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Typology of Argentine Beaches: Composition, Tidal Range and Wave Energy

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ABSTRACT

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Morphodynamic-based beach models assume uniform grain-size availability. However, uniform grain sizes seldom occur in present beaches. Waves and longshore currents induce sediment distribution, parallel or transverse to the coastline. And tidal ranges condition the temporal effects of waves and wave-induced currents.
Argentine beaches are particularly sensitive to these effects. Beach composition varies from fine sand to uniform gravel up to 5 cm in diameter. Atlantic waves are higher than 1 m and 10 sec period; within gulfs and rias outlets local waves are significantly lower and with shorter periods. Spring tidal ranges also vary, from less than 1 m in Buenos Aires coastline to more than 8 m in southern Patagonia. More than 78 beaches were seasonally analyzed from the microtidal coast of northern Buenos Aires Province. 20 beaches, composed of gravel, sand or both textures, were also surveyed from the mesotidal regime of northern Patagonia. Finally, 35 macrotidal beaches were analyzed from southern Patagonia and Tierra del Fuego; some of them composed exclusively of fine sand, others composed of coarse gravel, with fine sand segregated along the beach profile (low tide terrace). Microtidal beaches do fit to the morphodynamic model proposed by Australian researchers. Mesotidal beaches have a different behavior in regard to the sediment composition and wave effects. Macrotidal beaches behave in relation to the type of sediment and its availability: Dissipative beaches may occur where there is a significant source of sand. Gravel availability is responsible for a dual behavior of a single beach: reflective close to high tide and dissipative during low tide.

ADDITIONAL ÍNDEX WORDS: *Beaches, grain-size, tidal range, Argentina.*

INTRODUCTION

Argentine beaches respond to several wave and tidal regimes. Composition also varies from sandy beaches at the north to gravel beaches to the southern coast, glaciated during the Pleistocene.

Beaches were historically classified by their composition. Today, we can distinguish if they are composed by sand, gravel or gravel and sand (MC LEAN and KIRK, 1968; MASON and COATES, 2001).

In relation to their dynamics they were classified into high-energy and low-energy beaches; with time this knowledge developed into the Australian beach-stage morphodynamics model, originally applied to the microtidal regime (SHORT, 1979; SHORT and WRIGHT, 1984). Later, this concept of reflective, dissipative and intermediate beaches were also applied to the meso and macrotidal regimes (SHORT, 1991; MASSELINK and SHORT, 1993; MASSELINK and HEGGE, 1995).

In the present paper, beaches along the Argentine coast were analyzed in relation to their grain-size composition and, dynamics in order to test the applicability of morphodynamics models.

SETTING

In a regional description, the northern coast of Argentina is dominated by storms coming from the south and southeast. The southern coast is dominated by semidiurnal tides (ESTEVES et al., 2000). Tidal range is microtidal at the northern Buenos Aires coasts, and within the Beagle Channel (Tierra del Fuego) where there is a restricted mixing between the Pacific and Atlantic regimes (**Fig. 1).** Mesotidal regimes are present at the south of Buenos Aires province, and at the Peninsula Mitre (Tierra del Fuego), transition from the Atlantic tides towards the Beagle Channel (ISLA and BUJALESKY, 1995). Macrotides dominate at the Patagonian coast, increasing inside gulfs or in relation to the width of the continental shelf (Figure 1).

High-energy coasts dominate where the width of the continental shelf is narrow (few km). Waves become very small within the Patagonian gulfs where the fetch is restricted.

Coastal sediment composition varies in relation to climate and geologic history. Template beaches of Buenos Aires are dominated by fine sand transported by the regional longshore drift from south to north. The coast of Patagonia is characterized by the availability of gravel that have been transported by mostly gravity-dominated phenomena from the Andes (Shingle Formation or Patagonian Gravel). At the coast of Tierra del Fuego and Magellan Strait, gravel was transported by piedmont glaciers during the Pleistocene, mainly Lower Pleistocene (ISLA and SCHNACK, 1995). The composition of patagonian and fueguian beaches is dominated by volcanic rocks (GELOS *et al.,* 2000).

Groundwater seepage can be minimized at the microtidal beaches of Buenos Aires, or at the semidesertic climate of Patagonia. However, seepage become very important at the macrotidal beaches of southern Tierra del Fuego (rainy region).

