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## MESOZOIC VERTEBRATES FROM THAILAND: A REVIEW

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Newly discovered Mesozoic vertebrate localities in Thailand are reviewed. A Late Triassic (probably Norian) fauna from the Huai Hin Lat Formation at Chulabhorn Dam includes actinopterygian fishes, a lungfish, stegocephalian (*Cyclotosaurus*), and phytosaurs. The Phu Kradung Formation (?Liassic) has yielded a nearly complete lower jaw of the mesosuchian crocodile *Sunosuchus thailandicus*. Isolated dinosaur remains (indicative of sauropods and theropods) have also been found in various places in Jurassic and Cretaceous rocks. Vertebrate remains will be important for dating the predominantly continental formations of the Khorat Plateau of northeastern Thailand. All the Mesozoic vertebrates hitherto found in Thailand apparently have Laurasian affinities, which would indicate a collision of the Southeast Asian blocks with mainland Asia no later than the beginning of the Late Triassic.

**Key words:** fossil vertebrates, Dipnoa, Stegocephalia, Phytosauria, Crocodylia, Sauropoda, Theropoda, biostratigraphy, continental drift, Triassic, Jurassic, Cretaceous, Asia, Thailand.

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## INTRODUCTION

Until recently, little was known about the Mesozoic continental vertebrates of Southeast Asia. A possibly early Triassic therapsid had been found near Luang Prabang (Laos) as early as the end of the last century by Counillon (1896), and identified as *Dicynodon* by Repelin (1923) and by Piveteau (1938); and Late Cretaceous dinosaurs from Muong Phalane (Laos), including titanosaurs and hadrosaurs, had been described by Hoffet (1942, 1944). All this material from Laos would be worth revising. In Thailand, the fossil record of Mesozoic vertebrates was even scantier: a few isolated reptilian teeth found in the presumably Liassic Phu Kradung Formation of northeastern Thailand had been referred by Takai (Kobayashi, Takai and Hayami 1963) to plesiosaurs and ichthyo-

saur, but apart from this, virtually nothing was known. In 1978, the distal end of the femur of a sauropod dinosaur was reported from Phu Wieng, also in northeastern Thailand (Ingavat, Janvier and Taquet 1978; Ingavat and Taquet 1978). In the same year, a first Thai-French expedition collected more dinosaur remains (including theropod fragments) which have not yet been described. In 1979, a fragment of the lower jaw of a large crocodylian was collected from the Phu Kradung Formation near Nong Bua Lam Phu; it was subsequently described as a new species, *Sunosuchus thailandicus*, by Buffetaut and Ingavat (1980). In 1980, a second Thai-French palaeontological expedition was organised, and several vertebrate localities were discovered. The purpose of this paper is to give a brief review of what is known of the continental vertebrates from the Mesozoic of Thailand and of their significance.

#### THE GEOLOGICAL BACKGROUND

Almost all the known Mesozoic vertebrate localities of Thailand are in the northeastern part of the country, on what is known as the Khorat Plateau, a vast tabular area occupying about 155 000 km<sup>2</sup> (fig. 1). There, mainly continental Mesozoic sedimentary rocks reach a thickness of several thousand metres. This series, known as the Khorat Group, comprises conglomerates, sandstones, clays and sometimes limestones, which lie unconformably on folded Triassic or older rocks. The largely detritic rocks of the Khorat Group are now interpreted as a molasse deposit, resulting from the erosion of mountains created by the collision of the Southeast Asian blocks (see below) with southern China, sometime during the Triassic (Ridd 1980). The Khorat Group has been subdivided by various authors into several formations, but the stratigraphic nomenclature is still fluctuating, and different formation names are sometimes applied to the same unit. Ramingwong (1978) has recently published a useful review of the Khorat Group and its subdivisions. The nomenclature used here (fig. 2) is a compromise between several proposals.

Identifiable fossils are relatively scarce in the Khorat Group (see Iwai *et al.* 1975), and correlation with marine deposits is difficult, so that the age of the different formations is still rather uncertain, despite dating attempts mainly based on fossil plants. However, fossil vertebrates are locally fairly abundant, and it is hoped that they may ultimately be of great help in dating the terms of the Khorat Group. So far, fossil vertebrates of Late Triassic, Jurassic, and presumably Cretaceous age have been found on the Khorat Plateau. The main localities are briefly described below, from the oldest to the youngest.

