CHAPTER 3

PROBOSCIDEAN FOSSILS IN THAILAND

3.1 Introduction

This chapter is the part of the proboscidean fossil study that concerns methods, descriptions, and identifications. It begins with basic tooth nomenclature. In primitive fossils, teeth have primitive characteristics. Over time, teeth characteristics gradually changed, becoming varied from species to species. It is these tooth structures and their change over time that was used in identifying proboscidean fossils in this study.

3.2 Methodology

3.2.1 Standard terminology

1) Terminology of dental notation of mammals

The system, which is more commonly applied to mammal fossils, identifies individual teeth using the following abbreviations:

Incisors: I, i; Canines: C, c; Premolars: P, p; Molars: M, m. The tooth number follows these characters. Right: R and Left: L is also used.

Capital letters indicate permanent teeth and lower case letters indicate deciduous teeth. Upper and lower tooth rows are indicated by superscripts and subscripts, respectively, such as I^1, P_2, i^2 (Smith and Dodson, 2003). If upper and lower teeth are

not separately identified, a tooth designation, such as M3, will refer to both third molars.

2) Terminology of anatomical orientation

In paleontology, “anterior” is often used for that area of the tooth row or direction that is towards the front of the skull, and “posterior” is used for the area or direction that is towards the rear of the skull (Currie, 1987, 1995; Sereno and Novas, 1993; Fiorillo and Currie, 1994). The surfaces of the crown that face the lips and the tongue are often referred to as labial and lingual, respectively. Hillson (1986) preferred the commonly used term buccal, referring to cheek, instead of labial; this term works just as well.

3) Terminology of proboscidean teeth

The basic structure of a proboscidean tooth (Figs. 3.1 and 3.2) was gained from a rather primitive genus, *Gomphotherium*. This tooth has a certain number of cone-like elements, arranged in several transverse ridges called “lophs” in the upper molars and “lophids” in the lower molars. On each loph, the main cusp that is less worn is called “posttrite”, the main cusp that is more worn is called “pretrite”. Every transverse ridge is divided by a more or less well developed, but in most cases clearly visible, longitudinal or “median sulcus” in two half-crests or half-lophs: an outer, labial, ectoloph and an inner, lingual, entoloph. Every fully developed half-loph has at least two small cones that are more or less distinctly separated. These elements were named “conelets” by Osborn (1942). Another typical characteristic of mastodont molars are the “conules” (Osborn, 1942).

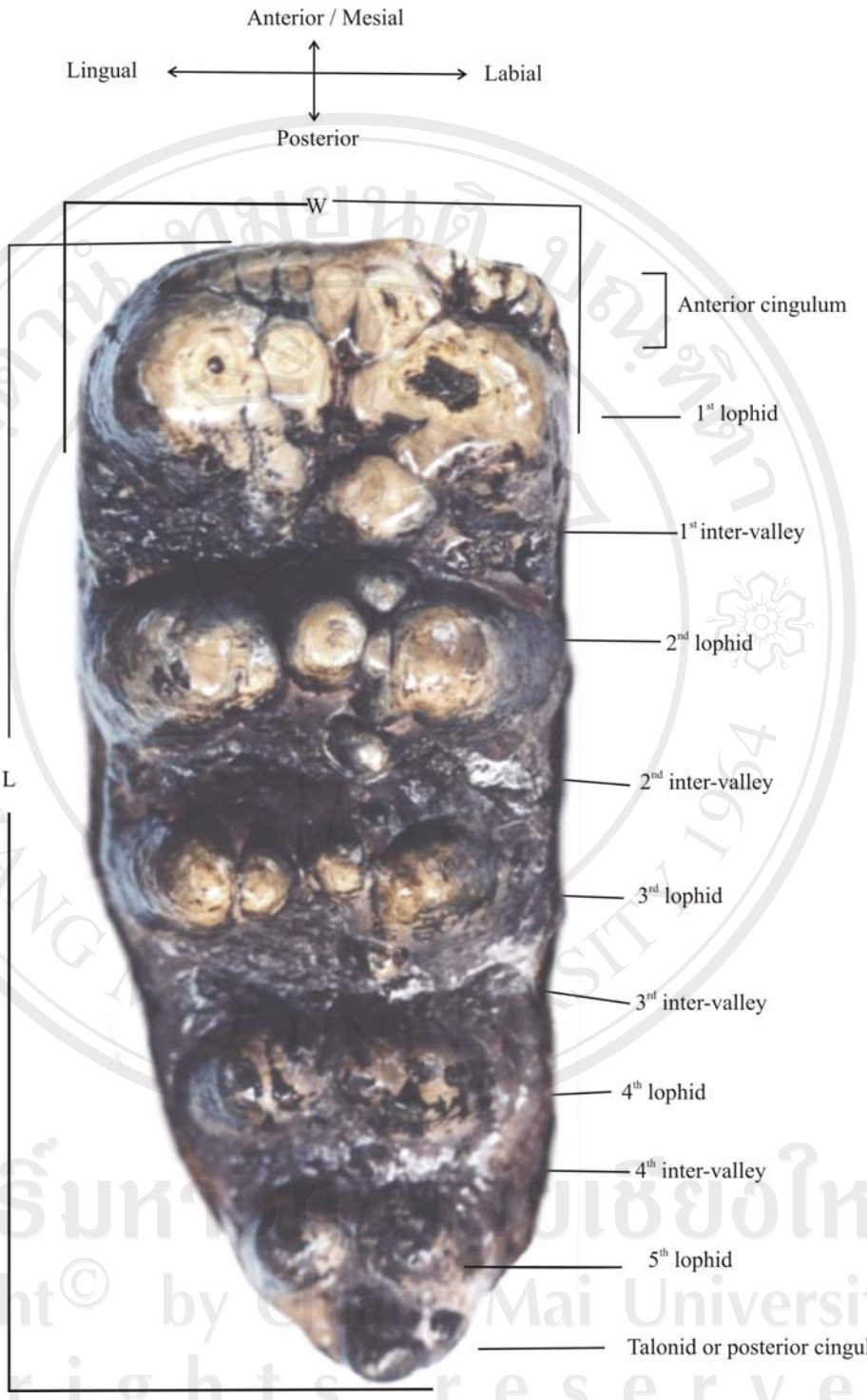

Fig. 3.1 Anatomical orientation and number of molar lophid of the right lower third molar, M_3, of *Gomphotherium* having X5X tooth formula. X in the front and the back of the number refer to the anterior cingulum and posterior cingulum, or talonid, respectively. L = maximum length, W = maximum width.

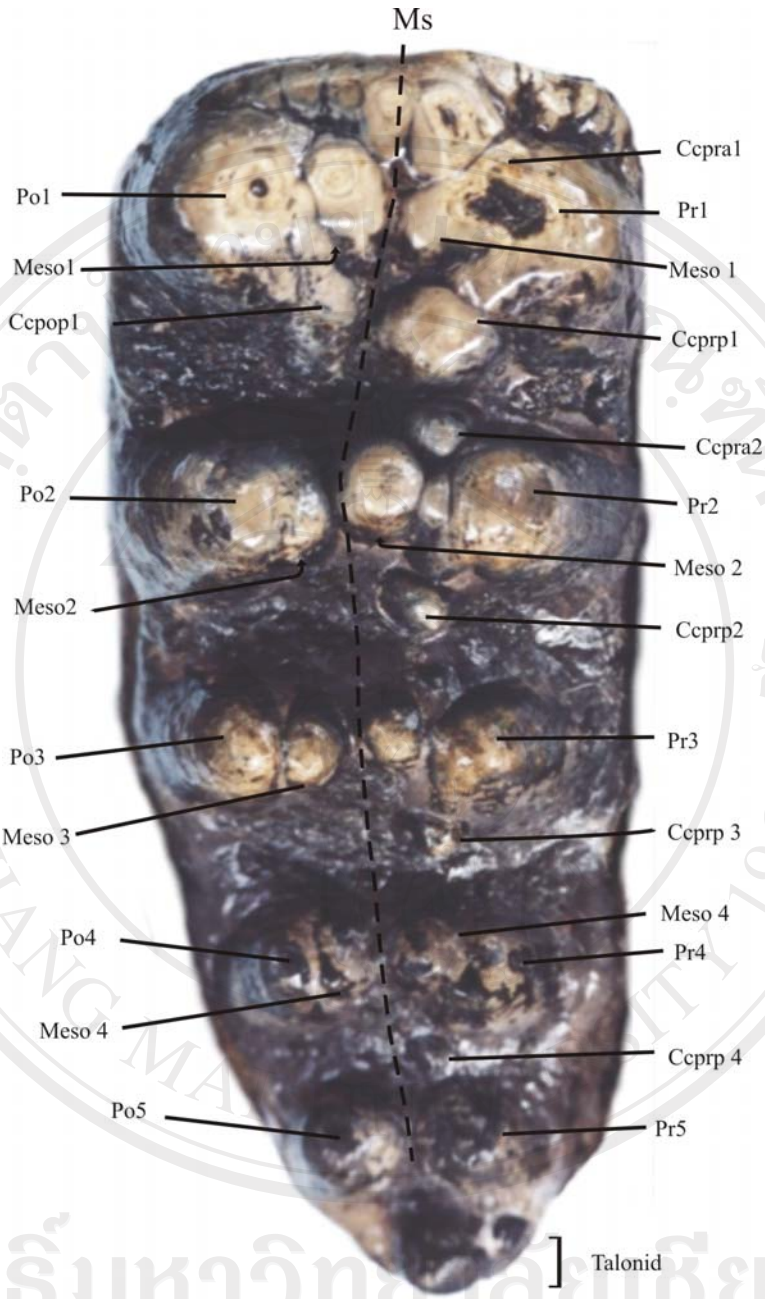

Fig. 3.2 Proboscidean dental nomenclatures. Key: Po1, 2, 3, 4, 5, 6, posttrite main cusp of 1st, 2nd, 3rd, 4th, 5th and 6th lophids; Pr1, 2, 3, 4, 5, 6, pretrite main cusp of 1st, 2nd, 3rd, 4th, 5th, and 6th lophids; Ccpop1,2,3,4, posterior posttrite central conule of 1st, 2nd, 3rd and 4th lophids; Ccprp1,2,3, 4, posterior pretrite central conule of 1st, 2nd, 3rd, and 4th lophids; Ccpra 1, 2, 3, anterior pretrite central conule of 1st, 2nd, and 3rd lophids, Meso, mesoconelet of each half-lophid, on both sides of median sulcus (adaxial cone), Ms, median sulcus (Tassy, 1996).

These are enamel covered, more or less high and voluminous pillars situated at the anterior and posterior slopes of the transverse ridge or in the transverse valleys blocking them inthe middle part. These conules are called “mesoconelets” and are connected with the entolophs in the upper molars and with the ectolophids in the lower molars. Worn conules have anterior and posterior trefoil patterns. The hind-most shelf, posterior to the last true loph of a tooth is called the “talon” in the upper molar and the “talonid” in the lower molar (Osborn, 1942; MacInnes, 1942; Tobien, 1973b; and Tassy, 1996). Additional technical terms are in Appendix A.

3.2.2 Measurement and basic classification

1) Measurement

All tooth specimens were measured by using the methods used for studying teeth of fossil elephants of East Africa (Beden, 1979).

N = Number of plates/lophs. This is the total number of major plates and does not include the small, poorly developed platelets that occur at the anterior and posterior extremities of a tooth; these latter are indicated by the symbol X.

NF= Number of worn plates. This refers to the use of teeth during the life time of the animal.

L = Total length of the tooth, measured along the longitudinal axis of the tooth at right angles to the plane of the middle plates.

LF = Length of the worn surface, measured along its longitudinal axis.

H = Maximum height of the tooth, measured on one of the middle plates along the medial axis of the plate between the summit of the tubercles and the lateral base of

the plates. A middle plate is used for this because the anterior and posterior plates are generally less tall.

W = Maximum width of the tooth, measured on the widest plate perpendicular to the median axis of the plate. W1, W2, and so on indicate the width of the first loph, the second loph, and so on, respectively.

e = Thickness of enamel, measured parallel to the longitudinal axis of the plate, but not parallel to the plane of wear.

- = The sample is not complete or is broken and the length is shorter than it should be, thus the minus sign.

All measurements are listed in Appendix B.

2) Basic classification

The basic classification applies to the intermediate molars, including P4, M1, and M2, and the last molar M3 (Fig. 3.3). The trilophodont group is the group that has X3X or X3 on the intermediate molars. The last molar, probably from X3X to more than X6X, varies in each species. The tetralophodont group has X4X or X4 on the intermediate molar and varied numbers on the last molar, from X4X to more than X6X, as in the trilophodont group. Thus, it is difficult to classify the isolated last molars. The pentalophodont group is the more advanced group, with X5X or X5 on the intermediate molar and more than X5 on the last molar. The molars of all early members of the Elephantoidea share the trilophodont grade. The tetralophodont grade occurred in genera *Anancus, Tetralophodon* and *Stegolophodon*. Stegodontid and elephantid molars were derived from gomphothere tetralophodont molars, and reached the pentalophodont grade or higher (Tassy, 1996).

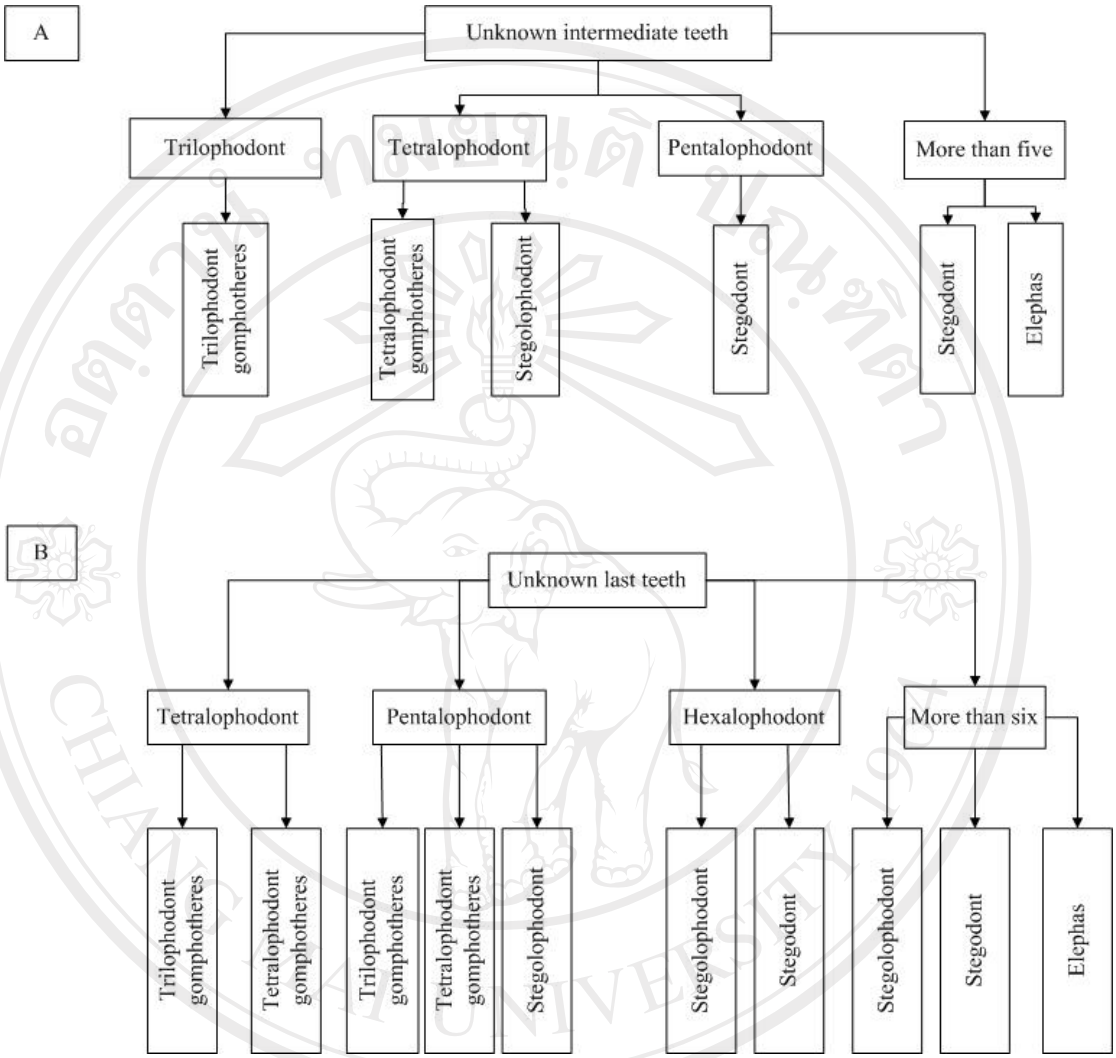

Fig. 3.3 Flow charts show the first step of classifying the unknown specimens of intermediate teeth (A) and last teeth (B).

3.2.3 Structures in proboscidean teeth and their evolution trends

1) Characteristics of proboscideans molar structures

The structure and composition of teeth evolved from being very simple to being complex. Tobien (1973b) explained a simple tooth structure of *Gomphotherium*, which had bunodont molars, consisting of a certain number of cone-like elements arranged in several transverse ridges. In *Gomphotherium*, the loph numbers are three on the first molars, M1, at least three lophs and talon, 3X, on the second molars, M2, and mostly four or more on the third molar, M3. Every transverse ridge is divided by a more or less well developed, but in most cases clearly visible, longitudinal median sulcus in two half-lophs. Every fully developed half-loph is built up of at least two small conelets that are more or less distinctly separated. Trefoil pattern on the worn molars surfaces is a typical for bunodont mastodonts.

The tooth patterns of Gomphotheriidae were modified from the second loph of M3 of each species or specimen (Fig. 3.4). The upper molar of Gomphotheriidae usually contains both anterior and posterior pretrite central conules but these have different degrees of development. This study classified the tooth structural pattern into five types in the upper molar and six types in the lower molar. The tooth structural pattern in each specimen is useful for species identification. The details of each type are:

G-Type 1: The main cusps are larger than mesoconelets, the fissure between them is not obvious, and the anterior and posterior central conules are large in both upper and lower molars and clear median sulcus and close to the main cusp rather than mesoconelet. This type is the most primitive character.

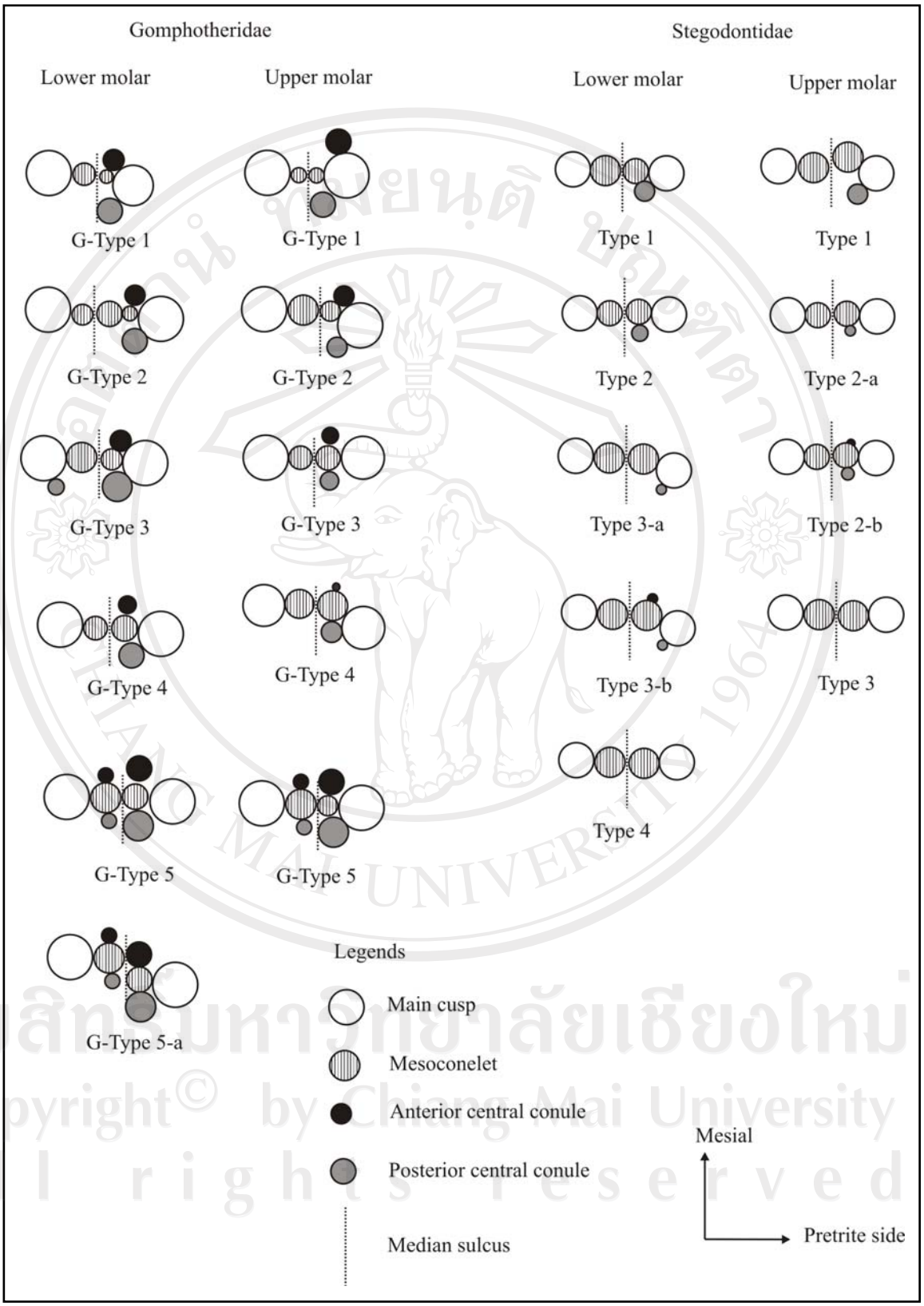

Fig. 3.4 Tooth structural patterns of the second loph(id) of Gomphotheriidae (this study), and Stegodontid (modified from Saegusa *et al*., 2005).

G-type 2: The mesoconelets are larger and well subdivided than in G-type 1, the position of anterior and posterior pretrite central conule is similar to G-type 1.

G-Type 3: The mesoconelets are not well subdivided from the main cusps. In upper molar, the same size anterior and posterior central conules are close to mesoconelets. In the lower molar, the posterior central conule is larger than the anterior conule. Conules are developed in the secondary posttrite.

G-type 4: The mesoconelets are large but they are not well subdivided from the main cusp. The posterior central conule is expanded but the anterior one is fused and is located closer to the mesoconelet than to main cusp.

G-type 5: The main cusps are larger than the mesoconelets; the anterior and posterior central conules are well developed in both pretrite and posttrite half-lophs. The secondary posttrite conules are small or large. The pretrite half-loph(id) may be posteriorly located.

G-type 5a: This type differs from the G-type 5 by its strong posterior pretrite dislocation.

Saegusa *et al*. (2005) classified the structure of lophs in stegodontids. Lophs of stegodontid can be considered as mesio-distally compressed versions of those of gomphotheres, especially tetralophodons, accompanied by various degrees of degeneration, or in some cases hypothophy, of the central conules. According to the degree of degeneration and displacement of the central conules, Saegusa *et al*. classified the structural patterns of lophs into several types (Fig. 3.4). The structure of the first loph may differ from that of the second and tends to be more conservative. The lophs following the second loph can be considered as incomplete copies of the second loph. Stegodontidae may have been derived from tetralophodont

gomphotheres. On the lower molar of *Tetralophodon longirostris*, the main posttrite cusp and mesoconelets are in line, while the main pretrite cusps are heavily displaced distally. This character is so persistent that it can be recognized even in some stegodont molars.

Type 1: the mesoconelet is slightly anteriorly located and the posterior pretrite central conule is close to the main cusp in the upper molar. The main cusps and mesoconelets are in line and the posterior pretrite central conule is located between the main cusp and the mesoconelet in the lower molar.

Type 2: the main cusps and mesoconelets are in line, the posterior pretrite conule is located between the main cusp and the mesoconelet (Type 2-a) or close to the mesoconelet and still present in the anterior central conule (Type 2-b) in the upper molar. The posterior pretrite central conule is close to the mesoconelet in Type 2 of the lower molar.

Type 3: the pretrite main cusp is a distal displacement of the lower molar. The posterior pretrite central conule is fused without the anterior (Type 3-a) or is still present (Type 3-b) in the lower molar. The posterior pretrite central conule is reduced and incorporated into the pretrite mesoconelet of the upper molar.

Type 4: The anterior and posterior central conules are fused and have disappeared in the lower molar.

2) Worn surface of enamel loop in Stegodontidae and Elephantidae

It has long been recognized that *Stegodon* has step-like worn surface reliefs of the enamel layer. Molar enamel can be divided into inner and outer layers, hereafter, IE and OE, respectively. The OE is thicker and softer than the IE and, after wear, its

worn surface forms a broad shelf below the shearing blade at the boundary between the two enamel layers. Thus, on the worn surface of *Stegodon* molars, a step-like structure, or stufenbilbung, is formed. In elephants, there are also two layers of enamel, an inner and outer layer. A shearing blade of dentine is also developed at the boundary between the two layers, but the situation is different from that of *Stegodon*. The OE is very thin in elephants and, consequently, its worn surface does not show a step-like structure. The pattern of enamel folding also eliminates the difference between *Stegodon* and elephantids (Kamiya, 1991). In primitive stegodonts, for example, *S. zdanskyi*, enamel folding is, though very faint, distributed throughout the whole length and height of the ridge, except for its apex. On the contary, in early elephants, for example *Elephant recki atavus* and *Loxodonta exoptata*, enamel folding is rough and its distribution is centered on the median portion of the plate at the middle height of the plate. In *Stegolophodon*, most specimens have no folding but an intermediate molar of a *Stegolophodon* from Japan shows fine folding distributed the entire length of the enamel loph and type 2 stufenbildung. This may suggest a close relationship between *Stegodon* and *Stegolophdon* from Japan (Fig. 3.5) (Kamiya and Taruno, 1986).

3) Evolution trends of proboscideans

The characters of tooth are useful for using as evolution indices and comparative age for the fossils. Moreover, it is important key to hint it's ancestral or descendant species. Carefully, it restricts to use to compare between the same tooth position and same age of the individual. The general tendencies of the primitive to advanced characters are concur with the literatures are:

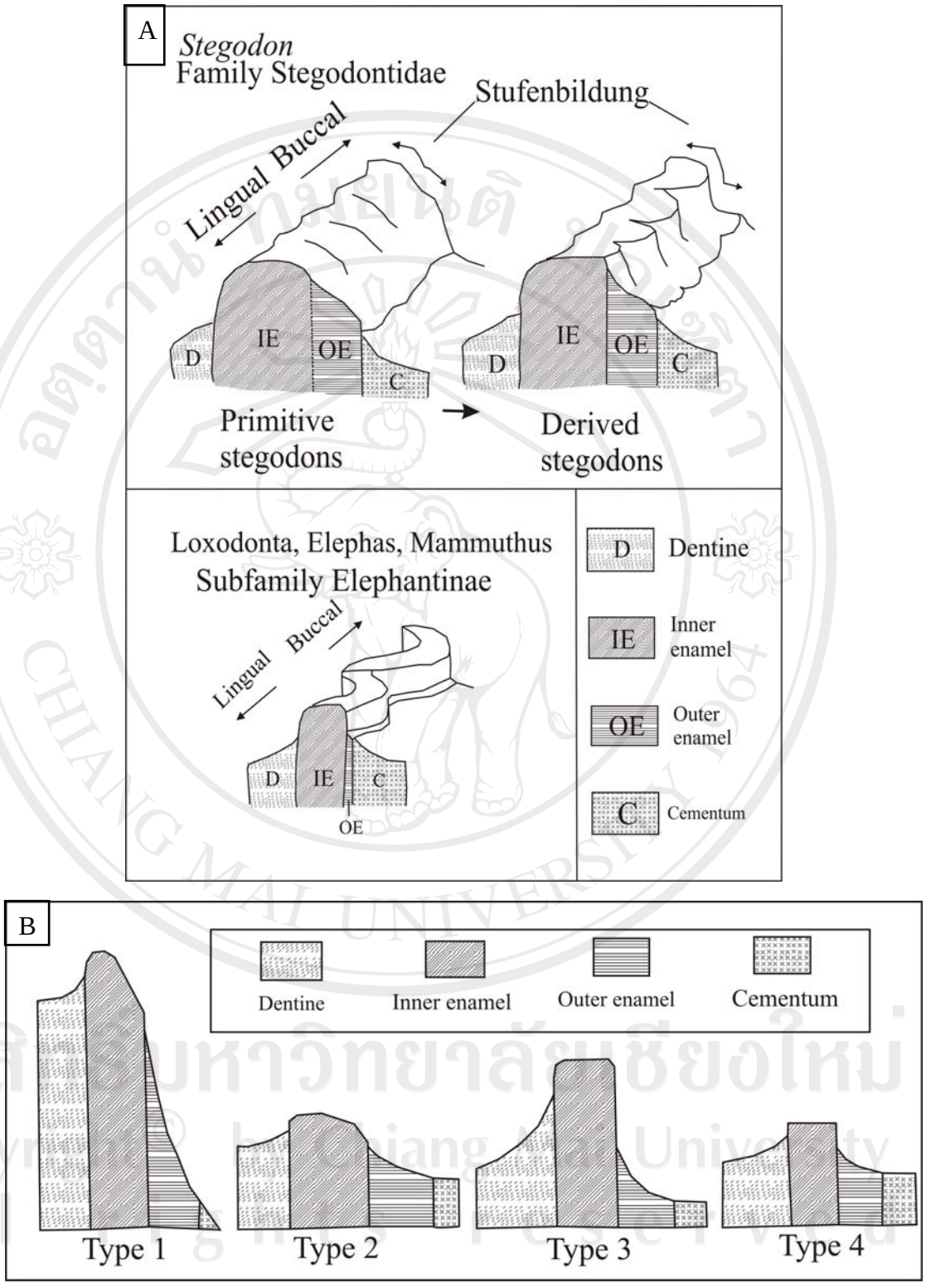

Fig. 3.5 (A) Worn surface relief of Stegodont molars. A step-like profile is formed in Stegodonts because the inner enamel (IE) layer is more resistant than the outer enamel (OE) layer, which is thick. Elephantids have a very thin layer of OE which does not provide space for the development of a step-like structure. (B) Typology of step-like structure of stegodont molars can be classified into four types (after Saegusa, 1996b).

a) The tooth sizes are trend to large. For instant, the primitive form *Gomphotherium* was smaller size than *Tetralophodon* but both smaller than the advanced *Stegolophodon*. *Stegodon* and *Elephas* was trend to be in the same size but larger than *Stegolophodon*. However, dwalfism may exclude.

b) The number of loph(id) is increased. For example in comparison between the primitive form *Gomphotherium* and advanced form *Tetralophodon*, *Gomphotherium* contains 3 loph(id) in the second molar (M2) and 4 to 5 loph(id) in the third molar (M3) but *Tetralophodon* has 4 loph(id) on M2 and 4 to 5 loph(id) in M3. The number of loph(id) of M2 in *Tetralophodon* are higher than in *Gomphotherium* but the number of loph(id) in M3 are similar, suggesting *Tetralophodon* was evolved after *Gomphotherium* by the increasing the number of loph(id) in M2 only. In comparing between *Tetralophodon* and *Stegolophodon*, the latter contain 4 loph(id) in M2 as same as in *Tetralophodon*, but it has 5 or more than 5 loph(id) on M3. It is indicated that *Stegolophodon* has high evolution than *Tetralophodon* by the increasing of the number of loph(id) in M3 and retain the primitive character by contain 4 loph(id) in M2. In comparing between *Stegolophodon* and *Stegodon*, the latter has 5 loph(id) in M2 and 6 or more than 6 loph(id) on M3. *Stegodon* was evolved by increasing the number of loph(id) in both M2 and M3. The most advanced form is *Elephas* sp. that contain more than 10 plates in the M2.

c) The loph(id) width are decreased and the crown height is increased. The primitive forms such as *Gomphotherium* and *Tetralophodon* have the wider loph(id) and lower crown than in *Stegolophodon* and *Stegodon*. The loph(id)s are much narrow in advanced *Stegodon* and to be plate-like in *Elephas* with the increasing of crown height.

d) The number of conelet is increased but the number of conule is decreased and median sulcus is indistinct. In the primitive forms contain 4 cusps in each loph(id) and the main cusps are usually larger than mesoconelet. Anterior and/or posterior conules usually found in the inter-valley of pretrite half-loph and median sulcus is clear. In the advanced form the conelets are subdivided to more than 4 cusps, the main cusps are nearly same size as the main cusp. The anterior and/or posterior pretrite central conules are fused or disappeared and median sulcus is difficult to identify.

e) The folding of enamel-dentine junction (EDJ) trends from smooth to coarse folding and symmetry, then develop to fine folding and asymmetry. Generally, in *Gomphotherium*, *Tetralophodon*, and *Stegolophodon* contain smooth worn surfaces. This character is useful to study in *Stegodon* and *Elephas*. In the primitive *Stegodon*, the EDJ is coarse and symmetry, and finer and asymmetry in the advanced forms caused by the difference of the hardness of inner and outer enamel.

Additional, the other characters such as cement, cusp shape, and the secondary trefoil are crucial for indicate the evolution.

3.2.4 Proboscidean fossils materials

Teeth are the hardest structures in mammal bodies and are usually well preserved as fossils. They have played an important role for paleontologists and physical anthropologists in the study of evolution. Even when represented by only a single tooth, a fossil mammal can often be identified by cusp numbers, relative cusp. positions, and cusp heights. These parameters not only help to identify an animal, but they also give information on its way of life, its parents and descendants, its history

and evolution. In proboscidean fossils, teeth are useful for classification of genus and species. A tusk, or ivory, is the incisor that develops to a large size. Early species carried four tusks, small and large. The lower tusks were reduced in later species and species carried only the two upper tusks. However, deinotheres had two lower tusks. Tusk cross sections are variable, from round, piriform, to flat. Skull and limb bones are also useful for studying elephants, particularly when they were found together with other fragments and then used to estimate the height and size of the animal. The specimens from the study areas include two specimens from the Mae Moh coal mine, prefix MM, three specimens from the Ban Na Sai coal mine, prefix NS, three specimens from the Sop Mae Tham locality, prefix SMT, three specimens from the Mae Soi locality, prefix DC for Doi Chang sub-locality and KHT for Kew Hoi Tal sub-locality, four specimens from the Chiang Muan coal mine, prefix CMn, three specimens from the Mae Teep coal mine, TF2019 for tusk specimens and BP for the Ban Pu exhibition center, and 108 teeth specimens from the Tha Chang sand pits that had been housed in the Rajabhat Institute Nakhon Ratchasima, prefix RIN. These specimens are now housed in the Northeastern Research Institute of Petrified Wood and Mineral Resources, which honors His Majesty the King, at Nakhon Ratchasima Rajabhat University, in the Phu Khum Khaw dinosaur research center, prefix NM and KHO, respectively, the Chavalit zoological private collection, prefix CCZ, and the private collection of Piriya Vachajitpan, prefix PRY.

These specimens were measured, studied for details of tooth structure, and compared with the type species and other identied species.

3.3 Results

The specimens of proboscidean fossils in Thailand vary from the small size to large size. The numbers of intermediate molars are from three to five lophs. The last molars vary from four to more than 10 lophs. This means that fossil proboscideans in Thailand were different in both age and species.

The proboscidean fossils in Thailand were classified into four families, 10 genera, and 23 species by differences of size and tooth structures as follows:

Family Deinotheriidae Bonaparte, 1845

Genus *Prodeinotherium* Ehik, 1930

Prodeinotherium pentapotamiae

Family Gomphotheriidae Hay, 1922

Genus *Archaeobelodon* Tassy, 1984

Archaeobelodon sp.

Genus *Protanancus* Arambourg, 1945

cf *Protanancus macinnesi*

Genus *Gomphotherium* Burmeister, 1837

Gomphotherium sp.1

Gomphotherium sp. 2

Gomphotherium n. sp.1

Genus *Sinomastodon* Tobien *et al*., 1986

Sinomastodon aff. *yangziensis*

Sinomastodon n. sp. 1

Genus *Tetralophodon* Falconer, 1857

Tetralophodon cf. *xiaolongtanensis*

Genus *Anancus* Aymard, 1855

Anancus sp.

Familty Stegodontidae Osborn, 1918

Genus *Stegolophodon* Schlesinger, 1917

Stegolophodon nasaiensis

Stegolophodon cf. *latidens*

Stegolophodon cf. *stegodontoides*

Stegolophodon sp.

Stegolophodon n. sp. 1

Stegolophodon n. sp. 2

Stegolophodon n. sp. 3

Stegolophodon n. sp. 4

Genus *Stegodon* Falconer, 1857

Stegodon n. sp.1

Stegodon n. sp.2

Stegodon n. sp.3

Stegodon sp.

Family Elephantidae Gray, 1821

Genus *Elephas* Linnaeus, 1758

Elephas sp.

3.3.1 Family Deinotheriidae Bonaparte, 1845

Diagnosis: Dental formula for deciduous teeth is i 0/1, c 0/0, p 3/3. Dental formula for permanent dentition is I 0/1, C 0/0, P 2/2, M3/3, loss of four incisors, one canine, and two premolars derived from it ancestral condition, *Moeritherium*. Lack of tusks in the upper jaw is an autapomorphy for Deinotheriidae.

A primitive character of Deinotheriidae is a flat cranium on its dorsum, in contrast to the high domed crania of most advanced proboscideans. Premolars and molars of *Prodeinotherium* and *Deinotherium* had two or three ridges, with very simple cusps; the enamel on the teeth of deinotheres was about 5 to 8 millimeters thick compared to 1 to 5 millimeters in elephantids; cheek teeth were replaced in a vertical fashion as in other primitive proboscideans, including *Palaeomastodon* and *Phiomia*.

Derived characters of Deinotheriidae are slightly elevated skull, pneumatized bones in the cranium, elevated external naris, loss of teeth, long, down-recurved incisors (I2), or tusks, in the mandibles; radius fixed in pronation position, a well-developed medial process (tuberculum mediale) on the astragalus, and large size and graviportal stance – *Deinotherium giganteum* was about 4 meters tall. Skeletal characters of Deinotheriidae were summarized by Harris (1978).

