

Terminology & General Concepts

Syngenetic Karst

Refers to the dissolutional development of karst features in newly-formed calcareous sediments, simultaneously with cementation of the sediment into a rock.

Terminology - Syngenetic Karst

The terms "**Syngenetic**" and "**Eogenetic**" Karst overlap. Both refer to karst features in soft, poorly cemented sediments.

Syngenetic karst (Jennings, 1968; Grimes, 2006) was applied to karst features in sediments, especially dune calcarenites, that were being cemented into a soft rock at the same time as the dissolutional cavities formed.

Eogenetic karst (Vacher & Mylroie, 2002) is a later term that describes the same situation.

White et al (2007) advocated "Syngenetic" as the broader term with "Eogenetic" restricted to the "late syngenetic" stage described below.

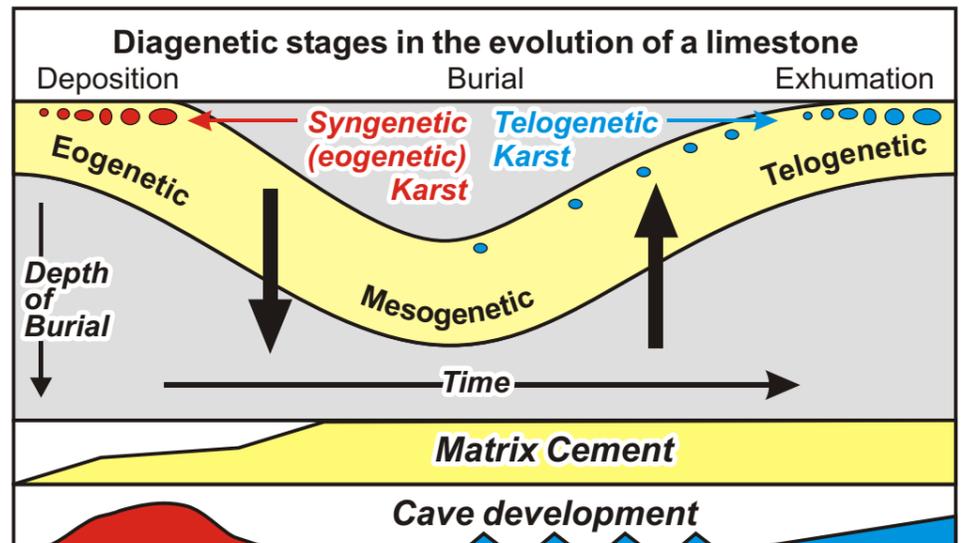
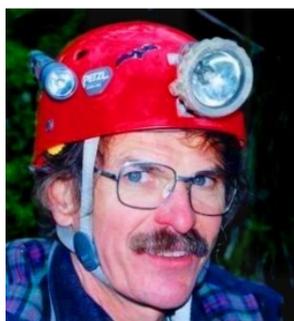
Early syngeneses is the stage prior to significant cementation. It involves soil development (including calcrete hard-pans), and deeper solution with small-scale brecciation and subsidence structures, but the sediment is too soft to support large cavities.

Late syngeneses (or "eogenetic karst") begins when the sediment is sufficiently cemented for larger cavities (caves) to form. However, the limited strength means that roof collapse will be common. Late syngeneses continues, to include more mature sediments in which the early cementation is essentially complete, but which have not been deeply buried and indurated. In addition to the dune limestones, examples include the Cretaceous Chalk of Europe and the Tertiary (mainly Miocene) marine calcarenites of Australia (Grimes, 2006).

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and to my predecessors: Lex Bastian, Alan Hill,
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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.

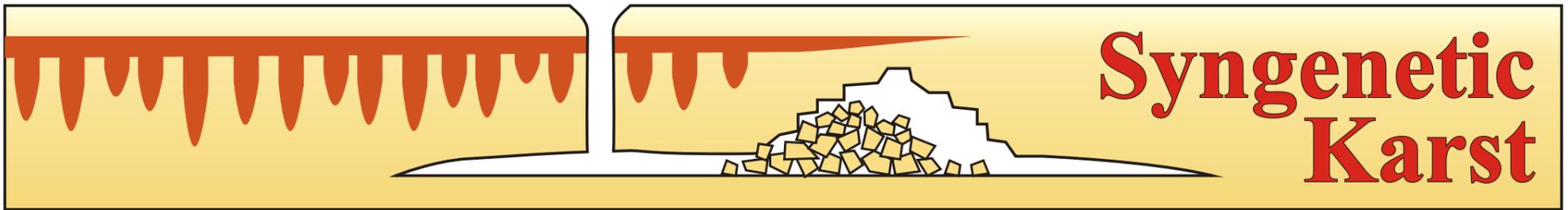
Mesogenetic diagenesis starts after the sediment is buried; and for limestones involves further cementation, re-crystallisation and pressure solution (e.g. stylolites)

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

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

References

- Choquette, PW., & Pray, LC., 1970:** Geological Nomenclature and classification of porosity in sedimentary carbonates. *Am. Assoc. Petrol. Geol. Bull.* **54**: 207-250.
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Syngenetic Karst

