An Adult Specimen of *Hongshanosaurus houi* (Dinosauria: Psittacosauridae) from the Lower Cretaceous of Western Liaoning Province, China

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Abstract A new specimen consisting of a complete skull and lower jaw was discovered from the Lujiatun bed of the Lower Cretaceous Yixian Formation in the Lujiatun site, Beipiao, western Liaoning Province. It represents an adult specimen of *Hongshanosaurus houi*. Comparative studies show that *Hongshanosaurus* is distinguishable from its sister taxon *Psittacosaurus* by having the preorbital portion about half of the basal skull length, and the elliptical external naris, orbit, and a lower temporal fenestra oriented caudodorsally.

Key words: Dinosauria, Psittacosauridae, *Hongshanosaurus*, ontogeny, Lower Cretaceous, western Liaoning

1 Introduction

Psittacosaurids, or parrot-beaked dinosaurs, were a group of small-sized, bipedal herbivorous dinosaurs known only from the Early Cretaceous of East Asia (You and Dodson, 2004). *Hongshanosaurus houi* You et al. 2003 from western Liaoning Province of China represents the second genus of Psittacosauridae (You et al., 2003). The holotype of *Hongshanosaurus houi* is an almost complete juvenile skull and lower jaw. Here, we describe an adult specimen consisting of a complete skull and lower jaw from the same locality and horizon of the holotype. Comparative studies of these two specimens show that they can be assigned to the same species, and different features between them can be explained ontogenetically.

2 Systematic Paleontology

Dinosauria Owen, 1841
Ornithischia Seeley, 1887
Ornithopoda Marsh, 1881
Marginocephalia Sereno, 1986
Psittacosauridae Osborn, 1923
Hongshanosaurus You, Xu et Wang, 2003

Type species: *Hongshanosaurus houi* You, Xu et Wang, 2003

Diagnosis: As for the type and only known species.

Hongshanosaurus houi You, Xu et Wang, 2003

Holotype: Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) V 12704, an almost complete juvenile skull with articulated lower jaw.

Referred specimen: IVPP V 12617, a complete skull and lower jaw of an adult.

Type locality and horizon: Lujiatun site, Beipiao City, Liaoning Province, China. Lujiatun Bed, Yixian Formation, Early Cretaceous (Wang et al., 1998; Zhou et al., 2003; but see Ji et al., 2004 for different opinion on the age of the Lujiatun Bed).

Revised diagnosis: Psittacosaurid distinguishable from *Psittacosaurus* by having preorbital portion about half of basal skull length, and the elliptical external naris, orbit, and lower temporal fenestra with the major axis oriented caudodorsally.

Description of the referred specimen

The virtually complete skull is preserved in three-dimensions (Figs. 1, 2a–f). In dorsal view, the skull has a width than length, with a narrow beak, a relatively wide and straight caudal margin, and the robust jugal horns flaring laterally ventral to the orbit. In lateral view, the snout slopes rostroventrally from the orbit to the rostralmost tip. As a diagnostic feature, the preorbital portion composes about half of the basal skull length. The skull roof is flat directly above the orbit but curves slightly caudoventrally above the lower temporal fenestra.

The external naris is elliptical and is located high in the caudodorsalof the snout. The narial opening is bordered by the nasal dorsally and by the premaxilla ventrally. No antorbital fossa or fenestra is evident but a small opening

