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Depositional mechanisms and architecture of a pre-early Cambrian mixed sand–mud deepwater ramp (Apiúna Unit, South Brazil)

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Abstract

The Apiúna Unit is located in the south of Brazil, in the State of Santa Catarina. It is a deepwater depositional system, which is part of the sedimentary fill of the Itajaí Basin, pre-early Cambrian in age, interpreted as a foredeep basin. We have described and interpreted the depositional mechanisms according to the terminology proposed by Mulder and Alexander [Mulder, T., Alexander, J., 2001. The Physical Character of Subaqueous Sedimentary Density Flows and their Deposits. Sedimentology 48 (2), 269–299] and have recognized seven architectural elements. The Apiúna Unit is interpreted as a mixed sand–mud deepwater ramp system. The slope deposits are characterized by laminated argillite with slumped beds. The proximal and medial ramp is characterized by channel–levee systems. The distal ramp shows sandstone sheet, which pass distally into interlayered sandstone/pelite. The sequence development of this ramp unit differs from other known ancient ramp systems. The Apiúna Unit shows at least five phases of sandy input, recording times of progradation or retrogradation of the ramp, interstratified with muddy deposits, related to sand-starved phases. In the upper part of the succession, the ramp building was interrupted and the sandy deposits are replaced by pelitic slope deposits.

The depositional mechanisms have a direct relationship to the architectural elements and the regions of the depositional system. Settling, very low-density turbidity currents and slumps formed the slope deposits. Channel deposits are formed by debris flows, hyperconcentrated density flows and concentrated density flows, in that vertical sequence order. Levee deposits were made of surge-like turbidity flows. Proximal sandstone sheet deposits were formed by concentrated density flows. Distal sandstone sheet deposits are formed by concentrated density flows and surge-like turbidity flows. Surge-like turbidity flows and quasi-steady (?) turbidity flows formed the interchannel deposits.

Keywords: Deepwater clastic ramp; Sediment gravity flows; Architectural elements; Apiúna Unit; Itajaí Basin, Pre-early Cambrian

1. Introduction

During the last 10 years, the sedimentological literature has shown more frequent attention to the depositional mechanisms in deepwater environments. This is due to the fact that there has been a recent theoretical revision of all the gravity-flow mechanisms that are considered the main cause of the physical characteristics of reservoir rocks (Kneller and Branney, 1995; Kneller, 1995; Shanmugam, 1997; Shanmugam, 2000; Mulder and Alexander, 2001). For example, being able to distinguish between short-lived surge-like gravitational flows and longer-lived steady gravitational flows is of primary importance in the understanding of shape, dimensions and lateral variability of the resulting deposits (Stow and Mayall, 1995). Furthermore, a new

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vision of these depositional systems has gained ground in recent years, according to which a canyon-fed fan appears to be too simple a model. So it has displaced by more complex models, depending on grain-size and mode of sediment input (Reading and Richards, 1994; Richards, 1996; Richards and Bowman, 1998; Richards et al., 1998; Galloway, 1998).

The aim of this work is to establish relationships between depositional mechanisms and facies architectural elements in deepwater systems. Our study object is a depositional system, generated during the pre-early Cambrian period in a deepwater ramp environment in Brazil, known as Apiúna Unit. Data came from detailed sedimentological analyses of the well-exposed 276 m sections in the lower part of the Apiúna Unit, from a total of 716 m of less detailed stratigraphic sections and detailed geological mapping of the middle and upper part of the Apiúna Unit, for a total thickness of about 3500 m of sedimentary succession. The paper considers the depositional mechanisms as the base-block for constructing the architectural model. It also uses conceptual models to create links among the depositional mechanisms and between the depositional mechanisms and the facies architecture. Finally, a depositional model is developed to predict the distribution and the stratigraphic evolution of the Apiúna Unit. The application of this method is very useful where data acquisition is fragmentary and punctuated, as it occurs in study areas where climatic and vegetation features limit the rock exposures and their continuity.

2. Geological setting

2.1. Basin history

The Apiúna Unit is a siliciclastic unit located in the Itajaí Basin (Santa Catarina State, Brazil) (Fig. 1). The Itajaí Basin has an extent of 1200 km^2, a NE–SW orientation, with a maximum width of about 30 km in the southwestern part, wedging out to the NE. To the SE, the basin is delimited by the Dom Feliciano orogenic thrust–fold belt, whereas to the NW it is limited by a craton, the granulitic complex of Santa Catarina. To the SW it is covered by deposits of the Paraná Basin (Fig. 1).

The Itajaí Basin was formed during the "Brasiliano Orogenic Cycle", and is associated with the Dom Feliciano thrust–fold belt. The age of the basin is not well defined. Macedo et al. (1984), from Rb–Sr and K–Ar analyses of muddy sediments, stated an age of 556±44 my for the anchimetamorphic phase that affected these sediments, and indicated an age of 588± 48 my as the age of sedimentation. Paim et al. (1997) described *Chancelloria* sp. from the lower part of the succession and attributed it to the Cambrian period. Silva et al. (2002), using the SHRIMP U–Pb method, obtained an age of 606±8 Ma from a euhedral crystal of zircon in a tuff bed from the lower part of the Itajaí Basin fill.

Various hypotheses have been formulated about the geotectonic origin of the basin, interpreting it as peripheral, rift, post-collision, foredeep and strike-slip basin (see a review with bibliography in Rostirolla et al., 1992a). The last two hypotheses seem the most plausible. Rostirolla et al. (1992a,b) interpreted the Itajaí Basin as a foredeep basin, linked to the overload of the orogenic Dom Feliciano thrust-belt. This hypothesis is based on structural analysis, which indicates a main compressive phase with shear stress (σ_1) directed towards NW. Krebs et al. (1990) suggested a strike-slip origin for the Itajaí Basin. A transtensive phase, which formed the basin, was followed by a transpressive phase, inducing tectonic inversion and the present geometry of the basin.

The stratigraphic interpretation of the basin is also debated. Rostirolla et al. (1992b) distinguished four "facies associations" labeled from A to D. These associations testify to the deposition of alluvial fans and delta progradation from N–NW (facies association A), overlain, across a disconformity with correlative downflow concordance, by deepwater sandstone deposits (facies association B). Facies association C, comprising offshore shelf pelitic deposits, overlies the deepwater system, Finally, the topmost facies association D represents deltaic progradation from the south. Krebs et al. (1990) filling model differs substantially from the previous authors and consists of five "facies units". The first two represent alluvial fans and deltas depositional systems; the last three represent deepwater gravitational deposits, from the distal platform to the basin plain. This stratigraphic model indicates a progressive deepening of the basin, before the tectonic inversion.

This paper deals with the "facies association B" and "facies association C" of Rostirolla et al. (1992b).

2.2. General features of the Apiúna Unit

According to our field analyses, "facies associations B and C" of Rostirolla et al. (1992b) show analogous deepwater depositional conditions: the mudstone deposits, typical of "facies association C", are interbedded with sandstone in the "facies association B", and it is not possible to clearly delimit the two "facies associations". For this reason, we have used the term Apiúna Unit