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The First Occurrence of a Basal Tyrannosauroid in Southeast Asia: Dental Evidence from the Upper Jurassic of Northeastern Thailand

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ABSTRACT. – Isolated theropod teeth are one of the most common vertebrate fossils that have been found in the Khorat Group of Thailand. Furthermore, several isolated teeth have been discovered from the Upper Jurassic Phu Kradung Formation, located in Phu Noi locality of Kalasin Province, Northeastern Thailand. Three of those theropod teeth from the Phu Noi locality show unique dental features that can be distinguished from previous discovered metriacanthosaurid theropod, including the lateral teeth with mesiolingual twisted mesial carinae extending above the cervix line and braided enamel surface texture. Morphological examination with cladistics and morphometric analyses show that these isolated teeth exhibit the synapomorphies of basal tyrannosauroids, closely related to *Guanlong wucaii* and *Proceratosaurus bradleyi* from the Jurassic Period. This paper notes the first report of a basal tyrannosauroid in Southeast Asia as well as significantly contributes to our understanding of paleoecology of the Upper Jurassic Phu Kradung Formation and paleobiogeography of Tyrannosauroidea during the Jurassic Period.

KEYWORDS: Dinosauria, Theropod, isolated teeth, Phu Kradung Formation, Mesozoic Era

INTRODUCTION

Tyrannosauroidea is a clade of theropods, including well-known carnivorous dinosaurs such as *Tyrannosaurus rex* from Late Cretaceous North America (Osborn, 1905). They primarily inhabited in the Laurasian supercontinent throughout the Middle Jurassic to Late Cretaceous (Brusatte et al., 2016). The earliest-known members of tyrannosauroids have been discovered in the Middle Jurassic of Europe and Russia (Woodward, 1910; Averianov et al., 2010), suggesting the origin of this theropod group within Eurasia (Delcourt and Grillo, 2018). Tyrannosauroids were distributed from the Late Jurassic to the Late Cretaceous of Asia, with most Asian tyrannosaurs found in China and Mongolia, including *Guanlong wucaii* (Xu et al., 2006), *Yutyrannus huali* (Xu et al., 2012), *Sinotyrannus kazuoensis* (Ji et al., 2009), *Dilong paradoxus* (Xu et al., 2004), *Xiongguanlong baimoensis* (Li et al., 2009), *Timurlengia euotica* (Brusatte et al. 2016), *Alectrosaurus olseni* (Gilmore, 1933), *Qianzhousaurus sinensis* (Lü et al., 2014), *Alioramus remotus* and *A. altai* (Kuzanov, 1976; Brusatte et al., 2009), *Zhuchengtyrannus magnus* (Hone et al., 2011), and *Tarbosaurus bataar* (Marleev, 1955).

Tyrannosauroids have also been reported in Southeast Asia. Post-cranial elements of *Siamotyrannus isanensis* were found in the Early Cretaceous Sao Khua Formation in the Phu Wiang locality, Khon Kaen Province, Northeastern Thailand (Buffetaut et al., 1996). Initially, *Siamotyrannus* was described as the earliest known tyrannosaurid based on pelvic features (Buffetaut et al., 1996). However, lacking distinct tyrannosauroid synapomorphies, it has been considered to belong to other theropod groups, such as an allosauroid (Rauhut, 2003), a metriacanthosaurid (Carrano et al., 2012), or possibly a basal coelurosaur (Samathi et al., 2019). Hence, the presence of tyrannosauroids in Southeast Asia remains ambiguous.

Isolated theropod teeth are frequently reported in the fossil records of Thailand. Many reports of these findings come from different locations within the Khorat Plateau. These discoveries are spread across three geological formations within the Khorat Group, including the Phu Kradung, Sao Khua, and Khok Kruat Formations (Buffetaut et al. 2005a; Tong et al. 2019; Manitkoon et al. 2022; Samathi et al. 2023). Due to the abundance of the dental evidence, isolated teeth are often used for taxonomic identification to reveal the paleoecological diversity of vertebrates when the complete elements of fossil are insufficient (Hendrickx et al. 2015; Barker et al. 2023; Yin et al. 2023).

This contribution presents the first distinct record of a tyrannosauroid from the Upper Jurassic Phu Kradung Formation based on dental evidence from the Phu Noi locality of Kalasin Province, northeastern Thailand. This discovery not only confirms the presence of tyrannosaurs in Thailand but also sheds light on the paleogeographic distribution of this dinosaur clade and provides valuable information regarding the diversity

