# Carboniferous Brachiopods from Akiyoshi, Southwest Japan Part I

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# Carboniferous Brachiopods from Akiyoshi, Southwest Japan*

# Part I

By

**Juichi YANAGIDA**

## Abstract

A large collection of brachiopods made from the *Millerella* zone of the Akiyoshi limestone group at Yobara, Akiyoshi limestone plateau thirteen species distributed among ten genera. Known species of *Phricodothyris*, *Spirifer*, *Cleiothyridina*, *Actinoconchus*, *Composita*, *Dielasma*, *Pugnax*, *Schizophoria*, and new species of *Brachythyris* and *Yanishewskiella* are described in this paper. Brachiopods are rare in Japanese Carboniferous rocks, but the fauna herein described is the richest and best preserved yet found. It constitutes a unique faunal assemblage allied to the Upper Visean brachiopods of Europe and to those of southern Asia and Australia.

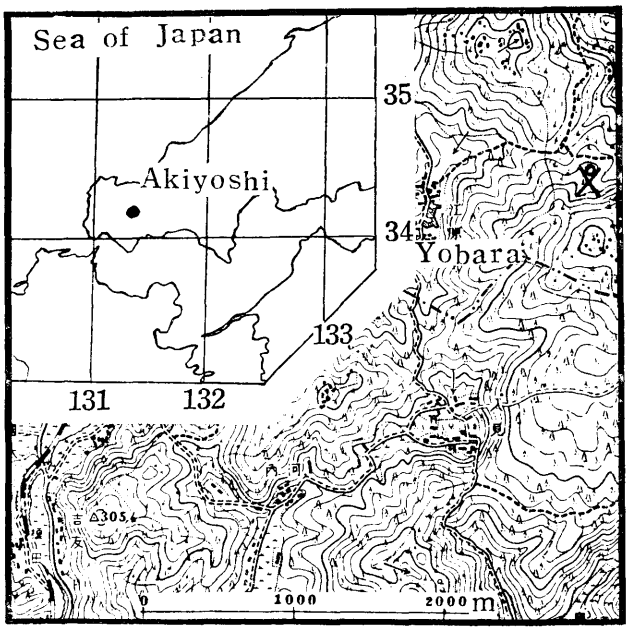
## Introduction

The Akiyoshi limestone group has received much attention from many geologists not only from the biostratigraphical but also from the structural points of view since OZAWA (1925) described many fusulinids and corals from it and presumed the presence of a large scale recumbent fold in it. Recently the work of TORIYAMA (1958) greatly clarified the stratigraphy and structure of the limestone group, particularly his zoning and remapping of almost the whole area on the basis of fusulinids. However, the lowest part of the limestone group, TORIYAMA's *Millerella* sp. $\alpha$ zone, containing only most primitive forms of fusulinids and some corals, is still to be studied on contained fossils and its precise correlation established.

Brachiopod fossils are rare in most of the Japanese Carboniferous, except that of the Kitakami massif and of the Omi Limestone. In a limited part of the *Millerella* sp. $\alpha$ zone of the Akiyoshi limestone group at the Uzura quarry** is intercalated a coquinoid bed consisting of abundant brachiopod shells near Yobara on the Ofuku plateau. This paper includes a part of the studies of the brachiopod fossils collected at the quarry and contains descriptions of species belonging to the Families *Spiriferidae*, *Athyridae*, *Dielasmatidae*, *Camarotoechiidae*, *Stenoscismatidae*, and *Schizophoriidae*. Publications which will include a discussion of the stratigraphic significance of the complete fauna, are contemplated for the near future.

* Received October 17, 1961.

** In TORIYAMA's paper the Uzura quarry is numbered 363, but the locality is erroneously noted as "1200 m *W* of Yobara" (Pt. III, p. 15), which should read "1200 m *E* of Yobara."




Text-fig. 1. Location map of Yobara, Akiyoshi.

**Acknowledgements**

I am deeply indebted to Dr. G. A. Arthur COOPER, Head Curator of the Department of Geology, Smithsonian Institution of United States National Museum, who has given me valuable suggestions and critically read the typescript. Dr. Riuji ENDO of Saitama has given me many facilities during the course of this study. Dr. Ryuzo TORIYAMA provided me many specimens for this study, read the typescript of this paper and has given me helpful advices and suggestions during the course of the work. Dr. Tatsuro MATSUMOTO also helped with valuable suggestions.

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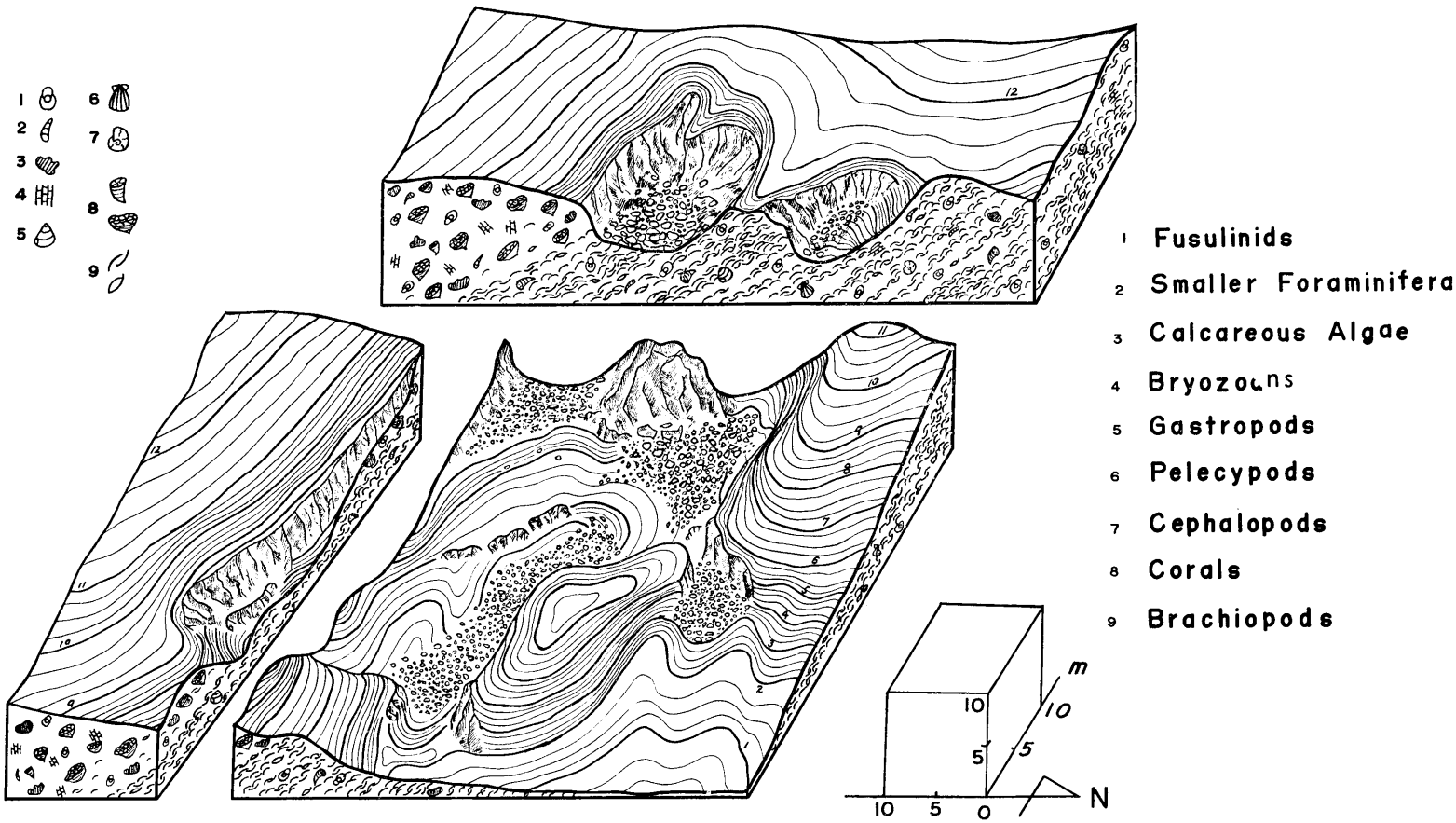



Text-fig. 2. Block diagram showing the occurence of brachiopods and other fossils at the Uzura quarry.

## Systematic descriptions

Family *Spiriferidae* KING, 1846

Subfamily *Phricodothyrinae* CASTER, 1939

Genus *Phricodothyris* GEORGE, 1932

Type-species.—*Phricodothyris lucerna* GEORGE, 1932

*Remarks.*—*Phricodothyris* was established by T. N. GEORGE in 1932 with *P. lucerna* from the Lower Carboniferous $D_2$ zone of Northumberland of England as the type-species. According to GEORGE, it has a simple internal structure and usually has no dental lamellae. He, therefore, laid stress for its distinction from other genera mainly on external features, such as concentric lamellae, biramous barbed spines, and the shape of the scars of spine bases. He described seven species from the Lower Carboniferous $D_2$ zone of Derbyshire, Yorkshire, Northumberland and $D_2$-$D_3$ zones of Lanarkshire. *Phricodothyris* has a world-wide distribution ranging from Carboniferous to Permian and its most numerous occurrence is in Lower Carboniferous Viséan rocks. CAMPBELL (1955) emended the diagnosis of GEORGE and discussed the variation of the external and internal characters of this genus based on many specimens from England, western Europe and New South Wales, Australia. CAMPBELL (1957) indicated that the European *Phricodothyris* is characterized by poorly developed dental lamellae, absence of a median septum in the ventral valve and the uniplicate commissure, and that the British species have been known only in the knoll-reef facies of the Viséan. In Asia *Phricodothyris* is represented by *P. lineata* (MARTIN) which is similar to *P. insolita*. *P. lineata* was found in the Lower Carboniferous of Siberia, China, Japan, and Malaya which is considered to be equivalent to the Viséan of Europe. The Japanese *Phricodothyris* includes species from the Lower Carboniferous limestone of Omi-mura Niigata Prefecture reported under the name of *Reticularia lineata* by HAYASAKA (1924). *Kitakamithyris* MINATO recorded from the Lower Carboniferous Hikoroichi series of the Kitakami massif was proposed (1951), however, regarded it as a synonym of *Phricodothyris*.

When the outermost layer of the shell is worn off even a little, a different pattern in the shape of the spine bases is noted. In that case longitudinal striae appear on the decorticoted shell-surface, and each spine base assumes a longitudinally striated structure and simulated the ornament of some species of *Squamularia* which were reported by CHAO (1929) from the Carboniferous and Permian of China. *Squamularia asiatica* is a species whose shell ornament is essentially of the kind just mentioned. However, it had originally neither biramous barbed spines nor spine bases but is characterized by fine pustules.

### *Phricodothyris insolita* GEORGE

Pl. 14, figs. 1-7; Text-fig. 3

1932. *Phricoaothyris insolita* GEORGE, Quart. Jour. Geol. Soc., Vol. 88, pp. 542-543, pl. 35, figs. 5a-d.

*Material.*—Sixteen specimens are referable to this species, of which eleven are represented by ventral valves, four by dorsal ones, and the remaining one is small but complete. The description given below is mainly based on the following specimens: GK. D30001 (Pl. 14, fig. 1a-c), GK. D30002 (Pl. 14, fig. 5a-b), GK. D30003, GK. D30004 (Pl. 14, fig. 4), GK. D30005 (Pl. 14, fig. 7a-c), GK. D30006 (Pl. 14, fig. 6a-b), GK. D30007 (Pl. 14, fig. 2), and GK. D30008 (Pl. 14, fig. 3).

*Description.*—The shell is small to moderate, laterally suborbicular in outline, and moderately biconvex. There is a weakly depressed median sulcus on the ventral valve but no fold on the dorsal one. The hinge line is slightly shorter than the widest part of the shell. The width is greater than the length or is nearly equal to it in immature stages.

The beak of the ventral valve is prominent, strongly incurved over the hinge. The greatest convexity of the shell is in the umbonal region. The longitudinal convexity is uniformly strong. The lateral profile is arched with inflated mid-portion. The cardinal extremities are rounded. The interarea is triangular, plane and high with a strongly depressed delthyrium beneath the beak. The height of the interarea is slightly shorter than the greatest shell-width. The apical angle ranges from 115 to 120 degrees.

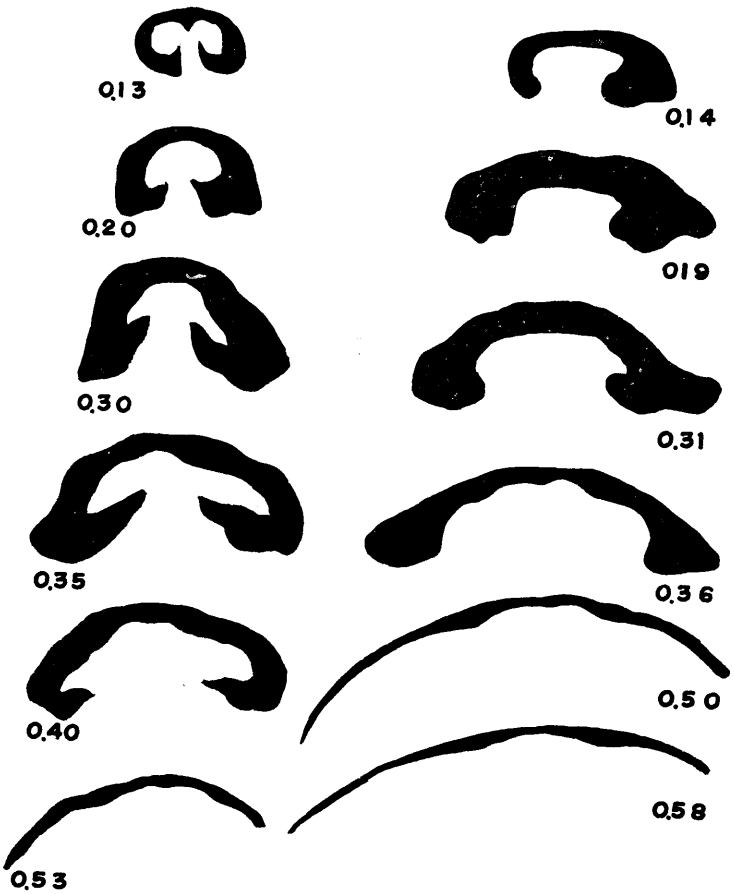
The dorsal valve is subrounded in outline and wider than long. It is less convex than the ventral valve, having uniformly and slightly arched lateral and longitudinal profiles. The beak is prominent but not so highly incurved as that of the ventral valve.

Measurements of eight specimens in mm and degrees:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| length | | | | | | | | |
| ventral valve | 30.1 | | 19.8 | 18.9 | | 17.5 | 11.0 | 7.8 |
| dorsal valve | | 22.8 | | | 19.0 | | | |
| width | 37.2 | 28.0 | 28.8 | 24.3 | 22.0 | 25.0 | 13.0 | 8.4 |
| width of the hinge line | 28.0 | 21.2 | 22.0 | 17.0 | 12.0 | | 7.5 | 4.5 |
| thickness | | | | | | | | |
| ventral valve | 9.0 | | 7.0 | 8.3 | | 7.2 | 4.5 | 3.2 |
| dorsal valve | | 6.2 | | | 6.0 | | | |
| height of the area | 9.6 | | 6.0 | 3.6 | | | | 2.5 |
| apical angle | | | | | | | | |
| ventral valve | 115° | | 120° | 118° | | 120° | 115° | 120° |
| dorsal valve | | 150° | | | 140° | | | |

The shell-surface is ornamented with very fine, concentric growth-bands and very faint, circular spine-scars arranged concentrically. Each band is generally smooth and slightly arched, but when it is exfoliated even a little, longitudinally fibrous texture is exposed. There are six to ten bands in the space of 5 mm. Between the bands closely arranged, circular spine scars are present, numbering eight to ten in the space of 1 mm, only under the microscope. On exfoliated shell-surfaces they are subrounded or longitudinally elliptical.

The ventral valve has neither dental lamellae nor median septum, but a rudimentary thickening of the inner wall occurs at the apical extremity. The hinge teeth are short and stout, supported by the interareal plate.




Text-fig. 3. *Phricodothyris insolita*. Serial sections × 3 of ventral valve, GK. D30074 (left), and dorsal valve, GK. D30003 (right). Minute ridge is observed at the beak region of ventral valve (0.13).

*Remarks*.—The specimens described above are identical with *Phricodothyris insolita* from the $D_2$ zone of the Settle district in the following characters: general shape and size, moderately short hinge line, strongly incurved ventral umbo, very weakly depressed sulcus on the ventral valve, closely set growth-lines and minute spine-bases. The spine bases of the Akiyoshi specimens are smaller and are set more closely than those of the British specimens. In the former there are seventy to ninety spine bases in the space of 10 mm, whereas in the latter fifty-five to sixty appear in the same space. The biramous character of the spine bases can hardly be observed in the Japanese present specimens, as in the British specimens, and this is the important character for this species.

*Phricodothyris* sp. reported by MUIR-WOOD (1946) from the Lower Carboniferous

of Bukit Sagu and Bukit Tinggik of the Malayan Peninsula includes two types, one has a uniplicate anterior commissure and fine closely-placed concentric ribs and the other is rectimarginate and has fewer ribs. The former was compared with *P. periculosa* GEORGE, and the latter with *P. lineata* (MARTIN) from the $D_2$ zone of Derbyshire. The specimens which were compared with *P. periculosa* resemble the present ones in the ornament of the shell although the specimens which were compared with *P. lineata* have the faintly sinuated anterior commissure. The anterior commissures of the present specimens are equivalent to that of the English ones which have rectimarginate or slightly sulcate commissure.

## Subfamily *Brachythyrinae* FREDERICKS, 1924

## Genus *Brachythyris* M'COY, 1884

Type-species.—*Spirifera ovalis* PHILLIPS, 1836

*Remarks.*—The genus *Brachythyris* was established by M'COY (1884) with *Spirifera ovalis* PHILLIPS as the type-species. After BUCKMAN (1908) briefly mentioned the internal structures of the genus, FREDERICKS (1926) established the subfamily *Brachythyrinae*, mainly on the basis of internal structures. GEORGE (1927) revised the genus and classified British species into two groups: the *Brachythyris pinguis* group and the *B. integricosta* group. The former is characterized by a median groove on the median fold of the dorsal valve and the latter by a median rib on the fold. However species of *Brachythyris* which have a very weak median groove and ribs on the median fold are ambiguous. It is difficult to decide to which groups they belong. A new species described below is such a case.

As BUCKMAN (1908) and GEORGE (1927) stated, *Martinia* closely resembles *Brachythyris* both in external shape and internal structure. The shell of *Martinia* is smooth in most species and has numerous minute punctures in the outer layer. These, however, are so easily destroyed by mechanical erosion that partially ribbed *Martinia* is difficult to distinguish from smooth brachythyrids.

*Brachythyris* has a world-wide distribution in the Lower Carboniferous Tournaisian and Viséan of England, Belgium, Germany, the Donetz Basin, Turkestan, Tian Shan, Malaya, Australia, North America and Japan.

### *Brachythyris akiyoshiensis* sp. nov.

Pl. 14, fig. 8a-c, Pl. 15, figs. 1-3; Text-fig. 4

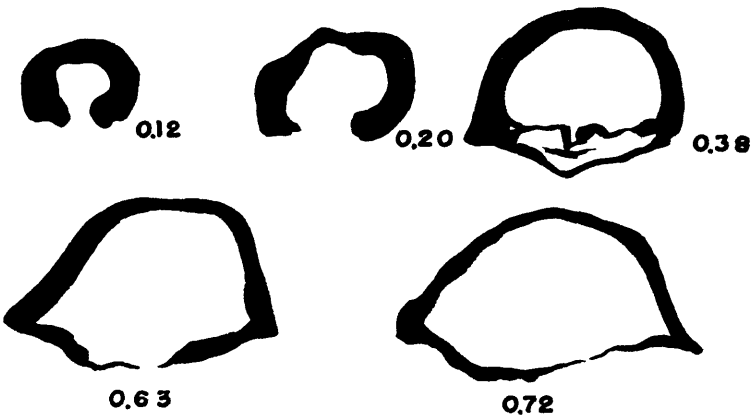
*Material.*—Holotype, GK. D30009 (Pl. 15, fig. 1a-c). Paratypes GK. D30010 (Pl. 15, fig. 3a-b) and GK. D30011 (Pl. 14, fig. 8a-c). Four other comparable specimens are also available. A paratype specimen (GK. D30012, Pl. 15, fig. 2a-b) was sectioned to examine internal structures (Text-fig. 4).

