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Spinosaurid teeth from the Lower Cretaceous of Ko Kut, eastern Thailand.

Dents de spinosauridés du Crétacé inférieur de Ko Kut, Est de la Thaïlande

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Abstract

Isolated theropod dinosaur teeth from Ko Kut (Kut Island) in eastern Thailand are referred to an indeterminate spinosaurid on the basis of their morphology and ornamentation. On the basis of other spinosaurid occurrences in Thailand and other parts of Asia, they support the attribution of the fossil-bearing beds on Ko Kut to the Lower Cretaceous rather than the Jurassic. The lack of ornithischian remains in the Ko Kut faunal assemblage suggests that it is coeval with the Sao Khua Formation (Barremian) of NE Thailand.

Key words : Dinosauria, Theropoda, Spinosauridae, Kut Island, Thailand, Early Cretaceous.

Résumé

Des dents de théropodes isolées provenant de Ko Kut (île de Kut) dans l'Est de la Thaïlande sont attribuées à des spinosauridés indéterminés d'après leur morphologie et leur ornementation. Compte tenu de la distribution des spinosauridés dans d'autres régions de Thaïlande et d'Asie, elles soutiennent l'attribution des couches fossilifères de Ko Kut au Crétacé inférieur plutôt qu'au Jurassique. L'absence de restes d'ornithischiens dans l'assemblage faunique de Ko Kut suggère qu'il est contemporain de la Formation Sao Khua (Barrémien) du NE de la Thaïlande.

Mots-clés : Dinosauria, Theropoda, Spinosauridae, île de Kut, Thaïlande, Crétacé inférieur.

1. Introduction

Ko Kut (Kut Island, sometimes spelled Ko Kood), in Trat Province, lies in the north-eastern part of the Gulf of Thailand (Fig. 1), some 35 km W of the mainland (11°39'30" N, 102°32'32" E). Following an initial discovery on the south-eastern coast of the island by Michael F. Ridd in the 1970s, the first fossil vertebrates from Ko Kut Island were reported by Buffetaut and Ingavat (1983), who listed remains of hybodont sharks, *Lepidotes* sp., turtles, crocodiles and possibly plesiosaurs found on grey sandstone outcrops at two sites on the shores of the island, just above sea level. This assemblage was tentatively assigned an Early Jurassic age, which was in agreement with the attribution of the fossil-bearing strata to the Phu Kradung Formation (at that time referred to the Lower Jurassic) on the geological map of Thailand (Tansathien et al., 1979).

More recently, in 2007, fossil vertebrates were collected from the seaside outcrop on the south-eastern coast (Ao Kalang, see map in Cuny et al., 2010) by a party from the Palaeontological Research and Education Centre (PRC) of Mahasarakham University and the Natural History Museum of Denmark. This new material was described by Cuny et al. (2010), who identified hybodont sharks (*Hybodus* sp., *Isanodus paladeji*, *Heteroptychodus kokutensis*), actinopterygians (Semionotiformes indet., *Lepidotes* sp.), indeterminate turtles, crocodiles (goniopholidids and cf. *Theriosuchus* sp.) and theropod dinosaurs. This assemblage is indicative of a freshwater environment and was considered as similar to those from the Sao Khua Formation of the Khorat Plateau of north-eastern Thailand by Cuny et al. (2010) who therefore assigned an Early Cretaceous age to the vertebrate-bearing beds on Ko Kut.

During a further PRC field trip in 2011, additional vertebrate fossils were collected from the same exposure at Ao Kalang. Specimens from Ko Kut in the PRC collection (institutional abbreviation: PRC) not previously reported include poorly preserved vertebrae of sauropod dinosaurs and teeth of spinosaurid theropods. The latter are described in the present paper and their biostratigraphic significance is discussed.

2. Systematic description

Dinosauria Owen, 1842
Ornithoscelida Huxley, 1870 (*sensu* Baron et al., 2017)
Theropoda Marsh, 1881
Spinosauridae Stromer, 1915

Spinosauridae indet.

Two teeth from Kut Island are referable to spinosaurid theropods. One (PRC 33) is poorly preserved, lacking the root and the tip of the crown (Fig. 2). It is 25 mm long as preserved. The crown shows a slight mediolateral compression and is recurved, the distal margin being concave and the mesial margin convex. The surface of the tooth is markedly ribbed, with about a dozen distinct longitudinal ridges on each face. No prominent, well-defined carinae are distinguishable on the mesial and distal margins. Although the enamel surface is poorly preserved, a faint wrinkling is discernible in some places, between the ridges.