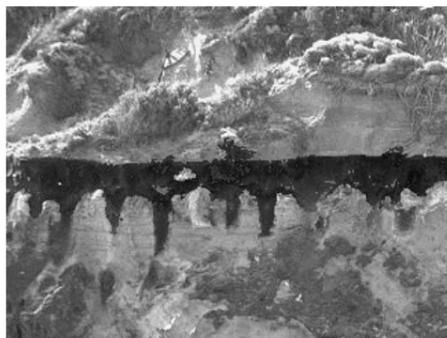
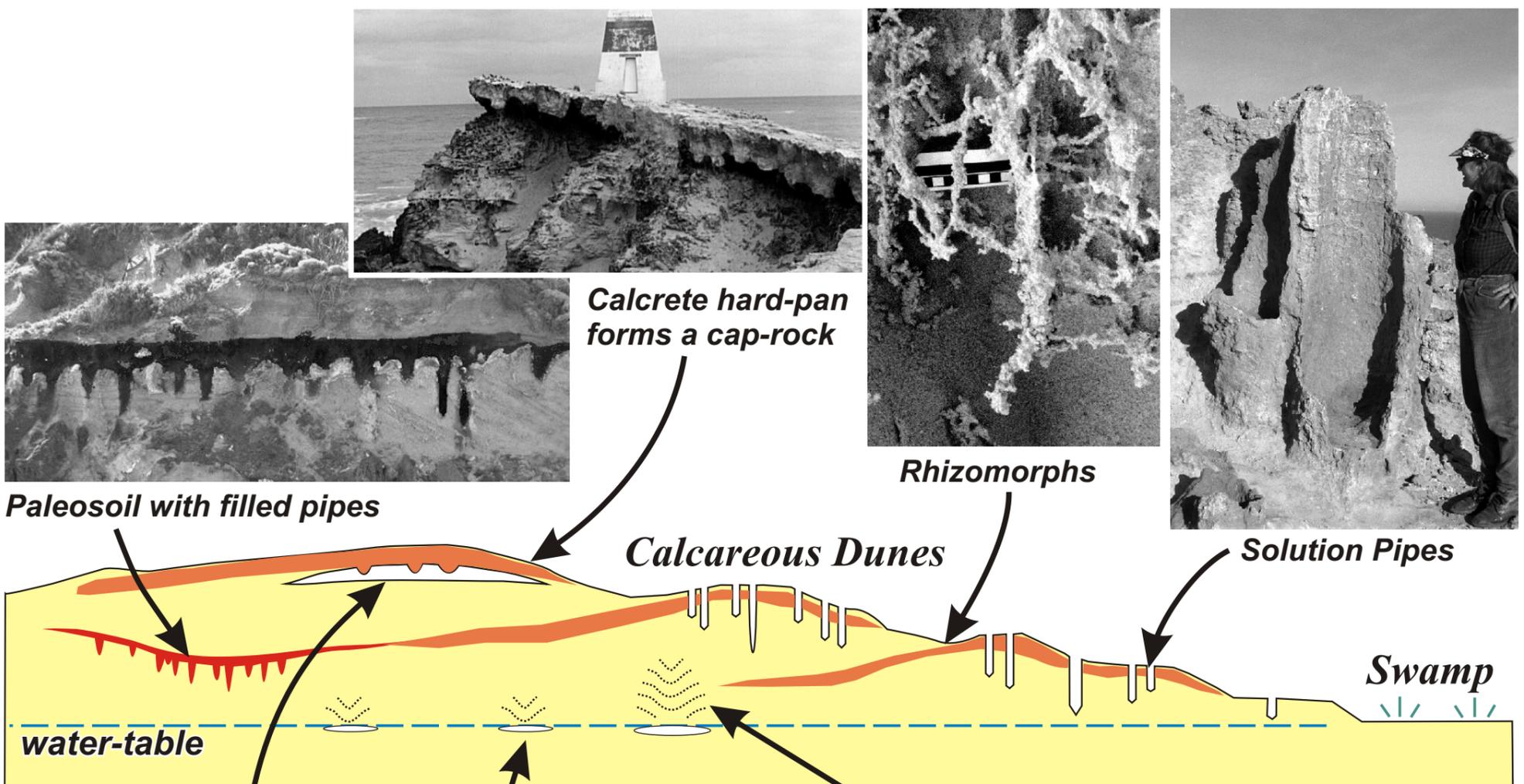
Early Syngenetic Karst in Dune Limestones

Early syngenesi

In Early Syngenesi the sediment is too soft to support a cave roof, but other features form.

- ▶ 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.

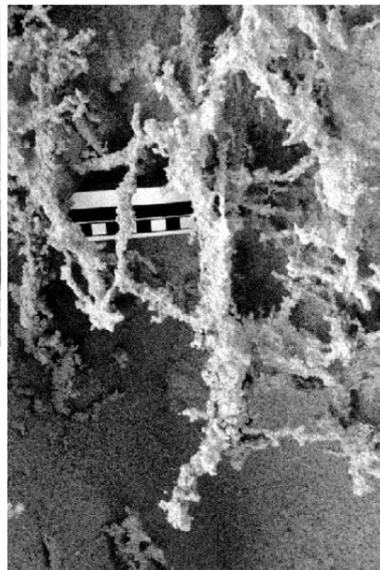
- ▶ Early cementation about roots forms distinctive rhizomorphs or rhizocretions.
- ▶ Small shallow caves can develop by subsidence of loose sand from beneath a cap-rock formed by the calcrete hard-pan.
- ▶ Below the hard pan the downward percolating water becomes focussed to dissolve vertical "solution pipes", or to cement pinnacles, and simultaneously cements the surrounding sand.
- ▶ Eventually cementation is sufficient for caves to form – the **Late Syngenetic Stage**.



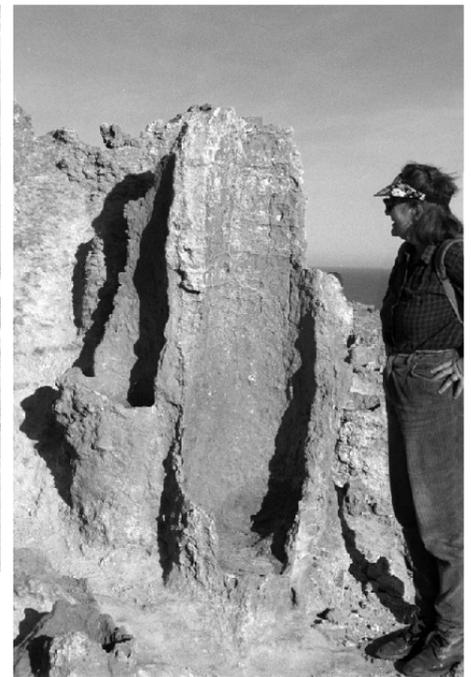
Paleosol with filled pipes



Calcrete hard-pan forms a cap-rock



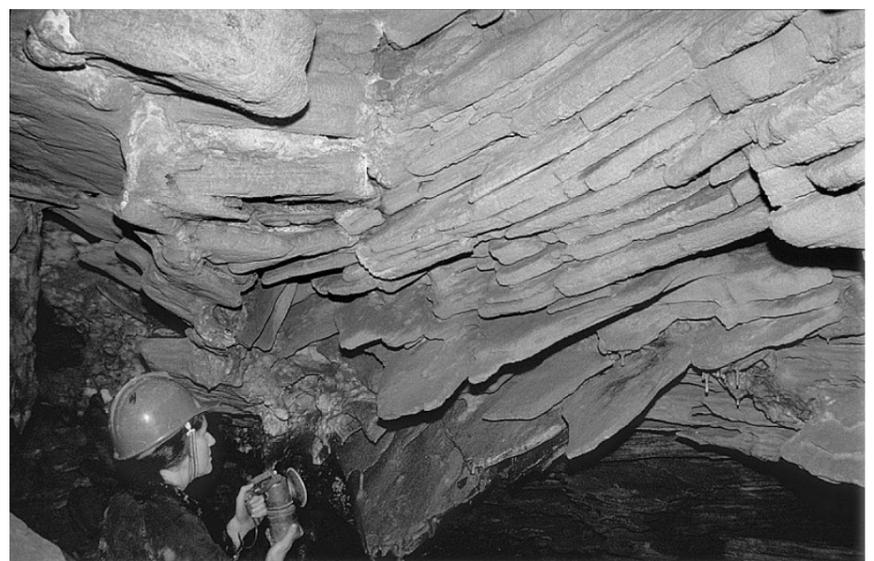
Rhizomorphs



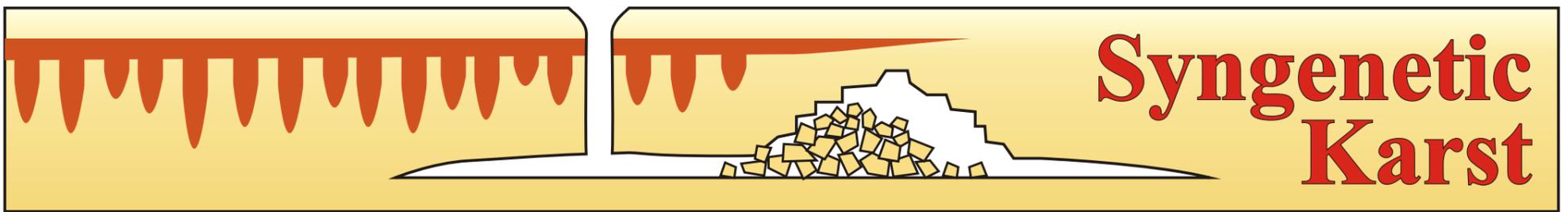
Solution Pipes

Initial solution at watertable does not form permanent caves.

