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Thungwa, Satun Province, southern Thailand**

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**Proboscidean fossils (Mammalia) from the Quaternary deposits on *Stegodon* Cave,
Thungwa, Satun Province, southern Thailand**

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Abstract

The mammalian fossil assemblage was newly discovered from Quaternary deposits on *Stegodon* Cave, Thungwa District, Satun Province, southern Thailand. The fossil-bearing laterite is distributed on the floor throughout the cave, which had been possibly transported and reworked several times by tidal stream-flow in the cave, and yields many dental and bone fossils of mammals. The mammalian fossil assemblage is preliminarily classified into six genera belonging to three orders: Proboscidea (*Stegodon*, *Elephas*), Perissodactyla (*Rhinoceros*), and Artiodactyla (*Bubalus*, *Capricornis*, *Cervus/Rusa*). *Stegodon* molars have irregular enamel folding with scallop chevrons and low amplitude, which are similar to *S. orientalis* from East Asia rather than *S. trigonocephalus* from Java. *Elephas* sp. is indeterminate taxonomically in a species level, but it is somewhat more primitive than extant *E. maximus*, in having molars with thicker enamel, higher enamel amplitude folding, and lower number of laminae. These characteristics are observed in Pleistocene species of *Elephas*, such as *E. kiangnanensis* from middle–late Pleistocene of southern China. Taxonomic and morphological evidence on the basis of the proboscidean fossils suggests a strong faunal relationship in the middle or late Pleistocene between the Malay Peninsula and southern China.

Keywords: evolution; mammal; Pleistocene; Southeast Asia

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1. Introduction

The Malay Peninsula extends to the south of the Kra Isthmus as a biogeographic boundary between the Indochinese and Sundaic subregions (Corbet and Hill, 1992). Faunal interchange between these subregions is currently weak, but terrestrial mammals on continental Southeast Asia, including humans, had dispersed over the Kra Isthmus and migrated into Southeast Asian islands during the Plio-Pleistocene (e.g., Tougaard, 2001; Louys et al., 2007; Nishioka and Vidthayanon, 2018). Such faunal relationship of the Pleistocene mammals in Southeast Asia have been discussed based primarily on comparisons of paleontological data between the Asian continent and Java (e.g., Van den Bergh et al., 2001; Van der Geer et al., 2010). Especially, proboscideans are useful to verify the existence of faunal interchange between two localities, because they can disperse widely for a short period of geological time.

In Thailand, proboscidean fossils have been commonly found from the northern and northeastern parts where the Neogene and Quaternary fluvial sediments are distributed (Buffetaut et al., 1988; Saegusa et al., 2000, 2005; Duangkrayom et al., 2017). The Malay Peninsula, including southern Thailand and Malaysia, is also known as Quaternary mammalian fossil localities (Hooijer, 1962; Lim, 2013), but there have been no fossil records of proboscideans in southern Thailand. The first proboscidean fossil from southern Thailand was unexpectedly discovered in 2008 when Yutthanan Kaewpitak and his colleagues went prawn fishing into Wang Kluai Cave (later, named as *Stegodon* Cave by Narongrit Thungprue), and we started a collaboration research project, studying this first specimen (TW1-001 in this paper). *Stegodon* Cave has come to be recognized as a significant geological and paleontological spot by our fieldwork for five years, and currently it is registered in a part of Satun UNESCO Global Geopark.

In this study, we give systematic descriptions for proboscidean fossils from *Stegodon* Cave in order to understand the past mammalian fauna in the Malay Peninsula and a faunal relationship between the north and south areas of the Kra Isthmus.

2. Material and methods

2.1. Fossil locality

Proboscidean fossils examined in this study were collected in *Stegodon* Cave which is situated at Thungwa District, Satun Province, southern Thailand (Fig.1). The cave is a north-south horizontal tunnel (3389 m long) formed by two streams from the Ya Ra and Wang Kluai Mountains. These streams flow into the cave at the east side of each mountain, and join each other at a three-forked branching point near the west exit of the cave (Fig. 2). The cave

stream flows out to the Ya Ra River on a mangrove thicket, which leads to the Andaman Sea.

The base rock of *Stegodon* Cave is Ordovician limestone in the Rung Nok and Pa Kae Formations (Siripatphurinon and Chaleonkhuntham, 2016; Department of Mineral Resources, 2017), and the cave stream has accumulated Quaternary sediments, or laterite, composed primarily of coarse- and fine-grained sand/mud with gravel. Fossils of vertebrate animals are scattered on the cave floor and channel deposits of the stream, and they are polished and rounded due to transporting process by the stream (Fig. 2).

2.2. Sampling methods and mammalian fossil assemblage

The research team organized by the present authors and the Satun Geopark Project members has had fieldwork at *Stegodon* Cave since 2008 and collected geographical and geological data with 236 vertebrate fossils including mammalian teeth and bone fragments (Fig. 2). Most fossils were found on the surface of the channel deposits when the water level of the cave stream fell down due to a tidal cycle.

A total of 55 specimens (54 teeth and 1 antler) of the mammalian fossils from *Stegodon* Cave were identified, and they were preliminarily classified into six genera belonging to three orders: Perissodactyla (*Rhinoceros*), Artiodactyla (*Cervus/Rusa*, *Bubalus*, and *Capricornis*), and Proboscidea (*Stegodon* and *Elephas*) (Appendix 1). The remains of *Rhinoceros* are commonly included in the fossil assemblage (29 specimens). They are similar with *R. sondaicus* living in Java, although this species was disappeared on continental Southeast Asia at the present time. Taxonomic identification of the artiodactyl fossils has not been completed yet, but they are composed of extant genera in Southeast Asia.

The proboscidean remains described in this study were collected from both northern and southern branches of *Stegodon* Cave. The tooth fragments of *Elephas* are found, being concentrated on the floor of 600 m inside from the southern exit, and 1 specimen (TW1-131) was retrieved from the deposits on the cave wall near the western exit (Fig. 2: white stars). The tooth remains of *Stegodon* are scattered on the northern branch and at the western exit (Fig. 2: black stars).

