

Neogene Bovidae from Tha Chang Sandpits, Nakhon Ratchasima, Northeastern Thailand

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ABSTRACT

The Neogene bovids (Artiodactyla, Mammalia) from Tha Chang sandpits No. 8 and No. 10, Nakhon Ratchasima, northeastern Thailand were taxonomically examined, with systematic descriptions of ancestral bovins, *Selenoportax* and *Pachyportax* species. The fossil assemblage from sandpit No. 8 is composed of one species, *S. vexillarius*, with many early late Miocene mammals corresponding to the *Hipparion* datum of South Asia. The fossil assemblage from sandpit No. 10 includes two species, *S. falconeri* and *P. giganteus*. The occurrence range of *S. falconeri* is slightly older than that of *P. giganteus* in South Asia, but they probably coexisted during the late Miocene in continental Southeast Asia. The finding of *Selenoportax* and *Pachyportax* species from Tha Chang sandpits confirms early dispersal of these species between South Asia and Southeast Asia during the late Miocene.

Keywords: Bovini, mammal, fossil, Miocene, Khorat, Southeast Asia

INTRODUCTION

Since the 1980's a huge number of terrestrial mammalian fossils have been found in the Neogene and Quaternary deposits at Tha Chang sandpits which are located along the Mun River in the Khorat basin, Chaloem Phra Kiat District, Nakhon Ratchasima Province, northeastern Thailand (Fig. 1). Owing to the few Neogene fossil localities in Thailand, the mammalian fossil assemblage from the Tha Chang sandpits is valued as significant paleontological evidence to understanding the evolutionary process of late Neogene mammals. In particular, the discovery of Miocene orangutans, *Khoratpithecus piriyai* Chaimanee *et al.* (2004), from sandpit No. 8 (Somsak sandpit) provided a new fossil record filling the missing link in Asian hominoids.

The fossil-bearing beds at the Tha Chang sandpits (we call 'Tha Chang beds' in this paper) are overlain

by Quaternary alluvial deposits. The Tha Chang beds at sandpit No. 8 are more than ca. 10 m thick and separated basically into two units: the lower stratigraphic unit is dominantly composed of sand, along with organic-rich clay (reduced zone); the upper stratigraphic unit is characterized by yellowish sand and gravel (oxidized zone) (e.g., Chaimanee *et al.*, 2006). Some tektites have been collected from the lowermost part of the upper unit (ca. 8 m thick), which are originated from the 0.8 Ma Australasian strewn field (Howard *et al.*, 2003; Haines *et al.*, 2004). This lithological difference seemingly reflects a sedimentary matrix with fossils; that is, most fossils from the lower unit have a black coloration, and include sulfide minerals such as FeS₂. Mammalian fossils are entombed mostly in a clay or sandstone bed in the lower unit (Chaimanee *et al.*, 2007; Hanta *et al.*, 2008; Thasod *et al.*, 2011). The Tha Chang beds include no dating material, such as tuffaceous minerals.

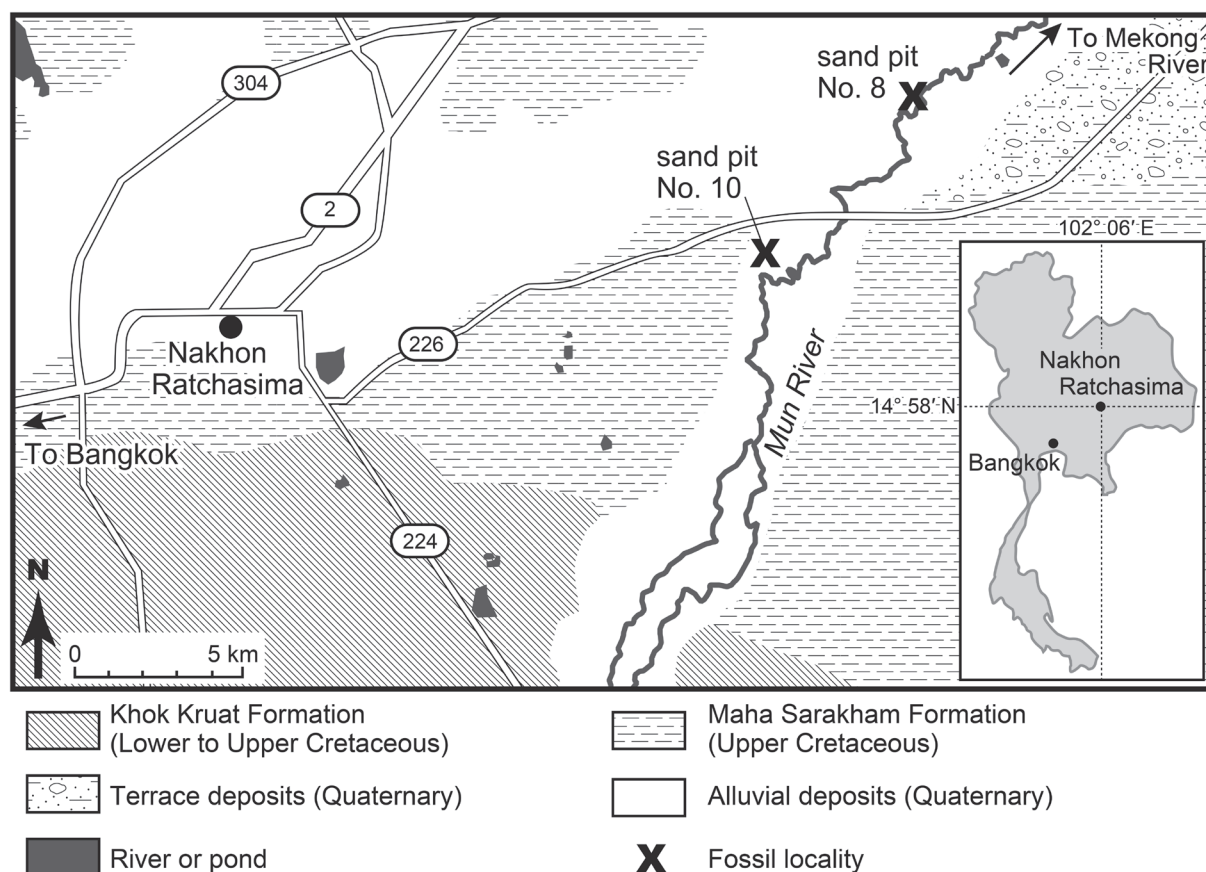


Figure 1. Geological map of the Khorat basin, Nakhon Ratchasima, northeastern Thailand, indicating the locations of Tha Chang sandpits No. 8 and No. 10 (modified after Department of Mineral Resources, 1999).

