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A NEW MORPHOLOGY OF BEACHROCK: STALACTITIC DEPOSITS OF LITHIFIED BEACH SAND

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ABSTRACT

Beachrock deposits can be extremely variable in terms of composition, grain size, and cement mineralogy, but are consistent in overall morphology, taking the form of lithified, gently-dipping strata. On the island of Tinian (Mariana Islands), however, in addition to the conventional beachrock deposits, certain pocket beaches exhibit unusual stalactitic features, which are morphologically unique, but can be petrologically indistinguishable from beachrock.

INTRODUCTION

Beachrock is lithified beach sand, commonly composed of sand grains cemented by $CaCO_3$ (Scoffin and Stoddart, 1983). Beachrock is highly variable in composition, grain size, and mineralogy, but is characteristically consistent in morphology, taking the form of subhorizontal layers of cemented beach sand dipping gently toward the sea (Bernier and Dalongeville, 1996).

Beachrock appears to be a group of allied, but diverse deposits. Disparities related to composition (e.g., Strecker et al., 1987), grain size (e.g., Scoffin, 1970), cement mineralogy and origin (Scoffin and Stoddart, 1983), and climatic (e.g., Kneale and Viles, 2000) and hydrologic settings (e.g., Binkley and Wilkinson, 1980) have all been reported. However, the morphological aspect of beachrock is quite constant and although variations exist in bedding (e.g., Boekschoten, 1962), thickness, and secondary shaping by waves and swash (e.g., McLean, 1967), beachrock deposits consistently take the form of beds or slabs. Nevertheless, a particular combination of local factors can result in deposits petrologically analogous to beachrock but which exhibit an utterly different appearance.

METHODOLOGY

Fieldwork was carried out in December 2002 and May 2003, as a part of a project to inventory the karst features of Tinian (Mariana Islands, western Pacific; for location see inset in Fig.1 in Taboroši et al., this volume). During field reconnaissance of elevated marine notches, conspicuous secondary deposits attached to coastal rock overhangs were recognized and were sampled with hammer and chisel. Samples were cut, dried, and examined macroscopically and with a binocular scope. Then a detailed study was conducted of resin-impregnated petrographic thin sections, using conventional transmitted-light microscopy and SEM microscopy of small fragments sputter-coated with platinum.

RESULTS

Coastal cliffs and scarps on Tinian and other tropical carbonate islands sometimes exhibit unusual stalactitic and drapery-like secondary deposits reminiscent of speleothems. Termed "littoral dripstone and flowstone" (Taboroši et al., 2003), these deposits are a unique coastal variety of outside tufa stalactites commonly seen plastered to limestone cliffs in the humid tropics (Taboroši et al., 2004a; Taboroši and Hirakawa, 2005). Composed of poorly organized microcrystalline calcite and aragonite, these rudimentary deposits arise from the same underlying mechanisms as typical carbonate speleothems, but exhibit a tufaceous and highly irregular makeup (rather than macrocrystalline), due to the specific microclimatic and biologic conditions operating in coastal epigean settings (Taboroši et al., 2005). Surprisingly, we have observed that, in certain cases, these coastal "stalactites" are composed of cemented beach sand instead of the wholly precipitated microcrystalline calcareous tufa-like material as expected.

Shaped like bulbous stalactites and draperies up to 25 cm wide and long, the cemented sand features occur attached to the roofs and walls of coastal notches (Figure 1). They are easily identified as deposits secondary to the bedrock to which they are attached. They are superimposed on bioerosional and dissolutional karren (Taboroši et al., 2004b), and their dark exterior coloration, caused by well developed supratidal biofilms, can be in stark contrast to the surrounding rock. The incidence of these cemented sand deposits is highly localized. They are found exclusively at elevations up to 2 m above the mean sea level in those coastal notches that partly extend above unconsolidated beach sand, a situation common in alcove beaches. These deposits are superficially identical to littoral dripstone and flowstone, and their outermost parts are often composed of the same material, layered tufa, which envelops the cemented sand bodies.

The makeup of the lithified sand mass reflects the composition of carbonate beaches on Tinian and consists of cemented, locally-derived fossiliferous grains, including foraminiferal tests and fragments of scleractinian corals, calcareous algae, gastropods, and bivalves (Figure 2). The grains are generally coated with microcrystalline cement of variable thickness, and locally surrounded by isopachous rims of acicular cement (Figure 3) as in typical beachrock (Scoffin and Stoddart, 1983). The two types of cement frequently occur in succession, forming up to four sequences, similar to what has been reported by Bernier et al. (1990) in beachrock from Tahiti. The cement also occludes intergranular and intragranular pores and exhibits meniscus and rim shapes, which are indicative of vadose conditions (Meyers, 1987). The mineralogy of the cement is low-Mg calcite (typical of meteoric environments) and aragonite (indicating marine influence).

