

Large theropod teeth from the Upper Cretaceous of Jiangxi, southern China

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Abstract Two isolated, large theropod teeth from the Upper Cretaceous Nanxiong Formation of Nankang County, Jiangxi Province, southern China, are described. Their crown heights (CH) are 76 and 91 mm, respectively. The smaller tooth is referable to the Tyrannosauridae based on its size and sub-oval cross-section (the crown base ratio (CBR) is about 0.72). The larger tooth is moderately laterally compressed (the CBR is about 0.47), with well defined longitudinal oriented enamel wrinkles at the basal halves of the mesial and distal margins, probably represents a previously unknown large theropod inhabited Asia during the Late Cretaceous. The recovered large theropod teeth add to the known diversity of vertebrates from the Upper Cretaceous Nanxiong Formation, southern China.

Key words Nankang, Jiangxi, Upper Cretaceous, Nanxiong Formation, Theropoda, tooth

1 Introduction

Large carnivorous dinosaurs, the top members of the trophic chain, are common in the Late Cretaceous of Asia (Weishampel et al., 2004). Although well diversified in central Asia and northern China (Riabinin, 1930; Gilmore, 1933; Maleev, 1955; Young, 1958; Hu, 1964; Kurzanov, 1976; Dong, 1977; Osmólska, 1996; Currie and Dong, 2001; Benson and Xu, 2008; Brusatte et al., 2009, 2010; Hone et al., 2010, 2011; Averianov et al., 2012; Lü and Han, 2012), only some fragment teeth have been recovered from southern China (Dong, 1979; Lü et al., 2009a). Here we report two isolated, large predatory theropod teeth from the Upper Cretaceous of southern China; the smaller tooth is assigned to a tyrannosaurid, whereas the larger one is greatly distinct from other known Late Cretaceous theropods, probably represents a previously unrecognized large predatory dinosaur.

The teeth were collected from the Upper Cretaceous Nanxiong Formation in Nankang County, Jiangxi Province. The Nanxiong Formation or its equivalents are exposed in several provinces of southeastern China and represented by a thick sequence of red mudstones, sandstones and conglomerates. In Jiangxi, these red beds have yielded dinosaurs and other vertebrate fossils since 1965, including turtles (Tong and Mo, 2010), lizards (Young, 1973; Mo

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et al., 2010, 2012), dinosaur eggs (Young, 1965; Ji, 2009), small theropods (Sato et al., 2005; Cheng et al., 2008; Xu and Han, 2010; Wei et al., 2013; Wang et al., 2013; Lü et al., 2013a), and sauropods (Lü et al., 2013b). Large predatory theropod teeth described in this paper were for the first time discovered from the Upper Cretaceous Nanxiong Formation of Jiangxi. The specimens are housed in the Natural History Museum of Guangxi (NHMG 8500, 8501). The dental description terms follow Smith et al. (2005).

2 Systematic paleontology

Dinosauria Owen, 1842

Theropoda Marsh, 1881

Tyrannosauridae Osborn, 1906

Gen. et sp. indet.

(Fig. 1)

Referred specimen NHMG 8501, a relatively complete left maxillary or right dentary tooth.

Description NHMG 8501 loses the root and the crown is damaged lingually. Most of the enamel surface is not preserved. The maximum preserved length is 85.6 mm, and the crown height (CH) is about 76 mm. The crown base length (CBL) and crown base width (CBW) are about 40.4 and 29 mm, respectively. Its crown base ratio (CBR) equals 0.72.

The tooth has convex mesial, labial, lingual surfaces and somewhat flat distal surface. The poorly preserved tooth enamel surface is smooth. There are many irregularly distributed striations on the labial surface near the distal carina (Fig. 1A). It seems that no wrinkles are present.

The distal and mesial edges curve apically from the base. The crown angle (CA) is about 67° . The distal carina is present. In distal view, it starts from the apex and curves labially such that at the base of the crown, it is nearly on the labial side of the base. The mesial carina is somewhat lingually positioned, though its ventral part is not preserved. The tip slightly medially inclined and the medial displacement of the mesial carina imply that NHMG 8051 is a left maxillary or right dentary tooth.

