

CHAPTER 3

Results

Twenty specimens of the Miocene proboscideans from Thailand including *Stegolophodon nasaiensis*, *Stegolophodon* cf. *latidens*, *Stegolophodon* cf. *stegodontoides*, *Tetralophodon* cf. *xiaolongtanensis*, cf. *Protanancus macinnesi* and *Prodeinotherium pentapotamiae* were examined for dental microwear. The results of studied microwear in each specimen are as follows.

3.1 The characteristic of dental microwear of *Stegolophodon*

1. *Stegolophodon nasaiensis* (early Middle Miocene)

There are four samples of *Stegolophodon nasaiensis*. The fossil locality is located at Ban Na Sai coal mine, Li District, Lamphun Province. All specimens of *Stegolophodon nasaiensis* were suitable for microwear analysis. The dentine was entirely covered by enamel, with nearly no taphonomic defects.

NS-01a and NS-01b are the left upper third molar (left M³). The first loph is missing. The second loph is very well preserved. It has X5X loph formula. The posttrite mesoconelete of the second loph was molded for microwear analysis. The fourth loph of the same molar was included in the analysis to increase the sample size. The posttrite mesoconelete of the fourth loph was selected and molded. The selected positions on molar for microwear analysis were shown in Figs. 3.1 A and 3.1 B.

M4732a1 and M4732a2 are the holotype of *Stegolophodon nasaiensis*. The right lower second molar was completely attached to the third one. It has X4X lophid formula. The second molar exhibited the late wearing stage. The occlusal surface of the crown is worn nearly flat, with nearly all the enamel worn away and an extensive area of the dentine disclosed. However, a very trivial degree of taphonomic defects made this second molar suitable for microwear analysis. The pretrite fourth lophid was molded. The third molar shows less worn surface. It has X5X formula. The pretrite second

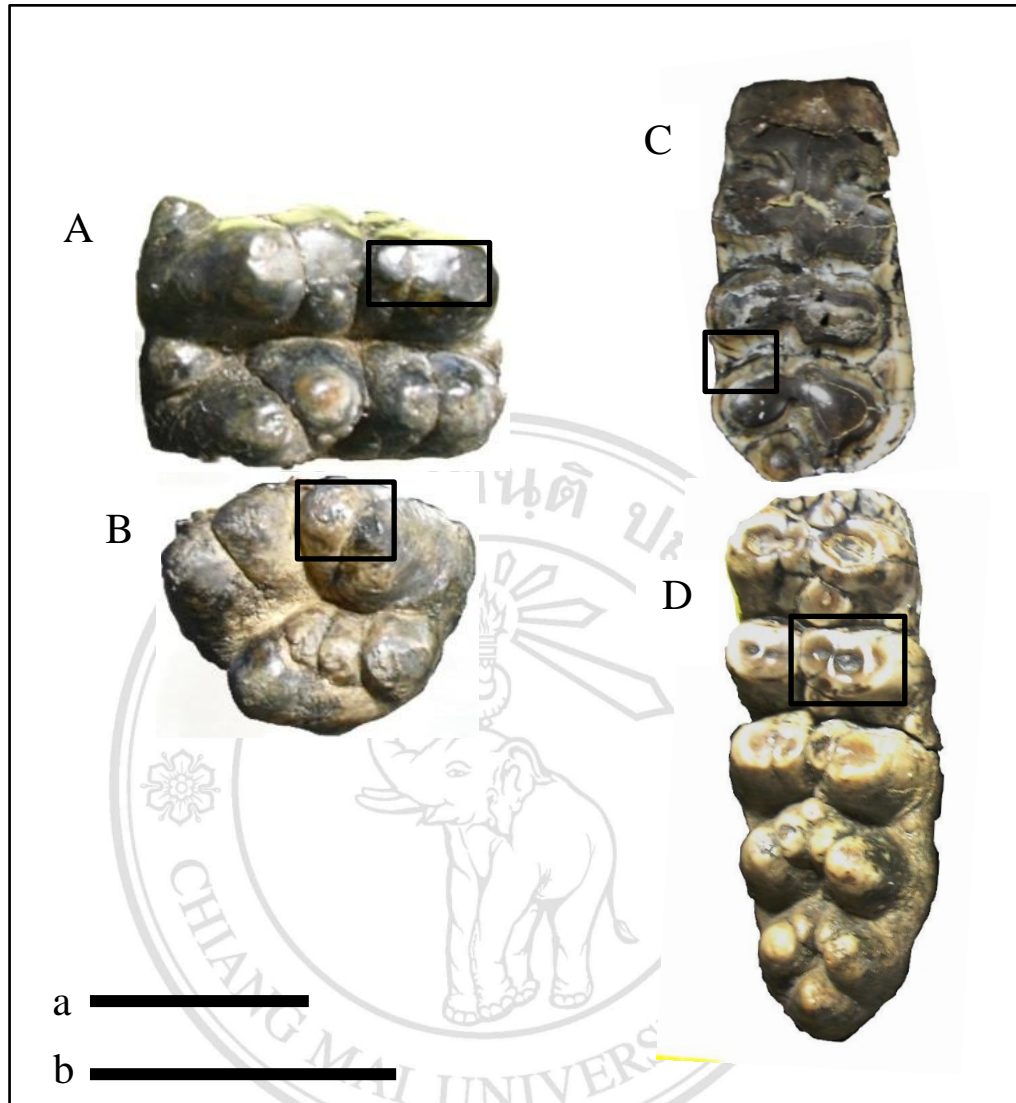


Fig. 3.1 *Stegolophodon nasaiensis* from the Ban Na Sai coal mine, Li District, Lamphun Province. A = NS-01a (left M^3): B = NS-01b (left M^3): C = type specimen, M4732a1 (right M_2): D = type specimen, M4732a2 (right M_3). Selected positions for microwear analyses are indicated by square markers. All images are occlusal view. Scale bar a, 5 cm. applies to A and B, scale bar b, 10 cm. applies to C and D.

lophid was selected for microwear analysis. The selected positions on molar for microwear analysis were shown in Figs. 3.1 C and 3.1 D.

The microwear results of NS-01a of light microscope show that large pits, including fine scratches are the outstanding microwear pattern. Puncture pits were also observed sporadically and the pit shape is typically round to ovoid (Fig. 3.2 A and B). The average number of pits is 36 and the average number of scratches is 7 (Table 3.1).

The detail characteristic of the microwear on scanning electron microscope show that puncture pits, small pits, and fine to coarse scratches are the outstanding microwear pattern. Puncture pits are apparent and typically round. Puncture pits were distinguished from the small pit by deeper cavity and sharper edges around the rim. Coarse scratches are about two times wider than fine scratches (Fig. 3.2 C). The microwear orientation of the NS-01a show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 90°.

The microwear results of NS-01b of light microscope show that puncture pits and coarse scratches are the outstanding microwear pattern. The puncture pit shape is typically ovoid to rectangle (Fig. 3.3 A and B). The average number of pits is 22 and the average number of scratches is 9 (Table 3.1).

The detail characteristic of the microwear on scanning electron microscope show that puncture pits and coarse scratches are also the dominant microwear features. Puncture pits are mostly ovoid and the coarse scratches are scattered with an equivalent width (Fig. 3.3 C). The microwear orientation on the NS-01b show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 120°.

The microwear results of M4732a1 of light microscope show that large pits and coarse scratches are the outstanding microwear pattern. The large pit shape is mostly ovoid (Fig. 3.4). The average number of pits is 30 and the average number of scratches is 12 (Table 3.1).

The detail characteristic of the microwear on scanning electron microscope show that large pits with the apparent puncture pit and coarse scratches are the dominant microwear features. Large pits are mostly ovoid and coarse scratches are dispersed with an equivalent width (Fig. 3.4 C). The microwear orientation on the M4732a1 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 120°.

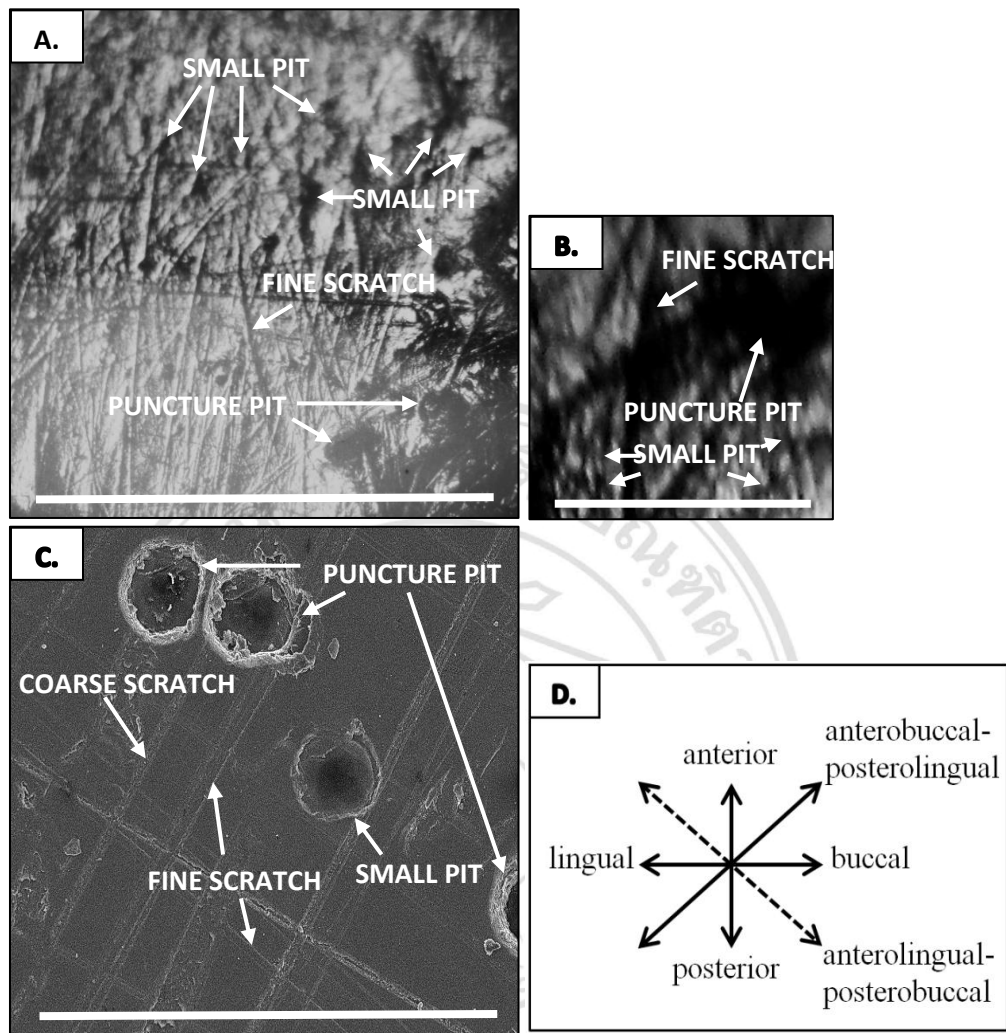


Fig. 3.2 Microwear images of *Stegolophodon nasaiensis* (NS-01a), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

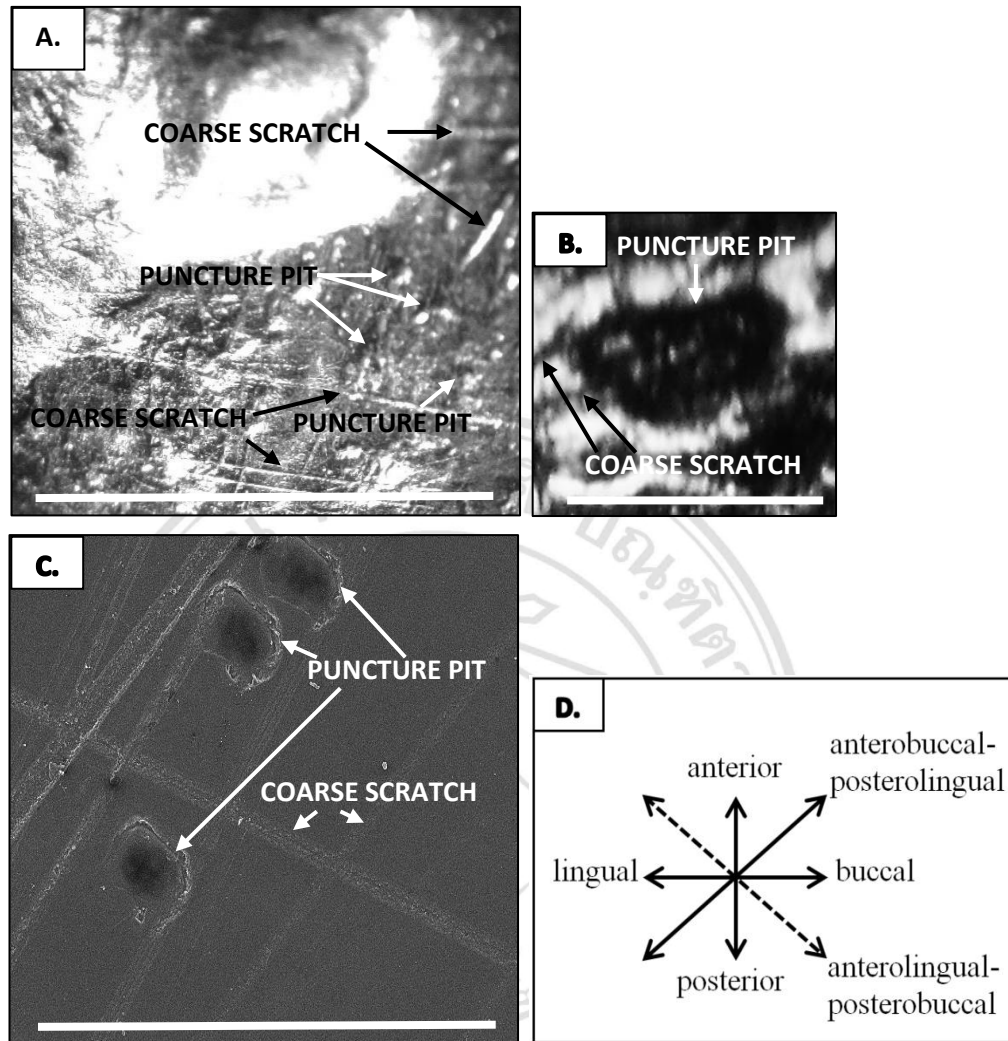


Fig. 3.3 Microwear images of *Stegolophodon nasaiensis* (NS-01b), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

