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Formation, exposure, and evolution of a high-latitude beachrock in the intertidal zone of the Corrubedo complex (Ria de Arousa, Galicia, NW Spain)

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Abstract

The presence of beachrocks is noted on the Galician shoreline at 41°N, a latitude at which this phenomenon is rarely found. The present study focuses on the petrological characterization and sedimentological evolution of a beachrock that was exhumed during an exceptional storm in the winter of 2001 in the intertidal zone of a high-energy beach. The cemented material comprises medium-to-coarse mixed siliciclastic-carbonate sands. Unlike tropical beachrocks, the cement consists of epitaxial low-Mg calcite presenting varied morphologies and textures: acicular and bladed coatings and pore linings, pore fillings of sparitic calcite, and meniscus-style cements. Seawater, dominantly wave action, plus marine and meteoric mixed waters are invoked as the main generative fluids. Beachrock formation and evolution are approached from a morphodynamic viewpoint, considering four progressive stages:

1. initial cementation in the intertidal zone;
2. exposure and modelling by wave action;
3. colonization and hardening; and
4. disintegration/preservation and burial.

Finally, the morphodynamic significance, climatic implications, and occurrence of this type of cementation along the north and northwest shoreline of Spain are discussed.

Keywords: Beachrock; Galician coast; Island–barrier–lagoon complex; Beach morphodynamic; Sedimentology; Petrology; Cementation

1. Introduction

The rapid cementation of sediments in the intertidal zone on tropical and subtropical beaches leads to the formation of characteristic synsedimentary lithified structures termed as beachrocks, which have been

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described in humid climates (e.g., Ginsburg, 1953; Moore, 1973; Hanor, 1978; Beier, 1985; Amieux et al., 1989; Meyers, 1987; Bernier et al., 1990; Font and Calvet, 1997; Neumeier, 1998, 1999; Webb et al., 1999) as well as arid or semiarid climates (Taylor and Illing, 1969; Friedman and Gavish, 1971; Holail and Rashed, 1992; Neumeier, 1998). These structures have also been described in more temperate areas (e.g., Friedman and Gavish, 1971; Alexandersson, 1972; Bernier and Dalongeville, 1988; Holail and Rashed, 1992; Sellwood, 1994; Neumeier, 1998; Calvet et al., 2003), and more exceptionally, in cold climates or even in lake systems (e.g., Jones et al., 1997; Kneale and Viles, 2000). The mineralogy of these cements is mainly high-magnesium calcite or aragonite, adopting highly varied and complex morphologies and textures (Bricker, 1971; Given and Wilkinson, 1985; Bernier et al., 1990; Chaves and Sial, 1998; Neumeier, 1999; Kneale and Viles, 2000).

Today, the origin of these cements is the subject of intense debate, although the majority of authors accepts that the chief processes involved are physicochemical in nature, such as: supersaturation with $CaCO_3$ through direct evaporation of seawater (Scoffin, 1970), groundwater CO_2 degassing in the vadose zone (Hanor, 1978), or mixing of marine and meteoric water fluxes (Schmalz, 1971). Some authors (Krumbein, 1979; Bernier et al., 1990; Neumeier, 1999; Wilkinson et al., 1997) have also noted that these physicochemical factors are somehow controlled and/or induced by diverse forms of microbial activity. The mineralogical variety of materials in which they occur (siliciclastics, carbonates, mixed, volcanoclastics) (Knox, 1973; Meyers, 1987; El Sayed, 1988; Kendall et al., 1994; Jones et al., 1997, *inter alia*) and the natural diversity of the conditions in the sedimentary environment suggest that several of these processes may intervene simultaneously, depending on the geological context in which they appear.

The development of beachrock-type cements in temperate latitudes, where the seawater is slightly subsaturated in $CaCO_3$, is exceptional and very rarely noted in the scientific literature. However, when beachrocks do appear, they are associated with skeletal grains of volcanic origin (Knox, 1973) or with mineralogical peculiarities related to high geothermal gradients (Jones et al., 1997). The present work describes the main characteristics of the beachrocks observed at 41°N in the intertidal zone of the island–barrier–lagoon of Corrubedo in the Ria of Arousa (NW Spain).

