THE EARLIEST TIME OF KARST CAVE FORMATION

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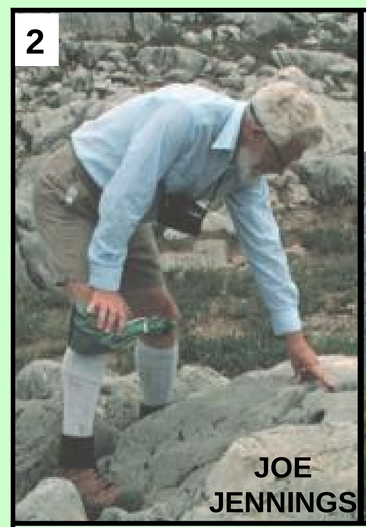
1 Abstract

The earliest cave genesis is *constructional cave* formation, as in tufa caves and reef macro-porosity, which occurs simultaneously with carbonate rock deposition but without *in situ* dissolution. *Syngenetic caves* form by dissolution in unlithified sediments, as *syndepositonal caves;* and by dissolution in lithified but diagenetically-immature carbonate rocks, as *eogenetic caves*. Carbonate burial results in diagenetic maturity, and produces *mesogenetic caves* by hypogenic processes. Re-exposure of diagenetically-mature carbonates on the earth's surface results in *telogenetic caves.* *Marble caves* form in metamorphosed carbonates derived from mesogenetic or telogenetic conditions.

KEYWORDS: carbonates, caves, constructional caves, diagenetic maturity, eogenetic, karst, syndepositional, syngenetic

2 EOLIAN CALCARENITES AND CAVES, MARGARET RIVER, WESTERN AUSTRALIA



Joe Jennings introduced the term "Syngenetic Karst" at a presentation in 1964, and subsequently published it in 1968. His definition was somewhat open-ended: "*To a certain degree karst processes have gone on concurrently with the consolidation of calcareous shell sand into aeolian calcarenite, i.e. the karst is partially 'syngenetic'.*" (Jennings, 1968, p. 41). This term arose out of work in Quaternary eolian calcarenites of southern and western Australia (Grimes, 2006), and was the first attempt to characterize cave and karst development in very young and diagenetically-immature limestones.

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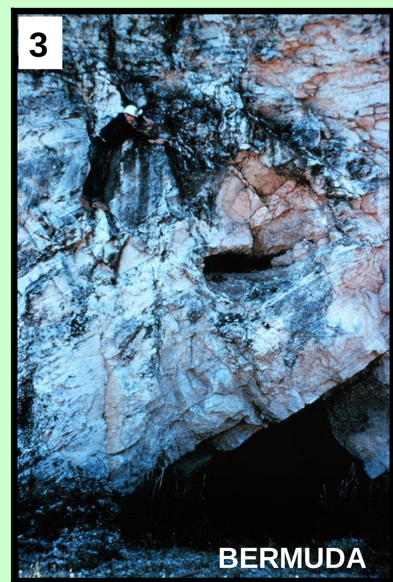
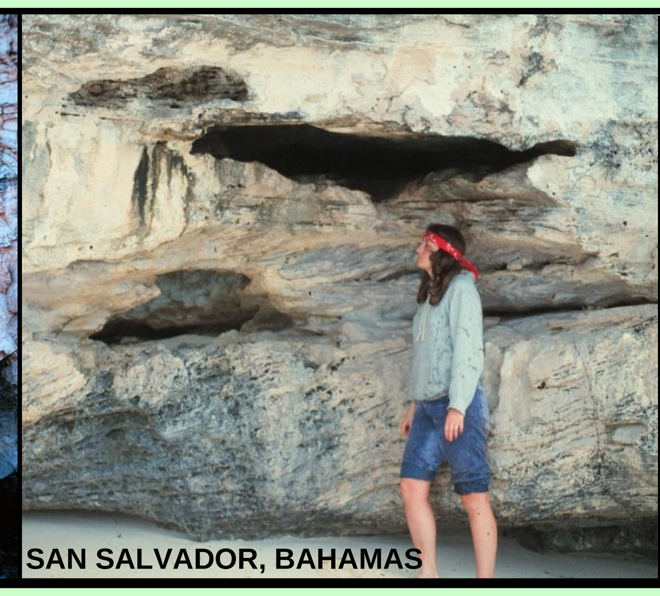
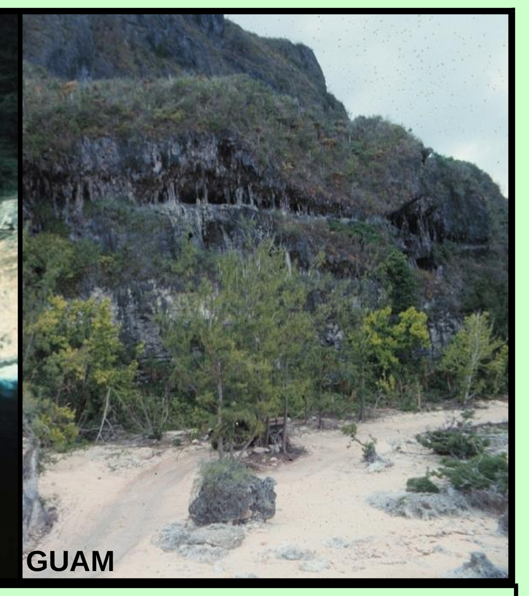