*Description.*—The shell is brachythyrid and the length and width are nearly equal. The ventral valve is more convex than the dorsal one. The ventral umbo is markedly incurved with a strong concavity over the low interarea. An extremely

shallow sulcus with obtuse lateral ridges widens towards the anterior margin, but it is hardly observable in immature shells. The umbo of the dorsal valve is slightly incurved. The median fold is slightly higher anteriorly with a little inflated margin. The shell is ornamented with five to nine weak ribs, which are relatively distinct umbonally and become more flattened and weaker towards the anterior margin in both lateral slopes. In the cardinal margin the surface is completely smooth. Concentric growth-lines are observed only near the anterior margin. Internal structures of the shell were examined by serially sectioning. Neither dental lamellae nor median septum are present. Minute teeth and sockets are observed.

Measurements in mm and degrees:

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| length | 22.5 | 14.5 | 16.3 | 15.0 | 16.0 |
| width | 22.0 | 15.0 | 16.8 | 12.7 | 16.5 |
| length of hinge line | 13.0 | 9.0 | 7.5 | 6.5 | 10.0 |
| number of radial ribs | 18 | 14 | 14 | 10 | 10 |
| apical angle | 105° | 110° | 110° | 100° | 110° |




Text-fig. 4. *Brachythyris akiyoshiensis*. Serial sections ×3 of GK. D30012.

*Remarks*.—This new species is referred to the genus *Brachythyris* on the basis of its internal and external characters, especially the shell ornament. It is not certain, however, to which of the two groups proposed by GEORGE (1927) *B. akiyoshiensis* belongs, because it has neither a groove nor ribs on the median fold. The diagnostic characters of the species are the strongly convex ventral valve, very weak and flat-topped radial ribs, the extremely shallow ventral sulcus, and the entirely smooth median fold without a median groove and ribs.

*B. akiyoshiensis* somewhat resembles *B. pinguis* (SOWERBY) from the $D_2$ zone of Ireland in its general form, especially in the strongly incurved ventral valve. But the latter species is relatively wider than the former and has a distinct median groove on the fold.

MINATO (1951) described *B. kitakamiensis*, *B.* aff. *B. pinguis*, and *B.* ? sp. from the Lower Carboniferous of the Kitakami massif of northern Japan. Detailed comparison of *B. akiyoshiensis* with *B. kitakamiensis* can not be made, because the latter

is known only by a dorsal valve. But the Kitakami species clearly differs from the present one by its much larger shell, and by having median groove on the fold and radial ribs. According to MINATO, *B.* aff. *pinguis* closely resembles *B. pinguis* (SOWERBY) described by DAVIDSON (1858). The Akiyoshi species differs from *B. pinguis* mainly in having a narrow but high fold and deep sulcus.

Subfamily *Spiriferinae* SCHUCHERT, 1913

Genus *Spirifer* SOWERBY, 1814 and 1818

Type-species.—*Anomites striatus* MARTIN, 1809

*Remarks.*—Since the genus *Spirifer* was erected by SOWERBY, various interpretations on its generic diagnosis and taxonomic distinction from other allied genera have been presented. The loss of the holotype and inadequate original definition of the type-species caused serious confusions on these problems. The internal structure of the holotype has never been well described, and we know only that it has a spiral brachidia. Therefore the distinction of the genus from other allied genera is largely based on the external characters, and the genus differs from the most closely allied genus *Neospirifer* FREDERICKS only in having no strongly fasciculated ribs. However this distinction is not always clear as discussed by DUNBAR (1955) who indicated that even in *S. striatus* a moderate degree of fasciculation of ribs is commonly visible near the beak. On the other hand, *Neospirifer cameratus* (MORTON) described by DUNBAR and CONDRA (1932), one of the Pennsylvanian *Neospirifer*, scarcely has the fasciculation except in the beak region.

Among the species identified with *Neospirifer* there are some similar forms to *Spirifer* (s. s.), which have non-fasciculate costae. They are, for example, *N. pristinus* MAXWELL (1951) from the Middle Upper Carboniferous of Livingstone county, Queensland, and *N. denis* (ROTAI) from the Viséan (Cm, Cv) of the Kuznetsk basin of Russia.

DUNBAR (1932) stated that the internal structures of the type-species of *Spirifer* (s. s.) are characterized by long and subconical dental sockets, heavy curved socket-plates, crural lamellae, a narrow hinge-plate, a broad cardinal process, and strong dental lamellae.

Having taken into consideration the internal structure of *Neospirifer* described by DUNBAR and CONDRA (1932), IVANOV and IVANOVA (1937), and MUIR-WOOD and OAKLEY (1941) for the species from the Carboniferous of Nebraska, the Moscow Basin, and North Sikkim respectively, and MAXWELL pointed out that they show small variation in internal characters but greatly varies in external ones, and that generally speaking the older species of the genus usually have fewer or non-fasciculate ribs and weaker dental lamellae than the younger species.

Such being the case I would prefer to confine the genus *Neospirifer* to species which have a distinct fasciculation of ribs, until the internal structures of *Spirifer striatus* and *Neospirifer fasciger*, the type-species of the genus *Neospirifer*, are precisely examined.

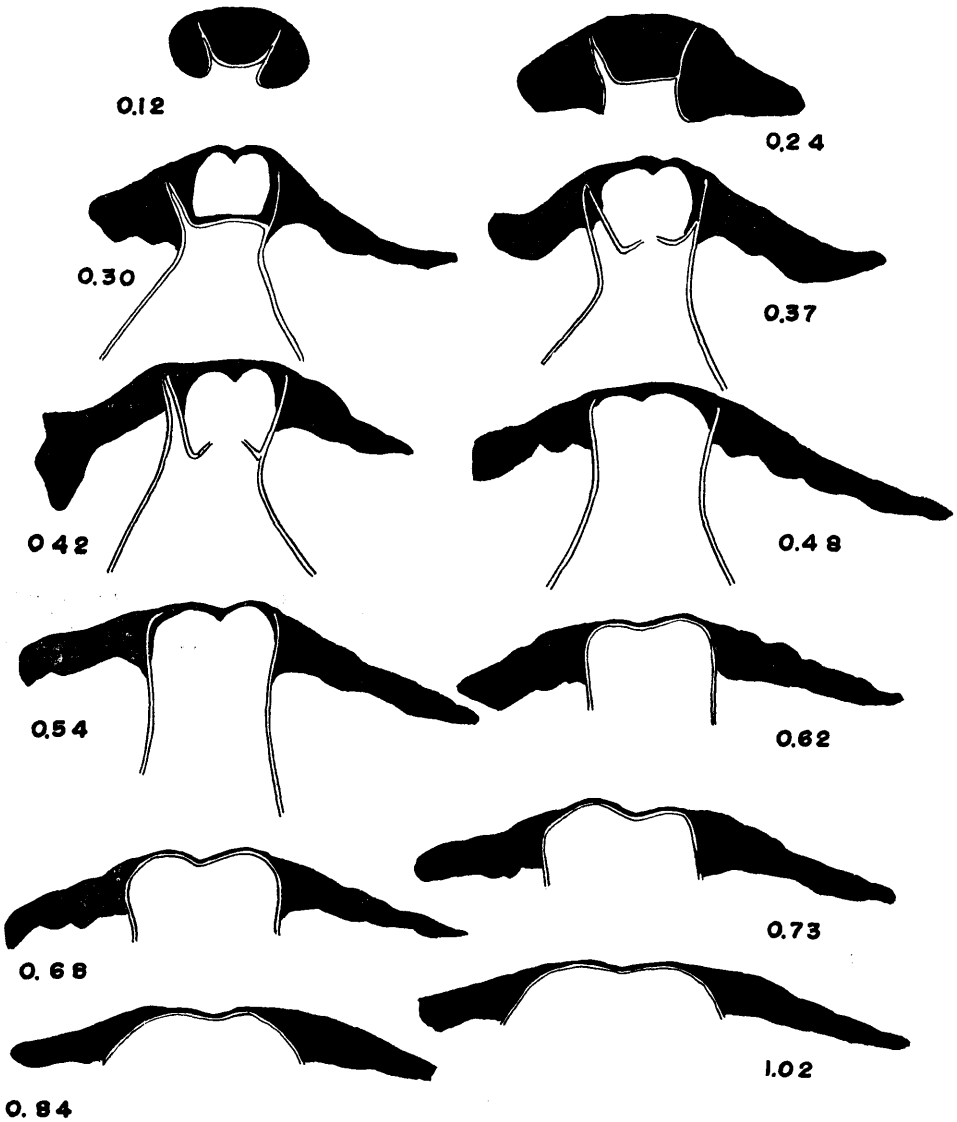
*Spirifer* aff. *S. liangchowensis* CHAO

Pl. 15, fig. 7; Text-figs. 5, 6

Compare.—

1929. *Spirifer liangchowensis* CHAO. Palaeontologia Sinica, Ser. B, Vol. 11, Fasc. 1, pp. 6-8, pl. 1, figs. 1-7.

*Material.*—The specimens which I describe under this heading include an incomplete ventral mould of GK. D30013 and its fragmentary cast GK. D30014. GK. D30015




Text-fig. 5. *Spirifer* aff. *S. liangchowensis.* Serial sections ×2.5 of GK. D30013. Note long and slendar dental lamellae, deep delthyrial cavity, and callosity-like wall (0.30 to 0.42).

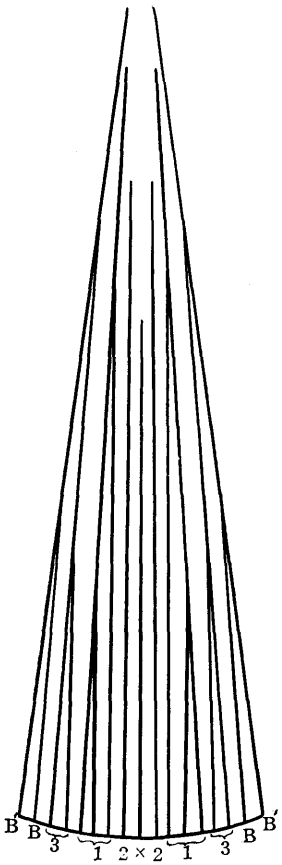
(Pl. 15, fig. 7) is the ventral plaster cast obtained from GK. D30013. Internal structures are shown by serially sectioning of GK. D30014.

*Description.*—The shell is elliptical to thick rhomboidal in outline and is subequally biconvex. The ventral valve is moderately convex longitudinally and laterally with a broad and fairly distinct median sulcus. The beak is prominent and slightly incurved. The shoulder is moderately concave. The surface has fairly strong radial costae which increase in number anteriorly by bifurcation. The ventral sulcus is deep and bounded on both sides by a pair of strong costae in the apical region. These bifurcate towards the posterior margin, and an inside pair of the bifurcated costae on the edges of the sinal slopes bifurcate once more. Two pairs of costae appear at an early stage near the mid portion of the sulcus and the earlier inside one bifurcates twice. A single median costa appears at about a third of the shell-length from the beak and on both sides of it therefore there are eight pairs of costae in the sulcus. The deep groove of the sulcus in the umbonal region becomes gradually broader and shallower towards the anterior margin. The costae of the lateral slopes bifurcate respectively at least three times at intervals in the course of their length. The bifurcation takes place in all ribs except the median costa and there are sixty to seventy-five costae along the anterior margin of the ventral valve. The costae are never fasciculated. Every costa is narrow and acute in the posterior area and gradually decreases in strength anteriorly.

Measurements of GK. D30015 in mm and degrees:

| | |
|---|---|
| length | |
| ventral valve | 47.0 |
| width | 66.0 |
| apical angle | |
| ventral valve | 160° |

Internally the ventral valve has two long, thin, divergent dental lamellae which extend from the floor of the valve to the delthyrial margin. Serial sections show that the dental lamellae are so long that they make a deep delthyrial cavity. They decrease their length anteriorly and make straight ridges which adjoin an oval muscle scar. The apical extremities of the shell are highly thickened. A callosity-like wall connected with the thickened shell




Text-fig. 6. *Spirifer* aff. *S. liangchowensis.* Diagram showing the arrangement of sinal plications and the branching lateral plications of GK. D30015. B, bounding plication; B', branch of bounding plication; 1, 2, 3, 1st, 2nd, and 3rd lateral sinal plications ×2

occurs in the delthyrial cavity. An anteriorly opened semi-circular wall is developed at the extremity of the callosity-like wall and its lateral flanges are parallel to the dental lamellae.

*Remarks.*—In having no fasciculated costae externally the Akiyoshi specimens are preferably referable to the genus *Spirifer*. The sectioned specimen, however, internally has a thick callosity-like wall and slender dental lamellae. In these respects they show a similarity to the older representatives of Neospirifer described by MAXWELL (1951, 1954).

They closely resemble *Spirifer liangchowensis* CHAO from the Viséan Choniukou formation of Kansu, northwest China, which belongs to *striatus* group in its general size and proportion, number of costae and kind of costation of both wings, and costal formula in the ventral sulcus. Minor differences of the former from the latter are: absence of weakly fasciculated costae in the beak region, and thicker shell in the umbonal region of the ventral interior.

The specimens described by MAXWELL (1954) under the name *Spirifer* cf. *S. liangchowensis* from the Vinséan rocks of the Mt. Morgan District, northeast Australia, are similar to the Akiyoshi specimens. MAXWELL suggested that the Queensland specimens can be distinguished from the types by their less convex valves and lack of fasciculated costae. The Akiyoshi specimens are closer to the Queensland ones than to the types not only in the external characters but also in the internal structures of the ventral valve. There is a little difference, however, in the shape of the dental lamellae between the Queensland and Akiyoshi specimens, and the latter has longer and slenderer ones.

The general characters of the shell of the Akiyoshi specimens recall those of the Lower Carboniferous *Spirifer striatus* (MARTIN), especially the convexity of the shell and the kind of costation. The former specimens are, however, different from the latter by their smaller shell, more subrhomboidal outline, thicker umbonal callosity-like wall of the ventral valve, and their slender dental lamellae.

### *Spirifer* sp.

Pl. 15, figs. 4, 5, 6, 8

*Material.*—The following specimens are described under the above heading. Three incomplete dorsal valves; GK. D30016 (Pl. 15, fig. 6), GK. D30017 (Pl. 15, fig. 8), GK. D30018 (Pl. 15, fig. 5), and a very small ventral valve; GK. D30020 (Pl. 15, fig. 4). Other ten specimens are fragmentary.

*Descriptive remarks.*—The dorsal valves are wide, having a slightly inflated median fold and bifurcated radial costae. The wings are ornamented with sharp costae, which are bifurcated at least once, and twenty-five to thirty costae are present at the anterior margin. The costae are not fasciculated.

Measurements in mm and degrees:

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| length | | | | |
| ventral valve | | | | 8.1 |
| dorsal valve | 15.0 | 19.5 | 17.5 | |
| width | 26.0 | 34.0 | 38.0 | 10.5 |
| apical angle | | | | |
| ventral valve | | | | 150° |
| dorsal valve | 165° | 170° | 165° | |

In the outline of the shell and the character of the costae these specimens belong to a species of *Spirifer* striatus group. They are most similar to *Spirifer* sp. described by MUIR-WOOD (1948) from the Viséan of Bukit Charas and Pahang of Malaya in the convexity of the dorsal valve and the kind of costation, although they are smaller in size.

Family *Athyridae* PHILLIPS, 1841

Subfamily *Athyrinae* WAAGEN, 1883

Genus *Cleiothyridina* BUCKMAN, 1906

Type-species.—*Spirifer deroissii* LÉVEILLE, 1835 (=*Athyris royssii* DAVIDSON, partim)

*Cleiothyridina expansa* (PHILLIPS), 1836

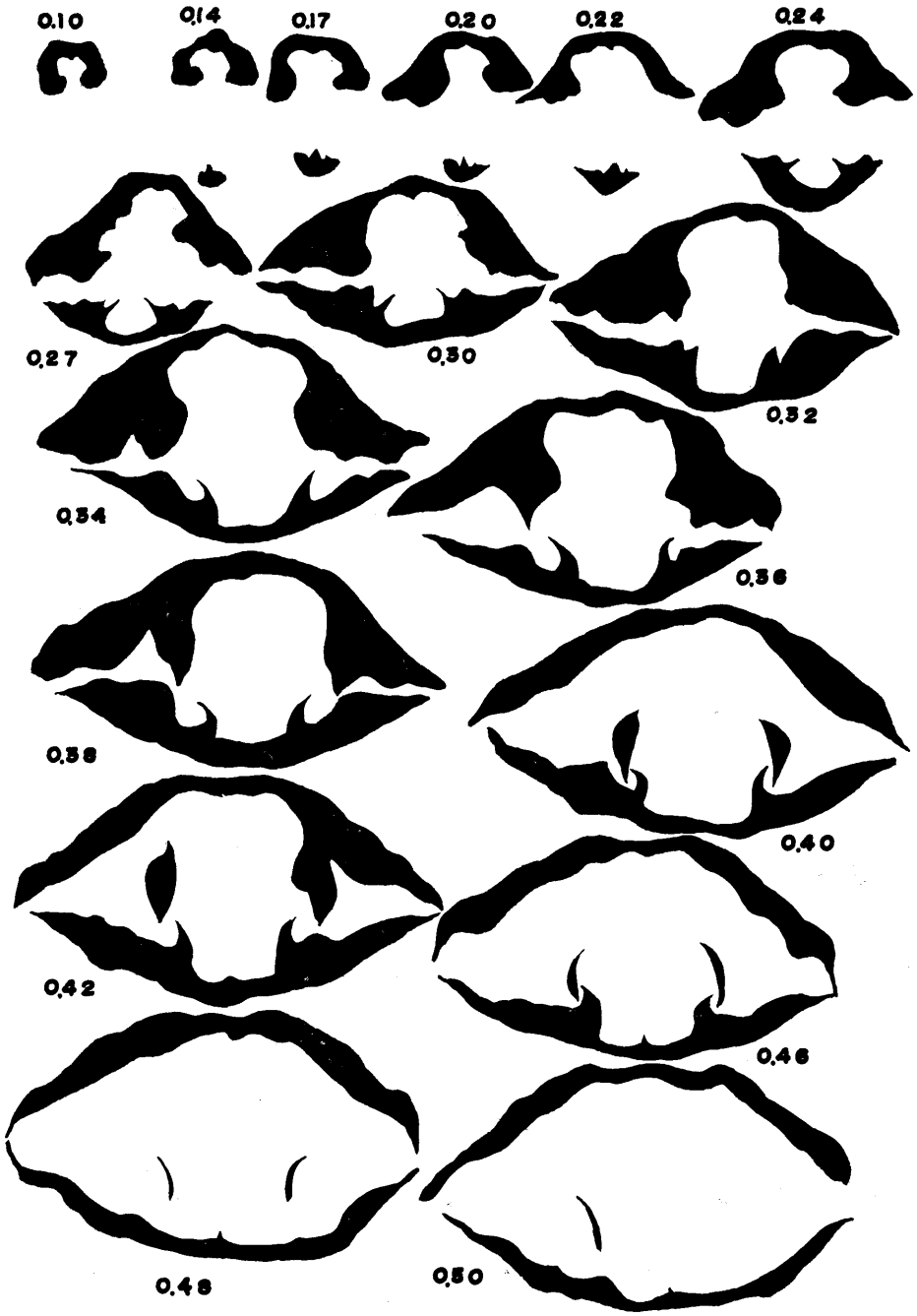
Pl. 16, figs. 1-9, Pl. 17, fig. 1; Text-figs. 7, 8, 9

1836. *Spirifera expansa* PHILLIPS, Geol. of Yorkshire, Vol. 2, p. 220, pl. 10, fig. 18.
1855. *Athyris expansa*, M'COY, British Palaeozoic Fossils, p. 433.
1858. *Athyris expansa*, DAVIDSON, Paleont. Soc., Vol. 2, Part 5, pp. 82-83, pl. 16, figs. 14, 16-18, pl. 17, figs. 1-5.