Genus *Prodeinotherium* Ehik, 1930

Diagnosis: Small deinotheres, dental formulae as for the family Deinotheriidae; M^{2-3} with well defined postmetaloph ornamentation. Skull rostrum turned down parallel to the mandiblular symphysis; rostral trough and external nares narrow;

preorbital swelling close to the orbit; external nares anteriorly sited and nasal bones with anterior median projection; skull roof relatively longer and wider than in *Deinotherium*; occiput more vertically inclined; occipital condyles sited more ventrally than in *Deinotherium* and level with the Frankfurt Plane; paroccipital process short. Postcranial skeleton was graviportally adapted; scapula with well defined spine and stout acromion and metacromion; tarsals and carpals narrow but not dichopodous (Harris, 1973).

Type species*: *Prodeinotherium bavaricum (von Meyer, 1831)

Prodeinotherium pentapotamiae (Lydekker, 1876)

Fig. 3.6

Synonymy

1868 *Antoletherium* Falconer, p. 416.

1876 *Dinotherium pentapotamiae* Lydekker, pl. xxxi, fig. 4.

1880 *Dinotherium sindiense* Lydekker, p. 196.

Materials: RIN 15: a fragmented right mandible with the first molar M_1, second molar M_2, and third molar M_3; KHO: a right mandible with the fourth premolar, P_4, to M_3.

Description: RIN 15 has trilophodont, or three transverse lophids, on the M_1 and small posterior cingulum. The labial is more heavily worn than the lingual side. The surface of the tooth is broken and covered by sediment. The details of anterior cingulum and anterior face are not apparent. The anterior faces of hypolophid and tritolophid are well developed. The anterior and posterior median valleys are open at

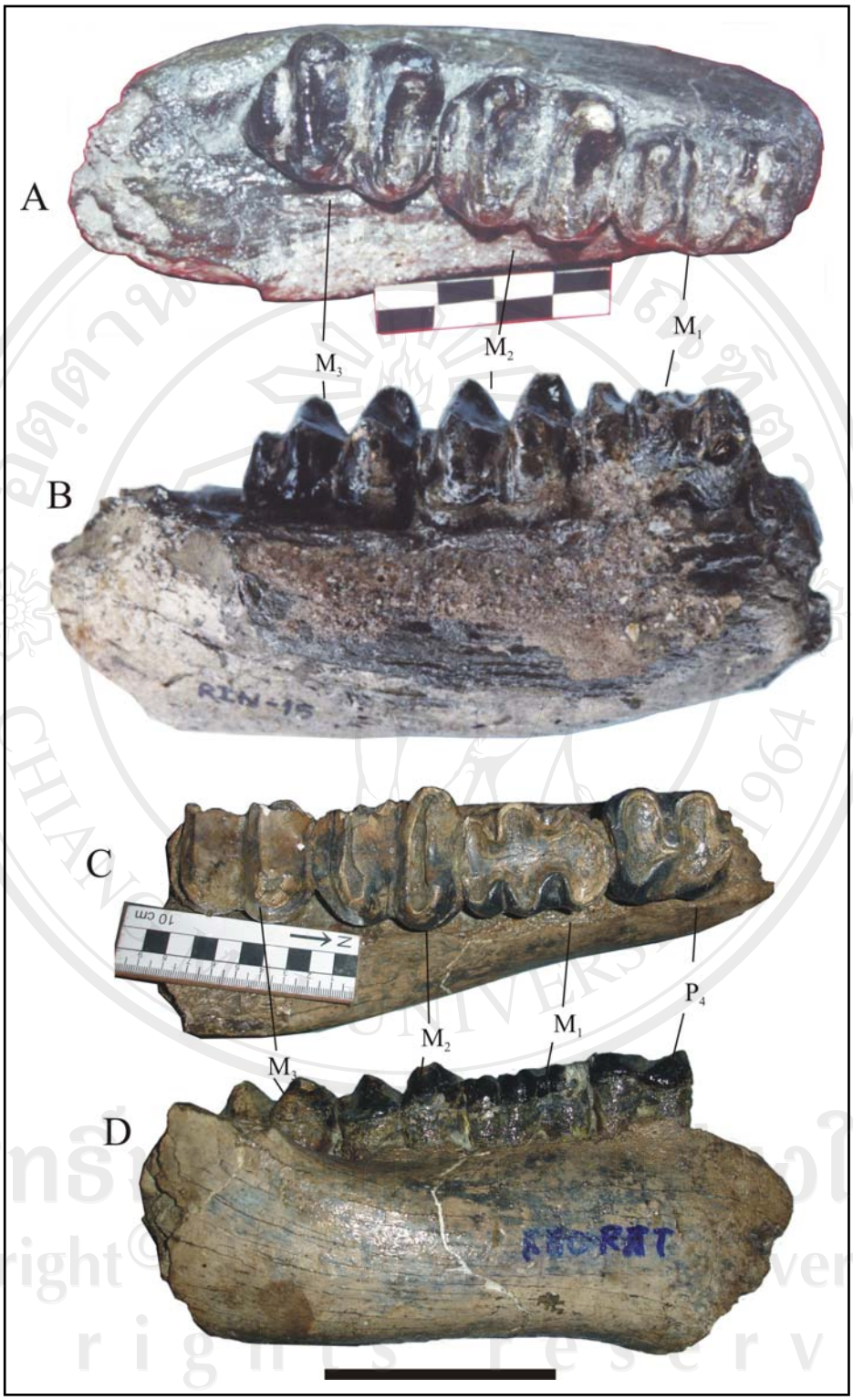

Fig. 3.6 *Prodeinotherium pentapotamiae*: RIN 15 is a right mandible with M_1 to M_3, A: occlusal view, B: buccal view; KHO is a right mandible with P_4 to M_3. C: occlusal view, D: lingual view. Scale bar 10 centimeters applies to all.

both sides. The wear facets are on the posterior. The length is 69.5millimeters. The width is 45 millimeters on the hypolophid. The M_2 is bilophodont with posterior cingulum and no anterior cingulum. The lingual and labial ridges are strong on the protolophid and connected at the mid-line of the tooth. The wear facets occur on the posterior surface. The structures on the hypolophid are similar to the protolophid but the ridge on the lingual is fused. The posterior cingulum is well developed and the inter-valley is open. The shape is nearly rectangular. Length is 63.40 millimeters. The width is 60 millimeters on the protolophid. The M_3 is bilophodont with posterior cingulum and no anterior cingulum. The tooth structure is similar to the second molar, but there are stronger anterior ridges on the protolophid and strong labial ridges on the hypolophid. The shape of the tooth is triangular. The length is 72 millimeters. The width is 61.60 millimeters on the protolophid. On both the second and third molars, the lophs are curved, the concave side facing anteriorly.

KHO is a right mandible with P_4 to M_3. The P_4 has a nearly square shape. There are two lophids that are deeply worn. An abrasion groove occurred at the posterior pretrite of the first lophid. The M_1 is a full trilophodont. It is deeply worn to dentine, so much so that the structures of this tooth can not be described. This M_1 differs from the M_1 of RIN 15 by having no posterior cingulum and is a smaller size. The M_2 is bilophodont with well developed posterior cingulum. It is moderately worn. The second lophid is broken at the posttrite side. Wear facets occur on the posterior surface. The M_3 is bilophodont with posterior cingulum but is somewhat broken on the tooth surface and posttrite side. The tooth structure of M_3 is similar to that of M_2, but it has a stronger anterior ridge on the protolophid and strong labial ridge on the hypolophid. The measurement of each molar is shown in Table 3.1.

Table 3.1 Measurements of *Prodeinotherium pentapotamiae* specimens from the Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province

Species/ specimen	L (mm)	W 1 (mm)	W 2 (mm)	W 3 (mm)	H (mm)
P_4: KHO	48	43	46	-	-
M_1: RIN15	69.62	42.46-	45.06-	43.58	-
M_1: KHO	51.5	42	45.5	42.5	-
M_2: RIN15	63.40	60	59.12	-	40.16 (2^{nd})
M_2: KHO	64	56	52	-	-
M_3: RIN15	72	61.6	56.84	-	42.76 (1^{st})
M_3: KHO	63.5	53.5	46-	-	-

***Fossil locality**:* Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province, Sand pit no. 4?

Remarks: *Prodeinotherium* is smaller than *Deinotherium*. The genus is recognized in three species in different geographic locations, *P. bavaricum* in Europe, *P. hobleyi* in Africa, and *P. pentapotamiae* and, perhaps, *P. orlovii*, in Asia (Shoshani *et al*., 1996). Features of the skull and dentition serve to distinguish the deinotheres from the elephantoids. Distinctive characters can also be seen in the postcranial skeleton.

The specimens of *Prodeinotherium pentapotamiae* in this study are more complete than previously reported from the Pong basin in Thailand (Sickenburg, 1971). The size and character of teeth are comparable with *P. hobley*i from Africa (Harris, 1973), *P. pentapotamiae* from India (Lydekker, 1884), and *P. bavaricum* from Europe (Huttunen and Göhlich, 2002) (Fig. 3.7). Identification of this genus can be made by using the structure on the third premolar. Unfortunately, none is preserved in both RIN15 and KHO. These specimens are located in the species *Prodeinotherium pentapotamiae* because it is smaller than *Deinotherium* and was discovered in Asia.

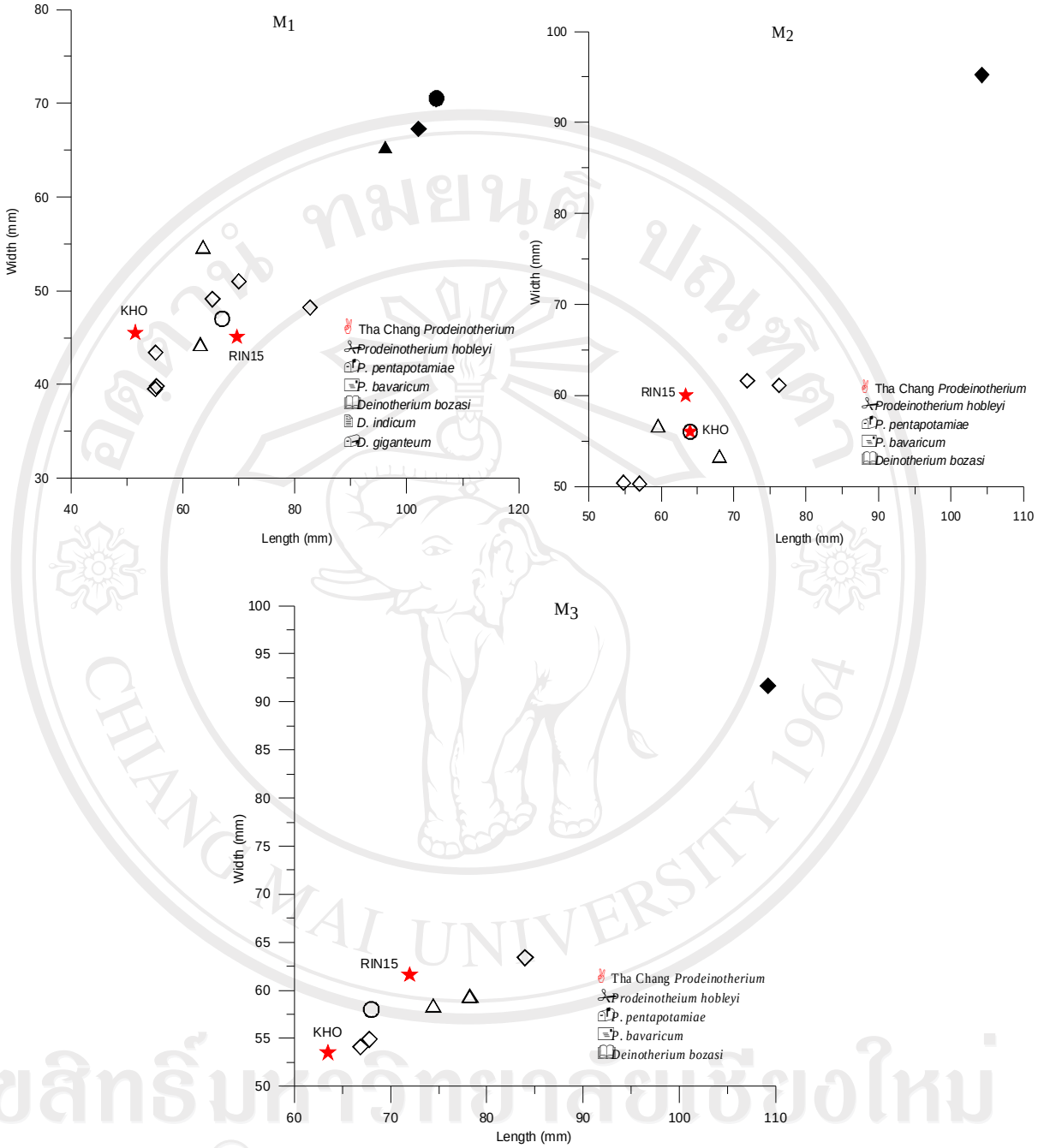

Fig. 3.7 Scatter diagrams of M_1, M_2, and M_3 of Deinotheriidae. The specimens from Tha Chang sand pits are in the distributed size of *Prodeinotherium*.

Data sources: *Prodeinotherium pentapotamiae* from Lydekker, 1880; *Prodeinotherium hobleyi* from Harris, 1973; *Prodeinotheirum bavaricum* from Huttunen & Göhlich, 2002; *Deinotherium indicum* from Lydekker, 1880; *Deinotheirum bozasi* from Harris, 1973, and Beden, 1987, and *Deinotherium giganteum* from Athannassios, 2004).

3.3.2 Family Gomphotheriidae Hay, 1922

Subfamily Amebelodontinae Barbour, 1927

Genus *Archaeobelodon* Tassy, 1984

***Diagnosis*:** Small amebelodontine; crown relatively narrow; main cones massive and bunodont; mesoconelets comparatively tiny; anterior and posterior accessory central conules small and present on each pretrite half-loph;anterior accessory central conules slightly larger than posterior central conules; small anterior accessory cental conules present on each half-loph of the posttrite side. It is distinguished from other amebelodontines by the small size of its pretrite accessory central conules, and from *Protanancus*, in particular, by lack of anancoidy of lophs, lesser development of cementum, and smaller size (Tassy, 1983, 1984, 1986).

Archaeobelodon sp.

Figs. 3.8 and 3.9

Materials: DC-1: upper tusks; DC-2: lower tusks from the Mae Soi locality, which have been described by Saegusa *et al*. (1999); KHT-1; posterior part of the third lower right molar, RM_3.

Description: DC-1 is the upper tusk samples; they are gently curved ventrally and have a distinct enamel band along the lateralo-ventral border, as in most gomphotheres.

DC-2 is the lower tusk samples; they lack of enamel and are slightly flat dorso-ventrally. Shallow longitudinal grooves and sillon longitudinal occurs on the dorsal

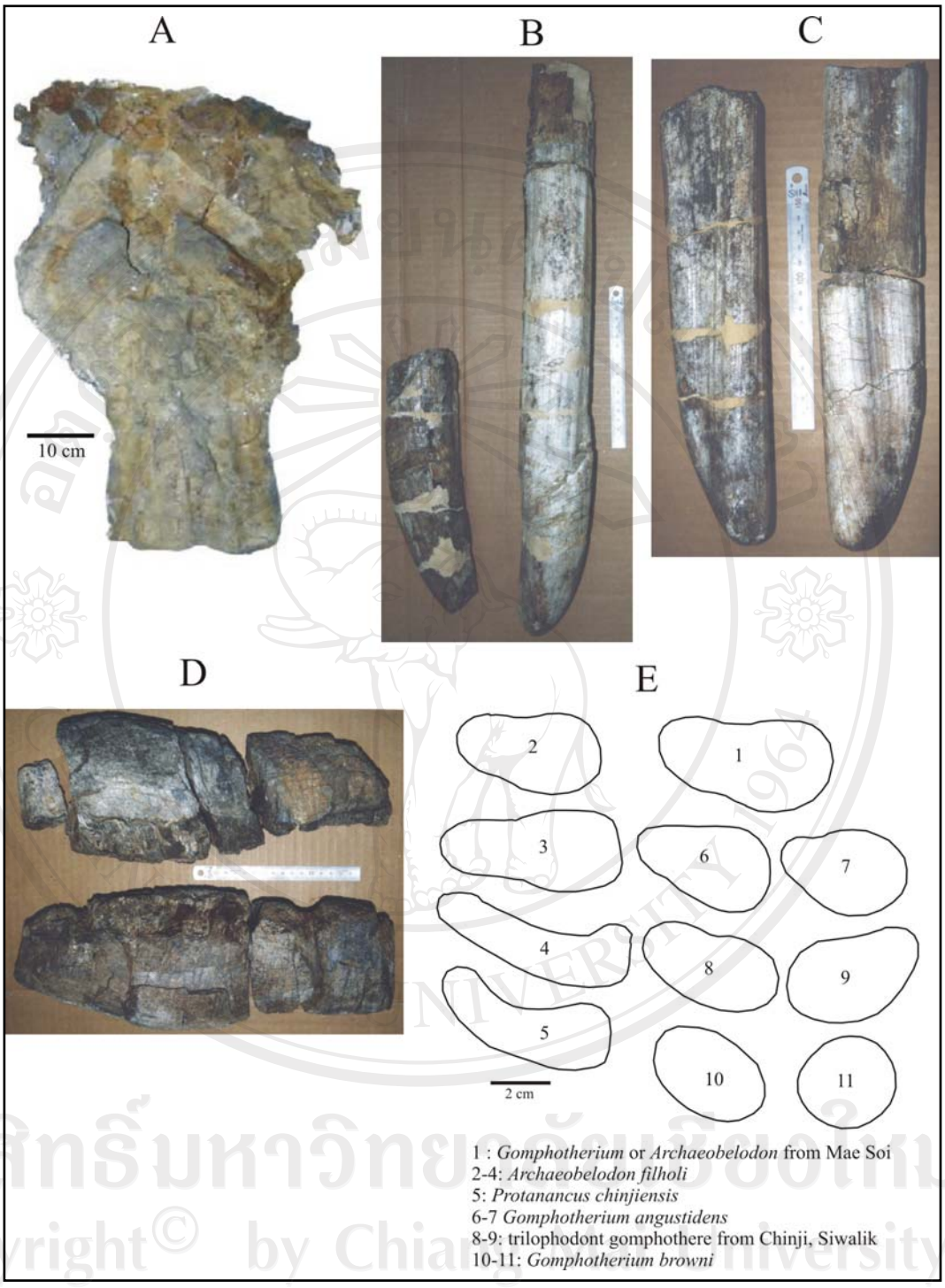

Fig. 3.8 *Archaeobelodon* sp. from Doi Chang sub-locality, Mae Soi locality, Chom Thong District, Chiang Mai Province. (A) Skull, (B) Upper tusks (DC-1), (C) Lower tusks (DC-2), (D) Lower molars, and (E) Cross section of the lower tusks from Mae Soi (#1) compared to the other gomphotheres from various localities of Asia and Europe, Data sources from Tassy (1982, 1983) (A and E from Saegusa *et al*., 1999; B, C, and D took by Dr. Benjavun Ratanasthien).

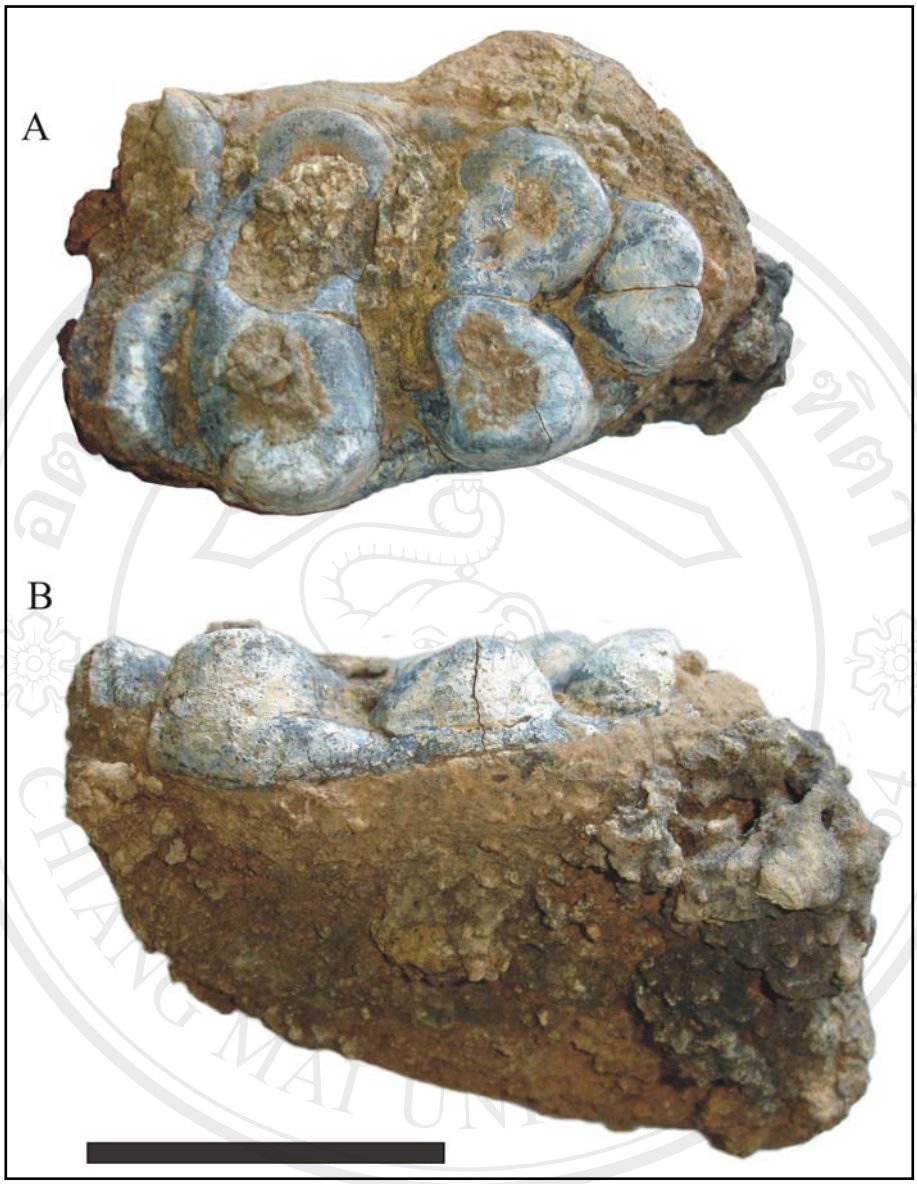

Fig. 3.9 *Archaeobelodon* sp., KHT-1 from Kew Hoi Tal sub-locality, Mae Soi locality, Chom Thong District, Chiang Mai Province. A: occlusal view, B: lateral view. Natural size, scale bar 5 centimeters.

and ventral surfaces of the tusks.

KHT-1: a posterior part of the bunodont lower right M_3 contains half of the second lophid and the last two lophids and talonid. Its preserved part is 94 millimeters long. Its average longitudinal lophid width indicates the complete molar was 140 millimeters long. The maximum width is about 60 millimeters, measured at the second lophid. The distal root is preserved and it supports the posterior part of the second, third and fourth lophids. Commonly, the first lophid and the anterior part of the second lophid must be supported by the anterior root. Therefore, the assumed tooth formula is N=X4X. The tooth is worn through the talonid, which is well separated from the fourth lophid, suggesting it belonged to an old individual. Posterior orientation occurs on the pretrite side. The posttrite has a slight distal displacement or is inline. A small posterior pretrite central conule is present at the base of the second inter-valley, but it is absent on the third and fourth lophid, this being a G-Type 1 tooth structural pattern.

Fossil locality: Mae Soi locality, Chom Thong District, Chiang Mai Province.

***Comparison*:** The cross section of the lower tusks suggests that the Mae Soi gomphothere can belong to either *Archaeobelodon* or to *Gomphotherium* (Fig. 3.8 E). However, the characteristics of the Mae Soi mastodont tusks, which are moderately flat and have ventral and dorsal grooves, were found in a bed that might be Middle Miocene or older (Saegusa *et al*. 1999). The lower tusks of *Gomphotherium browni* and *Protanancus chinjiensis* from the Chinji Formaiton of the Siwalik Group are more derived in morphology than the Mae Soi mastodont (Tassy, 1983; Saegusa *et al*., 1999). *Gomphotherium browni* has a round or oblong tusk cross section and *Protanancus chinjiensis* has a flat tusk cross section, which is a distinctly derived

character of Amebelodontinae (Tassy, 1983). Thus, it is sensible that the Mae Soi locality is older than the Chinji Formation. Also, the M_3 specimen, KHT-1, is similar in size to cf. *Archaeobelondon* Tassy, 1984, *G. inopinatum* (Borissiak and Belyaeva, 1928), primitive species of *G. angustidens* (Cuvier, 1806), *G. subtapiroideum* (Schlesinger, 1917), and *G. cooperi* (Osborn, 1932) (Fig. 3.10). It differs from *G. angustidens*, *G. inopinatum*, and *G. cooperi* by lack of anterior and posterior central conules. It differs from *G. subtapiroideum* by fewer subdivisions of the main cusps and mesoconelet. It is different from *Choerolophodon*, which is characterized by the mesoconelets and fused central conules and by the oblique orientation of pretrite and posttrite half-lophs. This gives anterior chevroning, or V-points. The tusks and molar characters on Mae Soi's mastodont suggest are comparable to *Archaeobelodon* sp. that survived during the Early Miocene to early Middle Miocene.

Remarks: *Archaeobelodon* of the Early to Middle Miocene of Europe and East Africa is identified by the small size of it pretrite and posttrite accescory central conules, absence of posterior accessory central conules, and lack of anacoidy, which is expressed in varying degree in *Protanancus* (Tassy, 1983a, 1984, 1985, 1986).

Note: Saegusa *et al*., 1999, also reported on the other specimens of this fossil, including molars that have five ridges and exhibit the bunodont condition with heavy wear of molar crowns, cranium, fragments of the left and right mandible, seven cervical vertebrae, more than eight thoracic vertebrae, three sacral vertebrae, more than 20 rib bones, the left scapula, left humorous, left ulna, left radius, left and right innominate, the distal end of the right and left femur, the left tibia, and fragments of calcaneus, left astragalus, and right navicular.

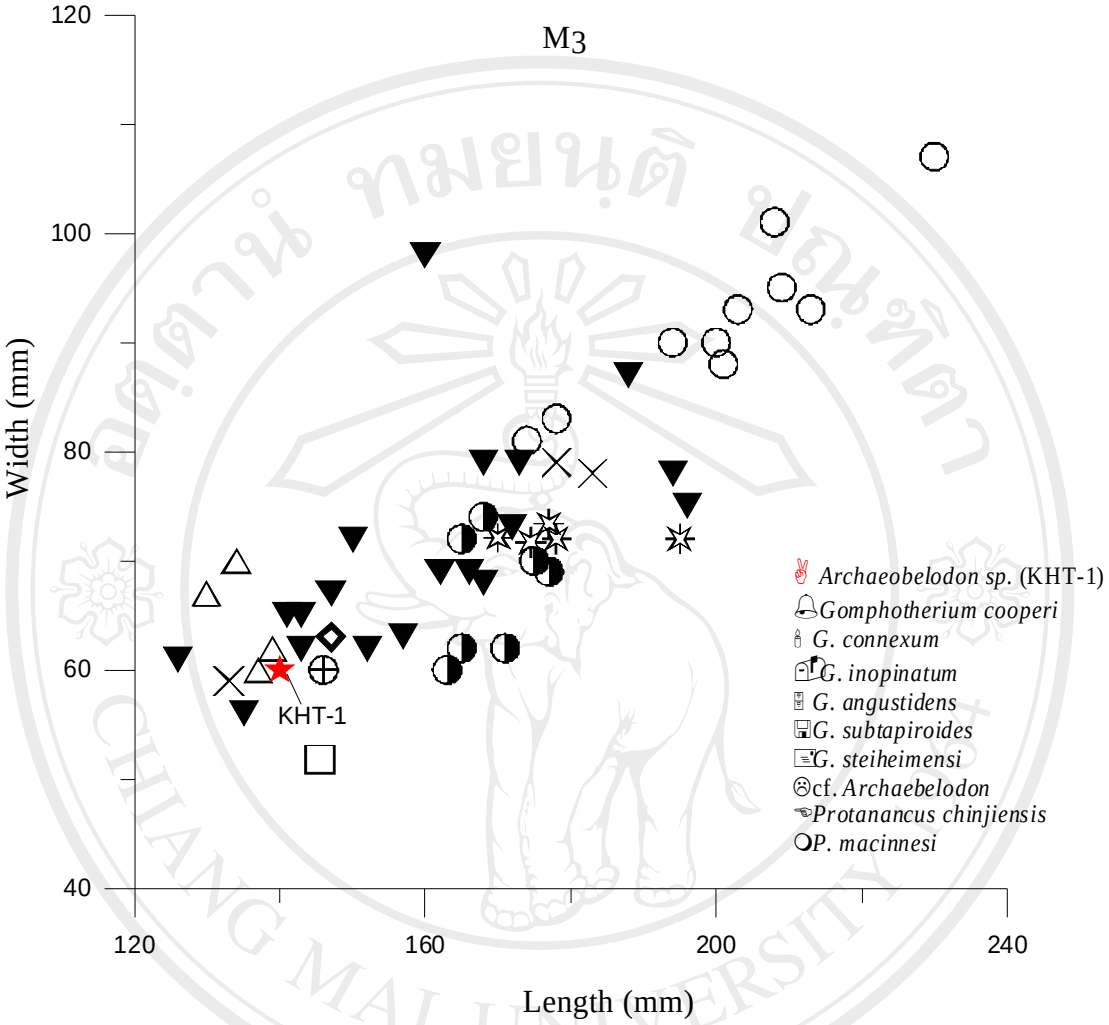

Fig. 3.10 The scatter diagram of length and width compared between the Kew Hoi Tal specimen and *Gomphotherium* and cf. *Archaeobelodon*. Data sources: *Gomphotherium cooperi* from Osborn, 1932; *G. connexum* from Hopwood, 1935; *G. inopinatum* from Borissiak and Belyaeva,1928; *G. angustidens* from Osborn, 1936; Bergounioux *et al*., 1953; Bergounioux & Crouzel, 1960; and Göhlich, 1999; *G. subtapiroideum* and *G. steinheimense* from Göhlich, 1999; cf. *Archaeobelodon* from Tassy, 1986, *Protanancus chinjiensis* from Tassy, 1983; *P. maccinnesi* (MacInnes, 1942).

Genus *Protanancus* Arambourg, 1945

***Emended diagnostic*:** *Amebelodon* has large upper tusks that are strongly curved outward (known only with *P. macinnesi*); lower tusks have concentric dentine, more set back dorally, as with *Archaeobelodon.* The pretrite and posttrite parts of the molar lophs have dislocated pseudo-anancoïde contact, especially on M3; cement covering of the molars is more distinct than with *Archaeobelodon* (Tassy, 1984).

Protanancus macinnesi Arambourg, 1945

Synonymy

1942 *Trilophodon angustidens kisumuensis* MacInnes, part.: pl. 5, fig. 1, 2, 8, 10 à, 12; pl. 6, fig. 1 à, 4, 6.

1945 *Trilophodon angustidens kisunuensis* part.: Arambourg, << MacInnes fig. 8, 12; fig. 4, 6, pl. VI>>.

1945 *Protanancus MacInnesi* Arambourg, <MacInnes, fig. 1 à, 4, pl. IV; 2, 10, 11, pl. V; 1, 2, pl. VI>>.

1963 *Trilophodon angustidens* cf. *kisumuensis* part.: Hooijer, pl. 1, fig. 3, 4.

1973a *Platybelodon kisumuensis* (MacInnes, 1942) part.: Tobien, p. 256, p. 261-2, fig. 15, p. 251.

1973 *Gomphotherium angustidens* part.: Maglio, p. 88, fig. 22.

1976 *Gomphotherium* sp. part.: Andrews & Walker, p. 300.

1976 *Platybelodon kisumuensis* (MacInnes, 1942) part.: Van Couvering & Van Couvering, p. 201

1977 *Pr. macinnesi*: Tassy, p. 2487.

1981 *Platybelodon*: Shipman *et al*., p. 67.

***Diagnosis*:** Dislocation of the half-loph(id)s pretrite and posttrite of molars, M3, are not very stressed in comparison with *Protanancus chinjiensis* (Pilgrim, 1913), central conules are less developed, posttrite half-loph(id) is not always making a contact pseudo-anancoidy, the trefoil posttrite can be reduced to the intermediary molars, narrower molars than with *P. chinjiensis*, upper tusks are large, provided with an enamel band, heavily curved towards the exterior one, this not known with *P. chinjiensis*, shorter face than with *P. chinjiensis*.

cf. *Protanancus macinnesi*

Fig. 3.11

***Materials*:** NM1-9: left upper M^3; RIN 25: right mandible with M_{1-3}; NM1-3: right lower M_3; and NM1-17: left lower M_3.

***Description*:** NM1-9 is an isolated left M^3 with fully five lophs, X5, but the last loph is small compared with the fourth loph. There is a small anterior cingulum but no posterior cingulum. The lateral cingulum is developed on the pretrite side, which is lined along the anterior cingulum to the second valley. There are simple tooth structures and strong median sulcus, this being a G-Type 3 tooth structural pattern. The pretrite half-loph is composed of large main cusps and smaller mesoconets.

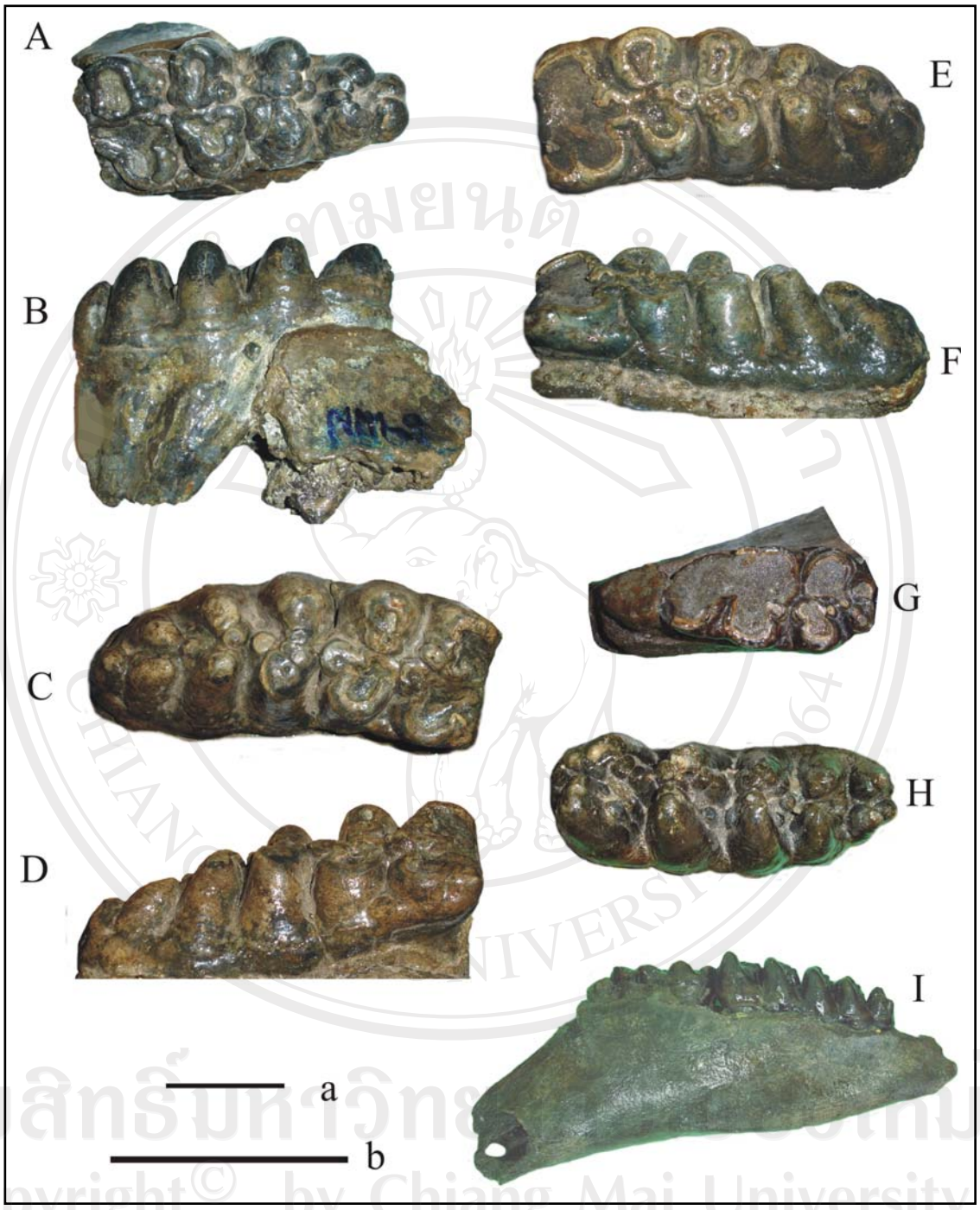

Fig. 3.11 cf. *Protanancus macinnesi* from the Tha Chang sand pits, Nakhon Ratchasima Province. NM1-9 is an upper left M^3, A: occlusal view, B: labial view; NM1-3 is a right M_3, C: occlusal view, D: buccal view; NM1-17 is a left M_3, E: occlusal view, F: lingual view; RIN25 is a right mandible with M_{1-3}, G: occlusal view of M_2, H: occlusal view of M_3, I: lateral view of mandible and crown. Scale bars 10 centimeters, scale bar a applies to I and scale bar b applies to A to H.

These structures are present on the first four lophs but the fifth loph is composed only of the main cones. The anterior and posterior central conules are strong on the first two lophs but small or fuse on the third to the fifth lophs. The posttrite half-loph is composed of the main cusps and mesoconelets as large as the main cusps in the first three lophs but the last two lophs are smaller, which is considered to be the talon.

The first and second lophs are heavily worn and there is a strong trefoil figure on the pretrite half-loph as a result of the large anterior and posterior central conules. On the pretrite side, the third and fouth lophs are strong anterior pretrite central conules but the posterior conules were not developed. The last loph is composed of two large main cusps and but its height is abruptly reduced. The posttrite half-loph has incipient anterior and posterior central conules at the base of the mesoconelet. This is seen on the second and third lophs. The tooth cusps are cone shaped, round, and slim. The interlophs are narrow.

RIN 25 is the right mandible with totally worn M_1, heavily worn M_2, and slightly worn M_3 of a bunodont trilophodont gomphothere. The heavily worn M_2 shows few details. However, its posterior posttrite central conule appears on the second and the third lophids. The pretrite half-lophid is heavily oriented in the posterior-external direction. The third molar is slightly worn on the first lophid. The main cusps are larger than the adaxial conelets. Their tips are narrow due to the inclination to the central part. The posterior pretrite central conules are double conules in the first three lophids. These conules connect with the main cusp of each lophid. Posterior pretrite central conules 1 and 3 are totally blocked the transverse valleys. The posterior posttrite central conules are developed as small conules at the base of the main cusps in each lophid. There is no cement. The mandible is long.

