Vol. 81 No. 4 pp. 550–554 ACTA GEOLOGICA SINICA Aug. 2007

The First Hadrosaurid Dinosaur from Southern China

MO Jinyou [1, 2, *], ZHAO Zhongru[2], WANG Wei [1, 2] and XU Xing[3]
1 *Faculty of Earth Sciences, China University of Geosciences, Wuhan, Hubei 430074*
2 *Natural History Museum of Guangxi, Nanning, Guangxi 530012*
3 *Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044*

Abstract: A new hadrosaurid dinosaur, *Nanningosaurus dashiensis* gen. et sp. nov., is described based on an incomplete skeleton from the Late Cretaceous red beds of the Nalong Basin, Guangxi, southern China. Diagnostic features for the new taxon include the presence of a tall and sharply peaked dorsal process of the maxilla with reduced process of the jugal and a distinct lacrimal facet, gracile humerus with low, rounded deltopectoral crest, mandibular condyle of the quadrate transversly broad with reduced paraquadrate notch, dentary tooth with sinuous median carina and subsidiary ridge, relatively few tooth positions, ischial shaft straight along most of its distance, but to curve dorsally and expand at the distal end before the ischial foot begins. Phylogenetic analysis suggests that *Nanningosaurus dashiensis* is a basal member of Lambeosaurinae.

Key words: Hadrosauridae, Lambeosaurinae, Late Cretaceous, Guangxi, southern China

1 Introduction

Hadrosaurids were relatively less diverse and abundant in central and eastern Asia (Horner et al., 2004). In contrast to several hadrosaurid dinosaurs reported from northern China (Riabinin, 1925, 1930; Wiman, 1929; Gilmore, 1933; Young, 1958; Hu, 1973; Zhen, 1976; Godefroit et al., 1998, 2000; You et al., 2003), no hadrosaurids has been recovered from southern China (*Microhadrosaurus nanshiungensis* (Dong, 1979) is a nomen dubium (Horner et al., 2004)). In 1991, an incomplete hadrosaur skeleton and a partial sauropod skeleton were discovered from the purple-red muddy siltstone of the Upper Cretaceous red beds at the Dashi site of Nanning City, Guangxi by the Natural History Museum of Guangxi (NHMG) (Mo et al., 1998). Here we provide a preliminary description of the hadrosaur specimen, erect a new taxon based on the recovered information, and establish its systematic relationships among hadrosaurids. The taxonomy follows Horner et al. (2004).

2 Systematic Paleontology

Superorder Dinosauria Owen, 1842
Order Ornithischia Seeley, 1887
Suborder Ornithopoda Marsh, 1881
Family Hadrosauridae Cope, 1869
Subfamily Lambeosaurinae Parks, 1923

Nanningosaurus dashiensis gen. et sp. nov.

Etymology: Nanning, after the fossil-producing Nanning City; "dashi", Pinyin, means "big stone", after the name of the village where the specimens were excavated.

Locality and horizon: Dashi village, suburb of Nanning City, Guangxi Zhuang Autonomous Region; Upper Cretaceous red beds.

Holotype: NHMG8142 (Fig. 1a-c and e-u), disarticulated partial skeleton including relatively complete right and left maxillae, left dentary, left squamosal, lower portion of right quadrate, incomplete basioccipital, one isolated dentary tooth, one cervical vertebra, incomplete left scapula, incomplete left and right humeri, relatively complete left ischium, complete left femur and both tibiae.

Paratype: NHMG8143 (Fig. 1d), relatively complete right maxilla.

