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Morphodynamics of a mesotidal rocky beach: Palmeras beach, Gorgona Island National Natural Park, Colombia

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ABSTRACT

The response of a rocky beach to different possible combinations of hydrodynamic conditions (tides, waves, oceanic currents) has been little studied. In this work, the morphodynamic response to different hydrodynamic forcing is evaluated from sedimentological and geomorphological analysis in seasonal and medium term (19 years) scale in Palmeras beach, located in the southwest of Gorgona Island National Natural Park (NNP), a mesotidal rocky island on the Colombian Pacific continental shelf. Palmeras is an important nesting area of two types of marine turtles, with no anthropogenic stress. In the last years, coastal erosion has reduced the beach width, restricting the safe areas for nesting and conservation of these species. Until now, the sinks, sources, reservoirs, rates, and paths of sediments were unknown, as well as their hydrodynamic forcing. The beach seasonal variability, from October 2010 to August 2012, was analyzed based on biweekly or monthly measurements of five beach profiles distributed every 200 m along the 1.2 km of beach length. The main paths for sediment transport were defined from the modeling of wave currents with the SMC model (Coastal Modeling System), as well as the oceanic currents, simulated for the dry and wet seasons of 2011 using the ELCOM model (Estuary and Lake COmputer Model). Extreme morphologic variations over a time span of 19 years were analyzed with the Hsu and Evans beach static equilibrium parabolic model, from one wave diffraction point which dominates the general beach plan shape. The beach lost 672 m^3/m during the measuring period, and erosional processes were intensified during the wet season. The beach trends responded directly to a wave mean energy flux change, resulting in an increase of up to 14 m in the width northward and loss of sediments in the beach southward. This study showed that to obtain the integral morphodynamic behavior of a rocky beach it is necessary to combine information of hydrodynamic, sedimentology and geomorphology in different time scales.

1. Introduction

Beach geomorphology in rocky coastlines is influenced by geology (lithology, physical and mechanical properties, discontinuities and degree of weathering of rock masses, tectonics, local and regional seismicity); as well as the bathymetry, maritime climate, hydrology, and meteorology (Andriani and Walsh, 2007). All these combined variables give the final result of the littoral morphology, the paths and rates of sediment transport, and the sectors susceptible to erosional processes.

In the last years, many researchers have studied the rocky coast geomorphology and the interrelationships between factors controlling their erosional processes (e.g. Andriani and Walsh, 2007; Dail et al., 2000; Storlazzi and Field, 2000). It has been found that the main factors controlling rocky beach geomorphology are wave climate, sediment characteristics, and tidal range (Bernabeu et al., 2003), although the magnitude of the tidal currents has a transversal gradient to the coast in embedded beaches, being relatively strong offshore, but insignificant on the beach (Dehouck et al., 2009). However, studies that integrate geology, waves and oceanic currents, sedimentology and geomorphology are scarce, as well as researches that consider the responses to extreme events and climate change on these systems (Naylor et al., 2010).

From a geomorphological point of view, the rocky beach dynamics present unique features due to the hydrodynamic interference with rocky lows and headlands that usually delimit the