All of the examined material is currently catalogued by temporal numbers (TW1-XXX), and they will be stored at an institute or museum in Thailand after completing essential studies.

2.3. Methods on taxonomic study

The anatomical nomenclature and measurement of proboscidean teeth are modified from

methods by Osborn (1942), MacInnes (1942), Maglio (1973), Beden (1979), Tassy (1983, 1996), and Van den Bergh (1999). Dental morphology of the family Stegodontidae, which defines homology of molar cusps, ridge structure, worn surface of enamel loop, and mastication, follows Saegusa (1996) and Van den Bergh (1999).

3. Systematic paleontology

Order Proboscidea Illiger, 1811

Family Stegodontidae Young, 1935/Hopwood, 1935

Genus *Stegodon* Falconer, 1857

***Stegodon orientalis* Owen, 1870**

(Fig. 3)

Examined specimens.—A distal part (2 lophs) of M^3 (TW1-136); a right hemimandible with fragmentary M_2 and M_3 (TW1-001); a fragment (2 lophs/ids) of M_2 (TW1-163); a mesial part (6 lophids) of M_3 (TW1-215).

Description.—TW1-136 (M^3 fragment) is brachydont and preserves two lophs. The enamel surface of the anterior loph is moderately worn and forms stufenbildung as type 3 defined by Saegusa (1996). The occlusal surface is slightly curved as an S-letter. The median sulcus is clearly developed but not deep. There is a deep valley between each loph. The valley does not have cement possibly due to a taphonomic cause. A very small knob is present in the buccal valley, forming a lateral cingulum. The anterior loph has 13 mammillae (pretrite-MMmMmMmMmmMmM-postrite), and the posterior loph has 11 mammillae (pretrite-MM MM MM mM MM M-postrite). Mesoconelet is laterally as large as the main cones. Measurements are as follows: occlusal bucco-lingual width, 94.6 mm (anterior side) and 94.3 mm (posterior side); and crown height, 48.4 mm (anterior side) and 48.6 mm (posterior side).

TW1-001 is a right hemimandible preserving a symphysis and a mandibular body with M_2 and M_3 . The mandibular body is slim in buccal view and relatively compressed bucco-lingually. The anterior part of the mandibular body is short and does not have the alveoli of lower incisors. The interalveolar crest is 120 mm long, although that on the symphysis tip is broken. The other measurements are as follows: dorso-ventral depth of the mandibular body at the body/ramus boundary, 139.5 mm; dorso-ventral depth of the mandibular body below the anterior edge of the alveolus, 96 mm; maximum bucco-lingual width of the mandibular body, 138 mm; minimum bucco-lingual width of the mandibular body, 36 mm; occlusal wear

surface, 207 mm; maximum occlusal wear surface, 71 mm.

M₂ of TW1-001 preserves the posterior part with 4 lophids. The occlusal surface shows a rectangular shape. The three anterior lophids are strongly worn and form scallop enamel folding with low amplitude. The folding has 5 chevrons in every 10 mm width. Stufenbildung is categorized in type 3. There is a median sulcus on the two anterior lophids extending from the occlusal surface to the base. Measurements as follows: occlusal bucco-lingual width in maximum, 81 mm; and enamel thickness, ca. 4–4.5 mm.

TW1-163 is an isolated left M₂ preserving the posteriormost part with 2 lophids and a small talonid. The anterior lophid is strongly worn. The enamel folding develops as an irregular scallop pattern with low amplitude. The folding has 4 or 5 chevrons in every 10 mm width. Stufenbildung is categorized in type 3. The posterior lophid has 11 mammillae. The mesoconelet and conelet are distinct as well as the main cones. Measurements as follows: occlusal bucco-lingual width in maximum, 75 mm; crown height, 36.2+ mm (brachydont); and enamel thickness, ca. 4.4 mm.

M₃ of TW1-001 preserves the anterior part with 4 lophids and a strong anterior cingulum. The tooth is rectangular in the occlusal outline and weakly curves with a lingual convex in the occlusal view. The anterior cingulum is as high as the other lophids. There is a deep gap between the anterior cingulum and the first lophid, and no crest connects between these lophids. Only the first lophid is worn by wearing process. The median sulcus on the first lophid is deep, and those on the other lophids are clear but relatively shallow. The pretrite mesoconelet of the first lophid is enlarged, approaching the anterior cingulum. The first lophid has 7 mammillae (pretrite-MmM mmMM-postrite), the second/third lophid has 10 imammillae (pretrite-MM MmmMm MmM-postrite and pretrite-Mmm MmM mmMM-postrite), and the fourth lophid has 12 mammillae (pretrite-MMmMmm MmM mmM-postrite). The mesoconelet is as large as the main cones. The central conule is absent. Cement covers the basal valleys of each lophid, but it is not relatively thick. Measurements as follows: occlusal bucco-lingual width in maximum, 82.6 mm; and crown height, 50.5 mm (brachydont).

TW1-215 is an isolated left M₃ preserving the anterior part with six lophids and a strong anterior cingulum. Only the first lophid is slightly worn. The cement is strongly worn by its lifework and/or taphonomic cause. The tooth is rectangular in the occlusal outline and weakly curves with a lingual convex. The first lophid has a deep median sulcus. There is no crest between the anterior cingulum and the first lophid. The pretrite mesoconelet of the first lophid is enlarged, approaching the anterior cingulum. The first lophid has 11 mammillae

(pretrite-mMMmmm mMmM-postrite), the second lophid has 10 mammillae (pretrite-mmMMM mMMmM-postrite), the third lophid has 11 mammillae (pretrite-Mm mMMM MMMMM-postrite), the fourth lophid has 11 mammillae (pretrite-Mm mMM MmMmmM-postrite), the fifth lophid has 10 mammillae (pretrite-Mm mMMm MMMM-postrite), and the sixth lophid has 9 mammillae (pretrite-MMMM MMMMM-postrite). The mesoconelet is almost as large as the main cones. The central conule is absent. Cement covers the basal valleys of each lophid. TW1-215 is similar in both size and shape (including a wearing stage) with M₃ of TW1-001. Moreover, these specimens were collected from almost the same point of *Stegodon* Cave. These evidences possibly indicate that TW1-001 and TW1-215 belong to a single individual. Measurements as follows: occlusal bucco-lingual width in maximum, 85.2 mm; and crown height, 54.0 mm (brachydont).

