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Permian Bivalves of Japan

By

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Abstract

Permian bivalve molluscs of Japan shed interesting new light on the paleontological composition of the youngest, post-fusulinid, marine faunas of the highest Paleozoic, and the bivalves tend to bridge the gap between the uppermost Permian and the lowest Triassic occupied in most regions of the world by a hiatus. However, there is a noteworthy break, even in Japan, between the Permian and Triassic systems where there are no bivalve species in common between the Permian and Triassic.

Ninety-six species belonging to 46 genera of bivalves are distinguished in the Japanese Permian. Among these, 58 species, of which 18 are new, are described in this paper. *Towapteria*, *Ensipteria*, *Tambanella*, *Hayasakapecten*, and *Gujocardita* are proposed herein as new genera, and *Permoperna* is presented as a new subgenus of *Waagenoperna*.

It is worthy of note that the bivalves did not decrease in number and diversity during the late Permian, in contrast to some other invertebrates, and that the late Permian Gujo Formation contains a mixed fauna of Permian and Triassic aspect. Some Mesozoic types, such as *Neoschizodus*, *Costatoria* and *Waagenoperna*, appeared in the middle Permian Kanokura Series.

The early Triassic fauna, comprising 45 species in 17 genera, is rich in cosmopolitan species, and not so differentiated as are the Permian forms. A strong diversification of the bivalves did not take place until late Triassic time.

Clearly, a marked change occurred among the bivalves at the close of the Permian. World changes in paleogeography and consequent climatic effects are considered to be a probable cause of the Permian extinctions, but these extinctions affected the bivalves less than most other Permian invertebrates, such as the brachiopods and cephalopods.

The Japanese Permian is divisible into three sedimentary regions or facies, eugeosynclinal, miogeosynclinal and carbonate shelf facies. Eugeosynclinal and carbonate shelf facies are characterized by fusuline fossils, whereas the miogeosynclinal facies contains various kinds of molluscs and brachiopods. In many places, the late Permian rocks are represented by thick shales and sandstones and frequent conglomerate beds. These sediments are considered to have been accumulated in a relict, inland sea during the final stage of geosynclinal development.

Fusulinid zonation is well established in the carbonate shelf and eugeosynclinal terrains. The bivalves are mostly confined to the miogeosynclinal facies of the southern Kitakami massif where a three-fold division of the Permian is herein adopted. These divisions are the Sakamotosawan (P 1), the Kanokuran (P 2), and the Toyoman Series (P 3), in ascending order. They roughly correspond to the *Pseudoschwagerina morikawai* zone to the *Pseudofusulina ambigua* zone (or

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Misellina claudiae zone), the *Parafusulina kaerimizensis* zone (or *Neoschwagerina simplex* zone) to the *Yabeina globosa* zone (or *Yabeina shiraiwensis-Lepidolina toriyamai* zone), and a post-*Yabeina* zone, respectively. Bivalve molluscs from all these divisions are considered.

Introduction

An important biological revolution took place at the close of the Paleozoic era. The span of time involved in the replacement of Permian by Triassic biotas is as yet unknown, but clearly it was geologically short. During late Permian time, approximately fifty percent of all animal families known to be then living became extinct (NEWELL, 1967 b). The resulting strong contrast between Permian and Triassic fossil faunas is very great and this contrast doubtless is accentuated wherever a hiatus separates the two systems (NEWELL, 1967a).

Some of the Permian sequences of Asia are of exceptional interest in this connection because they have been well subdivided by rapidly evolving fusuline faunas and are thought by many to range higher than the most complete sequences of America and Europe.

Much semantic confusion results from the partition of local sequences into two or three major divisions as Lower, Middle and Upper Permian, because these are employed with disparate biostratigraphic and time values in different parts of the world. In this report, we shall employ a biostratigraphic framework based on fusuline zones.

Most families of bivalves have been conservative in their evolution throughout their history. For example, many Permian genera originated during the early Carboniferous, enduring with only insignificant changes more than 100 million years. Yet, only a few of these survived into the earliest Triassic system, the rocks of which are notable for their curious depauperate but cosmopolitan benthonic faunas and their ceratite swarms.

In Japan, a number of bivalve genera which elsewhere characterize the Triassic appear high in the Permian in association with brachiopods and fusulines of Permian affinities. Especially the Gujo Formation of Kyoto Prefecture, younger than the *Yabeina-Lepidolina* zone, is exceptional for the large number of Triassic elements among what is otherwise an assemblage of Permian brachiopods, bryozoans and bivalves. Stratigraphic position and faunal content suggest to us a geologic age quite high in the Permian, perhaps as high as any Permian faunas thus far known.

The Japanese Permian lies within the northeastern extension of the Tethyan province. Our discovery here of several bivalve genera characteristic of the Permian cold-water Gondwana province of eastern Australia is unexpected and suggests deep-water deposition or Permian climatic oscillations in Japan.

Previous Studies of Permian Bivalves in Japan

The study of Permian bivalves in Japan has been neglected as compared with other invertebrate fossils such as fusulines, corals, and brachiopods. The chief reasons for this neglect are the scarcity of fossils, poor state of preservation, and consequently their diminished biostratigraphical utility. However, as a matter of fact, Permian bivalves are not uncommon, although their occurrence is almost limited in distribution to mudstones and sandstones. Pioneer studies were made by HAYASAKA (1923, 1924, 1925) mainly on collections from the southern Kitakami massif, northeast Japan, where the clastic rocks of shallow shelf seas are widely distributed. In later years fossil pelecypods have been neglected.

In 1951, ICHIKAWA described a rather unusual community of fossil invertebrates from the high Permian of Shikoku Island, southwest Japan, consisting of bivalves, gastropods and scaphopods. Other major groups, such as brachiopods, corals, and fusulines, that flourished elsewhere in Japan during the Permian period, were lacking in his collections. Later NAKAZAWA (1959, 1960) noted the occurrence of Permian myophoriids and bakevelliids in the Maizuru Belt, southwest Japan. More recently, MURATA (1964) described Aviculopectinidae from the southern Kitakami massif, and HAYASAKA (1967a, b) added several other bivalve species.

Those of the Takakurayama Group in the Abukuma massif were briefly described by KOBIYAMA (1961), and recently by YANAGISAWA (1967) together with many other invertebrate fossils.

A considerable number of pelecypods have been listed from the southern Kitakami massif but none of these, excepting those published by HAYASAKA and MURATA, was described. Consequently, much work remains to be done on the bivalve faunas of the Permian of Japan.

Permian System in Japan

Sedimentary Provinces

Three major sedimentary provinces can be distinguished in the Permian sediments in Japan. They are eugeosynclinal, miogeosynclinal and carbonate shelf facies (Figure 1).

The first facies is represented by thick shales, cherts, and basic volcanic tuffs. Sandstones are also important. Limestones usually are intercalated as relatively thin lenticular masses but in some places are as thick as several hundred meters. The total thickness is not less than ten thousand meters. Probably most of Japan was covered by eugeosynclinal deposits of Permian age. Fossils are extremely rare in these deposits excepting fusulinids in sparse limestones.

The miogeosynclinal sediments* are composed of terrigenous and carbonate rocks: shales, sandstones and limestones, with subordinate conglomerates. Cherts and basic tuffs are absent or subordinate. Molluscs and brachipods are mainly limited to the clastic rocks of this facies, fusulines and corals to the carbonate rocks. The thickness attains several thousand meters. The Permian of southern Kitakami massif, Abukuma massif and Hida massif provide examples of miogeosynclinal deposits.

