SURFACE AND VADOSE IMPLICATIONS OF KARSTIFICATION IN EOGENETIC CARBONATES

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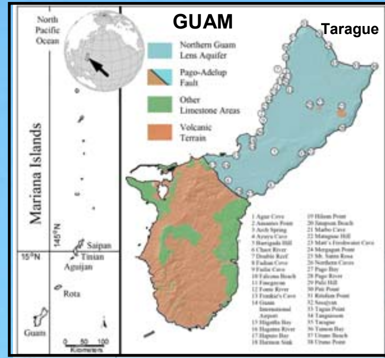

ABSTRACT

Eogenetic karst has gained much attention over the past decade with research being done in young, diagenetically immature carbonates in Florida, Yucatan, and carbonate islands world-wide. These projects have focused on phreatic fresh-water flow, mixing effects, speleogenesis, aquifer response and storage, and contaminant transport. Less well studied are the outcomes of surface karstification and subsequent vadose flow. Exposed eogenetic carbonates develop an epikarst quite different from that found on telogenetic carbonates. Eogenetic properties (retention of primary porosity, maintenance of allochem heterogeneity, and differential cementation) are essential to the development the unique karren landforms found on young carbonate surfaces, especially in coastal areas, which are not solely caused by biological action as commonly believed and expressed by the term "phytokarst". As eogenetic carbonates mature and approach telogenetic properties, their karren forms become more like classical examples from continental interiors. These results indicate that it is the tropically controlled depositional environment of eogenetic carbonates, rather than the tropical denudational climate, that makes eogenetic karren unique. The relative spatially uniform surficial denudation of eogenetic carbonates has lead researchers to underestimate denudation rates, producing incorrect sea-level positions from measurements of Pleistocene fossil coral terraces. The ~30% matrix porosity of young eogenetic carbonates leads to rapid (~64 mm/ka), but unfocussed, denudation that creates a uniform surface lowering (lowering exceeds observed pinnacle relief), as demonstrated by tropical Karrentisch on Guam. Below the surface, vadose flow is a mix of diffuse flow that on Guam can take up to 20 months to traverse a 100-150 m vertical section (70%), and pipe flow down vadose fast-flow routes, or pit caves, that arrives at the water table within a few hours or perhaps even minutes of the meteoric event (30%). In very young eogenetic carbonates, the high amount of depositional aragonite creates vadose flow that contains levels of Sr an order of magnitude greater than from older rocks (>2 Ma), potentially leading to incorrect trace element interpretations compared to speleothems in caves formed in older carbonates.

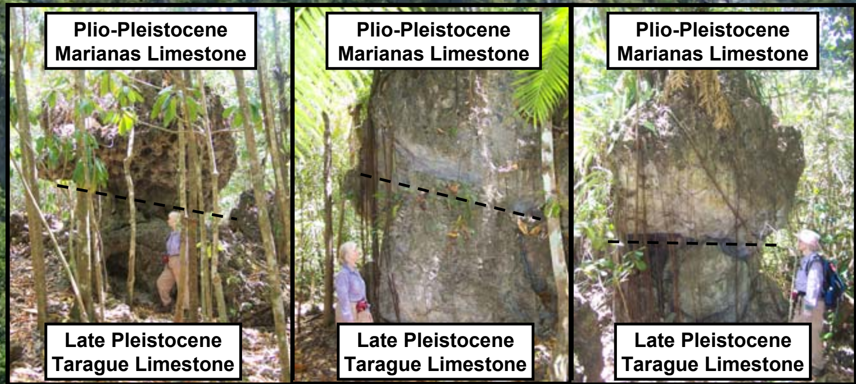

Figure 2: Three examples of *Karrentisch*, limestone pedestals covered by a less soluble cap rock. In these cases, the cap is a diagenetically mature Marianas Limestone boulder that fell onto a plain made of (MIS 5e) Tarague Limestone. The dashed line shows the top of the Tarague, and the minimum amount of denudation since MIS 5e.

Plio-Pleistocene Marianas Limestone cliff, source of the karrentisch cap boulders.

Late Pleistocene Tarague Limestone bench, on to which the boulders fell

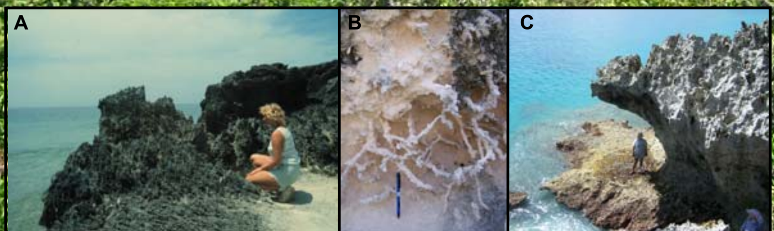

Figure 1: Karren in eogenetic settings, once described as *phytokarst* by Folk et al. (1973), now termed *eogenetic karren* (Taboroši et al. 2004), to recognize not only the biological contributions, but also grain heterogeneity, diagenetic immaturity, and mixing chemistry as controls of form. A) Irregular, jagged form of coastal karren in eolianite, Bahamas; B) Rhizomorphs in a Bahamian eolianite, showing influence of differential cementation; C) Irregular, jagged surface, coastal cliff in reef limestone, Guam.

