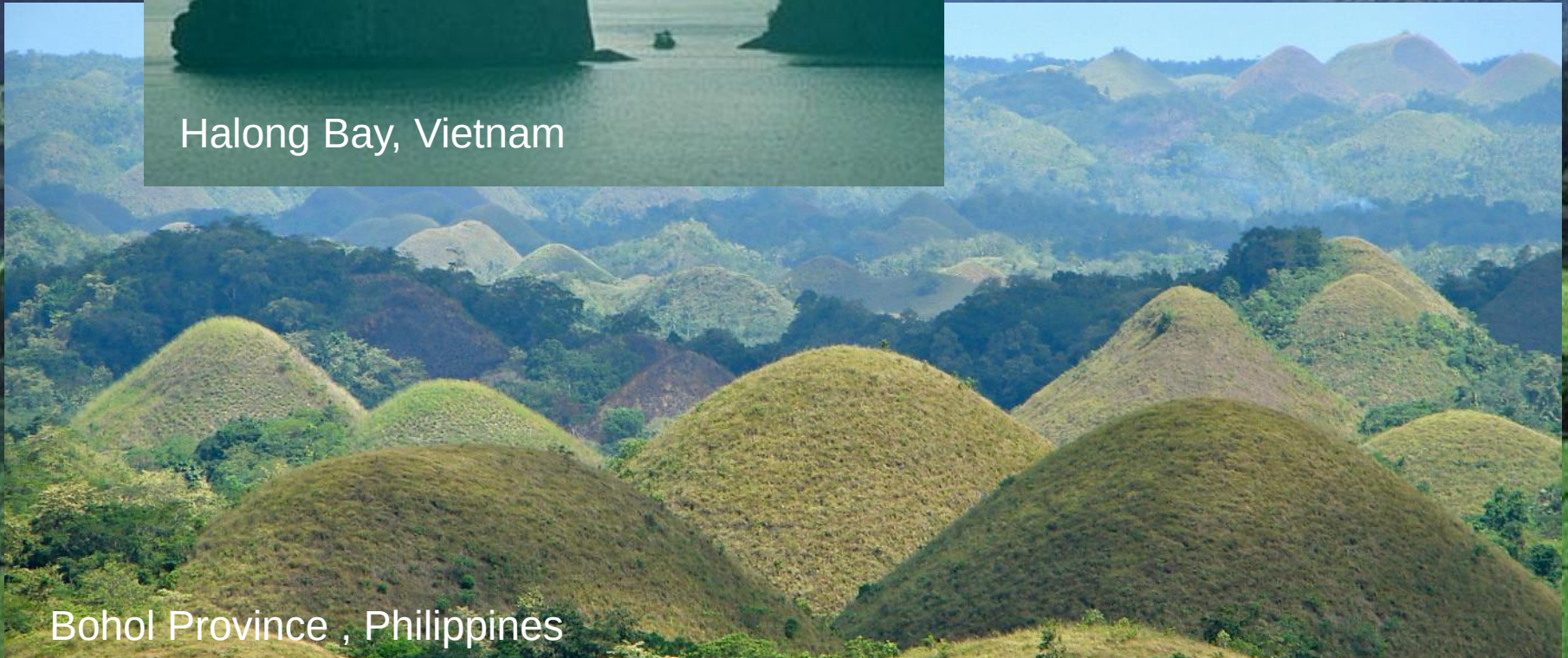
Karst Landforms 4



Halong Bay, Vietnam



Miniature karst towers,
Barkly Tableland, Qld



Bohol Province , Philippines

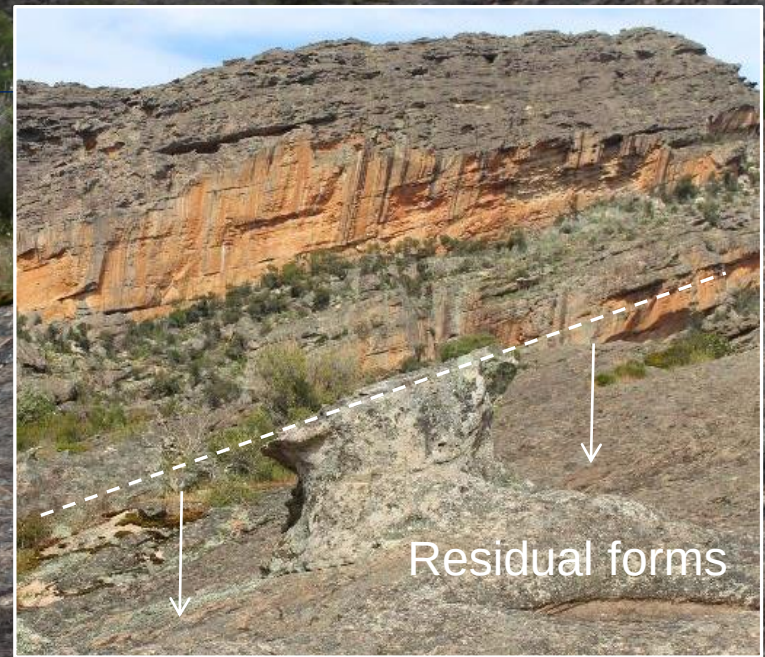
Karst Landforms 4

- **Solubility** of quartz 6-14 mg/l at earth-surface temperature (this is low...)



