

# First ceratopsid dinosaur from China and its biogeographical implications

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Ceratopsid dinosaurs represent one of the best known dinosaur groups in the Late Cretaceous, and their unquestionable fossil records are exclusively restricted to western North America. Here we report a new ceratopsid dinosaur, *Sinoceratops zhuchengensis* gen. et sp. nov., from the Upper Cretaceous Wangshi Group of Zhucheng, Shandong Province, China. Cladistic analysis places this new taxon as the only known ceratopsid from outside North America, in a basal position within the Centrosaurinae. It is considerably larger than most other centrosaurines but similar in size to basal chasmosaurines. Furthermore, it is more similar to chasmosaurines than to other centrosaurines in several features, thus blurring the distinction of the two ceratopsid subgroups. This new find not only provides significant information on the morphological transition from non-ceratopsid to ceratopsid dinosaurs, but also complicates the biogeography of the Ceratopsidae, and further demonstrates that fossil sampling has profound effects on reconstructing dinosaurian biogeography.

**Late Cretaceous, Wangshi Group, Ceratopsidae, Centrosaurinae, biogeography**

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Ceratopsids, or derived horned dinosaurs, are large, quadrupedal herbivorous ornithischian dinosaurs. They are among the best known dinosaur groups including famous member such as *Triceratops* [1,2]. Previously ceratopsid fossils have been known only from the Late Cretaceous deposits of the Western Interior Seaway of North America [1]. *Turanoceratops tardabilis*, a taxon based on fragmentary, unassociated material collected from the Upper Cretaceous of Uzbekistan, has been assigned to the Ceratopsidae [3,4]. This systematic proposal has been questioned [1,5,6], yet recent studies provide additional support for the ceratopsid affinity of *Turanoceratops tardabilis* [7,8]. In the summer of 2008, we opened a large quarry near Zangjia-zhuang, a site located in Zhucheng, Shandong Province, China and collected numerous bones from the Upper Cretaceous Wangshi Group [9]. Most bones are referable to the

largest known hadrosaurid *Shantungosaurus* as in the nearby Longgudian site [9]. However, some cranial material is apparently not derived from hadrosaurs but is referable to the Ceratopsidae. Here we report a new ceratopsid taxon based on the recovered cranial material. Given that *Turanoceratops tardabilis* is probably the sister taxon to the Ceratopsidae rather than a basal member of the group [6,10] (also see below for a detailed analysis), the new taxon represents the only known ceratopsid outside of North America [7,11,12], and its discovery has significant biogeographical implication for the Ceratopsidae.

## 1 Systematic paleontology

### 1.1 Taxonomy

#### Ornithischia Seeley, 1888

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**Ceratopsia Marsh, 1890****Ceratopsidae Marsh, 1888****Centrosaurinae Lambe, 1915*****Sinoceratops zhuchengensis* gen. et sp. nov.****1.2 Etymology**

*Sino* (China) and *ceratops* (horned-face, Latinized Greek); *Zhucheng* (the place that produced the specimens described here).

**1.3 Holotype**

Zhucheng Dinosaur Museum (ZCDM) V0010, a partial skull with most elements of the skull roof and partial braincase.

**1.4 Referred specimens**

ZCDM V0011, a partial skull with much of the skull roof and most of the braincase. ZCDM V0012, partial braincase.

**1.5 Type locality and horizon**

Zangjiazhuang, Zhucheng, Shandong Province, China. Upper Cretaceous Wangshi Group [9].

