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Syngenetic and Eogenetic Karst: an Australian viewpoint

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Abstract

In syngenetic karst speleogenesis and lithogenesis are concurrent. Eogenetic karst and soft-rock karst are closely related terms. The distinctive features of syngenetic karst are: shallow horizontal cave systems; a general lack of directed conduits (low irregular chambers occur instead); clustering of caves at the margins of topographic highs or along the coast; paleosoil horizons; vertical solution pipes which locally form dense fields; extensive breakdown and subsidence to form collapse-dominated cave systems, a variety of surface and subsurface breccias and locally large collapse dolines & cenotes; and limited surface sculpturing (karren). These features are best developed in host sediments that have well developed primary porosity and limited secondary cementation (and hence limited mechanical strength). Certain hydrological environments also assist: invading swamp waters or mixing at a well developed watertable; or, near the coast, mixing above and below a freshwater lens floating on salt water. Where these factors are absent the karst forms tend to be more akin to those of classical hard-rock or telogenetic karst.

keywords: syngenetic karst, eogenetic diagenesis, soft-rock karst, calcarenite, solution pipes.

Introduction and terminology

Syngenetic karst is a term coined by Jennings (1968) for karst features, including caves, that form within a soft, porous, soluble sediment at the same time as it is being cemented into a rock. Speleogenesis and lithogenesis are concurrent. Jennings based his discussion partly on prior observations reported in Bastian (1964) for West Australia and Hill (1984) for South Australia (Hill's paper was written in 1957, but published posthumously).

Jennings was describing the active karst geomorphology of the Quaternary dune calcarenites of Australia. Concurrent studies by sedimentologists of paleokarst horizons at unconformities in the stratigraphic record used the related concept of eogenetic diagenesis: processes that affect a newly-formed carbonate or evaporite sediment when it is exposed to subaerial weathering and meteoric waters (Choquette & Pray, 1970). The resulting eogenetic karst (or "soft-rock karst") is distinguished from telogenetic ("hard-rock") karst that has developed on hard indurated limestones that have been re-exposed after a deep burial stage.

The terms syngenetic and eogenetic overlap but involve different viewpoints. The former is best used for geomorphological studies of modern soft-rock karsts; whereas the latter is best retained for diagenetic studies of paleokarst porosities, where the sequence of dissolution and cementation events is much more complex. Some, but not all, paleokarst is eogenetic: the separation of eogenetic, mesogenetic (burial), and telogenetic features requires a detailed study of cement morphology, mineralogy, chemistry, and related dissolutional and brecciation features; at both the microscopic and macroscopic scale (Moore, 1989). Recently some authors have applied the term "eogenetic karst" to modern syngenetic karst features (e.g. Mylroie et al, 2001).

Features of Syngenetic Karst

Syngenetic karst has several distinctive features as well as many that are shared with classical (telogenetic) karst. Quaternary dune calcarenites, or aeolianites, show the most distinctive features of syngenetic karst. Examples include those of Australia (Jennings, 1968, White, 2000), South Africa (Marker, 1995), Bermuda (Mylroie et al, 1995) and the Caribbean (e.g. Mylroie et al, 1995, Lundberg & Taggart, 1995). However, other porous calcarenites, such as beach and shallow marine facies, can also develop distinctive syngenetic features; in particular solution pipes and calcreted caprocks. Examples include the Miocene Gambier and Nullarbor limestones in Australia (Grimes, 1994, Grimes et al 1999, Lowry & Jennings, 1974), as well as some of the limestones of the Yucatan and Florida. For less porous facies, such as micritic lagoonal limestones of oceanic islands, the syngenetic karst tends to show greater joint control and is more akin to the classical hard-rock karsts (Mylroie et al 2001, Grimes 2001). The Cretaceous chalk of Europe is a special case of a moderately consolidated limestone that has both a very fine-grained porosity and fractures—forming linear caves (Rodet, 1991; Gunn et al, 1998). Other soluble sediments (gypsum, halite) can also develop syngenetic karst when exposed to subaerial conditions (e.g. Sando, 1987) but these will not be discussed here. In the following discussion Australian dune calcarenites in a "Mediterranean" climate are used as an example (Figure 1).

In calcareous dunes, percolating rain water gradually converts the unconsolidated sand to limestone by dissolution and redeposition of calcium carbonate. Initial solution at the surface forms a terra rossa or similar soil depleted in carbonate but enriched in the insoluble grains (e.g. quartz). At the base of the soil precipitation of carbonate forms a cemented and locally brecciated calcrete layer or hard pan. Below this the downward percolating water becomes focussed to dissolve characteristic vertical "solution pipes" (Figure 2 & 3), and simultaneously cements the surrounding sand. Early cementation tends to be localized about roots to form distinctive rhizomorphs or rhizocretions. Cementation can progressively occlude the primary inter-granular porosity, but dissolution can generate localized secondary porosity of a moldic, vuggy or cavernous character.