The second specimen (PRC 32) is a nearly complete, well preserved tooth (Fig. 3), 39 mm long from the slightly worn apex to the base of the partly preserved root. The crown itself is 26 mm long. The root is smooth, hollow and, like the crown, slightly compressed mediolaterally, with an oval outline. The crown is slightly recurved, with a concave distal margin and a convex mesial margin. One of the faces, probably the lingual one, is flatter than the other. The crown is strongly ribbed, with about 15 longitudinal ridges on each face. The ridges are very distinct for most of their length but become less so close to the apex, where they are replaced by irregular wrinkles. A distinct wrinkling of the enamel is visible between the ridges, especially close to the boundary with the root (Fig. 4). There are no prominent well-defined carinae on the mesial and distal margins (in other words the carinae are not different from the rest of the ribs that cover the crown surface).

Measurements of PRC 32 (following Hendrickx et al., 2015):

Crown height (CH)	39 mm
Crown base length (CBL)	13 mm
Mid-crown length (MCL)	8 mm
Crown base width (CBW)	10 mm
Mid-crown width (MCW)	6 mm

Both teeth show characters usually found in Asian spinosaurids, notably the weak labiolingual compression of the crown and the type of curvature, with a convex mesial margin and a concave distal margin. The fine wrinkling seen on at least part of the enamel surface is commonly seen on spinosaurid teeth (Buffetaut, 2013) and the well-marked longitudinal ridges, which become less regular close to the apex, are to be found on most spinosaurid teeth from Asia, with the exception of the 'smooth morphotype' from Pra Prong in eastern Thailand (Suteethorn et al., 2018). The teeth from Ko Kut are easily distinguishable from crocodylian teeth because they are curved in the mesiodistal plane rather than the labiolingual plane. They differ from plesiosaur teeth in their labiolingual compression, the fine wrinkling of the enamel surface and the way the longitudinal ridges tend to become less regular close to the apex. Although there is no doubt that the teeth from Kut Island belong to a spinosaurid, they differ from *Siamosaurus suteethorni* Buffetaut & Ingavat, 1986, from the Sao Khua Formation of the Khorat Plateau, in the lack of distinct carinae on the mesial and distal margins. Because it is still difficult to assess the taxonomic diversity of Asian spinosaurs, it seems best to consider the teeth from Ko Kut as Spinosauridae indet.

3. Stratigraphic implications

The occurrence of spinosaurid theropods in Asia was first reported by Buffetaut and Ingavat (1986) on the basis of teeth from the Sao Khua Formation of the Khorat Plateau, north-eastern Thailand. Since then, spinosaurids have been reported from various other Asian countries : Japan (Hasegawa et al., 2003 ; Kubota et al., 2017), China (Buffetaut et al., 2008), Laos (Allain et al., 2012) and Malaysia (Sone et al., 2015). All localities that have yielded spinosaurid remains in Asia are Early Cretaceous in age. The purported baryonychine tooth from the Upper Cretaceous of Henan, China (Hone et al., 2010) lacks clear spinosaurid characters and is of doubtful affinities. Spinosaurid teeth are known from the Late Jurassic in Tanzania (Buffetaut, 2008, 2013) and France (Vullo et al., 2014) and teeth from the Middle Jurassic of Niger may also belong to this family (Serrano-Martínez et al., 2015, 2016), but no remains of these dinosaurs have hitherto been found in Jurassic deposits in Asia. They are conspicuously absent from the rich Jurassic dinosaur-bearing formations of China. In Thailand itself, the Phu Kradung Formation of the Khorat Plateau, which appears to be at least partly Late Jurassic in age, has yielded abundant and diverse vertebrate assemblages, including several groups of dinosaurs (Suteethorn et al., 2018), but spinosaurids are not present. It therefore seems legitimate to accept that the occurrence of spinosaurid teeth in the fossil vertebrate assemblage from Ko Kut is indicative of an Early Cretaceous rather than Jurassic age, in agreement with the conclusions of Cuny et al. (2010).

In north-eastern Thailand, spinosaurids are known from two formations of the Khorat Group, namely the Sao Khua Formation and the Khok Kruat Formation (Buffetaut et al., 2006). The Sao Khua Formation is referred to the Barremian on the basis of freshwater bivalves (Tumpeesawan et al., 2010), while the Khok Kruat Formation is probably Aptian in age, according to various lines of evidence, including hybodont sharks and palynomorphs (Racey et al. 2009). However, distinguishing spinosaurid teeth from the Sao Khua and Khok Kruat Formations is not easy. Several morphotypes, which at least in some cases seem to correspond to distinct taxa, occur both in the Sao Khua Formation (Suteethorn et al., 2018) and in the Khok Kruat Formation (Wongko et al., in press). Because of this morphological diversity, although the teeth from Kut Island differ from *Siamosaurus suteethorni*, from the Sao Khua Formation, in some respects, notably the lack of well-defined carinae, this does not imply that the fossil-bearing stratum cannot be correlated with the Sao Khua Formation.

