

Permian Brachiopods from Central Thailand : Contributions to the Geology and Palaeontology of Southeast Asia, IX.

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Permian Brachiopods from Central Thailand

Contributions to the Geology and Palaeontology
of Southeast Asia, IX.

By

Juichi YANAGIDA

Abstract

Seven species of Permian brachiopods, *Tyloplecta yangtzeensis* (CHAO), *Tyloplecta nankingensis* (FRECH), *Haydenella kiangsiensis* (KAYSER), *Marginifera banphotensis* sp. nov., *Orthotetina phetchabunensis* sp. nov., *Orthotichia javanapheti* sp. nov., and *Linoproductus* sp. are described from a mudstone in the Rat Buri Limestone of central Thailand. It is concluded that the age of the fauna is that of the zone of *Parafusulina* up to the lower part of the zone of *Yabeina-Lepidolina* and that there is strong affinity with the Permian faunas of the South Chinese region.

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Introduction

Permian brachiopods described in this paper occur in the dark calcareous mudstone near Tamban Ban Phot (15°57'N.L., Long. 100°52'E) of Phetchabun district. The materials dealt with are very important for determination of the age of the Rat Buri Limestone of Thailand. They include twenty five specimens belonging to seven species among six genera. The following species have been identified.

	original number and locality	number of specimens
<i>Tyloplecta yangtzeensis</i> (CHAO).....	TF 332, loc. 2	2
<i>Tyloplecta nankingensis</i> (FRECH).....	TF 332, loc. 2	1
<i>Haydenella kiangsiensis</i> (KAYSER).....	TF 332-3, loc. 2	4
<i>Marginifera banphotensis</i> sp. nov.	TF 338, loc. 3	7
<i>Orthotetina phetchabunensis</i> sp. nov.	TF 332-4, loc. 2	2
<i>Orthotichia javanapheti</i> sp. nov.	TF 339, loc. 3	7
<i>Linoproductus</i> sp.	TF 332-2, loc. 2	1

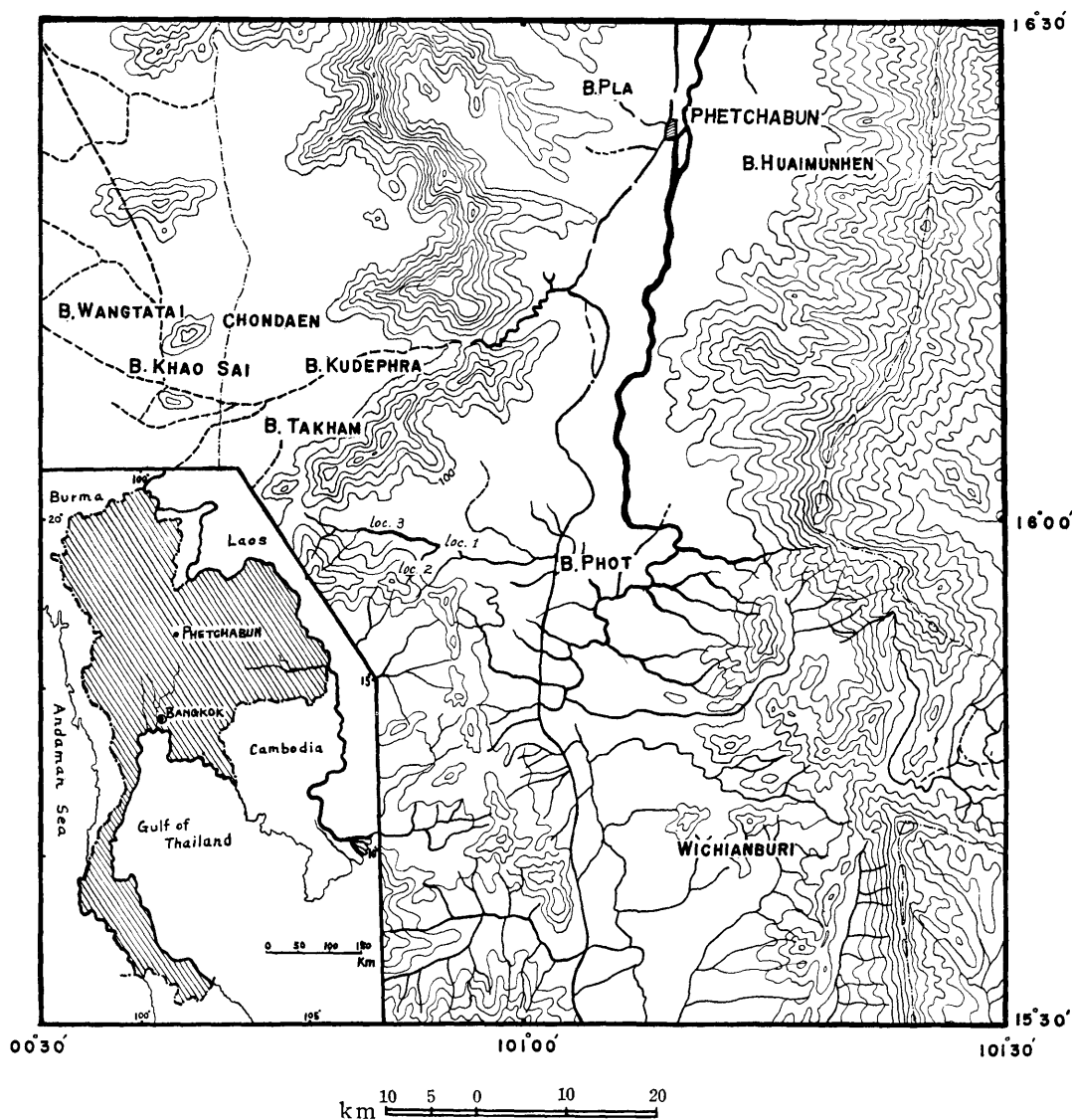


Fig. 1. Index map showing localities of brachiopoda collections from the Permian of central Thailand. Fossils from loc. 1 were not dealt in this paper.

The five species including a new one come from location 2 and the two new species are from location 3, about 6 km northwest of the former place. The two groups of brachiopods were found in the petrographically same calcareous mudstone. The brachiopods are believed to be of the same age.

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Systematic descriptions

Family Dictyoclostidae STEHLI, 1954

Subfamily Dictyoclostinae STEHLI, 1954

Genus *Tyloplecta* MUIR-WOOD and COOPER, 1960

Type-species.—*Productus scabriculus* mut. *nankingensis* FRECH, 1911

Tyloplecta yangtzeensis (CHAO)

Pl. 1, figs. 1, 3; Fig. 2

1927. *Productus yangtzeensis* CHAO, Palaeont. Sinica, Ser. B, vol. 5, fasc. 2, pp. 50-54, pl. 5, figs. 1-3, pl. 8, fig. 9.

1932. *Productus (Dictyoclostus) yangtzeensis* HUANG, Ibid., Ser. B, vol. 9, fasc. 1, p. 26, pl. 1, figs. 18-21.

Material.—The following two specimens are described under the heading; GK-D 31100 (Pl. 1, fig. 1), GK-D 31101 (Pl. 1, fig. 3). Internal structures are shown by the serial sections of GK-D 31101.

Description.—The shell is large, and subquadrate to subglobose in outline. The pedicle valve is strongly and regularly inflated. The visceral disc is moderately convex and the trail strongly curved. The flanks are steep and the venter flattened. The median sulcus is weakly defined by a broad flattening along the median portion of the trail. The ears are slightly convex and large. The cardinal extremities are rounded and almost rectangular in their angles. The umbo is rounded and the blunt beak incurved beyond the hinge-line which makes the greatest width of the shell. The brachial valve is strongly concave and the concavity is stronger in the anterior half.

The pedicle valve is ornamented by many, low, longitudinal costae and concentric rugae. The costae are round but narrow-topped. They widen and tend to become flattened anteriorly. They are obtuse on the ears. They commonly bifurcate and intercalate. About five costae are usually observed within 10 mm at a distance of 20 mm from the umbo. Each costa is about 1 mm in width in the anterior part of the valve. Between the costae the grooves are broad and shallow. Concentric rugae occupy the posterior part of the valve are

