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New discovery of a large-sized *Tetraconodon* (Artiodactyla, Suidae) from the lower part of the Irrawaddy Formation, Myanmar

Chit-Sein[1], Thaung-Htike[2], Takehisa Tsubamoto[2,3], Tin-Thein[4], and Gertrud E. Rössner[5]

[1]*Department of Geology, Hinthada University, Hinthada, Myanmar*
[2]*Primate Research Institute, Kyoto University, Inuyama, Aichi 484-8506, Japan*
[3]*Center for Paleobiological Research, Hayashibara Biochemical Laboratories, Inc., Okayama 700-0907, Japan*
[4]*Department of Geology, University of Yangon, Yangon, Myanmar*
[5]*Department of Earth and Environmental Sciences, Paleontology Section, and Geobio-Center, Ludwig-Maximilians-University Munich, 80333 Munich, Germany*

Abstract

New fossil dentitions of a large-sized *Tetraconodon* (Mammalia, Artiodactyla, Suidae) were discovered from the lower part of the Irrawaddy Formation, Migyaungye Township, Magway Division, central Myanmar. These specimens are the largest among the *Tetraconodon* specimens ever found in Myanmar. The molar dimensions of these specimens are similar with those of *Tetraconodon magnus* but are smaller in the dimensions of last two premolars than *T. magnus*. Therefore, we assigned these specimens as *Tetraconodon* sp. cf. *T. magnus*. The occurrence of a large *Tetraconodon* confirms an Upper Miocene age for the lower part of the Irrawaddy Formation.

Introduction

The Irrawaddy Formation (Upper Miocene to Lower Pleistocene) of Myanmar is famous for yielding many terrestrial mammalian fossils, such as proboscideans, rhinos, suids, hippos, giraffids, and bovids (Colbert, 1938, 1943; Thaung-Htike *et al.*, 2005).

In this short article, we describe three new fossil dentitions of a large-sized *Tetraconodon* (Mammalia, Artiodactyla, Suidae), which were recently collected from the lower part of the Irrawaddy Formation at the fossil locality Tebingan (West of Tebingan Village, Migyaungye Township, Magway Division, central Myanmar) and compare these specimens with the large-sized species of *Tetraconodon* from Indo-Pakistan as well as Myanmar. Additionally a detailed lithologic description of the lower part of the Irrawaddy Formation around the fossil locality is provided.

The new Irrawaddy specimens are morphologically distinct from the large-sized

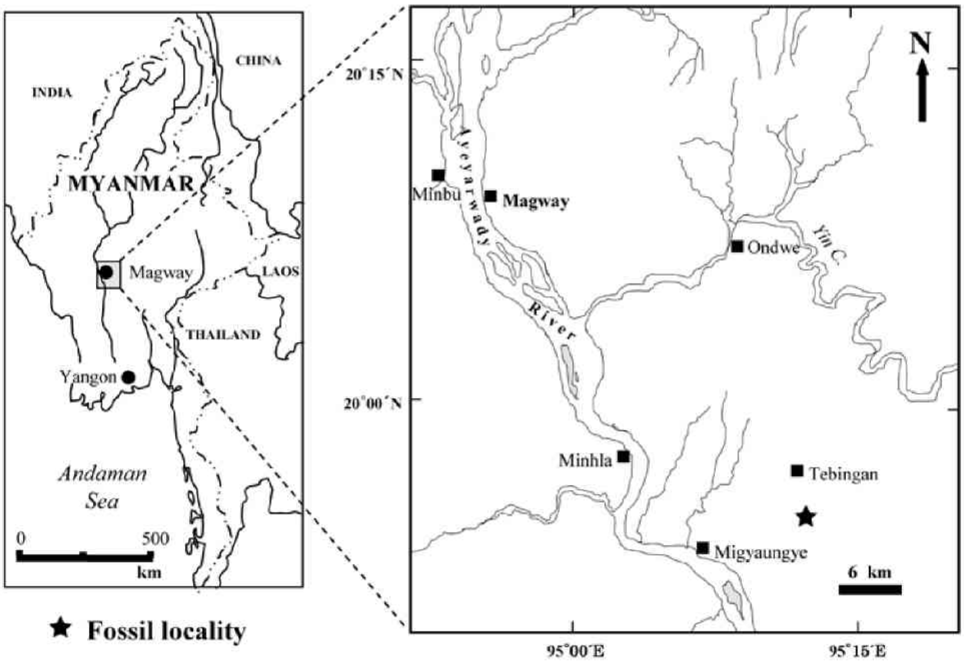

Figure 1. Map of the geographical position of the fossil locality Tebingan yielding *Tetraconodon* sp. cf. *T. magnus* in Myanmar.

