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https://doi.org/10.5109/1543605

出版情報：九州大學理學部紀要 : Series D, Geology. 14 (2), pp.69-78, 1963-03-01. Faculty of Science, Kyushu University
バージョン：
権利関係：

Mem. Fac. Sci., Kyushu Univ., Ser. D, Geology, Vol. XIV, No. 2,
pp. 69-78, 1 text-fig., pls. 8-10, March 1, 1963

Brachiopods from the Upper Permian Mizukoshi Formation, Central Kyushu*

By

Juichi YANAGIDA

Abstract

Four brachiopod species collected from the Upper Permian Mizukoshi formation are described as *Neospirifer fasciger* (KEYSERLING), *Spiriferella keilhavii* (von BUCH), and *Linoproductus* cf, *lineatus* (WAAGEN), These occur from a bed about 300m above the *Lepidolina toriyamai* limestone. Some comments are also given on the comparison of the fauna with the identical or closely related faunas from other parts of Japan and related provinces.

Introduction

The Mizukoshi formation which lies about 20 km southeast of Kumamoto, central Kyushu, is a thick series of black shale (converted to slate) in its lower part (900 m) and alternating sandstone and shale with some thick intraformational conglomerates and small lenticular limestones of four horizons in its upper part (500 m).

The limestone lenses intercalated in the lower part of the upper subformation contain *Lepidolina* cf. *toriyamai* KANMERA, *Yabeina* cf. *gubleri* KANMERA, *Yabeina* cf. *shiraiwensis* OZAWA, *Pseudodoliolina* cf. *pseudolepida* (DEPRAT), *Schwagerina* sp., and *Parafusulina* sp.. This fauna indicates that the upper subformation of the Mizukoshi formation is safely corelated with the middle part of the Kuma formation (KANMERA, 1952, 1953).

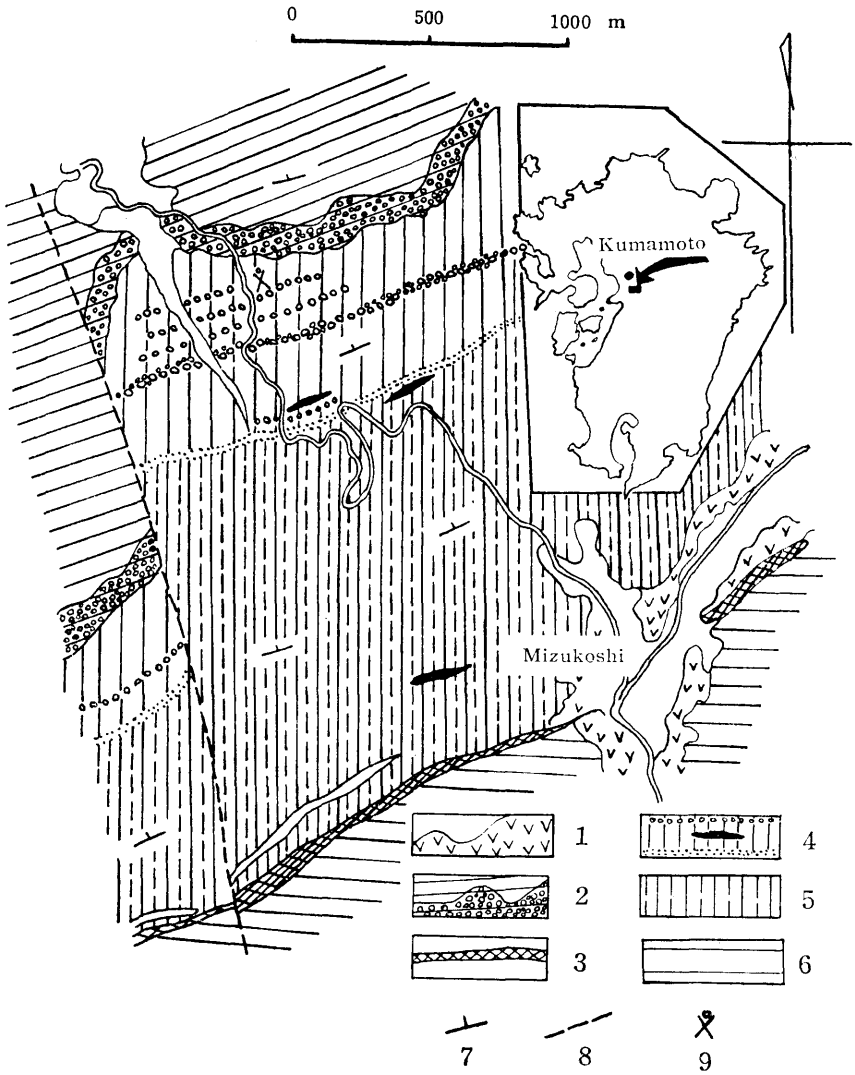
In a bed of pebble-bearing shale at about 300 m above this fusuline limestone occur some brachiopods in association with fragmentary specimens of pelecypods, gastropods, corals and crinoid oscicles. In my previous paper (YANAGIDA, 1958) which dealt with a detailed description of stratigraphy of the formation those brachiopods are listed under the name of *Neospirifer* cf. *fasciger* (KEYSERLING), *Spiriferella* sp. and *Productus* sp. On examining those specimens and some supplementary collections obtained later, I identified the following species, though they are strongly deformed or squashed.