NM1-3 is an isolated lower right M_3 with an X5X lophid formula. It is heavily worn on the first and second lophids. The main cusps of both pretrite and posttrite half-lophids are much larger than the mesoconelets. The posterior pretrite central conules are larger and fully block the first interlophid, but the others are not fully blocked. The anterior pretrite central conules are fused and small. The pretrite and posttrite half-lophids are in the same line. The cusps are cone shaped and round.

NM1-17 is a left M_3 with an X5X lophid formula. It is heavily worn on the first three lophids. The first lophid is heavily worn. Because of this, more details can not be described except for its large main cusps and large pretrite central conules. The first posterior pretrite central conules are connected with the second anterior central conules and the second posterior central conule is connected with the third anterior central conule, which has an anancoidy character in this specimen, but not strong alternation of pretrite and posttrite half-lophids. The measurements of these specimens are shown in Table 3.2.

***Comparison*:** The genus *Protanancus* is has only two known species; *P. macinnesi* from Makobo, Kenya, and *P. chinjiensis* from the Siwalik Group in Pakistan. Scatter diagrams show that the upper and lower molars of the Tha Chang specimens are small and in the group of *P. macinnesi*. From tooth structures and tooth size, the Tha Chang specimens are comparable to *Protanancus macinnesi* (MacInnes, 1942, pl.5, fig. 1, 2; Tassy, 1986, pl.6, fig. 2) from Makobo, Kenya. This species was in Africa during the Middle Miocene. The tooth pattern of RIN25 shows the development of posterior posttrite central conule. This indicates an advanced character and it is characteristic of this genus. The molars from Tha Chang are very small, narrow, and less anancoidy than *P. chinjiensis*, indicating it was a primitive

Table 3.2 Measurement of the size in sub-family Amebelodontinae (*Archaeobelodon* sp. and cf *Protanancus macinnesi*)

Species/ specimen	L (mm)	W1 (mm)	W 2 (mm)	W 3 (mm)	W 4 (mm)	W 5 (mm)
Archaeobelodon sp. M_3: KHT-1	94-	-	57	56	49	-
cf. *Protanancus macinnesi* M_2: RIN 25	92.1	41.65	47.47	51.40	-	-
M^3: NM1-9	134	60.6	63.09	56.10	45.78	31.75
M_3: RIN25	143	51.47	56.37	58.47	55.18	42.09
M_3: NM1-3	168	58.42	62.2	68.07	64.84	51.53
M_3: NM1-17	162	61.15	61.37	67.44	64.29	52.81

species. The narrow tip of these molars is similar to *Platybelodon*, a genus in Amebelodontinae that has very flat or shovel lower tusks (Fig. 3.12). Unfortunately, there no tusk was found together with the molar specimen from Tha Chang sand pits. Thus, the generic name of this species is tentative.

Genus *Gomphotherium* Burmeister, 1837

Synonymy

1841 *Gamphotherium* Gloger, p.119.

1857 *Trilophodon* Falconer, p.316.

1877 *Bunolophodon* Vacek, p.45.

1884 *Tetrabelodon* Cope, p.4.

1914 *Megabelodon* Barbour, p.217.

1923 *Serridentinus* Osborn, p.2.

1933 *Ocalientinus* Frick, p.579.

1933 *Tatabelodon* Frick, p.581.

1933 *Trobelodon* Frick, p. 580.

1942 *Hemilophodon* Kretzoi, p.139.

Original diagnosis: “Mastodon. Wie Elephas, aber die Backenzähne mit 2 Reihen kegelförmiger Höcker.- Von mehreren untergegangenen Arten findet man Knochen in Nord-amerika, besonders am Ohio, daher Ohiothier. Stoßzähne in beiden Kiefern besaß die gleichfalls untergegangene Gatt. *Gomphotherium*.” (Burmeister, 1837, p. 795).

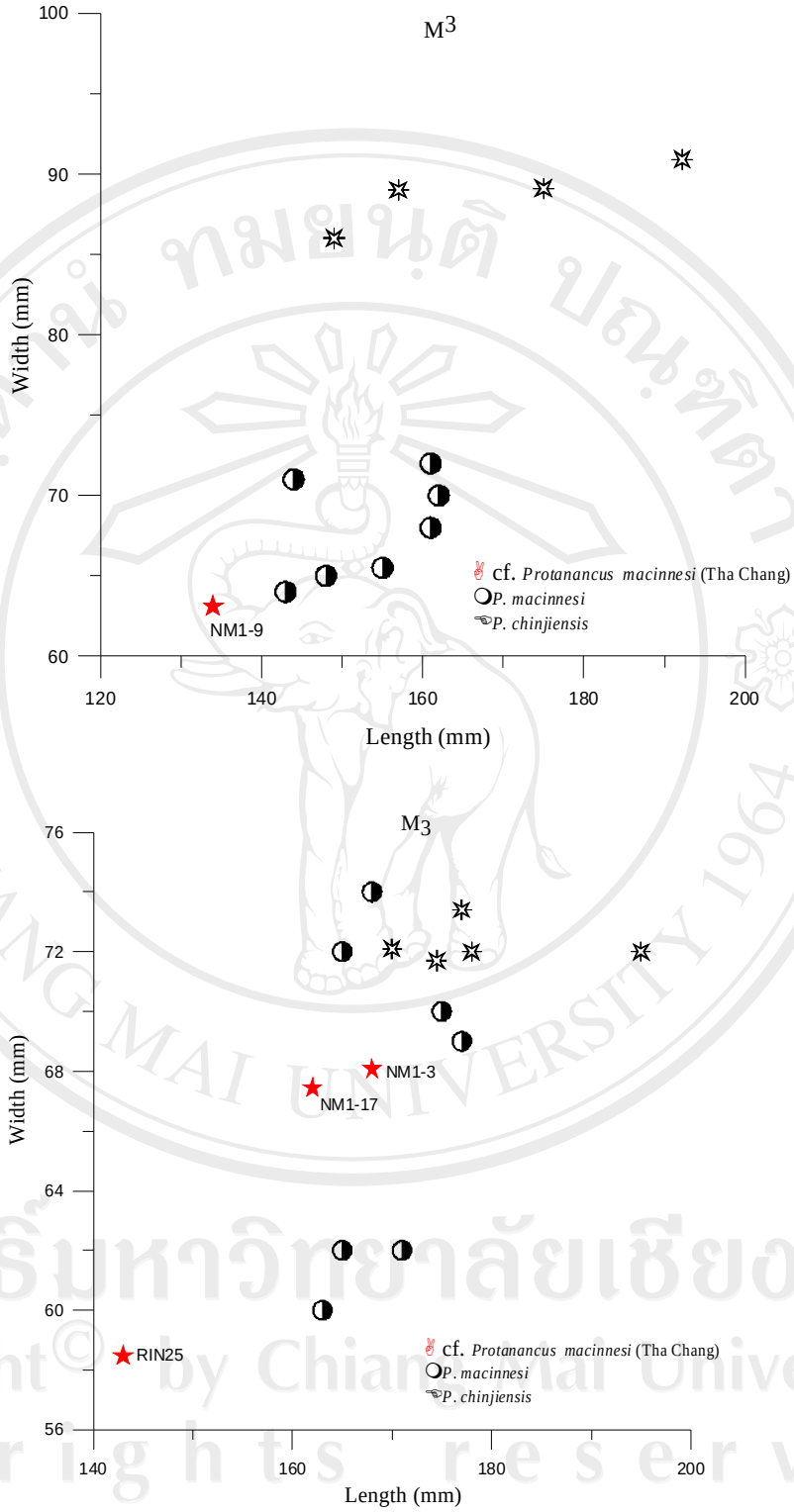

Fig. 3.12 Scatter diagrams of cf. *Protanancus macinnesi* from the Tha Chang sand pits comparing with *P. macinnesi* and *P. chinjiensis*.

Data sources: *Protanancus chinjiensis* from Tassy, 1983; *P. macinnesi* from MacInnes, 1942.

***Gomphotherium* sp. 1**

Fig. 3.13

Materials: CCZ49: the isolated upper right M^3 from Tha Chang sand pits; MMG-1, the upper left M^3 from Mae Moh.

Description: CCZ49 is a right upper third molar, M^3, with fully four lophs and small posterior cingulum, or talon, X4X. The tooth is clearly bunodont and has simple tooth structure. The crowns have strong distal tapering. There is no posttrite central conule. The pretrite half-loph is somewhat wider transversely than the posttrite half-loph. It is heavily worn on the first three lophs. The fourth loph is moderately worn, indicating the crown of the fourth should be much lower than the anterior as it was not highly develop. The median sulcus is seen through the tooth. There is no enamel folding on the worn surface. The slightly anterior and posterior pretrite central conules are on the first and second lophs, this being the G-Type 2 tooth structure pattern. The third loph has only the anterior central conule. The posttrite half-loph probably contains two cusps of the main cusp and mesoconelet. The pretrite half-loph probably contains the main cusp, mesoconelet, and small anterior and posterior central conules. The posttrite half-loph was compressed antero-posterior, which made the apex was much narrower than the base. It has no zygodont crest. There is a lateral tubercle blocking the entrance of the pretrite. It has big roots. The anterior pretrite root supports the first and the second lophs and the anterior posttrite root supports the first loph and the anterior part of the second loph. No cement was deposited in the inter-valleys. The dimensions are in Table 3.3.

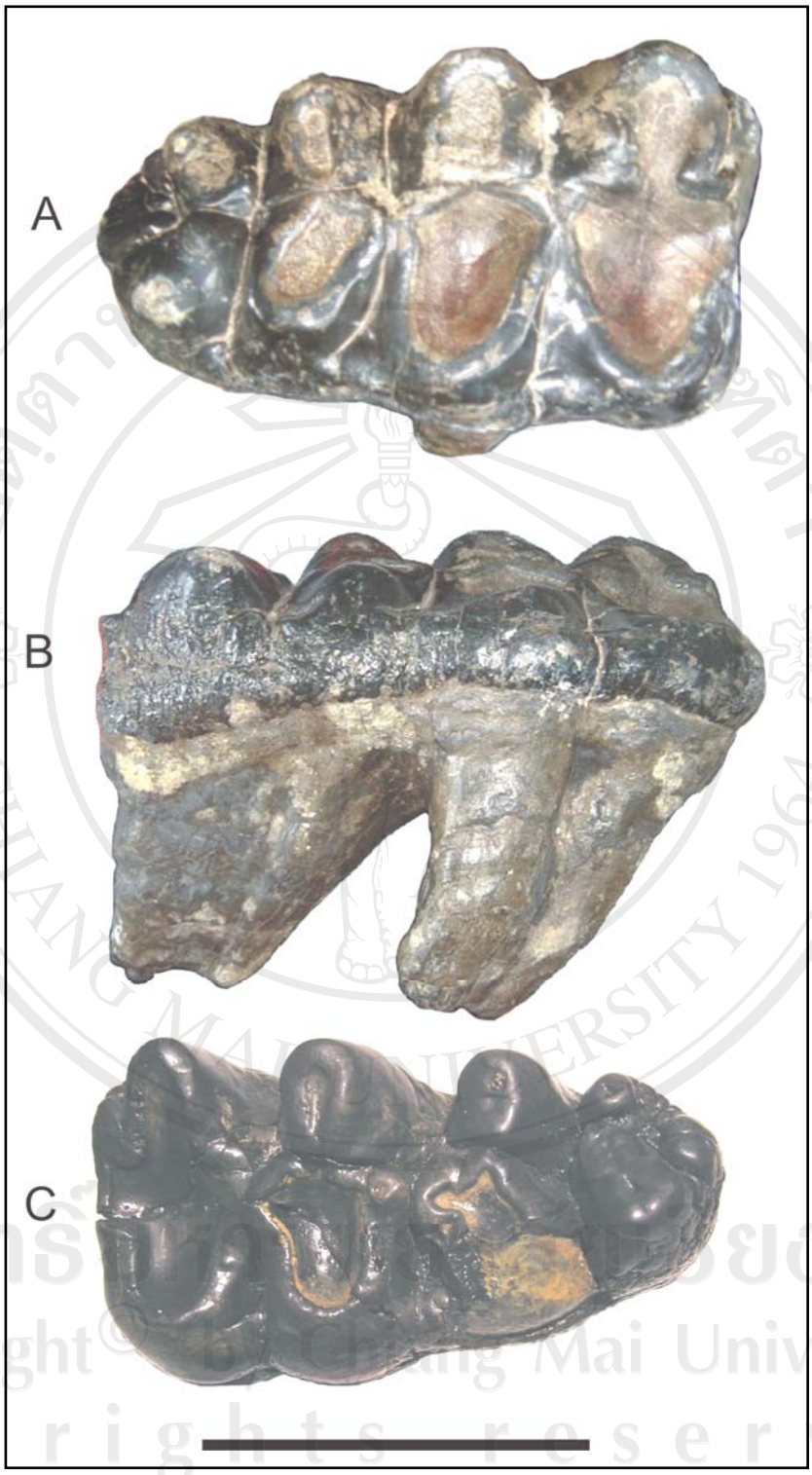

Fig. 3.13 *Gomphotherium* sp.1 from the Tha Chang sand pits and Mae Moh coal mine; CCZ49 is a right upper M^3, A: occlusal view, B: lingual view; MM-G1 is a left upper M^3, C: occlusal view. Scale bar 10 centimeters applies to all.

Table 3.3 Measurements of the size of the genus *Gomphotherium*

Species/ specimen	L (mm)	W 1 (mm)	W 2 (mm)	W 3 (mm)	W 4 (mm)	W 5 (mm)
***Gomphotherium* sp. 1**						
M^3: CCZ49	171	90.78	91.62	85.96	72.55	
M^3: MM-G1	162	85				
***Gomphotherium* sp. 2**						
M^3: NMX4	208.5	116.43	114.62	113.99	87.13	
M^3: KHO9	191-	97.77-	104.51	104.16	83.65	
M_3: NM1-2	225	81.37	97.58	101.74	91.74	58.04
M_3: NM1-10	212	84.32	95.40	100.96	93.26	56.50
M_3: NM1-5	223.5	95.27	99.1	106.41	93.35	60.42
***Gomphotherium* n. sp. 1**						
M^3: KHO13	202.5	96.53	97.39	97.21	84.63	66.46
M_2: RIN2	128.5	73.18	78.62	88.27		
M_3: RIN2	215	86.1	90.5	92.2	80.3	60.5
M_3: RIN353	220	101.75	115.7	116.13	81.2-	

MM-G1 (Fig. 3.13 C) is a left M^3, was found in the Q-Zone coal in the Mae Moh coal mine. It has an X4X tooth formula, but the fourth loph is much smaller and has a lower crown than the third loph. The anterior lophs are wider than the posterior lophs, this known as tapering of the crown. The anterior pretrite central conule is larger than the posterior, this being G-Type 2, and has blocked the inter-valley in the pretrite half- loph. There is no secondary trefoil. The inter-valleys in the posttrite half-loph are wide and have slight accessory conules in the valleys. The cusps are round. The pretrite half-loph is somewhat transversely wider than the posttrite half-loph. The length is 162 millimeters and the width is 85 millimeters. These dimensions were estimated from a photo sent to the author by Mr. Phankant Permsook since the specimen is exhibited in the Mae Moh Museum.

***Fossil locality**:* Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province and Q-Zone coal from the Mae Moh coal mine, Lampang Province.

Comparison: This species is characterized by the number of lophs and the tapering of crowns. The tooth structural pattern is G-Type 2, with simple structures and the anterior pretrite central conules are larger than the posterior ones. The specimen probably belongs to a primitive species of trilophodont gomphothers, such as *Gomphotherium browni, G. angustidens,* and *G. subtapiroides*, according its size (Fig. 3.14) and the number of lophs. However, it is more primitive than *G. steinheimense* as indicated by its smaller size and fewer lophs. The degree of distal tapering of the crown and the size of the fourth loph of CCZ49 from the Tha Chang sand pits and MM-G1 from the Mae Moh coal mine compares well with some molars of *Gomphotherium angustidens* from Simorre (Tobien, 1973b, fig. 3).

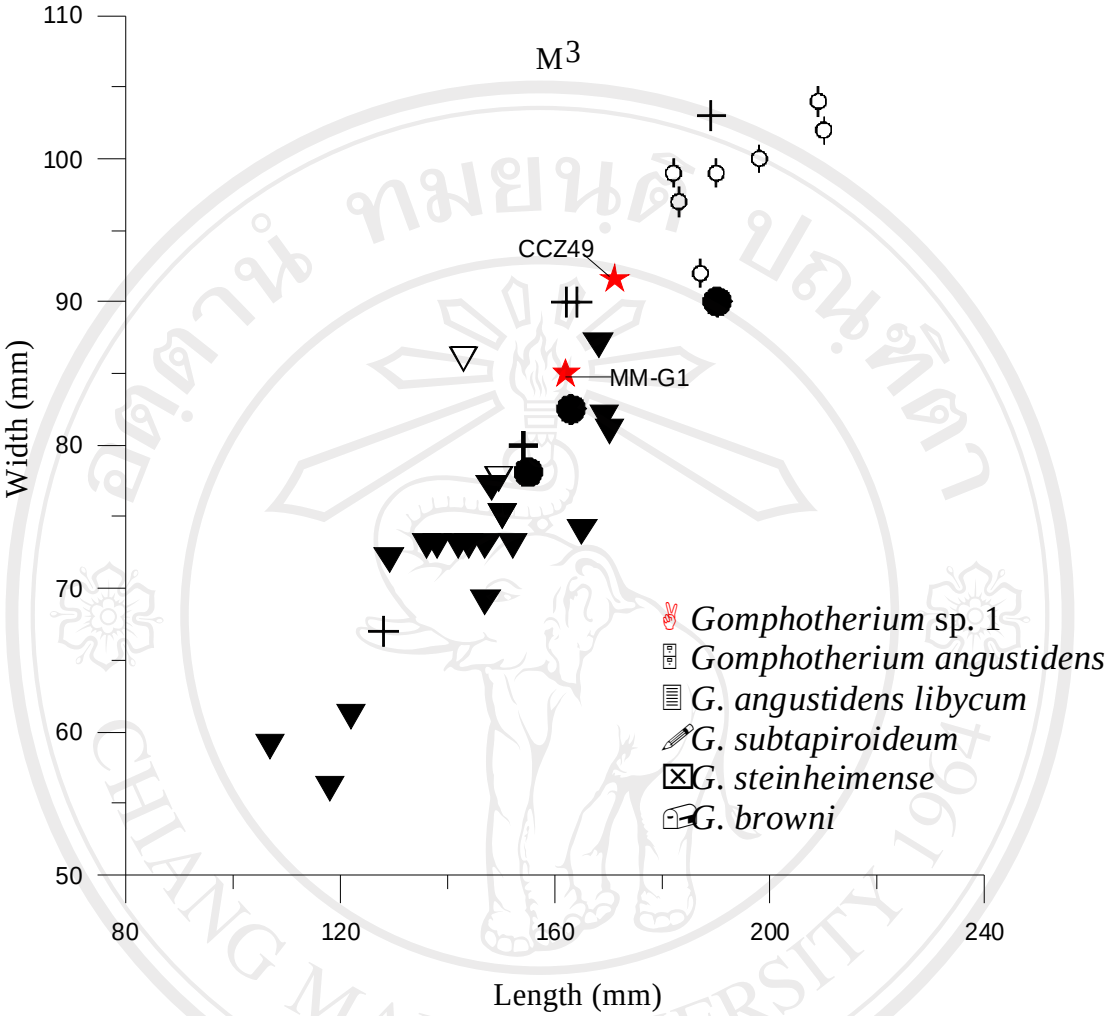

Fig. 3.14 Scatter diagram of upper M^3 compared the sized of *Gomphotherium* sp. 1 and other *Gomphotherium*. Data sources: *Gomphotherium. angustidens* from Bergounioux & Crouzel, 1960; Tassy, 1977, 1985; Göhlich, 1999; *G. angustidens libycum* from Sander & Miller, 2002; *G. subtapiroideum* and *G. steinheimense* from Göhlich, 1999; *G. browni* from Tassy, 1983.

However, the Thai's specimens are more compressed mesiodistally at the apical half than *G. browni*, *G. angustidens*, and *G. steinheimense*. The mesiodistally compression at the apical half was found in *G. subtapiroides*. However, the Thai specimens are different from *G. subtapiroides* in that they have a more accentuated distal tapering of the molar crown and a seemingly narrower posttrite half-loph. The characters and geological age of *Gomphotherium* sp. 1 make it possible that it actually is an ancester to *Sinomastodon* (Saegusa, 2007, personal communication).

***Gomphotherium* sp. 2**

Figs. 3.15 and 3.16

***Materials*:** NMX4: the upper left M^3; KHO9: the upper right M^3; NM1-2: the lower right M_3; NM1-10: the lower left M_3; NM1-5: the lower left M_3.

***Description*:** NMX4 is slightly worn M^3. Sediment covers the tooth surface. Posterior and anterior cingulae are present. The structures of the first loph are not clear because of the sediment cover. The second loph, the pretrite half-loph, has both anterior and posterior central conules but the posttrite had only a small anterior central conule of the G-Type 2 tooth structural pattern. The third loph has a large anterior pretrite central conule. The posterior central conule is small and set on the same line with the main cone. The fourth loph is highly developed.

A conule blocks the exits of the first and second valleys. These valleys have accessory conules. The anterior root is preserved and supports the first and second lophs.

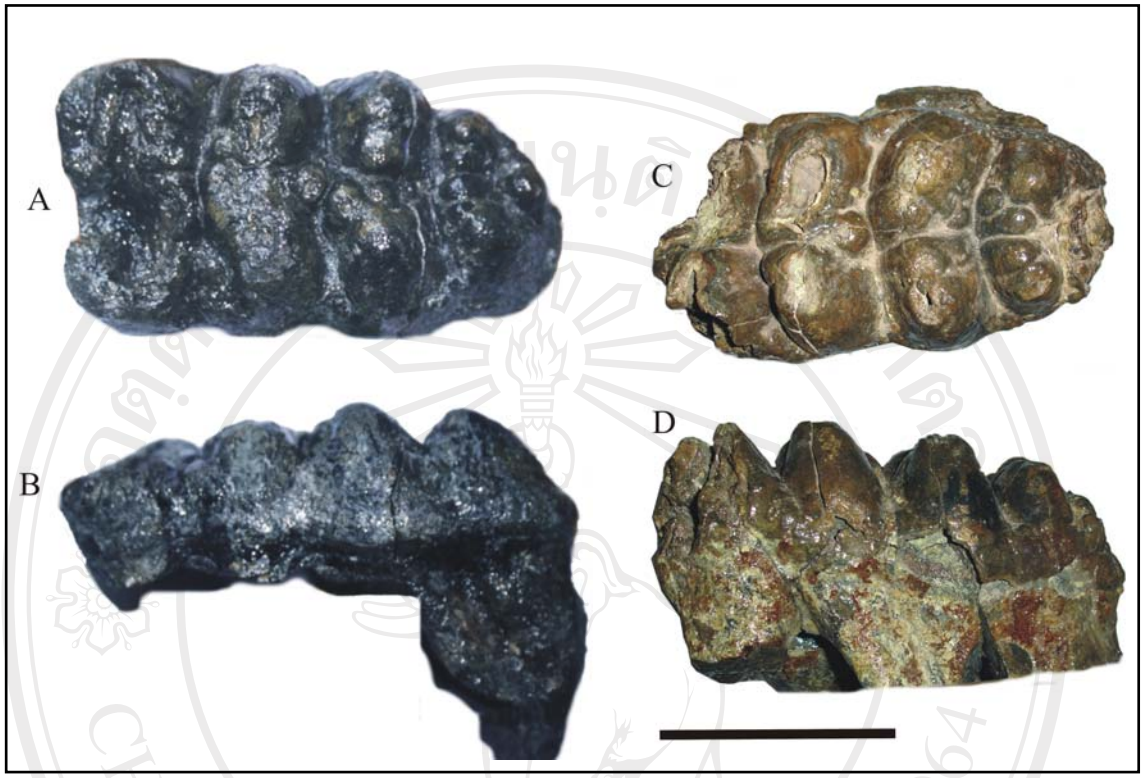

Fig. 3.15 The upper third molars (M^3) of *Gomphotherium* sp. 2 from Tha Chang sand pits. A: occlusal view, B: lateral view of NMX4; C: occlusal view, D: lateral view of KHO9. Scale bar 10 centimeters applies to all.

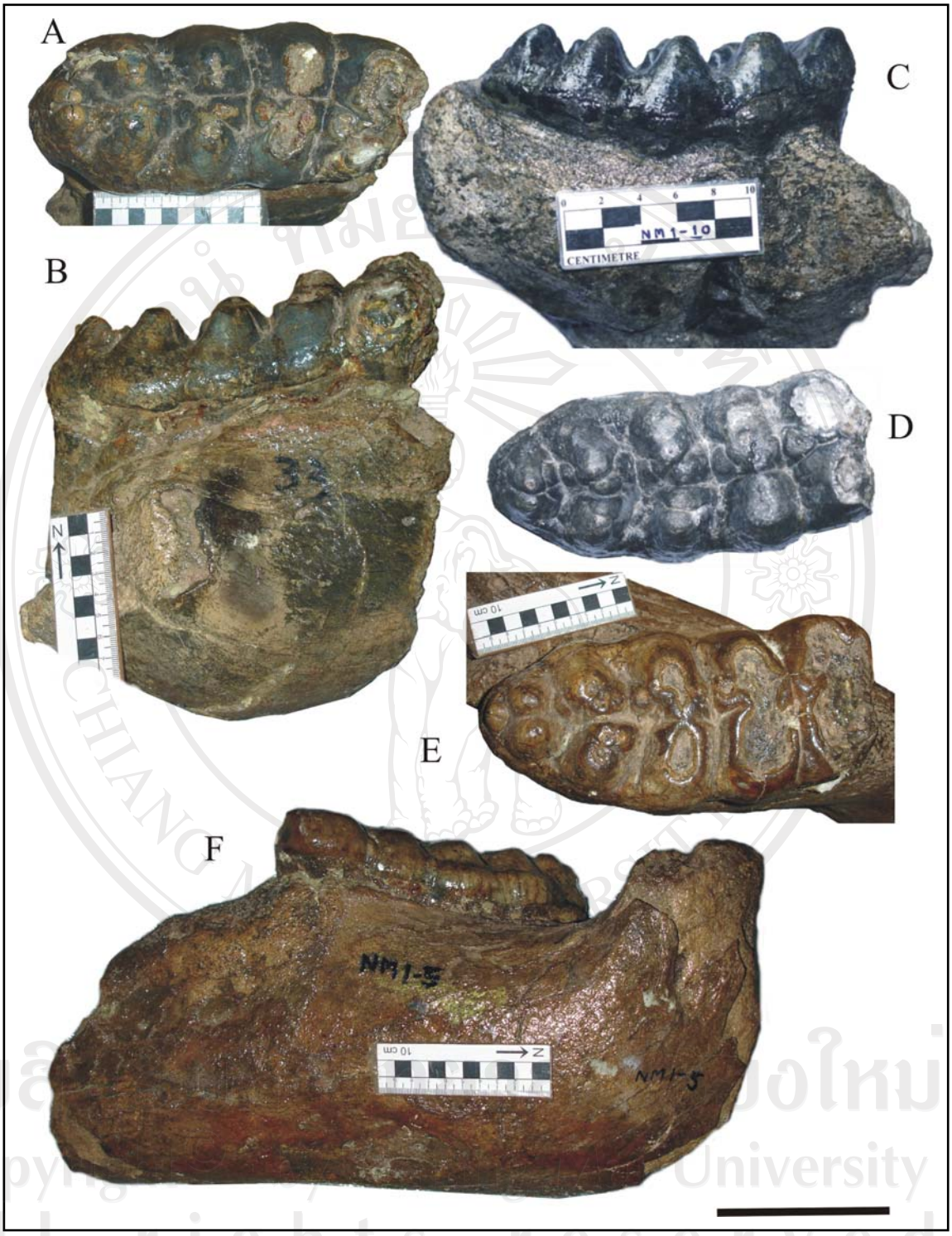

Fig. 3.16 The lower third molars, M_3, of *Gomphotherium* sp. 2 from Tha Chang sand pits. NM1-2 is a right M_3, A: occlusal view, B: lateral view; NN1-10 is a left M_3, C: lateral view, D: occlusal view; NM1-5 is a right M_3, E: occlusal view, F: lateral view and shape of mandible. Scale bar 10 centimeters applies to all.

KHO9 is a right M^3 and has a damaged anterior part. The posterior cingulum is present. The first loph is fully worn and damaged and has strong folding on the posttrite side. On the second loph, small mesoconuleis are separated by a shallow fissure. There is a posterior central conule blocking the median sulcus in the second valley. The third loph has the same structure as the second loph but the posterior central conule is smaller. The fourth loph is highly developed. The conules are separated into small conules, as in *Stegolophodon*. The pretrite conules are not larger than the posttrite. There is a conule at the exit of each valley on the posttrite side and at the second valley exit on the pretrite. The anterior root supports the first loph and the anterior part of the second loph.

NM1-2 is a right lower M_3. The anterior part was damaged. The structure of the first lophid shows that the posterior pretrite central conule is connected to the main cone and the mesoconulid. The conules of the second lophid are in the same line. The pretrite half-lophid has a large posterior central conule connected to the main cone and the mesoconulid. There is a tiny anterior posttrite central conule of the G-type 4 tooth structural pattern. The third lophid is slightly chevron. The mesoconulids, smaller than the main cone, are in a slightly anterior position. On the pretrite half-lophid, the mesoconulid is displaced and connects only with the main cone. It is smaller than the second lophid. The fourth lophid has the same structure as the third lophid. A conule is at the exits of the first valley of the pretrite half-lophid. There are many enamel knobs in the grooves of the second, third, and fourth lophs.

NM-10 is the left M_3. It is a fragmentary mandible and has four lophids and talonid. It has the same structures as the NM1-2 specimen and probably belongs to the same individual as NM1-2.

NM1-5 is a left fragmented mandible with a heavily worn M_3. It has an X5X tooth formula. The bunodont molar and distinct median sulcus is clearly defined. There are four main conelets. The mesoconelets are smaller than the main cusps, as in primitive gomphotheres. The talonid is composed of two large conules. The structure on the first three lophids is not very clear. However, the posterior pretrite central conules are present and distinct as in RIN2. The measurements of this species are shown in Table 3.3.

***Comparison*:** *Gomphotherium* sp. 2 is comparable in size to *G. steinheimense* and to *Tetralophodon longirostris* (Fig. 3.17) who lived in Europe during the Late Miocene. Since only the M3 was preserved, this species is only tentatively identified as *Gomphotherium*. The tooth structure of M_3 and M^3 relate to *Tetralophodon* cf. *xiolongtanensis* from the Chiang Muan coal mine, but the *Gomphotherium* sp. 2 is larger.

Remarks: *Gomphotherium* has trilophodont intermediate molars while *Tetralophodon* has tetralophodont intermediate molars. Unfortunely, the intermediate molar was not found together with these last molars. Thus, *Gomphotherium* is a more reasonable identification than *Tetralophodon* if it has no intermediate molars.

Gomphotherium n. sp. 1

Fig. 3.18

***Diagnosis*:** a large size *Gomphotherium* species with X3X on the second molars and X4X or X5 on M^3 and X4X to X5X on M_3. The widths of the first two lophs are nearly the same, but the fouth loph is noticeably narrower, tapering.

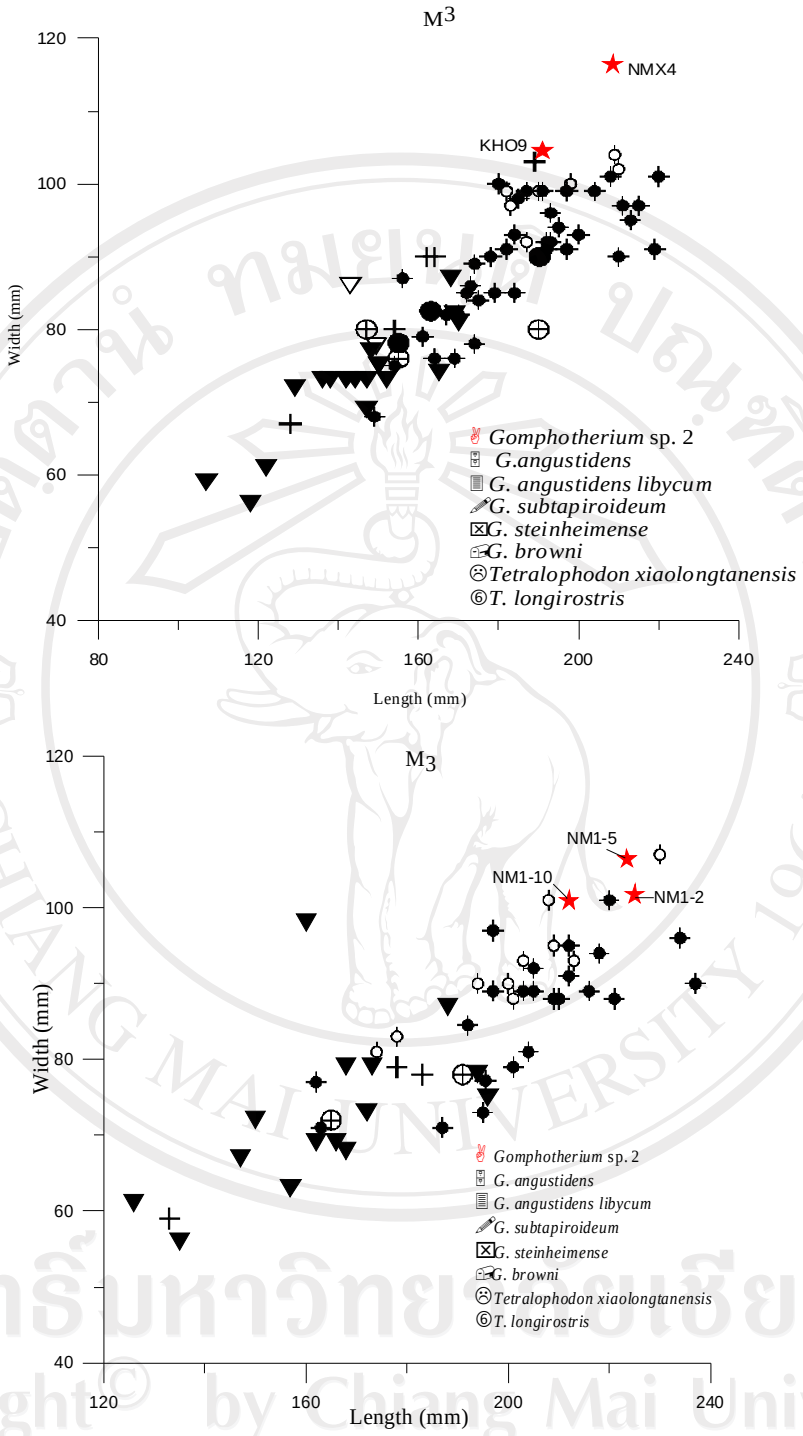

Fig. 3.17 Scatter diagrams of length versus width comparing the size of *Gomphotherium* sp. 2 and other proboscidean fossils. Data sources: *Gomphotherium. angustidens* from Bergounioux & Crouzel, 1960, Tassy, 1977, 1985 and Göhlich, 1999; *G. angustidens libycum* from Sander & Miller, 2002; *G. subtapiroideum* and *G. steinheimense* from Göhlich, 1999; *G. browni* from Tassy, 1983); *Tetralophodon xiaolongtanensis* from Tobien *et al*., 1986, 1988 and Dong, 1987, *T. longirostris* from Göhlich, 1999 and Geradds *et al*., 2005).

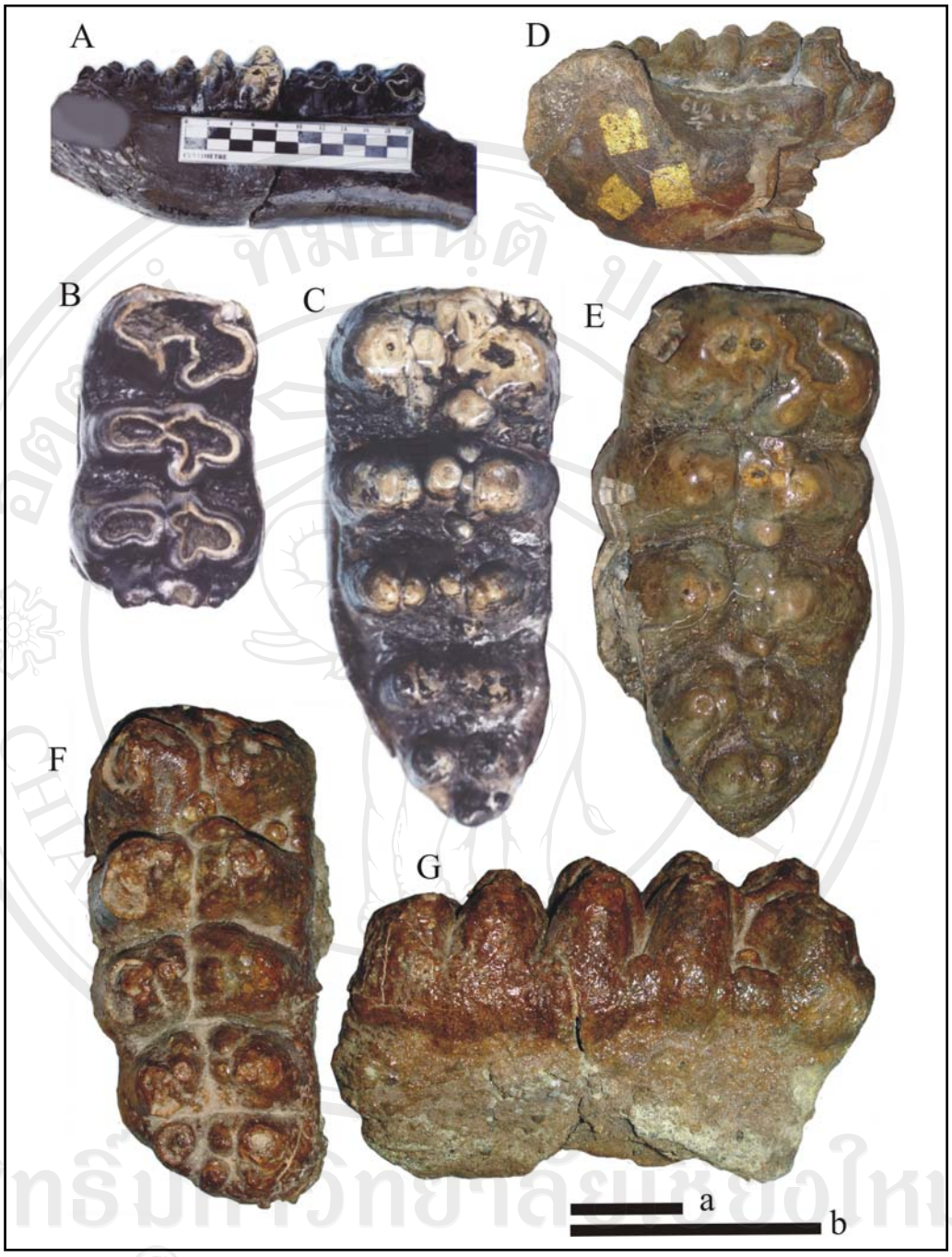

Fig. 3.18 *Gomphotherium* n. sp. 1 from the Tha Chang sand pits. RIN2 is a right mandible with M_{2-3}, A: lateral view of the molars and mandible, B: occlusal view of M_2, C: occlusal view of M_3; RIN 353 is right M_3, D: lateral view with mandible, E: occlusal view; KHO13 is right M^3, F: occlusal view, G: lateral view. Scale bars 10 centimeters, scale bar a applies to A and D, scale bar b applies to B, C, E, F, and G.

