PERISSODACTYLA FROM THE NEOGENE SEDIMENTS OF MYANMAR

Zin Maung Maung Thein[1], Thaung Htike[2], Maung Maung[3]

Abstract

The order Perissodactyla contains three distinct families, Equidae, Rhinocerotidae, Tapiridae, distributing in the tropical forest of Asia, North and South America and Savana of Africa. Extant species of this order are a remnant of the well-diversified group which probably originated during the Paleocene or early Eocene in Indian subcontinent. In Myanmar, fossil remains of this lineage have been documented in the Neogene sediments of central Myanmar representing Chalicotheriidae (*Chalicotherium*, cf. *Nesterotherium* and two indeterminate genera) Rhinoceritdae ("*Diceratherium*", *Brachypotherium*, *Rhinoceros*, *Dicerorhinus* and one indeterminate genus) and Equidae (*Hipparion* and *Equus*). In contrast to the present day arid condition in central Myanmar, the occurrences of the forest dwelling perissodactyla such as chalicotherids, *Dicerorhinus*, *Rhinoceros* indicates the existence of the considerable forested condition in central Myanmar. Stable isotope results of the *Hipparion* and *Brachypotherium* also suggest the dominance of closed environment in central Myanmar until the Pliocene. The expansion of grassland in central Myanmar is probably later than or different from that of Siwaliks of northern Pakistan due to occurrences of forest dwelling mammals in the Pliocene or later periods

Keywords: Chalicotheriidae, Equidae, Neogene, Paleoenvironment, Systematic Paleontology,

Introduction

The order Perissodactyla, the odd-toed ungulates, contains at least17 extant species belonging to three distinct families, Equidae (horses, zebras and asses), Rhinocerotidae (rhinoceros), and Tapiridae (tapirs). Most species of this order are now distributed in the tropical forest of Asia, North and South America and Savana of Africa. Extant species of perissodactyla are a remnant of the well-diversified group which probably originated during the Paleocene or early Eocene in Indian plate during its final drift toward Eurasia Continent in late Eocene and dispersed to India from Afro–Arabia or a contiguous area (Rose et al., 2014). Since then, this lineage became distributed in the Cenozoic of Europe, Asia, Africa and America. At the end of the Pleistocene, most species of this lineage became gradually extinct, now facing in the danger of extinction.

In Myanmar, fossil remains of Perissodactyla are recovered from the late Eocene Pondaung Formation and Neogene sediments of central Myanmar. The late Paleogene Pondaung Formation is well known for yielding at least 10 genera of archaic preissodactyla belonging to the families, Indolophidae, Deperetellidae, Amynodotidae, Brontotheriidae and Rhinocerotidae (Tsubamoto et al., 2006). In the Neogene sediments, remains of extant families, Rhinocerotidae and Equidae, and extinct family, Chalicotheriidae are discovered. However, the species diversity of this lineage as well as density of fossil finding is low compared to its counterparts, Artiodactyla and Proboscidea.

In the present work, we carry out the systematic paleontology of the newly discovered perissodactyla fossils from the Neogene sediments of central Myanmar and then elucidate the paleoecology of these extinct animals, implicating to the paleoenvironment of central Myanmar in the Neogene.

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Geological Setting

The terrestrial Neogene sediments are widely distributed along the Ayeyarwady and Chindwin Rivers in Central Myanmar Basin. This basin contains a series of pull-apart sub-basins, which were affected by the oblique subduction of the Indian oceanic Plate underneath the Myanmar micro-plate during early Eocene (Tankard et al., 1998; Naing Maw Than et al., 2017). In Myanmar, Neogene vertebrate fossils are mostly discovered from the Irrawaddy Formation of Salin Sub-basin (e.g. Colbert, 1935; Takai et al., 2006). Furthermore, Neogene vertebrate fossil were reported from the Khabo Formation of the northern most part of Bago Yoma sub-basin. This formation is characterized by fine- to medium-grained, cross-bedded to plane-bedded, yellow to buff sandstones, deposited under the tide dominated estuarine the tide dominated estuarine environment (Kyi Khin and Myitta, 1999; Myint Thein and Maung Maung, 2017). Towards the north of Bago Yoma sub-basin, the Khabo Formation becomes terrestrial and carries a rich assemblage of Middle Miocene mammalian fauna (Nwe New San, 2013; Myint Thein and Maung Maung, 2017).