Solution pipes (or, more strictly, dissolution pipes) are distinctive features of syngenetic karst on porous host rocks (Lundberg & Taggart, 1995). They are vertical cylindrical tubes with or without cemented walls, typically 0.3 to 0.6 m in diameter, which can penetrate down from the surface as far as 20 m into the soft limestone. The pipes may contain soil and calcified roots (and root growth may have occurred hand-in-hand with dissolution of the pipe). They occur as isolated features, or in clusters with spacings to less than a metre. In the Bahamas they have been referred to as Pit Caves, but that term also includes larger and more complex features (Mylroie & Carew, 2000).

Mixing corrosion occurs where percolation water meets the water table, which is frequently controlled by the level of a nearby swampy plain that also provides acidic water. In coastal areas, water levels fluctuate with changing sea levels and further complexity results from a fresh-water lens floating above sea water which results in two mixing zones, above and below the thin lens (Mylroie & Carew, 2000, Mylroie et al, 2001). Solution is strongest at 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 result is a "flank margin cave" (Mylroie et al, 2001) that has an irregular form of interconnected "mixing chambers" similar to those described below (Figure 4). At Yanchep, Western Australia, dune limestone overlies a quartz sand aquifer and aggressive water enters from below to dissolve caves (Bastian, 1991).

In the early stages of dissolution the loose sand subsides at once into any incipient cavities, possibly forming soft-sediment deformation structures. Subsidence dolines may form without caves (as described in South Africa by Marker, 1995). Once the rock is sufficiently hardened to support a roof, caves can develop. The uniform matrix porosity, slow moving groundwater, and lack of joint control means that directed linear conduits seldom form. Instead, horizontal cave systems of low, wide, irregular, interconnected chambers and passages (Figure 4) form either in the zone of maximum solution at the water table, or by subsidence of loose material from beneath stable calcrete layers. 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 (caprock) zone. Where a shallow impermeable basement occurs, its topography may concentrate water flow along buried valleys to form linear stream caves (Figure 5).

Sizable caves can form in less than 100 thousand years (Mylroie & Carew, 2000). Surface dissolutional sculpturing is rare, as there is little solid rock for it to act upon. However, some sculpturing can occur on exposed calcrete layers.

The subsidence of partly-consolidated material can form a variety of breccias and sag structures; these can be further cemented as diagenesis continues (Figure 6). Mantling breccias can occur as part of the surface soil (Figure 7). Within the caves breakdown of the soft rock is extensive. In many cases the original solutional cave system at the water table is largely replaced by rubble-filled collapse domes (e.g. Nannup cave in Figure 5). Subsidence may reach to the surface to form dolines; a special type referred to as a "banana hole" in the Bahamas results from the collapse of the near surface calcrete band above a shallow cave to form an overhanging doline. . In paleokarst exposures these collapse areas appear as both discordant and concordant (intrastratal) breccias. In extreme cases mass subsidence of broad areas can generate a chaotic surface of tumbled blocks and fissures (Bastian, 1995).

Variations can occur in different climates. For example, calcrete is supposedly best developed in semi-arid climates, whereas dissolution and brecciation are thought to be more abundant in wet climates.

Summary

Syngenetic karst shows a number of distinctive forms as a consequence of its formation from soft sediments that are being consolidated and cemented at the same time as karst cavities are forming within them. It is quite different to classical "hard-rock", telogenetic karst. The related term "Eogenetic karst" is best kept for diagenetic studies of paleokarsts.

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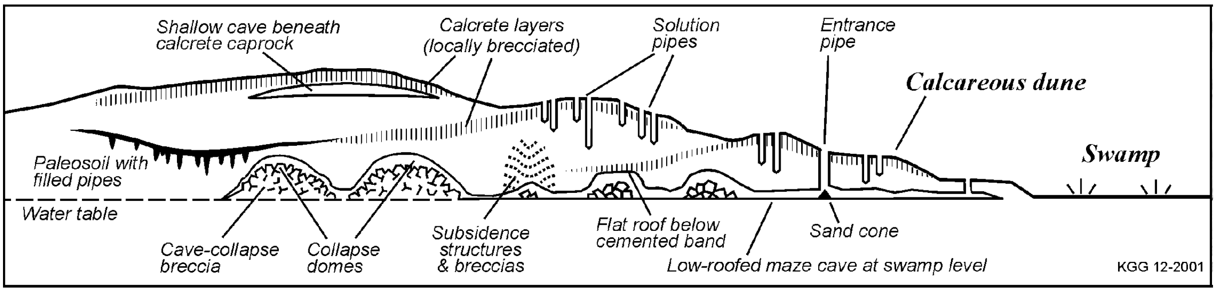

Figure 1: Features of syngenetic karst developed on a calcareous dunefield.