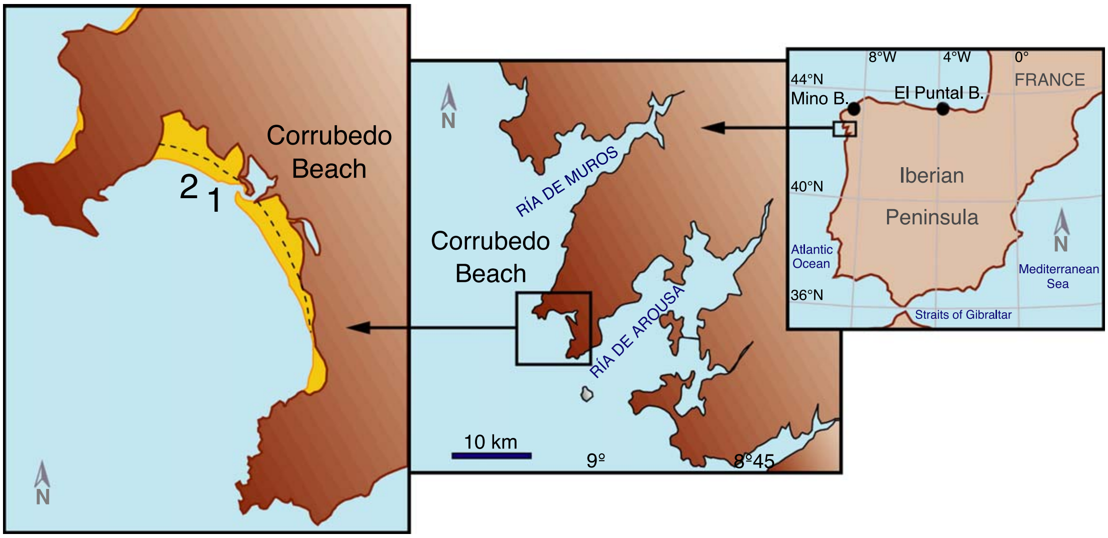


Fig. 1. Location of the Corrubedo Beach on the Galician coastline (NW Spain): (1) position of the most evolved beachrock; (2) position of the least evolved beachrock. Black dots show locations of the beachrocks on the beach of Miño (A Coruña) and El Puntal (Santander) identified on the northern Spanish coast.

2. Study area and methodology

The Corrubedo Bay is a coastal embayment, approximately 6 km in length, located between the rias of Arousa and Muros in southern Galicia (NW Spain; Fig. 1). The climate of the area is humid-temperate: average precipitation is 1200 mm/year, and mean temperatures range from 18.5 °C in summer to 9.5 °C in winter (Pérez-Alberti, 1982). Winds are strong from the SW in winter, turning weaker and from the north in summer. Exposure to wave action has resulted in a well-developed beach system, with an important dune complex and a highly evolved associated lagoon saltmarsh (Vilas and Nombela, 1986; Vilas et al., 1986, 1988, 1991). According to these authors and consistent with the small size and seasonal nature of the drainage basin, fluvial and alluvial contributions to the system are of little importance. The entire system is subjected to a semidiurnal mesotidal regime (modal amplitude of 3.25 m), with a slightly diurnal asymmetry. In terms of its sedimentological characteristics and their different sedimentary dynamics, Vilas et al. (1991) divided the system into an external high-energy zone of dominant marine influence and an internal low-energy zone of mostly continental influence.

The present study focuses on the petrological characterization and sedimentological evolution of

Fig. 2. (a) Least evolved beachrock (the sea to the left of the photograph). A build-up of gravels and blocks onshore of the beachrock can be observed here, and transversal channels excavated out where the water circulated during the tidal cycle. Note the flatter slope towards the land and the abrupt side towards the sea. (b) More evolved beachrock with an advanced algae colonization, giving it a bright greenish colouring and a more resistant cementation.

Table 1
Different wave climate cases (wave height, period, and direction) propagated by the numerical model REFDIF in the Corrubedo Bay. Probability refers to the annual probability of presentation of each condition, including all directions considered (SW, W, NW). Cases 1, 2, 3, and 4 correspond to summer, mild winter, energetic winter conditions, and a storm event, respectively, in the area studied

	Significant wave height *H* (m)	Significant period *T* (s)	Direction of incidence in deep water	Probability (%)
CASE 1	1	6	SW W NW	80
CASE 2	1.6	7.6	SW W NW	50
CASE 3	2.5	9.5	SW W NW	20
CASE 4	7.5	16.4	SW W NW	0.137

the cemented intertidal zone in the exposed part of the complex. In this zone, interaction between the main effluent and the SW waves has developed a long (8 km), gently sloping beach (7–8°). A seaward-prograding tidal inlet appears in the central part of the beach, whilst a partially active aeolian complex has developed at the back of the system. Two cemented sectors appear on the beach. The largest but least developed occurs some 50 m from the tidal inlet (Fig. 2a), whereas a smaller but more evolved sector is located at the north end of the inlet (Fig. 2b).

Outcrops were mapped and sampled. The petrology and mineralogy of the cemented sands were studied by scanning electronic microscopy (SEM), assisted by energy-dispersive X-ray microanalysis microprobe (EDXRA). A portion of the samples was set aside for subsequent analysis by X-ray diffraction (XRD) and thin sectioning. The mineralogical characterization of the cementation was based on the staining methods of Miller (1988).