Remarks.—The molar folding pattern described as above characterizes the genus *Stegodon* (family Stegodontidae). Mammillae division and high enamel folding frequency of the present specimens differ from those of early species of *Stegodon*: i.e., *S. zhaotongensis* from Yunnan (Chow & Zhai, 1962), *S. zhaotongensis* ssp. 1 from Tha Chang sandpits, northeastern Thailand (Duangkrayom, 2016), *S. bombrifrons* from Pakistan (Falconer and Cautley, 1846–1847), and *S. elephantoides* from Myanmar (Osborn, 1942). The specimens from *Stegodon* Cave have more advanced characteristics of molars which are shared with *S. insignis* from Pakistan (Falconer and Cautley, 1846–1847; Osborn, 1942), *S. trigonocephalus* from Indonesia (Osborn, 1942; Hooijer, 1955; Van den Bergh, 1999), *S. aurorae* from Japan (Matsumoto, 1918; Osborn, 1942), and *S. orientalis* from Central and South China (Owen, 1870; Osborn, 1942; Pei, 1987). Compared with these advanced species of *Stegodon*, the present specimens are allocated into *S. orientalis*, in having a slim mandibular body and irregular enamel folding with scallop chevrons and low amplitude.

Family Elephantidae Gray, 1821

Genus *Elephas* Linnaeus, 1758

***Elephas* sp. indet.**

(Fig. 4)

Examined material.—M¹ (TW1-224); tooth fragments (TW1-053, TW1-115, TW1-118, TW1-120, TW1-123, TW1-131, TW1-196, TW1-197, TW1-230).

Description.—M¹ (TW1-224) preserves the posterior part with 6 lamellae which are strongly worn. The tooth is lophodont. Based on the preserved part of the root, the tooth originally had 8 or 9 lamellae, including an anterior cingulum. The enamel folding is irregular. A deep median sulcus is present only at the first lamella. Each lamella shows a chevron outline in occlusal view. Enamel is thick. Stufenbildung is clear. The facet surface between OE and IE is not high, although the dentine is strongly worn and concaved. There is a lateral cingulum. Measurements as follows: occlusal antero-posterior length, 115.5 mm; occlusal bucco-lingual width in maximum, 60.0 mm; crown height at the fourth lamella, 91.6+ mm; and enamel thick, 1.9–2.0 mm. The other specimens are too fragmentary to be identified, but they have same basic characteristics of cheek teeth with TW1-224.

Remarks.—TW1-224 has a lophodont dental pattern characterizing the genus *Elephas*, but it is more primitive than M¹ of living *E. maximus* (Asian elephants), in having lower number of lamellae, enamel thicker, chevron-shaped, and with higher folding amplitude. These characteristics are observed in *E. kiangnanensis* that is known from the Pleistocene of southern China (Pei, 1987). We leave a species identification for the present specimens because of insufficient materials and comparative data at the present state.

4. Discussion

4.1. Age of the mammalian fossil assemblage from *Stegodon* Cave

The age for the fossil assemblage from *Stegodon* Cave is still indeterminate because of no material to obtain absolute age. Moreover, we have not clarified whether or not the mammalian fossil assemblage is composed of a mixture of several fauna from different ages. While the perissodactyl and artiodactyl fossils from *Stegodon* Cave are composed of extant genera or species, those of proboscideans clearly suggest difference from the Recent mammalian fauna in Southeast Asia.

Stegodon species had been diversified in continental Southeast Asia and South Asia in the late Neogene (e.g., Saegusa, 2005, 2018), but such Neogene species (e.g., *S. elephantoides*) have been never found in the mammalian fossil assemblage from *Stegodon* Cave. Early Pleistocene species, such as *S. insignis* from South Asia and *S. aurorae* from Japan, are also absent in the examined material. *Stegodon orientalis* is generally found in East Asia. Its fossils in China have been reported in the Pleistocene (after ca. 1 Ma) and those in Japan are restricted to the middle Pleistocene (around 0.5 Ma) (e.g., Colbert and Hooijer, 1953; Kamei et al., 1988; Saegusa, 1996). The occurrence of the genus *Elephas* indicates the

Pleistocene and Holocene, but a dental form of *Elephas* sp. from *Stegodon* Cave is similar to that of *E. kiangnanensis* from the middle–late Pleistocene of southern China (Pei, 1987; Wang et al., 2017) rather than that of modern *E. maximus*. In southern China, *S. orientalis* coexisted with *E. kiangnanensis* during the middle Pleistocene to the late Pleistocene (possibly to the early Holocene) (Pei, 1987; Haowen & Patou-Mathis, 2003). At least, the proboscidean fossil assemblage from *Stegodon* Cave is closely correlated with that of the middle or late Pleistocene fauna of southern China.

Rhinoceros sondaicus and extant genera of artiodactyls (e.g., *Bubalus*) appeared before or at the beginning of the middle Pleistocene in Myanmar and Thailand (Tougaard, 2001; Louys et al., 2007; Zin-Maung-Maung-Thein et al., 2010; Filoux et al., 2015; Suraprasit et al., 2016). What the mammalian fossil assemblage from *Stegodon* Cave is a mixture of extinct and extant taxa is biostratigraphically consistent, even if all of the mammalian fossils belong to a single fauna in the middle or late Pleistocene.

4.2. Faunal dispersion

Stegodon orientalis was distributed primarily in East Asia (Saegusa, 1996), but our discovery demonstrates that this species existed on the Malay Peninsula during the Pleistocene. Recently, some proboscidean tooth fossils from the middle Pleistocene deposits at Khok Sung, northeastern Thailand, were described as *Stegodon* cf. *orientalis* (Suraprasit et al., 2016). However, this species is still debatable in taxonomy because the enamel folding is more complicated with high amplitude than a normal condition of *S. orientalis* from China, which may be rather similar to *S. trigonocephalus* from the Pleistocene on Java. The same dental morphotype has been also found from the Neogene or Pleistocene deposits in Tha Chang sandpits, Nakhon Ratchasima, northeastern Thailand (Duangkrayom, 2016). These studies have not clarified a phylogenetic relationship between Chinese *S. orientalis* and “*S. trigonocephalus*-type” species, including *S.* cf. *orientalis* from Khok Sung, but both species existed during the Pleistocene in Thailand.

