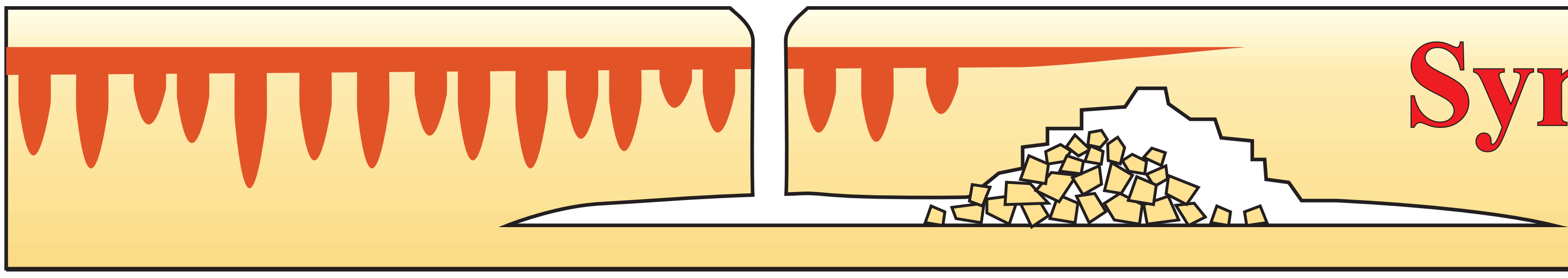


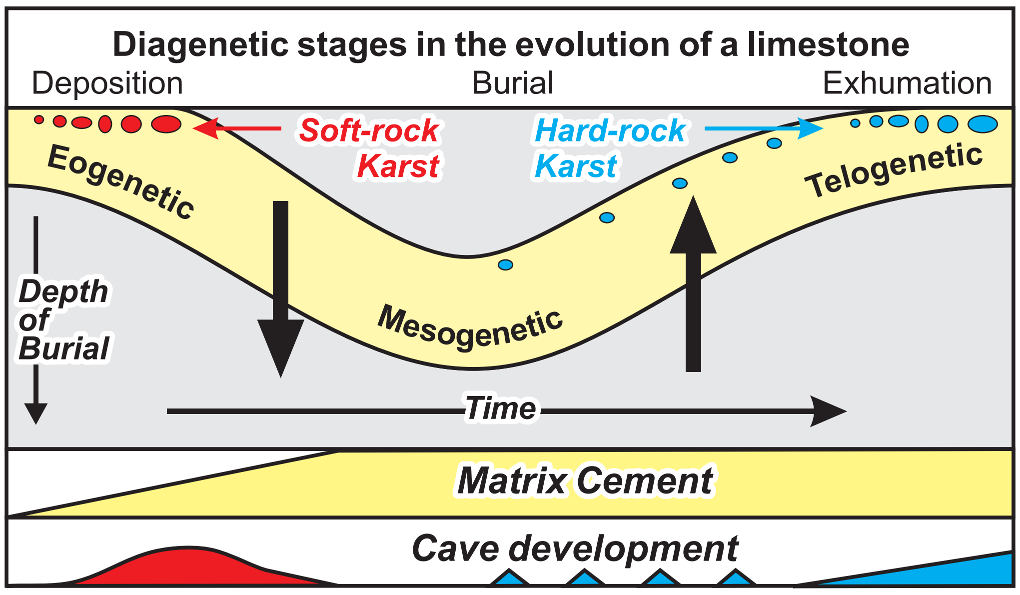
Syngenetic Karst

Terminology & General Concepts

Syngenetic Karst

In newly-formed calcareous sediments, the cementation that consolidates the sediment into a rock can occur at the same time as dissolutional development of karst cavities.

This process of simultaneous solution and induration is called **syngenetic karst.**



Terminology - Soft-Rock Karst

The field of **Soft-rock Karst** has several terms which deal with related and overlapping concepts. In all cases we are dealing with features in soft, poorly cemented sediments.

Syngenetic karst (Jennings, 1968) has been applied to recently formed karst features in sediments that were being cemented at the same time as the dissolutional cavities formed.

Early syngenesis is the stage prior to significant cementation. It involves soil development (including calcrete hard-pans), and deeper solution with small-scale brecciation and subsidence structures, but the sediment is too soft to support large cavities.

Late syngenesis begins when the sediment is sufficiently cemented for larger cavities (caves) to form. However, the limited strength means that roof collapse will be common.

Soft-rock Karst is a more general concept that includes both early and late syngenesis, and also more mature sediments that have not been deeply buried and indurated, but in which the early cementation is essentially complete. In addition to the dune limestones, examples of soft-rock karst include the Cretaceous Chalk of Europe and the Tertiary (mainly Miocene) marine calcarenites of Australia.

Terminology - Diagenetic stages.

Eogenetic diagenesis (Choquette & Pray 1970) refers to processes affecting recently deposited sediments prior to deep burial . The processes include cementation and solution (with brecciation) by meteoric waters and replacement of aragonite by calcite.

Mesogenetic diagenesis starts after the sediment is buried; and for limestones involves further cementation, re-crystallisation and pressure solution (e.g. styolites)

Telogenetic diagenesis occurs after uplift and erosion returns the limestone to the surface where meteoric waters can dissolve the limestone and form "classic"(hard-rock) karst.

Early diagenetic effects can be preserved within later diagenetic textures. These include paleokarst cavities, infills and breccias.

Suggested usage

Syngenetic Karst is best used for modern or recently-formed karsts in soft calcareous sediments.

Eogenetic Karst is better kept for discussion of paleokarst features associated with eogenetic diagenesis in the geological past.

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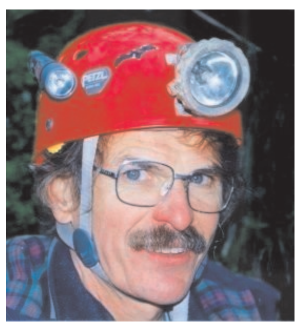
With acknowledgements to:
my co-worker, Susan Q White.
and to my predecessors: Lex Bastian, Alan Hill, Joe Jennings, and many other speleo-geologists.



Syngenetic Karst

Early Syngenetic Karst in Dune Limestones

Early syngenesis

In Early Syngenesis the sediment is too soft to support a cave roof.

Loose sand subsides at once into any incipient cavities, forming soft-sediment deformation structures.

Terra rossa or similar soils form at the surface.

At the base of the soil precipitation of carbonate forms a cemented and locally brecciated calcrete layer or hard-pan.

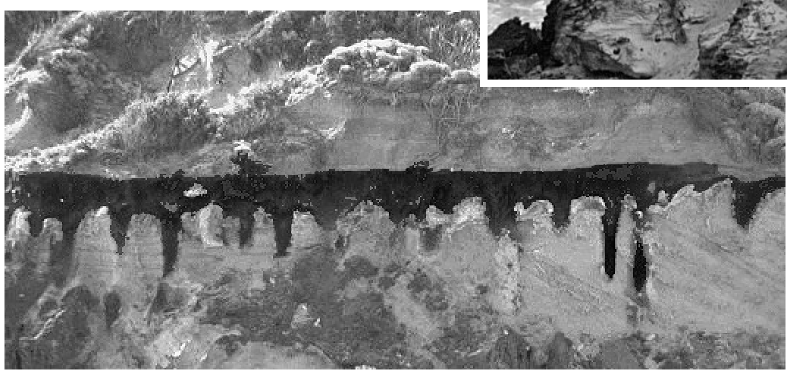
Early cementation about roots forms distinctive rhizomorphs or rhizocretions.

Small shallow caves can develop by subsidence of loose sand from beneath a cap-rock formed by the calcrete hard-pan.