Shallow caves & focussed cementation under cap-rock



Subsidence structures & breccias



Syngenetic Karst

Late Syngenetic Karst in Dune Limestones

Late syngeneses

Late Syngeneses 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.

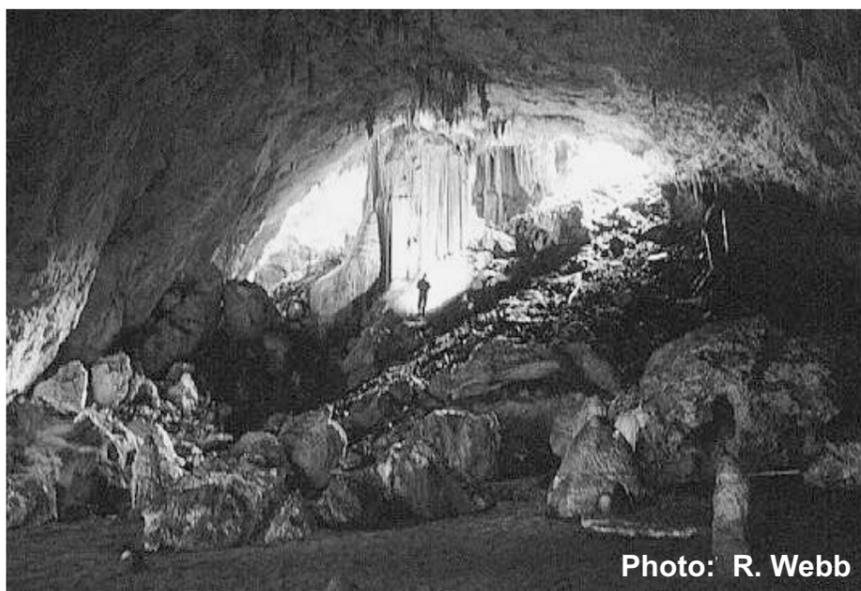
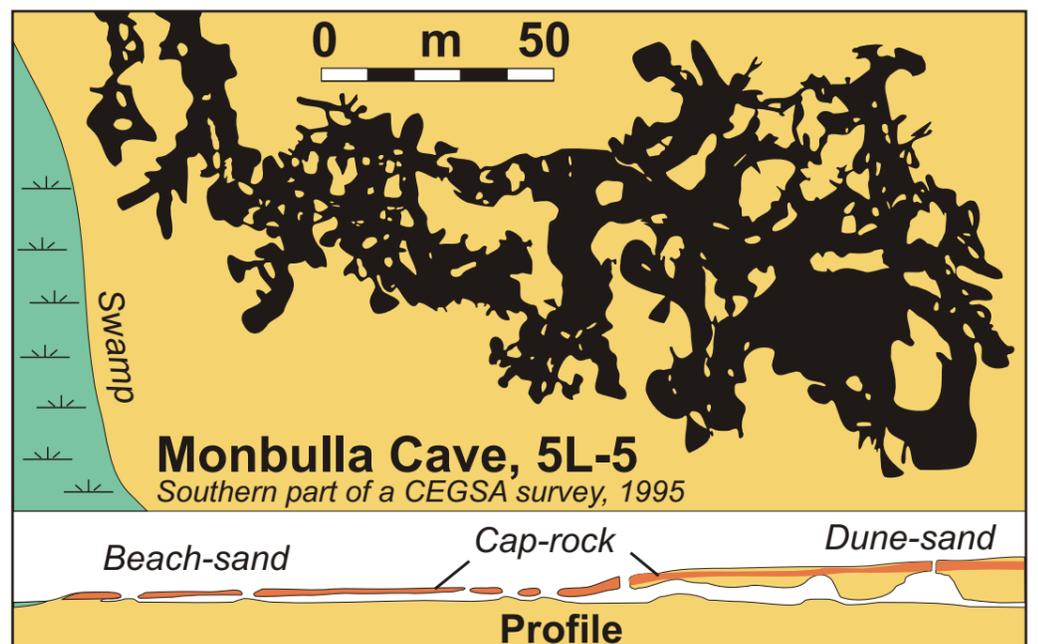
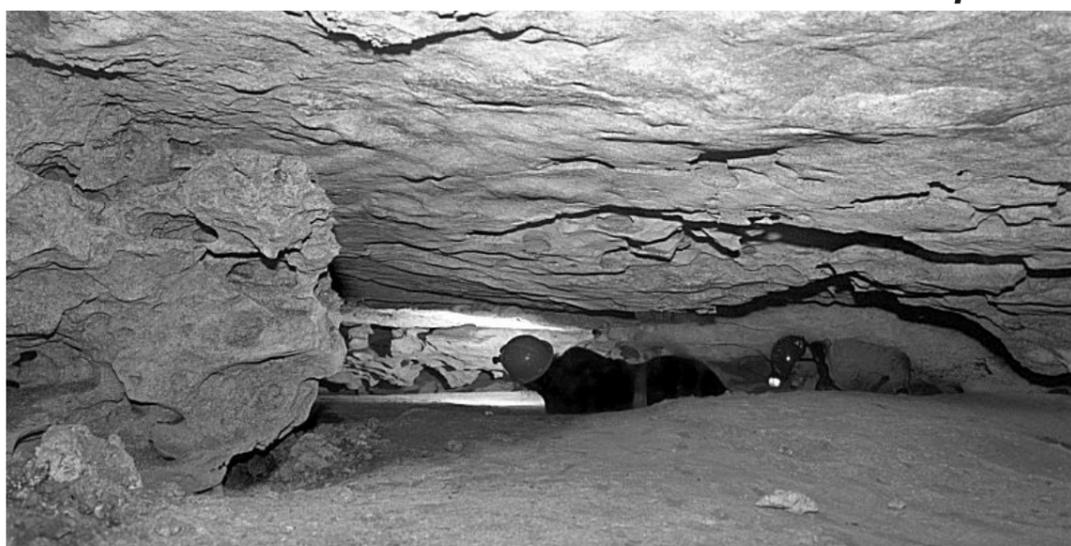
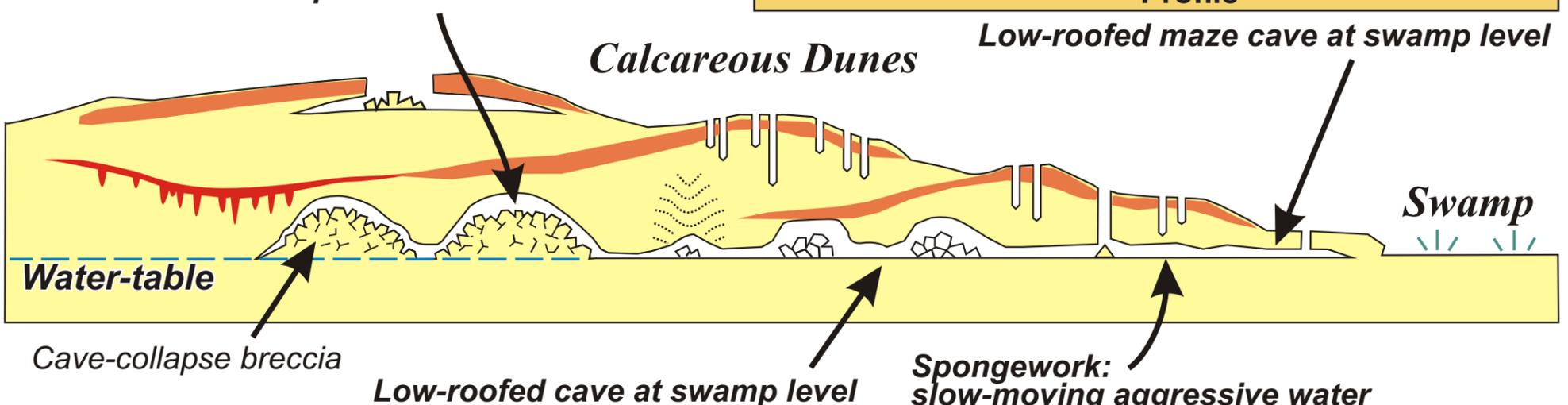