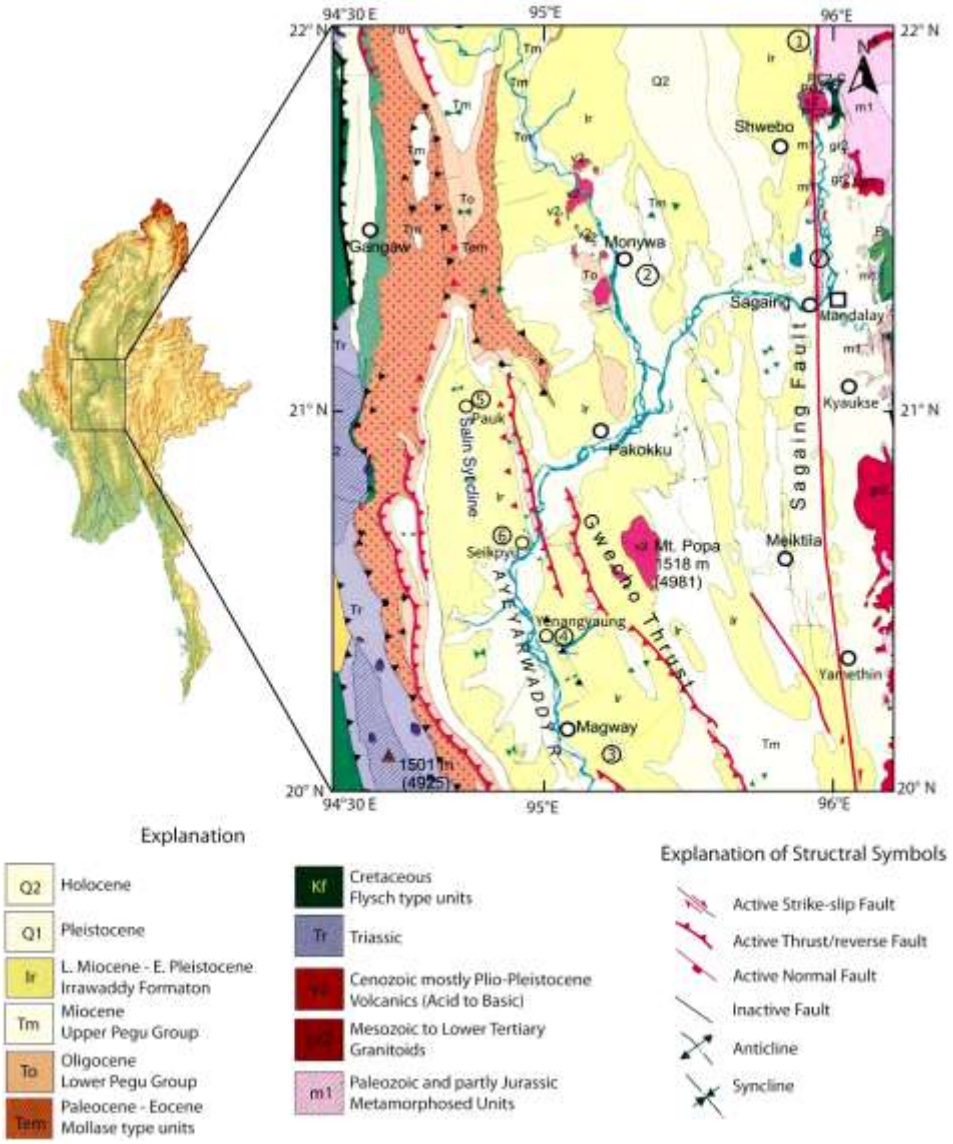

Figure 1 Geological Map of Central Myanmar showing vertebrate bearing fossil localities (After the Geological Map of Myanmar Geosciences Society, 2014)

① = Chaungtha, late middle Miocene, ② =Thanbinkan, late middle Miocene, ③ = Yinseik, late Miocene, ④ = Yenangyaung, late Miocene, ⑤ = Chaingzauk, latestMiocene to early Pliocene, ⑥ = Gwebin, Pliocene, ⑦ = Mingun, early Pleistocene

Materials and Methods

The specimens described here are housed in the National Museum, Yangon (NMMP-KU-IR), Geology Department of Mandalay University (MUDG-V), Geology Department of Magway University (Mgw-Ysk) and Zaykabar Museum, Yangon (MZKB-F). Dental morphology and distinct characteristics of fossil specimens were systematically studied and compared with available fossil specimens in the same phylogenetic group. Measurements of teeth were made with a digital caliper. All the measurements are given in mm. The taxonomy used in this paper follows that of Prothero and Schoch (1989). The terminology of anatomical designations and corresponding measurements generally follow the convention of Thenius (1989) (Fig. 2A, 4A & 6A).