The present discovery of *S. orientalis* is the first fossil record on the Malay Peninsula, or strictly at the south of the Kra Isthmus that divides current zoogeographical regions in Southeast Asia to the Indochinese and Sundaic subdivisions (Corbet and Hill, 1992). Many previous studies have suggested that some terrestrial mammals, such as hippos and buffaloes, had migrated from the Eurasian continent to Sundaic islands via the “Siva-Malayan” route and the “Sino-Malayan” route in the Plio-Pleistocene (e.g., Tougaard, 2001; Van der Geer et al., 2010). There is currently no clear fossil evidence of *S. orientalis* from Java and the other

Sundaic islands, but this species (and probably *Elephas* sp.) had undoubtedly dispersed on the Malay Peninsula over the Kra Isthmus, which supports a faunal migration via the “Sino-Malayan” route in the middle–late Pleistocene.

5. Conclusions

We preliminarily reported the mammalian fossil assemblage from *Stegodon* Cave, Thungwa District, southern Thailand, and described two species of Proboscidea: *Stegodon orientalis* and *Elephas* sp. closely related with *E. kiangnanensis*. The occurrence of these species suggests that the proboscidean fossil assemblage from *Stegodon* Cave is correlated biostratigraphically with the middle–late Pleistocene fauna of southern China, and it differs from contemporaneous fauna in South Asia and Island Southeast Asia. Continuous field research and taxonomic studies of the other taxa can reveal the faunal relationship in the Pleistocene between the Malay Peninsula and East Asia.

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References

- Beden, M., 1979. Les éléphants (*Loxodonta* et *Elephas*) d'Afrique Orientale: systématique, phylogénie, intérêt biochronologique. Ph.D. thesis, University Poitiers.
- Buffetaut, E., Helmcke-Ingavat, R., Jaeger, J.-J., Jongkanjanasontorn, Y., and Suteethorn, V., 1988. *Mastodon* remains from the Mae Teep Basin (northern Thailand) and their biostratigraphic significance. *Comptes rendus de l'Académie des Sciences*, 306(2), 249–254.
- Chow, M. Z. and Zhai, R., 1962. Early Pleistocene mammals of Chaotung, Yunnan, with notes on some Chinese stegodonts. *Vertebrata Palasiatica*, 6, 138–149. (In Chinese with English summary.)
- Colbert, E. H. and Hooijer, D. A., 1953. Pleistocene mammals from the limestone fissures of Szechwan, China. *Bulletin of the American Museum of Natural History*, 102(1), 7–134, 40 plates.
- Corbet, G. B. and Hill, J. E., 1992. *The mammals of the Indomalayan region*, Oxford University Press, USA, 488 pp.
- Department of Mineral Resources, 2017. *Satun Aspiring UNESCO Global Geopark*. Department of Mineral Resources, Bangkok, Thailand.
- Duangkrayom, J., 2016. Phylogenetic and dispersal analysis of Thailand's Stegodontidae (Mammalia, Proboscidea). Ph.D. thesis, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences. Beijing, China.
- Duangkrayom, J., Wang, S., Deng, T., and Jintasakul, P., 2017. The first Neogene record of *Zygodon* (Mammalia, Proboscidea) in Thailand: implications for the mammutid evolution and dispersal in Southeast Asia. *Journal of Paleontology*, 91(1), 179–193.
- Falconer, H., 1857. On the species of mastodon and elephant occurring in the fossil state in Great Britain. Part I. *Mastodon*. *The Quarterly Journal of the Geological Society of London*, 13, 307–360.
- Falconer, H. and Cautley, P. T., 1846–1847. *Fauna antiqua Sivalensis*, being the fossil zoology of the Siwalik Hills, in the north of India. Smith, Elder, London (plates only).
- Filoux, A., Wattanapituksakul, A., Lespes, C., and Thongcharoenchaikit, C., 2015. A

- Pleistocene mammal assemblage containing *Ailuropoda* and *Pondo* from Tham Prakai Phet cave, Chaiyaphum Province, Thailand. *Geobios*, 48, 341–349.
- Gray, J. E., 1821. On the natural arrangement of vertebrate animals. *The London Medical Repository*, 15, 296–310.
- Haowen T. and Patou-Mathis, M., 2003. Mammoth and other proboscideans in China during the Late Pleistocene. *Deinsea*, 9, 421–428.
- Hooijer, D. A., 1955. Fossil Proboscidea from the Malay Archipelago and India. *Zoologische Verhandelingen*, 28, 1–146.
- Hooijer, D. A., 1962. Report upon a collection of Pleistocene mammals from Tin-Bearing deposits in a limestone cave near Ipoh, Kinta Valley, Perak. *Federation Museums Journal*, 7, 1–5.
- Hopwood, A. T., 1935. Fossil Proboscidea from China. *Palaeontologia Sinica, Series C*, 9, 1–108.
- Illiger, C. D., 1811. *Prodromus systematis mammalium et avium additis terminis zoographicis utriusque classis*. Salfeld, Berlin, 301 pp.
- Kamei, T., Kawamura, Y., and Taruno, H. 1988. Mammalian stratigraphy of the Late Neogene and Quaternary in the Japanese Islands. *The Journal of the Geological Society of Japan*, 30, 181–204. (In Japanese with English abstract.)
- Lim, T. T., 2013. Quaternary *Elephas* fossils from Peninsular Malaysia: historical overview and new material. *The Raffles Bulletin of Zoology 2013 Supplement*, 29, 139–153.
- Linnaeus, C., 1758. *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species cum characteribus, differentiis, synonymis, locis*. Laurentii Salvii, Stockholm, 824 pp.
- Louys, J., Curnoe, D., and Tong, H., 2007. Characteristics of Pleistocene megafauna extinctions in Southeast Asia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 243, 152–173.
- MacInnes, D. G., 1942. Miocene and post-Miocene Proboscidea from East Africa. *Transactions of the Zoological Society of London*, 25, 33–106.
- Maglio, V. J., 1973. Origin and evolution of the Elephantidae. *Transactions of the American Philosophical Society, New Series*, 63(3), 1–149.
- Matsumoto, H., 1918. On a new archetypal fossil elephant from Mt. Tomuro, Kaga. *Science Reports of the Tôhoku Imperial University, Second Series*, 3, 51–60.
- Nishioka, Y. and Vidthayanon, C., 2018. First occurrence of *Duboisia* (Bovidae, Artiodactyla, Mammalia) from Thailand. *Fossil Records*, 21, 291–299.

