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A large predatory lizard (Platynota, Squamata) from the Late Cretaceous of South China

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The Late Cretaceous deposits of the Nanxiong Formation, southern China, have yielded some dinosaur bones and many eggs, but there has been little record of the associated fauna. A new locality in Jiangxi Province has recently produced a fossil lizard assemblage including two genera of herbivores and the partial skull and lower jaws of a terrestrial predator. The latter combines large size, the possession of a small number of recurved, well-separated marginal teeth, a blunt rostrum, and rounded cranial osteoderms. It resembles *Estesia* from the Late Cretaceous of Mongolia, but is distinct in its jaw morphology and the possession of cranial osteoderms. It is therefore placed in a new genus and species, *Chianghsia nankangensis*. Phylogenetic analysis groups *Chianghsia* unequivocally with the Platynota, the group to which living monitor lizards and extinct mosasaurs belong. Within Platynota, there is support for the attribution of *Chianghsia* to Monstersauria, the group that includes the living venomous Gila monster, *Heloderma suspectum*, and its fossil relatives. This is the first record of a large terrestrial predatory platynotan lizard from the Mesozoic of southern China.

Keywords: China; Squamata; Platynota; Monstersauria; predatory lizard; new taxon

Introduction

Lizards are relatively well represented in the Late Cretaceous fossil record, but most records are either from North America (e.g. Gilmore 1928; Gao & Fox 1996) or Mongolia (e.g. Gilmore 1943; Borsuk-Białynicka 1984; Norell *et al.* 1992, 2008; Gao & Norell 2000). The fossil lizard assemblage of Mongolia (Djadochta Formation (Fm)) is remarkably diverse (Gao & Norell 2000) and is represented by a large number of well-preserved skulls. Much less is known of the contemporary Chinese record, and this mainly documents Inner Mongolian localities similar to those of Mongolia (e.g. Gao & Hou 1996; Li *et al.* 2008). The only exception was a partial dentary from the Ganzhou Basin, Jiangxi Province (*Conicodontosaurus kanhsiensis*, Young 1973), but this specimen is lost and its age uncertain (Li *et al.* 2008). Recently, however, an herbivorous lizard, *Tianyusaurus zhengi*, was described from the Late Cretaceous of Henan Province (Lü *et al.* 2008). Additional specimens of *Tianyusaurus* were recovered from a new locality in the Nanxiong Fm of southern Jiangxi, near the city of Nankang (Mo *et al.* 2009; Fig. 1). This same locality has yielded further undescribed lizard taxa, including

the large predatory lizard described herein. The Nanxiong Fm, or its equivalents, outcrops across several provinces in south-eastern China as an extensive sequence of red bed mudstones, sandstones and conglomerates that have yielded a rich Maastrichtian age bone and egg assemblage (Zhao *et al.* 1991; Lucas 2001; Sato *et al.* 2005), including an oviraptorid dinosaur (Xu & Han 2010) and a turtle (Tong & Mo, unpubl. data).

Systematic palaeontology

Squamata Oppel 1811
Anguimorpha Fürbringer 1900
Platynota Camp 1923
Monstersauria Norell & Gao 2007
Chianghsia gen. nov.

Type species. *Chianghsia nankangensis* sp. nov.

Etymology. From Chiang-hsi, an alternative transliteration of Jiangxi.

Diagnosis. See type species.