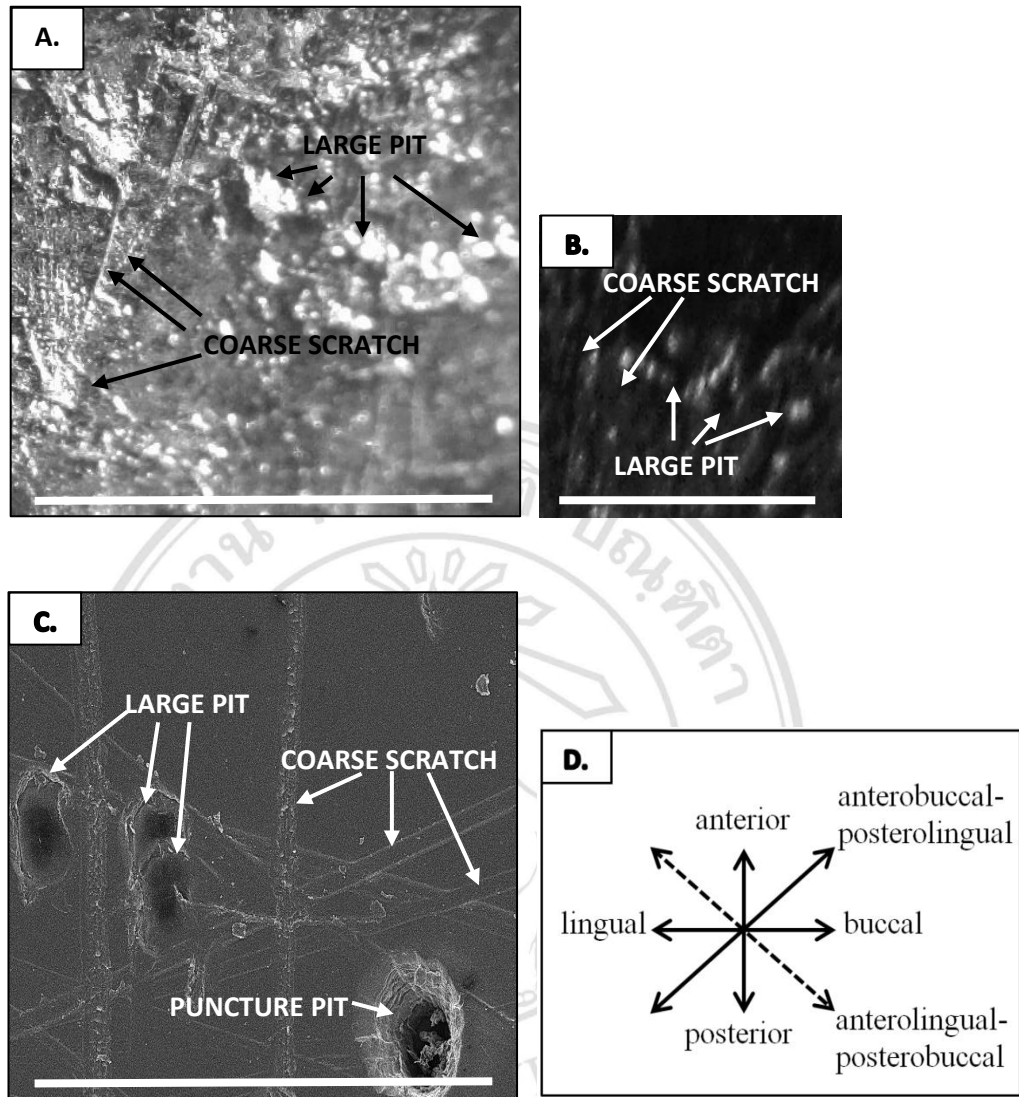


Fig. 3.4 Microwear images of *Stegolophodon nasaiensis* (M4732a1), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

The microwear results of M4732a2 of light microscope show that small pits and coarse scratches are the outstanding microwear features. Most of the pits are small pits with typically ovoid and rectangular shape. Large pits were found in the small fraction. Coarse scratches are scattered with equivalent width (Fig. 3.5 A and B). The average number of pits is 56 and the average number of scratches is 8 (Table 3.1).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the dominant microwear features. Small pits are mostly ovoid and coarse scratches are scattered with equivalent width. Puncture pit was apparently found with circular shape (Fig. 3.5 C). The microwear orientation on the M4732a2 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 120°.

Bivariate plots of scratch versus pit counts for *Stegolophodon nasaiensis* from Ban Na Sai coal mine suggested they are the browsers (Fig. 3.6).

2. *Stegolophodon cf. latidens* (middle Middle Miocene)

There are four samples of *Stegolophodon cf. latidens*. These fossils were discovered from Mae Moh coal mine, Lampang Province. All samples are kept at the museum of the mine. All specimens of *Stegolophodon cf. latidens* were suitable for microwear analysis with slightly corroded surface, due to lack of shellac coating.

M4733f is a left lower third molar (left M₃). It has X6X lophid formula. The occlusal surface was slightly corroded due to poor preservation. However, there is no evidence of post-mortem defects. The second lophid was selected for microwear analysis. The selected positions on molar for microwear analysis were shown in Fig. 3.7 A.

MMEL-3, MMEL-5 and MMEL-6 are fragmented molar with no description. Thus, it was unable to determine the orientation of these fragments. Nonetheless, the posterior end could be assumed from the presence of talons/talonids. The selected positions on molar for microwear analysis were shown in Figs. 3.7 B, 3.7 C and 3.7 D, respectively.

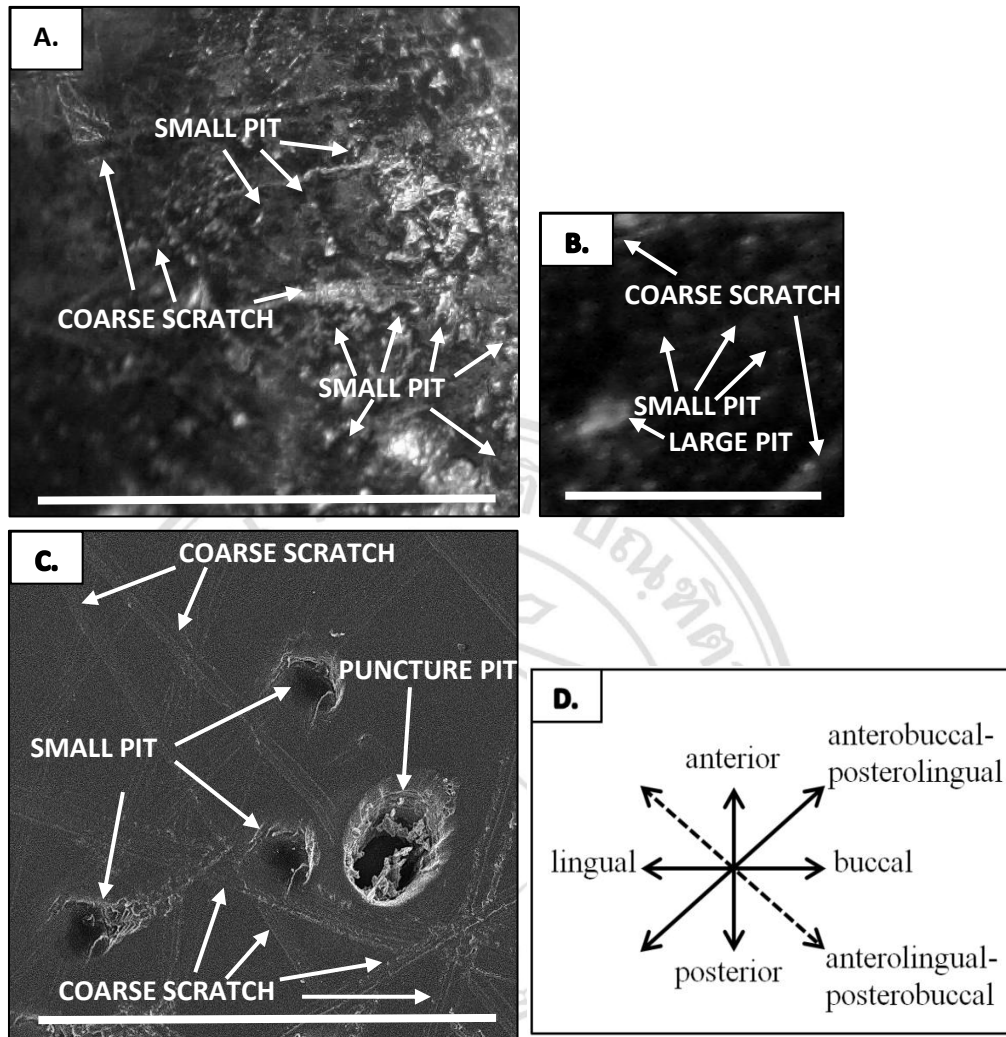


Fig. 3.5 Microwear images of *Stegolophodon nasaiensis* (M4732a2), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

Table 3.1 Microwear results of *Stegolophodon nasaiensis* specimens from Ban Na Sai coal mine, Li District, Lamphun Province. Data obtained from light microscope.

Specimens	Studied positions	Number of scratch	Number of pit	Percentage	
				scratch	pit
NS-01a: left M ³	Posttrite, second loph, mesoconelete	7	36	16%	84%
NS-01b: left M ³	Posttrite, fourth loph, mesoconelete	9	22	29%	71%
M4732a1: right M ₂	Posttrite, fourth lophid, main cusp	12	30	29%	71%
M4732a2: right M ₃	Pretrite, second lophid, mesoconelete	8	56	13%	88%

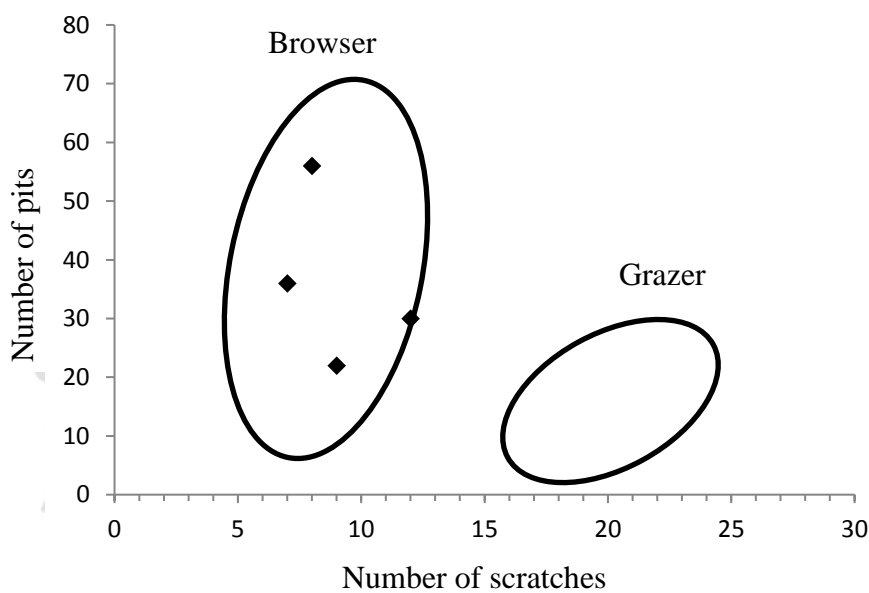


Fig. 3.6 Bivariate plots of scratch versus pit counts for *Stegolophodon nasaiensis*. Data obtained from light microscope. Gaussian confidence ellipses ($p = 0.95$) on the centroid are indicated for extant browsers and grazers adjusted by sample size (extant data from Solounias and Semperebon, 2002).

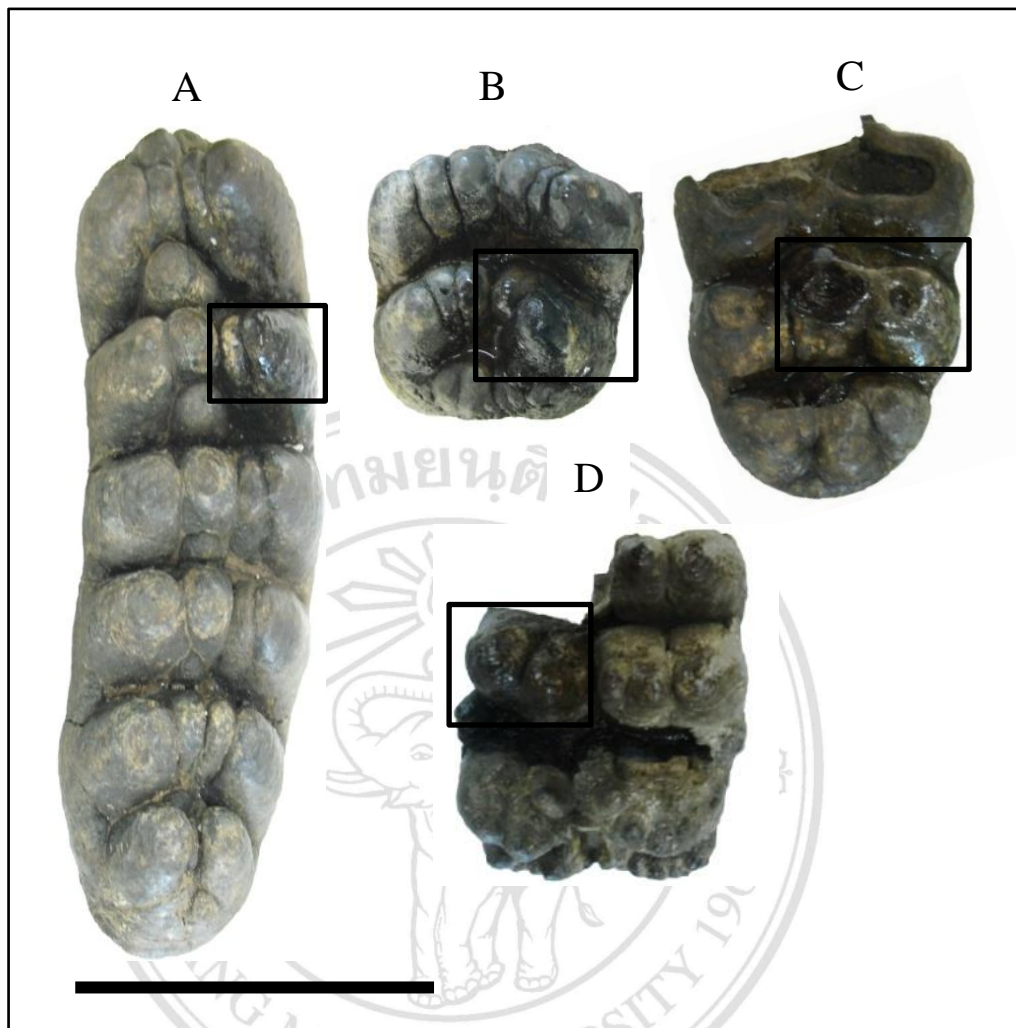


Fig. 3.7 *Stegolophodon cf. latidens* from Mae Moh coal mine, Lampang Province.

A = M4733f (left M₃): B = fragmented molar of MMEL-3: C = fragmented molar of MMEL-5: D = fragmented molar of MMEL-6. Selected positions for microwear analyses are indicated by square markers. All images are occlusal view. Scale bar = 10 cm. applied to all.

The microwear results of M4733f of light microscope show that small pits, including coarse scratches are the outstanding microwear pattern. Pit shape are typically round (Fig. 3.8). The average number of pits is 21 and the average number of scratches is 13 (Table 3.2).

The detail characteristic of the microwear on scanning electron microscope show that small pits and fine to coarse scratches are the outstanding microwear pattern. The pit shape is irregular and ovoid. Fine and coarse scratches were found in the same proportion. Coarse scratches are about two times wider than fine scratches (Fig. 3.8 C). The microwear orientation of the M4733f show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 90°.

The microwear results of MMEL-3 of light microscope show that small pits and coarse scratches are the outstanding microwear features. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.9 A and B). The average number of pits is 31 and the average number of scratches is 7 (Table 3.2).

The detail characteristic of the microwear on scanning electron microscope show that small pits, including coarse scratches are the outstanding microwear pattern. Small pits are apparent and typically round and shallow (Fig. 3.9 C). The microwear orientation of the MMEL-3 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 120°.

The microwear results of MMEL-5 of light microscope show that small pits, including coarse scratches are the outstanding microwear pattern. Small pits were observed all over the occlusal surface and the pit shape are typically round (Fig. 3.10 A and B). The average number of pits is 35 and the average number of scratches is 15 (Table 3.2).

The detail characteristic of the microwear on scanning electron microscope show that puncture pits and coarse scratches are the outstanding microwear pattern. Puncture pits are apparent and typically ovoid. Sharp edge was observed at the margin of the puncture pits (Fig. 3.10 C). The microwear orientation on the MMEL-5 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 90°.