- Osborn, H. F., 1942. Proboscidea. A monograph of the discovery, evolution, migration, and extinction of the mastodons and elephants of the world. J. Pierpont Morgan fund by the trustees of the American Museum of Natural History, the American Museum Press, New York.
- Owen, R., 1870. On fossil remains of mammal found in China. The Quarterly Journal of the Geological Society of London, 26, 417–343.
- Pei, W. Z., 1987. Carnivora, Proboscidea and Rodentia from Liucheng *Gigantopithecus* cave and other caves in Guangxi. Memorial of Institute of Vertebrate Paleontology and Paleoanthropology, Academy of Science. Beijing, 18, 1–119, 15 plates.
- Saegusa, H., 1996. Stegodontidae: evolutionary relationships. In: Shoshani J. and Tassy, P. (eds.), The Proboscidea. Evolution and Palaeoecology of Elephants and Their Relatives. Oxford University Press, 178–190.
- Saegusa, H., 2018. New proboscidean remains from the Late Cenozoic of central Myanmar. Fossils, 104, 35–49.
- Saegusa, H., Ratanasthien, B., and Nakaya, H., 2000. A new Miocene mammalian locality, Mae Soi, and the occurrence of partial skeletons of rhinocerotids and gomphotheres from northern Thailand. Asian Paleoprimateology, 1, 137–147.
- Saegusa, H., Thasod, Y., and Ratanasthien, B., 2005. Notes on Asian stegodontids, Quaternary International, 126, 31–48.
- Siripatphurinon, R. and Chaleonkhuntham, U., 2016. Result report for surveying and mapping in *Stegodon* Cave. Department of Mineral Resources, Bangkok.
- Suraprasit, K., Jaeger, J.-J., Chaimanee, Y., Chavasseau, O., Yamee, C., Tian, P., and Panha, S., 2016. The middle Pleistocene vertebrate fauna from Khok Sung (Nakhon Ratchasima, Thailand): biochronological and paleobiogeographical implications, ZooKeys, 613, 1–157.
- Tassy, P., 1983. Les Elephantoides miocènes du Plateau du Potwar, Groupe de Siwalik, Pakistan. Annales de Paléontologie, 69, 99–136, 317–354.
- Tassy, P., 1996. Who is who among the Proboscidea? In: Shoshani J., and Tassy, P. (eds.), The Proboscidea. Evolution and Palaeoecology of Elephants and Their Relatives. Oxford University Press, 39–48.
- Tougaard, C., 2001. Biogeography and migration routes of large mammal faunas in South-East Asia during the Late Middle Pleistocene: focus on the fossil and extant faunas from Thailand. Palaeogeography, Palaeoclimatology, Palaeoecology, 168, 337–358.
- Van den Bergh, G. D. 1999. The Late Neogene elephantoid-bearing faunas of Indonesia and

- their palaeozoogeographic implications. A study of the terrestrial faunal succession of Sulawesi, Flores, and Java, including evidence for early hominid dispersal east of Wallace's Line. *Scripta Geologica*, 117: 1–419.
- Van den Bergh, G. D., de Vos J., and Sondaar, P. Y., 2001. The Late Quaternary palaeogeography of mammal evolution in the Indonesian Archipelago. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 171, 385–408.
- Van der Geer, A., Lyras, G., de Vos, J., and Dermitzakis, M., 2010. Evolution of island mammals, Wiley-Blackwell, UK, 479 pp..
- Wang, Y., Qin, D., and Jin, C., 2017. New *Elephas* remains from the Zhiren cave of Mulan mountain, Chongzuo, Guangxi with discussion on Quaternary proboscidean evolution in southern China. *Quaternary Sciences*, 37(4), 853–859.
- Young, C. C. 1935. Miscellaneous mammalian fossils from Shansi and Honan. *Palaeontologia Sinica*, Series C, 9(2), 1–42.
- Zin-Maung-Maung-Thein, Takai, M., Tsubamoto, T., Egi, N., Thaung-Htike, Nishimura, T., Maung-Maung, and Zaw-Win, 2010. A review of fossil rhinoceroses from the Neogene of Myanmar with description of new specimens from the Irrawaddy Sediments. *Journal of Asian Earth Sciences*, 37, 154–165.