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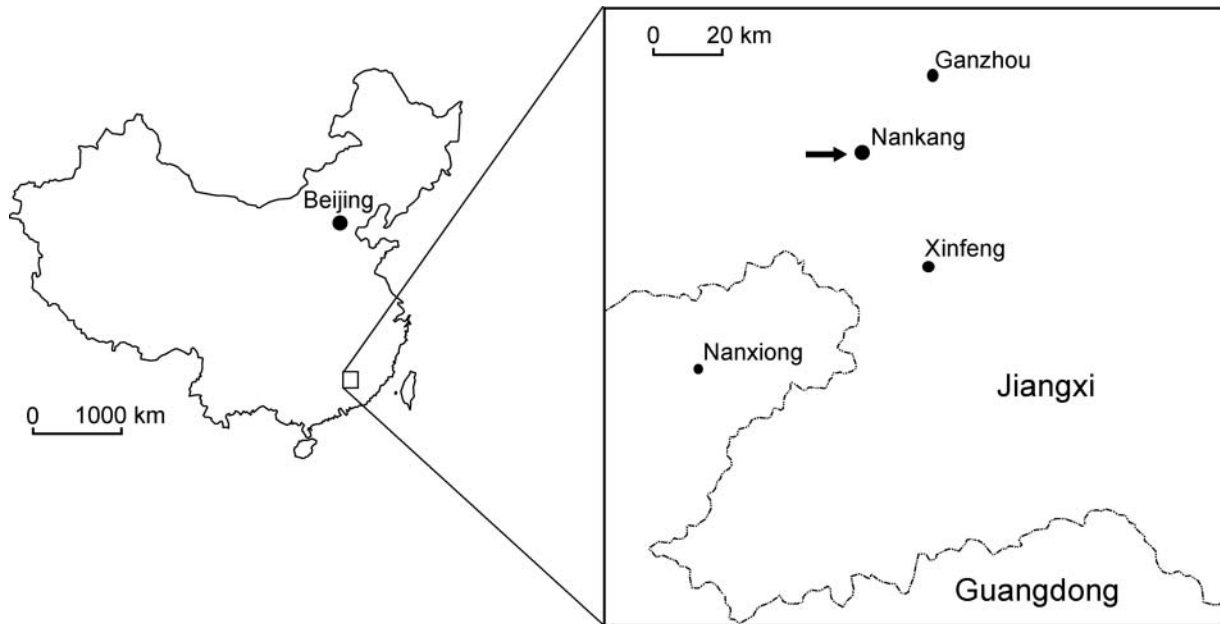


Figure 1. Map of PR China with enlargement of southern Jiangxi showing the location of Nankang close to the fossil site.

C. nankangensis sp. nov.
(Figs 1–4)

Etymology. From Nankang, the city closest to the locality

Type specimen. Guangxi Natural History Museum, Zoology Collection, NHMG 009318 (Nanning, Guangxi Province, China), a partial skull and lower jaws.

Diagnosis. Platynotan lizard (*sensu* Conrad 2008) uniquely combining large size (> 1 m snout–vent length (SVL)); blunt rostrum; substantial dentary–postdentary overlap; rounded and pitted cranial osteoderms attached, but not co-ossified, to lower jaws, and fused to some dorsal skull elements; four to five functional teeth on each maxilla and dentary; teeth large, high-crowned, laterally compressed and widely spaced with basal infolding. *Chianghsia* resembles other platynotans in the U-shaped palatine, septomaxilla partially flooring the narial opening, a narrow elongate vomer, anteroposteriorly directed ectopterygoid, size disparity between premaxillary and lateral teeth, shortened splenial, and widely spaced high-crowned teeth with broad bases and basal infolding; resembles *Lanthanotus* in having cranial osteoderms and a blunt rostrum, but differs from it and all varanids in the stronger dentary–postdentary overlap and the absence of a contact between the maxillae posterior to the premaxilla; resembles monstersaurs (*sensu* Norell & Gao 1997, Conrad 2008) in having thickened rounded cranial osteoderms, a low tooth count on the dentary and maxilla, a palatine expansion on the maxilla, a probable contact between the ectopterygoid and palatine anterior to

the suborbital fenestra, and a broad rostrum; resembles the fragmentary Late Cretaceous Canadian *Labrodectes* (Gao & Fox 1996) in having a straight rather than convex ventral jaw margin and inferred absence of a venom groove, but it is larger, and has fewer, more elongated teeth; resembles the Late Cretaceous Mongolian monstersaur *Estesia* (Norell *et al.* 1992), and differs from *Gobiderma* (Gao & Norell 2000), in large size, rostral shape (parallel-sided, relatively elongate, blunt), tooth number (4–5 in dentary and maxilla), a straight rather than strongly convex ventral dentary profile, and general skull proportions, but differs in having cranial osteoderms and in lacking the edentulous posterior portion of the jaw ramus.