*Material.*—Well preserved specimens are as follows: GK. D30021 (Pl. 17, fig. 1a-c), GK. D30022 (Pl. 16, fig. 2a-c), GK. D30027 (Pl. 16, fig. 1a-c), GK. D30023 (Pl. 16, fig. 3), GK. D30024 (Pl. 16, fig. 4), GK. D30025 (Pl. 16, fig. 5a-c), GK. D30026 (Pl. 16, fig. 7), GK. D30028 (Pl. 16, fig. 6a-b).

*Description.*—The shell is usually subequally biconxex but commonly flattened. Most of the specimens are laterally elliptical in outline and of moderate size but some are small and have a subelliptical to subcircular outline. The hinge line is straight and slightly shorter than the greatest width, but it is rather short in some specimens with the length about one-half the width. The cardinal extremities are rounded.

The ventral valve is more evenly convex than the dorsal one, is more or less flat in the anterior region, and is slightly inflated in the umbonal. A median sulcus is weakly developed anteriorly but is usually not observable in the posterior part. The beak is small, pointed, and slightly incurved. The dorsal valve has no fold and is more convex than the ventral valve with the greatest convexity in the umbonal region. It is relatively flattened anteriorly. Some valves are nearly twice as wide as long.




Text-fig. 7. *Cleiothyridina expansa*. Serial sections ×3.6 of GK. D30070. Sections 0.40 to 0.42 show strong teeth.

Both valves are almost smooth or covered with fine concentric growth-lamellae about eighteen to twenty in the space of 1 cm in the anterior region. Lamelliform growth-lines gradually become more distinct anteriorly. In some specimens they show a strongly imbricated structure, numbering six to eight in the space of 1 cm. Crossing the concentric lamellae, numerous faint radial striae are present in the anterior region. There are about twenty striae in the space of 1 cm, but at the posterior region none were observed.

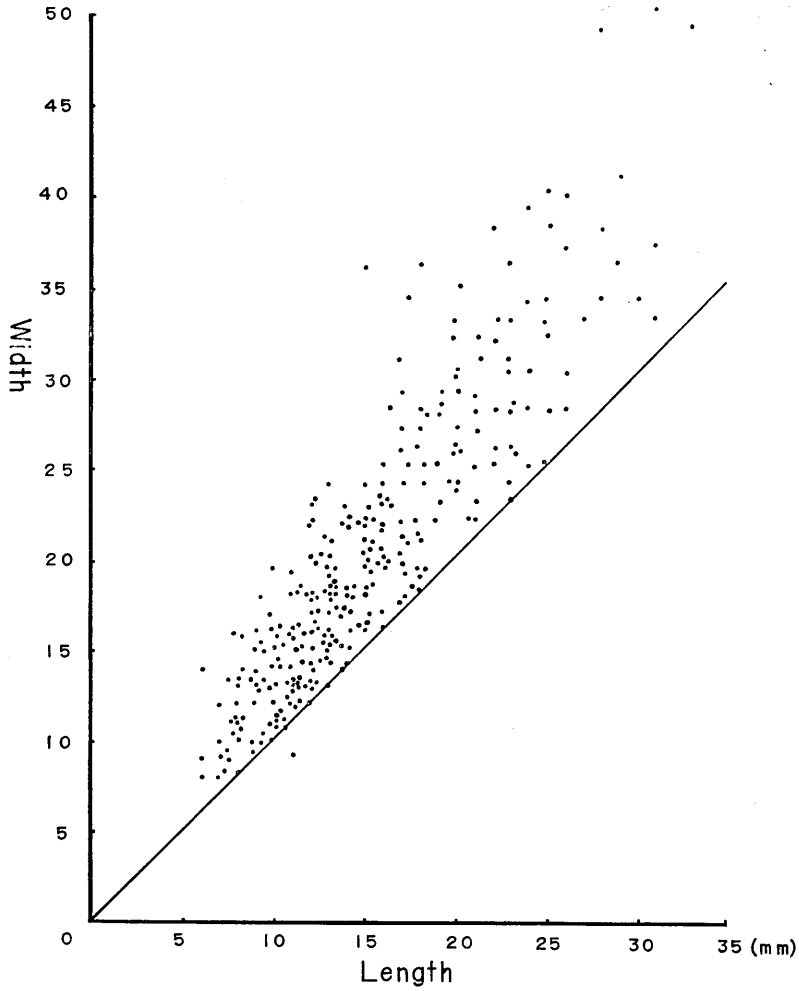
Measurements in mm and degrees:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| length | | | | | | | | | |
| ventral valve | 34 | | 27 | | 21 | 17 | 11 | 24 | 31 |
| dorsal valve | | 25 | | 20 | | 15 | 10 | 23 | 28 |
| width | 48 | 43 | 37 | 40 | 27 | 25 | 14 | 28 | 32 |
| thickness | 17 | | | | | 12 | 7 | 9 | 11 |
| apical angle | | | | | | | | | |
| ventral valve | 145° | | | | | | | | |
| dorsal valve | 163° | | | 160° | | | | 130° | 145° |

The shell is impunctate. The ventral valve has strong hinge teeth supported by short, stout dental lamellae. The dental lamellae slightly diverge anteriorly along the floor of the valve, and extend from the beak approximately to one-third the shell-length. A rudimentary median ridge occurs between the lamellae. The delthyrial cavity is relatively deep and broad. The interior of the dorsal valve contains a slightly thickened hinge plate. The median part of the plate slightly projects dorsally and its marginal parts are continuous with the septal plates. In some specimens the hinge plate is remarkable. The septal plates are rather strong, occurring near the apex of the dorsal valve, and are connected with the crura. A faint or weak median ridge extends approximately half the shell-length.

The specimens have a great variation in ornamentation and thickness and are divided into two forms: a laterally elongate one and a suborbicular form, though a gradual change between them can be seen. The former group is represented by GK. D30021 (fig. 1), GK. D30023 (fig. 3), GK. D30024 (fig. 4), GK. D30026 (fig. 7) and the latter by GK. D30022 (fig. 2) and GK. D30025 (fig. 5). The specimen GK. D30021 has weak concentric growth-lines and no median sulcus. The concentric growth-lines are stronger in specimen GK. D30023, and the imbricated growth-lamellae are observed in GK. D30024. A similar variation occurs in the suborbicular group. The median sulcus or the fold is usually very weak in both groups and shows little variation. Another variation is seen in the thickness of the shell. A shell having a smooth or weakly ornamented surface is usually thinner than that having imbricated growth-lamellae. In the internal characters little variation is recognized.

*Remarks.—Cleiothyridina expansa* (PHILLIPS) is a Viséan species and shows a wide distribution in the Tethys region. As described above, the Akiyoshi specimens show great variations in the shell ornament and thickness, but are identical with *C. expansa* in essential structures. The diagnostic characters of the species are the lamellose or imbricated concentric growth-lines and the radial striae of the surface



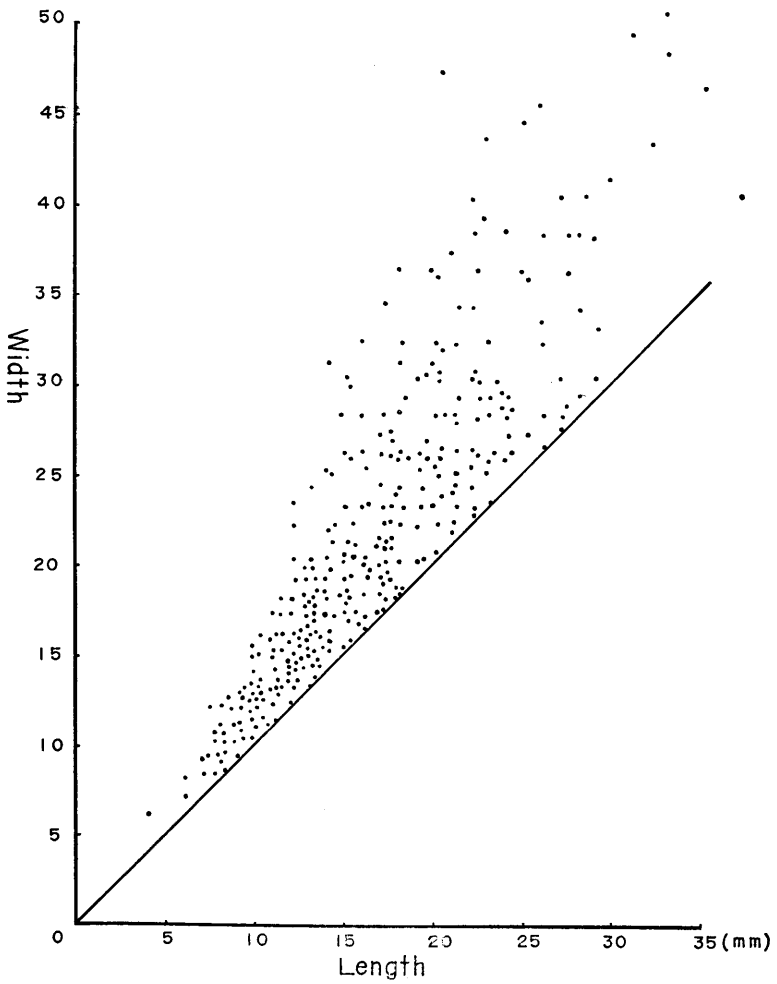

Text-fig. 8. *Cleiothyridina expansa*. Scatter diagram of the length-width relation of ventral valve.

as DAVIDSON (1858) indicated, and the laterally elliptical shape.

*Cleiothyridina lamellosa* (L'EVILLE) and *Actinoconchus planosulcata* (PHILLIPS) show a resemblance to the Akiyoshi species in having concentric growth-lamellae. But *C. lamellosa* is distinguished from the Japanese species by the remarkable growth lamellae, and *A. planosulcata* is distinguished by the lamelliform expansions on each growth-line.

The Akiyoshi specimens bear a resemblance in external configuration to examples described by WAAGEN (1883) as *Athyris subexpansa* from the middle and upper divisions of the Productus limestone in the Salt Range. The latter specimens, howevar, have a distinct sulcus and can be distinguished clearly from the former.

MAXWELL (1954) described *C. transversa* from the Lower Viséan Cleiothyridina zone of the Yarrol Basin in the Mt. Morgan district, Australia, which has a close resemblance to *C. expansa* in its external configuration although the former is the




Text-fig. 9. *Cl. expansa*. Scatter diagram of the length-width relation of dorsal valve.

smaller. MAXWELL distinguished *C. transversa* from *C. expansa* by its weaker concentric ornament and the fine spines. He indicated that *C. transversa* shows closest resemblance to *C. sublamellosa* (HALL) from the Chesterian of North America. *C. sublamellosa* differs from *C. expansa* by its more globose shape and the strong convexity of the valves.

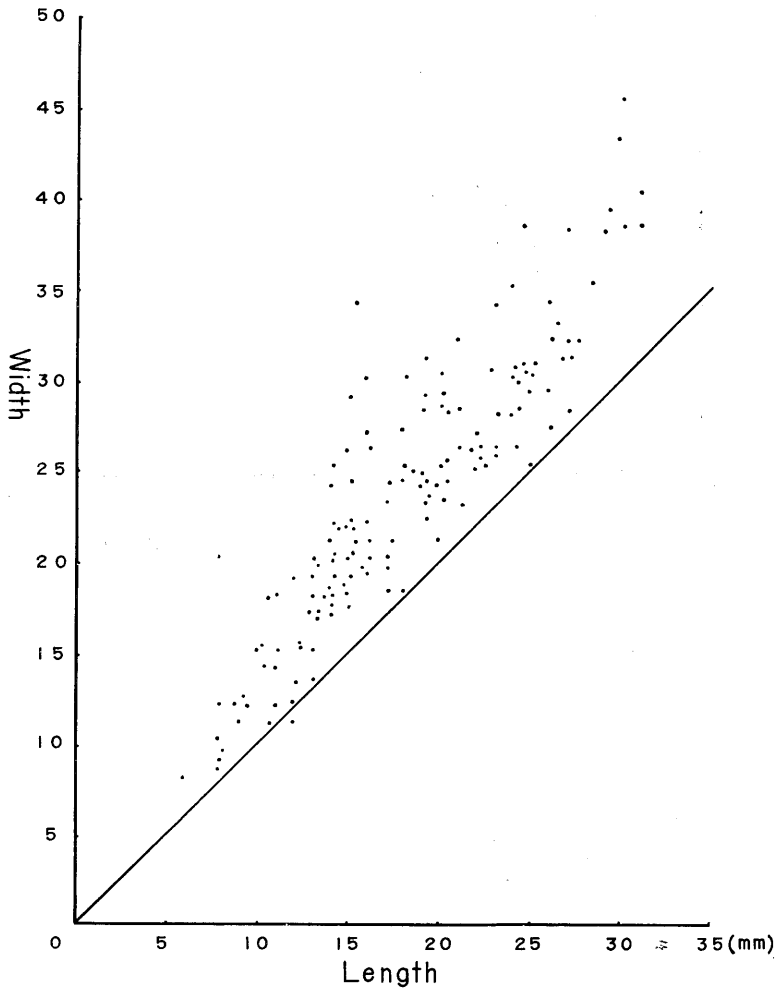
*Cleiothyridina* sp. recorded by MUIR-WOOD (1948) from the Viséan of Bukit Sagu, Malaya, is somewhat similar to the present species in concentric ornament and the absence of a median sulcus or a fold, but it differs in having an approximately circular shape.

### *Cleiothyridina royssii* (L'EVEILLÉ), 1835

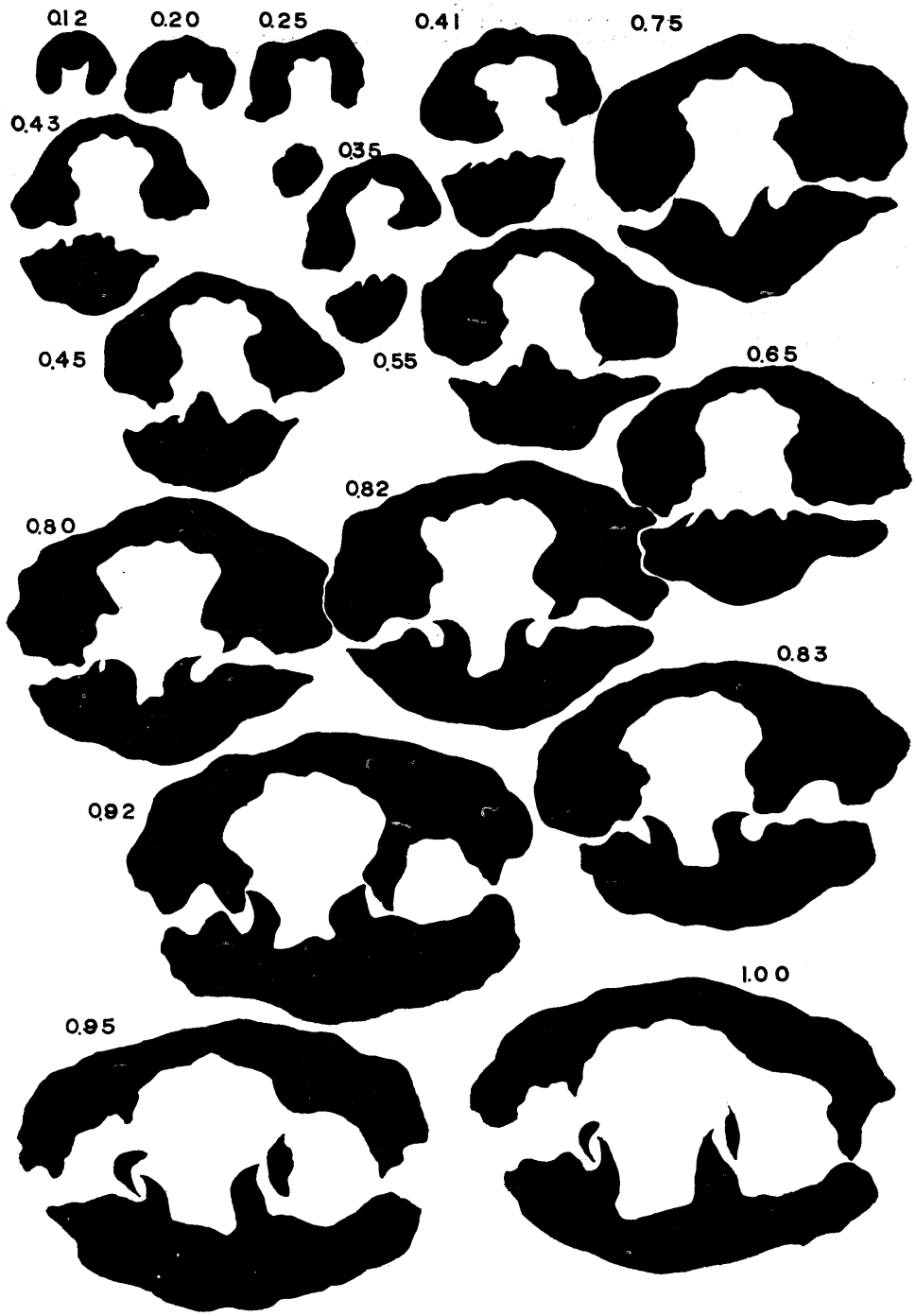
Pl. 17, figs. 2-11; Text-figs. 10-15

1835. *Spirifer deroyssii* L'EVEILLÉ, Mem. Soc. geol. France, Tom. 2, p. 39, pl. 2, figs. 18-20.
1858. *Athyris royssii*, DAVIDSON, Paleont. Soc., Vol. 2, Part 5, pp. 84-86, pl. 19, figs. 19-21.
1922. *Athyris royssii*, HAYASAKA, Sci. Rep. Tohoku Univ., Ser. 2, Vol. 6, No. 1. pp. 65-68, pl. 3, figs. 10-14.
1952. *Cleiothyridina royssii*, MINATO Jour. Fac. Sci., Hokkaido Univ., Ser. 4, Vol. 8, No. 2, pp. 172-173, pl. 9, figs. 2a-b.

*Material.*—A number of specimens were obtained, of which the following are the better preserved examples: GK. D30028 (Pl. 17, figs. 2a-c, 3a-c), GK. D30029 (Pl. 17, fig. 4), GK. D30030 (Pl. 17, fig. 5), GK. D30031 (Pl. 17, fig. 6), GK. D30032 (Pl. 17, fig. 7), GK. D30033 (Pl. 17, fig. 8), GK. D30034 (Pl. 17, fig. 9), GK. D30035 (Pl. 17, fig. 10), GK. D30036 (Pl. 17, fig. 11). Internal structures were examined by serial sectioning (Text-fig. 10) of GK. D30030.

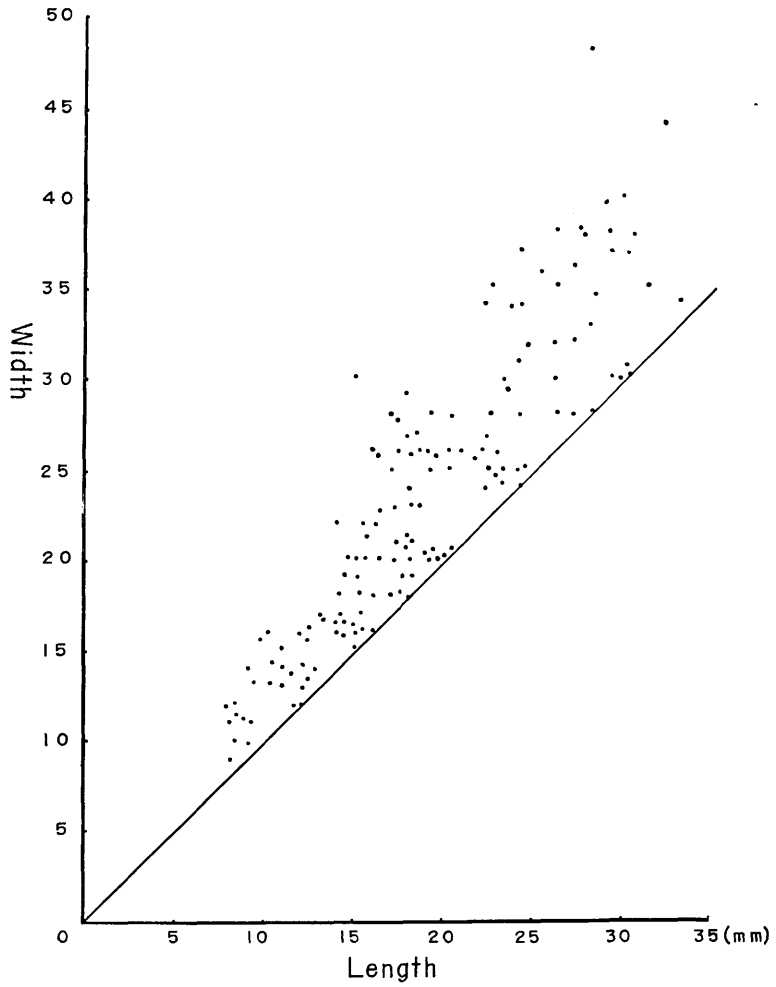



Text-fig. 10. *Cleiothyridina royssii.* Scatter diagram of the length-width relation of ventral valve.




