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Morphology and sedimentology of a microtidal beach with beachrocks: Vatera, Lesbos, NE Mediterranean

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ABSTRACT

The present contribution considers the dynamics of beaches occupied by outcropping/buried beachrocks, i.e. hard coastal formations consisting of beach material lithified by *in situ* precipitated carbonate cements. The dynamics of a Greek microtidal beach with beachrocks (Vatera, Lesbos) are examined through the collection and analysis of morphological and sedimentary field data, a 2-D nearshore hydrodynamic model and a specially constructed 1-D morphodynamic model. The results showed that the beachrock-occupied part of the beach is characterised by distinctive morphodynamics as: (i) its beachface is associated with large slopes; (ii) there is a good spatial correlation between the sub-aerial and shallow submerged mean beach profile and the buried/outcropping upper beachrock surface; and (iii) the seaward margins of the submerged beachrock outcrops are always associated with a 'scour step' i.e. a submerged cliff. The results also showed that beachrock outcrops can bias cross-shore sediment exchanges by impeding onshore transport due to the presence of the scour step. In this sense, beachrock outcrops may be considered as offshore transport 'conduits' for the beach sediments. A conceptual model of beach sediment transport, based on the field data and the hydrodynamic modelling is proposed. According to this model, fresh beach material from adjacent terrestrial sources is transported alongshore, towards the central part of the embayment, where a littoral transport convergence zone occurs under most wave conditions. There, the laterally supplied sediments are lost offshore.

1. Introduction

Beachrocks are solid sedimentary formations consisting of beach material bonded together by *in situ* precipitated carbonate (calcitic and/or aragonitic) cements (e.g. Bathurst, 1975; Vousdoukas et al., 2007). Sediment lithification usually takes place in the intertidal and/or supratidal zones either on the beach surface or, more commonly, beneath a veneer of unconsolidated sediments (e.g. Neumeier, 1999), and involves all sorts of beach sediments i.e. clastic, biogenic and authigenous sands and gravels, as well as human artifacts (Chivas et al., 1986; Gischler, 1994; Milliman, 1974).

The carbonate cements are precipitated from the beach interstitial waters and/or sea wave sprays (Ginsburg, 1953; Kelletat, 2006), mixed coastal aquifers (e.g. Milliman, 1974; Moore, 1973; Schmalz, 1971); coastal water tables due to CO_2 de-gassing (Hanor, 1978) and coastal waters due to biological activity (e.g. Davies and Kinsey, 1973; Neumeier, 1999). The main physicochemical controls of carbonate precipitation in coastal waters are considered to be the temperature, pH, salinity and the PCO_2 (Morse and Mackenzie, 1990), the magnitude/distribution of the wave energy (Gischler and Lomando, 1997) and the nature of the beach sediments (Russell and McIntire, 1965).

In terms of size, beachrock formations vary from tiny patches of cemented sediments to formations hundreds of metres wide and kilometres long. Their typical thickness also varies from ~0.3 m to more than 2 m, being greater along coastlines with more pronounced sea level fluctuations (e.g. Vousdoukas et al., 2007). In some cases, beachrocks have been found to occupy the entire length of the beach, but normally appear in patches bounded by unconsolidated sediments (e.g. Kelletat, 2006). They usually form band sequences, with the oldest bands found seaward (Strasser et al., 1989) and are often found outcropping in the surf and swash zones. In many cases, the outcropping formations may extend onto the onshore part of the beach as buried formations (Neumeier, 1998; Russell and McIntire, 1965).

Beachrocks can have significant impacts on beaches. Their formation/outcropping can result in important ecological changes, as the original beach fauna and flora assemblages are gradually replaced by those associated with rocky foreshores (Brattström,

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1992), with unpredictable consequences for the regional ecology (e.g. Airoldi, 2005). In addition, the presence of beachrocks can influence beach aesthetics and recreational uses, thus, affecting the amenity value of beaches (Vousdoukas et al., 2009). Finally, beachrock formation and outcropping can have significant impacts on beach morphodynamics, as it may alter the long- and cross-shore sediment transport patterns and budgets (Cooper, 1991; Rey et al., 2004).

Although beachrocks have been shown to be a common feature of the global coastline (Vousdoukas et al., 2007), which may affect significantly beach sediment dynamics and morphodynamics, only limited relevant research has been carried out (e.g. Hanson and Militello, 2005; Larson and Kraus, 2000). Therefore, the objective of the present contribution is to consider the dynamics of beaches with outcropping/buried beachrock formations. Towards this objective, the dynamics of a microtidal beach with beachrocks (Vatera Beach, Lesbos, Greece) have been studied through the collection and analysis of morphological and sedimentary data, hydrodynamic modelling and use of a specially constructed 1-D morphodynamic model.

