THE MIXOSAURID ICTHYOSAUR PHALARODON CF. P. FRAASI FROM THE MIDDLE TRIASSIC OF GUIZHOU PROVINCE, CHINA

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INTRODUCTION

THE FAMILY Mixosauridae Baur, 1887 is a dominant group of Middle Triassic ichthyosaurs. Its generic composition has been controversial, but recent findings from southern China enabled Jiang et al. (2006) to recognize two monophyletic taxa within the clade, suggesting the presence of two genera within the family, namely Mixosaurus Baur, 1887 and Phalarodon Merriam, 1910. The latter genus, which was invalidated at one point (Nicholls et al., 1999; McGowan and Motani, 2003), was recently resurrected by Schmitz (2005) by validating its type species. Mixosaurus is Tethyan in distribution, whereas Phalarodon had been known mostly from North America and Spitsbergen, apart from a possible juvenile from Switzerland (Brinkmann, 1997, 1998). More recently, Jiang et al. (2005) reported a largely complete, yet poorly preserved skeleton as the first record of the genus Phalarodon from Asia and referred it to Phalarodon sp. However, important synapomorphies were not clearly identified, and evidence has since emerged that the specimen had been tampered with by farmers after it was collected. In the light of the cladistic analysis by Jiang et al. (2006), the referral of the specimen to the genus Phalarodon is questionable.

A new specimen was excavated in Panxian County, near the western border of Guizhou Province, from the Geological Museum and Department of Geology of Peking University. The new material, the authenticity of which is unquestionable, is from the same stratigraphic horizon as the specimen of Jiang et al. (2003). It contains a well-preserved skull and some postcranial bones, and for the first time firmly establishes the presence of the genus Phalarodon in the western Pacific. Also, the skull is preserved in a very unusual condition: it had been split near the sagittal plane, enabling examination of the poorly known interior suture pattern. This illustrates that mixosaurids had extensive overlap of dermal skull elements, as in other ichthyosaurs (compare Sollas, 1916; McGowan and Motani, 2003).

SYSTEMATIC PALEONTOLOGY

Order Ichthyosauria de Blainville, 1835
Family Mixosauridae Baur, 1887

Diagnosis (modified from Motani, 1999a).—Premaxilla posteriorly narrow and nearly pointed, scarcely entering external naris; long sagittal crest reaching nasal; large anterior terrace of upper temporal fenestra, reaching nasal; pubis much larger than ischium; high, narrow neural spines; midcaudal vertebral centra with increased height.

Genus Phalarodon Merriam, 1910

Type species.—Phalarodon fraasi Merriam, 1910.

Diagnosis (Jiang et al., 2006).—Nasal region with pronounced narial shelf; maxillary tooth implantation with sockets.

Material examined.—The specimen is housed in the collections of the Geological Museum of Peking University (GMPKU-P-1032), bearing the number GMPKU-P-1032. It was prepared by a combination of mechanical and chemical methods.

Occurrence.—Yangjuan Village, Xinmin District, Panxian County, Guizhou Province, China. The fossil-bearing horizon, about 15 cm in thickness, lies immediately below a layer of white clay (ca. 5 cm thick, representing a marker bed for the most fossiliferous horizon). This marker bed is situated within the upper member of the Guanling Formation, which consists of alternating, thinly bedded bituminous limestones and marls. According to contributed data (Yang et al., 1999), the stratigraphic age of the horizon is Pelsonian (zone of Nicorella germanicus Kozur, 1990; Anisian, Middle Triassic).

DESCRIPTION

Skull.—The left half of the skull is preserved almost completely in GMPKU-P-1032, spanning 205 mm. The skull is mainly seen in medial view, but parts of the antorbital region have also been preserved from the external side. The skull bones are well preserved except for a partially destroyed region dorsal to the orbit (Figs. 1–3).

The anteriormost part of the premaxilla is broken. The premaxilla forms the alveolar margin for about 80 mm and is then replaced by the maxilla. Posteriorly, the premaxilla narrows and wedges in between nasal and maxilla to form a part of the anterior margin of the external naris (Figs. 1, 2), therefore lacking both supra- and subnarial processes. Its posteroventral suture with the maxilla is curved whereas its posterodorsal contact with the nasal is straight.

The triangular maxilla is completely preserved and has a postnarial maxillary process. It is not possible to discern its exact dorsal extent. The lateral aspect of the maxilla exhibits a long posterior ramus which extends below the orbit. Medially, this process seems to be covered by the jugal.

The elliptical external naris can be observed in both medial and external views. It is 6 mm long and 2 mm high externally and more laterally than dorsally oriented. The dorsal margin is completely formed by the nasal, the ventral by the maxilla. The distance between external naris and anterior orbital margin is about 22 mm. Anterolateral to the external naris, a small shelf, formed by the maxilla, is present.

The dorsal part of the nasal forms the anterior part of the sagittal crest, which extends anteriorly beyond the anterior margin of the external naris (Figs. 1, 2). The sagittal crest is broken along its dorsal margin posteriorly, but in its ventral part the crest is formed by the nasal, frontal, and parietal. The crest is 22 mm high at the level of the posterior margin of the orbit, and is 14 mm high at the level of the posterior margin of the external naris. The parietal is partly broken. It contributes to the posterior part of the sagittal crest, and meets the frontal in a concave suture. It joins the supratemporal posteriorly to form a domelike structure, as in other mixosaurids.
The orbit is 40 mm high dorsoventrally and 44 mm long anteroposteriorly. Its interior rim consists of the prefrontal, frontal, postorbital, jugal, and possibly the lacrimal. In medial view, the prefrontal has a much larger extent than in lateral view, which was unrecognized before. The frontal also forms a part of the interior rim of the orbit, which is different from the general lateral aspect known in Mixosauridae. Posteriorly, it meets a long anterior ramus of the postorbital, which consequently excludes the postfrontal from the orbit. The postorbital is a large element. Dorsally, it seems to form a concave suture with the postfrontal, and...
does not separate the postfrontal from supratemporal. Its maximum anteroposterior span is 9 mm, while the same for the postorbital skull region is 28 mm. The slender jugal comprises the suborbital bar and a high postorbitally ascending ramus that medially covers the postorbital. Anteriorly, the suborbital bar extends to the anterior margin of the orbit and meets the maxilla. It is not clear if the jugal internally meets lacrimal or not. An external contact between these bones is present.

