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Late Oligocene–Miocene transgressions along the equatorial and eastern margins of Brazil

Dilce F. Rossetti [a,*], Francisco H.R. Bezerra [b], José M.L. Dominguez [c]

[a] Instituto Nacional de Pesquisas Espaciais-INPE, Rua dos Astronautas 1758-CP 515, 12245-970 São José dos Campos, SP, Brazil
[b] Universidade Federal do Rio Grande do Norte, UFRN, Departamento de Geologia, Campus Universitário, 59078-970, Natal, RN, Brazil
[c] Universidade Federal da Bahia, UFBA, Instituto de Geociências—Rua Barão de Jeremoabo, s/n Campus Universitário de Ondina, CP: 40170-115, Salvador, BA, Brazil

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ABSTRACT

The seaboard of Brazil is a highly favorable setting for studying episodes of worldwide sea-level rise because of its passive nature. Previous studies of the equatorial coast of Brazil have led to the recognition of extensive Oligo-Miocene and Miocene marine-influenced deposits, but these deposits have been overlooked in other coastal areas of Brazil. The aim of the present study is to show the origin and evolution of late Oligocene and Miocene marine-influenced strata exposed in more than 5000 km of coastal areas along the WNW-trending equatorial and NNE-trending eastern Brazilian continental margins. We review the most relevant data concerning the strata of these ages exposed along the equatorial and eastern margins of Brazil, and combine them with new data. Based on these occurrences, we analyze the history of sea-level fluctuations and show that marine-influenced strata are more widespread in these margins than originally thought. Our main results indicate that a marine influence is not only imprinted in the deposits exposed along the equatorial margin, but it is also widespread in several areas of the eastern margin. For a long geological time interval ranging from the end of the Cretaceous or Paleogene up to the late Oligocene, most of the Brazilian coast remained a non-depositional site exposed to subaerial erosion and lateritic soil development. The combination of sea-level rise and tectonic subsidence promoted sediment accumulation in the onshore portion of several basins. Two transgressive episodes occurred: one in the Oligo-Miocene and another in the early/middle Miocene. The latter gave rise to deposition of the Barreiras Formation. However, during the supposedly middle Miocene eustatic sea-level highstand in coastal Brazil, there was a renewed and extensive phase of non-deposition and subaerial erosion with lateritic soil formation, a process that lasted up to the Late Quaternary. This mismatching of the sedimentary record with other South American and continental areas is discussed herein. As in many other areas of South America and of the world, the regressive–transgressive events recorded along the Brazilian coast most likely responded to a combination of eustatic sea-level fluctuations and local factors such as tectonic activity, intraplate stresses and changes in dynamic topography during the post-rift history of the eastern South American Plate.

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* Corresponding author. Tel.: +55 12 38026451.
E-mail addresses: rossetti@dsr.inpe.br (D.F. Rossetti), bezerrafh@geologia.ufrn.br (F.H.R. Bezerra), landim@ufba.br (J.M.L. Dominguez).

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1. Introduction

The Miocene (24 to 5 Ma) is a geological time of great significance, because it witnessed the transition to the modern world as we see it today (Potter and Szatmari, 2009). During this time interval, important transformations occurred in the planet, which concern the geological events that resulted in the modern configuration of the continents and also the biological processes, as most of the living species, in particular 95% of modern mammal fauna, including mankind, originated during this epoch (e.g., Steiner et al., 2005; Patterson and Velazco, 2008).

The Earth experienced the most significant sea-level rise during the Oligo-Miocene and Miocene since the Cenomanian. The magnitude and timing of these events remain controversial, with estimates varying from 180 m (Haq et al., 1987) to a few dozen meters above the modern sea level (Miller et al., 2005). As a consequence, there were marine incursions in various continental margins over the globe. Cool climates prevailed in the South American plate until the end of Miocene, as it moved northward, leading to the isolation of Antarctica at the South Pole. During this period, areas of forest were extensively replaced by grassland savanna (e.g., Barreda and Palazzesi, 2007). In addition, the global sea level experienced a drop of nearly 50–70 m from the Cenomanian highstand as a response to the expansion of the Antarctic ice sheet (e.g., John et al., 2011).

