A New Protoceratopsid (Dinosauria: Neoceratopsia) from the Late Cretaceous of Inner Mongolia, China

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Abstract An almost complete skull, which was collected from the Upper Cretaceous of the Bayan Mandahu area in Inner Mongolia, China by the Sino-Canadian Dinosaur Project, is described and assigned to a new genus of protoceratopsid dinosaur, *Magnirostris dodsoni* gen. et sp. nov. This new taxon is distinguished from other protoceratopsids by the robust rostral bone and the existence of incipient orbital horn cores. The existence of an additional antorbital fenestra indicates a close relationship between *Magnirostris* and *Bagaceratops*.

Key words: Dinosauria, Neoceratopsia, Late Cretaceous, Bayan Mandahu, Inner Mongolia, China

1 Introduction

The Bayan Mandahu area of Inner Mongolia, China, is one of the best known Late Cretaceous vertebrate fossil sites, due largely to the work of the Sino-Canadian Dinosaur Project (Jerzykiewicz and Russell, 1991; Dong, 1993; Jerzykiewicz et al., 1993; Jerzykiewicz, 2000). The dinosaur-bearing red beds here are generally thought to be correlative with the Campanian Djadokhta Formation of Mongolia (Eberth, 1993; Jerzykiewicz et al., 1993). Among the dinosaur remains, a virtually complete skull of a basal neoceratopsian was collected by the Sino-Canadian Dinosaur Project. It was prepared and labeled as a specimen of *Protoceratops* at the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) of the Chinese Academy of Sciences in Beijing. However, detailed observation shows that this specimen actually represents a new taxon of basal neoceratopsian dinosaur. This paper describes this specimen and discusses its phylogenetic relationships.

2 Systematic Paleontology

Dinosauria Owen, 1841
Ornithischia Seeley, 1887
Marginocephalia Sereno, 1986
Neoceratopsia Sereno, 1986
Coronosauria Sereno, 1986
Protoceratopsidae Granger and Gregory, 1923
Magnirostris dodsoni gen. et sp. nov.

Etymology: "*Magnus*" (Latin): "large" and "*rostrum*" (Latin): "beak" for the robust rostral bone of this specimen. Specific epithet for Professor Peter Dodson for his contribution to the study of horned dinosaurs.

Holotype: IVPP V 12513, an almost complete skull and articulated lower jaw lacking both squamosals and parietals, and the left jugal, postorbital, and quadrate.

Type locality and horizon: Bayan Mandahu, Inner Mongolia, China; Bayan Mandahu redbeds, Campanian, Late Cretaceous (Jerzykiewicz et al., 1993).

Diagnosis: Protoceratopsid distinguished from other members of the family in possessing a robust, elongate rostral bone and incipient orbital horn cores.

Description: The specimen consists of a nearly complete skull and articulated lower jaws preserved in three dimensions. The parietals and squamosals are not preserved, making it impossible to infer the morphology of the frill. The caudal portion of the right postorbital and the dorsal part of the right quadrate are missing. On the left side, all elements caudal to the maxilla (including the jugal, postorbital, and quadrate) are missing, but they have been restored based on corresponding elements from the right side. The jaws are articulated, making it difficult to ascertain details of the dentition. The following description is based on the right side of the skull unless stated otherwise.

The skull measures 350 mm long from the tip of the rostral bone to the caudal end of the epijugal, and 330 mm from the tip of the rostral to the end of the occipital condyle. The preorbital portion comprises about half the skull length. The height of the skull through the center of the orbit is 100 mm. The skull is triangular in dorsal view, tapering rostrally,