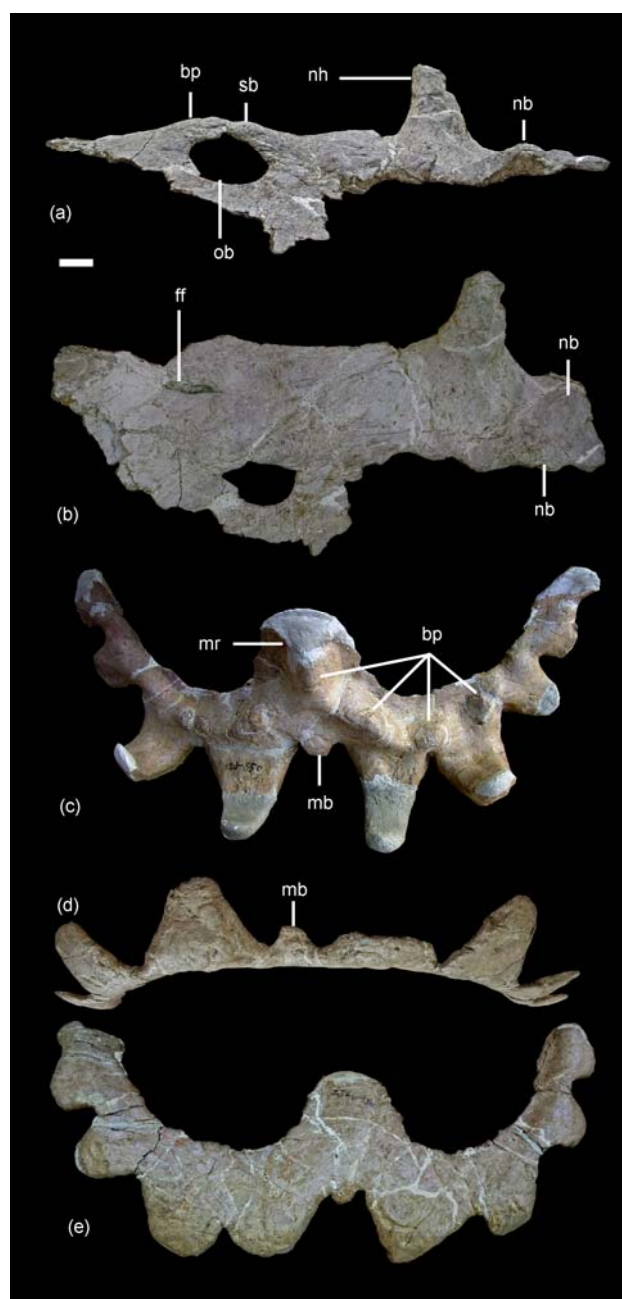
**1.6 Diagnosis**

Large centrosaurine ceratopsid with at least ten robust, strongly curved horn-like processes along the posterior margin of the parietals and at least four horn-like processes on the squamosals. It is also different from other centrosaurine in the following features: a large accessory fenestra anterior to the antorbital fenestra, weakly undulated external margin of the parietals and broadly based epoccipitals.

**1.7 Description and comparison**

The holotype skull (Figure 1) is estimated to be 180 cm in total length (from the snout tip to the posterior end of the parietals along the midline), being one of the largest centrosaurine skulls discovered so far [1,2].

As in many other ceratopsid specimens [1,2], the cranial sutures are obscured and thus no preserved elements could be precisely defined by their borders. The skull has a typical ceratopsid profile (Figure 2), being anteriorly narrow and posteriorly much wider in dorsal view [1]. The fused parietals of the holotype are 105 cm in the maximum transverse width. Also similar to other ceratopsids [13], the snout is proportionally long (estimated to be about 70% of the basal skull length). As in ceratopsids, the orbit is small (estimated to be less than 15% of the basal skull length) and its long axis is nearly vertically oriented, different from the proportionally larger orbit with an anteroposteriorly oriented long



**Figure 1** Photograph of *Sinoceratops zhuchengensis* holotype. ZCDM V0010 skull in right lateral (a) and right laterodorsal (b) views; ZCDM V0010 parietals in dorsal (c), posterior (d), and ventral (e) views. Abbreviations: bp, bump; ff, frontal fontanelle; mb, median bump; mr, midline ramus; nb, nasal bump; nh, nasal horn; ob, orbit; pb, postorbital bump; sb, supraorbital bump. Scale bar = 8 cm for (a), (b) and 6 cm for (c), (d), and (e).

axis in most more basal ceratopsians [5]. Similar to other ceratopsids, the infratemporal fenestra is small in size and is located considerably ventral to the orbit, though not to the degree seen in most other ceratopsids [1]. Similar to other ceratopsids, a highly reduced antorbital fenestra is present along the posterodorsal border of the maxilla. A second fenestra, much larger in size, is located anterior to the antorbital fenestra, as in an unnamed basal centrosaurine, and