Neospirifer fasciger (KEYSERLING)
Spiriferella keilhavii (von BUCH)
Linoproductus cf. *lineatus* (WAAGEN)

It is the purpose of this paper to describe these species and to give some comments on the comparison of them with those of the Upper Permian brachiopod faunas of other parts of Japan.

My sincere thanks are due to Dr. K. KANMERA who provided me with specimens and read typescripts of this paper.

* Received June 30, 1962



Text-fig. 1. Geological map of the Mizukoshi area and location of brachiopod collections.

Explanation: 1: Quaternary sediments and Aso welded tuff
2: Basal and lower formation of the Cretaceous Mifuné group
3: Serpentinite
4: Upper subformation of the Mizukoshi formation
circles-conglomerate
black lens-limestone
points-sandstone
5: Lower subformation of the Mizukoshi formation
6: Manotani schists
7: Strike and dip
8: Inferred fault
9: Location of brachiopod specimens

Systematic descriptions

Family *Spiriferidae* KING, 1846

Subfamily *Spiriferinae* KING, 1846

Genus *Neospirifer* FREDERICKS, 1924

Type-species.—*Spirifer fasciger* KEYSERLING, 1846

Remarks.—See YANAGIDA (1962, p. 95). Many species have been assigned to the genus *Neospirifer* from the Carboniferous and Permian formations of various parts of the world. However, as already indicated by MAXWELL (1951, 1954) the real nature of the genus and the distinction from other related genera, *Spirifer* SOWERBY 1814 and 1818, *Trigonotreta* KÖNIG 1825, have been subjects of much confusion because of inadequate original generic diagnosis and of unfavourable state of preservation of the types of the type-species.

I would refer the genus *Neospirifer* to spiriferid species which have the strong fasciculation of costae, untile the precise reexamination of the type-species of *Spirifer*, *Trigonotreta*, and *Neospirifer* is made out.

Neospirifer fasciger KEYSERLING
Pl. 8, figs. 1-7; Pl. 9, figs. 1-3

For the synonyms of this species see HAYASAKA, 1960, pp. 42–43.

Material.—More than twenty specimens are referrable to this species, of which the followings are better preserved examples. GK-D 31001 (Pl. 8, figs. 1a–d), GK-D 31002 (Pl. 8, figs. 2a–d), GK-D 31003 (Pl. 8, figs. 3a, b), GK-D 31031 (Pl. 8, figs. 4a–d), GK-D 31004 (Pl. 8, fig. 5), GK-D 31005 (Pl. 8, figs. 6a, b), GK-D 31006 (Pl. 8, fig. 7), GK-D 31007 (Pl. 9, fig. 1), GK-D 31008 (Pl. 9, fig. 2), GK-D 31009 (Pl. 9, fig. 3)

The following descriptions are entirely based on these specimens.

Description.—The shell is subequally and slightly biconvex and is laterally subrhomboidal in outline with the greatest width at the hinge-line.

The ventral valve is more convex than the dorsal one, with a moderately curved umbo. The beak is prominent and incurved over the hinge-line. The broad sulcus of the ventral valve rises at the ventral umbo and becomes slightly deeper and wider anteriorly. The dorsal valve has a conspicuous fold.

The entire surfaces of both valves are ornamented with a number of radiating costae which are crossed by numerous fine concentric wrinkles. The costae are round-topped and low. They increase in number anteriorly by bifurcation and by intercalation of new costae. About ten to twelve costae are observed on the median fold. Fasciculation of the radial costae is not distinct in some specimens, but two or three bundles comprising five to eight closely spaced costae are recognized on each side of the median fold of the dorsal valve in other several well preserved specimens.

Approximate measurements of four specimens are as follows (in mm):

	1	2	3	4
length	40	35	35	25
width	45	40	40	30
thickness	30	25	20	15

The ventral interiors are incompletely shown in some specimens. The shell is much thickened in the umbonal region. The strong teeth occur on the hinge-line, and they project anteriorly and dorsally. The middle part of the umbo is raised, and the muscle scars occur on it. They extend anteriorly for half the length of the shell along the floor of the ventral valve. The scar is bounded laterally by two ridges which unite anteriorly to a fold. The fold takes the counterpart for the external sulcus of the valve. A small median ridge is present between the teeth, supporting the adductor scars and extending anteriorly about half the shell-length. A number of minute pits are observed on the walls of the umbonal cavities. The anterior part of the valve is ornamented with fine radial costae and concentric growth-lines.

Remarks.—HAYASAKA (1960) identified *Neospirifer fasciger* from the member of the Middle Permian Kanokura formation in the southern Kitakami district. The Kitakami specimens are poorly preserved as equally as the Mizukoshi specimens, therefore it is difficult to compare critically with each other. However both specimens are quite alike in general shell-shape, size and surface ornamention, although the former specimens have a more transversely elongate shell and more distinct fasciculation of costae than in the latter.

Neospirifer sp. described by SHIMIZU (1961) from the Middle Permian Takauchi formation of the Permian Maizuru group of Kyoto Prefecture is somewhat similar to *Neospirifer fasciger* in its shape and surface ornamentation, but it is too incomplete for the comparison.