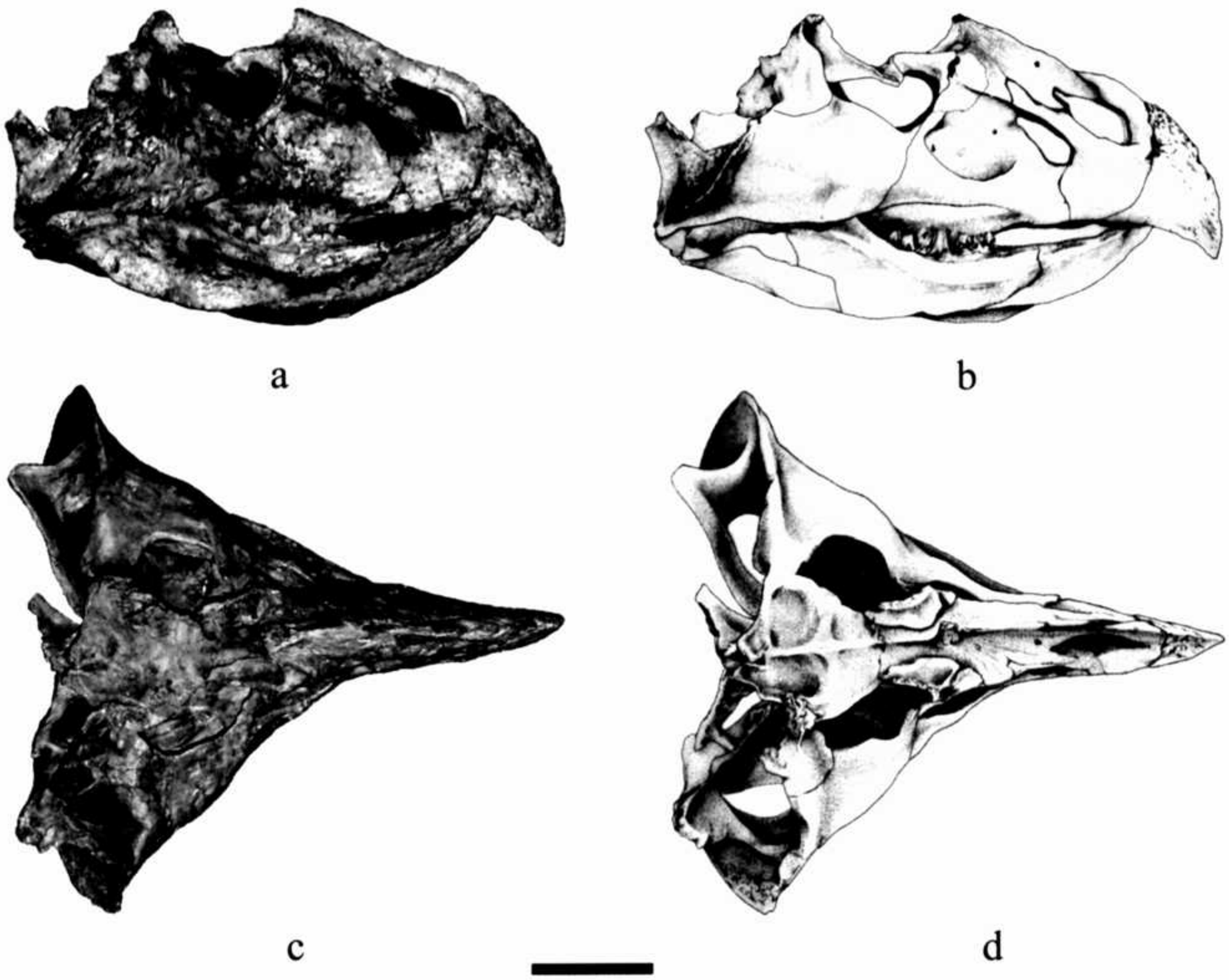

Fig. 1. Skull and lower jaw of *Magnirostris dodsoni* gen. et sp. nov. in right lateral (a, b) and dorsal (c, d) views.
a and c: photographs; b and d: schematic drawings. Scale bar equals 8 cm.

with well-developed, laterally flaring jugals. Mediolaterally, the skull measures 350 mm wide between the epijugals, and 210 mm between the quadrates. Both nasal and orbital horn cores are present (Fig. 1).

The external naris is prominent, elliptical, and situated far dorsally in lateral view. The external naris measures 60 mm in its longest, roughly rostrocaudal dimension, and a maximum of 23 mm in breadth. A fenestra is enclosed by the premaxilla and the maxilla. It is similar in shape and orientation to the naris, but is slightly smaller, with a maximum length of 50 mm and breadth of 20 mm. The antorbital fossa is prominent and subcircular, and is inset medially with a depth of about 13 mm from the buccal margin. Its caudal half underlies the rostral region of the orbit. The fossa measures approximately 60 mm in length by 45 mm in height. The orbit is relatively small, measuring 80 mm in length and 47 mm in height, and penetrated the upper half of the skull. The lower temporal fenestra is not completely preserved, but appears to be large judging from the space between the jugal and the preserved ventral portion of the quadrate.