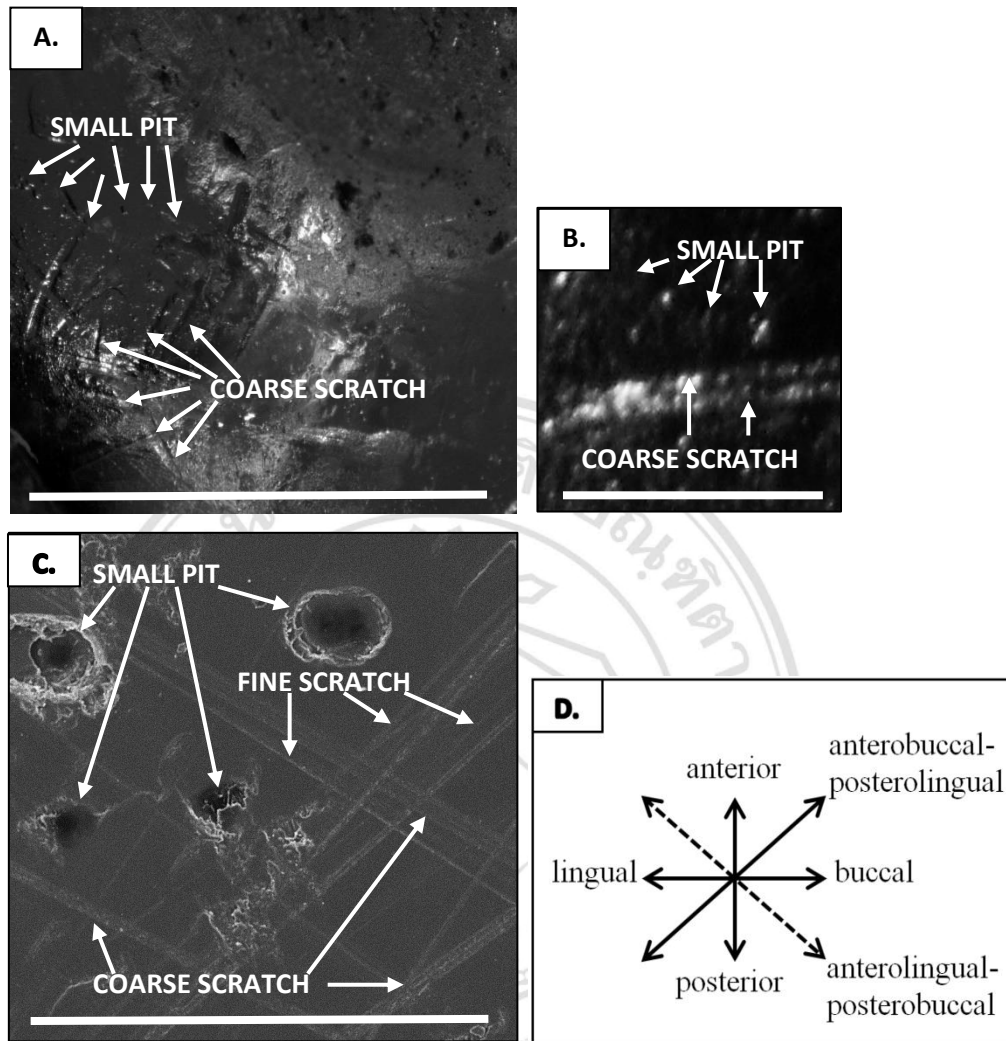


Fig. 3.8 Microwear images of *Stegolophodon cf. latidens* (M4733f), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

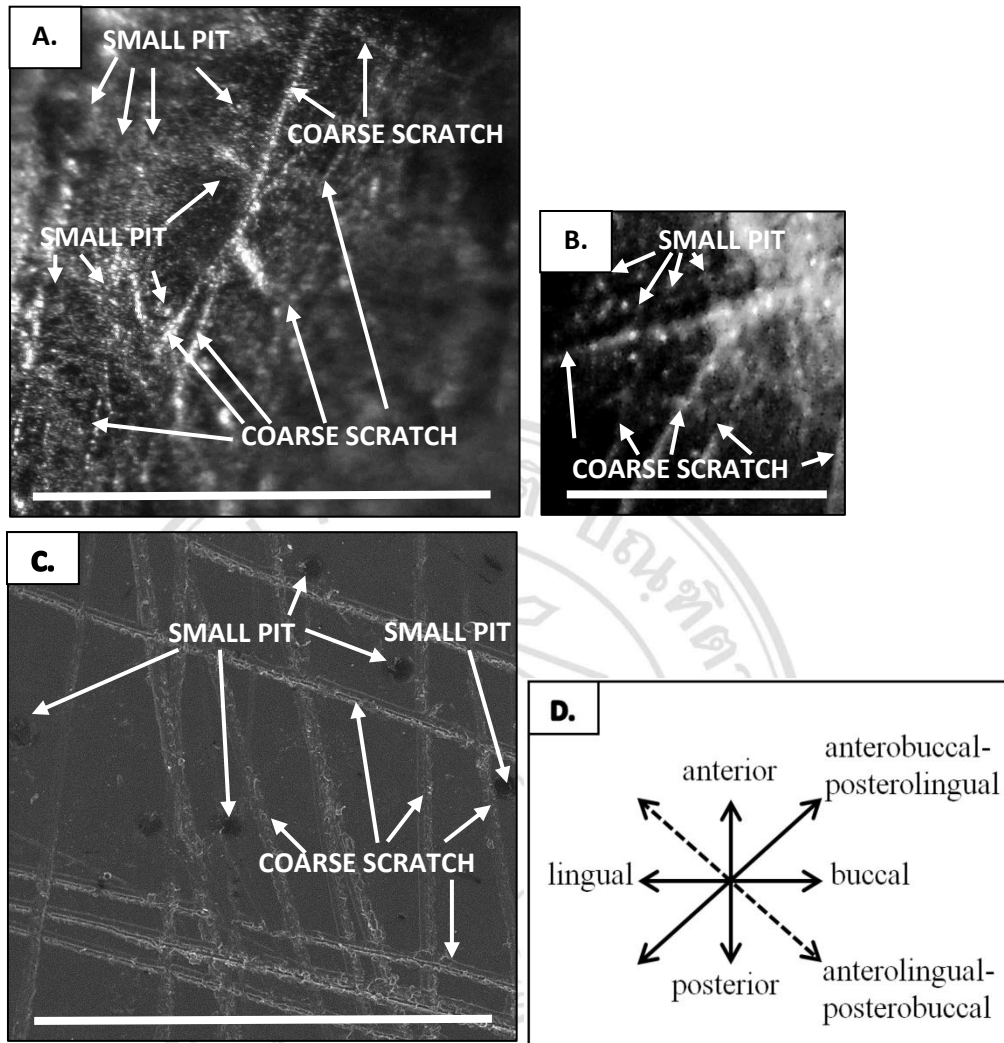


Fig. 3.9 Microwear images of *Stegolophodon cf. latidens* (MMEL-3), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

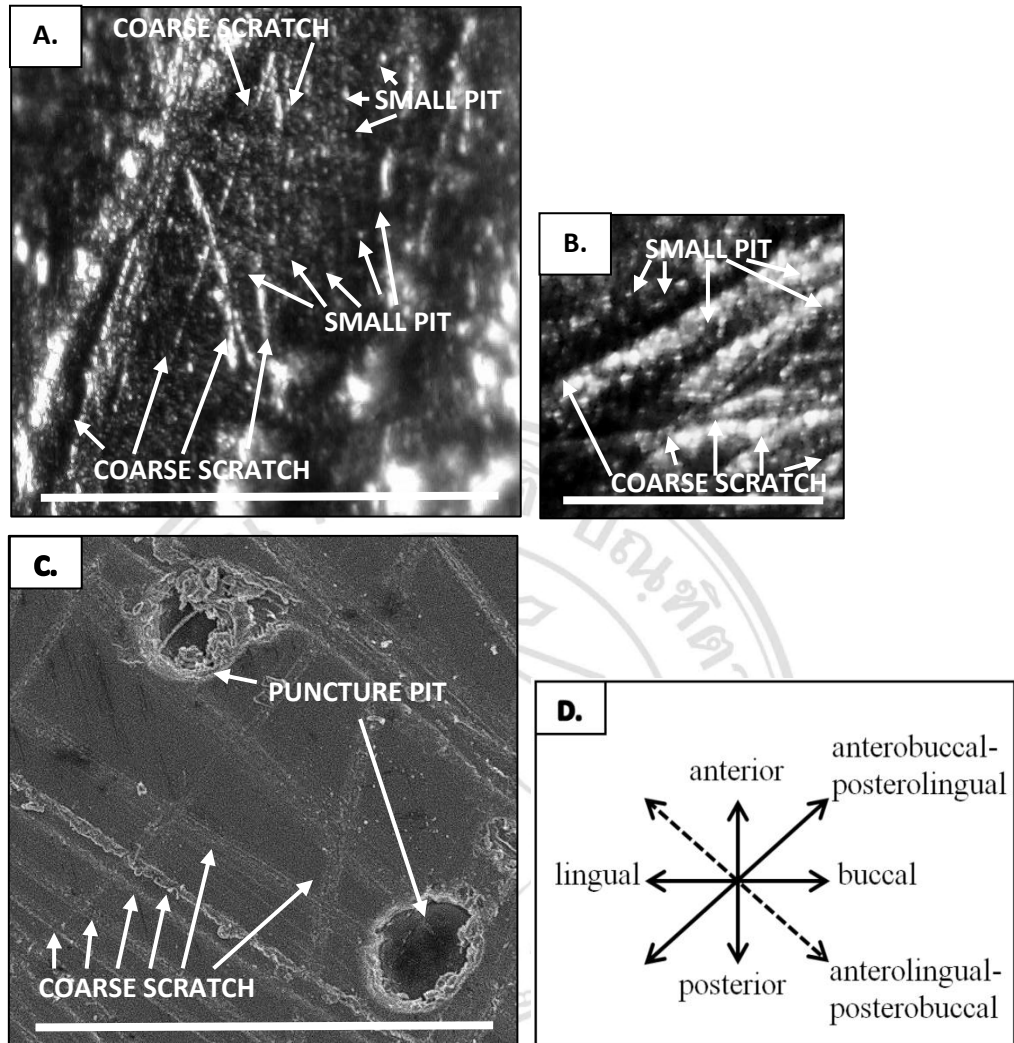


Fig. 3.10 Microwear images of *Stegolophodon cf. latidens* (MMEL-5), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

The microwear results of MMEL-6 of light microscope show that small pits, including coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape is typically round (Fig. 3.11 A and B). The average number of pits is 44 and the average number of scratches is 16 (Table 3.2).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits are typically round and shallow. (Fig. 3.11 C). The microwear orientation on the MMEL-6 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 60°.

Bivariate plots of scratch versus pit counts for *Stegolophodon cf. latidens* from Mae Moh coal mine suggested they are the mixed-feeders (Fig. 3.12).

3. *Stegolophodon cf. stegodontoides* (late Middle Miocene – Late Miocene)

The total number of the specimens of this species was thirty-nine. However, the suitable samples for microwear analysis were only three as a result of pyritization problem and poor preservation. All fossils were excavated from Tha Chang sand pits, Chaloeam Phra Kiat District, Nakhon Ratchasima Province

NM1-13 is a mandible with a left lower third molar (left M₃). It consists of seven lophids. The first four lophid were heavily worn with nearly no dentine left. The fifth lophid perfectly consists of four conelets. The posttrite main cusp was molded and examined for microwear analysis. The selected positions on molar for microwear analysis were shown in Fig. 3.13 A.

RIN55 is a right lower second molar (right M₂). It has X4X formula. It was heavily worn and the dentine exposed extensively. The talonid was broken. The pretrite side could be assumed from the position of the posterior central conelets. The pretrite of second lophid was selected and molded for microwear analysis. The selected positions on molar for microwear analysis were shown in Fig. 3.13 B.

RIN534 is a right lower third molar (right M₃). It consists of 6 lophids. The first and second lophids are broken. The fifth lophids consists of complete four conelets. The

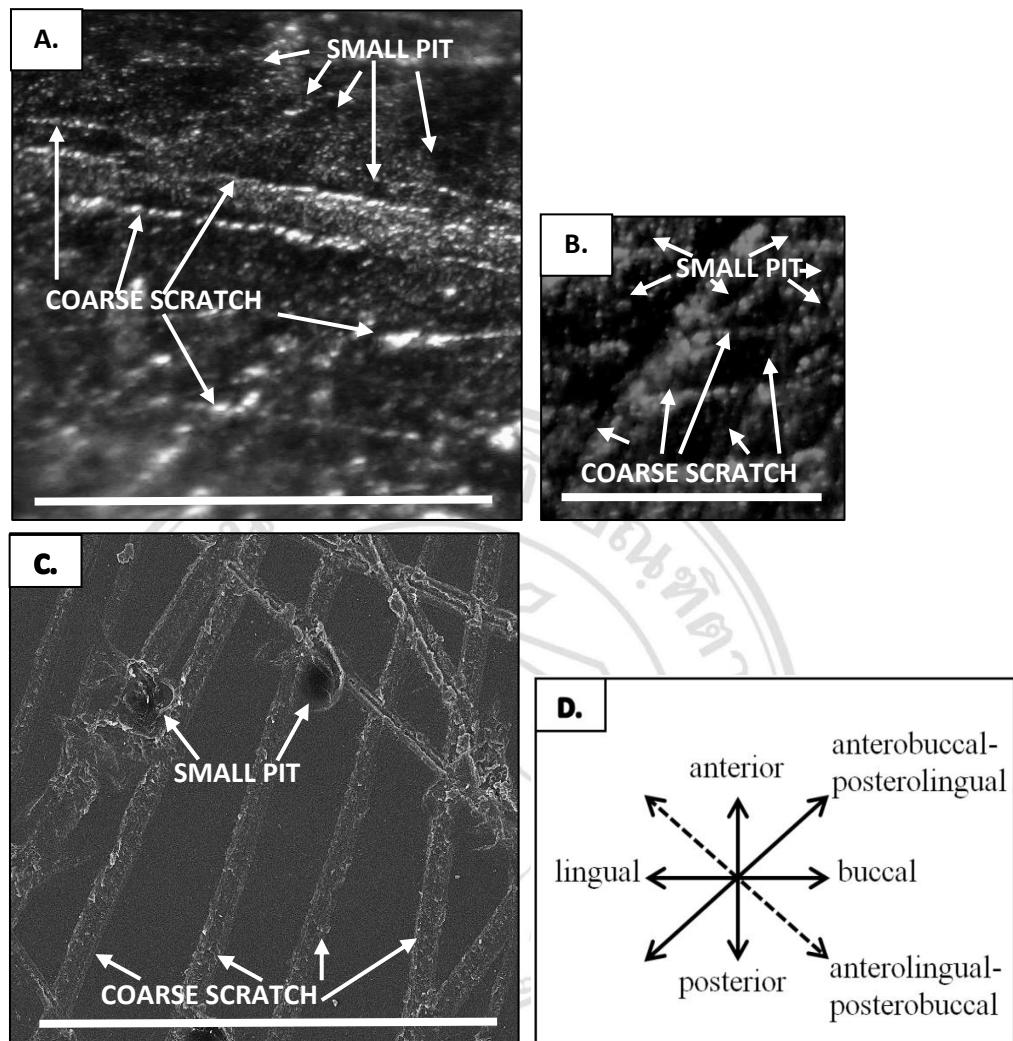


Fig. 3.11 Microwear images of *Stegolophodon* cf. *latidens* (MMEL-6), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

Table 3.2 Microwear results of *Stegolophodon* cf. *latidens* specimens from Mae Moh coal mine, Lampang Province. Data obtained from light microscope.