The distal denticles are preserved, missing most of the tips. The distal basal, middle, and apical denticle densities (the number of denticles per 5 mm of the carina length) are 10, 7.5, and 8, respectively. In labial view, the denticles appear subrectangular and chisel-like. Except near the apex, the mesiodistal length of the denticles exceeds their apicobasal width.

Discussion NHMG 8501 is a typical tooth of a large tyrannosaurid, being large and sub-oval in cross-section. Its CBR is 0.72, within the range seen in *Tyrannosaurus rex* (Smith, 2005). The distal denticles are chisel-shaped, with about 8.5 denticles per 5 mm (DAVG, average distal denticle density), similar to those of tyrannosaurids. NHMG 8501 possesses some scattered wear striations on the labial surface, as in some other tyrannosaurids (Schubert

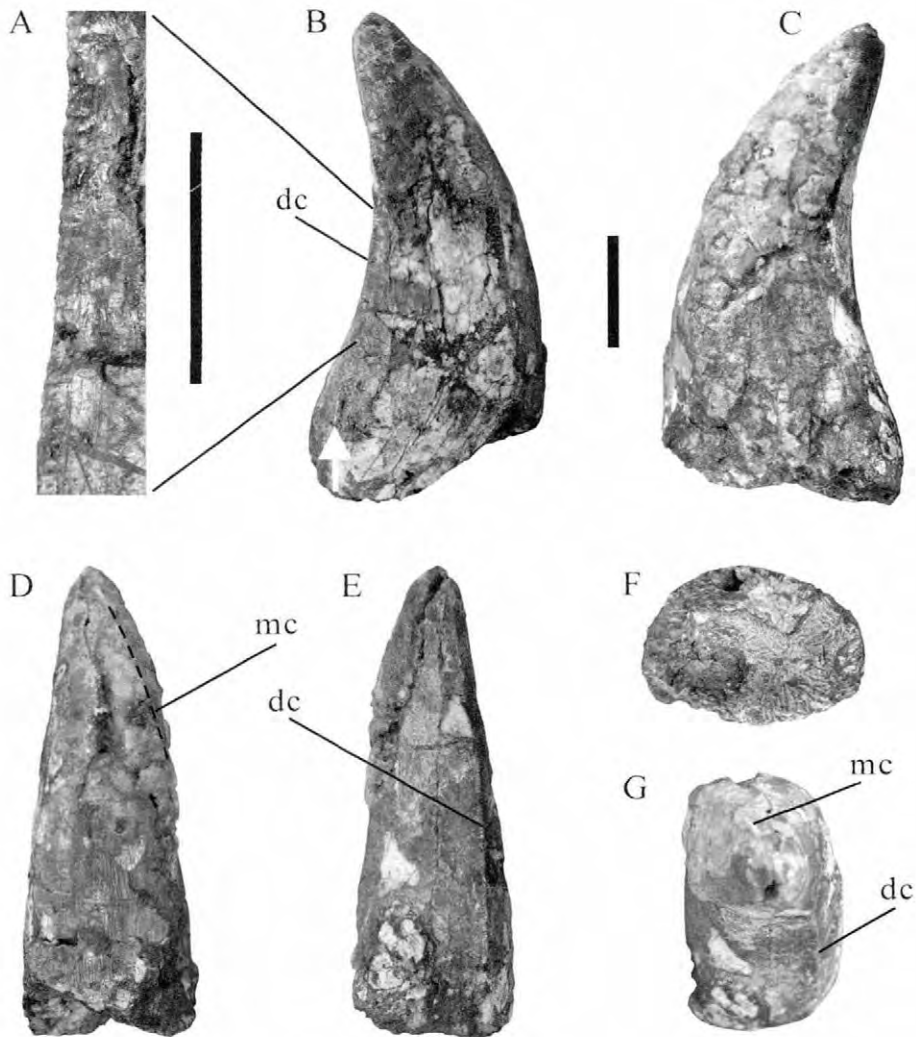


Fig. 1 Tyrannosaurid tooth (NHMG 8501) from the Nanxiong Formation of Jiangxi Province, in labial (A and B), lingual (C), mesial (D), distal (E), basal (F), and apical (G) views. Arrow indicates distal carina location. Scale bar equals 10 mm in A, and 20 mm in B-G. Abbreviations: dc. distal carina; mc. mesial carina.