Tetraconodon of the Middle Siwalik Group of Indo-Pakistan described by Pilgrim (1926); Made (1999) and from the *Tetraconodon* specimens of the Irrawaddy Formation that were previously reported by Thaung-Htike *et al.* (2005).

Abbreviations

NMM = National Museum, Yangon, Myanmar; NMMP-KU-IR = National Museum, Myanmar, Paleontology - Kyoto University - Irrawaddy (stored in the National Museum, Yangon); GSI= Geological Survey of India, Kolkata, India; YUDG-Mge=University of Yangon, Department of Geology-Migyaungye (name of the Township, Magway Division, central Myanmar) (stored in the Geology Museum of the University of Yangon, Yangon, Myanmar).

Geological setting and stratigraphy

The fossil locality is situated in the southern part of the central sub-basin of the Inner-Burman Tertiary Basin which is filled Paleogene and Neogene sediments (Bender, 1983). The Ayeyarwady (former Irrawaddy) River is flowing through the basin from north to south. On both sides of the Ayeyarwady River, the Irrawaddy Formation is widely distributed. It consists mainly of light grey to yellowish brown, medium to thick bedded, coarse-grained, gritty, and loosely consolidated sandstones with intercalated siltstones and light grey colored claystones. The most of the vertebrate fossils are found in occasionally occurring pebbly sandstones. Specimens of fossil wood and sandstone concretions are abundant.

Figure 2. Columnar section of the lower part of the Irrawaddy Formation at the fossil locality Tebingan (95° 08'15.2"E; 19°57'7.6"N) in the west of Tebingan Village, Migyaungye area, with indication of the strata which yielded suid fossils. Abbreviations: f, fine-grained; m, medium-grained; c, coarse-grained.

The fossils studied here were collected at the riverside of a tributary of the Ayeyarwady River in the west of Tebingan Village, about 13 km northeast of Migyaungye Township, Magway Division (Figure 1) from the lower part of the Irrawaddy Formation. A columnar section of the fossil locality Tebingan (Figure 2) shows that the Irrawaddy Formation overlies the Obogon Formation of the Upper Pegu Group (Middle Miocene) in a disconformity. This is indicated by a sudden change from fine-grained thin bedded sandstones, characteristic for the Obogon Formation, to yellowish or greyish coloured conglomerate bed, a lithologic feature of the Irrawaddy Formation. In the lowermost part (up to 200 m) the medium to thick bedded sandstones alternate with very thin bedded claystones. Small scale cross stratifications occur in the sandstones. Layers with red conglomerates of 20 to 50 cm thickness are frequently intercalated. These conglomerates consist mainly of quartz pebbles embedded in a deep red ferruginous matrix. The pebbles are 5 mm to 50 mm in diameter, are well-rounded to sub-rounded, and are moderately sorted. These conglomerate layers yield fragments of small bones, bony plates of turtles, and carapaces of crocodiles.

Towards the middle part of the section (from 200 to 400 m), thick-bedded and massive gritty sandstones are present with abundant mud nodules and large scale cross-beddings. The specimens of *Tetraconodon* sp. cf. *T. magnus* (YUDG-Mge 089, 090, 091) were found in these beds. There are intercalations of thin-bedded sandstone layers alternating with very thin claystone layers. Small-scale cross stratifications occur. Bedding and grain size increase to the top of this portion. (Figure 2). Frequently occurring conglomerate beds yield fragments of bone and teeth. Fossil wood is rare.

In the upper part (from 400 to 600 m), thin to medium bedded sandstones are dominant. Small scale cross stratification is recognized in these beds. The intercalation of siltstone and mudstone layers occurs in the lower portion (~ 425 m). Yellowish or reddish coloured conglomerate beds are also found. One of these beds yielded remains of *Propotamochoerus* "*hysudricus*", another suid. Concretions and fossil wood are still present.