The fifth loph is not well developed. There are a strong median sulcus and a lateral sulcus. The mesoconelets are smaller than the main cusps but subdivided into two small conules. Strong anterior and posterior central conules are on the pretrite half-loph. The lower third molar is characterized by the width of the lophid, which becomes narrower from the first to the last lophid. There is no secondary trefoil.

***Materials*:** RIN2: a fragmented mandible with M_2 and M_3; RIN353: fragmented mandible with M_3; KHO13: an isolated upper right M^3.

***Description*:** RIN2 is a fragmented right mandible with M_2 and M_3. The M_2 has three lophids and its posterior cingulum is heavily worn (Fig. 3.18). It has a strong median sulcus and there is no enamel folding on the worn surface. The pretrite half-lophid has a slight posterior displacement. The posttrite is in the strength line. The posterior pretrite central conules are larger than the anterior ones and block the inter-valleys. There is no secondary trefoil. The posterior cingulum is present as two small conules. The inter-valleys are wide and accessory conules are developed in the valleys. The M_3 has five lophids and a talonid. However, the fifth lophid should be mentioned as the talon because it is composed of two cusps and it is not a complete copy of the fourth lophid. The number of lophids of this specimen should be X4XX. Each lophid is composed of the main cusps and mesoconelets. The main cones are larger than the mesoconelet in both pretrite and posttrite half-lophids. The mesoconelets are subdivided into round cusps. There are double mesoconelets on the second lophid of the pretrite. The anterior and posterior central conules are present on the first three lophids but they tend to reduce their size and disappear on the fourth lophid. The tooth pattern belongs to G-Type 2 tooth structural pattern. There is a

slight amount of cement in the valley bottom and it somewhat covers the conules of the third lophid to the talonid. The inter-valleys are wide.

RIN353 is a right mandible with a broken M_2 and a nearly complete M_3 (Fig. 3.18). The M_3 consists of four lophids and talonid. The first lophid is moderately worn and the second and third lophids are slighty worn. The molar structures are similar to RIN2 on the first three lophids, but are different on the fourth lophid, which contains anterior central conules on both pretrite and posttrite. This was probably caused by variation. The talonid is composed of two large conules and a small one. There is no cement in the valleys. The crowns are moderately low. The width at the base is much wider than at the apex.

KHO13 is an isolated upper right M^3 with five lophs and small talon (Fig. 3.18). It is covered by sedimentary cement on the crown. Nonetheless, the structures of the tooth can be studied. It was broken at the apexes on the posttrite side. In each loph has a large main cusp and a small mesoconelet. The anterior and posterior central conules are nearly the same size in the first and second pretrite half-loph. In the posterior part, these conules tend to be small and also disappear. There is no secondary trefoil. The median sulcus is distinct. The last loph was not well developed. The measurements of these specimens are shown in Table 3.3.

***Fossil locality*:** Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province, sand pit number 8.

***Comparison*:** *Gomphotherium* n. sp. 1 is comparable in size with than *G. steinheimense* and *Tetralophodon longirostris* from Europe and *Gomphotherium* sp. 2 from the Tha Chang sand pits, these are the large size species (Fig. 3.19). *Gomphotherium* n. sp. 1 differs from *G. steinheimense* by its wider inter-valley and its

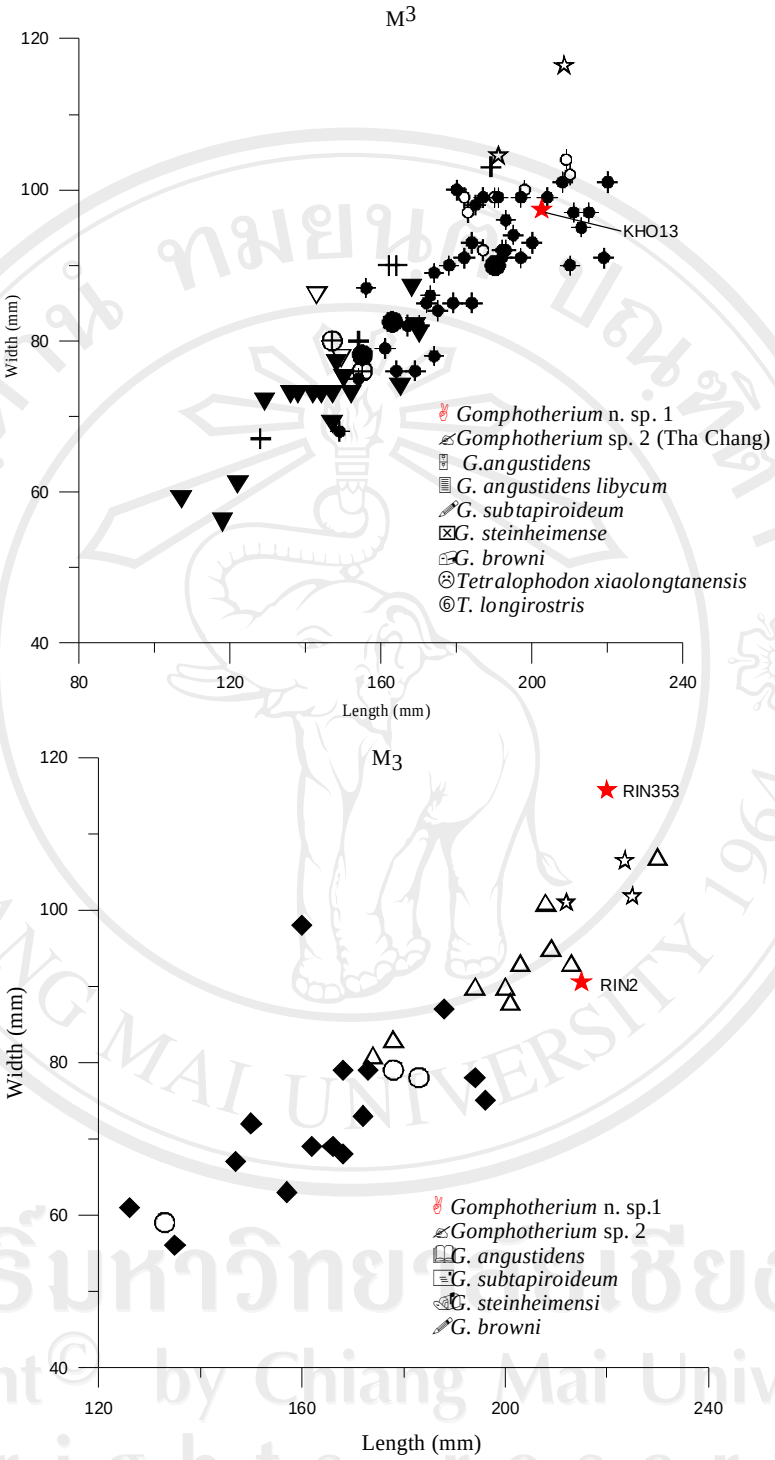

Fig. 3.19 Scatter diagrams of length versus width of *Gomphotherium* n. sp. 1 compared with other *Gomphotherium* species. Data sources: *Gomphotherium. angustidens* from Bergounioux & Crouzel, 1960, Tassy, 1977, 1985 and Göhlich, 1999; *G. angustidens libycum* from Sander & Miller, 2002; *G. subtapiroideum* and *G. steinheimense* from Göhlich, 1999; *G. browni* from Tassy, 1983); *Tetralophodon xiaolongtanensis* from Tobien *et al*., 1986, 1988 and Dong, 1987, *T. longirostris* from Göhlich, 1999 and Geradds *et al*., 2005).

prettrite side subdivided into three cusps. The pretrite distal orientation is not strong, or is absent, in the distal part of *Gomphotherium* n. sp. 1. Also, the width of the first three lophs on *Gomphotherium* n. sp. 1 is similar to that of *G. steinheimense* but it suddenly narrows in the following lophs. These characters are clearly more advanced than *Gomphotherium* sp. 1, being larger teeth and having one more tooth loph. *Gomphotherium* n. sp. 1 differs from *Gomphotherium* sp. 2 from the Tha Chang sand pits by its development of the fourth loph and by the width of the fourth and fifth lophs, which are suddenly decreased from that of the third loph, and by having a tapering crown. These features indicate that *Gomphotherium* n. sp. 1 was younger than *Gomphotherium* sp. 1, younger than 13.5 million years, and probably lived at the same time, or slightly later, as *G. steinheimense* that was identified in Europe on the basis of MN7 to MN9 and dated late Middle Miocene, about 12.5 to 9.5 million years ago (Göhlich, 1999).

Genus *Sinomastodon* Tobien *et al*., 1986

***Diagnosis*:** A member of the family Gomphotheriidae, subfamily Notiomastodontinae, with the following characters: bunodont molars, with trilophodont intermediates, elephantiod mandible, without lower incisors, reduced symphysis with narrow gutter and with b-3-2-b-type of dentition, which equals bunodont-trilophodont-dibelodont-brevirostrine mastodonts (Tobien, 1973a). It also has a transverse section of ramus horizontalis buccally widened and protruding angular to rounded processes.

***Type species*:** *Sinomastodon intermedius* (Teilhard and Trassaert, 1937)

***Emended Diagnosis*:** The cranium is compressed anteroposteriorly and high vertically, similar to that of Elephantoidea; the mandibular symphysis has a short gutter, the processus angularis is round, does not protrude; upper tusks are rather straight, elongated, cylindrical, turned out and up, and with no enamel band. Lower tusks are absent; molar bunodont, brachyodont; intermediate molars with three lophs, plus a small talon; posterior molar, M3, with four lophs and half-loph or more; lacks first tarsal bones (Zong *et al*., 1989).

***Differential diagnosis*:** The trilophodont *Sinomastodon* is different from *Gomphotherium* Burmeister (1837), *Platybelodon* Borissik (1928), *Amebelodon* Barbour (1927), *Choerolophodon* Schlesinger (1917), and laterr genera by having a well-developed, elongated symphysis, by its reduced symphysis without incisors, and by the elephantoid shape of its mandible. It is different from *Choerolophodon* by the absence, or only a small amount, of cement in molar valleys. It is different from *Anancus* Ayamard (1855), which has a similar elephantoid-shaped mandible, by its trilophodont intermediate molars D4, M1, and M2. *Sinomastodon* has resemblances to the American genera *Stegomastodon* Pohlig (1912), *Cuvieronius* Osborn (1923), *Notiomastodon* Cabrera (1929), and *Haplomastodon* Hoffstetter (1950), which had reduced symphysis with lost incisors and a buccally widened ramus mandibulae, which is an elephantoid shape. *Sinomastodon*, however, differs from *Stegomastodon* by its simple molar structure and the absence of cement. It is different from *Cuvieronius* and *Notiomastodon* by the absence of strong secondary trefoils. By this character *Sinomastodon* is nearest to *Haplomastodon*.

Sinomastodon yangziensis (Chow, 1959)

Synonymy

1959 *Trilophodon yangziensis* Chow, p. 256, pl. 1.

1959 *Trilophodon guangxiensis* Chow, p. 257, pl. 2.

1965 *Trilophodon wufengensis* Pei, p.213, pl. 1, figs. 1, 2.

1975 *Gomphotherium serridentoides* Pei, p. 251, pl. 1, fig. 1 (IVPP-V5184)

Sinomastodon aff. *yangziensis*

Fig. 3.20

***Materials*:** PRY8: left M_3; CCZ214: left M_3

***Description*:** The PRY8 is a lower left M_3 with five lophids and small talonid. The secondary trefoil is distinct and without anancoidy. These structures are comparible to *Sinomastodon yangziensis*. The cusps are large and blunt. It is highly worn. It is slightly oblique on the first two lophs. The pretrite half-lophid is oriented quite posteriorly. The transverse valleys are narrow and shallow. The anterior cingulum is small close to the first lophid.

On the first three lophids, the outlines of anterior and posterior central conules are very large. The posterior central conule of the first lophid connects to the anterior central conule of the second lophid. The posterior central conule of the second lophid connects to the anterior central conule of the third lophid, which is a G-Type 5 tooth structural pattern. The folding on worn surfaces is smooth or coarse. The outline of the worn surface of the posttrite half-lophid is nearly rectangular. The pretrite half-loph is much more worn than the posttrite an it has a high crown.

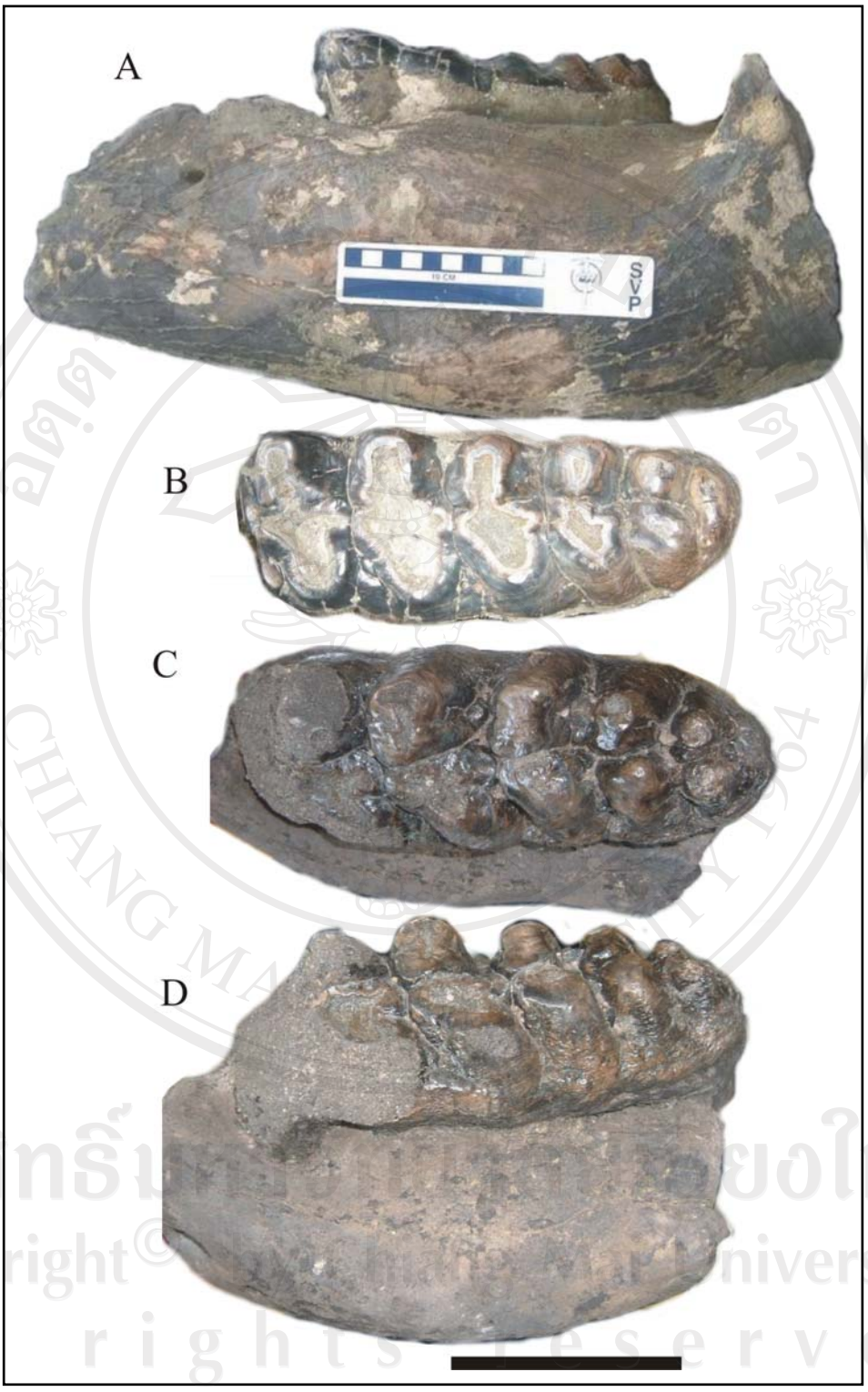

Fig. 3.20 *Sinomastodon* aff. *yangziensis* from the Tha Chang sand pits. PRY8 is a left mandible with M_3, A: buccal view and mandible shape, B: occlusal view; CCZ214 is a left M_3, C: occlusal view, D: lateral view. Scale bar 10 centimeters applies to B, C, and D.

The mandible is hard and strong and is quite short compared to the tooth.

CCZ214 is the M_3. It has a rounded mandibleand is bunodont. The anterior part is damaged. It has a preserved -4X lophid. However, the trace of the mesial root indicates that the first lophid should be destroyed. Strong conules block the valleys. The specimen has a chevron shape. The median sulcus is not straight. The main conule and other conules are robust and folded. The first lophid and the anterior part of the second lophid are damaged. The second lophid and the pretrite main conule are situated in the posterior part. The mesoconulid is in the same line as the base of the posttrite half-lophid with G-Type 5a tooth structural pattern. The third lophid has big conules and the mesoconulid is not clearly separated from the main conule. There are posttrite conules. The posterior pretrite is connected to the main conule. There is a conulid and accessory conulids in the transverse valley. The pretrite main cone is slightly posterior. The fourth lophid and talonid have the same structure as the third lophid but are smaller. The measurements of this species are shown in Table 3.4.

***Fossil locality*:** Tha Chang sand pit, number 8, Chaloem Phra Kiat District, Nakhon Ratchasima Province,

***Remarks*:** *Sinomastodon yangziensis* (Chow, 1959) was found in a Pleistocene cave deposit in southern China. This species was probably derived from *S. intermedius* (Teilhard & Trassaert, 1937) and *S. hangiangensis* Zong *et al*., 1989 from northern China. These forms were probably extinct by the Middle Pleistocene in China (Chen, 1999). Scatter diagrams are shown in Fig. 3.23.

Table 3.4 Measurements of the specimens of genus *Sinomastodon*

Species/ specimen	L (mm)	W1 (mm)	W2 (mm)	W3 (mm)	W4 (mm)	W5 (mm)	W6 (mm)	W7 (mm)
Sinomastodon aff. *yangziensis*								
M_3: PRY8	217	78.72	84.82	84.41	78.12	65.85		
M_3: CCZ214	234-	-	-	86.18-	90.18	27.09		
Sinomastodon n. sp. 1								
M^2: PRY9A	129.12	79.31	81.35	84.29				
M_2: CCZ48	134.29	72.98	82.14	85.93				
M^3: PRY9B	224.5	88.89	91.9	90.89	82.4	73.53	62.64	
M^3: PRY10	217	87.79	91.35	91.52	84.49	76.2	53.73	
M_3: PRY29L	255	-	79.96-	86.81	88.52	83.91	71.54	52.71
M_3: PRY29R	276	82.63	86.52	86.4	85.62	76.55	64.98	55.12

***Sinomastodon* n. sp. 1**

Figs. 3.21 and 3.22

***Diagnosis*:** It has bunodont molars with simple cusp structures. The M^2 has three lophs. The M^3 has six lophs and a large bicuspid talon. The lower M_3 have six to seven lophids. Each of these lophids has a strong median sulcus and chevroning figures. The anterior and posterior central conules are present on the pretrite half-lophs. The central conules are either absent or occur as traces on the posttrite half-loph. The worn surfaces show the highly folded dentine-enamel junction.

***Materials*:** CCZ48: the right M_2; PRY9A and PRY9B: the right M^2 and M^3; PRY10: the left M^3; PRY29L and PRY29R: left and right mandibles with M_3

***Description*:** The CCZ48 is a lower right M_2 with three lophids and a posterior cingulum. The anterior cingulum and the anterior posttrite portions are broken. Sediment fills the transverse valleys. The surfaces are broken in some parts. There is a strong median sulcus that shifts to the posttrite half-lophid. The pretrite half-lophid is oriented posteriorly; the mesoconelets seem too large as the main cone. The posterior and anterior central conules are present. The posttrite half-lophid is straight. The transverse valleys are deep and wide. There is strong and coarse folding. Lateral tubercles occur in the first valley of the pretrite. There are some accessory conules at the wall. On the first lophid, both anterior and posterior central conules connect with the mesoconelet. These are small cusps. The posttrite can not be defined because it is broken. On the second lophid, there are anterior central conules on both pretrite and posttrite but there are no posterior central conules.

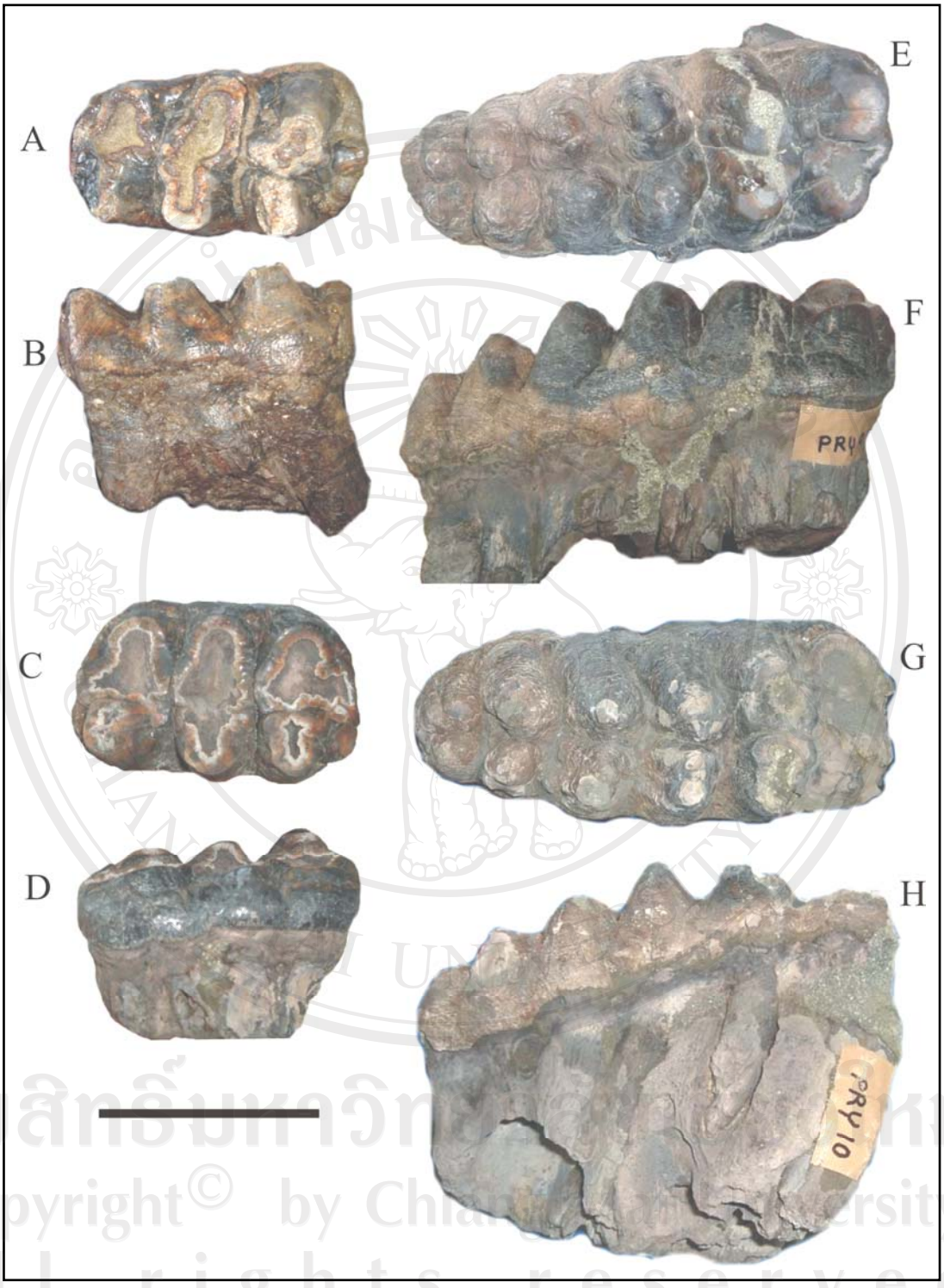

Fig. 3.21 The intermediate molars and upper third molars of *Sinomastodon* n. sp. 1 from the Tha Chang sand pits. CCZ48 is lower right M_2, A: occlusal view, B: lingual view; PRY9A is upper M^2, C: occlusal view, D: lateral view; PRY9B is right M^3, E: occlusal view, F: lateral view; PRY10 is left M^3, G: occlusal view, H: lateral view. Scale bar 10 centimeters applies to all.

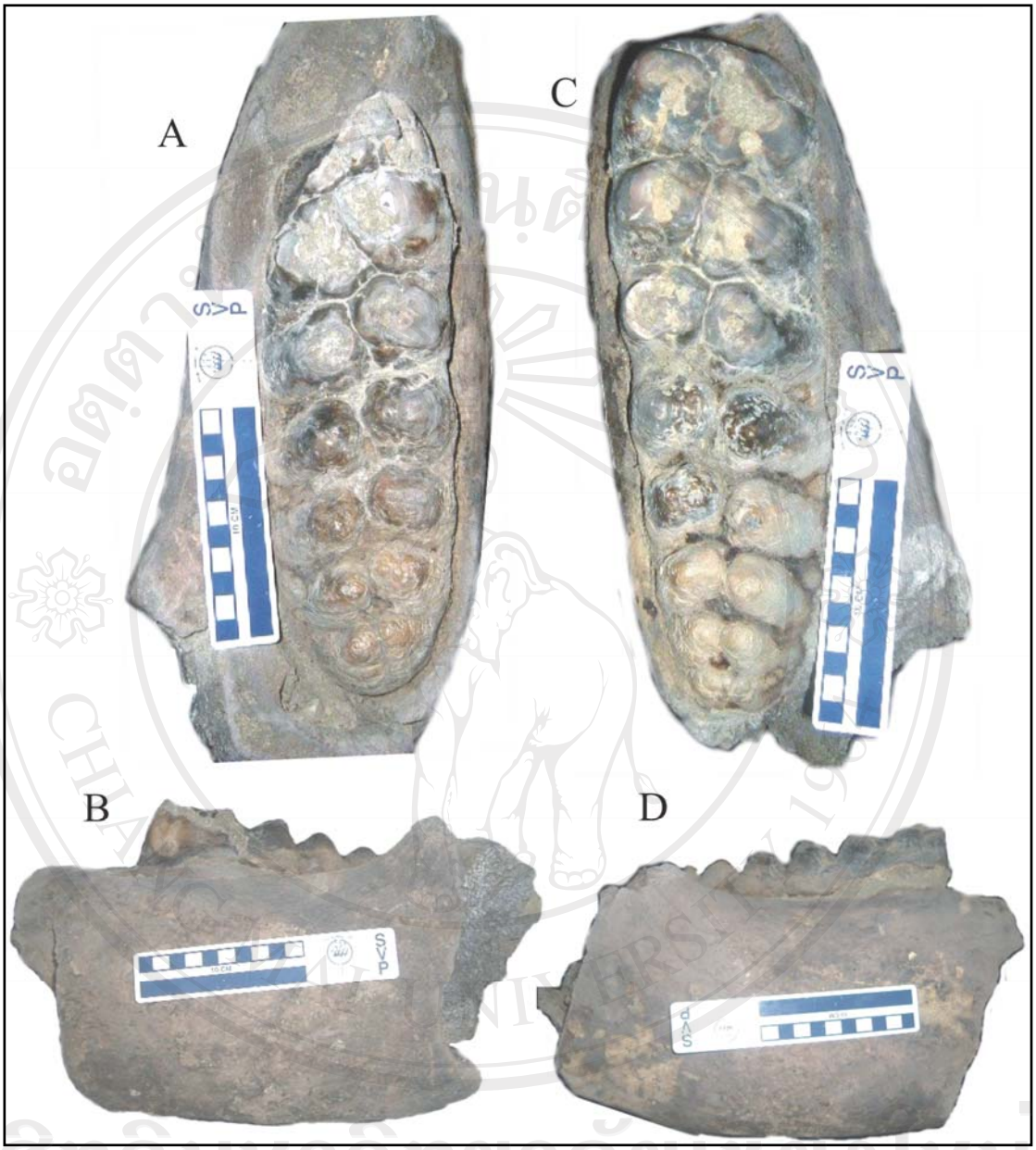

Fig. 3.22 The lower third molars of *Sinomastodon* n. sp. 1 from the Tha Chang sand pits. PRY29L and PRY29R are left and right lower M_{3s}, respectively, A: occusal view of the left M_3, B: lateral view of the left M_3, C: occusal view of the right M_3, D: lateral view of right M_3. Scale 10 centimeters.

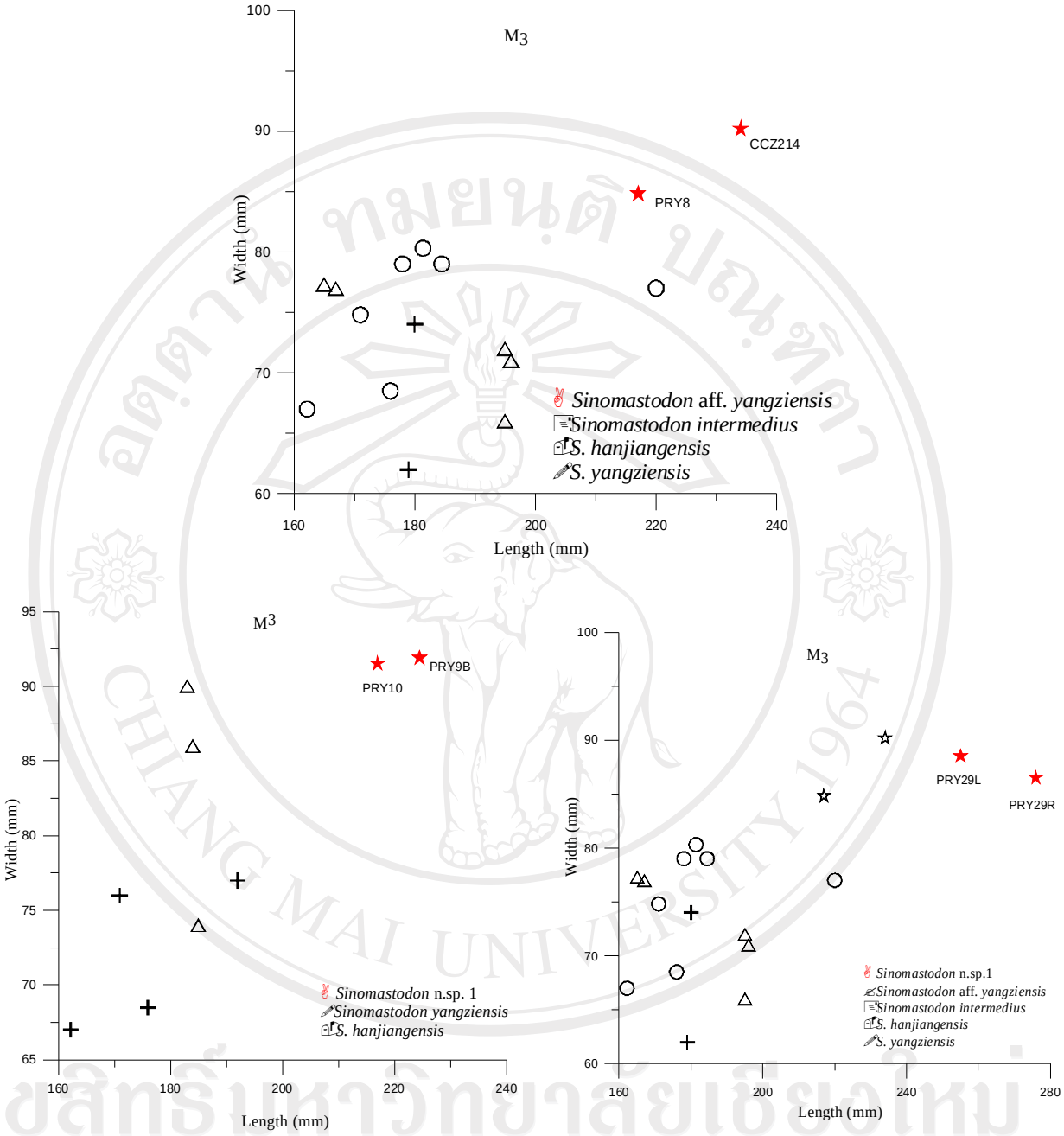

Fig. 3.23 Scatter diagrams of *Sinomastodon* compared the size of *Sinomastodon* aff. *yangziensis* and *Sinomastodon* n. sp. 1 from the Tha Chang sand pits with the other specimens found from China. Data sources: *Sinomastodon intermedius* fromTeilhard & Trassaert, 1937; Tobien *et al*., 1986; *S. hanjiangensis* from Zong *et al*., 1989; Chow, 1959; Chow & Chang., 1974; Zong, 1987; *S. yangziensis* from Chow, 1959; Pie, 1965,1986.

On the third lophid, the mesoconelet on the pretrite is as large as the main cone. The central conules are both anterior and posterior. There are no central conules on the posttrite. The posterior cingulum has many enamel knobs. The roots are preserved. The anterior root supports the first lophid and the anterior part of the second lophid. The posterior root supports the posterior part of the second lophid and also supports the third lophid.

PRY9A is the upper M^2 and has three lophs and a small anterior cingulum. The orientation of each loph is strong. There is a median sulcus. It is highly worn and the worn surface has fining folding. There is a secondary trefoil. The lateral cingulum is on the pretrite side. The transverse valleys are narrow and blocked by the connection of the posterior central conule with the anterior central conule.

PRY9B is the upper M^3 of same individual as PRY9A. It has six lophs and a very small talon. The median sulcus is clearly defined. The conules are blunt and large. The pretrite seems to have a large conule and anterior and posterior central conules. The conule on the posttrite is separated into two conules by a shallow fissure. The first loph is highly worn on the pretrite side and the posttrite is slightly worn. The roots are preserved.

PRY10 is the upper M^3. It has five lophs and a large talon. The median sulcus is clearly defined. The first loph is broken on the posttrite. The pretrite is heavily worn. The second and third lophs are slightly worn. The pretrite half-loph is oriented anteriorly and is slightly V-shaped. Details of the first two lophs can not be seen. The third loph has five conules, two conules on the pretrite and three conules on the posttrite. Each conule is separated by a shallow fissure. There seem to be only two conules on the fourth and the fifth lophs. However, there are small fissures that

separate the mesoconule from the main cone. The large talon has three conules. The roots are long. The anterior roots support the first loph. There are the lateral conules at the entry of transverse valleys.

PRY29L is the lower left M_3 and it has an X7 lophid formula. The first loph is partly broken and the structural details can not be observed. The second and third lophids are highly worn. The pretrite half-lophid has a slight posterior orientation. The median sulcus is not strong. Most conules have a main cone and a small mesoconule that are separated by an indistinct fissure.

PRY29R is the lower right M_3 and it has an X7X lophid formula. The first three lophids are highly worn and have trefoil patterns on both half-lophids. The median sulcus is zigzaged. On the fourth, fifth, and sixth lophids, the mesocunulid is slightly separated from th***e*** main cone. There is cement in the transverse valleys of the last three lophids. The measurements of this species are shown in Table 3.4.

***Fossil locality*:** Tha Chang sand pit number 8, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Comparison: This species has more advanced characters than the species found in China. It differs from the type species *Sinomastodon intermedius* and *Sinomastodon hanjiangensis* in that it has more and larger lophs. It also differs from *Sinomastodon yangziensis* form China and *Sinomastodon* aff. *yangziensis* from the Tha Chang sand pits by its greater number of lophs, larger size, and a less posterior orientation of the pretrite half-lophid (Fig 3.23).

3.3.3 Family *incertae sedis* (Tetralophodont gomphotheres)

Genus *Tetalophodon* Falconer, 1857

***Diagnosis*:** Gomphotheriid genus with tetralophodont intermediate molars, that is, it has four completely developed lophs together with an individualized strong talon. Symphysis is deflected and under reduction. Lower incisors are small relatively to molar sizes. They are reduced and mostly separated, that is, without contact at their tips. Upper incisors have no enamel band and are slightly curved downward and/or outward. Cement is absent or vestigial. There is no alternation of half-lophs.

Type species: *Tetralophodon longirostris* (Kaup, 1832)

Tetralophodon xiaolongtanensis (Chow and Chang, 1974)

Synonymy

1974 *Gomphotherium xiaolongtanensis* n. sp. Chow and Chang, p.24, pl.5, fig. 1, 2.

1978 *Gomphotherium xiaolongtanensis* Chow and Chang, Chow and Chang, p.68, pl.4, 5.

1986 *Gomphotherium* sp. (*'Gomphotherium xiaolongtanensis'*), Tobien *et al*., p. 139, fig. 16, p. 175.

1987 *Tetralophodon xiaolongtanensis* (Chow and Chang, 1974). Dong, p. 119, pl. 2, fig. 1-4.

***Diagnosis*:** A small species of the genus *Tetralophodon*, with well developed conules on the anterior pretrites and incipient trefoils on the posttrites. The upper and

lower M2 have four complete lophs, but only small talons. M3 has five lophs and a small talonid. There is no cement.

Tetralophodon cf. *xiaolongtanensis*

Fig. 3.24

***Materials*:** CMn1: the upper left and right M^3; CMn2: the incomplete upper M^2; CMn3: the lower left M_3; CMn4: the lower right M_3.