Photo: R. Webb

Collapse Dome



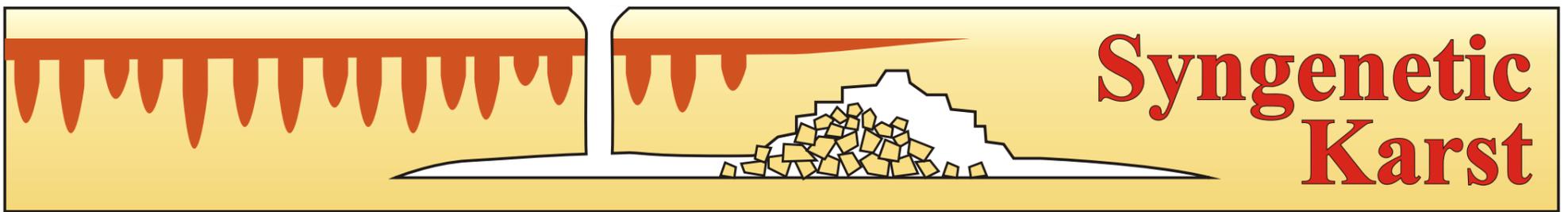
Monbulla Cave, 5L-5
Southern part of a CEGSA survey, 1995



Low-roofed cave at swamp level



Spongework: slow-moving aggressive water



Coastal Karst (flank margin caves)

The Effect of the Sea

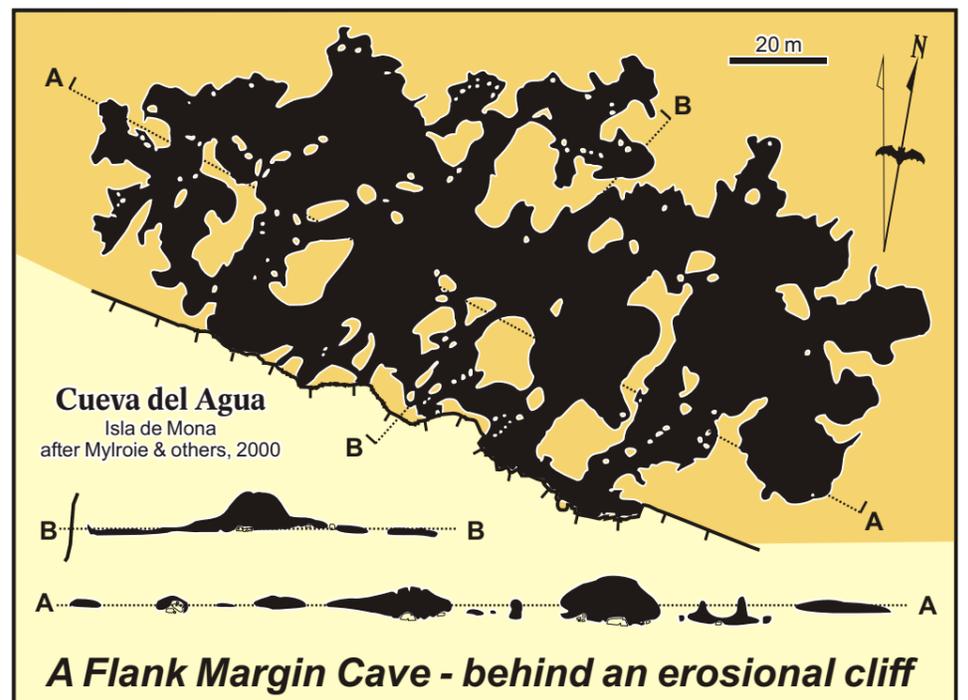
In coastal areas, a special influence is introduced by sea water.

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

Mixing at the contacts causes strong cave solution.

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 (Myroie et al, 2000, 2001).
- ▶ Solution is strongest beside the coast where the lens thins so that: firstly, the two zones overlap (within the fluctuating range 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 (Myroie et al, 2000) and have an irregular form of interconnected "mixing chambers" and blind passages.
- ▶ Tidal pumping can also contribute to circulation and solution.

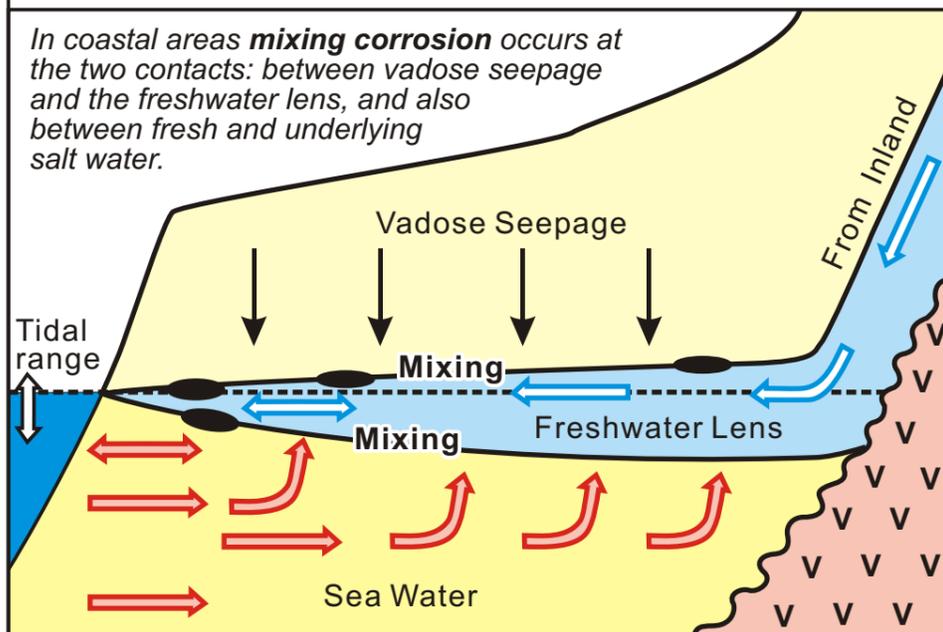


- ▶ Changing sea levels can generate multiple levels of caves. These can be used as indicators of past sea levels and uplift rates.
- ▶ The bottom of the freshwater lens may be sharp (a halocline) or a diffuse mixing zone.
- ▶ There is little conduit flow. Flow is diffuse through the porous sand, and 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.

