Tropical Natural History 10(1): 93-106, April 2010


# A New Species of *Pseudohyria (Matsumotoina)* (Bivalvia: Trigonioidoidea) from the Early Cretaceous Sao Khua Formation, Khorat Group, Northeastern Thailand

**SAKBOWORN TUMPEESUWAN, YOSHIO SATO* AND SOMCHAI NAKHAPADUNGRAT**

*Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok, 10330, THAILAND*
* Corresponding author; E-mail: tkio@geo.sc.chula.ac.th
Received: 9 October 2009; Accepted: 19 March 2010

**ABSTRACT.– A new freshwater bivalve species, *Pseudohyria (Matsumotoina) somanai* n. sp. from the Early Cretaceous Sao Khua Formation of northeastern Thailand is described. The new species possesses the unique characters of subgenus *Matsumotoina*, including smooth hinge teeth and submedian pseudocardinal teeth, but it differs from the preceding sole species, *Pseudohyria (Matsumotoina) matsumotoi* Yang, 1979, from Korea in the number of pseudocardinal teeth, number of posterior ribs and shell shape. The new species is interpreted as a river species, and the dominant species among the bivalve assemblage in the type stratum. The temporal distribution of this subgenus is limited to the Late Barremian Formations of Japan and Korea, thus we suggest a Late Barremian age for the Sao Khua Formation.**

**KEY WORDS: *Pseudohyria (Matsumotoina)*, Trigonioidoidea, Early Cretaceous, Sao Khua Formation, Northeastern Thailand**

## INTRODUCTION

In the 1960s, many Bivalve fossils were reported and described from the Phu Kradung, Sao Khua and Khok Kruat Formations of the Khorat Group in ascending order (Table 1).

*Unio thailandica* was described from the red calcareous siltstone of the Phu Kradung Formation at Wat Ray Rai, Khon San District, Chaiyaphum Province. *Unio* sp. was reported from red siltstone at Ban Pa along the Choen River, Phu Khiew District Chaiyaphum Province. *Neomiodon khoratensis* was described from red kaolinite siltstone at Ban Khok Sung, Chum Phae District, Khon Kaen Province (Hayami, 1968).

*Mytilus (Pachymytilus) rectangularis* Kobayashi and Hayami, 1963; *Cardinioides magnus* Kobayashi and Hayami, 1963; *Goniomya koratensis* Kobayashi and Hayami, 1963 were described from the Sao Khua Formation. The first and the second ones were found at Km 39.04 and 39.25 at Udon Thani–Nong Bua Lamphu Road, respectively, whereas the third one was found from Ban Krok Namtao at Km 49.8 of Khorat-Kabinburi Road (Kobayashi et al., 1963).

Four species were reported and described from the Khok Kruat Formation at Ban Na Yo, Mukdahan Province including *Trigonioides* sp., *Plicatounio* sp., *Nippononaia mekongensis* and *Paranodonta koratensis* (Kobayashi, 1963).

Then, seven species of freshwater bivalves of the Khok Kruat Formation were described and reported from the Nam Phung Dam, including *Plicatotrigonioides subovalis, Pseudohyria* sp., *Nippononaia carinata, N. (Mekongiconcha) robusta, N. (M.) sub-*

**TABLE 1.** A summary of the bivalve assemblages of the Khorat Group (Data from Kobayashi (1963, 1968), Kobayashi et al. (1963), Hayami (1968), Hahn (1982), Meesook and Wongprayoon (1999), Jearanaiwong (2000), Imsamut (2003), Tumpeesuwan (2005) and Tumpeesuwan and Sato (2005).

| Formation | Bivalve assemblages |
|---|---|
| Khok Kruat | |
| Phu Phan | |
| Sao Khua | |
| Phra Wihan | |
| Phu Kradung | |

*Trigonioides* sp.

*Plicatounio* sp.

*Nippononaia mekongensis*

*Paranodonta khoratensis*

*Sainshandia nagnomensis*

*Nippononaia (Mekongiconcha) subquadrata*

*Nippononaia (Mekongiconcha) robusta*

*Nippononaia carinata*

*Plicatounio namphungensis*

*Unio sampanoides*

*Pseudohyria* sp.

*Cardinioides magnus*

*Mytilus (Pachymytilus) rectangularis*

*Goniomya koratensis*

Mytilinae *gen. et sp. indet.*

*Unio* sp. cf. *U. sampanoides*

*Nippononaia* sp. cf. *N. mekongensis*

*Trigonioides (Diversitrigonioides)* sp. cf. *T. (D.) diversicostatus*

*Pseudohyria (Matsumotoina) somanai* **sp. nov.**

*Unio thailandica*

*Unio* sp.