Occurrence. The type and only specimen is from the Upper Cretaceous (Maastrichtian) Nanxiong Fm near the city of Nankang, southern Jiangxi Province, China (Fig. 1).

Morphology

NHMG 009318 preserves the tooth-bearing margins of the maxillae and premaxilla, the septomaxillae, parts of the dorsal surface of the palate, and the lower jaws (Figs 2, 3). As preserved, the skull is 113 mm along the midline, but roughly one third is missing from the posterior end (by comparison with other platynotans), and the skull would originally have been *c.* 175–180 mm long. Based on living relatives, this would suggest a snout–vent length (SVL) of 1–1.25 m. The skull has been prepared as fully as possible,

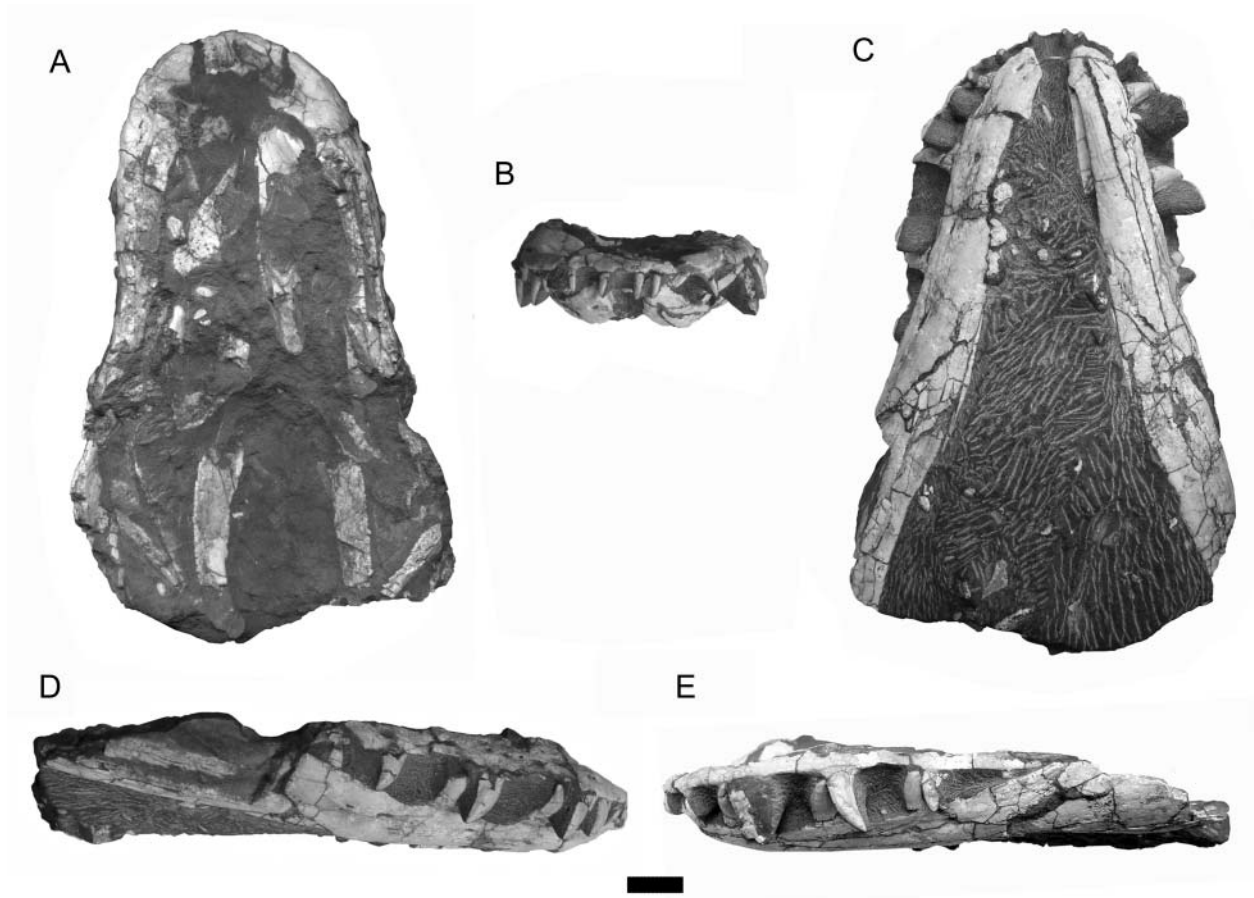


Figure 2. *Chianghsia nankangensis* gen. et sp. nov. type specimen NHMG 009318 in: **A**, dorsal; **B**, anterior; **C**, ventral; **D**, right lateral; and **E**, left lateral views. Scale bar: 10 mm, applies to all.

but attempts to CT scan material from this locality proved disappointing.

The premaxilla is single, dorsoventrally shallow and anteroposteriorly broad (Fig. 2B). Behind it, the maxillary margins run in parallel so that, with the premaxilla, they give the snout a blunt profile. Broad maxillary shelves curve anteromedially and meet the edges of the premaxilla but do not appear to make contact posterior to it (Fig. 3A). Although the anteromedial margins are partly embayed, the morphology is not suggestive of premaxillary–maxillary fontanelles. Posteromedially the maxillary shelf (left side) expands to meet the palatine. The facial processes are broken, but the anterior edge is somewhat set back suggesting elongation of the narial margin. Pitted sculpture on