Specimens	Studied positions	Number of scratch	Number of pit	Percentage	
				scratch	pit
M4733f: left M ₃	Posttrite, second lophid, mesoconelete	13	21	38%	62%
MMEL-3	Fragmented molar	17	31	35%	65%
MMEL-5	Fragmented molar	15	35	30%	70%
MMEL-6	Fragmented molar	16	44	27%	73%

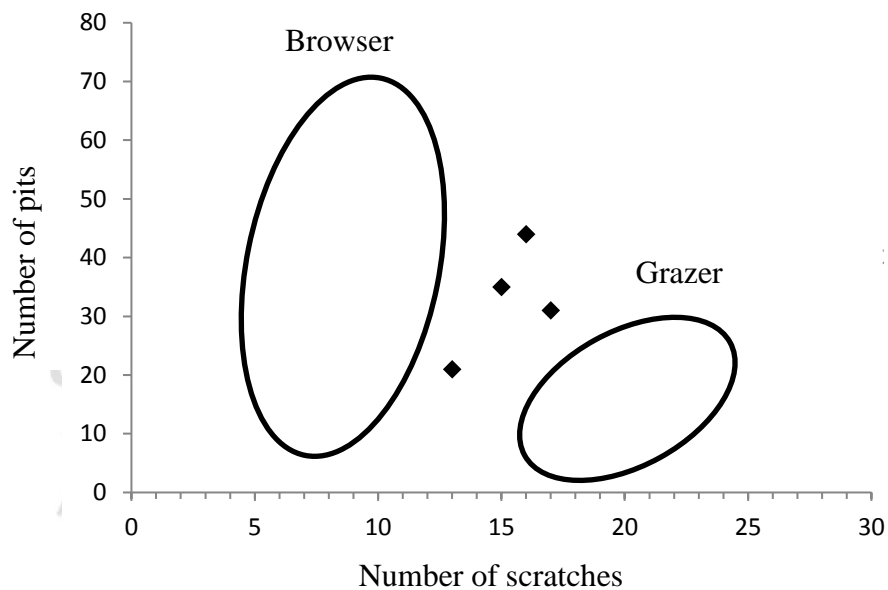


Fig. 3.12 Bivariate plots of scratch versus pit counts for *Stegolophodon* cf. *latidens*. Data obtained from light microscope. Gaussian confidence ellipses ($p = 0.95$) on the centroid are indicated for extant browsers and grazers adjusted by sample size (extant data from Solounias and Semprebon, 2002).

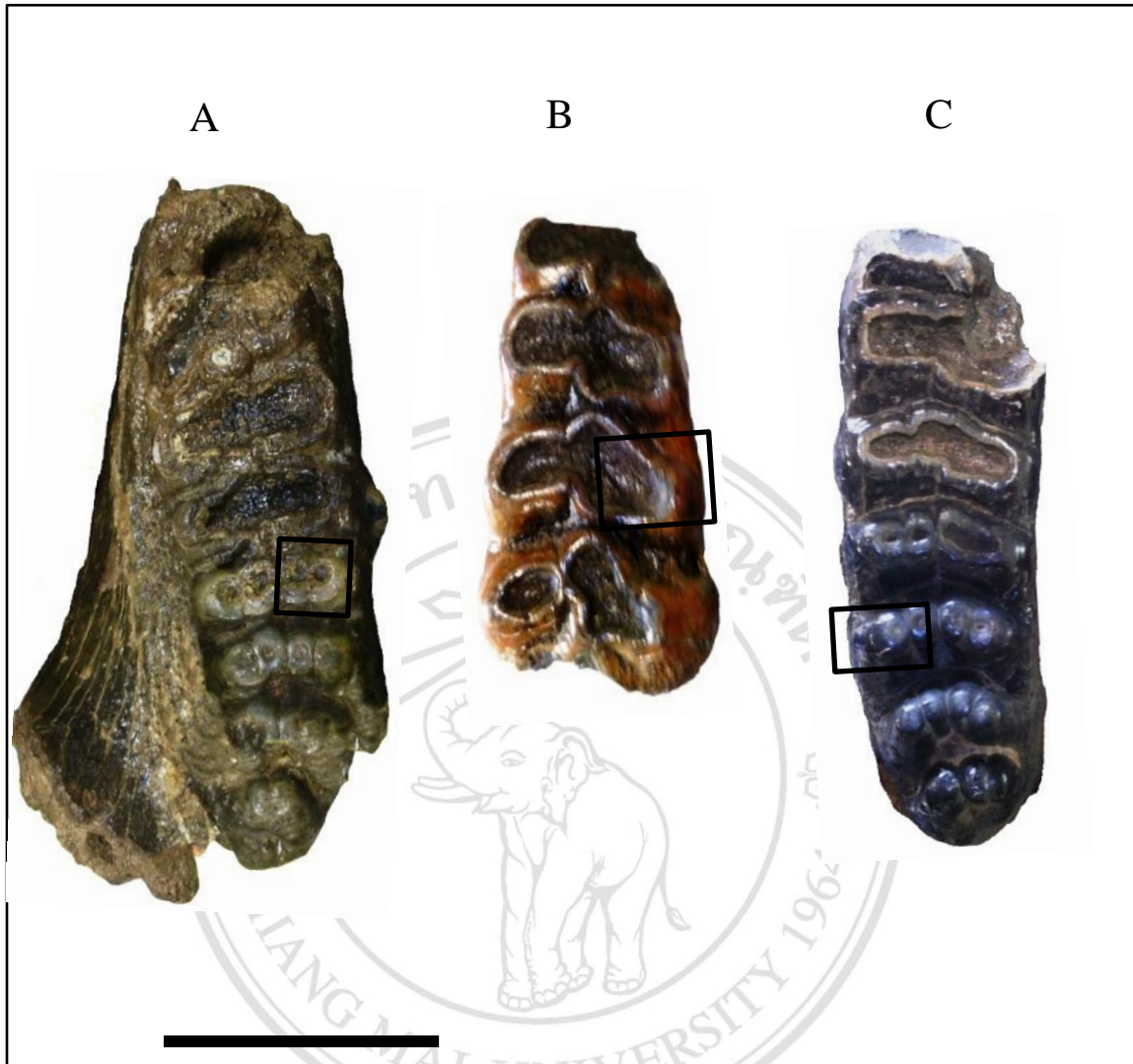


Fig. 3.13 *Stegolophodon* cf. *stegodontoides* from Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province. A = NM1-13 (left M₃): B = RIN55 (right M₂): C = RIN534 (right M₃) Selected positions for microwear analyses are indicated by square markers. All images are occlusal view. Scale bar = 10 cm. applied to all.

posttrite of the main cusp was examined by microwear analysis. The selected and molded positions on molar for microwear analysis were shown in Fig. 3.13 C.

The microwear results of NM1-13 of light microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.14 A and B). The average number of pits is 26 and the average number of scratches is 20 (Table 3.3).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits are typically round and ovoid. Fine scratches were also found. The width of coarse scratches is typically three times wider than those of fine scratches (Fig. 3.14 C). The microwear orientation on the NM1-13 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 60° .

The microwear results of RIN55 of light microscope show that small pits and coarse scratches are the outstanding microwear features. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.15 A and B). The average number of pits is 18 and the average number of scratches is 24 (Table 3.3).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits are typically round and shallow. Fine scratches were also found. The width of coarse scratches is typically three times wider than those of fine scratches (Fig. 3.15 C). The microwear orientation of the RIN55 shows anterobuccal-posterolingual and anterolingual-posterobuccal with angle 120° .

The microwear results of RIN534 of light microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.16 A and B). The average number of pits is 16 and the average number of scratches is 23 (Table 3.3).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits are typically ovoid. Fine scratches were also found. The width of coarse scratches is typically three times wider than those of fine scratches (Fig. 3.16 C). The microwear

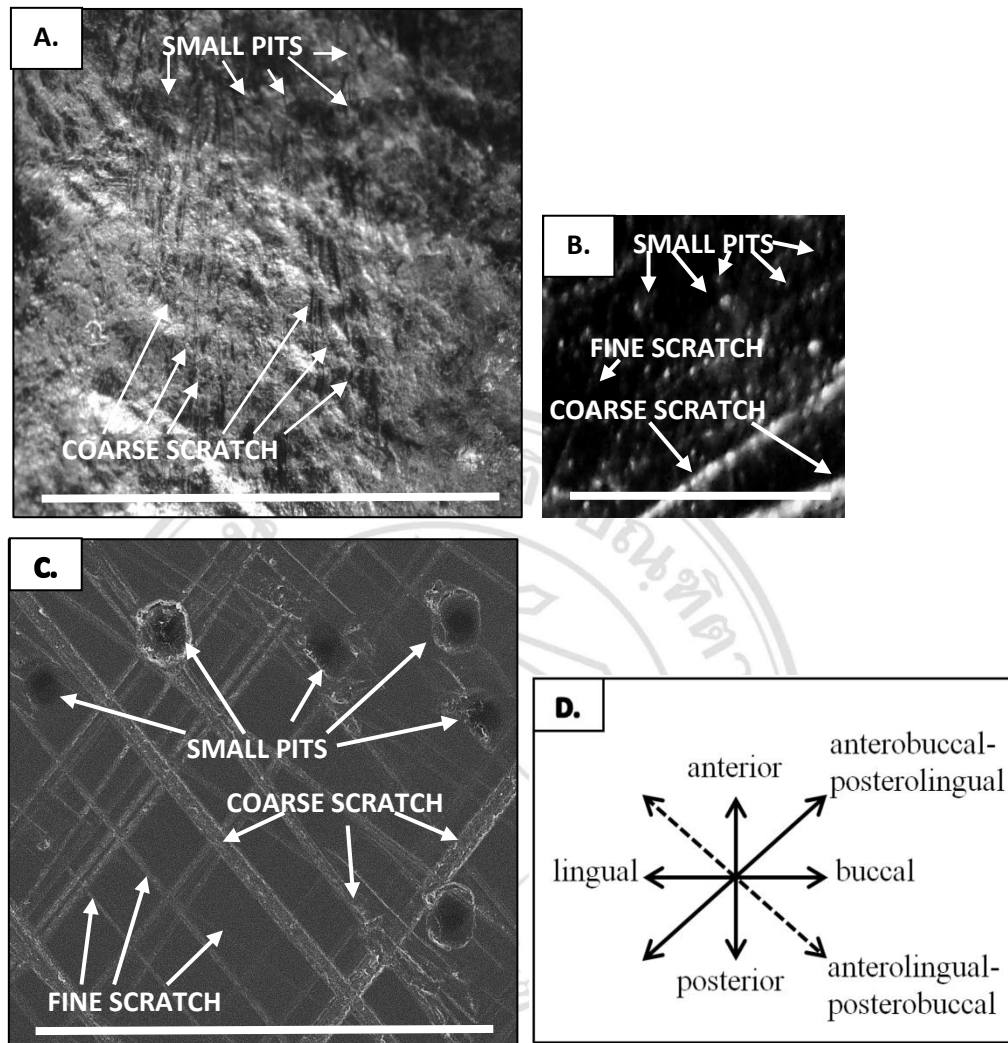


Fig. 3.14 Microwear images of *Stegolophodon cf. stegodontoides* (NM1-13), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

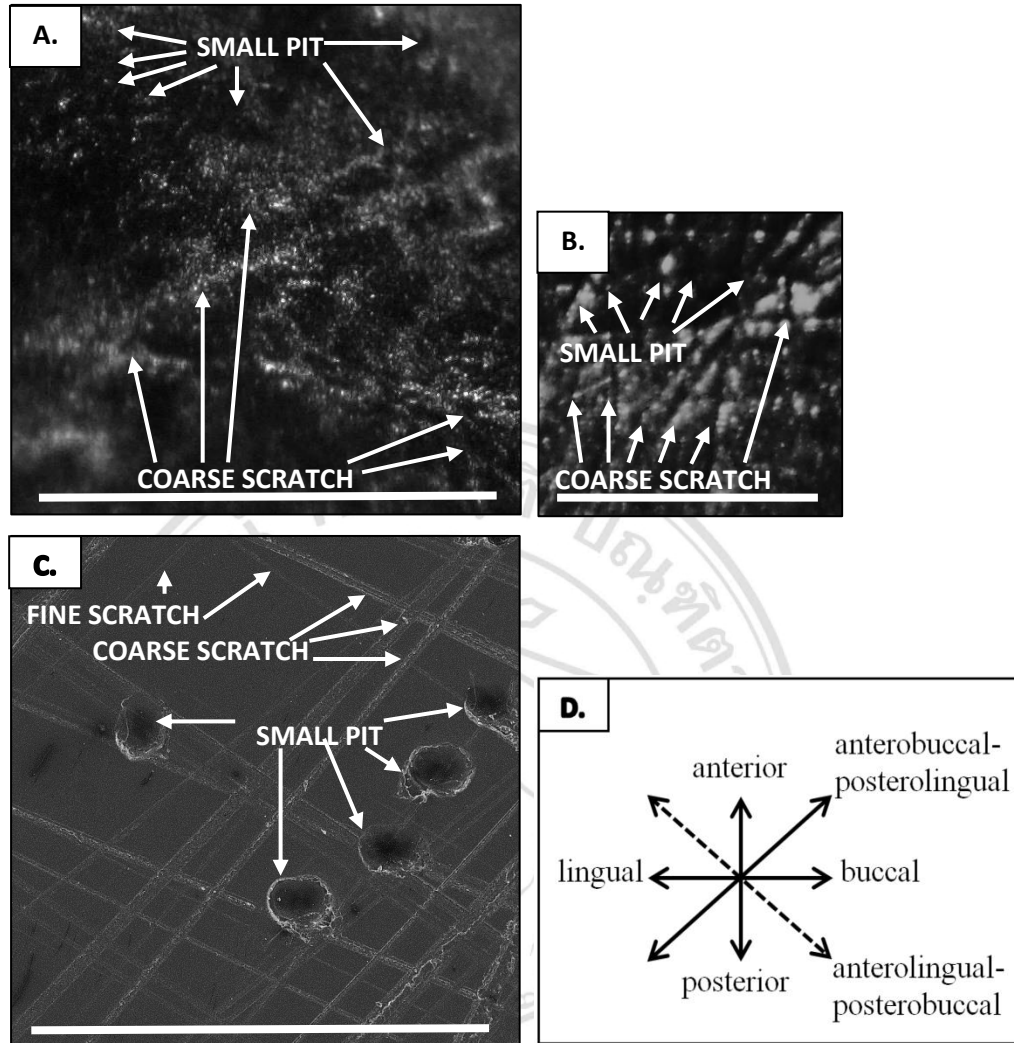


Fig. 3.15 Microwear images of *Stegolophodon cf. stegodontoides* (RIN55), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

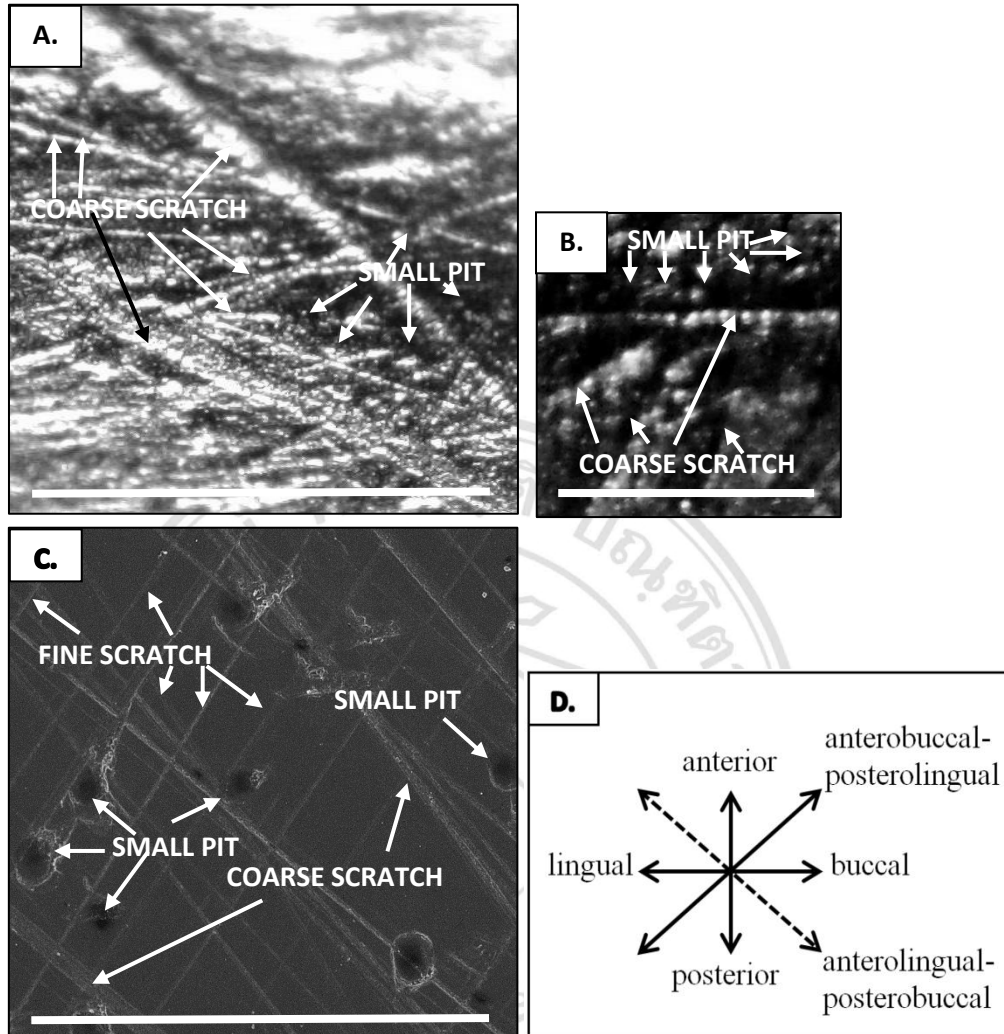


Fig. 3.16 Microwear images of *Stegolophodon cf. stegodontoides* (RIN534), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the antero-lingual-postero-buccal direction and the bold-line showing the antero-buccal-postero-lingual direction.

orientation on the RIN534 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 60°.