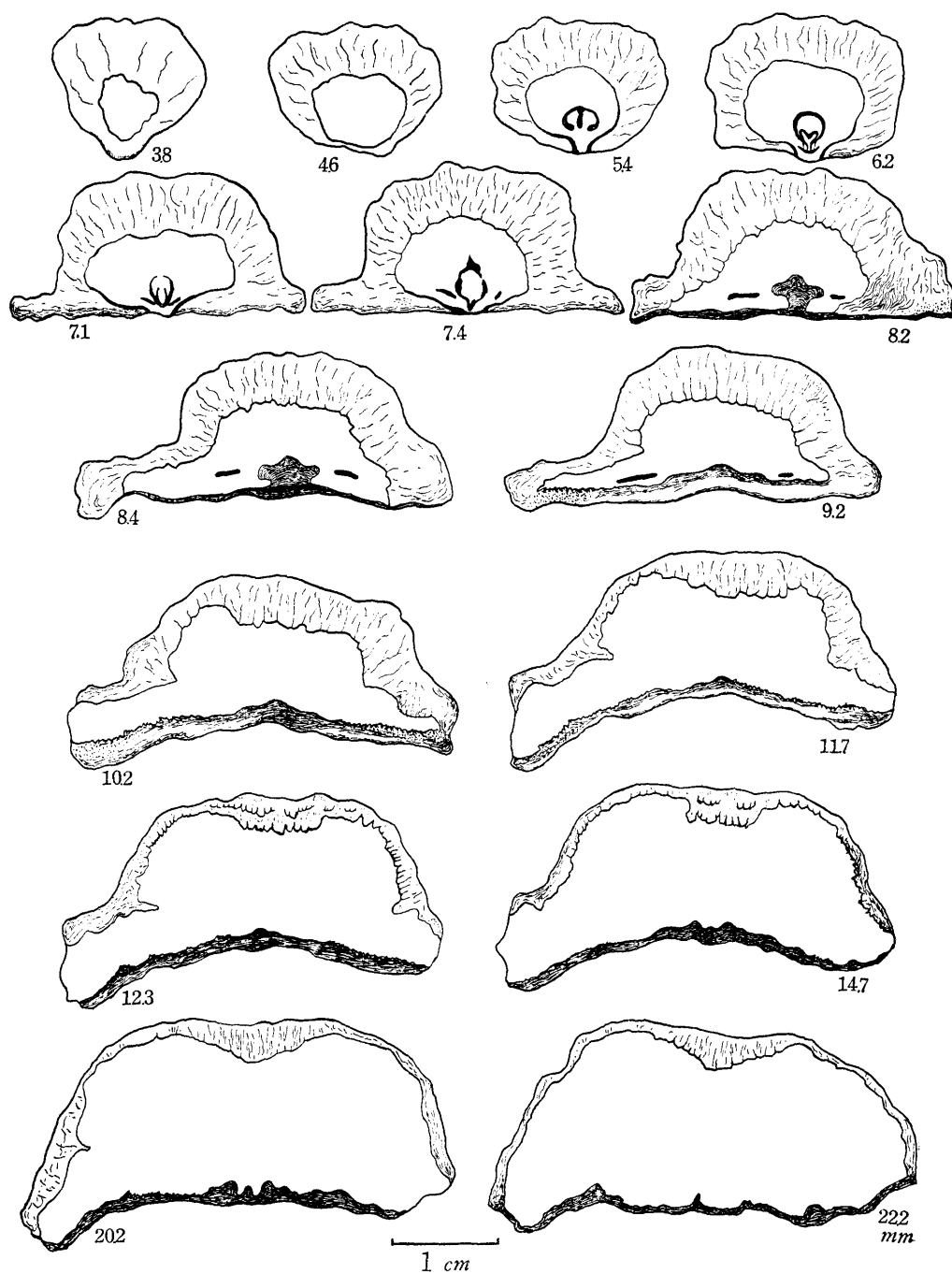


Fig. 2. *Tyloplecta yangtzeensis* (CHAO). Serial sections of specimen GK-D 31101 (Pl. 1, fig. 3).

crowded on the ears and hinge. On the visceral disc, they are represented by strong nodes at the points of their intersection with the costae. Spine-bases of small diameter occur on the top of the costae in the posterior part of the valve. They are arranged in rows along the hinge margin, on the ears, and on the enlargement of the visceral disc. They appear sporadically on the trail and were not observed near the anterior margin.

The ornament of the brachial valve is too poorly preserved to describe. It seems to be almost the same as that of the opposite valve. However the spines are very rare.

Very fine growth lines are numerous on the whole surface. Slightly ex-foliated valves reveal closely crowded, microscopic granulations on the whole surface.

The pedicle valve is much thickened in the umbonal region. The adductors are distinct, dendritic, broad, and long. The widest part of the adductor field is 7 mm and its length is about a third that of the visceral disc. The diductor scars are deeply impressed and their surface is longitudinally striated. The lateral margin of the scars is bounded by a distinct ridge. The adductors are connected with a broad, thickened ridge-like area anteriorly. Each of the dendritic and striated characters of the adductors and diductors is remarkably observed in the serial sections.

Internal surface of the brachial valve is ornamented by numerous fine endospines. The cardinal process is trilobate and supported by a broad, low shaft. The median septum becomes more distinct anteriorly but not so prominent. Anterior adductor scars are narrow and are elevated in their inner parts along the median septum. The branchial ridges are slightly elevated.

Dimensions of two specimens in mm:

	1	2
length	41.8	35.5
surface measure	90.5	72.0
thickness		6.7
height	28.3	22.7
width	46.3	39.5

Remarks.—The Thailand specimens agree most in external characters with those of the holotype and paratypes of the species described by CHAO (1927). However it is impossible to compare the internal structures of both the specimens as he did not give any information about the internal characters of the holotype. Internal characters of the Thailand specimens well represent those of the genus, and most resemble those of *T. nankingensis* (FRECH), the type-species, as shown by MUIR-WOOD and COOPER (1960, pl. 102, figs. 6-13) in the excellent hypotypes. *T. yangtzeensis*, however, clearly differs from *T. nankingensis* by the surface characters upon which CHAO laid much emphasis in establishing the species. At present more importance is attached to the external characters rather than the internal one in defining species of *Tyloplecta*. As a matter of fact, there are only a few species among the group which are assigned to the genus. Therefore

it is necessary to study the interior characters of all the species of the genus.

According to CHAO (1927), important characters of *T. yangtzeensis* are its rather irregular longitudinal costae which often bifurcate and intercalate near the anterior margin. The costae are broad at the base and upwardly thin down. Therefore broad interspaces between them make shallow grooves where some fine radial striae often branch out from the costae. These characters are well preserved in the Thailand specimens except the radiating capillae in the grooves between the costae. Because the Thailand shells are slightly exfoliated, the minute sculpture of the surface is hardly preserved in any of the specimens. But they are traceable in a specimen.

HUANG (1932) described and figured *T. yangtzeensis* under the name of *Productus* (*Dictyoclostus*) *yangtzeensis* from the *Lyttonia* horizon in the coal-bearing shales at Wantze, Ch'ichianghsien, Szechuan, and cherty beds of the Wushan Limestone of Lungtunpei, northern Szechuan. The Thailand specimens well agree with those from Szechuan not only in external characters but also in the internal ones which were briefly described by Huang.

The Thailand specimens resemble externally *T. sumatrensis* which was described by ROEMER (1880) under the name of *Productus sumatrensis* from the Permian of Pandan, Sumatra of the East Indies. The Sumatran specimens, however, can be clearly distinguished from the Thailand ones by their strong and simple costae.

Tyloplecta nankingensis (FRECH)

pl. 1, fig. 2

- 1911. *Productus scabriculus* MARTIN mut. *nankingensis* FRECH, RICHTHOFEN's China, vol. 5, p. 163, pl. 22, figs. 3a-c.
- 1927. *Productus nankingensis*, CHAO, Palaeont. Sinica, Ser. B, vol. 5, fasc. 2, pp. 54-56, pl. 8, figs. 12-13.
- 1932. *Productus* (*Dictyoclostus*) *nankingensis*, HUANG, Ibid., Ser. B, vol. 9, fasc. 1, pp. 28-30, pl. 2, figs. 1, 2.
- 1933. *Productus* (*Dictyoclostus*) *nankingensis*, HUANG, Ibid., Ser. B, vol. 9, fasc. 2, pp. 87-88, pl. 11, figs. 16, 17.
- 1960. *Tyloplecta nankingensis*, MUIR-WOOD and COOPER, Geol. Soc. Am. Mem. 81, p. 291, pl. 101, figs. 4-6, pl. 102, figs. 1-13.
- ?1961. *Dictyoclostus nankingensis*, THUAN, Ann. Fac. Sci. Saigon, p. 281, pl. 1, fig. 11.

Material.—Only a pedicle valve (specimen GK-D 31102) is well identified with the heading.

Descriptive remarks.—The shell is fairly large and subquadrate in outline. The pedicle valve is strongly inflated with moderately convex visceral disc, convex ears, very steep flanks, and fairly curved trail.

The valve is ornamented by many, prominent, longitudinal costae and concentric rugae. The costae slightly increase in width anteriorly and are about 1 to 1.5 mm in width near the anterior margin. About 6 costae are counted within 10 mm at a distance of 20 mm from the umbo. Some bifurcate and

distinct, round grooves are impressed among them. The rugae are developed in the posterior part of the shell which is remarkably reticulated. The reticulation occupies about 16 mm from the umbo and about two fifths the length of the shell. Spine bases of very small diameter are developed in the posterior part and are sopradic anteriorly. They are disposed along the hinge margin, on the ears, on the nodes of the visceral disc, and on the costae of the trail. Very fine, numerous growth-capillae are observed on the surface. Microscopic granulations are arranged on the inner layer of the shell.

The dimensions of the shell are approximately 42.2 mm's long, 24.5 mm's high, and 41.2 mm's wide. The surface measure of the valve is 79.5 mm's long.