The carbonate shelf facies is made up almost exclusively of limestone units up to several hundred meters thick. These rocks are found in southwest Japan in Omi, Akasaka, Ibuki, Atetsu, Taishaku and Akiyoshi. The limestone masses were once considered to be remnants of a large thrust sheet that moved from the north (KOBAYASHI, 1940) but recent studies indicate that they are more or less autochthonous (TORIYAMA, 1954; MITSUNO, 1963; MIYAMURA, 1966). It has been suggested that they accumulated on submarine volcanic mounds as carbonate banks (YABE, 1958). Fusulines are prolific in this facies.

In many places, the uppermost part of the Permian of both eu- and miogeosynclinal facies is composed of rather thick, monotonous black shales or argillites accompanied by frequent conglomerates bearing granitic pebbles. These sediments are considered to have accumulated in rather rapidly sinking basins in a final stage of geosynclinal development. The depth of waters may have varied greatly. The Toyoma Formation in the southern Kitakami massif, the upper part (including the Gujo Formation) of the Maizuru Group in the Maizuru Belt, the Katsura Formation in Shikoku, and the upper member of the Kuma Formation in Kyushu are referred to this facies. Predominant fossils are brachiopods, bivalves and gastropods.

Fusulinid Zonation

Most of the Permian fossils in Japan are found in shelf and miogeosynclinal deposits. Two stratigraphic arrangements have been developed for these sequences and the correlation of the two is not settled.

The miogeosynclinal sediments are typically developed in the southern Kitakami massif (MINATO *et al.*, 1954; MINATO and KATO, 1965):

* The miogeosynclinal sediments, as distinguished in Japan, are based on lithofacies. They are not tectonic units. Mostly they are considered to have been deposited in basins on a mobile island shelf within the eugeosyncline. True miogeosynclines comparable to those of North America occupying areas marginal to a continent apparently were not developed in the region of the present Japanese Islands.

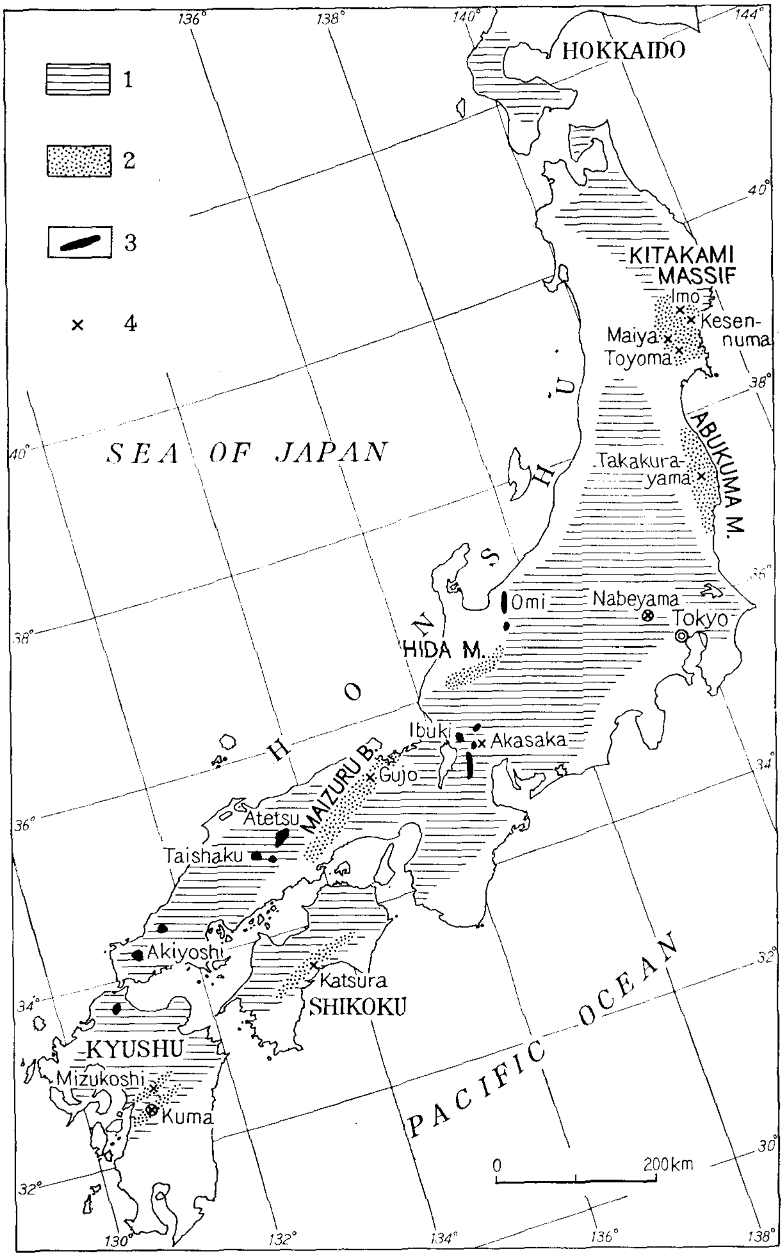

Fig. 1. Schematic lithofacies map of the Permian in Japan, and main fossil localities of bivalves (×).

1. Eugeosynclinal facies, 2. "Miogeosynclinal" facies and relict sea facies, 3. Carbonate shelf facies.

Toyoma Subsystem	without fusulinids	
Yukisawa Subsystem		
Kanokura Series	Iwaizaki Stage	*Yabeina* zone
		Neoschwagerina zone
	Kattisawa Stage	*Parafusulina* zone
Sakamotosawa Series	Kabayama Stage	*Pseudofusulina* zone
	Kawaguch Stage	*Pseudoschwagerina* zone

Thus, a two-fold division into subsystems was based on the presence or absence of fusulinids, the lower part containing fusulinids, whereas these fossils are absent in the upper part (YABE, 1948).

TORIYAMA (1963) divided the Japanese Permian into four series based on fusulinid ranges in the limestone facies in each type area.

Kuma Series: *Yabeina yasubaensis-Lepidolina toriyamai* zone.

Akasaka Series: *Neoschwagerina craticulifera-Verbeekina verbeeki* zone

Yabeina globosa-Y. shiraiwensis subzone
Neoschwagerina margaritae-N. douvillei subzone
Neoschwagerina craticulifera subzone

Nabeyama Series: *Parafusulina kaerimizensis-Neoschwagerina simplex* zone

Neoschwagerina simplex subzone
Parafusulina kaerimizensis subzone

Sakamotozawa Series: *Pseudoschwagerina morikawai-Pseudofusulina vulgaris* zone.

Pseudofusulina vulgaris subzone
Pseudoschwagerina morikawai subzone

TORIYAMA's Sakamotozawa Series is more restricted than MINATO's since he confined the series to the *Pseudoschwagerina* zone.

Later MIKAMI (1965) and KANMERA and MIKAMI (1965) distinguished the following fusulinid zones and subzones in the Sakamotozawa Group at the type locality of the Sakamotosawa Series of MINATO *et al.*, as follows:

Upper Member

5. *Pseudofusulina ambigua* subzone
4. *Pseudofusulina fusiformis* subzone
3. *Pseudofusulina vulgaris* subzone

Lower Member

2. *Monodiexodina longsonensis* zone
1. *Zellia nunosei* zone

The lower Sakamotozawa (Sakamotosawa) Member corresponds to the Kawaguchi Stage of MINATO *et al.*, and the Upper one to the Kabayama Stage.

Reviewing thoroughly the occurrences of fusulinids in Japan, TORIYAMA (1967) recently emended his former division of the Japanese Permian, and classified the Permian into the following stages and species zones:

Upper Permian

Kuman Stage

Yabeina globosa zone = { *Lepidolina toriyamai* zone / *Yabeina shiraiwensis* zone }

Middle Permian

Akasakan Stage
Neoschwagerina margaritae zone
Neoschwagerina craticulifera zone
Nabeyaman Stage
Neoschwagerina simplex zone = *Parafusulina kaerimizensis* zone

Lower Permian

Sakamotozawan Stage
Pseudofusulina ambigua zone
Pseudofusulina vulgaris zone
Pseudoschwagerina morikawai zone

One of the unsettled problems is the correlation of the lower Kanokura Series (Kattisawa Stage) with the fusulinid zones. The lower Kanokura is represented by sandstones containing many brachiopods (the so-called *Lyttonia* fauna=*Leptodus*), and bivalves. An associated fusulinid is a cylindrical form, *Monodiexodina matsubaishi* (FUJIMOTO).