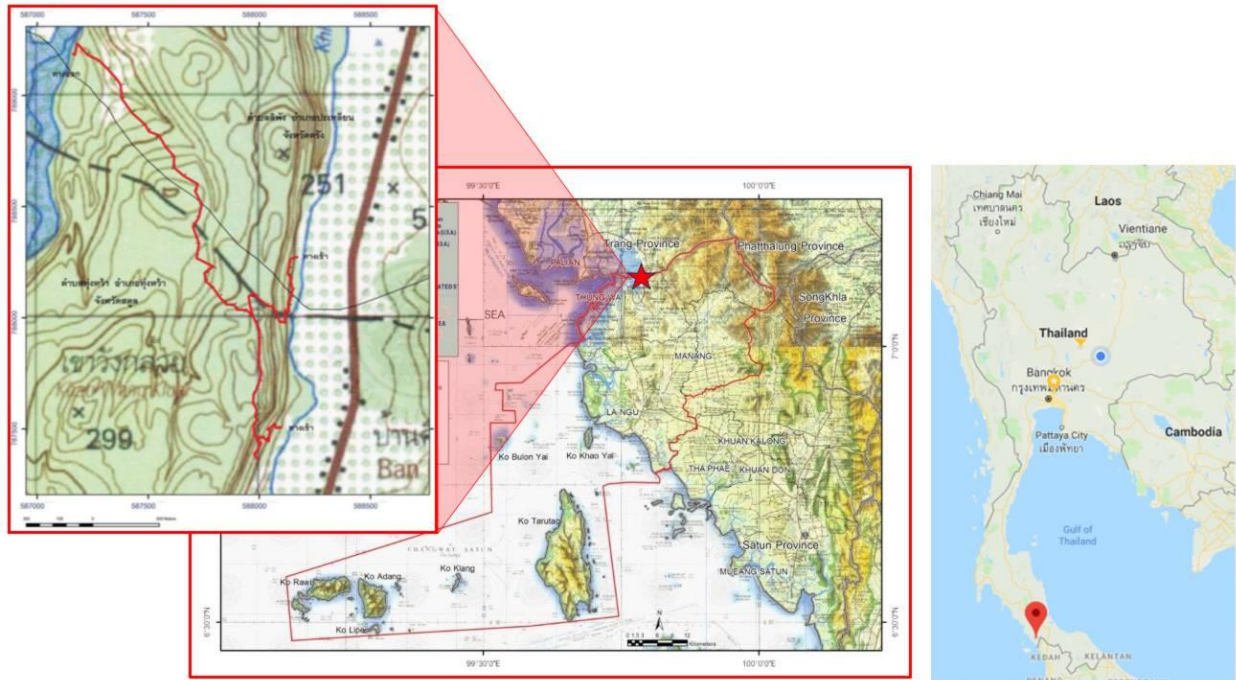


Fig. 1. Geographical map showing the location of *Stegodon* Cave, Thungwa District, Satun Province, southern Thailand (modified from Siripatphurinon and Chaleonkhuntham, 2016).

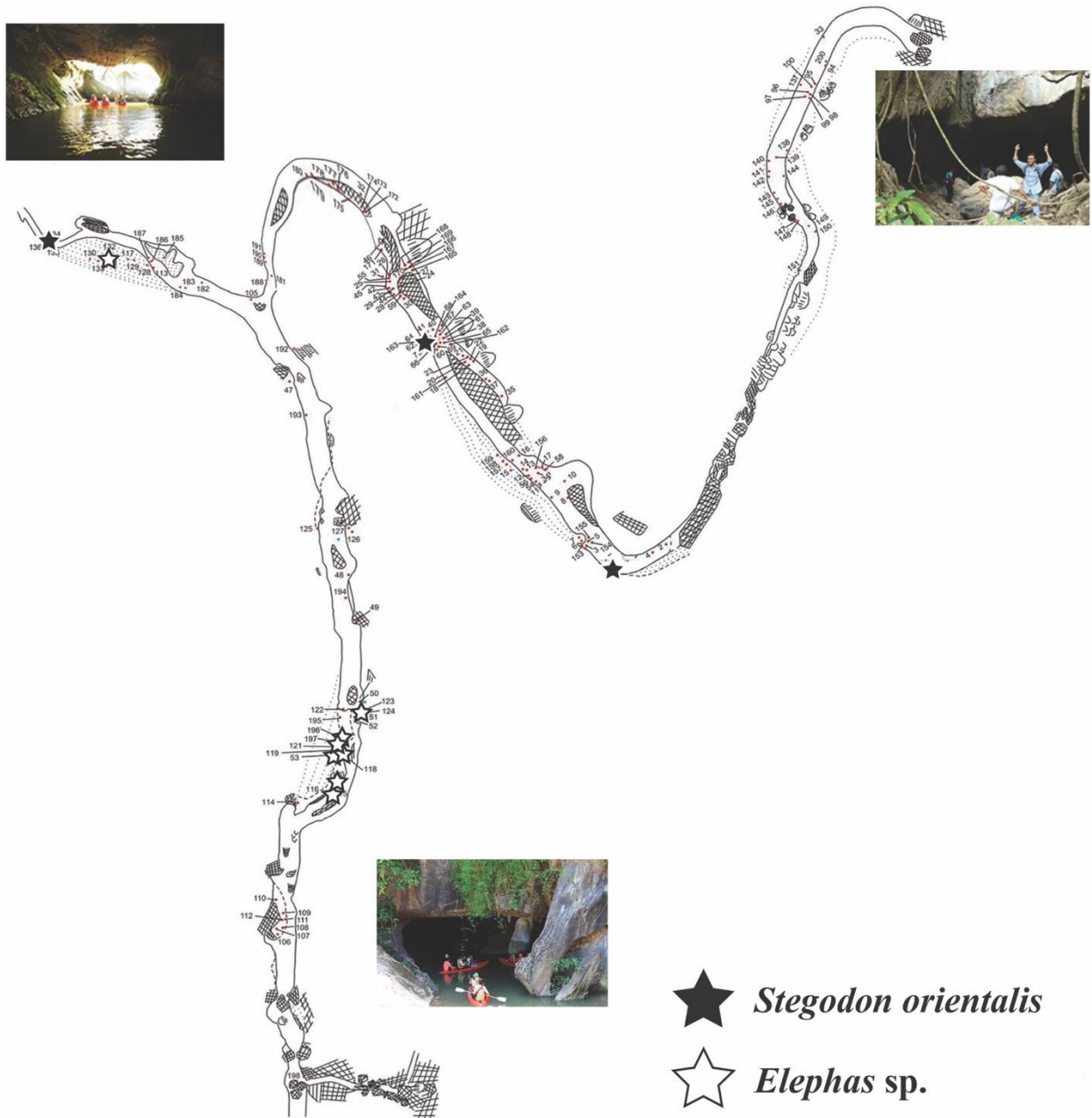


Fig. 2. Horizontal map (north-up) of *Stegodon* Cave with sampling points of all fossils and pictures of the cave exits.