and Ungar, 2005). Though large tyrannosaurids are well known from the Late Cretaceous of North America and eastern Asia, only some isolated tyrannosaurid teeth have been discovered from the Upper Cretaceous of southern China (Dong, 1979; Lü et al., 2009a). However, these isolated teeth were not described in detail for comparison with the Jiangxi specimen. Recently recovered large tyrannosaurid *Zhuchengtyrannus* from Shandong possesses seven maxillary and eight dentary teeth in situ (Hone et al., 2011). The largest maxillary and dentary alveolus are the sixth (43 mm long by 27 mm wide) and the fifth (approximately 38 mm long by 32 mm wide) respectively, suggesting a comparable size with NHMG 8501. However, the distal edge of the tooth from Jiangxi is more recurved, being very different from those from Shandong, in

which the preserved teeth have slightly concave or even straight distal edges.

Theropoda Marsh, 1881

Theropoda indet.

(Fig. 2)

Referred specimen NHMG 8500, a nearly complete right maxillary tooth.

Description The specimen is a large, well preserved tooth crown missing most of the root (Fig. 2). The maximum preserved length is 103 mm, the CH is 91 mm.

The specimen is laterally compressed. Basally, it is 45.2 mm long mesiodistally and 21 mm wide labiolingually, measuring for a CBR of 0.47. Its crown height ratio (CHR) is 2.01.