Diagnosis: *Nanningosaurus dashiensis* is distinguished from all other hadrosaurids by a unique combination of derived and primitive features: tall and sharply peaked dorsal process of the maxilla with reduced process of the jugal and a distinct lacrimal facet, gracile humerus with low, rounded deltopectoral crest, mandibular condyle of the quadrate transversly broad with weakly developed paraquadrate notch, dentary tooth with sinuous median carina and subsidiary ridge, relatively few tooth positions, and ischial shaft straight along most of its distance, but to curve dorsally and expand at the distal end before the

* Corresponding author. E-mail: youhailu@gmail.com

Fig. 1. *Nanningosaurus dashiensis* (NHMG8142, holotype (a–c and e–u); NHMG8143, paratype (d)).
Right maxilla in lateral (a) and medial (b) views; (c) left maxilla in lateral view; (d) right maxilla in lateral view; (e) left dentary in medial view; (f) left scapula in lateral view; (g) anterior cervical in lateral view; (h) left humerus in anterior view; (i) right humerus in posterior view; isolated dentary tooth in lingual (j) and mesial (k) views; (l) right quadrate in posterior view; (m) left squamosal in lateral view; (n) basioccipital in dorsal view; (o) left ischium in lateral view; left femur in posterior (p), proximal (q), distal (r) and anterior (s) views; (t) right tibia in lateral view; (u) left tibia in lateral view. Scale bar equals 1 cm in (j) and (k); 5 cm in (l) –(n); 10 cm in (a) –(i) and (o) –(u).

ischial foot begins.

Description: The maxilla is subtriangular in shape in lateral view (Fig. 1a, b, c and d). The tall, sharply peaked apex is located considerably posterior to the mid-length of the maxilla, with its posterior margin nearly vertical and slightly hooked. This condition is sharply different from *Shuangmiaosaurus* in which prominent dorsal process is absent (You et al., 2003). A rostroventrally oriented facet along the rostrodorsal side of the dorsal process marks the contact with the lacrimal as in *Bactrosaurus* (Godefroit et al., 1998). Ventrally, a distinct depression is seen at the base of the dorsal process. Just posterior to this depression, there is a short apophysis pointing caudolaterally to receive the maxillary process of the jugal, though the apophysis is not prominent. Anteriorly, the concave dorsal surface of the maxilla develops a dorsomedial shelf to receive the posterior portion of the premaxilla, as in all other members of Lambeosaurinae (Horner, 1990; Weishampel et al., 1993; Horner et al., 2004). The maxillary foramen opens on the dorsal surface of the maxilla along the maxilla-premaxilla suture. The 26-cm-long maxilla as preserved has 27 tooth positions, only two functional teeth are present through the whole maxillary battery. Posteriorly, one replacement tooth can be seen from the maxillary broken section (Fig. 1c). The maxillary teeth are lanceolate and their height is much greater than width, and only the labial side of crown bears enamel and a prominent, posteriorly displaced median carina.

The ventral aspect of the quadrate is slightly broken (Fig. 1l). Above the mandibular condyle, the anterior margin of the shaft is concave to form a poorly defined paraquadratic notch for reception of the quadratojugal. Ventrally, the mandibular condyle is transversely broad, with the lateral condyle larger than the medial one. In *Tsintaosaurus* (Young, 1958), the quadrate is more curved, the paraquadratic notch is well defined, and the ventral aspect of the quadrate is dominated by a large hemispheric lateral condyle.

The body of the squamosal forms a deep cotylus for reception of the head of the quadrate (Fig. 1m). The precotyloid process is slender and triangular in cross-section, whereas the blade-like postcotyloid is elongate, and nearly perpendicular to the body of the squamosal, while it is more horizontal in *Tsintaosaurus*.

The relatively complete basioccipital consists of a prominent occipital condyle (Fig. 1n). In posterior view, the condyle has an elliptical outline, with a horizontally oriented long axis. The articular surface of the condyle is perfectly vertical and perpenticular to the axis of the floor of the neurocranium.

The left dentary is nearly complete, with the ventral and anterior margin slightly broken (Fig. 1e). The coronoid process is very high and angled slightly anteriorly. The apex of the coronoid process is markedly anteroposteriorly expanded. The distal extension of the dentary tooth row is well posterior to the apex of the coronoid process. In *Shuangmiaosaurus*, the coronoid process is developed posterior to the alveolar trough and inclined caudodorsally without an expanded apex. In medial view, there are 27 vertical narrow parallel-sided grooves and it is possible that more alveoli are present. The number of tooth positions is 27 in *Shuangmiaosaurus*, 35 in *Mandschurosaurus* (Riabinin, 1930), 38 in *Tsintaosaurus* and 63 in *Shantungosaurus* (Hu, 1973).

