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EXPOSED BEACHROCK: ITS INFLUENCE ON BEACH PROCESSES AND CRITERIA FOR RECOGNITION

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ABSTRACT

Beachrock forms where sediment is cemented within the beach deposit beneath a thin cover of sediment. In this buried state, sand no longer experiences transportation. Carbonate-rich water from adjacent land migrates through and cements these sands. Short-term erosional conditions along a coast exhume this lithified sand and result in the presence of exposed beachrock.

Beachrock modifies the beach environment by providing a rocky-bottom near shore where previously sandy sediment existed. This change in substrate causes a change in the shorezone population from one that preferred a sandy bottom to one which prefers a firm substrate. As a result encrusting and boring organisms invade and leave their skeletons in the accumulating beach sediment.

As a result of the lithified buttress which beachrock provides, the beach is somewhat more protected from erosion, however water depths increase more rapidly offshore because unlithified subtidal sands are eroded. Wave energy therefore decreases more drastically over the beachrock resulting in an accumulation on the beach of less sorted, coarser bioclastic material which is derived from the rocky-bottom population. Clasts of beachrock likewise become incorporated in beach sediment.

Criteria for recognizing the presence of exposed beachrock in a beach deposit include: 1) occurrence of rocky bottom fauna and flora, 2) low profile growth forms of larger fauna such as coral, 3) micritized bioclastic texture, 4) recognition of marine cement, 5) borings into beachrock, 6) increase in grain size, 7) decrease in sorting, 8) inclusion of chaotic blocks of beachrock, and 9) possible darkening of beachrock surface. These features must occur within a beach-subtidal sequence of deposits otherwise they might represent merely a marine hardground.

INTRODUCTION

Beachrock was first described more than 80 years ago (Branner, 1904) and since then innumerable papers have described beachrock in various settings from around the world. While beach sediment can be cemented rapidly under a wide range of conditions, beachrock most commonly occurs along carbonate coasts in tropical and subtropical climates. Most papers published in the past 50 years have suggested mechanisms for rapid cementation of beach sediment. Bathurst (1975) reviews proposed mechanisms for beachrock formation. Scoffin (1987) provides a brief but more up-to-date review of mechanisms but overemphasizes the importance of unusual or less common occurrences of beachrock and also fails to recognize that intertidal beachrock is commonly associated with supratidal-cemented sediment which Kuenen (1933) referred to as "cay sandstone". It is indeed common to find beachrock cemented by aragonite and/or Mg-calcite as Scoffin indicates but it is also common in tropical-subtropical carbonate beach deposits to find associated coastal deposits cemented by sparry calcite. It is this author's opinion that the mechanisms described by Moore & Hanor (1974) and Hanor (1978) adequately explain such cementation. Hanor (1978) and Moore & Hanor (1974) suggest that meteoric water which resides in landward carbonate deposits dissolves aragonitic carbonates. Upon migration seaward, possibly due to recharge of groundwater, this carbonate-rich water precipitates $CaCO_3$ within shallow-buried beach and lower dune sediment, either as a result of mixing water (Moore & Hanor, 1974) or degassing of CO_2 (Hanor, 1978). The purpose of this paper is not to explain mechanisms of cementation but rather to analyze the importance of beachrock in terms of beach processes, beach deposits and the interpretation of beach deposits in the geologic record.

In order to appreciate the role of beachrock one must first recognize that beachrock does not form in the setting in which it is generally observed. The exposed nature of beachrock is secondary to its original creation. Beachrock forms when beach sediment, generally medium- to coarse-grained carbonate sand, is cemented in the shallow subsurface (<1 meter). Cementation occurs beneath a thin cover of sediment where it is not actively being transported or reworked. The zone of cementation extends from subtidal to lower dune. In a matter of a few years inactive beach sediment can be cemented sufficiently such that upon exhumation it resists erosion by normal beach energy. Until such time it is exhumed, it does not represent beachrock, only rapidly cemented beach sediment. Its impact on beach processes and beach deposition occurs only upon exposure.

Removal of the thin cover of sediment thus exposing weakly cemented beachrock initiates modification of the beach rock. If cementation is insufficient to withstand erosive forces of the beach environment there will be little effect and no record of this early cementation. If, on the other hand, cementation is sufficient to hold sand grains in place, exposure can lead to numerous changes in the beachrock, the associated beach environment and beach deposit.

Beachrock exposed to sea water undergoes several modifications which readily distinguish it from beach sediment which was cemented but never experienced later exposure. Exposed beachrock is hardened by micritization (Bathurst, 1975). Micritization is the result of biochemical activity of organisms, fungi and algae in particular, and possible physio-chemical precipitation of additional micritic cement. The hard substrate of beachrock provides a surface which is inhabited quickly by encrusting and boring organisms. Probably as a result of endolithic algae and fungi the exposed beachrock is darkened to a depth of several millimeters. While beachrock may gain additional material during exposure as a result of encrustation and additional cementation, erosion dominates in the total modification picture and, in general, beachrock volume decreases. Bioeroders bore, scrape and bite to reduce the volume of rock but, to even a greater degree, physical forces erode and transport beachrock.

