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First evidence of marine influence in the Cretaceous of the Amazonas Basin, Brazil

D.F. Rossetti [a,*], R.G. Netto [b]

[a] *INPE, Rua dos Astronautas 1758, Jardim da Granja-CP 515, 12245-970 São José dos Campos-SP, Brazil*
[b] *PPGeo UNISINOS, Av. Unisinos, 950, 93022-000 São Leopoldo, RS, Brazil*

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Abstract

An integrated investigation emphasizing sedimentological and ichnological studies of Cretaceous deposits of the Alter do Chão Formation, exposed in the western Amazonas Basin, was undertaken with the aim of determining depositional environments. Four facies associations attributed to upper shoreface, foreshore, delta mouth bar, and lower/middle shoreface-prodelta depositional environments were recognized. The upper shoreface deposits were deposited by storm flows. They are interbedded with highly bioturbated sandstones displaying *Thalassinoides, Planolites* and *Diplocraterion* traces. The foreshore deposits, which are coarser-grained than the shoreface strata, are characterized by tabular sandstones with planar or trough cross-lamination/stratification, wavy/flaser lamination, and parallel lamination. These strata also contain an abundance of trace fossils. The delta mouth bar deposits comprise upward-coarsening beds displaying a lobed geometry. The lower/middle shoreface-prodelta settings consist of well-stratified, very fine-grained sandstones and mudstones deposited mostly by storm wave action. A wave-dominated delta system that prograded into a marine-influenced basin is supported for the study area. Therefore, in contrast to previous interpretations, it seems that a widespread transgression during the Cretaceous would have resulted in the submergence of large continental areas in the north of Brazil, affecting sediment deposition even in the innermost portions of the intracratonic Amazonas Basin.

Keywords: Cretaceous; Amazonas Basin; Marine influence; Sedimentary facies; Ichnology

1. Introduction

The distinction between open marine and continental strata in the geological record is, in general, straightforward, but the recognition of transitional depositional settings can be problematic because they produce sediments formed by a mixture of marine and non-marine processes. Interpretations are particularly problematic in successions that lack fossils, when analysis of the depositional setting has to rely solely on understanding of physical sedimentary structures. Many papers published in recent years have contributed to our knowledge of the sedimentary imprint of marine processes, particularly involving tidal currents and storm waves (e.g., Boersma and Terwindt, 1981; Dott and Bourgeois, 1982; Walker, 1984; Yang and Nio, 1985; McCrory and Walker, 1986; Arnott and Southard, 1990; Leckie and Singh, 1991; Nio and Yang, 1991; Shanley et al., 1992; Arnott, 1992, 1993; Cheel and Middleton, 1993; Hadley and Elliot, 1993; Amos et al., 1996). As a result, many deposits recorded in the literature previously as continental may be partly of marine origin.

The sedimentological criteria that aid recognition of tidal and storm deposits have helped to provide new interpretations of many Cretaceous deposits exposed in northern Brazilian marginal basins, which are dominated by transitional marine deposits. Hence, a number of studies undertaken during the past ten years on exposures of Albian–Cenomanian rocks of the São Luís-Grajaú and Cametá (Marajó Graben System) basins, have demonstrated the significance of tidal currents and storm waves as dominant depositional agents, even in southernmost

* Corresponding author.
E-mail addresses: rossetti@dsr.inpe.br (D.F. Rossetti), nettorg@euler.unisinos.br (R.G. Netto).

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areas at the basin margins, located several hundreds of kilometres from the modern coastline (e.g., Rossetti, 1998; Rossetti et al., 2000; Rossetti and Santos Jr., 2003; Rossetti and Góes, 2004). These authors have shown that shallow-marine to transitional environments were extensive as a result of widespread marine incursions throughout these basins, in contrast to previous suggestions of an entirely continental origin (e.g., Petri and Fúlfaro, 1983). Transgressions of such magnitude should have had an influence on adjacent regions to the west in the intracratonic Amazonas Basin, which has been of low overall relief since at least the Cretaceous. No marine or marginal marine Cretaceous strata have been recorded previously in this basin. The 500-m-thick Alter do Chão Formation is composed of siliciclastic red beds (sandstones and mudstones) that have been interpreted as continental in origin (e.g., Daemon, 1975; Dino et al., 1999), but a lack of widespread paleontological and sedimentological studies has precluded full recognition of the sedimentary processes.