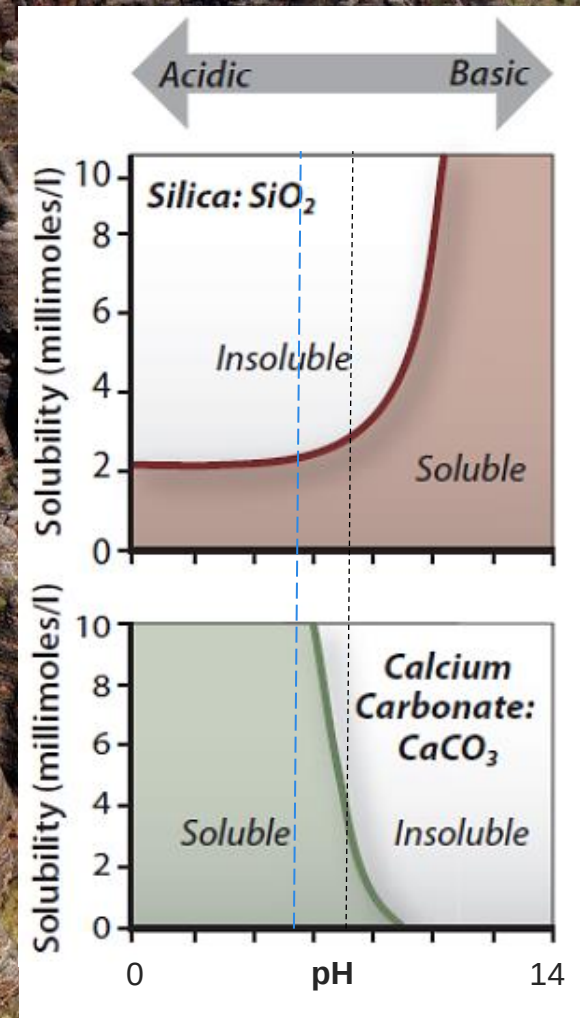
Solubility of limestone / calcium carbonate ~47 mg/l at earth-surface temperature and pH = 7... (85 mg/l at pH = 3)

Solution channels



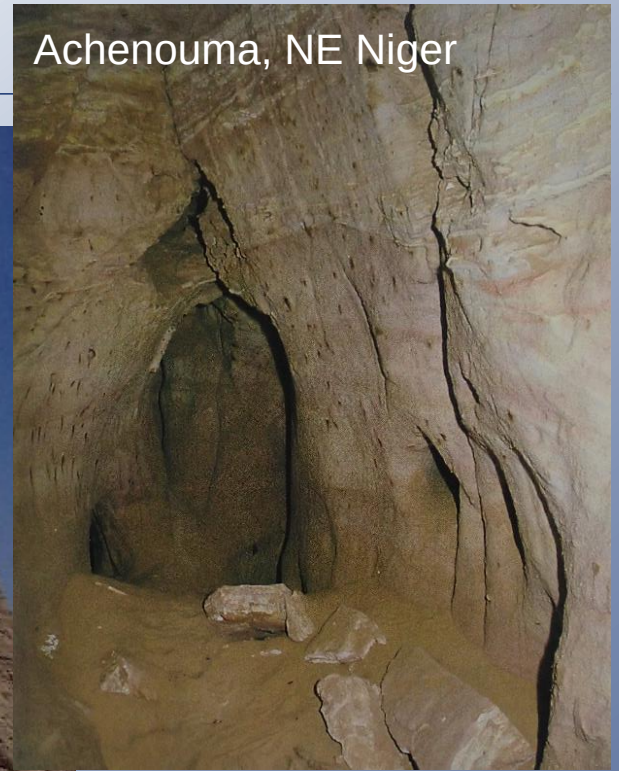
Karst Landforms 4

- Silica soluble in highly alkaline conditions (NaOH or KOH)
- Dissolution of **Silica** – Pseudokarst ?



