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Continental fossil vertebrates from the mid-Cretaceous (Albian–Cenomanian) Alcântara Formation, Brazil, and their relationship with contemporaneous faunas from North Africa

Carlos Roberto A. Candeiro [a,*], Federico Fanti [b], François Therrien [c], Matthew C. Lamanna [d]

[a] Laboratório de Geologia, Curso de Geografia, Universidade Federal de Uberlândia, Av. João Naves de Ávilla, 2160, Sta. Mônica, Uberlândia, Minas Gerais, Brazil
[b] Dipartimento di Scienze della Terra e Geologico-Ambientali, Alma Mater Studiorum, Università di Bologna, Via Zamboni 67, I-40127 Bologna, Italy
[c] Royal Tyrrell Museum of Palaeontology, Box 7500, Drumheller, Alberta T0J 0Y0, Canada
[d] Section of Vertebrate Paleontology, Carnegie Museum of Natural History, 4400 Forbes Ave., Pittsburgh, PA 15213, USA

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ABSTRACT

The Albian–Cenomanian Alcântara Formation of northeastern Brazil preserves the most diverse continental vertebrate fauna of this age yet known from northern South America. The Alcântara vertebrate assemblage, consisting of elasmobranchs, actinopterygians, sarcopterygians, turtles, crocodyliforms, pterosaurs, and non-avian dinosaurs, displays close similarities to contemporaneous faunas from North Africa. The co-occurrence of as many as eight freshwater or estuarine fish taxa (*Onchopristis*, *Bartschichthys*, *Lepidotes*, *Stephanodus*, *Mawsonia*, *Arganodus*, *Ceratodus africanus*, and possibly *Ceratodus humei*) and up to seven terrestrial archosaur taxa (*Sigilmassasaurus*, Rebbachisauridae, Baryonychinae, Spinosaurinae, Carcharodontosauridae, possibly Pholidosauridae, and doubtfully *Bahariasaurus*) suggests that a land route connecting northeastern Brazil and North Africa existed at least until the Albian. Interestingly, most components of this mid-Cretaceous northern South American/North African assemblage are not shared with coeval southern South American faunas, which are themselves characterized by a number of distinct freshwater and terrestrial vertebrate taxa (e.g., chelid turtles, megaraptoran and unenlagiine theropods). These results suggest that, although mid-Cretaceous faunal interchange was probably possible between northern South America and North Africa, paleogeographic, paleoclimatic, and/or paleoenvironmental barriers may have hindered continental vertebrate dispersal between northern and southern South America during this time.

1. Introduction

Knowledge of the continental vertebrate faunas of the extensive, mid-Cretaceous to ?Cenozoic, coastal to continental deposits of the Itapecuru Group in northern Maranhão State, Brazil (Fig. 1), has improved dramatically over the past 30 years (e.g., Cunha and Ferreira, 1980; Carvalho and Campos, 1988; Carvalho, 1994, 1995; Carvalho and Gonçalves, 1994; Medeiros and Schultz, 2001a, 2002, 2004; Nobre and Carvalho, 2002; Carvalho et al., 2003; Castro et al., 2004, 2007; Nobre, 2004; Medeiros, 2006; Elias et al., 2007a,b; Medeiros et al., 2007; Kellner et al., 2009). Vertebrate fossils from the Itapecuru Group include those of fishes, turtles, plesiosaurs, mosasaurs, crocodyliforms, pterosaurs, and non-avian dinosaurs. Within the Itapecuru Group, the Albian–Cenomanian Alcântara Formation has yielded the greatest diversity and abundance of continental vertebrates. However, few studies documenting the variety of taxa known from this unit have been published (e.g., Corrêa Martins, 1997; Medeiros and Schultz, 2001a, 2002; Medeiros et al., 2007). In this paper, we review and revise the continental (i.e., freshwater, estuarine, and terrestrial) vertebrate taxa recovered from the Alcântara Formation, and compare the fauna of this unit to those of other mid-Cretaceous West Gondwanan (i.e., African and other South American) deposits, to better establish the paleobiogeographic relationships of South America and Africa during this interval.

2. Geological setting

Located in northeastern Brazil (Fig. 1), the Itapecuru Group comprises intercalated marine, paralic, and continental sediments that range in age from the Early Cretaceous (Albian) to possibly the early Cenozoic (Pedrão et al., 1993; Rossetti, 1997; Rossetti and Truckenbrodt, 1997). Rifting between South America and Africa that began during the Early Cretaceous led to rapid marine transgression and, eventually, the deposition of the Itapecuru

* Corresponding author. Tel.: +55 54 34 3268 6118; fax: +55 51 34 3269 2389.
E-mail addresses: candeiro@yahoo.com.br, candeiro@pontal.ufu.br (Carlos Roberto A. Candeiro).

