

Carboniferous Brachiopods from Akiyoshi, Southwest Japan Part II

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Carboniferous Brachiopods from Akiyoshi, Southwest Japan*

Part II

By

Juichi YANAGIDA

Abstract

This paper is the second part of "Carboniferous Brachiopods from Akiyoshi Southwest Japan". In part I thirteen species in ten genera were described from the *Millerella* zone of the "Uzura" quarry. In addition to the foregoing species, eight species among eight genera are described in this paper. They are *Rugicostella nystiana* (de KONINCK), *Rugosochonetes* aff. *R. hardrensis* (PHILLIPS), *Orthotetes* sp., *Eomarginifera* sp., "*Spirifer*" *triangularis* MARTIN, *Dictyoclostus* sp., *Antiquatonia* sp., and *Prospira* aff. *P. burnettensis* MAXWELL. Summarizing, the complete fauna of brachiopods is correctly recognized as a faunal assemblage closely related to the Late Visean faunas of Europe, Asia, and Australia. It is concluded that the limestone of the "Uzura" quarry is Late Visean in age. A preliminary note concerning the age of the "Uzura" limestone is made on a brachiopod-coral assemblage newly found near the lowest part of the Akiyoshi limestone Group. The age of the lower formation of the Akiyoshi limestone Group and the boundary between the Visean and the Namurian are also discussed.

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Introduction

Since OZAWA (1923) established the C₁ subzone=*Nagatophyllum satoi* subzone in the lowest part of the Akiyoshi limestone Group some differing opinions have held on the age of the lower part of the limestone group.

* Manuscript received September 30, 1964.

MINATO and KATO (1957) correlated the *Nagatophyllum satoi* subzone with the lower Upper Carboniferous (s. l.) mainly on an assemblage of corals. TORIYAMA (1958) found the *Millerella* zone in the lower part of the *Profusulinella* zone and established the *Millerella* sp. α zone.

After that HASEGAWA (1958, 1963) and MINATO and KATO (1963) reiterated their opinions that the age of the lowest part of the Akiyoshi limestone Group is the lower Upper Carboniferous (s. l.) mainly based on corals.

In opposition to them MURATA (1961) and OKIMURA (1963) on the basis of Foraminifera asserted the existence of the Lower Carboniferous in the lower part of the Akiyoshi limestone Group.

The author (1962) described some brachiopods from the *Millerella* limestone of the "Uzura" quarry. Some corals from the same quarry were also described by YAMAGIWA and OTA (1963). Twenty-one species among 18 genera of brachiopods and some corals including *Nagatophyllum* cf. *N. satoi* OZAWA were distinguished from the limestone.

It is concluded that the brachiopod fauna consists mainly of Late Visean elements. It is also recognized that the assemblage of the smaller foraminifers from the quarry is mainly represented by Visean elements, and their age is in harmony with that of the brachiopod fauna.

Recently many kinds of brachiopods and corals were found near the lowest part of the Akiyoshi limestone Group. Although palaeontological study of them is still unfinished they apparently represent elements of the Late Tournaisian to the Medial Visean.

Accordingly, the existence of the Lower Carboniferous in the Akiyoshi limestone Group is certain though the exact biostratigraphy of the underlying part of the *Millerella* zone has not yet been established. The age of the lowest part and the boundary between the Upper and Lower Carboniferous (s. l.) still remain as unsolved problems in the Akiyoshi limestone Group.

Systematic descriptions

Family Institinidae MUIR-WOOD and COOPER, 1960

Genus *Rugicostella* MUIR-WOOD and COOPER, 1960

Type-species.—*Productus nystianus* de KONINCK, 1842

Rugicostella nystiana (de KONINCK)

Pl. 25, figs. 1-5; Text-fig. 1

1842. *Productus nystianus* de KONINCK, Description des animaux fossiles, p. 202, pl. 7, figs. 3a, b; pl. 9, figs. 7a-c; pl. 20, figs. 9a-d.

1847. *Productus nystianus* de KONINCK, Recherches sur les animaux fossiles, Pt. I, pl. 14, figs. 5a-e.

1861. *Productus nystianus*, DAVIDSON, Palaeontographical Soc. Mon. Brit. Foss. Brachiopoda, vol. 2, Pt. 5, no. 5, pp. 231-232, pl. 53, fig. 9.

Material.—The better preserved of eight incomplete specimens are as follows; GK-D 30105 (Pl. 25, figs. 4a-d), GK-D 30079 (Pl. 25, figs. 1a-d), GK-D 30080 (Pl. 25,

figs. 3a-c), GK-D 30081 (Pl. 25, figs. 2a-d), and GK-D 30082 (Pl. 25, fig. 5).

Description.—Shell small, subcircular; hinge line slightly shorter than or approximately equal to the shell-width. Pedicle valve strongly geniculated. Visceral disc of pedicle valve slightly convex and ornamented by low convex costae, numbering 3 to 4 in 5 mm near the anterior margin.

Approximate measurement of three specimens in mm:

	1	2	3
length	11.0	14.0	
width	12.0	16.5	12.4
thickness	7.0	9.5	6.0

Remarks.—The Akiyoshi specimens are poorly preserved, but are readily identified with the type-species of the genus by their peculiar external characters and size. *Rugicostella nystiana* has hitherto been known only from the Visean of Visé, Belgium (de KONINCK, 1842, 1847) and Yorkshire, England (DAVIDSON, 1861). This is the first record of *Rugicostella* from the Asiatic region.

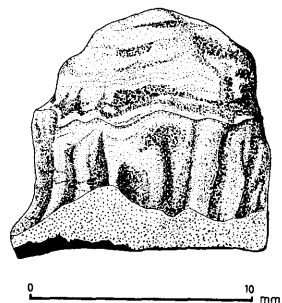


Fig. 1. Inked drawing of anterior view of *Rugicostella nystiana* (DE KONINCK).

Family Chonetidae HALL and CLARKE, 1895

Subfamily Chonetinae HALL and CLARKE, 1895

Genus *Rugosochonetes* SOKOLSKAYA, 1950

Type-species.—*Orthis hardrensis* PHILLIPS

Rugosochonetes aff. *R. hardrensis* (PHILLIPS)

Pl. 27, figs. 2-8.

Compare.—

- 1841. *Orthis hardrensis* PHILLIPS, Mem. Geol. Surv. Gt. Britain I, p. 138, pl. 58, figs. 104 b-d.
- 1843. *Chonetes laguessiana* de KONINCK, Description des animaux fossiles, p. 211, pl. 12, figs. 4a-b.
- 1858. *Chonetes hardrensis*, DAVIDSON, Palaeont. Soc., vol. 2, pt. 2, pp. 186-188, pl. 47, figs. 12-18.
- 1928. *Chonetes hardrensis* var. *kansuensis* CHAO, Palaeont. Sinica, ser. B, vol. 5, fasc. 3, pp. 10-12, pl. 1, figs. 1-6.
- 1962. *Chonetes klondikia* ARMSTRONG, New Mexico Bur. Mine., Mem. 8, pp. 47-48, pl. 6, figs. 1-7.

Material.—Seven specimens are available of which three are pedicle valves and the others are internal casts of brachial valves; GK-D 30083 (Pl. 27, fig. 4), GK-D 30084 (Pl. 27, fig. 5), GK-D 30085 (Pl. 27, fig. 6), GK-D 30086 (Pl. 27, fig. 3), GK-D 30087 (Pl. 27, fig. 2), GK-D 30088 (Pl. 27, fig. 7), and GK-D 30089 (Pl. 27, fig. 8).

Description.—Small and transversely subcircular, the greatest width at, or slightly anterior to the hinge line. Cardinal extremities bluntly rounded, forming an angle of about 90°. Beak very small, not incurved over the hinge-line. Pedicle valve slightly and uniformly convex the convexity decreasing laterally from the median portion to the cardinal extremities. Ears flat. No sulcus on venter. Surface orna-

mented by very fine, closely arranged capillae, 6 to 7 in 1 mm near the anterior margin, and more than 80 around the margin of the pedicle valve. Capillae bifurcating near the anterior extremity, and imperceptible or absent on ears. Concentric growth lines faintly observed in a specimen near the anterior margin.

Brachial valve moderately concave, having convexity like of the opposite one. Ears flat. Interior surface of brachial valve strongly papillose except for ears. Other internal characters not preserved except for a trace of very shallow sockets and socket plates in the cardinal region.

Measurements of six specimens in mm:

	pedicle valve				brachial valve		
	1	2	3		1	2	3
length	7.0	7.1	6.0	length	7.0	7.5	8.0
width	11.5	11.2	9.4	width	10.0	10.5	11.5
width at hinge	10.0		7.6	width at hinge	10.0		10.7
height	2.4	2.1	1.5				

Remarks.—The Akiyoshi specimens are characterized by very small size, weakly concavo-convex shell and very fine and numerous capillae which bifurcate near the anterior margin. General outline and surface sculpture indicate the closest affinity to those of the type-species from England. However the Akiyoshi species is distinguished from the latter by its uniformly small size. Very fine and numerous capillae on the valves are in harmony with those of *Chonetes laguessiana* de KONINCK. However, the latter species is clearly distinguished from the Akiyoshi one by its more transverse outline.

In the Japanese Lower Carboniferous there are reports of occurrences of *Chonetes hardrensis* and *Ch. sp.* from the Ohdaira Formation of the Kitakami massif by MINATO et al. (1953).

The Chinese Visean species, *Chonetes hardrensis* var. *kansuensis* CHAO from the Choniukou Formation of Kansu, shows resemblance to the Akiyoshi one in its size and outline. But the former species differs from the latter in having a distinct sulcus on the pedicle valve.

The American Mississippian species *Chonetes klondikia* ARMSTRONG from the Keating Formation of New Mexico and Arizona is similar to the Akiyoshi one in its size and ornament but has a weaker sulcus and more circular outline than the latter.

Family Spiriferidae KING, 1846

Subfamily Spiriferinae KING, 1846

Genus *Spirifer* SOWERBY, 1816, emend

Remarks.—The generic position of the Akiyoshi specimens herein described is in doubt. *Spirifer triangularis* MARTIN was included in the genus *Fusella* MCCOY by BUCKMAN (1906, p. 29). Much confusion developed from this revised diagnosis of the genus. The type-species of *Fusella*, *Spirifer fusiformis* PHILLIPS (1836, p. 217, pl. 9, figs. 10-11; DAVIDSON, 1862, pl. 13, figs. 15, 15a), has a finely striated shell to the contrary to the diagnosis by BUCKMAN. He stated that the type is in the smooth stage when

nearly all ribs have been lost. PHILLIPS original specimen, however, is imperfect by exfoliation as DAVIDSON pointed out (1862, p. 57) and the internal structures are unknown. Such being the case it is impossible to know the character of *Fusella* until its type species is precisely defined by study of well preserved materials from the original locality. *Spirifer triangularis*, also, does not seem to belong to *Spirifer* (s. s.) in its outline and ornament. Taking into consideration these problems I prefer to refer the Akiyoshi species to the genus *Spirifer* until the type species of *Fusella* is clearly redefined.

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

“*Spirifer*” *triangularis* MARTIN

Pl. 26, figs 1, 3; Text-fig. 2

1843. *Spirifer triangularis*, de KONINCK, Animaux fossils de la Belgique, p. 234, pl. 15, fig. 1.
1857. *Sp. triangularis*, DAVIDSON, Palaeont. Soc. Mon. Brit. Foss. Brachiopoda, vol. 2, part 5, pp. 27-29, pl. 5, figs. 16-24.
1887. *Sp. triangularis*, de KONINCK, Ann. Mus. Roy. Hist. Nat. Belgique, vol. 14, pp. 124-125, pl. 29, figs. 7-15.

Material.—Two small specimens, one incomplete, GK-D 30109 (Pl. 26, figs. 1a-d), and a pedicle valve, GK-D 30090 (Pl. 26, figs. 3a-c), are available, of which the latter is immature.