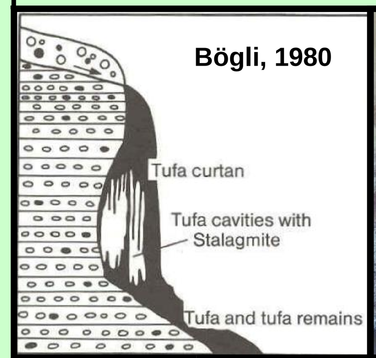
Since the 1960's, work has been conducted on caves in young, diagenetically-immature limestones from a variety of locations around the world, including eolian calcarenites from Bermuda and the Bahamas (Mylroie et al, 1995), and subtidal limestones from Isla de Mona (Frank et al, 1998) and Guam (Jenson, et al, 2006). Young limestones place a limit on how fast caves can develop, as the caves must be younger than the rock that hosts them. How quickly cave formation can initiate after limestone deposition occurs is also constrained by a very young limestone age. Jennings' (1968) definition of syngenetic caves is not sufficient to provide the resolution necessary for accurate description of cave formation as young carbonate rocks mature.

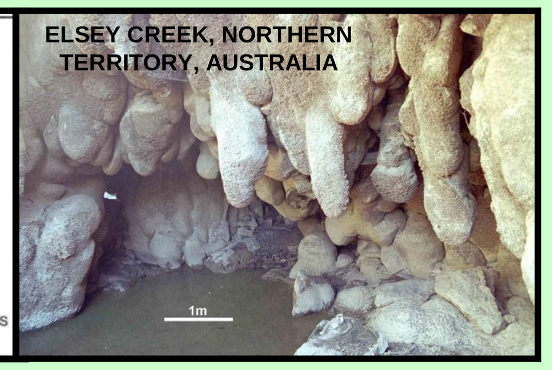
4

The purpose of this poster is to re-visit the term "syngenetic karst" with respect to a larger body of literature involving cave and karst development in young carbonates that has appeared since the 1960's, and to address the boundary condition of the earliest possible developmental time frame for initiation of karst caves. Carbonates have been selected as the representative karst rock to use in this presentation, as other common karst rocks (e.g. gypsum and halite) are not as easily discussed in terms of diagenetic maturity. A hierarchy of the maturity of the host carbonate rock is presented here: ⟶

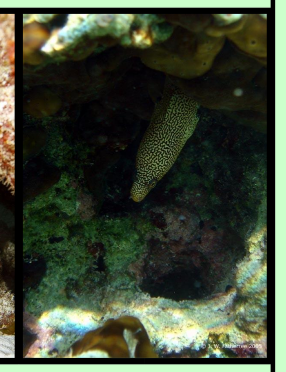
5 I. CONSTRUCTIONAL CAVES

I. CONSTRUCTIONAL CAVES: The development of a void or cave in a carbonate rock at the moment the rock is precipitated. Tufa caves are a subaerial example, and macroscopic voids produced by coral reef growth are a subtidal example. Constructional caves represent the earliest mechanism by which caves can form in carbonate rock, but they are not karst caves formed by *in situ* carbonate dissolution.





