



江西赣州盆地上白垩统似鲨齿龙科 牙齿新发现及意义*

于娟¹ 曾翠敏¹ 张盈² 姚涵³ 严翔¹ 马嘉欣¹ 韩凤禄^{3**}

¹ 江西省地质博物馆, 南昌 330002;

² 赣州市国土整治修复中心, 江西赣州 341000;

³ 地球与行星科学学院, 中国地质大学(武汉), 武汉 430074

提要 赣州盆地白垩系红层含有丰富的恐龙骨骼和蛋化石, 但兽脚类恐龙主要包括窃蛋龙类和暴龙科, 还未报道其他类型的兽脚类恐龙。本文报道了江西赣州盆地晚白垩世地层中发现的一枚完整的兽脚类恐龙牙齿。该牙齿宽扁, 冠高约6 cm, 前后发育锯齿, 齿冠基部宽而内外向窄(CBR值为0.47), 冠面上发育横向条纹。根据以上特征, 认为该牙齿可能为鲨齿龙科的牙齿; 白垩纪兽脚类牙齿的判别分析结果也支持该结论。这进一步拓展了该类群在亚洲的分布范围, 增加了赣州盆地兽脚类恐龙的多样性。其牙齿与腔尾赣州巨龙同时保存, 表明它们曾共同生活在同一地域。赣州盆地白垩纪不同时期的恐龙面貌有明显差异, 早期以鲨齿龙科和泰坦巨龙类组合为主, 晚期以窃蛋龙类、鸭嘴龙类和暴龙类组合为主, 这为认识华南地区晚白垩世古生态及其演变提供了重要依据。

关键词 赣州盆地 晚白垩世 兽脚类恐龙 鲨齿龙科 牙齿化石

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A new discovery of a carcharodontosaurid-like tooth from the Upper Cretaceous of the Ganzhou Basin, Jiangxi Province and its significance

YU Juan¹, ZENG Cui-min¹, ZHANG Ying², YAO Han³, YAN Xiang¹, MA Jia-xin¹, HAN Feng-lu³

¹ Jiangxi Geological Museum, Nanchang 330002, Jiangxi, China;

² Ganzhou Land Consolidation and Rehabilitation Center, Ganzhou 341001, Jiangxi, China;

³ School of Earth and Planetary Sciences, China University of Geosciences (Wuhan), Wuhan 430074, Hubei, China

Abstract The Cretaceous red beds of the Ganzhou Basin have yielded abundant fossils of dinosaur skeletons and eggs. However, theropod fossils from this basin have so far been limited to oviraptorosaurs and tyrannosaurids, with no other theropod groups previously reported. Here, we describe a complete theropod tooth from the Upper Cretaceous strata of the Ganzhou Basin, Jiangxi Province. The tooth is labiolingually compressed and has a crown height of approximately 6 cm.

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** 通讯作者: 韩凤禄, 副教授, e-mail: hanfl@cug.edu.cn

Denticles are present on both the mesial and distal carinae. The crown base is broad mesiodistally and narrow labiolingually (CBR = 0.47), and transverse enamel undulations occur on the crown surface. Based on these features, the tooth is tentatively referred to Carcharodontosauridae, an assignment further supported by discriminant analysis of Cretaceous theropod teeth. This finding expands the geographic distribution of carcharodontosaurids in Asia and increases the known diversity of theropods in the Ganzhou Basin. The tooth was recovered in association with *Gandititan cavocaudatus*, indicating that they coexisted in this region. Dinosaur assemblages in the Ganzhou Basin differ between the Early and Late Cretaceous: the Early Cretaceous fauna is dominated by carcharodontosaurids and titanosaurs, whereas the Late Cretaceous fauna is primarily composed of oviraptorosaurs, hadrosaurids, and tyrannosaurids. These compositional changes provide important evidence for understanding the paleoecology and ecosystem evolution in South China during the Late Cretaceous.

Key words Ganzhou Basin, Late Cretaceous, Theropoda, Carcharodontosauridae, fossil tooth

SYSTEMATIC PALEONTOLOGY

Suborder Theropoda Marsh, 1881

Superfamily Allosauroidae Marsh, 1878

Family Carcharodontosauridae Stromer, 1931

Genus et species indet.

(Fig. 2)

Material Referred specimen, JXGM-F-2023-8.

Diagnosis Crown height ≥ 6 cm. Tooth crown strongly compressed labiolingually, with a Crown Base Ratio (CBR) less than 0.50. Transverse undulations on tooth crown well preserved. Mesial carina extending to the tip of the crown. Distal carina S-shaped in posterior view. Denticles on anterior carina taller and shorter than those on posterior carina.

Remarks The new specimen described here represents a large theropod tooth that coexisted with the titanosaurian *Gandititan cavocaudatus*. It differs from tyrannosaurid, allosaurid, and spinosaurid teeth in having a CBR value less than 0.5, indicating a strongly labiolingually

compressed crown. The CBR value of the current specimen is similar to that of Ceratosauridae, it lacks the autapomorphies of the latter, such as a wide concave surface on the labial crown and the presence of both labial and lingual concavities near the distal carina. The current specimen also differs from typical abelisaurid teeth, which are comparatively low-crowned (CHR < 2), possess a straight or convex distal carina, and exhibit a lenticular cross section. Teeth of the Neovenatorids, a large theropod group, are also similar in size and shape to the tooth described here, but the current specimen lacks diagnostic neovenatorid features, including a centrally positioned, flattened surface on the labial surface and concave surfaces adjacent to the distal carina both labially and lingually.