Bivariate plots of scratch versus pit counts for *Stegolophodon cf. stegodontoides* from Tha Chang sand pits suggested they are the grazers (Fig. 3.17).

3.2 The characteristic of dental microwear of *Tetralophodon*

Tetralophodon cf. xiaolongtanensis (latest Middle Miocene)

There are four samples of *Tetralophodon cf. xiaolongtanensis*. The fossils were discovered at Chiang Muan coal mine, Chiang Muan District, Phayao Province. Now, these fossils are housed at the museum of the coal mine. All specimens are in good condition. There is no sign of any taphonomic defects made from sediment or the collecting process. All specimens show heavily worn surface. The enamel, mostly worn away and the extensive area of dentine exposed.

CMn2 is a left upper second molar (left M²) with the missing first loph. It has an X4X loph formula. The main cusp of the second loph on the pretrite side was molded for microwear examination. The selected positions on molar for microwear analysis were shown in Fig. 3.18 A.

CMn5 is a left upper second molar (left M²). The first loph is broken. It has an X4X loph formula. The main cusp of the third loph was the most suitable position and was molded for microwear analysis. The selected positions on molar for microwear analysis were shown in Fig. 3.18 B.

CMn6 is a left lower third molar (left M₃). It has X5X lophid formula. The first and second lophid was broken. The main cusp of the third lophid was selected for microwear analysis. The selected positions on molar for microwear analysis were shown in Fig. 3.18 C.

CMn7 is a fragmented molar with the well-preserved talonid. This sample was included in the analysis to increase the sample size of this species. The talonid was molded for microwear examination. The selected positions on molar for microwear analysis were shown in Fig. 3.18 D.

Table 3.3 Microwear results of *Stegolophodon* cf. *stegodontoides* specimens from Tha Chang sand pits, Chaloe Phra Kiat District, Nakhon Ratchasima Province. Data obtained from light microscope.

Specimens	Studied positions	Number of scratch	Number of pit	Percentage	
				scratch	pit
NM1-13: left M ₃	Posttrite, fifth lophid, main cusp	20	26	43%	57%
RIN55: right M ₂	Pretrite, third lophid, main cusp	24	18	57%	43%
RIN534: right M ₃	Posttrite fifth lophid, main cusp	23	16	59%	41%

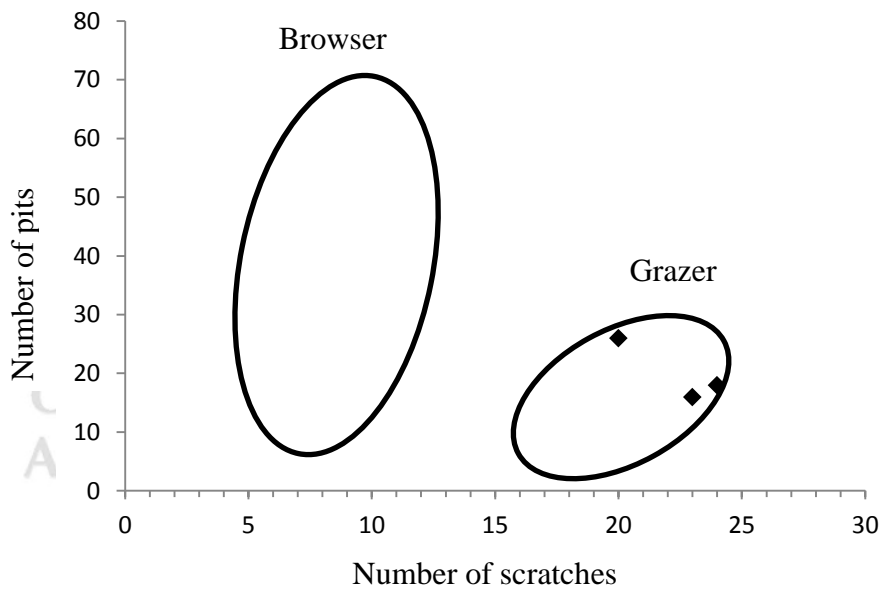


Fig. 3.17 Bivariate plots of scratch versus pit counts for *Stegolophodon* cf. *stegodontoides*. Data obtained from light microscope. Gaussian confidence ellipses ($p = 0.95$) on the centroid are indicated for extant browsers and grazers adjusted by sample size (extant data from Solounias and Semperebon, 2002).

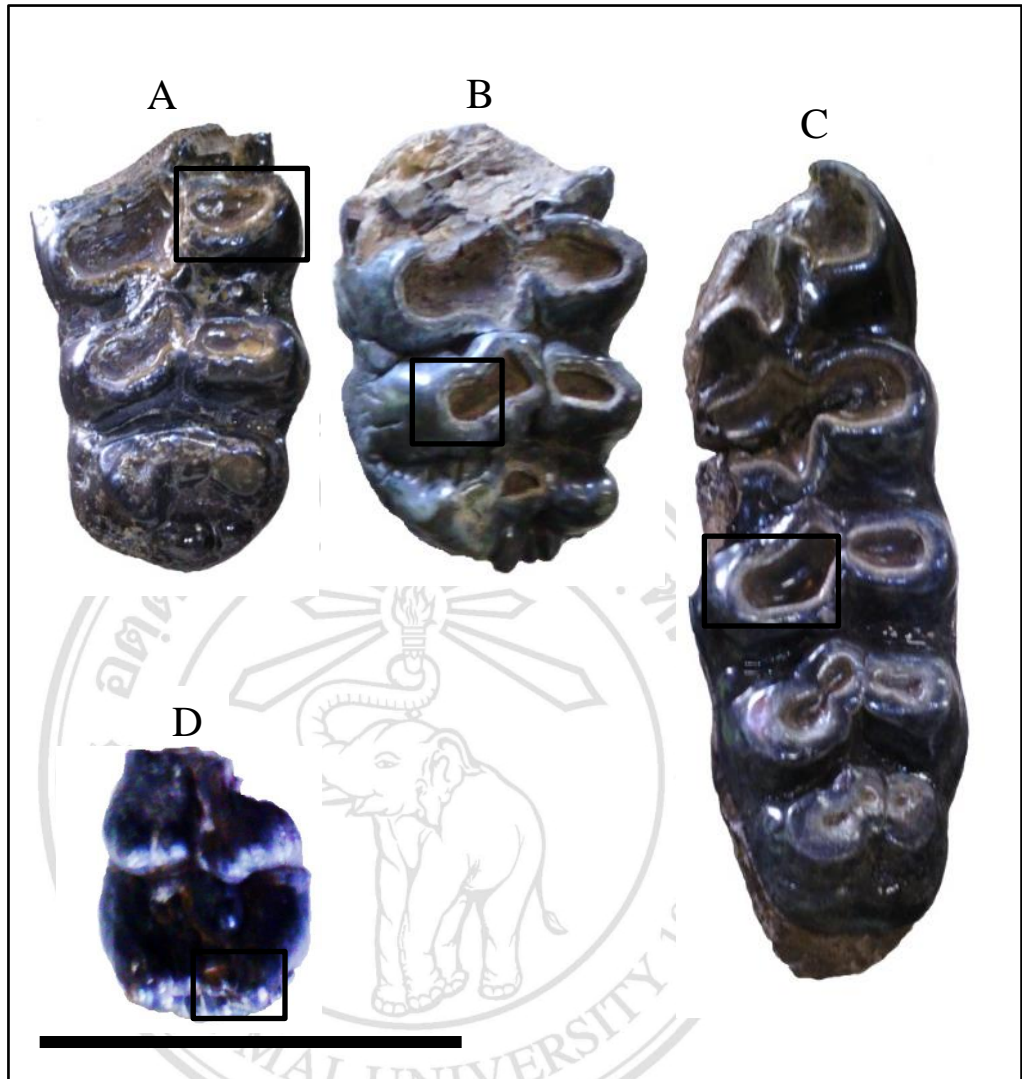


Fig. 3.18 *Tetralophodon cf. xiaolongtanensis* from Chiang Muan coal mine, Chiang Muan District, Phayao Province. A = CMn2 (left M²): B = CMn5 (left M²): C = CMn6 (left M₃): D = fragmented molar of CMn7. Selected positions for microwear analyses are indicated by square markers. All images are occlusal view. Scale bar = 10 cm. applied to all.

The microwear results of CMn2 of light microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.19 A and B). The average number of pits is 15 and the average number of scratches is 11 (Table 3.4).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits are typically ovoid. Fine scratches were also found. The width of coarse scratches is typically three times wider than those of fine scratches (Fig. 3.19 C). The microwear orientation on the CMn2 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 120°.

The microwear results of CMn5 of light microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.20 A and B). The average number of pits is 17 and the average number of scratches is 13 (Table 3.4).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits are typically ovoid. Fine scratches were also found. The width of coarse scratches is typically three times wider than those of fine scratches (Fig. 3.20 C). The microwear orientation on the CMn5 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 60°.

The microwear results of CMn6 of light microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.21 A and B). The average number of pits is 23 and the average number of scratches is 13 (Table 3.4).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits are typically ovoid. Fine scratches were also found. The width of coarse scratches is typically three times wider than those of fine scratches (Fig. 3.21 C). The microwear orientation on the CMn6 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 110°.

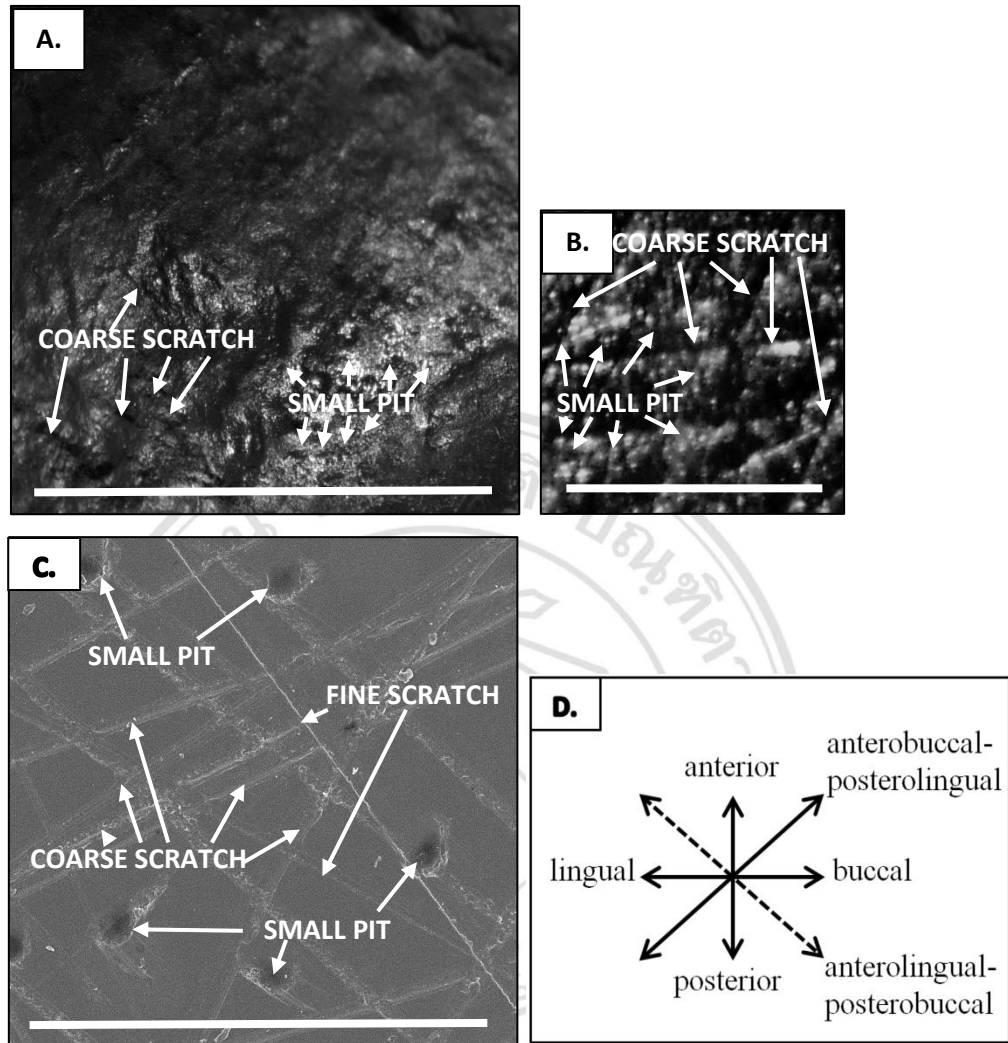


Fig. 3.19 Microwear images of *Tetralophodon cf. xiaolongtanensis* (CMn2), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

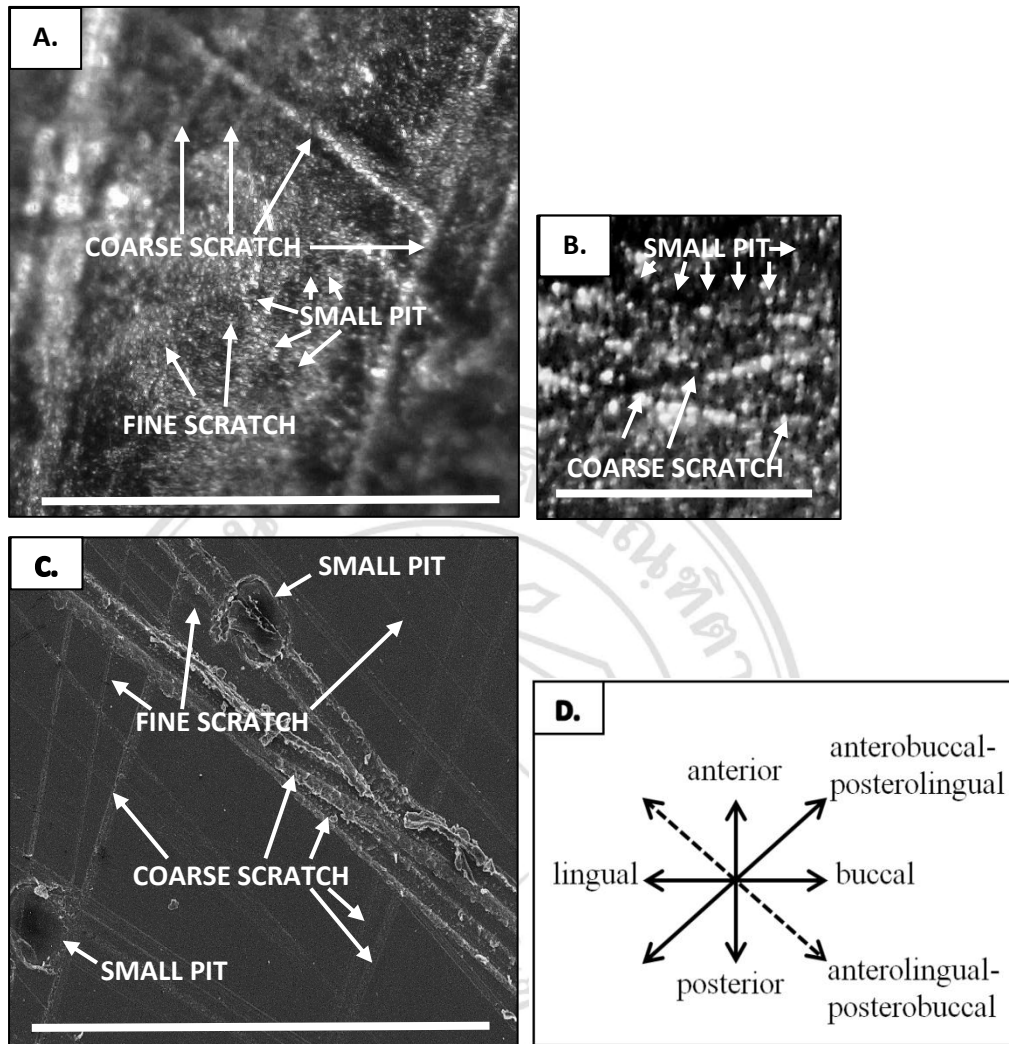


Fig. 3.20 Microwear images of *Tetralophodon cf. xiaolongtanensis* (CMn5), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