Exposure of beachrock also results in modification of the beach environment in terms of substrate, biota, sediment grain size and composition, and shoreline progradation rates. Prior to the exposure of beachrock the beach/shore environment consists of a sandy substrate. With removal of the thin sediment cover and exposure of the semi-lithified beachrock, a hard substrate is present inviting an invasion by a new population. The sandy bottom likely would be dominated by burrowing organisms whereas the hard substrate is populated by encrusting coral, barnacles, algae, fungi, pelecypods, gastropods and worms. Boring organisms such as barnacles, pelecypods, worms, sponges, algae and fungi as well as grazing gastropods, echinoids and chiton also inhabit the rocky bottom. The presence of these organisms in turn modifies the composition of sediment produced locally since their skeletons will be either encrusted onto the beachrock or incorporated into associated sediment. As a result of the incorporation of large skeletal fragments and large clasts of beachrock into beach sediment, grain size increases and the degree of sorting decreases.

On a larger scale shoreline progradation rates may also be altered in favor of more rapid shoreline accretion. Where beachrock is exposed by temporary erosional conditions, the beach will be somewhat protected and shoreline erosion will be less than on a beach that is not protected by exposed beachrock. Therefore when depositional conditions return the net effect will be a more rapid seaward advance of beach sediment.

Failure to recognize beachrock in a sedimentary sequence could lead to the misinterpretation of conditions and timing of deposition as suggested by Strasser and Davaud (1986). A rocky substrate provided by beachrock and associated change in biota could be misinterpreted as a major change in water depth and energy. The textural and stratigraphic features could be mistaken for a record of sea level change, a diastem or perhaps an unconformity.

BEACHROCK ON SAN SALVADOR

General

Exposures of beachrock are common along the coasts of San Salvador. Exposures along the shore of Grahams Harbour near the CCFL Field Station and near the Government Dock on French Bay on the southwest shore were studied in detail. Both areas offer not only beachrock as described by other workers (ie. cemented intertidal sediment) but also the "cay sandstone" of Kuenen (1933) where sediment of the upper beach and lower dune is cemented.

At French Bay, depending on existing conditions, beachrock may be exposed from subtidal to lower dune or it may be nearly entirely buried. Conditions vary tremendously such that sediment cover changes daily. Generally cemented supratidal beach sediment is covered by less then .5 meters of sand and weakly cemented dune sediment is exposed at several locations 200 meters west of the dock (Fig. 1). Subtidal and intertidal beachrock is exposed for a distance of several hundred meters west of the dock (Fig. 2). The intertidal beachrock of French Bay is a textbook example. It consists of three sets of laminated carbonate sandstone beds which lie perfectly parallel to the present beach face, dip seaward at the same angle and consist of sediment nearly identical to modern beach sand. Fenestral porosity indicative of intertidal deposition is common (Fig. 3). While laminae are present in beachrock from subtidal to supratidal (Fig. 4), the lithified dune deposits generally lack laminae perhaps as a result of root action or bioturbation (Fig. 1).

At Grahams Harbour directly north of CCFL beachrock is widely exposed and lithified sediment is continuous from subtidal to supratidal dune deposits. It appears that several generations of lithified deposits exist along the coast, however it is believed that conditions under which lithification occurred did not differ from those presently observed.

Cement

Samples of lithified beach and dune sediment were studied in thin section in order to examine the nature of cement. Samples were collected from subtidal to dune at both locations. At French Bay sand grains in the subtidal to lower supratidal beach are cemented by isopachous micritic Mg-calcite. Upper beach and dune sand is weakly cemented by isopachous and meniscus calcite microspar. Grahams Harbour beachrock is cemented by isopachous acicular aragonite. Subtidal samples are weakly cemented by discontinuous less well-developed cement whereas intertidal (yellow zone) and supratidal (black zone) samples show a more extensive growth of isopachous aragonite cement. Upper beach and dune samples are cemented by both isopachous and meniscus sparry calcite. Grahams Harbour dune samples are older and much more indurated than French Bay samples. Sand of French Bay dunes is still being reworked.

In reviewing mechanisms for cementation, Hanor (1978) provides an adequate model which will produce the characteristics of these deposits. Because cements are forming above high tide as well as below and because cements are not only aragonite and/or Mg-calcite but also calcite, evaporation of sea water is not a satisfactory mechanism by itself. At both French Bay and Grahams Harbour broad areas landward of the beach provide porous reservoirs for groundwater. As groundwater migrates into the subsurface and seaward, CO_2-content increases and temperature decreases resulting in the dissolution of less stable carbonate materials. When these carbonate-enriched waters reach the coast, temperature increases, CO_2-content decreases (Hanor, 1978) and possible mixing of fresh water and seawater (Moore & Hanor, 1974) results in the precipitation of calcium carbonate which cements sand grains of the basal dune to subtidal sediment. Other mechanisms might work also but mechanism of beachrock formation is not the topic of this paper. Instead let us look at the influence of beachrock on beach processes and beach deposits.

Exposed Beachrock

The exposed nature of beachrock does not represent the environment in which it forms but instead results in modification of beachrock which was previously cemented beneath beach sediment. This modification includes a slight increase in volume of rigid beachrock through encrustation by organisms, a more significant reduction in beachrock volume as a result of erosion and bioerosion, and increased cementation resulting from biochemical and physio-chemical precipitation and alteration.

Where beachrock becomes exposed because surficial beach sand is eroded, encrusting organisms quickly occupy the newly exposed firm substrate. Vermetid gastropods (Fig. 5) occur most commonly encrusting beachrock in areas below low tide. As a result of this encrustation, beachrock increases in volume as encrusting masses of aragonitic skeletons attain thicknesses of 10 cm or more. In addition to the skeletal mass, sediment which fills between and within the gastropod skeletons also increases beachrock volume.