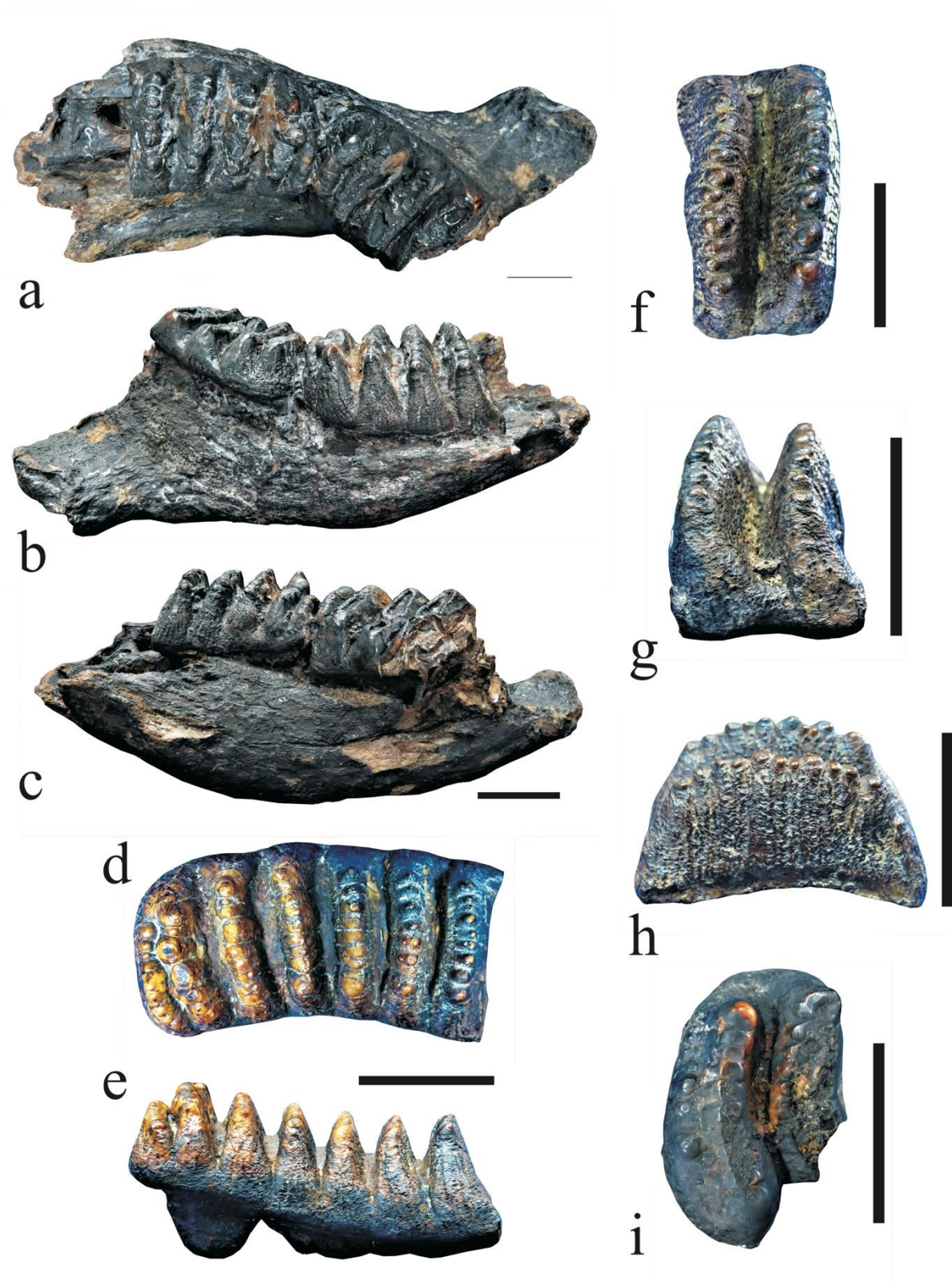


Fig. 3. *Stegodon orientalis* from *Stegodon* Cave. Right mandible with M₂ and M₃ (TW1-001): **a**, occlusal view; **b**, buccal view; **c**, lingual view; right M₃ (TW1-215): **d**, occlusal view; **e**, buccal view; molar fragment (TW1-136): **f**, occlusal view; **g**, lateral view; **h**, anterior view; M³ (TW1-163): **i**, occlusal view. Scale bars: 5 cm.