*Neomiodon khoratensis*

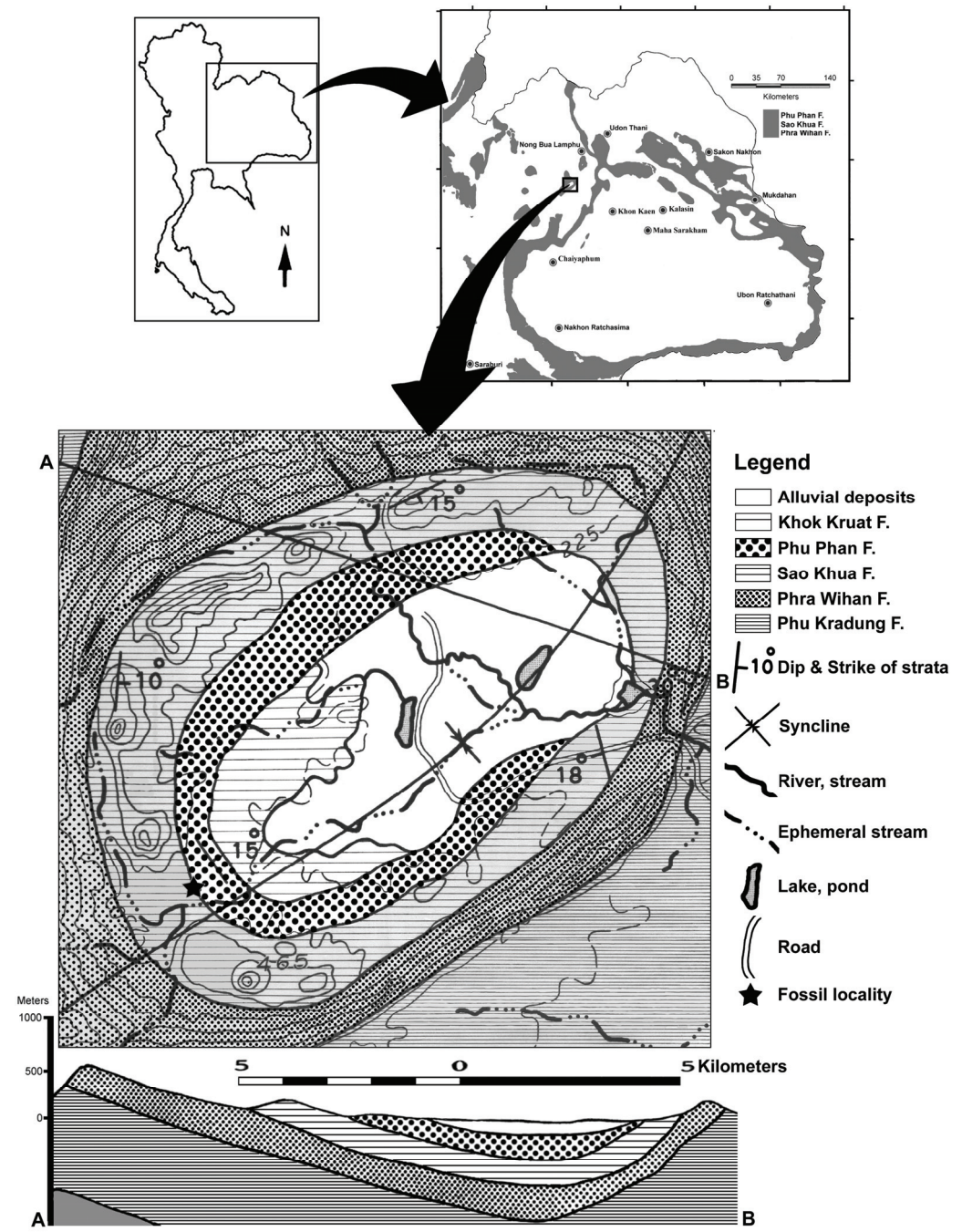


**FIGURE 1.** Geologic map of Phu Wiang Area showing the type locality of the new species (star) (modified after Geological map of Thailand sheet Changwat Khon Kaen, NE 48-13, Chonglakmani et al., 1985)

*quadrata, Plicatounio namphungensis,* and *Unio sampanoides* (Kobayashi, 1968).

The Sao Khua Fomation contains abundant bivalve fossil localities (Kobayashi et al., 1963; Hahn, 1982; Meesook and Wongprayoon, 1999; Imsamut, 2003; Tumpeesuwan, 2005), but these fossils have not been studied in taxonomic details, yet. Recently, new bivalve fossil localities of the Sao Khua Formation were discovered in the Phu Wiang area (Tumpeesuwan, 2005). One of them contains well preserved bivalve fossils in the weathering out of a mud-nodule conglomeratic sandstone bed. Included in these specimens is a new species of *Pseudohyria (Matsumotoina)*, a genus and subgenus that has not been reported from the Sao Khua Formation in Thailand. From the shell morphology and stratigraphic reference, the new species is similar to the preceding sole species of the subgenus *Pseudohyria (Matsumotoina) matsumotoi* Yang, 1979 from Korea. This article is aimed to describe the new species taxonomically with brief notes on its taphonomy, palaeoecology, stratigraphic distribution of the taxon and the geological age of the Sao Khua Formation.

The fossil locality of the new species is situated at the southern side of Phu Noi of the Phu Wiang Area in Khon Kaen Province (Fig. 1), which recently was named as Phu Wiang Molluscan Locality 5 (PW-M-5) in Tumpeesuwan (2005). The conglomeratic sandstone of the Phu Phan Formation covers the top of Phu Noi, indicating that the shell bed belongs to the Sao Khua Formation. The formation was determined as deposited in a meandering river system under semiarid conditions (Racey et al., 1996; Meesook, 2000). The age of the formation is older than Aptian (Buffetaut et al., 2005).

## MATERIALS AND METHODS

The fossils have been collected from the surface of the weathering out of the mud-nodule conglomeratic sandstone (Fig. 2A - B). The individual fossils and small blocks were soaked in a mixture of water and detergent. The matrix was carefully removed from the fossils by air pen, sand blaster and small cutter, respectively. This bivalve assemblage includes *Pseudohyria (Matsumotoina) somanai* n. sp., *Trigonioides (Diversitrigonioides)* sp. cf. *T. (D.) diversicostatus* Hoffet, 1937 and *Nippononaia* sp. cf. *N. mekongensis* Kobayashi, 1963. Holotype (CUMZ 3201) and two paratypes (CUMZ 3202, 3203) are housed in Chulalongkorn University, Museum of Zoology, Bangkok. Other paratypes are housed in the Palaeontological Research and Education Centre, Faculty of Science, Mahasarakham University, Maha Sarakham Province (PRC-M-M-106 to 236). Replica of the holotype are deposited in Sirindhorn Museum, Sahat Sakhan, Kalasin Province; Phu Wiang Dinosaur Museum, Phu Wiang, Khon Kaen Province; Geological Museum, Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok. All specimens of the new species are examined and described below.

## SYSTEMATICS

### Family Pseudohyriidae Kobayashi, 1968

### Subfamily Pseudohyriinae Kobayashi, 1963

### Genus *Pseudohyria* MacNeil, 1936

**Diagnosis.**– The anterior pedal retractor scar is separated from the anterior adductor scar. The shell surface is ornamented with

**TABLE 2.** Analysis of *Pseudohyria (Matsumotoina) somanai* n. sp. from the Phu Wiang Molluscan Locality 5 (PW-M-5).

| Articulated valves | | Disarticulated valves | | | Fragmentation |
|---|---|---|---|---|---|
| Unmoved | Slightly moved | Left valve | Right valve | Unidentified | |
| 26 | 5 | 97 | 72 | 15 | 133 |

chevron radial ribs only in the posterior area.