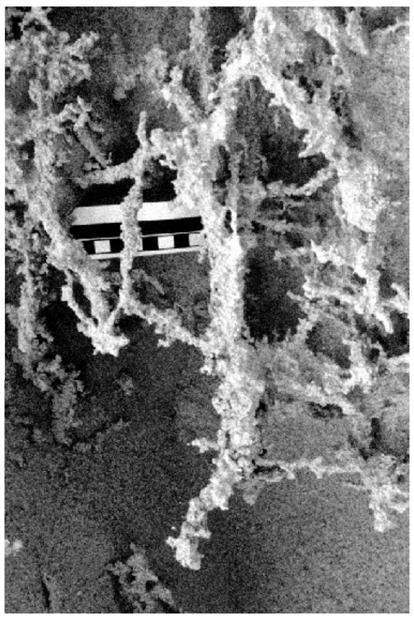
Below the hard pan the downward percolating water becomes focussed to dissolve vertical "solution pipes", and simultaneously cements the surrounding sand.

Eventually cementation is sufficient for caves to form - the **Late Syngenetic Stage.**

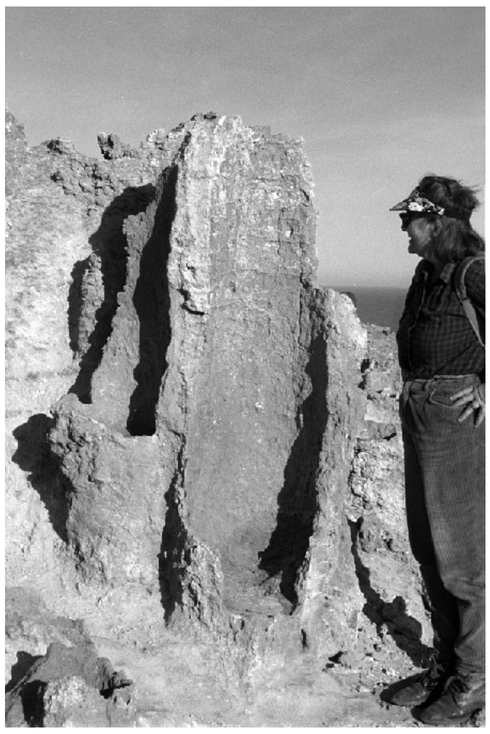
Calcrete hard-pan



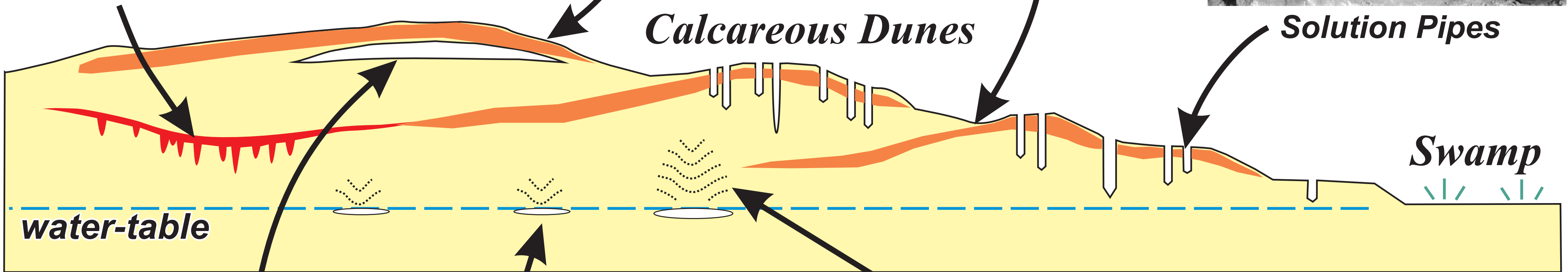
Paleosoil with filled pipes



Rhyzomorphs



Solution Pipes



Initial solution at watertable does not form permanent caves.

Subsidence structures & breccias

Shallow caves under cap-rock

Syngenetic Karst

Late Syngenetic Karst in Dune Limestones

Late syngenesis

Late Syngenesis starts once the bulk of the rock is sufficiently hardened to support a cave

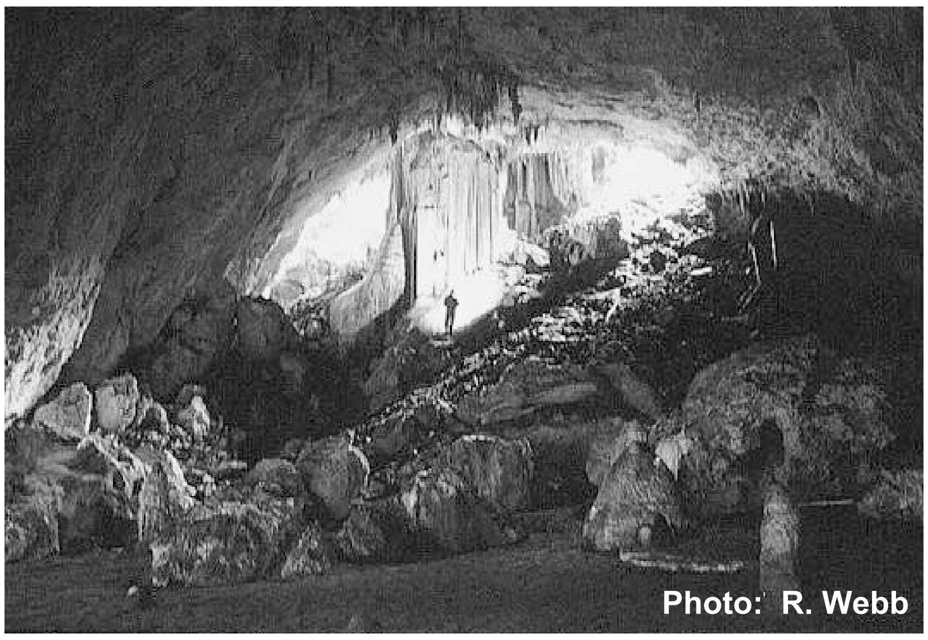
Mixing corrosion occurs where the percolation water meets the watertable; e.g. at the level of a nearby swamp - which also provides acid water.

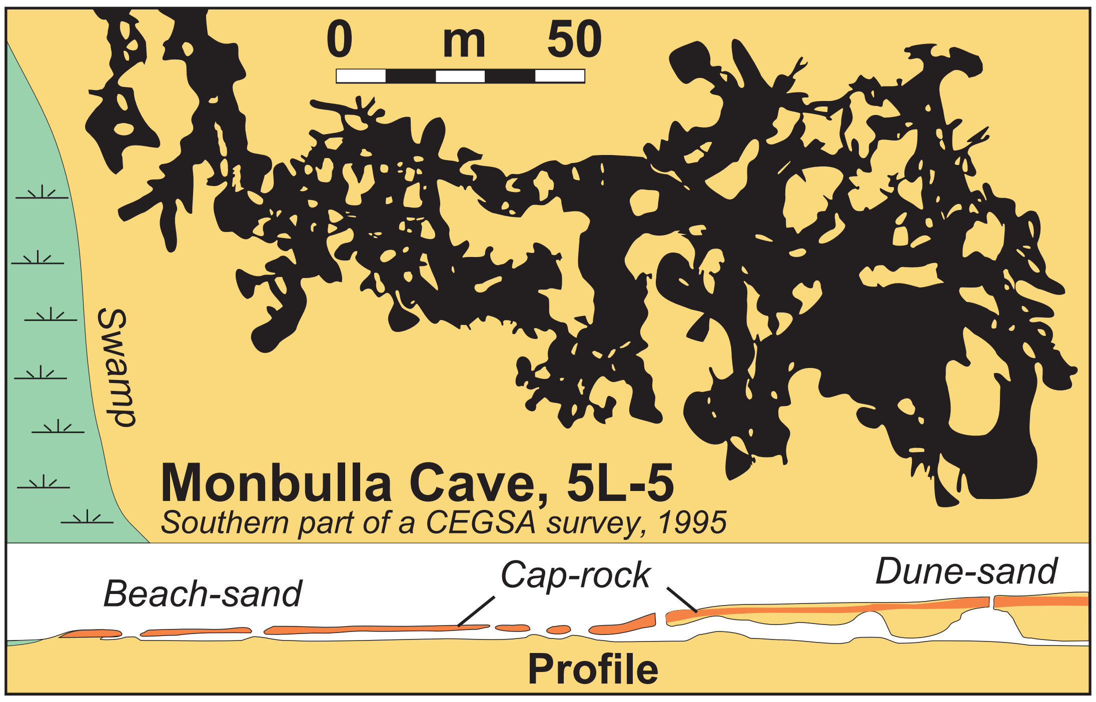
The uniform matrix porosity, slow moving groundwater, and lack of joint control means that directed linear conduits seldom form. Instead, horizontal maze cave systems of low, wide, irregular, interconnected chambers and passages form in the zone of maximum solution at the water table.