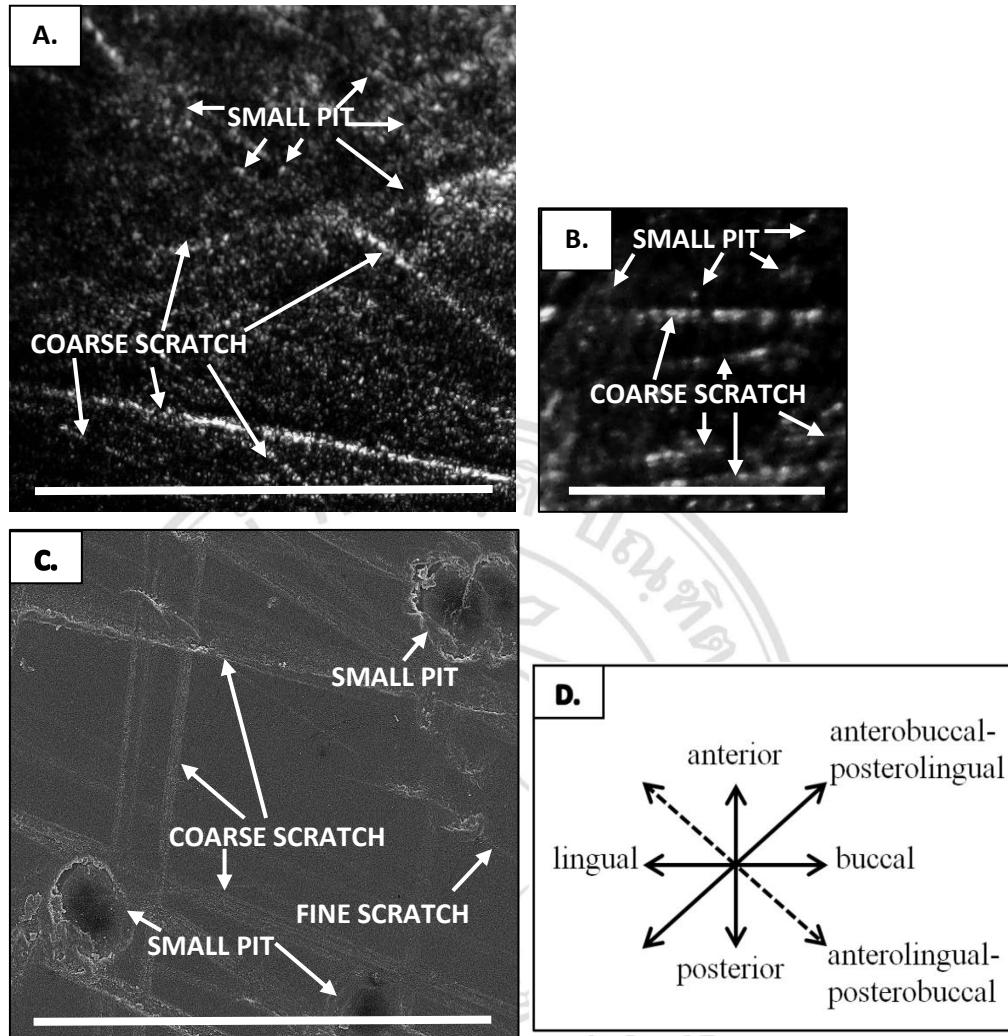


Fig. 3.21 Microwear images of *Tetralophodon cf. xiaolongtanensis* (CMn6), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

The microwear results of CMn7 of light microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.22 A and B). The average number of pits is 15 and the average number of scratches is 14 (Table 3.4).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. The pit shape is typically irregular in outline (Fig. 3.22 C). The microwear orientation on the CMn7 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 90°.

Bivariate plots of scratch versus pit counts for *Tetralophodon* cf. *xiaolongtanensis* from Chiang Muan coal mine suggested they are the mixed-feeders (Fig. 3.23).

3.3 The characteristic of dental microwear of *Protanancus*

cf. *Protanancus macinnesi* (Middle Miocene)

There are three samples of cf. *Protanancus macinnesi*. All of them were excavated from Tha Chang sand pits, Chaloeam Phra Kiat District, Nakhon Ratchasima Province. All specimens of cf. *Protanancus macinnesi* were suitable for microwear analysis. The microwear features did not interfere by taphonomic defects. The estimated age of this species is about Middle Miocene.

NM1-17 is a left lower third molar (left M₃). It has X5X lophid formula. The first three lophids are heavily worn. The occlusal surface is still fresh. The pretrite side of the second lophid was selected for microwear examination. The selected positions on molar for microwear analysis were shown in Fig. 3.24 A.

NM1-9 is a left upper third molar (left M³). It has X5X loph formula. The enamel of the first two lophs worn away and the dentine exposed. The pretrite of the second loph was selected and molded. The selected positions for microwear analysis were shown in Fig. 3.24 B.

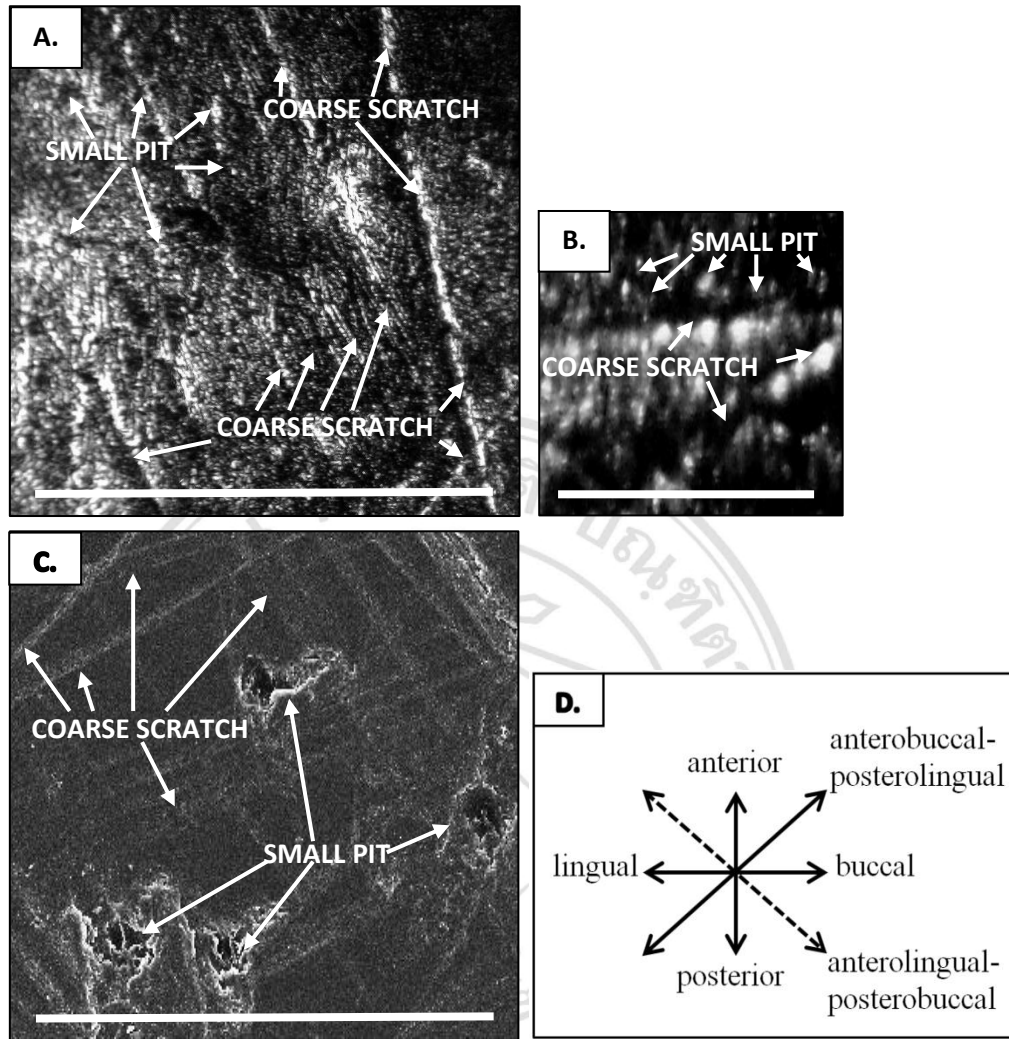


Fig. 3.22 Microwear images of *Tetralophodon cf. xiaolongtanensis* (CMn7), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

Table 3.4 Microwear results of *Tetralophodon* cf. *xiaolongtanensis* specimens from Chiang Muan coal mine, Chiang Muan District, Phayao Province. Data obtained from light microscope.

Specimens	Studied positions	Number of scratch	Number of pit	Percentage	
				scratch	pit
CMn2: left M ²	Pretrite, second loph, main cusp	11	15	42%	58%
CMn5: left M ²	Pretrite, third loph, main cusp	13	17	43%	57%
CMn6: left M ₃	Pretrite, third lophid, main cusp	13	23	36%	64%
CMn7	Talonid of fragmented molar	14	15	48%	52%

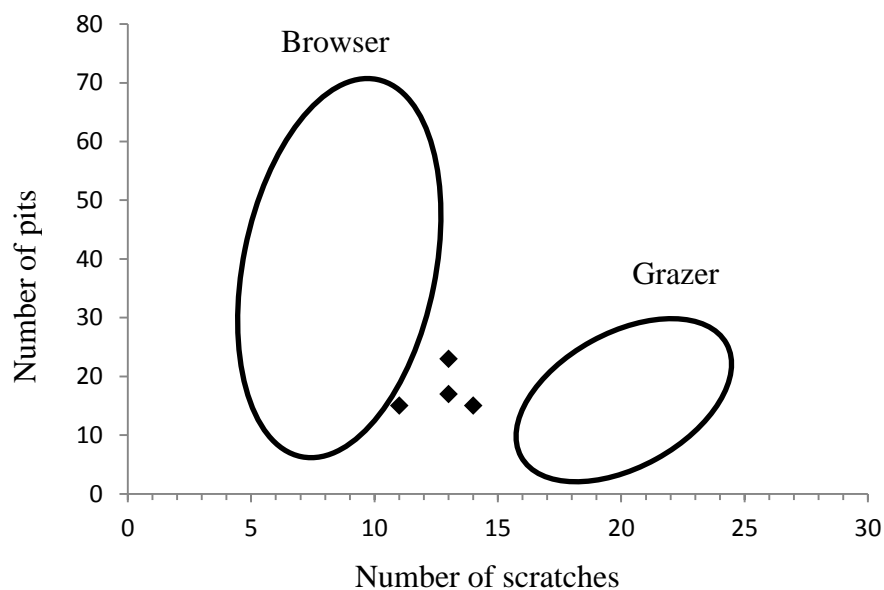


Fig. 3.23 Bivariate plots of scratch versus pit counts for *Tetralophodon* cf. *xiaolongtanensis*. Data obtained from light microscope. Gaussian confidence ellipses ($p = 0.95$) on the centroid are indicated for extant browsers and grazers adjusted by sample size (extant data from Solounias and Semperebon, 2002).



Fig. 3.24 cf. *Protanancus macinnesi* from Tha Chang sand pits, Chaloe Phra Kiat District, Nakhon Ratchasima Province. A = NM1-17 (left M₃): B = NM1-9 (left M³): C = NM1-3 (right M₃). Selected positions for microwear analyses are indicated by square markers. All images are occlusal view. Scale bar = 10 cm. applied to all.

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NM1-3 is a right lower third molar (right M₃). It has X5X lophid formula. The first and second lophid was heavily worn. However, they were suitable for microwear analysis. The posterior pretrite central conule of the second lophid was selected for microwear observation. The selected positions for microwear analysis were shown in Fig. 3.24 C.

The microwear results of NM1-17 of light microscope show that small pits and hypercoarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.25 A and B). The average number of pits is 27 and the average number of scratches is 23 (Table 3.5).

The detail characteristic of the microwear on scanning electron microscope show that small pits and hypercoarse scratches are the outstanding microwear pattern. The sharp edges of hypercoarse scratches were obviously observed. The pit shape is typically ovoid. Fine and coarse scratches were also found (Fig. 3.25 C). The microwear orientation of the NM1-17 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 60°.

The microwear results of NM1-9 of light microscope show that small pits and hypercoarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.26 A and B). The average number of pits is 26 and the average number of scratches is 25 (Table 3.5).

The detail characteristic of the microwear on scanning electron microscope show that puncture pits and hypercoarse scratches are the outstanding microwear pattern. Sharp edges were observed around the border of puncture pits. The shape of puncture pits is round and ovoid. Small pits and coarse scratches were also present. The faint lines of fine scratches were observed sporadically (Fig. 3.26 C). The microwear orientation of the NM1-9 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 50°.

The microwear results of NM1-3 of light microscope show that small pits and hypercoarse scratches are the outstanding microwear pattern. Coarse scratches were also found. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.27 A and B). The average number of pits is 28 and the average number of scratches is 25 (Table 3.5).