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.

In coastal areas **mixing corrosion** occurs at the two contacts: between vadose seepage and the freshwater lens, and also between fresh and underlying salt water.



References

Myroie, JE., & Carew, JL., 2000: Speleogenesis in Coastal and Oceanic Settings. in A.B. Klimchouk, D.C. Ford, A.N. Palmer and W. Dreybrodt [eds] *Speleogenesis: Evolution of Karst Aquifers*, Huntsville, Alabama: National Speleological Society. pp. 226-233.

Myroie, 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

Syngenetic Karst

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. Lundberg & Taggart, 1995; Grimes, 2004).
- ▶ 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 paleosol. 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.

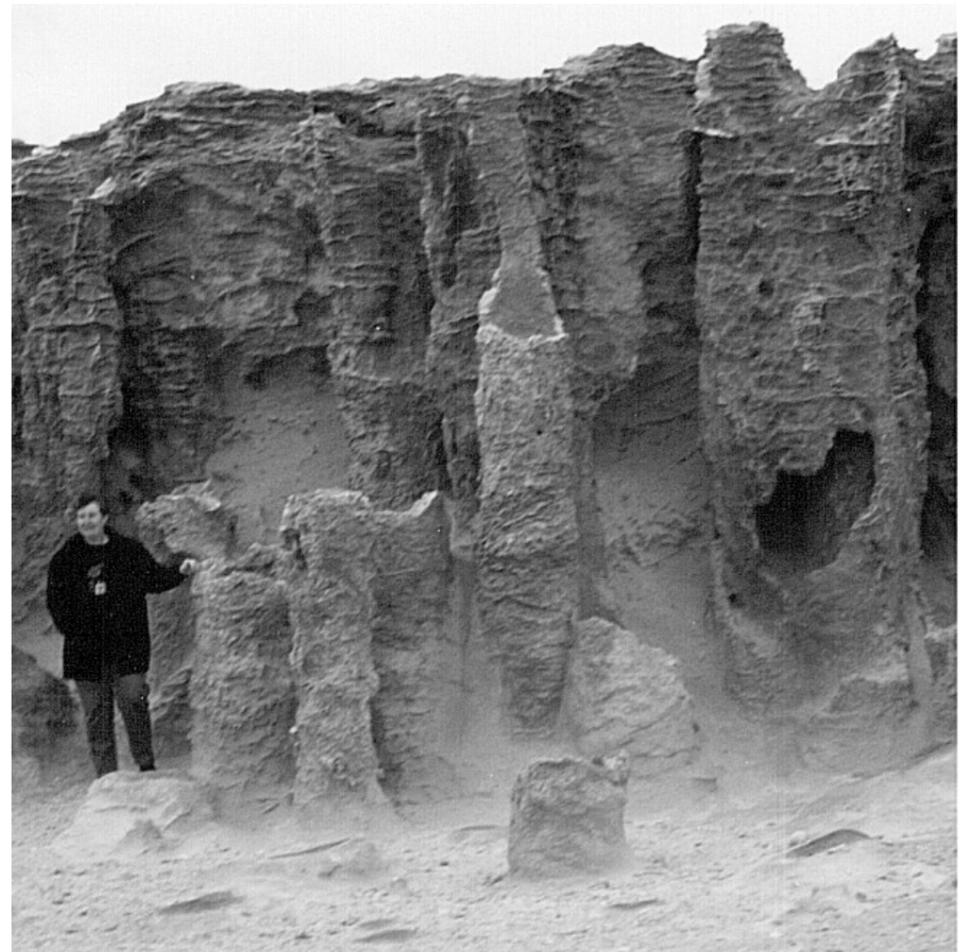


Cross-section of soil-filled pipes at an unconformity between two sand dunes.



Hemispherical base to a pipe.

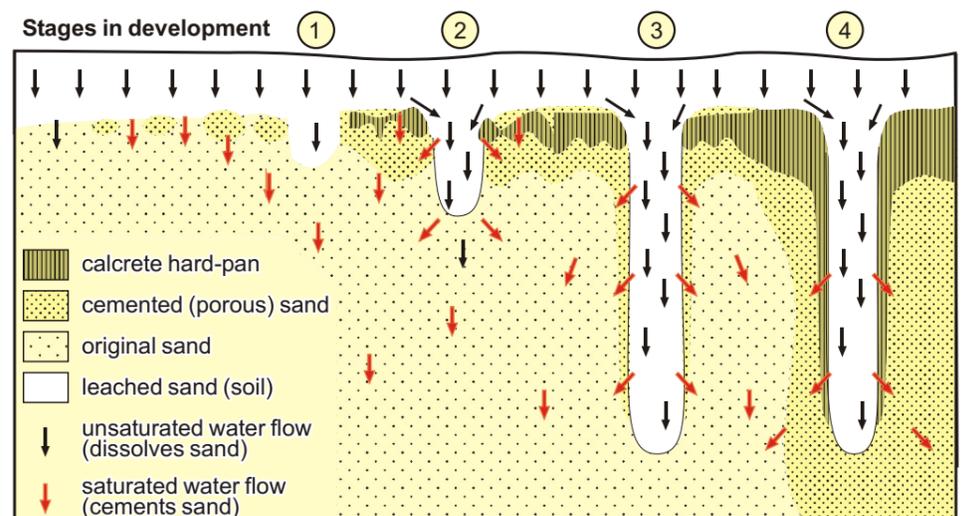
Solution pipe entrance to a cave



Solution pipes with well-developed cemented rims at the "Petriified Forest", western Victoria.

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

The pipes form by focussed vertical vadose flow through the porous sediment. The focussing may be spontaneous (finger flow) or 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.



Reference

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

Grimes, KG., 2004: Solution pipes or petrified forests: Drifting sands and drifting opinions! *The Victorian Naturalist*, 121(1): 14-22.