Flat cave ceilings are common: either marking the limit of solution at the top of the water table, or where collapse has reached the base of an indurated (cap-rock) zone.

Breakdown of the weakly-cemented cave roof forms collapse domes.

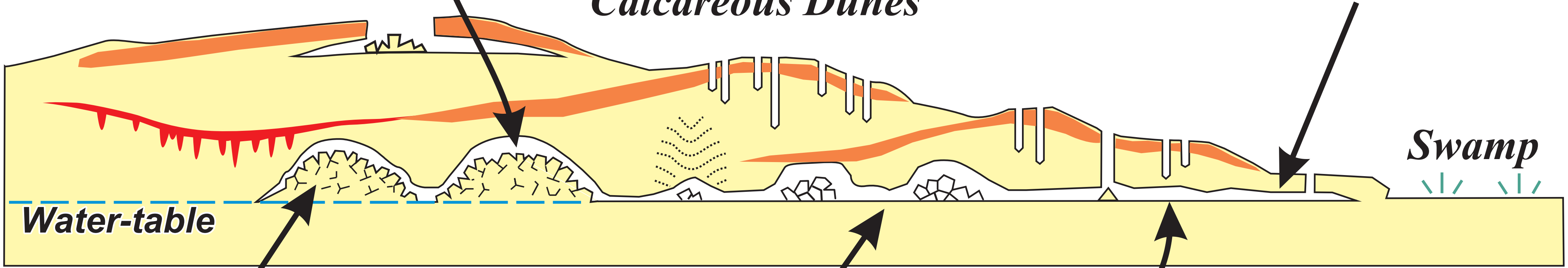
In the very late stage, some joint control may appear.