The upper Kanokura (Iwaizaki limestone) is characterized in the upper part by *Yabeina shiraiwensis* OZAWA, and in the lower half by *Codonofusiella* sp., *Pseudofusulina paramotohashii* MORIKAWA, *Schwagerina paraguembeli* MORIKAWA and others (MORIKAWA *et al.*, 1960). Although MINATO and KATO (1965) correlate these beds with the *Neoschwagerina* zone, the genus *Neoschwagerina* has not yet been found here. These beds are underlain conformably by *Monodiexodina*-bearing sandstones and shales.

The lower half of the Iwaizaki limestone is roughly correlated with the *Neoschwagerina* zone (*N. craticulifera* and *N. margaritae* zones of TORIYAMA), and the upper half with the lower *Yabeina globosa* zone, that is, *Yabeina shiraiwensis* zone. *Monodiexodina* is considered here as a facies fossil. In Kamiyasse, *Monodiexodina*-bearing sandstone is directly overlain by *Yabeina*-bearing limestone (MURATA, 1964).

We consider it highly probable that the upper half of the Kattisawa stage (or more correctly the lower Kanokura Formation) in places overlaps part of the lower part ("*Neoschwagerina*" zone) of the Iwaizaki Stage.

Another problem in Permian correlations is the stratigraphic position of the *Yabeina-Lepidolina* zone.

KANMERA (1951) proposed a *Lepedolina toriyamai-Yabeina yasubaensis* zone above the *Yabeina globosa* zone, which had been previously considered as the highest fusulinid zone. This view was once adopted by TORIYAMA (1963) who thought that the Toyoma Series belonged in this zone. The *Lepidolina-Yabeina* fauna commonly is found in the shelf deposits throughout Japan. This assemblage of fusulines generally lacks *Neoschwagerina** and contains the most advanced fusulinids, such as *Lepidolina toriyamai*.

The *Lepidolina-Yabeina* assemblage contains:

*******Lepidolina toriyamai* KANMERA
L. kumaensis KANMERA
Yabeina yasubaensis TORIYAMA
Y. shiraiwensis OZAWA
Y. columbiana (DAWSON)
Y. gubleri KANMERA
Pseudodoliolina gravitesta K.
Schwagerina pseudocrassa K.
Codonofusiella cuniculata K.

In the southern Kitakami massif, *Lepidolina gigantea* TORIYAMA and *L.* spp. are found directly above *Neoschwagerina*-bearing limestones and their correlatives. Consequently, the *Lepidolina* zone is considered synonymous with the *Yabeina* zone by MINATO and KATO (1965, pp. 21 22), and YABE (1966).

On the other hand, HANZAWA and MURATA (1963) insisted that the *Lepidolina* zone is lower than the *Yabeina globosa* zone, correlating the former with the *Neoschwagerina-Verbeekina* limestone of Akasaka. Unfortunately, it is not yet possible to determine the stratigraphical relations between the species *Lepidolina toriyamai* and *Yabeina globosa*. It is quite possible that there are two independent phylogenetic

* In the Maizuru belt one individual of *Neoschwagerina* cf. *margaritae* was reported in association with the *Lepidolina* fauna (NOGAMI, 1958).

** *Lepidolina multiseptata* (DEPRAT), type species of the genus *Lepidolina*, is considered to be inseparable from *Yabeina* by some experts (HANZAWA and MURATA, 1963; ISHII and NOGAMI, 1964) in which case *Lepidolina* would be a subjective synonym of *Yabeina*. But YABE (1964) insisted on retaining *Lepidolina* as a subgenus distinguished by a large proloculus. In any case, we believe that *Lepidoina toriyamai* is more advanced, phylogenetically, than species commonly classed in *Yabeina* s.s.

Cart 1. Correlation chart of fusulinid zones of the Permian.

Standard division by fusulinids (Toriyama) (1953)			(1967)			Akiyoshi Ls. (Toriyama, 1958)		Akasaka Ls. (Ozwa, 1927)	Akasaka Ls. Honjo (1959)		Kitakami Massif Morikawa *et al.* (1958), Kanmera & Mikami (1965)			Kitakami Massif Minato & Kato (1965)		Kyushu Kanmera (1953)		Outside Japan South China (Sheng, 1963)				U.S.A.	
											Toyoma Subsystem		no fusulinid					Lopingian	Changhsing Ls.	*Palaeofusulina* zone *Palaeofusulina*, *Reichelina*		Ochoan	
KUMAN	*Y. yasubaensis*-*L. toriyamai* zone		KUMAN	*Y. globosa* z.	*L. toriyamai* z.											Kuma Formation	*L. toriyamai*, *L. kumaensis*, *Y. yasubaensis*, *Codonofusiella*	Lopingian	Wuchiaoping Ls.	*Codonofusiella* zone *Codonofusiella*, *Reichelina*		Ochoan	
KUMAN	*Y. yasubaensis*-*L. toriyamai* zone		KUMAN	*Y. globosa* z.	*Y. shiraiwens.* z	*Yabeina* z.	*Yabeina shiraiwensis* zone	*Yabeina globosa* zone	*Yabeina globosa* zone		Kanokura Series	Iwaizaki Stage	*Y. shiraiwensis* zone *Y. shiraiw.*, *Verbeekina* sp. (*L. gigantea*)	*Lepidolina* zone	*Yab.* Z	Kuma Formation	*Y. yasubaensis* *Y. columbiana*	Yangsinian	Maokou Limestone	*Yabeina* zone *Yabeina*, *Neoschwagerina*, *Kahlerina*		Ochoan	
AKASKAN	*Ns. craticulifera*-*V. verbeeki* zone	*V. verb.*-*Y. shiraiw.* sz.	AKASAKAN	*Ns. margaritae* zone		*Neoschwagerina* z.	*Neoschwagerina douvillei* sz. *Verbeekina verbeeki* sz.	*Neosdhwagerina margaritae* zone	*Neoschwagerina* z.	*Gifuella douvillei* sz. *Y. ozawai* sz.	Kanokura Series	Iwaizaki Stage	*Psf. paramotohashii* zone *Pfs. paramot.*, *Pfs. kiyoharai* (*Neoschwag*, sp.) (*Monodiexodina matsubaishi*)	*Gifuella douvillei* zone *Neoschwagerina* zone	*Neosch.* Z			Yangsinian	Maokou Limestone	*Neoschwagerina* zone *Neoschwagerina*, *Verbeekina*, *Sumatrina* *Afghanella*, *Pseudodoliolina*, *Schwagerina*, *Pseudofusulina*,		Guadalupian	*Polydiexodina* zone
AKASKAN	*Ns. craticulifera*-*V. verbeeki* zone	*Ns. cratic.* sz.	AKASAKAN	*Ns. craticulifera* zone		*Neoschwagerina* z.	*Neoschwagerina craticulif.* sz.	*Neoschwag. craticulifera* zone	*Neoschwagerina* z.	*Ns. cratic.* subzone *Psf. ozawai* subzone	Kanokura Series	Iwaizaki Stage		*Neoschwagerina* zone	*Neosch.* Z			Yangsinian	Maokou Limestone			Guadalupian	*Polydiexodina* zone
NABEYAMAN	*Paf. kaerimizensis*-*Ns. simplex* zone	*Ns. simpl.* sz.	NABEYAMAN	*Paf. kaerimizensis* zone	*Ns. simplex* zone	*Parafusulina* zone	*Parafusulina kaerimizensis* subzone	*Cancellina nipponica* zone	*Minoella* zone *Parafusulina* zone		Kanokura Series	Kattisawa Stage	*Monodiexodina matsubaishi* zone	*Monodiexod.* zone *Parafus.* zone	*Paf.* Z			Yangsinian	Maokou Limestone	*Parafusulina* zone	*Cancellina* subzone *Cancellina*, *Yangchienia*, *Parafusulina*, *Verbeekina*	Leonardian	*Parafusulina* zone
NABEYAMAN	*Paf. kaerimizensis*-*Ns. simplex* zone	*Paf. kaeri-miz.* sz.	SAKAMOTOSAWAN	*Psf. ambigua* zone	*Mis. claudiae* z.	*Parafusulina* zone	*Pseudofusulina ambigua* sz.				Sakamotosawa Series	Kabayama Stage	*Pfs. ambigua* zone *Pfs. fusiformis* zone	*Psf. kraffti*	*Psf.* Z			Yangsinian	Chisia Ls.	*Parafusulina* zone	*Misellina* subzone *Misellina*, *Parafusulina*, *Schwagerina*	Leonardian	*Parafusulina* zone
SAKAMOTOZAWAN	*Pss. morikawai*-*Psf. vulgaris* z.	*Psf. vulgaris* sz.	SAKAMOTOSAWAN	*Psf. vulgaris* zone		*Pseudoschwagerina* zone	*Pseudofusulina vulgaris* sz.				Sakamotosawa Series	Kabayama Stage	*Pfs. vulgaris* zone	*Psf. vulgaris*	*Psf.* Z			Mapingian	Maping Limestone	*Pseudoschwagerina* zone		Wolfcampian	*Pseudoschwagerina* zone
SAKAMOTOZAWAN	*Pss. morikawai*-*Psf. vulgaris* z.	*Pss. morikawai* sz.	SAKAMOTOSAWAN	*Pss. morikawai* zone		*Pseudoschwagerina* zone	*Triticites simplex* sz.				Sakamotosawa Series	Kawaguchi St.	*Mon. longsonensis* zone *Zellia nunosei* zone	*Pss. schellwieni* *Pss.* sp.	*Pss.* Z			Mapingian	Maping Limestone			Wolfcampian	*Pseudoschwagerina* zone