In the uppermost part of the section (from 600 m to the top), the sandstones are less coherent than those in the lower part described above. Very thin-bedded clay layers gradually decrease towards the top of this portion. In the pebbly sandstone beds, the grain sizes progressively decrease towards the top, whereas the sandstone beds are getting thicker toward the top. Specimens of fossil wood are abundant with the vast majority being siliceous, but some are calcareous. Conglomerate beds are often found. Hollow hematitic or limonitic iron concretions are abundant.

Systematic paleontology

We used the dental terminology and measuring method according to Made (1996; Figure 3). Dental measurements of the new *Tetraconodon* specimens are shown in Table 1.

Order Artiodactyla Owen, 1848
Family Suidae Gray, 1821
Subfamily Tetraconodontinae Lydekker, 1876
Genus *Tetraconodon* Falconer, 1868
Type species *Tetraconodon magnum* Falconer, 1868

Tetraconodon sp. cf. *T. magnus* Falconer, 1868
Figures 4, 5

Material.—YUDG-Mge 089, a right maxillary fragment with P^3-M^2 and anterior half of M^3; YUDG-Mge 090, a left mandibular fragment with P_4; YUDG-Mge 091, a left maxillary fragment with M2-3.

Stratum.—Lower part of Irrawaddy Formation.

Locality.—Tebingan (19°57'51.1"N; 95°08'37.8"E), located west from Tebingan Village, Migyaungye Township, Magway Division, central Myanmar.

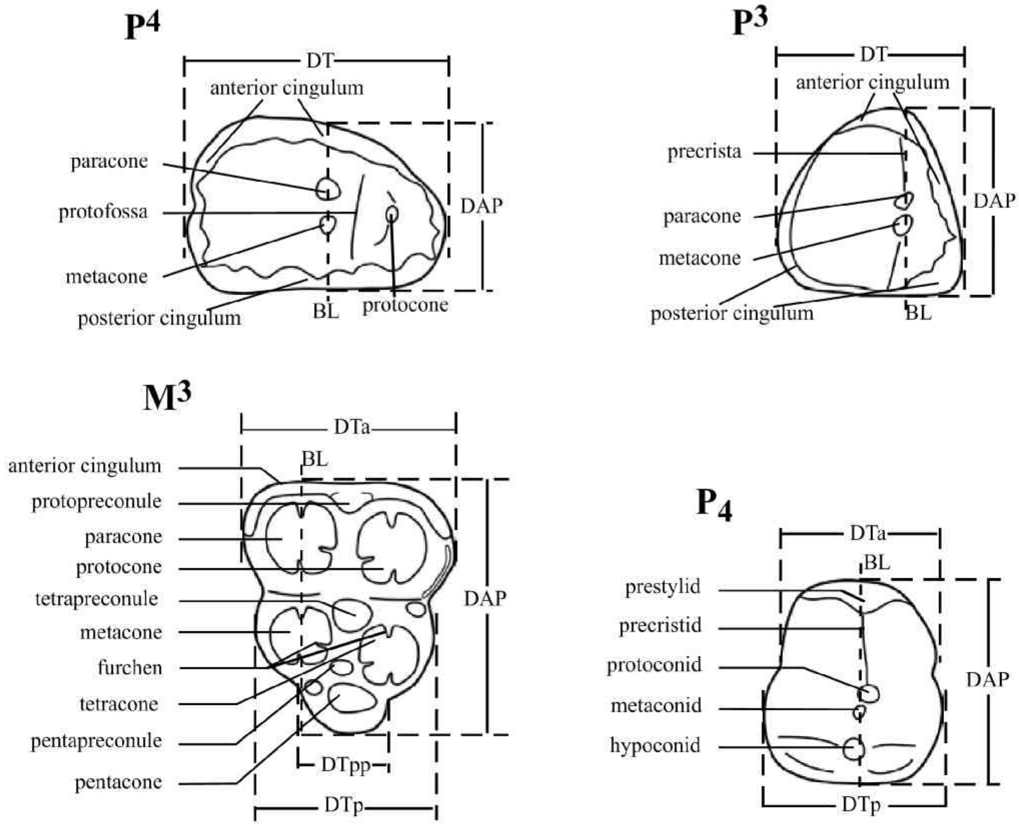

Figure 3. Dental terminology and measuring method of tetraconodontine teeth following Made (1996). All are right cheek teeth. Abbreviations: BL = base line; DAP = length; DT = maximum width; DTa = width of the first lobe in cheek tooth; DTp = width of the second lobe in cheek tooth; DTpp= width of the third lobe in $M^3/_3$. Figures modified from Thaung-Htike *et al.* (2005).