Collapse Dome

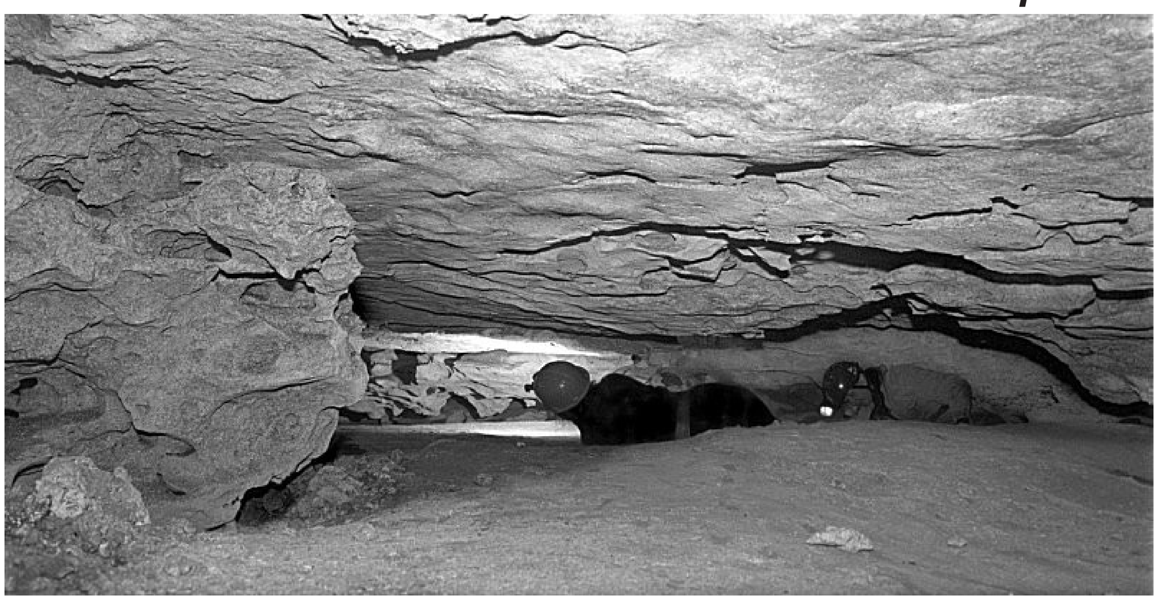
Low-roofed maze cave at swamp level

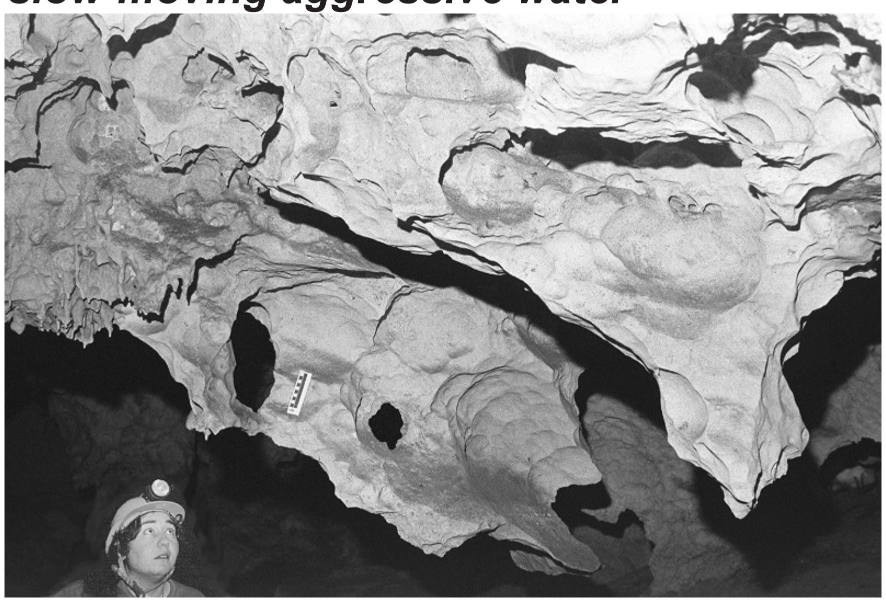


Cave-collapse breccia

Low-roofed cave at swamp level

Spongework: slow-moving aggressive water





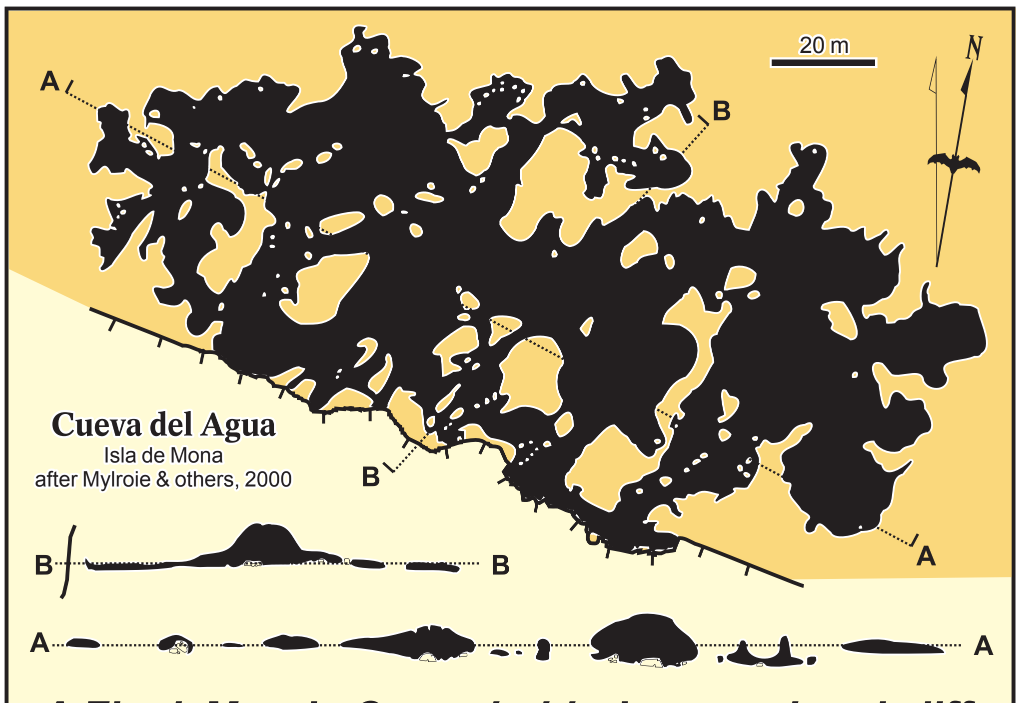
Coastal Karst (flank margin caves)

The Effect of the Sea

In coastal areas, a special influence is introduced by sea water.

Typically, in coastal aquifers a thin lens of fresh water floats over the denser sea water.

Mixing at the contacts causes strong cave solution.



A Flank Margin Cave - behind an erosional cliff

Coastal syngenetic karst

In coastal areas a fresh-water lens floating above sea water results in two mixing zones, above and below the thin lens (Mylroie et al, 2000, 2001).

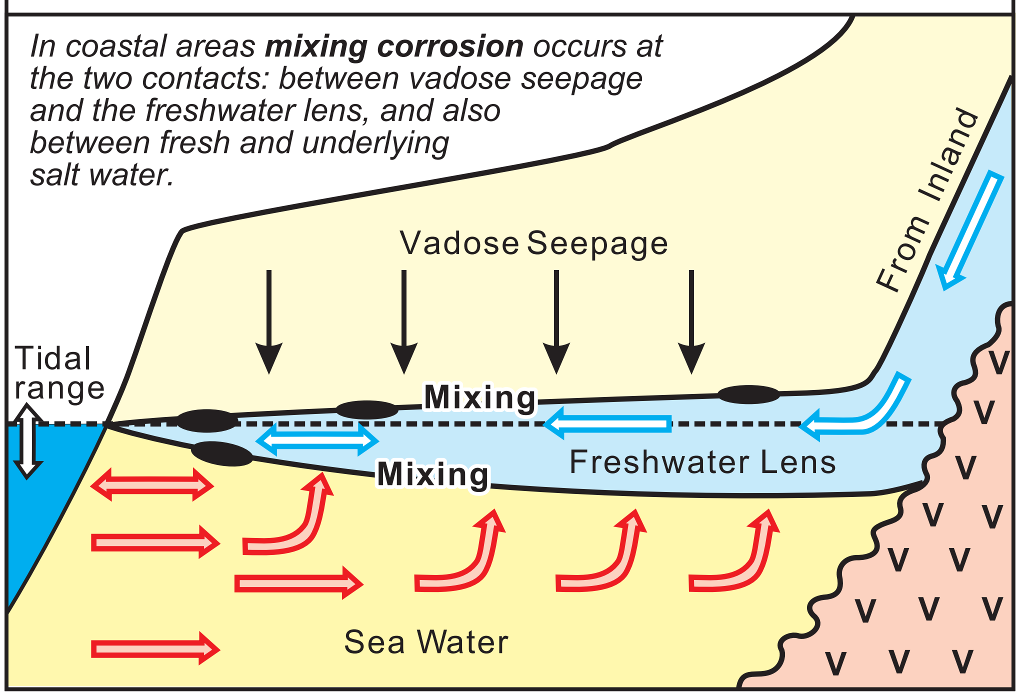
Solution is strongest beside the coast where the lens thins so that: firstly, the two zones overlap (within the fluctuating zone of the sea level) and, secondly, the thinning of the lens causes stronger flow rates which also promotes solution.

The resulting "flank margin caves" form clusters along old coasts (Mylroie et al, 2000) and have an irregular form of interconnected "mixing chambers" and blind passages.

Tidal pumping can also contribute to circulation and solution.

The coastal freshwater lens

Note: the vertical scale is strongly exaggerated in all diagrams of this type. The slopes are not as steep as they appear.



Changing sea levels can generate multiple levels of caves. These can be used as indicators of past sea levels and uplift rates.

The bottom of the freshwater lens may be sharp (a halocline) or a diffuse mixing zone.

There is little conduit flow. Flow is diffuse through the porous sand, and even within the mixing cavities it is slow.

This slow water movement is reflected in the irregular plan of the chambers and the sponge-work sculpturing of the walls.

Where impermeable rocks occur beneath the limestone, these can perch and direct the flow towards the sea. Linear conduits can result.

Inland, beyond the limit of salt water intrusion, only a single mixing zone occurs. Scattered horizontal maze caves can form.

In all cases collapse and solution of the resulting rubble where it sits on the cave floor can form larger chambers.

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Mylroie, JE., Jenson, J.W., Taborosi, D., Jocson, J.M.U., Vann, D.T., & Wexel, C. 2001: Karst Features of Guam in Terms of a General Model of Carbonate Island Karst. *Journal of Cave and Karst Studies*, **63(1):** 9-22