the base of the right facial process may indicate the presence of fused osteoderms. There is similar pitting on a bony sheet that extends from the left maxilla toward the midline. This is probably the left nasal. It is relatively wide and its dorsal surface seems to be covered with fused, interdigitating osteoderms (Fig. 4A).

The palatal elements are preserved as bone fragments and impressions. A smooth septomaxilla forms the

anteroventral floor of the nasal cavity on the right side and there is a similar, more fragmentary element on the left. The right vomer is a relatively thick, narrow bone that runs parallel to the maxilla, but is broken at both ends. Posterior to it on both sides are fragments and impressions of paired U-shaped palatines, roughly equal in width and length. Each bears a lateral process that meets the maxillary shelf expansion, and a short posterior stem. The left palatine approaches the anterior end of the ectopterygoid, and probably contacted it to exclude the maxilla from the suborbital foramen. The pterygoids are represented by parts of their palatal and ectopterygoid rami (pterygoid flanges), with an impression of the palatal plate between them. There is no trace of pterygoid teeth in the areas of impression but as the medial edge of the bone is preserved in dorsal view, small teeth may have been present on the palatal surface. Large ectopterygoids lie posterior to the maxillae and are oriented anteroposteriorly. NHMG 009318 is broken just posterior to the pterygoid flanges, so the quadrate rami of the pterygoids, the quadrates and the braincase are missing.

In the lower jaws, the dentaries are relatively shallow, with little ventral curvature. Five neurovascular foramina