Systematic Paleontology

Order Perissodactyla Owen, 1848

Family Chalicotheriidae Gill, 1972

Subfamily Chalicotheriinae Gill, 1872

Gen. et sp. indet.

Material: Right maxillary fragment with M1/-M3/

Horizon and Age: Lower Irrawaddy Formation: Late Miocene

Locality: unknown, Pauk Township

Description: MZKB- F 011 can be assigned to the family Chaliocotheriidae in having the W-shaped ectoloph with rhombic shape outline in upper molars. The teeth are brachyodont and M1/ is smaller than M2/ and M3/ and its occlusal surface on lingual side is broken.

The zygomatic arc is located at the level of M2/ and M3/. The teeth are moderately worn, indicating the remains of adult individual. Protocones in M2/ and M3/ are large and isolated consisting the rounded base and the conical top. In molars, there are V-shaped central valleys, closed to typical W-shaped ectoloph. The paracone is similar to the metacone, both reaching the midline of the tooth. According to its preserved dental characteristics, it will be difficult to assign a specific genera. Thus, it is preferable to assign it to indeterminate genus rather than specific assignment at present.

Discussion: Chalicotheriidae is an extinct clawed perissodactyls, documented from the Eocene to the Pleistocene, reaching its highest diversity in the Miocene of Asia, Europe, Africa and North America (Combs and Cote, 2010). To date, *Chalicotherium salinum*, cf. Nestotherium and two inderteminate genus are reported from the Neogene sediments of Myanmar (Tsubamoto et al., 2006; Chavasseau et al., 2010; Chit Sein, 2013).

The presence of chalicotheres in a fauna is usually assumed to be an indicator of the occurrence of trees and shrubs (Coombs and Cote, 2010). The microwear analysis on the teeth of this lineage suggests bark and twig feeding with considerable fruit consumption (Coombs and Semprebon, 2005). Stable isotope analysis on the tooth enamel of chalicotherids from Indian Subcontinent also suggests that they are forest dwelling browser (Nelson, 2007). Thus, discovery of this animal from the Irrawaddy Formation in Pauk area suggest the occurrence of forested condition in this area.

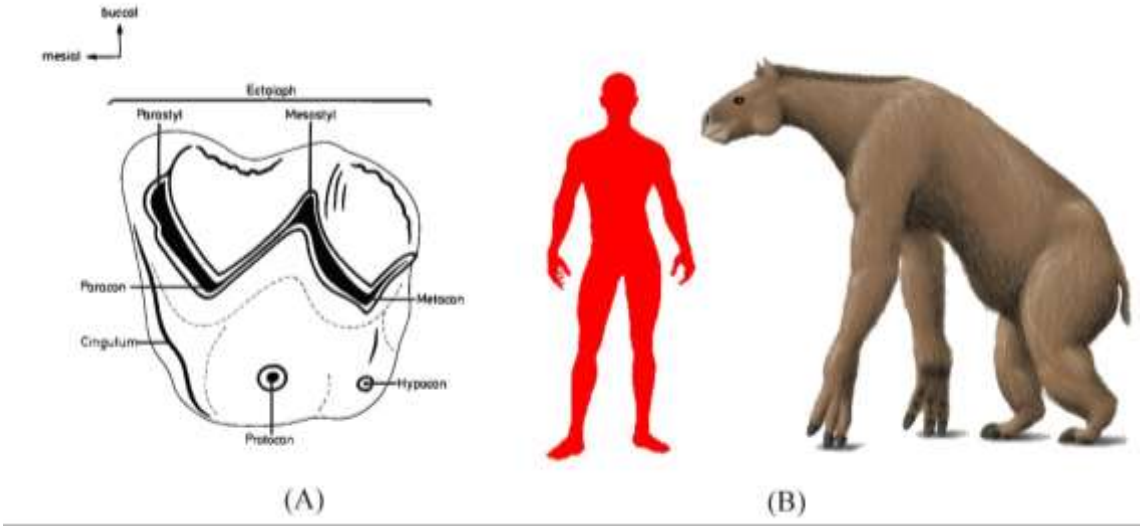

Figure 2 A. Terminology of *Chalicotheriidae* upper molar (After Thennius, 2003), B. Reconstruction of Chalicotheriidae (Zapfe, 1979)