Locality and horizon Datangkeng, Ganxian District, Ganzhou City, Jiangxi Province, China; Zhoutian Formation, lower Upper Cretaceous (Cenomanian-Turonian).

1 前 言

江西赣州盆地白垩系红层广泛发育, 含有大量的脊椎动物和恐龙蛋化石(季强, 2009; 于成涛、凡秀君, 2022)。脊椎动物多样性高, 目前已经报道包括恐龙11种、蜥蜴6种、鳄类2种、龟和哺乳动物各2种(许梦园等, 2023)。在发现的恐龙当中以窃蛋龙类的多样性最高, 已发现7种(Lü et al., 2013a,

2016a, 2017)。其次为蜥脚类恐龙, 已经报道3种(Lü et al., 2013b; Mo et al., 2023; Han et al., 2024)。但是除了窃蛋龙之外的其他兽脚类恐龙发现较少, 目前仅报道暴龙超科(Tyrannosauroidae)两种: 中国虔州龙(*Qianzhousaurus sinensis*) (Lü et al., 2014)和徐氏亚洲暴龙(*Asiatyrannus xui*) (Zheng et al., 2024), 另外赣州盆地还发现了一些暴龙科(Tyrannosauridae)

的牙齿和足迹化石,进一步丰富了该地区暴龙科物种的多样性(于娟等, 2025; Mo and Xu, 2015; Xing *et al.*, 2019)。

2021年6月,江西省地质博物馆联合江西省地质调查院在赣州市赣县区幸福村大塘坑一建筑工地边缘的小山坡发现并采集了一具保存较完整的蜥脚类恐龙,后经研究命名为腔尾赣地巨龙(*Gandititan cavocaudatus*) (Han *et al.*, 2024)。在修复该标本的过程中,荐椎旁边发现一枚完整的大型兽脚类恐龙牙齿。本文对该牙齿进行了详细的描述和对比,认为该牙齿可能属于鲨齿龙科(Carcharodontosauridae),这对认识赣州盆地兽脚类恐龙的多样性以及当时的古生态具有重要的意义。

2 材料和方法

本文中研究材料为一枚完整保存的兽脚类恐龙牙齿,保存在江西省地质博物馆中,化石编号为JXGM-F-2023-8。本文中采用的牙齿形态术语主要参考Smith等(2005)和Hendrickx等(2015) (图1)。描述方位区分牙齿前侧和后侧,前侧指靠近头骨前端中线的位置,后侧与之相反。另外还有内侧(或舌侧)和外侧(或唇侧)。顶部指靠近齿尖的位置,基部

指牙齿的底部和齿根相连。对于锯齿,近端指靠近齿冠的位置,远端指远离齿冠的位置。

牙齿形态学测量及判别分析包括13个变量: 齿冠基部横截面的长度(Crown basal length, CBL)和宽度(crown basal width, CBW)和它们之间的比值CBR (CBW/CBL); 牙齿中间横截面的长度(mid-crown length, MCL)和宽度(mid-crown width, MCW)及比值(MCR); 从齿尖到基部前缘长度(apical length, AL), 从齿尖到基部具锯齿前缘长度(mesial serrated carina length, MSL), 从齿尖到基部后缘长度——齿冠高(crown height, CH); 齿冠高和基部横截面长的比值CHR (CH/CBL), CBL和AL之间的夹角(crown angle, CA); 前缘和后缘锯齿的长度(mesial denticle length, MDL和distal denticle length, DDL) (Hendrickx *et al.*, 2015)。

除了以上需要测量的信息之外,形态描述部分还有一些常用的形态学特征: 包括齿冠表面具有纵向的沟槽或脊; 很多大型兽脚类具有横向条纹和边缘条纹; 另外还有在显微镜下才能看到的釉质纹理; 齿冠前后缘一般都着生锯齿,锯齿间形成间隙,锯齿基部还会形成间齿沟(图1)。

