EMBAYMENT CHARACTERISTICS AND SHORELINE ATTRIBUTES OF POCKET BEACHES IN CRETE

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Abstract
The formation of pocket beaches is a complex process being the result of a large number of processes and mechanisms that vary on space and time scales. The aim of this study is to define evolution processes dominating the Cretan pocket beaches, and to determine their vulnerabilities and risks. Thus, data from 46 pocket beaches along the coastline of Crete were collected. The pocket beaches under investigation are characterized by different geomorphological and hydrodynamical setting.

Keywords: Coastal processes, North-Eastern Mediterranean, Geomorphology, Shoreline evolution

Introduction
Pocket beaches are constrained coastal morphological cells nested between rocky headlands. Embayed beaches are often rather singular environments with great variability in terms of wave exposure, geomorphology and sedimentology and can be extremely sensitive to storm events. Pocket beach embayments have often been described and typified by geometric indices that include the planform parameters. Planform parameters represent the geometric characteristics of a beach. Previous studies [1] suggest that the geometric indices approach provides a useful first step in the study of embayed coasts. Geometric indices can make an important contribution in estimating the exposure of the coastal segments to incident waves, beach response to big storms, and the longshore migration of hotspots of erosion and accumulation, beach and nearshore morphological changes and shoreline progradation or recession. At regional scales, geometric indices, can used before detailed dynamic field experiments are undertaken. The aims of the present study are to assess the significance of planform parameters, to the formation and evolution of pocket beaches and to estimate the vulnerability and risks under climate change.

Study area
Crete coastline totals 1300 km, and consists from various landforms that include rocky coasts and coastal cliffs, while 15% of coastline consists of sandy beaches [2]. The wave climate is primarily wind-driven with average offshore wave heights <1.5 m, which may exceed 6 m during storms. The Cretan coast can be subdivided into 8 sections, based on the wave conditions and 3 tectonic sections based on Holocene crustal movements. Western and eastern tectonic sections of Crete are subjected to uplift movements, while the central section is subjected to subsidence.

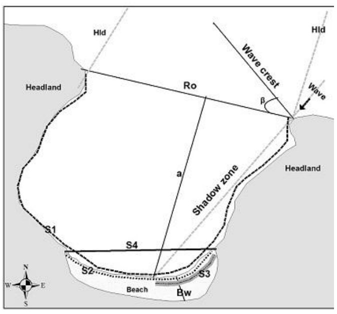

Fig. 1. Pocket beach planform parameters.

Methodology
Planform parameters and geometric indexes from the bibliography [3] were applied. Planform parameters used are: Headland spacing (R_o); Bay indentation (a); (S_1): Embayed shoreline length(S_1); Embayed beach length (S_2); Length of a beach segment located at the shadow of a headland (S_3); Linear distance and orientation between the edges of the embayed beach (S_4); f: Direction of the incident wave (f); Wave crest obliquity to the headland spacing (ß); Beach area (A_r); Maximum beach width (B_w); Headland orientation (H_{ld}) (Fig. 1). The planview Indices used include: two beach embaymentization indices (a/R_o and S_1/R_o). Stability (relation between a/Ro and the angle of wave incidence *(ß)* compared to a theoretical equilibrium curve. Sheltering index (S_3/S_2); Sediment availability index (S_2/S_1) and the Embayment scaling parameter $\delta'=S_1^2/(100RoH_b)$. For the vulnerability estimations the BVI (4) index was used.

Results and Conclusions
Five classes of indentation were recognized. The first class includes the least indented, shorelines with the smaller sheltered segments. The second class consists of a larger headland spacing and shorter shorelines and beaches. Third class included similar bays indentation characteristics with the previous, but less sheltered beaches. In the fourth class, indentation (a) almost equals the headland spacing (R_o) and the bays are more circular-shaped. Finally the fifth class include the most sheltered beaches. The small range of indentation suggests that similar factors may control their morphology. Tectonism is an important factor that controls pocket beach formation in Crete. Statistically high correlations was found between beach embaymentization indices, a) ratio between bay indentation and headland spacing a/R_o, and the ratio between embayed shoreline and headland spacing (S_1/R_o). Also between headland spacing Ro with beach length (S_2) and Beach area A_r and Beach length S_2 and sheltered beach length S_3. Related to the stability of beaches, the majority of the beaches present that are in equilibrium with natural processes. The few beaches that fall below the stability curve, belong to the North coast of the central tectonic section, which is subjected to subsistence. Beaches under the stability curve also host man-made structures. Low embayment scaling values ($\delta'>10$) indicate wide beach exposure (R_o) and high H_b per relative short shoreline (S_1). As the scaling class increases the beach exposure (R_o) and the wave breaking height H_b decrease. Finally, low scaling beaches receive more energy. Cretan pocket beaches display a small range of indentation index values. Beaches become shorter with increasing bay indentation, while wider exposure seems to be related to an increase beach length. More than half of the Cretan pocket beaches are lacking of "sediment supply" in their embayment. The most indented class has the highest values for S_1/R_o and low S_2/S_1, indicating the best shore protection. The least indented pocket beaches show the opposite values (high S_1/R_o, low S_2/S_1). Based on the equilibrium status, most of the beaches are currently in a stable mode. Exception are a few beaches which are mainly influenced by man-made structures. The majority of beaches in central tectonic section are in low indented class, this may be related to landmass subsidence. Beaches with low scaling parameter, are those confronted by high wave energy. Based on their erosion vulnerability most of the beaches are classified as medium vulnerable.

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