NODA (1956) described *Spirifer moosakhailensis* and *S.* cf. *moosakhailensis* from the Upper Permian Toman formation of eastern Manchuria, to which the Mizukoshi specimens show a close resemblance in the surface ornamentation. HAYASAKA (1960) pointed out that the specimens of *Neospirifer moosakhailensis* (DAVIDSON) reported from the various regions of Asia are referable to *Neospirifer fasciger*.

Genus *Spiriferella* TSCHERNYSCHEW, 1902

Type-species.—*Spirifer saranae* de VERNEUIL, 1845

Spiriferella keilhavii (von BUCH)

Pl. 9, figs. 4-9; Pl. 10, figs. 1-7

1846. *Spirifer keilhavii* v. BUCH. Abhandl. K. Akad. Wissen. Berlin, p. 74, fig. 2a and b.

1931. *Spiriferella keilhavii*, GRABAU. Natural History of Central Asia, Vol. 4, pp. 164-168, pl. 20, figs. 9a-c; pl. 21, figs. 1, 2a-c, 3, 4, 5.

1955. *Spiriferella keilhavii*, DUNBAR. Meddelelser om Grønland, Bd. 110, Nr. 3, pp. 139-147, pl. 25, figs. 1-9; pl. 26, figs. 1-11; pl. 27, figs. 1-14.

Material.—More than fifteen specimens are available, but no complete shell has been obtained. Most of them are internal moulds. The followings are better preserved specimens. GK-D 31011 (Pl. 9, figs. 4a-c), GK-D 31012 (Pl. 9, figs. 5a-c, 6b), GK-D 31013 (Pl. 9, figs 6a, c), GK-D 31014 (Pl. 9, figs. 7a, b), GK-D 31015 (Pl. 9, fig. 8), GK-D 31016 (Pl. 9, fig. 9), GK-D 31017 (Pl. 10, figs. 1a, b), GK-D 31018 (Pl. 10, fig. 2), GK-D 31019 (Pl. 10, figs. 3a-d), GK-D 31020 (Pl. 10, fig. 4), GK-D 31021 (Pl. 10, fig. 5), GK-D 31022 (Pl. 10, fig. 6), GK-D 31023 (Pl. 10, fig. 7)

Description.—The shell is biconvex, moderate to large in size, and is laterally elliptical or subpentagonal in outline. The ventral umbo is moderately incurved.

The hinge-line is straight and is slightly shorter than the greatest width of the shell. The cardinal extremities are rounded or bluntly pointed. The interarea is high and distinct, and broad delthyrium is present beneath the elevated beak. The immature shells have the greatest width at the hinge-line and form a little laterally elongate outline with the ratio of approximately one and a half times to one.

In the ventral valve, a broad and shallow median sulcus opens anteriorly. Its transverse profile is slightly and uniformly concave. There is no median plication in the sulcus. Two or three sulcal plications are faintly recognizable in some specimens. Five to seven broad and round-topped lateral plications are present on each side of the sulcus. The inner two occasionally bifurcate near the anterior extremity. Thus the plications are usually simple.

The dorsal valve has a slightly curved beak with nearly straight shoulders. The median fold is low and usually bears a pair of distinct and broad ribs which bifurcate near the anterior margin. Between them is present a median groove which anteriorly opens and becomes deeper and broader.

The surface of the shell is ornamented with numerous, very fine growth-lirae and the longitudinal lirae. There are three to five growth-lirae in the space of one mm near the anterior margin. In addition minute pustules arranged in regular rows, two to three per one mm, are rarely detected in the anterior part of some specimens.

Measurements of four specimens are as follows (in mm):

	1	2	3	4
length	55	45	40	35
width	65	50	60	45
thickness		25		
hinge-line	50	40		30

The posterior part of the shell is extremely thick and consists of thick fibrous shell-growth as seen in figure 4c of Plate 9.

Internally the ventral valve has two strong teeth which are disposed on the hinge-line and project anteriorly about a sixth the length of the shell. The muscular area is elongate, is distinctly striated longitudinally and has a median low ridge extending the whole length of the area. Numerous, radially arranged minute pits are present on the inner walls of the ventral valve near the umbo. The interior part of both wings are ornamented with the groove and costae which take the counterparts for those of the external surface.

Remarks.—The Mizukoshi specimens are represented by the external moulds and the internal ones so called *steinkern*. *Spiriferella keilhavii* and allied species have been known from many localities of the Asiatic region including Russia and the Arctic area. The Mizukoshi specimens are identical with *S. keilhavii* (GRABAU, 1931) from the Permian Jisu Honguer Limestone of Mongolia in characteristic features of every growth-stage. However we have little information on the internel characters and the minute surface details of the Mongolian specimens.

DUNBAR (1955) gave detailed descriptions and remarks on *Spiriferella keilhavii* from the Upper Permian (probably Kazanian) of East Greenland on the basis of a large number of excellent specimens. Due to the incompleteness of the shell of the Mizukoshi specimens the comparison on the shape can not be made, but their internal and external characteristics are well agree with those of the Greenland specimens. Furthermore the delicate external structures shown by DUNBAR on the latter

are clearly observed similarly in some of the Mizukoshi specimens. DUNBAR distinguished four groups in the Greenland specimens based on the mode of plications of the valves. Most of the Mizukoshi specimens seem to belong to his Form A which is characterized by broad simple ribs and a nonplicated sulcus, but some of them have slendar sulcal costae and bifurcated lateral costae near the anterior margin.