Wave climate conditions in the Corrubedo Bay were evaluated with the REFDIF (GIOC, 1995) numerical model, initially developed by Kirby and Dalrymple (1983, 1985). This model simulates wave propagation on an irregular bathymetry and estimates the variations in both direction of incidence and wave height from deep waters to the beach. Different situations were studied (Table 1), considering the typical summer and winter wave heights and periods as initial data, which were provided by the Spanish Wave Motion Measurement and Recording Network (known by its Spanish initials, REMRO).

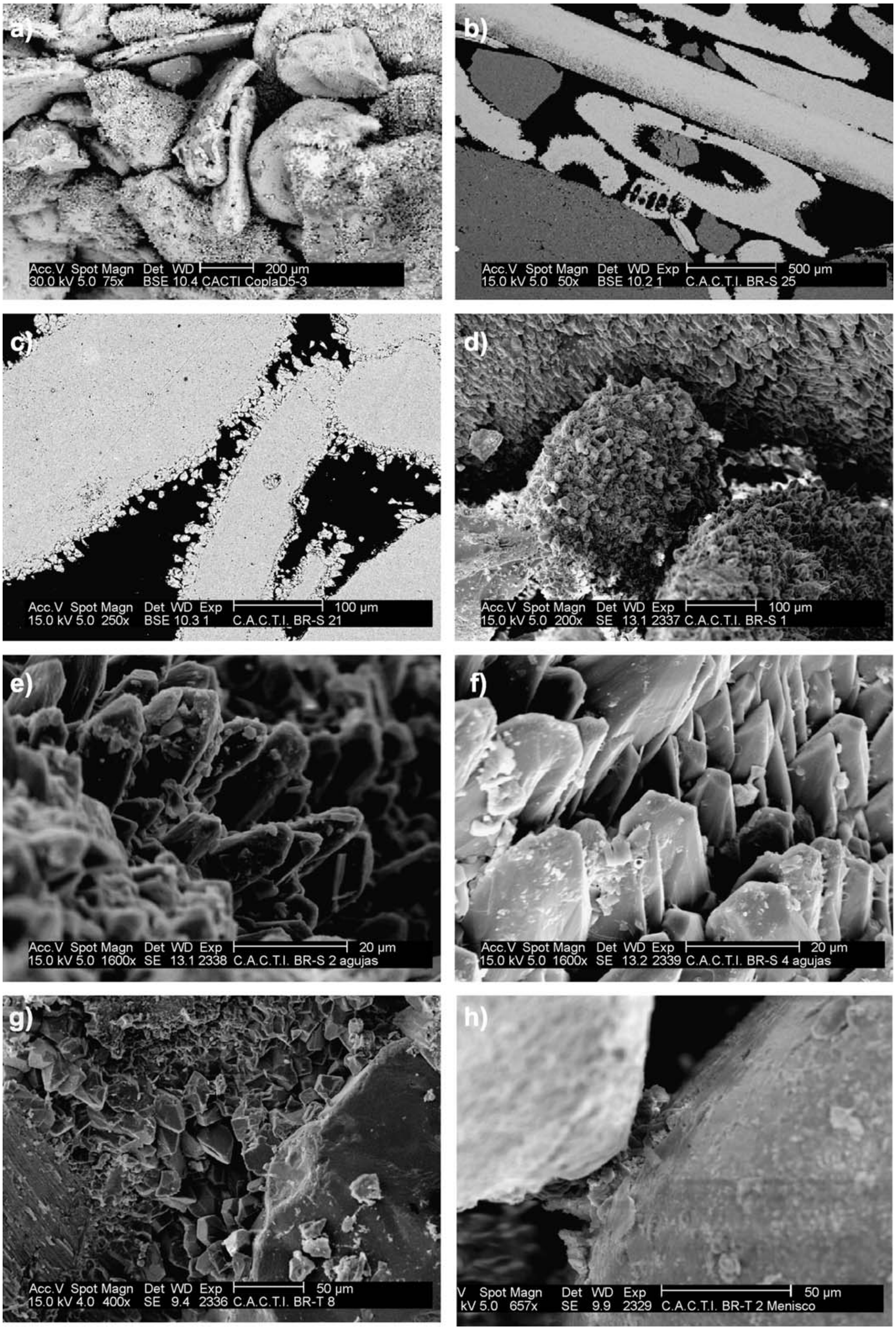
3. Morphological and petrological characteristics

The occasional outcrops of small fragments of beachrocks with an extension of 1–2 m^2, in the inlet zone of the Corrubedo island–barrier–lagoon complex, are well known to the researchers who have worked in this area (e.g., Vilas et al., 1991).