The rostral bone is extremely well developed, projecting well beyond the rostral end of the lower jaw. Its rostral extreme is narrow transversely and angles rostroventrally to a point ventral to the level of the tooth row. In lateral view, the length along its buccal margin is about the same as its height along the caudal margin. The rostral bone covers the premaxilla caudally, with an almost vertical edge. A short caudolateral process runs along the buccal margin of the premaxilla. The surface of the rostral is rugose.

The premaxilla consists of a square-shaped body and two caudodorsal processes. Rostrally, it is covered by the rostral bone. Caudoventrally, the premaxilla-maxilla suture is subvertical. Caudodorsally, the caudoventral margin of the more dorsal process borders the external naris, and articulates with the nasal caudally. The lower caudodorsal process inserts between the external naris rostrodorsally and the subnarial fenestra caudoventrally, with the nasal overlapping its caudalmost part. No premaxillary teeth are evident.

The maxilla is the largest facial bone, and alone encloses the subcircular antorbital fossa. It sutures with the premaxilla rostrally, and the nasal and the lacrimal dorsally. Its caudal edge articulates primarily with the jugal, but also comprises a portion of the rostral margin of the orbit. The rostral one-third of its ventral border is edentulous, while the caudal two-thirds are emarginated medially and dentigenous.

The lacrimal makes a small contribution to the rostral border of the orbit. In lateral view, it is separated from the jugal caudoventrally by the maxilla, although contact between these elements is visible in caudal view. The lacrimal is bordered by the maxilla ventrally, the nasal rostrally and dorsally, and the prefrontal caudodorsally.

The jugal is long rostrocaudally and robust dorsoventrally, caudolaterally spanning from the maxilla to the caudal end of the skull. The jugal borders the caudoventral margin of the orbit, articulates with the postorbital, and forms the ventral border of the lower temporal fenestra. Its caudalmost corner is covered by the rugose epijugal on both laterally and medially. The quadratojugal, visible only in dorsal view, seems to be reduced to a tiny element positioned between the jugal and the quadrate.

The paired, sagittally positioned nasals receive the tapering premaxilla rostrally; together, these two elements enclose the external naris. Ventrolaterally, the nasal articulates with the maxilla, the lacrimal, and the prefrontal. Caudally, the nasals suture with the frontals along a relatively straight line at a position above the center of the orbit. The nasals are elevated and converge to form an incipient horn core along the midline between the lacrimals.

The prefrontal borders the rostrodorsal quarter of the orbit. It is situated between the lacrimal rostrally and the frontal caudally, and is separated from its counterpart by the nasals medially. No palpebral is present.

The frontals are fused together and depressed slightly in dorsal view. They suture with the nasals and the prefrontals rostrally, and border the caudal half of the upper rim of the orbit. Caudolaterally, each frontal is elevated and fused to the postorbital to form an incipient orbital horn core. The caudalmost portion of the frontal is not preserved.

Only the rostral portion of the postorbital is preserved. Its most characteristic structure is its elevated dorsomedial corner, which is fused with the caudolateral process of the frontal. Together, they form an incipient orbital horn core. The rostral edge of the postorbital ventral to the orbital hore core borders the orbit caudally. The jugal process of the postorbital is short and stout, with an extensive contact with the underlying jugal. The caudal portion of the postorbital is not preserved.

The ventral part of the right quadrate is preserved. Its shaft is situated medial to both the jugal and the epijugal. The distal condyle is transversely wide. The occipital region is poorly preserved. Surrounding the small, subcircular foramen magnum are the supraoccipital dorsally, the paired but only partially preserved exoccipitals laterally, and the basioccipital ventrally. The sutures between these elements are not clear. The occipital condyle is ovoid, with width slightly larger than height. The palatal bones are not well exposed.