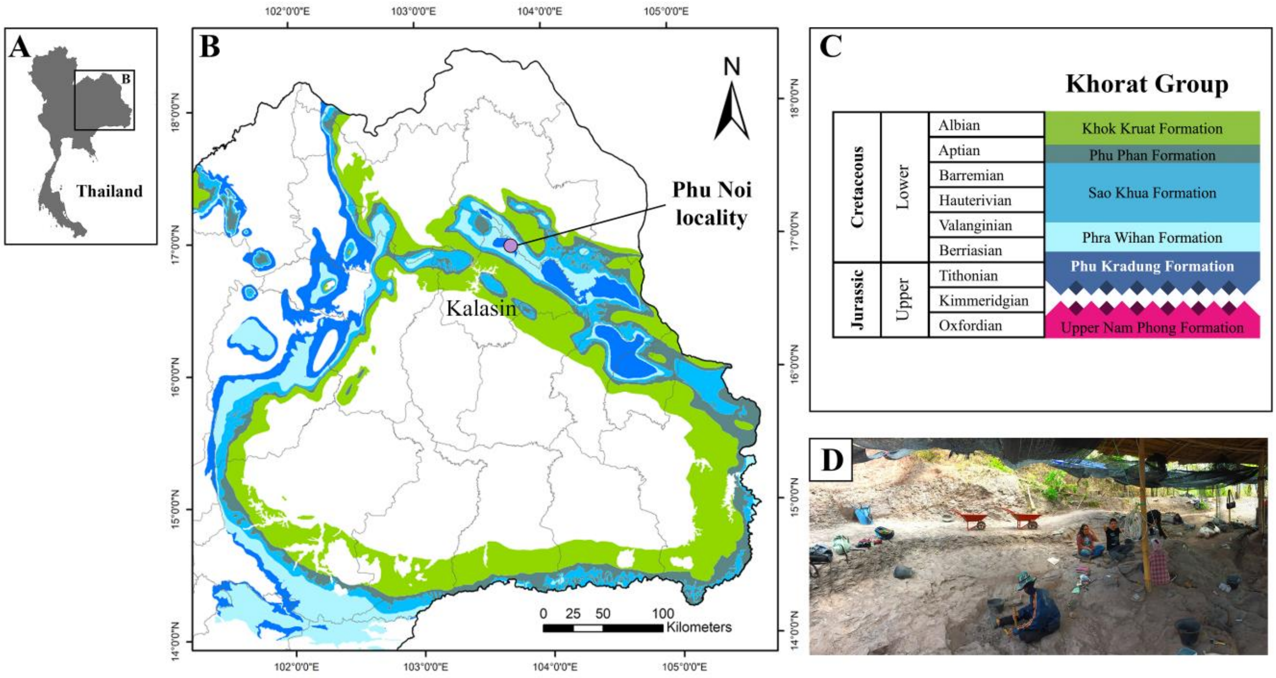

FIGURE 1. Geological map and stratigraphy of the Phu Noi locality. (A) Map of Thailand; (B) Distribution of the Khorat Group within the Khorat Plateau, Northeastern Thailand (modified from Manitkoon et al., 2023a); (C) Chronostratigraphic column of six geological formations of the Khorat Group based on subsurface data (modified from Booth and Sattayarak, 2011); (D). Photograph of the excavation site in the Phu Noi locality.

of theropod dinosaurs during the Late Jurassic of Southeast Asia.

Geological setting and paleontological context

The Phu Kradung Formation distributes along the western rim of the Khorat Plateau and the Phu Phan Mountain range in northeastern Thailand (Fig. 1A, B). It is underlain unconformably by the Upper Nam Phong Formation and overlain conformably by Phra Wihan Formation of the Mesozoic Khorat Group (Booth and Sattayarak, 2011) (Fig. 1C). The lithological features and palynological evidence in this formation indicate fluvial depositional environment and a subtropical paleoclimate (Racey and Goodall, 2009). The Phu Kradung Formation was initially classified as Late Jurassic in age based on the vertebrate fauna discovered in its lower part, which bears similarities to the Middle to Late Jurassic fauna of China (Buffetaut et al., 2005b; Tong et al, 2019; Manitkoon et al., 2023b). However, further investigations involving detrital zircon analysis and palynology have suggested an Early Cretaceous age for the upper part of this formation (Carter and Bristow, 2003; Racey and Goodall, 2009). The theropod teeth examined in this work were recovered from the Phu Noi locality, Kham Muang District of Kalasin Province, northeastern Thailand. This locality's outcrop is considered the lowest part of the Phu Kradung Formation (Buffetaut et al., 2001; Cuny et al., 2014) based on the differences in faunal composition such as hybodont shark, turtle and crocodylomorph compared to the upper part of the Phu Kradung Formation (Manitkoon et al., 2023a) (Fig. 1B, D).