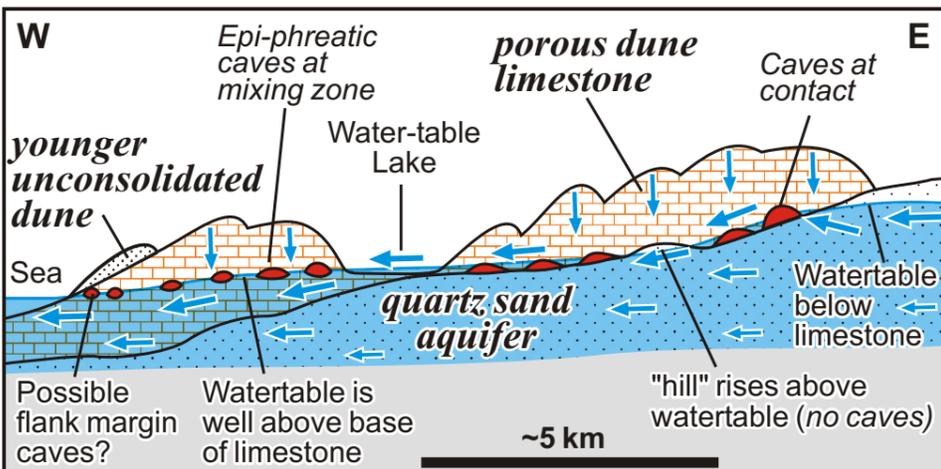
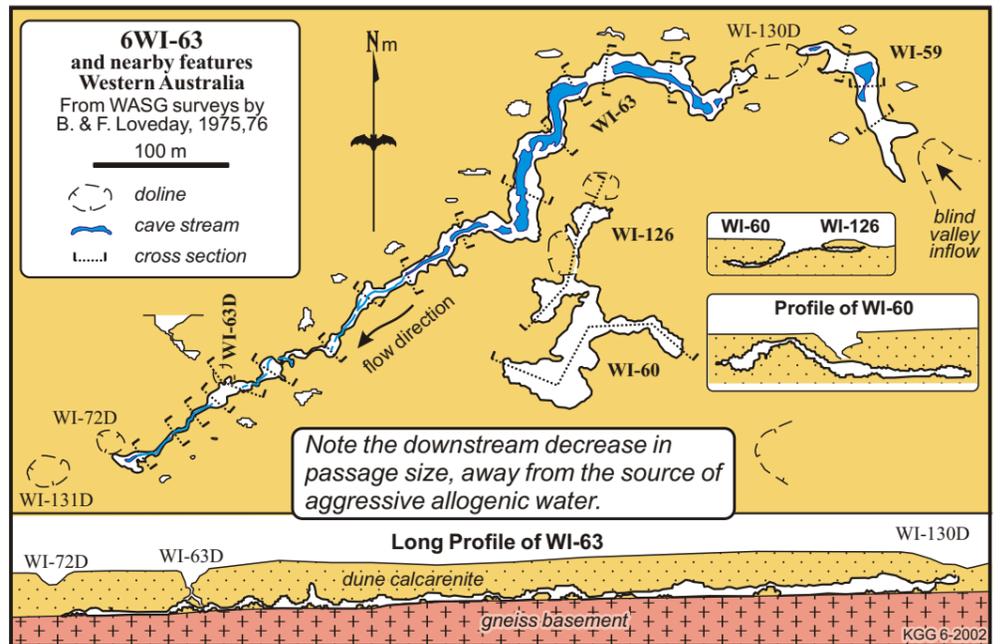


Syngenetic Karst

Examples: Western Australia

Syngenetic Karst in dune calcarenites

- ▶ At Yanchep, aggressive water enters the base of the limestone from an underlying non-karst 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.



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, 2003).

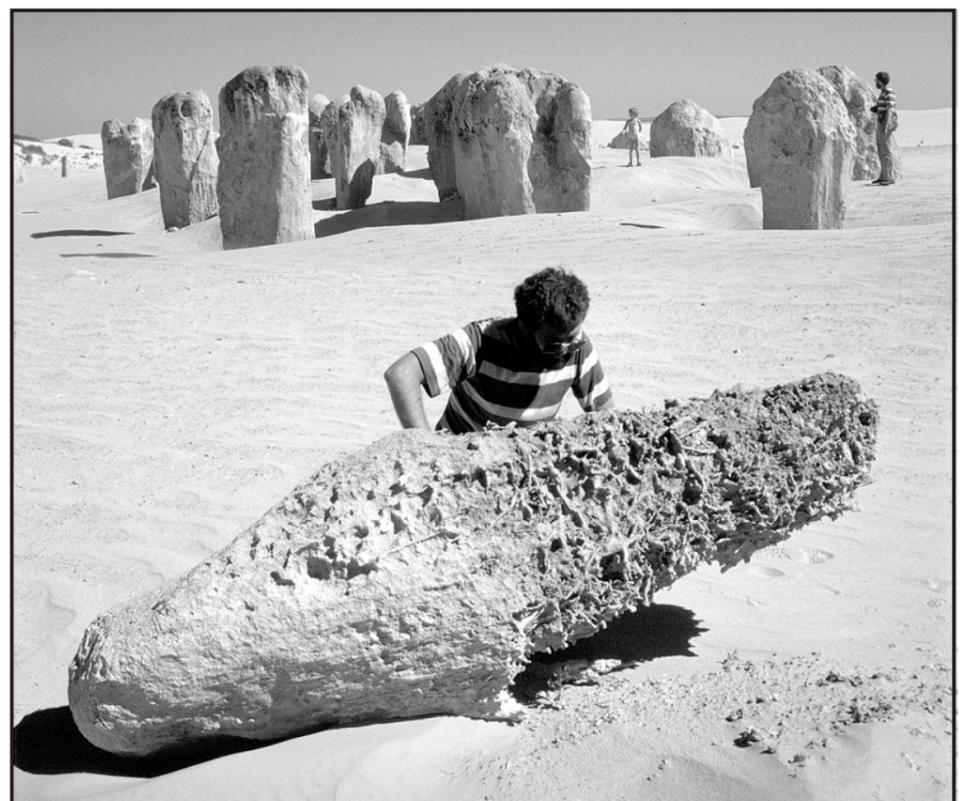
A belt of caves forms along the eastern threshold where the water first rises into the limestone. The increased transmissivity of the caves captures diffuse flow from the adjoining sand and forms local streams which follow the base of the limestone. This high conduit transmissivity maintains the water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

References

- Bastian, LV. 2003:** Hydrogeology and Speleogenesis update, the Yanchep Cave Area, Western Australia. *Proc. 24th Conference, Australian Speleological Federation, Bunbury, WA.* pp. 36-44.
- McNamara, KJ., 1995:** *Pinnacles*. Western Australian Museum. Perth. 24pp.
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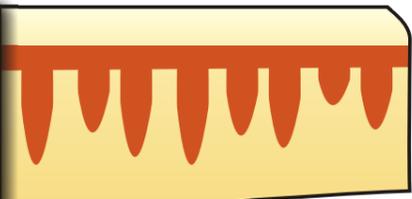
Basement control

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).



Pinnacles at Nambung.

These may be an extreme case of solution pipes coalescing to leave isolated cemented parts of the original dune (McNamara, 1995), or they may form by focussed cementation. Wind erosion has removed 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 with many rhizomorphs.