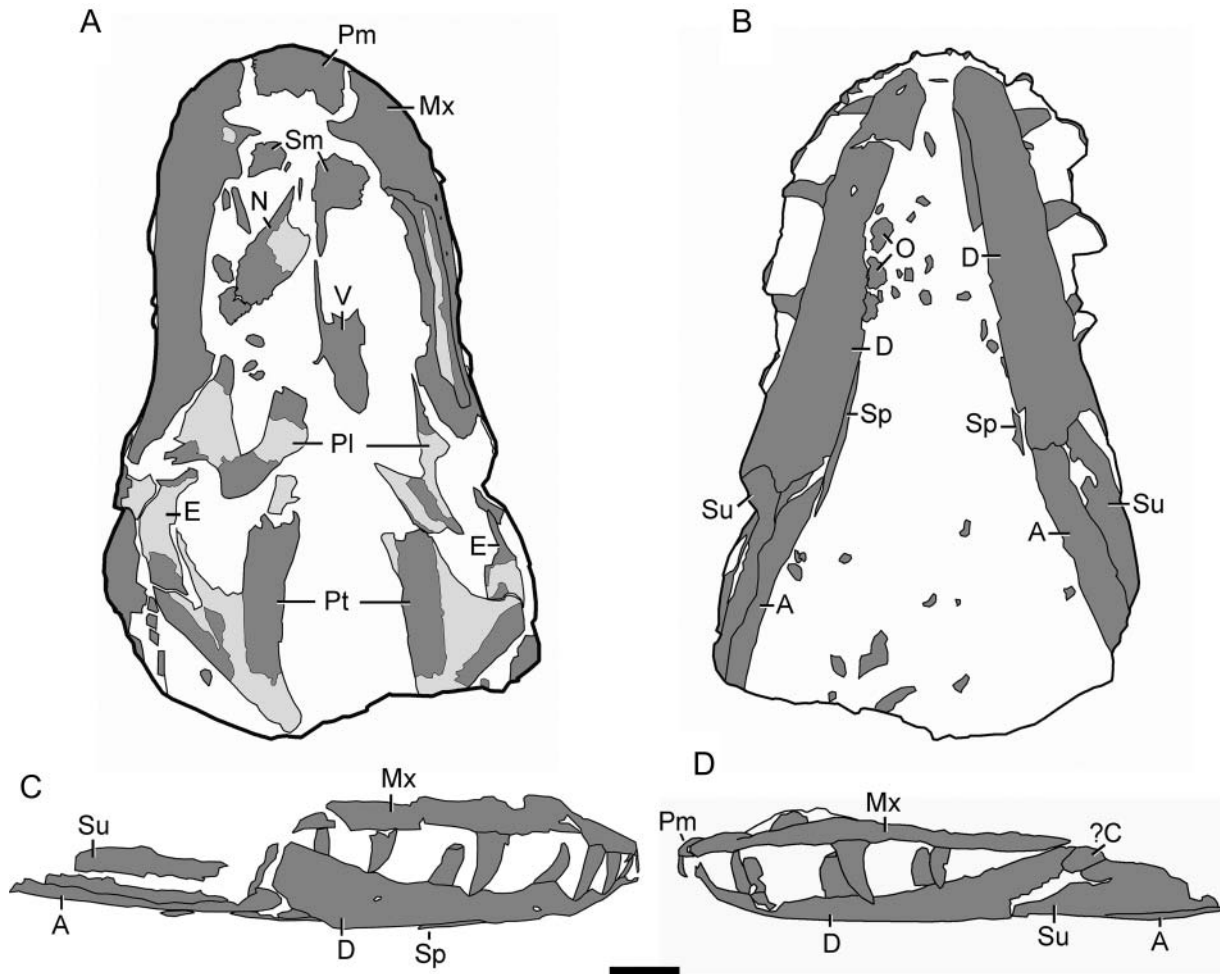


Figure 3. *Chianghsia nankangensis*. Line drawings of NHMG 009318 in: **A**, dorsal; **B**, ventral; **C**, right lateral; and **D**, left lateral views. Dark grey, bone; light grey, impression. Scale bar: 10 mm. Abbreviations: A, angular; ?C, possible coronoid fragment; D, dentary; E, ectopterygoid; Mx, maxilla; N, nasal; O, osteoderms; Pm, premaxilla; Pt, pterygoid; Sm, septomaxilla; Sp, splenial; Su, surangular; V, vomer.

open along the lateral surface. Posteriorly, the dentary overlapped the surangular and angular, although part of the overlapping surface has broken away. There is a clear, but small, surangular notch on each side (Fig. 2B). Both surangular and angular are exposed laterally (Fig. 3B). A slender strip of splenial is visible along each ventromedial jaw margin, spanning the dentary–postdentary contact but not obviously extending anterior to the mid-length of the dentary. Posterodorsally, on the left side (Figs 2E, 3D), the dentary contacts a fragment of a possible coronoid.