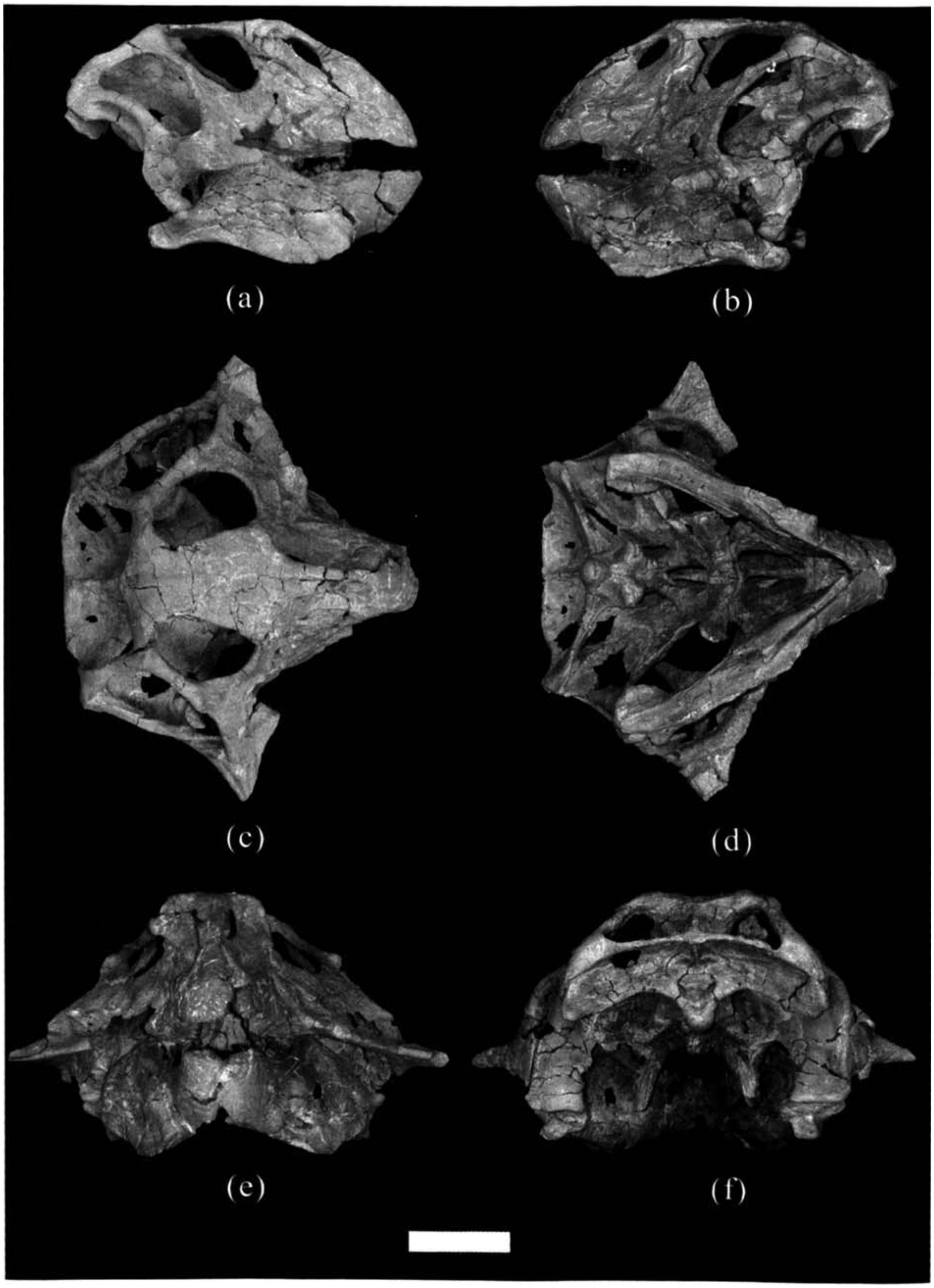

Fig. 1. Photographs of skull and lower jaw of referred specimen (IVPP V 12617) of *Hongshanosaurus houi* You, Xu et Wang, 2003 in right lateral (a), left lateral (b), dorsal (c), ventral (d), rostral (e), and caudal (f) views.
Scale bar is 5 cm.