Text-fig. 11. *Cleiothyridina royssii.* Serial sections ×3.1 of GK. D30030. Note strong hinge-plate and crural plates of dorsal valve and stout teeth and dental lamellae of ventral valve.

*Description.*—The shell is an athyrid form of moderate size, laterally subelliptical to subcircular in outline. The median sulcus is present in every specimen and is usually obsolete near the anterior margin but in some is distinctly impressed throughout the shell length. The hinge line is shorter than the greatest shell-width, but in some specimens it is nearly half as long as wide. Both valves are equally convex with the greatest convexity of each in the umbonal region. The beak is small, slightly incurved, and rather pointed. The apical angle ranges from 120° to 140° in the ventral valve and averages 140° in the dorsal valve. The dorsal valve has no fold. The entire surface is covered with numerous, concentric growth-lines which are weak in some specimens and are strongly imbricated in others. Near the margin 6 to 8 growth-lines occupy a space of 5 mm. They are crossed by very weak radial striae, about 10 in the space of 5 mm. The shell is impunctate.



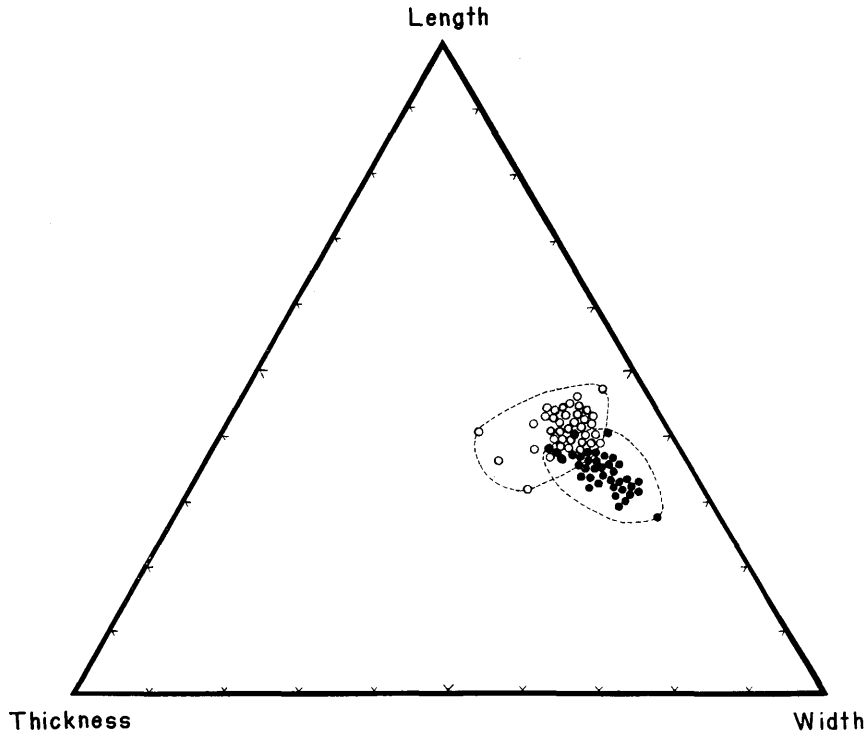

Text-fig. 12. *Cl. royssii.* Scatter diagram of the length-width relation of dorsal valve.

Measurements in mm and degrees:

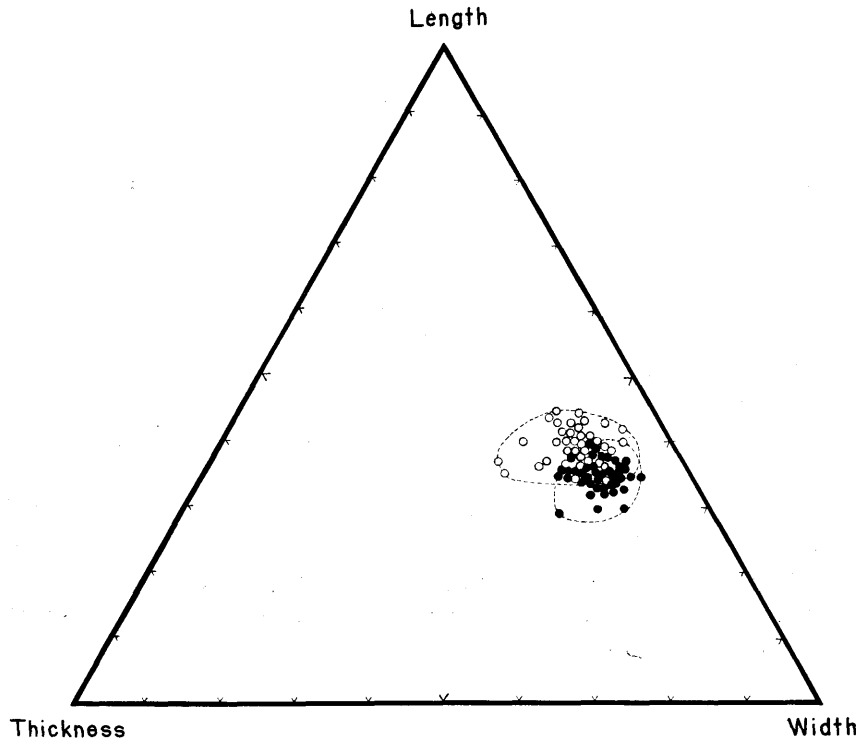
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| length | | | | | | | | |
| ventral valve | | 15.7 | 25.0 | 17.8 | 13.5 | 27.2 | 19.5 | 25.5 |
| dorsal valve | 22.8 | | | | 12.0 | | | |
| width | 2.5 | 18.5 | 29.0 | 26.5 | 13.8 | 32.3 | 21.0 | 27.0 |
| thickness | 8.7 | 6.0 | 12.0 | 6.0 | 7.4 | 7.5 | 7.2 | 5.5 |
| apical angle | | | | | | | | |
| ventral valve | 0° | 135° | 130° | 140° | 140° | 140° | 130° | |
| dorsal valve | 110° | | | | 150° | | | 145° |

The interior of the ventral valve contains a pair of strong teeth supported by short, stout dental lamellae. The apical part is thickly dilated. Two short thickened ridges occupy the large space on either side of the median ridge near the beak but they rapidly thin out anteriorly near the dental lamellae. The low median ridge extends approximately a half the shell-length, on either side of which a pair of muscle scars are present. The delthyrial cavity is deep.

In the dorsal valve interior some specimeds contain strongly inflated hinge plates and others contain sharply projected ones. The cardinalia are extremely strong. The dental sockets are relatively narrow, long, and deep. The septal plates occurring near the apex are strong, rather flat, and connected with the crura. The low median ridge occurs just before the hinge plate and extends about half of the shell length.




Text-fig. 13. Proportional diagram of ventral valve.
points—*Cl. expansa*, circles—*Cl. royssii*

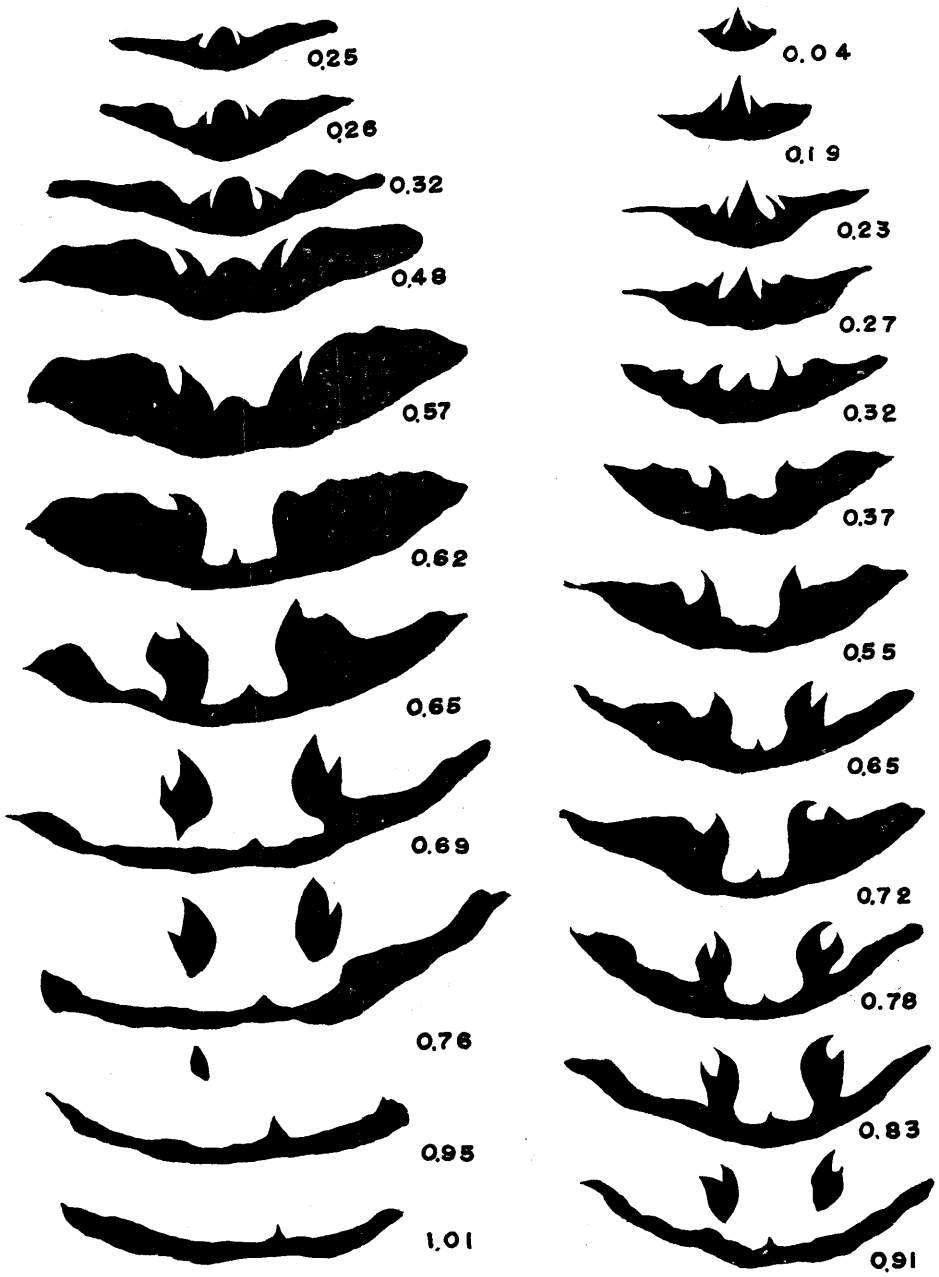



Tsxt-fig. 14. Proportional diagram of dorsal valve. points— *Cl. expansa*, circles—*Cl. royssii*

*Remarks.*—As understood from the above description, the specimens examined show some variation in the surface ornament and in the nature of the hinge-plate. In addition to a group of specimens having closely arranged and strongly imbricated growth-lines, there is another form, in which the growth-lines are generally weak but are distinct only near the front margin. In the former group the hinge-plate is sharply and strongly projected ventrally near the beak, whereas in the latter it is bluntly inflated. DAVIDSON (1858) indicated that the fringe-like minute spines on the concentric growth-lines are the diagnostic character of *C. royssii*. Unfortunately, since the shell surface of the available material was abraded in the process of deposition, no spines were detected. According to DAVIDSON, in the British specimens a broad median fold and a corresponding sulcus occur only in the late growth-stage. In the Akiyoshi specimens no median fold is observed at all, but the median sulcus occurs usually with a broad and shallow depression in the adult stage but occasionally with a distinct one even in the early stage.

The specimens at hand bear apparent resemblance to those of *Actinoconchus planosulcata* which lost their surface lamelliform expansions and exposed the traces of the growth-lines. The former specimens are, however, distinguished from the latter by the stronger median ridge of the ventral valve.

MINATO (1951) identified with *C. royssii* some fragmental specimens from the Lower Carboniferous Arisu series of the Kitakami massif. The Akiyoshi specimens




Text-fig. 15. *Cleiothyridina royssii*. Serial sections of dorsal valves ×2 of GK. D 30072 (left) and 30073 (right). Note strongly supported sockets with fulcral plates and stout inner socket plates. A remarkable variation is observed on hinge plate. Sections 0.25 to 0.48 of GK. D30072 show round topped hinge-plate; 0.04 to 0.27 of GK. D30073 show sharply projected one.

somewhat resemble Kitakami ones in having a very short hinge line, an obsolete median sulcus and in lacking a fold in the dorsal valve, but they are larger and less wide.

HAYASAKA (1922) described the same species from the Lower Carboniferous of Huang-tu-pu of Hu-nan, South China. The Chinese specimens have no spines on the surface and neither sulcus nor fold. In these respects they are different from the type specimen but are similar to the Akiyoshi ones, except that they are much smaller in size.

DAVIDSON described *Athyris royssii* on the basis of a large number of specimens from England. English specimens, however, generally have a broad but shallow median sulcus on the ventral valve and a corresponding fold on the dorsal valve.

*Cleiothyridina expansa* described in the former pages has a close resemblance to the specimens under consideration in external configuration, but internally, that is, in the kind of median ridge, hinge plate, and hinge sockets are different as shown in the figures (Text-fig. 7). There is no fundamental difference between both the two. Intermediate forms are observed in the present specimens.

*Cleiothyridina* sp. reported by MUIR-WOOD (1948) from Bukit Sagu of Malaya has neither fold nor sulcus and an approximately circular outline. The Malayan specimens have close resemblance to some of the Akiyoshi specimens in external configuration.

## Genus *Actinoconchus* M'COY, 1844

Type-species.—*Actinoconchus paradoxus* McCOY=*Spirifera planosulcata* PHILLIPS, 1836

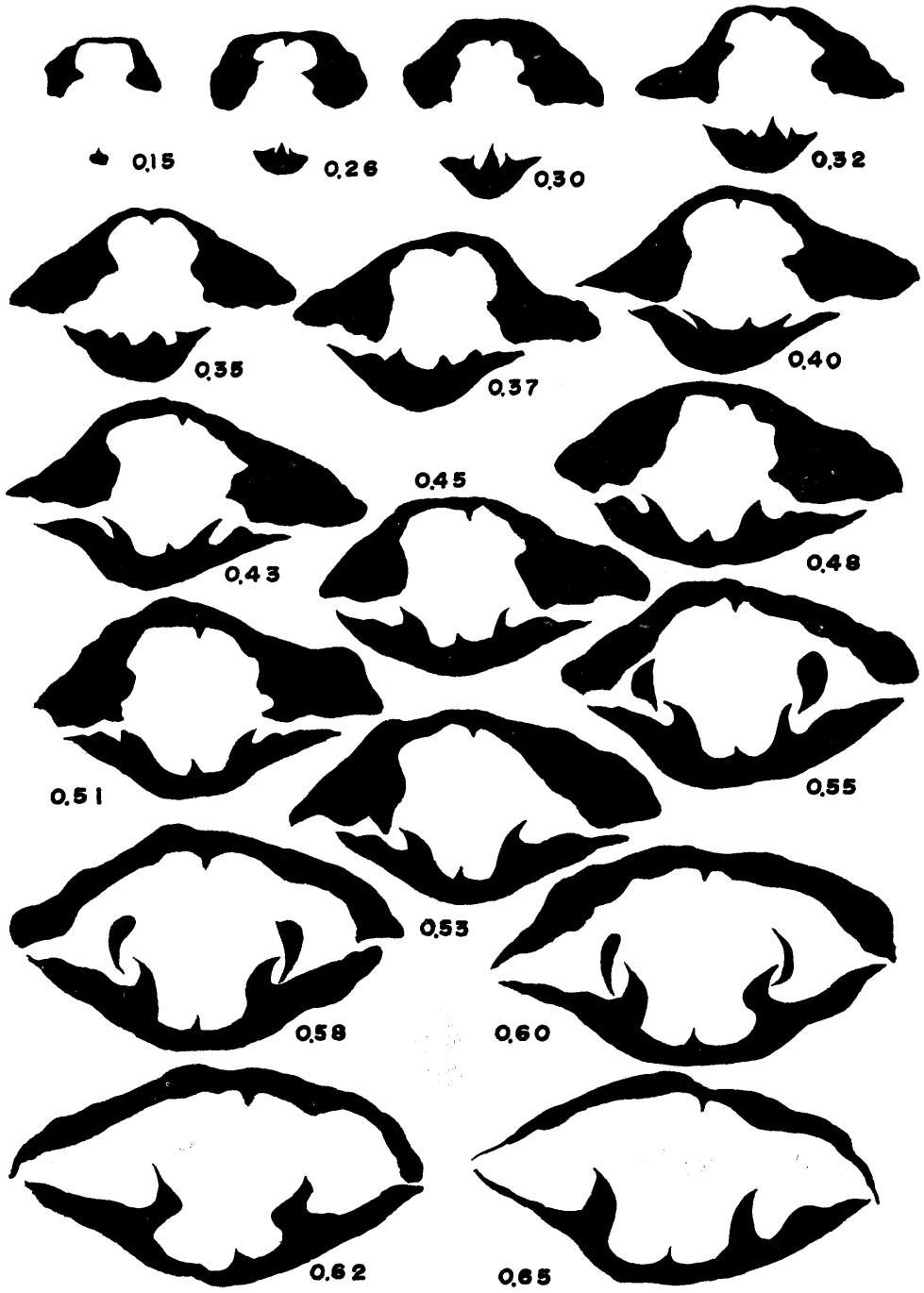
### *Actinoconchus planosulcata* (PHILLIPS), 1836

Pl. 18, figs. 1-5; Text-fig. 16

1836. *Spirifera planosulcata* PHILLIPS, Geol. of York., Vol. 2, p. 220, pl. 10, fig. 15.
1844. *Actinoconchus paradoxus* M'COY, Synopsis of Carb. Foss. of Ireland, pl. 21, fig. 6.
1855. *Athyris paradoxa* M'COY, British Palaeozoic Fossils, p. 436.
1858. *Atyhris planosulcata*, DAVIDSON, British Carb. Brachiopoda, p. 80, pl. 16, figs. 2-10, 12-15.
1887. *Athyris planosulcata*, DE KONINCK, Ann. Mus. Roy. d'Hist. Tom. 14, pp. 86-88, pl. 21, figs. 16, 32.
1952. *Actinoconchus planosulcata*, MINATO, Jour. Fac. Sci. Hokkaido Univ., Ser. 4, Vol. 8, No. 2. p. 174, pl. 8, fig. 4, pl. 11, fig. 4.

*Material.*—Eight incomplete specimens are at my disposal, of which one is the ventral valve and two are the dorsal valves. Relatively better preserved specimens are as follows: GK. D30037 (Pl. 18, fig. 1a-c), GK. D30039 (Pl. 18, fig. 2), GK. D30038 (Pl. 18, fig.3a-c), GK. D30040 (Pl. 18, fig. 4). Internal structures are shown by the serial sections of GK. D30041.