Red algae likewise quickly inhabit the new rocky substrate adding to rock volume and rigidity. Serpulid worms cement their calcareous tubes to the exposed underside of beachrock slabs. Barnacles locally can be quite abundant. Coral encrust subtidal exposures (Fig. 6) and spread in low-profile growth forms taking advantage of the high energy and firm substrate. Pelecypods attach to the beachrock especially wedging into depressions and crevices.

While encrustation is most common on the upper surface of beachrock, lower exposed surfaces are repleat with borings (Fig. 7). These organisms by their action remove rock material and their occurrence leads to further physical erosion. Boring pelecypods, barnacles, algae, fungi, worms and sponges weaken beachrock which results in more rapid erosion. Grazing organisms, in particular echinoids, chiton, gastropods and parrot fish, feed on encrusting organisms and reduce beachrock exposures.

Beachrock exposed as a result of erosion of beach sand is itself subject to erosion within the wave zone. Physical erosion reduces beachrock volume by dislodging weakly cemented grains as well as large slabs. A characteristic of beachrock is closely spaced joints which enable storm waves to erode and transport beachrock. As a result clasts of beachrock become incorporated in beach sediment. Large slabs of beachrock act as buttress on a sandy beach, thereby reducing erosion of sand.

Beachrock is diagenetically altered by endolithic fungi and algae. Clastic and/or oolitic textures become micritized adjacent to borings and, in intensely infested areas, total micritization has led to obliteration of original texture and increased cementation of the rock. Furthermore, as a result of endolithic algae and fungi beachrock surfaces are darkened.

The exposed beachrock with its population of encrusting, boring and feeding organisms changes the nature of sediment accumulating on the adjacent beach. Prior to beachrock exposure the shoreline probably was accumulating sandy bioclastic sediment derived from perhaps a barrier reef, patch reefs and a sandy carbonate shelf. Bioclastic grains were reworked before being deposited on the beach as fairly well-sorted sand. Sorting and grain size were the result of beach energy and distance of beach from the source. Generally few coarse fragments reached the beach from reefs. Bioclastic grains were dominated compositionally by fragments of burrowing pelecypods, worm tubes, and foraminifera.

With the introduction of a rocky substrate adjacent to the beach, the nature of beach sediment changes noticeably. Most striking is the introduction of large clasts of beachrock. More subtle but also easily recognizable is the compositional change of bioclasts. Included in the beach sand are remnants of the rocky bottom fauna and flora including echinoid spines, red algal fragments (*Goniolithon* primarily), patellid gastropods, *Halimeda*, coral and clusters of vermetid gastropods. Due to the proximity of the beachrock and its associated organisms, lithic and biologic clasts are not reworked to the same degree as on a sandy beach. Also because beachrock prevents beach erosion, water depths offshore from the beachrock increase slightly more rapidly than in a sandy shelf-beach environment. As a result, waves washing over the beachrock and onto the protected beach experience a more rapid energy reduction. These circumstances produce a deposit which is coarser and less sorted than on a sandy beach. Since the exposed beachrock represents lithified sediment which accumulated on a sandy beach, sediment deposited during the period of beachrock exposure will be coarser and less sorted than the sediment within the beachrock. Sand-sized particles will likely be nearly identical in both beach and beachrock however composition will differ.

On a larger scale the presence of beachrock in a depositional setting results in more rapid beach progradation. Figure 8 illustrates two coasts, one where sediment remains uncemented (A) and a second where rapid cementation lithifies beach sand beneath the surface (B). Under conditions dominated by deposition both coasts prograde equally (Fig. 8-1). If both coasts experience temporary erosional conditions (Fig. 8-2) erosion will be greater along the coast where no beachrock is exposed (Fig. 8-2A). The exposed rampart of beachrock (Fig. 8-2B) protects, to some degree, sand of the adjacent beach and dune. When both coasts revert to depositionally dominated conditions the coast protected by beachrock (Fig. 8-3B) begins progradation at a more seaward position. After repeated erosional-depositional events shoreline progradation should be noticeably more advanced in areas of beachrock formation.

RECOGNITION OF HOLOCENE BEACHROCK

In a subtidal-beach-dune sequence of sediments or sedimentary rocks where beachrock formed due to early cementation, exhumation and later burial by prograding coastal deposits, evidence of its presence may not be striking or noted at first glance. Beachrock consists of beach sediment and is therefore compositionally, texturally, and stratigraphically very similar to the host rock in which it occurs. Beachrock dips

Fig. 1. Exposure of cemented dune sand located approximately 200 m west of Government Dock, French Bay, San Salvador Island.

Fig. 2. View of exposed beachrock west of Government Dock, French Bay, San Salvador Island.

Fig. 3. Fresh surface of beachrock at French Bay displaying intertidal fenestral porosity in lower half of exposure and borings of pelecypods and barnacles in upper half.