Recently, more than 2000 specimens of vertebrate remains from the Tha Chang beds were catalogued in the collection by the Khorat Fossil Museum (= Northeastern Research Institutes of Petrified Wood and Mineral Resources), Nakhon Ratchasima Rajabhat University. However, most of them have not yet been systematically described. Chaimanee *et al.* (2007) listed the following mammalian species in the fossil assemblage from the lower unit of sandpit No. 8: Primates (*Khoratpithecus piriyai*); Perissodactyla (*Hipparion* spp., *Chilotherium palaeosinense*, *Brachypotherium perimense*, *Alicornops complanatum*); Artiodactyla (*Hippopotamodon* cf. *sivalense*, *Propotamochoerus* cf. *hysudricus*, *Merycopotamus medioximus*, *Microbunodon milaensis*, several bovid and giraffid species); and Proboscidea (*Prodeinotherium* sp., *Deinotherium* cf. *indicum*, *Gomphotherium* sp., *Stegolophodon* sp., *Stegodon* sp.). Recent studies have renewed some taxonomic positions and added new taxa: *Merycopotamus thachangensis* Hanta *et al.* (2008); *Aceratherium porpani* Deng *et al.* (2013); *Bramatherium* sp. by Nishioka *et al.* (2014); *Zygolophodon* sp. by Duangkrayom *et al.* (2017); *Duboisia* aff. *santeng* by Nishioka and Vidthayanon

(2018). Moreover, Thasod *et al.* (2011) gave short description of 8 species of proboscideans, including *Prodeinotherium pentapotamiae*, *Gomphotherium* sp., *Tetralophodon* sp., *Sinomastodon* sp., cf. *Protanancus macinnesi*, *Stegolophodon* sp., *Stegodon* sp., and *Elephas* sp. Most of the species from the Tha Chang beds indicate late Miocene (around 9–6 Ma), based on biostratigraphic comparisons with the Siwalik fauna from Indo-Pakistan (e.g., Barry *et al.*, 2002), but ongoing taxonomic work on additional fossil mammal taxa is necessary for more precise discussion for the age of Tha Chang mammalian fossils (Chaimanee *et al.*, 2006). In the present paper, we give systematic description of bovid cranial remains from the Tha Chang beds, noting taxonomic and stratigraphic correlation in Neogene bovids between Thailand and South Asia.

MATERIALS AND METHODS

Abbreviations

AMNH, American Museum of Natural History, New York; BMNH, British Museum Natural History

(Natural History Museum, London); **NRRU**, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima; **GSI**, Geological Survey of India, Kolkata; **PMNH**, Pakistan Museum of Natural History, Islamabad; **RIN**, Rajabhat Institute of Nakhon Ratchasima, Nakhon Ratchasima; **TKK**, Takut Khon, Nakhon Ratchasima.

Examined fossils

A total of 30 cranial specimens of bovid fossils collected from the lower unit of the Tha Chang beds at Tha Chang sandpits No.8 and No. 10 (Fig. 1) were described in this study. The Khorat Fossil Museum houses the NRRU-RIN (hereafter abbreviated as 'RIN') and NRRU-TKK (hereafter abbreviated as 'TKK') collections. The former includes specimens collected from sandpit No. 8 before 2007. The latter is the collection from sandpit No. 10 in 2012 and 2013.

Measuring methods

Skull morphometry was measured in mm using a digital caliper (model no. NTD12P-15C by

Mitutoyo Corp., Japan) and angles of horn cores were measured in degree using a protractor, following the method by Nishioka *et al.* (2019) (see also Fig. 2). Five measurements (2, 3, 4, 6, and 11) were obtained by doubling the distance between the interfrontal or sagittal suture and each structure if they lacked one side. Horn core cross sections were observed at the base (above the pedicel) in the superior view.

Explanation for each measurement. (1) antero-posterior length of interfrontal suture (not available for the examined specimens in this study); (2) distance between right and left dorsal orbital rims; (3) distance between right and left supraorbital foramina; (4) minimum distance between right and left horn pedicels at base; (5) antero-posterior length of brain case (from bregma to superior nuchal line); (6) maximum width of brain case; (7) dorso-ventral depth of brain case (from the highest point of temporal crest to mastoid process); (8) height of occipital (from superior nuchal line to foramen magnum); (9) transverse thickness of basioccipital at anterior tuberosities; (10) transverse thickness of basioccipital at posterior tuberosities; (11)

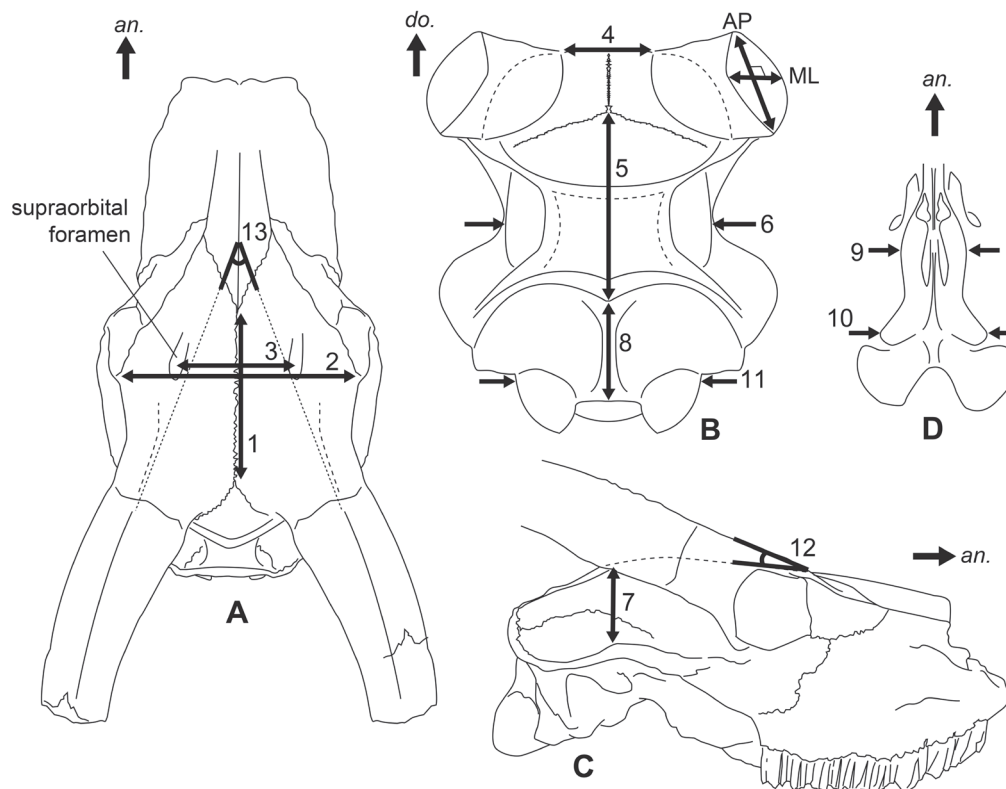


Figure 2. Measurements in skull of bovids. (A) dorsal view of skull. (B) posterodorsal view of skull. (C) right lateral view of skull. (D) ventral view of basioccipital. Measuring numbers and abbreviations are explained in the sentence. Schematic drawings of the skull (A and C) were modified from those of *Proamphibos kashmiricus* by Pilgrim (1939). Abbreviations: an, anterior; do, dorsal.