series (IGO, 1960; ISHII, 1966):

Neoschwageirna margaritae-Yabeina katoi-Y. globosa, and *Neoschwagerina douvillei-Yabeina asiatica-Y. multiseptata-Lepidolina toriyamai.* These two series apparently are never associated with each other.

In the Kuma Formation in Kyushu, the type of the Kuman of TORIYAMA, *Lepidolina toriyamai-Yabeina yasubaensis* assemblage is found above *Y. yasubaensis-Y. columbiana* horizon bearing no *Lepidolina* (KANMERA, 1953). In the Maizuru Belt *L. toriyamai-Y. yasubaensis-Y. shiraiwensis* assemblage is in the same horizon with *Palaeofuslina* cf. *sinensis, Reichelina matsushitai* and *Colaniella* sp. or still higher horizon. The latter faunule is comparable with that of the Lopingian in South China (SHENG, 1963) and the Pamirian in Pamir (LEVEN, 1967).

We think that it is improbable that the *L. toriyamai* zone is older than *Yabeina globosa.* We are inclined to consider that the *Lepidoliua* zone (*Yabeina shiraiwensis* zone and *Lepidolina toriyamai* zone combined) is roughly contemporaneous with the *Yabeina globosa* zone, but ranges higher than the latter as presumed by TORIYAMA (1967). Correlation of fusulinacean zonation is given in chart 1. The Guadalupian Series of Texas, characterized by *Polydiexodina,* is correlated here with the *Neoschwagerina* zone. *Yabeina texana* from the top of the Capitanian (Upper Guadalupian) is so primitive in the genus that can hardly be considered to represent the *Yabeina* zone of Japan and China.

The *Yabeina* zone in South China containing *Yabeina gubleri, Y. hayasakai, Neoschwagerina doubillei,* etc., may be correlated with the lower part of the *Lepidolina* zone, that is, *Yabeina shiraiwensis* zone.

Stratigraphic Classification

Since most of the Permian bivalves are found in miogeosynclinal and shelf facies, it is convenient to adopt a stratigraphic division proposed by MINATO *et al.* (1954) for the bivalve faunas, that is, a three-fold divison, Sakamotosawa (P 1), Kanokura (P 2) and Toyama Series (P 3) in ascending order. The terms Lower, Middle and Upper Permian are not used, because these terms involve disparate usage by various authors and are also confused with the terms of a two-fold division employed in some countries.

The Sakamotosawa Series is divided into two stages, Kawaguchi below, and Kabayama, above. The Kanokura Series is divided into the Iwaizaki Stage, above, and Kattisawa Stage, below. These roughly correspond to the *Neoschwagerina craticulifera* zone to the *Lepidolina-Yabeina* zone above, and the *Neoschwagerina simplex-Parafusulina kaerimizensis* zone, below, of TORIYAMA (1967), respectively.

In this paper, a somewhat different division is used. The lower Kanokura

(P 21) Formation includes the sequence from the *Parafusulina kaerimizensis* zone to the *Neoschwagerina margaritae* zone, inclusive. The Upper Kanokura (P 2u) corresponds to the *Yabeina globosa* or *Y. shiraiwensis-Lepidolina toriyamai* zone. In the main fossil localities it is not certain whether the fossil horizons of the Lower Kanokura are correlated with the *Parafusulina kaerimizensis* zone, the *Neoschwagerina craticulifera*, or the *N. margaritae* zone.

The upper part of *Lepidolina-Yabeina* zone in Maizuru Belt and Kuma Formation of Kyushu may extend as high as the Toyoma Series as stated above.

Faunas of the Tenjinnoki and Shigejizawa units are of lower Kanokura (P 21) age; those of the Maizuru and Mizukoshi units are included in the upper Kanokura (P 2u), and the Gujo fauna is roughly correlated with the Toyoma fauna of post-*Yabeina* (P 3) age.

The Kashiwadaira fauna of the Takakurayama Group is similar to that of lower Kanokura, but according to MURATA (1964), *Yabeina multiseptata* is found below the bivalve fossils and a nautiloid, *Tainoceras abukumaensis* HAYASAKA associated with pelecypods is from the *Yabeina* zone, at Iwaizaki. This fauna is here tentatively placed in the upper Kanokura.

The stratigraphic position of the Katsura fauna is uncertain. It is most similar to the Gujo fauna of the Toyoma Series. *Costatoria katsurensis* and *Neoschizodus (Neoschizodus) kobayashii* are very similar to *C. kobayashii* and *N. (N.) permicus* of the Gujo Formation, respectively. *Actinodontophora* cf. *katsurensis* occurs in the Gujo, represented by one individual.

On the other hand, the last named species was collected by KOIZUMI from the lower Kanokura Formation where it is associated with *Costatoria* sp. at Omotematsukawa, Kesennuma City. Since the Katsura fauna contains no fusulinids, brachiopods or corals, its placement is uncertain. We tentatively place it with the Toyoma Series.

Stratigraphy of the most Important Localities of Permian Bivalves

Permian strata are widely distributed throughout Japan making the basement rocks of most of the younger geologic systems. Fossil bivalves, however, are quite rare and are mainly limited to the following areas (see index map, fig. 1 and chart 2).

1. Southern Kitakami massif, northeast Japan.
2. Abukuma massif, northeast Japan.
3. Akasaka limestone, central Japan.
4. Maizuru Belt, west Japan.