The complete mandible is preserved in articulation with the skull. The predentary is long, and curves rostrodorsally, ending in a sharp point. The dentary is long, with a slightly convex ventral edge. The tooth row continues medial to a coronoid process that is composed mainly of the caudodorsal portion of the dentary. The angular is situated on the caudoventral third of the lower jaw, and is visible in lateral view. The surangular is short dorsoventrally, and sits dorsal to the caudal two-thirds of the angular. The articular forms the caudodorsal terminus of the lower jaw. The medial aspect of the lower jaw cannot be observed.

No premaxillary teeth are visible. The maxillary teeth are placed along the caudal two-thirds of the ventral margin of the maxilla. There is a single functional tooth at each tooth position. Nine maxillary teeth are visible on the right side, with the fifth being the largest. Each crown has a single primary ridge that is not centrally positioned. The dentary teeth are somewhat obscured by the maxillary crowns, but seem to possess similar characteristics.

3 Discussion

The presence of the rostral bone and the lateral flaring of the jugals demonstrate that the Bayan Mandahu specimen belongs to Ceratopsia (Sereno, 1986, 1999). Furthermore, the shape of the rostral and predentary, which are pointed, and the nature of the jugal flare, (initiating near the caudal end of the jugals), differentiate the Bayan Mandahu specimen from members of Psittacosauridae, placing it instead within Neoceratopsia (Sereno, 1986; Dodson and Currie, 1990; Sereno, 1999). The lack of prominent nasal and orbital horn cores and the relatively small external naris exclude it from Ceratopsidae (Dodson, 1990).

Multiple basal neoceratopsians are known. Among them, *Liaoceratops* (Xu et al., 2002), *Archaeoceratops* (Dong and Azuma, 1997; You, 2002), *Leptoceratops* (Brown, 1914; Sternberg, 1951), *Protoceratops* (Brown and Schlaikjer, 1940), and *Bagaceratops* (Maryańska and Osmólska, 1975) are recognized by relatively well-preserved material.

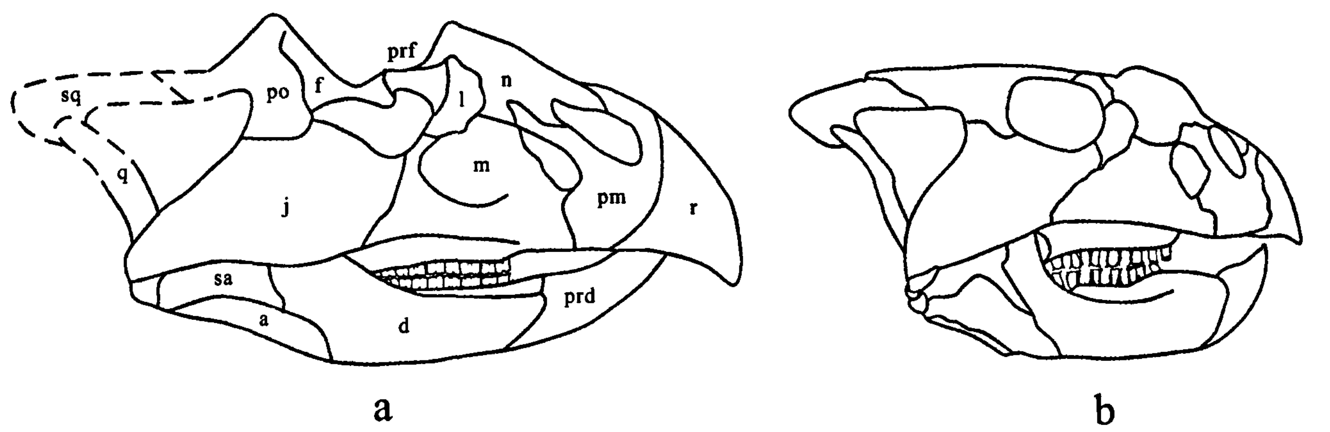

Fig. 2. Comparison of the skull and lower jaw in *Magnirostris dodsoni* gen. et sp. nov. (a) and *Bagaceratops rozhdestvenskyi* (b). Notice the differences in the length of the rostral and predentary, the shape of the nasal horn core, and the presence of orbital horn cores in *Magnirostris*. Abbreviations: a – angular; d – dentary; f – frontal; j – jugal; l – lacrimal; m – maxilla; n – nasal; pm – premaxilla; po – postorbital; prd – predentary; prf – prefrontal; q – quadrate; r – rostral; sa – surangular; sq – squamosal.