*Description.*—The specimens are incomplete and the surface of their umbonal region is a little exfoliated but other important structures of this species are well preserved. The shell is small to moderate in size and suborbicular or longitudinally orbicular in outline with subequally and uniformly convex valves. The widest part




Text-fig. 16. *Actinoconchus planosulcata*. Serial sections ×3.6 of GK. D30041. Note sharp hinge-plate (sections 0.26 to 0.32), low but distinct median ridge, and high crural plates (0.62 to 0.65) of dorsal valve. Sections 0.55 to 0.60 show strong teeth. Median adductor ridge of ventral valve is observable in all sections.

is located just anterior to the hinge line and the thickest part is near the umbo. The median sulcus and fold are usually indistinct, but a very shallow depression is present at the anterior margin of the ventral valve. The beak is very small, pointed, and slightly incurved. The surface of the anterior of both valves is covered with fine or obscure growth-lines, and 4 lines occupy the space of 1 mm. Radially striated strong ridges are present on the posterior half and 3 to 5 ridges cover the umbonal region.

The interior of the ventral valve has hinge teeth with short and stout dental lamellae. A low median ridge extends half the shell-length. Internally the dorsal valve contains a strongly projected hinge plate which is bordered on both sides by deep dental sockets. The frontal extension of the septal plates is connected with the crural plates. A distinct but relatively low median ridge is present in front of the hinge plate. It extends approximately a half the shell-length.

Measurements in mm and degrees:

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| length | | | | | |
| ventral valve | 14.9 | 12.5 | 10.5 | 9.6 | 12.7 |
| dorsal valve | 14.0 | 11.6 | 9.3 | | |
| width | 16.4 | 12.3 | 10.5 | 11.9 | 11.8 |
| thickness | 9.3 | 7.2 | 6.5 | 3.4 | 5.5 |
| apical angle | | | | | |
| ventral valve | 130° | 120° | 120° | 130° | 120° |
| dorsal valve | 145° | 140° | 140° | | |

*Remarks.*—The specimens obtained are referred to *Actinoconchus planosulcata*, the type-species of the genus, although the lamelliform expansions on the growth-lines cannot be observed in the available specimens. The most diagnostic characters are the radial ridges, and the very fine concentric and imbricated growth-lines on the surface.

DAVIDSON (1858) described *Athyris planosulcata* on the basis of many excellent specimens collected from the Lower Carboniferous limestones of England, Scotland, and Ireland. The specimens from Akiyoshi resemble the specimen of fig. 6 on pl. 16 of his monograph of the Carboniferous brachiopoda, which shows the typical internal structure of the species. The Akiyoshi specimens are smaller in size than the English ones but are similar in outline when they have no lamelliform expansions.

Belgian specimens described by DE KONINCK (1887) from the Lower Carboniferous limestone of Visé show a similarity in the outline and size to the Japanese specimens. An example (pl. 21, figs. 14, 15) under the name of *A. paradoxa* described by DE KONINCK from the Lower Carboniferous limestone of Visé shows the distinct radial ridges which are observed also in the Akiyoshi specimens.

VAUGHAN (1908) described some specimens under the name of *Athyris* cfr. *planosulcata* from the Lower Posidonomya Beds of Loughshinny of County Dublin. His example shown as fig. 6 on pl. 50, seems to be identical with the Akiyoshi specimens in the radial ridges, subcircular outline, and the traces of fine concentric growth-lines.

MINATO (1951) referred some specimens from the Lower Carboniferous Hikoroiti series of the Kitakami massif of Japan to the species under consideration. The Kitakami form is, however, much larger than the Akiyoshi specimens and, according to MINATO, five concentric lamelliform expansions are present on the surface of both valves.

The Akiyoshi specimens also show a close resemblance to those of *Athyris royssii* described by HAYASAKA (1922) from the Lower Carboniferous of Hu-nan, South China and also to those of *Athyris submabranacea* GRABAU described by CHU (1933) from the Lower Carboniferous Kinling limestone. The former specimens, however, differ from the latter two in outline and size. The interior structure of *A. submabranacea* is somewhat similar to that of the Akiyoshi species. It is considered that *A. royssii* and *A. submabranacea* from China are related to the Japanese species.

The internal characters of the Akiyoshi specimens are like those of *Cleiothyridina expannsa* described before. Their hinge plates are, however, more strongly projected ventrally than those of the latter, but not so prominent as those of one variant of the Japanese specimens of *Cleiothyridina royssii*. The shape and mode of their dental sockets are also equivalent to those of *C. expansa*. The inner wall of the sockets is projected sharply and is stronger than the outer wall which is usually united with the lateral shell wall. Median ridges are distinct in both valves of the Akiyoshi specimens, whereas they are rudimentary or very weak in *C. expansa*.

## Genus *Composita* BROWN, 1849

Type-species.—*Spirifer ambiguus* SOWERBY, 1838

### *Composita* aff. *C. argentea* (SHEPARD), 1838

Pl. 18, figs. 6-8, Pl. 19, fig. 3; Text-fig. 17

Compare.—

1838. *Terebratula argentea*, SHEPARD, Am. Jour. Sci., Vol. 34, p. 152, fig. 8.
1932. *Composita argentea*, DUNBAR & CONDRA, Bull. Geol. Surv. Nebraska, Ser. 2, Bull. 5, pp. 367-369, pl. 43, figs. 1-6.

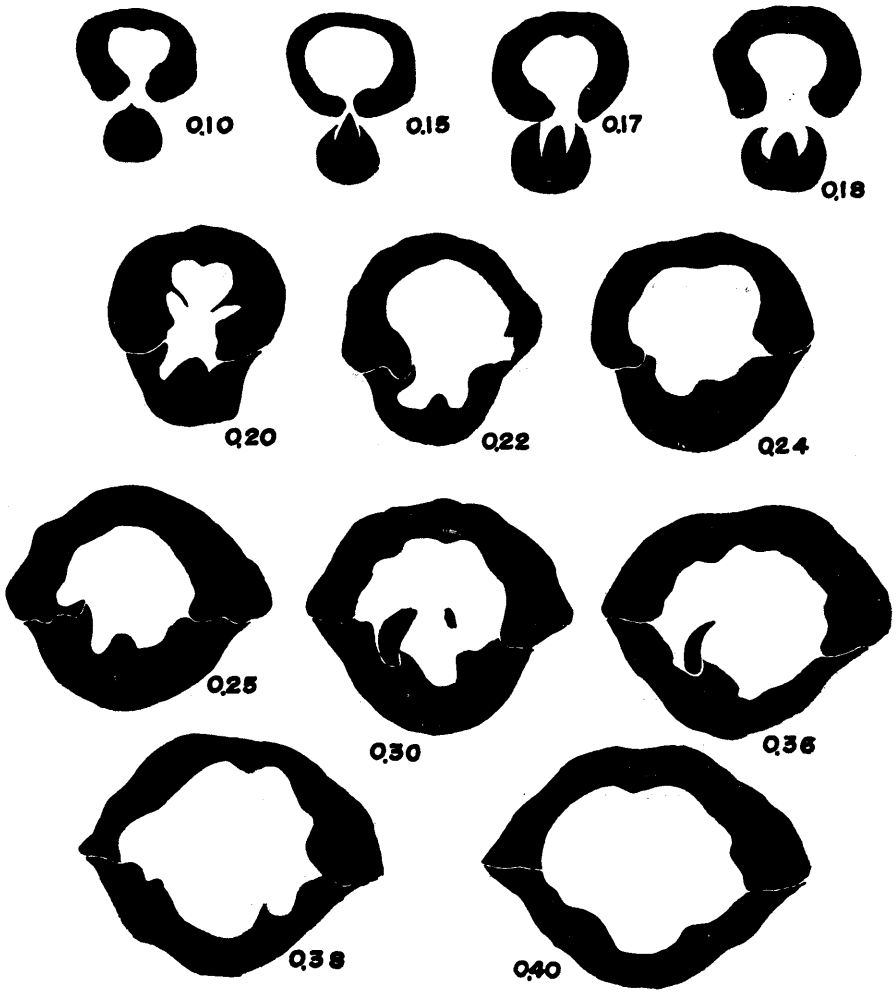
*Material.*—Fourteen complete specimens were examined. The following are the better preserved specimens: GK. D30042 (Pl. 18, fig. 6a-c), GK. D30043 (Pl. 18, fig. 7a-d),GK. D30044 (Pl. 18, fig. 8a-d), GK. D30045 (Pl. 19, fig. 3a-c).

*Description.*—The shell is very small and is terebratuliform or subcircular to suboval in outline. The valves are biconvex with subequal convexity. The widest part of the shell is located at half the shell-length from the beak. The hinge is extremely short and without a cardinal area. The ventral beak is not prominent, rather bluntly pointed and usually is tightly incurved over the obtuse dorsal beak. The dorsal valve is inflated in the umbonal region and rather rapidly decreases in convexity towards the sides and the front. A small rounded foramen is in the tip of the beak. The ventral sulcus and dorsal fold are distinct and are developed uauslly near the anterior commissure. The surface is provided with very fine striae which are rather distinct near the lateral margins and are closely crowded in the anter-

ior. The shell is impunctate.

Measurements in mm and degrees:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| length | | | | | | | | |
| ventral valve | 11.8 | 11.4 | 10.1 | 9.5 | 8.3 | 9.0 | 8.0 | 8.6 |
| dorsal valve | 10.7 | 10.5 | 9.5 | 8.1 | 7.9 | 8.3 | 7.3 | 7.9 |
| width | 11.5 | 10.1 | 9.5 | 8.0 | 8.2 | 8.5 | 7.5 | 7.6 |
| thickness | 7.8 | 6.7 | 6.9 | 6.1 | 6.0 | 5.9 | 5.5 | 5.5 |
| apical angle | | | | | | | | |
| ventral valve | 100° | 95° | 90° | 85° | 95° | 90° | 110° | 100° |
| dorsal valve | 110° | 115° | 110° | 90° | 120° | 115° | 120° | 120° |




Text-fig. 17. *Composita* aff. *C. argentea*. Serial sections ×6 of GK. D30042. Note strong hinge-plate (0.15 to 0.18) and stout teeth (0.25 to 0.36). Median adductor ridge is slightly observed (0.30 to 0.40).

The internal structures were examined by serial sections of a specimen. Internally, the ventral valve has short but stout teeth. The dental lamellae appear to be rudimentary. The interior of the dorsal valve has a hinge plate between the dental sockets and it projects ventrally. The transverse section shows that it is sharply triangular in the umbonal region and becomes blunter and lower anteriorly.

*Remarks.*—The specimens examined include a number of small shells, but the precise comparison of them with known species is difficult because of lack of knowledge of their internal structures.

The species which shows the closest resemblance to the Akiyoshi species is *Composita argentea* (SHEPARD) which was first reported in 1836 from the Lower Pennsylvanian limestone of Illinois and was later described at length by DUNBAR and CONDRA (1932). According to them, important charters of *C. argentea* are shown by the subcircular outline, very short ventral beak and low fold and sulcus. The present specimens are similar to those of the American species in the subcircular outline and the mode of development of the ventral sulcus. One of the American specimens has a shallow but distinct ventral sulcus throughout the growth-stages and the rest have a very shallow but rather distinct sulcus which appears at two-thirds the length from the beak. The most distinct difference of the Japanese species from *C. argentea* is in their size. The biggest one of the Akiyoshi specimens attains only two-thirds the size of the American specimens and most of them are less than half of the larger examples reported by DUNBAR and CONDRA. Another significant difference is in the ventral sulcus. In the young shells of *C. argentea* the median fold and sulcus occur faintly only at the front margin. In the specimens under consideration, distinct sulcus is present throughot the length of the shell even if it is very shallow.

In external configuration the present specimens also show a resemblance to those of *C. subtilita* HALL which had been considered for many years to be a synonym of *C. argentea* until DUNBAR and CONDRA (1932) distinguished them as two valid species. Japanese species clearly differ from *C. subtilita* in having a smaller shell, more rounded outline and a less prominent beak. The median sulcus and fold of *C. subtilita* appear only in the mature stage.

Family *Dielasmatidae* SCHUCHERT and LE VENE, 1929

Subfamily *Dielasmatinae* SCHUCHERT, 1913

Genus *Dielasma* KING, 1859

Type-species.—*Terebratulites elongatus* SCHLOTHEIM, 1816

*Dielasma* cf. *D. kingi* DE KONINCK

Pl. 19, fig. 1

Compare.—

1887. *Dielasma kingi*, DE KONINCK, Ann. Mus. Roy. Hist. Nat. Belgique, Tom. 14, pp. 13–14, pl. 4, figs. 9–18.

*Material.*—Specimens examined include a complete shell, ten very small shells,

and two incomplete ventral valves. The better preserved specimens are as follows: GK. D30046 (Pl. 19, fig. 1a-c), GK. D30047.

*Description.*—The shell is small to moderate in size, posteriorly elongate-oval in outline, and subequal in convexity. The greatest width is located approximately three-fifths of the shell length from the beak. The ventral valve is evenly and rather slightly convex, showing an equally arched profile. The beak is small and incurved closely to the dorsal valve. The beak ridges are subangular and acute. The umbonal region tapers sharply. The foramen is rounded and very small. The posterior area of the dorsal valve is more highly convex than that of the opposite valve. It becomes flatter anteriorly. A very faint median sulcus appears only at the anterior margin and the anterior commissure is rudimentarily uniplicate. The lateral commissure is bowed toward the ventral valve. The surface is nearly smooth, provided with growth-lines only, which are usually very fine but often distinct. The anterior margin is truncated. The internal structures of the present specimens are unknown.

Measurements in mm and degrees:

| | 1 | 2 | 3 |
|---|---|---|---|
| length | | | |
| ventral valve | 16.2 | 18.6 | 11.4 |
| dorsal valve | 13.3 | | |
| width | 12.9 | 17.4 | 9.2 |
| thickness | 7.5 | 5.5 | 4.2 |
| apical angle | | | |
| ventral valve | 60° | 70° | 60° |
| dorsal valve | 95° | | |

*Remarks.*—The specimens described above resemble *D. kingi* reported by DE KONINCK from the Lower Carboniferous (étage II) of Belgium in their shape and outline, especially close to the specimen illustrated by him as figs. 17 and 18. The diagnostic feature of the Japanese specimens is that the sides are slightly concave posteriorly, moderately convex at the anterior, and tapered at the beak-region. The complete Akiyoshi specimen is smaller than the Belgian form and its umbo is less incurved than that of the latter. But in the small rounded foramen, the acutely tapered umbo, the acute beak-ridges, the convexity of both valves, and the truncated anterior margin, the Japanese specimens are similar to the Belgian form.

HAYASAKA (1924) reported *D.* cf. *D. kingi* from the Omi Limestone of Niigata Prefecture, Japan, to which the present species shows a close resemblance in the size, shape, and outline of the shell.

### *Dielasma* sp.

Pl. 19, fig. 2

*Material.*—One incomplete specimen. GK. D30048 (Pl. 19, fig. 2a-c).

*Descriptive remarks.*—A single incomplete specimen which lacks the lateral area and the beak-region was obtained. It is elongate-oval in outline, and 14.9 mm long,

12.8 mm wide, and 6.1 mm thick, with an apical angle of 70°. The ventral and dorsal valves are posteriorly convex and flattened anteriorly. Neither median fold nor sulcus are present. The surface of the shell is covered with very fine concentric growth-lines which are rather distinct anteriorly.

The present specimen is most like that of *D.* cf. *D. attenuatum* reported by MUIR-WOOD (1948) from the Viséan of Bukit Sagu, Malaya, from which it is distinguished by its smaller shell.

Family *Camarotoechiidae* SCHUCHERT and LE VENE, 1929

Subfamily *Camarotoechiinae* SCHUCHERT and LE VENE, 1929

Genus *Yanishewskiella* LICHAREW, 1957

Type-species.—*Goniophoria angulata* YANISHEWSKY, 1918

*Remarks.*—This genus was erected by LICHAREW in 1957 with *Goniophoria angulata* YANISHEWSKY as the type-species. The possession of a pair of subspondilial plates in its ventral valve is the most important criterion to distinguish the genus from *Goniophoria*.

*Yanishewskiella japonica* sp. nov.

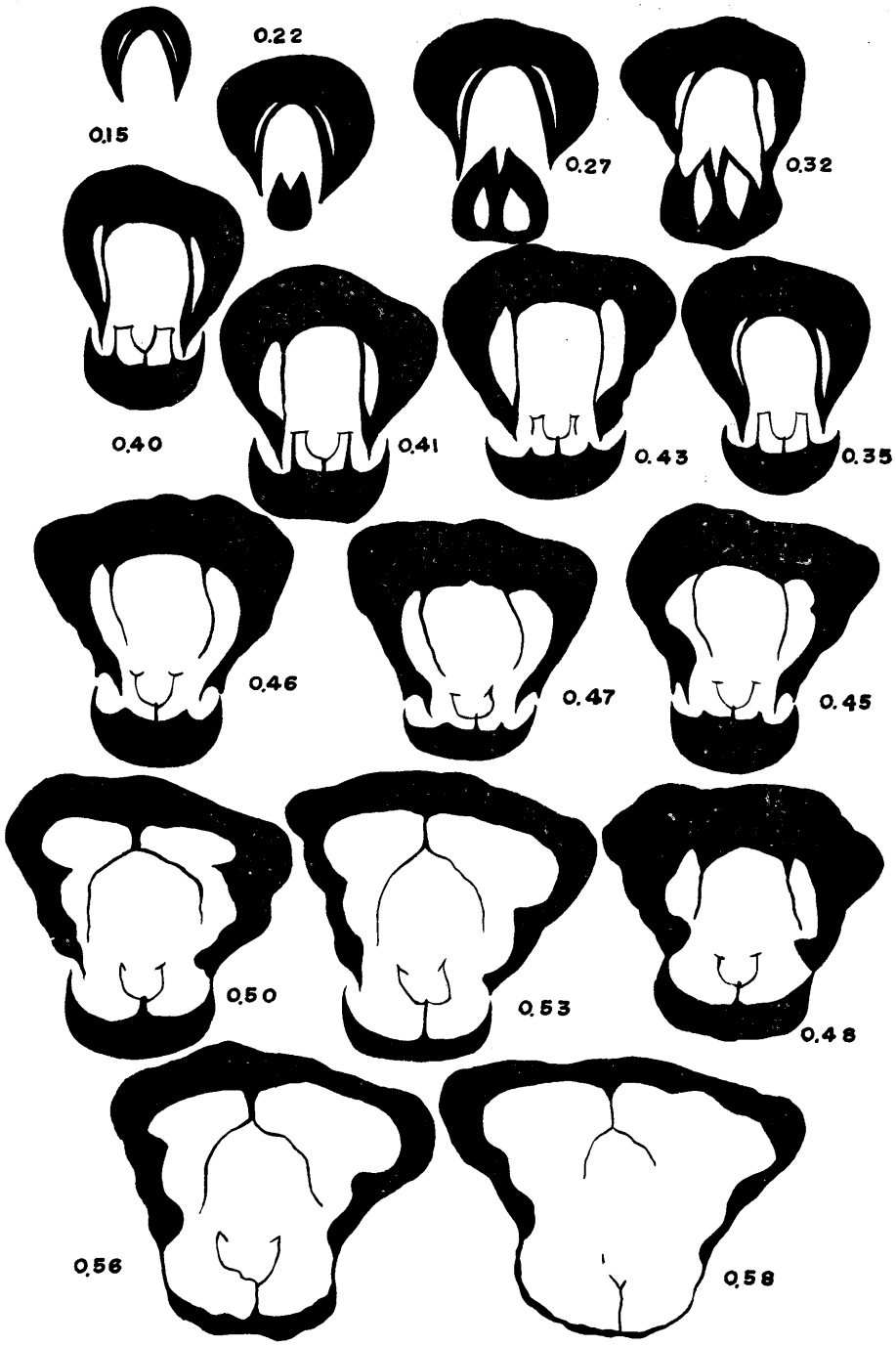
Pl. 20, figs. 1, 2; Pl. 19, figs. 4, 5; Text-figs. 18, 19

*Material.*—There are seven specimens at my disposal, which include four complete shells, two dorsal valves and a ventral one: Holotype, GK. D30054 (Pl. 20, fig. 2a-d). Paratypes GK. D30053 (Pl. 20, fig. 1a-b), GK. D30055 (Pl. 19, fig. 4a-d) and GK. D30056 (Pl. 19, fig. 5a-d). Internal structures were examined by serial sections (Text-fig. 18) of GK. D30053.