The Thailand specimen agrees well in most external characters, the surface sculpture, size, and proportions, with those described and figured by FRECH (1911) from the Permian Chihhsia Limestone of Anhui of China and with those explained and figured by MUIR-WOOD and COOPER (1960) concerning the description of the genus from the Permian of Shin k'ai Shih, Mt. Omei, Szechuan, China. The Thailand specimen is characterized by strong, round costae which bifurcate and by distinct but small spine bases. These characteristics were already pointed out by CHAO (1927) as the specific character in his description of the species from the Chihhsia Limestone at Hochow, Anhui, China. Some specimens described by HUANG (1932) under the name of *Productus* (*Dictyoclostus*) *nankingensis* from the Upper Permian Wushan Limestone of Ch'aot'ienkuan and Chaohuahsien of Szechuan, and from the Upper Permian limestone of Lihusukou, Hauyuanhsien, Szechuan agree with the Thailand specimen in their external characters.

THUAN (1961) described the species by the name of *Dictyoclostus nankingensis* from the Upper Permian of Phnom-Tup, Cambodia. The specimen is so poorly preserved that nothing is known about the internal characters. Therefore the no detailed comparison of the Cambodian specimen with the Thailand one can be made.

Family Marginiferidae STEHLI, 1954

Subfamily Costispiniiferinae MUIR-WOOD and COOPER, 1960

Genus *Haydenella* REED, 1944

Remarks.—Generic diagnosis was described by Reed (1944) and MUIR-WOOD and COOPER (1960). The latter authors discussed it in detail. According to KAYSER's original description of *Productus kiangsiensis*, and also to the definition by Reed and MUIR-WOOD and COOPER, there exists a short but distinct interarea in the pedicle valve. Thailand specimens, on the other hand, never have the interarea. However, the other characters of the Thailand specimens are in harmony with those of the genus. It is considered that the existence of the interarea is not so important for the generic character.

HUANG (1932) assigned *P. kiangsiensis*, the type-species of the genus, to *Linoproductus*. *Haydenella*, however, differs internally from *Linoproductus* by the form of the cardinal process and the existence of rows of endospines.

Type-species.—*Productus kiangsiensis* KAYSER, 1883

Haydenella kiangsiensis (KAYSER)

Pl. 2, fig. 1, Pl. 3, fig. 4; Fig. 3.

- 1882. *Productus kiangsiensis* KAYSER, RICHTHOFEN's China, Bd. 4, p. 185, pl. 26, figs. 6-11.
- 1911. *Productus kiangsiensis*, FRECH, Ibid., Bd. 5, p. 129, pl. 21, figs. 3, 5.
- 1927. *Avonia? kiangsiensis*, CHAO, Palaeontologia Sinica, Ser. B, vol. 5, fasc. 2, p. 125, pl. 14, figs. 14-16.
- 1928. *Thomasia kiangsiensis*, CHAO, Ibid., Ser. B, vol. 5, fasc. 3, p. 59, pl. 6, fig. 18.
- 1932. *Linoproductus kiangsiensis*, HUANG, Ibid., Ser. B, vol. 9, fasc. 1, pp. 46-48, pl. 3, figs. 13-15, 19.
- 1961. *Linoproductus kiangsiensis*, SHIMIZU, Mem. College of Sci., Univ. Kyoto, Ser. B, vol. 27, no. 3, pp. 326-327, pl. 15, figs. 16, 17.

Material.—The following four specimens are described; GK-D 31104, GK-D 31105 (Pl. 2, fig. 1), GK-D 31106 (Pl. 3, fig. 4), GK-D 31107. Internal structures are shown by the serial sections of GK-D 31105. The outer surface of the brachial valve is not preserved at all.

Description.—The shell is medium in size and subcircular in outline. The shell-surface is lustrous. The pedicle valve is fairly inflated with the greatest convexity at its umbonal portion. The brachial valve is moderately concave. Flanks are rather steep and the trail is slightly and evenly curved. The transverse profile of the pedicle valve is regularly and uniformly curved and slightly steepened on either side of the valve. The median sulcus is absent without any traces of flattening. The beak is tapered, pointed, and slightly overhangs the hinge-line. The latter is shorter than the greatest width of the shell which is at about midvalve. The ears are small and flattened.

Pedicle valve is ornamented by very fine capillae which bifurcate and intercalate anteriorly. Two capillae are counted in general in 1 mm at about 1 cm from the umbo. Interspaces are characterized by broad and indistinct depressions which are usually wider than the capillae. The capillae are regularly disposed in the umbonal region but rather irregular and wavy on the trail and flanks. In two specimens, the capillae rapidly increase in strength and number on the venter. Taleolae are scattered in the inner layer of the shell. The surface of the valve is covered by numerous, very fine growth-lines. Remarkable rugae are only developed on ears. Seven strong, longitudinal crenulations are counted on the ears along the hinge margin. Spine bases are observed sporadically on the capillae on the boundary between the ears and the visceral disc. Six to 7 of them are counted on the former and 3 to 4 on the latter. They are small but have a larger diameter than the width of the capillae.

Interior of the pedicle valve has indistinct but fine longitudinal striae on the diductor scars which are bounded laterally by a distinct ridge. Interior surfaces of the spine bases are strongly thickened by round walls.

Interior of the brachial valve is longitudinally striated and has a sessile,

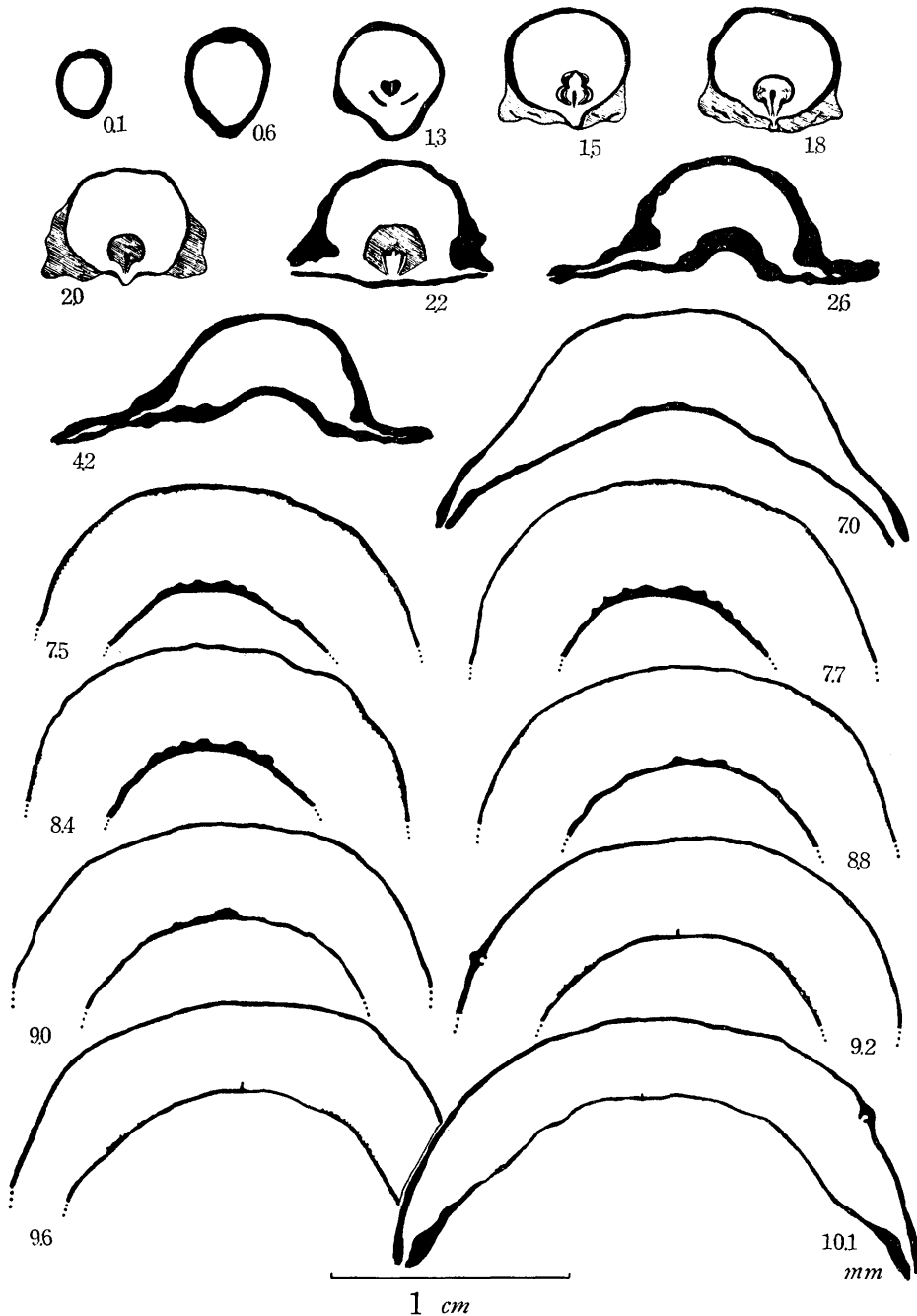


Fig. 3. *Haydenella kiangsiensis* (KAYSER). Serial sections of specimen GK-D 31105 (Pl. 2, fig. 1).

trilobate cardinal process. The median lobe curves dorsally and is medianly sulcate. The posterior extremities of the lateral lobes form angles of 30° to the hinge-line. Adductors and the brachial ridges are very low and the former are

smooth. The median septum is very short and extends anteriorly about a half of the shell length. The endospines are very small. Marginal region of the valve is slightly thickened. These characters are well shown by the serial sectionings.

