Cretaceous Research 64 (2016) 88–109

Contents lists available at ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

First sauropod bones from Italy offer new insights on the radiation of Titanosauria between Africa and Europe

Cristiano Dal Sasso [a, *], Gustavo Pierangelini [b], Federico Famiani [c], Andrea Cau [d, e], Umberto Nicosia [f]

[a] Museo di Storia Naturale di Milano, Corso Venezia 55, Milano 20121 Italy
[b] 160 rue Pierre Valdo, Lyon 69005, France
[c] Mostra Permanente di Geo-Paleontologia, Parco Regionale del Monte Subasio, Cà Piombino, Assisi 06081, Italy
[d] Dipartimento di Scienze Biologiche, Geologiche ed Ambientali, Università di Bologna, Via Zamboni 67, Bologna 40126, Italy
[e] Museo Geologico e Paleontologico "Giovanni Capellini", Via Zamboni 63, Bologna 40126, Italy
[f] Dipartimento di Scienze della Terra, "Sapienza" Università di Roma, Piazzale Aldo Moro 5, Roma 00185, Italy

ARTICLE INFO

Article history:
Received 22 November 2015
Received in revised form
20 February 2016
Accepted in revised form 14 March 2016
Available online 17 March 2016

Keywords:
Sauropoda
Titanosauria
Early Cretaceous
Aptian–Albian
Italy
Palaeobiogeography

ABSTRACT

Here we describe the first sauropod skeletal remains from the Italian peninsula that also represent the earliest record of titanosaurs in Southern Europe. Scattered bones, including an almost complete anterior caudal vertebra, were found in Cretaceous (Aptian–Albian) marine deposits, some 50 km East of Rome. The vertebra shows a bizarre and perhaps unique orientation of the zygapophyseal articular facets that renders their interpretation problematic. Phylogenetic retrofitting tests support the placement of the Italian titanosaur among basal lithostrotians. Palaeobiogeographic analysis based on the resulting phyletic relationships suggests an Afro-Eurasian route for the ancestors of the Italian titanosaur, a scenario compatible with the palaeogeographic evolution of the Italian microplates during the Cretaceous. Together with previously recorded titanosaurian-like ichnites from a Cenomanian locality in Latium, this new find suggests a quite long emersion for the Apenninic carbonate platform. We suggest that the Italian titanosaur was member of a population that crossed the western Tethys Sea through a "filtering bridge" composed of a chain of ephemeral islands and peninsulae, known as Periadriatic (Adria) carbonate platforms, that connected sporadically Africa and Europe since the Early Cretaceous.

1. Introduction

Titanosauriformes is a successful group of sauropod dinosaurs, with over 90 distinct species, a global distribution, and a temporal range extending from the Middle Jurassic to the end of the Cretaceous (Mannion et al., 2013, and references therein). Nevertheless, Early Cretaceous titanosauriforms are still poorly known in Europe (Le Loeuff et al., 2013), and remain rare in Africa (Gorscak and O'Connor, 2014). Cretaceous dinosaurs of the peri-Mediterranean regions offer new insights into some of the most important and debated topics in vertebrate palaeontology, such as Cretaceous biogeography and insular faunas, biodiversity, timing of radiation of groups, and phylogenetic relationships among Gondwanan dinosaur clades with respect to their European counterparts (Fanti et al., 2013, 2015). In this context, the finding of the first sauropod bones from the Italian peninsula, reported herein, confirms once again the perception of Italy as a land suitable for dinosaurs, and as a possible connecting passage between Eurasia and Gondwana in Cretaceous times (Citton et al., 2015b, and references therein). In fact, this find represents the third dinosaurian skeletal record in central-southern Italy, after the exceptionally preserved theropod *Scipionyx samniticus* from Pietraroja, Campania (Dal Sasso and Signore, 1998; Dal Sasso and Maganuco, 2011), and the theropod bone fragment from Capaci, Sicily (Garilli et al., 2009).

In 2008, some rocks that seemed to contain large bone remains were spotted during the construction of a garden wall in a private house, located in the municipality of Rocca di Cave (Rome). Those rocks had been excavated from a close-by Cretaceous limestones outcrop, at the border between the Cave and the Rocca di Cave municipalities. Only in 2012 the fossil bones were shown to expert eyes that recognised their real nature.

* Corresponding author.
E-mail addresses: cdalsasso@yahoo.com (C. Dal Sasso), gpierangelini@gmail.com (G. Pierangelini), federico.famiani@gmail.com (F. Famiani), cauand@gmail.com (A. Cau), umberto.nicosia@uniroma1.it (U. Nicosia).

http://dx.doi.org/10.1016/j.cretres.2016.03.008
0195-6671/

2. Age and geological setting

2.1. The Monti Prenestini ridge: geological framework

The Monti Prenestini (central Italian Apennines) are the nearest relief emerging ESE of Rome. They are represented by a NNO-SSE mountain ridge, approximately ten kilometers long, constituted by an asymmetric anticline (East dip) and made by outcropping Meso-Cenozoic deposits, from which the studied specimens come. After the Early Jurassic rifting to the end of the Cretaceous, the present-day central Italy was characterised by carbonate platform areas surrounded by intervening deeper basins. The main platform areas are included into a domain defined as Laziale-Abruzzese-Campana platform (LACP), also referred as Apenninic carbonate platform by most authors (e.g. Petti et al., 2008b; Rosenbaum et al., 2004; Zarcone et al., 2010), bordered N and W by deeper areas in which the strata pertaining to the Umbro-Marchigiano-Sabino domain were deposited.