The exceptionally high wave-energy conditions affecting the majority of beach systems on the northwest coast of the Iberian Peninsula during winter 2001 resulted in an anomalous flattening of the winter beach profile. This seasonal erosive process was particularly intense on those beaches that, like Corrubedo, are highly exposed because they lie outside the sheltered ria zone. As a result of this process, in early May 2002, it was possible to observe two outcrops of beachrock in this zone.

The largest cemented area was located in the intertidal zone of the central sector of the beach, north of the tidal inlet opening (Fig. 1). The exposed cemented zone, at that time, occupied an area approximately 100-m long by 8- to 10-m wide. Morphologically, it presented an abrupt side seaward and a more

Fig. 3. (a) General view of the clasts and their cementing to the SEM. Note the flattened form of the bioclasts as opposed to the more rounded form of the detritic grains. The dark patches are remains of marine salt. (b) BSE image clearly showing the presence of the cementing in the bioclastic grains, and their absence in the siliciclastic grains. Also note the micritic-type cementing in the elongated carbonate. (c) Seen in greater detail, the coatings of equigranular calcite, which may constitute real pore lining. (d) Note the two main textures of the pore lining calcite. The grains, in the foreground, present acicular epitaxials orientated orthogonally to the grain. The crystals, in the middle distance, are arranged homogenously like pore linings. The homogeneity in size and orientation is to be noted. (e) Detail of the acicular coatings of calcite. Note how, in some cases, certain signs of dissolution appear in the apical zone of the crystals. (f) Detailed image of the epitaxial growth of bladed-type coatings, perfectly aligned. (g) Pore filling seen in detail, showing the growth and arrangement of geode-type crystals. (h) Detail of typical cementation in meniscus.


a)
Acc.V Spot Magn Det WD 200 µm
30.0 kV 5.0 75x BSE 10.4 CACTI CoplaD5-3
b)
Acc.V Spot Magn Det WD Exp 500 µm
15.0 kV 5.0 50x BSE 10.2 1 C.A.C.T.I. BR-S 25
c)
Acc.V Spot Magn Det WD Exp 100 µm
15.0 kV 5.0 250x BSE 10.3 1 C.A.C.T.I. BR-S 21
d)
Acc.V Spot Magn Det WD Exp 100 µm
15.0 kV 5.0 200x SE 13.1 2337 C.A.C.T.I. BR-S 1
e)
Acc.V Spot Magn Det WD Exp 20 µm
15.0 kV 5.0 1600x SE 13.1 2338 C.A.C.T.I. BR-S 2 agujas
f)
Acc.V Spot Magn Det WD Exp 20 µm
15.0 kV 5.0 1600x SE 13.2 2339 C.A.C.T.I. BR-S 4 agujas
g)
Acc.V Spot Magn Det WD Exp 50 µm
15.0 kV 4.0 400x SE 9.4 2336 C.A.C.T.I. BR-T 8
h)
V Spot Magn Det WD Exp 50 µm
kV 5.0 657x SE 9.9 2329 C.A.C.T.I. BR-T 2 Menisco

gently sloping onshore side (Fig. 2a). At the back of the gently sloping side, an erosive fluting approximately 2-m wide appears, similar to a ridge and runnel system. This morphology is contrary to that which has generally been described in tropical beachrocks (El Sayed, 1999, among others), where the abrupt side corresponds to the zone nearest the shore. Typical prograding seaward-dipping sequences (i.e., Friedman, 2002; Turner, 2002), which usually help to interpret eustatic and/or tectonic controls, were also absent. On-site observations indicate that this singular feature is mostly controlled by wave modelling during and after exhumation, giving an idea of the fragility of the cementation of this outcrop, and that it does not reflect the morphology of the cemented area. Generally, dispersed gravels and small dark patches of heavy mineral concentrations appear along the length of the backside fluting, which is the area most sheltered from wave action. The upper and more exposed part of the outcrop presents a light greenish colouring, mainly due to colonization by algae and microorganisms. Lamination on the beachface is very apparent due to differential erosion (Fig. 2a).

The second outcrop lies on the most northerly edge of the tidal inlet, also within the intertidal zone (Fig. 1). The outcropping area is considerably smaller, occupying some 2 m^2 in total. It appears partially buried in unconsolidated sand. It is noteworthy that the exposed part of the outcrop shows a brighter green colouration and is completely colonized by algae (Fig. 2b). Cementation in this zone is also more intense, conferring greater durability.