2. The study area

Vatera beach (southern Lesbos) is a 7-km-long embayment beach, bounded by rocky headlands (Fig. 1). The sub-aerial part of the beach is less than 50 m wide and the tidal range is small, being less than 0.2 m on springs (Tsimplis, 1994). The area is characterised by a Mediterranean climate, with dry hot summers and mild winters. The highest precipitation occurs in January/February, whereas the highest temperatures occur in July/August, when the mean temperature reaches ~27 °C; by comparison, the January mean temperature is ~7 °C. The prevailing winds are from the NE and can routinely reach speeds of 20 m/s (Hellenic

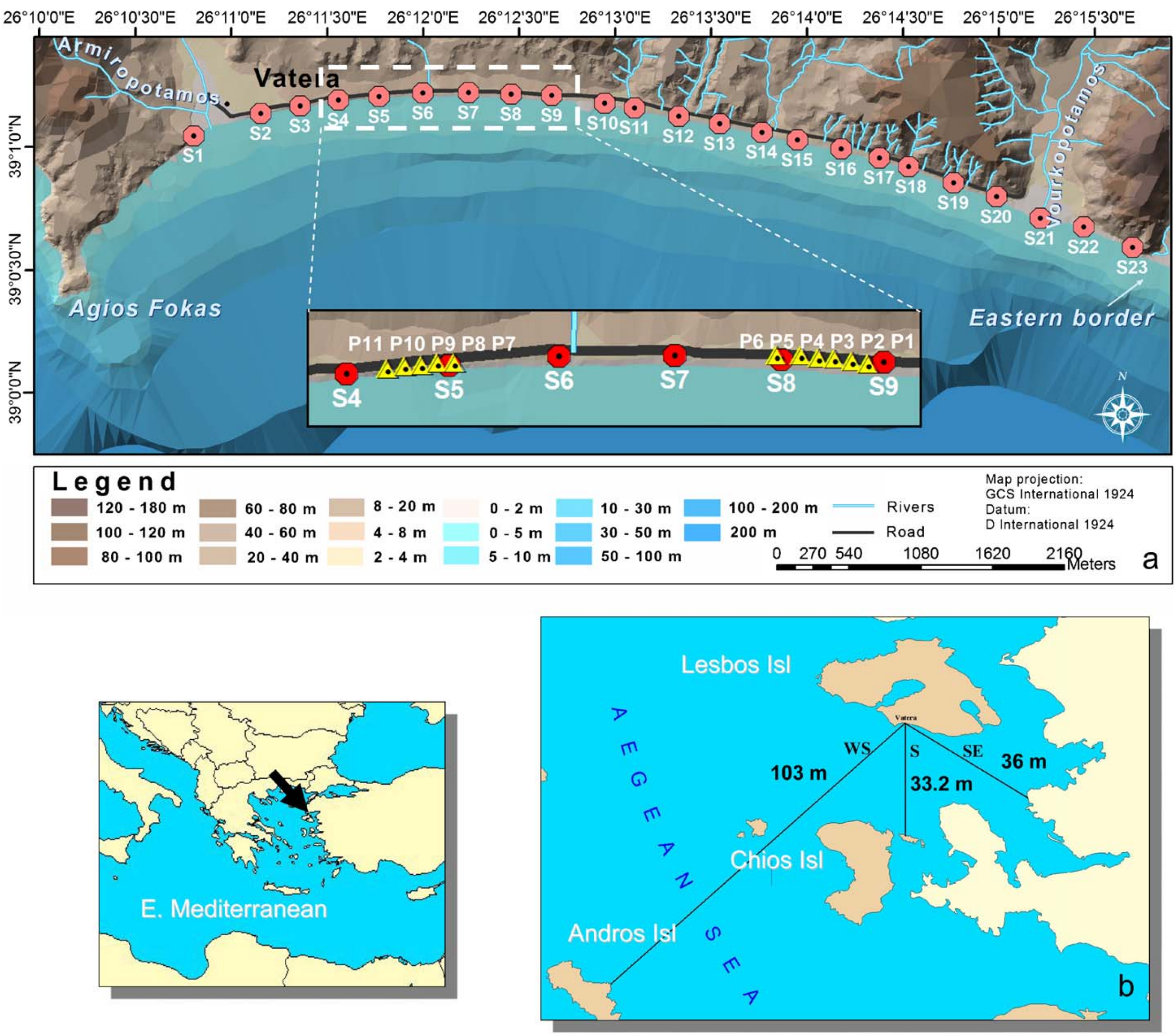

Fig. 1. (a) Coastal morphology and hydrology of the Vatera embayment (S. Lesbos, Greece), showing also the location of the monitored beach transects. For further explanation of the difference between Transects S and P, see text. Land morphology is based on the regional topographic maps of the Greek Army Geographic Service, whereas the bathymetry on combined information from the latest bathymetric chart of the area (Greek Navy Hydrographic Office, 2000) and a bathymetric survey of the embayment carried out by the authors. (b) The wind fetch (in nautical miles) for 3 main directions affecting the beach are also shown.