Syngenetic Karst

Examples: Southeast Australia

Syngenetic Karst on a prograding coast

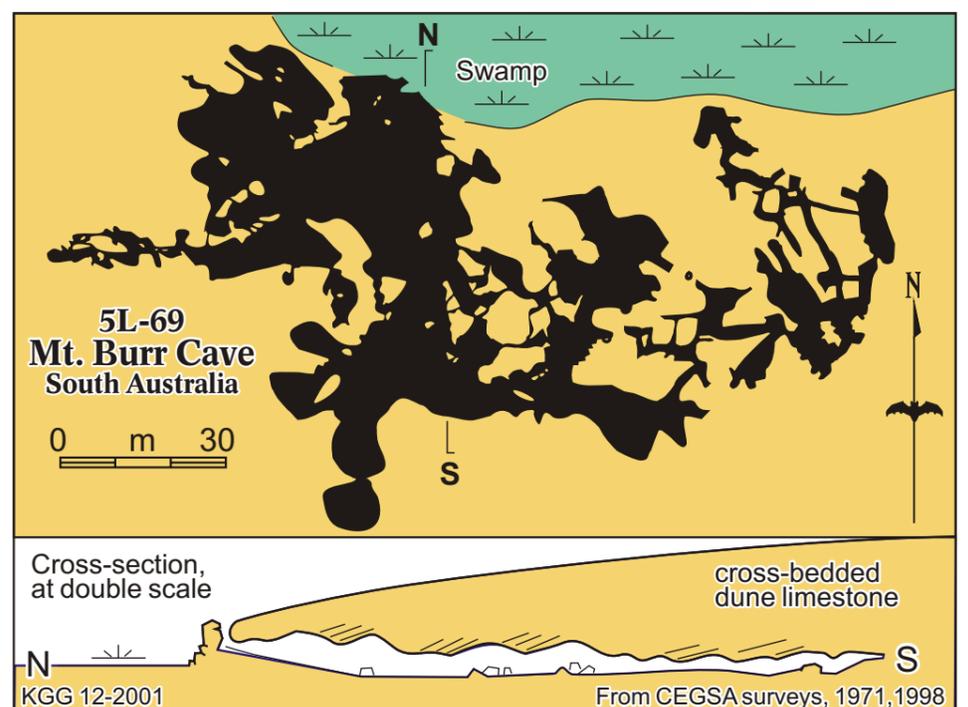
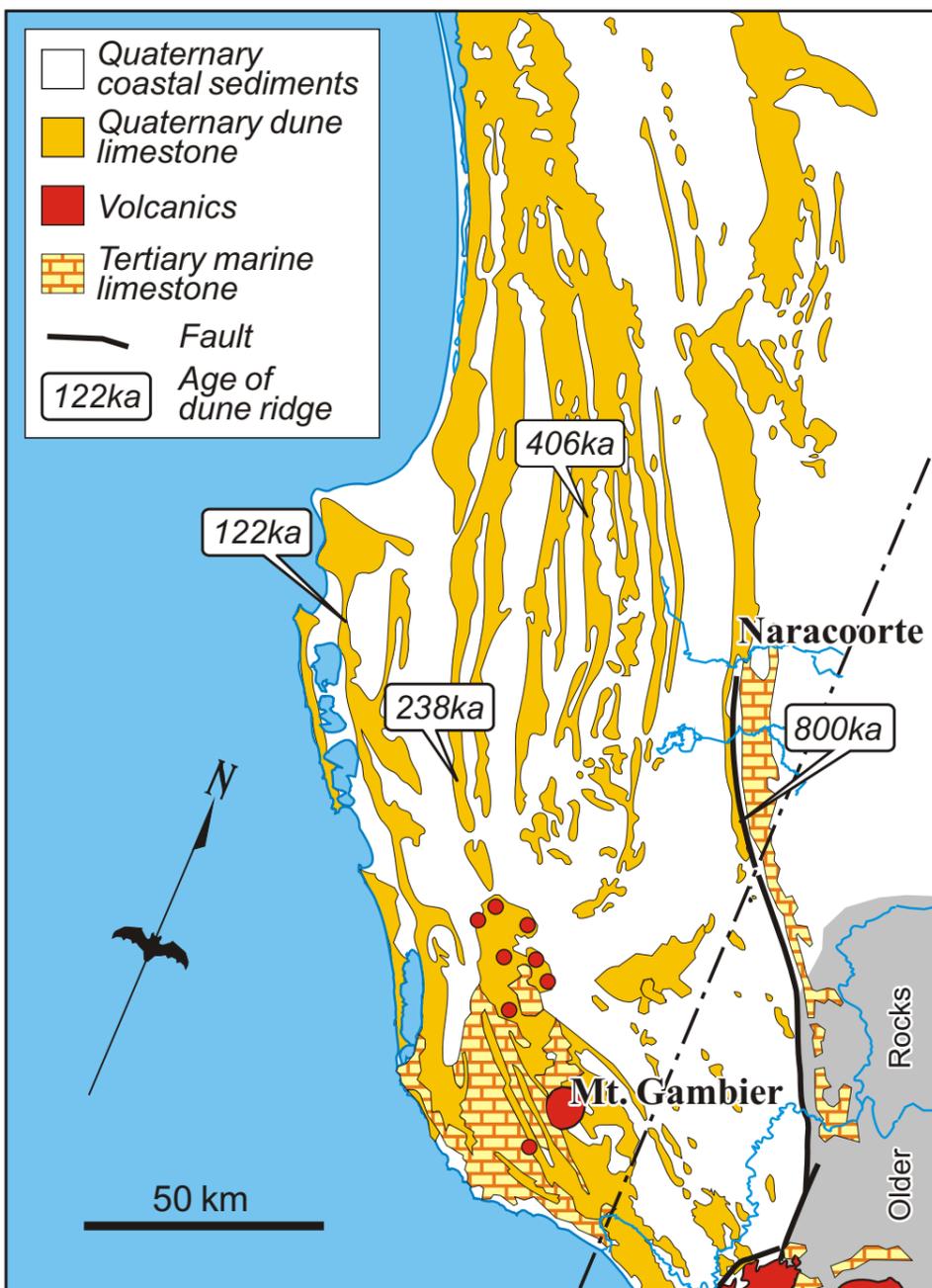
In the Gambier region of SE Australia uplift coupled with sea-level changes has produced a broad sequence of coastal dune ridges and intervening swamps dating back at least 800,000 years.



Horizontal ceiling, with sculptured pendant, cut 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 limestone, which is also an eogenetic calcarenite. Many caves have entrances in the dune limestone, but their main development is in the underlying Tertiary limestone.
- ▶ During each high-stand of the sea, some flank margin caves may have formed in the associated coastal dune ridge by fresh/salt-water mixing, but aggressive swamp water has been the main agent in cave formation since then.