The lithology of the Phu Noi locality is composed of conglomerate, greyish green medium to very fine-grained sandstone, and grey siltstone (Ditbanjong and Chanthasit, 2019), which the stratigraphical succession can be divided into three parts. The lower part is characterized by conglomerate and sandstone in the lowest unit, while the upper unit consits of grey siltstone with bioturbations, calcretes, and conglomeratic limestone lenses. Isolated teeth of shark and crocodile, fish scales, and turtle shell fragments are found in conglomerate layers of the lowest unit. The middle part is mainly characterized by grey ripple siltstone with the main bone bed is in thin-bedded maroon micaceous very fine-grained sandstone. The upper unit of the middle part shares similar lithology with the lowest unit of the lower part. The upper part of the Phu Noi succesion comprises of medium to fine-grained sandstone with planar and cross beddings (Fig. 2)

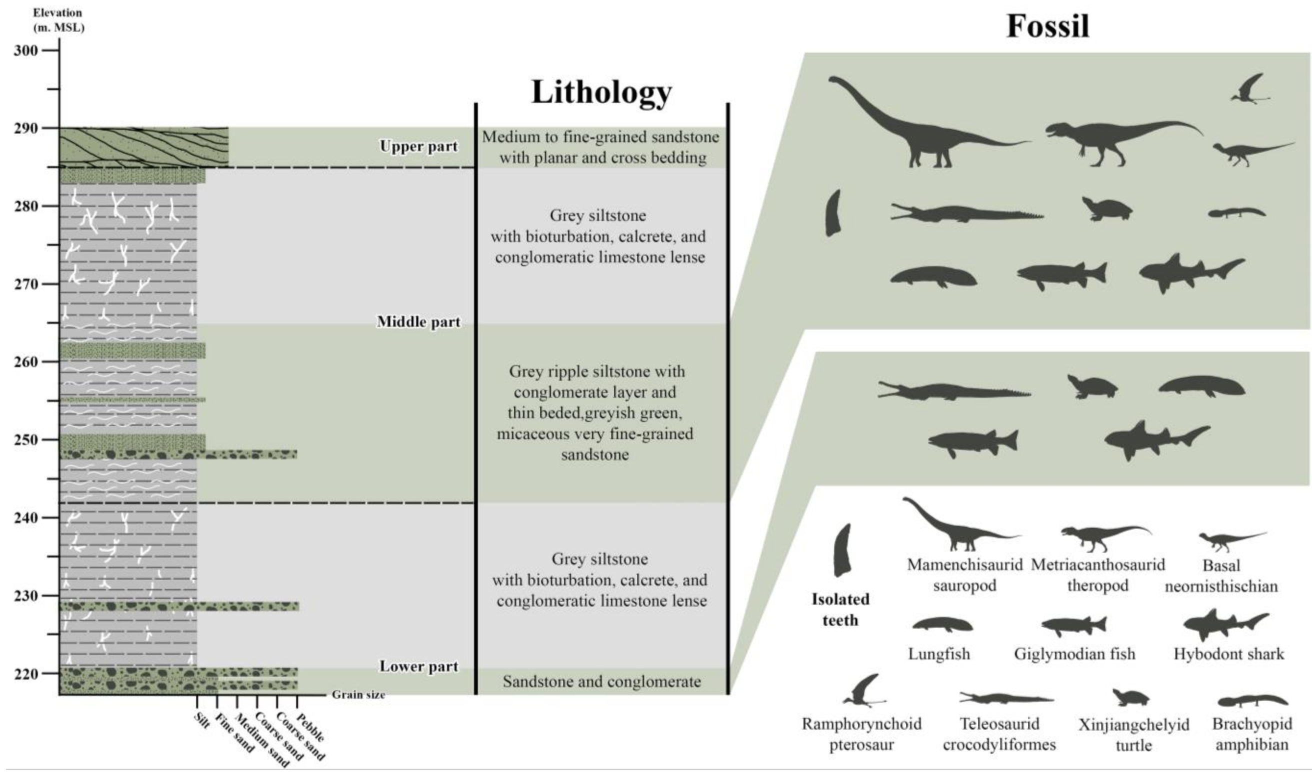

FIGURE 2. Lithostratigraphic column and fossil record of the Phu Noi locality (modified from Boonchai et al., 2019; Ditbanjong and Chanthasit, 2019; Manitkoon et al. 2023b). Silhouettes by Wongwech Chowchuvech and Chatcharin Somboon. All silhouettes are not to scale.

The Phu Noi locality is renowned as one of the most prolific Mesozoic vertebrate deposits in Southeast Asia. Numerous taxa have been unearthed from this site, including freshwater sharks (Cuny et al., 2014), ray-finned fishes (Deesri et al., 2014), lungfishes (Cavin et al., 2020), amphibians (Nonsrirach et al., 2023), turtles (Tong et al., 2015; 2019), crocodyliforms (Martin et al., 2019; Johnson et al., 2020), pterosaurs (Buffetaut et al., 2015), and dinosaurs (Chanthasit et al., 2015). Within the Phu Noi locality, three dinosaur taxa have been identified, comprising metriacanthosaurid theropods (Samathi et al., 2019), mamenchisaurid sauropods, and a basal neornithischians *Minimocursor phunoiensis* (Manitkoon et al., 2023b) (Fig 2).