*Description.*—The shell is small in size and subtriangular to subpentagonal in outline with the greatest width at about two-thirds the shell-length from the beak or near the anterior margin. The ventral valve is a little more convex than the dorsal one. The median sulcus is weakly developed only near the anterior margin. There are five to seven remarkable costae, which occur only in the anterior quarter and rapidly decrease in strength posteriorly. There are some variations in the form of the commissure of both valves. The holotype (GK. D30054) and one paratype (GK. D30056) show a remarkably sulciplicate anterior commissure, whereas another paratype (GK. D30053) is antiplicate. The berk is bluntly pointed and slightly incurved. The umbonal region of the dorsal valve is more strongly convex than that of the ventral one. The median fold is indistinct. The surface of the shell of the holotype and two paratypes is smooth, but that of the remaining paratype (GK. D30056) has concentric growth-lines.

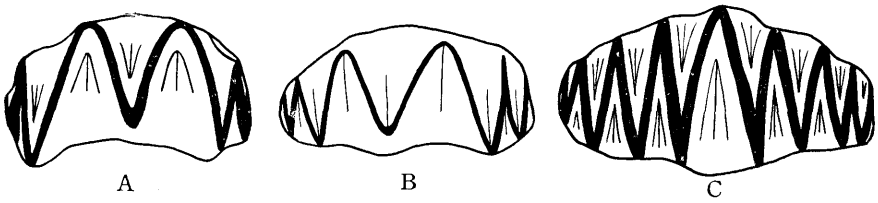
Measurements in mm and degrees:

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| length | | | | | |
| ventral valve | 13.3 | 14.3 | 13.5 | 15.0 | 9.9 |




Text-fig. 18. *Yanishewskiella japonica*. Serial sections ×5.5 of GK. D30053. Note strongly duplex spondylium on high median septum (0.50 to 0.58), septalium (0.35 to 0.56), subspondilial plates (0.32 to 0.48), and split hinge-plate (0.27 to 0.32). Median septum of dorsal valve slightly penetrates into the septalium (0.43 to 0.53).

| | | | | | |
|---|---|---|---|---|---|
| dorsal valve | 13.0 | 14.4 | | 14.9 | 9.2 |
| width | 14.5 | 14.7 | 14.0 | 17.5 | 10.0 |
| thickness | 9.5 | 8.3 | | 11.5 | 7.1 |
| apical angle | | | | | |
| ventral valve | 80° | 75° | 85° | 95° | 80° |
| dorsal valve | 85° | 80° | | 115° | 85° |




Text-fig. 19. *Yanishewskiella japonica*. Variations observed on the mode of anterior commissure of A, GK. D30054, B, GK. D30055, and C, GK. D30053, ×2.4.

In the interior of the ventral valve the hinge teeth are supported by thin dental lamellae which form a spondylium. The dental lamellae become thinner and gradually retreat ventrally as they are traced anteriorly, merging into the floor of the valve at about 2 mm from the beak. Their upper border, however, diverges gradually into thin and parallel plates which run along the internal borders of the shell. At about 5 mm from the beak they unite with the spondylium, which is, in turn, supported ventrally by a well developed median septum and become shallower anteriorly, merging into the median septum.

In the interior of the dorsal valve a separated hinge plate and a septalium are present. The septalium is supported by the median septum, and both become thinner and slenderer anteriorly. The median septum slightly projects into the septalium. The ventral extremity of the septalium is united with the internal side of the hinge plate. A delicate crural process is observed at about 6 mm from the beak.

*Remarks.*—The Akiyoshi specimens are characterized by the coarse plications which are restricted in the anterior portion of the shell, a strong duplex spondylium, a pair of subspondilial plates, the presence of a septalium and a median septum projecting into the septalium for a very short distance. In these respects they are confidently referable to the genus *Yanishewskiella*.

According to LICHAREW, the type-species of the genus, *Goniophoria angulata*, which was originally described by YANISHEWSKY from West Fergana, shows a considerable variation in the shape of the shell, one of the extremities has a flat shell with an alate subpentagonal outline, and other has a trapezoidal contour and is inflated ventro-dorsally. The development of the radial striae is distinct in the flat specimen but very faint in the inflated one.

The Akiyoshi specimens possess the similar characters to those of both types of the Fergana specimens. They are similar to the flat one on one hand in their subpentagonal or subtrigonal outline and in the character of the median septum of the dorsal valve. On the other they are in harmony with the inflated specimen in having the faint radial striae, the duplex spondylium on the high median septum, and a pair of parallel subspondilial plates at about 4.8 mm from the beak.

Thus the Akiyoshi specimens are very close to the type-species of *Yanishewskiella* but are not identical with it in their indistinct median fold and sulcus, much shorter and fewer costae at the anterior portion of the shell, more trigonal outline, and uniformly smaller size. They also differ externally from many specimens described previously under the name *Rhynchonella angulata* from the Lower Carboniferous of England, Ireland, and Belgium. The smallest specimen (GK. D30056) among them, however, shows a similarity to a specimen figured by DE KONINCK (1887, pl. 16, fig. 53) in its external configurations, especially in its having the distinct growth-lines.

## Genus *Pugnax* HALL and CLARKE, 1893

Type-species.—*Terebratula acuminata* SOWERBY, 1822

### *Pugnax* aff. *P. sulcatus* (SOWERBY), 1825

Pl. 20, figs. 3-5, Pl. 21, figs. 1-3; Text-figs. 20, 21

Compare.—

1858. *Rhynchonella acuminata*, DAVIDSON, British Carboniferous Brachiopoda, pp. 93-97, pl. 20, figs. 1-13, pl. 21, figs. 1-20.

1887. *Rhynchonella acuminata*, DE KONINCK, Ann. Mus. Roy. d'Hist., Tom. 14, pp. 35-38, pl. 9, figs. 1-22, pl. 10, figs. 1-37, pl. 11, figs. 1-42, pl. 12, figs. 1-44.

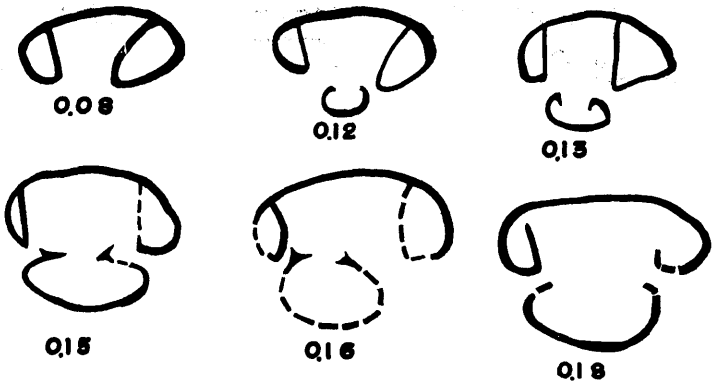
1926. *Pugnax sulcatus*, PARKINSON, Quart. Jour. Geol. Soc., Vol. 82, part 2, pp. 235-238, pl. 14, figs. 1-4.

*Material.*—Fifteen complete specimens are available, of which the following are well preserved: GK. D30049 (Pl. 20, fig. 3a-d), GK. D30050 (Pl. 20, fig. 4a-d), GK. D30051, GK. D30052, GK. D30057 (Pl. 20, fig. 5a, b).

*Description.*—The shell is small, slightly wider than long, usually subtrigonal to subrhomboidal in outline. The ventral valve is slightly convex. The umbo is small. The median sulcus occurs only in the anterior quarter of the valve. The beak is small but rather acute, and is slightly incurved. The dorsal valve is more evenly convex than the ventral one with a slightly inflated fold occurring only in the anterior margin. Both valves are ornamented with weak or faint growth-lines numbering three to four in the space of 1 mm at midvalve. The radial plicae occur incipiently in the sulcus and fold near the anterior margin. They are rounded, usually numbering three to four in the anterior commissure, and rapidly disappear posteriorly never to reach midvalve. Flanks of both valves are usually smooth but incipient plicae are occasionally recognized near the sulcus and the fold at the anterior commissure.

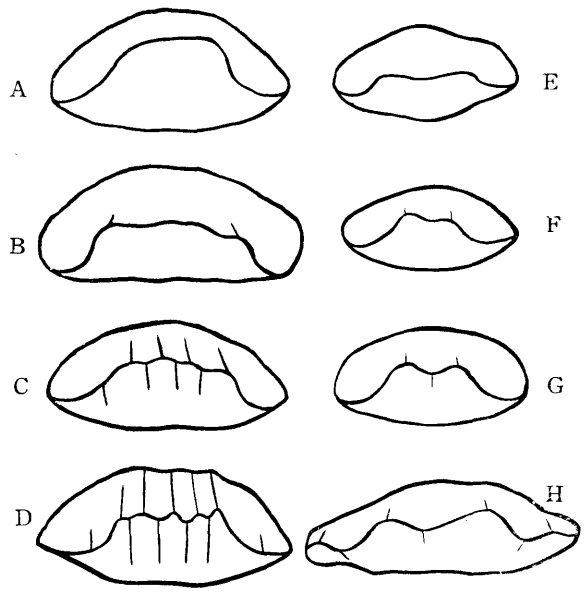
Measurements of six specimens in mm and degrees:

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| length | | | | | | |
| ventral valve | 11.3 | 10.5 | 10.2 | 9.5 | 10.8 | 9.7 |
| dorsal valve | 9.8 | 10.0 | 9.3 | 8.9 | 9.9 | 8.5 |
| width | 12.5 | 12.3 | 11.0 | 11.0 | 12.5 | 10.9 |
| thickness | 6.0 | 6.5 | 6.1 | 5.9 | 6.1 | 6.4 |
| apical angle | | | | | | |
| ventral valve | 90° | 110° | 90° | 110° | 110° | 90° |
| dorsal valve | 110° | 120° | 110° | 120° | 120° | 110° |




Text-fig. 20. *Pugnax* aff. *P. sulcatus*. Serial sections ×4 of GK. D30050. The dental lamellae are observed in all sectons. Sections 0.15 and 0.16 show distinct hinge sockets.

The details of the interior are unkown because that part of the shell is mineralized. The thin dental lamellae are developed in the ventral valve, and extend to one-third the shell-length from the beak. Distinct hinge sockets are developed in the dorsal valve.




Text-fig. 21. *Pugnax* aff. *P. sulcatus*. Variations observed on the mode of anterior commissure of A, GK. D30059, B, GK. D30050, C, GK. D30058, D, GK. D30049, E, GK. D30075, F, GK. D30076, G, GK. D30077, and H, GK. D30057. ×3

*Remarks.*—Although the internal structures of these specimens are insufficiently known, they essentially belong to the group of *Pugnax sulcatus* (SOWERBY). *Pugnax sulcatus* was first described by SOWERBY (1825) as a variety of *P. acuminatus* under the name of *Terebratula acuminata* var. *sulcata*, but later PARKINSON (1926) separated *P. sulcatus* and *P. sulcatus* var. *platylobus* from *P. acuminatus* as distinct species. According to PARKINSON there is a plicated variant in *P. sulcatus* in which four weak plications are observed in the rounded sulcus. Similar variants are also recognized in the Japanese specimens (Pl. 20, fig. 3).

The specimen GK. D30057 (Pl. 20, fig. 5) resembles, in external features, *Rhynchonella acuminata* var. *platiloba* DAVIDSON (1858, pl. 21, figs. 16-20), and *R. acuminata* DE KONINCK (1898, pl. 12, figs. 1-22), from the Lower Carboniferous limestone of Waulsort (étage II), and also *Pugnax sulcatus* var. *platylobus* PARKINSON (1926, pl.

14, fig. 4) from C zone of England. All of them have relatively flattened shells as in the Akiyoshi specimens.

The most significant difference is their much smaller size compared with the types of *P. sulcatus*. They do not attain half the length of the latter. All the specimens are considered to be mature shells because of their uniformity of size.

*Leiorhynchus carboniferum* reported by GIRTY (1911) from the Lower Carboniferous Moorefield shale of Arkansas resembles the present species in shape and out-line. However, it is much larger and has different internal structures.

Family *Schizophoriidae* SCHUCHERT and COOPER, 1932

Subfamily *Schizophoriinae* SCHUCHERT and COOPER, 1932

Genus *Schizophoria* KING, 1859

Type-species.—*Conchyliolites anomites resupinatus* MARTIN, 1809

*Schizophoria* aff. *S. resupinata* (MARTIN)

Pl. 21, figs. 4-13; Text-fig. 22

Compare.—

1863. *Orthis resupinata*, DAVIDSON, British Carboniferous Brachiopoda, pp. 130-131, pl. 29, figs. 1-7, pl. 30, figs. 1-5.
1918. *Schizophoria resupinata*, Yanishewsky, Mém. Com. Géol., N. S., Livr. 162, p. 19, pl. 1, figs. 4, 12, pl. 4, figs. 2a-b, pl. 6, fig. 16a-b.
1941. *Schizophoria resupinata*, Bond, Proc. Geol. Ass., Vol. 52, 4, pp. 289-293, pl. 21, figs. a, b, c.

*Material.*—There are twenty specimens which include seventeen dorsal valves and three ventral ones. Completely preserved shell is not observed. The following specimens are the better preserved ones: GK. D30066 (Pl. 21, fig. 6), GK. D30067 (Pl. 21, fig. 12), GK. D30060 (Pl. 21, fig. 11), GK. D30061 (Pl. 21, fig. 9), GK. D30062 (Pl. 21, fig. 7), GK. D30063 (Pl. 21, fig. 4a, b), GK. D30064 (Pl. 21, fig. 5a, b), GK. D30065 (Pl. 21, fig. 10).

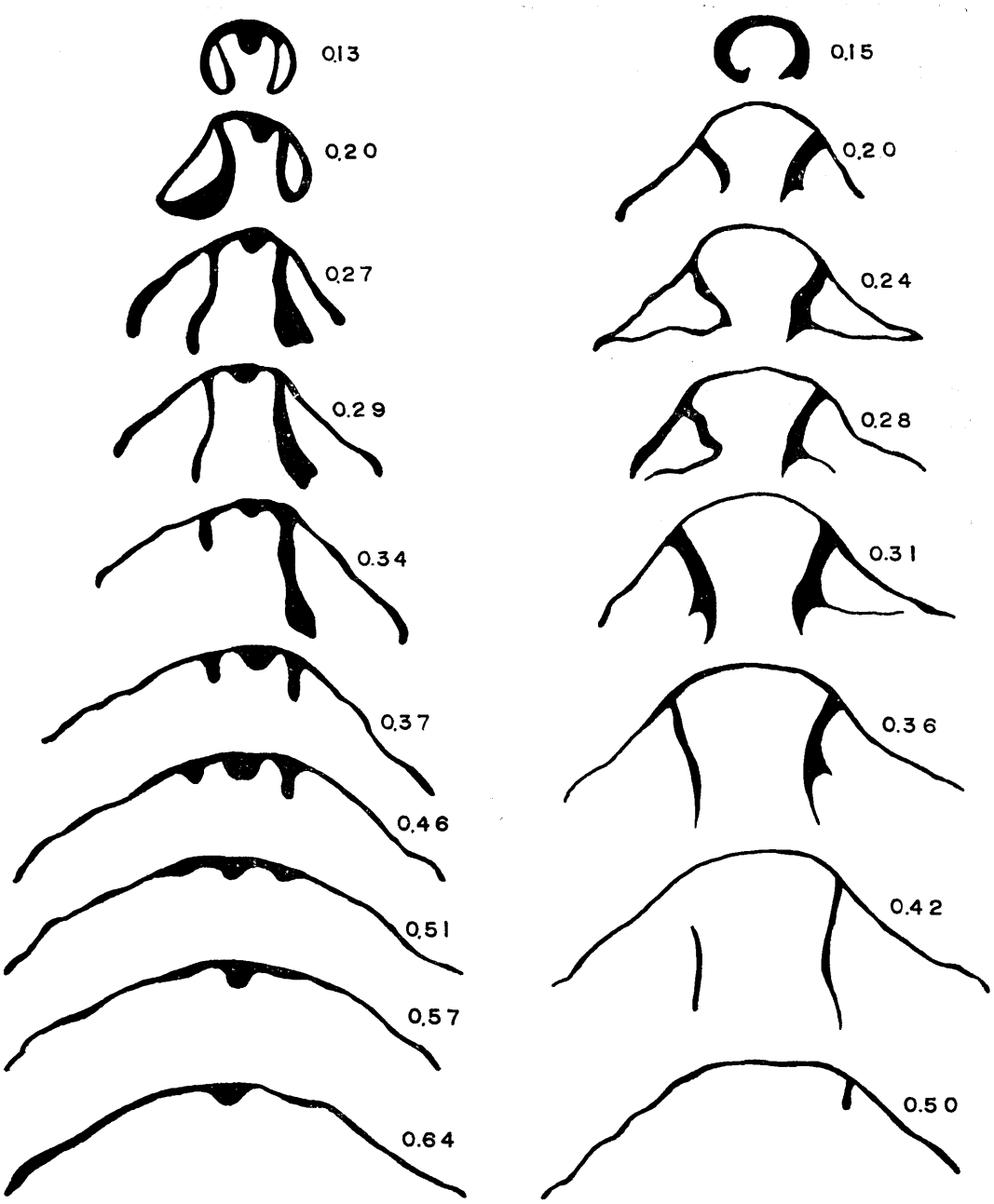
The internal structures of the valves were examined by serial sections (Text-fig. 22) of GK. D30066 and GK. D30061.

*Description.*—The shell is small to medium for the genus, suborbicular to transversely oval in outline, and biconvex. The dorsal valve is more convex than the ventral one. The cardinal extremities are well rounded. The hingeline is narrower than the greatest shell-width.

The ventral valve is without a sulcus and is slightly convex near the umbonal region, tending to be flat over the anterior half of the valve. The umbonal region is slightly incurved but the surface of the cardinal area is slightly concave. The minute spine bases are sparsely distributed.

The dorsal valve is without a fold and variable in convexity. Its height is about a half to one-third the valve-length. The beak is obtuse and strongly incurved. The anterior commissure is generally broadly uniplicate. However, it may be slightly sulciplicate with a slightly developed median sulcus.

Both valves are ornamented by rather fine costae which increase in number




Text-fig. 22. *Schizophoria* aff. *S. resupinata*. Serial sections ×3.5 of GK. D30066 (ventral valve) and GK. D30061 (dorsal valve). Note strong and long dental lamellae which support broad teeth (0.27 to 0.34). Diductor scar divided medianly by low and broad adductor ridge (0.13 to 0.64). Note strongly supported sockets with highly tapering inner socket plates and fulcral plates of dorsal valve.

anteriorly by intercalation and bifurcation. They number about fifty-five in 10 mm or four to five in 1 mm at a distance of 1 cm from the beak.

Measurements in mm and degrees:

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| length | | | | | | | | | | |
| ventral valve | | | | 19.8 | | | 12.1 | | | |
| dorsal valve | 32.5 | 13.0 | 17.5 | | 19.7 | 20.0 | | 11.0 | 12.0 | 11.7 |
| width | | | | 24.3 | | | 14.1 | | | |
| thickness | | | | | | | | | | |
| ventrrl valve | | | | 5.2 | | | 5.0 | | | |
| dorsal valve | 14.0 | 5.0 | 4.5 | | 7.2 | 7.5 | | 5.1 | 5.7 | 5.2 |

The shell is punctate. In the ventral valve, the deep delthyrial cavity is bounded laterally by thin and high dental lamellae, supporting the stout teeth. The dental lamellae extend from the umbo to about one-third the length, approximately 5 mm. They diverge initially at an angle of about 75° and gradually become sub-parallel anteriorly. The median septum extends from the apex of the valve to the anterior margin of the muscle-scar, bluntly projecting dorsally, and dividing the muscle field. The length of the septum is approximately 6 mm from the umbo.

In the dorsal valve, stout and oblique brachiophore plates extend anteriorly about 5 mm from the umbo, approximately a quarter of the valve-length. They diverge anteriorly and become gradually vertical to the valve-floor near the anterior margin of the brachiophore plates. The sockets are rather prominent, provided with stout and short fulcral plates not completely enclosing the sockets. The inner socket plates become long and high anteriorly and taper terminally.