From a petrological viewpoint, the cemented material is formed by mixed siliciclastic-carbonate sands of a medium-to-coarse grain size (Fig. 3a,b). The siliciclasts are mostly quartz, and to a lesser extent, feldspars, micas, and rock fragments, with a few heavy minerals as accessories. The carbonate fraction accounts for between 30–60% and is formed by fragments of bivalves, gastropods, equinoderms, calcareous algae, and foraminifera. The siliciclastic grains are generally subspherical and moderately to well-rounded (Fig. 3a). The carbonate grains are more angular, and some present signs of incipient dissolution, calcitic micritization, and boring. The petrological study highlighted the presence of a calcite cement with a low Mg content. This is supported by the absence of colouring in the diagnosis after subjecting the thin section to the staining sequence proposed by Miller (1988), the rhombohedric morphology of the crystals when observed with SEM (Fig. 3e), and the lack of Sr during EDXRA microprobing. These cements are epitaxial in nature and were found exclusively on the surface of the bioclasts (Fig. 3d). The electron microscope study showed four morphological types and characteristic textures (Fig. 3):

(a) Acicular coatings of calcite, with relatively variable length and thickness. Occasionally, signs of dissolution were observable at the apex of the individual crystals (Fig. 3e);
(b) Bladed-type, equigranular coatings, which may be formed by true pore linings (Fig. 3f);
(c) Pore linings/pore fillings of sparitic calcite, integrating blocky and druse-type textures (Figs. 3c,d and g); and
(d) Meniscus-style calcitic cements (Fig. 3h).

Acicular and bladed-type pore linings are the most abundant textures, whilst blocky and druse textures are less frequent. Meniscus types are generally quite rare and slightly more evident in the reddened uppermost part of the larger outcrop and in the more evolved patch. Apart from this, no specific pattern of these different textures was discernible.

4. Morphodynamic behaviour of the cementation zone: implications for the timing of formation

Exhumation of beachrock is conditioned by the cyclical movements of sediments due to seasonal changes in wave climate conditions. Thus, the morphodynamic behaviour of a beach, described in detail by Wright and Short (1984) for microtidal beaches and by Masselink and Short (1993) and Bernabeu et al. (2003) for tidal beaches, can be considered an important controlling factor in the genesis and evolution of a beachrock.

During periods of fair weather, the trend on a beach is accumulative, with sand accumulated preferentially in the supratidal and intertidal zones. This generates an increase in the slope of the beach profile and subsequent seaward progradation of the shoreline, keeping the beachrock buried. Contrariwise, typical winter conditions force an erosive tendency; sediments are then transported towards the subtidal zone, reducing the slope and causing the profile to retreat.

The shoreline moves landwards, although generally, the erosion of the profile is insufficient to unearth beachrock. However, under extreme conditions generally related to a sporadic event, the typical winter

