Erosion of rocky shores- protection promoted by sandy beaches and shore platforms

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Resumo: O sector costeiro do Algarve central entre as praias da Galé e Olhos de Água deve a sua fisiografia crenulada a um sistema cársico bem desenvolvido em rochas carbonatadas. As arribas possuem no sopé uma plataforma litoral rochosa ou uma praia arenosa. Os principais objectivos do projecto de investigação EROS são: (i) a quantificação da dissipação da energia das ondas ao longo de plataformas litorais e de praias arenosas com diferentes declives e exposição às ondas; (ii) a caracterização da refracção e difracção das ondas e da modificação das correntes forçadas pelo controle morfológico. A metodologia base centra-se na aquisição de dados de ondas e correntes utilizando transdutores de pressão e correntómetros colocados em transeptos normais à linha de costa, de modo a obter o espectro completo de ondas e correntes, desde a água profunda até aproximadamente à base das arribas, quer nas plataformas quer nas praias.

Palavras chave: Algarve, costa rochosa, plataforma litoral, ondas, correntes.

Key words: Algarve, rocky coast, shore platform, waves, currents.

1. INTRODUCTION

The ability and extent of waves on quarrying the cliff foot depends on the structure connecting the cliff with the sea floor (shore platform or sandy beach). Medium-term (centennial) cliff retreat has been reported as mainly controlled by the shore platform morphology on the cliff foot as well as by hydrodynamic processes acting on it (Duperret *et al.*, 2005; Walkden and Hall, 2005; Pierre, 2006; McGlashan *et al.*, 2008). The widen of the shore platform driven by several processes including the cliff retreat, leads to the successively topographic elevation of the cliff-platform junction and to wave energy dissipation, and therefore to the decrease of the recession rate through a negative feedback (McGlashan *et al.*, 2008). Where beaches develop at the cliff toe, the coastal equilibrium correlates positively with beach width, which responds very rapidly to changes on waves and tides characteristics (Morisawa and King, 1974). The ongoing research project named *Erosion of Rocky Shores-differences in protection promoted by sandy beaches and shore platforms* (EROS) aims, among other objectives: (i) to quantify the amount of the wave energy dissipation upon both shore platforms and sandy beaches; (ii) to characterize the wave and current fields and its dependency on the local beach morphology. Two study sites differently exposed to the incident waves are considered. This work presents the results of a field experiment, which led to the proposal of the EROS project. The data were collected in December 2009. Furthermore, two recent field campaigns made during March 2012 are also described.

2. STUDY AREA

The coastal zone of the centre Algarve between Galé and Olhos de Água (Fig.1) displays a complex karstic morphology leading to a strong morphological control of the hydrodynamic processes. Cliffs exposing near horizontal carbonate rocks back both shore platforms and beaches. Sandstones filling the palaeo relief into the carbonate rocks may reach the rocky cliffs lowermost portions. This crenulated shore with pocket beaches bounded by headlands and shore platforms, offers suitable conditions as a case study. It enables to quantify and compare the behaviour of waves and currents over both shore platforms and the adjacent beaches during the same time span and offshore conditions, but with different obliquity when approaching the coast. The waves incoming from WSW represent 72% of the year. Off the Algarve, the wave height ranges from 0.30 m to 1.8 m, with rare exceptional heights surpassing 3.7 m. Such high waves are usually associated with storms from the SW sector, during which waves attain an averaged height of 2-3 m with a period of 7-8 s

(Costa *et al*., 2001). The Algarve coast experiences a semi-diurnal mesotidal regime ranging from 2.70 to 1.36 m during neap tides and from 3.82 to 0.64 m during spring tides (Instituto Hidrográfico, IH, 1990).

Fig. 1. Location of the study area.

3. FIELD CAMPAINGN DECEMBER 2009

3.1- Methods

Four pressure transducers (pt) were used in order to simultaneously acquire the wave heights (H) and periods (T) crossing two shore platforms at different angles to the incident waves. Thus, two pressure transducers were used in Galé (pt1 and pt2, Fig. 2A) and the other two in Olhos de Água (pt3 and pt4, Fig. 2B). The seaward transducers (pt1 at Galé and pt3 at Olhos de Água) were positioned in the lower intertidal zone at the spring low tide level, whereas the landward pt2 and pt4 at Galé and Olhos de Água respectively were placed close to the cliff foot (Fig. 2). The height above mean sea level and geographical position were taken using a differential geographical position system (dGPS). The pt sensors were protected with stainless steel cages to prevent both the algae accumulation upon the sensors and the damage by gravel transported by waves.