**Subgenus *Matsumotoina* Guo, 1982**

**Diagnosis.**– Hinge teeth are smooth. The submedian pseudocardinal teeth are present.

***Pseudohyria (Matsumotoina) somanai* n. sp.**
**(Figures 4 and 5)**

"cf. *Cardinioides magnus*" Hahn, 1982: 22.
*Trigonioides* sp. Jearanaiwong, 2000: 72-76, pl. 2, figs 1-16.
*Trigonioides* sp. Imsamut, 2003: 42. Tumpeesuwan and Sato, 2005: 608.
Unionidae genus and species indetermined (2-4) Tumpeesuwan, 2005: 51-54. figs 4.19-4.22.

**Etymology.**– The specific epithet is dedicated to Professor Dr. Reon Somana, Director of the Palaeontological Research and Education Centre, Faculty of Science, Mahasarakham University. The first author is grateful for his support.

**Material Examined.**– Two-hundred and fifteen specimens of articulated and disarticulated valves of the new species were examined including, Holotype CUMZ 3201; Paratypes CUMZ 3202, 3203; PRC-M-M-106 to 236.

**Type locality.**– Phu Wiang Molluscan Locality 5 (PW-M-5), south of Phu Noi in Phu Wiang Area, Khon Kaen province (Fig. 1).

**Type stratum.**– The fossils were collected from red mud nodule conglomeratic sandstone of the Sao Khua Formation (Figs 2 and 3).

**Description.**– Shell fairly large in size, 19.1 - 54.0 mm in height and 24.2 - 56.6 mm in length, and trigonally suboval or subelliptical in outline, fairly inflated; subequilateral and equivalve; anterior margin well rounded, postero-dorsal one rather arcuated, postero-ventral corner sharp angulate, ventral margin fairly arcuated. Umbo fairly high and prominent, slightly prosogyrous, situated nearly centrally; escutcheon short, broad, and slightly deep; lunule rather short; narrow and shallow; test moderately thick.

Surface ornamented with concentric growth lines; they are strong and prominent around the umbo which is weakening ventrally. The posterior ridge is fairly prominent with short five to eight chevron ribs on the posterior ridge.

Hinge plate moderate in breadth, provided with smooth pseudocardinal and postero-lateral teeth; pseudocardinal teeth 4 on both valves; postero-lateral teeth one on right valve, two on left valve, forming the following dental formula: 5, 3, 1a, 1b, PIII/ 4, 2, 1'a, 1'b, PII, PIV, where 5: long, narrow, parallel to the antero-dorsal margin.

3: long, stout and high, subparallel to the antero-dorsal margin,

1a: low and short, immediately below the umbo, nearly vertical,
1b: low and short, smallest in the right valve, immmedietly below the umbo, nearly vertical,
PIII: distinct and elongated, parallel to the postero-dorsal margin,
4: long, stout and prominent, parallel to the antero-dorsal margin,
2: long, rather stout and slightly high, subparallel to the antero-dorsal margin,
1'a: low and short, isosceles triangle shape, nearly vertical.
1'b: low and short, isosceles triangle shape, about 45° of vertical.
PII and PIV: narrow and elongated, parallel to the postero-dorsal margin.

These hinge teeth are neither crenulated nor striated, but rather lamellar. Anterior adductor semicircular, strongly impressed, postero-dorsal side truncated and steep with slightly straight margin; anterior and postero-ventral side gentle. Anterior pedal retractor scar circular, minute, located at postero-dorsal side of the anterior adductor scar and isolated from it. Posterior adductor scar subcircular, and larger, but not so distinct. Ventral crenulation on the inner side not so distinct. Umbonal cavity moderately deep.

**Taphonomic Observation.**– This bivalve assemblage occurs in the red mud-nodule conglomeratic sandstone (Fig. 2A), that has been suggested to be a channel deposit of a meandering river system (Meesook, 2000; Wongprayoon and Meesook, 2002; Imsamut, 2003; Tumpeesuwan, 2005). The distribution and orientation of shells in the shell bed could not be determined exactly because most of the shell bed broke and scattered as small blocks or individual shells (Fig. 2B). They are abundant in terms of the number of individuals and very well preserved. Most specimens are disarticulated valves, with a ratio of left and right valves of 57.4:42.6 (Table 2). Half of the unbroken small shells show delicate growth lines in the umbonal region. This evidence indicates that the well preserved small articulated valves were preserved *in situ* (Fig. 4F-K). Shell fragments are also

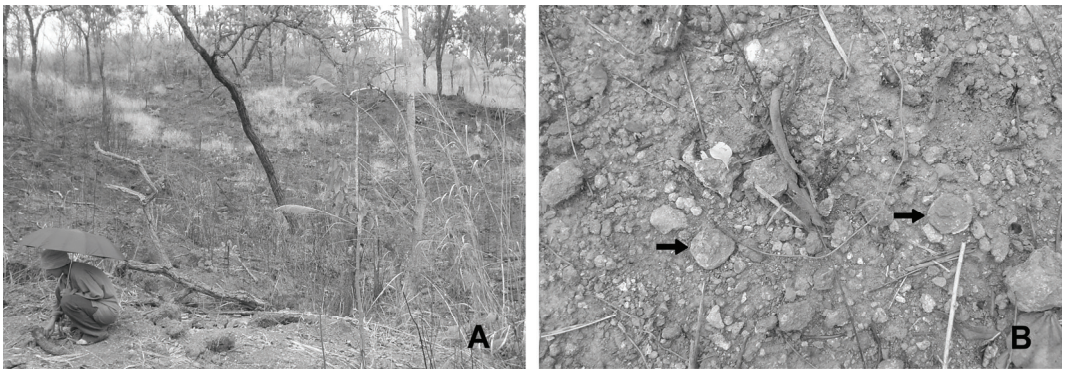


**FIGURE 2.** Phu Wiang Molluscan Locality 5 (PW-M-5). **A.** The weathering out of a red mud-nodule conglomeratic sandstone bed (stratum below the picture); **B.** Individual fossils on the surface of the shell bed (arrows; diameter of shell approximately 30 mm.).