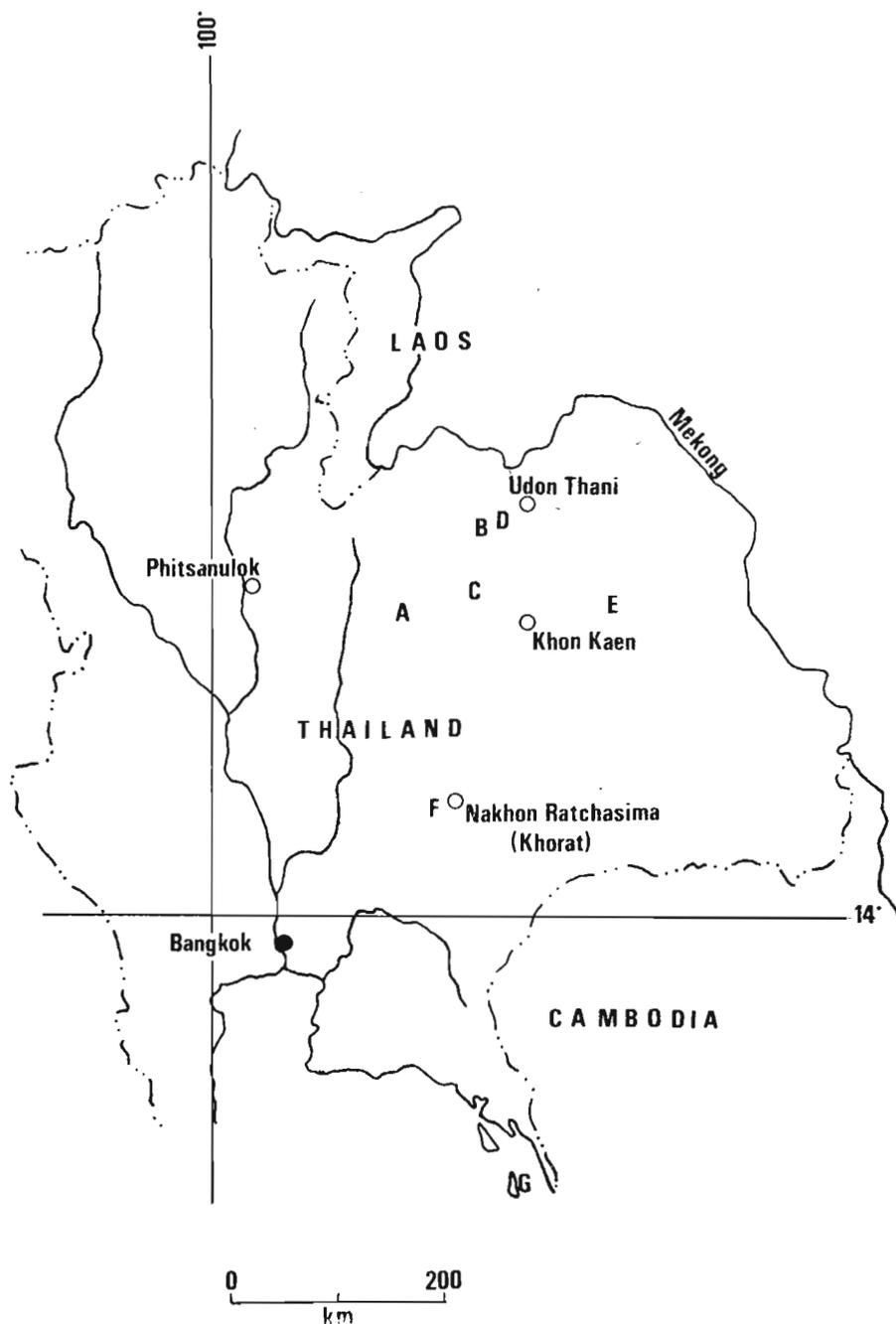


Fig. 1. Map of eastern Thailand showing the location of the vertebrate localities mentioned in text. A Chulabhorn Dam, Huai Hin Lat Formation, Late Triassic; B Nong Bua Lam Phu, Phu Kradung Formation, ?Liassic; C Phu Wieng, Sao Khua Formation, Middle or Late Jurassic; D Phu Hin Lat Tuppha, Sao Khua Formation, Middle or Late Jurassic; E Wat Sak Kawan, Sao Khua Formation, Middle or Late Jurassic; F Km 236.4 on the Friendship Highway, Khok Kruat Formation, Cretaceous; G Ko Kut Island, Phu Phan or Phra Wihan Formation, Jurassic.