Liaoceratops and *Archaeoceratops* from the Lower Cretaceous of northern China are both considered as the most basal members of Neoceratopsia (Xu et al., 2002; You, 2002). The skulls of these animals are relatively small, even in adults, and do not possess nasal horn cores. The Bayan Mandahu specimen is clearly more derived than these taxa.

Leptoceratops (Brown, 1914; Sternberg, 1951) is from the Late Cretaceous of North America. It differs from the Bayan Mandahu specimen in having no nasal horn (personal observation), a relatively rounded external naris in lateral view, and a convex buccal margin of the premaxilla. In both the Bayan Mandahu specimen and *Leptoceratops*, the length of the rostral bone is the same as the height. However, the enlargement of the rostral bone of the Bayan Mandahu specimen is mainly due to its rostral extension, while the expanded condition of the rostral bone in *Leptoceratops* is created by a caudolateral process along its buccal margin.

The Bayan Mandahu specimen is similar to *Protoceratops* and *Bagaceratops* in terms of geographical and stratigraphical distribution. All are from the Late Cretaceous (Campanian) of the Gobi Desert (Jerzykiewicz and Russell, 1991; Jerzykiewicz et al., 1993; Jerzykiewicz, 2000). The Bayan Mandahu specimen differs from *Protoceratops* in its general skull profile, which is relatively long in the Bayan Mandahu specimen, while high in *Protoceratops*. Other features in *Protoceratops*, such as the relatively long preorbital portion of its skull (more than 50% of basal skull length), the presence of premaxillary teeth, and the dorsoventrally high maxilla further differentiate this taxon from the Bayan Mandahu specimen.

The Bayan Mandahu specimen and *Bagaceratops* (Maryańska and Osmólska, 1975) share a single character not reported in any other ceratopsian: the presence of an additional fenestra ventral to the external nares. They are also similar in many other aspects, such as the general appearance of the skull; for example, the preorbital portion is about half of the basal skull length in both forms. However, many features differentiate them. The rostral bone of the Bayan Mandahu specimen is more robust (length same as height in lateral view) than that of *Bagaceratops*. The maxilla contributes to the orbit rim of the Bayan Mandahu specimen, but not in *Bagaceratops*. The nasal horn is pointed in the Bayan Mandahu specimen, while blunt in *Bagaceratops*. Most importantly, the Bayan Mandahu specimen possesses incipient orbital horn cores, and its frontals are depressed, characters which are not present in *Bagaceratops* (Fig. 2). Therefore, the Bayan Mandahu specimen is assigned to a new genus, *Magnirostris dodsoni* gen. et sp. nov.

Recent cladistic analyses advocate a sister group relationship between the Asian basal neoceratopsians *Protoceratops* and *Bagaceratops* (Sereno, 2000; Makovicky, 2001; Xu et al., 2002; You, 2002). These taxa constitute the only definitive members of Protoceratopsidae, a stem group taxon defined as all representatives of the Coronosauria closer to *Protoceratops* than to *Triceratops* (Sereno, 1998). The recognition of *Magnirostris* adds a third genus to Protoceratopsidae. The protoceratopsids from Bayan Mandahu are notable for their relatively large sizes (Lambert et al., 2001).

4 Conclusions

A new genus and species of Protoceratopsidae, *Magnirostris*, is described. It is from the Upper Cretaceous (Campanian) of the Bayan Mandahu area, Inner Mongolia, China. *Magnirostris* is closely related to *Bagaceratops*, as they share an additional antorbital fenestra.

Acknowledgements

We are grateful to Dr. Peter Dodson, Mr. Matthew Lamanna, and Mr. Jerry Harris for improving the manuscript, Mrs. Huang Jinling for drawing the illustrations, and Mrs. Zheng Fang for arranging access to the specimen.

Manuscript received Nov. 21, 2002
accepted Jan. 14, 2003
edited by Wang Si'en and Xie Guanglian

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