MATERIALS AND METHODS

The isolated teeth of tyrannosauroid were recovered alongside isolated teeth of metriacanthosaurid, mamenchisaurid, and neornithischian from the Phu Noi locality. These specimens were excavated by teams from the Palaeontological Research and Education Centre at Mahasarakham University and the Sirindhorn Museum, Department of Mineral Resources. The materials examined in this paper, SM2021-1-009, -048, and -050 are housed at the Sirindhorn Museum in Kalasin Province. Digital vernier caliper (Mitutoyo's Digimatic Caliper CD-6"ASX: 150 mm with an accuracy of 0.01 mm) was applied for morphometric measurements and a stereomicroscope (GEMAX Pro Digital Microscope MRS009P) for the morphological observation of dental features smaller than 1 cm such as denticles and crown ornamentations. The specimen description of the specimens follows the theropod teeth terminology protocol proposed by Hendrickx et al. (2015). Additionally, the positional nomenclature of the teeth followed the dental orientation proposed by Smith and Dodson (2003) and Hendrickx et al. (2015).

Taxonomic identification based on dental features of the studied specimens was performed using cladistics analysis. The analysis used a dental data matrix originally created by Hendrickx et al. (2015), with the most recent version of the data matrix published by Meso et al. (2022) and considered a dentition-based data matrix comprising 146 dental characters of 108 non-avian theropod taxa. The positive constraints were included in the analysis to recover a backbone topology, aligning with the results of previous phylogenetic studies. These constraints encompassed non-neotheropod saurischians (Müller et al., 2018), non-averostran neotheropods (Ezcurra, 2017), Ceratosauria (Rauhut and Carrano, 2016; Wang et al., 2017), non-coelurosaurian tetanurans (Carrano et al., 2012; Rauhut et al., 2012; 2016), Tyrannosauroidea (Brusatte and Carr, 2016), Megaraptora (Aranciaga Rolando et al., 2019), and neocoelurosaurs (Cau et al., 2017). All dental material were analyzed together, treating each tooth as a separate operational taxonomic unit (OTU), following the protocol of cladistic analysis established in previous works (Young et al., 2019; Hendrickx et al., 2020; Meso et al., 2021; Berrocal-Casero et al., 2022). All three analyses were conducted using TNT 1.6 (Goloboff and Morales, 2023), employing a combination of tree-search algorithms, including Wagner Trees, TBR branch swapping, sectorial searches, ratchet (perturbation phase stopped after 20), and tree fusing (5 rounds). The analysis continued until 100 hits of the same minimum tree length were obtained, followed by a final round of TBR branch swapping.

Furthermore, in order to determine the taxonomic position of three isolated teeth in family-level based on quantitative data, discriminant analysis was used in this study. We include three teeth into a morphometric dataset originally created by Hendrickx et al. (2015) and updated by Meso et al. (2022), which comprises 15 measurements (CBL, CBW, CH, AL, CBR, CHR, MCL, MCW, MCR, MSL, LAF, LIF, CA, MDL, DCL) obtained from 1373 teeth representing 91 non-avian theropod taxa (including 21 monophyletic or paraphyletic groups). The analysis was conducted using the linear discriminant analysis function (LDA) in Past version 4.11 (Hammer et al. 2001), treating all dental specimens under investigation as unidentified taxa.

RESULTS

Systematics Paleontology

Dinosauria Owen, 1842
Theropoda Marsh, 1881
Coelurosauria von Huene, 1914
Tyrannosauroidea Osborn, 1905
Tyrannosauroidea indet.

Description

Three isolated teeth consist of crowns and proximal parts of the root (Fig. 3). Several mesiodistal fractures are evident on the crowns. All crowns exhibit a ziphodont morphology, featuring distal curvatures and labiolingual compressions (Fig. 3A–C). Notably, the crown of SM2021-1-008 exhibits a less distinct distal curvature compared to the other two teeth (Fig. 3A). The cross-sections of the crowns are lenticular to elliptical (Fig. 3D–E). The three teeth measure between 15 to 24 mm in height, with a crown base ranging from 4.5 to 6.5 mm and a length of 9 to 11 mm. The crown base ratio varies from 0.5 to 0.6. The mesial carinae are not extended to the cervix in all specimens, with the mesial carina of SM2021-1-009 is terminating at approximately one-third of the crown height (Fig. 3F), whereas the mesial carinae of SM2021-1-048 and -050 are restricted to approximately two-thirds of the crown height (Fig. 3G). Distal carinae reach to the cervix in all teeth. Both the mesial and distal carinae of three theropod teeth exhibit serrations. The mesial carina of SM2021-1-009 shows a slight mesiolingual twist in mesial view (Fig. 3F), whereas SM2021-1-048 and -050 show a strong twist (Fig. 3G). The distal carinae exhibit straight to slight distolabial twist in distal view (Fig. 3H–I).