transverse distance between occipital condyles; (12) inclination angle of the horn core from the frontal plane; (13) divergence angle between right and left horn pedicels; (AP) antero-posterior diameter of horn core at base (or usually distance between anterior and postero-lateral keels); (ML) medio-lateral diameter of the orthogonal axis to the diameter AP.

Key to the species identification of *Selenoportax* and *Pachyportax*

Selenoportax and *Pachyportax* are phylogenetically placed in a stem clade of the tribe Bovini including buffalos and bison (Bibi, 2007; Bibi *et al.*, 2009). Pilgrim (1937), who originally established these genera, described three species (*S. vexillarius*, *S. lydekkeri*, and *P. latidens*) from the Dhok Pathan Formation of the Siwaliks. Later, he added a smaller form, *P. nagrii*, from the Nagri Formation (Pilgrim, 1939), but this species is currently replaced in *P. latidens* as an intraspecific variation (Gentry, 1974). According to Gentry *et al.* (2014), *S. lydekkeri* is possibly synonymized with *Strepsiceros(?) falconeri* (Lydekker, 1886) (=

Perimia falconeri Pilgrim, 1939). Akhtar (1995) described a larger form, *P. giganteus*, from the Dhok Pathan Formation; although, this species has been informally combined with the genus *Selenoportax* (Gentry *et al.*, 2014). There are some uncertain fossil records of *Selenoportax* sp. from the late Miocene site of Lufeng, China, but neither descriptions nor figures are given (Han, 1985).

Classification of *Selenoportax* and *Pachyportax* species is complex because their holotypes are isolated dental specimens or fragmentary/immature skulls which do not clearly show diagnostic characteristics in bovids. The continuing absence of consolidated specimens of calvaria and teeth have also confused the identification of these genera (Bibi, 2007). Recently, Nishioka *et al.* (2019) described many cranial fossils of *Selenoportax* and *Pachyportax* species from the late Neogene Irrawaddy beds, central Myanmar, and gave emended diagnosis for four species: *S. vexillarius*, *S. falconeri*, *P. latidens*, and *P. giganteus*. Based on this study, we defined the following key to distinguish these species (see also Fig. 3).

1. Frontal with narrow and elongate supraorbital foramen; brain case short and wide; occipital relatively low and wide; horn cores greatly diverged, curved inward through the upper half; cross section at the base elliptical/subtriangular/rounded diamond with a lateral angle *Selenoportax* (2)
 - Frontal with small supraorbital foramen, extending from the anterior keel on the pedicel; brain case relatively long; occipital relatively high; horn cores less diverged (50–80 degrees); anterior keel facing more anteriorly, sometimes with basal rugosities; cross section at the base subtriangular with a medial angle; lateral surface flattened *Pachyportax* (3)
2. Size smaller; horn cores widely diverging at base (ca. 100–120 degrees); lateral surface expanded, and medial surface flat *S. vexillarius*
 - Size larger; horn cores moderately diverging (ca. 70–80 degrees); cross section expanded medio-laterally *S. falconeri*
3. Size smaller; cross section less compressed medio-laterally; medial expansion strong *P. latidens*
 - Size larger; cross section strongly compressed medio-laterally; medial expansion weak *P. giganteus*

SYSTEMATIC PALEONTOLOGY

Family Bovidae Gray, 1821

Subfamily Bovinae Gray, 1821

Genus *Selenoportax* Pilgrim, 1937

Selenoportax vexillarius Pilgrim, 1937
(Figures 4, 5A–E)

1937 *Selenoportax vexillarius* Pilgrim, p. 740, figs. 2–5, 52–54, 56, 80.

1939 *Selenoportax lydekkeri* (Pilgrim); Pilgrim, p. 172, pl. 7 (fig. 10).

Examined material. 1 calvarium with right and left horn cores (RIN 523); 2 neurocrania (RIN 316, RIN 545); 1 partial calvarium with a right horn core (RIN 556); 1 occipital (RIN 311); 2 right horn cores (RIN 74, RIN 882); 2 left horn cores (RIN 73, RIN 438).

Locality and age. Tha Chang sandpit No. 8, late Miocene.

Measurements. Tables 1 and 2.

