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Evidence of titanosauriforms and rebbachisaurids (Dinosauria: Sauropoda) from the Early Cretaceous of Tunisia

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ABSTRACT

Isolated sauropod remains including vertebrae and a humerus from the Aïn El Guettar Formation (Albian, Early Cretaceous) of Tunisia are described. Vertebrae include a slightly procoelous anterior caudal vertebra, amphicoelous middle caudal vertebrae, and strongly procoelous distal caudal vertebrae. The humerus has an anteroposteriorly compressed shaft, robust deltopectoral crest restricted laterally and prominent condyles bounding a distinct distal fossa. The morphological characters present in the specimens suggests that isolated remains can be referred to at least two distinct sauropod taxa.

The anterior caudal vertebra is referred to Rebbachisauridae, whereas remaining caudal vertebrae show titanosauriform and titanosaurian derived features (anteriorly placed neural arches and, in the posterior vertebrae, distinctly procoelous centra); finally, the humerus may pertain to a somphospondylian titanosauriform, perhaps the same taxon represented by the middle and posterior caudal vertebrae. This study introduces some of the oldest titanosauriform remains from Northern Africa and provides additional data on the stratigraphic and geographic distribution of this clade during the Early Cretaceous.

1. Introduction

Titanosauriforms are the last surviving groups of the giant sauropod dinosaurs into the Late Cretaceous: they attained a global distribution during the Cretaceous period and represent a key clade for investigation of dinosaur macroevolutionary patterns and Mesozoic paleobiogeography. Considered for a long time as the most endemic group of Gondwanan dinosaurs, titanosauriforms (Titanosauria) are now known from an increasing number of localities of the northern hemisphere, including Europe (Sanz et al., 1999; Mannion and Upchurch, 2011; Vila et al., 2012; Diez Diaz et al., 2013; Mannion et al., 2013), and China (Tang et al., 2001; Mo et al., 2006; Xu et al., 2006; Barrett and Wang, 2007) (see also Wilson, 2006; Fanti, 2012). The oldest representative of the titanosaurian lineage are probably *Australodocus* and *Janenschia*, from the Tithonian beds of Tanzania (Janensch, 1961; Wild, 1991; Upchurch et al., 2004; Curry Rogers, 2005; Remes, 2007), although the affinities of both are controversial (see also Carballido et al., 2011; D'Emic, 2012; Mannion et al., 2013). In continental Afro-Arabia, Cretaceous titanosaurians have been also reported from Niger (Sereno and Brusatte, 2008), Malawi (Jacobs et al., 1993; Gomani, 2005), Egypt (Rauhut and Werner, 1997; Smith et al., 2001), and more recently from Kenya (Sertich et al., 2006), Angola (Jacobs et al., 2006; Mateus et al., 2011), Jordan (Wilson et al., 2006), and Morocco (Mannion and Barrett, 2013) supporting a Pan-African distribution of this clade.

In the Early Cretaceous, an increasing number of basal representatives of the titanosauriform branch has been found worldwide, including *Phuwiangosaurus sirindhornae* (Martin et al., 1994; Barremian-Aptian of Thailand), *Euhelopus zdanskyi* (Barremian-Aptian of China, Wilson and Upchurch, 2009); *Venenosaurus dicrocei* (Tidwell et al., 2001; Barremian of Utah), *Ligabuesaurus leanzai* (Bonaparte et al., 2006; Aptian-Albian of Argentina), *Tastavinsaurus sanzi* (Canudo et al., 2008; Aptian of Spain), and *Wintonotitan wattsi* (Hocknull et al., 2009; Albian-Cenomanian of Queensland, Australia). In this study we describe a series of sauropod remains from the lower Albian deposits of the Aïn El Guettar Formation of southern Tunisia. Specimens have been singularly collected from different spots of the same locality, named Oued el Khil, during the last thirty years: although the number of individuals and taxa represented by the specimens is unclear, the majority of the elements are referable to Titanosauriformes or Titanosauria and Rebbachisauridae provided the first possible record of titanosaurian remains from Tunisia in a short report on the paleontological sites located along the Dahar cliff exposures in the Tataouine region:

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'Sauropods: the presence of a herbivore, close in size to *Diplodocus* but belonging to the genus *Titanosaurus*, is represented by 6 caudal vertebrae, some apophysis of dorsal vertebrae, ribs and limb bone fragments, particularly of femurs'. However, the author did not provide any information on the exact locality of these findings, nor plates, nor indication of where such specimens would be stored. In a later publication, included a description of approximately 50 sauropod vertebrae from the '*Continental Intercalaire*' deposits of central Sahara (collected from several localities in Algeria, Tunisia, Libya, Niger and Chad) but in this later publication there is no mention of the titanosaur vertebrae from southern Tunisia. Questioningly, titanosaur elements are represented only by caudal vertebrae from the Mont Iguallala locality (Niger) referred to *Aegyptosaurus bahariensis* Stromer, 1932.

The fossil record of Rebbachisauridae from Africa is restricted to the Early and mid-Cretaceous of Morocco (Mannion and Barret, 2013), Niger (Sereno et al., 1999), and Tunisia (Fanti et al., 2012, 2013). Pending further studies on poorly described material from the Saharan countries, the geographic distribution of rebbachisaurid sauropods seems restricted to the north-western regions of continental Africa (see Mannion and Barrett, 2013 for a complete revision of African localities). In Tunisia, the sole report of rebbachisaurids is represented by *Tataouinea hannibalis* from the lower Albian deposits of the Aïn El Guettar Formation (Fanti et al., 2013).