*Remarks.*—The general shape and costation, remarkable dental lamellae, median adducter ridge, strongly supported sockets provided with fulcral plates, and long high tepering inner socket plates of the Japanese specimens all correspond very closely to those of *Schizophoria resupinata* described by DAVIDSON (1863) and BOND (1941). The Akiyoshi specimens, however, differ from the typical British ones in their size, lack of median sulcus on the dorsal valve except in one specimen, relatively finer costation, and oblique brachiophore plates.

BOND (1941) selected a specimen figured by DAVIDSON (1863, pl. 29, figs. 1, 1a, 1b) as the neotype of *Schizophoria resupinata*. According to BOND, British and Belgian Lower Carboniferous species of *Schizophoria* can be divided into two groups, the coarser ornament-group characterized by three or four costae in 1 mm at 1 cm from the ventral umbo, and the finer ornament-group characterized by six to ten costae in the same part.

The Akiyoshi species do not belong either to the coarser ornament-group or the finer ornament-group. The present specimens are all very small in size compared with the type specimen. Most of them, however, may be in the immature stage and the number of costae (four to five in 1 mm) suggests that the adult shells have rather coarse costae. The number of costae and the mode of divergence of the dental lamellae rather represent the nature of the coarser ornament-group.

In the Japanese specimens, there are slight variations on the convexity and the

median depression of the dorsal valve. There is a specimen which has a weak median sulcus on the dorsal valve. However, no difference is found between this specimen and other specimens on the other external and internal structures.

*Schizophoria mesoloba* described by YANISHEWSKY (1918) from the Viséan of Ferghana, and the same species described by MUIR-WOOD (1948) from the Viséan of Bukit Sagu and Bukit Tinggik of Malaya resemble the Akiyoshi species which has the median depression in external configuration. The former two, however, are larger than the latter one and their median depressions are clearer than that of the latter species.

The specimens described under the name of *Schizophoria resupinata* by YANISHEWSKY (1918, p. 19, pl. 4, figs. 2a, b, pl. 6, figs. 16a, b) from the Viséan of Ferghana, Russian Turkestan closely resemble the Akiyoshi specimens in external characters.

Similar specimens to the present ones were recorded from various localities. They are, for examples, *S.* aff. *S. resupinata* by REED (1927) from the Viséan of Yunnan, *S. resupinata* by ROTAI (1931) from the Viséan of Donets Basin, and by TOLMATCHOFF (1926) from the Viséan of Kuznetzk, Siberia, *S.* aff. *S. resupinata* by MAXWELL (1954) from the Upper Tournaisian of Mt. Morgan district of Queensland, and *S.* cf. *S. resupinata* by CAMPBELL (1957) from the Lower Carboniferous of Babinboon, New South Wales.

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Juichi YANAGIDA

Carboniferous Brachiopods from Akiyoshi, Southwest Japan

# Plates 14–21.

# Plate 14

## Explanation of Plate 14

Figs. 1-7. *Phricodothyris insolita* GEORGE .....page 90

1a-c. Largest ventral specimen (GK. D30001) with indistinct ornament of the surface, ×1.5.

2. Incomplete ventral specimen, GK. D30007, ×1.7.

3. Immature ventral specimen, GK. D30008, ×2.5.

4. Incomplete ventral specimen, GK. D30004, ×2.

5a. Dorsal specimen, GK. D30002, ×1.5.

5b. Enlarged part of apical region to show the delicate ornaments, ×60.

6a. Ventral specimen, GK. D30006, ×2.

6b. Enlarged part of umbonal region to show arrangement of the delicate ornaments, ×4.5.

7a-c. Posterior, lateral, and ventral views of an immature specimen, GK. D30005, ×4.

Fig. 8. *Brachythyris akiyoshiensis* sp. nov. .....page 93

8a-c. Ventral, dorsal, and lateral views of a paratype, GK. D30011, ×2.

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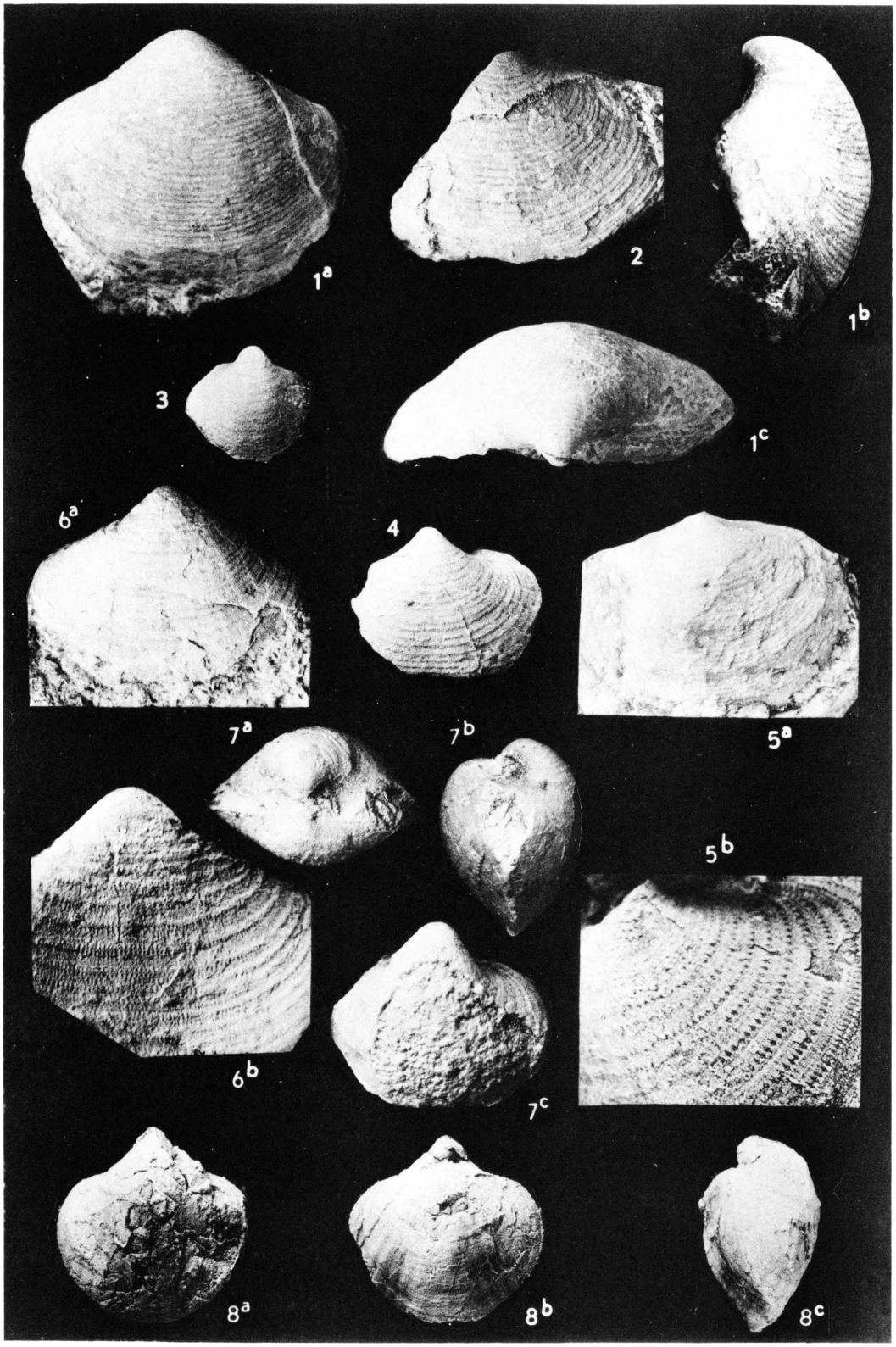


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# Plate 15

## Explanation of Plate 15

Figs. 1-3. *Brachythyris akiyoshiensis* sp. nov. .....page 93
1a-c. Ventral, lateral, and dorsal views of the holotype, GK. D30009, ×2.
2a, b. Ventral and dorsal views of a paratype, GK. D30012, ×2.
3a, b. Ventral and dorsal views of a paratype, GK. D300010, ×2.
Figs. 4-6, 8. *Spirifer sp.* .....page 98
4. Immature ventral specimen, GK. D30020, ×3.
5, 6, 8. Incomplete dorsal valves, GK. D30018, ×2, GK. D30016, ×1.5, and GK. D30017, ×2, respectively.
Fig. 7. *Spirifer* aff. *S. liangchowensis* CHAO.....page 96
Plaster cast of a large specimen, GK. D30015, ×1.

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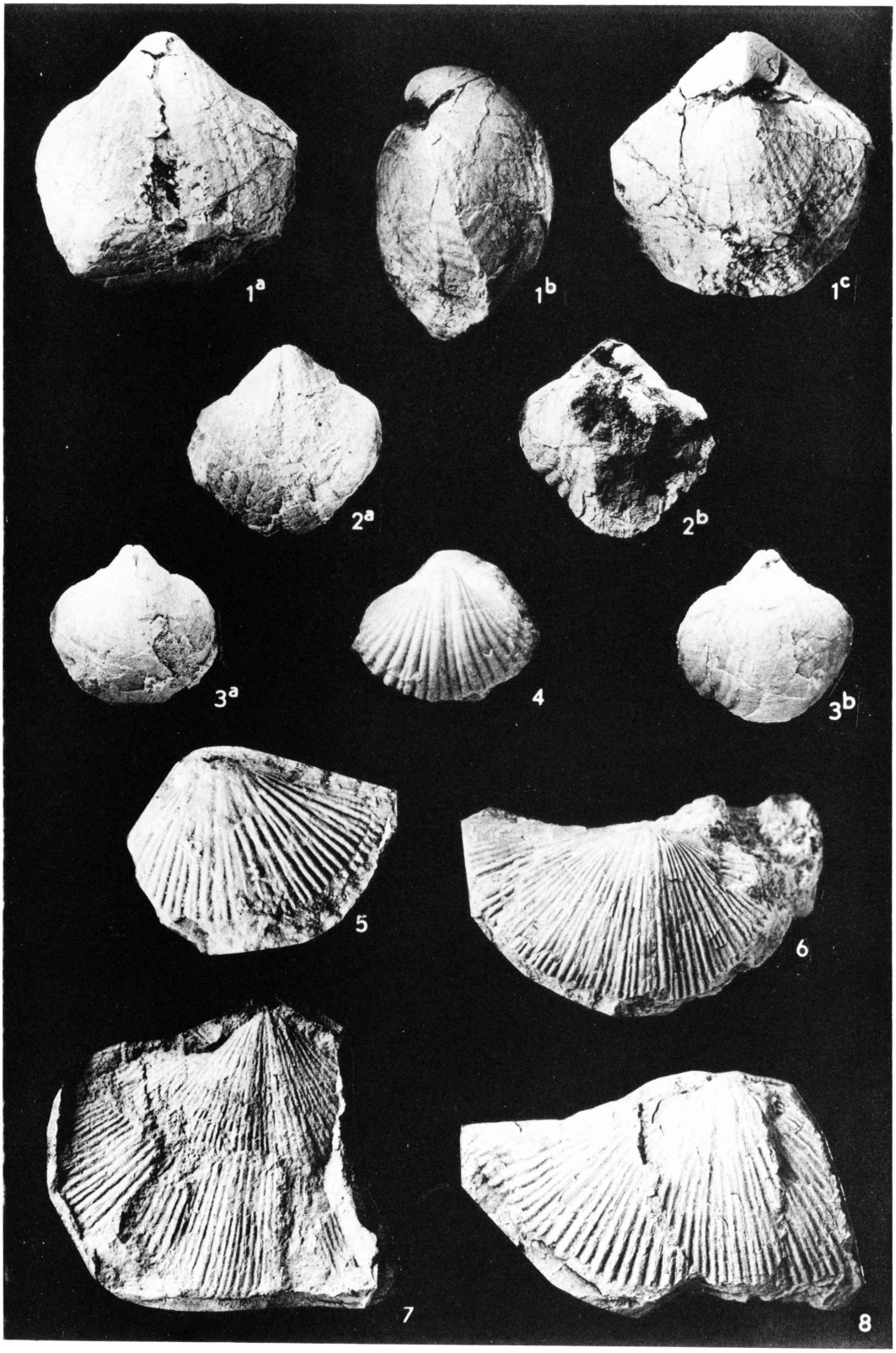


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Plate 16

## Explanation of Plate 16

Figs. 1-9. *Cleiothyridina expansa* (PHILLIPS) ..... page 99

1a-c. Ventral, lateral, and dorsal views of a specimen, GK. D30027; tip of the beak slightly exfoliated, ×1.

2a-c. Ventral, lateral, and dorsal views of a suboval specimen, GK. D30022, ×1.5.

3. Ventral specimen, GK. D30023, ×1.5.

4. Incomplete dorsal specimen, GK. D30024, ×1.5.

5a-c. Ventral, lateral, and dorsal views of a subtriangular specimen, GK. D30025, ×1.5.

6a, b. Lateral and dorsal views of an incomplete specimen, GK. D30028, ×1.5.

7. Ventral specimen, GK. D30026, ×1.5.

8. Incomplete ventral specimen, GK. D30070, ×1.5.

9. Incomplete ventral specimen, GK. D30071, ×1.5.

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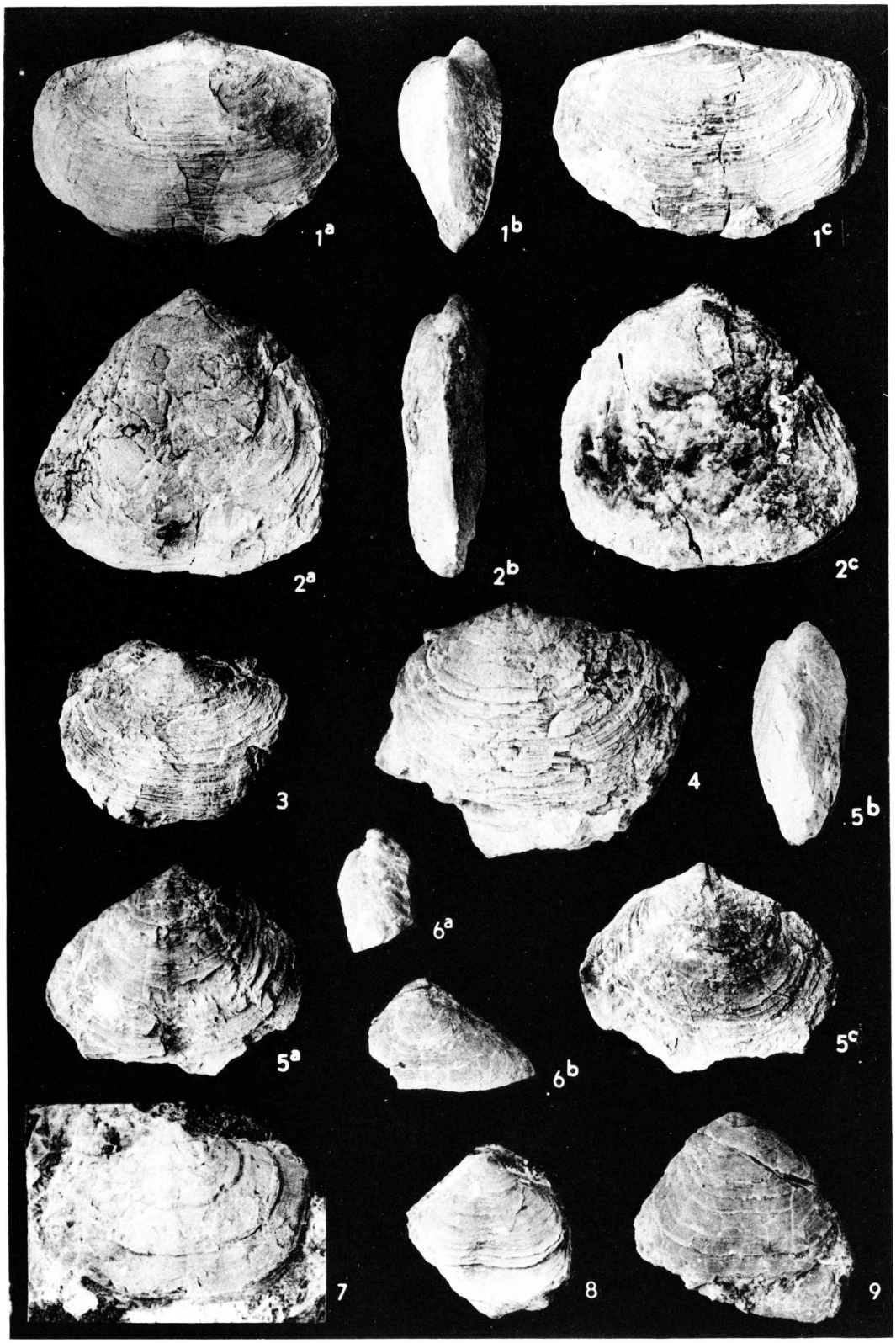


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Plate 17

## Explanation of Plate 17

Fig. 1. *Cleiothyridina expansa* (PHILLIPS) ..... page 99

1a-c. Ventral, lateral, and dorsal views of a subcircular specimen, GK. D30021, ×1.5.

Figs. 2-11. *Cleiothyridina royssii* (L'EVEILLÉ) ..... page 103

2a-c. Enlarged ventral, dorsal, and lateral views of a small specimen, GK. D30028, ×3.

3a, b. Ventral and dorsal views of the same specimen (GK. D30028) illustrated as Fig. 2, ×1.5.

4. Incomplete ventral specimen, GK. D30029, ×1.5.

5a, b. Lateral and ventral views of a specimen, GK. D30030, ×1.5.

6. Ventral specimen, GK. D30031, ×1.5.

7. Incomplete ventral specimen, GK. D30032; surface ornamentation partly preserved, ×2.5.

8. Incomplete ventral specimen, GK. D30033, ×1.5.

9. Incompete dorsal specimen, GK. D30034, ×1.5.

10, 11. Incomplete ventral specimens, GK. D30035 and GK. D30036, ×1.5.

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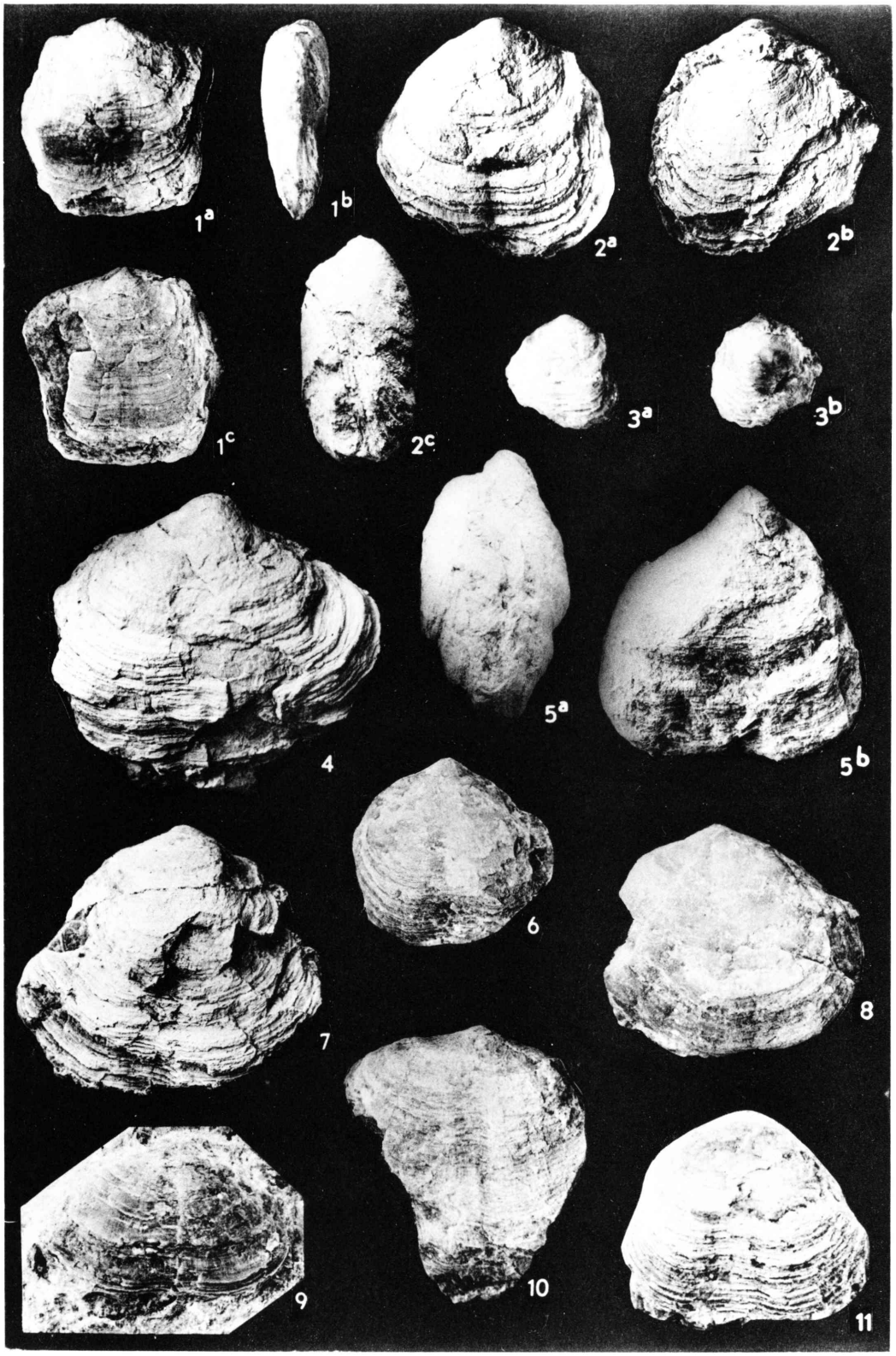


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Plate 18

## Explanation of Plate 18

Figs. 1-5. *Actinoconchus planosulcata* (PHILLIPS) ..... page 110

1a-c. Ventral, dorsal, and lateral views of a specimen, GK. D30037, ×3.

