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Invited review article

Geological constraints on mesoscale coastal barrier behaviour

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ABSTRACT

Barrier/lagoon systems occupy a significant part of the world's coast. They are diverse in size, morphology, geological and oceanographic setting, and morphodynamic behaviour. Understanding the behaviour of barriers at 10^1 to 10^2 year and 10^1 to 10^2 km scales (mesoscale) is an important scientific and societal goal, not least because of the preponderance of intensive coastal development in a time of global climate change. Such understanding presents significant challenges. Challenges in *describing* mesoscale system behaviour relate largely to the incomplete evidence base of (i) morphological change in system components, (ii) dynamic and internal forcing factors (drivers) and (iii) geological constraints. These shortcomings curtail the development of baseline datasets against which to test models. *Understanding* observed changes and thereby predicting future behavioural patterns demands assumptions and simplifications regarding the linkages between initial state, dynamic drivers, system feedbacks and a multiplicity of geological constraints that are often location-specific.

The record of mesoscale change is improving with the acquisition of long-term morphological datasets. Advances in technology and chronological control mean that geological investigations can now provide decadal to century-scale temporal resolution of morphological change. In addition, exploratory modelling is improving understanding of the influence of various dynamic and geological factors.

Straightforward linking of dynamic forcing and response is seldom able to account for observed mesoscale behaviour. Geological factors exert a significant or even dominant control on barrier behaviour at decadal to century timescales. Whereas these geological controls can be quantified to some extent by detailed investigations of contemporary barrier/lagoon morphology and constituent materials, underlying geology and topography and sediment supply, in all but a few locations, such data are absent. This sets an unavoidable constraint on efforts to quantitatively predict the future behaviour of barrier systems, which are strongly site-specific in terms of their geological setting and morphology. Geological controls exist in a network of interactions that individually and collectively influence mesoscale barrier behaviour. Dominant, first-order controls are:

- Basement slope;
- Basement irregularity and erodibility;
- External sediment supply;
- Orientation; and
- Shoreline lithification (beachrock and aeolianite)

An important intermediate level of geological control is exerted by shoreface morphology. Shorefaces are themselves influenced by underlying geological factors, but they are dynamic at longer timescales than barriers. Geological influences are in most cases unquantified and are usually disregarded when conceptualizing and modelling barrier evolution. Consideration of the geological influences is, however, essential in efforts to predict future behaviour at mesoscale (management) timescales.

1. Introduction

Coastal barrier and barrier-island systems occupy a significant proportion of the world's coastline. They are chiefly composed of sand, with a significant minority of gravel-dominated barriers concentrated in formerly glaciated areas (Orford et al., 1991). Barrier islands occur on about 10% of the open ocean coast (Stutz and Pilkey, 2011), and, combined with mainland-attached examples, barriers make up about