## THE LATE TRIASSIC ASSEMBLAGE FROM CHULABHORN DAM

Fossil vertebrates were first discovered at Chulabhorn Dam (formerly Nam Phrom Dam, fig. 1: A) in 1980 (Buffetaut *et al.* 1981), in an outcrop which had already yielded conchostracans and plant remains. The locality is near the power station of Chulabhorn Dam, a large hydroelectric dam between the cities of Khon Kaen and Phitsanulok, not very far from the western edge of the Khorat Plateau. The geology of this area has been described in detail by Bunopas (1971). The vertebrate remains come from the basal unit of the Khorat Group, which is now called the Huai Hin Lat Formation. At Chulabhorn Dam, the Huai Hin Lat Formation is 900 m thick, and lithologically varied, with a basal conglomerate overlain by a succession of alternating sandstones, shales and limestones (Chonglakmani and Sattayarak 1978). The vertebrate fossils have been found in dark grey shales and limestones containing a large amount of organic matter. According to Chonglakmani and Sattayarak (1978), the Huai Hin Lat Formation is a post-orogenic deposit which was formed under lacustrine and deltaic conditions. The dark shales and limestones from which the vertebrate remains have been collected suggest a quiet lacustrine environment, with anaerobic conditions presumably prevailing at the bottom. This was of course favourable to the fossilisation of vertebrates, and the material recovered so far is well preserved, although incomplete. Studies on plant remains (Iwai *et al.* 1966), pollen and spores (Haile 1973), and estheriids (Kobayashi 1975) have indicated a Late Triassic age (probably Norian) for the Huai Hin Lat Formation. As will be shown below, the vertebrate fauna is in agreement with this age determination.

The vertebrate remains from Chulabhorn Dam include many fish scales, indicative of semionotids and palaeonisciforms. Fragments of coelacanth scales may also be present. A single lungfish tooth, belonging to a ceratodontid, has been found; it is reminiscent of Chinese Triassic forms (M. Martin, pers. comm.). The best specimen hitherto found at Chulabhorn Dam is the back part of a stegocephalian skull with closed otic notches, which belongs to the genus *Cyclotosaurus* (Ingavat and Janvier in press). *Cyclotosaurus* is known with certainty only from Laurasia. Phytosaur remains are also present; although very incomplete (jaw fragments, isolated teeth), they indicate a form with a slender but somewhat elevated snout, similar to the European *Belodon* or the North American *Rutiodon* (Buffetaut and Ingavat in press). Such phytosaurs apparently do not occur before the middle Norian, and may be restricted to Laurasia.

Generally speaking, the Chulabhorn Dam fauna is not especially endemic. Similar assemblages with ceratodontids, large stegocephalians and phytosaurs occur in the upper Triassic of many parts of the world,

both in Laurasia and Gondwana. However, a more detailed analysis points towards Laurasian affinities, mainly because of the occurrence of *Cyclotossaurus* and a *Belodon*-like phytosaur. Additional discoveries may confirm this palaeobiogeographical conclusion.

It should also be mentioned that another locality in the Huai Hin Lat Formation, farther to the northeast, has yielded fragmentary turtle plates, currently studied by F. de Broin. Turtle remains are rather unusual finds in the Triassic and it is hoped that more will turn up.

#### A CROCODYLIAN FROM THE PHU KRADUNG FORMATION: *SUNOSUCHUS THAILANDICUS*

In 1979, Mr. Nares Sattayarak (Geological Survey, Bangkok) found the back part of a right lower jaw ramus of a large crocodylian in a road cut along the Udon Thani-Nong Bua Lam Phu highway, near Nong Bua Lam Phu (fig. 1: B). The specimen came from red clays with conglomeratic lenses in the Phu Kradung Formation, which directly overlies the Huai Hin Lat Formation, and is usually referred to the Liassic. The specimen was identified (Buffetaut and Ingavat 1980) as belonging to a new species of the genus *Sunosuchus* Young, *S. thailandicus*. In 1980, the French-Thai expedition went to the site and was fortunate enough to be able to recover most of the remaining parts of the lower jaw. Although at the time of writing preparation of the specimen is still going on, it is possible to make a few additional remarks on the anatomy and palaeontological significance of *Sunosuchus thailandicus*. This crocodylian was a long-snouted form (a fact already suspected by Young 1948, in the case of the type species, *S. miaoi*, from the Hokou series of north-central China): the mandibular symphysis reaches the level of the 25th tooth (out of a total of about 30). The lower jaw is very robust and large (the total length of the mandible is about 120 cm). The anterior end is somewhat expanded, and the 3rd and 4th teeth are especially large. On the whole, the lower jaw of *Sunosuchus thailandicus* is somewhat similar to that of some robust pholidosaurids, such as *Sarcosuchus* from the Lower Cretaceous of Niger and Brazil (Buffetaut and Taquet 1977). However, the back part of the skull of the Chinese *Sunosuchus miaoi* is more reminiscent of the Goniopholididae, with supratemporal fossae which are smaller than the orbits, and paired openings in the palate, anterior to the internal nares, which otherwise are known only in North American Late Jurassic goniopholidids (Buffetaut and Ingavat 1980). The genus *Sunosuchus* has thus been referred by Buffetaut and Ingavat (1980) to the Goniopholididae, while, following Young (1948), it had previously been classified among the Pholidosauridae. However, because of its long