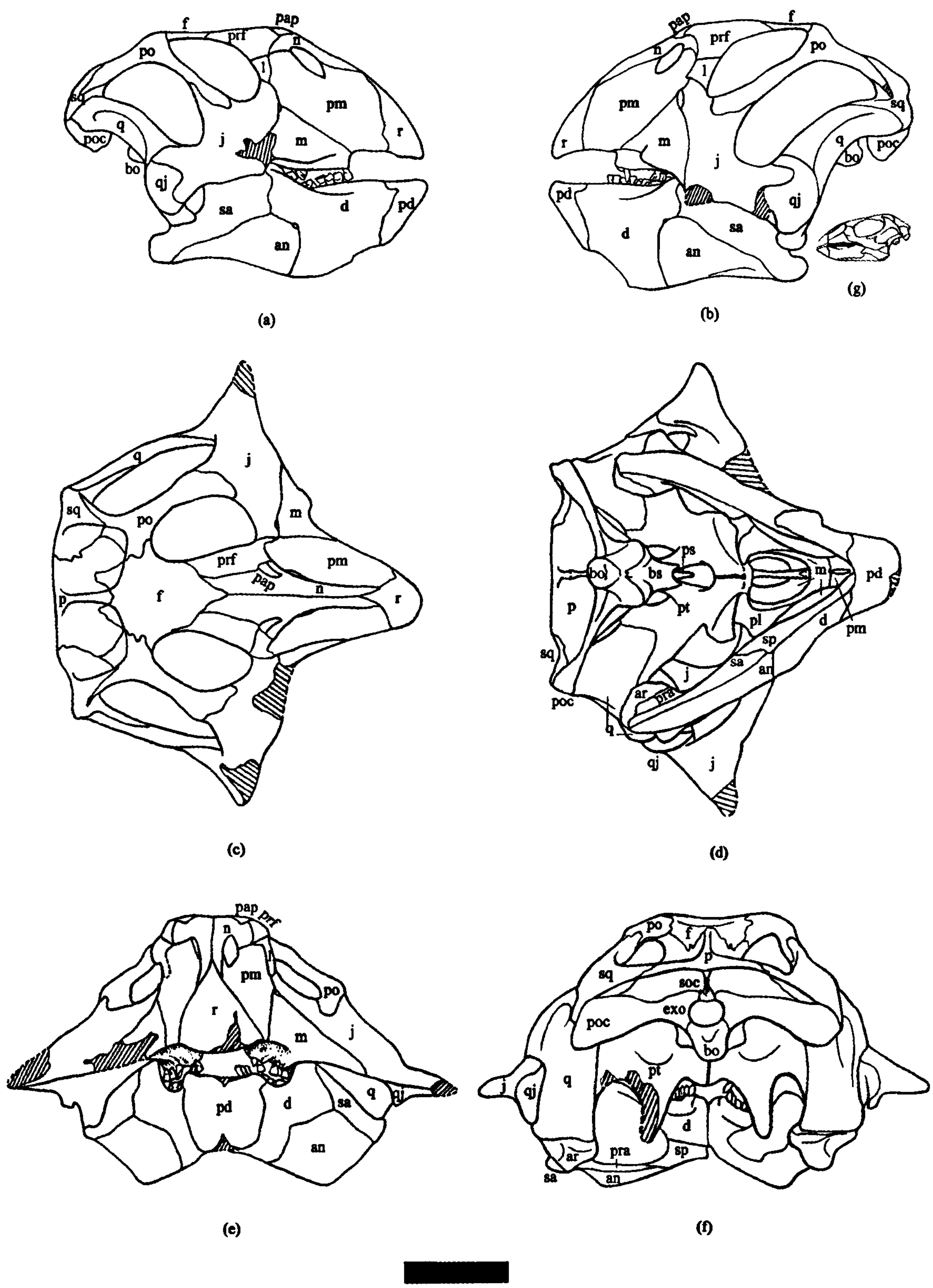

Fig. 2 a–f: Outlines of skull and lower jaw of referred specimen (IVPP V 12617) of *Hongshanosaurus houi* You, Xu et Wang, 2003 in right lateral (a), left lateral (b), dorsal (c), ventral (d), rostral (e), and caudal (f) views. g: Outline of skull and lower jaw of holotype (IVPP V 12704) of *Hongshanosaurus houi* You, Xu et Wang, 2003 in left lateral view.

Abbreviations: an – angular; ar – articular; bo – basioccipital; bs – basisphenoid; d – dentary; exo – exoccipital; f – frontal; j – jugal; l – lacrimal; m – maxilla; n – nasal; p – parietal; pap – palpebral; pd – predentary; pl – palatine; pm – premaxilla; po – postorbital; poc – paroccipital process; pra – prearticular; pre – prefrontal; pt – pterygoid; q – quadrate; qj – quadratojugal; r – rostral; sa – surangular; soc – supraoccipital; sp – splenial; sq – squamosal; v – vomer. Scale bar is 5 cm.

occurs at the joint between the premaxilla, maxilla, and jugal. The orbit is likewise elliptical, located on the upper half of the lateral surface of the skull. Its major axis is directed caudodorsally where the orbit tapers to an acute end. The lower temporal fenestra, also elliptical, is larger than the orbit. The upper temporal fenestra is subrectangular in shape, extending almost to the caudal edge of the skull. A very small mandibular foramen on the middle of the lateral surface of the lower jaw is bounded by the dentary dorsally and the angular ventrally.

Skull roof: The rostral bone covers the premaxillae on both sides and wedges caudodorsally between the nasals at the midline. In lateral view, the rostral bone is triangular in shape, with a long, vertical caudal margin but a short, horizontal ventral border. The rostral bone does not extend beyond the rostral tip of the lower jaw, and does not curve downward. It appears round, rather than pointed, in dorsal view.

The premaxilla is the dominant element on the lateral surface of the skull. Its sheet-like, dorsoventrally broad caudolateral process contacts the nasal dorsally, the lacrimal and the jugal caudally, and the maxilla ventrally. The ventral edge of the premaxilla is short, horizontal, and is edentulous. In palatal view, the palatal processes of the premaxillae meet at the midline, enclosing a small oval foramen. The caudal margins of the premaxillae are straight and contact the palatal processes of the maxillae caudally, forming a short secondary palate together.