形态学描述部分采用肉眼观察和显微观察的方法。齿冠的形状,冠面条纹的分布,齿尖的弯曲

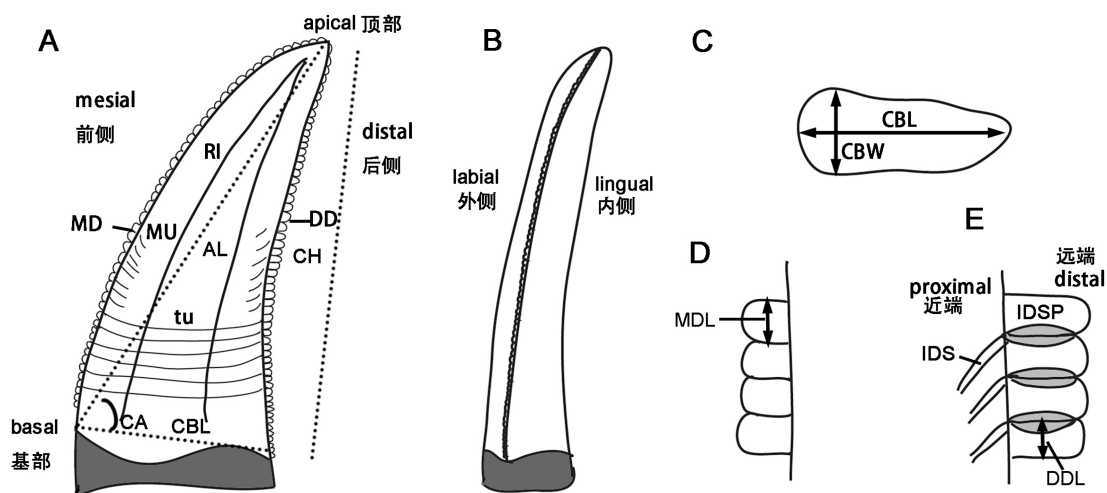


图1 牙齿形态术语

Fig. 1 Terminology of tooth morphology

A. 外侧视, B. 后侧视; C. 基部横切面; D. 前缘锯齿; E. 后缘锯齿。缩写释义(Abbreviations): AL, Apical length, 齿长; CA, crown angle, 齿冠角; CBL, crown basal length, 齿冠基部长; CBW, crown basal width, 齿冠基部宽; CH, crown height, 齿高; DD, distal denticle, 后缘锯齿; DDL, distal denticle length, 后缘锯齿长; IDS, interdenticular sulcus, 间齿沟; IDSP, interdenticular space, 齿间窝; MD, mesial denticle, 前缘锯齿; MDL, mesial denticle length, 前缘锯齿长; MU, marginal undulation, 边缘纹饰; RI, ridge, 脊线; TU, transverse undulation, 横向纹饰。

A, labial view; B, distal view; C, basal cross-section view; D, mesial denticles; E, distal denticles.

程度,横截面的形状都可以通过肉眼观察的方法。其中冠面条纹往往不明显,需要在光下观察。在显微镜下主要观察齿冠前缘和后缘锯齿的形状,大小和数量,以及牙齿釉质纹理的形态。综合以上特征将兽脚类牙齿分成不同的类型,并讨论它们应属于哪些恐龙类群或和哪些类群关系最近。

为了能对化石进行正确的归类,除了形态对比之外,本文将该牙齿进行形态测量,并代入已建立的兽脚类恐龙牙齿数据库中进行线性判别分析(Linear Discriminant Analysis, LDA)。本文利用Hen-drickx等(2020b)建立的兽脚类牙齿数据库进行分析,选择CBL、CBW、CH、AL、CBR、CHR、MCL、MCW、MCR、MSL、CA、MDL和DDL共13个变量来进行分析。为了尽量减少相似牙齿形态对本文判别分析的干扰,本研究主要选择白垩纪时期的大型兽脚类牙齿($CH > 2\text{ cm}$) 364颗,包括:角鼻龙类(Ceratosauria)、阿贝力龙科(Abelisauridae)、棘龙科(Spinosauridae)、鲨齿龙科、新猎龙科(Neovenatoridae)和暴龙科共25个属种。判别分析主要在古生物统计软件Past 5.3进行(Hammer *et al.*, 2001),数据以csv格式导入Past软件,将分类单元列设置为group,并选择该列及13个测量变量进行线性判别分析,所有变量在分析前均进行log转换。分析后记录判别轴的特征值,并导出样本在主要典型判别轴上的得分和分类结果,以评估样本的判别归属及分析可靠性。随后根据导出的scores数据,在R Studio中绘制判别分析散点图,并用三角形符号标出本文研究的牙齿,以展示其在兽脚类牙齿形态空间中的位置。

3 地质背景

赣州盆地位于江西省南部,属于华南板块南岭东段,为晚白垩世断陷盆地,整体呈北东—南西延伸,涵盖赣州、南康和大余等地,在演化上受到中生代三大构造动力体系的影响,包括古太平洋板块的俯冲作用、特提斯构造域以及华南和华北板块的碰撞作用。白垩纪时期,华南板块主体以大陆伸展为主,形成了一系列的断陷盆地(江西省地质矿产局, 1984)。

赣州盆地出露的地层以中生代为主,主要为上

白垩统赣州群(K_2G)和龟峰群(K_2GF),为一套河湖相的碎屑岩沉积。前者自下而上包括茅店组(K_2m)、周田组(K_2z),后者包括河口组(K_2h)、塘边组(K_2t)和莲荷组(K_2l) (江西省地质矿产勘查开发局, 2017; 于娟等, 2025)。这些地层主要呈北东—南西向展布,向南东倾斜,倾角 10° — 20° 。赣州盆地脊椎动物化石及蛋化石在各个组中都有分布,主要集中在周田组、河口组、塘边组和莲荷组。本文所描述的兽脚类牙齿与腔尾赣州地巨龙骨骼保存在一起,位于周田组上部(Han *et al.*, 2024)。

赣州盆地恐龙所产出层位的时代目前仍有争议。下伏茅店组玄武岩夹层K-Ar法获得年龄为 $101 \pm 3\text{ Ma}$ (李坤英, 1989),陈坑火山岩段安山质凝灰岩夹层砂岩中石英的ESR年龄值为 96.5 — 87.5 Ma (衷存堤, 2002),而孢粉组合分析认为其应为森诺曼期(100.5 — 93.9 Ma)。而基于孢粉组合分析推测的周田组时代为土伦期(93.9 — 89.8 Ma),龟峰群则对应于科尼亚克期到马斯特里赫特期,但是仍然缺乏绝对地质年龄结果的约束(江西省地质矿产勘查开发局, 2017)。综上,本文将该牙齿产出时代大致归入晚白垩世早期(森诺曼期到土伦期)。

4 系统古生物学

兽脚亚目 Theropoda Marsh, 1881

异特龙超科 Allosauroidae Marsh, 1878

鲨齿龙科 Carcharodontosauridae Stromer, 1931

属种未定 Genus et species indet.