Description.—Occlusal outline of the P^3 of YUDG-Mge 089 (Figure 4A-C) is triangular. It is slightly larger and mesiodistally longer than the P^4. The paracone and metacone are worn and look like a single confluent large cusp. The enamel is thick and highly wrinkled. The cingula are well developed mesio-lingually and disto-lingually but weakly developed mesio-buccally.

The P^4 of YUDG-Mge 089 (Figure 4A-C) is much wider than the P^3. It is nearly sub-triangular shaped in occlusal outline. The buccolingual width is larger than the mesiodistal length. Shape of the protocone is round, and the cusp is isolated from the others. Because of the heavy wear, the paracone and metacone are fused. They are separated from the protocone by a deep protofossa. The cingula are strongly developed anteriorly and posteriorly but weakly developed in buccal and lingual faces. The enamel is thick and wrinkled especially buccally.

The M^1 of YUDG-Mge 089 (Figure 4A-C) is slightly narrower and smaller than the other teeth. In occlusal view, it is square shaped. Unfortunately, the heavy wear removed all morphological details on the occlusal surface. The enamel is slightly thinner and less wrinkled than that of P^{3-4} and M^{2-3}.

The M^2 of YUDG-Mge 089, 091 (Figure 4) is larger than the M^1. The four main cusps

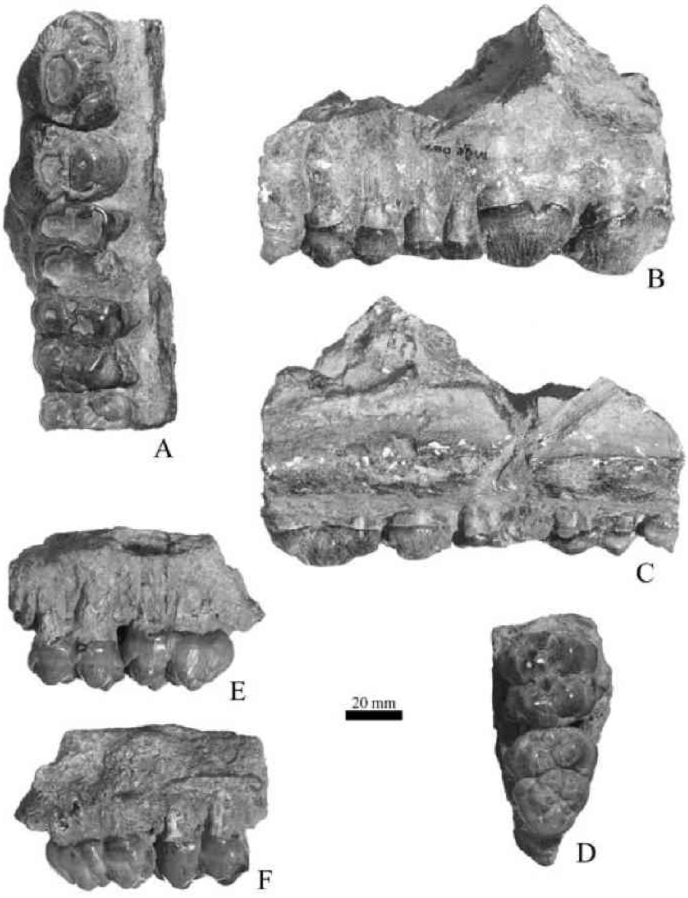

Figure 4. Upper cheek teeth of *Tetraconodon* sp. cf. *T. magnus*. **A-C**, YUDG-Mge 089, a right maxillary fragment with P^3–M^2 with anterior half of M^3: **A**, occlusal view; **B**, buccal view; **C**, lingual view. **D-F**, YUDG-Mge 091, a left maxillary fragment with M^{2-3}: **D**, occlusal view; **E**, buccal view; **F**, lingual view.