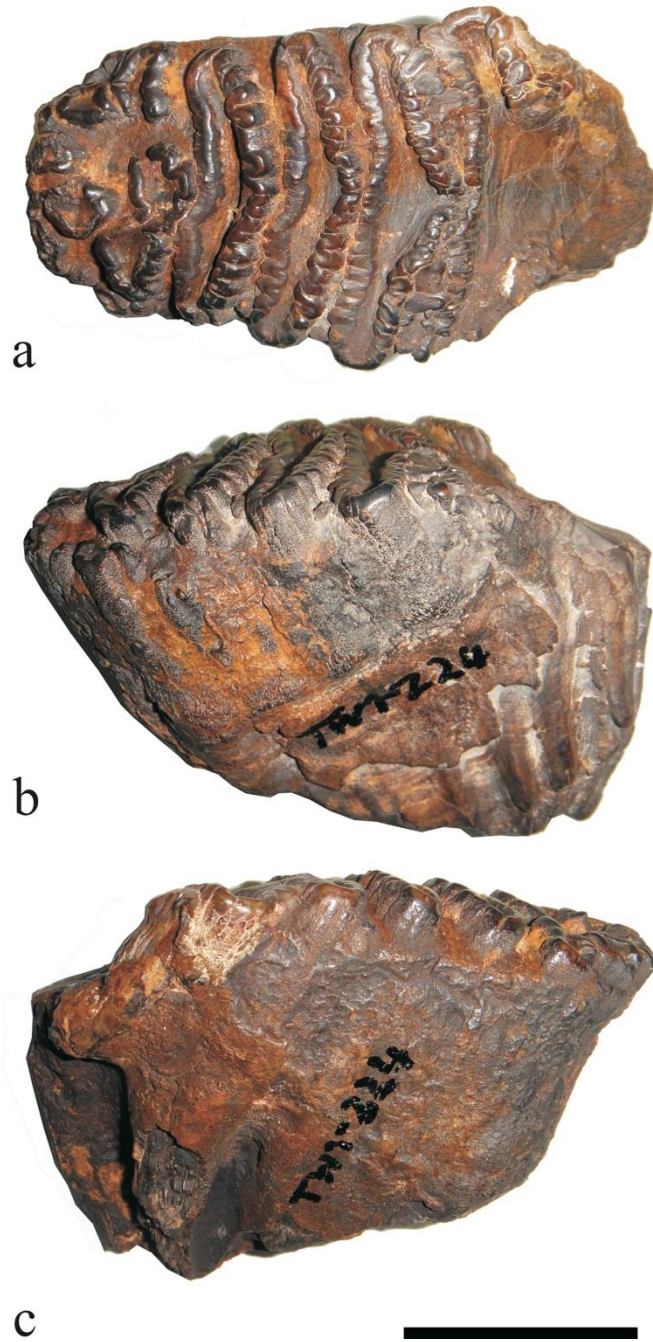


Fig. 4. *Elephas* sp. from *Stegodon* Cave. Right M¹ (TW1-224): **a**, occlusal view; **b**, lingual view; **c**, buccal view. Scale bar: 5 cm.

Appendix 1. List of the mammalian fossil assemblage (preliminary identification) from *Stegodon* Cave. Abbreviations: L, left; R, right.

No.	Material	Identification
Perissodactyla		
Rhinocerotidae		
TW1-002	L. P ⁴	<i>Rhinoceros sondaicus</i>
TW1-003	L. mandible (M ₂ –M ₃)	<i>Rhinoceros sondaicus</i>
TW1-009	L. P ⁴	<i>Rhinoceros sondaicus</i>
TW1-011	R. M ₁ / M ₂	<i>Rhinoceros sondaicus</i>
TW1-024	R.M ³	<i>Rhinoceros sondaicus</i>
TW1-026	R. P ² –P ³	<i>Rhinoceros sondaicus</i>
TW1-028	L. lower incisor	<i>Rhinoceros sondaicus</i>
TW1-039	L. lower molar	<i>Rhinoceros sondaicus</i>
TW1-044	L. P ⁴	<i>Rhinoceros sondaicus</i>
TW1-052	R. mandible fragment	<i>Rhinoceros sondaicus</i>
TW1-054	R. M ₁ /M ₂	<i>Rhinoceros sondaicus</i>
TW1-055	L. P ₂ /P ₃	<i>Rhinoceros sondaicus</i>
TW1-061	R. P ⁴	<i>Rhinoceros sondaicus</i>
TW1-062	L. M ²	<i>Rhinoceros sondaicus</i>
TW1-063	L. M ¹ /M ²	<i>Rhinoceros sondaicus</i>
TW1-064	L. dP ⁴ ?	<i>Rhinoceros sondaicus</i>
TW1-065	R. M ¹ –M ²	<i>Rhinoceros sondaicus</i>
TW1-106	L. mandible (P ₃ –P ₄)	<i>Rhinoceros sondaicus</i>
TW1-107	R. mandible fragment	<i>Rhinoceros sondaicus</i>
TW1-109	R. M ₁ /M ₂	<i>Rhinoceros sondaicus</i>
TW1-114	R. lower incisor	<i>Rhinoceros sondaicus</i>
TW1-156	R. mandible (P ₄ /M ₁)	<i>Rhinoceros sondaicus</i>
TW1-204	R. lower cheek tooth	<i>Rhinoceros sondaicus</i>
TW1-205	L. lower molar	<i>Rhinoceros sondaicus</i>
TW1-208	L. P ³ /P ⁴	<i>Rhinoceros sondaicus</i>
TW1-211	L. mandible (P ₂ –P ₃)	<i>Rhinoceros sondaicus</i>
TW1-233	R. lower cheek tooth	<i>Rhinoceros sondaicus</i>
TW1-234	L. P ³ /P ⁴	<i>Rhinoceros sondaicus</i>
TW1-235	L. P ⁴ /M ¹	<i>Rhinoceros sondaicus</i>
Artiodactyla		
Cervidae		
TW1-098	R. M ³	<i>Cervus/Rusa</i> sp.
TW1-141	L. M ³	<i>Cervus/Rusa</i> sp.
TW1-181	Brow tine of right antler	<i>Cervus/Rusa</i> sp.
Bovidae		
TW1-021	R. mandible (M ₁ –M ₂)	<i>Bubalus</i> sp.
TW1-128	R. upper molar	<i>Bubalus</i> sp.
TW1-143	Upper molar	<i>Bubalus</i> sp.
TW1-193	R. M ₃ fragment	<i>Bubalus</i> sp.
TW1-201	R. upper molar	<i>Bubalus</i> sp.
TW1-216	R. mandible (dP ₄ , M ₁ –M ₂)	<i>Bubalus</i> sp.

TW1-218	L. M ₁ /M ₂	<i>Bubalus</i> sp.
TW1-219	R. M ₁ /M ₂	Caprinae gen. et sp. indet.
TW1-223	R. M ₃	Caprinae gen. et sp. indet.
Proboscidea		
Stegodontidae		
TW1-001	R. hemimandible (M ₂ –M ₃)	<i>Stegodon orientalis</i>
TW1-136	2 lophs of M ³	<i>Stegodon orientalis</i>
TW1-163	2 lophids of M ₂	<i>Stegodon orientalis</i>
TW1-215	6 lophids of M ₃	<i>Stegodon orientalis</i>
Elephantidae		
TW1-053	tooth fragment	<i>Elephas</i> sp.
TW1-115	tooth fragment	<i>Elephas</i> sp.
TW1-118	tooth fragment	<i>Elephas</i> sp.
TW1-120	tooth fragment	<i>Elephas</i> sp.
TW1-123	tooth fragment	<i>Elephas</i> sp.
TW1-131	tooth fragment	<i>Elephas</i> sp.
TW1-196	tooth fragment	<i>Elephas</i> sp.
TW1-197	tooth fragment	<i>Elephas</i> sp.
TW1-224	R. M ¹	<i>Elephas</i> sp.
TW1-230	tooth fragment	<i>Elephas</i> sp.