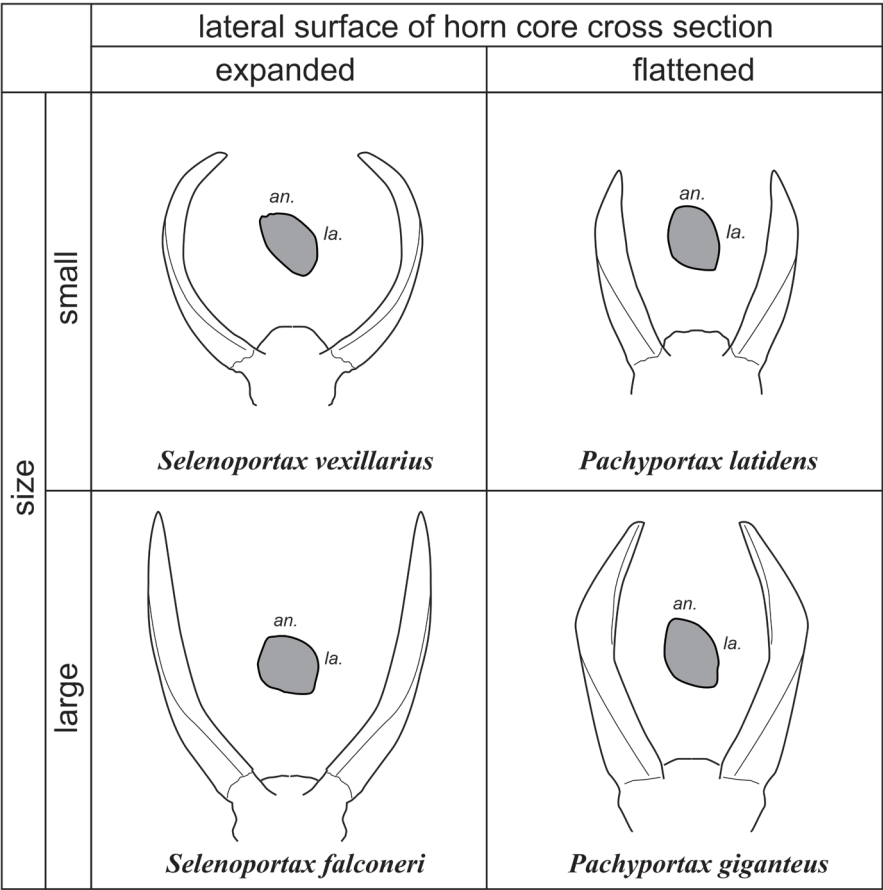


Figure 3. Comparisons in cranial morphology and right horn core cross section of *Selenoportax* and *Pachyportax* species (non-scale). Schematic drawings were reconstructed from pictures by Pilgrim (1937) and Nishioka *et al.* (2019). Abbreviations: an, anterior; la, lateral.

Description

Neurocranium/calvarium: RIN 316, 523, 545, and 556 are composed of frontal, parietal, temporal, and occipital bones. RIN 523 and RIN 556 preserve almost complete horn cores directly above the orbits. Sutures of all the skull specimens are closed and slightly bulge out. RIN 316 and RIN 523 are somewhat smaller than RIN 545 and RIN 556. Right and left horn pedicels are separated each other by a broad interspace. The pedicel is short. The horn cores or pedicels diverge at 120 or 130 degrees. The postcornual region, or frontal surface behind each horn core, is slightly depressed in a circle. The supraorbital foramen is situated at the anterior side of the pedicel, being equidistant from the interfrontal suture and the orbital arch. There is a single lacrimal foramen below the supraorbital foramen. The postcornual fossa behind the orbital arch is absent or indistinct. Temporal crests are strong, extending on the parietal and supraoccipital bones. The dorsal surface of the parietal is smooth

without a rugose sculpture which is represented by the tribe Boselaphini and Tragoportacini. The parietal unites robustly with the temporal by the squamous suture. There is a weak ridge along the squamous suture on the temporal fossa. This ridge is relatively prominent during the supraoccipital and the center of the temporal fossa. The temporal fossa is dorsoventrally shallow. The supraoccipital is elongated laterally. The superior nuchal line is strong. The posterior brain case (during the bregma and the superior nuchal line) is relatively short: length (Measurement #5)/width (Measurement #6) is within the range between 0.78 and 0.95. The occipital surface crosses the parietal or supraoccipital surface at right angles and bends somewhat posteriorly at the one-third height below the supraoccipital surface. The median nuchal line on the occipital weakly develops as a keel. The maximum occipital height (Measurement #8) is almost half of the brain case width: Measurement #8/Measurement #6 = 0.49 in RIN 316 and RIN 545. The maximum interval between the occipital