One isolated left dentary tooth is asymmetrically diamond-shaped and is relatively broader than that seen in *Tsintaosaurus* (Fig. 1j and k). It is slightly bowed laterally, forming an angle of about 150° between the crown and root, as in Lambeosaurinae (Horner, 1990; Weishampel and Horner, 1990; Horner et al., 2004). The lingual surface of the crown is bisected unequally by a prominent sinuous primary ridge, as seen in *Tsintaosaurus* (Young, 1958). Mesial to the primary ridge the crown surface is further divided equally by a lower secondary ridge which runs exactly parellel to the primary ridge, whereas in *Tsintaosaurus*, the secondary ridge is absent. Both ridges progressively diverge ventrally, toward the base of the enameled crown. The lower portion of the enameled surface develops a distinct depression, possibly a pathological condition. The marginal denticles are relatively small and papillae in shape.

One cervical vertebra is preserved (Fig. 1g). Its centrum is longer than the height of the neural arch. The postzygapophyseal processes are long and dorsally arched.

The proximal end of the scapula is massive (Fig. 1f). The acromion process projects laterodorsally. Beneath the acromion process, the edge of the scapula is thickened and bi-facetted to form a subrectangular coracoid facet and crescentic glenoid. Medially, the dorsal portion of the glenoid forms a large depression at the posterior end of the coracoid suture.

The left humerus is relatively gracile (Fig. 1h). In anterior view, it narrows from the proximal end and then slightly expands distally along the proximal half of the humerus. The deltopectoral crest is less prominent and less angular than that observed in other lambeosaurines such as *Tsintaosaurus* (Young, 1958), *Charonosaurus* (Godefroit et al., 2001), and *Amurosaurus* (Godefroit et al., 2004). The shaft of the right humerus expands distally into the markedly mediolaterally broad distal condyles (Fig. 1i).

The left ischium is long and robust (Fig. 1o). The ischial shaft is strongly compressed mediolaterally. It is straight along most of its distance, and starts to curve dorsally and expand at the distal end before the ischial foot begins. The foot is not well developed in comparison with that seen in *Tsintaosaurus*.

The left femur is long and robust (Fig. 1p, q, r and s). The femoral head is large and globular. The femoral shaft is straight and compressed anteroposteriorly. The fourth trochanter is relatively small and subtriangular in lateral view. It lies along its caudomedial side at about mid-shaft