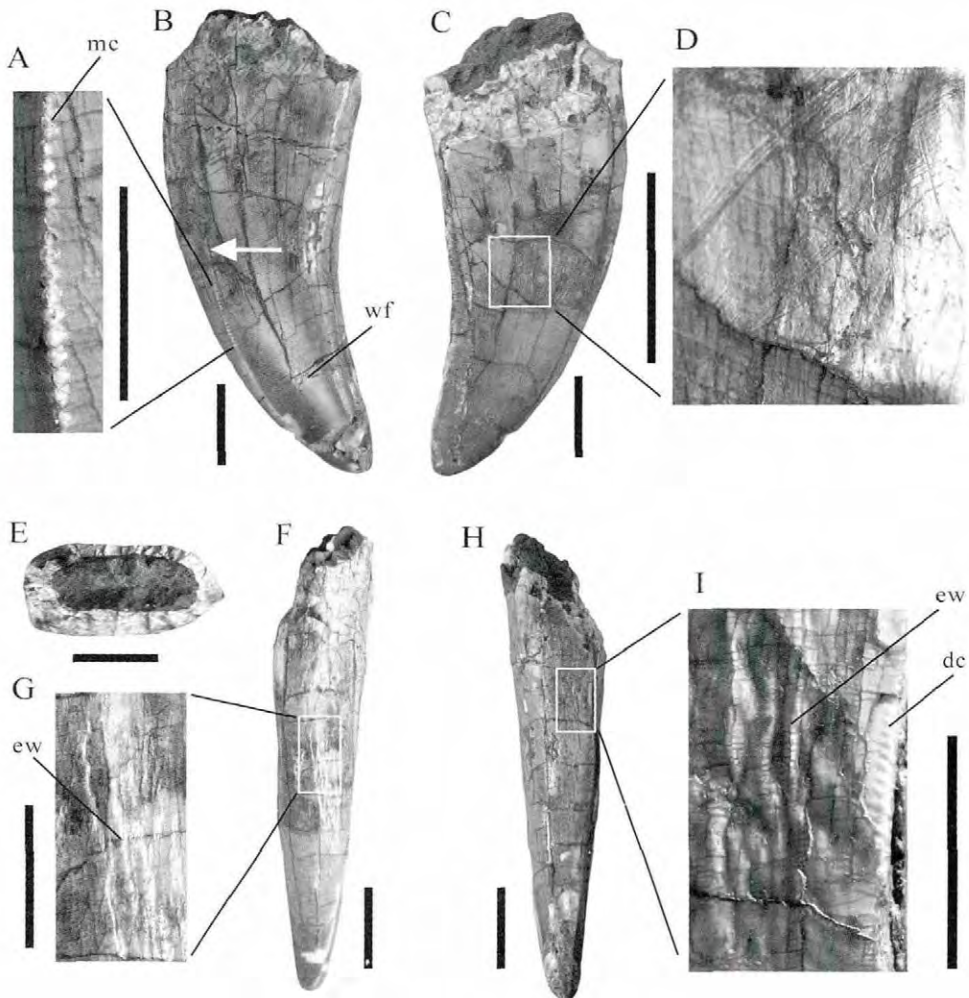


Fig. 2 Large theropod tooth (NHMG 8500) from the Nanxiong Formation of Jiangxi Province, in lingual (A, B), labial (C, D), basal (E), mesial (F, G), and distal (H, I) views. Arrow marks the end of mesial carina. The white frames in C, F, and H mark the tooth area displayed in enlarged form in images D, G, and I, respectively. Scale bars equal 10 mm in A, D, G, and I; 20 mm in B, C, E, F, and H

Abbreviations: dc. distal carina; ew. enamel wrinkles; mc. mesial carina; wf. wear facet

The tooth crown is smooth on the lingual and labial surfaces, whereas the mesial and distal surfaces are covered with irregular ridges (Fig. 2G, I). These ridges develop more strongly on the basal half of the crown than on the apical half of the crown, covering 3/4 height of the crown from base, and do not reach the apex of the crown. They are curved, ripple-like, and tend to be parallel to the apicobasal axis of the crown.

The basal half of the distal margin is almost straight in lateral view, and is recurved throughout the apical half, while it is strongly recurved along the whole mesial margin. The CA is about 63°.

The tooth has clearly defined carinae on both the mesial and distal margins, and both have small, fine serrations (Fig. 2A, I). The mesial carina ends about the midway between the tip and the base of crown, whereas the distal one continues almost to the base, though there is slight damage at the base. It seems that the mesial and distal carinae do not contact through the tip of the tooth. The denticulated carina is 56 mm long along the mesial margin, and much longer (greater than 76 mm) along the distal margin. In mesial and distal views, the carinae are strongly offset from the mesial and distal margins of the tooth, respectively. The mesial carina, in mesial view, starts at the middle of the apex and curves lingually such that at the middle of the crown, it is completely on the lingual side of the crown. The distal carina locates at the linguodistal corner of the crown.

The labial and lingual surfaces are nearly flat. A slightly concave region is present on the labial surface, just near the base, giving a sigmoid curved distal carina in distal view (Fig. 2H, I). The mesial surface is convex, whereas the distal surface is somewhat flat. The flat labial surface of the crown is covered with numerous small holes and many scattered wear striations (Fig. 2D). These heterogeneously oriented wear striations are unusual among tyrannosaurids. They are positioned neither within the irregular “spalled” surfaces nor wear facets, two types of tyrannosaurid wear features proposed by Schubert and Ungar (2005). In the lingual surface, a marked wear facet is present near the upper half of the tooth where a slightly concave area is present (Fig. 2B). It is apicobasally oriented and is somewhat elliptic in shape. Similar patterns of parallel wear striations are present within the wear facet, reflecting a tooth-tooth contact between the lingual side of maxillary teeth and labial side of dentary teeth, like in other tyrannosaurids (Schubert and Ungar, 2005). The wear facet and the lingual displacement of the mesial carina imply that NHMG 8500 possibly represents the anterior right maxillary tooth.

