Modern beachrock formation in Durban, KwaZulu-Natal

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We explored the recent cementation of modern beachrock on the seaward margin of the Durban Bluff, central KwaZulu-Natal. The low latitude and subtropical climatic setting is a unique context compared to the more commonly documented contemporary beachrock formation in the tropics. Geological field mapping was carried out and here we present results based on sedimentary facies of a clastic shoreline and carbonate diagenesis of interstitial cements using transmitted light microscopy. The beachrock was cemented by micrite and aragonite, and iron oxide infilled voids. The presence of human artefacts within the deposit showed evidence for cementation within the last century. The elevation (at Mean Low Water) and correlation to rates of sea level change for the east coast of South Africa showed that the beachrock is less than 72 years in age. In contrast to older local Pleistocene deposits, beachrocks have cemented along this stretch of coast during successive sea level highstands with similar climatic regimes – the last Interglacial, the Holocene High and the present. Here we report the most southerly documentation of modern beachrock in KwaZulu-Natal, which, to our knowledge, represents the youngest deposit reported in southern Africa.

Introduction

Beachrocks are consolidated coastal sedimentary formations, which consist of beach material that is bonded together relatively rapidly by *in-situ* precipitated carbonate cements (calcite and/or aragonite),[1,2] and are commonly found along warm equatorial-tropical coasts.[3,4,5,6] Constituent particles include clastic, biogenic and authigenous sands and gravels, as well as human artefacts at some localities.[3]

Although lithification occurs in the intertidal and/or supratidal zone, either on the beach surface or beneath a thin veneer of unconsolidated sediment,[7,8] the significance of beachrock as a reliable sea level indicator has been questioned.[9] In addition, beachrock formation and resulting outcrops have a significant impact on beach morphodynamics, altering longshore and cross-shore sediment transport and budget.[10,11]

Although carbonate cemented Pleistocene beachrocks are common along the South African coastline,[12,13,14,15,16] modern beachrocks are rare.[17] Here we describe and report the occurrence of a modern beachrock formation at present Mean Low Water level. This report is the most southerly documentation of modern beachrock in central KwaZulu-Natal and, to our knowledge, represents the youngest deposit reported in southern Africa. The beachrocks have developed along a coastline that comprises older Pleistocene and Holocene carbonate cemented beachrocks and aeolianites, which form the seaward margin of the Bluff extending along a 16-km stretch from Durban Harbour to Isipingo Beach[15] (Figure 1). The area lies at 29°52′S and experiences a subtropical climate with warm wet humid summers and dry moderate winters.[18] The coastline is a high-energy, wave-dominated microtidal or low mesotidal system[10] with a mean spring tidal range of 1.72 m and a mean neap tidal range of 0.5 m.

Facies association and description

The modern beachrock has developed seaward of a pipeline support structure that formed part of whaling station operations between 1908 and 1975 and extends seaward of an embayment of a ‘Type 2’ intertidal platform[19] of older beachrock (Figure 2). The exposure has a maximum coast-parallel extent of 40 m that extends seaward for approximately 6 m and is estimated to be no more than 30 cm thick. The site is only exposed at spring low tides and is normally submerged and covered by unconsolidated beach sand. The rocks have developed within the breaker to swash zone at the foreshore–shoreface transition, corresponding to the Mean Low Water level.

The sedimentary facies comprises a poorly sorted, locally pebbly, very coarse to coarse sand. A matrix of quartz, feldspar and bioclastic sediment supports pebbles of older beachrock and

FIGURE 1: (a) Regional context of the locality of the study area. (b) Enlarged area of interest in the vicinity of Durban. The study area lies on the seaward margin of the Durban Bluff, central KwaZulu-Natal. The Bluff Ridge, Isipingo and the whaling station are indicated.

aeolianite as well as lithic fragments of lydianite and sandstone, and most importantly an assortment of waste from the whaling station and military dump. This waste comprises harpoon heads, bricks and unexploded hand grenades and is linked to the activities of the whaling station and military disposal (Figure 2). The human artefacts date the deposit to the last century of active whaling between 1908 and 1975.[20]

Mode of cementation

The beachrock cement forms bladed isopachous rims of micrite and prominent aragonite crystals around sediment grains that radiate into voids (Figures 3b and 3d). Aragonite and micrite are volumetrically the most abundant cement phases and the remaining interstitial porosity of the deposit appears either empty or is infilled by iron oxide (Figure 3a). Carbonate precipitation on grains commenced with micrite followed by a generation of acicular aragonite. The regular distribution and isopachous nature of the two cement generations suggests precipitation in a marine phreatic environment for beachrock formation[2] where sea water is conducted into sediments by tides, waves and currents.[21] The regular orientation and uniform size of rims are the result of simultaneous crystal nucleation at a magnitude of sites on the grain surface.[22] Inner portions of isopachous rims are more equant in form, enveloped by an outer prismatic variety. The absence of organic structures, such as microbial filaments, suggests that the beachrock cementation was an inorganic process.

