



# Middle Cretaceous dinosaur assemblages from northern Brazil and northern Africa and their implications for northern Gondwanan composition



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## ABSTRACT

Dinosaurs are one of the most dominant groups in Cretaceous reptilian faunas. A summary of their record in northern Brazil and northern Africa during the middle of the Cretaceous Period (Aptian–Cenomanian) is presented here. Dinosaurs are represented by 32 species (three ornithischians, six sauropods and 23 theropods) from Brazil, Egypt, Lybia, Morocco, Niger, Sudan and Tunisia. These dinosaur assemblages provide fundamental data about distribution and composition of sauropods and theropods in northern Gondwana during the middle of the Cretaceous Period and confirm these assemblages to be among the most important dinosaur faunas in the north Gondwana areas.

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## 1. Introduction

The three major clades of dinosaurs (Ornithischia, Sauropoda and Theropoda) were widespread and diverse during the middle of the Cretaceous Period in Gondwana. Cretaceous dinosaur assemblages have long been known from southern continents where appropriate rocks are exposed. This northern Gondwana dinosaur fauna has considerable potential for new discoveries (e.g., Brazil: Hauterivian Corda Formation in north Tocantins State; Albion Santana Formation in eastern Piauí State; Lybia: Aptian–Albian Chicla Formation; Sudan: Cenomanian Wadi Milk Formation). Gondwanan dinosaur records from these southern continents could foster an increased understanding of the global composition of the fauna during the middle Cretaceous Period.

This analysis is based on the dinosaur taxa in northern Brazil and northern Africa, which provide a significant amount of information on dinosaur faunas and allow an understanding of the composition of these assemblages from the Aptian to the Cenomanian on northern Gondwanan continents.

Gondwana paleobiogeography during the Cretaceous Period has been studied and analyzed by many geoscientists (e.g., Krause et al., 1997; Hay et al., 1999; Novas et al., 2005; Yoder and Nowak, 2006; Upchurch, 2008; Novas, 2009; Candeiro, 2010; Candeiro et al., 2011; Jacobs et al., 2011; Fanti, 2012; Fanti et al., 2012, 2013, 2014), and

northern Brazil and northern Africa are prominent topics of these studies due to the close similarities between their close geological and dinosaur faunal content. In this paper I review the northern Brazilian and African Cretaceous dinosaur fauna distribution during the middle of the Cretaceous Period.

## 2. Methods

Extensive records were collected from the literature for three major dinosaur groups: ornithischians, sauropods and non-avian theropods. These clades represent the major dinosaur groups using a logical diversity and distribution of comparison. Geological and chronological data were obtained from Itapecuru Group (Rossetti and Truckenbrodt, 1997), Santana (Martill, 1993), Elrhaz and Echkar (Taquet, 1976), Wadi Milk (Werner, 1994), Bahariya (Catuneanu et al., 2006), Chicla (Barale et al., 1997; Barale and Ouaja, 2002), Douiret and Ain El Guettar formations (Bouaziz et al., 1988; Bondin et al., 2010), and Kem Kem beds (Cavin et al., 2010).

## 3. Cretaceous dinosaurs record from North Brazil and North Africa

The dinosaur record (Fig. 1) analyzed here is restricted to continental middle Cretaceous rocks from Brazil, Egypt, Lybia, Morocco, Niger, Sudan and Tunisia. Most information on the middle

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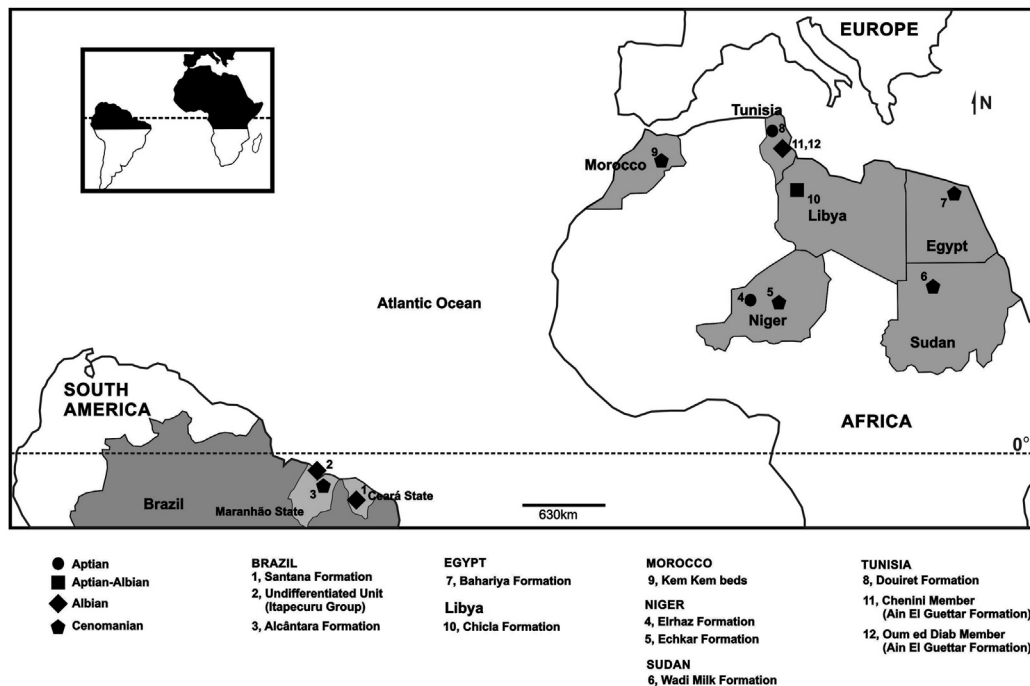


Fig. 1. Middle Cretaceous dinosaur-bearing units of northern Gondwana (modified from Scotese, 2000).