TUFA CAVE



REEF MACRO-POROSITY

PHOTO CREDIT: JAMES FATHEREE

6 II. SYNGENETIC CAVES

II. SYNGENETIC CAVES: The development of karst caves by dissolution in a carbonate material undergoing consolidation and lithification. There are two categories of syngenetic karst caves:

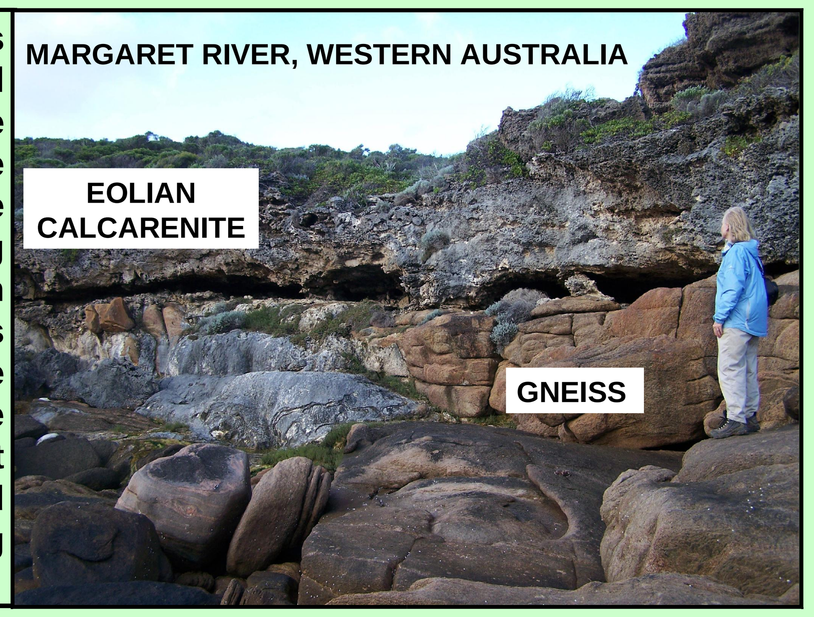
A) Syndepositional Caves - Karst caves formed by dissolution while the carbonate sediment is still being deposited. The carbonate material has sufficient consolidation to mechanically sustain the dissolutional voids produced.

B) Eogenetic Caves – Karst caves formed by dissolution in carbonate material that has consolidated and lithified to create carbonate rock, but rock which is diagenetically immature. This is the post-depositional environment, which contains a progression of carbonate rock maturation as stated by Choquette & Pray (1970, p. 215): "the time of early burial as *eogenetic*, the time of deeper burial as *mesogenetic*, and the late stage associated with erosion of long-buried carbonates as *telogenetic*". Vacher & Mylroie (2002, p. 183) defined "the term *eogenetic karst* for the land surface evolving on, and the pore system developing in, rocks undergoing eogenetic, meteoric diagenesis."

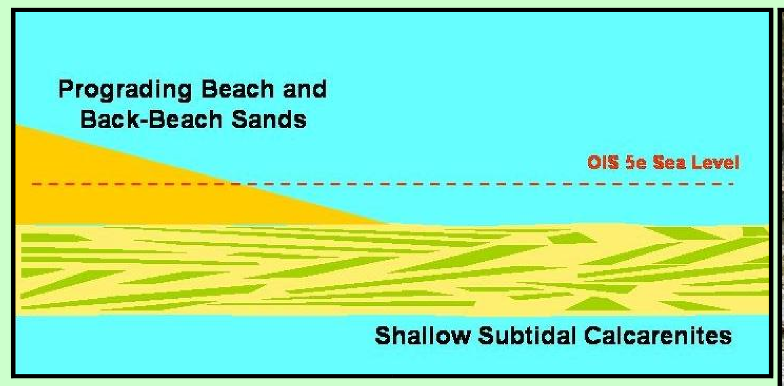
Using this broad model as a framework, syngenetic karst can be seen as the environment that includes the entire eogenetic stage of rock maturation, as well as the pre-rock stage of carbonate deposition and consolidation. The syngenetic environment, and the eogenetic stage, end when deeper burial occurs and the carbonate rock enters the mesogenetic realm.

7 EXAMPLES OF SYNDEPOSITIONAL CAVES

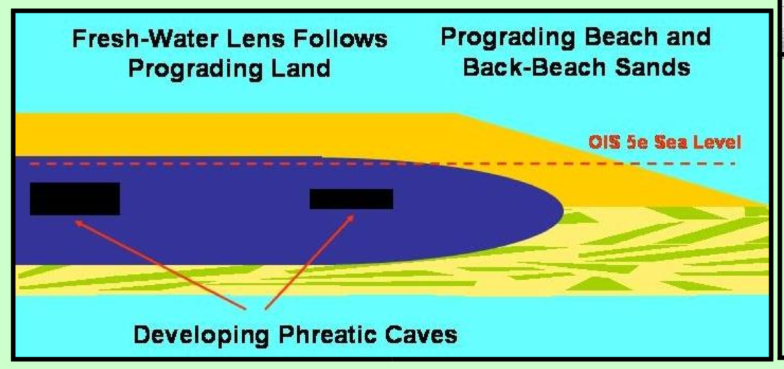
Hypothetical case: An eolian calcarenite is deposited across the axis of a small surface stream perched on non-carbonate rock. Dissolution could be initiated in the lower portions of the eolian body while the upper portions are still undergoing deposition. Once deposition of the eolian body ceases, a calcrete crust develops rapidly and stabilizes the dune and the eolian body has passed from the syndepositional cave-forming environment into the later post-depositional and eogenetic stage of the cave-forming environment.