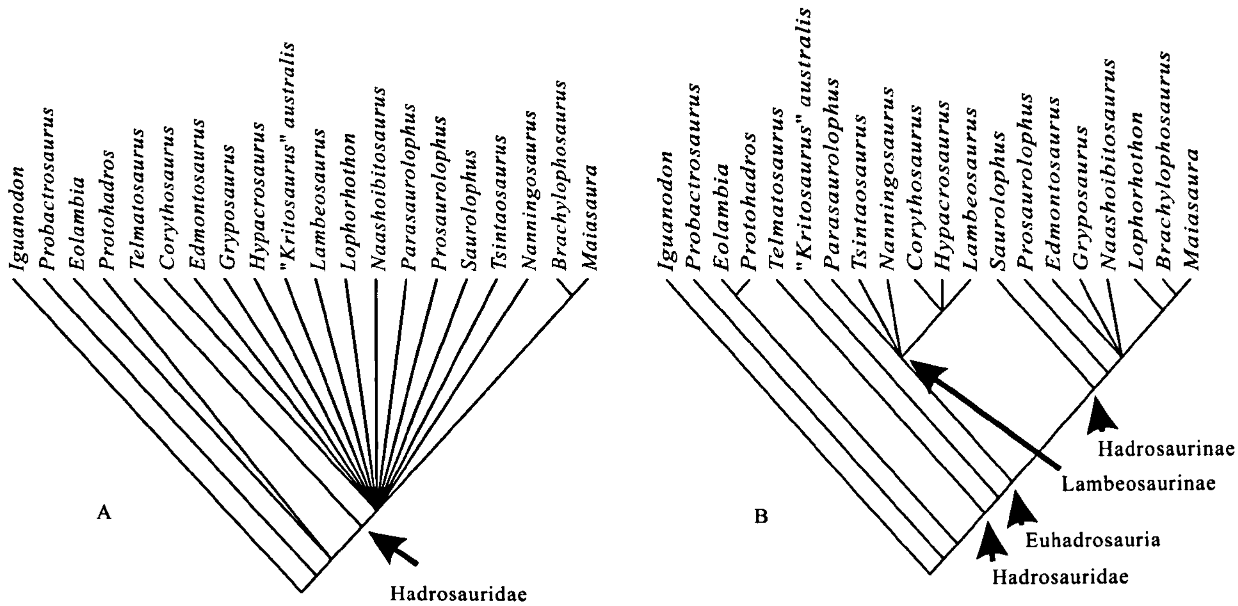

Fig. 2. Strict consensus tree (A) and majority consensus tree (B) based on 46 equally most parsimonious trees showing the phylogenetic position of *Nanningosaurus dashiensis*, gen. et sp. nov. by the analysis of 105 unordered characters and 20 comparative taxa using WinClada (Nixon, 1999).
The consistency index is 0.40 (A), 0.61 (B), and the retention index is 0.34 (A), 0.71 (B). The matrix is based on Horner et al. (2004), with the addition of the new taxon.

Table 1 Coding of phylogenetically informative characters in *Nanningosaurus dashiensis* gen. et sp. nov.

Nanningosaurus	0?11? 111?1 ?0??? ?11?? ????? ????? ????? ????? ?1?10 100?? ????? ????1 1??1? ????? ??01? ????? 1?10? ????? ????? ??11? 1????

The 105 unordered characters are based on Horner et al. (2004).

level and is laterally compressed. The distal condyles are greatly expanded anteroposteriorly. Anteriorly, the expanded anterior intercondylar groove is tunnel-like, though the two condyles are not fused. Posteriorly, the medial condyle is distinctly expanded laterally to form a tunnel-like groove, as in *Tsintaosaurus spinorhinus* (Young, 1958: fig. 30).

Two tibiae are perfectly preserved (Fig. 1t and u). They are similar to those of hadrosaurids generally.

3 Comparison and Discussion

According to Horner et al. (2004), *Nanningosaurus dashiensis* displays 5 unambiguous hadrosaurid features: distal extension of the dentary tooth row to terminate posterior to the apex of the coronoid process; posteriormost termination of the dentary well behind the coronoid process; elevation of the cervical zygapophyseal peduncles on neural arches to extend well above the level of the neural canal, long and dorsally arched postzygapophyses; a scapula with a notched cranioventral corner and a reduced area for its articulation with the coracoid; a deep intercondylar extensor groove on the femur, whose edges meet or nearly meet anteriorly to enclose the extensor tunnel. It also displays 2 uncertain hadrosaurid features (three or more replacement teeth per tooth family; a dorsoventrally narrow proximal scapula with an acromion process that projects horizontally) and 2 unambiguous Euhadrosauria features (a deep and nearly vertical face formed by the squamosals is seen in posterior view; nearly all of the expanded apex of the coronoid process is formed by the dentary with surangular reduced to thin sliver along the posterior margin).