Description.—Biconvex, small, and very transverse, the greatest shell-width at the hinge line, approximately $2\frac{1}{2}$ times as wide as long.

Cardinal extremities alate; cardinal angles 35° to 40° . Cardinal area remarkably wide, slightly concave, and tapers abruptly at the lateral margins. Cardinal ridges sharp with acute angles to lateral slopes. Denticle grooves weak, disposed on the cardinal area except for the beak region where they are obsolete or absent. Three denticles in 1 mm, crossed by microscopic growth lines well preserved in the umbonal region. The delthyrium about 3 mm wide at the hinge making an angle of about 40° . Median sulcus narrow bounded on both sides by distinct costae. Median costa low and distinct occurring at about 2 mm from the beak and increasing in strength anteriorly. Lateral slopes covered by simple, round-topped costae. Without either bifurcation or intercalation. Four costae appear on each side of sulcus in younger shells and 6 to 7 in adult ones. Costae rapidly decreasing in strength toward the cardinal margins, the outer 1 or 2 very faint. Valley between the costae shallow and round with approximately same width as the costae. Both valves covered by regularly and closely arranged concentric lamellae which number 3 to 4 in 1 mm near the anterior margin.

Brachial valve less convex than the pedicle one; median fold narrow, acute and rapidly increasing in height anteriorly. Shell substance impunctate.

Measurements in mm.—Larger specimen (GK-D 30089); 10.5 mm long, ca. 26.0 mm wide, and 8.0 mm thick. Smaller pedicle valve (GK-D 30090); 7.0 mm long and 10.0 mm wide.

Remarks.—The Akiyoshi specimens are characterized by strongly transverse

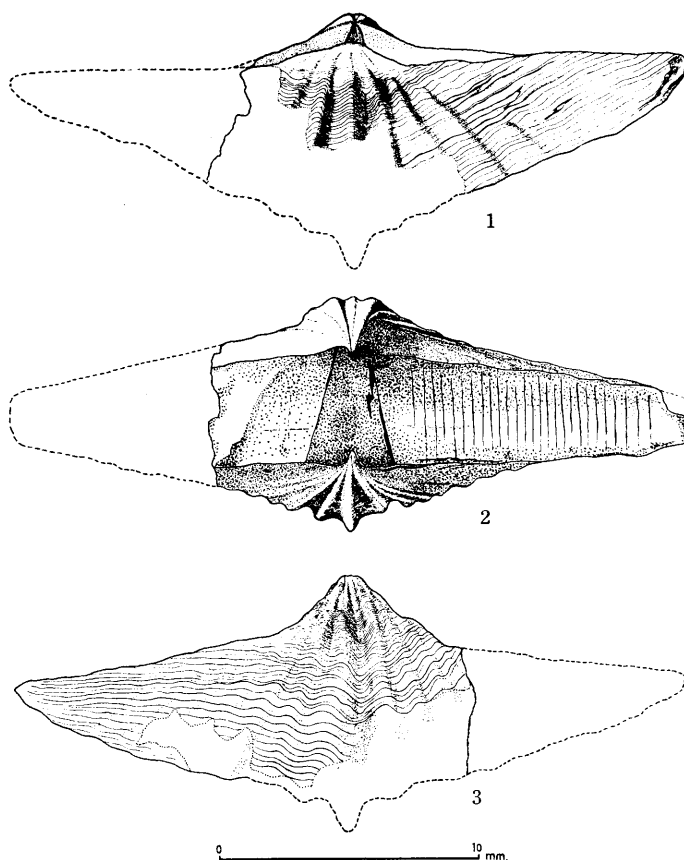


Fig. 2. Inked drawing of "*Spirifer*" *triangularis* MARTIN;
1, brachial, 2, posterior, 3, pedicle views.

outline, a median costa in the sulcus, acutely projected fold, and numerous concentric growth lamellae. Those characters are in harmony with those of the species of the Visean of England and Belgium. Slight differences in the Akiyoshi specimens from the original one are smaller size, transversely more elongate shell, and more remarkable concentric lamellae. The last character was well revealed in the Belgium specimen (de KONINCK, 1887, pl. 29, figs. 16-24). Generally speaking the Akiyoshi species is more transverse in form and has weaker and fewer ribs than the European species.

Alispirifer laminosus (CAMPBELL, 1961, pp. 435-437, pl. 55, figs. 17-23) from the Upper Carboniferous Booral and Isacs Formations of New South Wales, Australia resembles the Akiyoshi species in its outline and external characters. But the latter is clearly distinguished from the former by its acute fold and a remarkable costa in the sulcus. *Alispirifer* usually lacks the costa in the sulcus and rarely has a very weak plication. It also has fine radial lirae on the surface, which were not observed in the Akiyoshi species.

Mucrospirifer ? sp. (SARYCHEVA, et al, 1963, p. 267, pl. 43, fig. 6) from the Carboniferous Ostrogsкая Group of the Kuznetsk basin closely resembles the Akiyoshi

species in its size, outline, and ornament. Both species may be closely related to each other. It is interesting that the age of the Ostrogszkaya Group is from the Latest Visean to the Namurian.

Subfamily Cyrtiinae FREDERICKS, 1926

Genus *Prospira* MAXWELL, 1954

Type-species.—*Prospira tyta* MAXWELL, 1954

Prospira aff. *P. burnettensis* MAXWELL

Pl. 26, fig. 2; Text-fig. 3

Compare.—

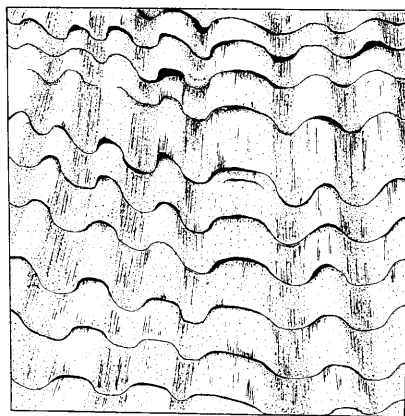
1961. *Prospira burnettensis* MAXWELL, Jour. Palaeont., vol. 35, no. 1, pp. 91-92, pl. 20, figs. 1-7.

Material.—One pedicle valve, GK-D 30091 (Pl. 26, figs. 2a-d).

Description.—Small, subtriangular and moderately convex with the maximum convexity at the umbonal region. Lateral slopes becoming flat toward the cardinal extremities which are slightly alate. Widest along the hinge line with the width approximately $1\frac{1}{2}$ times the length. Beak pointed, slightly incurved over the narrow area. Sulcus well defined, bounded by strong simple radial costae. Median costa distinct in sulcus, not bifurcated, but bounded by a pair of costae arising from the bounding costae between the sulcus and the lateral slopes. Lateral slopes bearing 18 rounded costae near the anterior margin, usually simple, occasionally with new costae intercalated, and decreasing in strength laterally and posteriorly. Microscopic radial striae occurring on the shell surface. Regularly spaced, anteriorly distinct, and occasionally imbricate concentric growth lines occur on the whole surface. Shell substance impunctate.

Dimensions: 9.0 mm long, 14.0 mm wide, and 4.0 mm thick.

Remarks.—The Akiyoshi species is characterized by transverse outline of about 2:3 of length-width ratio, median sulcus with weak costae, concentric growth lines, and microscopic radial striae. From these characters the Akiyoshi species is closely related to *Prospira burnettensis* from the Upper Tournaisian of Queensland described by MAXWELL (1961). Slight differences of the former species from the Australian one are in its more distinct growth lines and stronger simple costae in the sulcus. Ribs on both wings are simple in the Australian species. On the other hand the Akiyoshi one increases in number of ribs by intercalation which occurs occasionally.



0 25 mm.

Fig. 3. Inked drawing of enlarged view of shell-surface of *Prospira* aff. *P. burnettensis* (MAXWELL).

Of European species, it is similar to *Spirifer trigonalis* MARTIN, figured by DAVIDSON (1865, pp. 29-31, pl. 5, figs. 25-34) and de KONINCK (1887, pp. 121-123, pl. 26, figs. 5-8, pl. 28, figs. 7, 8, 24-44, 48) from the Visean of England and Belgium.

In China CHAO (1927, pp. 65-67, pl. 8, figs. 1, 2) has described *Brachythyryna kansuensis* from the Visean Choniukou Formation; his species shows resemblance to *P. aff. P. burnettensis* in external characters.

Family Orthotetidae WAAGEN, 1884

Subfamily Orthotetinae WAAGEN, 1884

Genus *Orthotetes* FISCHER de WALDHEIM, 1829

Type-species.—*Orthotetes radiata* FISCHER, 1850

Orthotetes sp.

Pl. 27, figs. 9-14.

Material.—Several incomplete specimens are figured under the heading; GK-D 30106 (Pl. 27, fig. 12), GK-D 30093 (Pl. 27, fig. 9), GK-D 30094 (Pl. 27, fig. 13).

Description.—Large, subcircular, suggesting the greatest width near the hinge. Pedicle valve flat or slightly resupinate. Concentric growth folds irregular. Ornament consisting of narrow, sharp costae increasing in number by intercalation, 7 to 8 in 5 mm in anterior portion of adults, separated by flat, broad interspaces of about 1 mm width. Whole surface covered by very fine, closely spaced growth lines. Brachial valve slightly and uniformly convex with the ornament similar to that of the pedicle valve.

Internal structures not preserved except in a fragmentary specimen in which a crural plate is distinctly observed.

Correct dimensions uncertain. Largest specimen suggests about 60 to 70 mm wide and 50 to 60 mm long.

Remarks.—The Akiyoshi specimens are characterized by their large size, slightly convex brachial valves, closely and uniformly arranged radial costae, and short, heavy crural plate. From these characters it is considered that the Akiyoshi species has a close relation with that of the Lower Carboniferous genus *Werriea* (CAMPBELL, 1957, pp. 45-47) although the internal structures of the pedicle valve of the former is not known.

In the Japanese Lower Carboniferous, *Orthotetes keokuk* (HALL) and *Orthotetes* sp. were described by MINATO (1952) from an impure limestone of the Arisu Series of the Kitakami massif. The Akiyoshi specimens and the Kitakami ones are similar with each other in external configuration, the former are slightly larger in size and coarser in radial ornament than the latter.

Family Marginiferidae STEHLI, 1954

Subfamily Marginiferinae STEHLI, 1954

Genus *Eomarginifera* MUIR-WOOD, 1930

Type-species.—*Productus longispinus* SOWERBY, 1814

Eomarginifera sp.

Pl. 28, figs. 3, 4, 7, 8; Pl. 27, fig. 1.

Material.—Four incomplete pedicle valves and two fragmentary brachial ones: GK-D 30095 (Pl. 28, fig. 7), GK-D 30096 (Pl. 28, figs. 3a-c), GK-D 30097 (Pl. 28, fig. 8), GK-D 30098 (Pl. 28, fig. 4), and GK-D 30099 (Pl. 27, figs. 1a-c).

Description.—Small, subcircular to subquadrate; profile subgeniculate to subcircular; umbo bluntly pointed and slightly incurved over the hinge line; venter weakly and uniformly rounded. Maximum width slightly anterior to the hinge line. Cardinal extremities rectangular to slightly mucronate. Ears small. Visceral disc of pedicle valve subcircular and with several weak rugae. Costellae round-topped, low, and irregular but well-developed on the whole surface and occasionally bifurcated, about 8 or 9 of them in 5 mm near the anterior margin of the trail. Spines and spine bases not preserved. Pedicle valve with ginglymoid joint. Dimensions of a pedicle valve (GK-D 30095): length 13.5 mm; width 13.0 mm; hinge 12.0 mm; height 4 mm. Internal surface along the hinge line of pedicle valve slightly concave and showing more or less a ginglymoid articulation.