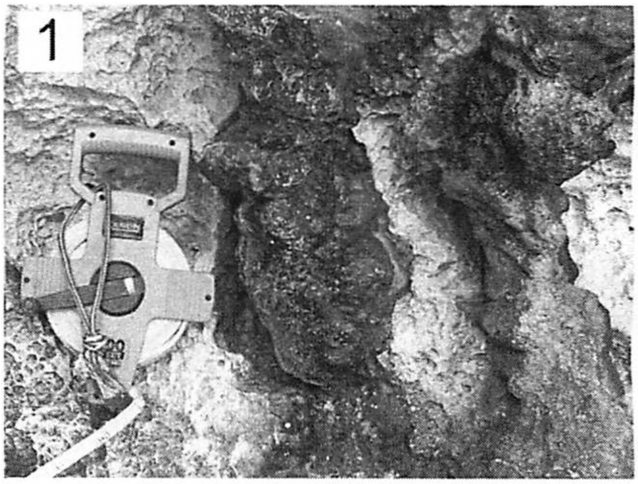

Figure 1. Stalactitic deposits of cemented beach sand in situ. They are attached to the roof and back wall of a coastal notch. Note their position superimposed on karren, and the dark color in contrast to the bedrock. Tape reel is 14.5 cm in diameter.

DISCUSSION

The origin of these deposits is rather obvious from the fact that they never cover wide tracts, as normal beachrock does, but instead hang from distinct points in the coastal notch ceilings. Shifting of beach sands can fill coastal notches, placing unconsolidated sand beneath the vadose zone of an indurated bedrock outcrop. As vadose water (both meteoric precipitation as well as sea spray) percolates directly into the beach sediment from the pores or cracks in the overhanging bedrock, CO_2 degassing, which has been experimentally demonstrated by Hanor (1978) as sufficient to cause beachrock cementation, triggers the precipitation of calcium carbonate which acts as cement. Only sand close to the input source is cemented, as precipitation ceases when the dissolved calcium carbonate is consumed, leaving the surrounding sediment uncemented. The resulting lithified sand bodies are revealed once the loose beach sediment is removed by storm events or relative sea level changes. They continue to form in the absence of loose sand by addition of tufa-like layers of microcrystalline calcite precipitated from dripping epikarstic water.

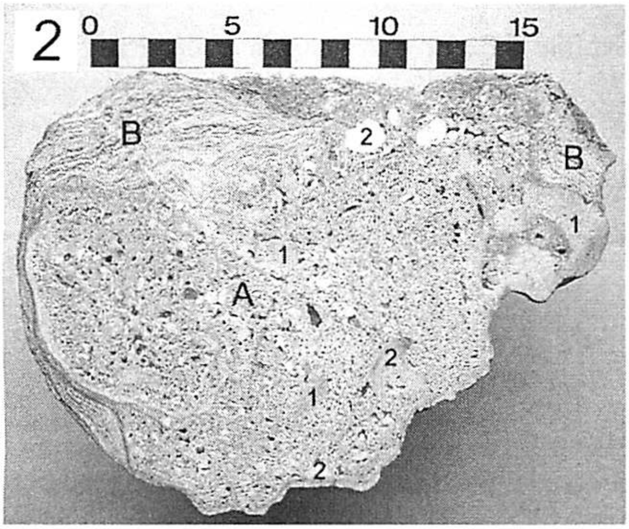

Figure 2. Cross-section of the bulbous specimen illustrated in Figure 1. Note that it is predominantly composed of cemented unsorted beach sand. The smallest particles are mostly tests of benthic foraminifera, while the largest are fragments of corals (1) and mollusks (2). Surrounding the cemented sand mass (A) is an outer envelope of layered microcrystalline tufaceous material (B) that is devoid of any pre-existing grains and was entirely precipitated in situ. Scale in centimeters.

CONCLUSION

Despite no genetic relations, these unusual deposits convincingly mimic beachrock and are hereby termed "beachrock pendants". They are genetically related to and morphologically reminiscent of stalactites, but are petrologically indistinguishable from beachrock. Regardless of whether their incidence proves to be scarce and highly localized or geographically widespread but previously unrecognized, they provide a valuable insight into carbonate cementation under conditions of point input of vadose groundwater directly into beach sediment. Downward percolation of vadose water is generally not considered important in beachrock cementation, but has been recognized as a possibility by Russell (1962).

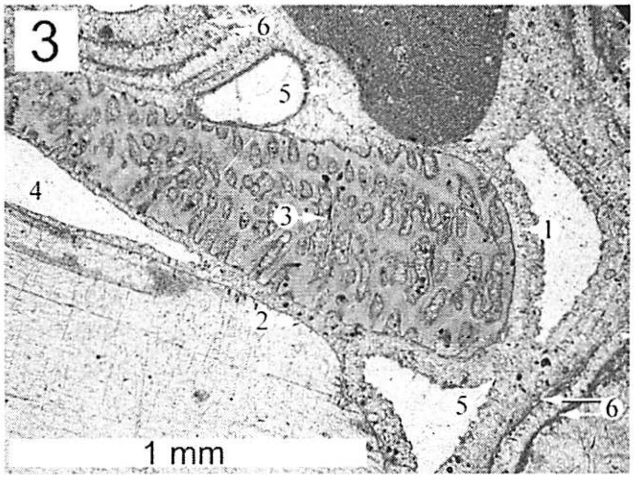

Figure 3. Thin-section photomicrographs of cemented material impregnated with clear, undyed epoxy resin. Note that the skeletal grains are cemented by isopachous rims of acicular cement (1), underlain by pronounced dark layers of micrite (2). The rims probably formed by microbial activity and then served as nucleation sites for crystals. Also note the complete infilling of intragranular pore space (3), the remaining empty intergranular space (4), meniscus cement typical of vadose conditions (5), and multiple layers of microcrystalline and acicular needle cement (6).

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