5. Katsura Formation, Shikoku Island, west Japan.
6. Mizukoshi Formation, Kyushu Island, west Japan.

Southern Kitakami Massif

In most cases, the Permian rocks of Japan are composed of eugeosynclinal sediments of somewhat altered shales (argillites, slates), cherts, basic or intermediate volcanic tuffs and lavas with subordinate sandstone and limestone. Southen Kitakami massif is exceptional in the great development of sandstones, shales and limestones of miogeosynclinal and shelf sea deposits ranging throughout the Permian System. They are also noteworthy for the common occurrence of brachipods and molluscs. Many geologists have made detailed surveys extending over a long period of time. Among the most notable contributions are those of MINATO, ONUKI, and their collaborators, who have elucidated the stratigraphy and geologic structure and history of this province. The main occurrences of bivalves are found around Kesennuma City and Maiya, in Towa-cho, Miyagi Prefecture.

Kesennuma Area

According to ONUKI (1956) and MURATA (1964b) the Permian sequences of this area may be described as follows in descending order:

3. Toyoma Formation

This stratigraphic unit is composed mainly of black shales with sporadic conglomerate sandstones with an aggregate thickness of about 500 meters.

2. Kanokura Formation

Chayazawa Member

This member consists of alternating sandstone and shale with conglomerate layers in the upper part. The entire unit measures about 130 meters. Representative fossils include *Yabeina multiseptata* (DEPRAT) and *Kahlerina pachytheca* KOCHANSKY-DEVIDÉ.

Shigejizawa Member

This unit consits mainly of sandstones and conglomerate at the base, with thin limestone at the top, the whole being about 100 meters thick. It is very fossiliferous.

1. Sakamotosawa Formation

Tateishizawa Member*

Alternation of predominant sandstone and subordinate shale with intercalated limestone lenses, totalling about 200 meters in thickness. The chief fossils include *Monodiexodina matsubaishi* (FUJIMOTO), "*Parafusulina*" sp.

Hosoozawa Limestone Member

This member consists cheifly of limestones totalling 200 to 250 meters in thickness. The chief fossils are *Michelinia multitabulata* YABE and HAYASAKA, *Monodiexodina matsubaishi* (FUJIMOTO), "*Parafusulina*" sp.

Minamisawabe Member.

The lower half consists mainly of sandstones and conglomerates and the upper half of shales and sandstones. The total thickness is about 150 meters.

Most of the bivalves and brachiopods are found in the middle part of the Shigejizawa Member of the Kanokura Formation. All the materials described in this paper were collected by NAKAZAWA. MURATA (1946) reported that fusulinids taken from a limestone lens near the top of this member belong to the genus *Yabeina*, and the main part of the member was correlated by ONUKI and MURATA, with the *Neoschwagerina* zone. Presumably, our pelecypods were derived from the *Neoschwagerina* zone.

The main fossil localities are Shigejizawa (K) in Kamiyasse, Kesennuma City, Miyagi Prefecture, and Imo (I) in Yahagi, Iwate Prefecture. The bivalve species previously reported, and those described in this paper (indicated by asterisks), are as follows: (The following abbreviations are used: VR, very rare; R, rare; C, common; A, abundant).

**Parallelodon* cf. *longus* MASLENNIKOV	VR (K)
**P.* cf. *tenuistriatus* (MEEK & WORTHEN)	VR (K)
**Aviculopinna rectangularis* (HAYASAKA)	VR (K)
Aviculopecten hataii MURATA	R (K)
**A.* cf. *hataii* MURATA	R (K)
**A.* sp. *a*	R (K)
**Hayasakapecten sasakii* (MURATA)	C (K)
**Etheripecten? hayasakai* (MURATA)	C (K & I)
Acanthopecten spinosus HAYASAKA	VR (I)
Acanthopecten onukii MRUATA	C (K & I)
A. cf. *coloradoensis* (NEWBERRY)	R (K & I)
**Streblopteria* sp.	R (K)

* Judging from the contained fossils this member is correlated with the Lower Kanokuran (Kattisawa Stage) of MINATO, *et al.*

**S*. ? sp.	VR (K)
**Cyrtorostra* cf. *lunwalensis* (REED)	VR (K)
Euchondria ? kesennensis (HAYASAKA)	VR (I)
Annuliconcha kitakamiensis MURATA	R (K & I)
**Schizodus tobai* (HAYASAKA)	C (K & I)
**Astartella* ? sp.	VR (K)
**Sanguinolites* sp.	VR (K)
**S. kamiyassensis* NAKAZAWA and NEWELL, n. sp.	VR (K)
**Wilkingia* sp.	VR (K & I)
**Waagenoperna (Permoperna) hayamii* NAKAZAWA and NEWELL, n. subg. and n. sp.	VR (K & I)

In addition to these species, the following species were obtained by KOIZUMI from approximately the same horizon at two other localities.

Waagenoperna (*Permoperna*) *ihayami* NAKAZAWA and NEWELL, n. subg. and n. sp. from Omotematsukawa in Kesennuma City, **Actinodontophora katsurensis* ICHIKAWA and *Costatoria* sp., from Nabekoshi-yama in the same city. HAYASAKA (1967a, b) described *Aviculopecten hiemalis* SALTER and *Edmondia* sp. from Omotematsukawa, *Allorisma* [=*Wilkingia*] sp., "*Myoconcha*" sp. and *Edmondia* sp. from Kamiyasse. The associated fossils from the Shigejizawa Member are as follows:

Brachiopods (HAYASAKA, 1960b)

Derbyia magnifica LICHAREW, *Meekella gigantea* HAYASAKA, *Productus* (*Dictyoclostus*) *semireticulatus* MARTIN, *P.* (*D.*) *gratiosus* WAAGEN, *P.* (*Horridonia*) *horridus* SOWERBY, *Productella patula* GIRTY, *Leptodus richthofeni* (KEYSERLING), *Spirifer? lyra* KUTORGA, *Martinia* spp., *Spiriferina cristata* SCHLOTHEIM and *Neospirifer fasciger* (KEYSERLING).

Fusulinids

Monodiexodina matsubaishi (FUJIMOTO)

Cephalopods (HAYASAKA, 1940, 1954, 1960a, 1963)

Paraceltites aff. *elegans* GIRTY, *Propinacoceras* aff. *galilaei* GEMMELLARO, *Agathiceras* aff. *suessi* GEMMELLARO, *Cibolites* cf. *uddeni* PLUMMER, *Tainoceras kitakamiensis* HAYASAKA, *Foordiceras akiyamai* HAYASAKA, *Foordiceras*? sp.

According to MURATA (1964b) *Agathiceras* aff. *suessi* came from the Chayazawa Member and the rest are from the Shigejizawa Member.

Trilobite

Pseudophyllipsia sp.

Maiya Area

The Permian system in the Maiya area has been divided into five formations as follows, in descending order (ONUKI *et al.*, 1960; CHISAKA, 1962):

5. Toyoma Formation

Mostly composed of black shales and intercalating thin layers of sandstone and sandy shale, the lower part interfingering with conglomerates of the Yamazaki Formation. This formation is characterized by *Bellerophon*, the whole being more than 1200 meters thick.

4. Yamazaki Conglomerate Formation

Massive or thick-bedded conglomerates, interbedded sandstones, shales and limestones, 0 to 800 meters thick. It is characterized by *Yabeina hayasakai* OZAWA, *Y. shiraiwensis* OZAWA. *Pseudodoliolina pseudolepida* (DEPRAT) *Waagenophyllum indicum* (WAAGEN and WENTZEL), *Wentzelella timorica* (GERTH), etc.

3. Tenjinnoki Formation

Alternations of sandstone and shale and thin intercalations of limestone, 280–330 meters thick. The unit is characterized by *Monodiexodina matsubaishi*, *Leptodus* and many pelecypods.