Remarks.—The Akiyoshi specimens superficially resemble those of *Eomarginifera paradoxa* (CAMPBELL) from the Middle Visean of Watts, Babbinsboon, New South Wales. The species was originally described by CAMPBELL (1957) under the name of *Dictyoclostus paradoxus* and was correlated with the Late Tournaisian.*

Family Dictyoclostidae STEHLI, 1954

Subfamily Dictyoclostinae STEHLI, 1954

Genus *Dictyoclostus* MUIR-WOOD, 1930

Type-species.—*Productus semireticulatus* (MARTIN), 1809

Dictyoclostus sp.

Pl. 28, figs. 5, 6

Material.—A pedicle valve (GK-D 30101, Pl. 28, figs. 5a-c) and a small external mould of a brachial valve (GK-D 30102, Pl. 28, figs. 6a-c).

Description.—Pedicle valve medium and subcircular with mucronate cardinal extremities. Visceral disc slightly convex. Hinge line slightly shorter than the greatest width which is at the mid portion of the valve. Umbo moderately large and pointed, but not incurved beyond the hinge line. Venter uniformly convex and flanks gently sloping. No median sulcus. Costae well developed on the whole surface, increasing in number by bifurcation and intercalation, 8 to 9 in 5 mm on the median portion near the anterior margin. Rugae strong and irregular on the whole surface, specially stronger than the costae, strong on the flanks, and numbering about 25 on whole surface. Three to 5 small spine bases indistinctly observed on the trail.

Brachial valve moderately geniculate, visceral disc round and flat, or slightly

* This emendation was shown by a personal communication.

concave. Ears flat. Ornamentation similar to that of the pedicle valve.

Dimensions: pedicle valve; 27.5 mm wide, 24.5 mm long, 21.5 mm hinge line, 8.5 mm high; brachial valve; 18.0 mm wide, 13.5 mm long, 13.5 mm hinge line, 5.8 mm high.

Remarks.—Although the Akiyoshi specimens are represented by slightly exfoliated shells and the internal characters are unknown, they are characterized by the sub-round shape with slightly mucronate ears, evenly arched profile both longitudinally and laterally, weak costae, strong rugae, and shallow but sharply geniculate brachial valve. These characters resemble those of *Eomarginifera paradoxa* (CAMPBELL) from the Middle Visean of New South Wales. However, the dimensions of the pedicle valve are larger in the Akiyoshi specimens and the rugae more developed than those of the Australian species.

The American *Dictyoclostus welleri* (MATHER) from the Morrow Group is similar to the Akiyoshi species in its outline and lack of a median sulcus, but it differs from the latter in its coarser costation, weaker rugae, and stronger convexity.

It is worthy of note that the Russian Upper Carboniferous *Productus volgensis* described by STUCKENBERG (1905, p. 65, pl. 7, figs. 1, 2; pl. 9, figs. 2a, b) from Samara appears to be closely similar to the Akiyoshi species in external characters. Slight differences appear in the concentric rugae which are stronger and more numerous in the Akiyoshi species than the Russian one. The costae of the Russian species are coarser than the other.

A variety of *P. volgensis* described by REED (1925, pp. 35-36, pl. 3, fig. 11) from the Upper Carboniferous of Pamir also resembles the Akiyoshi species in external characters, but it is distinguished from the latter by the same characters above stated.

Genus *Antiquatonia* MILORADOVICH, 1945

Remarks.—Although the Akiyoshi specimens are poorly preserved, they are very weakly rugose on the visceral disc only and the reticulation is hardly visible. Costae, on the contrary, are well defined over the whole surface except ears. The pedicle valve ornament and the relatively broad visceral disc of the Akiyoshi specimens show close resemblance to those of the genus *Pugilis*. However, the former are clearly distinguished from the latter by having the diagonal ridges which separate the ears from the visceral disc.

Type-species.—*Productus antiquatus* SOWERBY, 1821

Antiquatonia sp.

Pl. 28, figs. 1, 2; Text-fig. 4

Material.—Two incomplete pedicle valves, GK-D 30103 (Pl. 28, figs. 2a-d) and GK-D 30104 (Pl. 28, figs. 1a-d).

Description.—Shell small, subrectangular, the greatest width at the hinge line. Pedicle valve strongly convex with a short, flattened trail, steep flanks, and the greatest convexity near the hinge line. Beak pointed with a slightly inflated umbo which extends more or less over the hinge line. Visceral disc weakly and uniformly convex. Ears well developed and moderately convex, a pair of low and round ridges.

occurring near the umbo and diverging anterolaterally separating the ears from the umbonal flanks. Ridges extending about 10 mm from the beak and merging into the lower part of the flanks. Whole surface excepting the ears covered by numerous and round costae. Bifurcations occur on the visceral disc. About 10 costae in 5 mm near the anterior margin and about 4 to 5 rugae faintly observable in the posterior portion of the visceral disc. Reticulation hardly recognizable. Microscopic growth striae of about 5 in 1 mm visible on the trail. About 4 to 5 spine bases of small diameter indistinctly scattered on trail, visceral disc, and the ridges on the flanks, those on the ridges disposed near the anterior extremities of each one.

Dimensions of two pedicle valves: width, 20.0 mm, 23.0 mm; length, 12.5 mm 17.0 mm; height, 8.5 mm, 9.0 mm.

Remarks.—The Akiyoshi specimens are uniformly small. It is considered, however, that they are probably adults from their external characters. The greatest convexity near the hinge line, flat trail, largely convex ears, and weak rugae reveal the specific character of the Akiyoshi species. There seems to be no identical species of the genus with the Akiyoshi one as far as I am aware.

List of species

The following species were found and described from the "Uzura" quarry of Akiyoshi.

Specific name	Number of specimens
<i>Cleiothyridina expansa</i> (PHILLIPS).....	630
<i>Cleiothyridina royssii</i> (L'EVEILLE).....	287
<i>Schizophoria</i> aff. <i>S. resupinata</i> (MARTIN)	23
<i>Pugnax</i> aff. <i>P. sulcatus</i> (SOWERBY)	19
<i>Phricodothyris insolita</i> GEORGE	17
<i>Yanishewskiella japonica</i> YANAGIDA	15
<i>Composita</i> aff. <i>C. argentea</i> (SHEPARD).....	15
<i>Dielasma</i> cf. <i>D. kingi</i> de KONINCK	13
<i>Actinoconchus planosulcatus</i> (PHILLIPS) .	9
<i>Rugicostella nystiana</i> (de KONINCK)	8
<i>Brachythyris akiyoshiensis</i> YANAGIDA	7
<i>Rugosochonetes</i> aff. <i>R. hardrensis</i> (PHILLIPS)	6
<i>Orthotetes</i> sp.	6
<i>Eomarginifera</i> sp.	6
<i>Spirifer</i> sp.	4
" <i>Spirifer</i> " <i>triangularis</i> MARTIN	2
<i>Dictyoclostus</i> sp.	2
<i>Antiquatonia</i> sp.	2

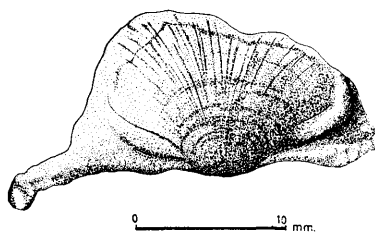


Fig. 4. Inked drawing of posterior view of *Antiquatonia* sp.

<i>Dielasma</i> sp.	2
<i>Prospira</i> aff. <i>P. burnettensis</i> MAXWELL.....	1
<i>Spirifer</i> aff. <i>S. liangchowensis</i> CHAO	1

Ecology

The limestone of the Uzura quarry is massive and fossiliferous (YANAGIDA, 1962, p. 89) and in a textural sense is a calcirudite. It is a bioclastic breccia composed of brachiopods, corals, fusulinids, pelecypods, gastropods, and other organisms, and their fragments. The limestone contains a great number and many kinds of brachiopods which form the majority of its fossils. The matrix of the calcirudite can be divided into two groups, the calcarenite of those of fine sand size and bioclastic calcarenite mainly composed of fine fragments of brachiopod-shells. Each bioclastic calcirudite containing different grain-size of matrix shows gradual mergence with the other both longitudinally and laterally. It is observed in usual about the matrices that each of the calcarenite and bioclastic calcarenite is gray and dark gray respectively.

It is very difficult to discover the general trend of the limestone at the quarry as it is massive. However, it is considered from the arrangement of the brachiopod-shells that the strike of the limestone is from east to west and it dips gently southward at about 30°. This fossiliferous limestone is more than 50 m thick and more than 60 m in widest extent. Although its whole aspect can not be recognized correctly because of poor exposures, abrupt and gradual extinction of the mass of brachiopod-shells is partly observed near the margin of the shell-bed. The boundary between the fossiliferous and non-fossiliferous parts irregularly interfinger with each other. The chemical compositions of some specimens of the bioclastic calcirudite, and the matrix show close resemblance to each other.

Most of the brachiopod fossils at the quarry are composed of shells of *Cleiothyridina*

Table 1. Chemical composition.

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Loss on ignition	Total
1	0.06	0.08	0.04	55.36	0.54	0	43.08	99.16
2	0.08	0.03	0.09	55.11	0.70	0	43.30	99.31
3	0.10	0.04	0.10	55.10	0.54	0	43.53	99.41
4	0.10	0.08	0.06	55.41	0.50	0	43.14	99.29
5	0.12	0.05	0.05	55.48	0.49	0	43.40	99.59
6	0.06	0.05	0.09	55.32	0.48	0.03	43.69	99.72
7	0.04	0.04	0.04	55.15	0.69	0.08	44.03	100.07
8	0.06	0.06	0.04	55.13	0.60	0.03	43.83	99.75
9	0.04	0.02	0.04	55.25	0.54	0.04	43.76	99.69
10	0.06	0.05	0.15	55.45	0.33	0.22	43.82	100.08

1-9. Fine calcirudites of the "Uzura" quarry.

10. Shell substance of a brachiopod specimen belonging to *Cleiothyridina expansa* (PHILLIPS). [Analyst: Masao NAKAMURA]

expansa and *C. royssii* making up approximately 80%. Among the other genera, *Eomarginifera*, *Antiquatonia*, *Rugicostella*, *Orthotetes*, *Prospira*, and *Rugosochonetes* are very rare. The faunal differences in different horizons in the limestone are not recognized.

Most valves are disarticulated. This character is especially well seen in the larger shells of *Cleiothyridina*, *Orthotetes*, and *Spirifer* etc. but the smaller ones, such as *Composita*, *Dielasma*, *Pugnax*, and *Yanishewskiella* usually have both valves associated.

Occasionally the larger shells are well polished and rounded by wave or current action. However, preservation is generally good and even the minute ornament of shell-surface is fully preserved in the larger shells. Small brachiopods and remains of other small organisms are always preserved in excellent condition. The sorting of the limestone is very poor, as shown by assemblages of miscellaneous organisms of every stage of growth. *Orthotetes*, *Rugicostella*, and *Spirifer* are usually found in the calcarenite. Waves or currents had an important effect on sweeping the organisms during deposition. But sorting of them was rather poor. Most of the brachiopods and other organisms were transported in short distance after their death from their original habitat. A shallow water is indicated.

Dissociated valves are usually scattered in heaps. Most of the brachiopod valves are arranged with convex side up. Therefore the limestone of the quarry is in normal order from the lower to the upper.

The upper part of the limestone at the quarry of about 15 m thick is especially characterized by a number of corals often in colonies. Their calyces are directed upward in all occurrences. A small number of brachiopods are associated with the corals. The valves are usually separated. The occurrence of corals indicates that they are apparently autochthonous. The upper part conformably overlies the lower brachiopod limestone. They gradually merge into each other and are composed of the same matrices. It is considered that the limestone of the upper part has the character of a reef.