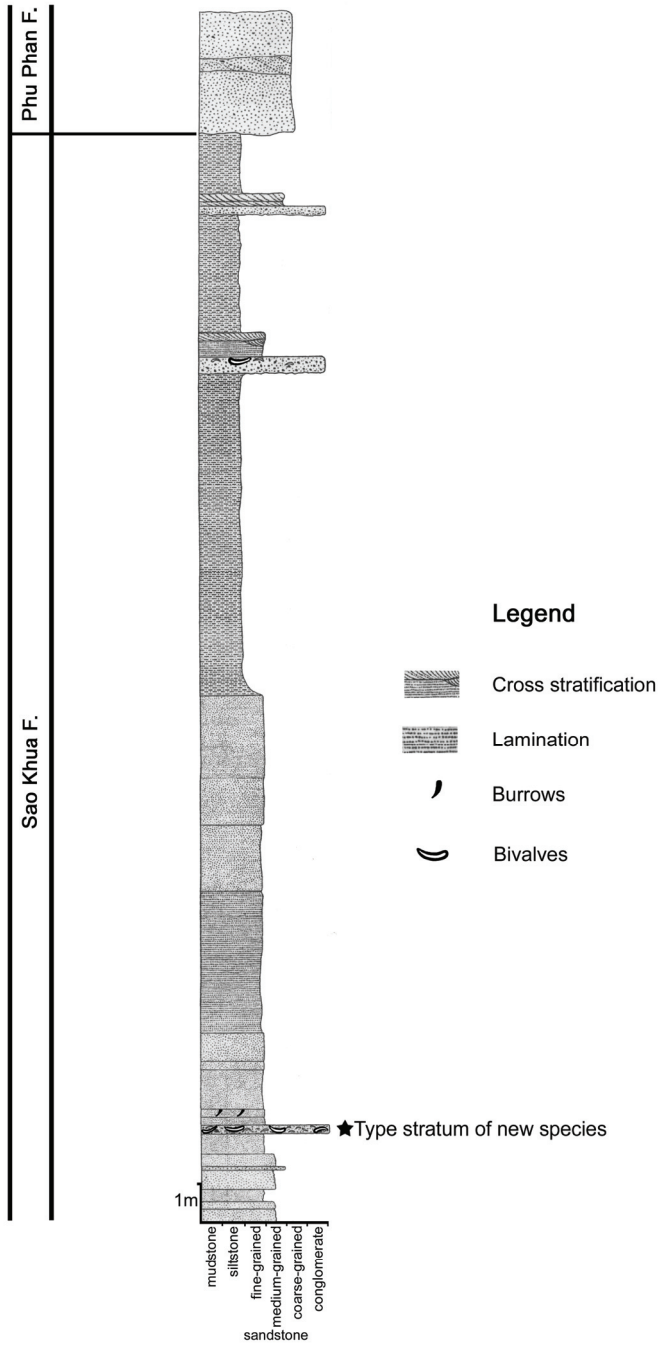


**FIGURE 3.** Columnar section of the Sao Khua Formation at the type locality of the new species, showing the stratigraphic horizon of the fossil locality.