Figure 3 Chalicotheriidae, MZKB- F 011, Right maxillary fragment with M1/-M3/: A. occlusal view, B. buccal view (Scale bar= 10 mm)

Family Rhinocerotidae Owen, 1845

Subfamily Aceratheriinae Dollo, 1885

Genus *Brachypotherium* Roger, 1904

Brachypotherium perimense Falconer and Cautley, 1847

Materials: MUDG-V 1011: Right mandibular fragment with M/1-M/3

Horizon and Age: Upper Part of Khabo Sandstone: Late Middle Miocene

Locality: Thanbinkan (21° 58' 35" N; 95° 21' 30" E), Monywa Township, Sagaing Division, Central Myanmar

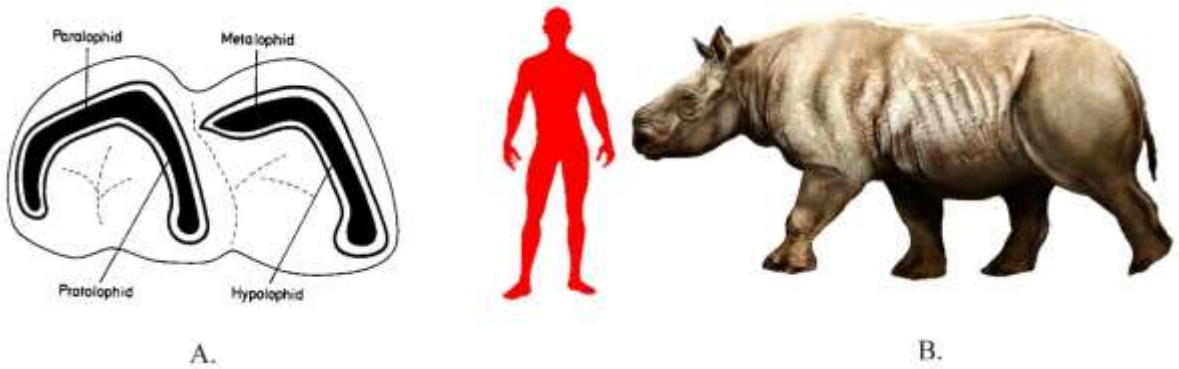

Figure 4 A. Terminology of rhinoceros cheek teeth (after Thenius, 1989), B. Reconstruction of *Brachypotherium* (www. memim.com)

Description: The mandible (MUDG-V 1011) is shallow with respect to height of the teeth (64 mm at level of M/1 and 70 mm at M/3), and is preserved from the level of M/1 to M/3. The teeth are moderately worn; the lingual groove is quite shallow and hypolophid is long; the posterior valley is deeper than the anterior one and show V shape in lingual view; the slanted posterior and anterior cingula are observed, although there is no posterior cingulum in M/3; the lingual cingulum is absent, but the labial cingulum is represented by the array of the small tubercle. On M/1 (Length=58.1 mm, Width=31.9 mm), anterior valley is unpreserved; trigonid and talonid are nearly same level due to the advanced wear stage; the talonid show the obtuse curve line. On M/2 (Length=54.2 mm, Width=32.1 mm), protocone is weak; the paralophid is short; the hypolophid is long and show smooth curve. M/3 (Length=56.2, Width=32.1) generally shows similar characteristic with M_2 although it is in early wear stage; lingual portion of hypolophid is broken; the posterior valley run down to the neck of the posterior root (Fig. 4).

Discussion: Rhinoceros fossils are common in the Neogene sediments of central Myanmar, representing four genera and eight species. ("*Diceratherium*" *naricum*, *Brachypotherium perimense*, *Brachypotherium fatehjangense*, *Rhinoceros sondaicus*, *Rhinoceros* sp.,