The maxilla is triangular in lateral view, with the upper apex positioned rostroventral to the ventral border of the orbit. Its rostral portion, which is covered by the premaxilla, is larger than the caudal portion, which abuts the jugal. The tooth-bearing lower edge is well emarginated medially, and protrudes further ventrally than the ventral borders of the rostral and the premaxilla. The palatal processes of the maxilla appear to fuse to each other while suturing with the premaxilla rostrally and the palatine caudolaterally.

The nasal is a long bone, flanking its counterpart while running caudodorsally up the midline. It is narrowest where it contacts the rostral bone rostrally, and expands slightly caudally, reaching the maximum width where it first meets the prefrontal. It terminates caudally with the frontal above the orbit.

The lacrimal is a relatively small, squarish element, bounded by the premaxilla rostrally, the prefrontal dorsally, and the jugal ventrally. It contributes to a small part of the rostroventral border of the orbit. No openings or canals are developed on the lateral surface of the lacrimal.

The prefrontal forms the rostrodorsal border of the orbit. It is bounded by the lacrimal ventrally, the nasal rostrally and dorsally, and the frontal caudally. Its rostrolateral edge forms a ridge that encloses a small, concave, smooth medial surface.

A small, triangular bone attached to the rostrodorsal edge of the prefrontal, and lying on the nasal, is probably the palpebral, although it is not located in the expected position for that element.

The stout jugal borders the orbit and the lower temporal fenestra ventrally. It protrudes laterally, forming the well-developed horn that is triangular in dorsal view. The ventral surface of this horn is flat and level with the maxillary tooth row. The dorsoventral height of the jugal under the orbit is greater than that under the lower temporal fenestra. Its postorbital process is short and largely covered laterally by the jugal process of the postorbital. The caudal process of the jugal is bifurcated and is covered laterally by the rostral portion of the quadratojugal. The jugal does not reach the caudal end of the skull.

The quadratojugal is a small, dish-like element wedged between the jugal laterally and the quadrate medially. Its rostral portion is covered by the jugal, and the caudal part is exposed laterally at the caudoventral end of the skull. The quadratojugal is relatively short dorsoventrally, approximately the same height as the caudal process of the jugal.

The postorbital is a triradiate element. Its jugal process is very long, covering the medially placed postorbital process of the jugal. Together, these form the caudal border of the orbit. The squamosal process of the postorbital is equally long to the jugal process; it roofs the lower temporal fenestra and has a pointed end that contacts the medial squamosal. In dorsal view, the postorbital sends a short but wide process medially to interdigitate with the frontal; together, these elements form the rostral border of the upper temporal fenestra.

The frontals are fused into a single unit. Visible in dorsal view, the rostral tip inserts between the two nasals along the midline, terminating at a position above the midpoint of the orbit. The frontal contacts the prefrontal rostrolaterally, then forms the caudodorsal border of the orbit. The caudal portion of the frontal contacts the postorbital laterally and the parietal medially, forming the rostromedial border of the upper temporal fenestra.

The fused parietals form a midline ridge that separates the two upper temporal fenestrae. Rostrally, the element contacts the frontals. It terminates caudally with a straight, transverse edge that conceals the occipital region from dorsal view. Caudolaterally, it contacts the squamosal and constitutes the caudal border of the upper temporal fenestra. In caudal view, a thin sheet of bone wraps downward, contacting the underlying supraoccipital and exoccipitals.

The squamosal is located at the upper caudolateral corner of the skull. Rostrally, it contacts the postorbital with which it forms the bar separating the upper- and lower temporal fenestrae. Ventrally, the squamosal sends a process medial to the quadrate that extends about half the length of the latter's shaft. Medially, the squamosal sutures with the parietal; each constitutes roughly half of the skull's caudal margin. In caudal view, the squamosal contacts the enlarged paroccipital process along its ventrolateral corner.

Quadrate and palate: The quadrate is composed of a stout shaft and a sheet-like pterygoid ramus that spreads rostromedially onto the quadrate ramus of the pterygoid. In lateral view, the otic process slopes caudodorsally, but the lower half of the shaft is relatively vertical. It is mostly covered by the medial surface of the quadratojugal laterally; only the small, ventral portion that articulates with the lower jaw is exposed. A shallow groove runs dorsoventrally along the caudolateral surface of the quadrate. In caudal view, the shaft is revealed to be much stouter than is apparent in lateral view, and covered by the squamosal dorsally. The mandibular process articulates with the lower jaw across a mediolaterally wide joint.