symphysis, *Sunosuchus thailandicus* would be a good morphological link between the Goniopholididae and the Pholidosauridae. The two families are obviously closely related, and the Pholidosauridae are probably descended from early Goniopholididae. The systematic position of *Sunosuchus* is thus still somewhat uncertain. It may be a specialized long-snouted goniopholidid, close to the ancestry of the Pholidosauridae. More data about early pholidosaurids would be welcome.

The age of *Sunosuchus thailandicus* is also rather uncertain. The Phu Kradung Formation is usually referred to the Liassic, but supporting palaeontological evidence is scanty (Buffetaut and Ingavat 1980), and resemblances with *S. miaoi* are of little help, since the age of the Chinese form is also debatable (although it is usually considered Late Jurassic). If the Phu Kradung is indeed Liassic (which stratigraphically is not unlikely), *Sunosuchus thailandicus* is one of the very few continental crocodylians of that age to be known.

From a palaeobiogeographical point of view, the occurrence of *Sunosuchus* in Thailand is apparently indicative of links with the Chinese region, since the only other known representative of the genus is *S. miaoi* from Kansu (Buffetaut and Ingavat 1980).

#### DINOSAUR LOCALITIES OF NORTHEASTERN THAILAND

Dinosaur remains have been found in several localities on the Khorat Plateau. However, the material discovered so far is fragmentary, and identifications are still relatively imprecise.

One of the best specimens is the distal end of a large femur from the Sao Khua Formation (?Middle Jurassic) at Phu Wieng, northeast of the city of Khon Kaen (fig. 1: C). The fragment was identified as belonging to a sauropod which may have reached a length of 15 m (Ingavat *et al.* 1978; Ingavat and Taquet 1978). Two vertebrae have also been found at Phu Wieng in 1978; they may also belong to sauropods (P. Taquet, pers. comm.). In 1981, additional remains of sauropods and theropods have been collected at Phu Wieng, as well as a crocodylian jaw.

In 1980, dinosaur remains were found by the Thai-French expedition in a quarry (Phu Hin Lat Tuppha) at km 84+500 on the Chum Phae-Udon Thani highway (fig. 1: D; not very far from the *Sunosuchus thailandicus* locality). The quarry is dug in very hard red sandstones of the Sao Khua Formation, and most of the bones which were detected were only vertebral fragments which could not be excavated. However, a fairly well preserved dinosaur scapula, about 70 cm long, could be recovered. It is still being prepared, and has not yet been accurately identified, but it can be said that it is a rather slender bone that may have belonged to a small sauropod.

FORMATIONS	AGE	FOSSIL TETRAPODS
Khok Kruat	Cretaceous	
Phu Phan	Late Jurassic	
Sao Khua	Middle or Late Jurassic	
Phra Wihan	Middle Jurassic	
Phu Kradung	Liassic	
Huai Hin Lat	Late Triassic	

Fig. 2. The formations of the Khorat Group and their fossil tetrapods. The ages given here are still tentative (except for the Huai Hin Lat Formation). A *Cyclotosaurus*; B. *Belodon*-like phytosaur; C *Sunosuchus thailandicus*; D sauropod; E theropod; F crocodylian (*Goniopholis*); G theropod.

Other dinosaur remains from the Sao Khua Formation were found in 1980 in a temple (Wat Sak Kawan) near the city of Kalasin (fig. 1: E). The specimen is a fragmentary left humerus of a sauropod found in the hill on which the temple is built, and we were kindly allowed to take it away for study by Abbot Kruvichit Thakhoun. Lastly, a few dinosaur remains have been found in 1978 in sandstone quarries near the Friendship Highway, between Bangkok and Nakon Ratchasima (another name for the city of Khorat), at km 236.4 (fig. 1: F). According to Ward and Bunnag's measured section (Ward and Bunnag 1964), they must come from the Khok Kruat Formation, which is probably Cretaceous. The fossils recovered from that locality are a theropod tooth and a quadrate which probably also belongs to a theropod (P. Taquet, pers. comm.).

From this brief review, it can be seen that the dinosaurs from the Khorat Group are still very incompletely known, but also that their remains occur in a number of places, and continued search will certainly bring additional evidence to light.