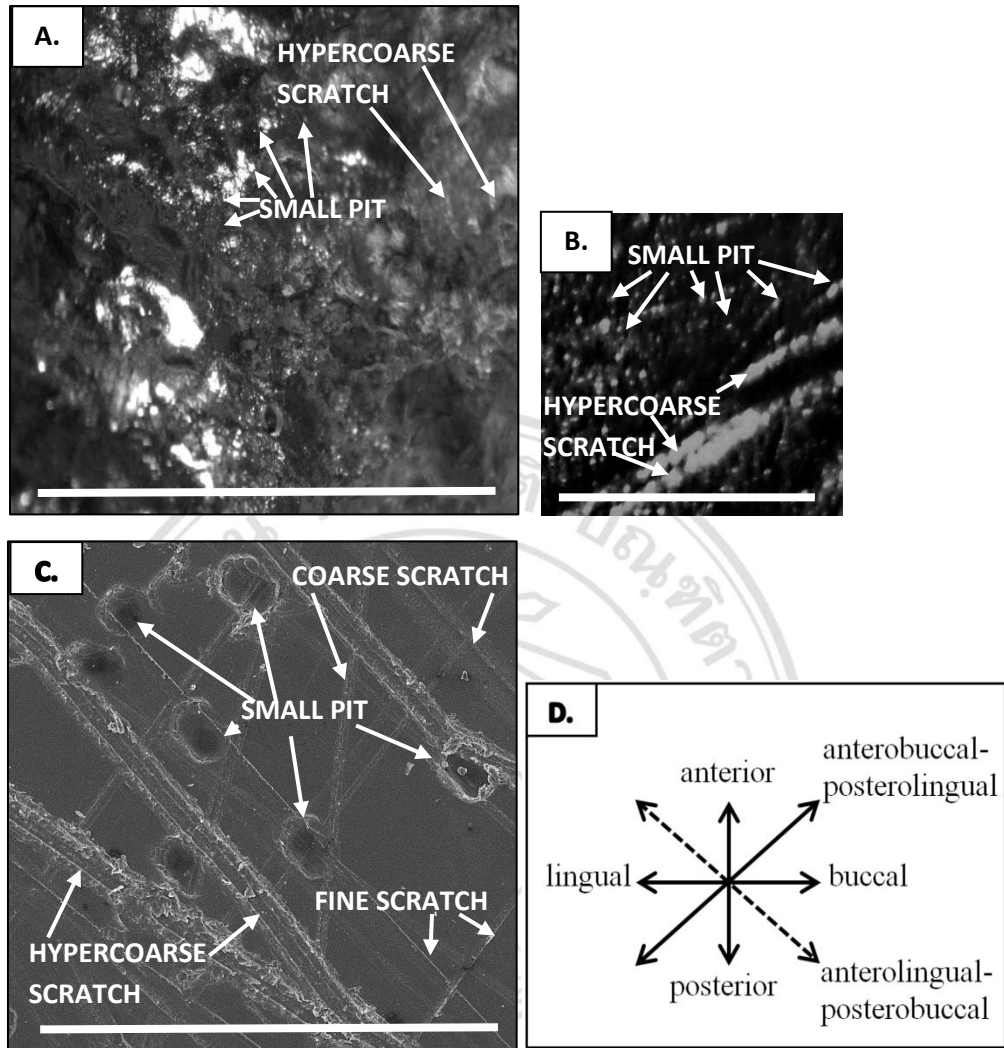


Fig. 3.25 Microwear images of cf. *Protanancus macinnesi* (NM1-17), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

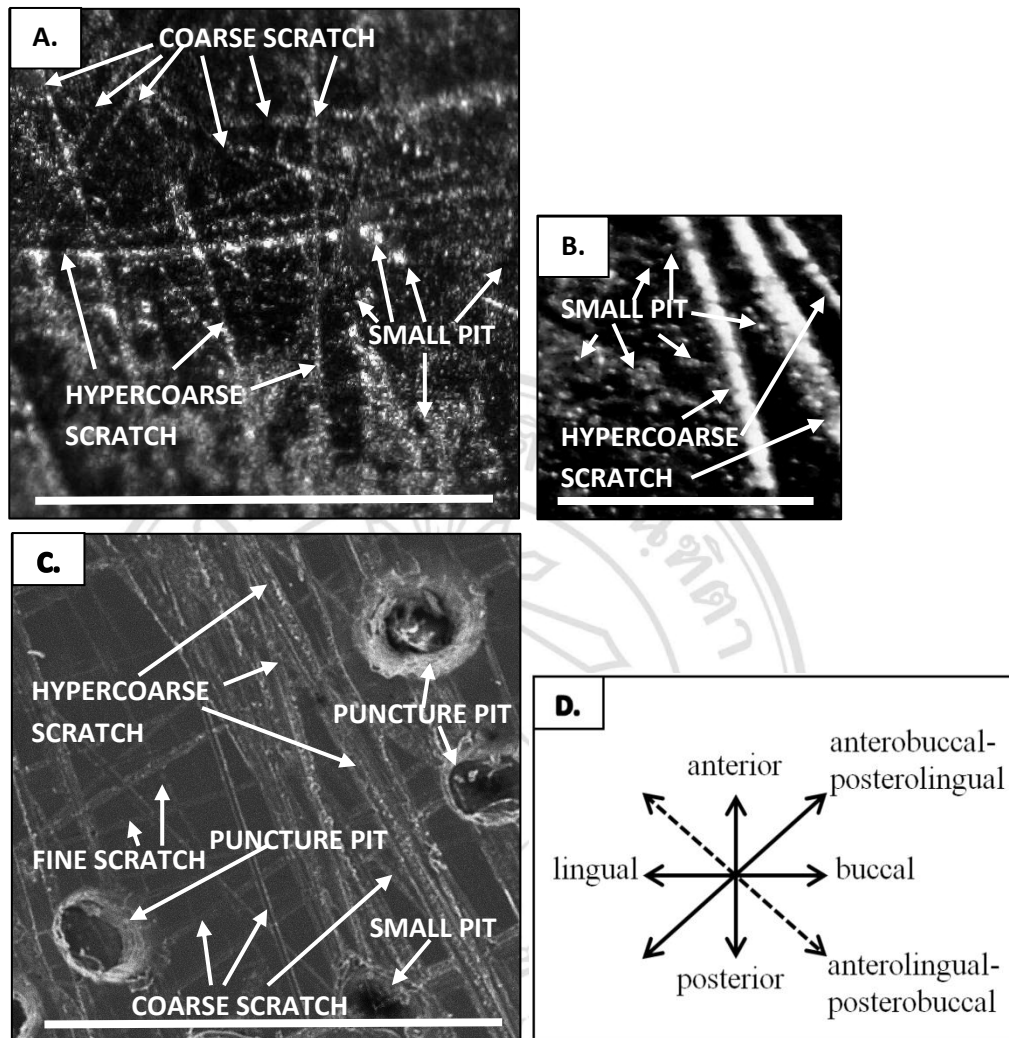


Fig. 3.26 Microwear images of cf. *Protanancus macinnesi* (NM1-9), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

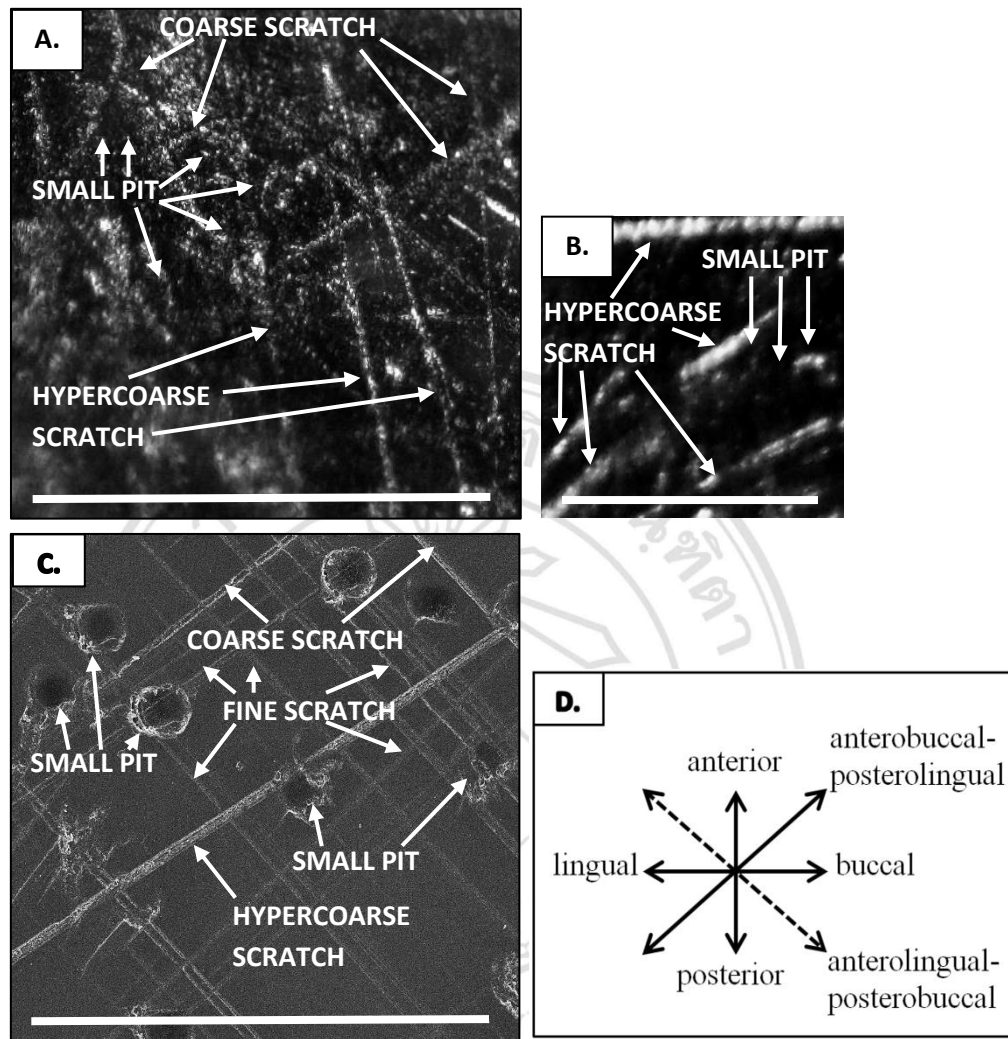


Fig. 3.27 Microwear images of cf. *Protanancus macinnesi* (NM1-3), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

The detail characteristic of the microwear on scanning electron microscope show that small pits and hypercoarse scratches are the outstanding microwear pattern. The faint lines of fine scratches were observed sporadically. The width of coarse scratches is two times wider than those of fine scratches. The pit shape is typically ovoid (Fig. 3.27 C). The microwear orientation of the NM1-3 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 110° .

Bivariate plots of scratch versus pit counts for cf. *Protanancus macinnesi* from Tha Chang sand pits suggested they are the grazers (Fig. 3.28).

3.4 The characteristic of dental microwear of *Prodeinotherium*

***Prodeinotherium pentapotamiae* (Middle Miocene)**

There are only two samples of *Prodeinotherium pentapotamiae*. The fossil locality is located at Tha Chang sand pits, Chaloe Phra Kiat District, Nakhon Ratchasima Province. Both specimens show heavily worn occlusal surface. The microwear results might be preliminary. The estimated age of this species is about Middle Miocene.

KHO is a right mandible with the fourth premolar to the third molar. The fourth premolar was molded for microwear examination because it showed less worn surface. The selected positions for microwear analysis were shown in Fig. 3.29 A.

RIN15 is a right mandible with the first molar to the third molar. All molars showed heavily worn surface. The third one was selected for microwear observation. The exact positions for microwear analysis were shown in Fig. 3.29 B.

The microwear results of KHO of light microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape is typically round. Puncture pits with the sharp edge around the rim were also observed (Fig. 3.30 A and B). The average number of pits is 20 and the average number of scratches is 6 (Table 3.6).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. The pit shape

Table 3.5 Microwear results of cf. *Protanancus macinnesi* from Tha Chang sand pits, Chaloeam Phra Kiat District, Nakhon Ratchasima Province. Data obtained from light microscope.

Specimens	Studied positions	Number of scratch	Number of pit	Percentage	
				scratch	pit
NM1-17: left M ₃	Pretrite, second lophid, main cusp	23	27	46%	54%
NM1-9: left M ³	Pretrite, second loph, main cusp	25	26	49%	51%
NM1-3: right M ₃	Pretrite, second lophid, posterior pretrite central conule	25	28	47%	53%

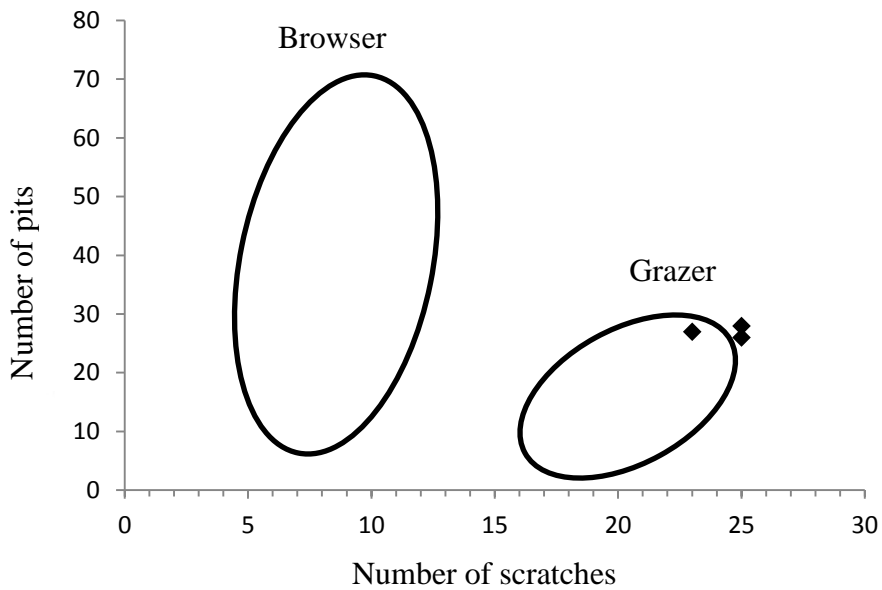


Fig. 3.28 Bivariate plots of scratch versus pit counts for cf. *Protanancus macinnesi*. Data obtained from light microscope. Gaussian confidence ellipses ($p = 0.95$) on the centroid are indicated for extant browsers and grazers adjusted by sample size (extant data from Solounias and Semperebon, 2002).

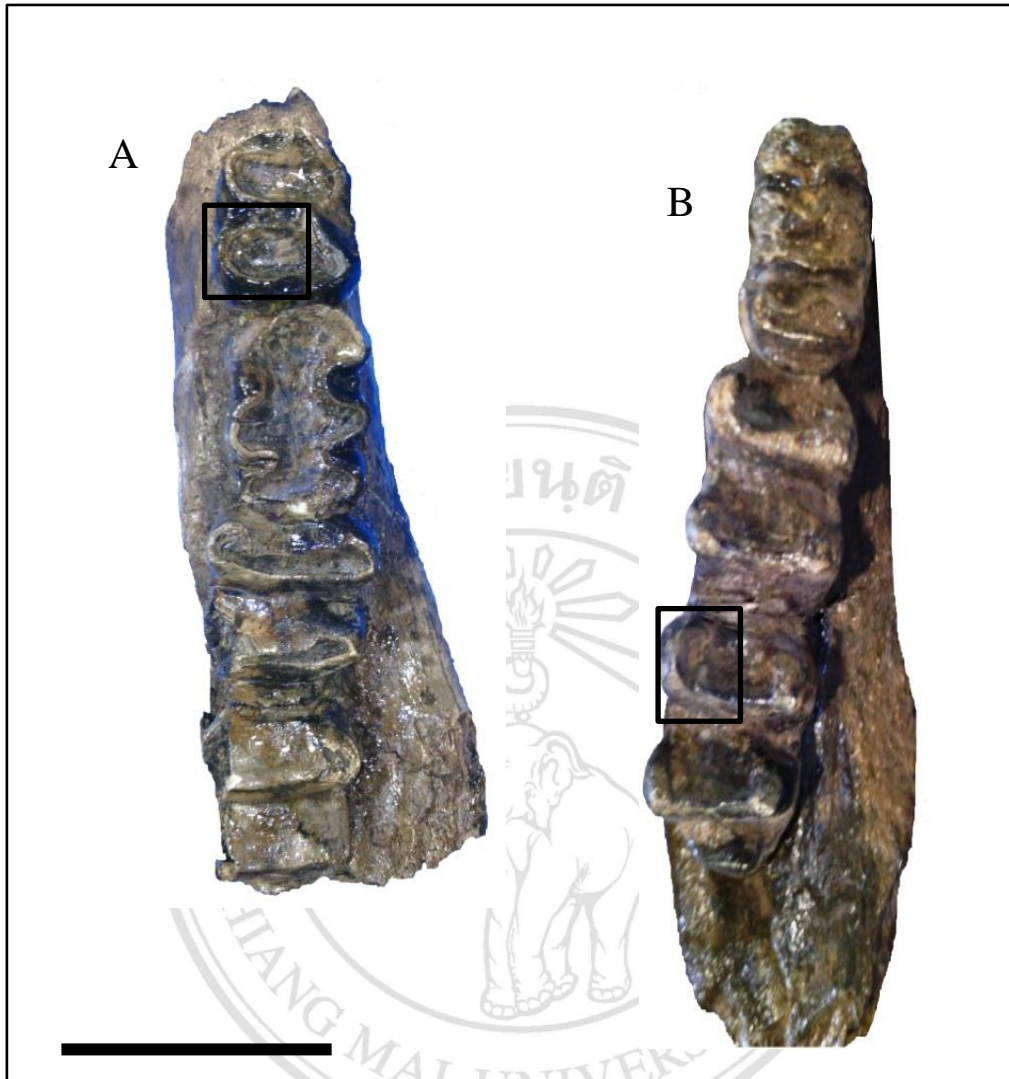


Fig. 3.29 *Prodeinotherium pentapotamiae* from Tha Chang sand pits, Chaloem Phra Kiat District, Nakhon Ratchasima Province. A = KHO (right mandible with P₄ to M₃): B = RIN15 (right mandible with M₁ to M₃). Selected positions for microwear analyses are indicated by square markers. All images are occlusal view. Scale bar = 10 cm. applied to all.

