Title

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

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**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
A large-sized Tetraconodon from Myanmar

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.
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. A columnar section of the fossil locality Tebingan 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 P3-M2 and anterior half of M3; YUDG-Mge 090, a left mandibular fragment with P4; 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 M3. Figures modified from Thaung-Htike et al. (2005).

Description. — Occlusal outline of the P3 of YUDG-Mge 089 (Figure 4A-C) is triangular. It is slightly larger and mesiodistally longer than the P4. 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 P4 of YUDG-Mge 089 (Figure 4A-C) is much wider than the P3. 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 M3 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 P3-4 and M2-3.

The M2 of YUDG-Mge 089, 091 (Figure 4) is larger than the M1. The four main cusps
A large-sized *Tetraconodon* from Myanmar

Figure 4. Upper cheek teeth of *Tetraconodon* sp. cf. *T. magnus*. A-C, YUDG-Mge 089, a right maxillary fragment with P3—M2 with anterior half of M3: A, occlusal view; B, buccal view; C, lingual view. D-F, YUDG-Mge 091, a left maxillary fragment with M2—3: D, occlusal view; E, buccal view; F, lingual view.

The 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 protoproconule and tetraproconule are distinct. The pentaproconule 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 M3 of YUDG-Mge 089, 091 (Figure 4) is longer but narrower than the M2, and has a triangular outline in occlusal view. The two anterior lobes with four main cusps are similar in morphology with those of M2. The pentacone is distinct. The tetraproconule is well developed and larger than the protoproconule and pentaproconule. 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 M3 are longer than those of M2. All the roots of M1 and M2 are nearly vertical. However the distolingual root of M3 is slightly bifurcated towards posterior.

The surfaces of molar crowns in YUDG-Mge 091 are hardly affected by wear, while the
Figure 5. Lower P4 of *Tetraconodon* sp. cf. *T. magnus*. A-C, YUDG-Mge 090, a left mandibular fragment with P4: A, occlusal view; B, buccal view; C, lingual view.

molar crowns of YUDG-Mge 089 are heavy worn. The M2 of YUDG-Mge 091 is slightly smaller than YUDG-Mge 089. Such differences can be considered as intraspecific variations.

The P4 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 M1 and M2). 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 M1 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. M1 and M2 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 P4-M3 for the largest *Tetraconodon*. However, the dental morphology and the enlargements of P3 and P4 relative to M1-M2 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
A large-sized *Tetraconodon* from Myanmar

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 M3/3; *italics* = estimate.

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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 M2-3) 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 P3-M3, 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 (M1-3), P3, and P4. 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 M1 length (Figure 6).

*Tetraconodon* sp. cf. *T. magnus* described here is characterized by the extremely enlarged P3-4, thick and highly wrinkled enamel, as well as morphologically simple and relatively small M3. *Tetraconodon* sp. cf. *T. magnus* is more similar to *T. magnus* than *T. intermedius* in size. Unfortunately, upper premolars associated with the M1 are still unknown for *T. magnus*, making it impossible to evaluate the enlargement of the premolars relative to the M1 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
premolars and molars and greatly enlarged P3-4 relative to M1. 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 P3-4 relative to M1 is nearly identical. However, the former is much larger than the latter in absolute size (anteroposterior length of M1 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 P4 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 P4 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 P4 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).

Acknowledgements
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