2. Rodai Formation

The upper half is represented mainly by limestones, the lower half by alternations of sandstone and shale, aggregating 210 meters thick. It is characterized by *Michelinia multitabulata* YABE and HAYASAKA, "*Parafusulina*" *japonica* (GÜMBEL), *Pseudofusulina kraffti* (SCHELLWIEN), *Nankinella discoides* (LEE), etc., and so-called Rodai flora containing *Sphenophyllum*, *Gigantopteris*, *Taeniopteris*, *Cordaites*, and others.

1. Nishikori Formation

Composed mostly of limestones, intercalated with sandstone and black shale, aggregating 50–80 meters thick. It is characterized by *Pseudofusulina vulgaris globosa* (SCHELLWIEN), *Pseudoschwagerina schellwieni* HANZAWA, *Zellia nunosei* H., *Triticites* cf. *simplex* (SCH.), etc.

From the Rodai Formation ONUKI *et al.* reported the following bivalves:

Actinodontophora katsurensis ICHIKAWA, *Aviculopecten* sp., and *Deltopecten* sp. We have identified *Promytilus* sp. and *Leptodesma* sp. from the north end of the town of Maiya, Towa-cho, Miyagi Prefecture.

The Tenjinnoki Formation yields abundant brachiopds and bivalves. Our collections were obtained by NAKAZAWA and SHIMIZU of Kyoto University from Tenjinnoki (Tj), east of Maiya, and from Teranosawa (Tr) at its southern outcrop. The following bivalves are discriminated in this paper:

Edmondia sp.	VR (Tr)
Sanguinolites sp.	VR (Tj)
Promytilus maiyensis NAKAZAWA and NEWELL, n. sp.	C (Tj)
Leptodesma (*Leiopteria*) sp.	R (Tr), VR (Tj)
Towapteria nipponica NAKAZAWA and NEWELL, n. gen. and n. sp.	C (Tj), R (Tr)
Waagenoperna (*Permoperna*) *hayamii* NAKAZAWA and NEWELL, n. subg. and n. sp.	R (Tj)
Ensipteria onukii NAKAZAWA and NEWELL, n. gen. and n. sp.	C (Tj), R (Tr)
Aviculopecten cf. *hataii* MURATA	R (Tj)
A. sp.	R (Tj, Tr)
Hayasakapecten shimizui NAKAZAWA and NEWELL, n. gen. and n. sp.	C (Tj)
Acanthopecten onkuii MURATA	R (Tj)
Streblopteria sp.	VR (Tj)
Pernopecten sp.	VR (Tj)
Lopha ? *teranosawensis* NAKAZAWA and NEWELL, n. sp.	VR (Tr)
Neoschizodus (*Neoschizodus*) *kitakamiensis* NAKAZAWA and NEWELL, n. sp.	R (Tr)
Netschajewia sp.	VR (Tj)
Stutchburia ? sp.	VR (Tj)

ONUKI *et al.* (1960) listed the occurrence of *Monodiexodina matsubaishi* (FUJIMOTO), *Leptodus richthofeni* (KEYSER), *Martinia lopingensis* (GRABAU), *Marginifera typica* WAAGEN, *Productus grunewaldti* KROTOW, *Richthofenia jaiponica* MABUTI, *Spiriferina cristata* SCHLOTHEIM, *Phyllipsia* sp., *Anisopyge* sp., etc. NAKAZAWA (1960) described a nautiloid species, *Stenopoceras japonicum* NAKAZAWA.

In the collections from the Toyoma Formation at Nagahata (N), Towa-cho by NAKAZAWA and SHIMIZU, and at Kitazawa (K), Toyoma-cho by NAKAZAWA, the following species are identified:

Myalina (*Myalina*) sp.	VR (K)
Aviculopecten sp.	VR (K)
Pseudopermophorus uedai NAKAZAWA and NEWELL, n. sp.	C (N), R (K)

Netschajewia cf. *elongata* (NETSCHAJEW) VR (N)
Astartella toyomensis NAKAZAWA and NEWELL, n. sp. A (N, K)

Abukuma Massif

Miogeosynclinal Permian sediments similar to those of the southern Kitakami massif are distributed along the Pacific coast of the Abukuma massif. The Permian strata of this region are included in the Takakurayama Group which is classified into three formations by YANAGISAWA and NEMOTO (1961) and YANAGISAWA (1967), in descending order:

3. Kashiwadaira Formation

   Composed predominantly of shales, with subordinate sandstones and conglomerates. Many fossils. The whole is 420–530 meters thick.

2. Motomura Formation

   Alternations of sandstone, conglomerate and shale, 70–170 meters thick, yielding *Parafusulina* ? sp., *Pseudofusulina* cf. *ambigua*, *Ps.* cf. *vulgaris*, *Wentzellela minor* EGUCHI (MS), *Lophophyllum* cf. *pendulum* GRABAU, *Liebea* cf. *mapingensis* GRABAU, bryozoans and algae.

1. Iriishikura Formation

   Composed mainly of shales with thin beds of sandstone and limestone in the middle part. The whole is 90–170 meters thick. It has yielded *Gerthia kobiyamai* (MS), *Spirifer* sp., *Bellerophon* sp., and *Paraceltites* aff. *elegans* GIRTY.

The Kashiwadaira Formation is quite fossiliferous. KOBIYAMA (1961) described eight bivalves from it, e. g., *Sanguinolites* cf. *plicatus* PORTLOCK, *Lima takakurayamana* KOBIYAMA, *Myophoria* cf. *subelegans* WAAGEN, *Myophoria* [=*Schizodus*] *japonica* HAYASAKA, *Nuculites* cf. *kimurai* HAYASAKA, *Solenomorpha elegantissima* HAYASAKA, *Aviculopecten interstitialis* PHILLIPS and *Acanthopecten spinosus* HAYASAKA. Only the first three of these species were illustrated. Judging from KOBIYAMA's illustrations, *Myophoria* cf. *subelegans* suggests *Undulomya.* Recently YANAGISAWA (1967) described the following bivalves from the same formation together with brachiopods, cephalopods, gastropods and others:

Acanthopecten cf. *carboniferous* STEVENS, *Anthraconeilo* aff. *taffiana* GIRTY, *Astartella* cf. *permocarbonica* TACHERNYSCHEW, *Aviculopecten* cf. *hataii* MURATA, *Conocardium kansuensis* CHAO, *Lima* cf. *retifera* SCHUMARD, *Limipecten* cf. *burnettensis* MAXWELL, *Nucula* aff. *subnuda* d'ORBIGNY, *Nucula* sp., *Solemya* aff. *costellata* M'COY, and *Sterblochondria* cf. *stantonensis* NEWELL.

All these species need further examination. *Parallelodon* cf. *multistriatus* GRITY is described in the present paper.

HAYASAKA (1957, 1965) described several cephalopod species from this formation: *Tylonautilus permicus* HAYASAKA, *Tainoceras abukumaense* H., *T.* aff. *unklesbayi* MILLER & YOUNGQUIST, *Propinacoceras* spp., Medlicottid?, *Paraceltites* aff. *elegans* GIRTY, *Pseudogastrioceras*? sp., *Agathiceras* cf. *suessi* GEMMELLARO, *Stacheoceras* aff. *grunewaldti* G., *Popanoceras* sp., and *Waagenoceras* cf. *dieneri richardsoni* MILLER & FURNISH. According to MURATA (1964b), fusulinids obtained from the lower part of this formation include *Yabeina multiseptata* (DEPART) and *Yabeina* sp.