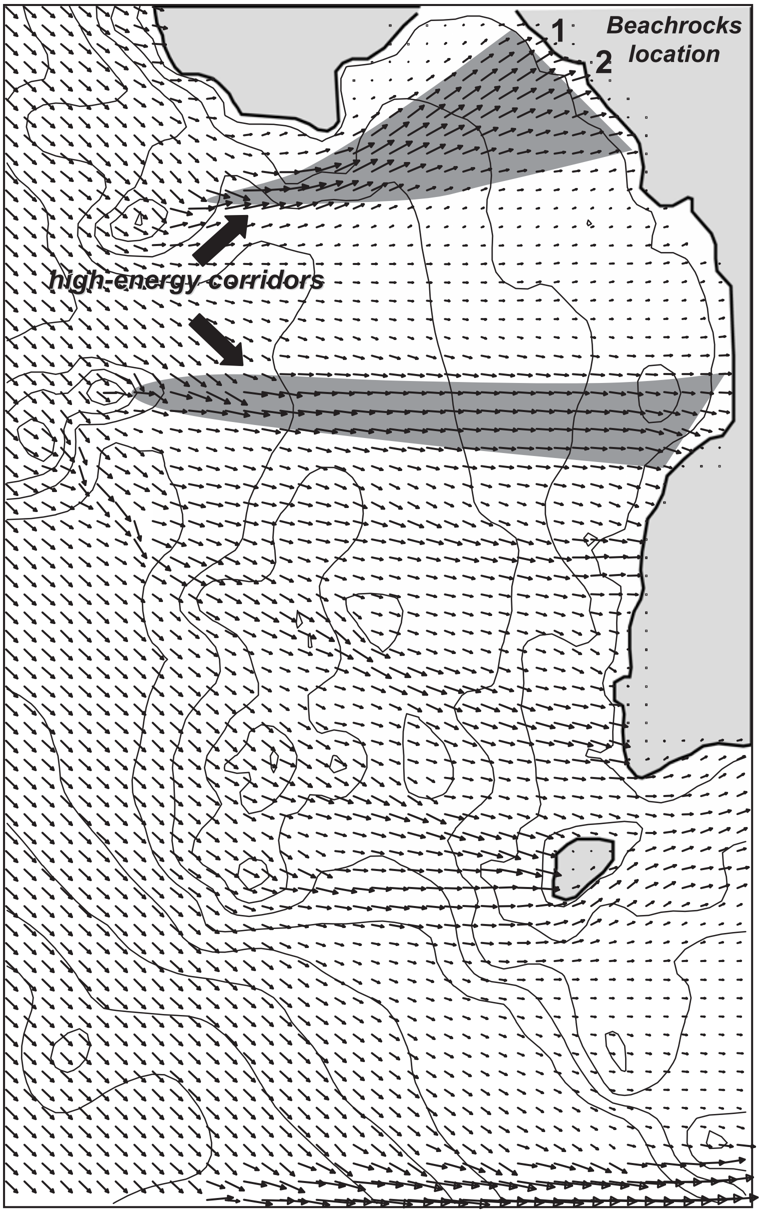


Fig. 4. Example of numerical modelling of the wave propagation in Corrubedo Bay. The wave parameters in deep waters used in this case correspond to a significant wave height of 2.5 m, a period of 9.5 s, and an incidence direction of NW. The presence of two high-energy corridors is noted, channelled by the rocky bottoms at the entrance to the bay. The incidence of the north corridor on the Corrubedo beach coincides with the location of the beachrocks.

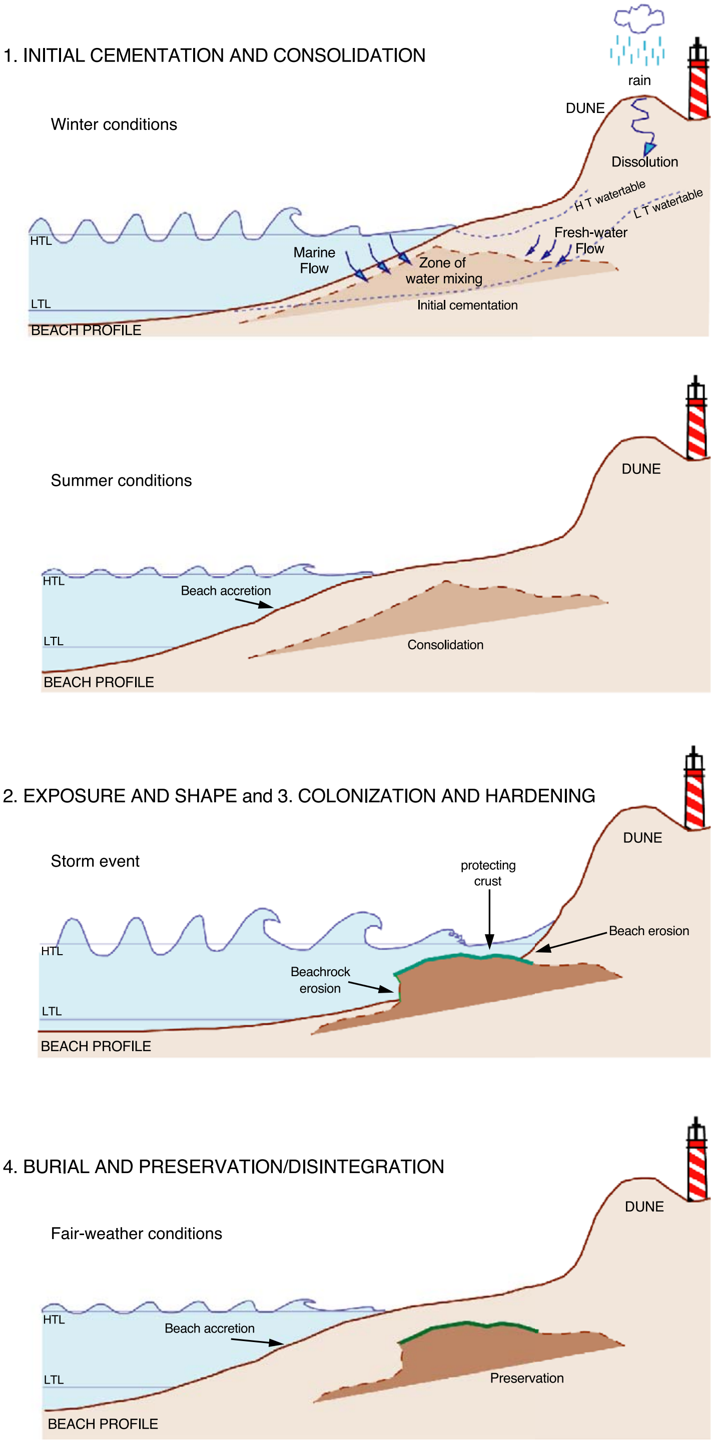


Fig. 5. Model proposed for the genesis and evolution of a beachrock in temperate latitudes (based on similar multistage models, e.g., Bernier et al., 1990; Turner, 1999a,b).

erosion tendency is accentuated, increasing the volume of sediment transported towards the sea and increasing the retreat of the profile. This situation promotes exhumation of beachrock and its exposure to wave action.