The dinosaur material previously reported from Ko Kut (Cuny et al., 2010), consisting of a single blade-like, serrated tooth could not be identified beyond Theropoda indet. and is therefore of little use for stratigraphic correlation. The spinosaurid teeth described in the present paper are more useful in this respect, since they apparently exclude a Jurassic age. As noted above, they cannot really be used to decide whether the fossil-bearing beds on Kut Island are closer in age to the Sao Khua or Khok Kruat Formations of the Khorat Group, and the above-mentioned poorly preserved sauropod vertebrae are of no use in this respect. However, the absence (so far) of any ornithischian remains in the fossil assemblage from Kut Island may suggest similarities with the Sao Khu assemblage rather than that from the Khok Kruat Formation. Despite the fact that thousands of dinosaur bones and teeth have been found in the Sao Khua Formation, no ornithischian remains have so far been found (Buffetaut & Suteethorn, 1999; Buffetaut et al., 2006), whereas they are abundant in the Khok Kruat Formation, where they are represented by iguanodontians and psittacosaurids (Buffetaut et al., 2005). If confirmed, the lack of ornithischians in the Ko Kut fauna would certainly support the correlation with the Sao Khua Formation proposed by Cuny et al. (2010). On this basis, Cuny et al. (2010) concluded that the Ko Kut fossil assemblage was no older than Berriasian. As the Sao Khua Formation has been referred to the Barremian by Tumpeesawan et al. (2010), a similar age can be suggested for the fossil-bearing beds on Ko Kut. Whether the formation names used on the Khorat Plateau can be used for Ko Kut is a different question. The Khorat Group and the Mesozoic formations on Kut Island were probably deposited in different basins. The fossil-bearing beds on Kut Island are not very similar lithologically to the red beds of the Sao Khua Formation.

4. Conclusions

The spinosaurid teeth from Ko Kut extend the known geographical range of that dinosaur family in Thailand (spinosaurid remains were hitherto known from many localities on the Khorat Plateau and the Pra Prong locality in eastern Thailand). From a stratigraphic point of view, they confirm that the vertebrate-bearing beds on Kut Island are Early Cretaceous rather than Jurassic in age, as already shown by the freshwater shark assemblage described by Cuny et al. (2010). Spinosaurid teeth are known from both the Sao Khua and Khok Kruat formations in north-eastern Thailand and show notable variations in their ornamentation so that it is difficult to decide whether the teeth from Ko Kut are more reminiscent of those from either of these formations. However, the fact that no ornithischian remains have yet been found in the fossil assemblage from Ko Kut suggests closer faunal similarities with the Sao Khua Formation, in which this group of dinosaurs is conspicuously absent. This in turn suggests a Barremian age for the vertebrate-bearing beds on Ko Kut.

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Fig. 1. Location map showing the position of Ko Kut (Kut island) in the Gulf of Thailand.
Carte de localisation montrant la position de Ko Kut (île de Kut) dans le golfe de Thaïlande.

Fig. 2. Spinosaurid tooth from Ko Kut, PRC 33, in apical (A), labial (B), distal (C) and lingual (D) views. Scale bar : 1 cm.
Dent de spinosauridé provenant de Ko Kut, PR 33, en vues apicale (A), labiale (B), distale (C) et linguale (D). Barre d'échelle : 1 cm.

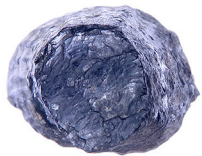
Fig. 3. Spinosaurid tooth from Ko Kut, PRC 32, in mesial (A), lingual (B), distal (C) and labial (D) views. Scale bar : 1 cm.
Dent de spinosauridé provenant de Ko Kut, PR 32, en vues mésiale (A), linguale (B), distale (C) et labiale (D). Barre d'échelle : 1 cm.

Fig. 4. Close up view of enamel wrinkling at the base of the crown of spinosaurid tooth PRC 32, from Kok Kut.
Vue rapprochée des plissements de l'émail à la base de la couronne de la dent de spinosauridé PRC 32, de Ko Kut.



*Bangkok

Ko Kut



A



B



C



D





A



B



C



D



5 mm