Akasaka Limestone

Akasaka is a classic locality for fusulinids following the studies of DEPART (1914) and OZAWA (1927). HAYASAKA (1925) described the following bivalves from the fusulinid beds:

Aviculopecten minoensis HAYASAKA [=*Hayasakapecten*]	Upper Dairi Zone
A. reticularis HAYASAKA [=*Hayasakapecten*]	Upper Dairi Zone
Liebea sinensis FRECH [=*Waagernoperna* (*Permoperna*) sp.]	Kuro Zone
Myophoria japonica H. [=*Schizodus*]	Kuro Zone
Parallelodon obsoletiformis H.	Kuro Zone
Solenomorpha elegantissima H.	Kuro Zone

The Upper Dairi Zone is correlated with the *Yabeina globosa* zone. The Kuro Zone is considered to range from the *Neoschwagerina margaritae* zone to the *Yabeina globosa* zone, inclusive, and, according to OZAWA (1927), the above-mentioned bivalves occur in the *Yabeina globosa* zone.

Maizuru Belt

The Permian System in the Maizuru tectonic belt is collectively called the Maizuru Group. It has been studied in detail by NAKAZAWA and his collaborators (1954–1959) and summarized by SHIMIZU (1962). This group is divided into three formations as follows in descending order:

3. Upper Maizuru

   Composed predominantly of black shales alternating with sandstones and conglomerates; fossiliferous in the sandy and conglomeratic parts. It is more than 500 meters thick.

2. Middle Maizuru

   Lithologically, this is divided into two facies; the southern part of the

Maizuru Belt contains a shaly facies characterized by monotonous shales intercalated with sandstones, conglomerates and limestones. The northern half is characterized by a graded-bedding facies with thin, flysch-type alternations of shale and sandstone and minor conglomerates. Fossils are mainly found in the limestone and coarse-grained sandstone. The whole is 500–600 meters thick.

1. Lower Maizuru

This unit is composed mainly of basic tuffs and lavas and intercalated shales, aggregating more than 500 meters thick. It is almost lacking in fossils. The only fossils found from the Lower Maizuru are *Lophophyllidium*? and some bryozoans contained in an agglomeratic tuff at Matsunoodera, in Maizuru City.

SHIMIZU (1961) described several brachiopods which he included in his Takauchi faunule. These were collected from limestone in the middle part of the Middle Maizuru at Takauchi, Yakuno-cho, Kyoto Prefecture. They include: *Leptodus richthofeni, Squamularia indica, S. elegantula, Streblorynchus keyseri, Martinia elegans, Kiangsiella deltoidens,* and *Neospirifer* sp. Limestones of the upper part of the Middle Maizuru contain the *Palaeofusulina-Reichelina* faunule characterized by *P.* cf. *sinensis* SHENG and *Reichelina matsushitai* NOGAMI (NOGAMI, 1958). From the same or upper horizon but in coarse-grained sandstone, the *Lepidolina-Yabeina* assemblage is commonly found. The main fusuline species are *Lepidolina kumaensis, L. toriyamai, L. toriyamai maizurensis, Yabeina columbiana, Y. yasubaensis* (=*shiraiwensis*?), *Pseudodoliolina gravitesta, Codonofusiella cuniculata,* etc.

Two species of bivalves were collected by NAKAZAWA from shale several meters above a limestone in the upper part of the Middle Maizuru south of Matsunoodera Station, in Maizuru City. They are *Palaeoneilo* ? sp., and *Phestia* (*Polydevcia*) ? sp. *Guizhoupecten* sp. was obtained from shale at nearly same horizon as *Palaeofusulina*-bearing limestone, in Mikata-machi, Hyogo Prefecture.

The Upper Maizuru is characterized by the *Lepidolina-Yabeina* faunule in coarse-grained sandstones and conglomerates. The contents of this faunule are identical to those of the upper part of the Middle Maizuru. Abundant brachiopods constituting the Kawahigashi faunule (SHIMIZU, *op. cit.*) occur in coarse-grained sandstones at several places in association with bivalves, but fusulines are lacking. The brachiopods are as follows:

Derbyia altestriata, D. cf. grandis, Chonetina substrophomenoides, Chonetina matsushitai, Lissochonetes bipartita, L. morahensis, Productus (*Dictyoclostus*) *gratiosus, Linoproductus kiangsiensis, Hustedia indica, Eolyttonia nakazawai,* etc.

The bivalves collected by NAKAZAWA and others from the Upper Maizuru Group are as follows:

Kuwanoe Pass, Monobe, Ayabe City, Kyoto Prefecture (KP 14)

Edmondia sp.
Parallelodon cf. *longus*

Katsuradani, Oe-cho, Kawahigashi, Kyoto Prefecture (KP 5)

Astartella sp.
Pernopecten sp. (not described)

Nomaru, Kawahigashi, Oe-cho, Kyoto Prefecture (KP 7)

Aviculopecten cf. *shiroshitai* n. sp. (not described)
Astartella sp.

Gujo Formation

This is an interesting formation in lithofacies as well as in its faunal constituents. The Gujo Formation is very limited in distribution occupying only a small outcrop area of about 600 meters by 1000 meters. The geologic sturcture is very complicated, and a complete section probably cannot be determined. The Permian Maizuru Group, the Gujo Formation and the Lower to Middle Triassic Yakuno Group lie in complicated sequence in which the boundaries lie along fault contacts, as shown in the geologic map (Figure 2).

The Gujo Formation is composed of alternating conglomerate, sandstone and greenish black shale with a total thickness of about 250 meters. Conglomerate beds containing subangular pebbles of various kinds of rocks attain a maximum of 50 meters in one bed, but these change laterally into sandy facies. Sandstones and shales are rather well-bedded and seemingly less disturbed than the surrounding Permian strata. NAKAZAWA collected *Meekoceras* sp. at about 200 m. higher than the lower boundary of the Yakuno Group, where it is in fault contact with the Maizuru Group. The basal conglomeratic member is lacking there. The lower limit of the Yakuno Group must be older than the *Meekoceras* horizon, probably pre-Owenitan in age. About 5 km to the south of Gujo, the Yakuno Group overlies the Maizuru Group with angular unconformity, indicating a crustal movement at the close of the Permian or the beginning of the Triassic. According to SHIKI (1959, 1961, 1962), sandstones of the Maizuru Group correspond to greywacke of PETTIJOHN (1949), or KRUMBEIN and SLOSS (1951), and their sedimentary structure indicates deposition by turbidity currents. Sandstones of the Upper Triassic Nabae Group are arkosic.

Sandstones of the Yakuno Group have rather a wide range from arkose to greywacke, showing an intermediate character between the Maizuru and Nabae. On the other hand, the extreme greywacke tendency of the sandstones and the poorly sorted texture of sandstones and conglomerates of the Gujo Formation suggest short transportation and rapid deposition. Probably they accumulated at the foot of rising mountains (SHIKI, 1962). Some fossils in greenish black shale are coated with iron sulfide (pyrite) suggesting a reducing condition after or during deposition.

It is known that the Permian Maizuru Sea initially was an open sea in which submarine volcanism occurred. It then changed into an inland sea during the late Permian orogeny. From these conclusions it is reasonable to consider that the Gujo Formation represents a relict of the Maizuru Sea, in other words, the final stage of Permian geosynclinal development.