Karst Landforms 4

Achenouma, NE Niger



Ehdi Ouarek, NE Niger



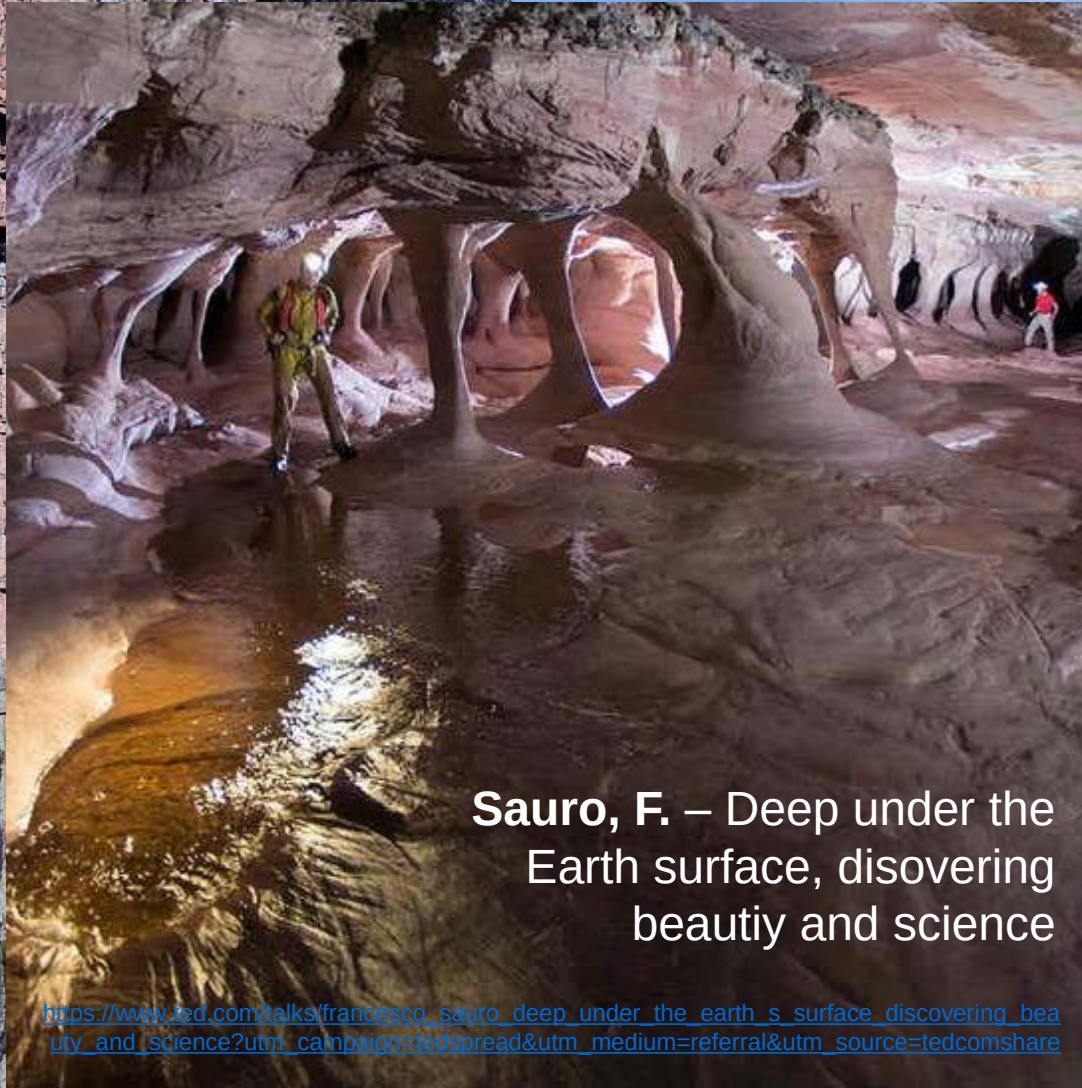
- Sandstone Karst in central Sahara...
- Palaeoform (due to different, more moist conditions in the past?)



Tin Teferist, S Algeria

Karst Landforms 4

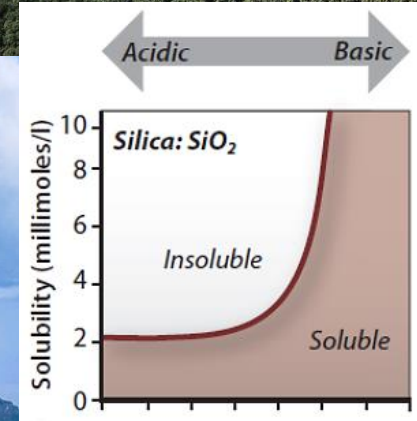
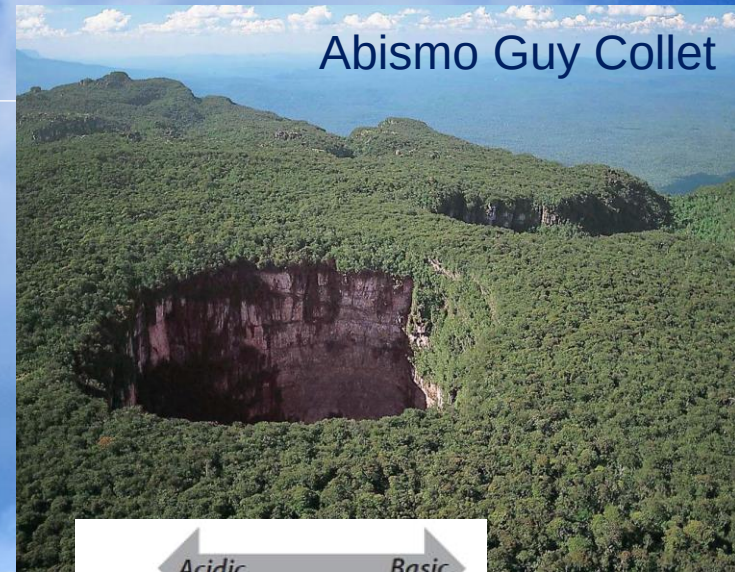
Roraima region (N Brazil)



Sauro, F. – Deep under the Earth surface, discovering beauty and science

https://www.ted.com/talks/francesco_sauro_deep_under_the_earth_s_surface_discovering_beauty_and_science?utm_campaign=tetspread&utm_medium=referral&utm_source=tedcomshare