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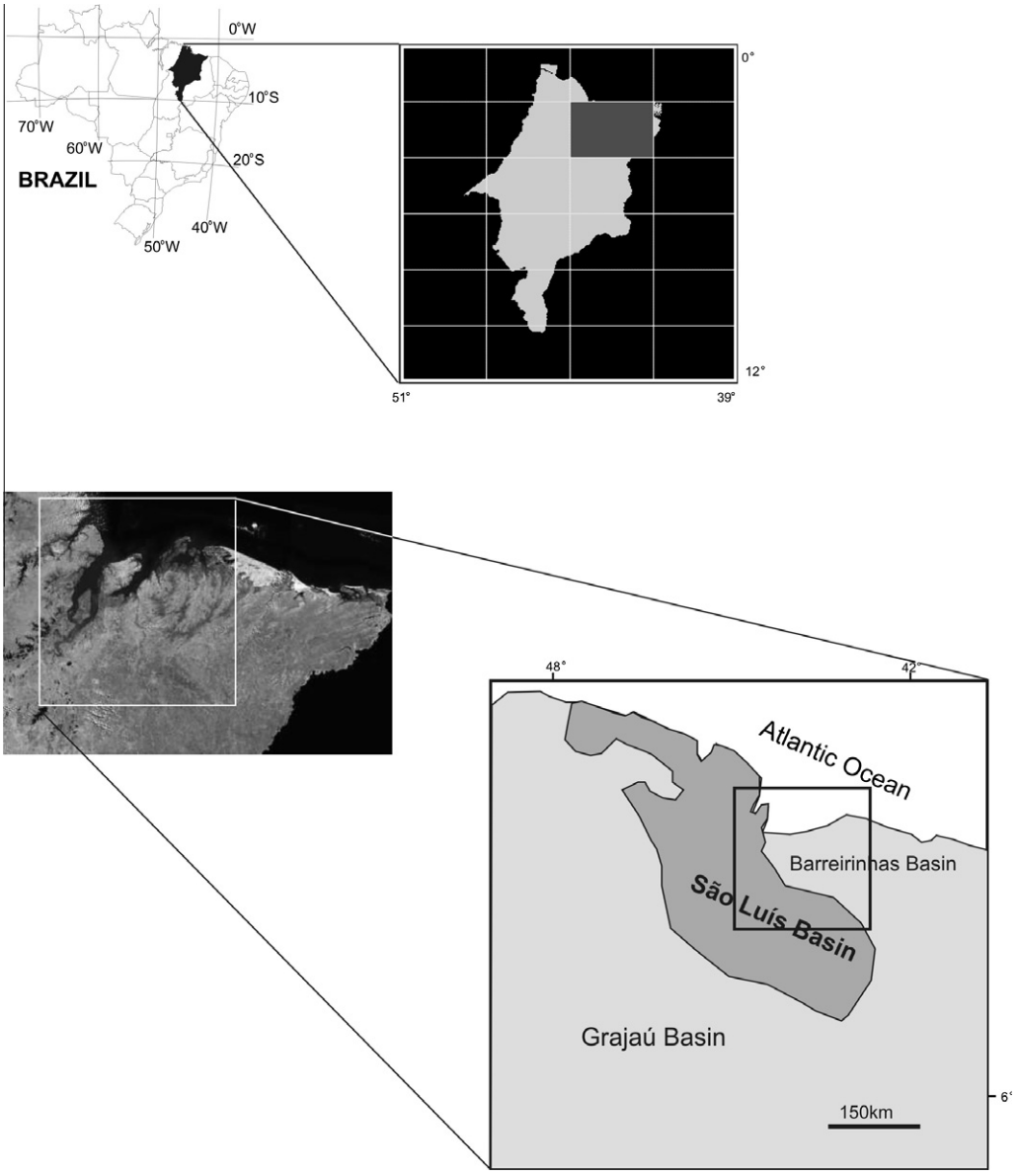

Fig. 1. Location and schematic geological map of the São Luis Basin in northeastern Maranhão State, Brazil.

Group. Although the lowermost portion of the Itapecuru Group consists of undifferentiated deposits (informally termed the "Undifferentiated Unit" by some authors [e.g., Castro et al., 2007]), two formal stratigraphic units are recognized in the upper portion: the Alcântara and Cujupe formations (Rossetti, 1997; Rossetti and Truckenbrodt, 1997, 1999). The Alcântara Formation is extensively exposed in the São Luís Basin (Fig. 1), where it conformably overlies undifferentiated strata of the lower Itapecuru Group (Fig. 2). Considered Albian–Cenomanian in age by most workers (e.g., Rossetti and Truckenbrodt, 1997, 1999), this formation reaches a maximum thickness of 35 m and is composed of fine- to medium-grained sandstones interbedded with mudstones and limestones (Rossetti, 1997). Late Cretaceous through possibly early Cenozoic deposits of the Cujupe Formation overlie the Alcântara Formation (Rossetti and Truckenbrodt, 1997; Dias Lima and Rossetti, 1999) (Fig. 2).

2.1. Paleogeographic context

Cretaceous faunal similarities between continental Africa and South America are widely documented in the dinosaurian fossil record (e.g., Calvo and Salgado, 1995; Russell, 1996; Sereno et al., 1996, 1998, 1999, 2004; Forster, 1999; Sues et al., 2002; Upchurch et al., 2002; Candeiro et al., 2004, 2006; Holtz et al., 2004; Coria and Currie, 2006; Wilson, 2006; Sereno and Brusatte, 2008; Cavin et al., 2010; Le Loeuff et al., 2010; Smith et al., 2010). However, it is important to view paleontological discoveries in light of stratigraphic and paleogeographic data when generating and evaluating paleobiogeographic hypotheses. According to current paleogeographic models, the South Atlantic began to open northward in the Early Cretaceous, with emplacement of oceanic crust between southern Africa and southern South America initiating at approximately 135 Ma (Viramonte et al., 1999; Jokat et al., 2003; Macdonald et al., 2003). Continental extension between West Africa and Brazil resulted in the development of the evaporites of the South Atlantic salt basin, Barremian-aged oceanic crust, and rift propagation from east to west across the West African margin (Karner and Gamboa, 2007). The barrier to southern Atlantic marine incursions relates to the magmatic constructions of a proto-Walvis Ridge and the long-lived anomalous topography of the southeastern Brazilian highlands (Gradstein et al., 2004; Karner and Gamboa, 2007). In the Early Cretaceous, isolated rift/