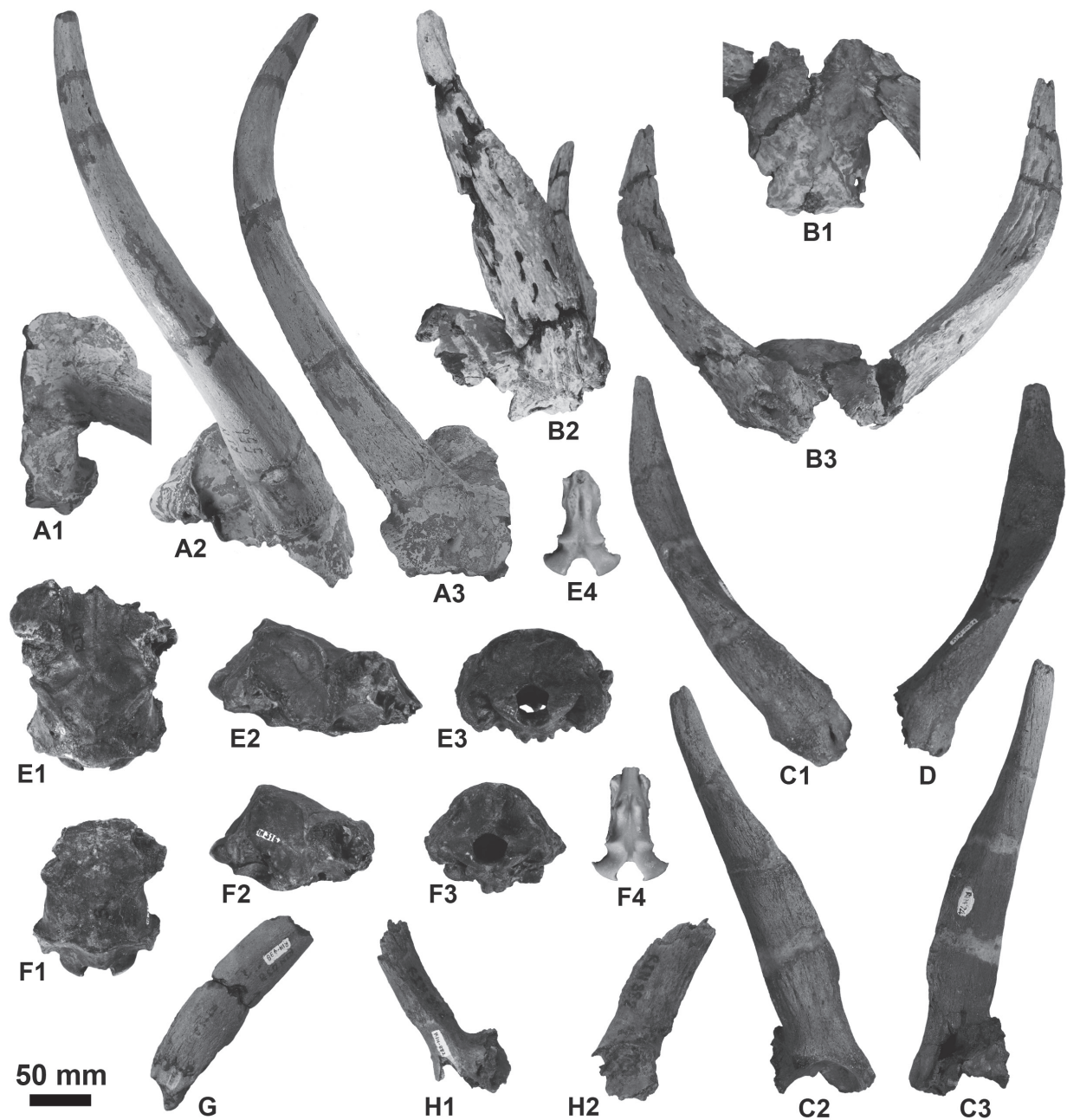


Figure 4. Skulls and horn cores of *Selenoportax vexillarius* from Tha Chang sandpit No. 8. (A) RIN 556 (right): (A1) dorsal view; (A2) lateral view; (A3) anterior view. (B) RIN 523: (B1) dorsal view; (B2) right lateral view; (B3) anterior view. (C) RIN 74 (right): (C1) anterior view; (C2) lateral view; (C3) medial view. (D) RIN 73 (left): anterior view. (E) RIN 545: (E1) dorsal view; (E2) right lateral view; (E3) posterior view; (E4) basioccipital (resin cast). (F) RIN 316: (F1) dorsal view; (F2) right lateral view; (F3) posterior view; (F4) basioccipital (resin cast). (G) RIN 438 (left): lateral view. (H) RIN 882 (right): (H1) anterior view; (H2) medial view.

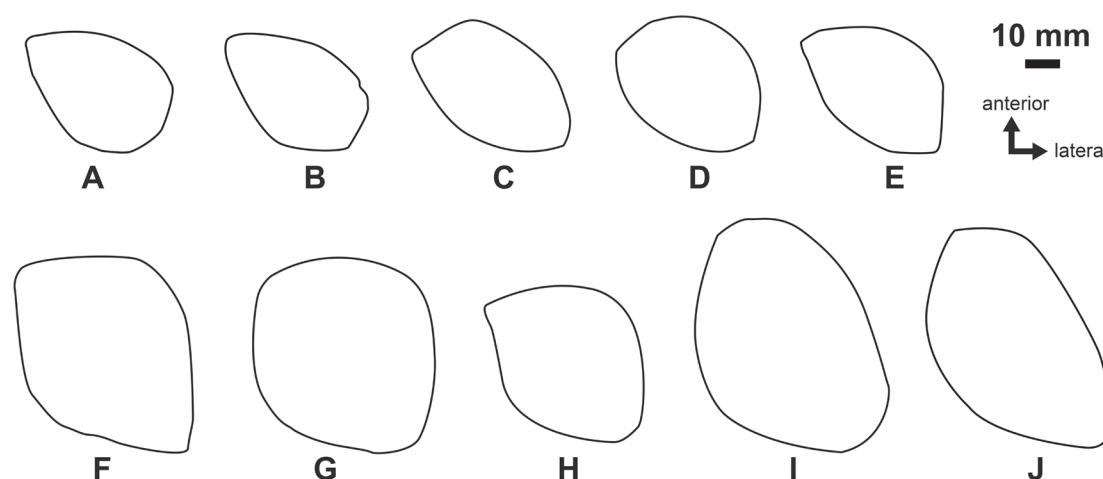


Figure 5. Horn core cross sections of *Selenoportax vexillarius* (A–E), *S. falconeri* (F–G), *S. sp. indet.* (H), and *Pachyportax giganteus* (I–J). (A) RIN 73 (left, mirror image). (B) RIN 74 (right). (C) RIN 523 (right). (D) RIN 556 (right). (E) RIN 882 (right). (F) TKK 128–129 (right). (G) TKK 150 (right). (H) RIN 437 (left, mirror image). (I) TKK 61 (right). (J) TKK 153 (right).

condyles is as wide as the supraoccipital surface. The auditory bullae and the mastoid processes are moderately prominent. The outline of the basioccipital base shows a slender triangle on the ventral view. The anterior muscular tuberosities are small but projected ventrally. The posterior muscular tuberosities are prominent with a central ridge. There is a tiny slender keel between the anterior tuberosities.

Horn core: The entire length of complete horn cores measured along the posterior keel reaches 250 mm in RIN 523 and 400 mm in RIN 556. The horn shaft moderately curves inward, and twists weakly clockwise. The cross section of RIN 556 is elliptical at base, with two keels at the anterointernal and posteroexternal sides. These keels are relatively obtuse from the base to 50 mm above, and get sharp between 50 mm and 250 mm. The external side of the cross section expands prominently between 50 mm and 150 mm. The cross section at the tip is considerably rounded like a circle shape. The keels on the right horn core rotate 45 degrees clockwise at 200 mm above and 90 degrees clockwise at the tip. There are two deep grooves along each keel at base. The external side between 100 mm and 150 mm expands laterally like a keel. RIN 438 and RIN 882 are same morphologically with RIN 556, while three specimens (RIN 73, RIN 74, and RIN 523) show a minor difference in cross section morphology (Fig. 5). The cross sections of the latter specimens are rounded subtriangular with

a sharper anterointernal keel and weaker external angle than that of RIN 556.

Remarks. RIN 556 is similar in neurocranial and horn core morphology with the holotype of *S. vexillarius* (AMNH 19748) from the Siwaliks, which was described by Pilgrim (1937) (see the identification key as mentioned above). In cranial and horn core measurements, the specimens examined in this study are as large as the holotype of *S. vexillarius* (Tables 1 and 2). RIN 73, RIN 74, and RIN 523 are unique in having cross sections flattened mediolaterally, or weak lateral angle, but this minor difference is treated as an intraspecific variation because RIN 523 shares basic calvarial characteristics with AMNH 19748 and RIN 556. Similar morphological variation was found in *S. vexillarius* from the upper Miocene Irrawaddy beds of central Myanmar (Nishioka *et al.*, 2019). The occurrence range of *S. vexillarius* is from 10.2 Ma to 9.8 Ma, based on Harvard's collection from the Siwaliks (Gentry *et al.*, 2014). In the case of the Irrawaddy fauna of central Myanmar, *S. vexillarius* first appeared in the Asian *Hipparion* datum, or after 10.7 Ma by Barry *et al.* (2002) and survived at least until the latest Miocene or early Pliocene (Nishioka *et al.*, 2019). Therefore, the presence of *S. vexillarius* in the late Miocene fauna of Thailand is consistent biostratigraphically with contemporaneous Irrawaddy fauna of central Myanmar.

Table 1. Skull measurements of *Selenoportax vexillarius* and *S. falconeri* (unit: mm).