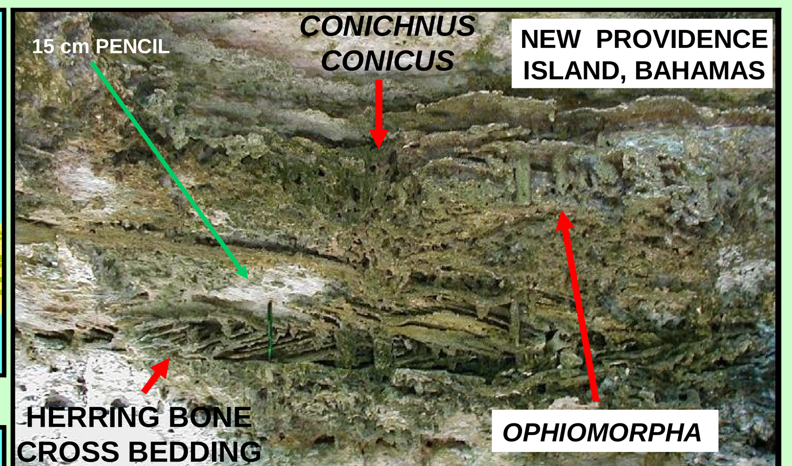


Subtidal Case: Lagoonal carbonates being overlain by beach sands. The seaward migration of the terrestrial beach environment allows the fresh-water lens of the coastal area to also extend seaward, and invade the now-covered lagoonal carbonates. Mixing dissolution creates voids within the lagoonal and beach facies even as the beach continues to grow above the incipient voids, and beach and lagoonal sediments are deposited in adjacent areas. Syndepositional caves have been described in the Bahamas from San Salvador (Florea, *et al*., 2004) and New Providence (Mylroie, *et al*., 2006).



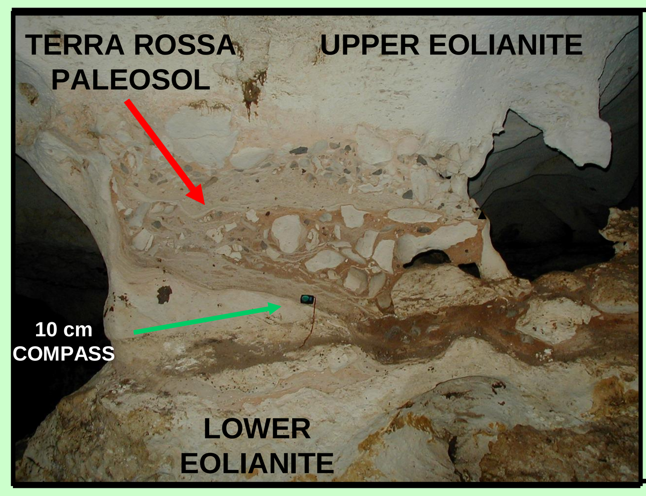
PROGRADING SANDS ALLOW KARST CAVES TO FORM



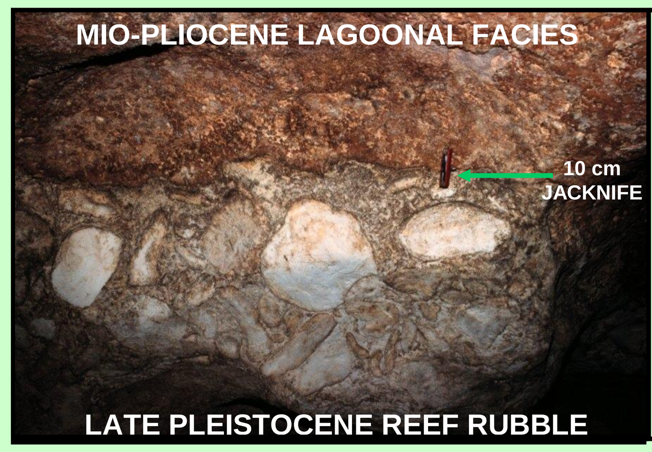


The bedrock that hosts the caves developed as lagoonal carbonates, as shown by trace fossils and bed forms. The only sea-level event that could both create the rock and elevate the fresh-water lens was the last interglacial highstand (OIS 5e) ~125,000 years ago, so the caves are syndepositional.