The denticles are not well preserved. The upper half of the distal denticles and all of the tips of the mesial denticles are suffered from breaks during handling. The upper half of the mesial denticles is abraded. Both the mesial and distal denticles are rectangular and chisel-like. The basal half of the distal denticles is strongly pointed towards the apex of the crown in distal view (Fig. 2I). The size of the denticles is variable along both the mesial and distal carinae. The mesial denticle densities are 6/5 mm in the mid-crown and 7.5/5 mm in the apical crown, while the distal denticle densities are 6.5/5 mm in the mid-crown and 10/5 mm in the basal crown. The mesial denticles become mesiodistally narrower and apicobasally shorter towards

the apex and basal of the tooth. For example, the mesiodistal widths at basal, middle and apical crowns are 0.5, 0.94 and 0.3 mm, respectively, while the apicobasal lengths at basal, middle and apical crowns are 0.28, 0.74 and 0.44 mm, respectively.

Discussion NHMG 8500 might well represent a tooth of a large predatory theropod, comparable in size to *Tyrannosaurus* from North America, *Carcharodontosaurus* and *Spinosaurus* from Africa. For example, the CH is 90.04 mm in mx01 of *Tyrannosaurus rex* (Smith, 2005), the maximum CBL is 42 mm in mx03 of *Carcharodontosaurus* (Smith et al., 2005), and the CBL is 44 mm in *Spinosaurus* from Morocco (Niedźwiedzki and Gierliński, 2002), similar to NHMG 8500.

NHMG 8500 is moderately compressed labiolingually. Its CBR is 0.47, falling in between those of *Acracanthosaurus* (0.66 in mx01) and *Carcharodontosaurus* (0.36 in right mx03), and much less than that of *Tyrannosaurus* (0.73 in mx01 of LACM (Los Angeles County Museum) 23844) (Smith et al., 2005). Laterally compressed maxillary crown of NHMG 8500 is more similar to those teeth of carcharodontosaurids than to those stout, subcylindrical tyrannosaurid or spinosaurid teeth. However, NHMG 8500 possesses distinct, longitudinally oriented enamel ridges (wrinkles) on the crown surface near the mesial and distal carinae, markedly differs from those of carcharodontosaurids in which wrinkles originate from mesial and distal carinae and form a continuous band across the labial and lingual surfaces (Brusatte et al., 2007). Late Cretaceous carcharodontosaurids are dominated by Gondwanan taxa such as *Carcharodontosaurus* in Africa and *Giganotosaurus* and *Mapusaurus* in South America, only one carcharodontosaurid *Shaochilong* is known from the Turonian of China (Benson et al., 2010). However, some carcharodontosaurid teeth have been recently reported from the early Late Cretaceous of Henan Province, central China (Lü et al., 2009b). These teeth are blade-like, with both the anterior and posterior carinae extending to the base of the enameled crown, being very different from NHMG 8500.

NHMG 8500 possesses vertically oriented enamel wrinkles, a typical feature that also present on the surfaces of spinosaurid teeth. However, the enamel wrinkles present in NHMG 8500 are ripple-like and irregularly distributed on the mesial and distal surfaces (Fig. 2G, I), very different from those of spinosaurid teeth, including those from Asia (Buffetaut and Ingavat, 1986; Holtz et al., 2004; Buffetaut et al., 2008; Lü et al., 2009b; Hone et al., 2010; Lü and Han, 2012), in which the ridges and grooves are parallel and mainly located on the lingual or labial surface. In addition, most of the recovered spinosaurid teeth are nearly conical in shape, also different from the laterally compressed condition present in NHMG 8500, although some spinosaurid teeth possess significant degrees of variation, with labiolingually compressed crown (Medeiros, 2006). Furthermore, the denticles present in NHMG 8500 are relatively large, with 1-2 denticles per mm, markedly differs from most of the spinosaurid teeth, in which the denticles are small, with approximately 7 per mm (Buffetaut, 2007), although some spinosaurid tooth possesses relatively large denticles (2-4 denticles per mm, Buffetaut, 2008, 2012).