(图2)

材料 JXGM-F-2023-8。

产地层位 赣州市赣县区幸福村大塘坑;上白垩统周田组(森诺曼阶到土伦阶)。

描述 该牙齿保存完整,但在齿尖处和基部釉质层略有破损。整体来看,齿冠高而侧扁,齿高约 60 mm ,齿前后侧长达到了 28 mm ,而内外侧的宽只有 13 mm 。CBR值为 0.47 ,前后缘发育脊和锯齿。

外侧观,齿冠内外向强烈压缩,齿尖后弯。后缘基部到中部较竖直。从中部到齿尖向后侧偏斜。偏斜角度不大,约为 10° 。在齿尖处,后缘向前侧收缩。使得整个后缘呈“S”形。前缘呈显著凸出的弧形。冠面凸出,平滑过渡。没有形成显著的纵向的

沟或脊。

在牙齿的外侧面形成显著的横向延伸的弧形条纹, 向牙齿基部浅凹, 在中部最发育, 几乎贯穿整个唇侧面, 靠近齿尖处, 该条纹主要分布在后缘并和锯齿的延长方向构成一定的角度(约60°)。

前侧视, 前缘锐利, 从齿尖到基部向舌侧偏斜。前缘锯齿从齿尖一直延伸到中部, 未达齿根。后侧视, 标本中后缘向外侧偏斜。从基部到中部锯齿主要分布在外侧。从中部到顶端, 后缘向内侧偏斜, 将齿冠分成不对称的两部分(图2-C)。后缘锯齿从齿尖一直延伸到齿根处。

该牙齿前后缘锯齿在中部都很发育(图3)。前缘中部锯齿密度与后缘中部锯齿的密度相近。前缘锯齿中部锯齿密度在8.2/5 mm, 后缘锯齿相对应的锯齿密度在8.7/5 mm。这说明该牙齿前缘锯齿的高度略高于后缘锯齿, 前缘锯齿的长度短于后缘锯齿。另外后缘锯齿之间的间隙明显, 而前缘锯齿间的间隙更小一些。从侧面看, 后缘锯齿呈柱状而前缘呈方形, 远端对称没有向齿尖方向偏斜。锯齿之间没有形成明显的间齿沟。

比较

(1)与赣州盆地已有的兽脚类牙齿比较

该牙齿主要特征包括: 齿冠高而侧扁(CBR < 0.5); 冠面上具有发育的横向条纹, 外侧观后缘呈“S”形。前缘锯齿与后缘锯齿相比高而短。该牙齿与

之前赣州盆地报道的兽脚类牙齿存在明显差异。

中国虔州龙保存有较完整的头骨, 但是没有保存牙齿(Lü *et al.*, 2014)。从齿槽中可以看出牙齿应该比较纤细, 齿冠基部横截面呈椭圆形, 和本文中的牙齿相比应该更粗壮一些(CBR > 0.5)。

赣州盆地之前报道了四枚大型兽脚类恐龙牙齿, 三枚被归入了暴龙超科。最大的一颗牙齿齿冠较直, 高度在10 cm以上, CBR值超过0.6, 表明齿冠较粗壮(于娟等, 2025), 另外一枚兽脚类牙齿短一些, 齿冠高度在7.6 cm, CBR值达到了0.72, 这两枚牙齿整体形态较粗壮, 可归入暴龙科, 但与本文中描述的侧扁的牙齿相差较大。而先前描述的另外两颗兽脚类牙齿均具有侧扁的牙齿, 而且侧扁程度与本文描述牙齿相似(CBR = 0.47), 但在其他形态方面也有显著不同: 其中较大的一颗牙齿NHMG 8500齿冠达到了9.1 cm, 表面光滑, 没有纹饰, 而且在前侧和后侧发育纵向的不规则线脊(Mo and Xu, 2015)。该牙齿兼有暴龙科和鲨齿龙科牙齿的特征, 因此难以归入更具体的类群中。而另外一颗牙齿保存不完整, 估测齿冠小于5 cm。牙齿表面光滑, 缺少纹饰, 和本文描述的牙齿相比更加细长。另外, 该牙齿齿冠只保存了一侧, 从横切面上并不能完全确定CBR值, 因此侧扁程度仍需要进一步评估。