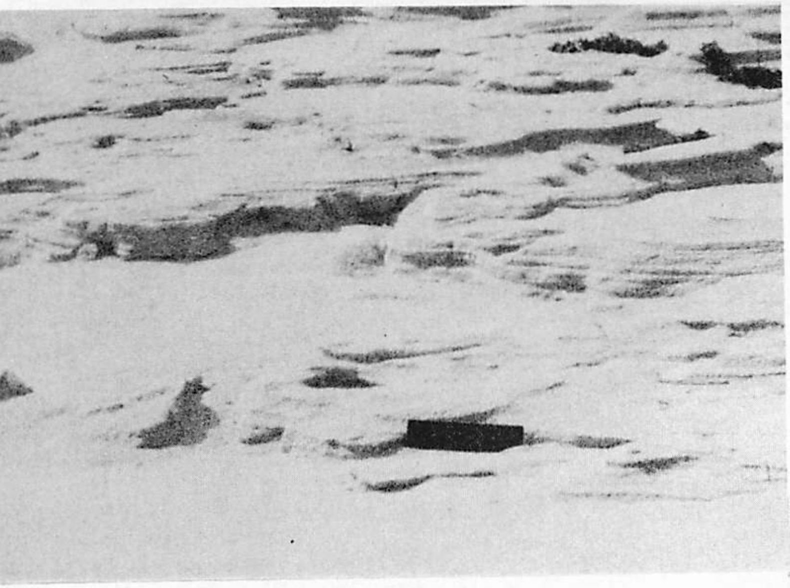


Fig. 4. Freshly exposed supratidal beachrock which was uncovered by recent storm. Note preservation of laminae, French Bay. Scale = 15m.

Fig. 5. Block of exposed beachrock which was eroded from subtidal location and deposited on beach at French Bay. Of particular interest is the dark encrustation of vermetid gastropods which increases beachrock volume.

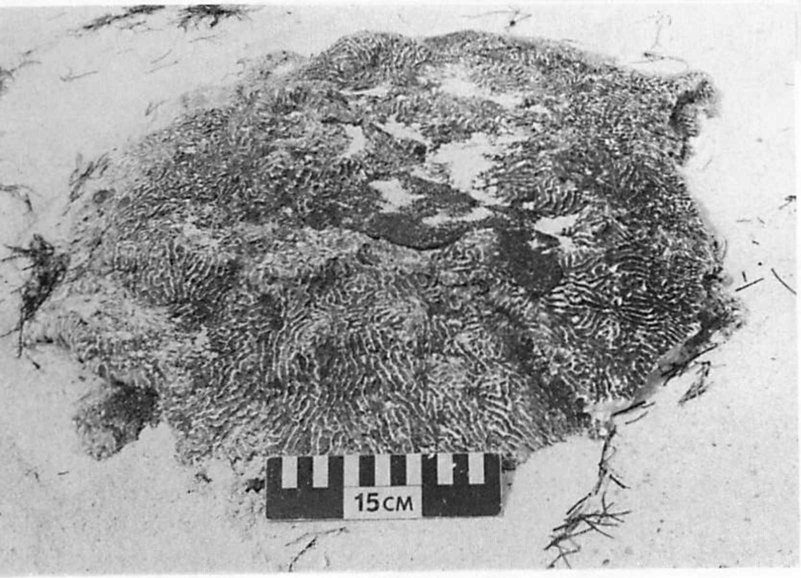
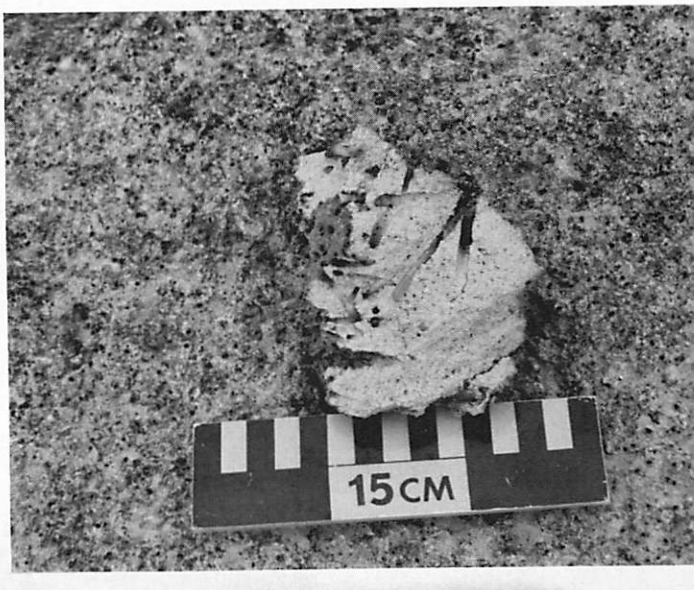


Fig. 6. Large low profile Diploria *which was eroded from shallow subtidal environment in French Bay where it encrusted exposed beachrock. Upward growth is restricted by water depth at low tide.*

Fig. 7. Closely spaced borings of pelecypods and barnacles exposed in broken sample of French Bay beachrock. Borings generally are concentrated on the underside of beachrock beds.