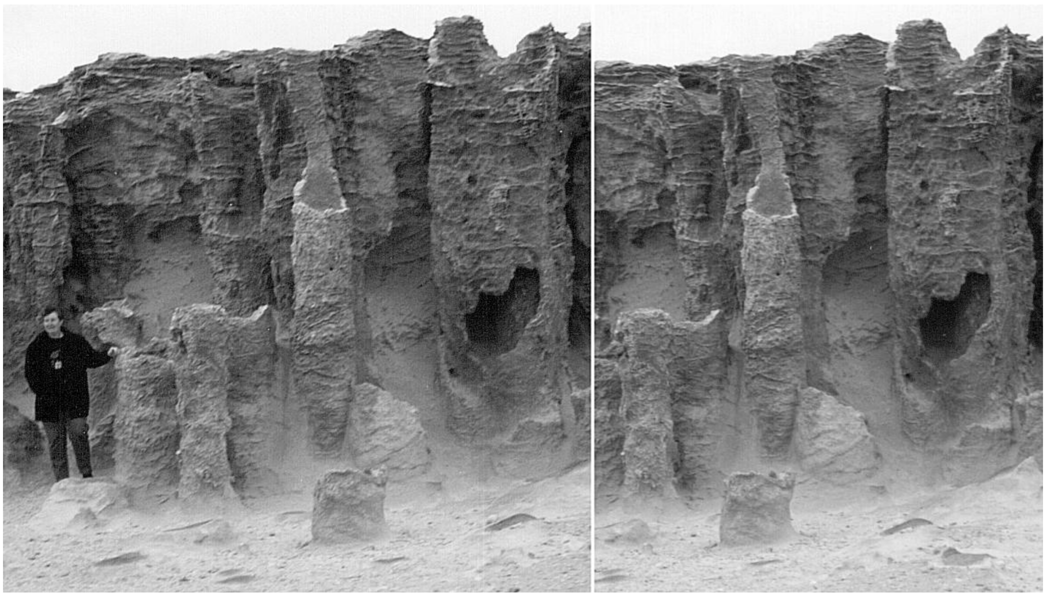

Figure 2: Solution pipes with cemented rims exposed by removal of less-cemented host sand (stereopair).

Figure 3: Red paleosoil with soil-filled solution pipes descending from it.

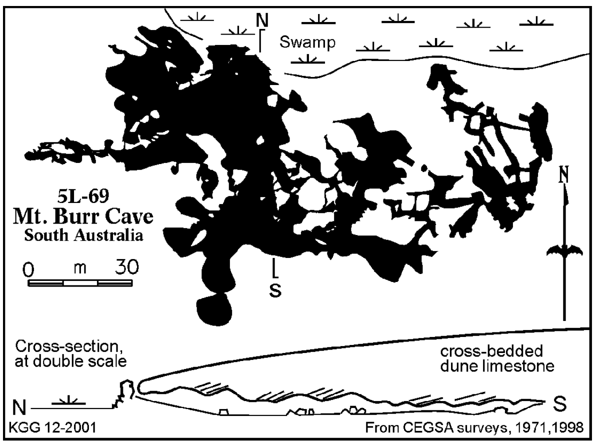

Figure 4: A typical horizontal syngenetic maze cave in dune limestone adjacent to a swamp.