NHMG 8500 is markedly distinct from those of known large-bodied theropods by possessing the following combination of features: 1) very large in size (CBL and CH are 45.2 and 91 mm, respectively); 2) laterally compressed (CBL as much as double CBW with CBR 0.47); 3) basal cross-section with flat distal margin and convex mesial margin; 4) nearly flat lingual and labial surfaces; and 5) longitudinally oriented mesial and distal enamel ridges (wrinkles). At present, it is hard to give an exact identification of this tooth. However, it is most likely that the tooth belongs to either a tyrannosaurid or a carcharodontosaurid. Nevertheless, the specimen from Jiangxi possibly represents a previously unrecognized large-bodied predatory theropod inhabited Asia during the Late Cretaceous, yet more materials need to be found to confirm this.

3 Conclusions

The teeth described in this paper represent a large tyrannosaurid and an unnamed large theropod from the Upper Cretaceous of Jiangxi, southern China. In this area, at least five small theropods and one large sauropod have been found recently. The recovered teeth from the Nanxiong Formation suggest that large theropods co-evolved with large herbivorous sauropod dinosaur such as *Gannansaurus* in this formation.

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江西晚白垩世大型兽脚类恐龙牙齿

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摘要: 描述了江西晚白垩世南雄组产出的两颗大型兽脚类恐龙牙齿。这两颗牙齿的齿冠高度分别为91和76 mm左右。较小牙齿近似圆锥形, 齿冠基部比率为0.72, 与典型的暴龙类牙齿相似。较大牙齿横向侧扁, 齿冠基部比率约为0.47, 舌侧和唇侧表面近乎平坦, 前后缘冠面基部发育明显的纵向褶皱, 区别于已发现的暴龙科、鲨齿龙科和棘龙科成员的牙齿。江西大型兽脚类恐龙牙齿的发现对于全面了解华南地区南雄组多样化的脊椎动物群组成具有一定的意义。

关键词: 江西, 晚白垩世, 南雄组, 兽脚类, 牙齿

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消息

《古脊椎动物学报》入选“中国最具国际影响力学术期刊”

2014年12月16日，中国学术期刊电子杂志社、中国科学文献计量评价研究中心与清华大学图书馆共同举办了2014中国最具国际影响力学术期刊暨中国学术期刊国际、国内引证报告发布会，公布了2014年“中国最具国际影响力学术期刊”名单，本刊再次入选。这是继2012年该机构首次公布“中国最具国际影响力学术期刊”以来，本刊连续第三年入选该名单。在本次评选出的175种科技类“中国最具国际影响力学术期刊”中，《古脊椎动物学报》综合排名第76位。相较于往年，《古脊椎动物学报》的国际他引影响因子上升明显，达到了0.949。在国际他引影响因子排序上，名列第47位，超过了多数国内SCI刊物。这一影响因子也超过了*Geodiversitas*、*Paleontological Journal*和*Alcheringa*等历史悠久的国际同类SCI期刊。

《中国学术期刊国际引证年报》以WOS的统计源(包括SCI、SSCI、A&HCI数据库及该等会议论文集)14425种期刊为基础，分别计算了我国4727种被SCI、SSCI引证的期刊(其中科技类期刊3489种，人文社科类期刊1238种)的总被引频次、影响因子等计量学指标，主要依据这两项指标，创设了综合指标“学术期刊影响力指数”(Clout Index, 简称CI)，经综合计算，并经专家审议，按科技类和人文社科类分别遴选出TOP5%期刊，其中科技类获选期刊175种，人文社科类60种。

《古脊椎动物学报》创刊50多年来，在推动中国的古脊椎动物学研究走向世界方面做出了积极贡献。古脊椎动物学是一门传统的基础学科，本刊近年国际影响力的显著提升，也反映了国家基金和中国科学院对基础学科的大力支持，与主办单位领导重视及刊物主编、编委会的共同努力密不可分。

(编辑部)