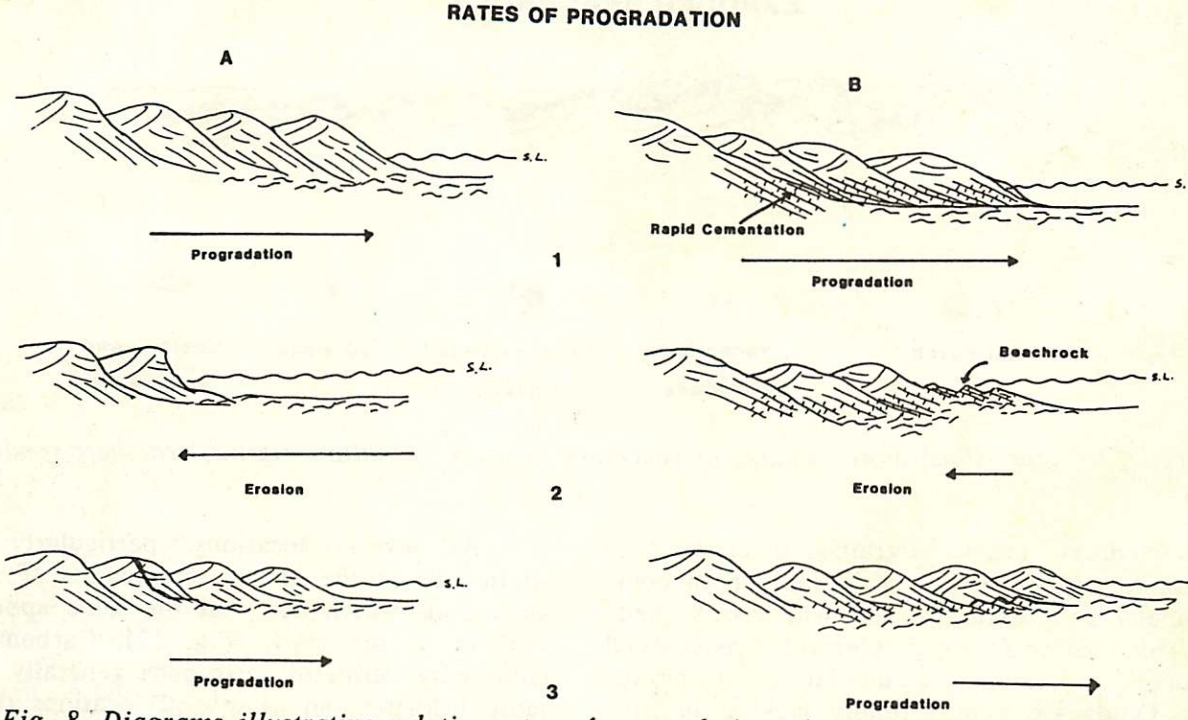


Fig. 8. Diagrams illustrating relative rates of progradation of two coasts, one which is unprotected by beachrock (A) and one which is protected (B). At stage 1 both coasts have prograded equally and early cementation has lithified sand within beach B. In stage 2 temporary erosional conditions prevail; beach A is eroded whereas beach B experiences erosion to a lesser extent as a result of protection by the beachrock rampart. When depositional conditions return to both coasts, B begins progradation at a more seaward position resulting in more rapid progradation rates through time.

parallel to beach strata and short term exposure at sea level does not create high relief erosion.

Upon closer inspection of exposures and petrographic examination the following features indicate the presence of beachrock (Fig. 9). Locally laminae of dislodged beachrock will occur in angular discordance with laminae of undisturbed beach sediment. Sediment is more coarse-grained and less sorted. Most striking is the localized occurrence of rocky bottom fauna and flora, in particular, flat growth forms of coral, vermetid gastropod encrustations, abundant *Goniolithon* fragments and colonies, patellid gastropods and *Halimeda* plates. Within the bioclastic host sediment or rock, beachrock may be more tightly cemented and commonly is micritized. This cemented, micritic rock displays borings and encrustations. Petrographic examination may reveal the presence of marine cement if diagenesis has not altered the original cement.

Most of these characteristics would also be present in any shallow-water carbonate hardground. Recognition as beachrock, therefore, depends on determination of its occurrence within a beach sequence.

Holocene Example of Exposed Beachrock

At quarry A (index map) on San Salvador Island, excavations for road material have exposed deposits which have been interpreted as representing eastwardly prograding dune-beach-subtidal marine environments (Fig. 10). Dune sediments consist of well-sorted, fine-grained oolitic sand which displays sweeping crossbeds typical of eolian deposits. In basal dune deposits, fine--grained bioclastic material increases in abundance and ooid percentages decrease downward into what is interpreted as beach sediment. Beach deposits contain a low percentage of ooids and are primarily composed of medium-grained bioclastic sand. Alternating fine-grained and medium--grained, planar laminae dip consistently to the east. A horizontal, 10 cm zone of fenestral porosity occurs throughout the north lobe of Quarry A and is interpreted as having formed by trapped air in intertidal sands during falling tides.

Beneath these beach sands occurs a poorly

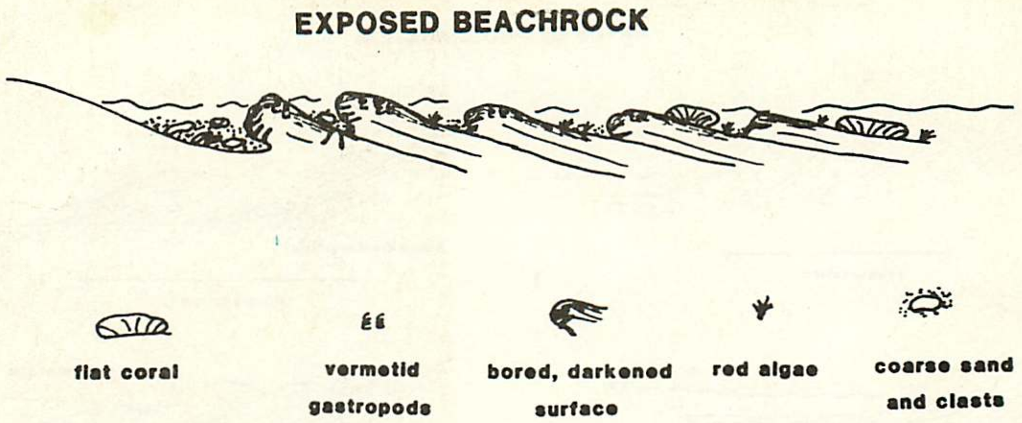


Fig. 9. Diagram illustrating features of beachrock exposed to shallow marine, nearshore conditions.