METHODS

Topographic beach surveys were carried out with teodolite during low tide. Sediment samples were usually taken at the backshore, foreshore, swash- and surf-zone. In bimodal macrotidal beaches, the toe of the beach was also sampled. Sediment samples were sieved every 0.5 phi units and grain-size parameters calculated graphically.

Ω and Relative Tidal Range (RTR) parameters were calculated for each beach and plotted in a bivariate graph (MASSELING and SHORT, 1993); in this paper RTR was plotted in a logarithmic scale (Figure 2). This graph was originally proposed exclusively for unimodal beaches.

RESULTS

More than 130 beaches were surveyed and sampled along the 3500 km of the Argentine coast.

Buenos Aires

Buenos Aires microtidal beaches are composed of fine sand. Dissipative beaches are more common to the north of this

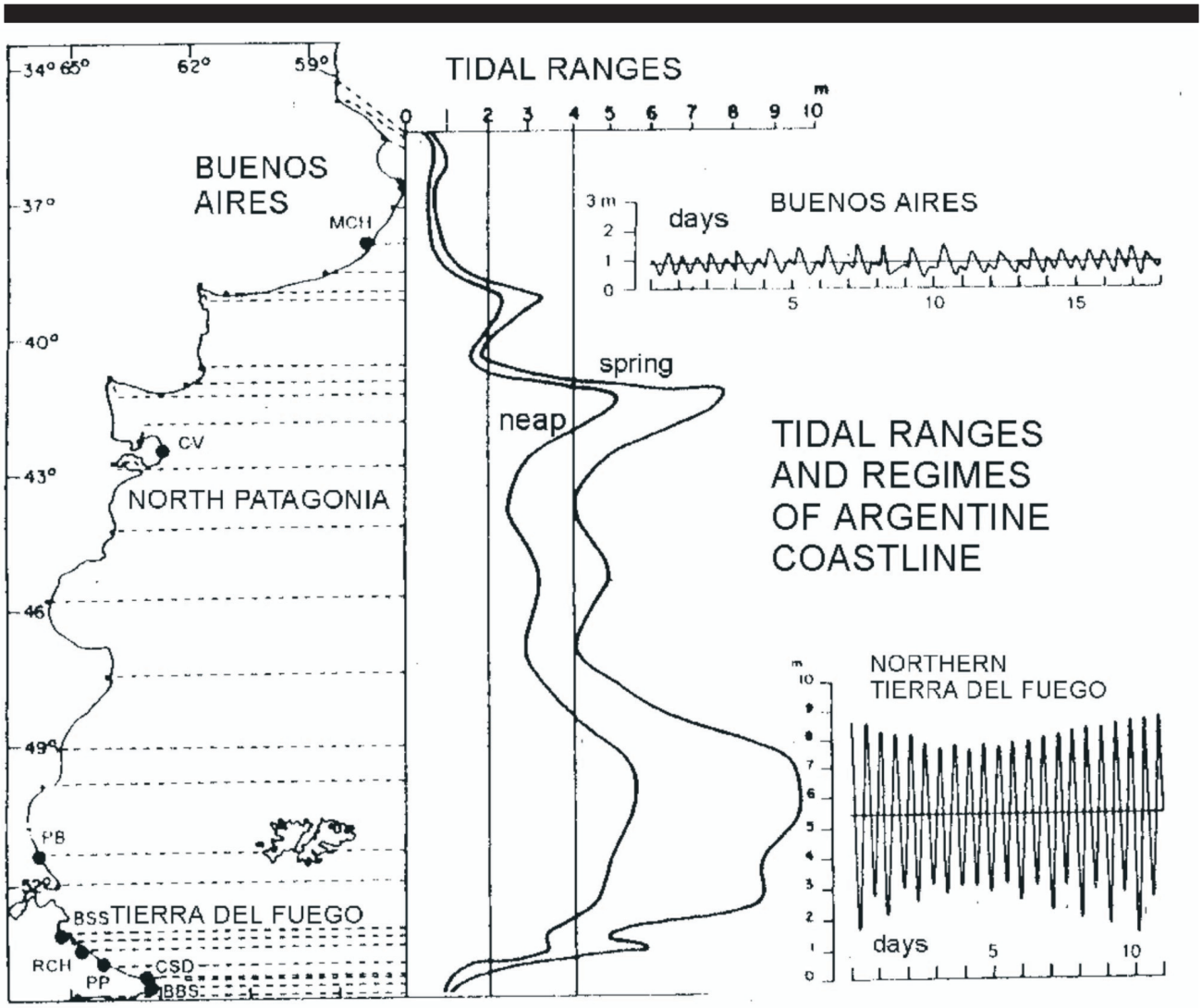

Figure 1. Tidal ranges and regimes along the Argentina coastline.