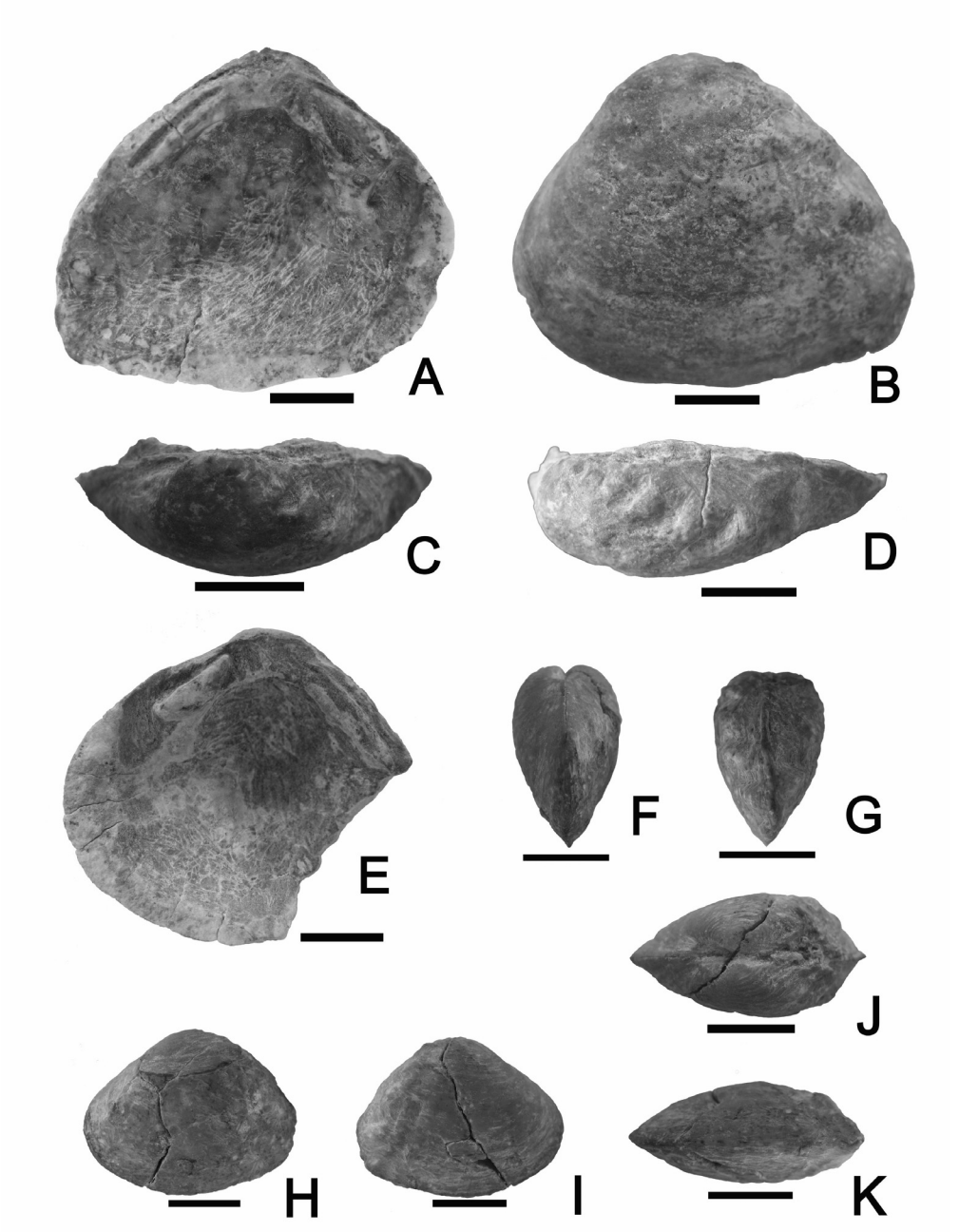


**FIGURE 4.** *Pseudohyria (Matsumotoina) somanai* n. sp. A - D, Left valve, holotype (CUMZ 3201) in A, internal view, B, external view, C, dorsal view and D, posterior view. E. Right valve, paratype (CUMZ 3202) in internal view. F-K, Articulated valve, paratype (CUMZ 3203) in F, anterior view and G, posterior view, H, left side view, I, right side view, J, dorsal view, K, ventral view. All scale bars represent 10 mm.

common (Table 2). Such preservation clearly demonstrates that this assemblage is a mixture of autochthonous and para-autochthonous bivalves.

The preservation described above suggests that the dead individuals of this bivalve assemblage were buried in or near their living place rather than being washed into inter-channel areas by floods. One likely explanation is that these bivalves were suddenly buried by sediments that were deposited so quickly that the slow moving bivalves could not escape from the rapid and thick accumulations.

The holotype (CUMZ 3201) and paratypes (CUMZ 3202 and 3203; PRC-M-M-106 to 236) are recrystallized shells. Among 215 specimens, 31 are articulated valves, 97 are left valves, 72 are right valves, and in addition, there were many fragmentary specimens (Table 2).

**Occurrence.**– The specimens described here were collected from a red mud nodule conglomeratic sandstone at Phu Noi in Phu Wiang Area, Khon Kaen province, northeastern Thailand (Fig. 1). This horizon contains the following bivalve species, *Pseudohyria (Matsumotoina) somanai* n. sp. (described above), *Trigonioides (Diversitrigonioides)* sp. cf. *T. (D.) diversicostatus* Hoffet, 1937 and *Nippononaia* sp. cf. *N. mekongensis* Kobayashi, 1963

**Comparison.**– *Pseudohyria (Matsumotoina) somanai* n. sp. similar to *P. (M.) matsumotoi* Yang, 1979 in both smooth hinge teeth and the present of submedian pseudocardinal teeth. The shell surface of *P. (M.) matsumotoi* are ornamented with more than 13 radial ribs on the posterior half, whereas the new species are ornamented with only 5 - 8 stout oblique posterior ribs. *P. (M.) matsumotoi* possess three or four pseudocardinal teeth on the right valve and three on the left valve, while the present species possess four on both valves (Table 3).

**Remarks.**– The preceding sole species of the subgenus, *Pseudohyria (Matsumotoina) matsumotoi* Yang, 1979 has been reported from the Lower Cretaceous Yeonwhadong Formation in Korea. The discovery of the new species, *Pseudohyria (Matsumotoina) somanai* n. sp. from the Sao Khua Formation of Phu Wiang Area is the first record of this subgenus in Thailand.

**Affinity.**– *Sainshandia nagnomensis* (Hoffet, 1937) has a subtrigonal outline with three or four very strong posterior radial ribs and four or five oblique posterior ribs which are stouter than radial ribs. The oblique posterior ribs branch off from the first posterior radial rib. This species was originally described by Hoffet (1937) as *"Unio" nagnomensis* Hoffet, 1937 for the specimens from Ban Na Gnom, Muong Phalane in southern Laos. Later, the generic name was changed by Kobayashi (1968) to *"Plicatotrigonioides" nagnomensis* (Hoffet, 1937) on the basis of strong oblique posterior ribs on the shell surface. Ma (1989) reassigned it to *Sainshandia nagnomensis* (Hoffet) and proposed his opinion that *Plicatotrigonioides* (?) *subovalis* (Kobayashi, 1968) from the Khok Kruat Formation at the Nam Phung Dam Site, Sakon Nakhon in northeastern Thailand is the junior synonym of *Sainshandia nagnomensis* (Hoffet, 1937). In addition, Ma (1994) suggested that *Pseudohyria (Matsumotoina) jingguoensis* Guo, 1985 from the Mangang Formation at Yunnan in southern China is identical with *Sainshandia nagnomensis* (Hoffet, 1937). This species was also discovered from the