Age of the brachiopod-fauna

For establishing the age of the limestone of the "Uzura" quarry, abundance of fossils offers several means. On the basis of brachiopods, the fauna is divided into three groups, the first group indicates Visean age, the second indicates an age from Tournaisian to the Visean, and the third has a longer range than other two.

The first group of Visean age consists of the following species: *Phricodothyris insolita* GEORGE, the typical species of the Upper Visean D₂ subzone of England, the genus is occasional below the Visean elsewhere in the world; *Brachythyris akiyoshiensis* related to *B. pinguis* (SOWERBY), from the C₁ to C₂ subzones of England; *Spirifer* aff. *S. liangchowensis* CHAO, closely related to *S. liangchowensis* from the Visean Choniukou Formation of northwest China and *S. cf. S. liangchowensis* from the Visean of Queensland of Australia, the Chinese species may be morphologically more advanced than the Japanese one; "*Spirifer*" *triangularis* MARTIN, a representative Visean species

in England and western Europe, but Akiyoshi species may be morphologically more primitive than the European one; *Dielasma* sp. related to *Dielasma attenuatum* (MARTIN) which is the representative species of the Visean of western Europe and England; *Yanishewskiella japonica* closely related to *Y. angulata* (YANISHEWSKY) which is the typical Visean species in Ferghana and western Europe; *Pugnax* aff. *P. sulcatus* (SOWERBY), related to *P. sulcatus* (SOWERBY) which is common in the Lower Visean of England and western Europe; *Rugicostella nystiana* (DE KONINCK), only known occurrence in the Visean of Belgium and England outside of Japan; *Cleiothyridina expansa* (PHILLIPS), the most numerous brachiopod in Akiyoshi, ranges from the Lower Visean S_1 subzone up to the Upper Visean D_3 subzone in England showing its peak of development from S_2 to D_1 subzone; *Orthotetes* sp., closely resembles *Werriea australis* CAMPBELL which is a representative species of the Australian Middle Visean.

The second group, ranging in age from the Tournaisian to the Visean consists of the following: *Dielasma* cf. *D. kingi* de KONINCK, closely comparable with the Upper Tournaisian to the Lower Visean *D. kingi* of Belgium; *Prospira* aff. *P. burnettensis* MAXWELL, closely related to *P. burnettensis* from the Upper Tournaisian of Queensland, northeast Australia, and the Japanese species may be morphologically more advanced than the another, and in Australia the genus is recorded from the Upper Tournaisian to Lower Visean; *Schizophoria* aff. *S. resupinata* (MARTIN), closely related to *S. resupinata* which is cosmopolitan and ranges from the Tournaisian Z_2 subzone up to the Lower Visean C_2 subzone in England and is most abundant in the Upper Tournaisian; *Actinoconchus planosulcatus* (PHILLIPS), first appears in the C zone and ranges to the Upper Visean D_2 subzone in England showing its peak in the Visean S_1 to D_1 subzones, and also occurs in the Visean of Belgium.

The species which belong to the third group have ranges longer than the other two groups. Among them *Cleiothyridina royssii* (L'EVEILLE) is very numerous next to *Cl. expansa*. This species ranges from the Etroeungtian K_m subzone to the Visean C_2 subzone in England and shows its acme at about the Tournaisian Z_1 subzone. It is also well known in the Tournaisian of Belgium. In Japan it is known from the Kitakami Etroeungtian Hikoroichi Formation up to the lower half of the Ohdaira Formation; *Rugosochonetes* aff. *R. hardrensis* (PHILLIPS), closely related to *R. hardrensis* which ranges from the Late Devonian to the Late Visean in England and is most abundant in the Etroeungtian K zone to the Tournaisian Z zone; *Composita* aff. *C. argentea* (SHEPARD) of Akiyoshi may be morphologically more primitive than *C. argentea* which first appears in the Lower Pennsylvanian of North America; *Antiquatonia* is known in post-Tournaisian Palaeozoic rocks and the type-species is from the Visean D_2 subzone in England; *Dictyoclostus* is common in the Carboniferous and Permian formations; *Eomarginifera* is known from the Visean of Europe and Asia and the Namurian of Europe.

Summarizing these evidences, it is concluded that the brachiopod-fauna of the "Uzura" quarry strongly suggests Medial to Late Visean age ($S_2 \sim D_3$) with a possibility of suggesting Late Visean ($D_1 \sim D_2$).

Table 2. Chart showing the known ranges of the Akiyoshi species or their close affinities and the age of limestone of the "Uzura" quarry. A—A', possible; B—B', highly possible; •, close affinity.

[illegible]

Faunal affinities in Japan

The Japanese Carboniferous brachiopods known are restricted to the Kitakami massif of Northeast Japan and the Hida massif of central Japan. The Visean brachiopods in them are reported from the Ohdaira and the Onimaru Formations of the Kitakami massif, and from the lowest formation of the Omi Limestone and the Hongo Formation of Hongo-Arakidani area of the Hida massif.

According to MINATO et al. (1953), ONUKI (1956), and MINATO (1960), the Ohdaira Formation of about 700 m thick consists of pyroclastic rocks, alternations of slates and pyroclastic rocks, and sandstones. The formation was correlated to the Lower Visean mainly on the brachiopod faunas. The Ohdaira Formation is overlain unconformably by the Onimaru Formation of about 300 m thick. The Onimaru Formation is characterized by thick limestones and is correlated to the Upper Visean mainly on the many kinds of characteristic corals.

The first appearance of *Millerella* in the Onimaru Formation creates a problem. MINATO (1960) subdivided the formation into a lower Hotokezaka subformation and an upper Hiishi subformation. He especially emphasized that the occurrence of *Millerella* is restricted to the latter. ONUKI (1956), on the other hand, correlated the Onimaru Formation to the zone of *Millerella* because of its occurrence in the Takauchi limestone member, the lowest member of the formation.

The following brachiopods are described by MINATO (1951, 1952) mainly from the lower and middle parts of the Ohdaira Formation: *Cleiothyridina royssii* (L'EVEILLE), *Spiriferina octoplicata* SOWERBY, *Syringothyris transversa* MINATO, *Syringothyris* sp., *Fusella nipponotrigonalis* var. *minor* MINATO, *Brachythyris* aff. *B. pinguis* (SOWERBY), *Brachythyris nagaoui* MINATO. Five other species *Productus* sp. b, *Pustula* sp., *Spirifer* sp. c, *Chonetes* sp., *Spirifer* sp. d were also reported by MINATO et al. (1953).

The following four species are known from the Onimaru Formation: *Dictyoclostus* sp., *Gigantoproductus* sp., *Rhynchonella* sp., *Spirifer* sp.. According to MINATO et al. (1953), *Gigantoproductus* first appears in the base of the formation.

Comparing the Kitakami faunas with that of the Akiyoshi *Cleiothyridina royssii* from the Ohdaira Formation is the only species common to the Akiyoshi. *Brachythyris* and *Spirifer* are the only common genera to those of Akiyoshi. *Fusella nipponotrigonalis* of Kitakami may be related to "*Spirifer*" *triangularis* of Akiyoshi. Nothing is common among species of the Onimaru and the Akiyoshi faunas. *Dictyoclostus* and *Spirifer* of the former are only known from the latter.

The Omi Limestone of the Hida massif ranging from the Lower Carboniferous to the Middle Permian was first divided into several fossil zones by HAYASAKA (1924). KAWADA (1954) and FUJITA (1958) revised the zonation and divided the Omi Limestone into five formations mainly based on the fusulinid zones. They are as follows in descending order respectively: P₂ formation, *Neoschwagerina* zone; P₁ formation, *Pseudoschwagerina* and *Pseudofusulina* zones; C₃ formation, *Triticites* zone; C₂ formation, *Fusulinella* zone; C₁ formation.

Abundant corals and brachiopods occur in the lowest C₁ formation and HAYASAKA (1924) correlated these faunas to those of the Tournaisian to Visean of Europe.

Brachiopods consist of the following species: *Gigantoproductus edelburgensis* (PHILLIPS), *Avonia* cf. *A. acculeata* (MARTIN), *Echinoconchus punctatus* var., *Productus semireticulatus* MARTIN, *Camarophoria globulina* PHILLIPS, *Martinia glabra decora* PHILLIPS, *Reticularia lineata* MARTIN, *R. elliptica* PHILLIPS, *Syringothyris cuspidata* (MARTIN). *Productus* (*Dictyoclostus*) is the only genus common to the Akiyoshi fauna and other genera are quite distinct from the Akiyoshi ones.

From the Arakigawa Formation of the Hongo—Arakigawa area, FUJIMOTO, KANUMA, and IGO (1962) reported the occurrences of *Gigantoproductus* sp. and *Schizophoria*? sp. associated with corals, bryozoans, and other fossils. They correlated the formation to the Lower to Upper Carboniferous.

As stated above, the Visean brachiopod-fauna which is in harmony with the Akiyoshi one has not been found in other districts of Japan. *Cleiothyridina royssii*, the same species both in Akiyoshi and Kitakami, has a long range in the Lower Carboniferous and is cosmopolitan in distribution. In the Kitakami Lower Tournaisian it is also reported from the Hikoroichi Formation. Other equivalent or related species of the Kitakami Carboniferous faunas to the Akiyoshi one are also characterized by those which have long ranges. They are *Actinoconchus planosulcatus* of the Hikoroichi Formation, *Schizophoria resupinata* of the Tournaisian Arisu Formation, and *Chonetes hardrensis* of the Etroeungian Karaumedate Formation.

It is worthy of note that the Late Visean cosmopolitan Genus *Gigantoproductus* is common in the Onimaru Formation, the C₁ formation of the Omi Limestone, and the Hongo Formation of the Hida massif. The genus *Gigantoproductus* shows its acme in the Visean D₂ subzone of the British Avonian and the equivalent sequences of Europe and Asia.

On the other hand, the Akiyoshi fauna is also characterized by representative Visean genera and species such as *Phricodothyris insolita*, *Yanisheviskiella japonica*, *Rugicostella nystiana*, and "*Spirifer*" *triangularis* etc.. Therefore it is believed that the difference of Akiyoshi fauna and others may be caused by difference of the province or facies.

Faunal affinities in other areas

The Akiyoshi fauna has affinities with those of the Visean outside of Japan.

In Australia the Queensland Visean faunas (MAXWELL, 1954) are related to parts of the Akiyoshi one. Among them the Late Visean *Spirifer* cf. *S. liangchowensis* and *Cleiothyridina transversa* are respectively similar and compared with *Spirifer* aff. *S. liangchowensis* and *Cleiothyridina expansa* of Akiyoshi; *Rugosochonetes*, *Phricodothyris*, *Prospira*, and *Brachythyris* of Queensland are genera common to the Akiyoshi fauna. Queensland Late Tournaisian *Prospira burnettensis* is related to *P.* aff. *P. burnettensis* of Akiyoshi. Among the New South Wales Visean fauna (CAMPBELL, 1957) *Eomarginifera paradoxa* resembles *Eomarginifera* sp; *Werriea australis* is similar to *Orthotetes* sp; *Schizophoria* cf. *S. resupinata* is comparable with *S.* aff. *S. resupinata*; *Rugosochonetes? werriensis* is related to *R.* aff. *R. hardrensis*.

MAXWELL (1954) has pointed out that the paucity of productids in the Queensland Visean faunas is in harmony with that of Japan. This evidence is also acceptable

in the Akiyoshi fauna in which productids are few and uniformly small.

In Malaya the Visean brachiopods described from the Kuantan district of Pahang, eastern Malaya by MUIR-WOOD (1948) also have resemblance to the Akiyoshi ones. Among the Akiyoshi fauna *Dielasma* sp. is similar to *Dielasma* cf. *D. attenuatum* and *Schizophoria* aff. *S. resupinata* resembles *Schizophoria* sp.. *Dictyoclostus*, *Brachythyris*, *Spirifer*, *Pugnax*, *Phricodothyris*, and *Cleiothyridina* are common in the Akiyoshi genera. *Spirifer* sp. (*striatus* group), according to MUIR-WOOD, may be closely related to *S. liangchowensis* of the Kansu Visean. However, the significant difference of the Malayan fauna to the Akiyoshi one is that the former contains many kinds of productid species among which some are in common to the fauna of northwest China and Yunnan.