3.2- Results and discussion

Changes in the direction of propagation due to variations in the group velocity may result in the increasing of wave heights when approaching the coast. During the monitored tidal cycle, the offshore wave direction was 247º and the offshore significant height (Hs_0) was 0.9 m (IH data, Faro buoy). According to the coastline orientation, the waves approached the shoreline obliquely with angles of incidence of 65º and 25º at Galé and Olhos de Água respectively. The deep-water waves shoal at the Galé outer edge (pt1) show a statistically significant increase ($P<0.05$) of the significant wave height (Hs) of 43%. In a sheltered position to the WSW waves, the Hs at the shore platform outer edge (pt3) at Olhos de Água, was 41% lower than Hs_0 but that Hs decrease was not statistically significant ($P>0.05$). This difference may be explained both by the relationship between the bathymetric contours and the waves direction and the bottom morphology (e.g., Davidson-Arnott, 2010). The inner continental shelf shows a steeper morphology at Galé and waves from WSW are less oblique to the coastline than in Olhos de Água.

The water depth on the platform changes with the tide being the main factor controlling the changes of the wave height. The highest Hs was observed four hours after the beginning of flood at the outer pressure transducers, and two and one hour later at the inner ones at Galé and Olhos de Água respectively (Fig. 3). The Hs modification along the shore platform was noted worthy different between the studied sites (Fig. 3).

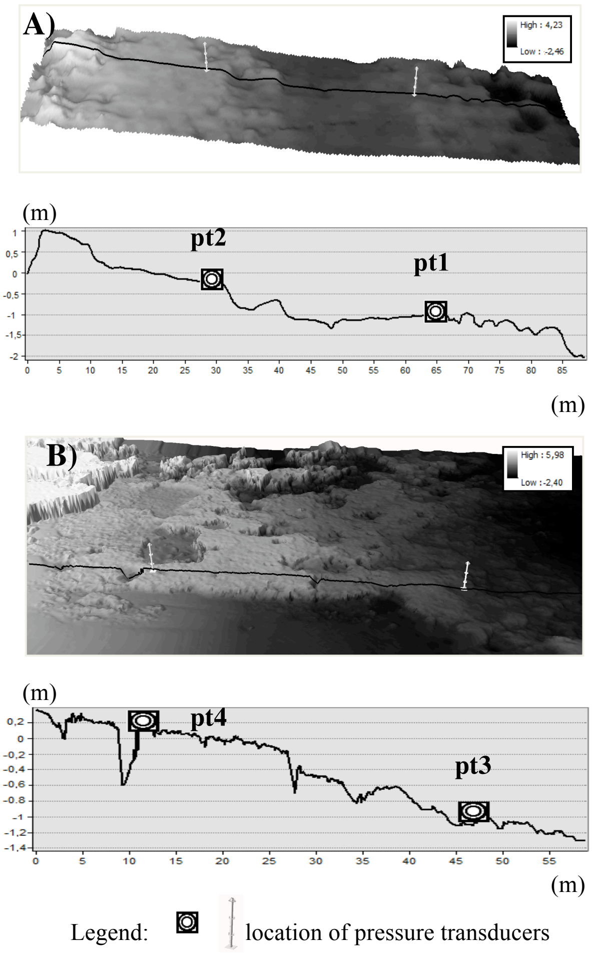

Fig. 2. Shore platforms and pressure transducers at A) Galé and B) Olhos de Água. The accuracy of images and profiles are quite different because at Olhos de Água they were produced through a laser scan survey whereas a dGPS survey was used at Galé. Elevations report to mean sea level.