sorted, medium- to coarse-grained bioclastic sand and gravel which varies considerably both compositionally and texturally and which lacks bedding. This coarser facies is interpreted as subtidal and offers a diverse accumulation of marine fossils. Ooids are almost totally lacking in subtidal deposits and occur only in beach-dune sediment as reported elsewhere (Florentino & Bain, 1984; Lloyd, Perkins, and Kerr, 1987). Of particular interest within lower beach and subtidal facies is the presence of large (>40 cm) *Diploria* which in most instances are relatively thin (<15 cm)(Fig. 11). The flat, low-profile corals are somewhat irregular, especially their lower surfaces, and occur, rather curiously, in medium--grained, bioclastic sand. In several associations, sand beneath coral is considerably more lithified than that overlying the coral.

At several locations, particularly in the south lobe of the quarry, are masses of vermetid gastropods which occur at the same approximate horizon as the coral (Fig. 12). Carbonate sand containing vermetid gastropods generally is much more lithified and at several locations the sands are intensely micritized. Gastropod encrustations are commonly 20 cm thick. In addition to gastropods and corals, micritic rock in Quarry A also contains boring pelecypods, perhaps *Lithophaga* (Fig. 13) and organisms which prefer rocky substrate such as *Fissurella* and *Brachiodontes*.

Within the lower beach-subtidal facies, excavation of loose carbonate sand has exposed and dislodged not only the micritized rock but also well-lithified slabs of bioclastic limestone. These slabs display borings, both filled and open, and encrustations of serpulid worms on the lower

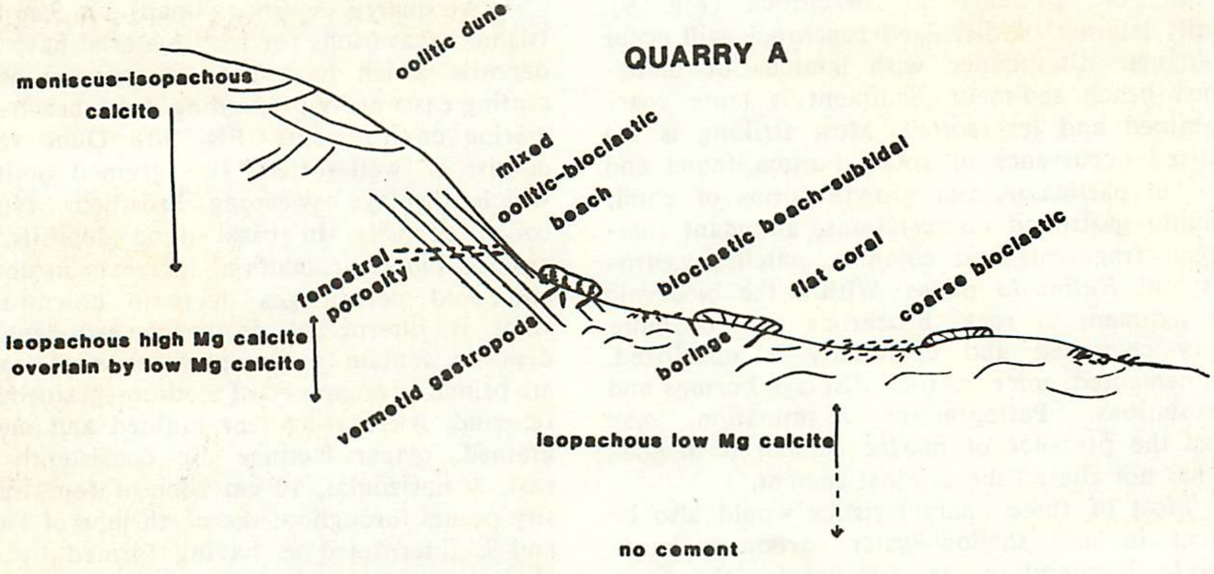


Fig. 10. Diagram illustrating lithologic and biologic features of Holocene sediment exposed in Quarry A, San Salvador Island. (Refer to index map)

Fig. 11. One of many Holocene Diploria *xposed in Quarry A, San Salvador Island. Coral easures approximately 30cm.*

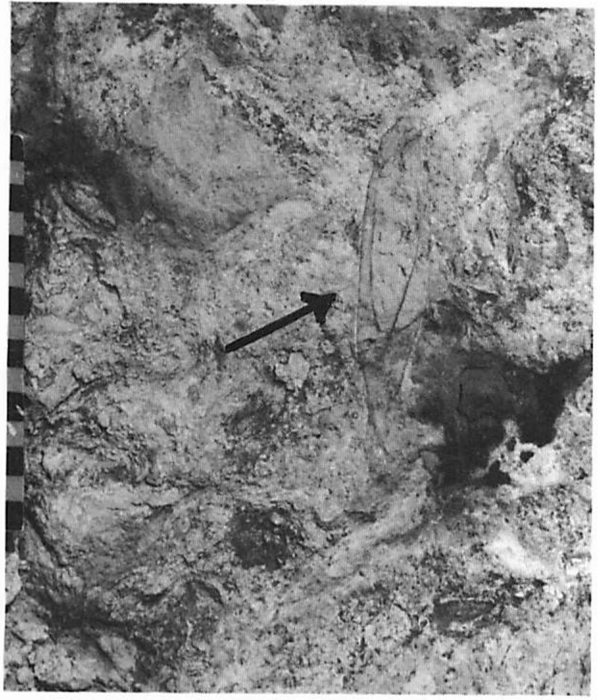


Fig. 13. Skeleton of boring pelecypod in micritized Holocene beachrock exposed in Quarry A, San Salvador Island. Pelecypod measures 12cm.