Dimensions of four specimens in mm:

	1	2	3	4
length	22.0	21.0	20.0	20.0
surface measure	36.0	39.5	35.5	37.3
thickness				4.0
height	12.5	12.0	11.0	12.0
width	24.5	24.0	22.3	25.0
hinge width	17.0	14.0	14.0	16.0

Remarks.—Although the Thailand specimens are not well preserved, they have a globose pedicle valve, lack a median sulcus, relatively short hinge-line, small ears, fine capillae, remarkable rugae on the ears, sporadically disposed spine bases, and internally sessile cardinal process, short median septum, and small endospines. In these respects they are most similar to those figured and described by KAYSER (1883) from the *Lyttonia* bed of Loping, China. The former specimens slightly differ from the Loping ones in lacking the interarea and in having fewer spines on the surface separating the ears and visceral disc. The interarea of the Loping specimens is very short, and the difference between the Loping and the Thailand specimens is presumed to be due to a variation in a species.

CHAO (1927) described *Haydenella kiangsiensis* under the name of *Avonia? kiangsiensis* which was later referred by him (1928) to *Thomasia*. The Thailand specimens agree with those of the Kiangsu ones in most characters. Some Kiangsu specimens, however, have shallow median depressions according to CHAO (1927). They have also stronger radial capillae than those of the Thailand ones. These characteristics were shown by CHAO (1927, pl. 14, figs. 14-16; 1928, pl. 6, figs. 18a-c).

HUANG (1932) referred *P. kiangsiensis* to *Linoproductus* and described the species from the *Lyttonia* horizon of Kueichow, southwest China. These Kueichow specimens show slight differences from the Thailand ones. The former has stronger capillae, more transverse outline, and less pronounced umbo than the latter. *Linoproductus kiangsiensis* var. *wengannensis* described by HUANG (1932) from the Permian of Kueichow is quite distinct from the Thailand species by its smaller dimension, more inflated pedicle valve, and stronger radial costae.

SHIMIZU (1961) described the same species as *Linoproductus* from the Permian Maizuru group, Japan. However, the detailed comparison of both the Japanese and Thailand specimens is not possible because of the unfortunate state of preservation of the former which is more transverse and has more distinct striae than the latter.

Some species allied to *Haydenella kiangsiensis* were recorded from the Middle and Upper *Productus* Limestone of Salt Range and Kashmir. They have been

described under the names of *Productus tumidus* by WAAGEN, *Marginifera vihiana* by DIENER, *Haydenella vihiana* var. *salinalia*, and *H. quesita* by REED. They are, however, easily distinguishable from *H. kiangsiensis* by their outlines, size, and the strength of the surface sculpture.

Subfamily Marginiferinae STEHLI, 1954

Genus *Marginifera* WAAGEN, 1884

Type-species.—*Marginifera typica* WAAGEN, 1884

Marginifera banphotensis sp. nov.

Pl. 3, figs. 2, 3; Figs. 4, 5.

Material.—Holotype GK-D 31113 (Pl. 3, fig. 3); paratypes GK-D 31108 (Pl. 3, fig. 2), GK-D 31109, GK-D 31114. Four other specimens are also referred to the species. Internal structures are shown by the serial sections of GK-D 31111 and GK-D 31114.

Description.—The shell is medium in size, slightly wider than long, and subcircular in outline. The greatest width is at the hinge-line or is situated more anteriorly.

The visceral disc of the pedicle valve is strongly inflated and the trail is slightly and uniformly convex. The umbo is acute, pointed and slightly incurved over the hinge-line. The flanks are steep and separated from the ears by a deep concavity. The ears are not well preserved, however, they are distinct and slightly convex. The venter is slightly rounded and there is no indication of a median sulcus.

The brachial valve is fairly concave and strongly geniculated anteriorly.

The pedicle valve is ornamented by strong, simple, and rounded costae. They gradually increase in strength and width towards the anterior margin. They are not sculptured at all in the umbo and ears. Shallow and round grooves separate the costae. About 4 costae occur in 5 mm at about 1 cm from the umbo and a total of 15 to 17 costae are counted on the pedicle valve. The entire surface is covered by numerous, fine spines disposed on the costae, umbo, and flanks. Five to 6 spines are counted on a costa. They are closely arranged in the posterior part of the costae and on the visceral disc, but they are very sporadic near the anterior margin. Two rows of spines are closely disposed on the flanks from the slightly anterior part of the umbo to the anterior margin. The inner row is composed of 8 spines and the outer one of 6 spines. Very weak rugae occur on the visceral disc and microscopic growth-lines are observed on the valve in some slightly exfoliated specimens.

The ornament of the brachial valve is unknown. The walls of both valves are thin.

The pedicle valve interior is characterized by adductors which are slightly ridged longitudinally in umbonal region. The shell is thickened at the inner part of ears and remarkable ridges project just inside the ears.

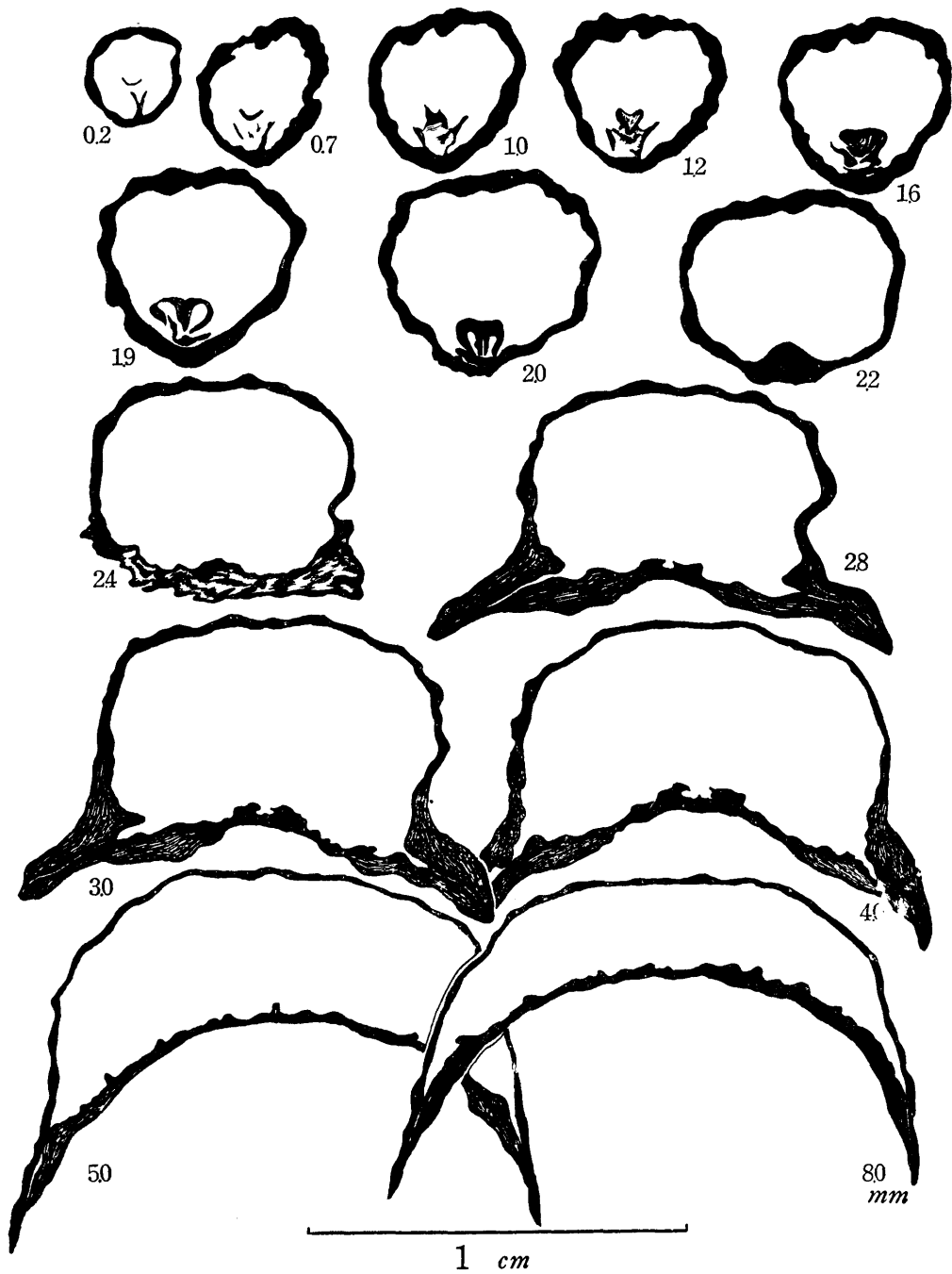


Fig. 4. *Marginifera banphotensis* sp. nov. Serial sections of specimen GK-D 31111.