Solution Pipes

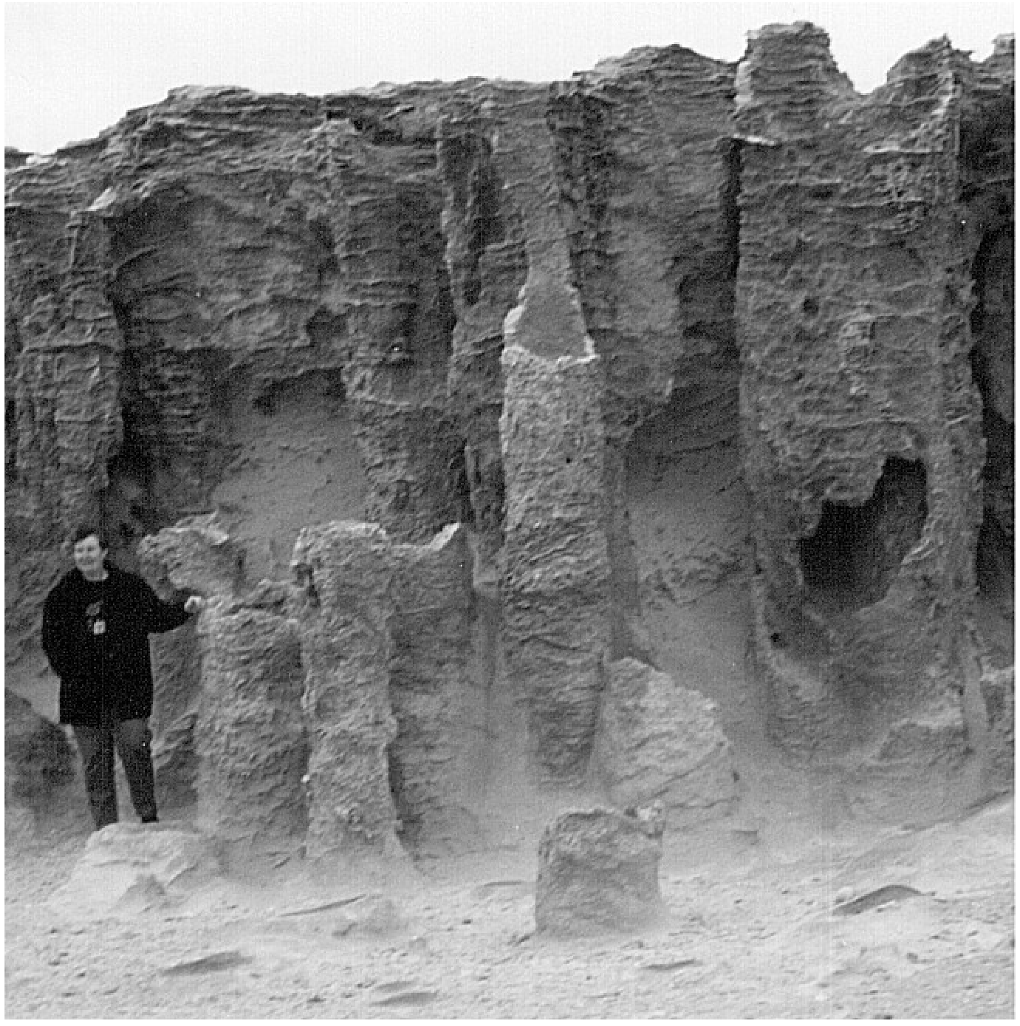
Solution Pipes

Solution pipes (or dissolution pipes) are common and distinctive features of syngenetic karst on porous host sediments.

Solution pipes have been recorded from calcarenites worldwide (e.g. Lyndberg & Taggart, 1995).

They are vertical cylindrical tubes, typically 0.3 to 0.6 m in diameter, with or without cemented rims, which can penetrate down from the surface as far as 20 m into the soft limestone. The top is the present surface or a buried paleosoil. The bottom (where seen) is generally abrupt and hemispherical. The pipes may contain soil and calcified roots.

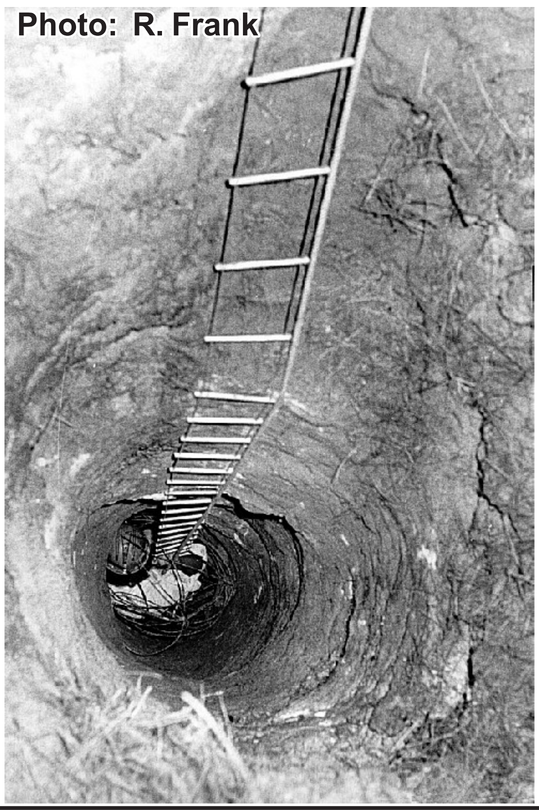
They occur as isolated features, or in clusters with spacings to less than a metre. Some pipes can intersect caves and act as entrances.



Solution pipes with well-developed rims at the Petrified Forest , western Victoria.

Cross-section of soil-filled pipes at an unconformity between two sand dunes.

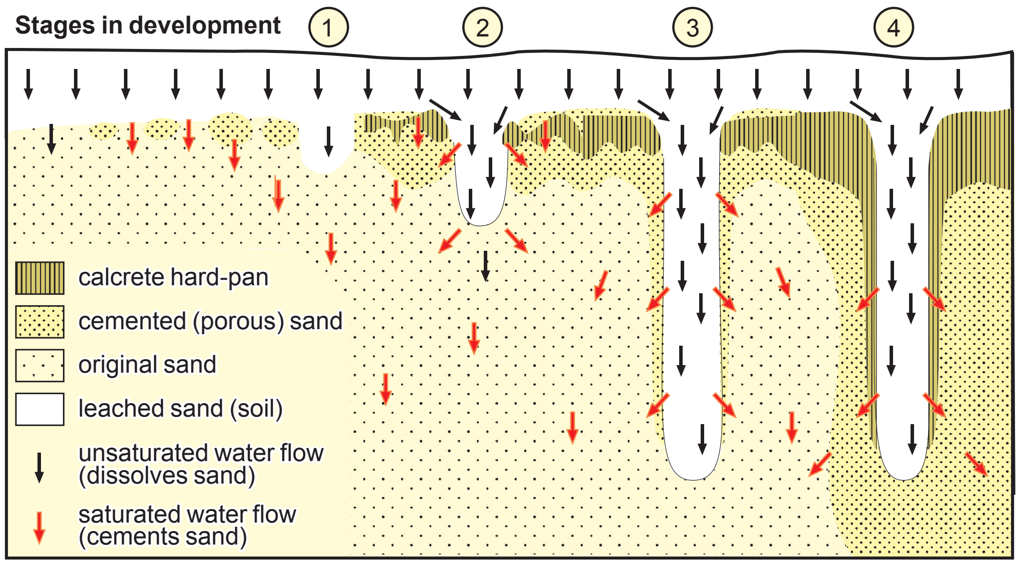
Hemispherical base to a pipe.



Solution pipe entrance to a cave

Formation of pipes, with rims, by focused vertical vadose flow

The pipes form by focussed vertical vadose flow through the porous sediment. The focussing may be spontaneous and associated with partial cementation of the hard pan of the soil, or it may be guided by other factors such as concentrated stem-flow, or along tap roots.



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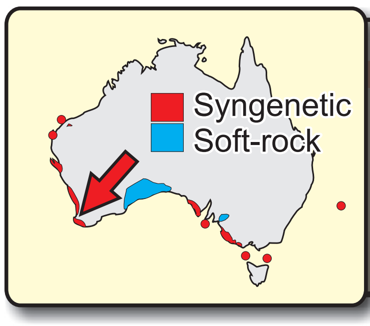
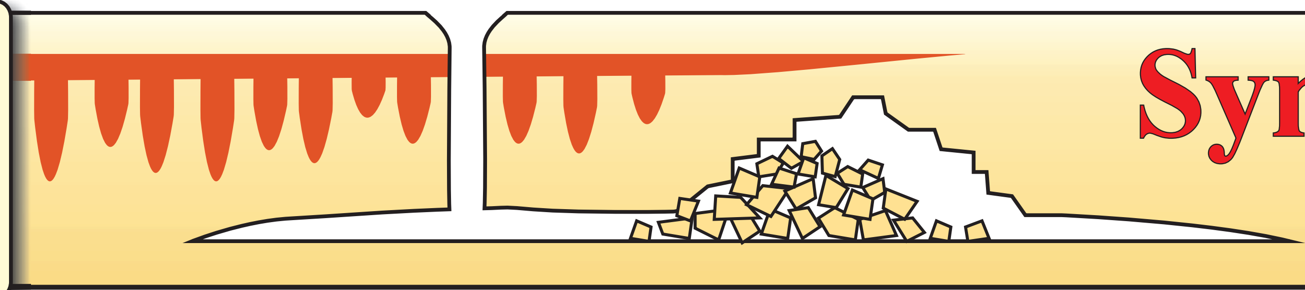
Lyndberg, J., & Taggart, B.E. 1995: Dissolution pipes in northern Puerto Rico: an exhumed paleokarst. *Carbonates and Evaporites* **10(2):** 171-183.