Abismo Guy Collet

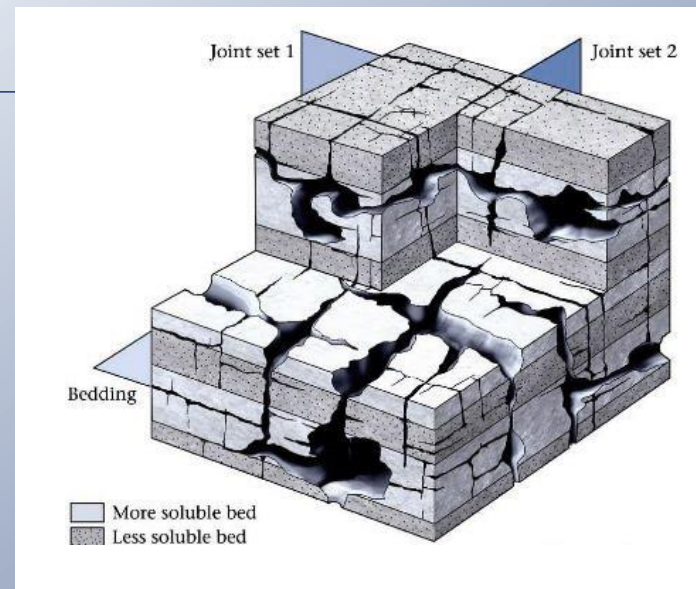


?

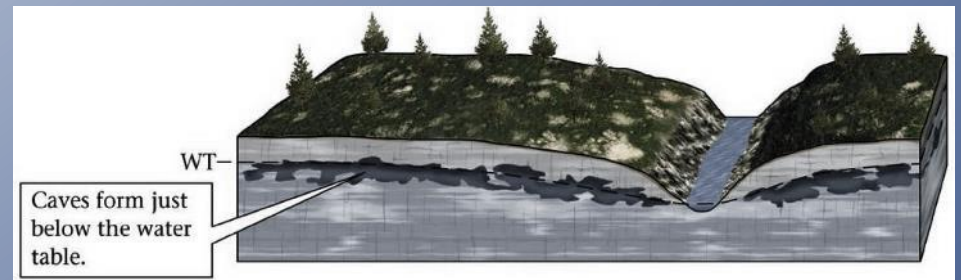
“... on the very highly karstified quartzites of Roraima, limited field measurements indicate that the chemical conditions under which the karst is forming are at odds with laboratory results, which indicate that highly alkaline conditions are necessary to achieve significant silica dissolution” (Wray 2003)

Karst and Caves

- 30,000 km traversed by explorers - tens of millions of km remain undiscovered
- Caves - conduits > 10 mm (turbulent flow) in diameter that move water between input and output points in a karst system