Spiriferella previously known in Japan is only *Spiriferella* cf. *saranae* (VERNEUIL) recorded by HAYASAKA (1925) from the *Lyttonia* horizon of the Kanokura formation of the Kitakami massif. It is represented by an incomplete ventral valve, therefore the detailed comparison is impossible.

Family *Linoproductidae* STEHLI, 1954

Subfamily *Linoproductinae* STEHLI, 1954

Genus *Linoproductus* CHAO, 1927

Type-species.—Productus cora d'ORBIGNY, 1842

Linoproductus cf. *lineatus* (WAAGEN)

Pl. 10, figs. 8-14

Compare.-

1884. *Productus lineatus* WAAGEN. Palaeontologia Indica, ser. 13, vol. 1, pt. 4, pp. 673-677, pl. 66, figs. 1, 2.

1922. *Productus cora*, HAYASAKA. Sci. Rep. Tohoku Imp. Univ., 2nd ser., vol. 6, no. 1, pp. 86-93.

1927. *Linoproductus lineatus*, CHAO. Palaeontologia Sinica, ser. B, vol. 5, fasc. 2, pp. 129-132, pl. 15, figs. 25-27.

1931. *Productus* (*Linoproductus*) *lineatus*, GRABAU. Natural History of Central Asia, vol. 4, pp. 273-295, pl. 29, figs. 25-27.

Material.—There are more than twenty specimens which I describe under this heading. Unfortunately they have been strongly deformed. The followings are better preserved specimens among them. GK-D 31024 (Pl. 10, figs. 8a–c), GK-D 31025 (Pl. 10, figs. 9a–c), GK-D 31026 (Pl. 10, figs. 10a, b), GK-D 31027 (Pl. 10, figs. 11a, b), GK-D 31028 (Pl. 10, fig. 12), GK-D 31029 (Pl. 10, fig. 13), GK-D 31030 (Pl. 10, fig. 14)

Description.—The shell is longitudinally oval or subpentagonal in outline with the greatest width at the hinge-line. The umbo is incurved over the hinge. The dorsal valve is slightly concave. The ventral valve is ornamented with sharp longitudinal costellae which increase in number by bifurcations and by many intercalations of new ones. There are usually eight to eleven costellae in the space of five mm in the adult shells and about six at fifteen mm from the umbo in the young shells. The sulcus is weakly indicated in the umbonal region of some specimens. The spines or spine bases were not observed. The dorsal valve possesses costellae which in turn are sometimes crossed by fine rugae.

Remarks.—The characteristics of the Mizukoshi specimens, although they are strongly deformed, are the short hinge-line, very small ears, distinct costellae, small number of rugae on the ventral valve, and the absence of the clear indications of distinct spines or spine bases. In these respects they are most similar to *Linoproductus lineatus* which was described first by WAAGEN (1884) from the *Productus* limestone of the Salt Range and was later transfered to the genus *Linoproductus* by CHAO (1928) with some emendation of the specific diagnosis. Especially the outline and the surface ornamentation of the shell strongly suggests that they are probably

referable to the species.

The Mizukoshi specimens are also somewhat similar in the external configurations to the holotype of *Linoproductus cora* (d'ORBIGNY), the type-species of *Linoproductus*, from the Wolfcampian of Bolivia, but differs in its smaller size than the latter.

Three Permian species of *Linoproductus* has been known from Japan. One of them, *L. cora* reported by HAYASAKA (1925) and HAYASAKA and MINATO (1956) from the Middle Permian Kanokura formation differs from the Mizukoshi specimens in the shape of the shell. The other two are *L. kiangsiensis* and *L. interruptus* described by SHIMIZU (1961) from the Upper Permian Maizuru group in which they are associated with the *Lepidolina toriyamai* fauna. They have a uniformly smaller and more elongate shell and better developed ears than the Mizukoshi specimens.

Faunal affinities in other areas

The brachiopod faunas in Japan which contain the identical or closely allied species to the Mizukoshi fauna have been known from the Middle Permian of the Kitakami massif, northeastern Japan, and the Upper Permian Maizuru group of Kyoto Prefecture.

Neospirifer fasciger from the Kitakami massif, according to HAYASAKA (1960), occurs from the shale formation of the Middle Permian Kanokura group near Kesennuma in association with *Derbya magnifica* LICHAREW, *Meekella gigantea* HAYASAKA, *Hamletella kitakamiensis* HAYASAKA, *Productus* (*Dictyoclostus*) *semireticulatus* MARTIN, *Prod.* (*Dict.*) *gratiosus* WAAGEN, *Prod.* (*Horridonia*) *horridus* SOWERBY, *Productella patula* GIRTY, *Lyttonia richthofeni* KAYSER em. HAYASAKA, ?*Spirifer lyra* KUTORGA, *Martinia* spp., and *Spiriferina cristata* SCHLOTHEIM. He stated that this fauna is identical with those of other localities of the same area formerly recorded by him (1922, 1925).