(paracone, protocone, metacone, and tetracone) are distinct and inflated. The protocone is larger than the other cusps. The paracone is larger than the tetracone and metacone. The protopreconule and tetrapreconule are distinct. The pentapreconule is small but distinct. The mesial cusps and distal cusps are separated by a fairly deep median valley. The furchen are distinct. The enamel is thick, and it is more wrinkled buccally than lingually. The anterior and buccal cingula are distinct, but less developed than those of premolars.

The M^3 of YUDG-Mge 089, 091 (Figure 4) is longer but narrower than the M^2, and has a triangular outline in occlusal view. The two anterior lobes with four main cusps are similar in morphology with those of M^2. The pentacone is distinct. The tetrapreconule is well developed and larger than the protopreconule and pentapreconule. There is no connection between the furchen. The median valley is narrow and deep. The enamel is thick and buccally slightly wrinkled. The anterior cingulum is more developed than the posterior.

The roots of the premolars are much larger than those of the molars. The external roots of M^2 are longer than those of M^1. All the roots of M^1 and M^2 are nearly vertical. However the distolingual root of M^2 is slightly bifurcated towards posterior.

The surfaces of molar crowns in YUDG-Mge 091 are hardly affected by wear, while the

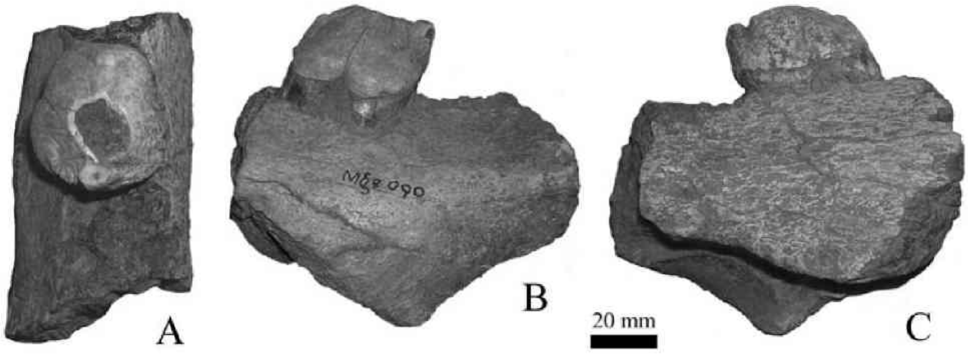

Figure 5. Lower P_4 of *Tetraconodon* sp. cf. *T. magnus*. **A-C**, YUDG-Mge 090, a left mandibular fragment with P_4: **A**, occlusal view; **B**, buccal view; **C**, lingual view.

molar crowns of YUDG-Mge 089 are heavy worn. The M^2 of YUDG-Mge 091 is slightly smaller than YUDG-Mge 089. Such differences can be considered as intraspecific variations.

The P_4 of YUDG-Mge 090 (Figure 5) is large and rugose. The protoconid and metaconid are strongly worn and cannot be differentiated. The hypoconid is large and isolated. The anterior precristid and prestylid are also isolated. The enamel is thick and slightly wrinkled distally. The posterior cingulum is distinct.

Discussion

The most outstanding character of the specimens described here are the extremely large last two premolars (YUDG-Mge 089, 090; Figures 4A-C, 5). This is congruent with the diagnostic traits of the genus *Tetraconodon* (Pilgrim, 1926; Made, 1999). In general, *Tetraconodon* species are distinguished based mainly on tooth size (i.e., dimensions of the M^1 and M_1). Four species of *Tetraconodon* are currently recognized: *T. magnus* Falconer, 1868; *T. minor* Pilgrim, 1910; *T. intermedius* Made, 1999; *T. malensis* Thaung-Htike *et al.*, 2005. The cheek teeth described here are bunodont and larger than those of *Tetraconodon intermedius*, *T. minor*, and *T. malensis*. The M^1 length (31.6 mm) of YUDG-Mge 089 (Table 1) is much larger than that of *T. intermedius* from Jammu (India) (GSI B.675; Pilgrim, 1926: pl. V). In *Tetraconodon*, an upper molar and the corresponding lower molar have approximately same length. M^1 and M^2 lengths of YUDG-Mge 089 are similar to those of *T. magnus* from Hasnot, India (GSI B. 71; Lydekker, 1879: pl. X) (Figure 6). The specimens described here, YUDG-Mge 089, 091, are the first discovery of maxillary fragments associated with well-preserved P^3-M^3 for the largest *Tetraconodon*. However, the dental morphology and the enlargements of P^3 and P^4 relative to M^1-M^3 are more similar to *T.* cf. *intermedius* from Pauk, Myanmar (Thaung-Htike *et al.*, 2005). According to these features, we assigned the present specimens to *Tetraconodon* sp. cf. *T. magnus*.