Oligo-Miocene and Miocene transgressive–regressive events have been recorded in several continental areas worldwide, particularly in those located near the modern coastlines. However, these episodes might have no synchronism when different areas are compared. Factors that might have contributed to overprinting these events in the geological record include tectonics, as well as changes in dynamic topography and local climate. For instance, significant uplift took place in the African eastern margin during the Miocene (Lavier et al., 2001), which caused a rain-shadow effect in large areas to the west. At the same time, the Mediterranean Sea dried out completely due to the closure of the Gibraltar Strait, aided by a drop in sea level during the Messinian salinity crisis (Jolivet et al., 2006).

In South America (Fig. 1A), the Andes experienced several episodes of uplift in the Miocene (Gregory-Wodzicki et al., 1998; Gregory-Wodzicki, 2000; Garzione et al., 2008). To compensate for this uplift, many forearc and foreland basins were established in the areas immediately to the west and east of the Andes Cordillera. Several studies have suggested that subsidence in these areas might have been the main cause of transgressions during the Oligo-Miocene and Miocene, producing events of relative sea-level rise that might or might not be coincidental with the overall global pattern (e.g., Scasso and del Río, 1987; Scasso and Castro, 1999; Scasso et al., 2001; Hernández et al., 2005; Marengo, 2006; Cuitiño et al., 2012).

The Brazilian coast is highly relevant for providing a complementary database to enable a better reconstruction of the impact of the global Oligo-Miocene and Miocene transgressive–regressive events, not only along the eastern margin of the South American plate, but also worldwide. Oligo-Miocene and Miocene deposits are well exposed in this region, where they form a narrow but extensive belt more than 5000 km long (Fig. 1B). Despite this significance, there is no work providing a synthesis of the several publications about these deposits integrating both the WNW-trending equatorial and NNE-trending eastern coastal margins. In particular, controversies about the paleoenvironmental setting of these deposits have been the main reason for limiting their use so far to recording changes in sea level in eastern South America. In general, these strata have been most often regarded as entirely continental in origin (e.g., Mabesoone et al., 1972; Suguio et al., 1986; Vilas-Bôas et al., 2001; Lima et al., 2006). However, a genesis mostly related to a tidally-influenced inner shelf and coastal marine setting was attested for the Oligo-Miocene and Miocene deposits exposed along the equatorial margin (e.g., Rossetti et al., 1989; Góes et al., 1990; Rossetti, 2000). Recently published additional information on other areas of eastern Brazil has demonstrated that these Miocene strata formed under the influence of tidal processes (e.g., Rossetti and Góes, 2009; Rossetti and Dominguez, 2012).

The recognition of Oligo-Miocene and/or Miocene marine strata in the eastern coast of Brazil and their integration with data available from the equatorial coast are vital for analyzing the impact of sea-level changes in eastern South America during this epoch. The Brazilian margins are located in a supposedly stable platform not directly affected by the Cenozoic orogenies, such as the Caribbean and Andean (Almeida et al., 2000). The last major tectonic event to affect the continental margins of Brazil was the South America–Africa breakup, which was followed by the opening of the South Atlantic ocean (e.g., Szatmari et al., 1987). As a result, a commonly held idea of tectonic stability of the Brazilian margin prevailed. Oligocene and Miocene sedimentary deposits exposed along these margins have been regarded as undeformed units that cap deformed Precambrian crystalline basement and Cretaceous grabens. Increasingly, however, a combination of sedimentary, structural, and geophysical studies indicates the occurrence of Miocene and post-Miocene deformation along the margin, which has influenced sedimentation and topography (Bezerra et al., 2001, 2007, 2008; Nóbrega et al., 2005; Ferreira et al., 2008; Nogueira et al., 2010). As for other areas of South America, this tectonic activity has potentially interfered with the accumulation of the Oligocene–Miocene strata. It was imprinted over the eustatic sea-level record through creation of additional accommodation space in some sedimentary basins, and caused post-depositional deformation of this transgressive–regressive record along the equatorial and eastern margins of Brazil.

This work provides a review of previously published data focusing on the sedimentological, paleontological, geomorphological, and structural aspects of the Oligocene and Miocene strata exposed along the equatorial and eastern coastal zones of Brazil. These data have been supplemented by unpublished data, particularly from the eastern margin. The aim of the study is three-fold: 1) to demonstrate that the Oligo-Miocene and Miocene sea-level highstands have a much more widespread record along the Brazilian seaboard than previously considered; 2) to show that intraplate tectonics might have promoted fault reactivation, creating additional accommodation