Four to five denticles per mm can be observed in mesial carinae of isolated teeth (Fig. 3J–K), while the distal carinae contain three to five denticles per mm (Fig. 3L–N). The denticle size density index (DSDI) is varied from 1.00 to 1.34. Both the mesial and distal denticles are perpendicular to their respective carinae, which are subrectangular (Fig. 3J–K) and proximo-distally subrectangular (Fig. 3L–N), respectively. Interdenticular sulci are absent on all crowns of the isolated teeth. The interdenticular space of SM2021-1-009 is shallow and narrow (Fig. 3J), while those of SM2021-1-048 and -050 are shallow and narrow interdenticular spaces (Fig. 3L). The external margins of both mesial and distal denticles exhibit symmetrical convex shapes with semicircular surfaces. Braided enamel texture is present on both labial and lingual surfaces of the teeth (Fig. 3O). The morphometric measurements of three isolated teeth are shown in Table 1.

Cladistics and Discriminant analyses

The results of cladistics analysis using a dentition-based data matrix with fully constrained tree topology recovered two most parsimonious trees (CI=0.198; RI=0.461; L=1319 steps). All three isolated teeth were found within the Tyrannosauroidea clade and nested within the Proceratosauridae family, closely related to *Guanlong* and *Proceratosaurus*. SM2021-1-048 and -050 are found as the sister taxon, while SM2021-1-009 positioned basally (Fig. 4). The discriminant analysis classified isolated teeth among three theropod groups. At the clade level, SM2021-1-009 was identified as belonging to Neovenatoridae, while SM2021-1-048 was placed in Non-megalosauran Megalosauroidea, and SM2021-1-048 was categorized as Non-tyrannosaurid Tyrannosauroidea. PC 1 and PC 2 contributed 48.18% and 19.82% to the variance, respectively, with a reclassification rate of 58.7% (Fig. 5).