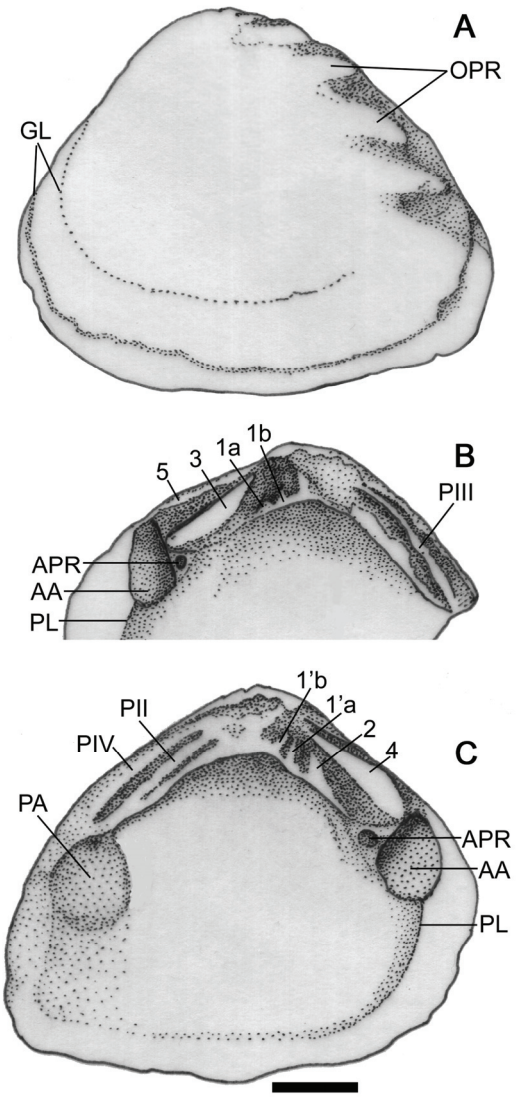


**FIGURE 5.** Interpretative drawings of *Pseudohyria (Matsumotoina) somanai* n. sp. **A and C**, Left valve, holotype in **A,** external view and **C,** internal view. **B**, Right valve, paratype, internal view. Abbreviations: AA, anterior adductor scar; APR, anterior pedal retractor scar; GL, growth line; OPR, oblique posterior rib; PA, posterior adductor scar; PL, pallial line; 1a, 1b, 3, 5, pseudocardinal teeth in right valve; 1'a, 1'b, 2, 4, pseudocardinal teeth in left valve; PIII, postero-lateral teeth in right valve; PII, PIV, postero-lateral teeth in left valve. Scale bars represent 10 mm. Drawing by S. Tumpeesuwan.

Bali Formation at Guangxi in southern China.

We can presume that *Sainshandia nagnomensis* (Hoffet, 1937) is the descendant of the *Pseudohyria (Matsumotoina) somanai* n. sp. from the Sao Khua Formation. Major morphological changes from *Pseudohyria (Matsumotoina) somanai* n. sp. to *Sainshandia nagnomensis* (Hoffet, 1937) are the formation of radial ribs and the decrease in number of pseudocardinal teeth and oblique posterior ribs.

## DISCUSSION

**Habitat.**– *Pseudohyria (Matsumotoina) somanai* n. sp. occurs in red mud nodule conglomeratic sandstone of the Sao Khua Formation (Figs. 2B and 3). The red mud nodule conglomeratic sandstone is thought to have been deposited in a river channel (Meesook, 2000; Meesook and Wongprayoon, 1999; Imsamut, 2003; Tumpeesuwan, 2005; Tumpeesuwan and Sato, 2005).

The shell bed is almost weathered out and the exact shell orientation could not be determined (Fig. 2A - B). Articulated valves of small shells are well preserved without abrasion of the delicate growth lines around the umbo (Fig. 4J). This evidence possibly reflects the absence of post-mortem transportation and it can be assumed that the valves were buried *in situ* by rapid sedimentation of flooding. This species may have lived in a muddy sand substratum which contained numerous granules to small pebbles.

**Geological range of *Pseudohyria (Matsumotoina)*.**– The characters of chevron ribs on posterior part, smooth hinge teeth, and four pseudocardinal teeth indicate that the new species belong to *Pseudohyria*

**TABLE 3.** Comparison between *Pseudohyria (Matsumotoina) matsumotoi* and *Pseudohyria (Matsumotoina) somanai* n. sp.

| Characters | *P. (M.) matsumotoi* | *P. (M.) somanai* n. sp. |
|---|---|---|
| Shell | | |
| Postero-dorsal | Rather straight | Rather arcuate |
| Postero-ventral corner | Rather angulate | Sharp angulate |
| Ventral margin | Broadly arcuate | Fairly arcuate |
| Escutcheon and lunule | Indistinct | Distinct |
| Surface ornamentation | 13 or more radial ribs on the posterior half | 5 - 8 short oblique posterior ribs |
| Ventral crenulation | Present | Absent |
| Pseudocardinal teeth | | |
| Left valve | 3 | 4 |
| Right valve | 3 - 4 | 4 |

*(Matsumotoina)*. This is very interesting because the preceding sole species, *Pseudohyria (Matsumotoina) matsumotoi* Yang, 1979, was discovered in Korea and Japan. This species was first discovered from the Yeonwhadong Formation, Geongsang Group in Korea. The formation also contains other bivalve species, such as *Nippononaia ryosekiana, Nagdongia soni, Trigonioides (Koreanaia) bongkyuni, Viviparus* sp. and *Micromelania katoensis*. The occurrence of *N. ryosekiana* can be considered to be correlated to the Aptian-Albian Sebayashi Formation in Japan (Yang, 1978), which has been reassigned to the Late Barremian to Early Aptian in age based on the analysis of ammonite assemblages of the underlying Ishido Formation and overlying Sanyama Formation (Matsukawa, 1983).

The second record of *Pseudohyria (Matsumotoina) matsumotoi* is the discovery of Ogasawara (1988), who discovered this species in association with *Plicatounio* sp. and *Nagdongia soni* from the Monomiyama Formation in northeastern Japan. The age of the formation is assigned to Hauterivian-Barremian.

Tamura (1990) reported the discovery of *Pseudohyria (Matsumotoina) matsumotoi* from the Kitadani and Sengoku formations in southwest Japan.

Isaji (1993) discovered *N. ryosekiana* from Kitadani Formation of the Tetori Group in Japan, where *N. ryosekiana* is associated with *Trigonioides (Wakinoa) tetoriensis, Plicatounio kobayashii, Nipponaia tetoriensis, Nagdongia soni* and *Viviparus* sp. Fujita (2003) assigned this formation to the Barremian on the basis of the occurrences of *N. ryosekiana* and TPN fauna.