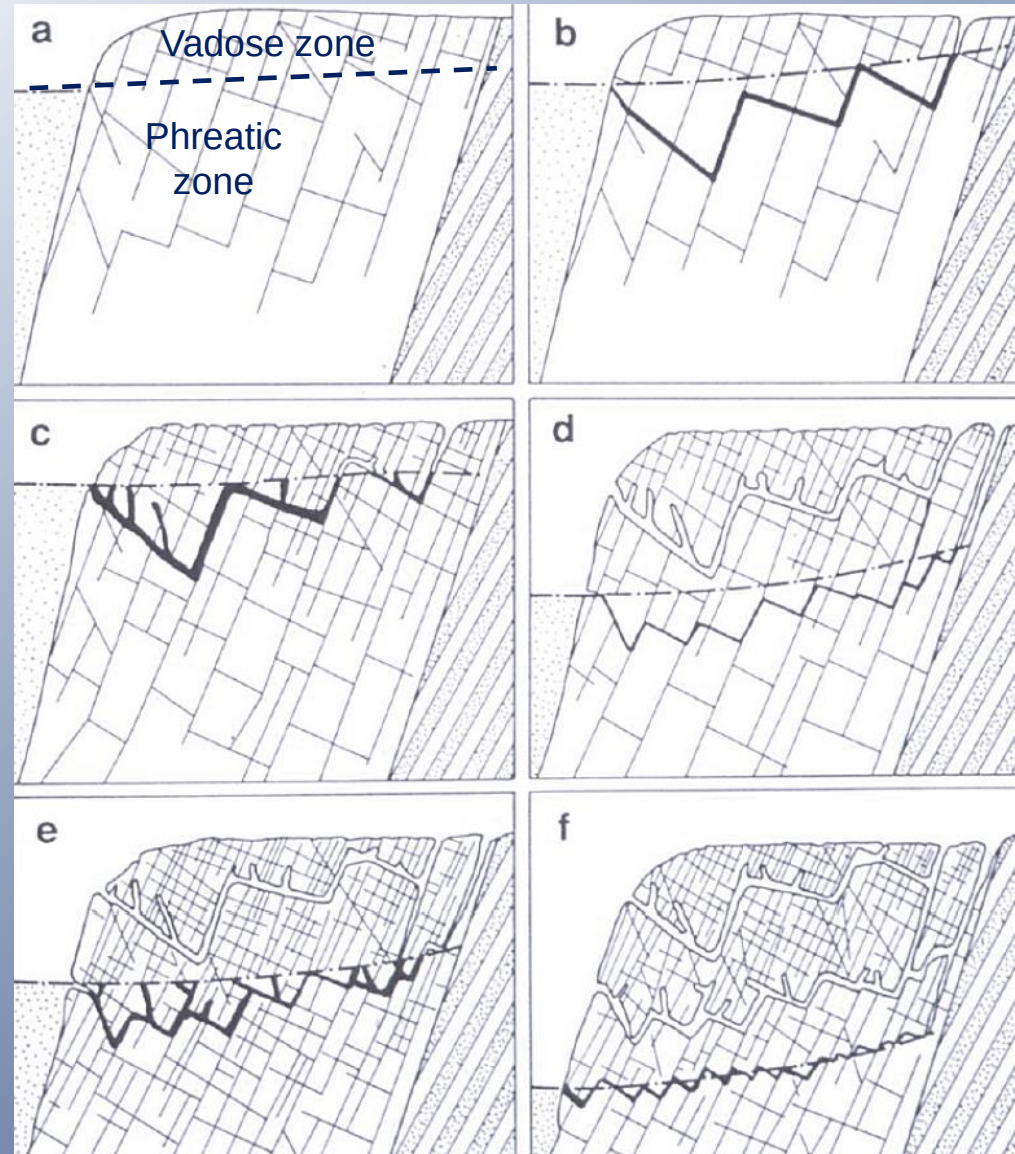
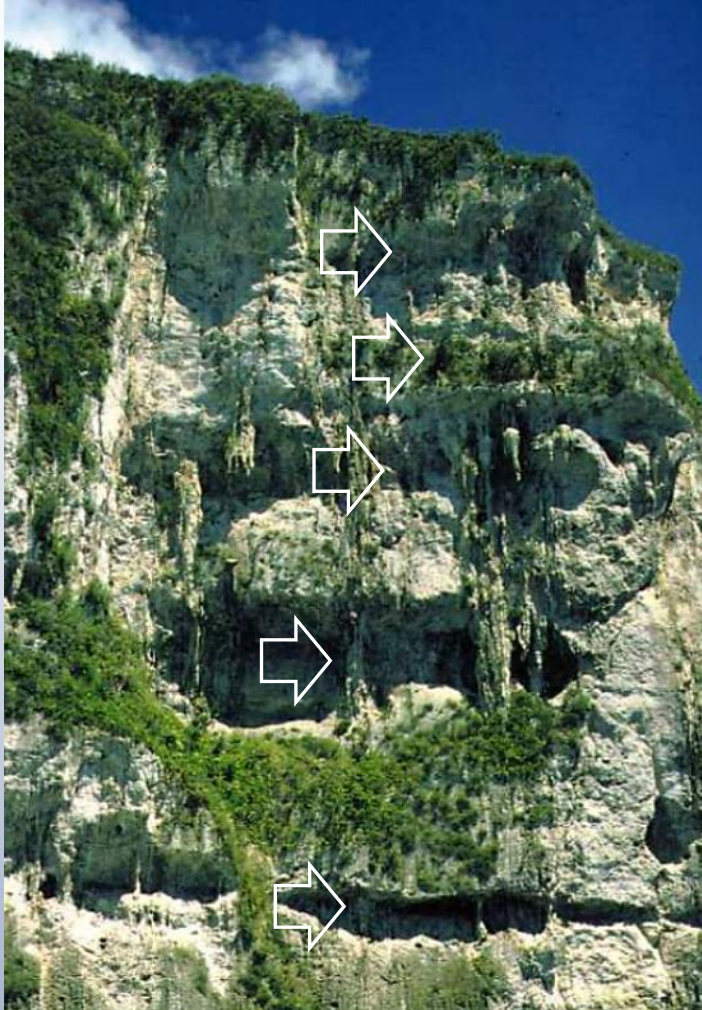
- Form along joints – geometry and **network pattern** reflects joint network; stratigraphy and bedding important



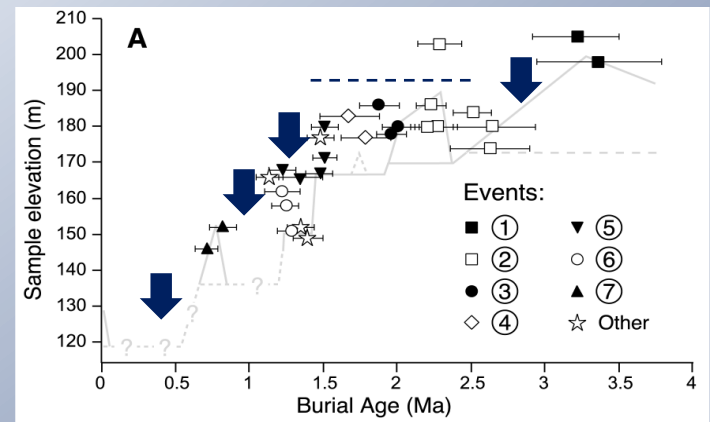
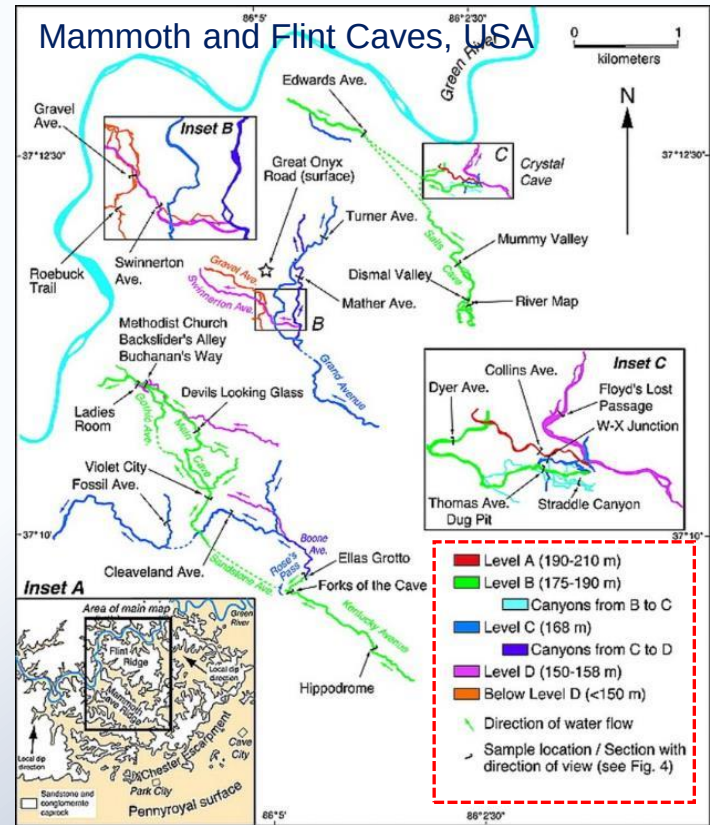
- Cave network develops near ground-water table – sequential development adjusting to uplift, incision etc.