It is interesting that the Akiyoshi fauna and that of the Chinese Visean Upper Fengningian have few affinities with each other and also there are no common species between the former and the Chinese Middle Carboniferous Pechian and Weiningian faunas. *Cleiothyridina royssii* of Hunan described by HAYASAKA (1922) is a common species in the Akiyoshi; *Athyris submabranacea* described by CHU (1933) from the Kinling Limestone is related to the Akiyoshi species *Actinoconchus planosulcatus*; *Spirifer* aff. *S. liangchowensis* of Akiyoshi is closely related to *S. liangchowensis* of the Visean Choniukou Formation of Kansu; *Rugosochonetes* aff. *R. hardrensis* is similar to *Chonetes hardrensis* var. *kansuensis* of the Choniukou Formation; *Schizophoria* aff. *S. resupinata* resembles *S. resupinata* of the Visean of Kansu and Hunan; *Composita* and *Dielasma* are common genera in the Akiyoshi. The Kansu and Hunan faunas are always associated with *Gigantoproductus*.

Among the Yunnan Carboniferous fauna, *Composita* cf. *C. argentea* and *Schizophoria* cf. *S. resupinata* respectively by GRABAU (1924) and REED (1927) are related to *Composita* aff. *C. argentea* and *Schizophoria* aff. *S. resupinata* of Akiyoshi.

Among the Visean fauna of Laos described by MANSUY (1913), *Chonetes hardrensis* and *Schizophoria resupinata* are closely related to *Rugosochonetes* aff. *R. hardrensis* and *Schizophoria* aff. *S. resupinata* of Akiyoshi respectively.

In Mongolia GRABAU (1924) recorded the occurrence of *Schizophoria resupinata* with other brachiopods including *Gigantoproductus* but a satisfactory correlation can not be made.

In Tien-Shan province in central Asia Visean faunas have been described by KRENKEL (1913), GRÖBER (1908, 1909) and other Russian and German authors. Among the Visean brachiopods *Cleiothyridina expansa* from Karkara and Mt. Khan Tengri, north and east Tien-Shan, and *Cleiothyridina royssii* from Mt. Khan Tengri have their equivalents in the Akiyoshi fauna. *Schizophoria resupinata* from Bash-Sugun, Chinese Turkestan, and Chodzchur-noe-ussun, east Tien-Shan and *Rugosochonetes hardrensis* from the latter are closely related to *Schizophoria* aff. *S. resupinata* and *Rugosochonetes* aff. *R. hardrensis* of Akiyoshi. A peculiar occurrence is *Yanishewskiella angulata* from Bash-Sugun, which is represented in Akiyoshi by closely related *Yanishewskiella japonica*. *Pugnax*, *Dielasma*, *Spirifer*, and *Dictyoclostus* are genera common to the Akiyoshi fauna.

In Ferghana, farther west of Tien-Shan, Visean faunas have been described by

many Russian authors. The following species described by YANISHEWSKY (1918) are common to the Akiyoshi fauna; *Actinoconchus planosulcatus*, *Spirifer triangularis*, *Cleiothyridina expansa*. The following is closely related to the Akiyoshi species; *Schizophoria resupinata* resembles *S. aff. S. resupinata*, *Yanishewskiella angulata* is closely similar to *Y. japonica*, and *Rugosochonetes hardrensis* is related to *R. aff. R. hardrensis*. *Dielasma* sp. of Akiyoshi resembles *Dielasma attenuatum* of the Ferghana Visean. A difference of the Ferghana fauna from the Akiyoshi one is abundant occurrence of productid species including *Gigantoproductus giganteus*.

The following species the same or closely related to Akiyoshi ones are known in the Visean of the Donetz basin: *Spirifer triangularis*, *Schizophoria resupinata*, *Cleiothyridina royssii*, *Rugosochonetes hardrensis*. These brachiopods are associated with *Gigantoproductus giganteus*. In Siberia *Rugosochonetes hardrensis* and *Mucrospirifer* sp. respectively from the Upper Tournaisian and Upper Visean to Namurian of the Kuznetzk coal basin (SARYTCHEVA et al., 1963) are closely related to *Rugosochonetes* aff. *R. hardrensis* and "*Spirifer*" *triangularis* of Akiyoshi.

The Visean of western Europe has many species in common with the Akiyoshi fauna. The characteristic Visean species recognized in the Akiyoshi fauna are the followings; *Cleiothyridina expansa*, *Phricodothyris insolita*, *Actinoconchus planosulcatus*, *Rugicostella nystiana*, and *Spirifer triangularis*. *Yanishewskiella japonica* and *Pugnax* aff. *P. sulcatus* have respectively closely related species *Y. angulata* and *Pugnax sulcatus* in the Visean of western Europe.

An American Pennsylvanian species *Composita argentea* is only related to *Composita* aff. *C. argentea* of Akiyoshi.

In summary, it is concluded that the Akiyoshi fauna consists of a number of cosmopolitan genera and some regional ones. It has a close relation to that of the Queensland Visean of Australia. The remarkable paucity of productid species in the Akiyoshi fauna is also in harmony with that of the latter. The Malayan fauna and the Akiyoshi one are not considered to be closely related because of the absence of the common species, the paucity of related ones, and the predominance of productid genera in the Malayan fauna. The same characters observed in the Malayan fauna are also recognized in the Fenningian fauna of south China. The disharmony of faunas of Akiyoshi and south China may be due to the difference of facies of both provinces. The Akiyoshi fauna, on the other hand, has a close relation to the Visean fauna of Kansu, northwest China. Moreover, farther west of Kansu, it is interesting to note the occurrence of *Yanishewskiella* continuously from Akiyoshi to western Europe through Tien-Shan, Ferghana, and Ural. Also the new occurrence of *Rugicostella* hitherto only known from the Visean of Belgium and England suggests that the sea at that time extended from western Europe to Akiyoshi through central Asia and northwest China. Also the sea was immediately connected with that of northeastern Australia in Visean time.

On the age of the "Uzura" limestone

Some opinions have been published on the age of the lower part of the Akiyoshi

limestone Group on different data, especially from the lowest up to the zone of *Millerella*. These are represented by those of MINATO and KATO (1957, 1963), and HASEGAWA (1958, 1963), which the lowest part of the Akiyoshi limestone Group is correlated to the Lowest Namurian. On the contrary, MURATA (1961) and OKIMURA (1963) correlated the lowest horizon of the limestone group to the Lower Carboniferous. The former opinions are mainly based on the zone of coral and the latter on zones of fusulinids and smaller foraminifers. The correlation of each division of their fossil zones are as follows.

MURATA (1961)	OKIMURA (1963)	HASEGAWA (1963), MINATO and KATO (1963)
<i>Profusulinella</i> zone	<i>Profusulinella beppensis</i> zone	<i>Profusulinella</i> zone
<i>Millerella</i> zone	<i>Pseudostaffella</i> sp. A zone	<i>Millerella</i> zone
	<i>Millerella</i> sp. A zone	
<i>Endothyra</i> zone	<i>Pseudoendothyra spiroides</i> zone	<i>Nagatophyllum</i> zone
	<i>Endothyra</i> sp. A zone	

MURATA has drawn the boundary of the Visean and Namurian in the lower part of the *Millerella* zone and OKIMURA considered it to be at the base of his *Millerella* sp. A zone.

Brachiopod-fauna from the "Uzura" limestone shows the close alliance to the Upper Visean faunas of Europe, Asia, and Australia. Among the fossils besides brachiopods YAMAGIWA and OTA (1963) described the following corals which are well preserved in the limestone: *Stylidophyllum ozawae* YAMAGIWA and OTA, *Clisiophyllum awa* (MINATO), *Clisiophyllum* sp. indet., *Lonsdaleoides toriyamai* MINATO, *Lophophyllidium uzurensis* YAMAGIWA and OTA. In addition to these species I confirmed the occurrence of *Nagatophyllum* cf. *N. satoi* OZAWA in association with them. Considering these corals, the following ranges of each are recognizable. *Clisiophyllum awa* occurs in Southwest Japan from the zone of *Pseudoendothyra spiroides* of Atetsu Limestone (OKIMURA, 1958), Okayama Prefecture, up to the zone of *Fusulinella* of Omi Limestone, Niigata Prefecture. *Lonsdaleoides toriyamai* occurs from the zone of *Millerella* to the zone of *Profusulinella* in Akiyoshi and Taishaku, western Chugoku. *Stylidophyllum ozawae* and *Lophophyllidium uzurensis* are only known in the "Uzura" limestone but the genera are known from the Lower to the Middle Carboniferous and from the Pennsylvanian to the Permian, respectively. The occurrence of *Nagatophyllum satoi* is restricted in western Chugoku and southwestern part of the Hida massif. Such being the case it is difficult to confirm the age of the "Uzura" limestone from these corals because they have relatively long ranges.

OKIMURA (1963) established five foraminiferal zones on the limestone underlying *Profusulinella* zone of the Akiyoshi limestone Group and correlated them to those of the Atetsu Limestone of Okayama Prefecture. They are as follows in descending order: the *Profusulinella beppensis* zone, the *Pseudostaffella* sp. A zone, the *Millerella*

sp. A zone, the *Pseudoendothyra spiroides* zone, and the *Endothyra* sp. A zone. OKIMURA correlated the *Millerella* zone to the Lower Bashkirian and considered that the *Pseudoendothyra spiroides* and *Endothyra* sp. A zones may be Lower Carboniferous respectively. The foraminiferal fauna of the *Millerella* sp. A zone, according to OKIMURA, shows the closest affinity to that of the Upper Visean of Sikhotealin. But abundant occurrences of *Ozawainella* and *Globivalvulina*, representative genera of Sikhotealin Bashkirian, in the *Millerella* sp. A zone confirm its correlation to the Lower Bashkirian.

When I reflect upon the foraminiferal fauna of the "Uzura" limestone, the following facts seem clear. It contains *Millerella* and *Eostaffella* most abundantly, and a number of *Pseudoendothyra* and *Plectogyra* are also associated. A few *Glomospira* and *Granulifella* also occur. *Ozawainella* is not found at all. Summing up the foraminiferal fauna of the "Uzura" limestone, it is characterized by the Upper Visean elements for the most part. Although a problem remains on the relation of lithofacies and fauna, the limestone hardly correlates to the Lower Bashkirian on the above assemblage. This is also supported by a relatively large occurrence of individuals of *Eostaffella* and *Pseudoendothyra* among the foraminiferal genera. The "Uzura" quarry is located about 7 km west of the southern margin of the Akiyoshi limestone plateau where OKIMURA dealt with his foraminiferal zones. It is impossible to know the relation of both limestone. But it is believed that a horizon which is absolutely lacking in *Ozawainella* and contains smaller foraminifers similar to those of the *Pseudoendothyra spiroides* zone will exist in the lower part of OKIMURA's *Millerella* sp. A zone.

According to MURATA (1961) the lower part of the *Millerella* zone of the Akiyoshi limestone Group is characterized by *Millerella komatui* IGO and *M. uzurensis* MURATA (M. S.). The former was originally described by Igo (1957) from the Ichinotani Formation of Fukuji, Gifu Prefecture. In Fukuji it is associated with *Millerella kanmerai* IGO and also abundant corals such as *Siphonodendron*, *Dibunophyllum*, *Kueichouphyllum*, *Clisaxophyllum*, *Hexaphyllia*, and *Neokoninckophyllum*. Most of these corals are representatives of the Upper Visean.