Kozai et al. (2005) proposed a Sebayashi faunal association that is characterized by the *Hayamina matsukawai - Nipponaia ryosekiana* assemblage. It is comprised of the freshwater bivalve, *N. ryosekiana,* and five other species of brackish water bivalves that are restricted to the Late Barremian. The Nagdong fauna of Korea, being characterized by *N. ryosekiana, Pseudohyria (Matsumotoina) matsumotoi,* and *Nagdongia soni* are correlated with the Kitadani, Sengoku, and Sebayashi faunas and belong to the Sebayashi faunal association (Kozai et al., 2005, p.107, Table 3).

Sha (2007) subdivided the trigonioidid bivalve assemblages in Asia into 7 assemblages, and *Pseudohyria (Matsumotoina) matsumotoi* is in the second assemblage. He suggested a Late Barremian

-Early Albian, but mainly Aptian Age for the assemblage.

Therefore, we can assume that the taxon *Pseudohyria (Matsumotoina)* is restricted to Late Barremian.

**Age of the Sao Khua Formation.**– The Phra Wihan Formation underlies the Sao Khua Formation, contains palynomorphs suggesting Berriasian-Barremian age (Racey et al., 1994, 1996). The Khok Kruat Formation overlies the Phu Phan Formation, and the latter overlies the Sao Khua formation, respectively. The presence of hybodont shark *Thaiodus* suggests an Aptian-Albian age for the Khok Kruat Formation (Cappetta et al., 1990), and it also yielded palynomorphs indicating an Aptian age (Sattayarak et al., 1991). Therefore, Buffetaut et al. (2005) suggested the Sao Khua Formation is older than Aptian in age.

In the present study, the discovery of the new species of *Pseudohyria (Matsumotoina)* from the Sao Khua Formation is very important for age determination. The preceding sole species of this subgenus *Pseudohyria (Matsumotoina) matsumotoi* is restricted to the Sebayashi faunal association suggesting a Late Barremian age (Kozai et al., 2005). Thus, it is likely that the occurrence of *Pseudohyria (Matsumotoina)* in the Sao Khua Formation roughly assigns the formation to a Late Barremian age based on the geological range of the subgenus.

## CONCLUSION

The freshwater bivalve assemblage found in the red mud nodule conglomeratic sandstone of the Sao Khua Formation of the Phu Wiang Area includes *Pseudohyria (Matsumotoina) somanai* n. sp., *Trigonioides (Diversitrigonioides)* sp. cf. *T. (D.) diversicostatus* Hoffet, 1937 and *Nippononaia* sp. cf. *N. mekongensis* Kobayashi, 1963.

The unique morphological features of *Pseudohyria (Matsumotoina) somanai* n, sp. are five to eight short chevron ribs on the posterior ridge, non-crenulation hinge teeth with four pseudocardinal teeth on both valves.

The occurrence of well preserved small articulated valves, without abrasion of the delicate growth lines around the umbonal region indicates that these fossils were likely to have been buried *in situ*.

*Pseudohyria (Matsumotoina) somanai* n. sp. may indicate a Late Barremian age for the Sao Khua Formation based on the preceding sole species *Pseudohyria (Matsumotoina) matsumotoi* being restricted to Late Barremian horizons in Japan and Korea.

## ACKNOWLEDGEMENTS

This research was supported by Graduated Thesis Grant of Chulalongkorn University (3/2551) for the first author. We would like to express our gratitude to all members of the Phu Wiang National Park and Phu Wiang Dinosaur Museum for their kindness and help, especially Wikanet Songtham and Prachaya Bamrungsong. We are also indebted to the Vorajuk family, Komsorn Lauprasert and his students, Athiwat Wattanapitaksakul, Suchada Kamha, Uthumporn Deesri and Wilailuck Naksri for their help in field investigation and collection. Special thanks to Petra Lutat for checking the manuscript. We are also grateful to Chen Jia-hua, Tochifumi Komatsu, Sha Jin-jeng, Seong Young Yang, Assanee Meesook, Marc Philippe, Fred Naggs, Takahiro Asami, Kenshiro Ogasawara, Shinji Isaji, Pitsanupong Kanjanapayont, Thanakhom Bundhitwongrat,

Sravut Klorvuttimontara, Chitchai Chantangsi, Wannasiri Wannarat, Suravech Suteethorn and Chirasak Sutcharit for helpful suggestions and sending us many papers, which were difficult to obtain in Thailand.

## LITERATURE CITED

Buffetaut, E., Dyke, G., Suteethorn, V. and Tong, H. 2005. First record of the fossil bird from the early Cretaceous of Thailand. Comptes-Rendus Palevol, 4: 681-686.

Cappetta, H., Buffetaut, E. and Suteethorn, V. 1990. A new hybodont shark from the Lower Cretaceous of Thailand. Neues Jahrbuch für Geologie und Paläontologie Monatshefte, 11: 659-666.

Chonglakmani, C., Sattayarak, N., Kanchanapan, P., and Sarapirome, S. 1985. Geological map of Thailand on 1: 250,000 scale: sheet Changwat Khon Kaen (NE 48-13), Geological Survey Division, Department of Mineral Resources, Bangkok.

Fujita, M. 2003. Geological Age and correlation of the vertebrate-bearing horizons in the Tetori Group. Memoir of the Fukui Prefectural Dinosuar Museum, 2: 3-14.

Guo, F. 1982. A new subgenus *Matsumotoina* (Bivalvia) from the Asian non-marine Cretaceous. Geological Review, 28: 145-147.

Hahn, L. 1982. Stratigraphy and marine ingressions of the Mesozoic Khorat Group in northern Thailand. Geologisches Jahrbuch, B43: 7-35.

Hayami, I. 1968. Some Non-marine Bivalves from the Mesozoic Khorat Group of Thailand. Geology and Paleontology of Southeast Asia, 4: 100-107.

Hoffet, J. H. 1937. Les lamellibranches saumatres du Senonien de Muong Phalane (Bas-Laos). Bulletin du Service Geologique de l' Indochine, 24: 4-25.