Our hydrodynamic study characterised the wave action conditions affecting the Corrubedo area (Fig. 4). The rocky outcrops at the entrance of the bay precondition the evolution of wave propagation. Thus, regardless of the characteristics and direction of waves offshore, between the rocky bottoms, waves are transformed and channelled, forming two high-energy corridors whose positions do not vary throughout the year. Consequently, two maximum-incidence zones are located along the Corrubedo beach. Between both zones lie in areas sheltered from wave action by the effect of the rocky outcrops.

One of the high-energy incidence zones is located on the northern half of the beach, coinciding both with where beachrocks appear and where the inlet and the dune lie. The other high-exposure zone is located on the southern half of the beach. At both points on the coast, the range of seasonal variation in the wave height is wide, responding to variations in the open sea. This promotes the morphodynamic variability in these stretches of the beach and the seasonal mobilization of sediments in both directions, landwards in summer and seawards in winter (step 1, Fig. 5), which provokes burial, and in extreme cases, the outcropping of beachrock.

This mechanism of beachrock exhumation, controlled by local wave climate conditions, is also important to estimate the timing of the cementation process. Four major considerations can be noted in this regard:

(a) The beachrock is formed by cementation of present-day beach sands, forming part of the beach–lagoon complex of Corrubedo (Vilas and Nombela, 1986; Vilas et al., 1986, 1988, 1991).

(b) The present-day beach is interpreted as the result of a relative sea-level rise in the area during the last 2000 years due to combined tecto- and glacio-eustatic processes (Vilas et al., 1991). This is based on ^{14}C dating of two peat levels (1045 ± 125 B.P. and 2280 ± 60 B.P.) sealed by the sand dune as it retrograded and accreted over the marsh within the beach–lagoon complex (Vilas et al., 1991).

(c) The exhumation of the beachrock does not occur every winter, but only under prolonged or exceptionally bad weather conditions. We have calculated a wave return period of 4 years, with a 90% confidence level for the conditions of winter 2001, based on wave climate studies for the Galician coast from the Spanish Ministry of Public Works (MOPTMA, 1991). This means that through a general accretion tendency, the beachrock is exhumed and eroded every 4 years, implying that new cementation processes must occur during this time span.

(d) The regional eustatic context since the last Glacial Minimum (Younger Dryas) at about 11 ky (García-Gil et al., 1999) comprises a local maximum at about 6 ky and a very slow and steady drop of less than 5 m over that period of time. Overall, this is fairly similar to more generalised eustatic curves (e.g., Pinot, 1968; Aloïsi et al., 1978; Fairbanks, 1989).

(e) In light of the above, the likable maximum time for at least the early cementation process to occur is about 4 years. The estimated rate of sea-level drop rules out beachrock exhumation related to a progressive incision of an ancient beachrock. However, this age estimate should be taken with caution because full-scale cementation processes leading to complex textures and increasing durability may take a significantly longer time than the period estimated here.

5. Genesis and evolution of beachrocks in Corrubedo

The two basic processes associated with the formation of beachrocks in Corrubedo are the degassing of groundwater CO_2 and supersaturation due to the direct evaporation of seawater in the vadose zone.

This idea is supported by the presence of relatively acicular coatings of calcite, whose texture is similar to that of aragonite, found in profusion in the intertidal zone on tropical and subtropical beaches. The presence of bladed-type calcite coatings may have a similar origin, given the unfavourable energy conditions for the formation of aragonite in subsaturated waters. The presence of traces of dissolution in the bioclasts and meniscus-type cements also lends support to this interpretation. In shallow water conditions and at this latitude, seawater tends to be subsaturated with $CaCO_3$, which induces the partial dissolution of carbonate grains, suggesting the need for an agitated medium in order to cause precipitation. The meniscus-type textures, typical of the vadose zone, also support the action of this type of process; however, meniscus cements may also have been formed in the course of the current exhumation.

It is highly likely that the mixing of marine and meteoric waters in this zone also plays an important role. The mixing of waters gives rise to changes in pH, which may promote the precipitation of carbonate and increase the concentration of dissolved carbonates associated with the higher pCO_2 level found in meteoric waters. This latter mechanism may be accentuated, in the case of the present study, by the presence of an important aeolian system at the back part of the beach. Its high permeability would enable it to act as a reservoir of carbonate-enriched meteoric waters coming from the dissolution of bioclasts in the dunes. $CaCO_3$ dissolution on uplifted beaches (palaeostrata) is a phenomenon that has been widely described along the Galician coast (Pazos et al., 1994, 1998), which may be favoured by the area's high average precipitation, some 1200 mm/year (Pérez-Alberti, 1982). Active carbonate precipitation fronts that support carbonate mobilization within the large Corrubedo dune were also described after the tidal channel dissected the dune, exposing the whole section in 1989 (Vilas et al., 1991). This type of process, although based on indirect evidence, may be of greater importance during the initial stages of forming the initial cementation and may promote the formation of subsequent cements.