***Description*:** CMn1 is the upper left and right M^3 and has an X4X loph formula. They are worn on the first and second lophs and there is a trefoil figure on the worn surface of the pretrite side. There is no enamel folding or secondary trefoil. The first two lophs are in line. However, in other lophs the pretrite side is oriented posteriorly.

CMn2 is the upper left M^2 and is broken on the first loph. An estimate of the missing loph can be made from the distal root. Generally, in primitive species the mesial root supports only the first loph. The loph formula is X4X. The pretrite worn surface has strong trefoil on the first and second lophs. The tooth structures are similar to CMn1, except having less wear.

CMn3 is a broken tooth that has the first, second, and fourth lophids and the talonid. It has no third lophid. The tooth is unworn. The main cusps are slightly larger than the mesoconelets. The first lophid has a strong posterior pretrite central conule. The second lophid probably had both anterior and posterior central conules, but it was broken. The fourth lophid is oriented posteriorly on both sides, making a chevron pattern. There is a posterior pretrite central conule. The talonid has three large conules.

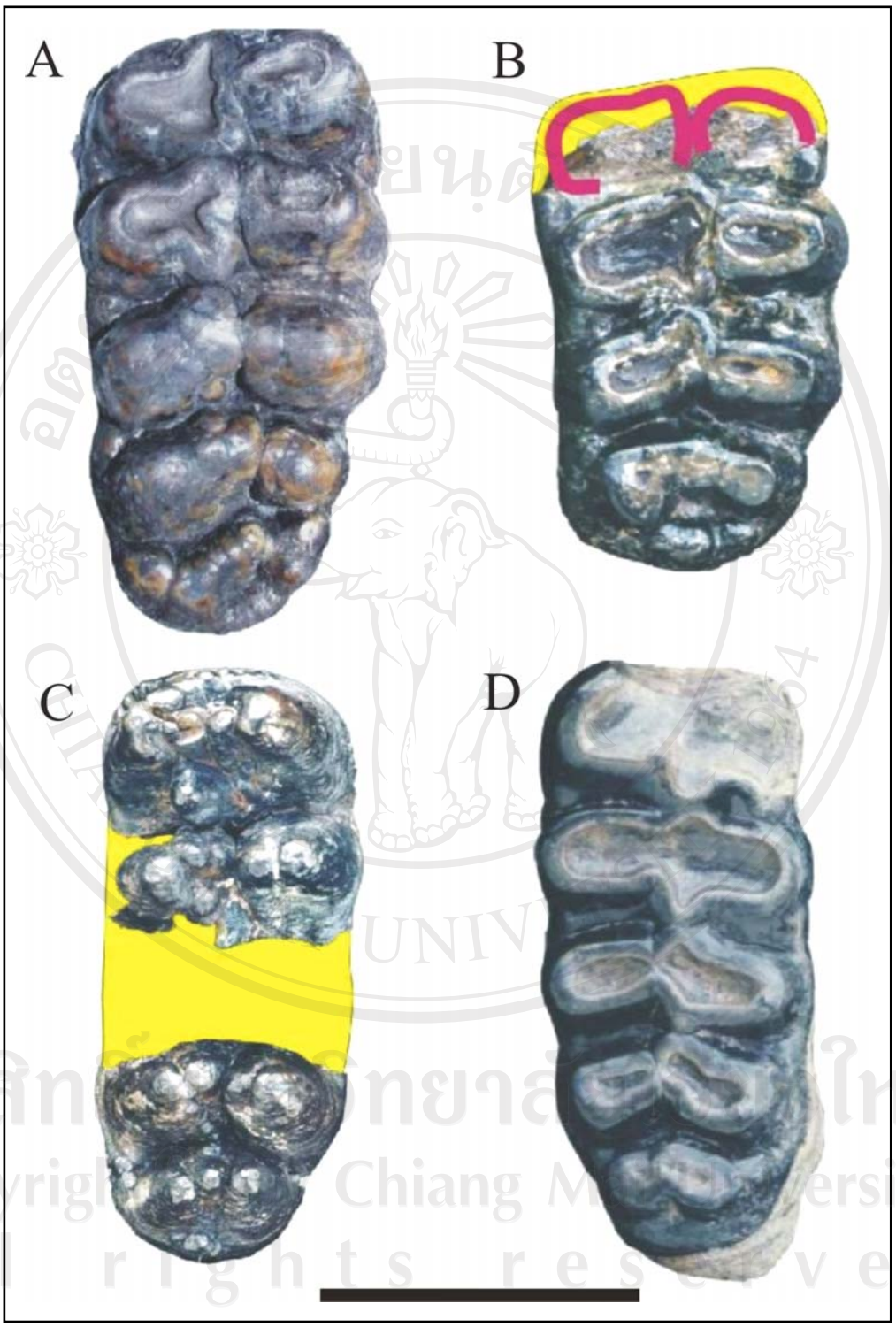

Fig. 3.24 *Tetralophodon* cf. *xialongtanensis* from Chiang Muan coal mine; CMn1: left M^3, A: occlusal view; CMn2: left M^2, B: occlusal view; CMn3:left M_3, C: occlusal view, and CMn4: right M_3, D: occlusal view (after Pickford *et al*., 2004) . Scale bar 10 centimeters applies to all.

CMn4 is a lower right M_3 with an X4X or X5 loph formula because the talonid is large. However, it is not well developed as the anterior lophid. The tooth is heavily worn and has a trefoil figure on the first three lophids. The first two lophids are in line, but the other lophs have a slight posterior orientation. There is no trace of a secondary trefoil. The measurements of this species are shown in Table 3.5.

***Comparison*:** Based on a comparison with the upper M^3 holotype, IVPP-V 4685,1 and the lower M_3 XV8095.3 (Dong, 1987), the Chiang Muan specimens are comparable to *T. xiaolongtanensis* in teeth structure and in tooth number formula. However, by it size, the Chiang Muan specimens are slightly larger than *Tetralophodon xiaolongtanensis* from Kaiyuan District, Yunnan Province in China (Fig. 3.25). *Tetralophodon xiaolongtanensis* is distinguished from *Tetralophodon longirostris* from the Europe Vallesian in having fewer lophs, a simpler loph structure, and smaller size. Thus, *Tetralophodon xiaolongtanensis* is more primitive than *T. longirostris* and may indicate a slightly older age than Vallesian, possible dating to the latest Astracian (MN7+8) (Kunimatsu *et al*., 2004).

Table 3.5 Measurements of *Tetralophodon* and *Anancus*

Species/ specimen	L (mm)	W1 (mm)	W2 (mm)	W3 (mm)	W4 (mm)	W5 (mm)
Tetralophodon cf. *xiaolontanensis*						
M^2: CMn2	140-(~160)	-	82.5	78.5	67.5	
M^3: CMn1	~ 190		80 (max)			
M_3:CMn3	-	68.5	70.5-	-	70	51
M_3:CMn4	185	67.5	73.5	74	68	49
Anancus sp.						
M^1: SMT1	100.95	68.57-	71.43	70.48	59.05	
M_2: SMT2	170	89.55	91.04	89.55	89.56	
$M^{2?}$: SMT3	79.1-	-	-	7.93	8.20	
M^3: NMX7	209-	-	93	95.45	95.59	87.61
M^3: KHO4	186-	-	95.43	96.61	90.33	69.01

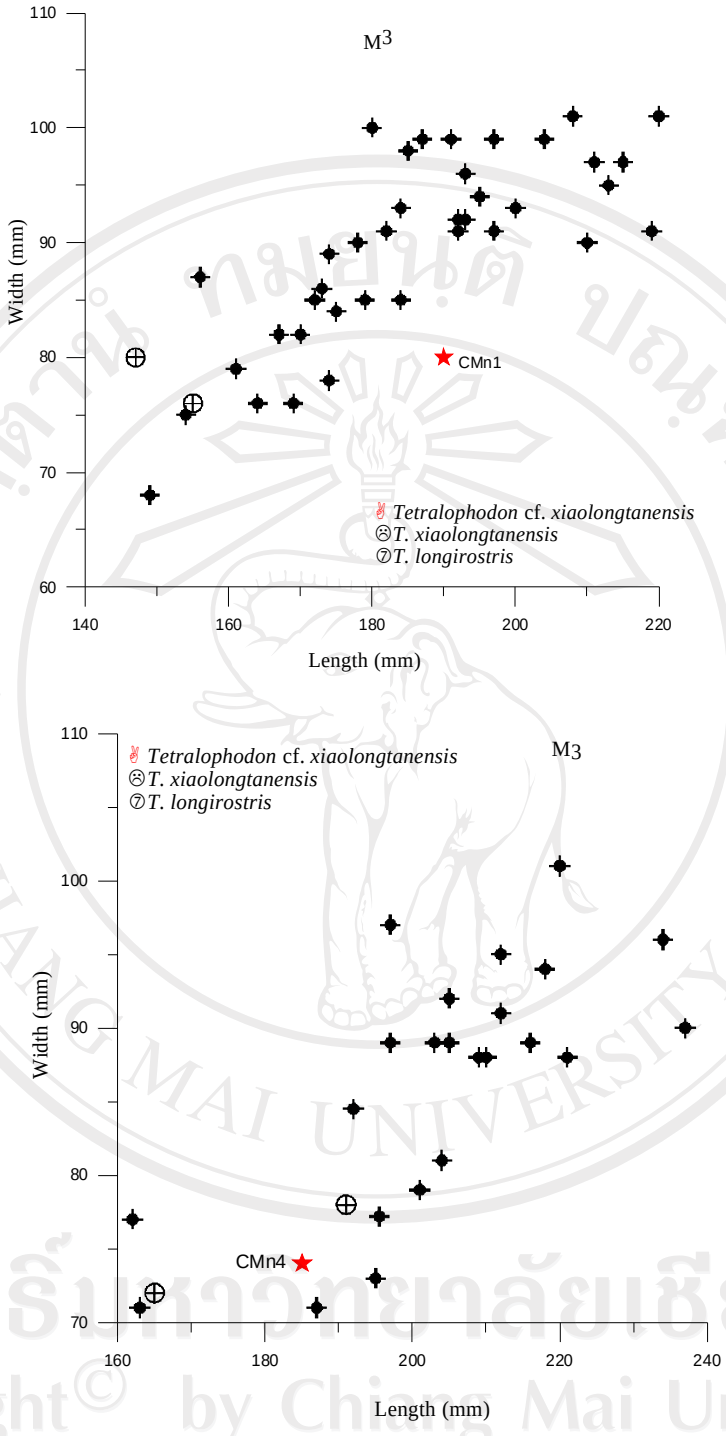

Fig. 3.25 The scatter diagrams of *Tetralophodon* cf. *xiaolongtanensis* from Chiang Muan coal mine compared with *Tetralophodon xiaolongtanensis* from China and *T. longirostris* from Europe. Data soureces: *Tetralophodon xiaolongtanensis* from Dong, 1987 and Tobien *et al*., 1988; *T. longirostris* from Göhlich, 1999.

Genus *Anancus* Aymard, 1855

***Diagnosis*:** Gomphotheriid genus with tetralophodont intermediate molar. The half-lophids in alternation position, especially in the lower intermediates and M3, tendency to simplification of the M3. Enamel in deciduous teeth ptychodont, in permanent teeth mostly smooth, mandible elephantoid, with reduced symphysis, sometimes with rudimentary incisors. Upper incisors long, strong, and straight, without an enamel band. Skull elephantoid, high domed with shortened basis carnie, crown heights variable. Cement absent, but present in advanced taxa.

Type species: *Anancus arvernensis* (Croizet and Jobert, 1828)

Anancus sp.

Fig. 3.26

***Materials*:** NMX7: left M^3; KHO4: right M^3; SMT1: left M^1, SMT2: left M_2, SMT3: fragmented $M^{2?}$.

Description: NMX7 is a nearly complete upper left M^3 that is partially broken on the anterior and posterior parts. It probably contained five lophs and talon. It is heavily worn on the first two lophs and slightly worn on the third loph. The molar structure of the first loph is not visible. The second loph has a strong posterior central conule. Details of the third loph show that the pretrite side has three cusps and posttrite side has two cusps. The main cusps are larger than the mesoconelets. The pretrite mesoconelet is divided into two small cusps. The posterior pretrite central conule is distinct and situated between the main cusp and mesoconelets.

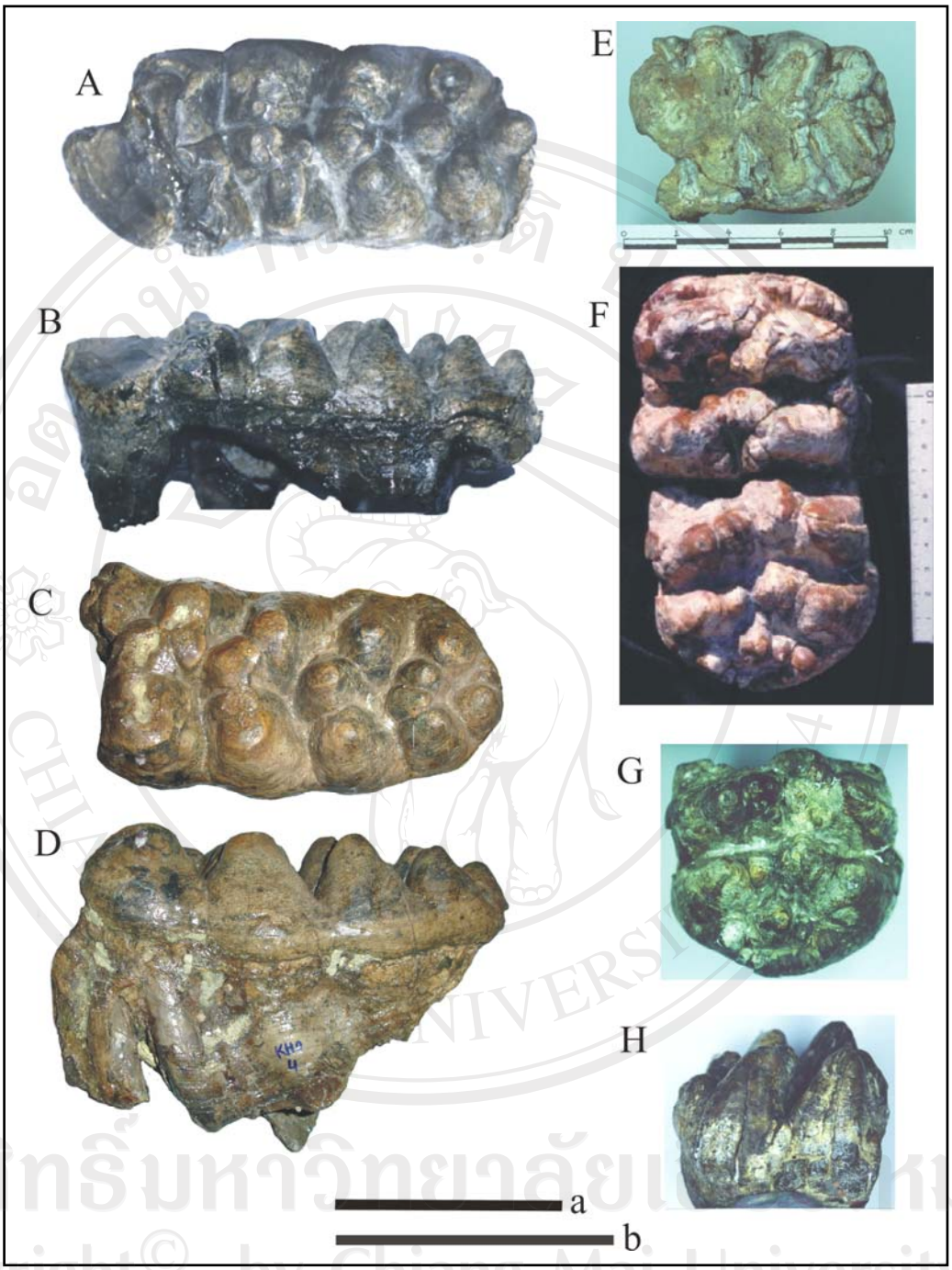

Fig. 3.26 *Anancus* sp. from the Tha Chang sand pits and Sop Mae Tham locality. NMX7 is a left M^3; A: occlusal view, B: lingual view, KHO4 is a right M^3; C: occlusal view, D: lingual view; SMT1: upper left M^1, E: occlusal view; SMT2: lower left M_2, F: occlusal view; SMT3: posterior part of upper $M^{2?}$, G: occlusal view, H: lateral view. Scale bars 10 centimeters, scale bar a applies to A, B, C, and D; scale bar b applies to G and H.

The pretrite main cusp has a posterior orientation. The pretrite mesoconelets are aligned with the posttrite conules, this being anancoidy structure. The fourth and the fifth lophs have this structure. The fourth loph is not a complete copy of the third loph. The difference is that the pretrite mesoconelet of the fourh loph is stronger, is subdivided into three small cusps, and has no posterior pretrite central conule. The fifth loph has only three large conelets. The mesoconelet is situated more anteriorly than the main cusps. The postrerior part is broken and retains only one conelet. The median sulcus is strong on the anterior part from the first to the third lophs, but is indistinct on the posterior part of the tooth. The tooth, as is, is 209 millimeters long and 95.59 millimeters wide at the fourth loph. Unbroken, it may have been 250 millimeters long.

KHO4 is a nearly complete upper right M^3 that is broken on the first lophid. The tooth formula is X5X. Although the first loph is somewhat broken, the mesial root is preserved. Thus, the number of lophids can be estimated. The tooth has stronger anancoidy than NMX7. The first lophid is broken and its details can not be clearly seen. The second lophid has two pretrite and two posttrite cusps. The posterior pretrite central conule is large and blocks the second inter-valley. The posttrite main cusp, mesoconelet, and pretrite mesoconelet are aligned but the pretrite main cusp is situated more posteriorly and aligned with the posterior pretrite central conule. These are the alternation of pretrite and posttrite half-lophids. This structure also occurs on the third lophid. The fourth lophid has three large cusps, each of which is subdivided by a poorly developed shallow groove. This lophid does not have strong anancoidy. The posterior pretrite central conule is reduced. The fifth lophid has four cusps. There is no posterior central conule. The talonid is small and has

three conules, one large and two small. The crown is not high. The cusps are blunt. There is a median sulcus. The tooth, as is, is 186.5 millimeters long and 96.61 millimeters wide at the third lophid. Unbroken, it may have been 230 millimeters long.

SMT1 is a left upper M^1, has four lophs and small talon. The anterior part of the tooth was broken. The tooth is strongly worn and can not observe the tooth structure.

SMT2 is a left lower M_2, has four lophids and a larg talonid. The tooth is unworn, contains five to six conules in each lophid and the talonid contains five conules. Cement is plentiful in the inter-valleys. The alternation of half-lophids is obviously seen on the first two lophids. On the third and fourth lophids, the arrangement of the half-lophid present V-shaped figure. The alternation of the half-loph(id)s is the important feature of this genus.

SMT3 is the posterior part of an upper molar, probably M^2. Each loph contains four to five conules and show V-shaped figure. The crown is high and slim. There is cenment plentiful in the inter-valleys. The measurements of these specimens are in the Table 3.5.

Comparison: *Anancus* sp. has the same number of lophs in the M^3 as as *A. sinensis* and *A. kenyensis*. The teeth morphology of *Anancus* sp. from Tha Chang sand pits is similar to *A. sinensis* (Hopwood) and the size of Tha Chang sand pits *Anancus* spp. fits in with *A. sinensis* (Hopwood, 1935). However, the lack of cement in the Tha Chang species may indicate that the Tha Chang *Anancus* and *A. sinensis* lived in different environment. *Anancus* sp. differs from *A. sivalensis* from Siwalik Group by its wider loph and low crown and it differs from *A. kenyensis* by its simple tooth pattern. *Anacus* sp. is much smaller than *A. arvernensis* (Fig. 3.27).

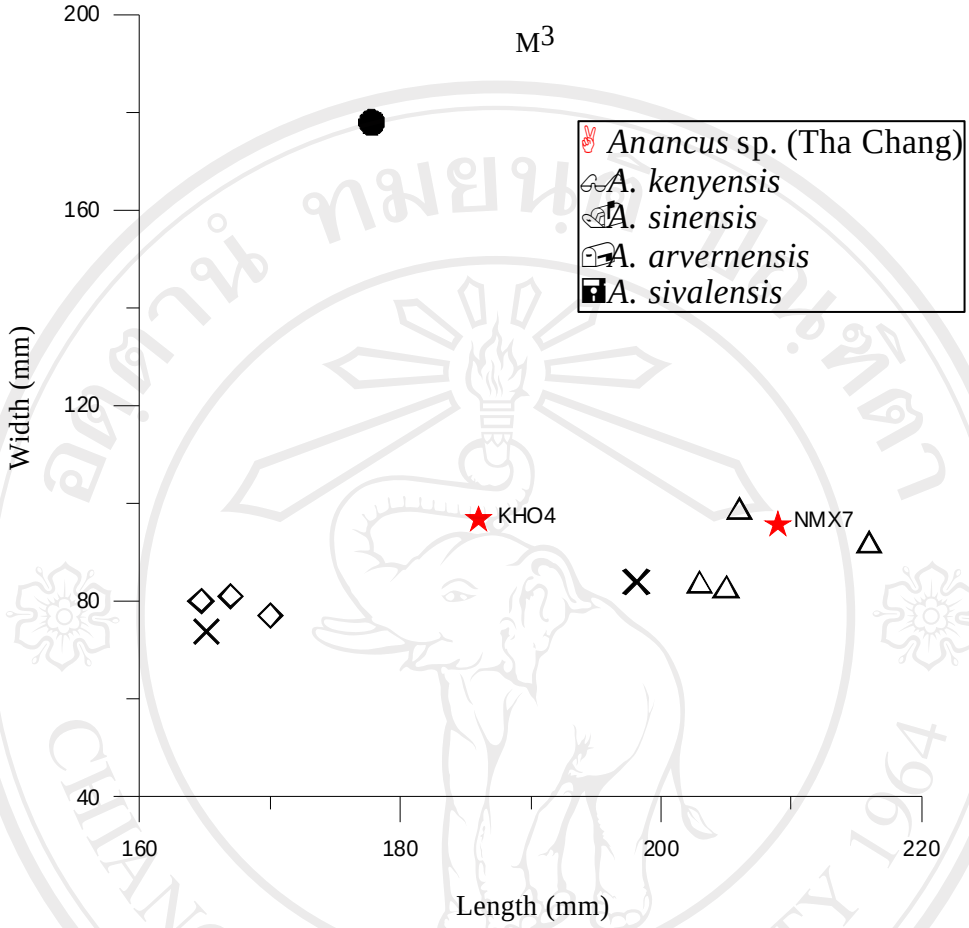

Fig. 3.27 Scatter diagram of *Anancus* sp. from Tha Chang sand pits compared with other *Anancus* species. Data sources: *Anancus kenyensis* from Tassy, 1986; *A. sinensis* from Hopwood, 1935 and Teilhard & Trassaert, 1937; *A. arvernensis* and *A. sivalensis* from Falconer, 1867.

***Remarks*:** The third molar was not found in the Sop Mae Tham locality and the intermediate molar was not found in the Tha Chang locality, thus it can not compare the Sop Mae Tham's specimens with the Tha Chang's specimens. These two localities may have same species or different species.

3.3.4 Family Stegodontidae

Genus *Stegolophodon* Schlesinger, 1917

Diagnosis: A genus of the subfamily Stegolophodontinae that has tetralophodont and bunodont dental characteristics. The lophs are six to seven blunt mammillae in a straight line, the adaxials of which are the same size as the abaxial ones, this being zygo-bunodont structure. The M3 has six lophs. Pretrites have at least a main cone and one adaxial conelet and posttrites have a main cone and two to three adaxial conelets. Conules in advanced forms are smaller. The sulcus is well developed in the two to three anterior lophs, though in the posterior part it is often indistinct. The mandible has reduced symphysis and small incisors or brevirostrin. There is no cement, or only a small amount.

Type species: *Stegolophodon latidens* (Clift, 1828)

Stegolophodon nasaiensis Tassy *et al*., 1992

Fig. 3.28

Diagnosis: Primitive *Stegolophodon* with persistence of bunodont trefoil pattern on molars. Mesoconelets are only slightly enlarged, there are upper pretrite central conules on M3, the pretrite fourth and fifth half-lophids on m3 have postero-buccal orientation associated with pretrite central conules (Tassy *et al*. 1992).

Materials*:* M4732a: partial mandible with right $M_{2\text{-}3}$, this is holotype; NS-01; a distal part of the upper M^3; NS-02 a deciduous molar.

Description: M4732a, M_2 is fully tetralophodont, with a posterior cingulum separated into two half-lophids, with the posttrite being well developed. The teeth are well worn and the wear patterns of the pretrite and posttrite half-lophids are confluent. These wear patterns show the existence of posterior pretrite conules in the three interlophids. The wear pattern of the lophs is linear, a derived condition seen in stegolophodont. The plesiomorphous state is seen in tetralophodont gomphotheres where the pretrite half-lophids are postero-buccally orientated (Tassy *et al*., 1992).

M4732a, M_3 is pentalophodont, though it is small. This number of lophids is often, but not exclusively, associated with the tetralophodont grade. The important feature is the association of a high number of lophids with small size. Brychyodonty is very likely a stegolophodont feature. Lophids consist of four cusps. The mesoconelets are well developed but less so than on the M_3 from Mae Moh (Tassy *et al*., 1992).

NS-01 is a fragmented M^3. The first cusp is slightly worn, and probably is the second loph. There are two large cusps on the posttrite and posterior central conule and three cusps on the pretrite, one large main cusp and two small mesoconelets. Two other posterior lophs have four cusps each and the cusps are nearly same size. The talon is large as a loph and has four cusps as large as main cusps and also has

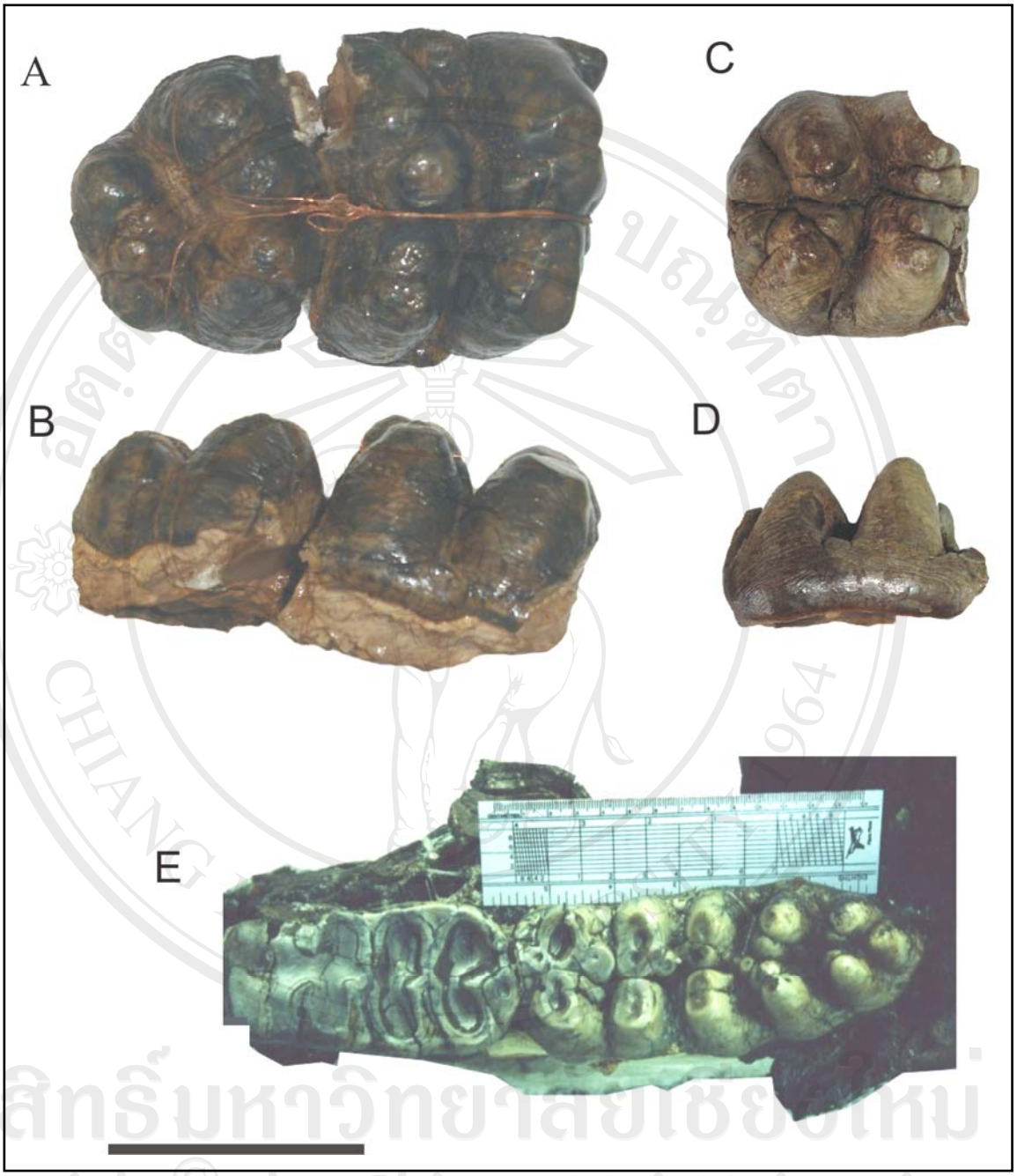

Fig. 3.28 *Stegolophodon nasaiensis* from the Ban Na Sai coal mine; NS-01 left M^3; A: occusal view, B: lateral view, NS-02 M^1?; C: occusal view, D: lateral view; E: type specimen (M4732a). Scale bar 5 centimeters applies to A, B, C, and D.

small mesoconelets. Lateral tubercles occur at the entrance of the first and second inter-valleys. There is a strong median sulcus through the tooth, except in the talon.The inter-valleys are closed. Tooth enamel is very thick and there is no enamel folding. The tooth is turned outward to the right, so this specimen should be a right molar. However, the posterior central conule at the posttrite may be caused by an individual variation. This specimen is probably an upper molar because the posterior part is not as heavily pointed as in the lower molar. It is wider and shorter compared to the lower molar of the type *Stegolophodon nasaiensis*. However, the posterior posttrite central conule can occur as an advanced character in gomphothere. The tooth is 110 millimeters long and 71 millimeters wide at the first preserved loph. Unbroken, it may have been 145 millileters long.

NS-02 is a deciduous molar and the posterior part of a milk molar that has four cusps in each loph, but not in the talon. The cusps are separated by deep furrows.

Fossil locality: Ban Na Sai coal mine, Li District, Lamphun Province.

Remarks: As descrbedt by Tassy *et al*., the important feature of this species is the association of a high number of lophids with small size. Moreover, the low crown, or brachyodonty, is meaningful and is not correlated with small size. A small *Tetralophodon longirostris* from the Vallesian locality has a much higer crown than *Stegolophodon nasaiensis*. The mesoconelet of *Stegolophodon nasaiensis* is well developed but is smaller than that of *Stegolophodon* cf. *latiden* from the Mae Moh coal mine. This is a plesiomorphous trait. The first three lophids are nearly oriented transversely and the pretrite main cusp is situated only slightly postero-buccal to the mesoconelet. These are derived stegolophodont features. However, the fourth and fifth lophids are not straight. The pretrite half-lophid is postero-buccally oriented, as

in gomphotheres. This is a plesiomorphous trait (Tassy *et al*., 1992). The occlusal directions of the type specimen have two striae orientations. This suggests that this species retains primitive transversal occlusal motion. If this is the case, *Stegolophodon* could be a paraphyletic group. In general, *Stegolophodon* has striae oriented nearly perpendicular to the ridges and inter-valleys. This suggests that they have distalomesial direction of jaw movement (Saegusa, 1996a).

***Stegolophodon* sp.**

Fig. 3.29 (A, B, C, D, E, and F)

Materials: TF2019; lower incisors, BP01a: left P_4; BP01b: right P_4

Description: TF2019 is the lower incisors and is in two fragments. These fragments are the first record of lower incisors in the genus *Stegolophodon*. The left fragment is 31 centimeters long, but its proximal end is broken. In cross section, it is piriform, pear-shaped, and has a distinct groove on the lingual side that ends some centimeters before the tip. The major axis of the section is vertical in the most posterior part, with a vertical diameter of 43 millimeters and a transverse diameter of 26 millimeters. The major axis gradually becomes horizontal towards distal end. The medial border is rounded. A 10-centimeter long contact facet stretches from the tip of the tusk to its posterior part. The incisors were closely united and are roughly straight. Their surface is longitudinally fluted on the external side (Buffetaut *et al*., 1988).

BP01a and BP01b are the left and right P_4s. They are characterized by their bilophodonty and the narrowness of the anterior lophid relative to the posterior one. A small paraconid is located on the anterior part of the tooth, in front of the

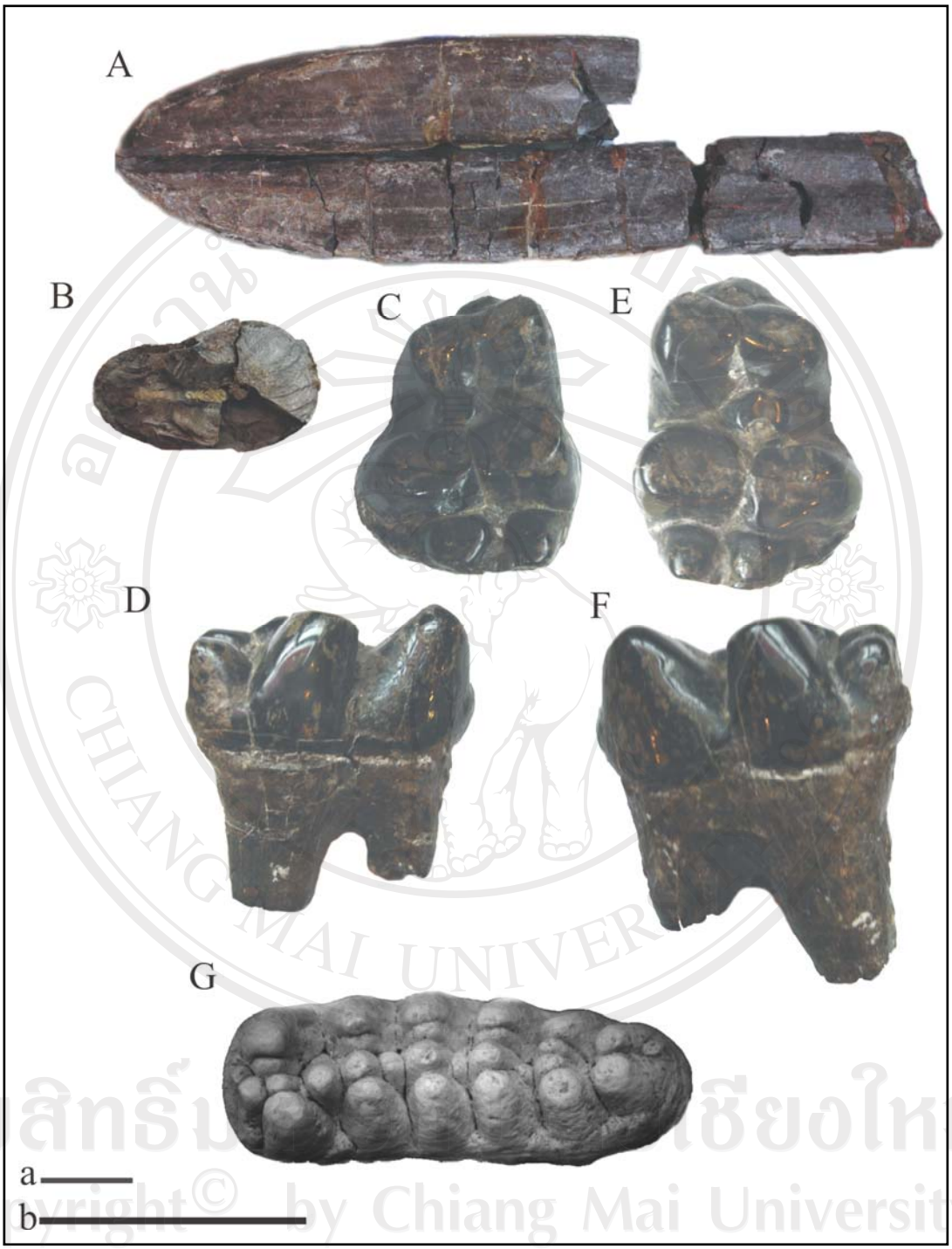

Fig. 3.29 *Stegolophodon* sp. from Mae Teep coal mine and *Stegolophodon* cf. *latidens* from Mae Moh coal mine. TF2019, A: lower tusks both left and right sides; B: cross section of the lower tusk; BP01a, C occlusal view, D: lateral view; BP01b, E: oclcusal view, F: lateral view; M4733f from Mae Moh, G: occlusal view. Scale bar a 2 centimeters applies to B, C, D, E, and F, scale bar b 10 centimeters applies to A and G.

protoconid. The protoconid and the metaconid are united in an anterior lophid, and are separated only by a shallow groove. In posterior view, this lophid appears oblique, the metaconid being higher than the protoconid. The posterior lophid unites the hypoconid to the entoconid, both being transversely elongated and separated by a distinct groove. The two lophids are separated by a deep interlophid valley, which is interrupted by a single pretrite conule, located between the protoconid and the hypoconid. The occlusal surface of the posterior lophid is nearly horizontal. In occlusal view, both lophids are orientated slightly obliquely. On the posterior wall of the hypoconid, there is a distinct wear facet that links the hypoconid to the hypocristid, which has two cusps, the largest and tallest being located behind the hypoconid. In lateral view, the tooth is low-crowned (Buffetaut *et al*., 1988).

Fossil locality: Mae Teep coal mine, Ngao District, Lampang Province.

Remarks: The piriform cross section of the lower tusks occurs in *Gomphotherium* (Bunolophodon) *angustidens* (Schlesinger, 1917, Taf. 1, Abb. 5) and in *Archaeobelodon* sp. from Mae Soi. It is a plesiomorphic character. The P_4s of *Stegolophodon* sp. have a more advanced character than those of *Mastodon* (Bunolophodon) *longirostris* (Schlesinger, 1917, Taf. XII, Abb. 7) by the development of the posterior cingulum into two large conules. The M_1 fragment is four cusps of roughly equal size. The structure and disposition of these cusps are very similar to those of the tooth from Mae Moh described as *Stegolophodon* cf. *latidens* as mentioned by Buffetaut *et al*., 1988.

Stegolophodon* cf. *latidens (Clift, 1828)

Fig. 3.29 (G)

Synonymy

1959 *Stegolophodon praelatidens* n. sp.: von Koenigswald, p. 27, figs. 1, 2.