In the Monti Prenestini area, the deposits formed between the Cretaceous and the Miocene, but the Cretaceous outcrops are of limited entity and are fragmented, due to a complex palaeogeography and intense tectonic activity. In the southern part of the Monti Prenestini ridge, that includes the Rocca di Cave area, Albian–Senonian neritic limestones are exposed, presenting lagoonal facies in the earliest deposits, and platform margin deposits in the most recent portions (Carbone et al., 1971; Praturlon and Sirna, 1976).

2.2. Stratigraphic section

The stratigraphic section that we examined in the type locality (Fig. 1) is just over two meters thick and is quite disturbed by tectonics. The sedimentary sequence is composed of white and hazelnut limestones with texture variable from mudstone to grainstone, alternated to subordinate oolitic levels and thin mudstone layers. Locally, miliolaceans and rudists are abundant, and there is some evidence of subaerial exposure, such as fenestrae.

The limestones that embedded the sauropod bones vary in thickness from 20 cm to one meter. Macrofossils are locally very abundant: rudist, broken bivalve and gastropod shells, echinoids, and rare brachiopods and corals. These bioclastic levels show isorientation of shell fragments. Thin-section analysis of the limestones sampled around the bones revealed the presence of dasycladacean algae (*Salpingoporella* spp.). Fragments of rudists and benthic foraminifera, including abundant nubecularids (*Spiroloculina* sp.) and miliolaceans, are also present.

The studied outcrop is the only one in the area that exposes this structure and palaeontological content. It can be ascribed to a lagoonal facies with muddy deposits rich in bioclasts, witness of a confined inner platform margin (Praturlon and Madonna, 2007). On the top of the section, these limestones transition continuously to a white bioclastic wackstone very rich in nerineids, small gastropods, echinoids, and corals, that can be referred to the “Caprinid and Nerineid limestones” unit (*sensu* Praturlon and Madonna, 2007).

Data collected from the field and from thin section analysis allow us to attribute the stratigraphic interval with sauropod bone remains to the “Ostracod and Gastropod limestones” unit (*sensu* Praturlon and Madonna, 2007). The fossil association can be referred to a late Aptian–early Albian age.

2.3. Depositional environment

The depositional environment is documented by fossil assemblages of different marine organisms, including rudists, gastropods, corals, sponges, echinoids and miliolaceans. In particular, the rock that embedded the bones here described shows a mudstone to wackstone texture, whitish to light brown in colour, rich in miliolaceans. These limestones also show levels with bioturbations and random distribution of nerineids and rudists. The lower levels of the sedimentary sequence, although rich in miliolaceans, are poor in macrofossils, whereas the upper levels are increasingly rich in echinoids, bivalves and gastropods. Based upon the macro- and microfacies characteristics, and the fossil content, the depositional environment can be considered of lagoon/inner platform type, with relevant tidal influence (Chiocchini et al., 2004, 2012). The area of Rocca di Cave thus represents a portion of the western margin of the LACP.

The vertebra here described (MSNM V7157) was found included in a block of rock as large as two or three vertebrae, therefore this bone was relatively isolated, certainly not in anatomical connection with other vertebrae (Pierangelini, pers. obs. 2012). A second bone (MSNM V7159) shows pre-diagenetic fragmentation, with fragments first displaced and then cemented as they were in motion during deposition in a still soft, soupy substrate. According to taphonomical models, longitudinal fractures parallel to bone fibres, such as those of MSNM V7159, indicate a low grade of pre-burial cracking and dispersion (stage 1 *sensu* Behrensmeyer, 1978).

3. Materials and methods

Three bones were recovered and subsequently deposited at the Museo di Storia Naturale di Milano, Italy, by permission of the Soprintendenza Archeologia del Lazio e dell'Etruria meridionale, Rome, Italy. The almost complete caudal vertebra turned out to be the most diagnostic element. This specimen was cast to produce replicas that were used to re-articulate a portion of the caudal vertebral series and study its anatomy.

The vertebra was also examined under computed tomography with a Siemens CT Dual Source Scanner Somatom Definition Flash at the Radiology Department of the Spedali Civili di Brescia, Italy, in order to study its internal morphology. Analysis and post-processing were performed at Siemens Milano, Italy, with SyngoVia post-processing system using Region Growing Algorithm to segment anatomical volumes.

Measurements and ratios cited in the text are grouped in Tables 1 and 2. On fragmentary elements, length indicates the maximum length of the preserved portion; width and thickness indicates the maximum measure, taken perpendicular to the maximum length. We follow Wilson (1999) and Wilson et al. (2011) for vertebral laminae and fossae nomenclature.

4. Systematic palaeontology

Dinosauria Owen, 1842
Saurischia Seeley, 1887
Sauropoda Marsh, 1878
Titanosauriformes Salgado, Coria and Calvo, 1997
Titanosauria Bonaparte and Coria, 1993
Titanosauria gen. et sp. indet.

4.1. Material

Three disarticulated bones, deposited at the Museo di Storia Naturale di Milano (MSNM), Milan, Italy: one anterior caudal vertebra (MSNM V7157), one portion of scapular blade or of ischial/pubic shaft (MSNM V7158), and another -possibly pelvic- bone fragment (MSNM V7159).