The marginal teeth are few, widely spaced, and very high-crowned (more than 50% of the tooth extending beyond the tooth-bearing elements; Bhullar & Smith 2008), with mesiodistally expanded bases that show basal ridging/infolding reminiscent of teeth with internal plicidentine (Fig. 4C, but see Kearney & Rieppel 2006). The degree of any lingual expansion of the base cannot be determined. There are four functional teeth on the premaxilla, four (left

or five (right) on the maxilla, and three (left) or four (right) on the dentary. The premaxillary teeth are straight and much smaller (3–4.4 mm long) than the largest maxillary (9.8 mm) or dentary (10.8 mm) teeth (Figs 2B, 4C), which are strongly recurved, labiolingually compressed (a narrow ovoid in mid-section) and have sharp anterior and posterior carinae. None of the teeth can be viewed in lingual aspect, but the preserved cross-sections show no obvious trace of venom grooves. The last dentary tooth (right side, Fig. 3C) lies close to the posterior end of the bone.

Before preparation, the block surface reportedly bore a scatter of small bone fragments (probably osteoderms). A small number of osteoderms remain on the ventral surface of the skull between the jaws. They vary in size but are rounded, thick, and have a ridged and pitted surface. Three lie against the edge of the right dentary (Figs 2C, 4B) and osteoderms probably covered all or part of the skull in life. As described above, the pitted surface of the left