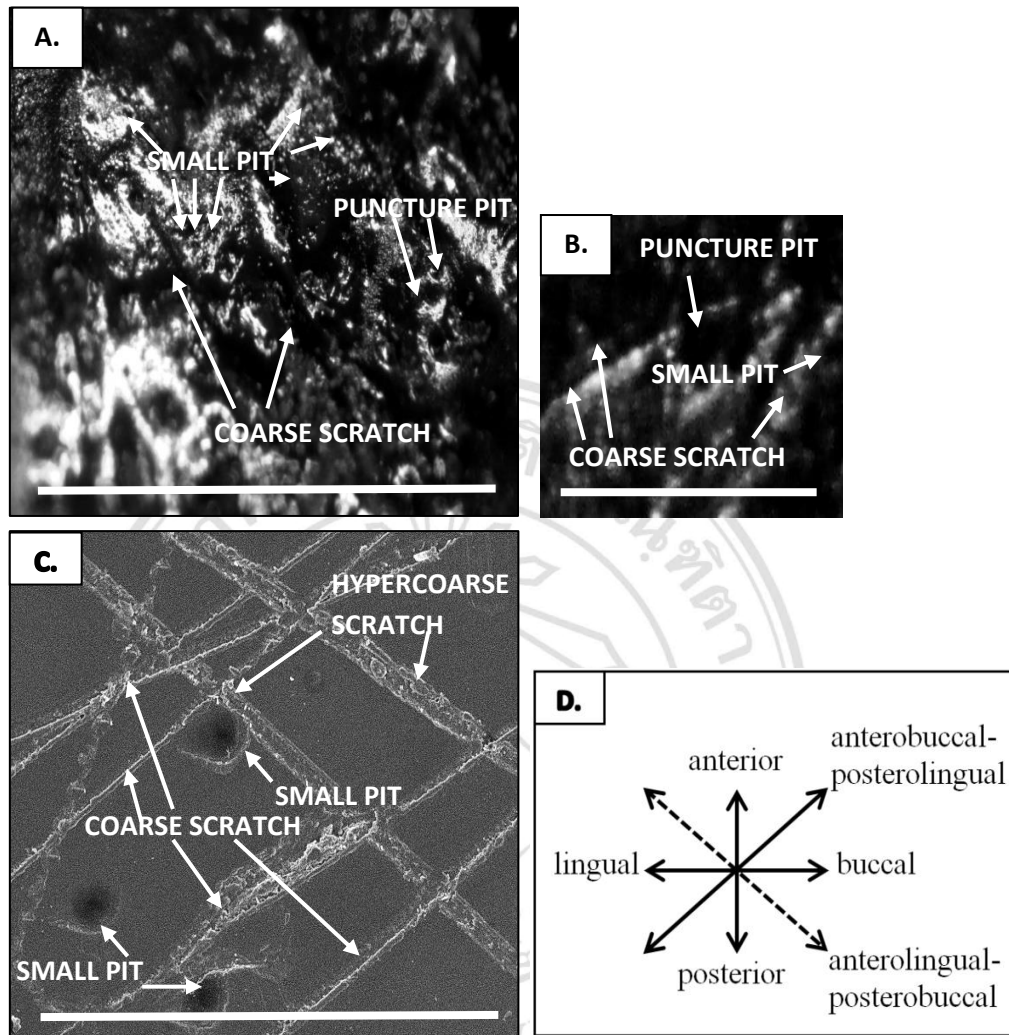


Fig. 3.30 Microwear images of *Prodeinotherium pentapotamiae* (KHO), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

is typically round. Hypercoarse scratches were also observed (Fig. 3.30 C). The microwear orientation on the KHO show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 120°.

The microwear results of RIN15 of light microscope show that small pits and coarse scratches are the outstanding microwear pattern. Small pits were observed dispersedly and the pit shape are typically round (Fig. 3.31 A and B). The average number of pits is 22 and the average number of scratches is 6 (Table 3.6).

The detail characteristic of the microwear on scanning electron microscope show that small pits and coarse scratches are the outstanding microwear pattern. The pit shape is typically round (Fig. 3.31 C). The microwear orientation on the RIN15 show anterobuccal-posterolingual and anterolingual-posterobuccal with angle 120°.

Bivariate plots of scratch versus pit counts for *Prodeinotherium pentapotamiae* from Tha Chang sand pits suggested they are the browsers (Fig. 3.32).

3.5 Microwear orientation of scratches

The microwear orientation of scratches was obviously observed by scanning electron microscopy. The outstanding orientation was divided into two directions; the anterolingual to the posterobuccal direction and the anterobuccal to the posterolingual direction (Fig. 3.33). The number of each direction, the angle between two directions and the average angles of each species were shown in Table 3.7. The angles of microwear orientation of *Stegolophodon nasaiensis* range from 90° to 120°, with the average of 113°. The angles of microwear orientation of *Stegolophodon cf. latidens* range from 60° to 120°, with the average of 90°. The angles of microwear orientation of *Stegolophodon cf. stegodontoides* range from 60° to 120°, with the average of 80°. The angles of microwear orientation of *Tetralophodon cf. xiaolongtanensis* range from 60° to 120°, with the average of 95°. The angles of microwear orientation of cf. *Protanancus macinnesi* range from 50° to 110°, with the average of 73°. The angles of microwear orientation of all the samples of *Prodeinotherium pentapotamiae* are 120°.

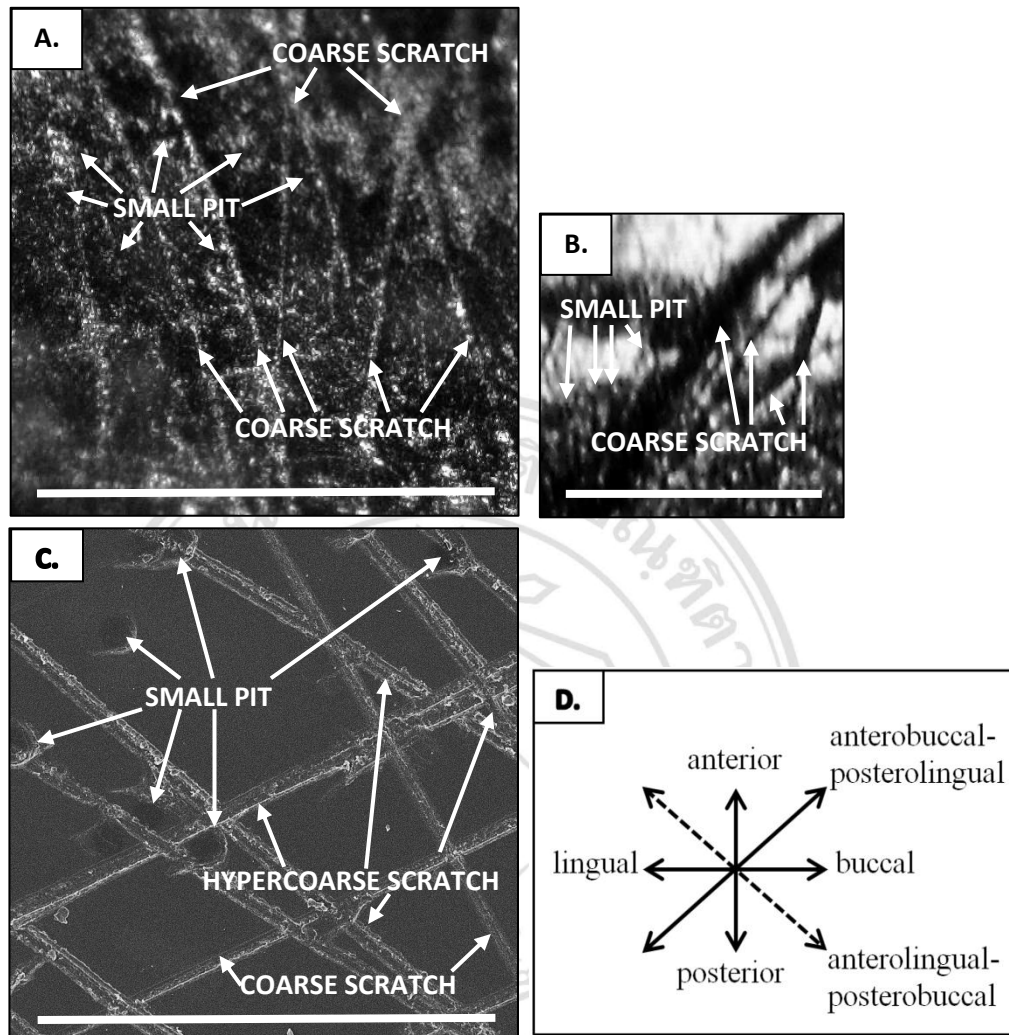


Fig. 3.31 Microwear images of *Prodeinotherium pentapotamiae* (RIN15), as seen under low-magnification microscope ($\times 35$); A. and B., and under scanning electron microscope ($\times 65$); C. Scale bar 10.0 mm. applies to A, scale bar 0.4 mm. applies to B and C. Microwear orientation; D. The dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

Table 3.6 Microwear results of *Prodeinotherium pentapotamiae* from Tha Chang sand pits, Chaloe Phra Kiat District, Nakhon Ratchasima Province. Data obtained from light microscope.

Specimens	Studied positions	Number of scratch	Number of pit	Percentage	
				scratch	pit
KHO: right P ₄	Posttrite, second lophid, main cusp	6	20	23%	77%
RIN15: right M ₃	Posttrite, first lophid, main cusp	6	22	21%	79%

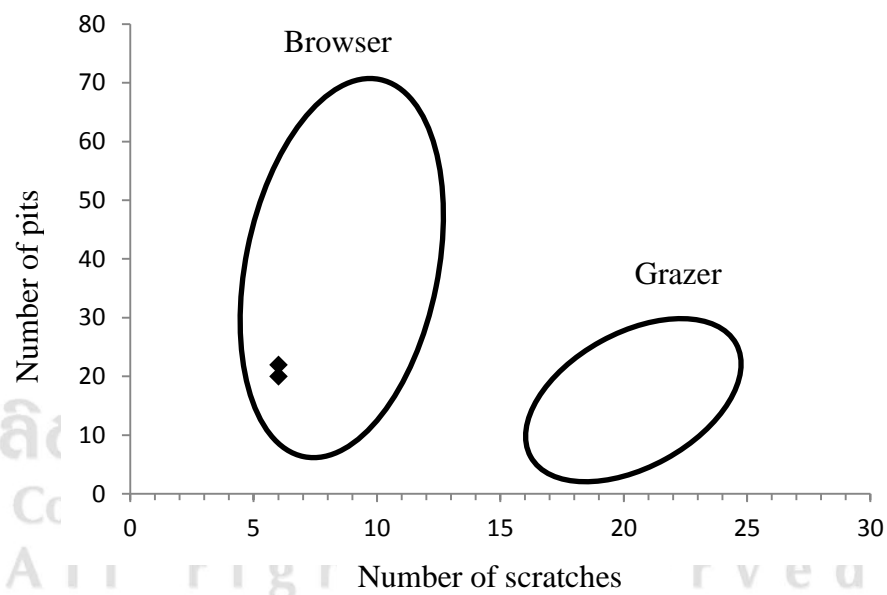


Fig. 3.32 Bivariate plots of scratch versus pit counts for *Prodeinotherium pentapotamiae*. Data obtained from light microscope. Gaussian confidence ellipses ($p = 0.95$) on the centroid are indicated for extant browsers and grazers adjusted by sample size (extant data from Solounias and Semprebon, 2002).

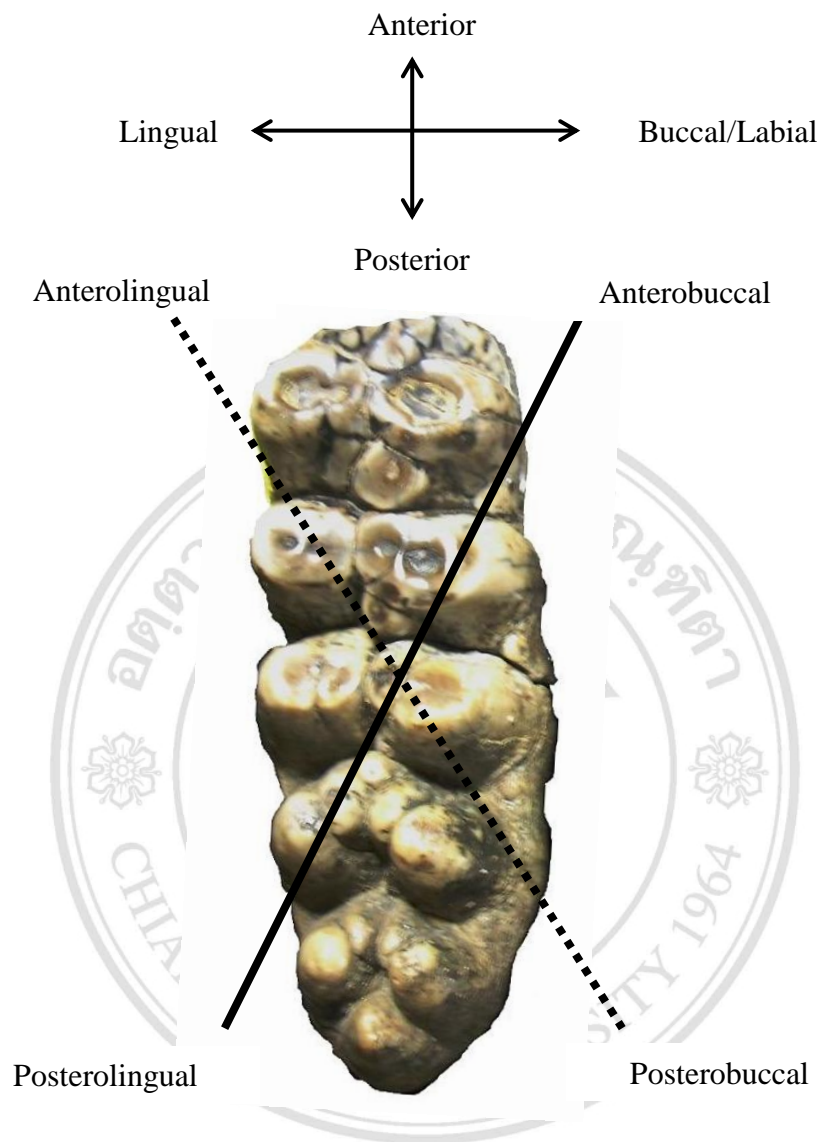


Fig. 3.33 The orientation of microwear features; the dash-line showing the anterolingual-posterobuccal direction and the bold-line showing the anterobuccal-posterolingual direction.

Table 3.7 Microwear orientation observed from scanning electron microscope.

Samples	Number of scratches		Angle of microwear orientation	
	Anterolingual-posterobuccal	Anterobuccal-posterolingual		
<i>S. nasaiensis</i>				
NS-01a	4	6	90°	average = 113°
NS-01b	2	5	120°	
M4732a1	3	3	120°	
M4732a2	4	7	120°	
<i>S. cf. latidens</i>				
M4733f	4	9	90°	average = 90°
MMEL-3	5	10	120°	
MMEL-5	12	3	90°	
MMEL-6	4	9	60°	
<i>S. cf. stegodontoides</i>				
NM1-13	12	17	60°	average = 80°
RIN55	10	16	120°	
RIN534	12	9	60°	
<i>T. cf. xiaolongtanensis</i>				
CMn2	6	9	120°	average = 95°
CMn5	11	5	60°	
CMn6	8	3	110°	
CMn7	6	10	90°	
<i>cf. P. macinnesi</i>				
NM1-17	11	7	60°	average = 73°
NM1-9	14	17	50°	
NM1-3	9	12	110°	
<i>P. pentapotamiae</i>				
KHO	2	6	120°	average = 120°
RIN15	7	2	120°	