Syngenetic Karst

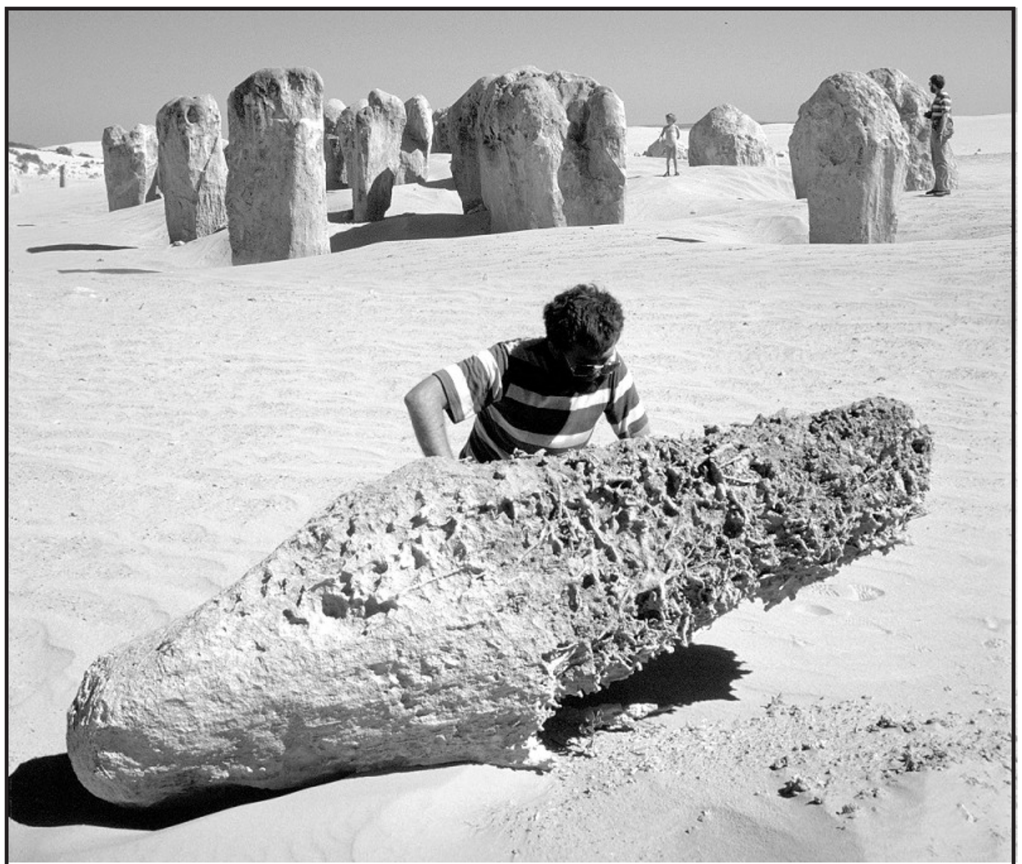
Examples: Western Australia

Southwest Australian Syngenetic Karsts

At Yanchep, aggressive water enters the base of the limestone from an underlying aquifer - forming watertable caves.

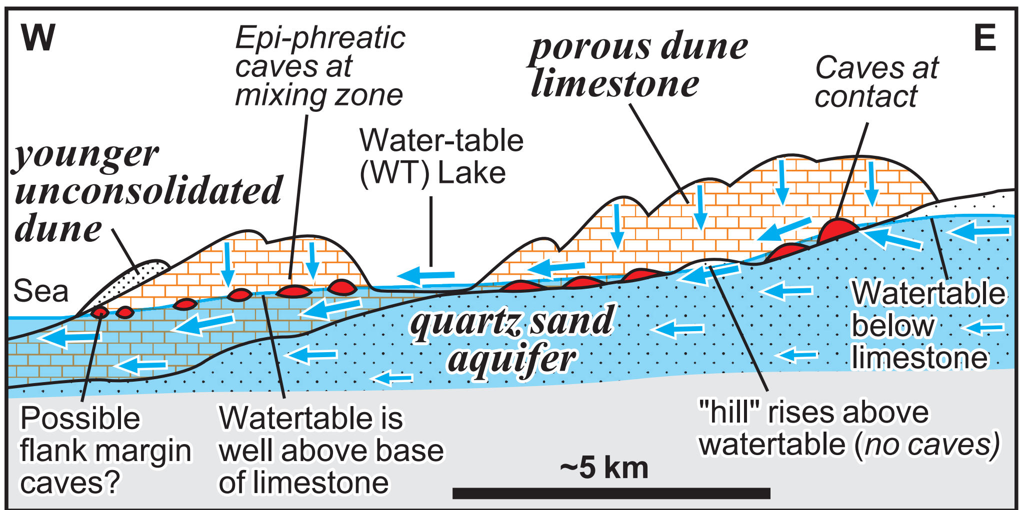
At Witchcliffe, an impermeable basement has directed water flow at the base of the dunes to form linear stream caves.

The Nambung Pinnacles are an unusual variant of solution pipes.



Pinnacles at Nambung.

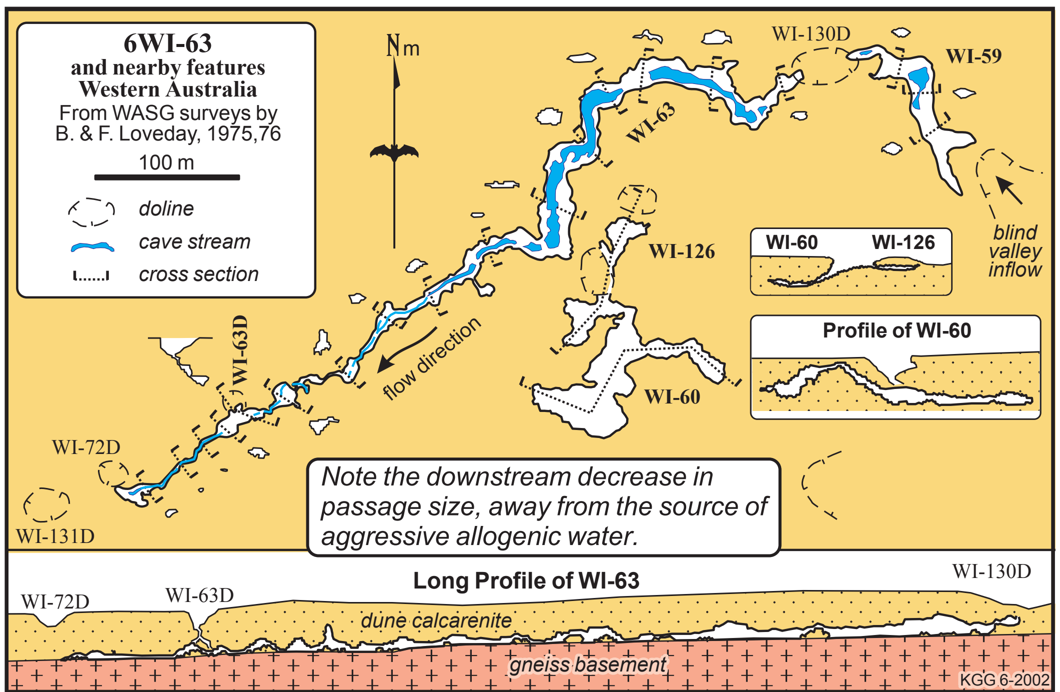
These pinnacles seem to be an extreme case in which solution pipes coalesced to leave only isolated cemented parts of the original dune (McNamara, 1995). They are exposed by wind erosion of the softer sand. In the uprooted specimen in the foreground, case hardening of the exposed upper surface has formed a smooth skin, in contrast to the softer buried core. Note the rhizomorphs in the core.