In order to determine the phylogenetic relationships of *Nanningosaurus dashiensis* among hadrosaurids, we ran a cladistic analysis based on a dataset by Horner et al. (2004), with the addition of the new taxon. Coding of phylogenetically informative characters in *N. dashiensis* are shown in Table 1. The strict consensus tree of the 46 trees obtained suggest that *N. dashiensis* is near the base of Hadrosauridae (Fig. 2A). The majority consensus tree shows that *N. dashiensis* is a basal Lambeosaurinae (Fig. 2B). Two Lambeosaurinae features (maxillary shelf and maxillary foramen) are shared among *Nanningosaurus, Parasaurolophus, Tsintaosaurus, Corythosaurus, Hypacrosaurus* and *Lambeosaurus*. The lambeosaurine affinity of *N. dashiensis* is also supported by some possible lambeosaurine features, such as sinuous dentary median carina, one subsidiary ridge alongside the median carina, the crown-root angle greater than 145°, and ischium with footlike expansion distally (Horner et al., 2004).

As discussed above, the Lambeosaurinae affinity of *Nanningosaurus dashiensis* is not strongly supported, in large part due to the incomplete preserved specimen. The systematic position of *Nanningosaurus dashiensis* as a basal Lambeosaurinae thus is tentative at present and in need of more recovered materials in the future. This result seems to provide further evidence supporting the Asia-origin hypothesis for Lambeosaurinae (Godefroit, 2003).

The age of the fossil-bearing deposit (purple-red muddy siltstone) in the Nalong Basin was once considered to be Paleogene (Yongning Group) or Eocene (Nadu Formation) according to paleontological and sendimentary characters (Bureau of Geology and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985). The presence of *N. dashiensis* and its close relationship with *Tsintaosaurus* suggests a Late Cretaceous age for *N. dashiensis* and the portion of the Nadu Formation from which it came is probably the same age as the fossil bearing locality that preserves *Tsintaosaurus* (Buffetaut, 1995), though more evidence is needed to support this proposal.

4 Conclusions

A new genus and species of hadrosaurid dinosaur, *Nanningosaurus dashiensis* gen. et sp. nov. are described based on an incomplete skeleton. Cladistic analysis shows that it is positioned near the base of Hadrosauridae, more probably, as a basal member of Lambeosaurinae. This result seems to provide further evidence supporting the Asia-origin hypothesis for Lambeosaurinae. The fossil-bearing deposit from which it came probably occurred during the Late Cretaceous.

Acknowledgements

We thank Bucky Gates (Utah Museum of Natural History) for reviewing the manuscript. Thanks also give to Zhang Guobin from IVPP, Zhou Shichu from NHMG for preparing the specimens. This work was supported by funds both from the Science and Technology Department of Guangxi and State Administration of Cultural Heritage. The research work was also supported by fund from the National Science Foundation of China and Chinese Academy of Sciences to Xu Xing.

Manuscript received Oct. 18, 2006
accepted Feb. 2, 2007
edited by Xie Guanglian

References

Buffetaut, E., 1995. An ankylosaurid dinosaur from the Upper Cretaceous of Shandong (China), *Geol. Mag.*, 132: 683–692.

Bureau of Geology and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985. *Regional Geology of Guangxi Zhuang Autonomous Region.* Beijing: Geological Publishing House, 267–280 (in Chinese with English summary).

Gilmore, C.W., 1933. On the dinosaurian fauna of the Iren Dabasu Formation. *Bull. Am. Mus. Nat. Hist.*, 67: 23–78.

Godefroit, P., Bolotsky Y.L., and Alifanov, V., 2003. A remarkable hollow-crested hadrosaur from Russia: an Asian origin for lambeosaurines. *Comptes Rendus Palevol.*, 2: 143–151.

Godefroit, P., Bolotsky, Y.L., and Van Itterbeeck, J., 2004. The lambeosaurine dinosaur *Amurosaurus riabinini* from the Maastrichtian of Far Eastern Russia. *Acta Palaeontologica Polonica*, 49 (4): 585–618.