MINATO, et al. (1954) subdivided the Kanokura group into two parts, the lower, the Kattisawa formation, and the upper, the Iwaizaki formation. They recognized two fossiliferous beds in the Kattisawa formation, the one in its lower part and the other in its upper part, and recorded from those beds many brachiopods including *Derbya magnifica*, *Lyttonia richthofeni*, *Marginifera* ? *gratiosa*, *Martinia semiplana*, and *Spiriferina cristata*, most of which are in common with those of the fauna of the *Neospirifer fasciger* beds of HAYASAKA. Since no remark on the correlation between the brachiopod beds of MINATO, et al. and HAYASAKA has been given, it is uncertain to us which one of the two beds of the Kattisawa formation is equivalent to HAYASAKA's shale formation. However high probability of the equivalency of the upper bed of MINATO et al. to HAYASAKA's shale formation is suggested by the occurence of the identical species between the both faunas and by that the upper bed consists mainly of shale which is well traceable.

Spiriferella cf. *saranae* which closely resembles *Spiriferella keilhavii* from the Mizukoshi formation has been known not only from the shale formation by HAYASAKA (1925) but also from the two horizons mentioned above of the Kattisawa and the upper end of *Yabeina-Lepidolina* limestone of the Iwaizaki formation.

Thus the Kitakami area the identical or similar species to the Mizukoshi fauna

are known from the underlying beds directly beneath or 50 to 100 m below the Iwaizaki Limestone and the limestone itself.

The Iwaizaki Limestone has been considered by TORIYAMA (1952) as belonging to the *Lepidolina* zone on the occurence of several species referred with some doubt to *Lepidolina* from the limestone. Whereas MINATO et al. (1954), being wary of explicitly designating, stated that the limestone is probaly referable to both or either of "the *Yabeina* zone"* and/or the *Lepidolina* zone in the term of the designation by KANMERA (1952). Anyhow, of the species described by TORIYAMA from the limestone *Lepidolina* ? sp. B and *L.* ? sp. C are very similar, if not identical to *L.* cf. *toriyamai* of the limestone of the Mizukoshi formation which lies at about 300 m below the brachipod bed under consideration. It is therefore, highly probable that the Iwaizaki and the Mizukoshi formation are equivalent in age to each other and that *Neospirifer fasciger* and *Spiriferella keilhavii* fauna has a somewhat wide stratigraphic range including the *Lepidolina toriyamai* zone. This view is supported also by the facts known in the Toman formation of the southeastern Manchurian border (NODA, 1956) and the Chanadalazskaya formation of the Sikhote-Alin range (YELISEYEVA, 1959).

HAYASAKA (1960) noted the occurence of an unnamed species of *Neospirifer* from the Permian black slate formation of Takakurayama, central Abukuma plateau but did not describe it.

SHIMIZU (1961) described a number of brachiopod fossils from the Permian Maizuru group. He discriminated two distinct faunas, the Kawahigashi and the Takauchi fauna, and pointed out that the species of both faunas are generally smaller in size than the types of the respective species. *Linoproductus kiangsiensis* and *L. interruptus* of the Kawahigashi fauna are very different from *L.* cf. *lineatus* of the Mizukoshi formation. *Neospirifer* sp. of the Takauchi fauna is somewhat similar to the *Neosp. fasciger* of the Mizukoshi formation. According to SHIMIZU (1961, 1962) and SHIMIZU, NAKAZAWA, SHIKI, and NOGAMI (1962), these faunas are not directly associated with the *Lepidolina toriyamai* fauna, and each of them is restricted to a different facies, respectively. However, they ascertained that the Kawahigashi fauna is stratigraphically equivalent to the *L. toriyamai* fauna and the Takauchi fauna comes from the lower horizon than that of the Kawahigashi fauna.

Outside the Japanese Islands there have been known several brachiopod faunas which include the identical or the closely allied species to those of the Mizukoshi formation.

GRABAU (1931) described many brachiopod species from the Middle Permian Jisu Honguer Limestone of Mongolia. Of them, *Spiriferella keilhavii, Productus lineatus,* and *Spirifer moosakhailensis*(=*Neospirifer fasciger*) are identical with those of the Mizukoshi formation.

The fauna from the upper part of the Toman formation of southeastern Manchurian border NODA (1956) includes *Sp.* cf. *moosakhailensis* which is hardly distinguishable from *Neospirifer fasciger* under consideration. In addition *Spiriferella* sp. is very similar to the unnamed species of the genus of the Mizukoshi formation. NODA correlated the Toman formation with the Upper Permian Kuma formation (KANMERA, 1952) of Kyushu on the occurence of comparable species of *Yabeina-Lepidolina* fauna from the lower part of the formation.

*They did not show any species of *Yabeina* from the limestone, so it is uncertain to us by what species the *Yabeina* zone is designated.

The Permian formation of the Toman area extends to the Sikhote-Alin range. FREDERICKS (1916) described some species of *Spiriferella* from the province of Vladivostok, of which *Spiriferella raja* resembles *Sp. keilhavii* of the Mizukoshi formation in the external characteristics. YELISEYEVA (1959) recorded *Neospirifer fasciger*, *Neospirifer moosakhailensis* (=*N. fasciger*), *Spiriferelle raja*, and *Sp. litha* from the Chanadalazskaya formation of the lowermost part of the Upper Permian together with *Lepidolina ussurica*, *Misselina lepida*, *Misselina lettensis*, and *Rauserella ellipsoidalis*. Although further comparison of the species of both the Chanadalazskaya and the Mizukoshi formation is impossible at present, the similar fact is thus known also in the Sikhote-Alin.