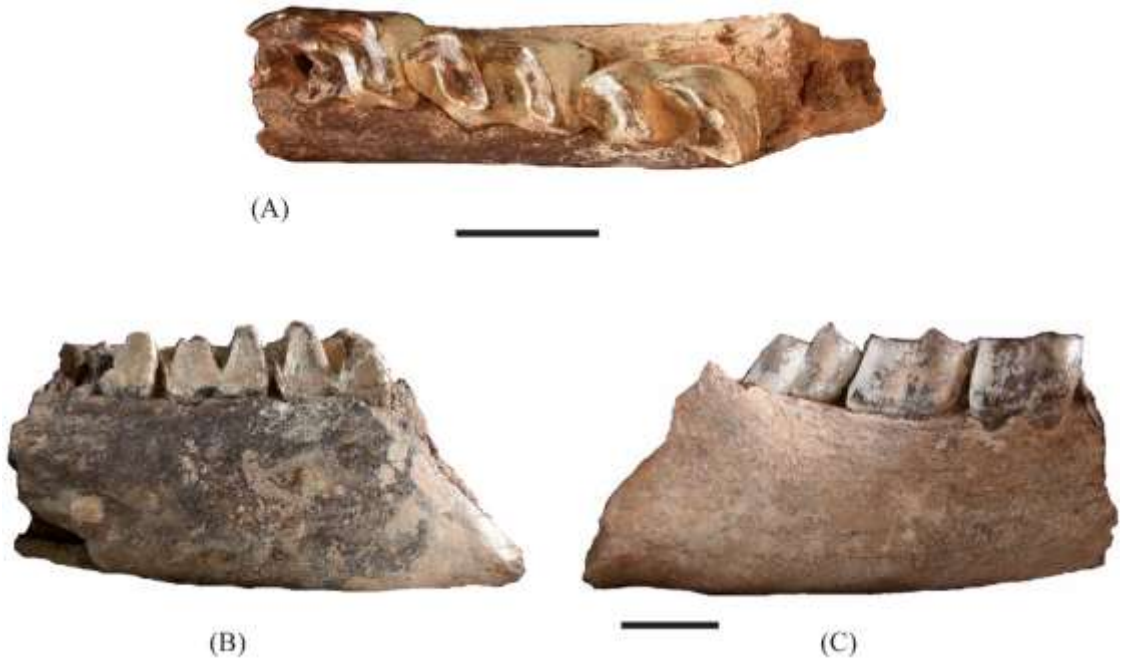

Figure 5 *Brachypotherium perimense*, MUDG-V-1011, Right mandibular fragment with M/1-M/3: : A, occlusal view; B. lingual view; C. buccal view (Scale bar = 20 mm)

Dicerorhinus gwebinensis, *Dicerorhinus* cf. *sumatrensis*) and one indeterminate genus (Chavasseau et al., 2006; Zin-Maung-Maung-Thein et al., 2008, 2010). Among them, *Brachypotherium* is a large, hornless rhinoceros and distributed in the Miocene of Old World, and survived until the late Pliocene in East Africa. Remains of this rhinoceros are recovered from middle to late Miocene localities in central Myanmar (Takai et al., 2006; Chavasseau et al., 2006; Zin-Maung-Maung-Thein et al., 2010). In the neighboring region of Myanmar, it has been discovered from the lower and middle Siwaliks of Indian subcontinent (Welcomme et al., 2001), from the early Miocene of China (Tong, 2001) and from the early late Miocene of Thailand (Chaimanee et al., 2004).

B. perimense is regarded as a hippo-like rhinoceros due to its morphological criteria, and might have spent a part of its daily life in water. The $\delta^{13}C$ values of the tooth enamel of this animal from the middle Miocene Thanbinkan locality ranges between -13.3 to -10.1‰ suggesting it consumes C_3 plants in the forest/woodland environment (Zin Maung Maung Thein et al., 2019).

Family Equidae Gray, 1821

Tribe Hipparionini Quinn, 1955

Genus *Hipparion* Christol, 1832

Hipparion sp.

Materials: Mgw-ysk-1: isolated right P4/

Horizon and Age: Lower Irrawaddy Formation, Late Miocene (~10.4 to 8.8 Ma)

Locality: Yinseik (20° 06' 13" N; 95° 07' 44" E), Magway Township

Description: The upper molar of *Hipparion* is characterized by hypsodont teeth with distinct oval shape protocone and the complicated enamel placation on the prefossette and postfossette. However, it is usually difficult to assign isolated dentition of *Hipparion* to a proper species.

The specimen, Mgw-ysk-1 (Dimension: Length= 25.6 mm; Width= 26.3 mm; Height= 44.8 mm), is square shape outline. This specimen is still in the stage of moderate wear.

The protocone is sub-rounded and lingually slightly convex. The parastyle and metastyle are moderately developed and mesostyle is developed as a pillar. There are at least three plications on the posterior border of the prefossette and anterior border postfossette respectively.