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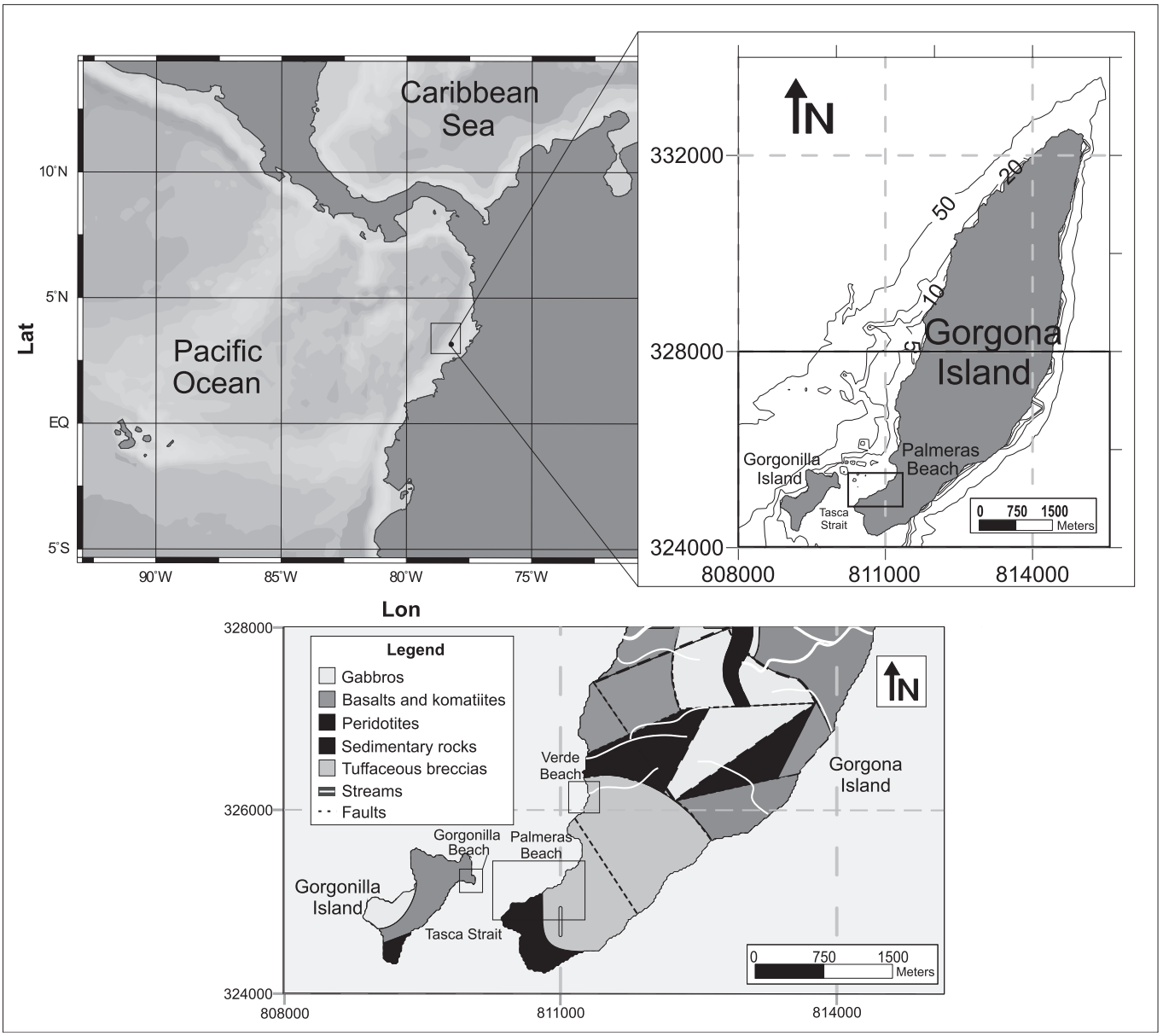

Fig. 1. Palmeras beach location at Gorgona Island NNP, Colombian Pacific. The geologic map of the southern end is also presented, modified from Serrano, 2009. Gorgona map in UTM zone 17N.

alongshore sediment transport or littoral drift in the surf zone. In these systems, it is necessary to analyze the sediment dynamics outside the surf zone, where the wave-induced cross shore currents and oceanic currents as induced by wind, tides, and geostrophy are important (Dehouck et al., 2009; Storlazzi and Field, 2000; Storlazzi and Jaffe, 2002).

There are various approaches to understand the dynamics of these systems, taking into account the most influential hydrodynamic factors and/or using tools such as numerical/analytical modeling. For example, works as Dail et al. (2000); Davidson et al. (2010); Dehouck et al. (2009); Falqués et al. (2008); and Trenhaile (2010), analyzed hydrodynamic factors; and others (Bernabeu et al., 2003; Hardaway and Gunn, 2010; Raabe et al., 2010; Ribas et al., 2011) considered the medium term variation from equilibrium plan beach theory.

The sediment provenance analysis is commonly used to characterize the terrigenous and biogenic contributions to the beaches, and is a useful tool to understand a supply unbalance (Calhoun et al., 2002). In the same way, the sediment balance is helpful to understand the temporal and spatial variations of volumes in time scales of millions of years (Hubbard et al., 1990) or a few days, as well as flow rates between different sedimentological units (sources, sinks, and reservoirs, Calhoun et al., 2002).

In order to analyze the morphodynamic responses of a mesotidal rocky beach in seasonal and medium term (19 years), to different forcing (waves, tides, wind, and geostrophic currents) and the sediment sources and pathways associated with beach geomorphology, a study of Palmeras beach, located in the southwest of Gorgona Island NNP (National Natural Park), Colombian Pacific (Fig. 1), was conducted. Palmeras has been used by two types of marine turtles for nesting, the Black and the Olive Ridley (Amorocho and Reina, 2008; Amorocho et al., 2012; Camacho-Mosquera et al., 2008); however, in recent years the shoreline regression has been more evident, restricting the nesting safe areas.