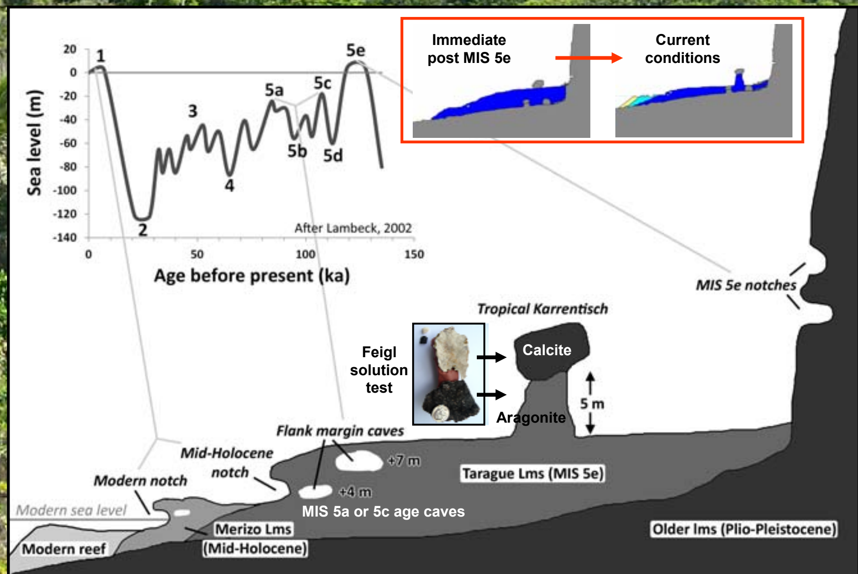

Figure 3, left: Sea level data from the Tarague bench on Guam. The Karrentisch give a minimum value for denudation; notches in the Plio-Pleistocene cliff give a true measure of past sea-level position and subsequent $CaCO_3$ denudation. The flat morphology of the Tarague bench can give the appearance of a depositional surface, leading to an incorrect interpretation of past sea-level position at this locality and by extension, Quaternary fossil reefs around the world.

Folk, R. L., Roberts, H. H. and Moore, C. H., 1973. Black Phytokarst from Hell, Cayman Islands, British West Indies. Geological Society of America Bulletin, v. 84, p. 2351-2360

Taboroši, D., Jenson, J.W. and Mylroie, J.E. 2004, Karren features in island karst: Guam, Mariana Islands: Zeitschrifft fur Geomorphologie. N.F. 48: 369-389.

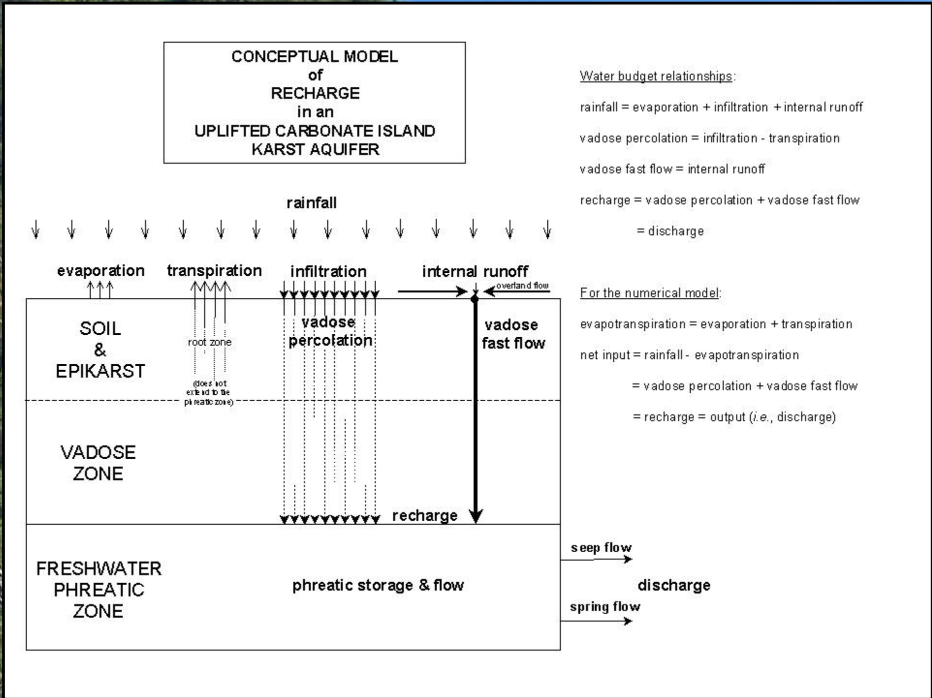

Figure 4: Unlike dense telogenetic limestones, eogenetic limestones retain significant primary porosity and associated permeability, which results in substantial slow vadose percolation as the majority recharge condition. Vadose fast flow, down pits and similar vertical conduits, accounts for only 30% of the recharge. Percolation flow can take 20 months to traverse 100 to 150 vertical meters, whereas fast flow can travel the same distance in minutes or a few hours.