Two hypotheses are suggested for the recent cementation of this unusual deposit. The first is that modern beachrock is forming along this section of the central KwaZulu-Natal coastline and is only recognisable at this site because of the presence of human artefacts. The second is that carbonate precipitation and cementation has occurred at the interface between oxidising runoff that infiltrates through the forebeach from the waste disposal site and the reducing seawater. The structure of the outcrop, with the erosional embayment on the landward margin, acted as a sediment trap and allowed the dumped artefacts to accumulate with beach sand from the swash zone. Because iron oxide only infills voids instead of binding to the grains, it could have only facilitated the cementation, which implies that the beachrock is a true beachrock. In this case, the iron oxide promoted the release of additional CO_2 as described in the Bay of Biscay, Spain.[7]

The cementation observed, bounded by aragonite and micrite, is as reported for modern beachrocks elsewhere[7,23] and is in contrast to older Holocene submerged beachrocks mapped offshore of the Bluff[24] which are characterised by micrite-only cements. However, Pleistocene beachrock deposits along a sea level highstand palaeoshoreline at Isipingo Beach[15] display a similar cementation history to the modern beachrock. Here, quartz grains of the swash zone facies are fringed by fibrous isopachous calcite cements, which indicate diagenesis in the marine environment.[1,21] These cements are considered to form early in the diagenetic history,[15] originally as aragonite inverting to calcite after several hundred or thousand years.[25] The sedimentology and mode of cementation thus assigns the modern beachrock described here to an environment of deposition within the swash zone.

Regional significance and applicability to local sea level change

Although the relationship of beachrock to sea level is not suitably resolved, and the potential use of beachrock as a reliable sea level indicator remains controversial,[9,26] beachrock can be used to establish former beach configurations.[2]

It is clear that the modern beachrock described here was deposited and cemented within the last century, was formed in the swash zone and is now at Mean Low Water. The tidal framework can be loosely applied to further constrain the age of the modern beachrock. Contemporary beachrock is thought to form at an elevation of 0.1 m – 0.2 m above Mean Low Water.[27,28] The rate of sea level rise of +2.74 mm/year[29] reported for the South African east coast suggests that the deposit may have formed 36 to 72 years before the present. This estimated age range falls within the time frame of whaling on the Bluff, post-dates World War II and is consistent with the distribution of the *in-situ* human artefacts observed.