Karst and Caves

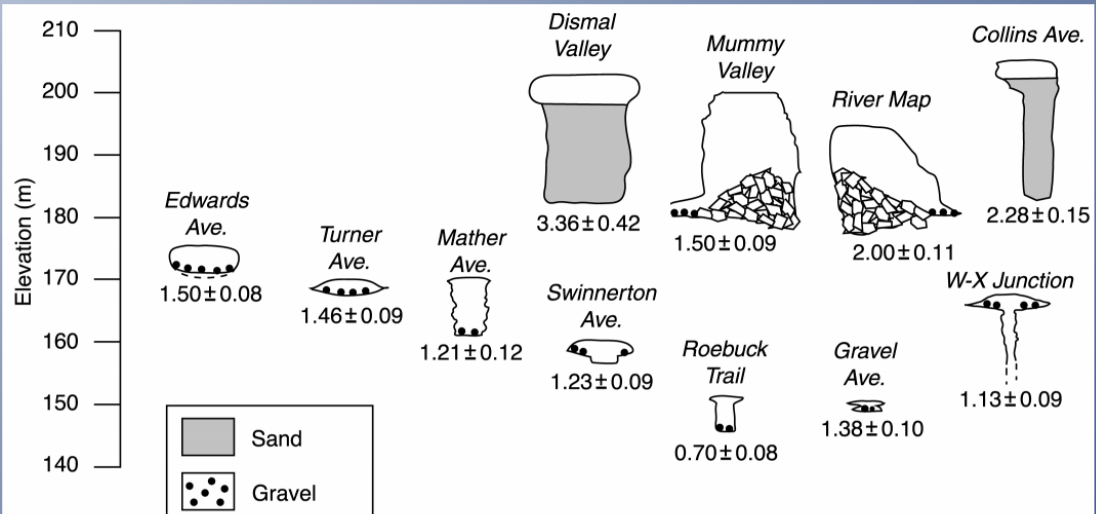
- Karst cave development stages
- Deepest cave ca. 2.5 km



Caves and Landscape

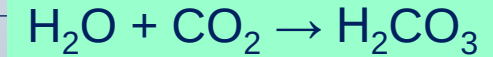


- Longest known cave in the world! (560 km passages, vertical range 200 km)
- Progressively lower levels
- Aggradation of surface rivers floods the lowest cave passages, allowing many to be filled with clastic sediment

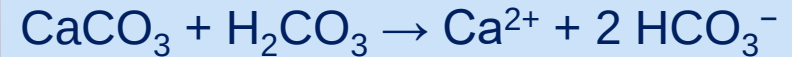


- Dating of (i) last exposure, or (ii) burial...

Cave Sediments



- Rainwater in soil zone reacts with soil CO_2 to create weakly acidic water
- This lower pH water travels through the calcium carbonate bedrock (surface to the cave ceiling), **dissolving** the bedrock...