Figure 5: A) Injection wells acting as artificial vadose fast flow routes at Anderson Air Force Base, northern Guam. The wells deliver runoff from the runway directly to the deep aquifer. B) Natural vertical shaft, acting as a 40 m deep vadose fast flow route, Amantes Point, Guam.

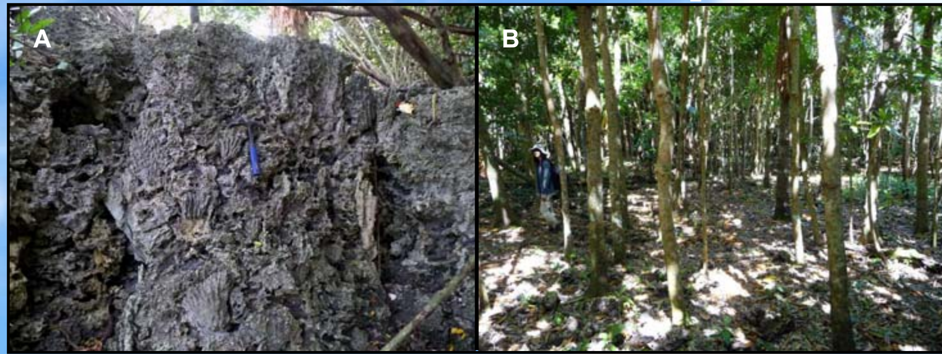

Figure 6: A) Outcrop of the Tarague Limestone, showing coral heads. Aragonite ranges from 23 to 97%, Calcite 1 to 77%, and High-Mg Calcite 1 to 40%. B) The flat Tarague Limestone plain at the foot of the cliffs. This plain slopes slightly inland, but represents the denudation surface after loss of up to 8 m.

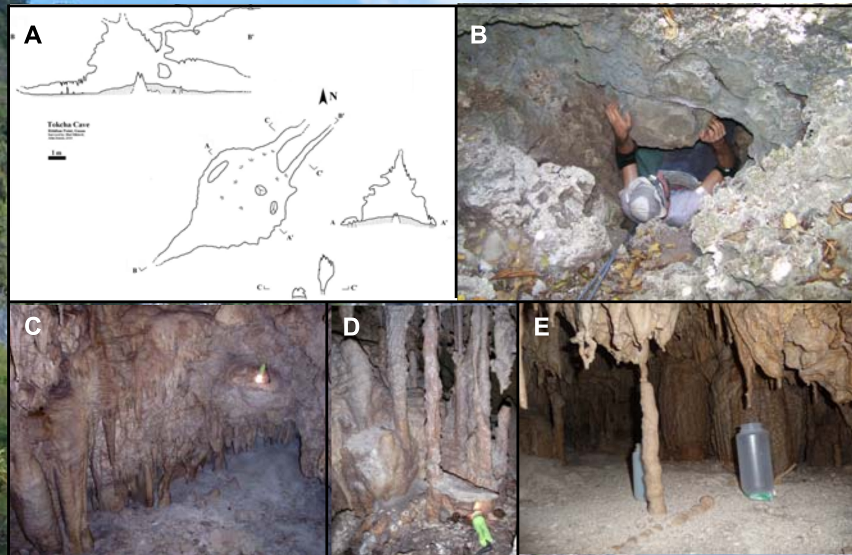

Figure 7: A) Map of Tokcha Cave, developed in the Tarague Limestone. B) Tight, awkward entrance. C) Typical cave chamber, note sand on floor entombing stalagmites. D) Stalagmite sampled for study. E) Drip water collection; note again sand covering the base of the stalagmite.

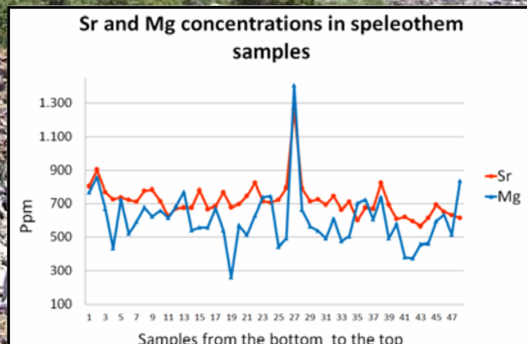

Figure 8: Plot of Mg and Sr variation with stalagmite height in Tokcha Cave. Oldest U/Th date is 36 ka. The Sr levels are 3 times those found in stalagmites from caves on Guam developed in older (all calcite) limestones, while Mg levels are only a third, indicating significant Sr enrichment. The drip water Sr concentration was 8 times that of drip water from older Guam caves. Use of Sr as a paleoclimatic indicator in tropical settings requires knowing the diagenetic state of the host rock.