In ventral view, a short secondary palate is exposed rostrally, formed by the palatal processes of the premaxillae and maxillae. The vomers appear to be fused to each other; the resultant element arches in the sagittal plane from the secondary palate at its rostral end to the pterygoid caudally. The palatine borders the internal nares laterally and contacts the maxilla rostromedially and the pterygoid caudomedially. The pterygoid comprises the caudal half of the palate. Its mandibular ramus is long and directed ventrolaterally toward the adductor fossa of the lower jaw. The thin, bifurcate quadrate ramus is widely applied to the pterygoid ramus of the quadrate caudolaterally. A tiny bar, visible along the midline and in front of the basisphenoid, is probably a part of the parasphenoid. The ectopterygoid is not visible in ventral view.

Braincase: In caudal view, the foramen magnum is bounded by the supraoccipital dorsally, the exoccipitals laterally, and the basioccipital ventrally. The supraoccipital is relatively small, and contributes only to the mid-portion of the dorsal border of the foramen magnum. It is covered by the parietal dorsally. The exoccipital, completely fused to the opisthotic, borders the foramen magnum laterally. The laterally directed paroccipital process enlarges slightly toward its distal end. The basioccipital borders the foramen magnum ventrally and forms an occipital condyle that is directed caudally and slightly downward. In ventral view, the short occipital condyler neck expands rostrally to form the basal tubera, which abut the rostral basisphenoid. The basisphenoid continues rostrally, giving rise to the basipterygoid process toward its rostrolateral end. The basisphenoid probably terminates rostrally adjacent to a short parasphenoid bar.

Lower jaw: The lower jaw is dorsoventrally deep in lateral view. The predentary is subtriangular in lateral view, with a rudimentary lateral process. The rostral tip of the predentary is round and U-shaped in ventral view. The dentary forms the rostral half of the coronoid process. The ventral border of the dentary is sinuous and forms the bulk of a prominent, low, ventrally convex flange at its caudoventral corner. A tiny external mandibular fenestra is bordered by the dentary and the angular. The angular is well exposed laterally with a sheet-like process that also wraps around the ventral margin of the mandible. In medial view, the angular is covered by the splenial rostrally and the prearticular dorsally. The surangular forms the caudodorsal portion of the lower jaw in lateral view. It contacts the dentary rostrally and forms the caudal half of the coronoid process. The surangular extends caudoventrally to the end of the lower jaw, covering the angular underneath. The articular is mediolaterally broad but dorsoventrally thin where it articulates with the stout quadrate.

Dentition: The premaxillae are edentulous. Maxillary and dentary crowns are positioned along the tooth rows without overlap along the crown edges. There are approximately eight teeth in each maxilla and dentary, all of which are approximately equal in size. All crown surfaces are covered with enamel; however, the enamel is thicker on the buccal surface of the maxillary crowns and the lingual surface of the dentary crowns than on their respective opposing sides. The buccal surfaces of the maxillary crowns are dominated by a prominent median ridge, while those of the dentary crowns are ornamented by several weak ridges.

3 Discussion

IVPP V 12617 is clearly demonstrated as a member of Psittacosauridae by the existence of the highly elevated naris, the lack of antorbital fossa and fenestra, the extremely broad caudolateral process of the premaxilla, long rostral process of nasal extending below the naris, well-developed jugal process from the midsection of the jugal, and elongate jugal and squamosal processes of postorbital (Sereno; 1990, 2000; Russell and Zhao, 1996; You and Dodson, 2004).

Furthermore, IVPP V 12617 can be assigned to *Hongshanosaurus*. *Hongshanosaurus* is distinguished from *Psittacosaurus* by a relatively long preorbital portion (about 50% of the basal skull length; while less than 40% in *Psittacosaurus*) and the elliptical and caudodorsally orientated external naris, orbit, and lower temporal fenestra (while these openings are generally round or subtriangular in shape and dorsoventrally oriented in *Psittacosaurus*) (You et al., 2003). All these features exist in IVPP V 12617.

IVPP V 12617 probably belongs to the type and only species of *Hongshanosaurus*: *H. houi*, and the differences between IVPP V 12617 and the holotype of *H. houi* can be explained ontogenetically. For example: in the adult specimen, the size of the orbit enlarged, the length of the jugal horns increased, and the dorsoventral depths of both the jugal and the lower jaw greatly enlarged (Fig. 2g).

4 Conclusions

IVPP V 12617 is an adult specimen of *Hongshanosaurus houi.* Within the family Psittacosauridae *Hongshanosaurus* is distinguishable from its sister taxon *Psittacosaurus* by haivng long preorbital portion about half of the basal skull length, and having elliptical external naris, orbit, and having the lower temporal fenestra oriented caudodorsally.

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