This paper provides a detailed description of the sedimentary features preserved in the Alter do Chão Formation that crops out along the left side of the Amazonas River near Careiro Island, about 50 km to the east of Manaus, in the middle of the Amazonas Basin (Fig. 1). Our investigation has revealed a set of exposures with well-preserved physical and biogenic structures, allowing detailed interpretations of their mode of origin. Hitherto, studies of this nature had not been carried out on the formation, our knowledge of it having had to rely mostly on regional geological studies. In this paper, we integrate sedimentological and ichnological interpretations and conclude from these that the formation is not entirely continental in origin, features suggesting marine influence being abundant throughout the exposures. Our data lead us to suggest that Cretaceous transgressions might have been much more widespread in Brazilian territory than previously thought, resulting in the submergence of large continental areas, even within intracratonic basins.

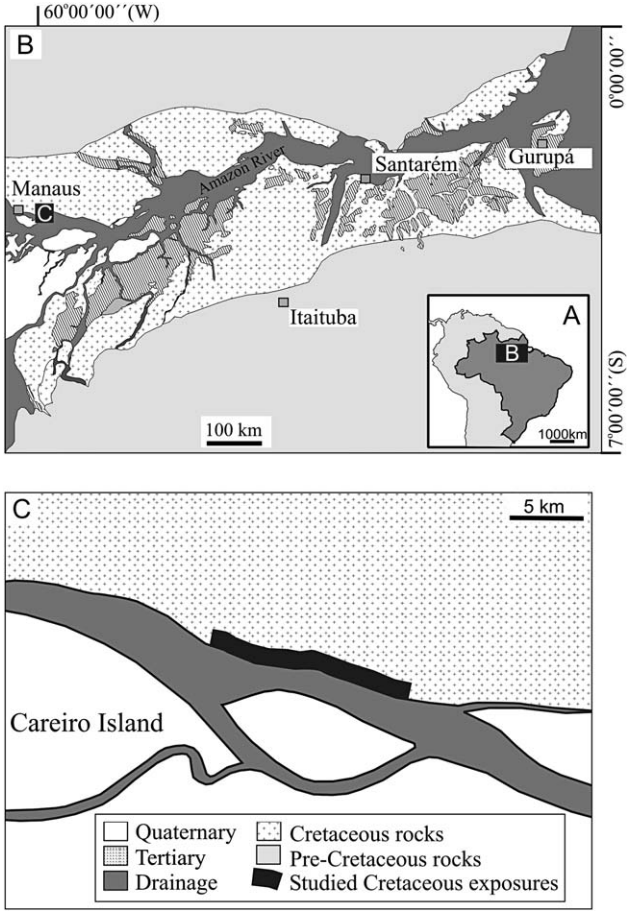

Fig. 1. A–C, location maps of the study area in Amazonas State, northern Brazil; the band of exposures of Cretaceous rocks along the riverbank to the north of the Careiro Island is shown in C.

2. Geological framework

The Amazonas Basin covers an area of up to 500,000 km^2, and is bounded by the Purus and Gurupá arches to the west and east, which separate this basin from the Solimões and Marajó basins, respectively. It is limited to the north by the Guiana Shield and to the south by the Brazilian Shield. The basement comprises igneous, metamorphic and volcano-sedimentary rocks of the Maroni-Itacaiunas and Amazônia Central provinces, which correspond to the oldest rocks of the Amazon Craton (Teixeira et al., 1989; Tassinari and Macambira, 1999; Tassinari et al., 2000). Near the Purus Arch, this basin is underlain by Proterozoic sedimentary rocks belonging to the Purus Group (Eiras et al., 1993).

The structure of the Amazonas Basin is defined by an east–west and a southwest–northeast orientated central trough, bounded by two platforms located to the north and south. Its origin is related to a rifting event controlled by Early Paleozoic intraplate extension. As the rift evolved, four main phases of deposition took place, which alternated with periods of thermal subsidence. The main trough, where the depocenter is located, contains four sedimentary successions, collectively up to 6500 m thick, which developed during the Ordovician–Early Devonian, Devonian–Early Carboniferous, Middle Carboniferous–Permian and Mesozoic–Cenozoic. The last succession is up to 500 m thick, and consists of the Javari Group (Cunha et al., 1994; Eiras et al., 1994), formed due to east–west extension associated with both the evolution of the South Atlantic Ocean and the Andean Cordillera. The Alter do Chão Formation, the subject of this paper, records the Cretaceous sedimentation of this group. Defined for the first time by Kistler (1954), it comprises red-coloured sandstones, mudstones, conglomerates and intraformational breccias, traditionally attributed to high-energy, westward-flowing fluvial and lacustrine/deltaic systems (Daemon, 1975). Its Cretaceous age was first suggested on the basis of therapod teeth (Price, 1960), with later papers considering it as Cenomanian–Maastrichtian (Daemon and Contreras, 1971), and middle Albian–Turonian (Daemon, 1975). Subsurface information (e-logs and a few cores) from areas located a few kilometres from the localities reported here led to the recognition of two sedimentary successions within the formation: an upper Aptian/lower Albian meandering to anastomosed fluvial and eolian unit; and