(2)与大型兽脚类恐龙牙齿比较

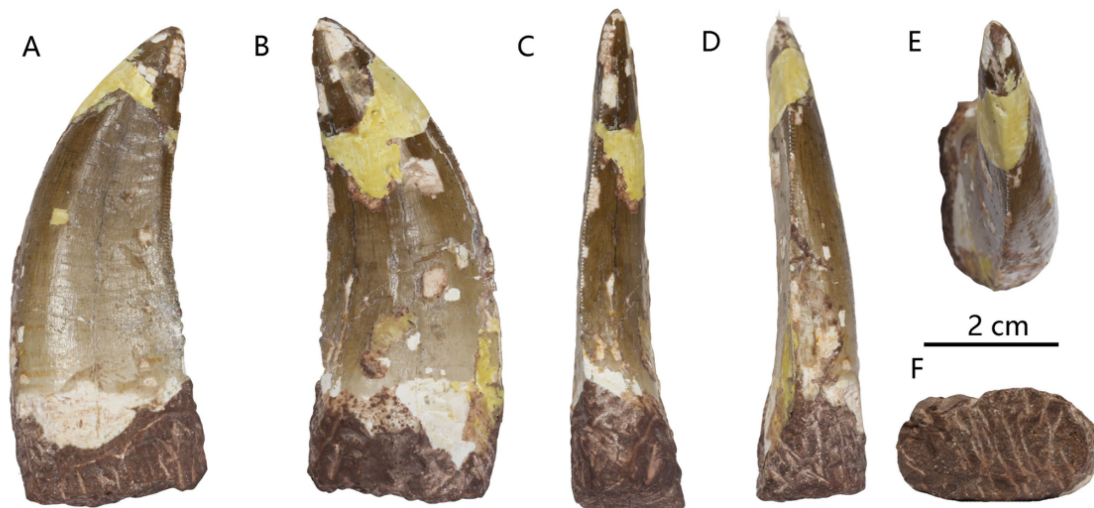


图2 JXGM-F-2023-8牙齿照片
Fig. 2 Photographs of specimen JXGM-F-2023-8

A. 外侧视; B. 内侧视; C. 后缘视; D. 前缘视; E. 顶部视; F. 底部视。

A, labial view; B, lingual view; C, distal view; D, mesial view; E, apical view; F, basal view.

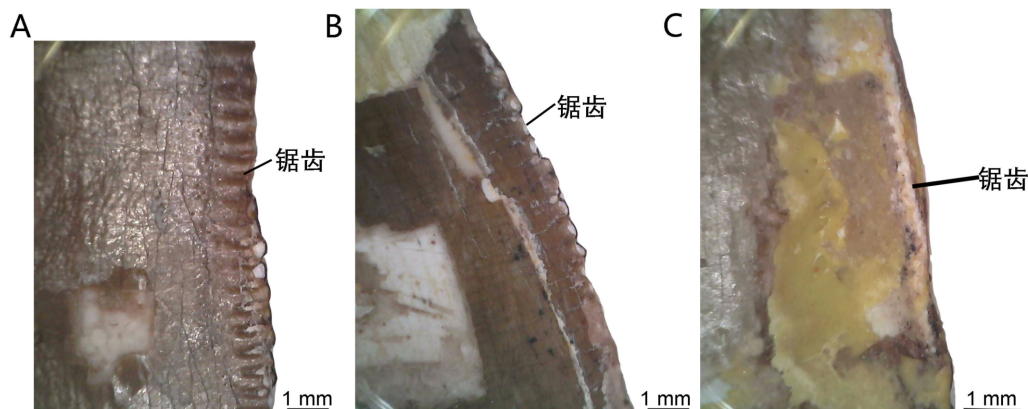


图3 JXGM-F-2023-8牙齿锯齿形态

Fig. 3 Dentine morphology of specimen JXGM-F-2023-8

A. 后缘锯齿; B. 前缘锯齿; C. 前缘基部锯齿, 延伸到根部。

A, distal denticles; B, mesial denticles; C, mesial basal denticles extending toward the root.

从该牙齿的形态和大小来看, 该牙齿应该代表了一类大型的兽脚类恐龙, 如异特龙超科 (Allosauroidae)、角鼻龙科 (Ceratosauridae)、暴龙科、棘龙科和阿贝力龙超科 (Abelisauroidae) 和鲨齿龙科的牙齿 (Currie *et al.*, 1990; Bakker, 1998; Harris, 1998; Smith and Dalla Vecchia, 2006)。其中棘龙科牙齿形态比较特殊, 如齿冠呈锥状, 具有纵向纹饰, 缺少锯齿等 (姬书安等, 2022; Sues *et al.*, 2002; Buffetaut *et al.*, 2019)。其它大型兽脚类恐龙具有一些普遍的特征: 牙齿后弯, 前后缘具有锯齿, 齿冠表面具有一些横向纹饰, 但在牙齿粗壮程度、锯齿形态和齿冠表面纹饰等具有一些区别 (Hendrickx *et al.*, 2015)。