MINATO (1960) considered that the *Millerella kanmerai* subzone of Fukuji is older than the *Nagatophyllum satoi* subzone (= *Nagatophyllum* zone, 1963) of Akiyoshi and the lowest part of the subzone is correlative to the Hiishi Stage, the upper half of the Onimaru Formation of Kitakami massif, from the coral fauna. According to MINATO, those formations which were characterized by the coral faunas of the lower half of the *Stylidophyllum* sp. subzone (= *Millerella* zone, 1963) and the *Nagatophyllum satoi* subzone of the Akiyoshi limestone Group widely distribute in the Taishaku, Ibuki, and Omi districts of Southwest Japan, and they are distinctly correlative to the Sabukura Stage, the lower half of the Nagaiwa Formation. He concluded their age to the Lowest Pennsylvanian. The basis of his correlation is that the representative corals of the *Nagatophyllum* zone are unknown in the Upper Visean Onimaru Formation and its equivalents widely distributed in Japan and that among the coral faunas of *Nagatophyllum satoi* and *Stylidophyllum* sp. subzones the Late Visean corals never occur.

I have some doubts about MINATO's opinions. Corals which form the subzones of *Nagatophyllum satoi* and *Stylidophyllum* sp. of MINATO and KATO (1957) respectively have long ranges in Southwest Japan as they were studied more in detail in relation to the zones of fusulinids. But the relation of the *Millerella* zone to the *Nagatophyllum* zone is not clear in Akiyoshi. The ranges of those characteristic corals of Southwest Japan must be clarified in detail with a possibility of their first appearance extending to the Lower Carboniferous. For instance OKIMURA (1958) recorded the occurrence of *Hexaphyllia* sp., *Siphonodendron* sp., *Amygdalophyllum giganteum* (YABE and HAYASAKA) associating with *Clissiophyllum awa* MINATO, *Cl. awa atetsuense* MINATO and NAKAZAWA, and *Stylidophyllum* sp. from a lower horizon of the *Endothyra spiroides* zone (= *Pseudoendothyra spiroides* zone, 1963) in the Nagoe Formation of the Atetsu limestone, Okayama Prefecture. *Haxaphyllia* and *Siphonodendron* are the representative corals of the Onimaru Formation of Kitakami. *Amygdalophyllum giganteum* was originally described from the Omi limestone in association with many brachiopods and corals most of which were compared with the fauna of the Onimaru Formation. This is a very important fact although it is only evidence of co-occurrence of faunal elements of the Onimaru Formation and subzones of *Nagatophyllum satoi* and *Stylidophyllum* sp. of Akiyoshi. It is considered that the independence of coral faunas in the Kamitakaran Epoch recognized between the Carboniferous of the Inner zone of Southwest Japan and Northeast Japan had already begun in the Onimaru.

HASEGAWA (1963) reported the occurrence of brachiopods and corals from reddish tuffaceous shale near the lowest part of the Akiyoshi limestone Group. MINATO and KATO (1963) described them and discussed their age. The discovery of these fossils is very important. Because the lower part of the Akiyoshi limestone Group is always characterized by reddish tuffaceous shale or pyroclastic rocks. Therefore if the faunal age is confirmed, the geological age of the lowest part of the Akiyoshi limestone Group is firmly recognized. MINATO and KATO distinguished the following corals and brachiopods: *Cyathaxonia* sp., *Pleurodictum dechenianum* KAYSER, *Schuchertella* sp. a, *Schuchertella* sp. b, *Chonetes* sp., *Waagenoconcha* sp., *Neophricodothyris*? sp., and *Nebenothyris hasegawai* MINATO and KATO. It seems to be difficult to adequately conclude the age of the fauna from these elements. But they regarded it to be Lowest Namurian. According to them, the reddish tuffaceous shale is overlain by the limestone of the *Nagatophyllum* zone and elements of the Upper Visean Onimaru fauna are lacking. Therefore the Akiyoshi fauna is younger than the Late Visean. However, their conclusions are hardly acceptable, because they laid more stress on the relation of the tuffaceous shale to the limestone of the *Nagatophyllum* zone than discussing the species assemblage. This has less meaning for establishing the age than discussing the fauna itself. Moreover it is doubtful that the Akiyoshi fauna is younger than the Onimaru fauna because of lack of the elements of the latter in the former. I consider that assignment of the Akiyoshi fauna to the Earliest Namurian from this assemblage of species is untenable.

Recently I obtained many specimens of brachiopods from the reddish tuffaceous shale to clarify their age. The following species were distinguished: *Rhynchopora* sp., *Setigerites* sp., *Werriea* cf. *W. australis* CAMPBELL, *Schuchertella* spp., *Orbinaria*

sp., *Eomarginifera* aff. *E. paradoxa* (CAMPBELL), and *Quadratia* sp..

This brachiopod-assemblage was too poorly preserved to know the detailed characters. But the following are valid for age determination of the assemblage: *Setigerites* sp., *Werriea* cf. *W. australis* CAMPBELL, *Eomarginifera* aff. *E. paradoxa* (CAMPBELL), *Oribinaria* sp., *Quadratia* sp.. *Setigerites* is known from the Osage and the Meramec Group of North America and from the Middle Tournaisian (C₁ td) to the Lower Visean (C₁ pd) of the Kuznetzk Basin of Russia. *Werriea* cf. *W. australis* is closely comparable to *W. australis* of the Lower Carboniferous of Babinboon, New South Wales (CAMPBELL, 1957). *Eomarginifera* aff. *E. paradoxa* is also closely related to *E. paradoxa* which is associated with *Werriea australis* in New South Wales. *Eomarginifera* ranges from the Visean up to the Namurian and is cosmopolitan in Visean time. Australian species were first compared by CAMPBELL with those of North America and were recorded as Upper Tournaisian. But, according to his personal communication from CAMPBELL, the age of the fauna must be revised to Medial Visean because of emendation of the age of the American fauna to which he correlated it.

Quadratia sp. and *Orbinaria* sp. are poorly preserved but the genera are known from the Mississippian of North America.

Rhynchopora and *Schuchertella* have long ranges from the Lower Carboniferous up to the Permian. Detailed comparison of the species with others is difficult because of poor preservation of the specimens.

These materials are not enough to determine their exact age, however, it is difficult to date them as Namurian.

The following important facts were added to the above evidence. From the oolitic limestone, partly clastic and tuffaceous, about 10 m below the reddish tuffaceous shale the following brachiopods, and corals were obtained with bryozoans, smaller foraminifers, and crinoid ossicles; *Syringothyris* spp., *Schizophoria* cf. *S. resupinata*, *Leptagonia* sp., *Spirifer* spp., *Zaphrentoides* sp., and *Cyathaxonia* sp*. The oolitic limestone conformably underlies the reddish tuffaceous shale.

Syringothyris is one of the leading fossils of the Lower Carboniferous. In Europe it is abundant in the Tournaisian and the Lower Visean showing its climax in the C zone in the English Avonian. In North America *Syringothyris* is known from the Kinderhookian up to the Meramecian. In Russia it is known from the Upper Tournaisian (C₁ nt) up to the Lower Visean (C₁ pd) and is most abundant in the Upper Tournaisian. In Japan it is known from the C₁ zone of the Omi Limestone and the Lower Carboniferous of the Kitakami massif. Kitakami *Syringothyris* ranges from the uppermost Hikoroichi Formation up to the lower Ohdaira Formation, and it is most abundant in the Upper Tournaisian Arisu Formation. *Leptagonia* is known from the Lower Devonian up to the Lower Carboniferous. *Schizophoria* ranges from the Silurian up to the Permian and is cosmopolitan in the Lower Carboniferous. *Zaphrentoides* is one of the index fossils of the Lower Carboniferous and a repre-

* YANAGIDA and OTA, read at the 71st annual meeting of the Geological Society of Japan, April, 1964.

sentative of "*Zaphrentis*" zone of English Avonian. *Cyathaxonia* is also a representative genus of the Lower Carboniferous of North America, Europe, Australia and Asia.

The assemblage of these brachiopods and corals apparently indicates the Lower Carboniferous. Although palaeontological study of them has not been sufficiently carried out the species assemblage shows the age of the Late Tournaisian to the Early Visean.

The following conclusions are apparent from this evidence. The age of the limestone which contains brachiopods and corals such as *Syringothyris*, *Spirifer*, *Cyathaxonia* and *Zaphrentoides* is Late Tournaisian or Early Visean. Reddish tuffaceous shale which conformably overlies the limestone and contains numerous brachiopods may be Early to Medial Visean in age.

Strict correlation of the lower part of the Akiyoshi limestone Group with other Carboniferous formations in Japan is difficult. In the Kitakami massif pyroclastic rocks begin to predominate below the middle part of the Lower Visean Ohdaira Formation. It is interesting that the Omi Limestone also has pyroclastic rock in the lowest part of the C₁ zone in association with sandstone and shale. Pyroclastic rocks are also recognized in the lower part of the Carboniferous formations of Taishaku, Hiroshima Prefecture and Atetsu of Okayama Prefecture.

With regard to the age of the lowest part of the Akiyoshi limestone Group I consider the age of the "Uzura" limestone to Late or Latest Visean. This is supported stratigraphically by the faunal assemblage of brachiopods and foraminifers. The Namurian in the Akiyoshi limestone Group lies at a higher horizon than that of the "Uzura" limestone. In relation to this problem it is worthy to note the existence of the *Pseudostaffella* sp. A zone over the *Millerella* sp. A zone. According to OKIMURA (1963), *Pseudostaffella* sp. A zone mainly consists of *Pseudostaffella*, *Ozawainella*, *Millerella*, and *Endothyra* but never contains *Profusulinella*.

Concluding Remarks

With the aid of biostratigraphy of the part underlying the *Millerella* sp. α zone of the Akiyoshi limestone Group, many kinds of brachiopods of the "Uzura" limestone which also contains abundant corals, fusulinids, and other smaller foraminifers were studied. Materials dealt with were restricted to a horizon and therefore successive change of faunas with age remained a problem. However, a number of brachiopods are sufficient to determine the age and affinities with other faunas in other districts. As brachiopods and other fossils from underlying parts of the "Uzura" limestone come to hand, further detailed palaeontological and stratigraphical studies will be possible in the near future.

A summary of this study follows. Brachiopods of the "Uzura" limestone mainly consist of Medial or Late Visean elements. It is believed that the age of the fauna is from the Medial to the Late Visean with a high possibility of the Late Visean. Associated fusulinids and other smaller foraminifers also support the age determined by the brachiopod fauna.

Regarding the relation with the Late Visean brachiopods of other districts of Japan I can not recognize any common species with the Akiyoshi one in the Onimaru Formation of the Kitakami massif and Omi Limestone of central Japan. *Gigantoproductus* recorded from these localities was not found in Akiyoshi. Adding the above evidence, productids from Akiyoshi are all extremely small and very few in numbers and kinds.

The Akiyoshi fauna has close alliances in northwest China, Tien Shan, Ferghana, Kuznetzk, and further west to Donetz, western Europe, and England. Species common to or closely allied with the Akiyoshi ones are often recognized in these districts and genera which are only known in some of these provinces are also found in the "Uzura" limestone. Therefore it is considered that the geosynclinal sea in Visean time developed in these European and Asiatic regions immediately extended further east to Japan and the migration of faunas accomplished.

On the other hand, I can recognize a close relation of species of the Akiyoshi fauna with those of the Visean faunas of eastern Australia. It is true that Japan and Australia were connected with each other in Visean time. It is not sure that both regions were immediately connected by a geosynclinal sea across the present ocean at that time. It is interesting that the Visean faunas of southern China and Malaya show less similarity to the Akiyoshi one than to the Australian faunas.

Regarding the species assemblage of corals with brachiopods there is a problem for the definite geological age of "*Nagatophyllum* fauna". It is clear that the following species of *Stylidophyllum ozawae*, *Clissiophyllum awa*, *Lonsdaleoides toriyamai*, *Lophophyllidium uzurensis*, and *Nagatophyllum* cf. *N. satoi* from the "Uzura" limestone respectively have longer stratigraphic ranges downward to the Late Visean than those hitherto known. It is necessary to know accurate ranges and stratigraphic position of these Carboniferous corals in the Akiyoshi limestone Group.

