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Shelf morphology as an indicator of sedimentary regimes: A synthesis from a mixed siliciclastic–carbonate shelf on the eastern Brazilian margin

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ABSTRACT

Modern shelf morphology is the result of the interplay between short and long term sedimentary processes. The relation between rates of sediment supply/carbonate growth and accommodation space creation will not only control coastal transgression and regression, but will also define the shelf sedimentary regimes acting to shape the seabed. Herein, shelf morphology and sedimentology are investigated in order to discuss how these characteristics can be representative of distinct sedimentary regimes. The study area is the eastern Brazilian shelf where coastal transgression and regression coexist with the most important coral reef system of the South Atlantic. A compilation of existing published and unpublished data was carried out in order to produce morphological and faciological maps and compare the mapped features with high-resolution seismic and sonographic data. The results show three major regions or morphological compartments: Abrolhos Shelf, Doce River Shelf and the Paleovalleys Shelf. In terms of shelf sedimentary domain, rhodolith beds predominate over the outer shelf along the entire area, coralline reefs are present along the northern Abrolhos inner shelf and a significant terrigenous mud deposit is observed associated to the Doce River adjacent inner shelf beds. The rest of the shelf is composed by bioclastic or terrigenous mud sand and gravel. Terrigenous sedimentation is always restricted to the shoreface or inner shelf shallower areas and carbonate sands and gravels are predominant elsewhere. The Abrolhos shelf shows two distinct sectors; the northern area is a typical mixed sediment environment that has a supply regime along the coast/shoreface, mainly due to longshore transport and a carbonate regime along the inner and outer shelf. The southern shelf morphology and sedimentation are controlled by the antecedent topography and is typically a accommodation regime shelf with associated rhodolith beds. The Doce river shelf is a supply regime environment with the formation of a 5–8 m thick regressive deposit with downlapping clinoforms. Southward from the Doce river shelf, a significant shift in sedimentary regime is observed as the morphology becomes very irregular with associated hardbottoms and unfilled paleovalleys. This sector of the shelf (Paleovalley shelf) is characterized by an accommodation regime. The interpretation shows that the entire study area can be defined as a mixed sedimentation shelf, showing supply and accommodation regimes. Shelf morphology worked as an indicator of these changes. Carbonate/terrigenous deposition during a high-stand/regressive phase coeval along the eastern Brazilian shelf, either laterally and across shelf. This lateral/along coast variation in sediment supply and carbonate production leads to distinct lateral facies

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and geometry. These spatial changes in morphology and facies, with coexistence of carbonate and siliciclastic sedimentation, are very important for the correlation and interpretation of the geological record, especially stratigraphic surfaces and sequence units.

1. Introduction

Shelf morphology is the result of a complex interplay between short- and long-term processes, such as: hydrodynamic conditions; sediment transport; relative sea-level changes; sediment input; biological activities and geological framework, etc (Sternberg and Nowell, 1999; Pratson et al., 2007; Schattner et al., 2010; Brothers et al., 2013). Modern shelf morphology framework is influenced strongly by Late Quaternary sea-level changes, when high frequency regression and transgression events were determinant in setting up distinct sedimentary regimes (Riggs et al., 1998; Locker et al., 2010; Porebski and Steel, 2006; Nichol and Brooke, 2011). Based upon this concept, sequence stratigraphy have been applied extensively to investigate the development of shelf deposits and stratigraphic surfaces.

The regime concept proposed by Swift and Thorne (1991) is used widely to understand clastic shelf sedimentation and, consequently, their morphological product. The regime concept follows the idea that over a geological time-scale, the shelf surface is in dynamic equilibrium, i.e., the variables (rates in base level changes, rates of sediment input, hydrodynamic energy and resulting sediment transport) will combine to produce the seabed morphology and the sedimentary deposits. These variables define the accommodation/starving and supply regimes; they may change with time, leading to shifts in prevailing sedimentary processes and products.