Cretaceous dinosaur faunas of north Brazil and north Africa come from Albian and Cenomanian stages and, above all, from collection made of Albian-Early Cenomanian Itapecuru Group and Albian Santana in North Brazil; Aptian-Albian Ain El Guettar Formation, Aptian-Albian Elrhaz Formation, Aptian-Albian Chicla Formation, Aptian Douret Formation, Early Cenomanian Bahariya, Cenomanian Wadi Milk Formation and Cenomanian Kem Kem beds in North Africa. On the tectonic divisions, North Brazil and North Africa belong to the same ancient Gondwana plate, and this is also supported by Cretaceous dinosaur content.

### 3.1. North Brazil

#### 3.1.1. Santana Formation (Arapipe Basin, *sensu* Martill, 1993)

The Albian Santana Formation has produced only theropod records with two described spinosaurid species and some additional postcranial remains (Kellner, 1996; Kellner and Campos, 1996; Martill et al., 1996; Sues et al., 2002; Bittencourt and Kellner, 2004; Machado and Kellner, 2005). *Irritator challengerii* Martill et al., 1996 was first described based on a partial skull from the Santana Formation. Later, *I. challengerii* was considered a senior synonym of *Angaturama limai* by Charig and Milner (1997), and Sereno et al. (1998) confirmed it as a spinosaurid species (Sues et al., 2002). Frey and Martill (1995) described a sacrum and assigned it to Oviraptorosauria indet., but it has been later suggested that this theropod needs to be revised (Makovicky and Sues, 1998; Kellner, 1996; Agnolín and Martinelli, 2007). The small-bodied *Santanaraptor placidus* Kellner, 1999 was attributed by Holz (2004) and Porfiri et al. (2014) to Tyrannosauroida. *Mirischia asymmetrica* Naish et al., 2004 was described as the first Brazilian Compsognathidae from the Santana Formation, based on incomplete skeletal remains.

#### 3.1.2. Itapecuru Group (Rossetti and Trukenbrodt, 1997)

The Itapecuru Group (Albian age “Undifferentiated Unit” and Early Cenomanian Alcântara; Rossetti and Trukenbrodt, 1997)

dinosaur fauna is composed of sauropods and theropods and a possible ornithischian record (Avilla et al., 2003; Candeiro et al., 2011). The sauropod dinosaur fauna recorded from the Albian “Undifferentiated Unit” includes the diplodocoid *Amazonasaurus maranhensis* Carvalho et al., 2003 and Titanosauria indet. (Castro and Medeiros, 2007; Lindoso et al., 2013). From the Early Cenomanian Alcântara Formation, large-bodied theropods are represented by the spinosaurid *Oxalaia quilombensis* Kellner et al., 2011, *Carcharodontosaurus* sp., *Spinosaurus* sp. (Medeiros et al., 2014), and Baryonychinae indet. (Furtado and Candeiro, 2009a,b). An isolated vertebra attributed to *Sigilmassasaurus brevicollis* Russell, 1996 was briefly described by Medeiros and Schultz (2002), but this Brazilian record needs to be revised and will probably be assigned to Spinosauridae indet. (Bradley Mcfeters *pers. comm.*). Small theropod dinosaurs are represented by Dromaeosauridae indet. that have been recently confirmed by Medeiros et al. (2014) as cf. *Masiakasaurus* (Lindoso et al., 2012). The sauropod dinosaur fauna recorded from this unit includes the rebbachisaurid cf. *Limaysaurus* (Medeiros and Schultz, 2004; Medeiros et al., 2014) and Diplodocoidea indet. (Medeiros and Schultz, 2004).

### 3.2. North Africa

#### 3.2.1. Egypt

3.2.1.1. Bahariya Formation (Catuneanu et al., 2006). The dinosaur fauna of the Egypt comes from Early Cenomanian Bahariya Formation (Catuneanu et al., 2006; Le Loeuff et al., 2012) and includes titanosaurs, ceratosaurs, and tetanuran theropods; titanosaurians are represented by *Aegyptosaurus bahariensis* Stromer, 1932 and *Paralititan stromeri* Smith et al., 2001. Large-bodied theropods have also been reported from Bahariya Formation: ceratosaurian *Bahariasaurus ingens* Stromer, 1934, the carcharodontosaurid *Carcharodontosaurus saharicus* Stromer, 1931, and the spinosaurid *Spinosaurus aegyptiacus* Stromer, 1915.

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