Fig. 12. Vermetid gastropod encrustation of Holocene beachrock in Quarry A, San Salvador Island. Scale shows cm.

Fig. 14. View of underside of well-lithified slab of Holocene beachrock from Quarry A, San Salvador Island. Note the encrustations of serpulid worms. Bar scale = 3cm.

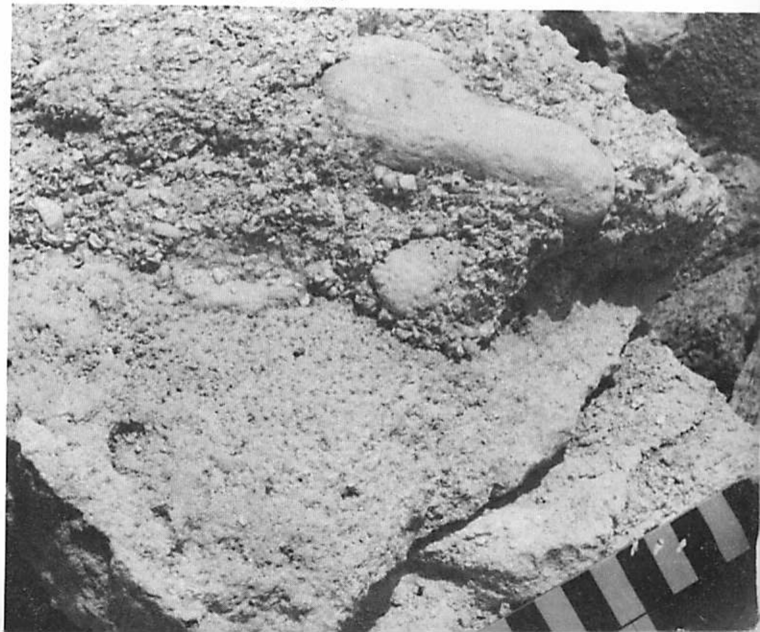


Fig. 15. Photograph of slab of well-lithified Holocene beachrock overlain by coarse-grained, poorly sorted beach sediment which includes several clasts of beachrock, Quarry A, San Salvador Island. Scale shows cm.

Fig. 16. Photomicrograph of Holocene ooids from dune facies, Quarry A, San Salvador Island. Note cementation of ooids by sparry calcite. Bar scale = .5mm.

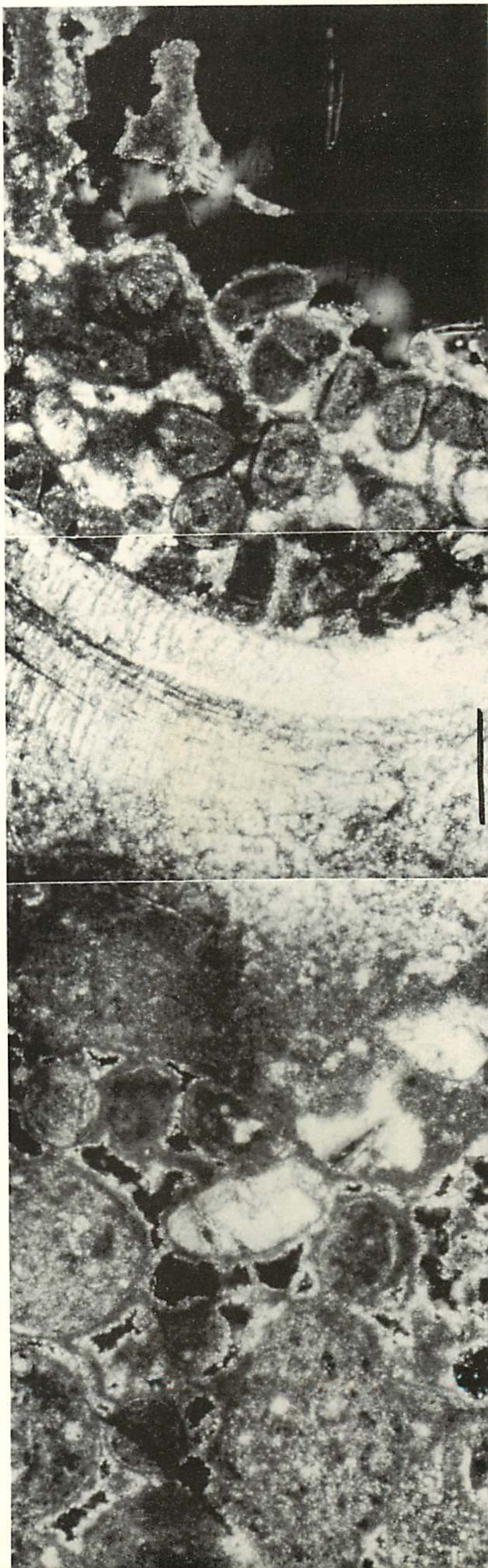


Fig. 17. Composite photomicrograph of Holocene vermetid encrustation on beachrock, Quarry A. Thin section displays body cavity and skeletal wall of vermetid gastropod and the beachrock on which the gastropod encrusted. Note ooids of beach sand within gastropod are cemented by sparry calcite whereas bioclastic grains of beachrock are cemented initially by micritic, isopachous Mg-calcite which is overlain by sparry calcite cement. Bar scale = 1mm.