Accommodation and supply shelves are described in terms of low/high sediment input and erosive processes. In a sense, these regimes will dictate the establishment of regressive or transgressive coasts (based on Catuneanu, 2002; Catuneanu et al., 2009; Zecchin and Catuneanu, 2013) and determine the morphology of the continental shelf. The regime concept is applied mostly to clastic shelves but, in many cases, mixed sedimentation and carbonate shelves are observed. In-situ carbonate production associated with terrigenous sediment input will imprint also a distinct morphology to the shelf. In many cases, a karstic paleotopography represents the maximum regressive surface of the last glacial maximum (Schlager, 2005).

The reciprocal sedimentation concept, proposed by Wilson (1967), describes the alternation in carbonate–siliciclastic sedimentation between the shelf, slope and basin. This concept indicates that carbonate facies dominate slope and basin sedimentation during transgression and highstand, while siliciclastic deposits are predominant during lowstand. Along the shelf, the predominance between carbonate or siliciclastic sedimentation is a matter of the prevailing type of sedimentary regime (Swift and Thorne, 1991) and, inevitably, if there are appropriate oceanographic conditions and sufficient space for carbonate growth. Several authors have remarked that the reciprocal sedimentation concept may not reflect exactly last post-glacial sedimentation processes.

Thus, modern shelf morphology could be used as a proxy for a preliminary understanding of prevailing sedimentary regimes on continental shelves, considering that it is in dynamical equilibrium for the period from the last glacial maximum up to the present day. It might be argued that the sedimentary distribution is not in equilibrium, on the basis of the occurrence of relict sediments (Swift et al., 1971); nevertheless, this is in accordance with the regime concept (accommodation regime).

Herein, two major topics are discussed, in relation to shelf morphology and sedimentology: a) the use of shelf morphology as an indicator of modern sedimentary regimes; and b) the implications of spatially-heterogeneous sedimentary regimes, for a geological/stratigraphic interpretation. The study area is part of the eastern Brazilian shelf, including Espirito Santo and South Bahia States. The analysis presented is based upon: a compilation of existing datasets; combined public databases; published papers; and unpublished geophysical and sedimentological datasets, collected over the past 10 years by the Geological Oceanography Laboratory – Federal University of Espirito Santo Brasil. Thus, the described results are based on unpublished and published data, in order to produce an overview of the shelf morphology and sedimentology. The discussion focuses on the interpretation of distinct shelf sedimentary regimes based on seabed morphology and comparison with other modern and ancient examples.

2. Study area

The study area is located between the southern latitudes of 17° 30′S and 21°, along the eastern Brazilian margin. It will be referred here as the Espírito Santo-Abrolhos Shelf (ESA) (Fig. 1). The ESA continental shelf is characterized by a significant variation in shelf width. From Guarapari to the Doce River, the shelf is around 50–60 km wide with a shelf break depth around 60–70 m water depth. Towards the north, the so-called Abrolhos Shelf or Bank is characterized by a wider shelf (of up to 240 km wide), breaking at water depth of 80–90 m. Shelf widening is associated to the Abrolhos volcanic complex, formed during the Paleogene (Sobreira and França, 2006).

Restricting the present investigation to the Quaternary, the eastern Brazilian shelf has undergone several changes in relative sea level; these have shaped its morphology and controlled patterns of sediment distribution. Dominguez (2009) has concluded that these changes have influenced the morphological elements of the Brazilian coastal zone.

In terms of sediment distribution, the major database is that obtained during the 1970's by the REMAC Program. Different sediment and facies distribution maps have been published for the area, focusing on different ways to describe seabed composition (França, 1979; Kowsman and Costa, 1979). The most comprehensive publication for part of the area is that of Melo et al. (1975). In general, sediment composition varies from terrigenous sand and mud along the coast, to bioclastic gravel towards the mid/outer shelf. Along the Abrolhos Shelf, reefs are observed. More recently, Amado Filho et al. (2012) have indicated that the majority of the Abrolhos shelf is composed of an extensive rhodolith bed. Moura et al. (2013) have produced also a map of seabed domains for the Abrolhos shelf; the shelf is composed mainly of rhodolith beds, reefs and unconsolidated sediments.

In terms of long-term shelf processes, the eastern Brazilian coast has undergone a major transgression, reaching a maximum height ranging from 2 to 5 m above modern sea level, around 5000 years BP (Angulo et al., 2006; Martin et al., 2003). The last