It is clear that the "*Kueichouphyllum* sea" of MINATO (1953) characterized by *Kueichouphyllum*, *Dibunophyllum*, and other corals is distinguished on its biofacies from the sedimentary province characterized by *Nagatophyllum satoi*, *Clissiophyllum awa*, and other corals. The former is represented in Japan by the Upper Visean Onimaru Formation of the Kitakami massif and its equivalents of Abukuma, Hida, and Kyushu. On the other hand, the latter province is represented by Akiyoshi, Taishaku, Atetsu, Otaki, and Omi districts disposing on the Inner zone of Southwest Japan.

The Late Visean sea in Japan was composed of two different faunal provinces. One was strongly connected with that of southern China but the other was related to that of northwest China to Europe. It is unknown whether a certain barrier was spread between those different faunal provinces or not. However, it is very interesting that the difference of faunas is related to the difference of the sedimentary facies between them. The Lower Carboniferous limestone of the inner zone of Southwest Japan is generally light grey to white, massive, very thick, and very pure, and is characterized by the *Nagatophyllum* and *Clissiophyllum* fauna. While the limestones of the outer zone of Southwest Japan and Northeast Japan are commonly dark grey, muddy, and often intercalate black slates, sandstones, pyroclastic rocks, and cherts, and are represented by the *Kueichouphyllum* fauna. An exception is the Ichinotani Formation of the Hida massif. It is near the Omi Limestone and

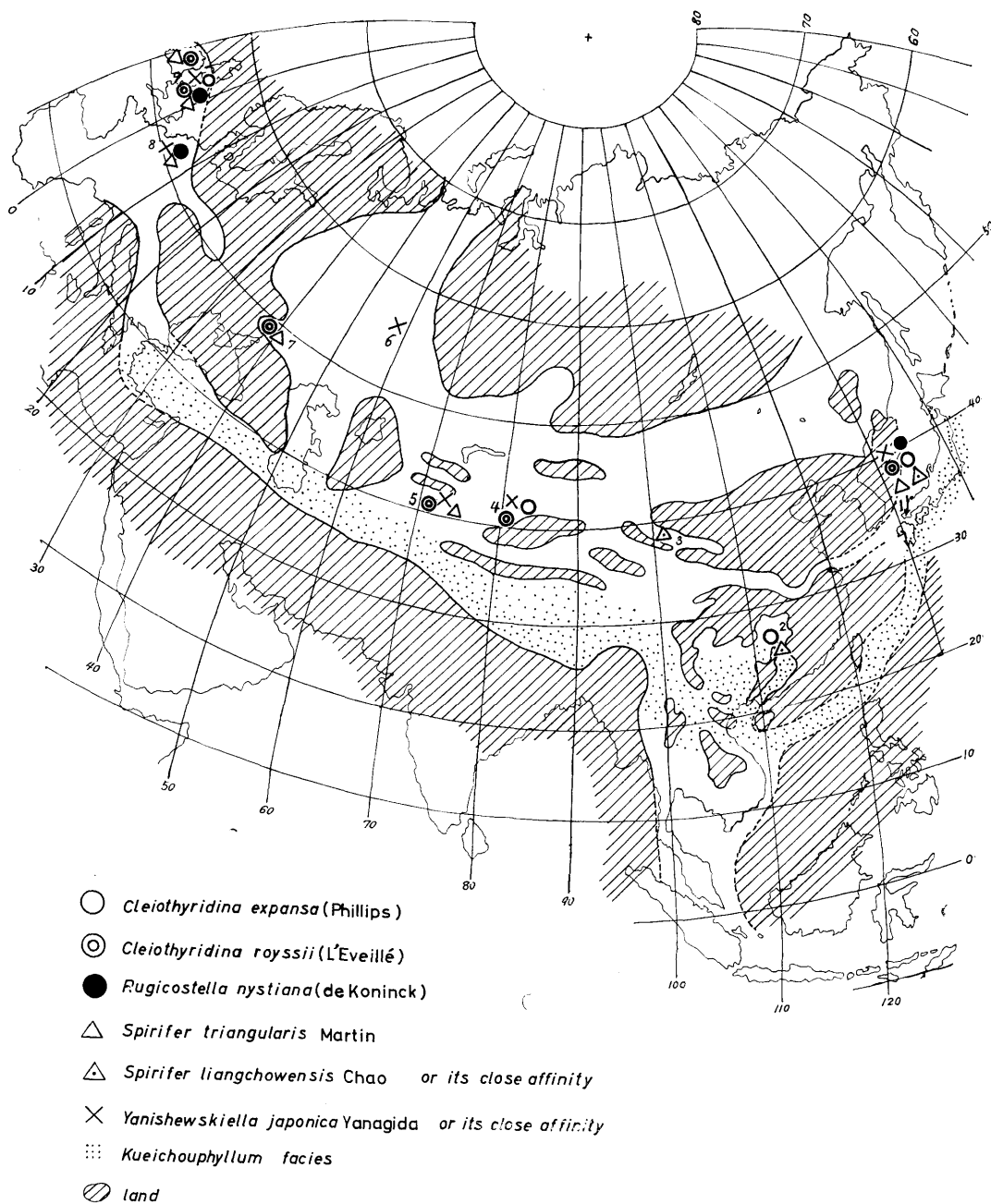


Fig. 5. Visean palaeogeography of Eurasia (Compiled after Muir-Wood, 1948; Minato, 1953; Liu, 1955 and Hamada, 1960, etc.) and distributions of some representative species of brachiopods or their close affinities of Akiyoshi. 1: Akiyoshi, 2: Central Hunan, 3: Northwest Kansu, 4: Tien-shan, 5: Ferghana, 6: Ural Mountains, 7: Donetz Basin, 8: Belgium, 9: Great Britain and Ireland.

in the Inner zone of Southwest Japan. It is characterized by impure limestone and the *Kueichouphyllum* fauna.

The age and correlation of the lowest part of each limestone formation distributed in Akiyoshi, Taishaku Oga, Atetsu, and Omi, from the west to the east of the Inner zone of Southwest Japan, must be confirmed. These limestone formations characteristically have a considerable amount of pyroclastic rocks near their lowest part. For the purpose of clarifying the faunal difference between the Lower Carboniferous of the inner zone of Southwest Japan and others, it is necessary to establish the characteristics of each faunal province and relation between them. It is also very important to make a detailed stratigraphical and petrographical study of the thick, noncalcareous sedimentary rocks which are distributed in the circumference of the limestone plateau of the inner zone of Southwest Japan ranging from the Carboniferous to the Upper Permian.

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Part II

Plates 25—28

Plate 25

Explanation of Plate 25

(all figures $\times 3$)

- Figs. 1-5. *Rugicostella nystiana* (DE KONINCK)page 114
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 - 2a-d. Respectively ventral, lateral, anterior, and posterior views of an incomplete pedicle valve, GK-D 30081.
 - 3a-c. Respectively ventral, anterior, and lateral views of an incomplete pedicle valve, GK-D 30080.
 - 4a-d. Respectively lateral, anterior, ventral, and posterior views of an incomplete pedicle valve, GK-D 30105.
 - 5. Anterior part of an incomplete pedicle valve, GK-D 30082.

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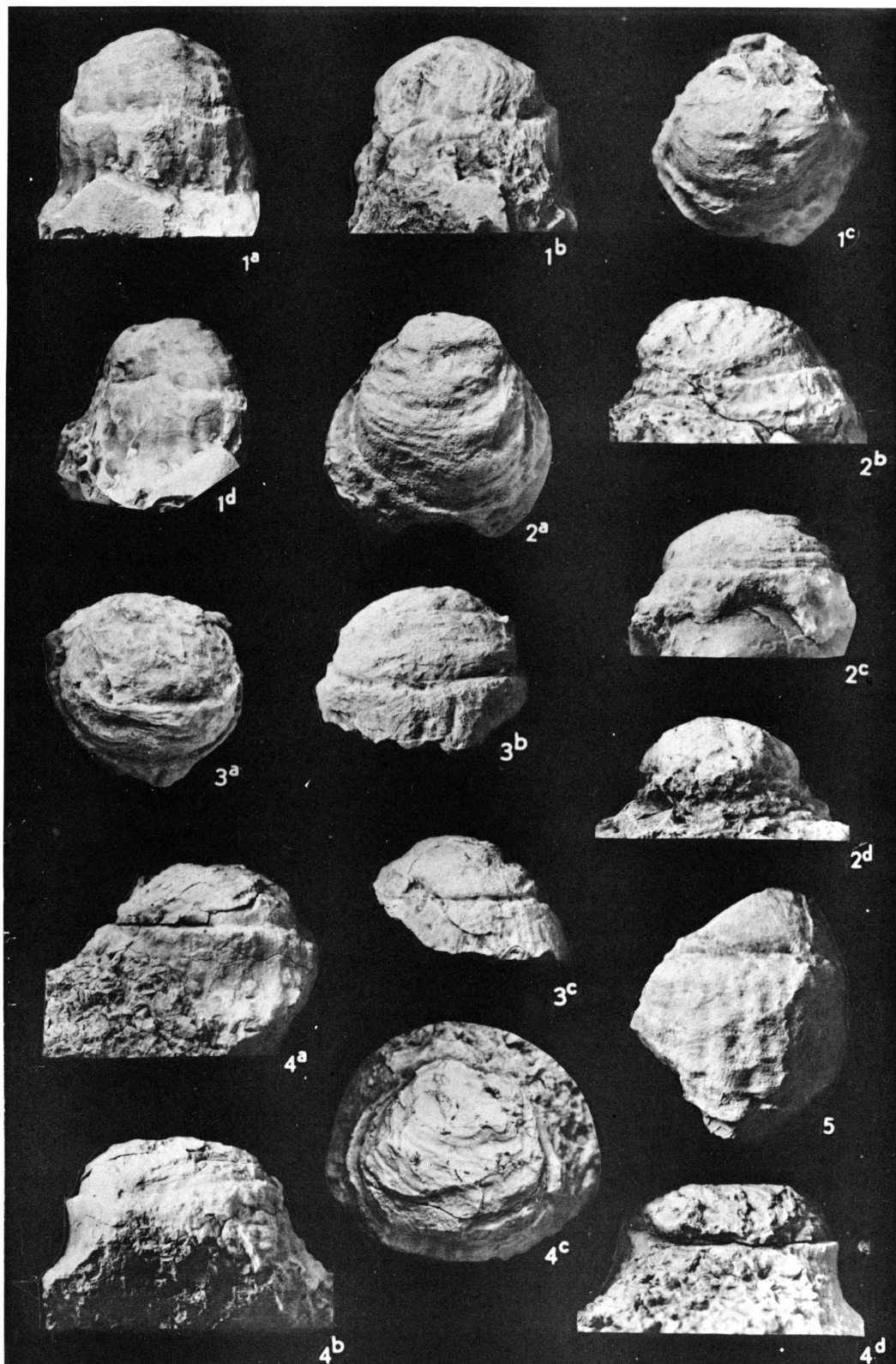


Plate 26

Explanation of Plate 26

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 1e. Enlarged view of a part of anterior region to show the ornament, ca. x 14.
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- Fig. 2. *Prospira* aff. *P. burnettensis* MAXWELLpage 119
 2a-c. Respectively ventral, lateral, and posterior views of a pedicle valve, GK-D 30091, x 4.
 2d. Enlarged view of a part of anterior region to show the delicate ornament, ca. x 13.