The averaged wave Hs was 1.18 m at the outer pt in Galé decreasing along the platform to 0.78 m as registered in the landward pt (pt2) close to the cliff foot, representing a statistically extremely significance ($P<0.001$) decreasing of 33%. The ratio between Hs and the water depth (Hs/h) ranged landward from 0.83 (SD=0.27) to 0.74 (SD = 0.10). Considering these thresholds and the Hs values in pt1, 65% of the waves broke before reaching the inner position at pt2. The remaining 35% of the

unbroken waves crossed the shore platform breaking close to the cliff foot (pt2 position). The wave power at breaking (Pb) in the shore platform outer edge (pt1) was 10819 Kw/m at Galé decreasing to more than half (4915 Kw/m) near the cliff foot at pt2.
In contrast to Galé, Hs increased from 0.53 to 0.68 m between the platform outer edge (pt3) and the landward pt (pt4) near the cliff foot at Olhos de Água. However, the observed 28% of Hs increasing between pt3 and pt4 was not statistically significant (P>0.05). Thereby, the sheltered (to WSW waves) and flatter shore platform at Olhos de Água did not show the effectiveness on dissipating the energy of the waves as observed at Galé. The Hs/h value of 0.6 was quite constant along the shore platform traducing it relative flatness with respect to the Galé site. Similarly to Galé, 64% of the incoming waves broke before attaining the inner portion of the platform. However, the remaining 36% of the waves shoaling along the platform represented a landward increasing of the Pb from 2165 Kw/m in pt3 to 3750 Kw/m pt4 close the cliff foot.
Those results show that, together with the tidal elevation, the platform slope has a major role on the wave energy dissipation as also observed by other authors (Marshall and Stephenson, 2011; Ogawa *et al*., 2011).

4. FIELD CAMPAINGNS MARCH 2012

Aiming to further quantify the amount of the wave energy dissipation upon shore platforms and sandy beaches, two field campaigns were recently performed (March, 8 and 22). We deployed electromagnetic current meters (ecm, *Infinity*) and pressure transducers (pt, *In Situ Level Troll 700*) in normal transepts to the shoreline both in shore platform and beach (Fig. 4). Permanent fixings have been made into the rock in shore platforms using bolts and chemical dowels in order to locate the pt and ecm equipments. The near shore wave climate (currents and waves) was obtained through an acoustic doppler current meter (adp, *Sonteck, Mini ADP 1.5 MHz*) anchored at the 8 m bathymetric contour. The frequency of data acquisition was 2 Hz for pt and 4Hz for adp and ecm. A cell size of 0.25 m and an averaging interval of 10 min with profiling interval of 5 min, that represents a 4 min of wave measurement, were adopted for the adp data acquisition. The experiences were performed during two tidal cycles, with simultaneous data acquisition in the shore platform and the adjacent beach, at Galé and Olhos de Água sites (Fig. 4). The present data set will be analysed in the scope of EROS project to give further insight of the waves dissipation both in the platform and beach at both study sites.

5. FINAL REMARKS AND FURTHER WORK

The role of shore platform in dissipating the wave energy is largely dependent of the coastal sector orientation and the platform slope. For the same offshore wave conditions, we observed that:
1- The waves shoaling at the steeper shelf adjacent to the well exposed site of Galé represented 63% of the Hs increase with respect to the offshore Hs_0, whereas the Hs increase at Olhos de Água, where the waves approached with a high obliquity, was not statistically significant;
2- The shore platform at Galé was more efficient in energy dissipation than at the Olhos de Água sheltered site, where both the inner continental shelf and the shore platform are flatter;
3- Hs/h ranged landward between 0.83 and 0.74 at Galé and showed a constant value of 0.6 across the platform at Olhos de Água.