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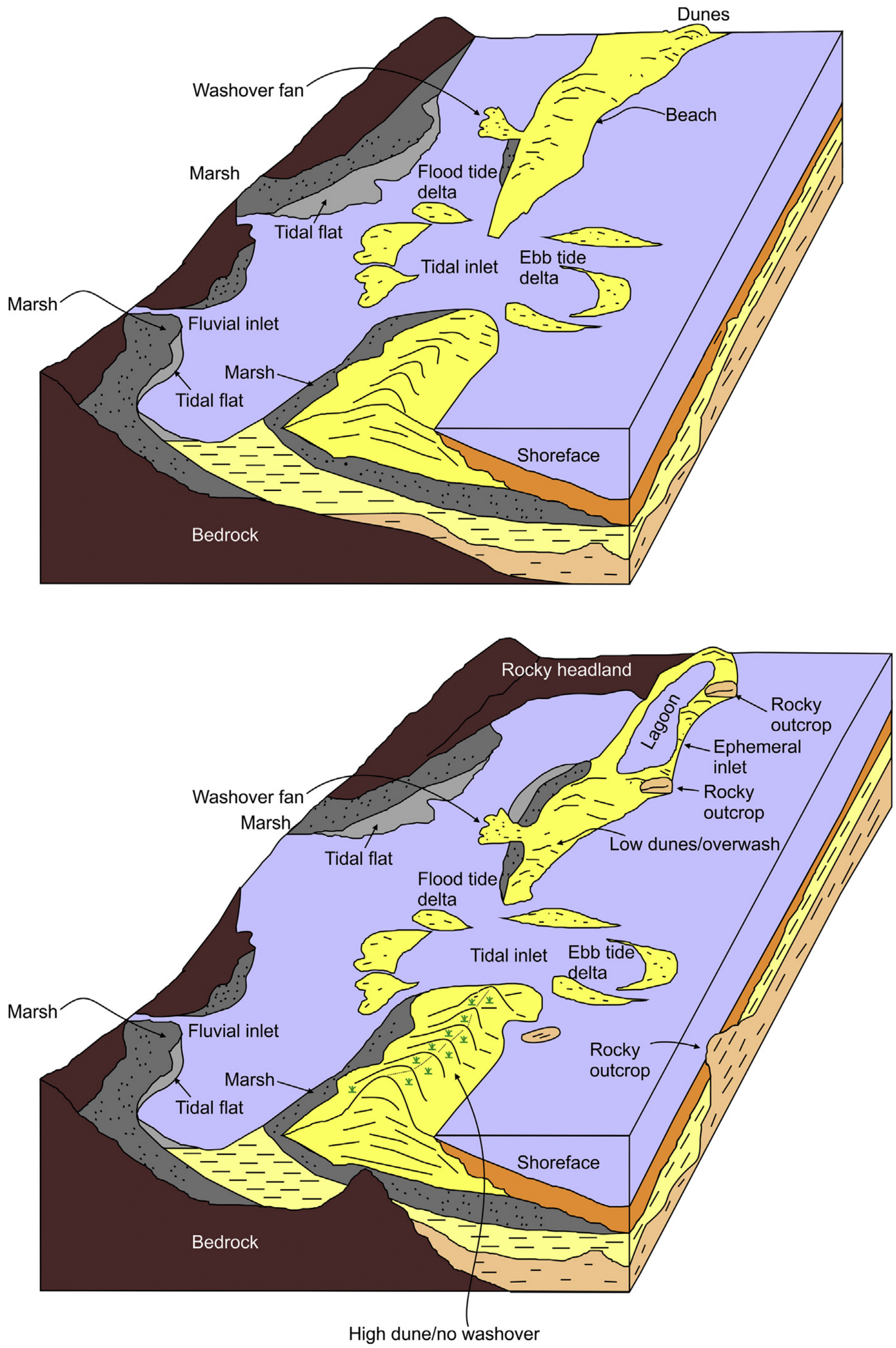

Fig. 1. A. Unconstrained barrier island facies model (after Reinson, 1992); B. Barrier island facies model showing geological influences and resulting morphological variations.

15% of the world's ocean shoreline (Davies, 1980). Barriers are also widespread in low-energy, fetch-limited settings of lagoons and bays (Cooper et al., 2007; Pilkey et al., 2009).

In morphodynamic terms, barriers are dynamic, unconsolidated sedimentary systems that respond to various drivers. These drivers may be short-term (e.g. low magnitude/high frequency or modal wave and tide processes), episodic (e.g. wave energy and water level changes during storms (Stone et al., 2004; Houser et al., 2008)), medium term (e.g. the cumulative effect of modal wave and tides; climate oscillations), or longer term (e.g. sea-level change, storminess patterns). The influence of these drivers, however, is mediated by non-dynamic (geological) variables such as the nature of the underlying geology and topography, sediment supply, and the morphology of the barrier/lagoon system itself. These geological controls are difficult to quantify and are often overlooked, ignored or grossly simplified in approaches to understanding or predicting barrier behaviour.

Aside from the importance of barrier-related sediments in the geological record (where they often form petroleum reservoirs), understanding barrier coast behaviour at timescales of decades to centuries is a pressing societal need because of the proximity of human development either on, or adjacent to, barrier systems. In some instances, this development takes advantage of aspects of barrier geomorphology (e.g. navigation through tidal inlets) or is based on proximity to the beach (Pilkey and Cooper, 2014). In many instances, barriers are so