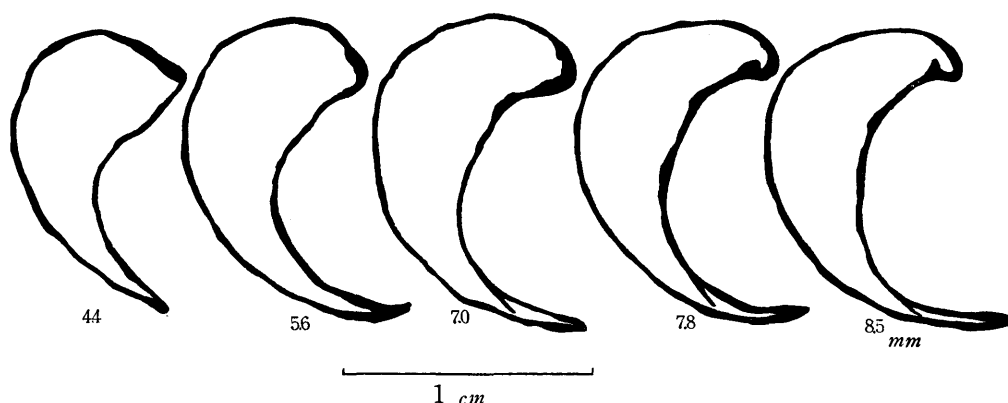


Fig. 5. *Marginifera banphotensis* sp. nov. Longitudinally serial sections of a paratype, GK-D 31114.

The brachial valve interior has a large, sessile, trilobate cardinal process. The median lobe is sulcated. The lateral ridges extend from the base of the cardinal process in an anterolateral direction. They are low but strongly ridged. Adductor muscle scars are slightly elevated and elongated longitudinally. Their inner margins are sharp and a deep groove occurs between the scars. Median septum is weak and low, and occurs in the groove between the adductor scars and tapers anteriorly. The endospines are low and scattered sporadically in the anterior region of the median septum.

Dimensions of five specimens in mm:

	1	2	3	4	5
length	14.5	15.5	16.5	15.0	17.5
surface measure	28.0	26.0	28.0	27.0	
thickness				5.0	5.3
height	10.4	9.0	10.0	8.9	8.3
width	17.0	15.7	16.0	16.0	16.2
hinge-width	15.0	15.7	14.5	15.0	14.0

Remarks.—MUIR-WOOD and COOPER (1960) redefined *Marginifera* and restricted it to species which are definitely allied to the type-species of the genus. The Thailand species differs superficially from *Marginifera typica*, the type-species of the genus, in having fairly defined costae and in not having a medianly sulcate trail. In *M. typica* the costae are poorly defined and the trail is medianly sulcate. Simple costae and the numerous erect spines on the pedicle valve are characteristic of species of *Costispinifera*. The Thailand species, however, is easily distinguished from the species of the genus *Costispinifera* by its internal characters. The Thailand species are closely similar to *M. typica* in the internal characters. On the other hand, other external characters of the Thailand species are in harmony with those of *M. typica*. They have a highly convex visceral disc, acute umbo, hinge line approximately equalling the greatest width of the shell, weak posterior rugae, scattered spines on the pedicle valve, and two rows of

spines on the flanks. These characters of the shell clearly reveal that the Thailand species is closely related to *M. typica*.

The Thailand species closely resembles *Productus (Marginifera) magniplicatus* HUANG from the Upper Permian of Kueichow of south China and *Marginifera lopingensis* (KAYSER) from the Permian *Lyttonia* and *Oldhamina* beds of south China in external configurations. The Thailand species, however, is distinguished from *P. (Marginifera) magniplicatus* by the difference in size, character and ornament of the shell. The Chinese species was established on three specimens all of which are smaller than the Thailand ones. According to Huang, the Chinese specimens have a narrow but fairly deep sulcus which commences near the beak and extends to the anterior margin. The Thailand ones, to the contrary, never have the sulcus on the pedicle valve. In the Chinese specimens the costae are coarser than those of the Thailand ones and they are developed more posteriorly in the former than in the latter. The Chinese specimens have strong, round spine bases. On the other hand, the Thailand ones have small, numerous spines. The internal structures of the Thailand specimens cannot be compared with those of the Chinese ones because of the unfortunate state of preservation of the latter. However, the Thailand species can easily be distinguished from the Chinese one by the differences stated above. GRABAU (1936) described *M. magniplicata* from the Lower Permian of Chini, Yunnan, south China. His specimens are larger than the Thailand ones and have coarser costae in the pedicle valve than those of the latter. It is difficult to compare both the specimens with each other, because the internal characters of the Yunnan specimens are not known and the rows of spines on the flanks such as in the Thailand specimens have not been described.

Another similar species, *Marginifera lopingensis*, first described by KAYSER (1884) under the name of *Productus nystianus* de KONINCK var. *lopingensis* and later emended by CHAO (1927), is also distinguishable from the Thailand one by the following characters. *Marginifera lopingensis* is larger than the Thailand species. In the former the costae are more numerous and thinner than those of the latter. According to CHAO, *M. lopingensis* has strongly undulating, concentric growth lines all over the surface. In the Thailand species they are microscopic and usually obscure except for weak rugae on the umbonal region. Two rows of spines on the flanks of the Thailand species are also one of the characteristics. Marginal ridge of *M. lopingensis* is more remarkable than that of the Thailand species. It is considered that the Chinese species, *Productus (Marginifera) magniplicatus* and *Marginifera lopingensis*, are closely allied to the Thailand species.

Family Orthotetidae WAAGEN, 1884
Subfamily Orthotetinae WAAGEN, 1884
Genus *Orthotetina* SCHELLWIEN, 1899

Type-species.—*Orthotetes persicus* SCHELLWIEN, 1899

Orthotetina phetchabunensis sp. nov.

Pl. 2, figs. 5, 6; Fig. 6

Material.—Holotype GK-D 31115 (Pl. 2, figs. 6a-d); paratype GK-D 31116 (pl. 2, figs. 5a-d). Holotype is well preserved except the slightly exfoliated beak region of the pedicle valve. Paratype is a pedicle valve.

Description.—The shell is medium in size and subcircular to suboval in outline. The greatest width is at midvalve. The hinge-line is slightly longer than half of the shell-width. Although the tip of the beak is exfoliated, it was probably pointed and not incurved.

Posterior half of the pedicle valve is moderately convex transversely. Anterior half of the valve is slightly flattened and resupinate near the anterior margin. The cardinal area is high, making an approximate angle of 110° to the commissure-plane. A narrow delthyrium is in the middle of the area bisecting the cardinal area. It is about 13 mm in width at its base and converges slightly, upward. The height of the area is approximately 9 mm. The delthyrium is covered by a slightly convex pseudodeltidium which is striated transversely. The surface of the valve is ornamented by sharp and narrow radiating capillae.

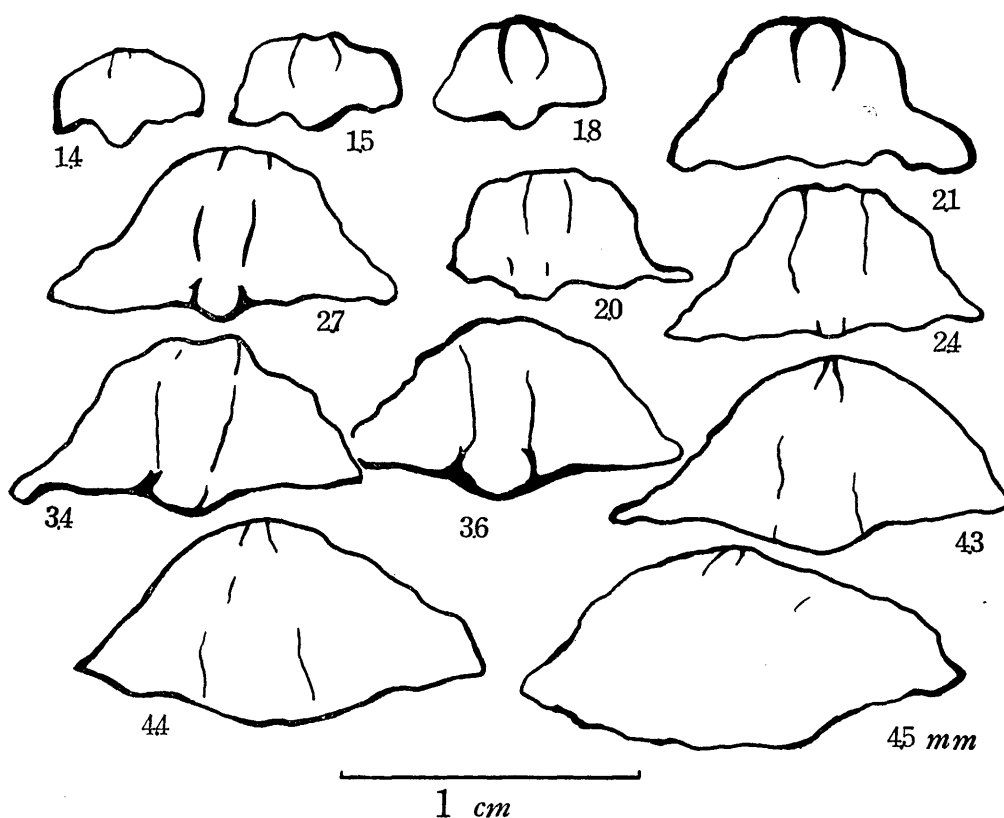


Fig. 6. *Orthotetina phetchabunensis* sp. nov. Serial sections of the holotype, GK-D 31115 (Pl. 2, fig. 6)

Rather flattened and broad striae occur between the capillae. Ten to 12 capillae are counted in 5 mm near the anterior margin. They increase in number by intercalation. Microscopic growth striae are closely disposed on the valve and the capillae show faint nodulations. This character is observed especially in the posterior region, and anteriorly it becomes obsolete.