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Juichi YANAGIDA

Brachiopods from the Upper Permian Mizukoshi Formation, Central Kyushu

Plates 8 - 10

Plate 8

Explanation of Plate 8

(Figures of natural size, unless otherwise stated)

Figs. 1–7. *Neospirifer fasciger* (KEYSERLING) ..... page 71

1a, c, d. Ventral, posterior, and dorsal views of a "steinkern", GK-D 31001.

1b. Rubber cast of ventral side of the preceding specimen.

2a, c, d. Ventral, posterior, and dorsal views of a "steinkern", GK-D 31002.

2b. Rubber cast of ventral side of the preceding specimen, showing deep delthyrial cavity and strong median ridge.

3a, b. Ventral and posterior views of a plaster cast, GK-D 31003.

4a, c, d. Dorsal, ventral, and posterior views of a "stinkern", GK-D 31031.

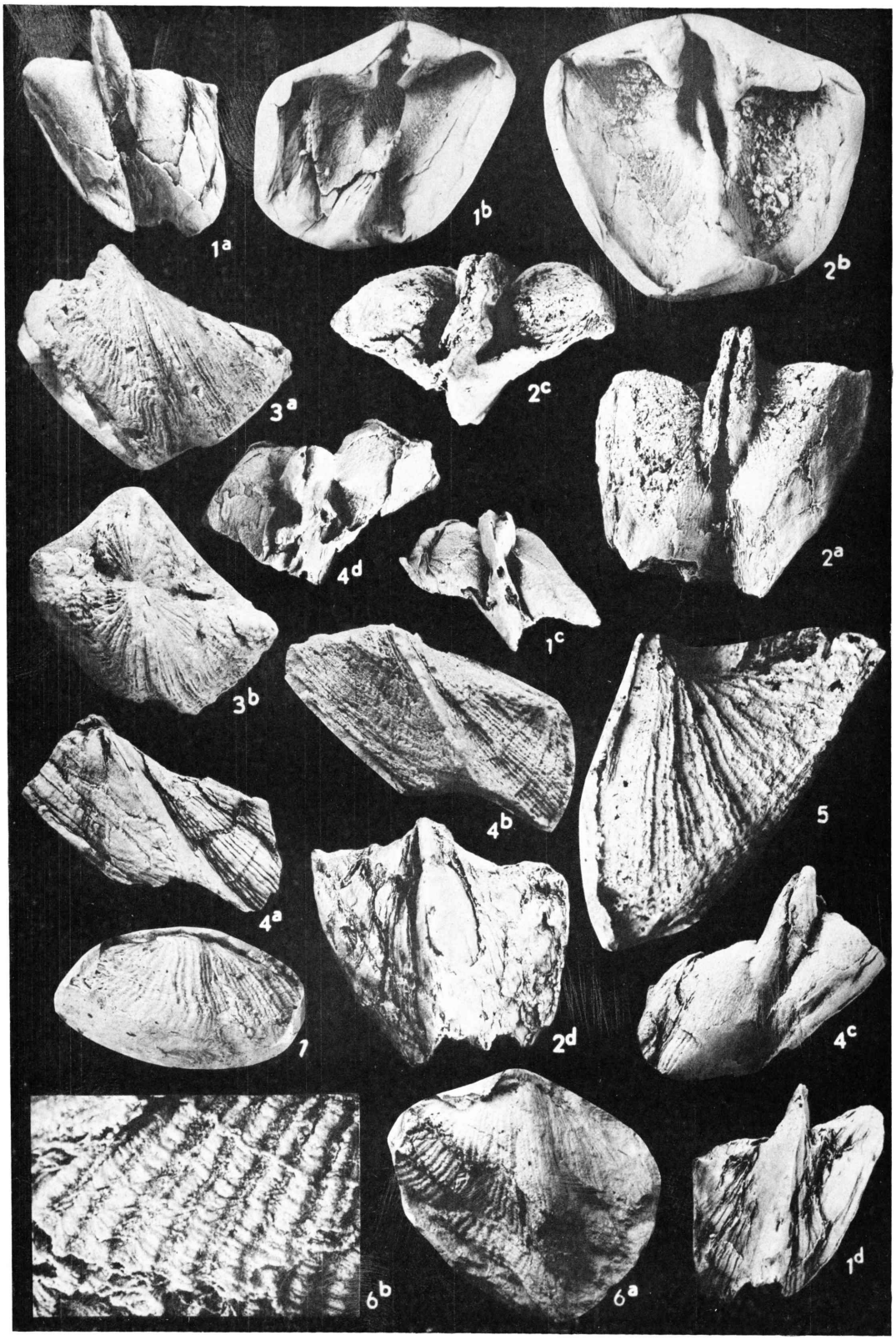
4b. Plaster cast of dorsal side of the preceding specimen.

5. Plaster cast of an incomplete ventral specimen, GK-D 31004, showing the fasciculation of ribs, x 2.

6a, b. Dorsal and partly enlarged (x 4.5) views of a plaster cast, GK-D 31005, showing details of the ornament.

7. Plaster cast of an incomplete ventral specimen, GK-D 31006.

Photos by YANAGIDA, with whitening.