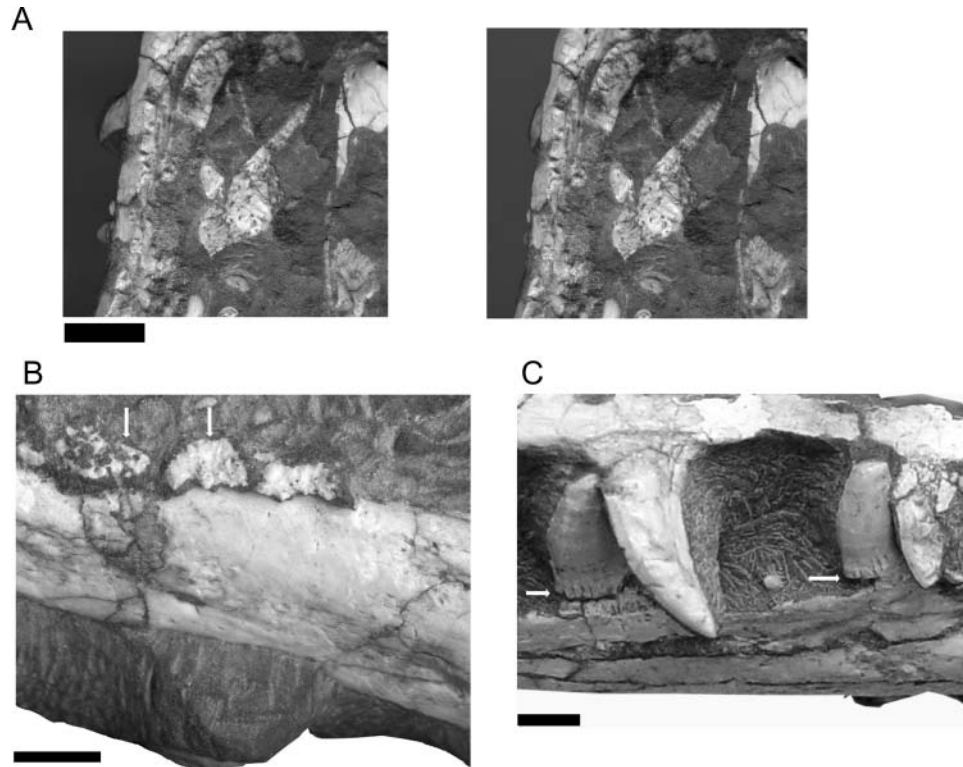


Figure 4. *Chianghsia nankangensis*, NHMG 009318: **A**, stereopair showing section of dorsal rostrum with osteodermal pitting; **B**, detail of osteoderms (arrowed) overlying edge of dentary; **C**, detail of teeth showing basal grooving/ridging suggestive of plicidentine (arrowed). Scale bars: 10 mm (A), 5 mm (B, C).

nasal seems to be due to fused, interdigitated osteoderms (Fig. 4A).

Phylogenetic analysis

We used the character matrix of Conrad (2008), with his character ordering, updated as in Norell *et al.* (2008) (372 characters; 254 active taxa including the new Jiangxi fossil, but excluding Tupinambinae, Teiinae, Iguanidae, Corytophanidae, Phrynosomatidae and Crotophytidae from the Conrad 2008 matrix as these were replaced by representative genera in the updated matrix; see Online Supplementary Material, Chianghsiamatrix.nexus). Character ordering (addictive characters) followed Conrad (2008). The matrix is too large to run in PAUP (Swofford 2002) and we therefore used TNT (Goloboff *et al.* 2003). The analysis was performed using the New Technology (NT) search with Ratchet (100 or 1000 ratchet iterations; 1000 Random Addition [RAM] sequences) and Kuehneosauridae as the designated outgroup taxon. A Traditional Search (1000 repetitions, TBR branch swapping) was then run using the trees obtained from the ratchet search as starting trees. However, in the Traditional Search, the saved trees always exceeded the available computer memory (at 90 000+ and 100 000+

trees on two different computers). This prohibited the calculation of either Bootstrap or Bremer decay indices. To compensate, the analysis was repeated several times. In each case, the ratchet trees showed the same topographical relationships for *Chianghsia* whether 100 or 1000 ratchet iterations were run. The strict consensus of the trees recovered by the Traditional TBR search also recovered the same placement of *Chianghsia*. We are therefore confident that the relationships of the new taxon have been explored as fully as possible. The topology of the monstrosaur clade was identical in each of these trees with *Chianghsia* placed as a sister taxon to the Mongolian *Estesia* (Fig. 5). The tree shown in Fig. 5 is that recovered by both the strict consensus of four Ratchet trees (Length, 3938; Consistency Index, 0.136; Retention Index, 0.705; Rescaled Consistency Index 0.096: as reported after importing into PAUP) and the strict consensus of 100 000 trees obtained from a Traditional TBR search using the ratchet trees as the starting point. These analyses also placed *Varanus* and its relatives (Varaniformes, Conrad 2008) closer to monstrosaur than to the aquatic mosasauroids (*contra* Conrad 2008).

Discussion

The phylogenetic analysis places *Chianghsia* within Platynota (*sensu* Conrad 2008), crownward of shinisaurs,