Godefroit, P., Dong, Z.-m., Bultynck, P., Li, H., and, Feng L., 1998. Sino-Belgian Cooperative Program. Cretaceous Dinosaurs and Mammals from Inner Mongolia: 1) New *Bactrosaurus* (Dinosauria: Hadrosauroidea) material from Iren Dabasu (Inner Mongolia, P. R. China). *Bulletin de l'Institut Royal des Science Naturelles de Belgique*, 68 (Suppl.): 1–70.

Godefroit, P., Zan, S., and Jin, L., 2000. *Charonosaurus jiayinensis* n. g., n. sp., a lambeosaurine dinosaur from the late Maastrichtian of north-eastern China. *Comptes rendus de l'Académie des Sciences de Paris, Sciences de la Terre et des Planétes*, 330: 875–882.

Godefroit, P., Zan, S., and Jin, L., 2001. The Maastrichtian (Late Cretaceous) lambeosaurine dinosaur *Charonosaurus jiayinensis* from north-eastern China. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, 71: 119–168.

Dong Zhiming, 1979. The Cretaceous dinosaur fossils in southern China. In: Institute of Vertebrate Paleontology and Paleoanthropology and Nanjing Institute of Geology and Paleontology (eds.). *Mesozoic and Cenozoic Red Beds in Southern China.* Beijing: Science Press. 342–350 (in Chinese).

Horner, J.R., 1990. Evidence of diphyletic origination of the hadrosaurian (Reptilia: Ornithischia) dinosaurs. In: Carpenter, K., and Currie, P.J. (eds.). *Dinosaur Systematics: Approaches and Perspectives.* Cambridge: Cambridge University Press. 179–187.

Horner, J.R., Weishampel, D.B., and Forster, C.A., 2004. Hadrosauridae. In: Weishampel, D.B., Dodson, P., and Osmólska, H. (eds.), *The Dinosauria* (Second Edition). Berkeley: University of California Press, 438–463.

Hu Chengzhi, 1973. A new hardosaur from the Cretaceous of Chucheng, Shantung. *Acta Geologica Sinica* (Chinese edition), 47(2): 179–206.

Mo Jinyou, Wang Wei and Huang Yunzhong, 1998. Dinosaur fauna from the Nalong Basin, Guangxi and new comments on related stratigraphy. *J. Guilin Inst. Tech.*, 18 (Suppl.):140–142 (in Chinese).

Nixon, K.C., 1999. WinClada (BETA) ver. 0.9.9 published by the author, Ithaca, New York, USA.

Riabinin, A.N., 1925. A mounted skeleton of the gigantic reptile *Trachodon amurense* nov. sp. *Izvest. Geol. Komissaya*, 44: 1–12 (in Russian).

Riabinin, A.N., 1930. *Mandschurosaurus amurensis* nov. gen., nov. sp., a hadrosaurian dinosaur from the Upper Cretaceous of the Amur River. *Soc. Palaeontol. Russ. Mem.* 2: 1–36 (in Russian).

Weishampel, D.B., and Horner, J.R., 1990. Hadrosauridae. In: Weishampel, D.B., Dodson, P., and Osmólska, H. (eds.), *The Dinosauria.* Berkeley: University of California Press, 534–561.

Weishampel, D.B., Norman, D.B., and Grigorescu, D., 1993. *Telmatosaurus transsylvanicus* from the Late Cretaceous of Romania: the most basal hadrosaurid dinosaur. *Palaeontology*, 36 (2): 361–385.

Wiman, C., 1929. Dir Kriede-Dinosaurier aus Shantung. *Palaeontol. Sinica (C)*, 6: 1–67.

You Hailu, Ji Qiang, Li Jinglu and Li Yinxian, 2003. A new hadrosauroid dinosaur from the mid-Cretaceous of Liaoning, China. *Acta Geologica Sinica* (English edition), 77 (2): 148–154.

Young, C.C. 1958. The dinosaurian remains of Laiyang, Shantung. *Palaeontol. Sinica (C)*, 16: 1–138 (in Chinese and English).

Zhen, S., 1976. A new species of hadrosaur from shandong. *Vert. PalAs.* 14: 166–168 (in Chinese with English summary).