首先, 牙齿的粗壮程度是兽脚类恐龙类群的重要指标, 因薄片状和粗壮型的牙齿代表不同的取食策略, 可以用 CBR 值来衡量 (Smith *et al.*, 2005)。CBR 值越接近于 1, 表明牙齿越粗壮。在同一个体中, 前侧靠近头骨中线的牙齿近圆形, 具有较高的 CBR 值 (> 0.6) 而外侧的牙齿比较扁平, CBR 值相对较低。以切割为主。因此本文描述的牙齿可以归入外侧牙齿。CBR 值虽然在同一个体中有一定的变异范围, 但仍是一个有效区分不同类型的特征 (Hendrickx and Mateus, 2014; Hendrickx *et al.*, 2020b)。本文描述牙齿 CBR 值较小, 在 0.4—0.5 之间, 这与鲨齿龙科、新猎龙科、中棘龙科 (Metriacanthosauridae) 和角鼻龙科牙齿类似, 而在其他大型的兽脚类牙齿则比较粗壮。如暴龙科、异特龙科 (Allosauridae) 和阿贝力龙科, CBR 值往往大于 0.5 (Smith *et al.*, 2005; Hen-

drickx *et al.*, 2020b), 巨齿龙科 (Megalosauridae) 牙齿 CBR 值在 0.3—0.6 之间 (Hendrickx *et al.*, 2014)。由于 CBR 值的变异范围大, 仍需要结合多个指标区分牙齿。

本文描述牙齿主要与白垩纪时期大型兽脚类恐龙牙齿进行对比, 包括角鼻龙科、暴龙科、阿贝力龙科、鲨齿龙科、新猎龙科和中棘龙科。角鼻龙科是一类生活在晚侏罗世到早白垩世时期的大型兽脚类恐龙, 全球分布广泛, 典型代表是生活在晚侏罗世的角鼻龙 (*Ceratosaurus*) 和早白垩世的锐颌龙 (*Genyodectes*, Delcourt, 2018)。该类外侧牙齿 CBR 值多在 0.4—0.5 之间, 与本文描述牙齿相似 (Smith *et al.*, 2005)。但角鼻龙科牙齿也具有一些独特的特征, 包括内侧边缘扁平, 后缘附近内外侧具有凹面。外侧面中央处往往形成宽的凹面 (Rauhut, 2004; Hendrickx *et al.*, 2014), 因此和本文描述牙齿区别明显。

与角鼻龙科亲缘关系比较近的是阿贝力龙科, 它们同属于角鼻龙亚目 (Ceratosauria)。阿贝力龙科繁盛于白垩纪, 化石主要见于南美洲、欧洲和马达加斯加等地, 某些类群延续到了白垩纪末期 (Carrano and Sampson, 2008; Hendrickx and Mateus, 2014)。虽然阿贝力龙科牙齿 CBR 值的变化范围较大 (0.3—0.84), 但多数仍在 0.5 以上。大多数阿贝力龙科牙齿较低矮 (CHR < 2), 但也有些类群如阿克猎龙 (*Arcovenator*) 的 CHR 值可达 2.3。阿贝力龙科另外一个比较重要的特征是后缘或者向后凸出或者较

直, 因此齿尖的水平位置往往在齿冠基部后缘的前侧或者持平。但阿贝力龙科前缘和后缘脊都位于中间(Hendrickx *et al.*, 2020b), 因此横切面呈一种对称的透镜状, 与本文描述的牙齿前缘向内侧偏斜不同。另外多数阿贝力龙科齿冠后缘锯齿长轴延伸方向向齿尖倾斜, 间齿沟发育(Smith, 2007), 与本文描述牙齿锯齿平伸且缺乏间齿沟不同。以上特征可将本文描述牙齿与大多数阿贝力龙科牙齿区分开。

暴龙科是活跃于白垩纪晚期北美洲和东亚的大型兽脚类恐龙, 典型代表是生活在北美洲的霸王龙(*Tyrannosaurus*), 前肢异常短小, 体长可达12—13 m (Brusatte *et al.*, 2010)。相对于其他兽脚类恐龙暴龙科牙齿更加粗壮($CBR > 0.6$), 前缘齿脊强烈向舌侧弯曲, 而且前缘锯齿小于后缘锯齿, 间齿沟发育(Currie *et al.*, 1990; Abler, 1992; Smith, 2005; Hendrickx *et al.*, 2019), 这些典型的特征均未在本牙齿中观察到, 虽然它们都具有横向的纹饰, 不过此特征在大型兽脚类恐龙牙齿中普遍存在, 并不是暴龙科独有特征(Smith, 2005; Brusatte *et al.*, 2007)。因此, 本牙齿不同于典型的暴龙科成员。

异特龙超科也是活跃于中侏罗世到晚白垩世的一类中到大型的兽脚类恐龙, 包括了中棘龙科、异特龙科、新猎龙科和鲨齿龙科四个主要分支。除了异特龙科之外, 其它类群都延续到了白垩纪(Hendrickx *et al.*, 2019)。中棘龙科代表永川龙和中华猛龙都生活在中—晚侏罗世, 只有萨氏挺足龙(*Erectopus superbus*)延续到了早白垩世(Allain and Carpenter, 2005; Hendrickx *et al.*, 2020a)。该类外侧牙齿侧扁, CBR 值较低, 与本文描述牙齿相似, 但牙齿齿冠基部外侧面平或者凹陷(部分牙齿横截面呈“8”字形), 间齿沟发育、齿冠表面具有不规则的纹理(Hendrickx *et al.*, 2019), 这些特征未见于本文标本。

新猎龙科也是一类中到大型兽脚类恐龙, 具有细长的前肢, 是异特龙超科在白垩纪的延续, 与鲨齿龙科构成姐妹群。该类群的化石发现于日本、澳大利亚和南美洲等地, 并延续到白垩纪末期(Benson *et al.*, 2010)。不过侧齿形态和本文中牙齿区别明显, 如齿冠外侧面和后缘附近会形成明显的凹面, 齿冠表面具有辫状的纹饰, 前侧齿脊往往缺失, 基部具有8字形的横切片(Hendrickx *et al.*, 2019)。