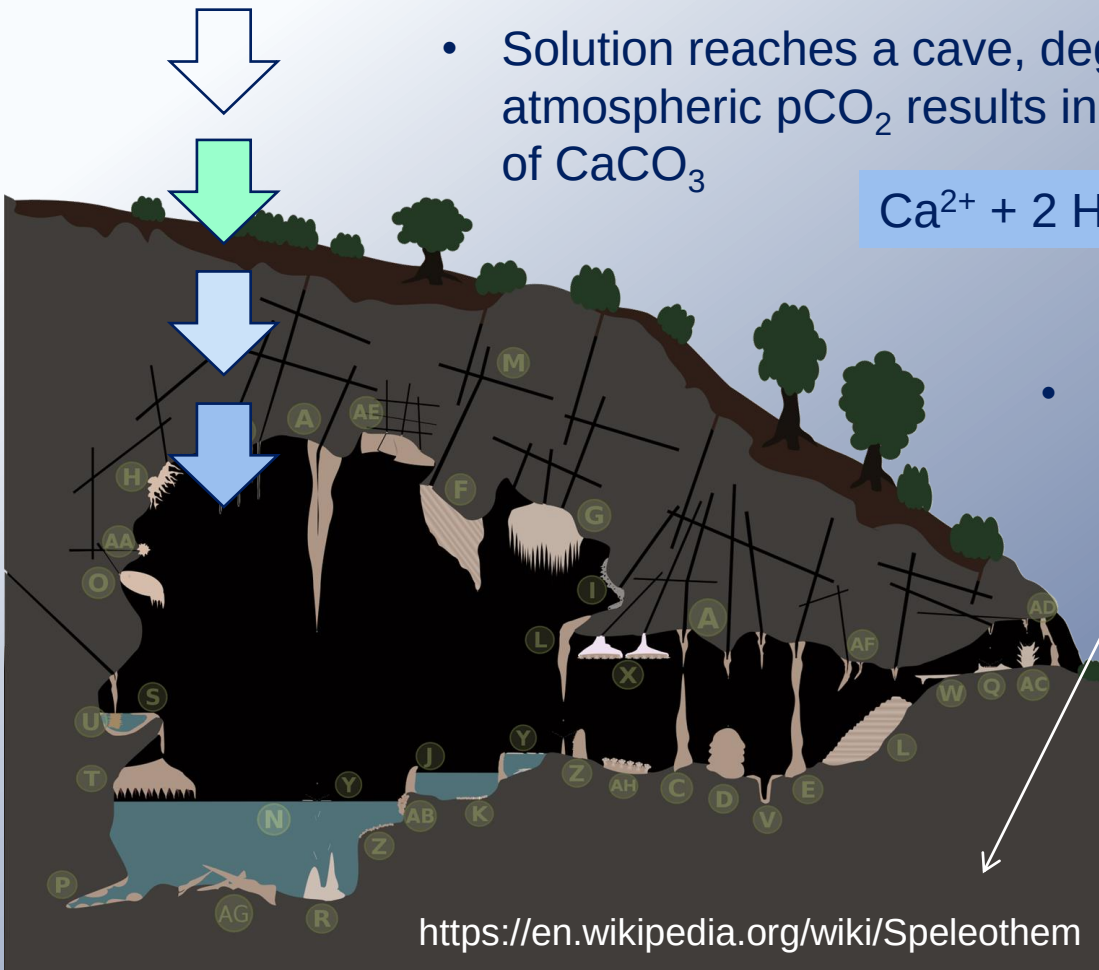


- Solution reaches a cave, degassing of CO_2 due to the lower atmospheric pCO_2 results in pH increase driving **precipitation** of CaCO_3

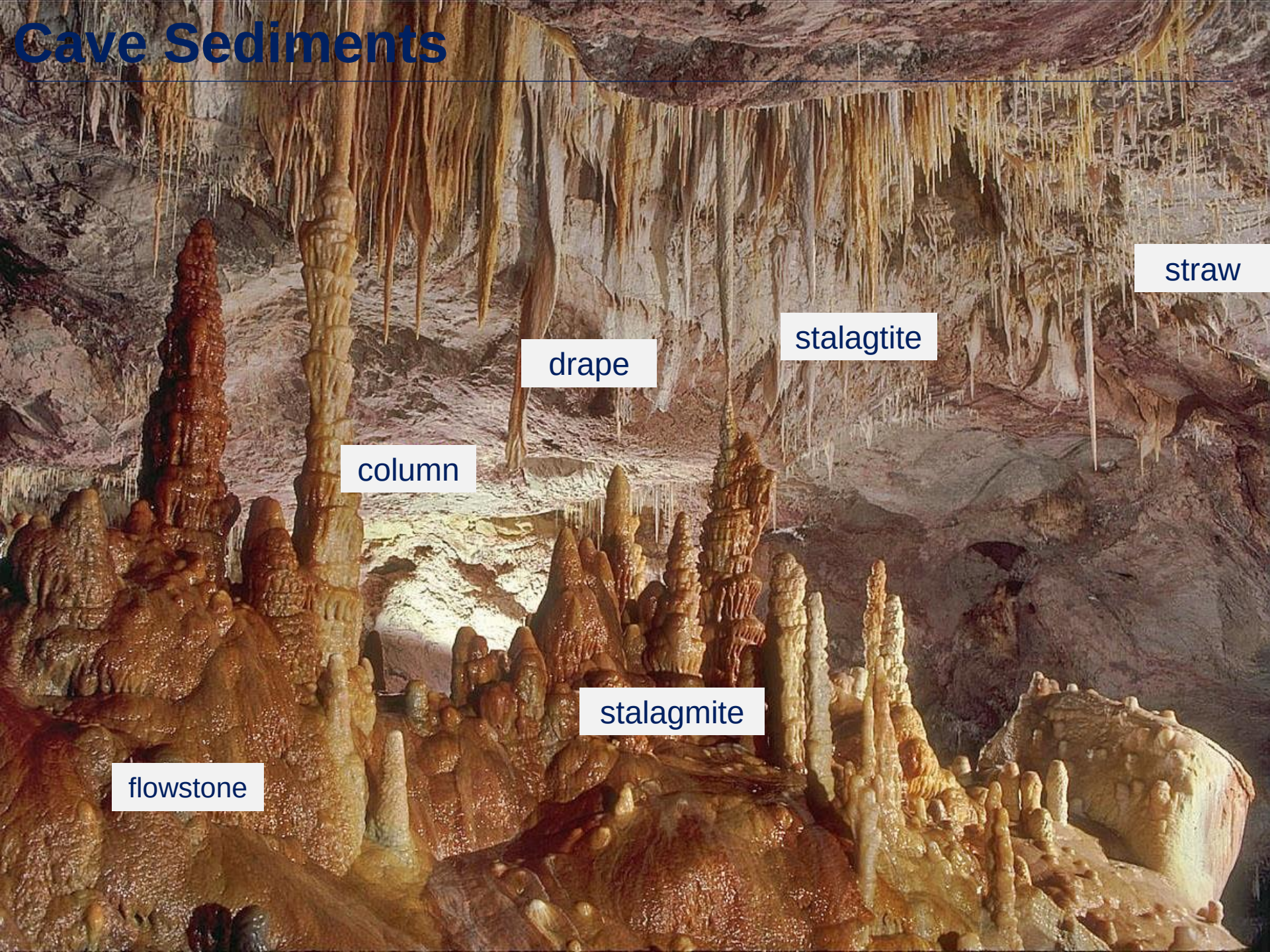


- accumulation of precipitates forms wide range of chemical deposits (speleothems)