Measurements	2	3	4	5	6	7	8	9	10	11	12	13
<i>S. vexillarius</i>												
RIN 316	140	47.3	31.2	73.0	93.8	43.8	45.5	25.8	39.7	64.5	—	—
RIN 523	—	—	35.1	83.0	87.4	—	—	—	—	—	40	120
RIN 545	140	53.1	36.9	76.1	93.1	44.1	45.9	25.9	40.2	65.6	—	130
RIN 556	173	76.6	38.9	—	86.5	41.2	—	—	—	—	25	120
AMNH 19748 ^{1,2}	102	60.8	37.9	75.6	88.6	41.9	—	—	—	—	15	110
<i>S. falconeri</i>												
TKK 151	—	—	34.9	96.8	108.6	53.6	68.6	31.2	55.6	93.6	—	—
IR 2306 ²	171	66.4	28.3	72.9	96.7	51.1	60.3	28.1	49.7	79.4	20	70

¹Holotype. ²Measurements by Nishioka *et al.* (2019).

Table 2. Diameters of horn core cross section of *Selenoportax vexillarius*, *S. falconeri*, *S. sp. indet.*, *Pachyporax giganteus*, and *P. latidens* (unit: mm).

	AP	ML
<i>S. vexillarius</i>		
RIN 73	47.0	37.2
RIN 74	56.5	35.7
RIN 438	49.4	41.5
RIN 523	52.1	35.1
RIN 556	52.8	39.9
RIN 882	50.3	31.6
AMNH 19748 ^{1,2}	55.3	34.8
<i>S. falconeri</i>		
TKK 150	71.1	63.2
BMNH M 2402a ³	60.5	45.0
IR 3905 ³	66.9	56.6
<i>S. sp. indet.</i>		
RIN 268	58.6	41.6
RIN 365	51.0	34.3
RIN 437	59.4	45.5
RIN 667	49.2	32.4
RIN 1193	46.5	38.4
<i>P. giganteus</i>		
TKK 61	79.8	52.7
TKK 153	84.7	60.1
PMNH No. 87/323 ^{1,4}	78.0	52.0
<i>P. latidens</i>		
GSI B488 ²	53.0	42.3

¹Holotype. ²Measurements by Nishioka *et al.* (2019). ³Measurements by Pilgrim (1939).

⁴Measurements by Akhtar (1995).

***Selenoportax falconeri* (Pilgrim, 1939)**
(Figures 5F–G, 6)

1884 *Boselaphus* sp. Lydekker, p. 114, figs. 1–4, 7, 8, 11, pl. 13.

1886 *Strepsiceros* (?) *falconeri* Lydekker, p. 8, figs. 2, 2a, pl. 2.

1910 *Boselaphus lydekkeri* Pilgrim, p. 70.

1937 *Selenoportax lydekkeri* (Pilgrim); Pilgrim, p. 745, figs. 55, 57–59.

1939 *Selenoportax lydekkeri* (Pilgrim); Pilgrim, p. 173, pl. 7 (fig. 11).

1939 *Perimia falconeri* (Lydekker); Pilgrim, p. 166,

fig. 15.

Examined material. 2 neurocrania (TKK 151, TKK 152); associated right and left horn cores (TKK 150); 2 right horn cores (TKK 128–129, TKK 149).

Locality and age. Tha Chang sandpit No. 10, late Miocene.

Measurements. Tables 1 and 2.

Description

Neurocranium: TKK 151 was wrongly combined with horn cores (TKK 150) when we obtained these specimens from a fossil trader, and thereafter, we removed adhesive material, separating each specimen. TKK 151 is similar in cranial shape with that of *S. vexillarius* (RIN 316, RIN 545), but larger than this species (Table 1). The dorsal surface of the frontals becomes slightly hollow behind the horn pedicels. The brain case, or the parietal and occipital region, is relatively short anteroposteriorly: Measurement #5/Measurement #6 = 0.89. The parietal and supraoccipital bones have strong temporal crests. The parieto-supraoccipital region surrounded by the temporal crests and the superior nuchal line rises dorsally as an oblong trapezoidal bulge. The parietal surface is smooth without rugose sculpture. The temporal fossa is dorsoventrally shallow relative to the brain case width. The supraoccipital is completely joined with the parietal. The center of the superior nuchal line slightly projects. The median nuchal line is well-developed as a keel and has ligament fossa on either side of the line. The posterior surface of the occipital is relatively high: Measurement #8/Measurement #6 = 0.63. The maximum distance between the occipital condyles is as wide as the brain case width. The basioccipital bone deeply projects at each muscular tuberosity. The outline of the basioccipital shows a slender triangle on the ventral view and is not strongly constricted at the midpoint between the anterior and posterior tuberosities. There is no keel on the basioccipital bone. TKK 152 is slightly smaller than TKK 151, but they are morphologically same each other.

Horn core: The entire length of the complete horn core, TKK 150 (left), measured along the posterior keel reaches 550 mm. TKK 150 is weakly twisted clockwise in the right side. The horn shaft curves inward. The cross section is rounded diamond at base, with anteromedial and posterolateral keels. The lateral angle is strong as a keel from the base to 200 mm above. The cross section from the half to the tip shows an elliptical outline compressed mediolaterally. The medial surface is weakly projected. The axis connecting the main keels rotates 45 degrees clockwise approximately above 150 mm high and 90 degrees clockwise above 250 mm high. There are many small grooves on the horn surface. The postcornual fossa is weak. TKK 128-129 and TKK 149 are each a middle portion of horn core, corresponding with TKK 150 in size and cross section shape.

Remarks. The type specimens of *S. falconeri*, including *S. lydekkeri* (Pilgrim) Pilgrim, 1937 and *Perimia falconeri* (Lydekker) Pilgrim, 1939, from the Siwaliks are a maxilla (GSI B 231) and a skull (BMNH 37262) of young individuals, respectively. These specimens do not completely elucidate difference between *S. falconeri* and the other *Selenoportax*/*Pachyportax* species (Nishioka *et al.*, 2019). However, the adult horn core (BMNH M 2402a) described as *S. lydekkeri* characterizes the diagnosis of this species (Pilgrim, 1937, 1939; see also the identification key by this study). Moreover, neurocranial and horn core measurements indicated close resemblance between the present specimens and *S. lydekkeri* from the Siwaliks or *S. falconeri* from the Irrawaddy beds, central Myanmar (Tables 1 and 2). In the Siwalik fauna, *S. falconeri* occurred from 9.3 Ma to 8.9 Ma (Gentry *et al.*, 2014), of which duration overlaps with the estimated age of Tha Chang mammalian fauna (ca. 9–6 Ma by Chaimanee *et al.*, 2006); although, this species had possibly existed in younger or longer terms in continental Southeast Asia, with *S. vexillarius* (Nishioka *et al.*, 2019).