Water from below

At Yanchep, the dune calcarenite overlies a quartz sand aquifer. Aggressive water moves upwards into the limestone and dissolves caves at the base of the limestone (Bastian, 1991).

A belt of caves forms along the eastern threshold where the water first rises into the limestone. The increased transmissivity of the caves captures diffuse flow from the adjoining sand and forms local streams which follow the base of the limestone. This high conduit transmissivity maintains the water table at the dipping contact.



Basement control

Where dune calcarenites overlie impermeable basement, water flow is concentrated at the contact and may be channeled by the basement topography into linear stream caves rather than irregular mazes (Williamson, & others, 1976).

References

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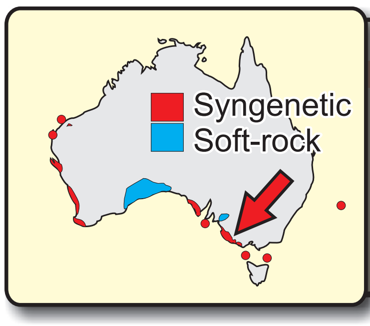
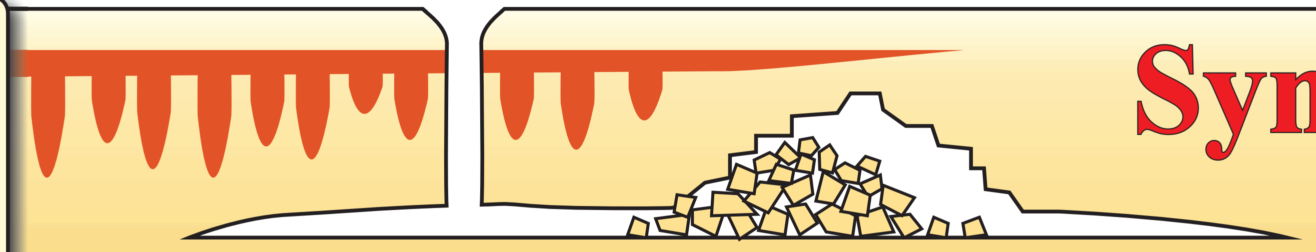




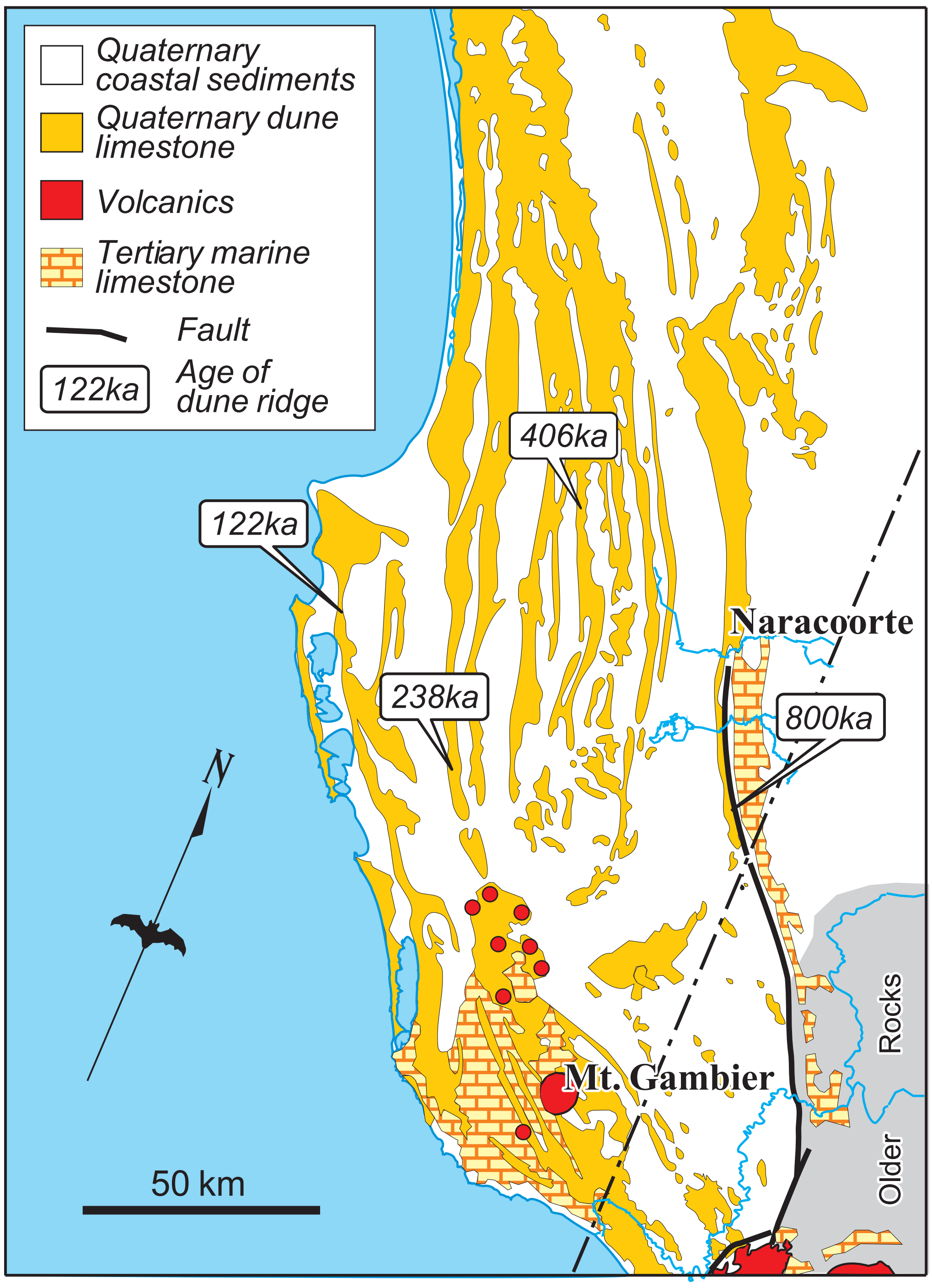
Syngenetic Karst

Examples: Southeast Australia

Syngenetic Karst on a prograding coast

In the Gambier region of SE Australia uplift coupled with sea-level changes has produced a broad sequence of coastal dune ridges and intervening swamps dating back at least 800,000 years.

Horizontal ceiling cut at at the water-table through a cross-bedded dune limestone.