1959 *Stegolophodon praelatidens* v. Koenigswald: Sithiprasana, p. 31, fig. 5.

1985 *Stegolophodon* sp.: Ginsburg & Tassy, p. 18; figs. 10-12, p. 18, figs. 13-14, p. 20.

Material: M4733f: left M_3

Description: The M_3 is bunodont and brachyodont with five lophids. Mesoconelets are inflated, almost the same size as the main cusps. On each lophid the fusion of the pretrite mesoconelet and the anterior pretrite central conule result in a big cusp. The traits are stegolophodont features. The occurrence on each lophid of large posterior pretrite conules that interrupt interlophids 1 to 4, is probably a plesiomorphous feature compared to other Upper Miocene stegolophodonts and to stegodonts, where these conules are reduced (Tassy *et al*., 1992). The measurement is 176 millimeters long and 68.84 millimeters wide.

Fossil locality: Mae Moh coal mine, Lampang Province

Remarks: The partial of M^3s of *Stegolophodon* cf. *latidens* also occur in the Mae Moh coal mine. This species had the same evolutionary stage as *Stegolophodon pseudolatidens* as the Japanese Middle Miocene specimens and the lectotype of *Stegolophodon latiden* from the Irrawady Formation in Burma. They have primitive features compared to *Stegolophodon stegodontoides* from the Dhok Pathan Formation, but are more advanced than *Stegolophodon nasaiensis*.

***Stegolophodon* cf. *stegodontoides* Tassy, 1983**

Figs. 3.30 to 3.37

Materials: *Upper* M^3; PRY3, PRY4, PRY5, RIN6, RIN33, RIN348, RIN804, RIN7, CCZ36, RIN61, RIN350, RIN66, RIN71.

Lower M_3; PRY15, RIN3, PRY19, PRY1, PRY2, RIN43, RIN805, RIN534, NM1-13, PRY17, CCZ61, CCZ65.

Intermediate molars; RIN39, RIN65, CCZ45, RIN67, PRY26, PRY27, PRY28, PRY7, RIN55, PRY22, CCZ06, RIN4.

***Upper M^3 description*:**

PRY 3 is the left M^3 with five lophs and a talon. The anterior and posterior cingulae are present. The median sulcus is clear. The conules are large and blunt. The first and second lophs are highly worn and show weak enamel folding. The worn figure of the first and second lophs has a trefoil figure, which is not strong, probably because of the posterior and anterior central conules at the base of these lophs. The third loph has four cusps as the principle cusps and the mesoconelet is as large as the main cusp and is with slightly worn. The fourth loph has five cusps because the pretrite mesoconet was subdivided. The fifth loph is same as the fourth loph but is smaller. The talon is small and developed as conules. The roots are preserved. The anterior roots support the first loph and the anterior part of the second loph. The crowns are low. There is cement in the valley in the posterior part. Dimensions are 191.8 millimeters long and 99.75 millimeters wide at the second loph.

PRY4 is the right M^3 of the same individual and has similar structures as specimen PRY3. However, it is different because of its double talon. Specimen PRY

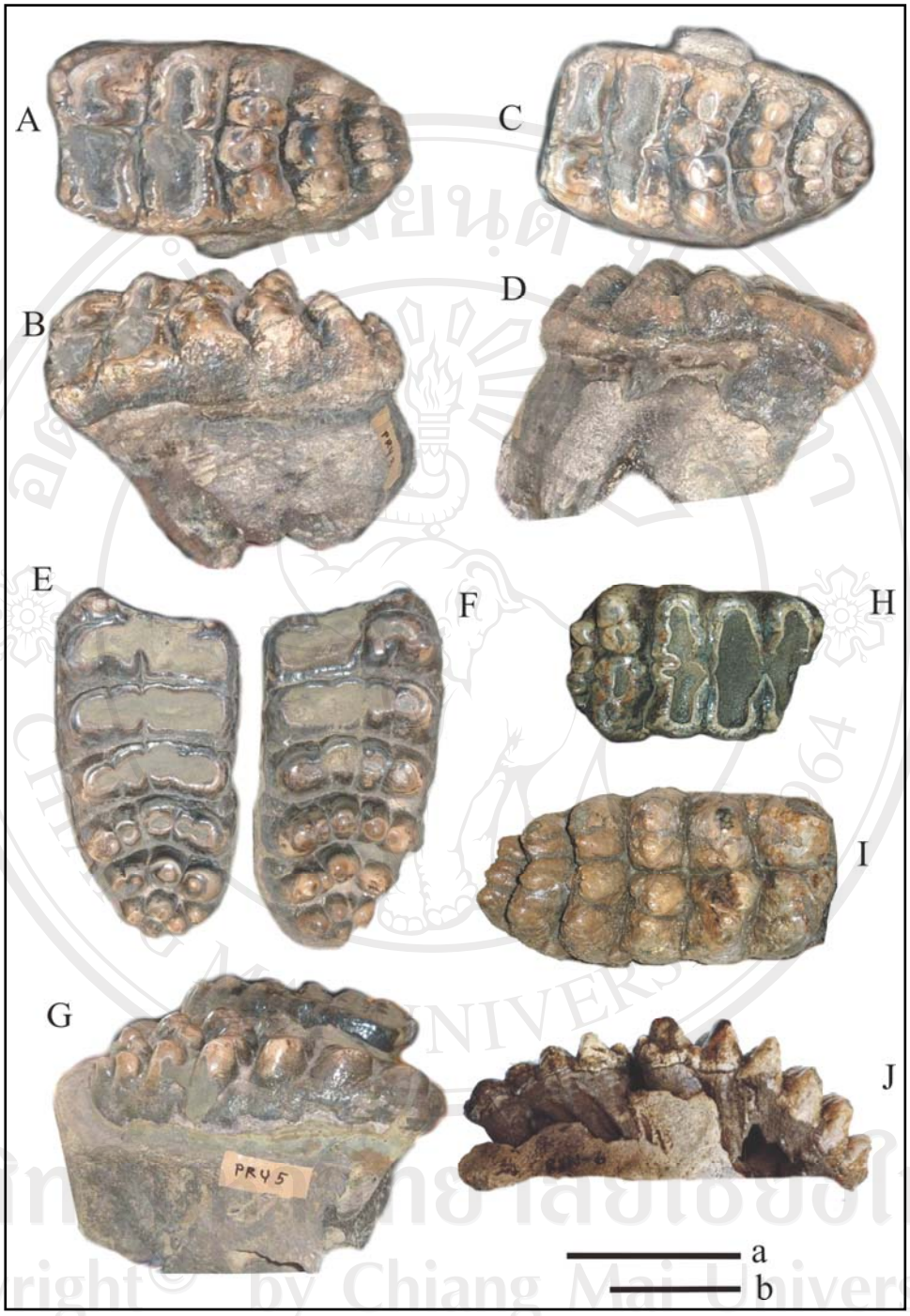

Fig. 3.30 Upper molars of *Stegolophodon* cf. *stegodontoides* from the Tha Chang sand pits; PRY3 left M^3, A: occlusal view, B: lingual view; PRY4 right M^3, C: occlusal view, D: lingual view; PRY5 left and right M^3; E: occlusal view of right M^3, F: occlusal view of left M^3, G: lateral view; RIN6 right M^{2-3}, H: occlusal view of M^2, I: occlusal view of $M^{3,}$ J: lateral view of RIN6. Scale bars 10 centimeters, scale bar a applies to A to I, scale bar b applies to J.

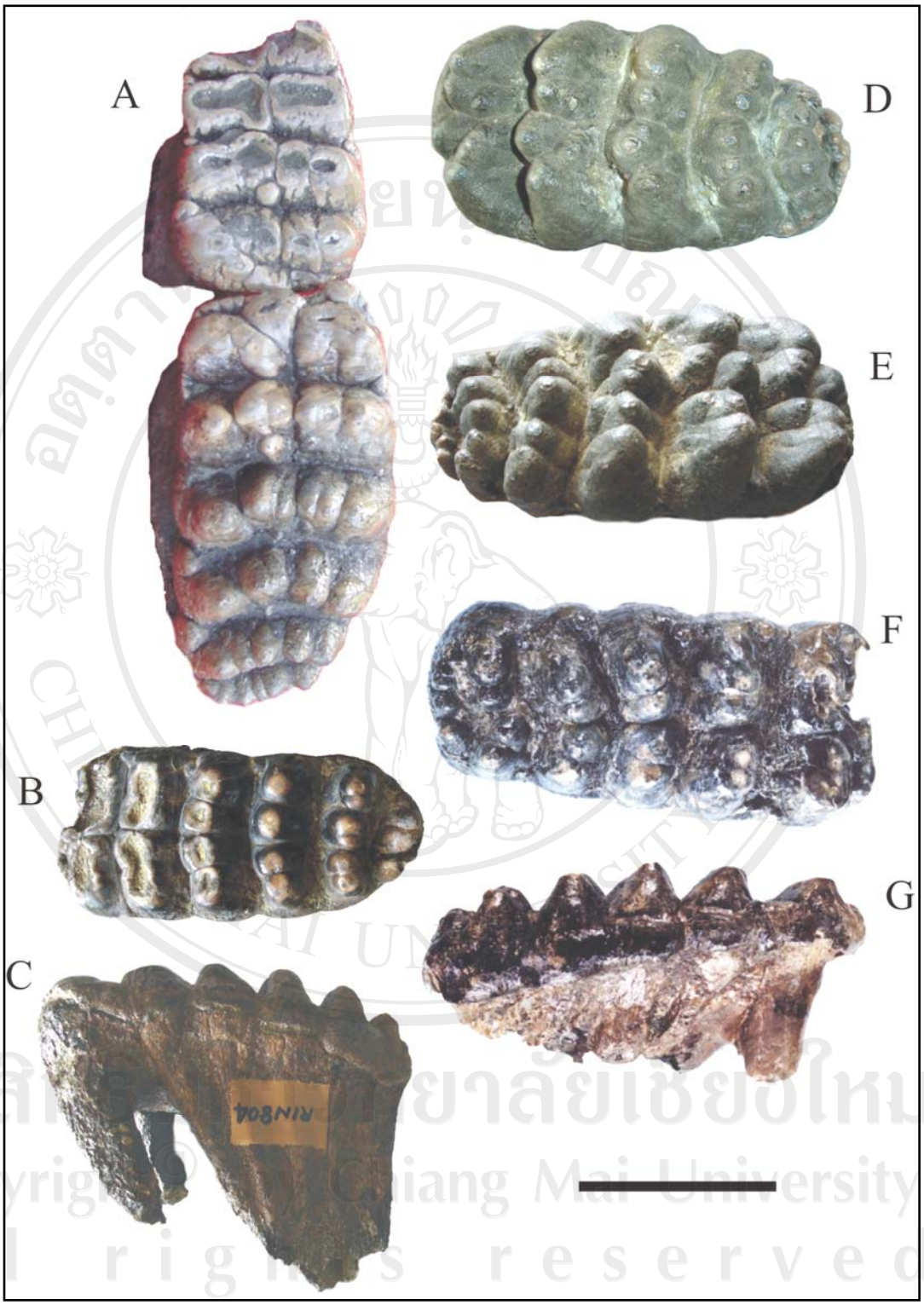

Fig. 3.31 Upper molars of *Stegolophodon* cf. *stegodontoides* from the Tha Chang sand pits, RIN33 left M^3, A: occlusal view; RIN804 right M^3, B: occlusal view, C: lateral view; RIN348 right M^3, D: occlusal view, E: oblique view; RIN7 left M^3, F: occlusal view, G: buccal view. Scale bar 10 centimeters applies to all.

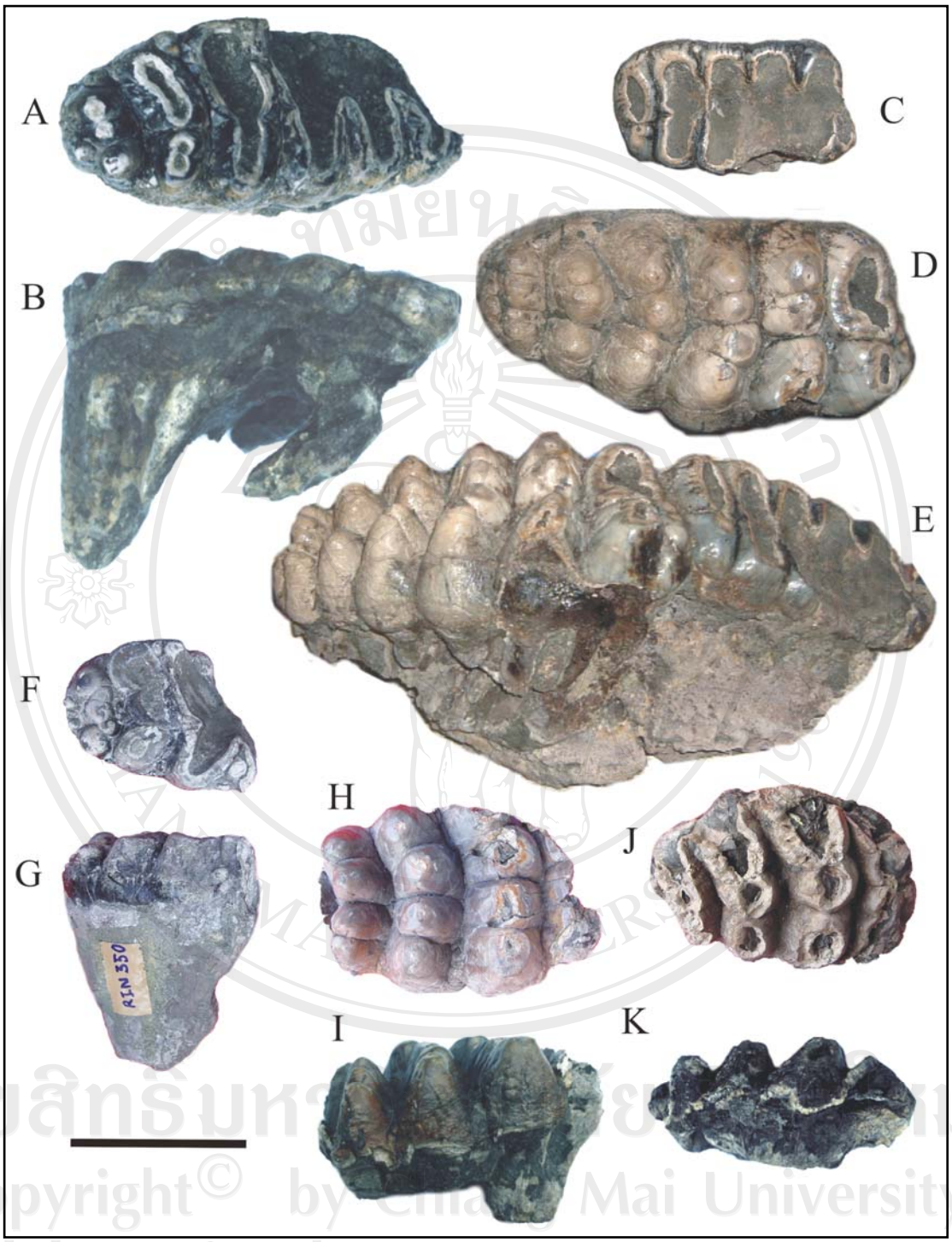

Fig. 3.32 Upper molar of *Stegolophodon* cf. *stegodontoides* from the Tha Chang sand pits, RIN61left M^3, A: occlusal view, B: lateral view; CCZ36 left M^{2-3}, C: occlusal view of M^2, D: occlusal view of M^3, E: lateral view; RIN350 fragmented left M^3; F: occlusal view, G: lateral view, RIN66 fragmented left M^3, H: occlusal view, I: lingual view; RIN71 fragmented molar left M^3, J: occlusal view, K: lateral view. Scale bar 10 centimeters, applies to all.

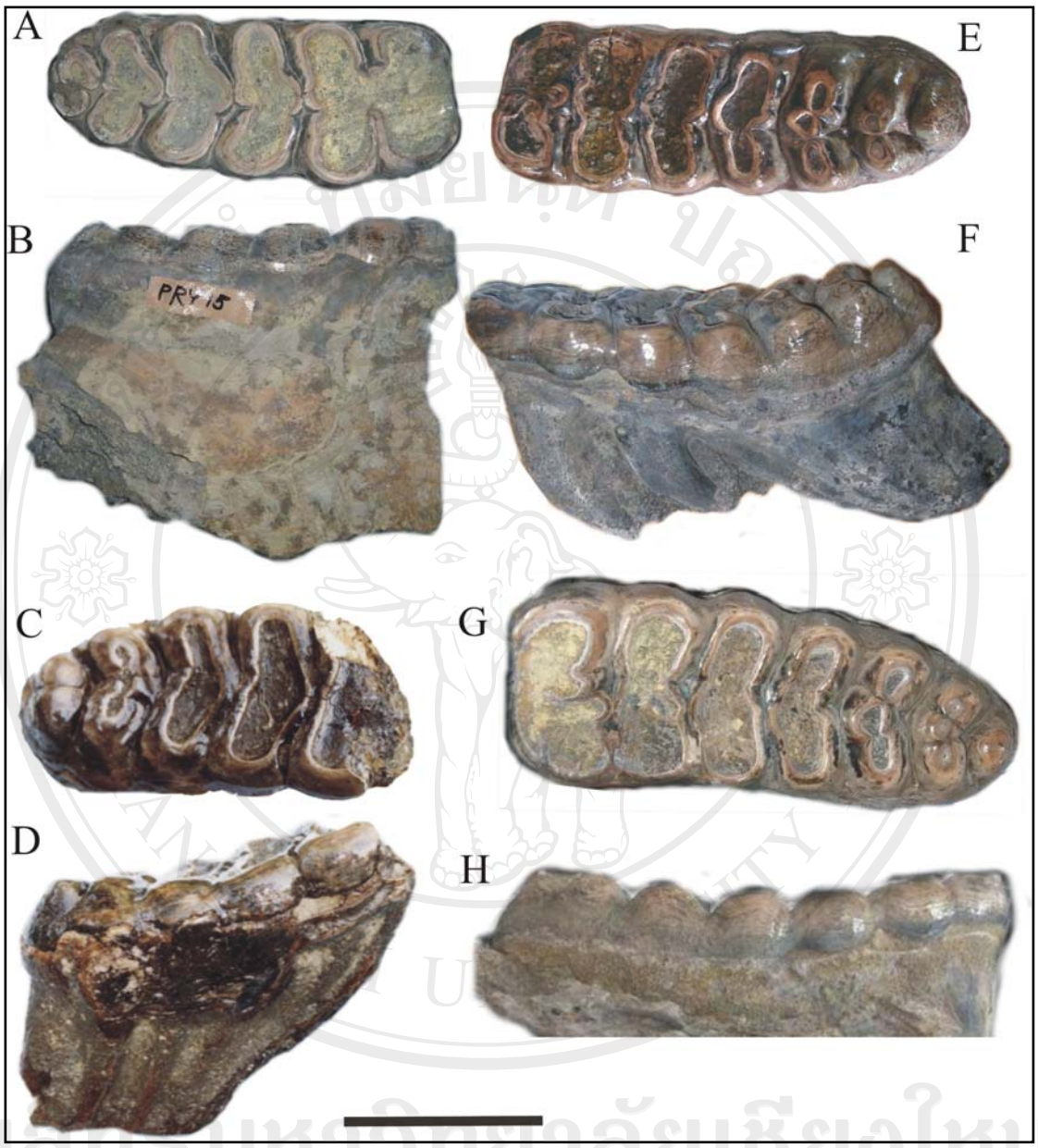

Fig. 3.33 Lower third molars of *Stegolophodo*n cf. *stegodontoides* of the Tha Chang sand pits, PRY15 left M_3; A: occlusal view, B: lateral view; RIN3 right M_3, C: occlusal view, D: lateral view; PRY1 right M_3; E: occlusal view, F: lateral view, PRY2 left M_3; G: occlusal view, H: lateral view. Scale bar 10 centimeters applies to all.

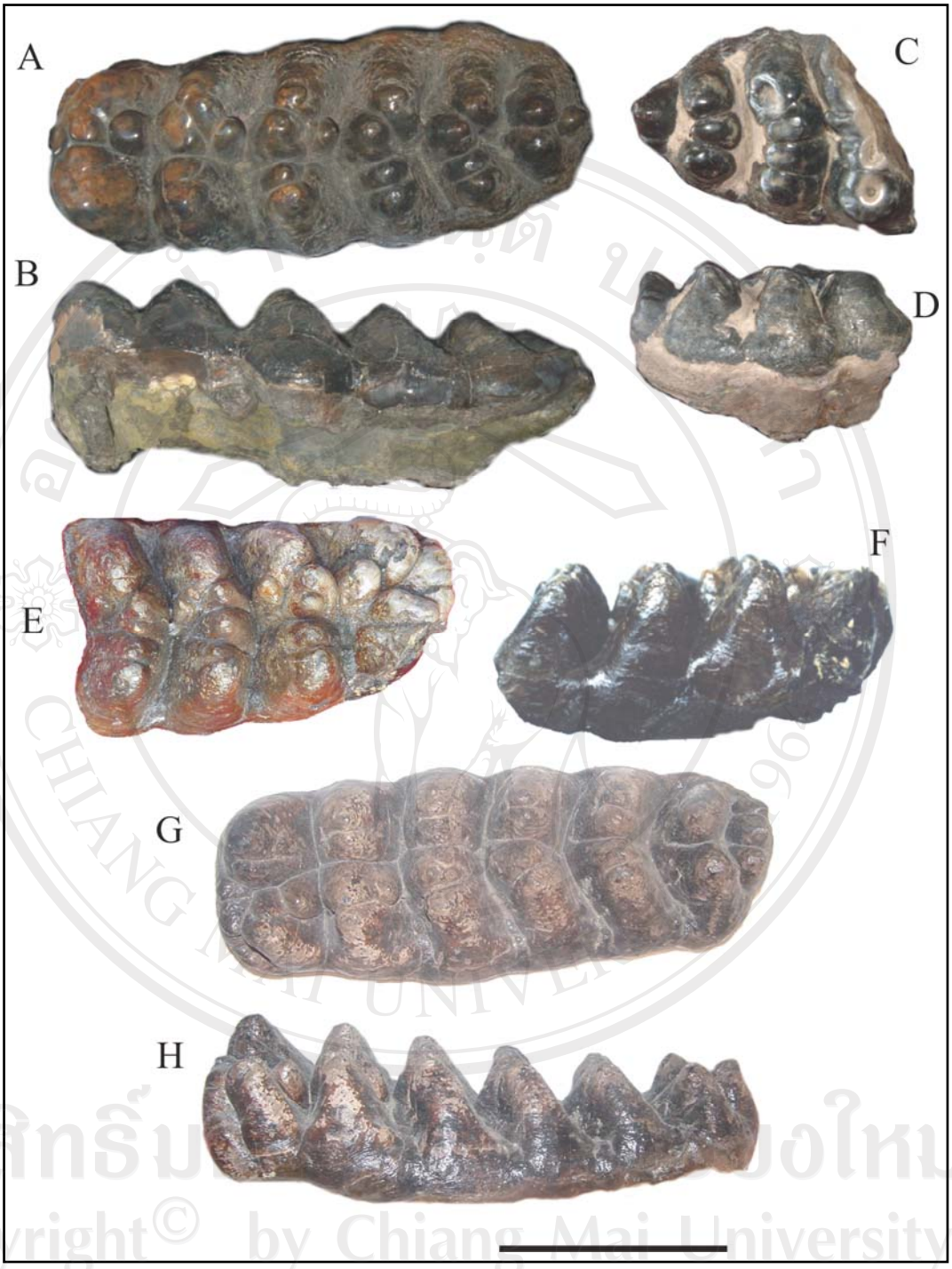

Fig. 3.34 Lower molars of *Stegolophodon* cf. *stegodontoides* from the Tha Chang sand pits; PRY19 right M_3, A: occlusal view, B: lateral view; CCZ65 fragmented left M_3, C: occlusal view, D: lingual view; RIN 43 fragmented left M_3, E: occlusal view, F: lingual view; PRY17 left M_3, G: occlusal view, H: lateral view. Scale bar 10 centimeters applies to all.

Fig. 3.35 Lower molars of *Stegolophodon* cf. *stegodontoides* from the Tha Chang sand pits, RIN 534 right M_3, A: occlusal view, B: lingual view, RIN805 left M_3, C: occlusal view, D: lateral view. NM1-13 left M_3, E: occlusal view, F: buccal view; CCZ61 fragmented left M_3, G: occlusal view, H: lingual view. Scale bar 10 centimeters applies to all.

Fig. 3.36 Upper intermediate teeth of *Stegolophodon* cf. *stegodontoides* from the Tha Chang sand pits; RIN65 left M^2; A: occlusal view, B: lateral view; RIN 39 left M^2; C: occlusal view, D:lateral view; CCZ45 fragmented $M^{2?}$, E: occlusal view, F: lingual view; PRY28 right M^1, G: occlusal view, H: buccal view; PRY26 left M^1, I: occlusal view, J: lateral view; PRY27 right M^1, K: occlusal view, L: buccal view; RIN67 right dm^3, M: occlusal view, N: lateral view. Scale bar 10 centimeters applies to all.

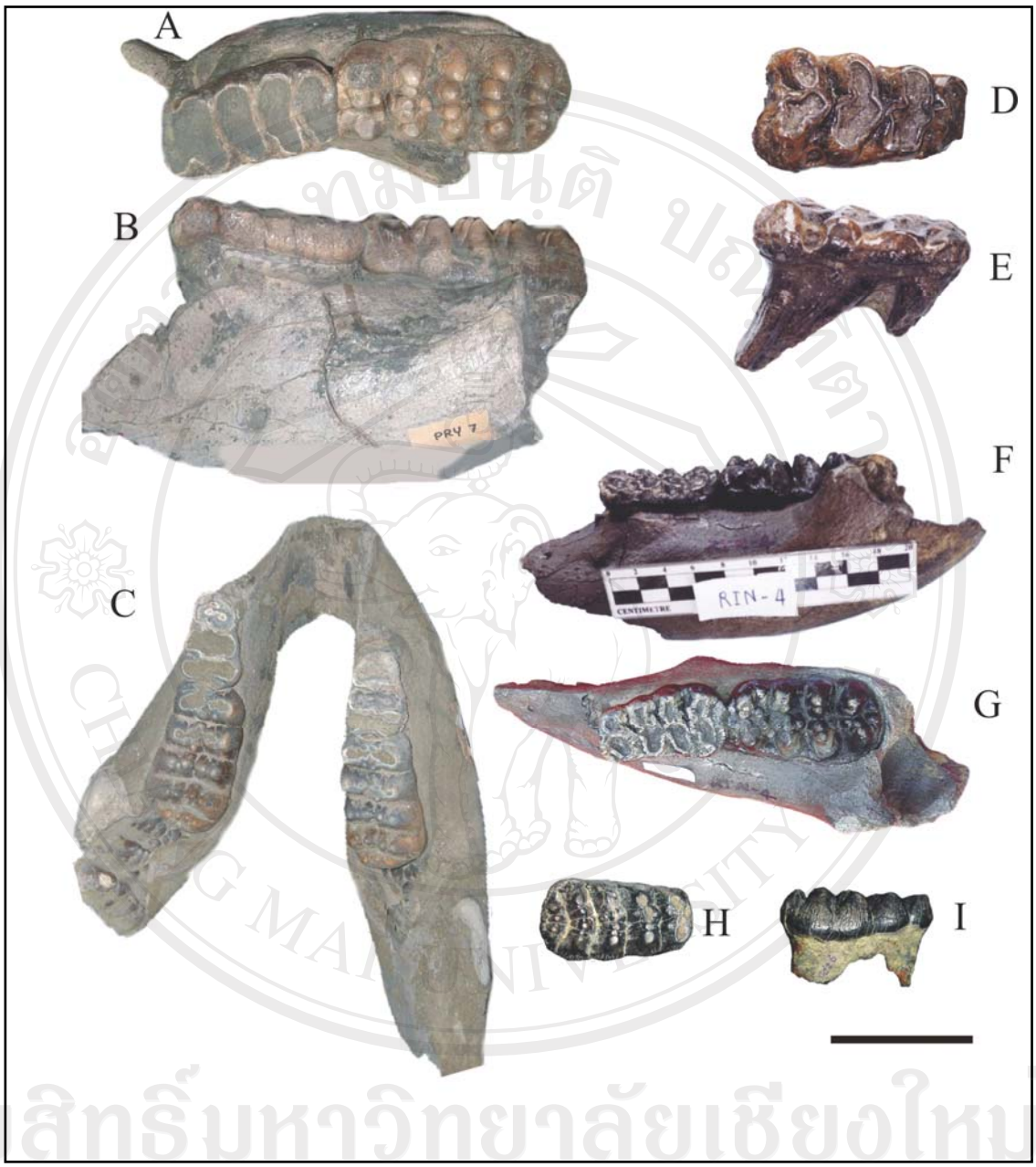

Fig. 3.37 Lower intermediate teeth of *Stegolophodon* cf. *stegodontoides* from the Tha Chang sand pits; PRY7 left mandible with $M_{1\text{-}2}$, A: occlusal-oblique view, B: lateral view; PRY22 left and right mandible with dm_2 and dm_3, C: occlusal view; RIN55 right M_2, D: occlusal view, E: lateral view; RIN4 left mandible with dm_3 and M_1, F: lateral view, G: occlusal view; CCZ06 left M_1, H: occlusal view, I: lateral view. Scale bar 10 centimeters applies to all.

4 is shorter and wider than PRY 3. Dimensions are 188 millimeters long and 100.56 millimeters wide at the second loph.

PRY5 is the left and right M^3 with maxilla. There are six lophs and small talons but the sixth loph is much smaller than the fifth and the talon occurs as a conule. It is highly worn on the first and second lophs. There is no enamel folding on the worn surface. Median sulcus is strong through the fourth loph. The tooth structures are similar to PRY3 and PRY4 in the anterior part. Posterior pretrite orientation is present on the third to the fifth lophs. Dimensions of the left molar are 204 millimeters long and 98.49 millimeters wide at the first loph; the first loph of the right molar is 198.2 millimeters long and 94.15 millimeters wide.

RIN 6 is a fragmented right maxilla that has the second and third molars. The second molar has four lophs and a posterior cingulum. The third molar has six lophs and a small talon. The second molar is heavily worn on all lophs. The worn surfaces have coarse enamel folding. There are traces of posterior and anterior pretrite central conules on the third and fourth lophs probably occur at the base of the inter-valleys. The posterior cingulum is well developed as three conules. The median sulcus is strong through the tooth. Dimensions are 146 millimeters long and 90.82 millimeters wide at the fourth loph.

The third molar is slightly worn on the first loph. The cusps are subdivided into a main cusp and a mesoconelet by a shallow groove. The pretrite side probably contains three cusps, but these are hidden under a sediment cover on the crown surface. The posttrite has two cusps. There is no posterior central conule. The second loph has five cusps and distinct posterior pretrite and posttrite central conules. The main cusps are larger than the mesoconelet. The pretrite mesoconelet is

subdivided into small cusps. The posterior pretrite central conule connects with the main cusp and the mesoconelet. The posterior posttrite central conule only connects with the mesoconelet. The third loph has a main cusp and a mesoconelet in each side. These mesoconelets are partially subdivided by small shallow furrows and they are as large as the main cusps. The posterior pretrite central conule is distinct and is connected to the mesoconelet. There is no posterior posttrite central conule, only a swollen surface instead. The fourth loph is a nearly complete copy of the third loph. It has a smaller posterior pretrite central conule. The fifth loph has six cusps. The pretrite main cusp and mesoconelet are subdivided into two smaller cusps by shallow grooves. The posterior pretrite central conule is very small. The sixth loph is much smaller than the fifth but has similar structures. The talon is very small and has three conules. The median sulcus is distinct on the first three lophs and is shifted buccally on the fourth and fifth lophs. Dimensions are 207.5 millimeters long and 106.3 millimeters wide at the third loph.

RIN 33 specimen has the upper left M2 and M3. The M2 has four lophs and a small posterior cingulum that is not well separated from the last loph. The anterior part is broken and is heavily worn through the tooth. The posterior part has four conules in each ridge and the cusps are the same size. There are pretrite posterior central conules except on the last loph. There is an obvious median sulcus. The transverse valleys are shallow and narrow because of heavy wear. There are small lateral tubercles at the entrance of each valley on both the buccal and lingual sides. Roots are well preserved, and the mesial roots support the first loph and the anterior part of the second loph. There is no enamel folding and cement. Dimensions are 134.5 millimeters long and 92.57 millimeters wide.

The M^3 has six lophs. The first and second lophs are entirely worn and indicate that this animal was an adult. M^3 contains five to six conelets in each ridge and has a simple structure, except for the first loph. Posterior pretrite central conules occur in the first to fourth valleys and tend to be reduced in size. The median sulcus is a strong trough in the fifth loph. M^3 has a low crown. The transverse valleys are wide. Lateral tubercles occur at the entrance of valleys. The roots are preserved and the mesial root supports only the first loph. Dimensions are 211 millimeters long and 99.31 millimeters wide.

RIN348 is a left M^3 with an X5X loph formula. The fifth loph is a copy of the anterior loph but very smaller in size. The talon is very small. The median sulcus is distinct throughout the tooth. Each loph has four to five conelets. The posterior central conules are well developed on both the pretrite and postrite of the first to the third lophs, but they are smaller. The pretrite central conules connet between the main cusp and mesoconelet but in the posttrite they are only connected to the mesoconelets. Dimensions are 212 millimeters long and 111.97 millimeters wide.

RIN804 is a right upper M^3 with an X5X loph formula. The fifth loph is well developed but the cusps are more subdivided than the anterior lophs. The talon is smaller than the fifth loph. The tooth is heavily worn on the first two lophs and moderately worn on the third and the fifth lophs. The median sulcus is distinct and it separates the tooth into two half-lophs. Each half-loph has two large round conules that can be seen on the third and the fourth lophs. The last loph is more advanced by being subdivided into six conules. The mesoconelet is as large as the main cusp and is swollen anteriorly. The pretrite main cusps are nearly in line. This structure makes the tooth slightly curved but not V-shaped. The tooth has a low crown. Worn

surfaces are smooth. The mesial roots support only the first loph. There is no posterior central conule. Dimensions are 187 millimeters long and 94 millimeters wide at the first loph.

RIN 7 is a left M^3 with five lophs and talon. Each loph has four principle cusps and simple structure. The first three cusps are slightly worn and they have coarse enamel folding. The cusps are large, blunt, and there is a low crown. There is no central conule. The median sulcus is distinct throughout the tooth. The cusps on the first and second lophs are in a straight line. Posterior pretrite orientation occurs on the third and fourth lophs. The talon is developed as conules. The inter-valleys are wide. The anterior roots support the first loph. Lateral tubercles are present at the entrance of the first, second, and third valleys. Dimensions are 223 millimeters long and 108.72 millimeters wide at the second loph.

CCZ36 is the left upper M^2 and M^3. The M^2 has an X4X loph formula, in which the talon is as large as the anterior loph. It is well worn and damaged on the posttrite. The M^3 has an X6X loph formula. The first loph is heavily worn, though the second and third lophs are only slightly worn. It is damaged on the posttrite side of the first and second lophs. The conelets are strong. There are four conelets on the first four loph, three on the fifth loph, and four on the sixth loph. The fifth loph is not a complete copy of the anterior loph and is much narrower. The sixth loph is very small. The M^2 is 114 millimeters long and 100.02 millimeters wide. The M^3 is 244 millimeters long and 117.24 millimeters at the third loph.

RIN61 is a left upper M^3 with an X6X or X5Xx loph formula because the sixth loph has a very low crown and a small talon. It is damaged on the pretrite of the first and second lophs. The crowns are heavily worn throughout the tooth. The worn

surface has no folding at the enamel-dentine junction. The enamel surfaces are coarsely folded. The median sulcus is distinct throughout the tooth. The mesial roots are well preserved and support the first loph and the anterior part of the second loph. Dimensions are 204.5 millimeters long and an estimated 98 millimeters wide at the first loph.

RIN350 probably belongs to the posterior part of M^3. The worn surface structures and the width of the loph are similar to those of RIN61.

RIN66 is the three anterior lophs of a molar, probably the upper M^3. The mesial root supports the first loph. The cusps are large, round, and strong. They are four conelets in each loph. The enamel surfaces are smooth but there is no enamel-dentine junction. The median sulcus is distinct. The maximum width on the first loph is 96 millimeters.

RIN71 is a strongly damaged molar but its loph has large conelets that can be attributed to this species.

Lower M_3 description:

PRY15 is a left lower third molar with an X5X tooth formula. It is heavily worn through the talonid. This specimen could belong to an old individual. The worn surface has no enamel folding. The first and second lophids are nearly in a straight line, the other lophids are V-shaped and pointed anteriorly. The median sulcus is strong throughout the tooth. Dimensions are 206.8 millimeters long and 80.42 millimeters wide at the second lophid.

RIN3 is an incomplete lower right third molar with an X5X tooth formula. It has four lophids and a talonid. The first lophid is broken and missing. It is heavily worn. The worn figure is V-shaped and pointed to the anterior and posterior pretrite

orientation. The worn surface has coarse enamel folding. Dimensions are 200 millimeters long and 97.45 millimeters wide at the third lophid. As a complete specimen, it would be about 245 millimeters long.

PRY19 is the unworn right M_3 with an X5X lophid formula. The median sulcus is distinct through to the fourth lophid. Each lophid has four to five conelets. Two of these are on the posttrite and two or three are on the pretrite. The conelets on the posttrite are usually smaller than those on the prettrite. The posterior pretrite central conule is very apparent at the first to the third lophid. It is close to the mesoconelet but well separated from it by a lateral groove. The tooth has a very low crown. Dimensions are 238.7 millimeters long and 102.69 millimeters wide at the fourth lophid.

PRY1 is the lower right M_3 with an X6X lophid formula. The tooth is heavily worn throughout. The median sulcus is distinct. There is no folding on enamel-dentine junction. The posterior prettrite central conule is distinct on the fist lophid and restricted in the second to the fourth lophids. The mesoconelets are swollen on the anterior part and form chevrons where worn. The enamel surfaces are smooth. The pretrite main cusps of the first and second lophids are in line but the others are slightly dislocated posteriorly. The mesial root supports the first lophid. Dimensions are 241 millimeters long and 89.81 millimeters wide at the third lophid.

PRY2 probably belongs to the same individual as PRY1. It is the lower left M_3 with an X6X formula regarding the number of lophids. Its wear is the same as that of PRY1. PRY2 is slightly larger than PRY1. Its dimensions are 259 millimeters long and 91.25 millimeters wide at the third lophid.