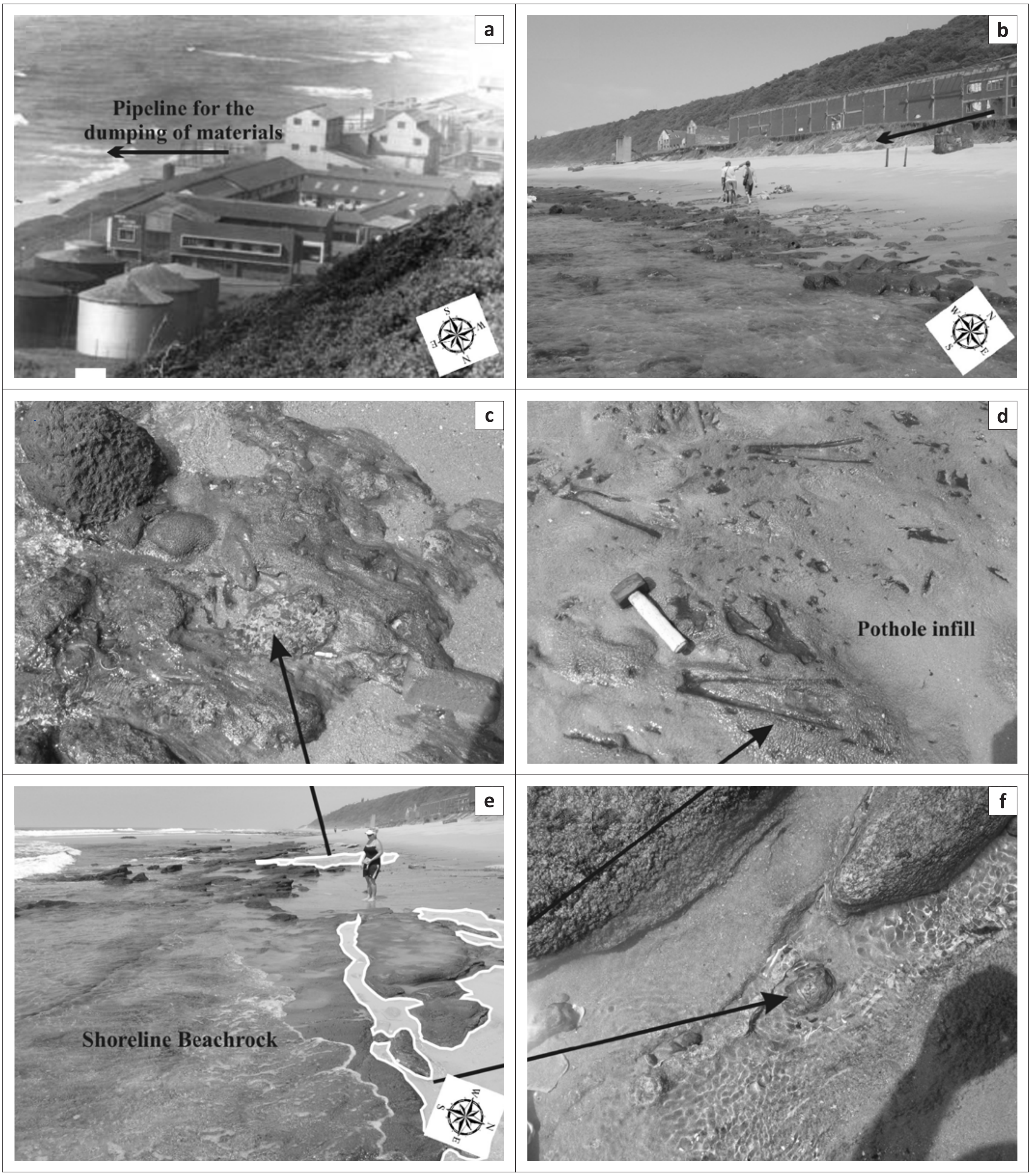

FIGURE 2: (a) Photograph of the whaling station on the seaward flank of the Bluff sometime between 1930 and 1950 (courtesy of W. Kidwell). The view is from the top of the Bluff Ridge, towards the south-east. Whale oil storage drums are in the foreground, the administration building for the Union Whaling Company lies adjacent to the drums and the processing plant forms the white building in the background. The pipeline used for dumping whaling debris is indicated. (b) The derelict administration building and supports for the pipeline which remain on the beach. The view is towards the south. (c and d) Modern beachrock containing human artefacts. The material consists of harpoon heads, bricks and other objects. The arrows from (e) indicate the position of the artefacts. (e) Geological association of the modern beachrock deposit in front of the whaling station with the relatively older unit of shoreline beachrock. (f) A photograph of a World War II grenade, cemented into the modern beachrock.

Conclusions

Although the described modern beachrock presents an unusual locality, the sedimentary structures, facies type and carbonate cements are comparable to those recorded in tropical areas and to the Pleistocene of Isipingo Beach. The steep swash zone, coarse grain size and similarity to the modern beach system suggest the deposition occurred on