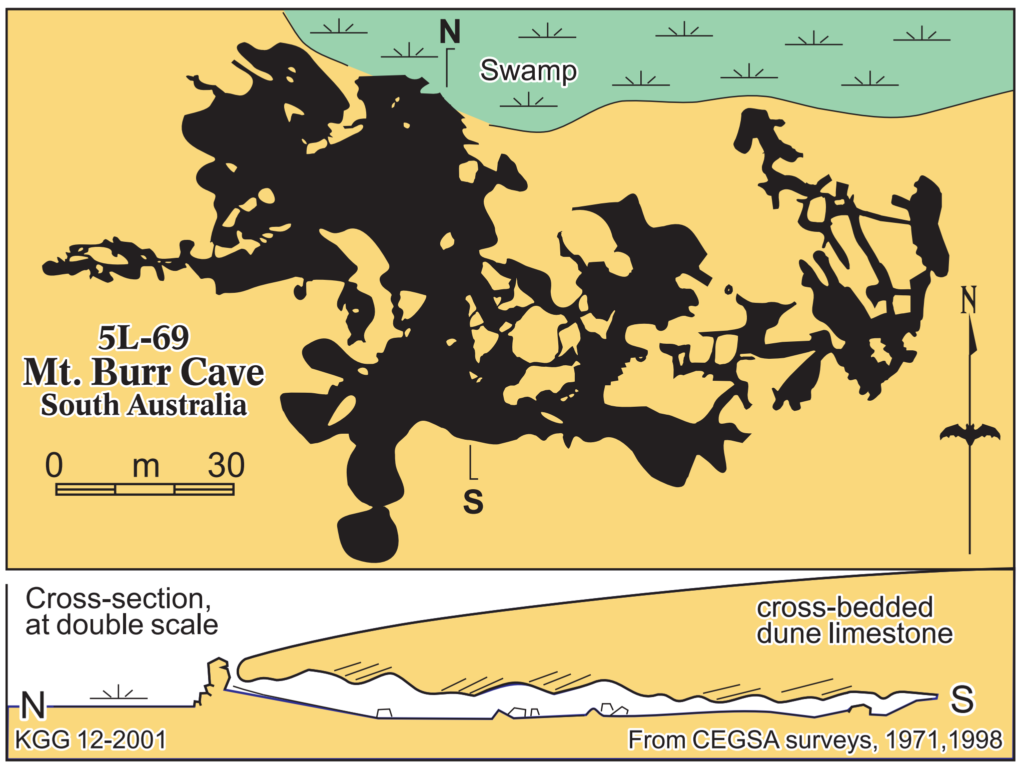
The Gambier Karst Region

Calcareous sand ridges of old coast lines alternate with broad swampy plains.

The plains have numerous shallow pans - some of which are karst dolines but others are degraded swales or drainage lines of the original coastal plain, or later deflation hollows.

Quaternary dune limestone overlies Tertiary marine (soft-rock) limestone. Many caves have entrances in the dune limestone, but their main development is in the underlying Tertiary limestone.

In the initial stages some flank margin caves may have formed in the dune ridges by fresh/salt-water mixing , but aggressive swamp water has been the major agent in cave formation.



Low-roofed maze cave at swamp level

References

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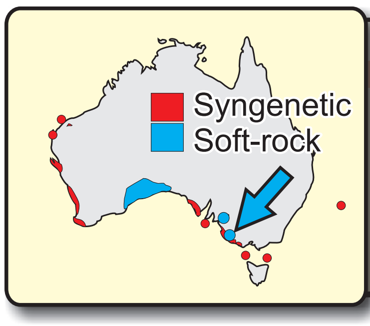


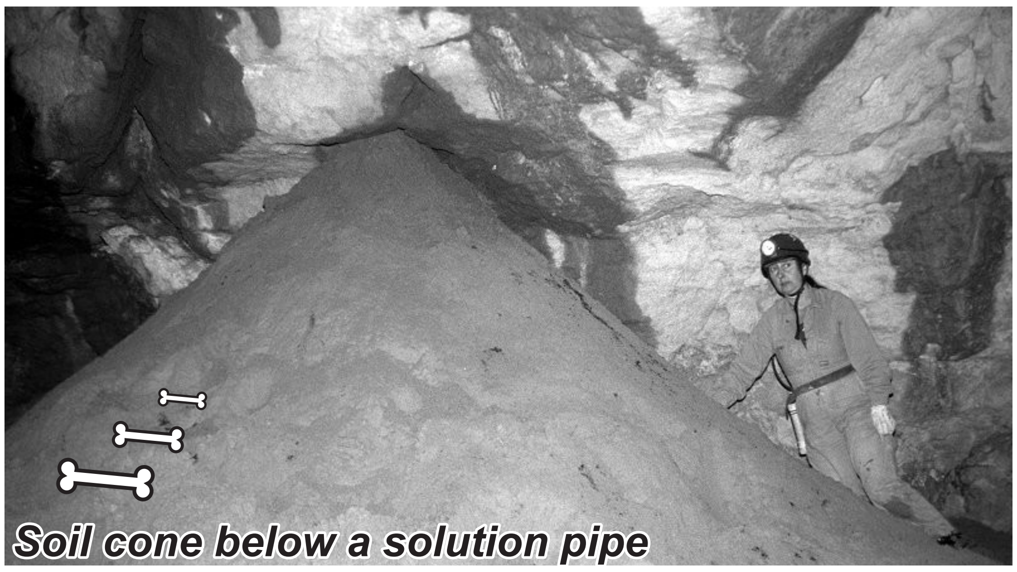
Syngenetic Karst

Examples: Soft-rock Karst

Soft-rock Karst in Tertiary marine calcarenites

The Gambier Limestone is a moderately consolidated porous calcarenite which shows some features similar to syngenetic karst.

However, it also has additional features resulting from its greater age, thickness and the evolution of geological structures such as well-developed joints.


Soil cone below a solution pipe

Similarities to syngenetic karst.

Water flows diffusely through a porous rock - so horizontal irregular mazes can occur at the well-developed water table.

Collapse modification is common in caves in the soft rock. Large collapse domes result.

Cemented hard-bands occur and can control cave ceilings

Solution pipes occur - but tend to be deeper although more scattered. Soil cones form in caves below the pipes.

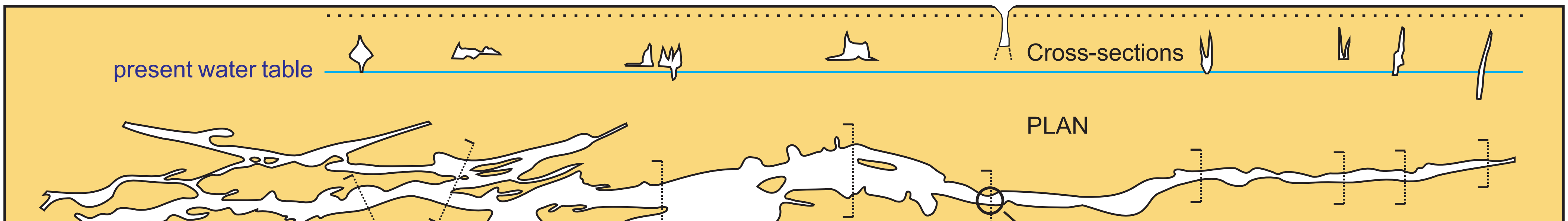
Differences from syngenetic karst.

Greater age and thickness allows further induration and development of joints and other structure, as well as response to varying water levels due to tectonism or sea level change.

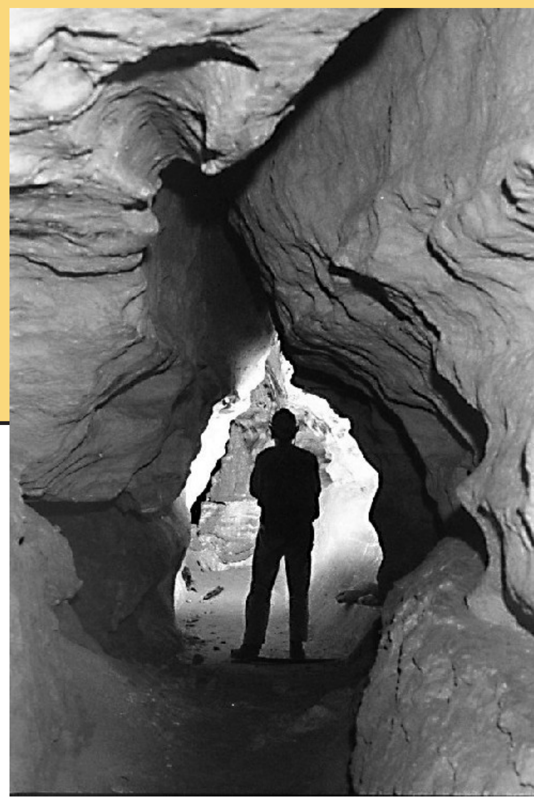
Joints can control the cave forms - e.g. to form rectilinear mazes

Changing water tables produce multi-level cave systems, including deep flooded systems up to 70m below the present watertable.

Soil cones beneath solution pipes, and entrance facies in general, can host fossil faunas of considerable age.



A joint-controlled cave developed in Gambier Limestone with a thin veneer of Quaternary beach sand.



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