Imsamut, S. 2003. The Sao Khua Formation, Khorat Group, Northeastern part of Thailand. Geological Survey Division, Department of Mineral Resources, Bangkok, 133 pp. (In Thai with English Abstract).

Isaji, S. 1993. *Nippononaia ryosekiana* (Bivalvia, Mollusca) from the Tetori Group in Central Japan. Bulletin of the Natural Science Museum of Tokyo, Series C, 19: 65-71.

Jearanaiwong, K. 2000. Early Cretaceous Bivalves of the Sao Khua Formation at Phuwiang National Park, Amphoe Phuwiang, Changwat Khon Kaen. Senior Project, Department of Geology, Faculty of Science, Chulalongkorn University, 95 pp. (Unpublished Senior Project).

Kobayashi, T. 1963. On the Cretaceous Ban Na Yo Fauna of East Thailand with a Note on the Distribution of *Nippononaia, Trigonioides* and *Plicatounio*. Japanese Journal of geology and geography, 34: 34-41.

Kobayashi, T. 1968. The Cretaceous Non-marine pelecypod the Nam Phung Dam Site in the Norteastern Part of the Khorat Plateau, Thailand with a Note on the Trigonioididae. Geology and Paleontology of Southeast Asia, 4: 109-138.

Kobayashi, T., Takai, F. and Hayami, I. 1963. On some Mesozoic Fossils from the Khorat Series of East Thailand and a Note on the Khorat Series. Japanese Journal of geology and geography, 34: 181-192.

Kozai, T., Ishida, K., Hirsch, F., Park, S. and Chang, K. 2005. Early Cretaceous non-marine mollusk faunas of Japan and Korea. Cretaceous Research, 26: 97-112.

Ma, Q. 1989. Evolution, classification of Trigonioidacea (Bivalvia) and its distribution in China. In: Chen, P.J., Xu, K.D. and Chen, J. H. (Eds). Selected papers for the symposium on Cretaceous of south China, Nanjing University Press, Nanjing, 246-291. (In Chinese with English Abstract).

Ma, Q. 1994. Non-marine Cretaceous bivalve assemblages in China. Cretaceous Research, 15: 271-284.

Matsukawa, M. 1983. Stratigraphy and sedimentary environments of the Sanchu Cretaceous, Japan. Memoirs of Ehime University Natural Science, Series D, 9: 1-50.

Meesook, A. 2000. Cretaceous environments of northeastern Thailand. In: Okada, H. and Mateer, N. J. (Eds). Cretaceous environments of Asia. Elsevier Science B, 17: 207-223.

Meesook, A. and Wongprayoon, T. 1999. Jurassic-Cretaceous Marine and non Marine Bivalves from the Northeastern and Peninsular Thailand: A preliminary Investigation. BRT Abstract of Research Project and Thesis 1999. Biodiversity Research and Training Program (BRT), 133.

Ogasawara, K. 1988. Early Cretaceous Freshwater Mollusc from the Monomiyama Formation, Southern Kitakami Mountains, Japan. In: Grant-Mackie, J.A., Masuda, K., Mori, K. and Ogasawara, K. (Eds). Professor Tamio Kotaka Commemorative Volume. Saito Ho-on Kai, Sendai, 301-315. (Special Publication).

Racey, A., Goodall, J. G. S., Love, M. A., Polachan, S. and Jones, P. D. 1994. New age data for the Mesozoic Khorat Group of Northeast Thailand. In: Angsuwathana, P., Wongwanich, T., Tansathien, W., Wongsomsak, S. and Tulyatid, J. (Eds). Proceedings of the International Symposium on Stratigraphic Correlation of Southeast Asia. Department of Mineral Resources, Bangkok, 245-252.

Racey, A., Love, M. A., Canham, A. C., Goodall, J. G. S., Polachan, S. and Jones, P. D. 1996. Stratigraphy and reservoir potential of the Mesozoic Khorat Group, NE Thailand. Part 1: stratigraphy and sedimentary evolution. Journal of Petroleum Geology, 19: 5-40.

Sha, J. 2007. Cretaceous trigonioidid (non-marine Bivalvia) assemblages and biostratigraphy in Asia with special remarks on the classification of Trigonioidacea. Journal of Asian Earth Sciences, 29: 62-83.

Tamura, M. 1990. Stratigraphic and Palaeontologic Studies on Non-marine Cretaceous Bivalve Faunas in Southwest Japan. Memoirs of the Faculty of Education Kumamoto University (Natural Science Supplement), 39: 1-47. (In Japanese with English Abstract).

Tumpeesuwan, S. 2005. Palaeontological and stratigraphy studies of freshwater molluscan assemblages from Sao Khua Formation, Khorat Group at Phu Wiang area, Changwat Khon Kaen. Master Thesis, Department of Geology, Faculty of Science, Chulalongkorn University, Thailand, 82 pp.

Tumpeesuwan, S. and Sato, Y. 2005. Freshwater bivalve assemblages from Sao Khua Formation of Phu Wiang Area, Northeastern Thailand- A preliminary report on Paleontological study. In: Wannakao, L., Youngme, W., Srisuk, K. and Lertsirivorakul, R. (Eds). Proceedings of the International Conference on Geology, Geotechnology and Mineral Resources of Indochina (GEOINDO 2005), Department of Geotechnology, Faculty of Technology, Khon Kaen University, Khon Kaen, 606-609.

Wongprayoon, T. and Meesook, A. 2002. Geology and Stratigraphy of the north-western rim of the Khorat Plateau, northeastern Thailand. (covering 2 topographic map sheets scale 1:50,000: Amphoe Phu Wiang (5442-II), Ban Khok Sung (5542-III), Geological Survey Division, Department of Mineral Resources, Bangkok, 61 pp. (In Thai with English Abstract).

Yang, S. Y. 1978. On the discovery of *Nippononaia ryosekiana* from the Gyeongsang Group, Korea. The Journal of the Geological Society of Korea, 14: 33-43.

Yang, S. Y. 1979. Some new Bivalve species from the Lower Gyeongsang Group, Korea. Transactions and Proceedings of the Palaeontological Society of Japan (New Series), 116: 223-234.