The brachial valve is round in outline and only slightly convex in the posterior region but as a whole is rather flattened. The umbo is rather flat and obtuse. No area is present.

The surface ornament resembles that of the pedicle valve.

The interior of the pedicle valve has a pair of thin and short but deep dental lamellae that extend about one fifth the valve-length from the beak. They converge more or less ventrally and diverge dorsally near their anterior extremities. However they never unite. A median septum is not present. The brachial valve-interior has rather strong socket plates.

Measurements of two specimens in mm:

	1	2
length of		
pedicle valve	ca. 24.0	21.4
brachial valve	20.0	
width	26.8	19.0
thickness	9.6	
length of hinge-line	14.6	10.6

Remarks.—The Thailand species is characterized by subcircular outline, short hinge-line, slightly convex brachial valve, and short but deep dental lamellae which are parallel and slightly converge anteriorly. Externally the Thailand species resembles some ones in the Asiatic region, from which the former is clearly distinguishable in the internal characters.

Among the Chinese species, *Schellwienella regularis* HUANG and *Streptorhynchus pelargonatus* var. *lenticularis* WAAGEN by HUANG are very similar to the Thailand species in external characters. Both species were described by HUANG (1933) from the *Lyttonia nobilis* horizon of the Permian coal-bearing formation in Kueichow and the Permian coal-bearing formation of Erhp'u of Kueichow respectively. *Schellwienella regularis* was established by the internal mould of a pedicle valve and several brachial valves. Although it is very doubtful whether the pedicle valve and the brachial valves belong to one and the same species, external characters are quite similar to the Thailand species. HUANG referred the species to *Schellwienella* by short and slightly diverging dental lamellae. The detailed comparison of the internal characters of the pedicle valve between Thailand and Chinese species is not possible, because HUANG's figures are too incomplete to understand the internal characters of the Chinese species. However, the dental lamellae of the Thailand species are short but subparallel and deep, having a tendency to converge anteriorly. This character of the Thailand species may be enough to distinguish it from *Schellwienella regularis*. One can not be sure whether the latter species clearly belongs to the genus or not.

Streptorhynchus pelargonatus var. *lenticularis* is also hardly distinguishable from the Thailand species in external characters though the latter is slightly larger than the former. No internal characters were given by HUANG, and there is a strong probability that the Thailand and Chinese species belong to one and the same species.

Streptorhynchus lenticularis WAAGEN and *Orthotetes semiplanus* WAAGEN known from the Salt Range region are similar to the Thailand species externally. They were described by WAAGEN (1882) from the compact limestone of the Middle *Productus* Limestone and the Cephalopoda-bed of the Upper *Productus* Limestone respectively. The latter is also reported from the Upper Permian of Timor by BROILI (1916) and from the Upper Permian Takauchi Formation of the Maizuru group of Japan by SHIMIZU (1961).

Streptorhynchus lenticularis especially resembles the Thailand species in its suboval outline and short hinge-line. *Orth. semiplanus*, on the other hand, is especially similar to the Thailand one in its rather flat brachial valve. Nothing is known about the interior characters of these species except that it lacks a median septum in *St. lenticularis*.

Orthotetina sp. described by SHIMIZU (1961) from the Upper Permian Gujo Formation of the Maizuru group of Japan resembles the Thailand species in outline, especially in having much shorter hinge-line than the greatest width.

Family Schizophoriidae SCHUCHERT and LEVENE, 1929
Subfamily Schizophoriinae SCHUCHERT and LEVENE, 1929
Genus *Orthotichia* HALL and CLARKE, 1892

Type-species.—*Orthis? morganiana* DERBY, 1874

Orthotichia javanapheti sp. nov.

Pl. 2, figs. 2-4; Fig. 7

Material.—Holotype GK-D 31122 (Pl. 2, figs. 3a-d); paratypes GK-D 31117 (Pl. 2, figs. 2a-e), GK-D 31123 (Pl. 2, figs. 4a-e). Two other complete specimens and two brachial valves are also available. Internal structures were shown by serial sections of GK-D 31123.

Description.—Shell is small in size, transversely oval in outline with the length nearly equal to the width. Anterior commissure is slightly sulcate. The hinge line is very short, about a half the shell width. The greatest width of the shell is situated at slightly posterior part of the anterior margin.

The pedicle valve is smaller and less inflated than the opposite valve. The convexity is stronger in the umbonal region than the anterior area where it is uniformly and slightly convex both longitudinally and laterally. The beak is rather pointed and slightly incurved. The area is narrow and slightly reclined or erect. Average height of the area is 2 mm.

The brachial valve is larger and more inflated than the pedicle valve. It has

an indistinct interarea. The umbonal region is strongly convex and with the beak overhanging the hinge line and nearly coming into contact with the interarea of the pedicle valve. A shallow but distinct median sulcus occurs at the posterior part which increases in width and depth anteriorly to become a broad sulcus at the anterior margin.

The surface is ornamented by numerous and fine radiating capillae, and is marked by growth-wrinkles near the anterior margin. The growth-wrinkles are irregularly arranged and rarely five may be counted. The radiating capillae number about 5 in 1 mm at 1.5 cm from the beak.

Measurements of seven specimens in mm:

	1	2	3	4	5	6	7
length of							
pedicle valve	20.3	18.0	19.5	17.7	18.0		
brachial valve	18.6	18.0	19.4	17.5	18.5	23.0	21.0
width	19.5	18.4	21.0	15.1	19.6	23.3	22.0
thickness	17.6	12.3	15.0	12.5	12.1		
thickness of							
pedicle valve	8.0	5.3	6.0	5.5	5.5		
brachial valve	9.6	7.0	9.0	7.0	6.6		
hinge-line	9.2	9.1	8.5	8.0	10.3	11.5	12.0

The pedicle valve interior has a pair of dental lamellae and a median septum. The former are deep, slender, slightly divergent and extend about a third of the valve-length from the beak. Anteriorly they increase in thickness. Median septum occurs near the beak and extends about two thirds the length of the valve from the beak. It is low and slender in the umbo but increases in strength anteriorly and is much longer than the dental lamellae.

The interior of the brachial valve has a pair of well developed septal plates supporting the hinge plate. They are wider than the dental lamellae at their floor and they converge ventrally. They extend about a fourth of the length of the valve.

Remarks.—*Orthotichia javanapheti* is characterized by a distinct sulcus on the brachial valve, slightly convex pedicle valve and strongly convex opposite one, nearly equal length of both valves, very short hinge-line, and deep dental lamellae with a strong median septum between them.

Externally the Thailand species resembles *Schizophoria tani* HUANG and *Sch. indica* (WAAGEN). Unfortunately their internal characters are unknown and therefore detailed comparisons with the Thailand species cannot be made.

Schizophoria tani described by HUANG (1933) from the top bed of the Permian limestone of Szechuan, southwest China is similar to the *Orthotichia javanapheti* in outline, in size, and in having a broad median depression in the brachial valve. The Thailand species, however, is externally distinguished from the former by having the larger and more inflated brachial valve and strongly convex brachial umbo. The beak of the pedicle valve of the Chinese species is strongly incurved and nearly comes in contact with the opposite beak. The