- Speleothems store **paleoclimate** info (e.g. drip rates = moisture, O isotopes = temperature, C isotopes = vegetation, trace elements = weathering ...)



Cave Sediments



straw

stalagtite

drape

column

stalagmite

flowstone

Tufa Deposits



- Precipitation of CaCO_3 can also be facilitated by other processes and conditions (leading to different forms and deposits!)
- Tufa - formed when carbonate minerals precipitate out of ambient temperature water saturated with calcite by CO_2 degassing...
- ...reduction in pCO_2 also by (i) evaporation, (ii) photosynthesis
- Springs, fluvial channels, wetland or lake environments – large macrobiological component and high porosity



Tufa Deposits



- ... **Air-water interactions** at waterfalls or rapids may be important for precipitation (turbulence and degassing)
- High-rates of calcite formation



- River blockage (barrage tufa) and exacerbation of waterfalls (cascade tufa)

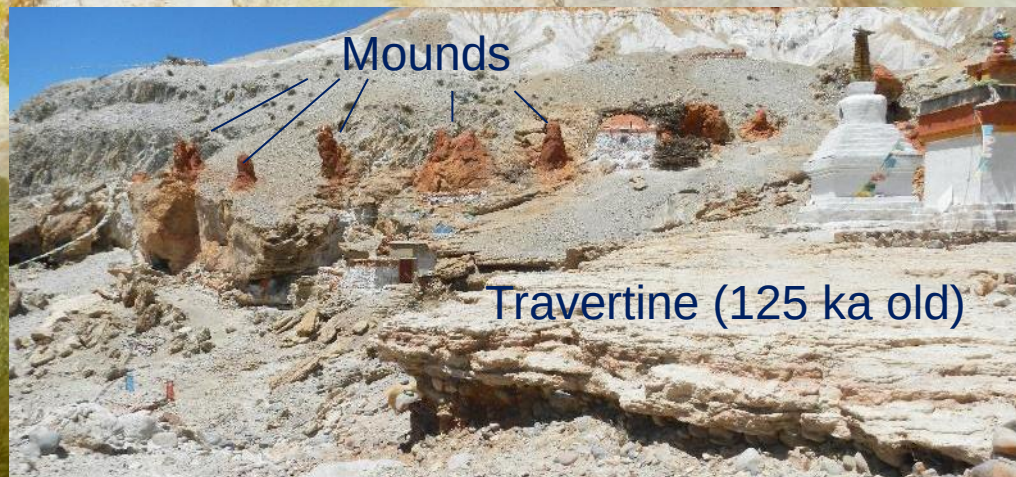
Travertine Deposits

- Travertine is deposited by mineral springs, especially hot springs
- ... formed from geothermally heated supersaturated alkaline waters, with raised $p\text{CO}_2$

Thirapuri, Tibet



Pamukkale, Turkey



Travertine (125 ka old)

Travertine Deposits

Tibet



Mound Springs, Central Australia



Karst Landscapes – Summary...

- Solution contributes to erosion / denudation of continents (to source-to-sink processes)
- Spectacular karst landscapes are the result of rock dissolution
- Most karst landscapes form in limestone, but silica karst is also important
- Caves are „unexplored underground world“ and contain valuable archives for the reconstruction of past landscapes and climates
- Calcite precipitates represent chemical sediment and build up a range of landforms

3 minutes...



Activity – Relative Age and Earth's Clues...

- <https://timescavengers.blog/introductory-material/geologic-time/principles-of-geology/>



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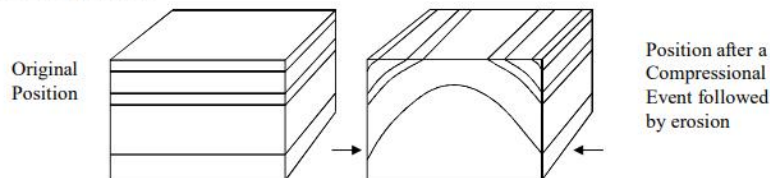
Physical Landscapes and the Geosphere (ACNA 4007)

Relative Ages of the Earth

Relative Ages

The Earth was not always thought to be so ancient. The ability to assign an absolute age of 4.6 billion years to the Earth is a recent accomplishment. Before modern dating techniques existed, geologists were only able to give relative ages to the formational events of the Earth. They could only state whether an event happened before or after another event, but could not assign an actual date to its occurrence. Geologists developed a relative time scale using clues from the Earth and their knowledge of the five basic geologic principles:

1) Principle of Original Horizontality: The materials that make up sedimentary rocks are deposited in horizontal sheets which create layers, or strata, within the Earth. If these strata are not found to be horizontal, then some geologic event has caused them to be displaced from their original horizontal position.



- Answers provided next week after guest lecture