## THE SIGNIFICANCE OF THE MESOZOIC VERTEBRATES OF THAILAND

In addition to their purely palaeontological interest, the vertebrate remains from the Mesozoic of Thailand also have important implications for the stratigraphy of the Khorat Group and for the reconstruction of the palaeogeographical history of Southeast Asia.

From a stratigraphic point of view, it should be stressed that useful fossils are very scarce in the predominantly continental deposits of the Khorat Plateau (Iwai *et al.* 1975). As pointed out by Ramingwong (1978), the major geological problems posed by this series are the dating of the different formations and their correlation. Until recently, the biostratigraphy of the Khorat Group has been based mostly on plant remains and freshwater invertebrates; intercalated fossiliferous marine beds are very rare (Iwai *et al.* 1975). Vertebrate remains can now be considered as potentially very useful aids in dating the members of the Khorat Group. The best example so far is provided by the Chulabhorn Dam Triassic fauna, which clearly indicates a Late Triassic, probably later than early Norian, age. For the overlying formations, the fossil vertebrate evidence is not yet as conclusive, but new finds and more accurate identifications should soon yield interesting stratigraphic results.

From a palaeobiogeographical point of view, the continental vertebrate faunas from the Mesozoic of Thailand are important in the context of palaeogeographical hypotheses put forward by various authors, and especially by Ridd (1971, 1980). Ridd has suggested that Southeast Asia was once part of Gondwana, and then drifted northwards, which eventually led to collision with Asia. According to his 1980 paper, Southeast Asia is made up of two "microcontinents", the Thai-Malay Peninsula block and the Indochina block (incidentally, all the vertebrate localities of the Khorat Plateau are on the Indochina block). The Thai-Malay Peninsula block is considered as a fragment of the northern margin of eastern Gondwana; the exact origin of the Indochina block is less certain. In any case, both blocks are supposed to have drifted northwards during the late Palaeozoic, and to have collided with the Chinese block and with each other in the Middle or Late Triassic. After meeting with some opposition, the basic ideas of Ridd's hypothesis are now gaining a wide acceptance. Within this geodynamic framework, some terrestrial vertebrates can indicate affinities with faunas from either Gondwana or Laurasia, and thus help in dating the collision of the Southeast Asian blocks with China. The Jurassic *Sunosuchus thailandicus* is related to the Chinese *S. miaoi*, and the genus *Sunosuchus*, as mentioned above, is unknown elsewhere; the distribution of this crocodylian thus suggests that Southeast Asia was faunally related to mainland Asia in the Jurassic, which is in agreement with the chronology now accepted by Ridd for the northward drift of the Southeast Asian blocks (but not with his 1971

hypothesis, according to which collision had taken place late, possibly in the early Cenozoic; see Buffetaut and Ingavat 1980). The newly discovered Late Triassic Chulabhorn Dam fauna is most interesting in this respect, since several of its components have Laurasian affinities. As mentioned above, the genus *Cyclotosaurus* is known only from the Laurasian regions, the phytosaur remains seem to belong to an animal similar to the European *Belodon* or the North American *Rutiodon* (a type of phytosaur which has not been reported from Gondwana), and the lungfish seems to resemble Chinese forms. These Laurasian faunal affinities are of course in agreement with Ridd's hypothesis of a Triassic collision of the Southeast Asian blocks with China. The latest allowable date for the collision would seem to be the beginning of the Late Triassic, to judge from vertebrates.

At the time of writing, no fossil vertebrates with exclusively Gondwana affinities have been reported from Thailand.

#### CONCLUSIONS

It can be said as a conclusion that the study of Mesozoic vertebrates from Thailand is just beginning. Although outcrops are not very extensive (because of the abundant vegetation), the Khorat Plateau is obviously a rich potential source of vertebrate fossils. Other parts of Thailand should not be neglected, either. I have received from M. F. Ridd a small collection of vertebrate remains from Ko Kut, an island in the Gulf of Thailand (fig. 1: G), near the Cambodian border. It includes crushing teeth from hybodontid sharks, button-like teeth referable to *Lepidotus* (S. Wenz, pers. comm.), a turtle plate probably belonging to a freshwater form (F. de Broin, pers. comm.), and crocodylian tooth fragments. The fossil-bearing formation is supposedly Jurassic, and the locality, according to M. F. Ridd, is very rich. It is hoped that a future Thai-French expedition will be able to visit it.

Much remains to be done (and found) before a satisfying picture of the evolution of terrestrial vertebrate faunas in Southeast Asia can emerge. Considering what has already been discovered and the good prospects for future finds, Thailand should play a major part in the elucidation of the many palaeontological problems still confronting us in this part of the world.

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