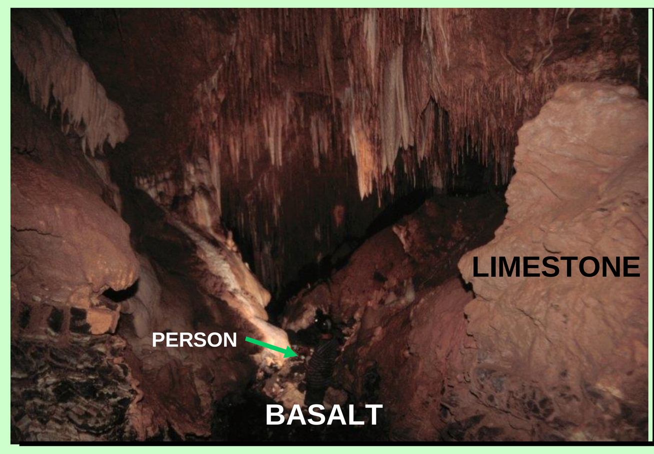
8 EXAMPLES OF EOGENETIC CAVES



Crooked Island, Bahamas, 1702 Cave has a dissolutional cave passage cutting through two dune sequences, with an included terra rossa paleosol. This sequence indicates that the rock was lithified but still not diagenetically mature at the time of cave formation, placing the karst cave in the eogenetic stage.



Cueva del Agua, Punta los Ingleses, Isla de Mona, PR shows cave development in Mio-Pliocene lagoonal facies; this initial eogenetic cave was infilled with Late Pleistocene reef rubble, and subsequent dissolution cut across both carbonate facies, producing a second eogenetic event.



Interesting Cave, on Guam, shows development of eogenetic cave passages in uplifted lagoonal carbonates, at the contact with underlying basalts. This setting resulted in cave development as perched vadose-water flow migrating down slope along the contact.

Bucara Cave, Fais Island, FSM, shows eogenetic cave development in uplifted reef carbonates. The cave's location is an indicator of past fresh-water lens outflow at this position.

9 III. MESOGENETIC CAVES

Carlsbad Caverns, New Mexico, USA, formed in the mesogenetic realm by mixing of fluids at depth; mesogenetic cave formation is an obligatory hypogenic process.

10 IV. TELOGENETIC CAVES

Devonian Onondaga Limestone of New York, USA, with a telogenetic cave formed in carbonate rocks uplifted from the mesogenetic realm into the epigenic environment.

11 V. MARBLE CAVES

Ordovician marble, Norway, hosting a marble cave in the epigenic environment of the telogenetic realm. Marble can also host caves in the mesogenetic realm.

PHOTO CREDIT: Art PALMER

12 CONCLUSIONS

The relationship of earliest time for the development of karst caves to the deposition of the carbonate sediments that host karst caves, and the subsequent stages of karst cave formation, are as follows:

I. *Constructional Caves* are the earliest possible type of cave to form when carbonates are deposited, but they are not karst caves produced by *in situ* dissolution. Tufa caves and coral reef macro-porosity are examples.

II. *Syngenetic Caves* are those produced during the consolidation, early diagenesis, and initial lithification of carbonate sediments. They fall into two categories:

- A) *Syndepositional Caves* form as the body of carbonate sediment is being deposited, as the very earliest diagenesis and consolidation allow mechanical support of the dissolutional void produced, even as carbonate deposition continues uninterrupted at that site.
- B) *Eogenetic Caves* form in carbonate rocks after deposition of the unit ceases, and lithification and diagenesis continue under meteoric conditions.

III. *Mesogenetic Caves* form after burial removes carbonate rocks from epigenic, meteoric diagenesis, and hence the syngenetic and eogenetic realms. The isolation from meteoric waters results in mesogenetic cave formation being an obligatory hypogenic process.

IV. *Telogenetic Caves* form after uplift and surficial exposure of formally mesogenetic carbonate rocks to epigenesis.

V. *Marble Caves* form after metamorphism of the carbonate rocks, can start from either the mesogenetic or telogenetic realm, and can occur in either hypogenic or epigenic environments.

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