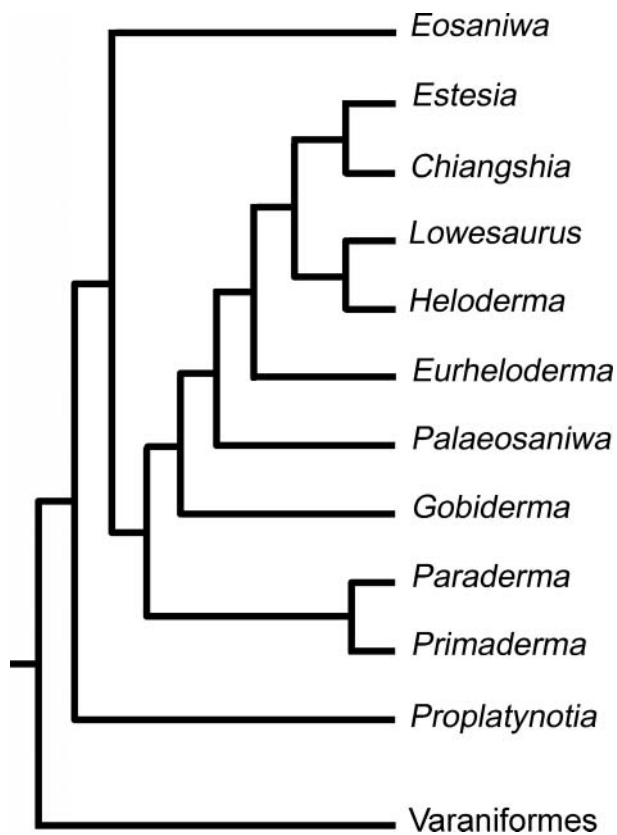


Figure 5. Monstersaur segment of a phylogenetic tree showing hypothesis of relationships for *Chianghsia*. See text for further discussion.

and this position is well supported by characters of the jaws and dentition (Conrad 2008: characters 33, 111, 112, 196, 211, 223), including some not included in the Conrad dataset, such as the possession of high-crowned, labiolingually compressed teeth (Bhullar & Smith 2008) with expanded bases (Conrad *et al.* 2010).

Following Norell & Gao (1997), Conrad (2008) and Conrad *et al.* (2010), those platynotans closer to *Heloderma* than to *Varanus* form the clade Monstersauria. From recent analyses (e.g. Conrad 2008, Conrad *et al.* 2010), fossil monstersaurs include *Eurheloderma* (Palaeogene, France, Hoffstetter 1957), *Lowesaurus* (Oligocene, North America, Yatkola 1976), *Primaderma* (mid-Cretaceous, North America, Nydam 2000), *Paraderma* (Late Cretaceous, North America, Pregill *et al.* 1986), *Estesia* (Late Cretaceous, Mongolia, Norell & Gao 1997) and *Gobiderma* (Late Cretaceous, Mongolia, Borsuk-Białynicka 1984). The fragmentary *Labrodictes* (Late Cretaceous, Canada, Gao & Fox 1996) has also been attributed to this group but with a single partial jaw (and uncertainly associated cranial material) further comparison is difficult.

The TNT analyses consistently support the attribution of *Chianghsia* to Monstersauria, based on the blunt snout, rounded cranial osteoderms, and strongly reduced tooth

count. The first two of these characters are also found in *Lanthanotus* (Maisano *et al.* 2002), and a blunt rostrum is present in some large varanids (e.g. *Varanus komodoensis*), but there is no trace of the varanid jaw hinge in *Chianghsia* and the inclusion of blunt-snouted varanids in the analysis did not affect the position of *Chianghsia*. *Estesia* is a near contemporary of *Chianghsia* and is most similar to it in terms of size, rostral shape (blunt but proportionally longer and narrower than that of *Heloderma*), the shallow premaxilla, the shape and position of the palatal and septomaxillary bones, and the low number (4–5) of functional teeth in each jaw quadrant, and this is reflected in the results of the TNT analysis. However, as described (Norell *et al.* 1992), *Estesia* differs from *Chianghsia* in lacking cranial osteoderms and having a long, edentulous, posterior dentary margin. Given the similarity in size of these two fossil taxa, it seems unlikely that the differences are ontogenetic. Generic separation therefore seems justified for *Chianghsia*.

Chianghsia thus provides the first record of a large platynotan lizard from the Late Cretaceous of southern China. Its cranial and dental characters support attribution to Monstersauria, as a relative of *Estesia*, but this needs to be confirmed with more complete cranial material. Nonetheless, *Chianghsia* is likely to have had a lifestyle similar to that of living large monitor lizards, as a predator of lizards and other small tetrapods, as well as of dinosaur eggs and hatchlings.

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Supplementary material

Supplementary material is available online DOI: 10.1080/14772019.2011.588254

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