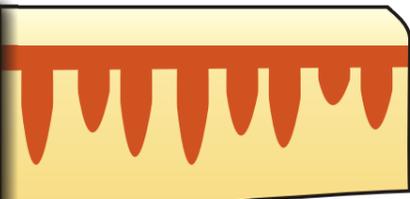


Low-roofed maze cave at swamp level

References

Grimes, K.G., Mott, K., & White, S., 1999: The Gambier Karst Province. In Henderson, K., [ed] Proceedings of the 13th Conference, Australasian Cave and Karst Management Association, Carlton South. pp.1-7.

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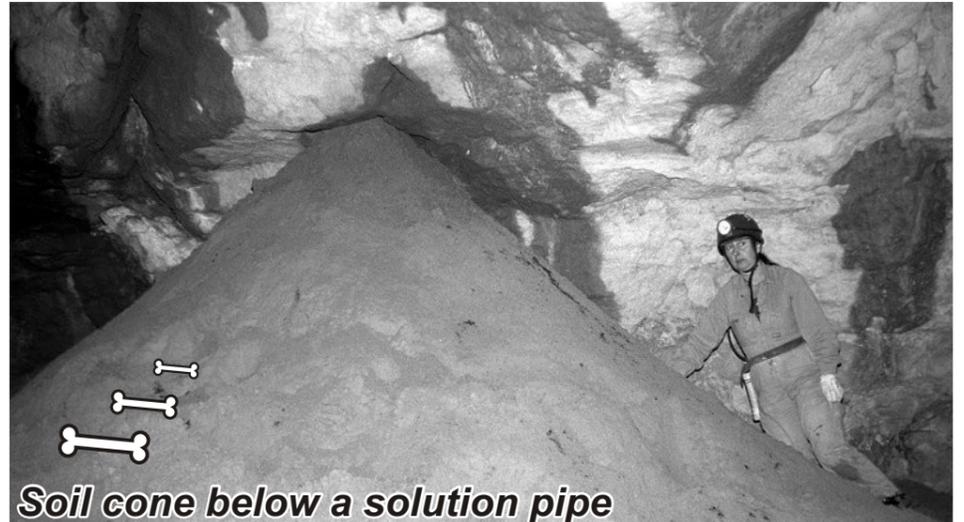
Syngenetic Karst

Examples: Older Syngenetic Karst

Syngenetic Karst in Tertiary marine calcarenites

The Gambier Limestone is a moderately consolidated porous marine calcarenite which shows syngenetic karst features.

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



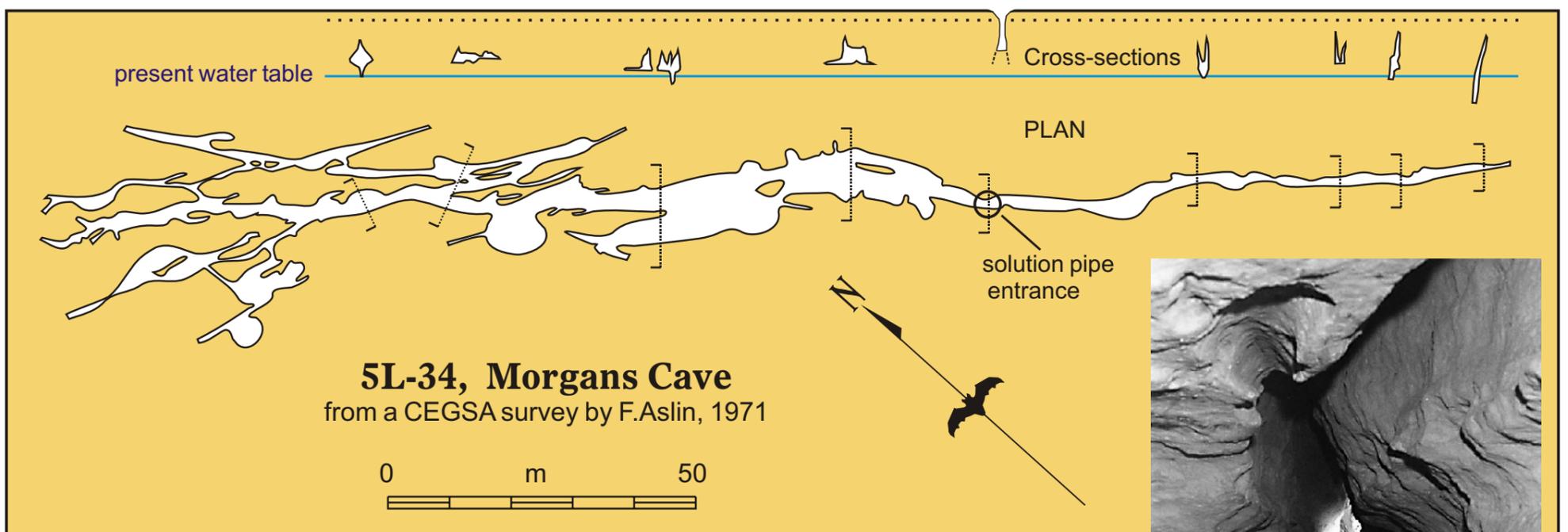
Soil cone below a solution pipe

Similarities to syngenetic karst in dune limestones.

- ▶ 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 dune limestones.

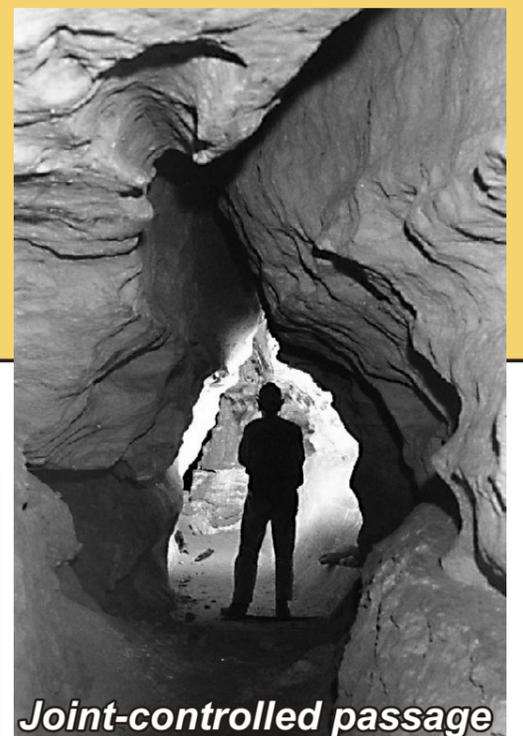
- ▶ Greater age and thickness allows further induration and development of joints and other structure, as well as response to varying water levels due to tectonism or sea level change.
- ▶ Joints can control the cave forms – e.g. to form rectilinear mazes
- ▶ Changing water tables produce multi-level cave systems, including deep flooded systems up to 125 m 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.

References

- Grimes, K.G., Mott, K., & White, S., 1999: The Gambier Karst Province. In Henderson, K., [ed] Proceedings of the 13th Conference, Australasian Cave and Karst Management Association, Carlton South. pp.1-7.
- Grimes, K.G. (editor), 2007: Field Guide to the Caves of the Gambier Karst and nearby areas. Cave Exploration Group, South Australia, Occasional Paper 10, 50 pp.



Joint-controlled passage