RIN43 is an incomplete third lower molar. It has four anterior lophids. The last two lophids are probably lost. The anterior cingulum is large and the main cusp is high but slightly broken. The first lophid has an irregular tooth pattern. It is slightly worn. The pretrite side probably contains a large main cusp and a smaller mesoconelet. The posterior pretrite central conule is as large as the main cusp. It blocks the valley and the median sulcus. The posttrite half-lophid is broken at the large main cusp, but the mesoconelet and posterior central conule are well preserved. The second lophid has three pretrite and two posttrite cusps. The posterior central conule is distinct on the pretrite and connects the main cusp and the mesoconelet. The main cusps are larger than mesoconelets on both sides. The third lophid has five cusps. The cusps on the pretrite side are developed as conules by a deep groove. The posterior pretrite central conules are double conules. The fourth lophid has six conules, both small and large, in three columns. The posterior pretrite central conule is distinct but reduced in size. The median sulcus is distinct on the first and second lophids. Dimensions are 173 millimeters long and 101.98 millimeters wide at the fourth lophid. If complete, it would probably be about 250 miimeters long.

RIN805 is a lower left M_3 with an X6X lophid formula. The first and second lophids are broken. The first four lophids are heavily worn. There is no folding on the enamel-dentine junction. The enamel surfaces are smooth. Each loph has four conelets. On the basis of the fourth lophid, the specimen is well preserved. The mesoconelets are as large as the main cones. The pretrite main cusps are oriented slightly posteriorly. The mesial root supports the first lophid and the anterior part of the second lophid. Dimensions are 221.82 millimeters long and 80.20 millimeters at the third lophid.

RIN534 is a fragmented mandible with a lower right M_3. The M_3 has an X6X lophid formula. It is broken on the first lophid and the buccal side of the second lophid. Its wear and tooth structures are similar to RIN804. These two specimens probably came from the same individual. The fragmented mandible is robust and heavy but its ramus is missing. If this missing ramus is round, it would be a derived character for Elephantidae but if it is angular, it would be a characteristic of Gomphotheriidae. Dimensions are 213.92 millimeters long and 79.58 millimeters wide at the third lophid.

NM1-13 is a fragmented mandible with a lower left M_3. It has an X7X or an X6Xx lophid formula because the seventh lophid is very small, as is the talonid, and is not exactly like the anterior lophid. The tooth is heavily worn from the first to the fourth lophid. The enamel-dentine junction is coarsely folded to smooth. It has four conelets on each lophid. The fourth lophid and following posterior lophids are slightly worn. The mesoconelets are as large as the main cusps and swollen in the anterior part. The posterior pretrite central conule is distinct on the first lophid and probably well developed on the second and third lophids, but missing on the other lophids. The median sulcus is distinct. The mandible is large and robust. Dimensions are 180 millimeters long and 70.83 millimeters wide.

PRY17 is a left lower M_3 with an X6X lophid formula. The tooth is unworn and has four conelets in each lophid. The first and second lophids have a distince posterior pretrite central conule that is connected to the mesoconelet. The other lophids have no central conule. The median sulcus is distinct. The lateral sulci are shallow but subdivide the mesoconelets and the mian cusps. The first and second lophids are in a line. From the third lophid onward, the pretrite main cusps have a

strong posterior orientation. The crowns are brachyodont, being wide at the base and much narrower at the apex. Dimensions are 245.8 millimeters long and 98.69 millimeters wide at the third lophid.

CCZ61 is a fragment of the posterior part of lower M_3, probably from the fourth lophid to the talonid. Its wear pattern is similar to that of RIN805 and RIN534. It has four conelets on each lophid. There is thin cement in the valley. The width of the first preserved lophid is about 97 millimeters, making it slightly larger than RIN805and RIN534.

CCZ65 is a fragment of the posterior part of a lower M_3 that has the last three lophids and talonid. The tooth structures are similar to CCZ61. There is thin cement in inter-valleys. The width of the first well preserved lophid is 92.7 millimeters.

Intermediate molars description:

RIN39 is an upper left M^2 with an X4X loph formula. It is a heavily worn tooth. The worn surface has smooth enamel folding. The first loph is partly broken and there is no detail on the first two lophs. The third loph probably has four cusps. The posterior posttrite central conule occurs on the surface of the third loph. The fourth loph probably has five cusps. The talon is large but not well developed as a conule. The median sulcus is strong. Dimensions are 162.5 millimeters long and 87.55 millimeters wide at the fourth loph.

RIN65 is a right M^2 with an X4X loph formula. It is completely worn and is damaged at the posterior part on the pretrite side. The enamel surfaces are coarsely folded but there is no folding at the enamel-dentine junction. It is slightly larger than RIN39. Dimensions are 175 millimeters long and 99.02 millimeters wide at the third loph.

CCZ45 is the anterior part of M^2? The tooth is heavily worn on its three lophs. There is neither folding on the tooth surface or on the enamel-detine junction. The posterior central conules are on the first loph on both prettrite and posttrite. The second and the third lophs probably have a large anterior prettrite central conule. The third loph is 83.38 millimeters wide.

RIN67 is a M^1 with an X4X loph formula. It is heavily worn throughout the tooth. The median sulcus is distinct and roughly separates the tooth into pretrite and posttrite. The wear on the second loph shows swelling on both the anterior and posterior surfaces. This suggests that the anterior and posterior central conules should be distinct at these positions. The enamel surfaces are coarse but there is no folding on enamel-dentine junction. There are conules at the entrance of both sides of the first and second valleys. Dimensions are 91 millimeters long and 55.34 millimeters wide.

PRY26 and PRY27 are the left and right M^1s, respectively. These probably came from the same individual. The teeth have an X4X loph formula. The cusps are round and separated into five or six conules in each loph. The posterior pretrite is distinct on the first and second lophs. There is a well developed median sulcus. PRY26 is 106.07 millimeters long and 75 millimeters wide at the third loph. PRY27 is 110.43 millimeters long and 73.66 millimeters wide at the third loph.

PRY 28 probably belongs to the right M^1. Its tooth structure is similar to PRY26 and PRY27 but it is slightly larger. Dimensions are 130.02 millimeters long and 76.13 millimeters wide at the fourth loph.

PRY7 is a fragmented mandible with lower left M_1 and M_2. The M_1 is completely worn, and composed of four lophids. There is no enamel-dentine junction.

The M_2 has an X5X lophid formula. There are four subdivided conelets in each lophid. The posterior and anterior pretrite central conules are distinct on the first and second lophids. The inter-valley surfaces are rough and there is no cement. M_1 is 123 millimeters long and 68.23 millimeters wide at the fourth lophid. M_2 is 166 millimeters long and 85.74 millimeters wide at the fourth lophid.

RIN55 is a right lower M_2 with an X4X lophid formula. The talonid is broken. The tooth is heaviky worn throughout. This wear shows that the pretrite half-lophid probably contains large mesoconelets located anteriorly. The posterior pretrite central conules are not always distinct. There is a median sulcus. The pretrite main cusps are oriented posteriorly. Dimensions are 152 millimeters long and 89.92 millimeters wide at the fourth lophid.

PRY22 is a fragmented mandible with dm_2 and dm_3. The dm_2 has an X3X lophid formula. It is heaviy worn. The dm_3 has an X4X lophid formula and is worn on the first and second lophids. It has four to six conelets on each lophid. The posterior pretrite and posttrite central conules are distinct on the first lophid. The anterior and posterior central conules are distinct on the second and third lophids. The enamel-dentine junction is coarsely folded. Ldm_2 is 62.03 millimeters long and 44.03 millimeters wide at the third lophid. Rdm_2 is 58.13 millimeters long and 40.42 millimeters wide at the third lophid. Ldm_3 is 105.51 millimeters long and 60.64 millimeters wide. Rdm_3 is 105.51 millimeters long and 61.52 millimeters wide.

CCZ06 is a left M_1 that is heavily worn on the first lophid and moderately worn on the second and third lophids. The posterior pretrite and posttrite central conules are stong on the first lophid. The anterior and posterior central conules are distinct on the second and third lophids on both the pretrite and posttrite. They are larger on the

prettrite side. Dimensions are 107.26 millimeters long and 59.47 millimeters wide at the fourth lophid.

RIN4 is a left fragmented mandible with dm_3 and M_1. It has an X4X lophid formula. The dm_3 is heavily worn throughout the tooth and it has coarse enamel surfaces. The median sulcus is distinct. The posterior central conule is distinct on the pretrite of the first lophid. The M_1 has four round cusps in each lophid. The posterior central conules are distinct on both the pretrite and posttrite of the first lophid. They are restricted on the pretrite side of the second lophid. Only the posterior pretrite central conule occurs on the third lophid. The dimensions of dm_3 are 88.27 millimeters long and 52.48 millimeters wide at the third lophid. M_1 is 105.57 millimeters long and 61.04 millimeters wide at the third lophid.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Comparison: *Stegolophodon* cf. *stegodontoides* was a common species in Thailand during the Late Miocene, especially in northeastern Thailand. The type species was found in Pakistan and was first described as *Mastodon latidens*. However, because of its six larger lophs on the M^3 and its strong reduction of the central conule, Pilgrim (1913) created a new species *Stegolophodon stegodontoides*. The numerous specimens from Tha Chang were allocated to this species because of their size, though there are different details of teeth morphology. Some specimens have more primitive characters, such as the number of lower M_3 being X5X in PRY15 and RIN 3. Some specimens have more simple structure where the conules are subdivided into only four conelets in each loph, as in RIN804, RIN7, RIN534, RIN805, NM1-13, and CCZ61. Even so, the number of lophs corresponds to *S. stegodontoides*. These were probably

caused by individual variations or by differences in evolutionary stages. In my opinion, this species may be a subspecies or new species. However, the stratigraphic positions of the fossils are still problematic. The scatter diagrams of this species are shown in Fig. 3.38.

***Stegolophodon* n. sp. 1**

Fig. 3.39

***Diagnosis*:** Large size *Stegolophodon* with X6X loph formula on M^3 and X7X lophid formula on M_3. The molars are complicated by the occurrence of anterior and posterior central conules on both pretrite and posttrite.

***Materials*:** RIN64 is right M^3, PRY13 is left M^3, and PRY12 is left and right M_3s.

***Description*:** RIN64 is a complete right M^3 with an X6X loph formula. It is heavily worn on the first three lophs, moderately worn on the fourth loph, and slightly worn on the fifth loph. The pretrite side is more worn than the posttrite side. The worn surface has a coarse enamel surface but no folding on the enamel-dentine junction. The median sulcus is distinct throughout the tooth. Each loph has four to six conules. The anterior and posterior central conules are distinct and connected with all mesoconelets in both the pretrite and posttrite from the first to the fifth lophs. Where heavily worn, such as in the second pretrite loph, the anterior central conule probably is not visible. However, the posterior central conule is visible because of the small groove between the mesoconelet and the main cusp. The pretrite side is in line but the posttrite side is oriented posteriorly. Dimensions are 272 millimeters long and

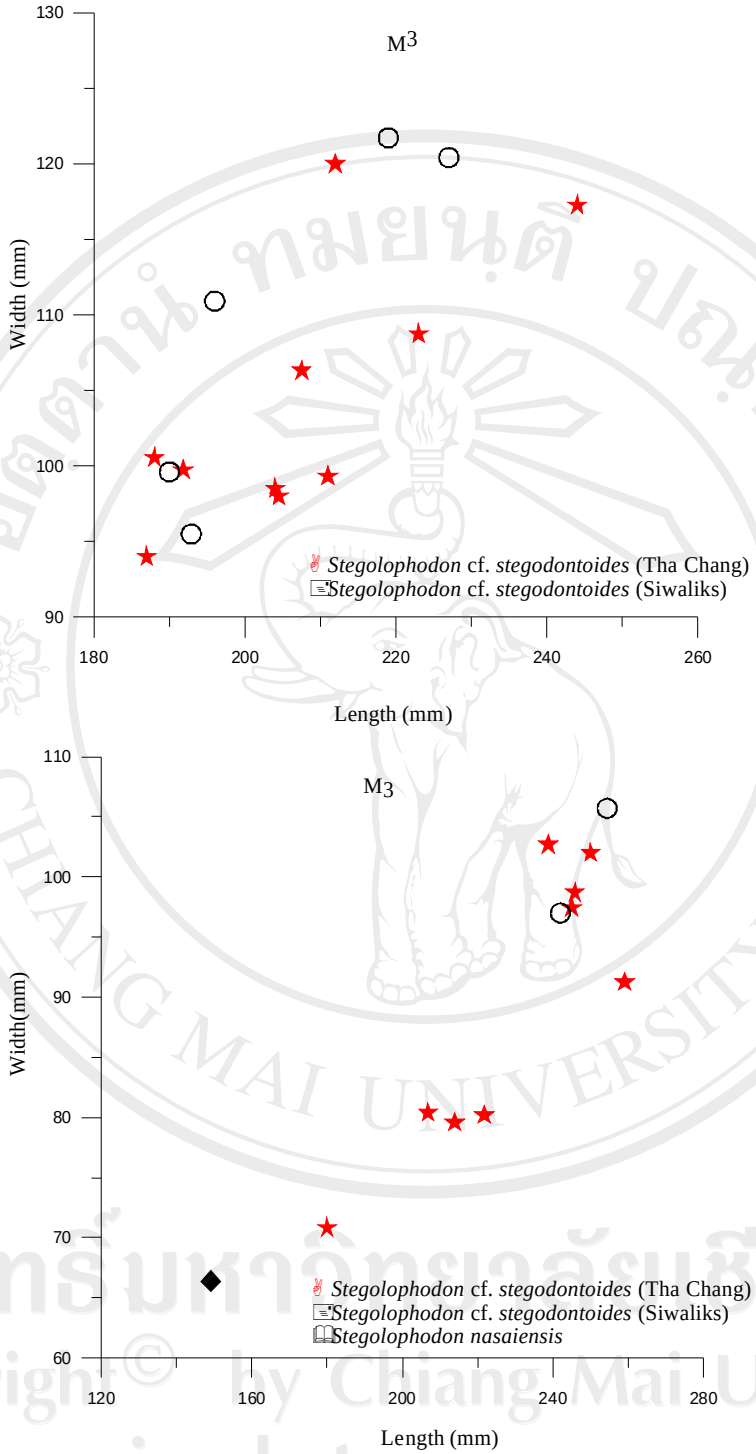

Fig. 3.38 Scatter diagrams of length versus width of *Stegolophodon* cf. *stegodontoides* from Tha Chang sand pits compared with *Stegolophodon* cf. *stegodontoides* from Siwaliks and *Stegolophodon nasaiensis*. Data sources: *Stegolophodon* cf. *stegodontoides* from Siwaliks (Tassy, 1983), *Stegolophodon nasaiensis* (Tassy *et al*., 1992).

Fig. 3.39 *Stegolophodon* n. sp.1 from the Tha Chang sand pits; RIN64 right M^3; A: occlusal view; PRY13 left M^3, B: occlusal view; C: lateral view; PRY 12 left and right M_3; D: occlusal view of the right, E: occlusal view of the left, F: lateral view and mandible of this species. Scale bar 10 centimeters applies to A, B, C, D, and

127.61 millimeters wide.

PRY13 is a left M^3 with the same tooth structure as in RIN64. It is different from RIN64 in that it has no anterior central conule on both the pretrite and posttrite on the fourth loph. Dimensions are 278 millimeters long and 129 millimeters wide at the fourth loph.

PRY12 is the left and right M_3 and has an X7X lophid formula. The teeth are heavily worn of the first three lophids and slightly worn on the fourth and fifth lophids. A distinction between the anterior and posterior central conules is seen on the first three lophids. From the fourth to the sixth lophids, there is an anterior central conule. However, the posterior central conules are still large and distinct. The teeth surfaces are smooth and there is no folding on the enamel-dentine junction. The pretrite and posttrite are nearly in line on the first three lophids but are slightly posterior on other lophids. LM_3 is 312 millimeters long and 117 millimeters wide at the third lophid. RM_3 is 305.6 millimeters long and 115.54 millimeters wide at the third lophid. The scatter diagrams of this species are shown in Fig. 3.40.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Comparison*: Stegolophodon* n. sp. 1 differs from other *Stegolophodon* species by its huge size and its complex tooth structure.

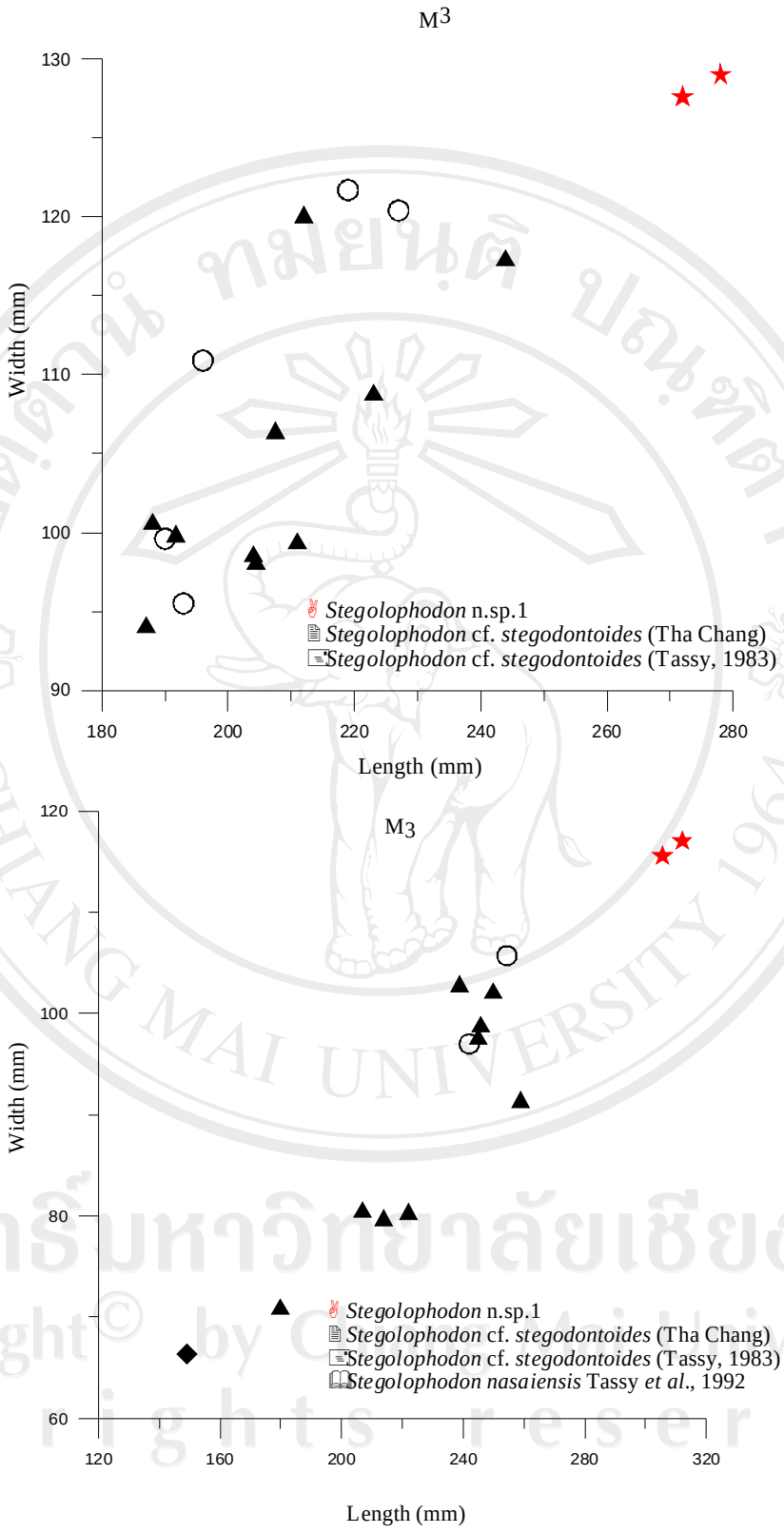

Fig. 3.40 Scatter diagrams of *Stegolophodon* n. sp. 1 compared with *Stegolophodon* cf. *stegodontoides* from Tha Chang sand pits and Siwalik Group and primitive form *Stegolophodon nasaiensis*.

***Stegolophodon* n. sp. 2**

Fig. 3.41 (A and B)

***Diagnosis*:** *Stegolophodon* that has distinct anterior and posterior central conules on the pretrite half-lophid throughout the tooth except for the last loph. Posttrite central conules are incipient. The molar crowns are low and have an X6X lophid formula on M_3.

***Material*:** NM1-1**,** a lower right mandible with M_3 from Tha Chang sand pits.

***Description*:** NM1-1 is a right fragmented mandible with M_3. The tooth was damaged on the anterior part and because of this probably has lost the anterior cingulum and the first lophid. The lophid formula iss assumed to be X6X. It is heavily worn on the the second to the fouth lophids and moderately worn on the fifth lophid. The sixth lophid is developed as large as the fifth lophid. The talonid is broken. Each lophid has four conelets. The mesoconelets are slightly smaller than the main cones**,** and they have large anterior and posterior pretrite central conules on the third and the fourth lophids. The anterior and posterior posttrite central conules are also well developed on the third lophid. However, the posterior conules are small in the later lophids and the anterior conules are fused with the cones, and they have large anterior and posterior pretrite central conules that can be seen on the third and the fourth lophids. The pretrite and posttrite are nearly in line. The crowns are low. Dimensions are 224 millimeters long and 80.87 millimeters wide at the fourth lophid. The scatter diagram of this species is shown in Fig. 3.42A.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

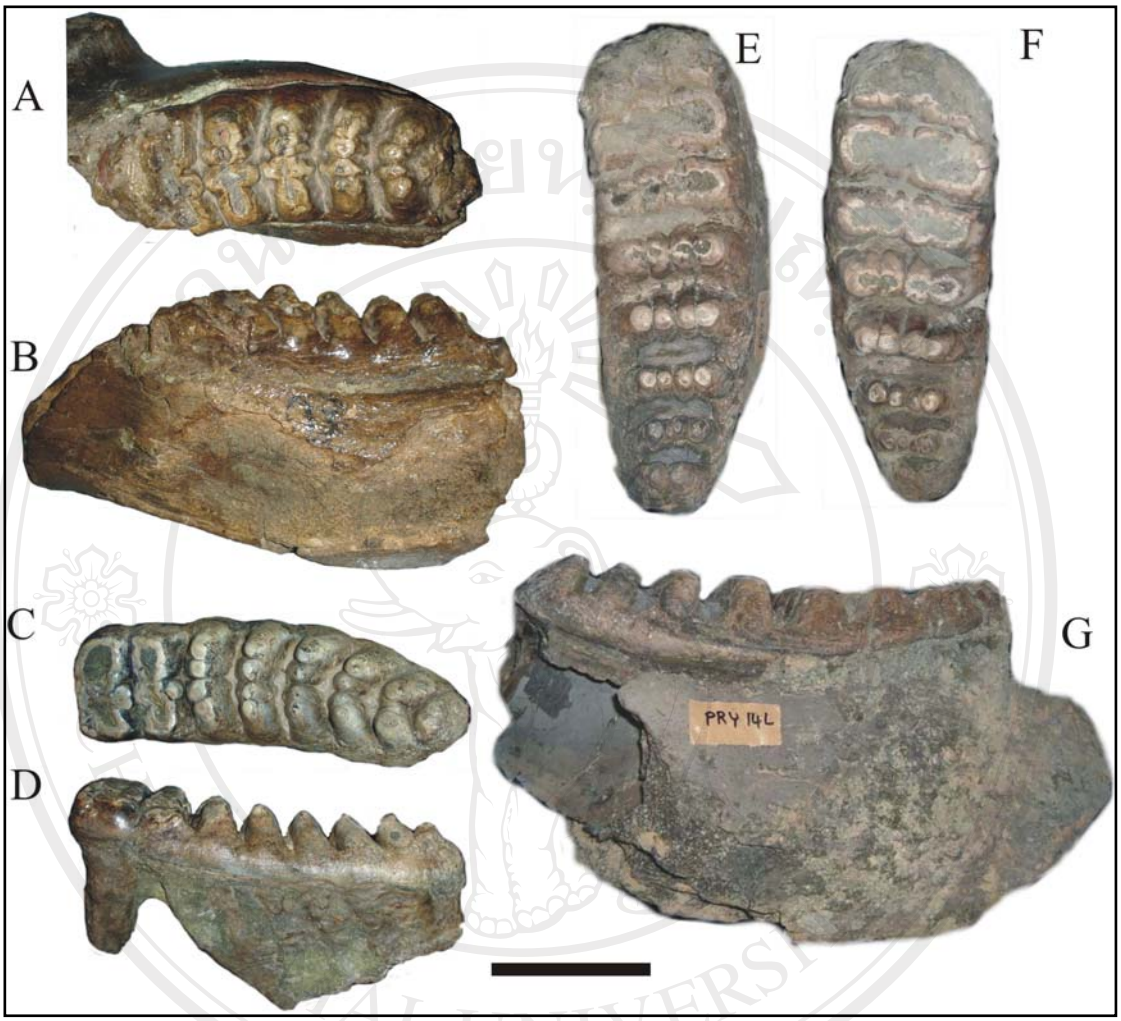

Fig. 3.41 *Stegolophodon* n. sp. 2 from the Tha Chang sand pits, NM1-1 left M_3 of the holotype, A: occlusal view, B: lingual view. *Stegolophodon* n. sp. 3, CCZ68 left M_3, C: occlusal view, D: buccal view; PRY14 left and right M_3, E: occlusal view of left M_3, F: occlusal view of right M_3, G: lateral view and mandible shape of left M_3. Scale bar 10 centimeters applies to all.

Comparison: *Stegolophodon* n. sp. 2 is a primitive stegolophodont that has an X6X tooth formula in M_3, as in *Stegolophodon* n. sp. 1 and *Stegolophodon* cf. *stegodontoides*. It differs from *Stegolophodon* n. sp. 1 and *Stegolophodon* cf. *stegodontoides* by its smaller size and by the anterior and posterior central conules in both the prettrite and posttrite half-lophids.

***Stegolophodon* n. sp. 3**

Fig. 3.41 (C, D, E, F, G and H)

***Diagnosis*:** *Stegolophodon* with an X7X lophid formula on M_3. The posterior pretrite central conules are probably distinct on the first and second lophids. It has a simple crown with four conelets in each loph. There is much cement in the inter-valleys.

Materials: PRY14, left and right M_3, CCZ68, left M_3

***Description*:** PRY14 is the left and right lower M_3. This tooth structure tooth structure is intermediate between PRY12 and CCZ68, which have X7X lophid formulas. PRY14 has four undivided conules in each lophid. The lophids are nearly in line. The first three lophids are heavily worn, the fouth lophid is moderately worn, and the fifth lophid is slightly worn. The first lophid is damaged on the anterior part. However, the preserved posterior part shows the outline of the posterior pretrite central conule. On the second to the fourth lophids, both anterior and posterior central conules are either large or small. The posterior part is swollen. Conules are fused or absent on the fifth and later lophids. There is much cement in posterior inter-valleys.

RM_3 is 291 millimeters long and 103 millimeters wide at the fourth lophid. LM_3 is 299 millimeters long and 102.58 millimeters wide at the fourth lophid.

CCZ68 is a left M_3 with an X7X lophid formula. The tooth is heavily worn on the first two lophids and slightly worn on the third and the fourth lophids. Each lophid has four, round and subdivided cusps. On the first and second lophids, the posterior pretrite central conules are distinct and connected with the mesoconelet. Conules are absent from the third lophid. The median sulcus is strong throughout the tooth. Thin cement occurs in the third to the last inter-valley. The pretrite and posttrite are in line in the first two lophids but the others are buccal-lingual compressed. Dimensions are 236 millimeters long and 80.52 millimeters wide. The scatter diagram of this species is shown in Fig. 3.42B.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Comparison: *Stegolophodon* n. sp. 3 is more advanced than *Stegolophodon* cf. *stegodontoides, Stegolophodon* n. sp. 1, and *Stegolophodon* n. sp. 2 by having an X7X lophid formula, simpler tooth pattern, and much cement in the valleys. It is probably the same size or larger than *Stegolophodon* n. sp. 2 and *Stegolophodon* cf. *stegodontoides,* but is much smaller than *Stegolophodon* n. sp. 1.

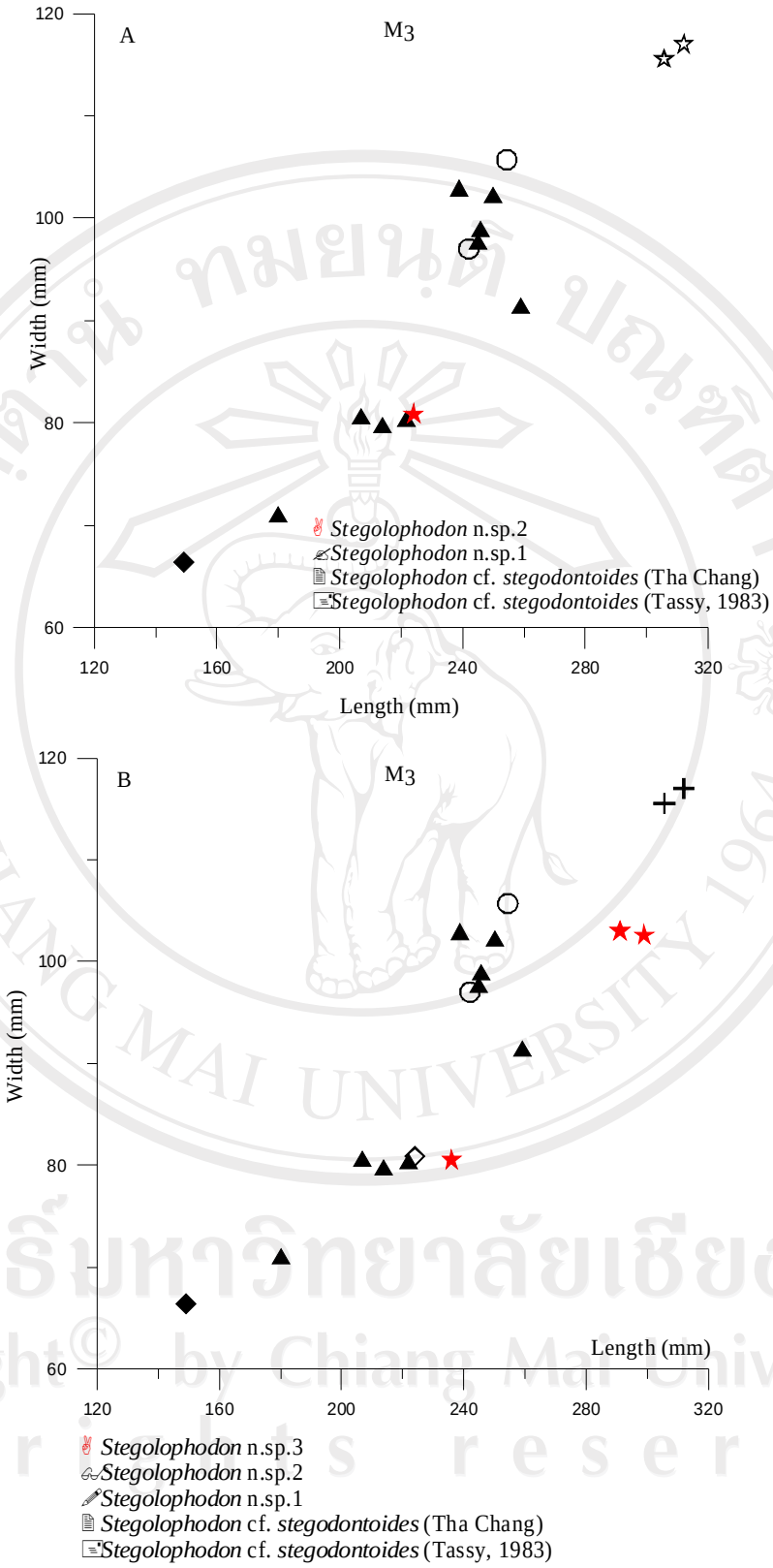

Fig. 3.42 The scatter diagrams of *Stegolophodn* n. sp. 2 (A) and *Stegolophodon* n. sp. 3 (B) from the Tha Chang sand pits compared with *Stegolophodon* n. sp. 1 and *Stegolophodon* cf. *stegodontoides*.

***Stegolophodon* n. sp. 4**

Fig. 3.43

***Diagnosis*:** *Stegolophodon* has an X6X tooth formula. Its tooth structure was derived by subdividing the crown into six to eight conules.

***Materials*:** RIN351, left and right upper M^3; RIN352, right M^3; PRY18, left M^3; PRY6, left M^3, CCZ50: a fragmented right $M_{3?}$, CCZ64: a fragmented left M_3

***Description*:** RIN351 right is partial maxilla that has a broken M^2 and nearly complete M^3. No detail can be seen on the broken M^2. The M^3 has an X6X loph formula. The first loph is somewhat broken. The tooth is worn on the first three lophs. However, the worn surface has coarse enamel folding. The posterior surface of the first loph is not swollen but the second loph has swelling in both the pretrite and posttrite. The enamel folding is coarse. The third loph has six cusps, three each in the pretrite and the posttrite because each mesoconelet is subdivided into two small cusps. The fourth loph has five cusps, three on the pretrite and two on the posttrite. The fifth loph has five cusps, each of which is subdivided. The sixth loph has six small cusps that are not well separated. The talon is small and not developed as a conule. The cement is thin in the valley at the posterior part. The median sulcus is strong on the first to the fourth lophs. Dimensions are 237 millimeters long and 110.83 millimeters wide at the second loph.

RIN351 left specimen is from the same individual as is the RIN351 right specimen. The M^2 and M^3 are preserved. The M^2 is broken on the anterior part. Its three lophs probably have four lophs in a complete specimen. The surface of the tooth is damaged. Its side has coarse enamel folding. The third molar has six lophs

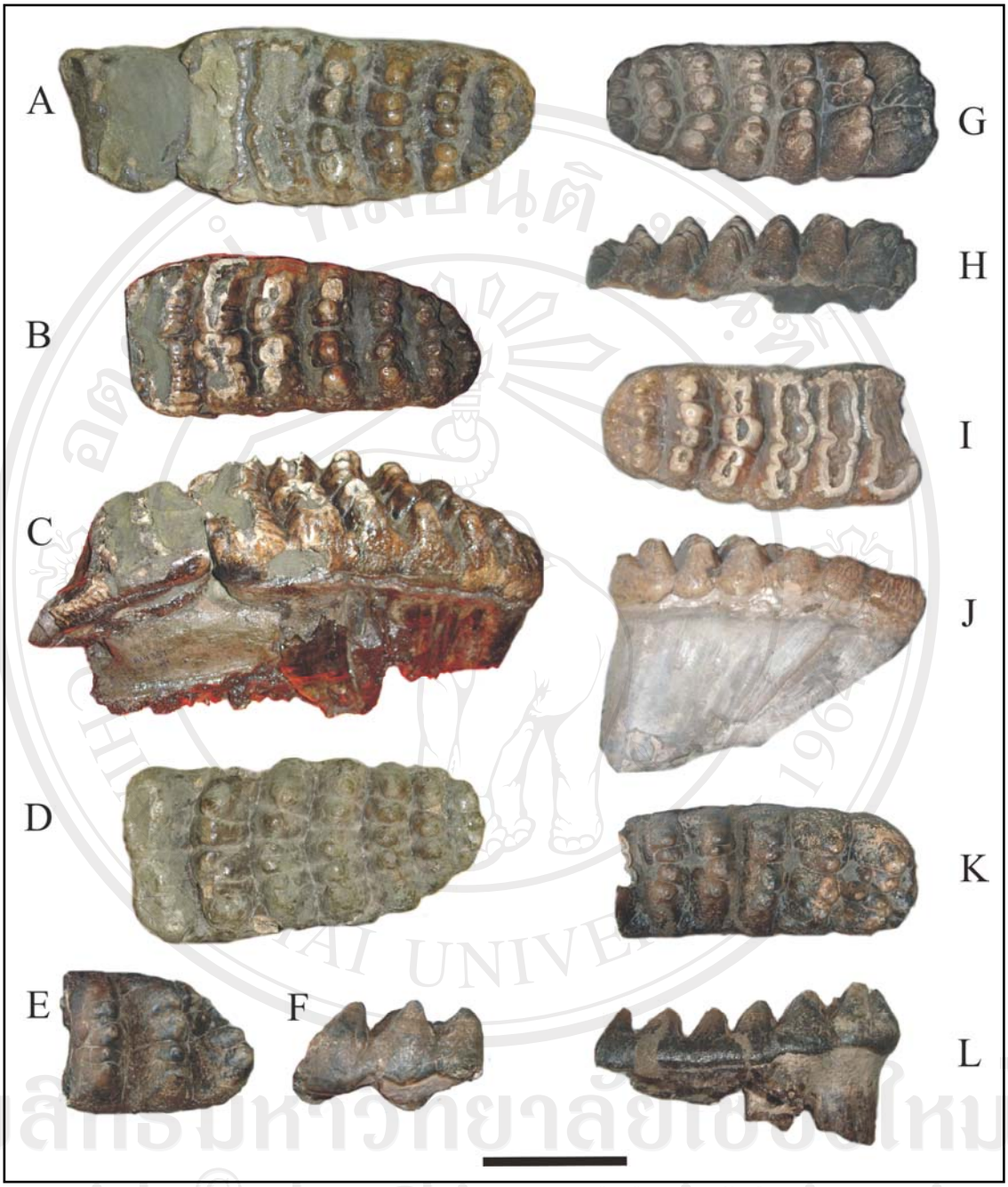

Fig. 3.43 *Stegolophodon* n.sp. 4 from the Tha Chang sand pits; RIN351 left and right M^3; A: occlusal view of right M^3, B: occlusal view of left M^3, C: lateral view of left M^3; RIN352 right M^3; D: occlusal view; CCZ64 fragmented left $M^{3?}$, E: occlusal view, F: lingual view; PRY18 left M^3, G: occlusal view, H: lingual view; PRY6 left M^3; I: occlusal view, J: lateral view; CCZ 50 fragmented right M_3; K: occlusal view, L: buccal view. Scale bar 10 centimeters applies to all.

and a small talon. The first to third lophs are worn and broken at the crown. Even so enamel folding is apparent. The posterior pretrite central conule on the first loph is indistinct. This differs from the second loph where both the anterior and posterior central conules are distinct. This character does not occur on RIN351 right. The third loph has the main structure as in the second loph, but it has a reduced posterior pretrite central conule and there is no anterior pretrite central conule. The fourth loph has six cusps, three on the pretrite and three on the posttrite. The fifth loph is a copy of the fourth loph, except that it is narrower. The sixth loph has five cusps and is very much narrower than the fifth loph. The talon is small and is developed as conules. The cement is thin in the posterior part. The median sulcus is distinct through the fifth loph. Dimensions are 246.05 millimeters long and 109.94 millimeters wide at the second loph.