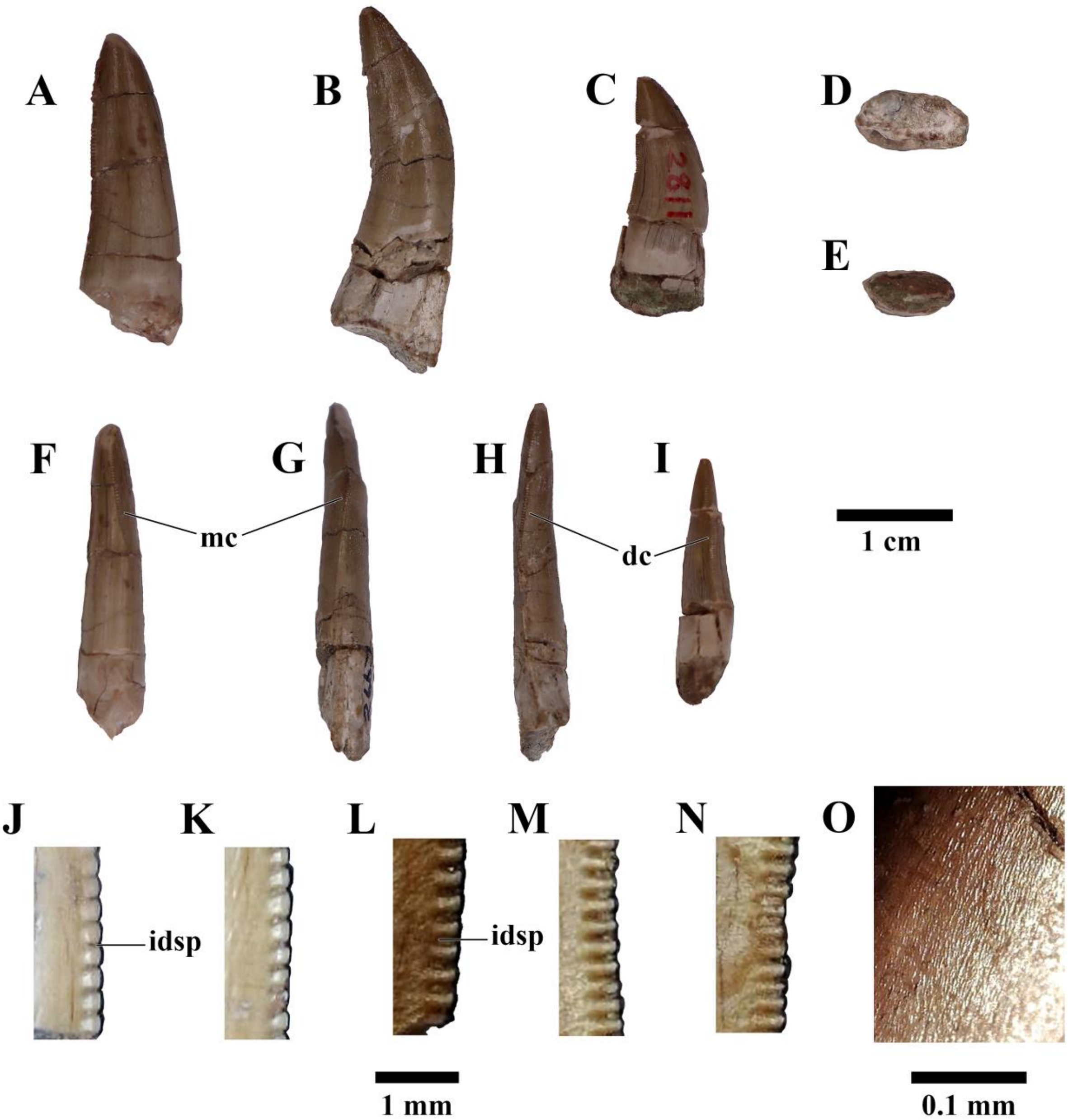

FIGURE 3. Isolated teeth of basal tyrannosauroid from the Phu Noi locality. SM2021-1-009 (A, F, and J–K), -048 (B, D, G–H, and O), and -050 (C, E, I, and L–N). in labial (A), lingual (B, C), basal (D, E), mesial (F, G), distal (H, I) views. mesioapical (J), mesiocentral (K), distoapical (L), distocentral (M), distobasal (N) denticles and enamel surface texture (O) in labial view. Abbreviations: dc, distal carina; idsp; interdenticular space; mc, mesial carina. Scale bars: A–I = 1 cm; J–N = 1 mm; O = 0.1 mm.

DISCUSSION

Taxonomic identification

Results of the cladistics and discriminant analyses both support the non-tyrannosaurid tyrannosauroid affinity for the three isolated teeth in term of qualitative and quantitative data. All three isolated teeth exhibit the typical dental features associated with theropod dinosaurs, including ziphodont teeth and serrated carinae (Hendrickx et al., 2019). The mesiodistal orientation of the carinae allows us to classify these teeth as lateral teeth (Hendrickx et al., 2015). Twisted mesial carinae in the lateral teeth is the dental feature that can be found among the coeluro-saurian theropod groups, namely tyrannosauroids,

TABLE 1. Morphometric measurement of isolated teeth from the Phu Noi locality.

Specimens	Crown height (mm)	Crown base width (mm)	Crown base length (mm)	Crown base ratio	Denticle size density index	Denticle per mm	
						Mesial denticle	Distal denticle
SM2021-1-009	21.82	6.48	9.87	0.66	1.34	4	3
SM2021-1-048	24.38	5.65	11.09	0.51	1.25	5	4
SM2021-1-050	15.33	4.49	9.07	0.50	1.00	5	5

therizinosaurs and dromaeosaurids (Hendrickx et al., 2019). The braided enamel surface texture is distributed among various theropod group, including non-abelisaurrid ceratosaurs, non-spinosaurid megalo-sauroids, carcharodontosaurs, non-neocoelurosaur coelurosaurs, eudromaeosaurs and most non-averostran theropods (Hendrickx et al., 2019). However, twisted mesial carinae that do not extend to the cervix and a braided enamel surface texture in the lateral teeth are the combination of dental features that can be found in Pianitzkysauridae and non-tyrannosaurid tyranno-sauroids (Hendrickx et al., 2019). For Piatnitzky-sauridae, numerous transverse undulations on the crown surface of the lateral dentition are considered as an unambigous dental synapomorphy (Hendrickx et al., 2019), whereas these are not present in the studied dental materials. Furthermore, Piatnitzkysauridae is known to be restricted to North and South America (Madsen, 1976; Bonaparte, 1979; Rauhut, 2005), with no fossil records of piatnitzkysaurids discovered in Asia. Therefore, three isolated teeth from the Phu Noi locality should be attributed to non-tyrannosaurid tyrannosauroids.

All three isolated teeth in this study possess dental features that align with the characteristics of Tyrannosauroidea. These features include mesial carinae that extend above the cervix and a braided enamel surface texture on the lateral teeth, which are recognized synapomorphies of non-tyrannosaurid Tyrannosauroidea (Hendrickx et al., 2019). Two of three isolated lateral teeth (SM2021-1-009 and -048) exhibit distal denticles that are larger than mesial denticles (DSDI > 1.25), while only SM2021-1-050 shows equal-sized mesial and distal denticles (DSDI = 1.00). This dental feature is common to most basal tyrannosauroids, especially proceratosaurids such as *Guanlong* and *Proceratosaurus*, in which most lateral teeth have distal denticles larger than their mesial denticles (Xu et al., 2006; Rauhut et al., 2010). In addition, the high to normal labiolingual compression of the crown (CBR < 0.75) observed in these three isolated teeth bears a resemblance to the lateral dentition of the non-tyrannosaurid tyrannosauroid *Guanlong*, which has a CBR value of 0.5 (Han et al., 2011) (Table 2.). However, due to the absence of non-dental elements, these teeth should be regarded as basal tyrannosauroid indet., pending more morphological and phylogenetic details in future studies.