In the cheek region, only two bones are preserved. The ventral one is the quadrate, the dorsal the supratemporal. The quadrate is exposed anteromedially. It has a massive condyle, being 18 mm high and 17 mm wide. The dorsal convexity of the quadrate abuts a concave socket of the supratemporal, as in *Ichthyosaurus* (McGowan, 1973). The supratemporal is the largest element in the temporal region.

**Mandible.**—The anteriormost part of the slender lower jaw is broken. Posteriorly, the dentary probably terminates at the level of the anterior margin of the orbit, not far posterior to the last preserved tooth. The surangular is exposed posterior to the dentary and extends anteriorly beyond the level of the posteriormost dentary tooth. A long retroarticular process is present (Figs. 1, 2). The angular has a large medial exposure and reaches far anteriorly. Other mandibular bones are not discernable.

**Dentition.**—Four closely spaced dentary teeth are preserved in situ (Figs. 1, 2; for dimensions see Table 1). The posteriormost tooth is placed below the lacrimal. The teeth are mesiodistally elongated and laterally compressed. The tooth crowns are very blunt or sometimes even flat with longitudinal striations on the surface. A constriction separates the tooth root from crown. A labiolingual constriction of the tooth crown, present in *Phalarodon fraasi* (Motani, 2005) and *P. callawayi* (Schmitz et al., 2004), is absent. There is no dental groove; the tooth implantation in the exposed part is ankylosed thecodonty for definition (Motani, 1997). The roots are largely exposed and form about half of the total tooth height, as in *P. fraasi*.

Five maxillary teeth are hidden from the internal view by matrix. To avoid damaging the internal side of the specimen, the area near the external naris was prepared from the external side. The teeth are placed more externally with respect to the lower jaw teeth, indicating a wide labial mandibular shelf, as in *Phalarodon fraasi* (Motani, 2005) and *P. callawayi*. The anteriormost exposed two teeth (m1 and m2) are conical, the next one (m3) is blunt, and the fourth (m4) is elongate, slightly laterally compressed, and low-crowned. It is slightly smaller than the posterior dentary teeth (Fig. 3; Table 1). Postero medial to m4, a small replacement tooth (m5) is present. The mode of tooth implantation is ankylosed thecodont.

There are two dislocated teeth. The anterior one (i1) is robust, with a domelike and blunt crown, which is clearly set off from the root. The posterior one (i2) has a conical and pointed crown (Figs. 1, 2; Table 1).

**Postcranial bones.**—Six complete and three damaged neural spines are present, which are about 30 mm high and 4 mm wide. The anterior part of a pectoral girdle element is also preserved (Fig. 1). It is a broad, fan-shaped element, at least 60 mm long. Its anterior extension is 24 mm long, with a notch at the dorsal margin, which might be caused by preservation. Because of the fragmentary preservation, a clear identification is not possible.

**DISCUSSION**

The described specimen can be clearly identified as a member of the Mixosauridae based on several features, including the shape of the premaxilla (Motani, 1999a, 1999b; Nicholls et al., 1999; Maisch and Matzke, 2000; Sander, 2000; Schmitz et al., 2004).

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Within the family, the narial shelf is a synapomorphy of the genus *Phalarodon* (Jiang et al., 2006). The absence of a dental groove in the maxilla is also a synapomorphy of the genus *Phalarodon*. Therefore, the assignment of the specimen to the genus *Phalarodon* seems warranted. These synapomorphies cannot be confirmed in the specimen described by Jiang et al. (2003) as *Phalarodon* sp., whereas the possible synapomorphies listed there are no longer apomorphic to the genus *Phalarodon* (Jiang et al., 2006). Therefore, the new specimen is the only definitive record of the genus in Asia at this point.

The species assignment is more problematic. The dentition indicates that GMPKU-P-1032 is morphologically closer to *Phalarodon fraasi* and *P. callawayi* (Schmitz et al., 2004) than to *P. atavus* (Merriam, 1910; Motani, 2005). The maxillary teeth, however, are intermediate between *P. fraasi* and *P. callawayi*: they are smaller than those of *P. fraasi* and are not massive below the external naris. Furthermore, the top of the tooth crowns seems to lack mesiodistal ridges, which are present in both *P. fraasi* and *P. callawayi*. As the maxillary dentition cannot be fully prepared without damaging the specimen, their detailed morphology is indiscernible. Another difference between the two species and GMPKU-P-1032 is the extent of the narial shelf, which is less pronounced in the Chinese specimen, as in *P. atavus*. However, this may be an artifact of preservational deformation. A further difference is present in the mandible: GMPKU-P-1032 has a low coronoid process, unlike in *P. fraasi* and *P. callawayi*. Within the family, the narial shelf is a synapomorphy of the genus in Asia at this point.

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The observed morphological differences indicate that GMPKU-P-1032 could represent a new taxon. Because of the similarity to *P. fraasi* in the lower dentition, we refer GMPKU-P-1032 to *Phalarodon* cf. *P. fraasi*, until new data become available.

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**REFERENCES**