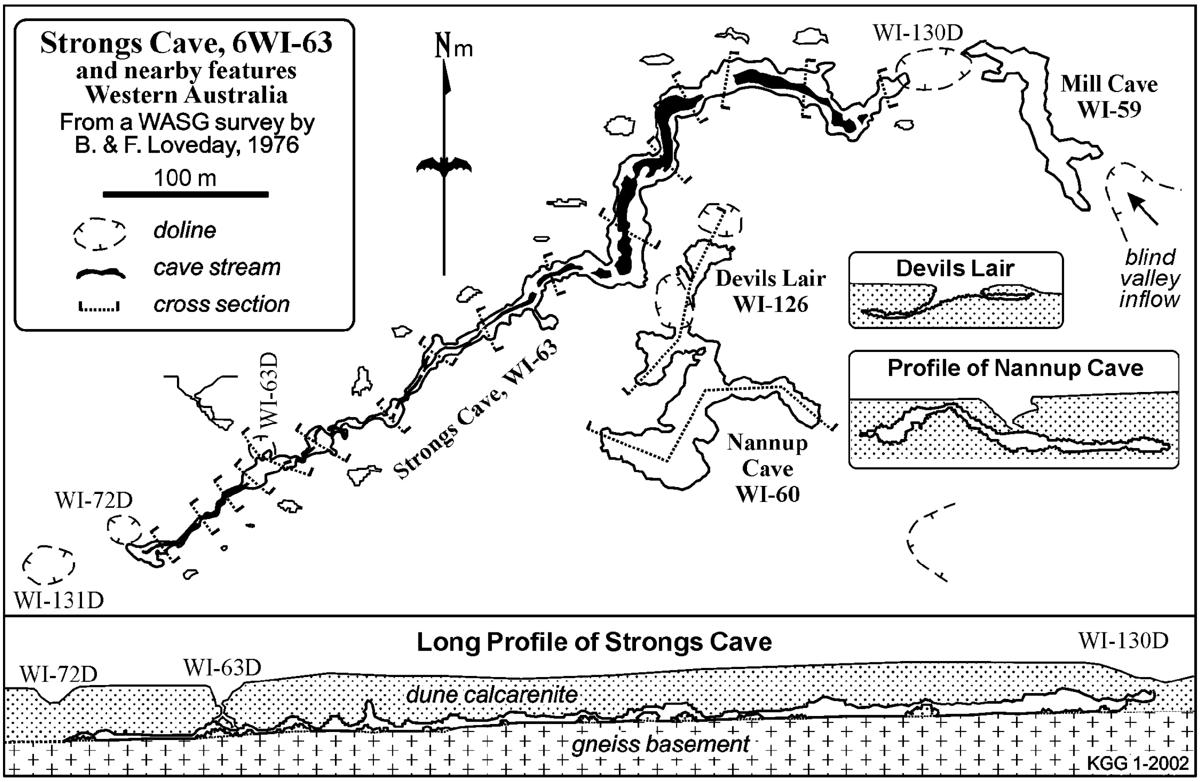

Figure 4: Strongs Cave is a linear stream cave that follows the basal contact between the dune limestone and impermeable gneiss. By contrast the main, western, part of Nannup Cave is more typical of caves in dune limestone; being a series of large collapse domes with little of the original dissolutional cave remaining.

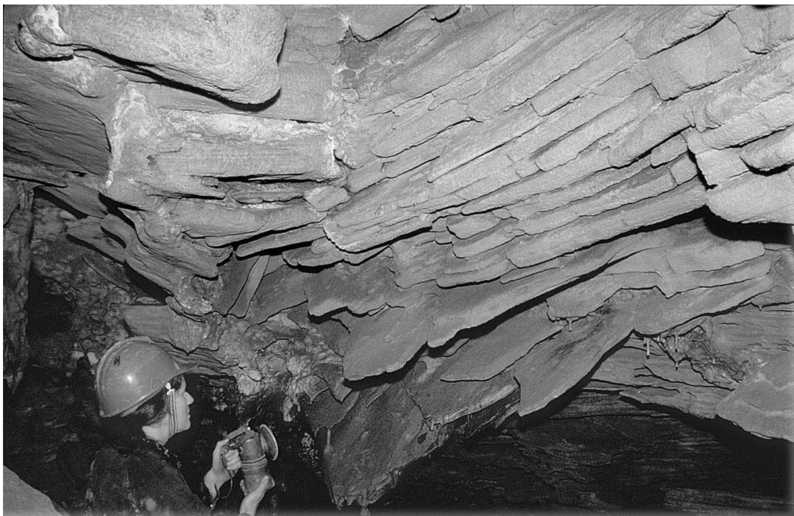

Figure 6: Subsidence structure in syngenetic karst. Thin horizontal beds of a beach calcarenite were partly cemented into individual plates that then subsided as dissolution undermined them. Continuing cementation stabilised the beds before the present cave formed.

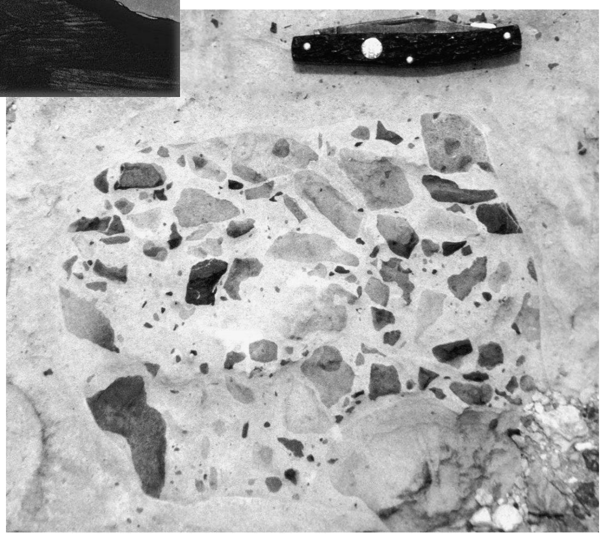

Figure 7: Calcreted, multi-generation, mantling breccia in dune calcarenite. The large, 20 cm, clast contains at least two earlier generations of smaller clasts.