surfaces (Fig. 14). Clasts of similarly lithified material, ranging in size up to 20 cm, occur throughout the lower beach-subtidal facies in the north lobe of Quarry A (Fig. 15). Associated sediment is dominated by fragments of echinoid spines, *Goniolithon, Porites* and fragments of *Halimeda.*

Petrographic and microprobe analyses of cements present within sediment of Quarry A indicate a variation in cement types including meniscus, isopachous, low-Mg calcite, and isopachous, micritic, high-Mg calcite. Distribution of these cements is illustrated in Figure 10. All carbonate deposits in Quarry A are at least partially cemented by sparry low-Mg calcite (Fig. 16). High-Mg calcite is restricted to lower beach-subtidal sediments and where it occurs it predates low-Mg calcite. This relationship is especially evident in Figure 17 which traverses a thin section of beachrock through the vermetid gastropod encrustation. Oolitic beach sediment which infilled gastropods is cemented by isopachous calcite whereas bioclastic beachrock, to which vermetid gastropods attached, is cemented first by micritic Mg-calcite and later by calcite. Similar cement relationships were noted associated with coral occurrences. Also whereas low-Mg calcite cement occurs both as meniscus and isopachous cement, high-Mg calcite occurs only as isopachous cement. At a depth of several meters into subtidal sediments, cement is absent.

The occurrence of low profile *Diploria*, serpulid worms and vermetid gastropods within what appears to be nearshore bioclastic sand suggests that these sands were lithified at the time of coral, worm and gastropod encrustation. Presence of other rocky-bottom organisms, namely *Fissurella*, echinoids, and *Brachiodontes* likewise indicates a hard substrate existed. Boring organisms within micritic limestone proves sediment was lithified. Cement variation and cement stratigraphy strongly suggest marine cementation. Low-Mg calcite cement was precipitated from vadose and phreatic fresh water and represents late- stage and present-day cementation. Isopachous, micritic high-Mg calcite cement was precipitated from seawater and resulted in the formation of beachrock. Clasts of early cemented, exhumed and eroded beachrock are scattered through lower beach-subtidal sediment. These clasts, as well as the exposed beachrock, provided the rocky substrate for organisms of Quarry A.

CONCLUSIONS

Beachrock results from the exhumation of early-cemented beach deposits and provides not only a rocky-bottom for fauna and flora but also alters the beach environment as a result of its presence. Beaches are less subject to erosion because of the lithified rampart of beachrock and rates of progradation are accelerated. Beach and subtidal sediment associated with beachrock differs from that of a sandy beach which lacks beachrock. Composition of beach sand is modified by the influx of nearby rocky-bottom organisms and texture of beach deposits becomes coarser and less sorted as a result of a change in wave energy.

These alterations of beach fauna, flora, sediment texture and composition are preserved in the sedimentary record and can be used to recognize ancient beachrock. Quarry A on San Salvador Island provides an excellent example of a Holocene beach where beachrock was exposed and beach sediment was thereby modified.

REFERENCES CITED

Branner, J.C., 1904, The stone reefs of Brazil, their geological and geographical relations, with a chapter on coral reefs.: Bulletin Museum of Comparative Zoology, Harvard College, v. 44, p. 1-285.

Bathurst, R.G.C., 1975, Carbonate sediments and their diagenesis (2nd ed): New York, Elsevier, 658 p.

Florentino, E. and Bain, R., 1984, Environment of deposition of the Granny Lake Oolite, San Salvador, Bahamas: p. 187-196, in Teeter, J.W., (ed.) Proceedings of the Second Symposium on the Geology of the Bahamas; CCFL Bahamian Field Station, San Salvador, Bahamas.

Hanor, J.S., 1978, Precipitation of beachrock cements: Mixing of marine and meteoric waters vs. CO_2-degassing: Journal of Sedimentary Petrology, v. 48, p. 489-501.

Kuenen, P.H., 1933, The Snellius-Expedition, 5. Geological Results, 2: Geology of Coral Reefs, Kemick, Utrecht, 125 p.

Lloyd, R.M., Perkins, R.C., and Kerr, S.D., 1987, Beach and shoreface ooid deposition on shallow interior banks, Turks and Caicos Islands, British West Indies: Journal of Sedimentary Petrology, v. 57, no. 6, p. 976-982.

Moore, C.H. and Hanor, J.S., 1974, Boiler Bay beach rock, St. Croix: West Indies Lab Special Publication 5, p. 71-75.

Scoffin, T.P., 1987, An Introduction to Carbonate Sediments and Rocks: Blackie, London/Chapman & Hall, New York, 274 p.

Strasser, A. and Davaud, E., 1986, Formation of Holocene limestone sequences by progradation, cementation, and erosion: Two examples from the Bahamas: Journal of Sedimentary Petrology, v. 56, no. 3, p. 422-428.