和以上类群相比, 该牙齿的主要特征和鲨齿龙

科牙齿具有更多的相似性, 特别是和高棘龙(*Acrocanthosaurus*)牙齿。主要包括: 齿冠高于6 cm, 前缘锯齿长度大于后缘锯齿(前缘与后缘锯齿密度比值 $DSDI < 0.9$), 前缘齿脊一直延伸到齿冠的顶部, 牙齿发育很好的横向条纹, 齿冠后缘呈“S”状(顶部突出而基部内凹)。但该牙齿也缺乏鲨齿龙科的一些常见特征: 如齿冠具有边缘条纹, 具有间齿沟, 齿冠表面具有辫状纹理(Hendrickx *et al.*, 2019; Currie and Carpenter, 2000)。

5 分析结果

基于科一级的判别函数分析得出的分类准确率在85.67%, 轴1和轴2解释了总方差的60.19%和20.37% (图4)。对轴1贡献较大的变量主要为牙齿横截面的形态(如CBL, CBW, CBR), 其次为齿高, 牙齿中部截面长度(MCL)以及后缘锯齿长度(DDL), 对轴2贡献比较大的也是牙齿横截面的形态, 其次为牙齿长度(AL)、齿高以及前缘锯齿和后缘锯齿的比值(MDL/DDL)。最终分类结果将本牙齿归入鲨齿龙科。但从分析图中也可以看出暴龙科、鲨齿龙科以及阿贝力龙科有较大的重叠区域, 本文研究牙齿落在交叉区域内, 不能排除是其他类型牙齿的可能性。另外基于属一级的分类结果准确率降到了71.43%, 分类结果将本牙齿归入鲨齿龙属。

6 讨论

6.1 鲨齿龙科古地理分布和演化

形态对比和白垩纪大型兽脚类恐龙牙齿的判别分析结果均支持了本文描述的牙齿为鲨齿龙科。鲨齿龙科化石记录主要集中于白垩纪早期和中期的冈瓦纳大陆, 特别是非洲和南美洲(Novas *et al.*, 2005; Coria and Currie, 2006; Brusatte and Sereno, 2007; Candeiro *et al.*, 2018; Kellermann *et al.*, 2025), 后来发现在北美洲、欧洲和亚洲也具有鲨齿龙科成员(Currie and Carpenter, 2000; Brusatte *et al.*, 2009; Ortega *et al.*, 2010), 说明鲨齿龙科白垩纪时期曾广泛分布至全球。鲨齿龙科最早的化石记录来自葡萄牙晚侏罗世的葡萄牙猎龙(*Lusovenator*)和阿根廷白垩纪早期的拉哈斯猎龙(*Lajasvenator*) (Coria *et*

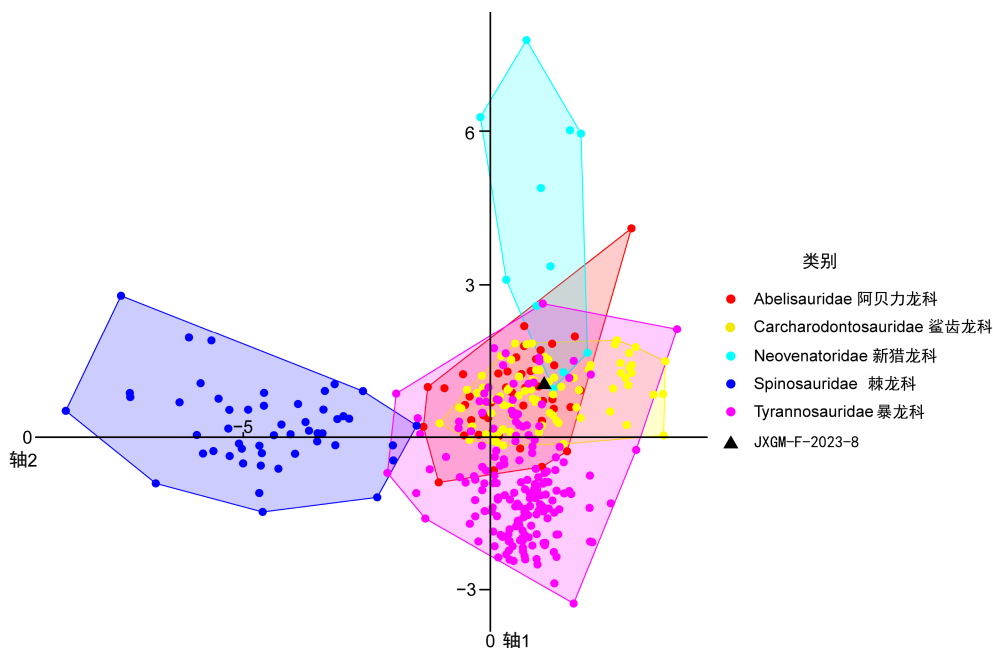


图4 基于兽脚类恐龙类群判别分析图形结果

Fig. 4 Results of the discriminant analysis based on theropod clades

该数据集包括白垩纪大型兽脚类恐龙25属种,共364颗牙齿以及本文研究牙齿。轴1特征值3.36,解释了总方差的60.19%;轴2特征值为1.14,解释了总变异的20.37%。