Selenoportax sp. indet.

(Figures 5H, 7)

Examined material. 1 neurocranium (TKK 60); 5 right horn cores (RIN 160, RIN 268, RIN 367, RIN 1192, RIN 1193); 7 left horn cores (RIN 314, RIN 365, RIN 366, RIN 437, RIN 667, RIN 1197, TKK 127).

Locality and age. RIN specimens are from Tha Chang sandpit No. 8, late Miocene; TKK specimens are from sandpit No. 10, late Miocene.

Measurements. Table 2.

Description

Calvarium: TKK 60 is a calvarium composed of frontal, parietal, temporal, and occipital bones. It is similar morphologically to skulls of *Selenoportax* species (e.g., RIN 545, TKK 151). The base of the right pedicel fits in size with the horn core of *S. vexillarius*, but the present specimen lacks no conclusive characteristics to distinguish from *S. falconeri*. At present, we should leave species identification for this material.

Horn core: RIN 437 is a basal part of left horn core. The cross section has two sharp keels on

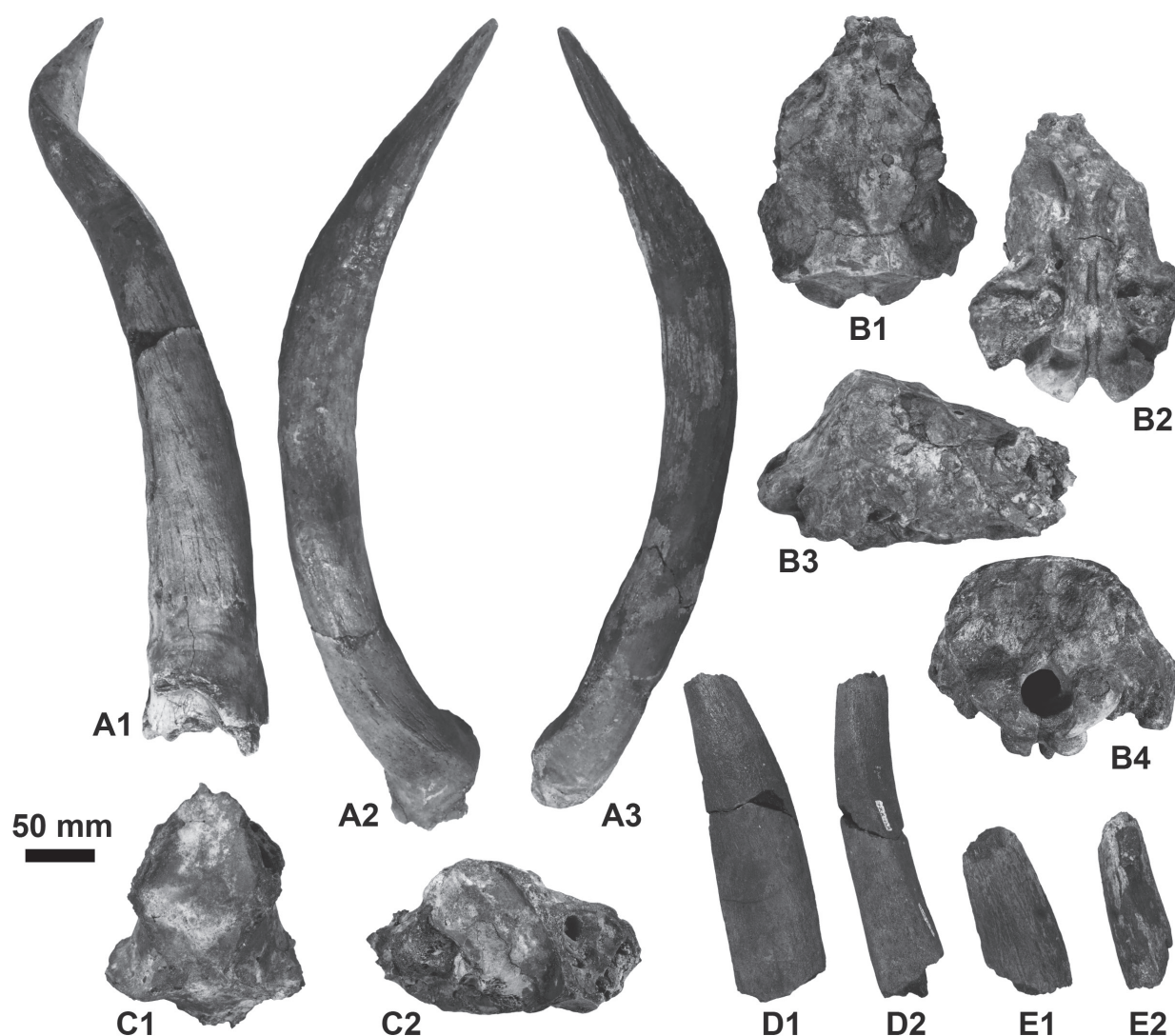


Figure 6. Skulls and horn cores of *Selenoportax falconeri* from Tha Chang sandpit No. 10. (A) TKK 150: (A1) lateral view (right); (A2) anterior view (right); (A3) anterior view (left). (B) TKK 151: (B1) dorsal view; (B2) ventral view; (B3) right lateral view; (B4) posterior view. (C) TKK 152: (C1) dorsal view; (C2) right lateral view. (D) TKK 128-129 (right): (D1) lateral view; (D2) anterior view. (E) TKK 149 (right): (E1) lateral view; (E2) anterior view.

the anteromedial and posterolateral sides and a lateral expansion. The medial angle is slightly stronger than that of *S. vexillarius*, but weaker than that of *S. falconeri*. RIN 268 is a middle portion of right horn core. Cross section shows an elliptical outline weakly expanded mediolaterally. The size is intermediate between *S. vexillarius* (e.g., RIN 556) and *S. falconeri* (e.g., TKK 150). TKK 127 is a middle portion (near the tip) of left horn core, with sharp keels. Cross section is expanded mediolaterally, like *S. falconeri*. The other specimens (RIN 160, RIN 314, RIN, 365, RIN 366, RIN 367, RIN 667, RIN 1192, RIN 1193,

RIN 1197) are characterized by elliptical cross section, but not identified in species level owing to fragmentary materials.

Genus *Pachyportax* Pilgrim, 1937

Pachyportax giganteus Akhtar, 1995
(Figures 5I–J, 8)

1995 *Pachyportax giganteus* Akhtar, p. 337.