province (north of 37°S). Towards the area of Mar del Plata, intermediate and reflective beaches are explained by the narrowness of the continental shelf; a significant littoral transport is from south to north. These beaches have been modified by the construction of jetty fields (ISLA *et al.,* 2001a) and can vary in their dynamics along the year (ISLA *et al.,* 1994).

At the south of Buenos Aires Province, mesotidal regimes and gravel availability conditioned beach dynamics; longshore drift diminishes (ISLA *et al.,* 1997; ISLA and BÉRTOLA, 2003).

Patagonia

In northern Patagonia, beach dynamics is conditioned by the availability of gravel and the magnitude of the tidal ranges. Sandy beaches are present in relation to barriers or ebb-tidal deltas. Within the gulfs of northern Patagonia, beach dynamics is conditioned by short fetchs (ISLA *et al.,* 2001b). The San Jorge Gulf (Chubut Province, 46° S) is a perfect area to test the effects of wave refraction and wind effects. Its semicircular shape makes it open to Atlantic waves, but very-strong westerly winds usually diminish the wave effects. At these pocket beaches, sand is provided by blowouts or lineate deflation corridors. Tidal regime increases from mesotidal at the entrance of the gulf to macrotidal at the westernmost coast, and these effects condition beach dynamics (ISLA *et al.,* 2002).

Tierra del Fuego

Southern Patagonia and Tierra del Fuego coasts were glaciated during Pleistocene. At the inlet of the Magellan Strait, glacial deposits are today several meters below present sea level. The reworking of these end moraines provided gravel and sand to spits formed under a longshore drift toward the south. Bimodal beaches consist on berms composed of uniform pebbles (sand is sieved below the gravel) with low-tide terraces composed exclusively of fine sand. These grain-size distributions condition beach dynamics: reflective during high tide, dissipative during low tide (ISLA *et al.*, in press). Berms may be constructed exclusively of uniform and rounded pebbles up to 5 cm long. Overpassing and saltation are dominant processes at these pebble beaches (ISLA, 1992; ISLA and BUJALESKY, 1993).

Ω Vs. RTR Graph

In the graph of MASSELINK and SHORT (1993), microtidal beaches of Buenos Aires clearly distribute into reflective, intermediate and dissipative morphodynamic fields (**Fig. 2**). Dissipative beaches have not been identified in the mesotidal and macrotidal regimes. The micro-mesotidal beaches of the Rincón de Bahía Blanca, were plotted as meso-macrotidal in this graph (ISLA and BÉRTOLA, 2003). Beaches within northern Patagonian gulfs are over value 11 in RTR (ISLA *at al.,* 2001).

DISCUSSION

Although the morphodynamics model applied to microtidal beaches was proved useful, its extrapolation to meso-macrotidal regimes has generated some doubts. This model was proposed only for unimodal beaches, but sediment-wave parameters are poor descriptors of mixed sand-gravel beaches (ANTHONY, 1998). In these mixed beaches sediment-transport processes are completely different (MASON and COATES,