Discussion: The earliest record of Equidae (horses) has been documented from the early Eocene of North America and Europe. In Myanmar, fossil record of the equidae is poor and two genera of fossil horses (*Hipparion antelopinum* and *Equus yunnanesis*) are known from the Neogene sediments of Myanmar (Colbert, 1938; Takai et al., 2006). The stable isotope study of the tooth enamel of *Hipparion* from Siwalik Group of Indian Subcontinent indicated that the equids around 9.1 Ma consumed a C3-dominated diet, then shifted to a C4-dominated diet in 8.1 Ma and finally adapted to a C4-dominated diet around 6 to 5 Ma (Quade et al., 1989; Cerling, 1993; Nelson, 2003). The enamel $\delta^{13}C$ values of *Hipparion* (-12.1 to -9.9 ‰) from the late Miocene Irrawaddy sediments at Yinseit localities in Magway area indicate consumption of a large proportion of C_3 plants in their diet and suggest the existence of a rather dense canopy forest (Jaeger et al., 2010). Thus, the expansion of grassland in central Myanmar is probably later than or different from that of Siwaliks of northern Pakistan due to occurrences of forest dwelling mammals in the Pliocene or later periods.

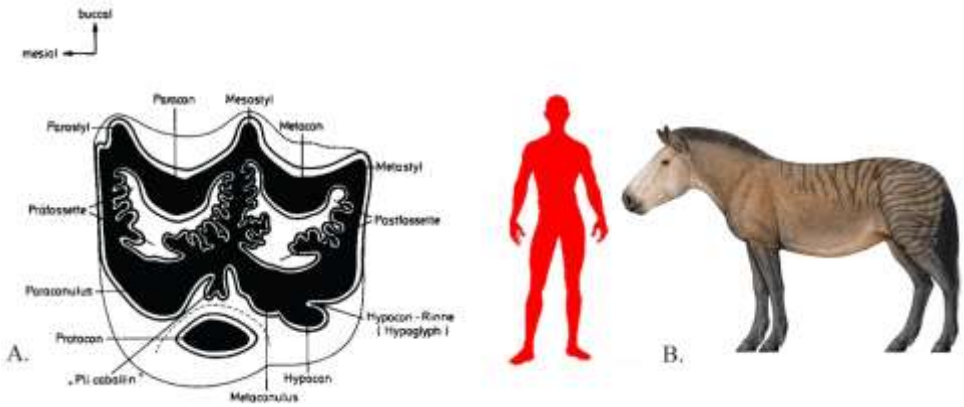

Figure 6 A. Dental Terminology of *Hipparion* upper molar (After Thennius, 2003), B. Reconstruction of the extinct *Hipparion* (www.pinterest.com)

Figure 7 *Hipparion*, Mgw-ysk-1, isolated right P4/: A, occlusal view; B. buccal view; C. lingual view (Scale bar= 10 mm)

Summary and Conclusion

In Myanmar, fossil remains of the Order Perissodactyal have been documented in the Neogene sediments of central Myanmar representing Chalicotheriidae (*Chalicotherium*, cf. *Nesterotherium* and two indeterminate genera) Rhinoceritdae ("*Diceratherium*", *Brachypotherium*, *Rhinoceros*, *Dicerorhinus* and one indeterminate genus) and Equidae (*Hipparion* and *Equus*). The occurrences of the forest dwelling perissodactyla such as chalicotherids, Dicerorhinus, Rhinoceros indicates the existence of the considerable forested condition in central Myanmar in the geological past. The presence of chalicotherids in a fauna is usually assumed to be an indicator of the occurrence of trees and shrubs. The $\delta^{13}C$ values of the tooth enamel of the *Brachypotherium* from the middle Miocene Thanbinkan locality indicate that it consumes C_3 plants in the forest/woodland environment. The enamel $\delta^{13}C$ values of *Hipparion* from the late Miocene Irrawaddy sediments at Yinseit and Yenangyaung suggest the predominance of forested condition in central Myanmar. The stable isotope study of the tooth enamel of *Hipparion* from Siwalik Group of Indian Subcontinent indicated that a decrease in forest habitation accompanied by an increase in open habitation in late Miocene (~8 Ma) (Nelson, 2003, 2007). However, the expansion of grassland in central Myanmar is probably later than or different from that of Siwaliks of northern Pakistan due to occurrences of forest dwelling mammals in the Pliocene or later periods.

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