Examined material. 2 right horn cores (TKK 61, TKK 153); 1 left horn core (TKK 134).

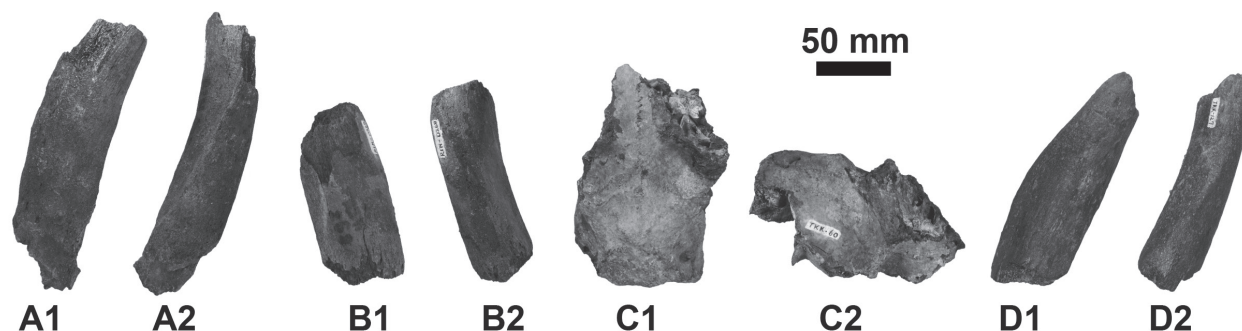


Figure 7. Skulls and horn cores of *Selenoportax* sp. indet. from Tha Chang sandpits No. 8 and No. 10. (A) RIN 437 (left): (A1) lateral view; (A2) anterior view. (B) RIN 268 (right): (B1) lateral view; (B2) anterior view. (C) TKK 60: (C1) dorsal view; (C2) right lateral view. (D) TKK 127 (left): (D1) lateral view; (D2) anterior view.

Locality and age. Tha Chang sandpit No. 10, late Miocene.

Measurements. Table 2.

Description

Horn core: The horn cores are large and compressed mediolaterally. TKK 153 preserves a basal part with a partial frontal. The supraorbital foramen is situated on the extension of the anteromedial keel. The pedicel connects directly to the orbital arch. The postcornual fossa is indistinct. The cross section is subtriangular with the anteromedial keel, the posterolateral keel, and a weak medial angle. The lateral surface is flat. Both main keels are sharp. The horn core surface has many longitudinal grooves. The angle between the horn core and the interfrontal suture is about 40

degrees, or the horn cores diverge at approximately 80 degrees. TKK 61 is same morphologically with TKK 153. TKK 134 is smaller than TKK 153 or TKK 61, but its cross section is compressed mediolaterally, as in the other specimens.

Remarks. There are two species of *Pachyportax*: *P. latidens* and *P. giganteus*. As we mentioned above, *P. giganteus* is not significantly different from *P. latidens*, except in size, but the present specimens are similar with the former rather than the latter, in having strong mediolateral compression that is definite apomorphy of *P. giganteus* (Akhtar, 1995). *P. giganteus* co-occurred with *S. falconeri* in the mammalian fossil assemblage from sandpit No. 10. The occurrence ranges of these species had shifted around 9 Ma, without overlapping, in the Siwalik fauna (Gentry *et al.*, 2014), whereas both species had

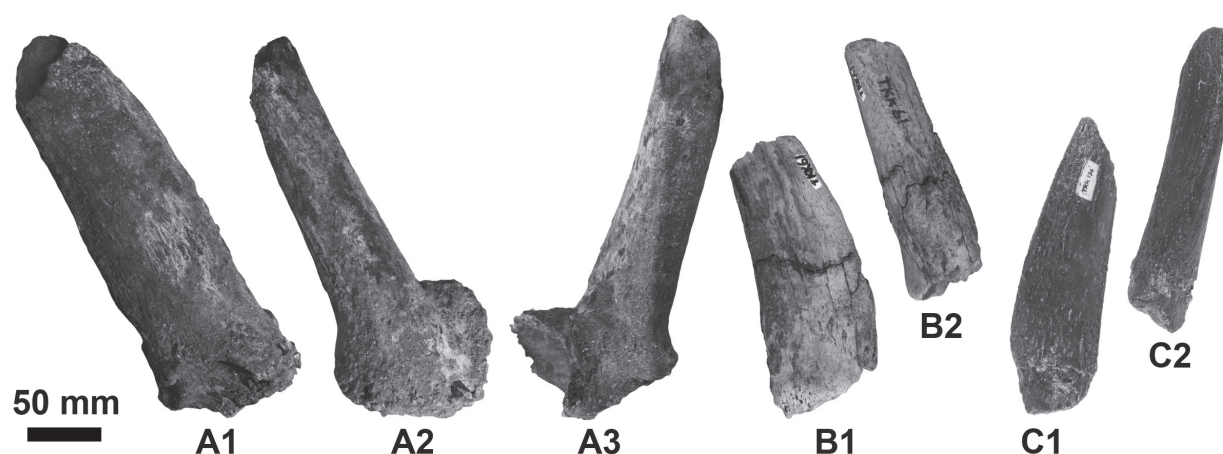


Figure 8. Horn cores of *Pachyportax giganteus* from Tha Chang sandpit No. 10. (A) TKK 153 (right): (A1) lateral view; (A2) anterior view; (A3) posterior view. (B) TKK 61 (right): (B1) lateral view; (B2) anterior view. (C) TKK 134 (left): (C1) lateral view; (C2) anterior view.

appeared during 6 Ma and 4 Ma in the Irrawaddy fauna (Nishioka *et al.*, 2019). Therefore, the findings of *S. falconeri* and *P. giganteus* from sandpit No. 10 suggested that these species had already dispersed onto continental Southeast Asia between 9 Ma and 6 Ma.

CONCLUSION

The bovid fossils from Tha Chang sandpits were classified into three species: *Selenoportax vexillarius* from sandpit No.8; and *S. falconeri* and *Pachyportax giganteus* from sandpit No. 10. The fossil records of *Selenoportax* and *Pachyportax* species from Tha Chang sandpits indicated their earliest occurrence in continental Southeast Asia, and supported that the mammalian fossil assemblages from the lower unit of both sandpits No. 8 and No. 10 are composed primarily of late Miocene fauna. The fossil assemblage from sandpit No. 8 differs from that from sandpit No.10 regarding bovid species composition, but more additional material will be required to verify chronological difference between those fossil assemblages.

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