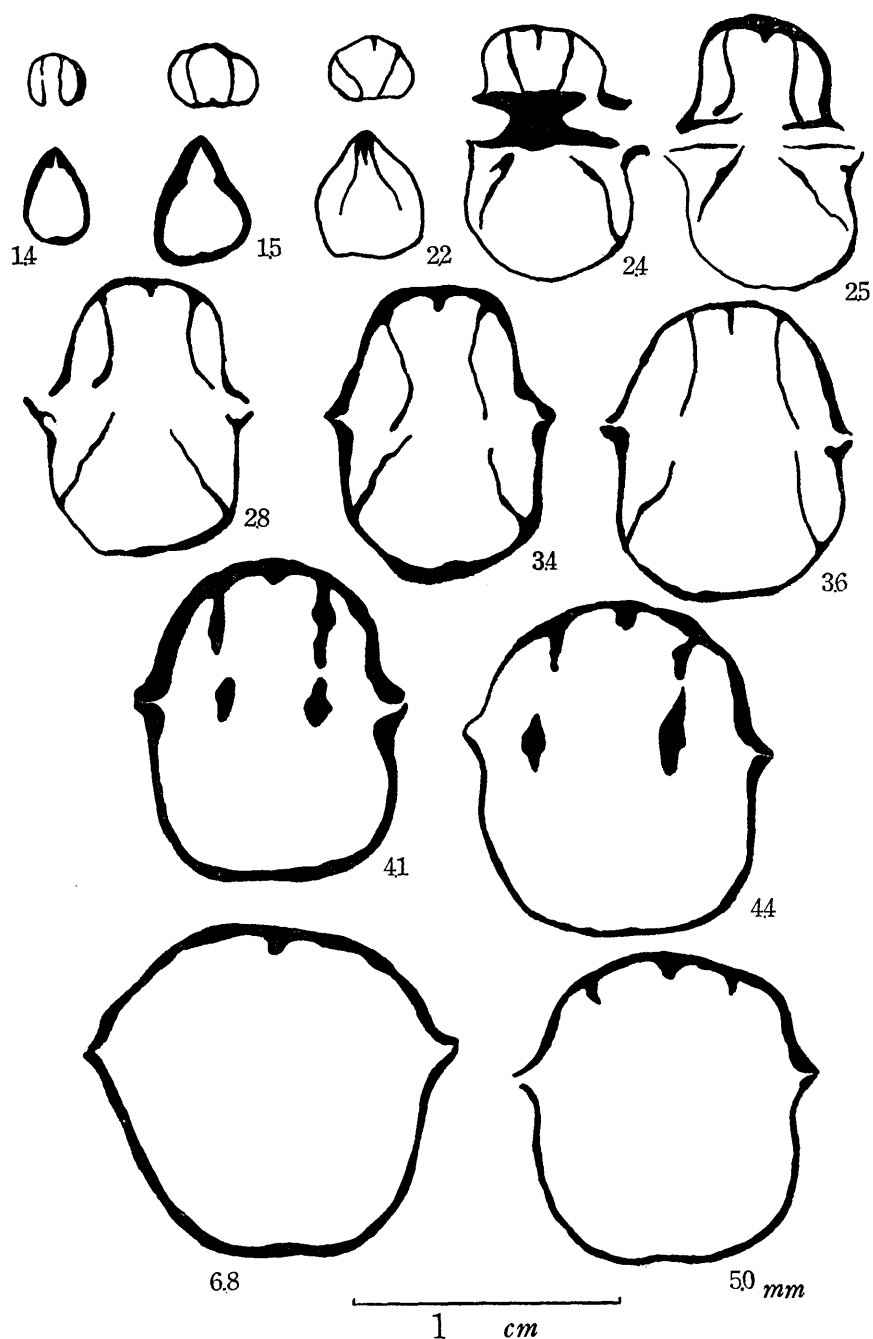


Fig. 7. *Orthotichia javanapheti* sp. nov. Serial sections of a paratype, GK-D 31123 (Pl. 2, fig. 4).

interarea is inclined. On the other hand the Thailand one has rather prominent and slightly incurved beak and the area is erect or more or less reclined.

Schizophoria indica originally described by WAAGEN (1883) under the name or *Orthis indica* from the Lower to Middle *Productus* Limestone of the Salt Range also resembles the Thailand species in having a median sulcus in the brachial valve. The former species is easily distinguished from the latter in having the pedicle valve larger than the opposite one. The shape of the posterior region of both species apparently differ from each other.

Family Linoproductidae STEHLI, 1954
Subfamily Linoproductinae STEHLI, 1954
Genus *Linoproductus* CHAO, 1927

Type-species.—*Productus cora* D'ORBIGNY, 1842

Linoproductus sp.

Pl. 3, fig. 5

Material.—Only one specimen of a pedicle valve, GK-D 31126 (Pl. 3, figs. 5a-d), is available.

Description.—The shell is medium in size and subquadrate in outline. The pedicle valve has a highly convex visceral disc, and massive umbo which is moderately incurved beyond the hinge. The ears are flat. The flanks are steep and laterally spreading. The trail is not long. The greatest width is at about a half the shell-length.

The pedicle valve is ornamented by numerous, fine costellae, numbering 10 to 12 in 5 mm near the anterior end of the visceral disc. They increase in number by numerous intercalations on the flanks and trail. New costellae often occur anteriorly contacting with the spine bases. The costellae are slightly irregular and thin. Broad and shallow depressions are marked between them. About 22 spine bases are scattered on the flanks and venter. Their diameters are larger than the widths of the costellae and measure about 1 mm near the anterior margin. Four to 5 rugae are developed on flanks and ears. They rapidly lessen in strength to the venter and are only obscurely traceable on it.

The approximate dimensions of the pedicle valve are: length, 28.1 mm; width, 35.8 mm; height, 20.2 mm; hinge line, 29.0 mm; and surface measure, 51.0 mm.

Remarks.—This species is associated with *Tyloplecta yangtzeensis*, *T. nankingensis*, and *Haydenella kiangsiensis*. Although nothing is known of its interior, the highly convex pedicle valve with steep flanks and long hinge give a characteristic appearance to this species. Spirally curved profile of the valve resembles that of *Ovatia*. However, long hinge, spreading ears, subquadrate outline, fine irregular costellae, and scattered spines on the venter apparently represent the characters of the genus *Linoproductus*. This species also suggests *Globiella* in outline. But the external characters clearly distinguish the species from the latter.

The age and affinities of the fauna

Through comparison with known faunas in other areas, Middle to Upper Permian age is suggested for the Phetchabun fauna.

Tyloplecta yangtzeensis is a characteristic species in the Upper Permian Lopingian which generally overlies the *Neoschwagerina* zone of the Maokouan of South China. Especially it is well known in the *Lyttonia* bed of the Choutangian, the lower subseries of the Lopingian series, in Kueichow and Szechuan of southern and southwestern China.

Tyloplecta nankingensis is also widely distributed in Kueichow, Szechuan, and Anhui, and restricted in its stratigraphical occurrence to the Yangsinian, from the *Tetrapora* bed of the Chihhsia Limestone up to the Maokou Limestone. The same species was recorded by CHI-THUAN (1960) from the Upper Permian marly limestone of Cambodia in association with a large number of brachiopods and two kinds of fusulinids, *Parafusulina* aff. *P. tunetana* DOUVILLÉ and *Yabeina joannis* SAURIN.

Haydenella kiangsiensis was originally described by KAYSER from the *Lyttonia* bed of Kiangsu. This species is restricted in its occurrence in the *Lyttonia* and *Oldhamina* beds of the Lopingian of Kiangsu and Kueichow. Closely related species, *Haydenella quaesita* and *H. vihiana* var. *salinaria* occur in the Middle *Productus* Limestone of the Salt Range. Also the allied species, *H. tumidus* and *H. vihiana* are well known in the Middle and Upper *Productus* Limestone of the Salt Range and the Upper Permian Zewan bed of Kashmir, respectively. *Haydenella kiangsiensis* was described by SHIMIZU (1961) from the Middle Permian Takauchi Formation of the Maizuru group in Japan associated with many kinds of brachiopods. He correlated the Takauchi faunas with the Lopingian of south China and briefly considered their age to be the zone of "*Yabeina*".

Marginifera banphotensis is nearest to *Productus* (*Marginifera*) *magniplacatus* HUANG (1932, pp. 25-26, pl. 1, figs. 15-17) from the Permian of Kueichow. The former also has a close affinity with the species identified as *Productus nystianus* var. *lopingensis* by KAYSER (1884, p. 187, pl. 28, figs. 1-5) from the *Lyttonia* bed of Loping coal-field of Kiangsi, and by CHAO (1927, pp. 153-156, pl. 16, figs. 8-12) by the name of *Marginifera lopingensis* from the *Lyttonia* beds of Kiangsi, Chekiang, and Hupeh of South China.

Orthotetina phetchabunensis externally resembles *Schellwienella regularis* HUANG (1933, pp. 25-27, pl. 3, figs. 10, 11) from the *Lyttonia* beds of Kueichow and *Streptorhynchus lenticularis* WAAGEN (1882, pp. 581-582, pl. 50, fig. 8) from the Middle *Productus* Limestone of the Salt Range.

Orthotichia javanapheti is much similar externally to *Schizophoria tani* HUANG (1933, pp. 4-5, pl. 1, figs. 3a-e) from the top bed of the limestone of west Szechuan in association with *Tyloplecta nankingensis*.

There is no species of *Linoproductus* identifiable with *Linoproductus* sp. of Thailand. But the latter may be an advanced form of this genus if the external

characters are taken into account.

In conclusion, the elements of the Phetchabun fauna are strongly similar to those of the Yansinian and Lopingian of South China. Most of them are equated with the Lopingian brachiopods. They are roughly correlated with the *Parafusulina* zone up to the middle part of the *Yabeina-Lepidolina* zone in the international correlation, with a high probability that the age of the Phetchabun fauna is limited to the lower part of the *Yabeina-Lepidolina* zone.