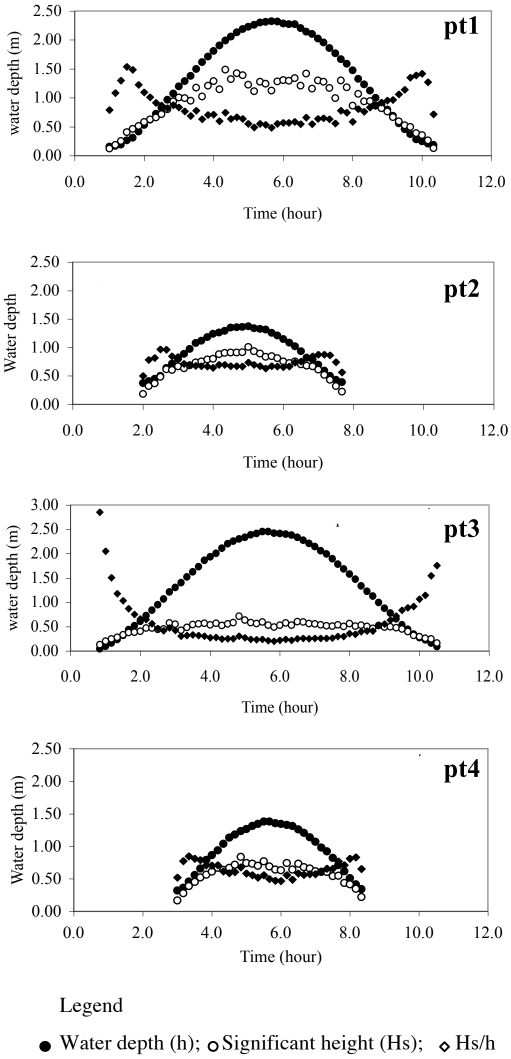

Fig.3. Measured Hs and h along the shore platforms at Galé and Olhos de Água (Fig. 2 for pt location).

Future work within the scope of the EROS project will involve: (i) the pt, ecm, adv and adp data processing, (ii) the comparison of the waves and currents behaviours both in the shore platform and adjacent beach in the study area and, (iii) the numerical and physical modelling.

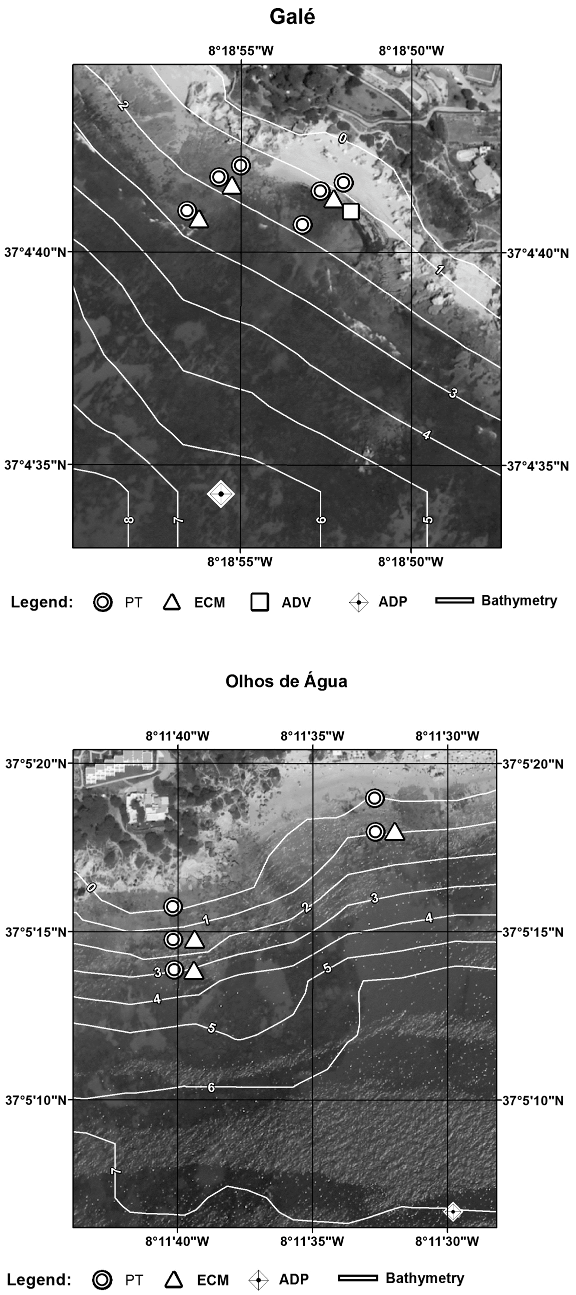

Fig. 4. Equipment position during the March field campaigns

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