J. YANAGIDA: Brachiopods from the Upper Permian Mizukoshi Formation

Plate 9

Explanation of Plate 9

(Figures of natural size, unless otherwise stated)

Figs. 1–3. *Neospirifer fasciger* (KEYSERLING) ..... page 71

1. Enlargement, x 2.5, of the exterior of the ventral valve of an incomplete specimen, GK-D 31007, showing details of the ornament.
2. Ventral view of a plaster cast, GK-D 31008.
3. Dorsal view of a plaster cast, GK-D 31009.

Figs. 4–9. *Spiriferella keilhavii* (von BUCH) ..... Page 72

4a, b. Ventral and posterior views of a specimen, GK-D 31011.

4c. Enlargement, x 3.5, of the beak region of the ventral valve of the preceding specimen showing thick fibrous shell-growth.

5a–c. Vental, posterior and dorsal views of a "steinkern", GK-D 31012.

6a, c. Plaster cast and external mould (x 2.5) of a specimen, GK-D 31013.

6b. Rubber cast of ventral side of the preceding "steinkern" (Fig. 5).

7a, b. Plaster cast and external mould of an incomplete ventral specimen, GK-D 31014.

8. Plaster cast of an incomplete ventral specimen, GK-D 31015.

9. Ventral view of a deformed "steinkern", GK-D 31016.

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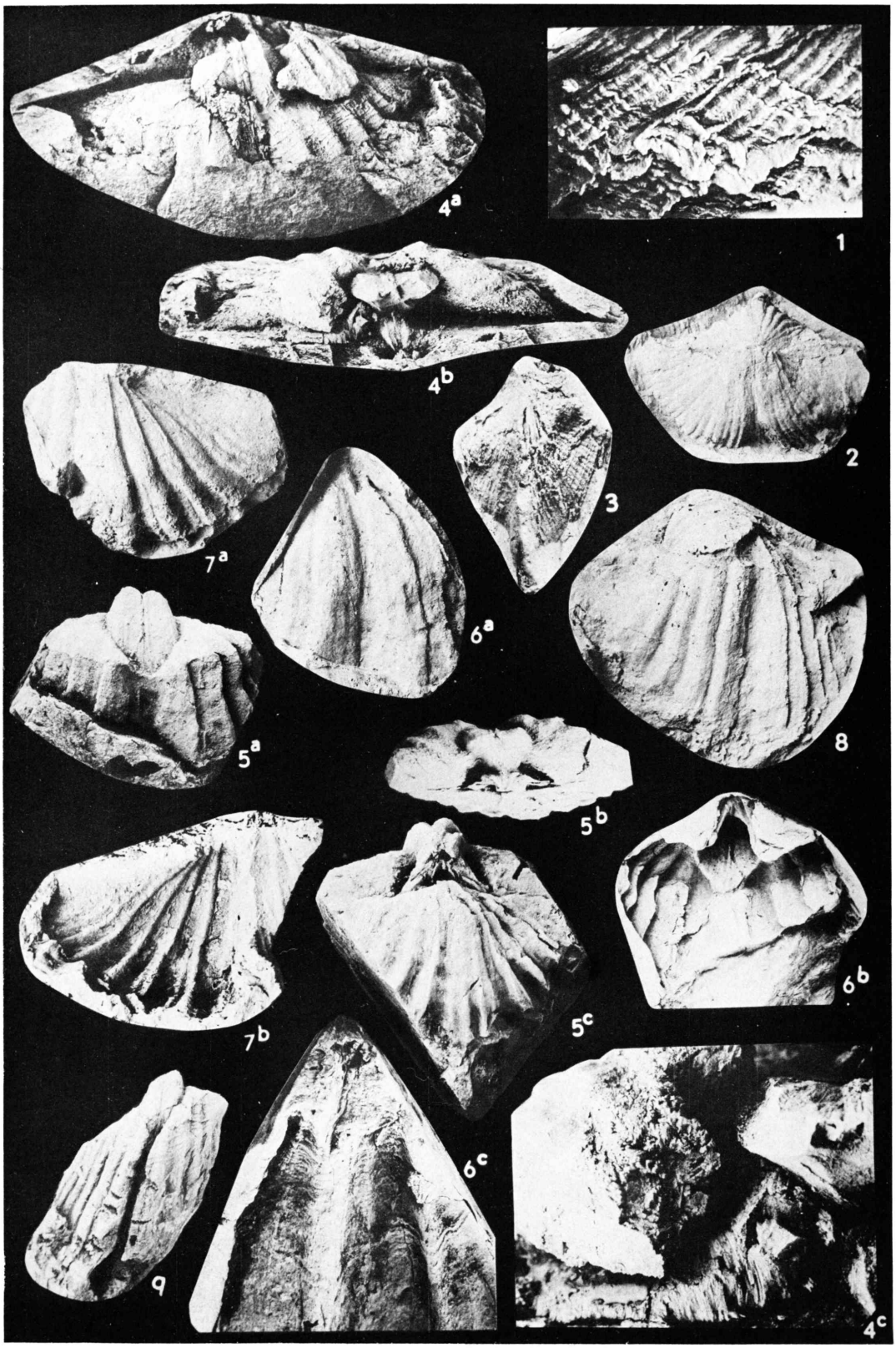


J. YANAGIDA: Brachiopods from the Upper Permian Mizukoshi Formation

Plate 10

Explanation of Plate 10

(Figures of natural size, unless otherwise stated)

Figs. 1-7. *Spiriferella keilhavii* (von BUCH) ..... page 72

1a, b. Enlargement, x6, of a external mould, GK-D 31017, showing details of the ornament and a plaster cast of the same specimen.