In general, the four species of *Tetraconodon* can be grouped into two size categories, large and small. The small-sized *Tetraconodon* species, *T. malensis* (the smallest) and *T. minor* (the second smallest), have been recovered only from Myanmar. The large-sized *Tetraconodon* species, *T. intermedius* (intermediate) and *T. magnus* (largest), have been

Table 1. Dental measurements (mm) of the *Tetraconodon* sp. cf. *T. magnus* from Tebingan. Abbreviations: DAP = length; DTa = width of the first lobe in cheek tooth; DTp = width of the second lobe in cheek tooth; DTpp= width of third lobe in $M^3/_3$; *italics* = estimate.

	$P^3/_3$			$P^4/_4$			$M^1/_1$			$M^2/_2$			$M^3/_3$			
	DAP	DTa	DTp	DAP	DTa	DTp	DAP	DTa	DTp	DAP	DTa	DTp	DAP	DTa	DTp	DTpp
upper dentition																
YUDG-Mge 089	39.05	30.00	38.23	28.99	42.40	47.10	31.6	32.23	*30.23*	35.85	37.10	35.93	-	34.24	-	-
YUDG-Mge 091	-	-	-	-	-	-	-	-	-	35.20	36.98	34.37	39.02	34.30	28.19	17.20
lower dentition																
YUDG-Mge 090	-	-	-	44.80	32.27	38.67	*32.00*	*27.82*	*26.80*	-	-	-	-	-	-	-

recovered from the Middle Siwalik Group of Indo-Pakistan. In Myanmar, *T. malensis* (Thaung-Htike *et al.*, 2005) has been described in the fresh water beds of the Upper Pegu Group, whereas *T. minor* (Pilgrim, 1926; Colbert, 1938; Thaung-Htike *et al.*, 2005), *T. intermedius*, and *T.* cf. *intermedius* (Thaung-Htike *et al.*, 2005) have been recovered from the lower part of the Irrawaddy Formation, same as the case of the newly discovered *Tetraconodon* specimens described here. Therefore, this largest *Tetraconodon* species occurs sympatrically with *T. intermedius* and *T.* cf. *intermedius* in the lower part of the Irrawaddy Formation of Myanmar.

Tetraconodon magnus (= *T. magnum*) from Markanda, India was first described by Falconer (1868) as the type species of *Tetraconodon*. The holotype (a maxilla with $M^{2\text{-}3}$) figured by Falconer (1868: fig. 5) was supposed to be lost. Lydekker (1879) described a new specimen (GSI B.71; Lydekker, 1879: pl. X), a right mandible with P^3-M^3, from Hasnot, Punjab, India, as *T. magnus*. Pilgrim (1926) described this specimen (GSI B.71) as a new species, *T. mirabilis*, and another maxillary fragment (GSI B.675) from Jammu as *T.* cf. *mirabilis*. In 1935, Colbert classified GSI B.71 from Hasnot, into *T. magnus* as the neotype. Pickford (1988) treated both *T. mirabilis* (Pilgrim, 1926) and *T. magnus* (Colbert, 1935) as *T. magnus* based on the lengths of the upper molar row ($M^{1\text{-}3}$), P^3, and P^4. However, Made (1999) re-described the maxillary fragment (GSI B. 675) as a new species, *T. intermedius*. He stated that the size of *T. intermedius* is between *T. minor* and *T. magnus* based on the M^1 length (Figure 6).