The dataset includes 364 teeth representing 25 genera and species of large Cretaceous theropods, as well as the tooth examined in this study. Axis 1 has an eigenvalue of 3.36 and explains 60.19% of the total variance; Axis 2 has an eigenvalue of 1.14 and explains 20.37% of the total variance.

al., 2020; Malafaia *et al.*, 2020)。确定的鲨齿龙科的化石记录从白垩纪早期一直延续到了晚白垩世土伦期(约9000万年前)。在这之后只有一些疑似鲨齿龙科破碎材料的发现(Candeiro *et al.*, 2012; Fernandes de Azevedo *et al.*, 2013)。与其对比来看,土伦期之后在北美和亚洲地区暴龙类多样性增加,而在冈瓦纳古陆阿贝力龙科的多样性增加(Novas *et al.*, 2013)。在亚欧和北美洲,鲨齿龙科化石很少。北美地区鲨齿龙科仅有早白垩世晚期的高棘龙(Curie and Carpenter, 2000)。亚洲地区发现于内蒙古乌兰苏海组早白垩世晚期的毛尔图鲨齿龙(*Shaochilong maortuensis*)一直被认为属于鲨齿龙科,不过在最近的系统发育分析中被归入了暴龙超科(Brusatte *et al.*, 2009; Kellermann *et al.*, 2025)。来自新疆早白垩世晚期的克拉玛依龙也被归入鲨齿龙科,不过其系统发育位置也不稳定(Kellermann *et al.*, 2025)。目前亚洲地区可能仅有在中国南方早白垩世产出的广西大塘龙(*Datanglong guangxiensis*)被认为是有效属种(Mo *et al.*, 2014),不过部分散碎的骨骼和疑似该类群的牙齿发现于白垩纪的早期和中期,如韩

国报道的早白垩世(Aptian-Albian) Hasandong组的疑似鲨齿龙科的牙齿(Yun, 2020),中亚乌兹别克斯坦报道的晚白垩世Turonian的一个不完整的前侧椎(Averianov and Sues, 2025),中国河南汝阳地区报道的郝岭组疑似鲨齿龙科的四颗牙齿(Lü *et al.*, 2016b)。赣州地区鲨齿龙科牙齿的发现扩展了该类群白垩纪中期在东亚的分布范围,它们和赣地巨龙生活在同一时代和地区,为恢复当时的古生态提供了依据。

6.2 赣州盆地恐龙动物群演化探讨

赣州盆地已报道了大量以恐龙为代表的古脊椎动物化石。由于缺乏精确的地层对比,先前研究将大部分化石,包括窃蛋龙类、暴龙类、大部分蜥脚类、鸭嘴龙类、蜥蜴类、南雄龟科、鳄形类和哺乳类,都归入南雄组,对应于现在的龟峰群,时代为晚白垩世晚期。相比之下,下部的赣州群发现的脊椎动物化石较少,除了赣地巨龙和本文鲨齿龙科牙齿之外,还包括江西会昌周田组产出的英良达奈龙(*Datai yingliangi*) (Xing *et al.*, 2024)。其他脊椎动

物仅报道了周田组产出的一泛螯科(pan-trionychid)化石(Ke *et al.*, 2025)。综上, 赣州盆地晚白垩世恐龙动物群的演化可以明显分为两个阶段, 上白垩统下部的周田组化石相对较少, 化石面貌包括泰坦巨龙类的基干类群、鲨齿龙科、甲龙科和泛螯科等, 上白垩统上部的龟峰群各门类化石多样性都很高, 以暴龙类、窃蛋龙类、鸭嘴龙类、蜥蜴类和南雄龟科最为繁盛, 这种演化趋势也与北美和亚洲其它地区演化趋势较一致。另外在邻区的于都盆地周田组发现了大量的形态多样的恐龙蛋化石, 表明该时期仍有很多恐龙化石未发现(于成涛等, 2020)。因此, 对赣州群层位和赋存化石的深入考察和研究有助于精确认识赣南地区恐龙动物群的演化。

7 结 论

本文报道了江西上白垩统周田组发现的一枚完整的兽脚类恐龙牙齿化石, 该牙齿与泰坦巨龙类保存在一起。根据牙齿的形态和判别分析结果将其归入鲨齿龙科, 这是该类群在赣南地区的首次报道, 拓展了鲨齿龙科在晚白垩世早期的古地理分布。先前发现的暴龙类骨骼及牙齿都产自龟峰群, 因此该牙齿产出层位低于其他兽脚类恐龙, 代表了晚白垩世早期的一类大型恐龙, 为该时期古生态提供了重要信息。从目前赣州盆地发现的恐龙化石来看, 晚白垩世早期和晚期具有不同的组合面貌, 晚白垩世早期该地区以鲨齿龙类和泰坦巨龙类为主, 而到了晚白垩世晚期窃蛋龙类、暴龙类和鸭嘴龙类多样性显著增加。

致谢 中国科学院古脊椎动物与古人类研究所向礼世对牙齿进行了修复, 感谢两位匿名评审专家的宝贵建议。

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