Considering the differences observed between the two outcrops and based on similar four-stage models (i.e., Bernier et al., 1990; El Sayed, 1999; Turner, 1999a,b) for beachrock formation, we propose an evolution model for Corrubedo (Fig. 5), as described in the following subsections.

5.1. Initial cementation of the intertidal zone

The aeolian dune acts as a reservoir of $CaCO_3$-enriched freshwater. Copious rains during the winter lead to the dune being recharged with meteoric water subsaturated with $CaCO_3$. The meteoric water, which is slightly acidic and subsaturated with carbonate, dissolves the bioclasts in the dune, removing Ca^{2+} and CO_3^{2-} from it. The pumping of phreatic waters, as a result of waves and tide along the beach, causes the mixing of marine and meteoric waters, inducing the precipitation of carbonate in the intergranular voids. This process may be quite nonhomogeneous because the differences in wave height along the beach lead to differences in pressure, which cause the outlet of phreatic waters to be concentrated in certain zones, promoting cementation at these points. The degassing of the CO_3^{2-} in carbonate-rich continental phreatic waters at the limit of the vadose/phreatic zone, caused by direct wave action in the intertidal zone, also promotes the precipitation of calcium carbonate. These processes are synsedimentary and require a relatively low sedimentation rate.

5.2. Exposure and modelling by waves

A succession of mild winters causes a metastable progradation of the beach by maintaining an average slope along the beach profile, which keeps the beachrock buried. In very harsh winters, the beach profile flattens, uncemented sand is conveyed to the subtidal zone, and the beachrock outcrops. Its exposure to the direct action of waves models it, giving it a characteristic profile: abrupt and concave on the exposed side and slightly flat and convex on the sheltered side. The cemented zone is fractured, forming a series of entrances through which water flows during the tidal cycle. This process may take weeks to months, depending on the recovery of the beach profile with regard to maximum erosion generated by a high-energy event.

5.3. Colonization and hardening

Once exposed, the beachrock is colonized by microorganisms and algae, giving it a characteristic greenish colour; the greener it is, the more time has passed. This process promotes the precipitation of new cements. Exposure and direct wave action over successive winters promote the precipitation of $CaCO_3$ by direct evaporation of seawater and by the degassing of CO_3^{2-}. Both processes form a protective coating, which tends to consolidate the structure, making it consistent and durable. This process may take months to decades.

5.4. Disintegration/preservation and immersion

With the arrival of fair weather, the beach profile becomes steeper and sand builds up in the high intertidal zone, gradually covering the beachrock. If cementation has been efficient, the beachrock will be preserved until the following winter, becoming part of a cycle whose balance may be sustained for several centuries.

6. Conclusions

This paper highlights the exhumation of beachrocks on the Galician shoreline at a high latitude rarely noted for the presence of this type of formation.

The genesis mechanism proposed for the beachrocks of Corrubedo entails the contribution of carbonate-enriched meteoric waters to the intertidal zone of a beach exposed to high-energy wave action, conditions which are relatively common along the entire Galician shoreline. The recent appearance of cemented fragments of beach on the Miño beachrock and on the Puntal beach at other localities in northwestern Spain (Fig. 1) suggests that this type of diagenetic process is more common at these latitudes than has been generally considered.

The petrological study highlighted the presence of calcite cement with a low Mg content in a variety of textures, ranging from acicular pore linings to blocky pore fillings. Colonization by algae and microorganisms and subsequent diagenetic processes associated with their exhumation cause a complex superposition of textures on the cements, which ultimately tends to increase their durability.

In beach systems such as Corrubedo, beachrocks are not only a morphogenetic unit. They constitute a clearly differentiable petrological unit as well, and their formation controls specific sedimentary processes with characteristic evolutionary patterns. Only very recently, some authors such as Millar and Mason (1994) and Turner (1999a,b) have also considered the morphodynamic implications of this type of formation for beach evolution. In this sense, high-latitude beachrocks play an important role in the beaches' seasonal sand balance as they attenuate wave energy during storm events in the areas of maximum wave incidence.

Finally, it should be noted that beachrock exhumation has a clear short-term hydrodynamic significance, inasmuch as it is indicative of a change in the conditions of the beach profile's morphodynamic equilibrium, manifested through an anomalous erosive process. From a middle- and long-term standpoint, the systematic exhumation of beachrocks on our shorelines may be considered a sign of change in the conditions of the beach system's sedimentary balance. Their two possible anthropic or eustatic origins deserve more in-depth research, due both to their environmental implications and/or what they may contribute to the study of global climatic change.

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