2. Geology and paleoecology

Specimens described in this study were collected at the Oued el Khil locality, approximately 25 km north-west of Tataouine in southern Tunisia. At the site, the basal, conglomeratic beds of the Oum ed Diab Member (Aïn El Guettar Formation) crop out discontinuously and have been known for decades to both locals and researchers as a source of vertebrate remains (Fig. 1). Significantly, vertebrate elements form up to 60% of the coarse-grained deposits which overall consist of poorly washed and barely reworked elements, usually mixed with clay chips, quartz-arenite clasts, and ironstone pebbles. To date, the fauna recovered from these marker beds of the Tataouine region includes elasmobranchs, bony fishes, crocodyliforms (e.g. *Sarcosuchus*, cf. *Araripesuchus* and cf. *Hamadasuchus*), turtles, and dinosaurs (carcharodontosaurids, spinosaurids, abelisauroids, rebbachisaurids, and ornithopods) (see Bouaziz et al., 1988; Benton et al., 2000; Anderson et al., 2007; Fanti et al., 2012, 2013, and references therein). As this faunal assemblage in the basal beds of the Oum ed Diab member has been interpreted as the result of a transgressive lag, part of the preserved taxa may have originally pertained to the underlying Chenini Member deposits (lowermost Albian) (Benton et al., 2000; Fanti et al., 2012). The coarse, Chenini Member beds are representative of high-energy fluvial deposits, similar to those observed in present day *wadi*-like drainage systems: furthermore, the absence of megaplants, the abundance of iron oxides and phosphatized organic remains (including dinosaur bones and teeth) support arid to strongly seasonal environments during the deposition of the Chenini Member. Although the sole direct evidence to constrain the age of these fossiliferous beds are represented by rare, upper Aptian-lower Albian palynomoprhs (Ben Ismaïl, 1991; Barale et al., 1998), recent stratigraphic and paleontological investigation in southern Tunisia and correlative deposits of Libya and Algeria support a lower Albian age for the basal deposits of the Aïn El Guettar Formation (Benton et al., 2000; Bodin et al., 2010; Le Loeuff et al., 2010; Fanti et al., 2012) (see Fig. 1).

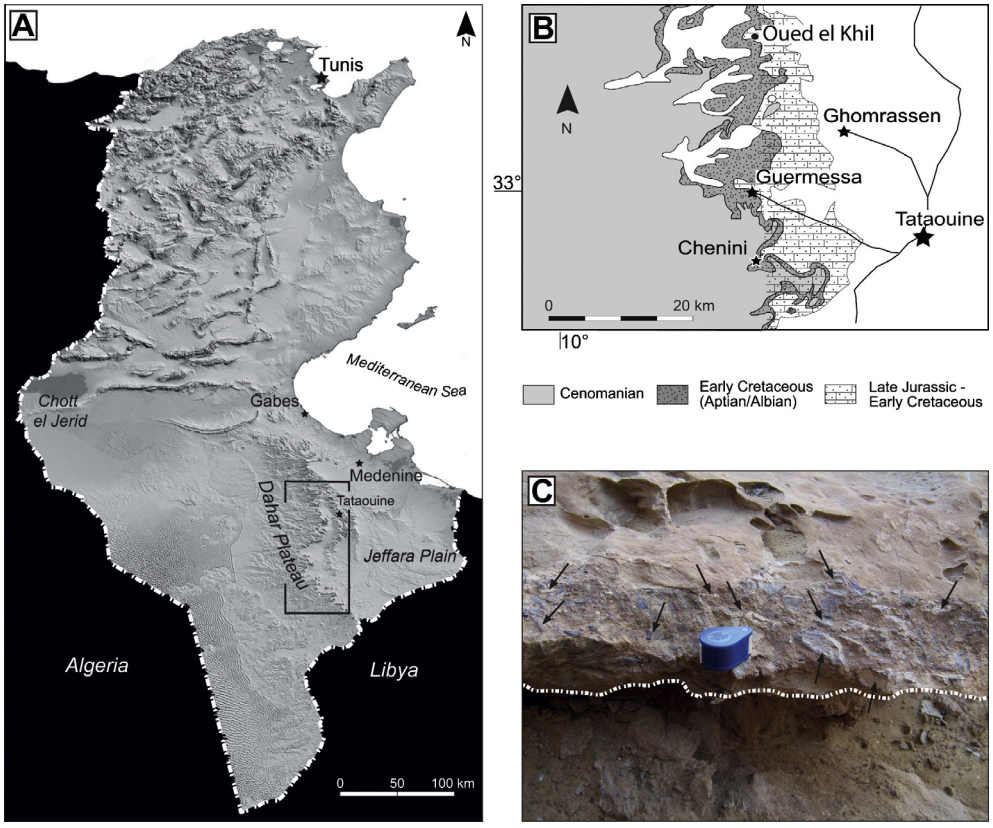

Fig. 1. (A) Reference map of Tunisia showing the position of the Tataouine region. (B) Simplified geological map of the study area showing the Oued el Khil locality. (C) Field photograph of the fossiliferous bed exposed at the Oued el Khil locality. Black arrows indicate fossil remains.