RIN352 is an isolated upper right molar with an X6X tooth formula. Sediment coovers the tooth crown. The first loph is heavily worn and it has a sediment cover on the surface. The second loph is slightly worn. There are seven cusps, four on the posttrite and three on the pretrite. There is a posterior posttrite central conule but none on the pretrite. The third loph has three cusps on the pretrite and four cusps on the posttrite. The fourth loph is nearly a complete copy of the third loph, but with a shift median sulcus. The fifth loph has five cusps, though the sixth loph has only four cusps. The talon is large and developed as conules. The median sulcus is strong from the first to the third loph and is slightly shifted to the lingual in the fourth and fifth lophs. Dimensions are 252 millimeters long and 125.46 millimeters wide at the first loph.

PRY18 is the upper left M^3 with an X6X loph formula. Each loph has four ti seven conules becaused of the subdivision of the main cusps and mesoconelet. The first loph has a distinct posterior pretrite and posttrite central conules. The second loph also has a distinct posterior pretrite. The median sulcus is distinct. The molar crowns are low. Dimensions are 226.8 millimeters long and 98.84 millimeters wide at the third lophid.

PRY6 is a left M^3 with an X6X loph formula. It is heavily worn on the first three lophs, moderately worn on the fourth loph, and slightly worn on the fifth loph. The worn surface has smooth enamel-dentine junction folding. The median sulcus is distinct. Dimensions are 220 millimeters long and 101.58 millimeters wide at the first lophid.

CCZ50 is a right M_3? that is broken in the posterior part. It has five anterior lophids. The first lophid has posterior central conules on both sides. The second lophid has both anterior and posterior pretrite central conules, but there are no conules on the posttrite side. Each lophid has four to five conules with low crowns. The median sulcus is distinct. The mesial root supports only the first lophid. Dimensions are 211 millimeters long and 98.44 millimeters wide at the third lophid.

CCZ64 is a fragmented left M_3 that has three anterior lophids. Each of these lophids has four to five conules. The posterior pretrite central conule is distinct on the first lophid and, though still apparent, is smaller on the second and the third lophids. The maximum width at the third lophid is 98.77 millimeters.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

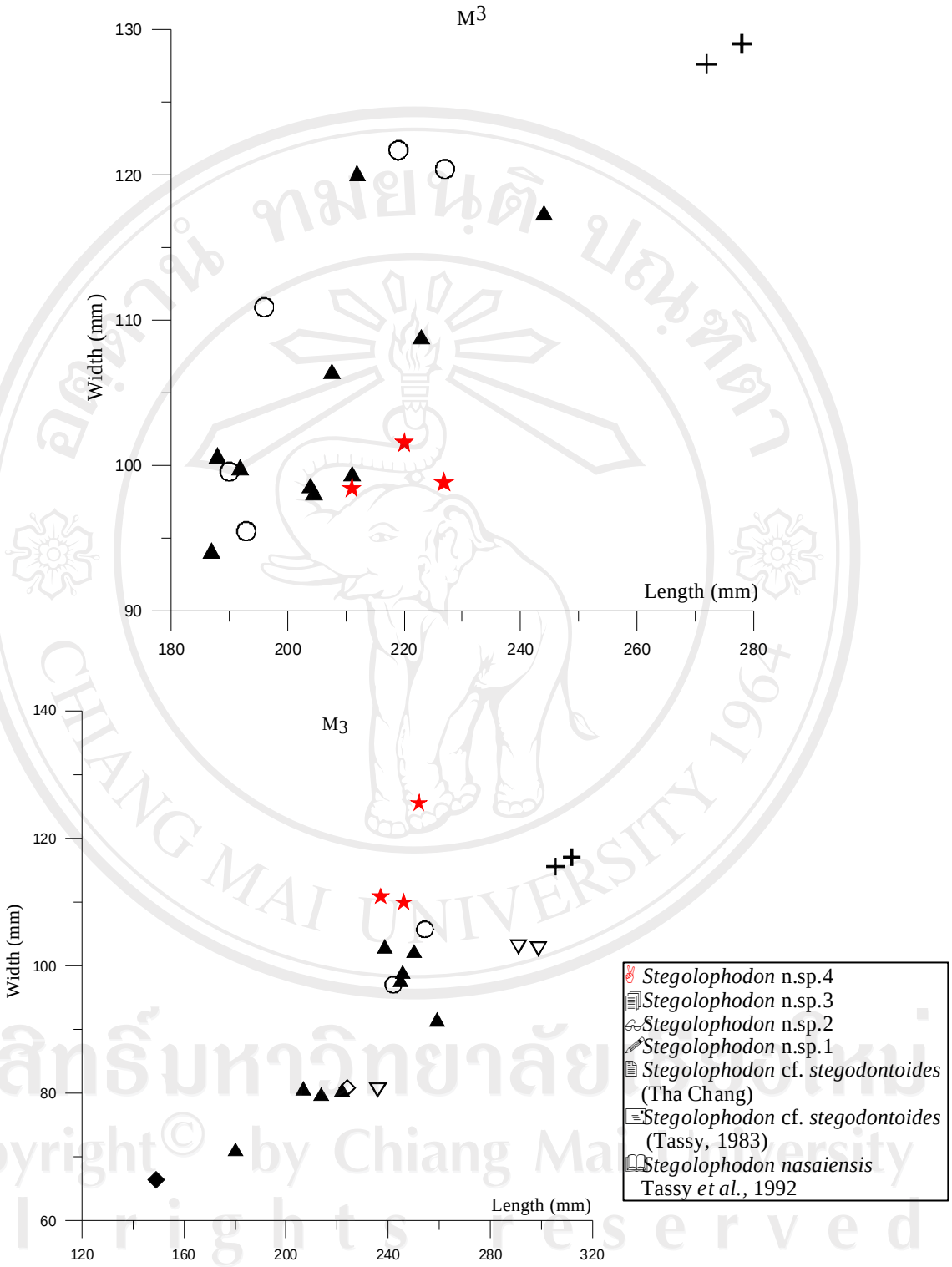

Fig. 3.44 The scatter diagrams of *Stegolophodon* n. sp. 4 compared with other *Stegolophodon* species.

Comparison: The number of lophs of *Stegolophodon* n. sp. 4 corresponds to the number of lophs of *Stegolophodon* cf. *stegodontoides*, *Stegolophodon* n. p.1 and *Stegolophodon* n. sp. 2. However, the subdivision of the molar cusps into six to eight mammillae is an advanced character. The size of *Stegolophodon* n. sp. 4 is not significantly different from that of the *Stegolophodon stegodontoides* group. However, *Stegolophodon* n. sp. 4 is much smaller than *Stegolophodon* n. sp. 1 (Fig. 3.44).

Genus *Stegodon*

Stegodonts were a group of elephant-like proboscideans that flourished during the Pliocene and Pleistocene in East and South Asia. They extended to Africa in the Middle Pleistocene. The generic definition of *Stegodon* was revised by Saegusa *et al*. (2005), based on the synapomorphy of a monophyletic taxon as follows:

1. intermediate molars carry five loph(id)s or more,
2. no distinct central conule on lower third molar,
3. no lower tusk, and
4. mesial root of lower third molar supports two lophids.

Stegodon n. sp. 1

Figs. 3.45 and 3.46

Diagnosis: *Stegodon* that has a molar structure between Group 6 *Stegolophodon* and Group 2 *Stegodon* of Seagusa *et al*., (2005). They have an X6X loph formula and

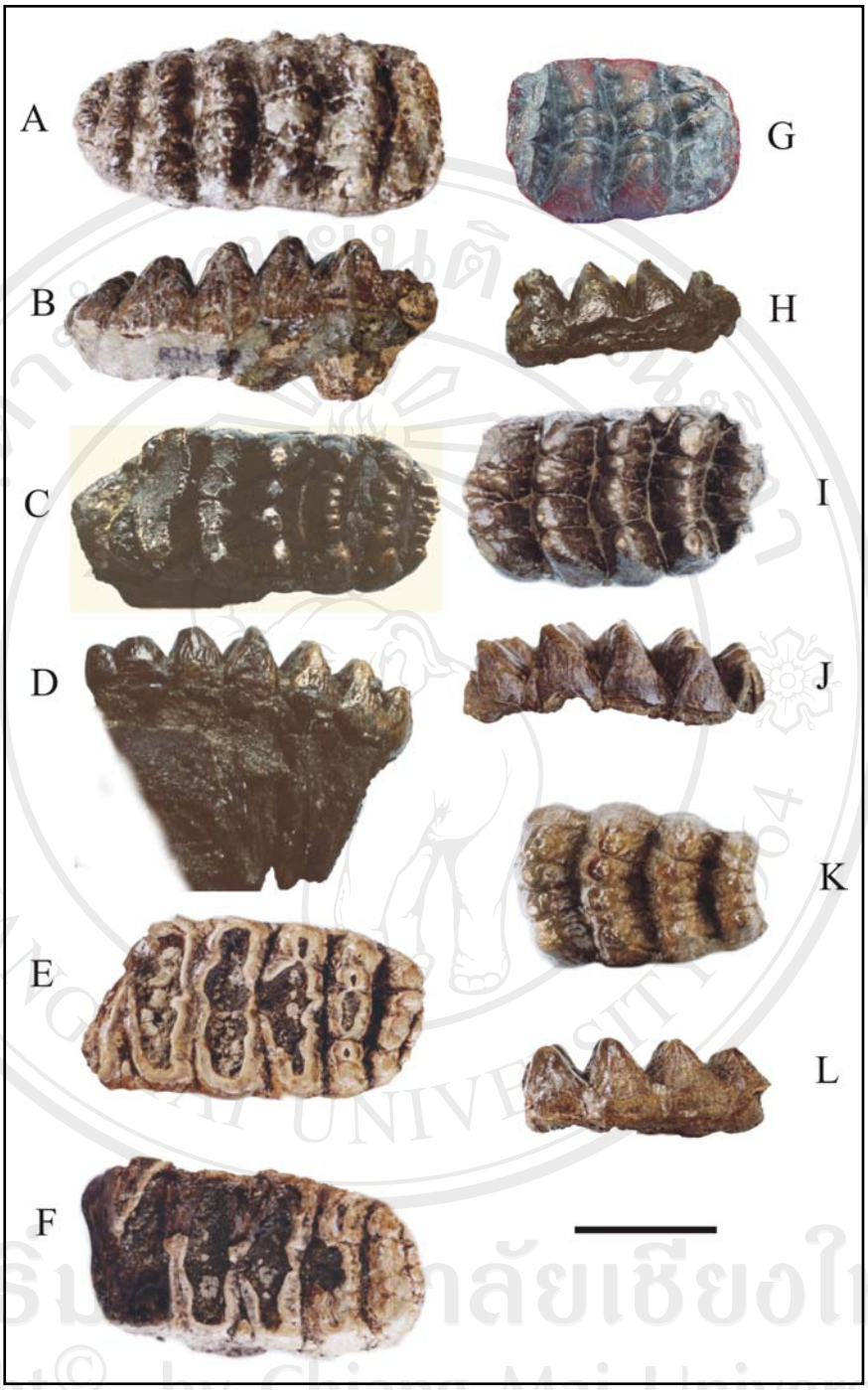

Fig. 3.45 Upper molars of *Stegodon* n. sp. 1 from the Tha Chang sand pits, RIN50 right M^3, A: occlusal view, B: lingual view; RIN24 right M^2, C: occlusal view, D: buccal view; RIN35 right M^2; E: occlusal view; RIN36 left M^2; F: occlusal view; RIN48 fragmented M^3, G: occlusal view, H: lateral view; RIN1 fragmented right M^3, I: occlusal view, J: lateral view. RIN31 fragmented M^2?; K: occlusal view, L: lateral view. Scale bar 10 centimeters applies to all.

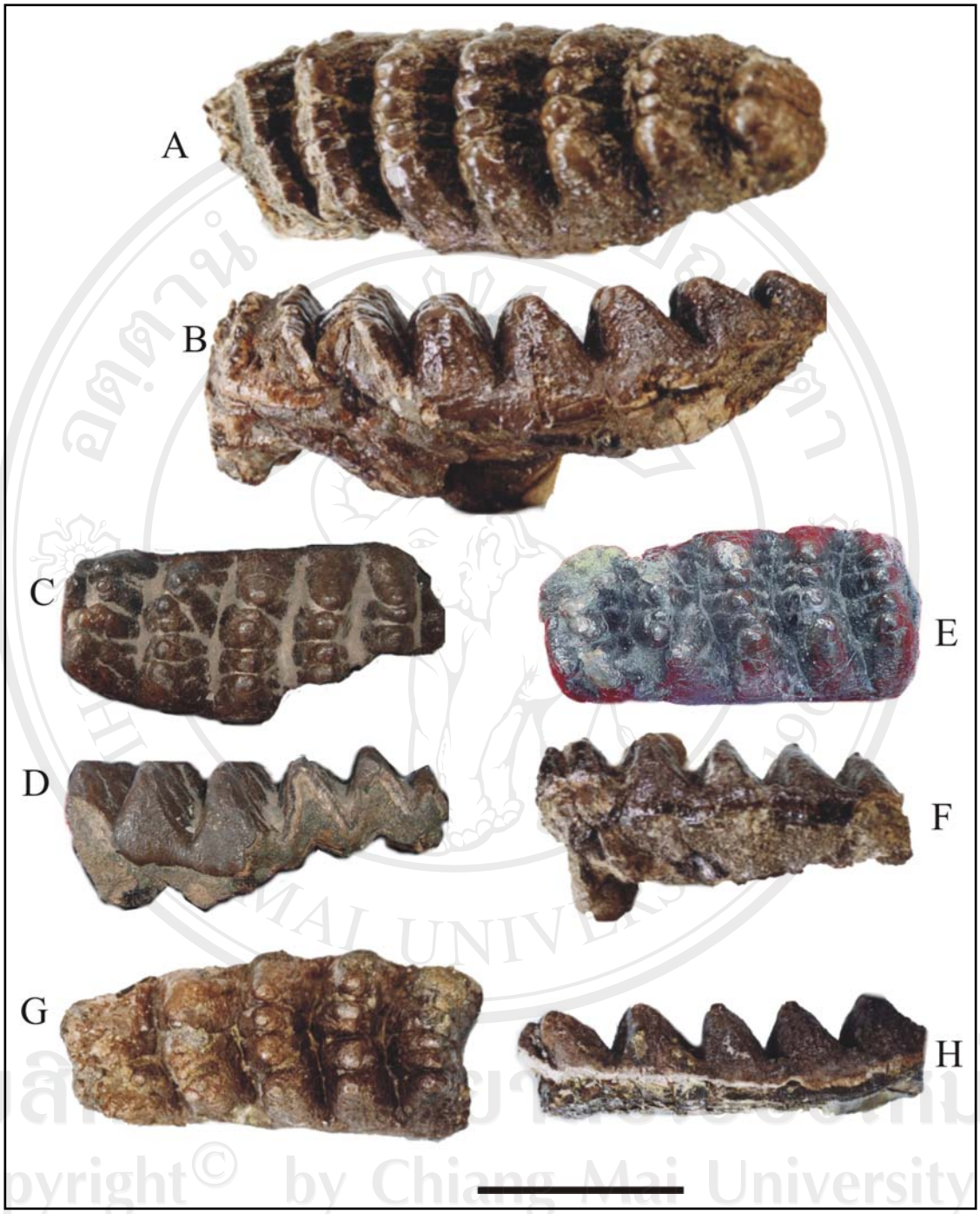

Fig. 3.46 Lower molars of *Stegodon* n. sp.1 from the Tha Chang sand pits; RIN46 left M_3, A: occlusal view, B: buccal view; CCZ02 right M_2, C: occlusal view, D: lingual view; RIN60 left M_2, E: occlusal view, F: lingual view; RIN32 left M_2, G: occlusal view, H: buccal view. Scale bar 10 centimeters applies to all.

an X6X or an X7X lophid formula. There are four conules on the anterior loph and these tend to be subdivided into six or more conules on the following loph. Enamel folding is irregular and wide stufenbildung, and has a large dimension. On the upper third molar, the median sulcus is distinct throughout the lophs but heavily displaced buccally. Buccal displacement of the median sulcus is commonly seen in stegolophodons and early stegodons. Cement corvering the crown is very thin, and the sulcus between cusps is very shallow.

Materials: RIN50: right M^3; RIN24: right M^3; RIN35: right M^3; RIN36: left M^3; RIN 48: fragmented M^3; RIN1: fragmented M^3; RIN3: fragmented M^2?; RIN46: left M_3; CCZ02: fragmented M_2; RIN60: fragmented M_2; RIN32: fragmented left M_2.

Upper molar description:

RIN50 is a complete right M^3 with an X6X loph formula. The median sulcus is distinct throughout the lophs but strongly displaced buccally. Cement covering the crown is very thin, and the sulcus between cusps is very shallow. It has distinct irregular enamel folding and wide stufenbildung. The cusps in each loph are subdivided into six to eight conules. Dimensions are 261 millimeters long and 122 millimeter wide at the second loph.

RIN24 is a complete right M^3 with an X6 loph formula. The first and second lophs are worn and have a coarse enamel-dentine junction. The slightly worn third loph has four conelets. The other loph crowns are subdivided into five to seven conules. Dimensions are 230 millimeters long and 115 millimeters wide at the fourth loph.

RIN35 is a right M^3 with an X6X loph formula. It is fully worn and incomplete. It has no anterior cingulum and nearly all of the first loph is missing. The tooth

surfaces are strongly folded. The median sulcus is not distinct. Each loph probably has four to six conelets. Dimensions are 236.5 millimeters long and 121.13 millimeters wide at the fourth loph.

RIN36 is a left M^3 with an X6X loph formula. The tooth is heavily worn and much damaged. The tooth structure is similar to RIN35. Dimensions are 239 millimeters long and 113.74 millimeters wide at the fourth loph.

RIN48 is a fragmented right M^3 that has three anterior lophs and the anterior part of the fourth loph. The first loph is broken. The posterior central conules are distinct on both the pretrite and the posttrite. The conelets of the second and third lophs are subdivided into six conules. The median sulcus is not distinct. The crowns are low. Width is 114.47 millimeters at the third loph.

RIN1 is a fragmented right M^3 that has four anterior lophs and the anterior part of the fifth loph. The tooth is slightly worn on the first and second lophs. The posterior central conules were distinct on the first loph. The median sulcus is distinct only on the first and second lophs. The conelets are subdivided into six conules in each loph. Dimensions are 212 millimeters long as of the preserved part and 129 millimeters wide on the second and third lophs.

RIN31 is an incomplete molar $M^2_?$ that is the middle part of the tooth. It has subdivided conules and no distinct median sulcus. The tooth probably belongs to this species. The maximum width is 112.5 millimeters.

Lower molar description:

RIN46 is a left M_3 with an X6X lophid formula. The anterior cingulum is damaged, though the others are well preserved. The first and second lophids are worn. The pretrite central conule is swollen on the posterior surface of the first lophid. Each

lophid crown is subdivided into four or five conules. The talonid is well developed as two conelets and separarted from the anterior lophid by a deep groove. It has a low crown. The median sulcus is not distinct. The tooth is in line. Dimensions are 290 millimeters long and 115 millimeters wide at the fourth loph.

CCZ02 is a left M_2 with an assumed X5X lophid formula because it is has a broken back part. The crowns are moderately high and subdivided into five or six conules. The median sulcus is not distinct. Dimensions are 189 millimeters long and 88.97 millimeters wide at the third lophid.

RIN60 is an incomplete left M_2 with an X5X lophid formula. There is no talonid. The crowns are low and subdivided into four or five conules. There are no distinct central conules and median sulcus. Dimensions are 177 millimeters long and 87 millimeters wide at the fourth lophid.

RIN32 is a left M_2 with an X5X lophid formula. It has no talonid caused by broken. Sediments cover the cown of the first and second lophids and cause the tooth structure to be indistinct. The third lophid has four conelets and these are subdivived into six conules in the following lophids. The length is 195 millimeters and the maximum width is 97.5 millimeters at the fourth lophid.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Comparison: *Stegodon* n. sp. 1 has an X6X tooth formula for M^3 and an X7X tooth formula for M_3. The intermediate molars are pentalophodont. It is comparable to *Stegodon officinalis* Hopwood, 1935, *S. baoshanensis* Yun Bo, 1975, and *S. zdanskyi* Hopwood, 1935, but the latter has no enamel folding and no stufenbildung. *Stegodon* n. sp. 1 differs from *S. elephantoides* (Clift, 1828) and *S. insignis biminicus*

Osborn, 1929, in having primitive characters, low cusps, and a small number of mammillae. Saegusa *et al*., (2005) mentioned that this species may be the ancestral of *Stegodon trigonocephalus* Martin, 1890, because of the irregular enamel folding and strong stufenbildung. These features could be derived characters and recall some morphotype of *Stegodon trigonocephalus* from Java.

***Stegodon* n. sp. 2**

Fig. 3.47

***Diagnosis*:** *Stegodon* with an X9X loph formula in M^3 and an X10X loph formula in M_3. The molar crowns are robust and subdivided into six to eight conules. There is coarse folding on the enamel-dentine junction. There is much cement in inter-valleys in the young individual and in the rear loph of the adult individual. The upper M^3s are more curved than in any other species.

***Materials*:** CCZ369: left M^3; PRY21: left M^3; CCZ362: left M^3; CCZ371: fragmented M^3; CCZ364: right M_3; CCZ363: left M_3; CCZ359: left M_3.

***Description*:** CCZ369 is a left M^3 with a -8X loph. However, the loph formula is probably X9X on the basis of its root. It is heavily worn on the fist two lophs and moderately worn on the next loph. It has coarse enamel folding on the enamel-dentine junction. The crowns are robust and low and subdivided into six conules. Cement is in the rear inter-valley. Dimensions are 255 millimeters long and 108.23 millimeters wide at the fifth loph. PRY21 is a left M^3 with an X10X loph formula. It is heavily worn on the anterior cingulum and on the fist three lophs and slightly worn on the fourth loph.

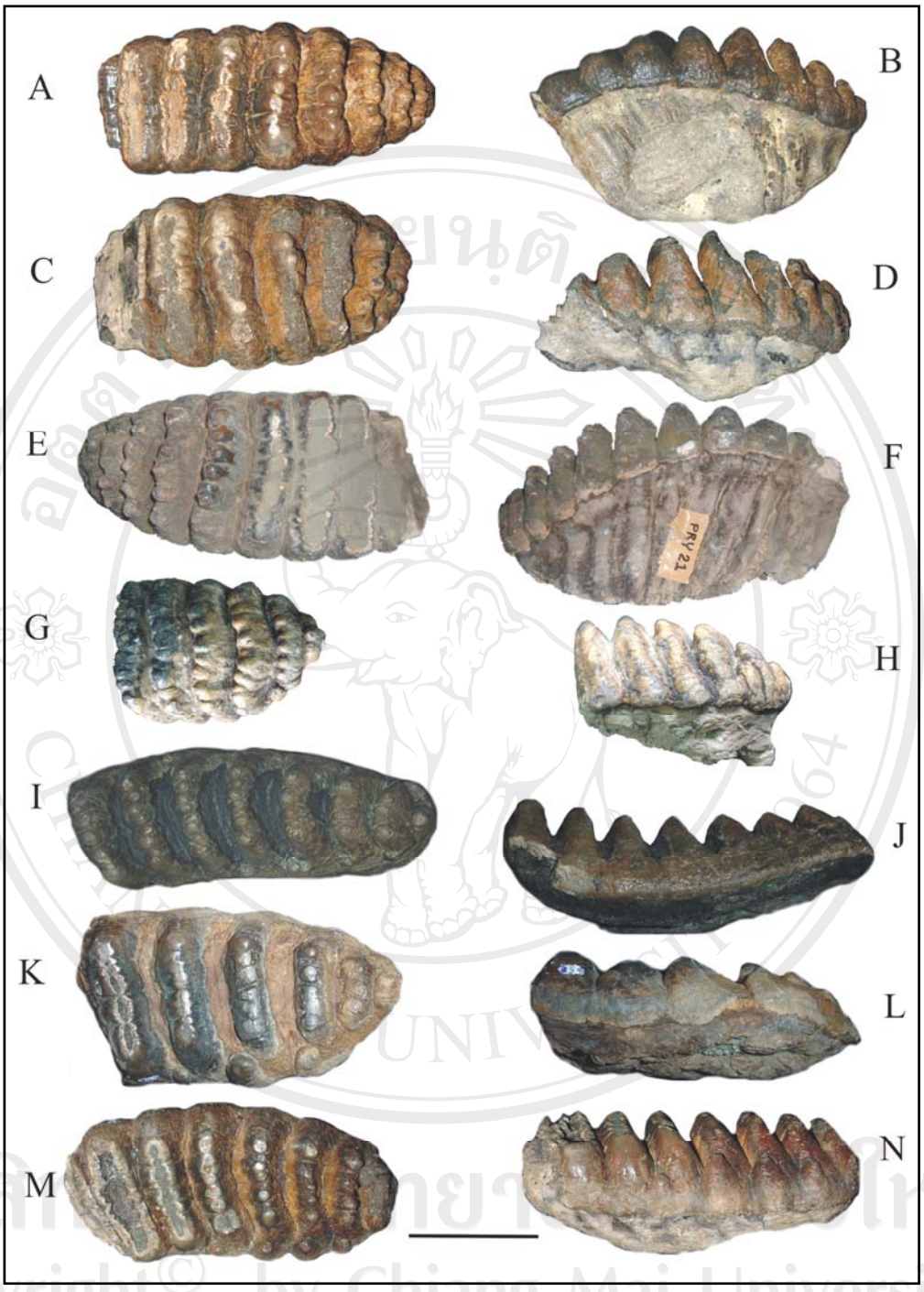

Fig. 3.47 The molars of *Stegodon* n. sp. 2 from the Tha Chang sand pits; CCZ369 right M^3, A: occlusal view, B: lateral view; CCZ362 left M^3, C: occlusal view, D: lateral view; PRY21 right M^3, E: occlusal view, F: lateral view; CCZ371 posterior part of M^3, G: occlusal view, H: lateral view; CCZ363 left M_3, I: occlusal view, J: lateral view; CCZ359 posterior part of left M_3, K: occlusal view, L: lateral view; CCZ364 left M_3, M: occlusal view, N: lateral view. Scale bar 10 centimeters applies to all.

The fifth loph is not worn. It has coarse enamel folding on the enamel-dentine junction. The crowns are low and subdivided into seven to ten conules. There is no cement in inter-valley. Dimensions are 264 millimeters long and 113.06 millimeters wide.

CCZ362 is a right M^3 with -6X lophs. Its loph formula is probably X8X. The anterior part is broken. The first and second lophs are worn and the worn surface has coarse enamel folding. The tooth crowns are moderately high, with six conules in each loph. Dimensions are 235 millimeters long and 129 millimeters wide.

CCZ371 is the posterior part of upper M^3 and has -5X lophs. The crowns are moderately high and have eight conules. The inter-valley has much cement. The maximum width is 93.87 millimeters on the first loph.

CCZ364 is a left M_3 with -6X lophids. The first and second lophids are heavily worn. The third lophid is moderately worn. Other lophids are unworn. It has coarse enamel-dentine folding. The tooth has low crowns and seven to eight conules. The rear valleys have cement. There are large lateral conules at the entrance of the fourth to six lophids. Dimensions are 255 millimeters long and 126.81 millimeters wide at the fourth lophid.

CCZ363 is a left M_3 with -7X lophids. The tooth is unworn. Its crown is low and has seven to eight conules. Its rear part has only four to five conules. The inter-valleys have much cement. The lateral conules are distinct of the pretrite half-lophid. Dimensions are 265 millimeters long and 103 millimeters wide at the third lophid.

CCZ359 is an incomplete left M_3 with -5X posterior lophids. The first lophid is moderately worn. The other lophids were slightly worn to unworn. The worn surface of the first lophid has coarse enamel folding. The tooth crowns are low and composed

of four to six conules. Every inter-valley has much cement. Lateral tublecles are at the entrance of the pretrite half-lophid. The second lophid is the widest, being 124.59 millimeters.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Comparison: *Stegodon* n. sp. 2 is as large as *Stegodon* n. sp. 1, *S. zdanskyi* Hopwood, 1935, and *S. elephantoides* (Clift, 1828). It differs from *Stegodon* n. sp. 1 and *S. zdanskyi* by having many lophs and much cement. It contains distinct irregular enamel folding that is more than that of *Stegodon* n. sp. 1. *Stegodon* n. sp. 2 is more primitive than *S. elephantoides* in its smaller number of mammillae and coarse enamel folding. This species has intermediate tooth structure between *S. zdanskyi* and *S. elephantoides*.

***Stegodon* n. sp. 3**

Fig. 3.48, A, B, C, D, E, F, and G

Diagnosis: Large *Stegodon* which has an X7X to an X8X loph formula on M^3 and an X9X to an X10X lophid formula on M_3. The crowns are subdivided into more than 10 fine conules. It has fine and irregular enamel folding.

Materials: CCZ367: left M^3; CCZ360: right M^3; RIN14: left M_3.

***Description*:** CCZ367 is a left M^3 with an X8X loph formula. The tooth is complete. However, it is damaged at the crowns. The crowns were finely subdivided into eight to ten conules in each loph. The inter-valleys have some traces of cement.

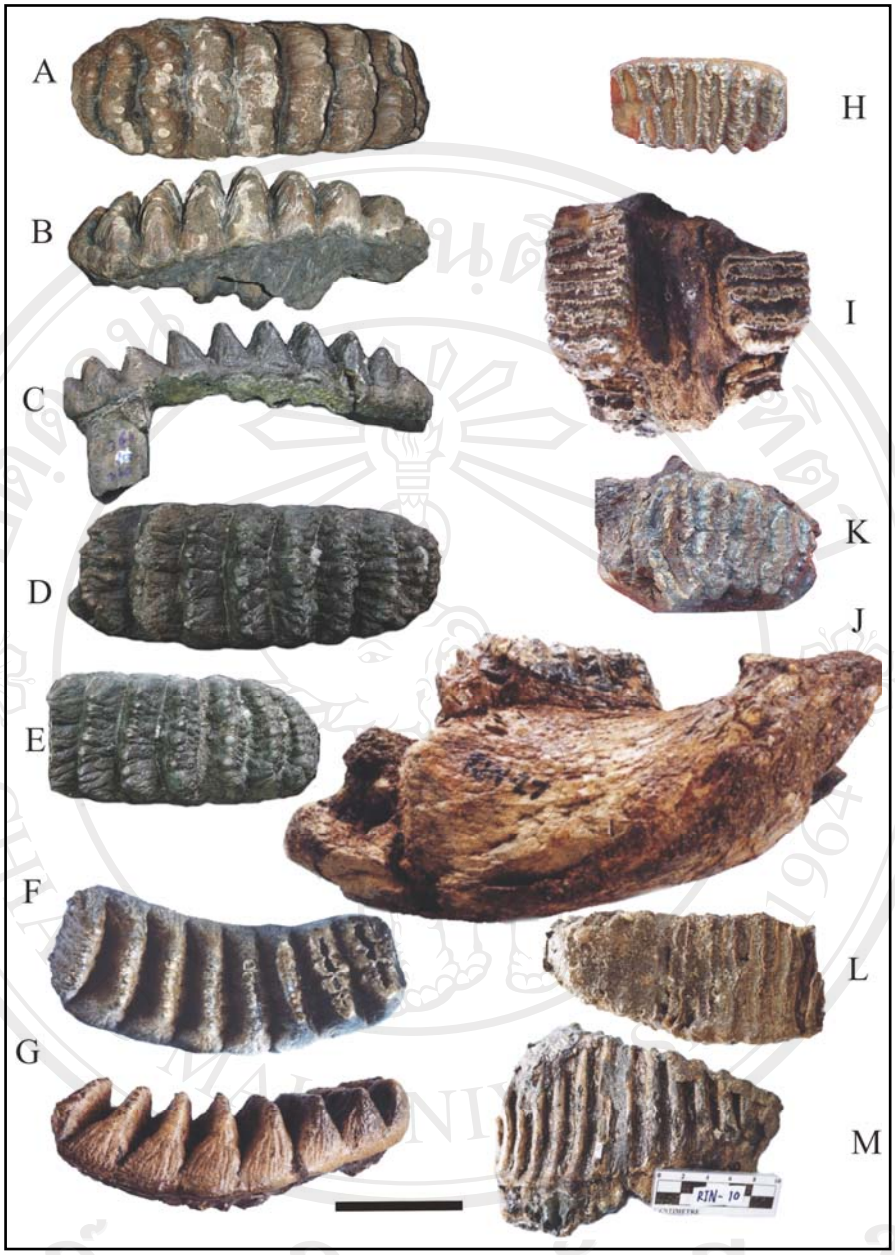

Fig. 3.48 The molars of *Stegodon* n. sp. 3, *Stegodon* sp., and *Elephas* sp. from the Tha Chang sand pits. *Stegodon* n. sp. 3, CCZ367 left M^3 A: occlusal view, B: lateral view; CCZ360 left and right M^3, C: lateral view of right M^3, D: occlusal view of right M^3, E: occlusal view of left M^3; RIN 14 left M_3, F: occlusal view, G: lateral view; *Stegodon* sp., RIN28 left and right M^1; H: occlusal-oblique view, I:maxillar with left and righ M^1; RIN27 left M_1, J: occlusal view, K: lateral view with mandible; *Elephas* sp. RIN10 $M^{1?,}$, L: occlusal view, M: lateral view. Scale bar 10 centimeters applies to all.

The crown is moderately high and the apex is perpendicular to the tooth axial. Dimensions are 292 millimeters long and 114.27 millimeters wide at the sixth loph.

CCZ360 is the left and right M^3. The left M^3 has a complete number of lophs but the right M^3 is broken at the anterior loph. These lophs have an X8X loph formula. The crown is subdivided into 10 to 12 conules. There is a median sulcus on the first three lophs of the left side but there is none on the right side. The widths of the intermediate lophs are nearly same, varying from 106 to 109 millimeters. The length of this tooth is 290 millimeters.

RIN14 is a left M_3 with X8- lophids, though there could be 10 lophids. The lophid formula is probably X10X. The first and second lophids are heavily worn. The third and the fourth are slightly worn. The crowns are subdivided into eight to ten conules in each loph. The lateral view is triangular as a result of the great difference of the width of the base and the apex. Dimensions are 267.8 millimeters long and 115.7 millimeters wide at the sixth lophid.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Comparison: *Stegodon* n. sp. 3 is an advanced species. It differs from *Stegodon* n. sp. 1 and *Stegodon* n. sp. 2 by its smaller mammillae, its finer enamel folding, and its greater number of lophs.

***Stegodon* sp.**

Fig. 3.48, H, I, J, and K

Materials: RIN28; a fragmented maxilla with left and right intermediate molars. RIN27 is a left mandible with an incomplete molar.

***Description*:** RIN28 is a fragmented maxilla with left and right molars. The right molar is complete and has an X8X loph formula. The left molar is incomplete, having only the last three lophs and talon. The teeth are heavily worn throughout. The worn surfaces have fine enamel-dentine junction folding. These teeth probably belong to M^1 or M^2. Dimensions are 145 millimeters long and 71 millimetes wide at the sixth loph.

RIN27 is a left mandible with $M_{1 \text{ or } 2}$. It has a heavily worn surface and is covered by sediment. The enamel-dentine junction folding is fine. The tooth has a -6X lophid formula. Dimensions are 156 millimeters long and 99 millimeters wide.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Remarks: This species has very fine enamel folding. The number of lophs on the intermediate molar is X8X. This corresponds to *Stegodon insignis* and *Stegodon ganesa* Falconer and Cautley, 1846, rather than to *Stegodon elephantoides* (Clift, 1828) and *Stegodon orientalis* Owen.

3.3.5 Family Elephantidae Gray, 1821

The evolution of the Elephantidae, *Loxodonta*, *Elephas*, and *Mamuthus*, was marked by and an enhancement of shearing and a reducing in grinding function. Permanent premolars were lost in most taxa, the molars elongated, and the jaw shortened. Paired cusps of the teeth became compressed into plates (lamellae) that incorporated in accessory columns. The lamellae are formed of pockets of dentine

encased in enamel, and the valleys between adjacent lamellae are filled with cementum. At their based the valleys are U-shaped in longitudinal section, an arrangement the permits the molars of elephantids to maintain shearing function through most of the height of the tooth (and which contrasts with the increasing compression of lamellae toward the base of the tooth in gomphotheriids, whose valleys are V-shaped; Maglio, 1972). Wear on the occlusal surface of the tooth horizontally section the series of lamellae into a series of broad transverse enamel loops surrounding dentine, separated and surrounded by cementum. Enamel, dentine, and cementum differ in hardness, and their differential wear leaves in relief a set of transverse, parallel enamel ridges, which act as cutting surfaces well adapted for shearing in a posterior-anterior direction. Interlocking occlusion between upper and lower dentitions is lost, and the cranium of elephantids shows modification for a forward shearing stroke of the masticatory muscles (Maglio, 1972).

Genus *Elephas* Linnaeus, 1758

***Elephas* sp.**

Fig. 3.48, L and M

Material: RIN10: an intermediate molar

Description: RIN 10 is an intermediate molar of *Elephas* sp. There are 13 plates on the tooth, may not be the last molar. The simplified closed lophs are not lozenge-shaped as in *Loxodon* sp.

Fossil locality: Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province.

Remarks: Throughout its evolutionary history, *Loxodonta* has remained in Africa. *Elephas* apparently dispersed twice out of Africa, in the mid-Pliocene into Asia where it evolved as a lineage terminating in *Elephas maximus*, and in the late Pliocene into Asia and Europe as lineages now extinct (Maglio, 1973, 114, 115). *Mammuthus* migrated out of Africa in the late Pliocene and subsequently spread rapidly throughout Europe, Asia, and North America (Todd and Roth, 1996). The last glaciation in the northern hemisphere coincided with the disappearance of *Elephas* from Africa and the extinction of *Elephas antiquus* and *Elephas falconeri* in Europe. The extinction of all remaining taxa of the Elephantidae, except for *Loxodonta africana* and *Elephas maximus*, occurred early in the Holocene (Maglio, 1972, 1973; Todd and Roth, 1996).

Elephantids are valuable for correlation of Plio-Pleistocene deposits because they underwent rapid evolution over a wide geological area, but the use of elephant taxa as biochronological indicators is complicated by the lack of an updated taxonomic revision or of general taxonomic consensus (Todd and Roth, 1996).