Tetraconodon sp. cf. *T. magnus* described here is characterized by the extremely enlarged $P^{3\text{-}4}$, thick and highly wrinkled enamel, as well as morphologically simple and relatively small M^3. *Tetraconodon* sp. cf. *T. magnus* is more similar to *T. magnus* than *T. intermedius* in size. Unfortunately, upper premolars associated with the M^1 are still unknown for *T. magnus*, making it impossible to evaluate the enlargement of the premolars relative to the M^1 in *T. magnus*. Compared with *T. intermedius* (GSI B.675; Pilgrim, 1926: pl. V), *Tetraconodon* sp. cf. *T. magnus* (YUDG-Mge 089; Figure 4A-C) have absolutely larger upper

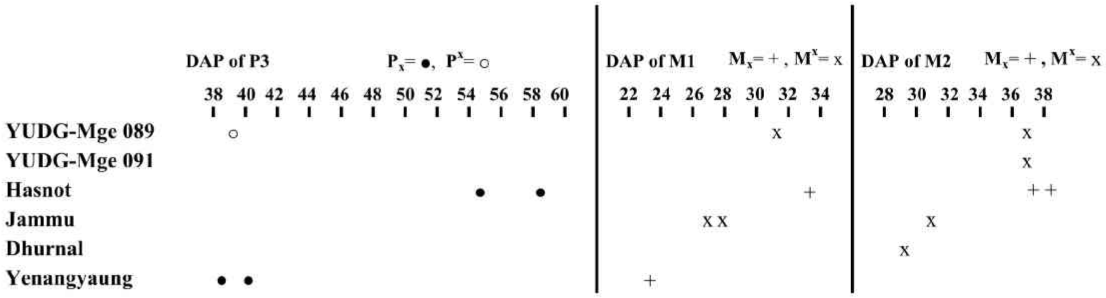

Figure 6. Comparisons of the anteroposterior length (=DAP; mm) of the $P^3/_3$, $M^1/_1$ and $M^2/_2$ in *Tetraconodon*. The localities are in approximate stratigraphical order from older (bottom) to younger (top); *T. minor*, the type locality Yenangyaung; *T. intermedius* (=*T. mirabilis*), Dhurmal and the type locality Jammu; *T. magnus*, the type locality Hasnot (after Made, 1999: fig. 7). Closed and open circles indicate lower and upper third premolars, respectively. Cross and X indicate lower and upper molars, respectively. The lengths of M^1 and M^2 of *Tetraconodon* sp. cf. *T. magnus* are larger than those of *T. intermedius*.

premolars and molars and greatly enlarged P^{3-4} relative to M^1. On the other hand, according to the size comparison by Made (1999), anteroposterior lengths (DAP) of the molars in *T.* cf. *magnus* (YUDG-Mge 089, 091; Figure 4) are much larger than those in *T. intermedius* from Jammu and are similar to those in *T. magnus* from Hasnot (Figure 6). Comparing the upper cheek teeth of the here described specimens with those of *T.* cf. *intermedius* from Myanmar (NMMP-KU-IR 0225; Thaung-Htike *et al.*, 2005: fig. 5), the enlargement of P^{3-4} relative to M^1 is nearly identical. However, the former is much larger than the latter in absolute size (anteroposterior length of M^1 are 31.6 mm in *T.* cf. *magnus* and 26.7 mm in *T.* cf. *intermedius*), indicating that the here described specimens should not be assigned into *T.* cf. *intermedius*.

The P_4 of YUDG-Mge 090 (Figure 5) is smaller than that of the neotype of *Tetraconodon magnus* (GSI B.71) (Lydekker, 1879: pl. X, p. 80; Pickford, 1988: p. 48; Made, 1999: fig. 7) from Hasnot, which is more robust with a more rugose enamel. The P_4 of YUDG-Mge 090 is much larger than those of *T. minor* and *T. intermedius* (NMM 839/80) from Myanmar (Thaung-Htike *et al.*, 2005: fig. 4). The occlusal shape of the P_4 of YUDG-Mge 090 is mesiodistally elongated (i.e., length (DAP) > maximum length (DT)), showing similarity to that of *T. minor* but differences from that of *T. magnus* and *T. intermedius*, which is round to buccolingually elongated.

As *Tetraconodon magnus*, described in Pickford (1988) and Made (1999), is recorded from the Middle Siwalik Group of the lower part of the Upper Miocene, we can confirm an Upper Miocene or at least Miocene age for the lower part of the Irrawaddy Formation and for the fossil locality Tebingan described in this paper (Figures 1, 2). This correlation is also supported by fossil remains of another suid, *Propotamochoerus*. *Propotamochoerus hysudricus* has been recorded from the Middle Siwalik Group (Barry *et al.*, 2002), and *Propotamochoerus* "*hysudricus*" has been found at a younger stratum of the Tebingan locality in the Irrawaddy Formation (Figure 2).

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