Paleoecology of the Upper Jurassic Phu Kradung Formation

The presence of basal tyrannosauroid in this contribution marks the reconstruction of paleoecology of the Upper Jurassic Phu Kradung Formation. The coexistence of tyrannosauroids and metriacantho-saurids in the Phu Noi locality also appears in the Upper Jurassic Shishugou Formation of China, where a basal tyrannosauroid *Guanlong wucaii* (Xu et al., 2006) and a metriacanthosaurid *Sinraptor dongi* (Currie and Zhao, 1993) are found together in the upper part of the formation. Additionally, the co-occurrence between large-bodied allosauroids and small-bodied tyrannosauroids is commonly found throughout Laurasia during the Late Jurassic to early Late Cretaceous, such as in the Late Jurassic Morrison Formation of North America (*Allosaurus fragilis*; Marsh, 1877 and *Stokesosaurus clevelandi*; Madsen, 1974), the Early Cretaceous Wessex Formation of southern England (*Neovenator salerii*; Hutt et al., 1996 and *Eotyrannus lengi*; Hutt et al., 2001), and the early Late Cretaceous Bissekty Formation of Uzbekistan (*Ulughbegsaurus uzbekistanensis*; Tanaka et al., 2021 and *Timurlengia euotica*; Brusatte et al., 2016). It can be suggested that the large allosauroids were probably the apex predator rather than the smaller tyrannosauroids in the Late Jurassic to early Late Cretaceous ecosystems of Laurasia (Tanaka et al., 2021). Hence, the ecosystem of the Upper Jurassic Phu Kradung Formation should share the same pattern with other ecosystems of Laurasia during Late Jurassic based on the same carnivorous dinosaur faunal composition.

Moreover, beyond theropod dinosaurs, the herbivorous dinosaur fauna of the Upper Jurassic Phu Kradung Formation and the Upper Jurassic Shishugou Formation also share similarities with each other. Each

FIGURE 4. A strict consensus tree from the cladistics analysis of three isolated theropod teeth of the Phu Noi locality.

formation contains large-bodied herbivorous dinosaurs such as mamenchisaurids (Phu Noi mamenchisaurid; Manitkoon et al., 2023b and *Mamenchisaurus sinocanadorum*; Russell and Zheng, 1993) or

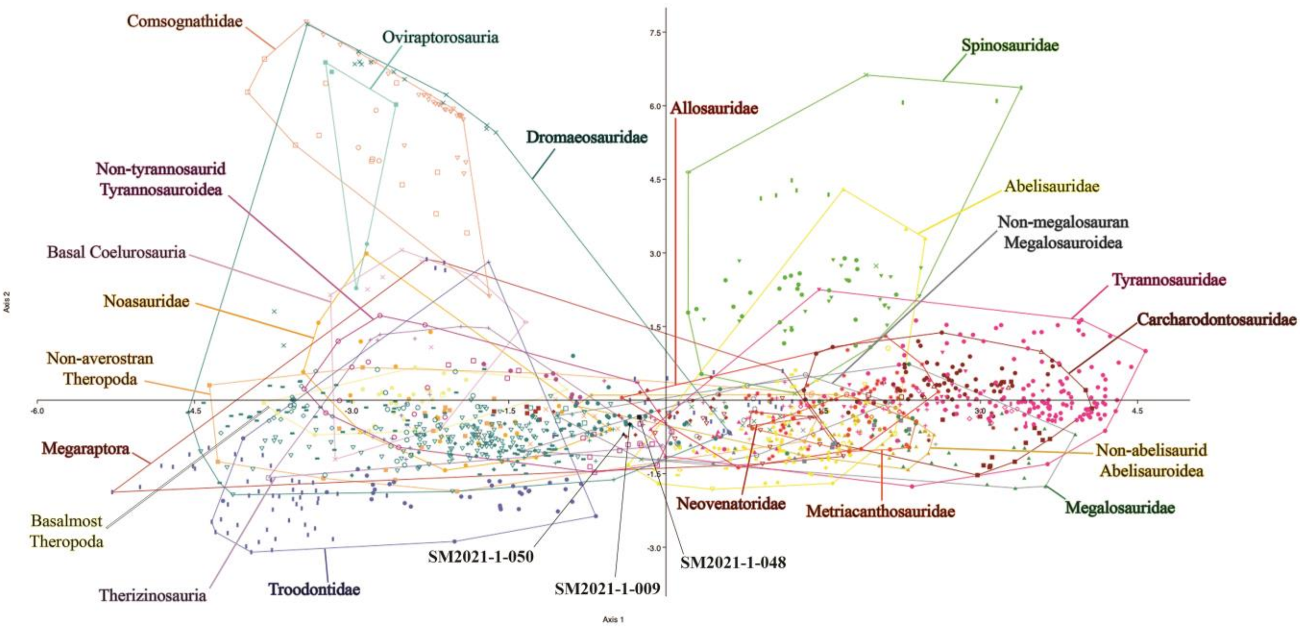

FIGURE 5. Result of the discriminant analysis performed at clade-level from the whole dataset with three isolated theropod teeth of the Phu Noi locality.