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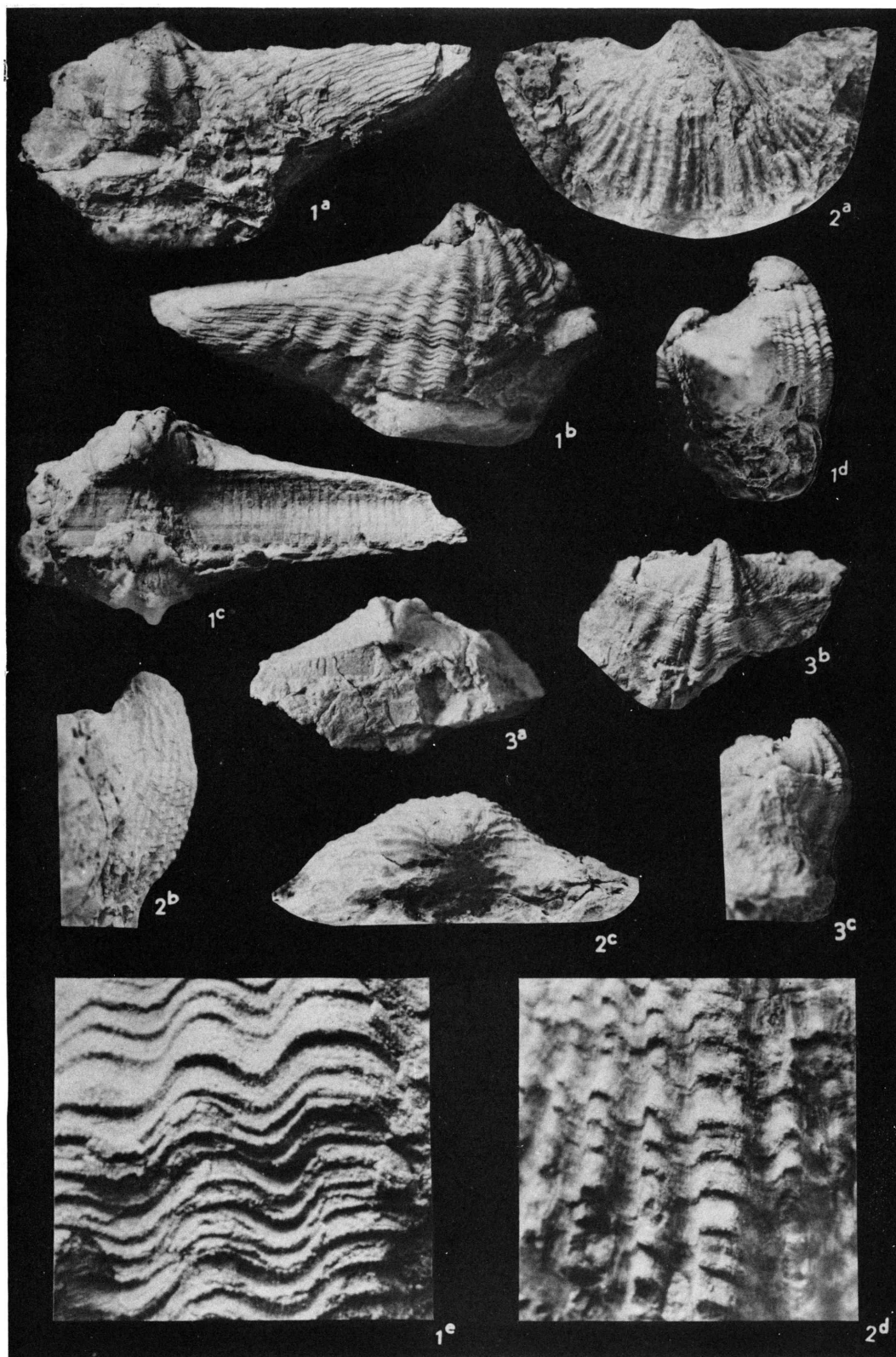
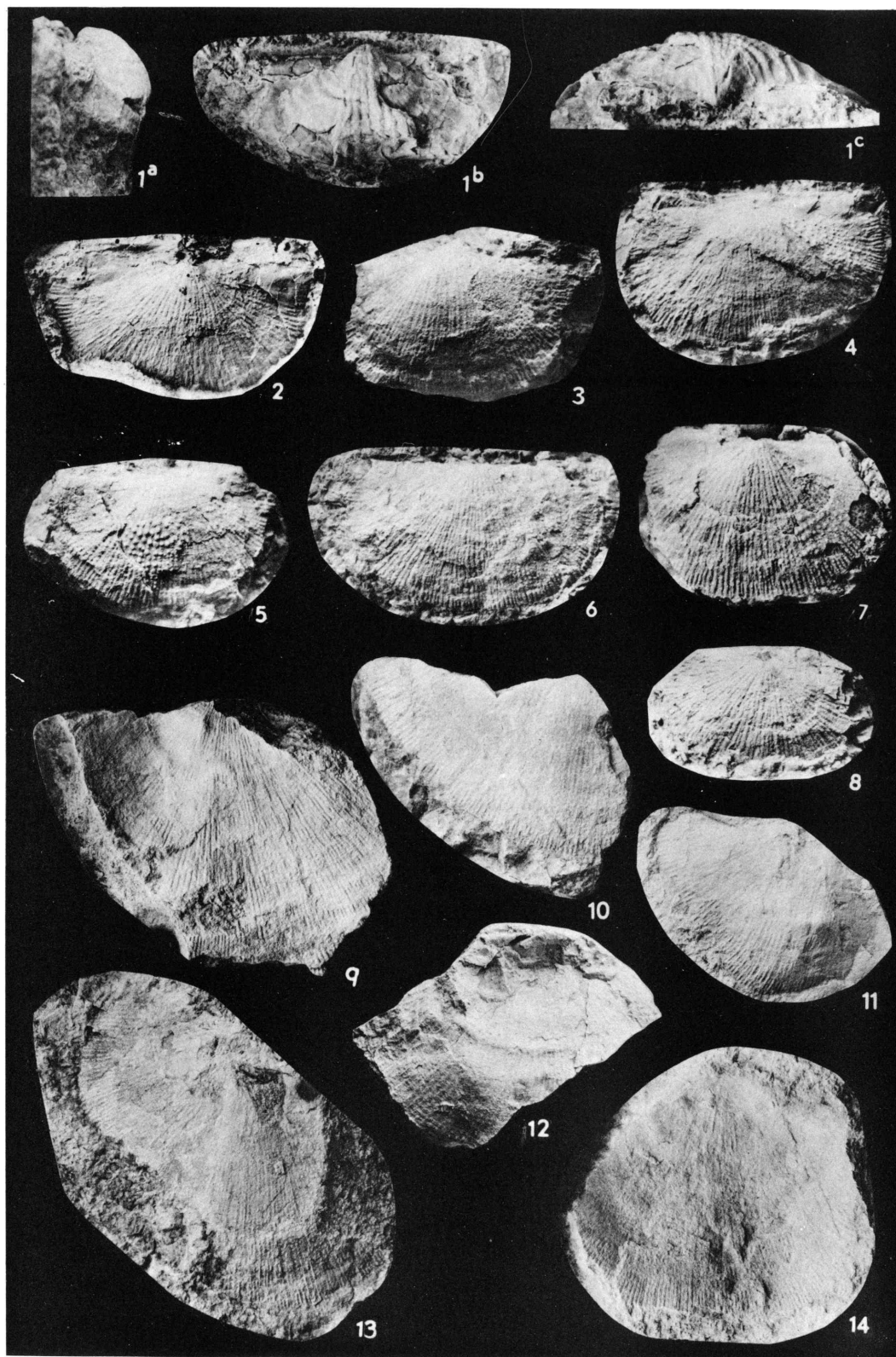


Plate 27

Explanation of Plate 27

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- Figs. 2-8. *Rugosochonetes* aff. *R. hardrensis* (PHILLIPS).....page 115
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 13. Incomplete brachial valve, GK-D 30094, x 1.
 14. Internal cast of an incomplete brachial valve, GK-D 30108, x 1.

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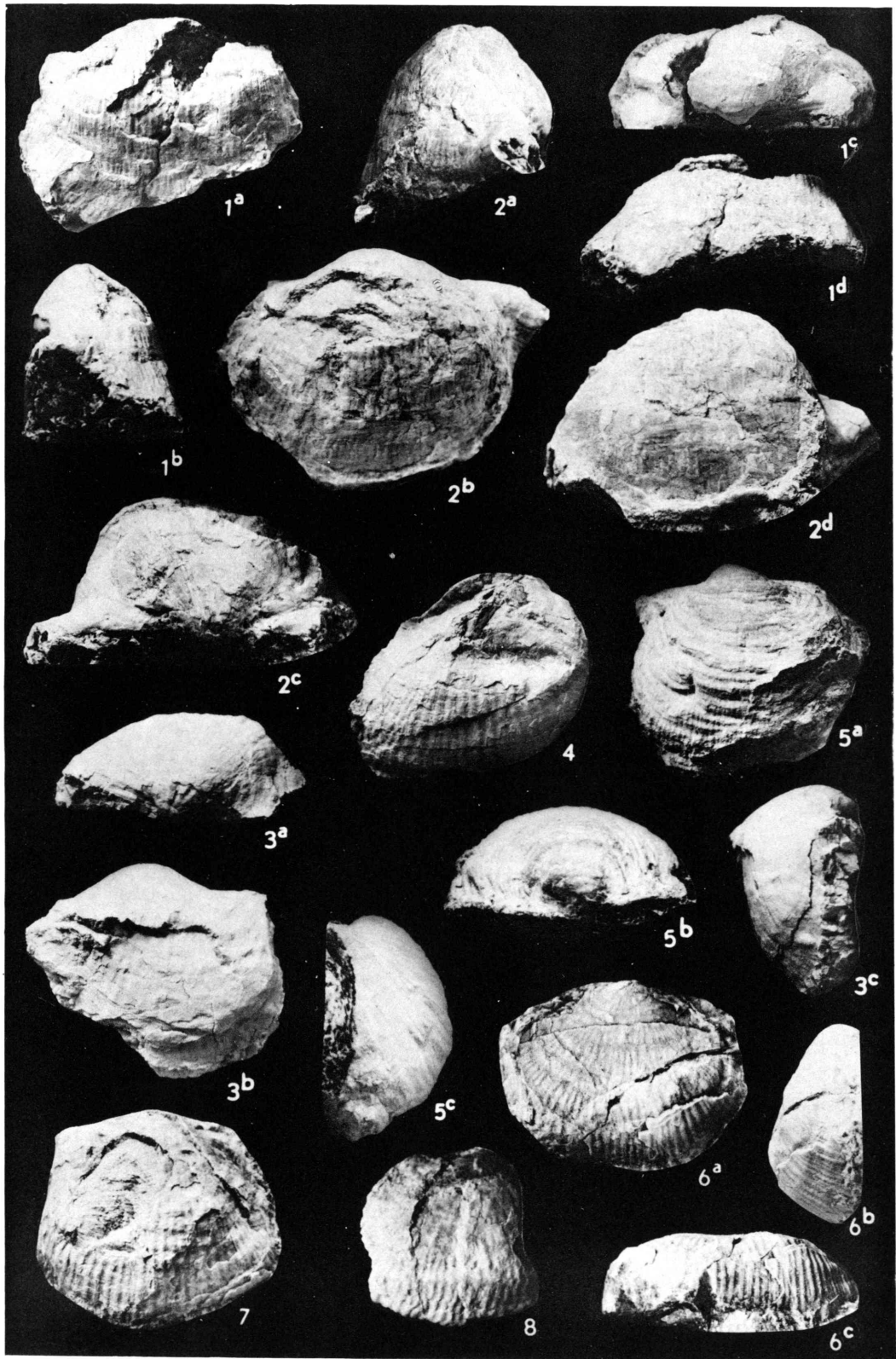
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Plate 28

Explanation of Plate 28

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7. Incomplete pedicle valve, GK-D 30095, $\times 2.5$.
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