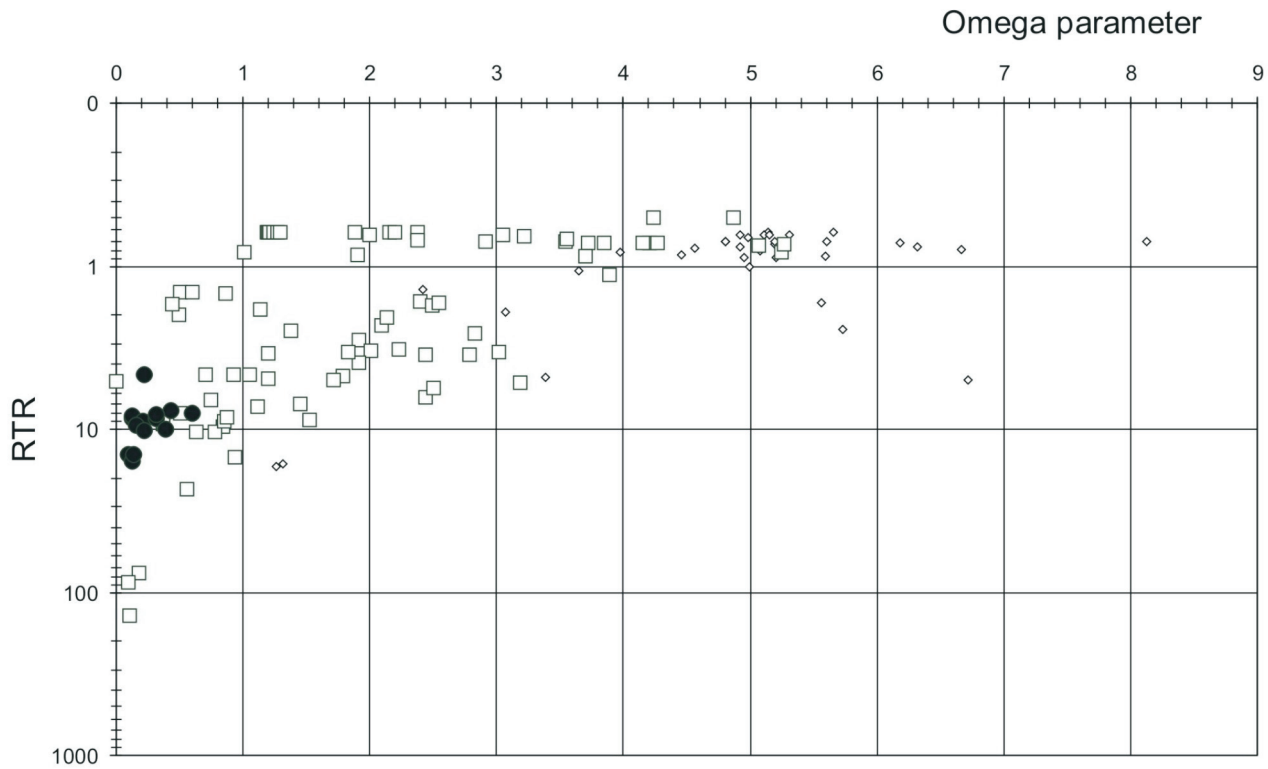

Figure 2. Ω Vs. RTR graph of the argentine beaches. Diamonds are microtidal beaches; squares are beaches composed of medium, coarse and very coarse sand; circles are gravel beaches (coarser than 1 phi).

2001). It is common that grain sizes vary significantly along the beach profile, and beach slope also varies significantly to characterize these beaches (ANTHONY, 1998).

In the sand-gravel beaches of Tierra del Fuego, morphodynamics models are difficult to apply: breaker wave height vary along the tide (therefore Ω does the same), and the value of RTR is difficult to estimate as it also depends on the breaker height. Sediment-transport models are worse difficult to apply for these type of beaches: during the dissipative low-tide phase, spilling breakers induce sand entrainment as suspended load from the low-tide terrace. The surf-zone processes become dominant in sediment transport. During the reflective high-tide phase, plunging breakers induce gravel saltation or overpassing at the upper foreshore. The swash-zone processes increase bed-load transport. As the waves are less refracted (higher beach slope), alongshore transport becomes more important (MASON and COATES, 2001). In sum, and without considering the spatial grain-size segregations along the profile, a sediment-transport approximation for bimodal macrotidal beaches should consider bed-load processes during high tide, and suspended-load formulas close to the low tide.

CONCLUSIONS

1.Grain-size sediment availability is the main factor controlling beach typology.

2. In microtidal beaches, wave height in relation to grain size and wave period, the adimensional fall velocity parameter, permit to recognize between reflective and dissipative behaviors of Buenos Aires beaches.

3.Macrotidal beaches are dominantly reflective in their behavior. Only those beaches emplaced within Patagonian gulfs, composed of medium to very coarse sand, occupied an intermediate morphodynamic field.

4. Bimodal (gravel and fine sand) macrotidal beaches vary in their response along the tide fluctuation: reflective during high tide and dissipative during low tide.

5.These processes should be considered when sediment-transport models would be envisaged for these beaches.

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