TABLE 2. Morphological and morphometric comparisons of lateral teeth in Jurassic basal tyrannosauroids.

Taxon	Crown height (mm)	Crown base length (mm)	Mesial carina not reaching the cervix	Spiraled mesial carina	Enamel surface texture	Denticle per mm		References
						Mesial denticle	Distal denticle	
Guanlong wucaii	8.9	4.54–9.34	Present	Present	Braided	-	-	Hendrickx et al. (2015)
Proceratosaurus bradleyi	4–12.8	2.6–6.9	Present	Present	Braided	6–7.5	4.5–7.5	Rauhut et al. (2010)
Kilekus aristotocus	-	11.5	-	-	-	-	-	Averianov et al. (2010)
SM2021-1-009	21.82	9.87	Present	Present	Braided	4	3	This study
SM2021-1-048	24.38	11.09	Present	Present	Braided	5	4	
SM2021-1-050	15.33	9.07	Present	Present	Braided	5	5	

stegosaurids (Khok Sanam stegosaurid; Buffetaut et al., 2001 and *Jiangjunosaurus junggarensis*; Jia et al., 2007), and small-bodied herbivorous dinosaur fauna, including basal ornithischians (*Minimocursor phunoiensis;* Manitkoon et al., 2023b and *Gongbusaurus wucaiwanensis*; Dong 1989). These similarities of both carnivorous and herbivorous dinosaur fauna can be implying niche-partitioning between large- and small-bodied carnivorous theropod dinosaur during the Late Jurassic of Laurasia. Since the differences of body size are among the factors that affect the dinosaur community structure and contribute to niche partitioning within the ecosystem (Schroeder et al., 2021; Wyenberg-Henzler, 2021), it is conceivable that the large theropod, such as metriacanthosaurids possibly hunting large herbivorous dinosaurs such as mamenchisaurids or stegosaurids, while the smaller herbivorous dinosaur like basal ornithischians may have been hunted by small-bodied tyrannosauroids (Fig. 6). Nevertheless, direct evidence of niche partitioning within the ecosystem of the Phu Kradung Formation should be investigated in future studies.

FIGURE 6. Paleoenvironmental reconstruction of the Late Jurassic Phu Kradung Formation of Northeastern Thailand. Illustrated by Chatcharin Somboon.

Paleobiogeography of Tyrannosauroidea

The discovery of tyrannosauroids in the Upper Jurassic Phu Kradung Formation of Northeastern Thailand, as reported in this study, marks the first substantial evidence of this theropod clade in Southeast Asia. It represents a remarkable extension of their known paleobiogeographical distribution. The fossil record of tyrannosauroids in Asia extends from the Middle Jurassic to the Late Cretaceous. However, there is a noticeable gap in the latest stage of the Jurassic Period (Tithonian Age) (Brusatte and Carr, 2016). The discovery of tyrannosauroids in the lower part of the Phu Kradung Formation, potentially from the Tithonian Age (Racey and Goodall, 2009), serves as crucial evidence to bridge this gap. It suggests that Asian tyrannosauroids were widespread from the Middle to the end of the Jurassic Period. This statement is supported by the discovery of *Kileskus* in the Middle Jurassic Itat Formation (Bajocian–Bathonian) of Sharypovsky, Southwestern Russia (Averianov et al., 2010), *Guanlong* in the Late Jurassic Shishugou Formation (Oxfordian) of Xinjiang, Northwestern China (Xu et al., 2006), and Thai basal tyrannosauroid. Furthermore, the occurrence of tyrannosauroids in the latest stage of the Jurassic Period is not limited to Asia. Tyrannosauroid *Stokesosaurus* was found in the Tithonian Morrison Formation of Utah, North America (Madsen, 1974), and *Juratyrant* in the Tithonian Kimmeridge Clay of Dorset, southwestern England (Benson, 2008; Brusatte and Benson, 2013). These findings collectively suggest that tyrannosauroids were widely distributed in the northern hemisphere during the Late Jurassic.

CONCLUSION

The results of morphological investigation with cladistics and discriminant analyses show that the isolated theropod teeth from the Phu Noi locality are classified as non-tyrannosaurid tyrannosauroids, which phylogenetically related to basal tyrannosauroids *Guanlong* and *Proceratosaurus* from the Jurassic of Asia and Europe, respectively. Three isolated teeth exhibit the twisted mesial carinae that do not reach the cervix and the braided enamel surface texture that are the dental synapomorphies of basal tyrannosauroids. This discovery notes the first report of Tyrannosauroidea in the Jurassic of Southeast Asia and contributes to the knowledge paleoecology of the lower Phu Kradung Formation, as well as paleobiogeographical distribution of tyrannosauroids during the Late Jurassic. Furthermore, this report sheds light on the possibility to finding new Thai dinosaur taxa in future excavations and studies.

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