2. External mould of an incomplete ventral valve, GK-D 31018.

3a-c. Ventral, posterior, and dorsal views of a "steinkern", GK-D 31019.

3d. Rubber cast of ventral side of the preceding specimen.

4. Largest specimen, GK-D 31020.

5. Ventral view of a laterally elongated "steinkern", GK-D 31021.

6, 7. Plaster casts of incomplete ventral specimens, GK-D 31022, and GK-D 31023.

Figs. 8-14. *Linoproductus* cf. *lineatus* (WAAGEN) ..... page 74

8a-c. Respectively ventral, side, and dorsal views of an incomplete specimen, GK-D 31024.

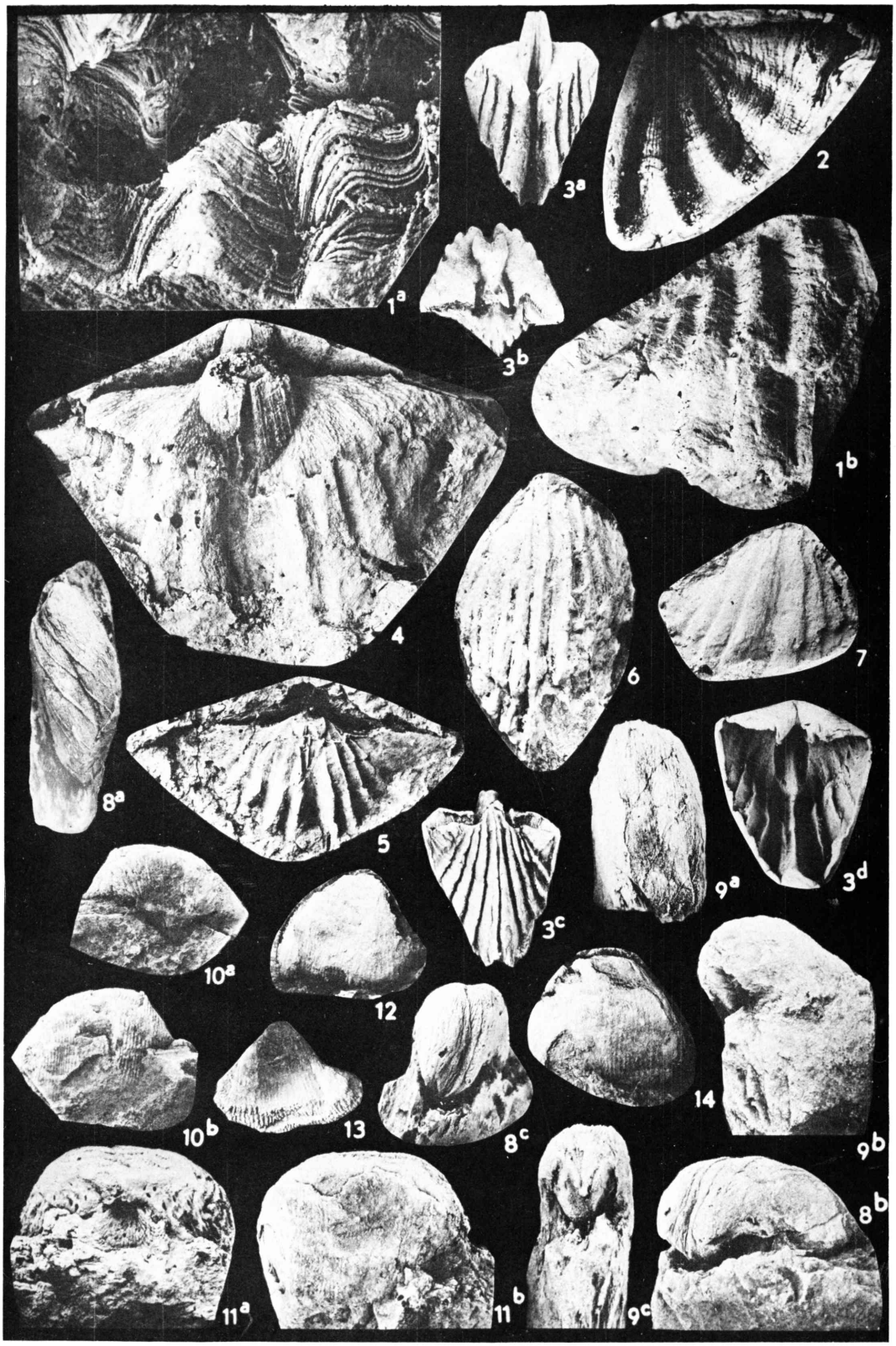
9a-c. Respectively ventral, side, and dorsal views of an incomplete specimen, GK-D 31025.

10a, b. Dorsal and ventral views of an incomplete specimen, GK-D 31026.

11a, b. Dorsal and ventral views of an incomplete specimen, GK-D 31027.

12, 13, 14. Incomplete ventral valves, GK-D 31028, GK-D 31029, and GK-D 31030, showing the ornament.

Photos by YANAGIDA, with whitening.



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