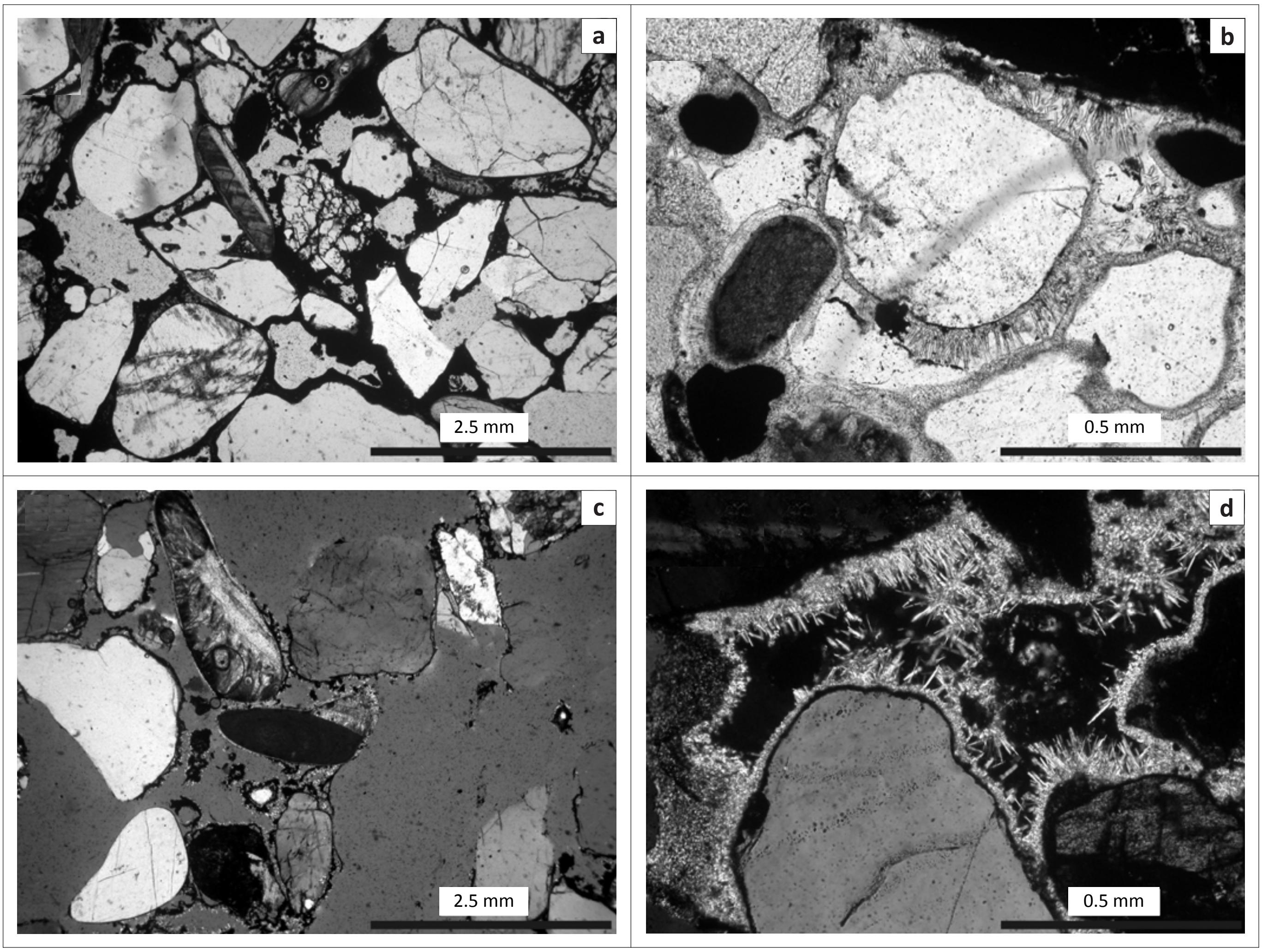

FIGURE 3: Transmitted light microscopy of the modern cemented beachrock. (a) Iron oxide infilling voids between coarse-grained, rounded to angular quartz crystals and rock fragments. (b) Beachrock cement forming bladed isopachous rims of micrite and prominent aragonite crystals around sediment grains radiating into voids. These cements are considered to form early in the diagenetic history. (c) Shell fragments, quartz and lithic fragments with iron oxide precipitated into pores. (d) Magnified micrite rims and aragonite crystals.

a high-energy, wave-dominated coastline equivalent to the modern intertidal zone environment.

The deposit is of significance because of the timing of diagenesis and the mode of cementation. The cementation is similar to the Pleistocene beachrocks at Isipingo Beach,[15] implying that beachrocks formed along this stretch of coast during successive sea level highstands with similar climatic regimes (the last Interglacial and the present).

The presence of modern artefacts cemented into the deposit provides evidence for the cementation occurring within the last century, and indicates that the beachrock described here is the youngest catalogued unit in southern Africa, considerably younger than that described from Vilancoulos, Mozambique which is aged at 920–910 BP.[13]

Although the validity of beachrock as a reliable sea level indicator has been questioned, in this case the data available has allowed a broad correlation to sea level change during the last ~72 years. The migration of the Mean Low Water mark to the position previously occupied by the swash zone may attest to facies stacking associated with a transgressional regime and the use of these clastic shoreline facies as reliable sea level indicators in this area. Our data are in agreement with the east coast rate of sea level rise.[29]

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Competing interests

We declare that we have no financial or personal relationships which may have inappropriately influenced us in writing this paper.

Authors’ contributions

This work formed part of H.C.’s MSc which was carried out through the Council for Geoscience Statutory Programme and the University of KwaZulu-Natal. R.U. was the academic supervisor of this project. H.C. mapped the deposit and subsequently H.C. and R.U. visited the site for sampling. H.C. and R.U. wrote the manuscript.

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