2. Incomplete ventral specimen, GK. D30039, ×3.

3a-c. Ventaal, dorsal, and lateral views of a specimen, GK. D30038, ×3.

4. Incomplete dorsal specimen, GK. D30040, ×3.5.

5. Incomplte ventral specimen, GK. D30072, ×3.

Figs. 6-8. *Composita* aff. *C. argentea* (SHEPARD) ..... page 113

6a-c. Ventral, dorsal, and lateral views of a specimen, GK. D30042, ×3.5.

7a-d. Ventral, dorsal, lateral, and anterior views of a specimen, GK. D30043, ×3.5.

8a-d. Ventral, dorsal, lateral, and anterior views of a specimen, GK. D30044, ×3.5.

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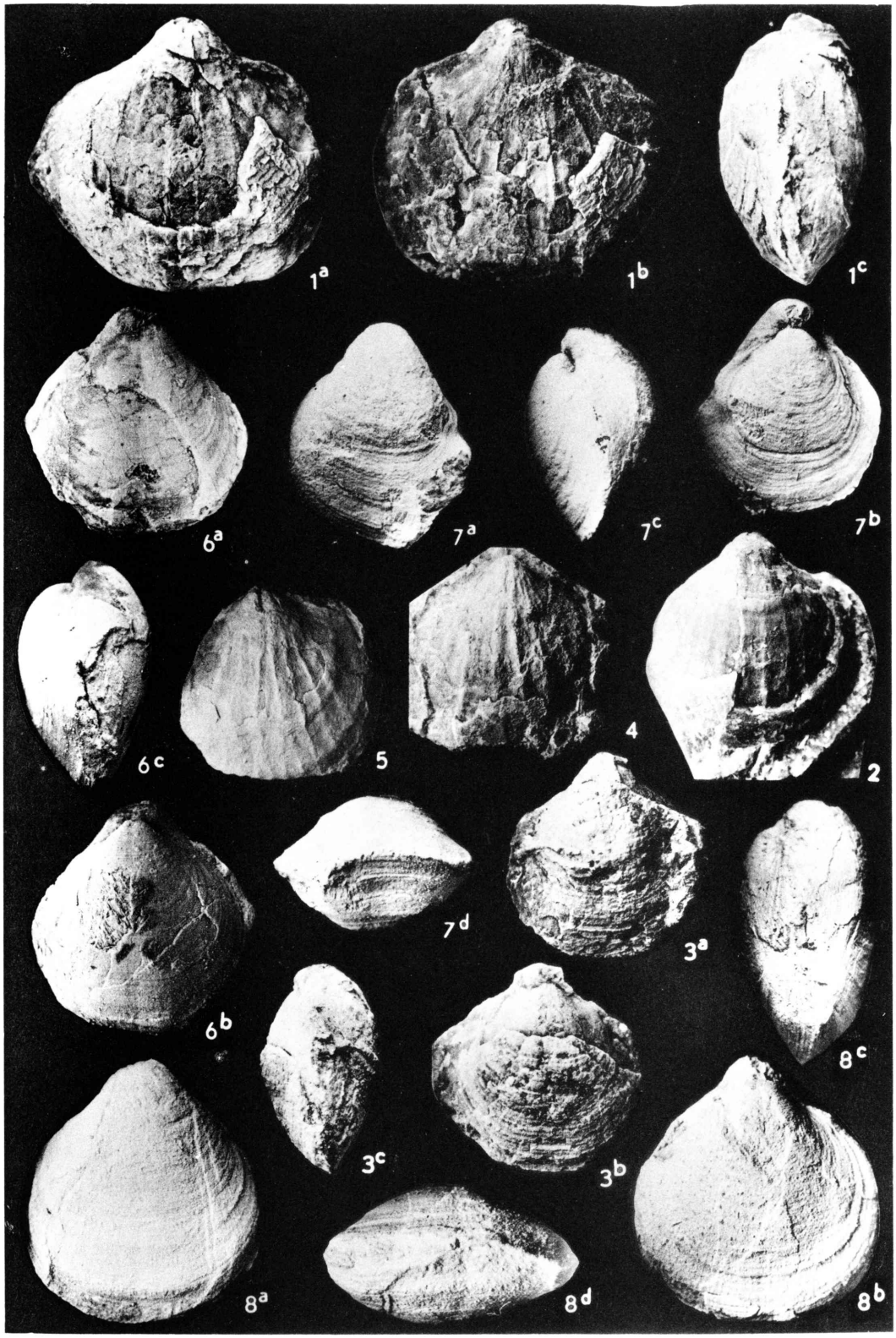


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Plate 19

## Explanation of Plate 19

Fig. 1. *Dielasma* cfr. *D. kingi* DE KONINCK .....page 115
1a-c. Ventral, lateral, and dorsal views of a specimen, GK. D30046, ×3.
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2a-c. Lateral, dorsal, and ventral views of an incomplete specimen, GK. D30048, ×3.
Fig. 3. *Composita* aff. *C. argentea* (SHEPARD) .....page 113
3a-c. Ventral, anterior, and, dorsal views of a specimen, GK. D30045, ×3.
Fig. 4, 5. *Yanishewskiella japonica* sp. nov. .....page 117
4a-d. Ventral, dorsal, lateral, and anterior views of a paratype, GK. D30055, ×3.
5a-d. Ventral, dorsal, lateral, and anterior views of a very small paratype, GK. D30056, ×4.

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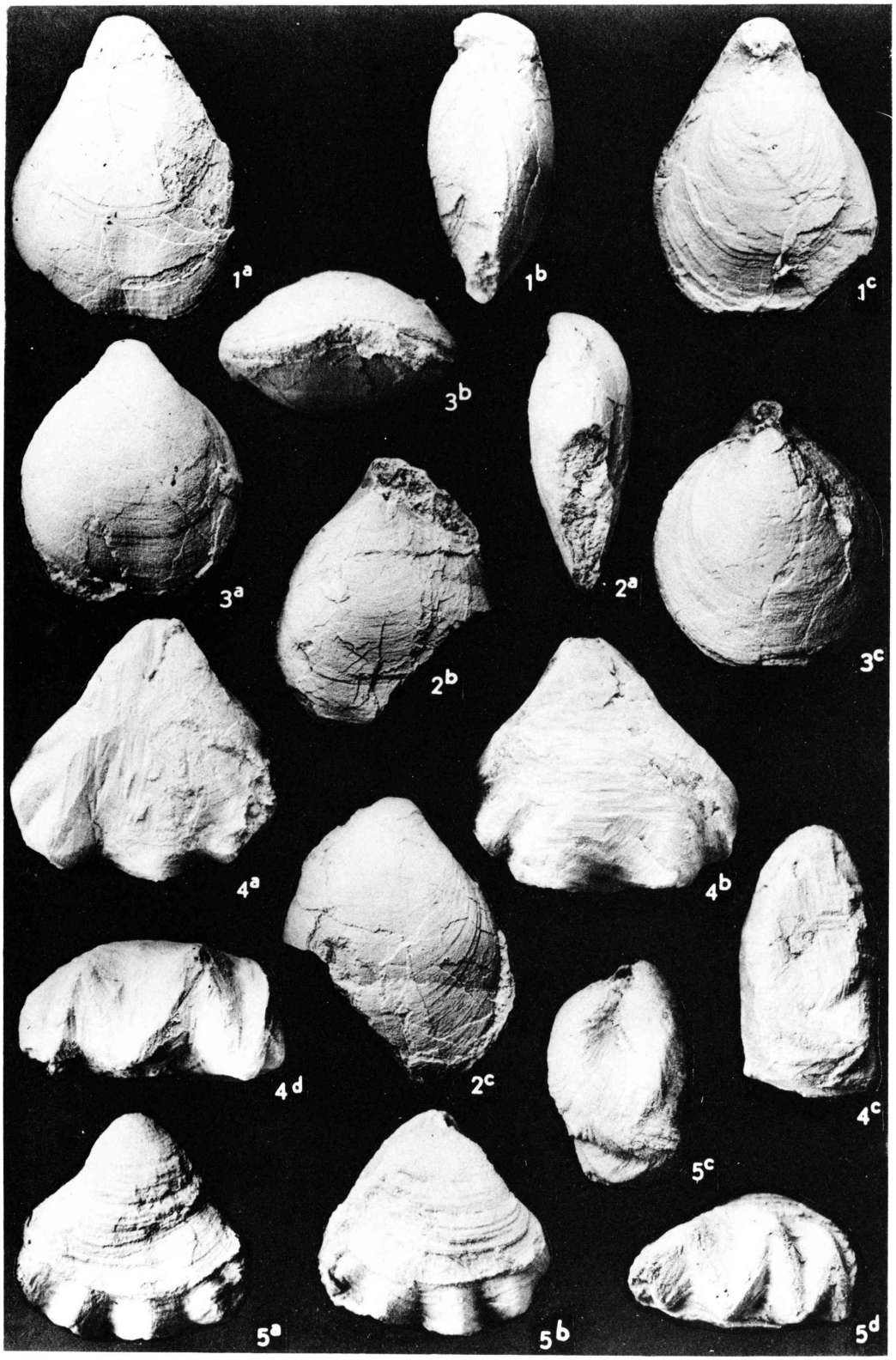


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Plate 20

## Explanation of Plate 20

Figs. 1, 2. *Yanishewskiella japonica* sp. nov. ..... page 117
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2a-d. Ventral, lateral, anterior, and dorsal views of the holotype, GK. D30054, ×3.
Figs. 3-5. *Pugnax* aff. *P. sulcatus* (SOWERBY) ..... page 120
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4a-d. Ventral, dorsal, anterior, and lateral views of a specimen, GK. D30050, ×3.5.
5a, b. Ventral and lateral views of a specimen, GK. D30057, ×3.5.

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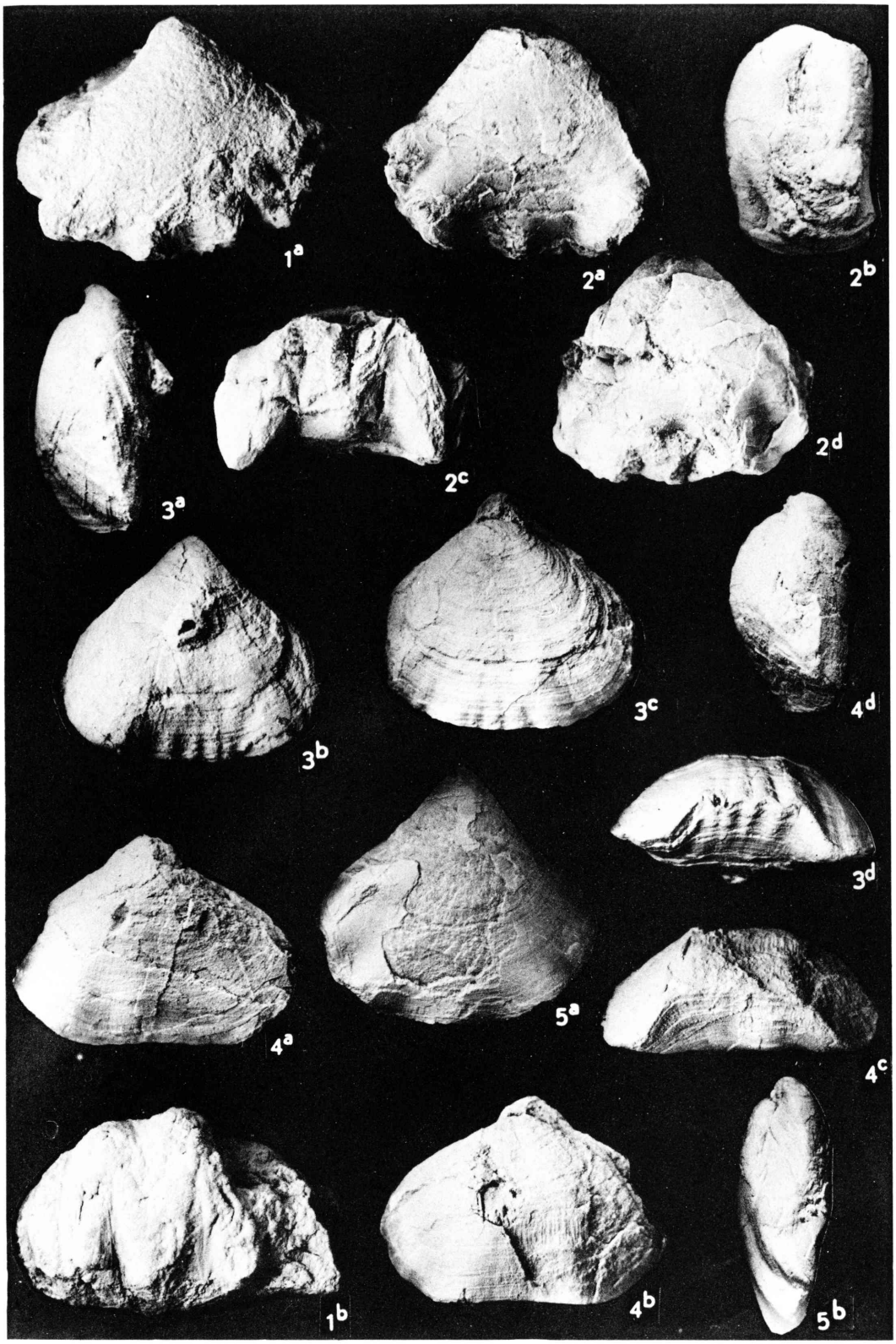


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# Plate 21

## Explanation of Plate 21

Figs. 1–3. *Pugnax* aff. *P. sulcatus* (SOWERBY) ..... page 120
1a, b. Dorsal and anterior views of a specimen, GK. D30057, ×3.5.
2. Anterior view of a specimen, GK. D30058, ×3.5.
3. Anterior view of a specimen, GK. D30059, ×3.5.

Figs. 4–13. *Schizophoria* aff. *S. resupinata* (MARTIN) ..... page 122
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5a, b. Dorsal and lateral views of a specimen, GK. D30064, ×4.
6. Ventral view of a specimen, GK. D30066, ×2.
7. Dorsal view of a specimen, GK. D30062, ×3.
8. Dorsal view of an incomplete specimen, GK. D30068, ×2.
9. Dorsal view of a specimen, GK. D30061, ×2.
10. Dorsal view of an incomplete specimen, GK. D30065, ×3.
11. Ventral view of an incomplete specimen, GK. D30060, ×2.
12. Ventral view of a specimen, GK. D30067, ×3.
13. Enlarged part of apical region of a specimen (GK. D30066) illustrated as Fig. 6.

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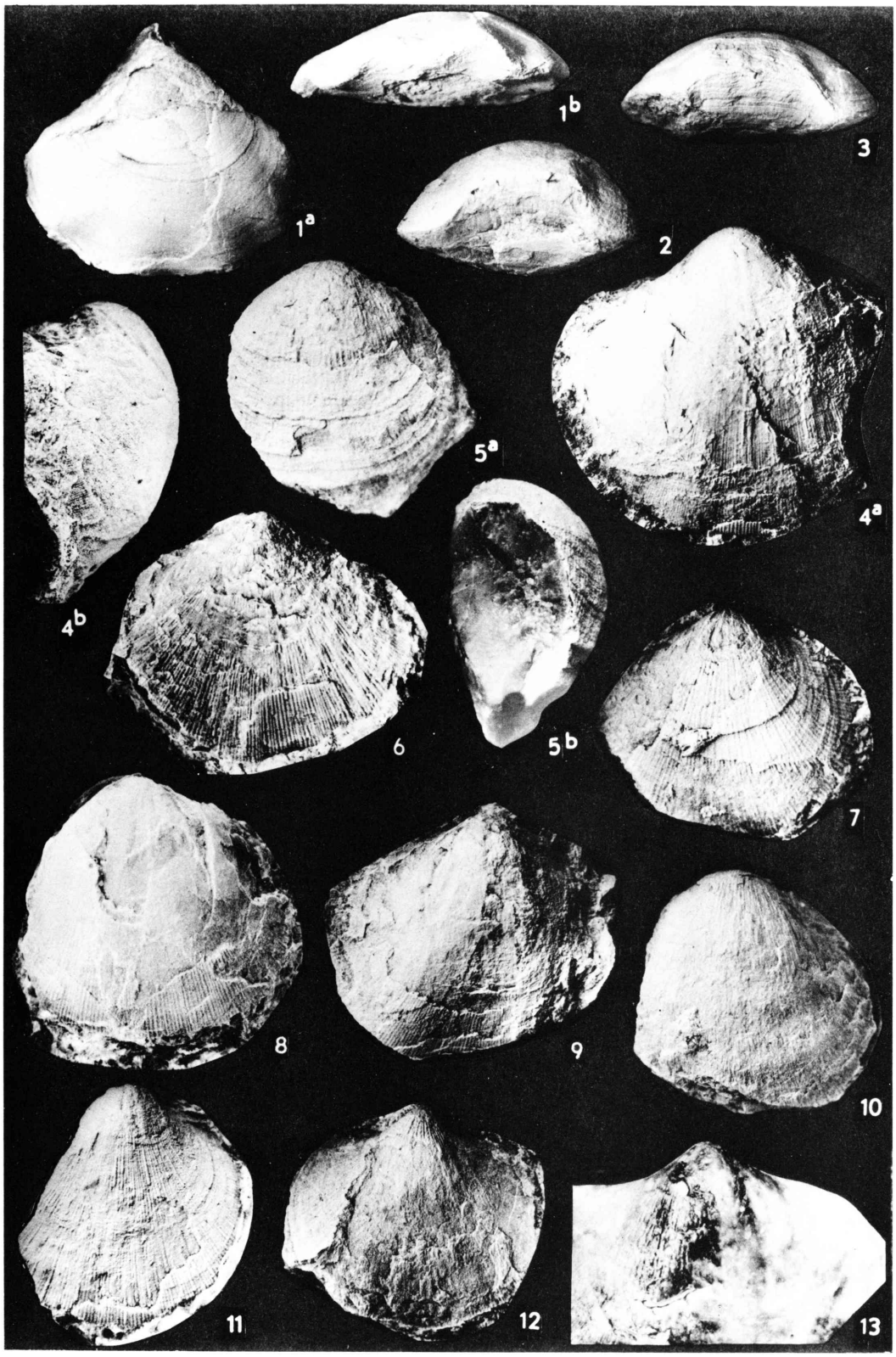


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