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Permian Brachiopods from Central Thailand

Plates 1–3

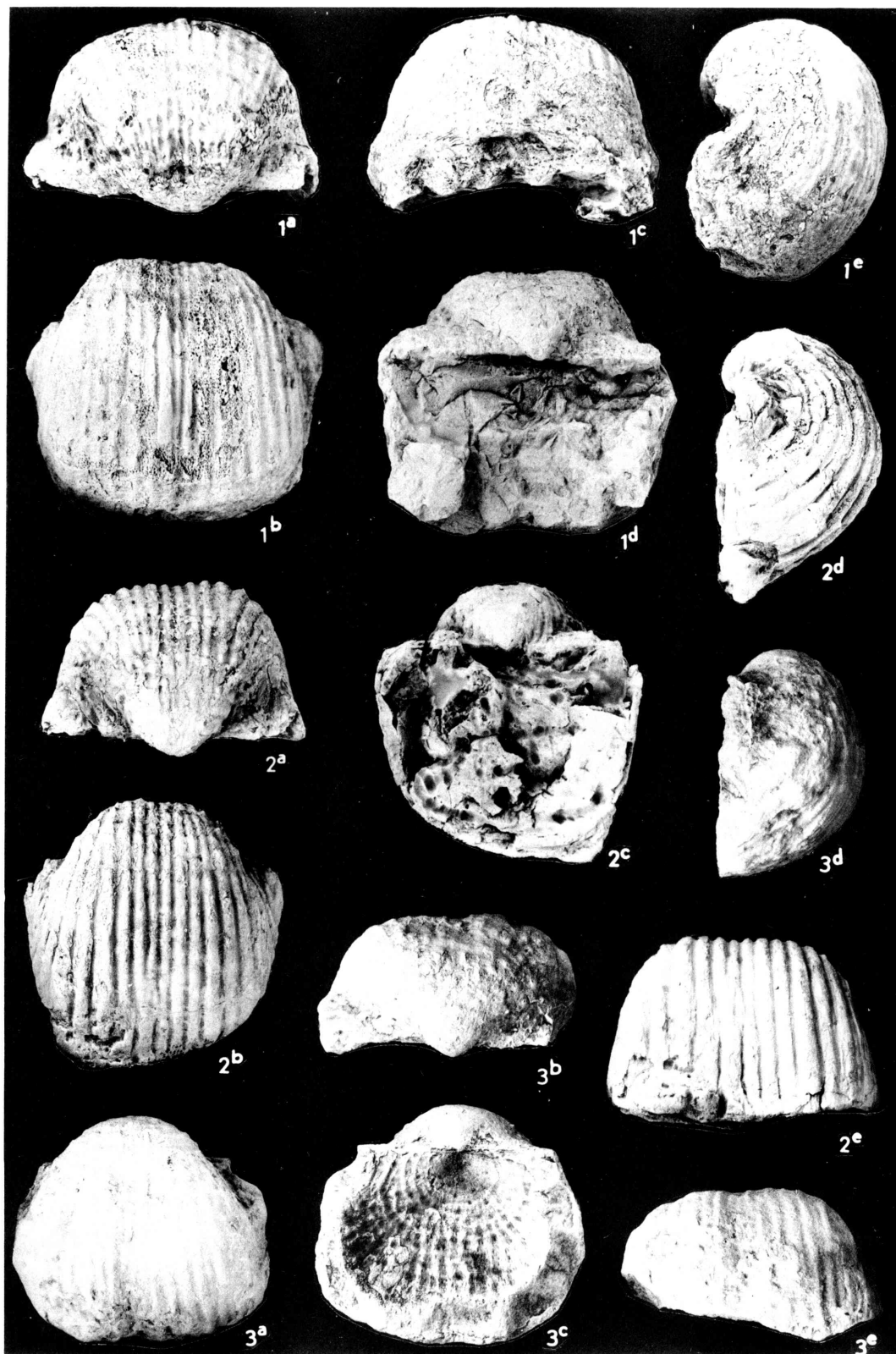
Plate 1

Explanation of Plate 1

(all figures of natural size)

- Figs. 1, 3. *Tyloplecta yangtzeensis* (CHAO)Page 3
1a-e. Posterior, ventral, anterior, dorsal, and lateral views of specimen GK-D
31100.
3a-e. Ventral, posterior, dorsal, lateral, and anterior views of specimen GK-D
31101.
Fig. 2. *Tyloplecta nankingensis* (FRECH)Page 6
2a-e. Posterior, ventral, dorsal, lateral, and anterior views of specimen GK-D
31102.

Photos by YANAGIDA, with whitening



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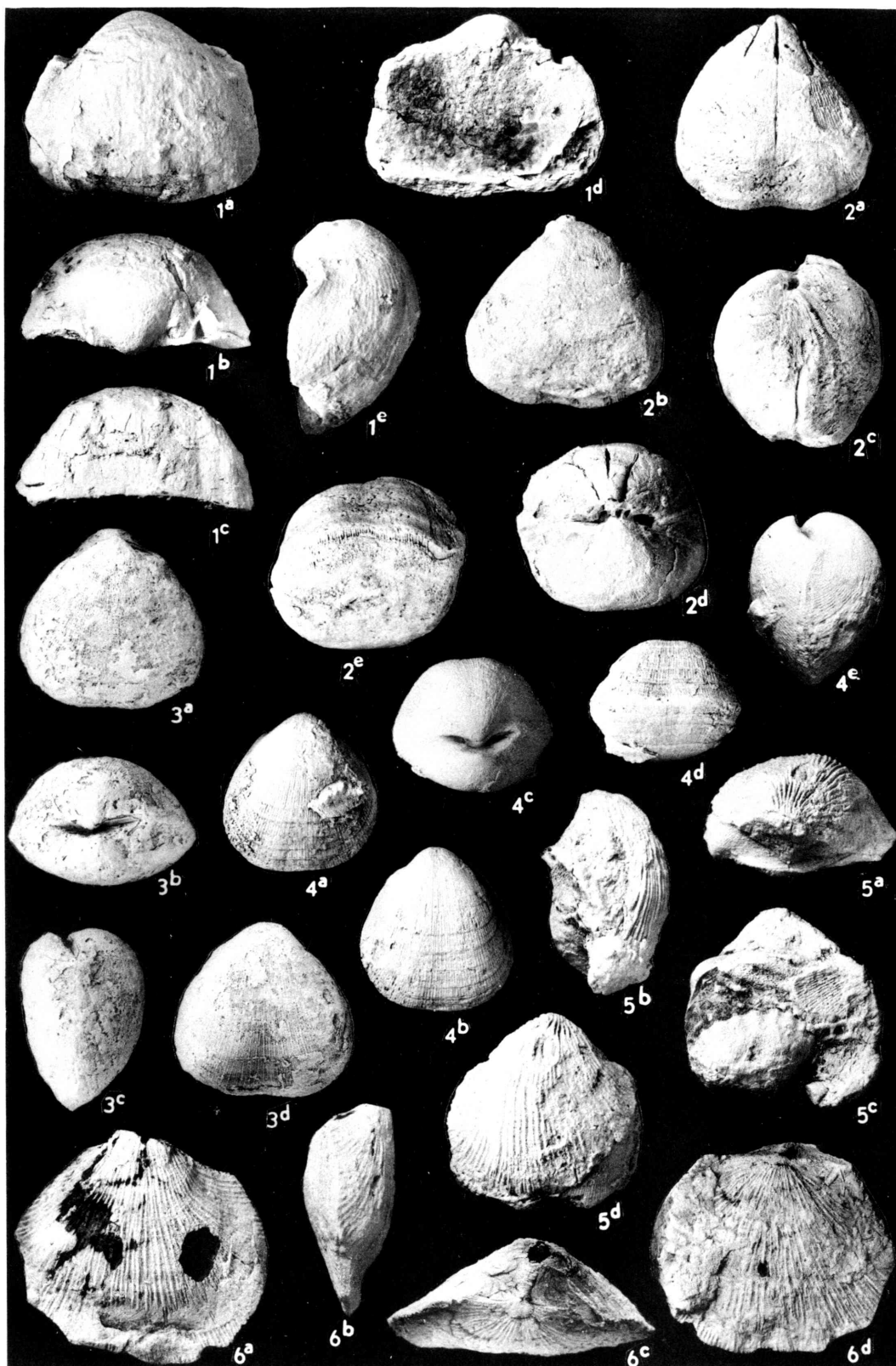
Plate 2

Explanation of Plate 2

(all figures ca $\times 1.5$)

- Fig. 1. *Haydenella kiangsiensis* (KAYSER)Page 7
1a-e. Ventral, posterior, anterior, dorsal, and lateral views of specimen GK-D 31105.
- Figs. 2-4. *Orthotichia javanapheti* sp. nov.Page 17
2a-e. Ventral, dorsal, lateral, posterior, and anterior views of a paratype, GK-D 31117.
3a-e. Ventral, posterior, lateral, and dorsal views of the holotype, GK-D 31122.
4a-e. Ventral, dorsal, posterior, anterior, and lateral views of a paratype, GK-D 31123.
- Figs. 5, 6. *Orthotetina phetchabunensis* sp. nov. Page 14
5a-d. Posterior, lateral, dorsal, and ventral views of a paratype, GK-D 31116.
6a-d. Ventral, lateral, posterior, and dorsal views of the holotype, GK-D 31115.

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Plate 3

Explanation of Plate 3

- Fig. 1. *Tyloplecta yangtzeensis* (CHAO)Page 3
 External mould of a brachial valve, GK-D 31101, $\times 1$.
- Figs. 2, 3. *Marginifera banphotensis* sp. nov.Page 11
 2a-e. Dorsal, ventral, lateral, posterior, and anterior views of a paratype, GK-D 31108, $\times 2$.
 3a-e. Ventral, lateral, posterior, dorsal, and anterior views of the holotype, GK-D 31113, $\times 2$.
- Fig. 4. *Haydenella kiangsiensis* (KAYSER)Page 7
 4a-e. Dorsal, posterior, ventral, lateral, and anterior views of specimen GK-D 31106, $\times 1.5$.
- Fig. 5. *Linoproductus* sp.Page 20
 5a-d. Lateral, anterior, ventral, and posterior views of specimen GK-D 31126, $\times 1.5$.

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