Productid brachiopods and other fossils are found in shales at several horizons but fusulines have not been discovered. Most of the described species were obtained from a fossiliferous bed exposed at a small cliff just behind Kawanishi Primary School at Gujo, Oe-cho, Kyoto Prefecture (Loc. "a" in fig. 2). The Gujo fauna consits mostly of bivalves and far fewer brachiopods and gastropods. These fossils are tabulated below:

Bivalves:

Edmondia spp.	C
Pyramus planus NAKAZAWA and NEWELL, n. sp.	C
Promytilus sp.	C
Aviculopinna sp.	VR
Septimyalina sp.	VR
Bakevellia (*Bakevellia*) *gujoensis* NAKAZAWA	R
Towapteria sp.	VR
Tombanella gujoensis NAKAZAWA and NEWELL, n. gen. and n. sp.	C
Aviculopecten shiroshitai NAKAZAWA and NEWELL, n. sp.	C
Leptochondria ? spp.	R
Pernopecten sp.	VR
Lopha ? *murakamii* NAKAZAWA and NEWELL, n. sp.	A
Neoschizodus (*Neoschizodus*) *permicus* NAKAZAWA	A
Costatoria kobayashii (KAMBE)	A
Gujocardita oviformis NAKAZAWA and NEWELL, n. gen. & n. sp.	C
Permophorus tenuistriatus NAKAZAWA and NEWELL, n. sp.	C
Actiondontophora cf. *katsurensis* ICHIKAWA	VR
Chaenomya (*Vacunella*) *rostrala* NAKAZAWA and NEWELL, n. sp.	R

Brachiopods (Shimizu, 1961b):

Spinomarginifera nipponica SHIMIZU	R
Schellwienella ruber (FRECH)	C
S. regularis HUANG	R
Orthotetina sp.	R

In addition to these fossils gastropods (*Bellerophon* sp., *Euphemites* sp., *Worthenia* spp., and others), trepostomatoid bryozoans and plant fragments are also found.

Katsura Formation

The geologic sturcture around the fossil locality of the Katsura Formation in Shikoku is so complicated that the stratigraphy is not yet satisfactorily known. The formation is composed of black shales accompanied by limestones and cherts. Bivalves are contained in coarse-grained to granular, muddy, sandstone in the uppermost part of the formation. Most specimens are fragmentary and small. ICHIKAWA (1951) described the following molluscs:

Palaeoneilo sp.
Nucula sp. [=*Nuculopsis* sp.]
Nuculopsis orientalis ICHIKAWA
N. sp.
Edmondia ? spp.
Schizodus kobayashii ICHIKAWA [=*Neoschizodus* (*Neoschizodus*) *kobayashii*]
Schizodus ? *radiata* ICHIKAWA [=*Costatoria katsurensis* NAKAZAWA]
Actinodontophora katsurensis ICHIKAWA
Myalina ? sp.
Dentalium (*Laevidentalium*) cf. *priscum* MÜNSTER, in HAYASAKA
Straparollus ? sp.

In addition, *Nuculites ichikawai*, n. sp. is described in this paper.

Mizukoshi Formation

The Mizukoshi Formation lies south of Kumamoto City, central Kyushu, where it was studied and divided into two members by YANAGIDA (1958).

2. Upper Member

The basal part of the division consists of coarse-grained sandstone about 40 meters thick, and the rest is composed of shales, sandstones and conglomerates with thin limestone lenses containing a *Lepidolina-Yabeina* fauna. The total thickness is about 500 meters.

1. Lower Member

The lower member consists of monotonous alternations of black shales and fine-grained sandstones, about 900 meters thick.

Near the top of the Upper Member, about 300 meters higher than the fusuline horizon, YANAGIDA reported the following fossils from a muddy conglomerate:

Neospirifer cf. *fasciger* (KEYSERLING)
Spiriferella sp.
Productus sp.
Acanthopecten cf. *spinosus* HAYASAKA
Pleurotomaria sp.

NAKAZAWA collected *Euchondria* sp. and *Astratella* sp. from the same locality.

The Bivalve Assemblages

Sakamotosawa Series (P 1)

In the early Permian rocks bivalves are poorly represented. From the lower Sakamotosawa (Kawaguchi Stage) *Aviculopecten* sp. and *Modiolus* sp. are reported.

From the Rodai Formation, ONUKI *et al.*, (1960) cited *Acitnodontophora katsurensis, Aviculopecten* sp., and *Deltopecten* sp., none of which is described. *Leptodesma* sp. and *Promytilus* sp., described in this paper, may have been obtained from the lower part of the formation (Upper Sakamotosawan), but the materials are too poor for significant analysis.

Kanokura Series (P 2)

Bivalves were prolific in Japan during the early Kanokura and Toyoma epochs. Forty-four species in twenty-nine genera are herein discriminated from the lower Kanokura Formation. Aviculopectinids are represented by sixteen species. In spite of the marked diversity, the number of individuals is small as compared with the brachiopods, and the assemblage changes laterally in small distances. For instance, only four species occur in common between the Tenjinnoki and lower Kanokuran Shigejizawa faunas even though the lithofacies are similar and the two fossil localities are near each other. The common species are *Waagenoperna (Permoperna) hayamii*, n. subg. and n. sp., *Aviculopecten* cf. *hataii, Acanthopecten onukii* and *Streblopteria* sp. In comparison with foreign species, only *Cyrtorostra* cf. *lunwalensis* (REED), *Parallelodon* cf. *tenuistriatus* (MEEK and WORTHEN), and *P.* cf. *longus* MASLENNIKOV are closely similar to forms of the Salt Range, the United States, and Russia, respectively. *Aviculopecten hiemalis* SALTER appears to be identical with the

Chart 2. Correlation chart of the representative bivalve-bearing Permian.

STAGE	Fusul. zone	Standard division in Kitakami Mssif	Kitakami Massif: Kesennuma	Kitakami Massif: Maiya	Abukuma Massif: Takakurayama	Central Japan: Akasaka	Central Japan: Maizuru Belt	Kyushu Is.: Mizukoshi	Outside Japan: China	Outside Japan: U.S.A.	Outside Japan: USSR
KUMAN	Y. globosa: Y. sh.; L. tor.; ?	TOYOMA SUBSYSTEM: no fusulinid; Toyoma (P3) YUKISAWA SUBSYSTEM, KANOKURA SERIES, IWAIZAKI STAGE: Yabeina Z. (Y. shiraiwen., L. gigantea); Upper Kanok. (P2u)	Toyoma Form.: *Bellelophon* Chayazawa M.: *Y. multiseptata*, *Kahlerina pachytheca*	Toyoma Form.: *Pseudopermoph.*, *Astrtella*, *Leptodus*, *Bellelophon* Yamazaki Cg. Form.: *Y. shiraiwensis*, *Kahlerina pchytheca*, *Waagenophyllum indicum*	Kashiwadaira Formation: *Waagenoceras*, *Paraceltites*, *Tainonautilus*, many brachiop. & bivalves, *Yabeina* sp. ?	*Y. globosa* zone: *Y. globosa*, *Y. katoi*, *Ns. minoensis*, *Schizodus japonicus*, *Hayasakapecten* sp.	Gujo F.: Gujo fauna ? Maizuru Group, Upper: *Lepidolina-Yabeina* fauna, brachiopods, bivalves Middle: *Pfl.*, *Reichelina*, *Colaniella*	? Mizukoshi F.: *Neposirifer fasciger*, *Spiriferella*, *Euchondria*, *L.* cf. *toriyamai*, *Y.* cf. *shiraiwensis*	Lopingian: Chiang-sing (*Palaeofus.* z.; *Pseudotir.-Pleur.* z.); Wuchiap-ing (*Codonof.* z.; *Protot.-Araxoc.* z.) Yangsinian, Maokou Limestone: *Yabeina* z.	Ochoan	Tartarian ?
AKASAKAN	Ns. marg.: Ns. dow.; Ns. craticulifera	Neoschwagerina Z. (Neoschwag. sp.; Monodiexodina matsubaishi); Lower Kanokura (P21)	Shigejizawa M.: *Mon. matsubaishi*, *Paraceltites*, *Agathiceras*, *Tainoceras*, abundant brachiopods & bivalves.	Tenjinnoki Form.: *Mon. matsubaishi*, *Paraceltites*, abundant brachiopods & bivalves		*Ns. margaritae* z.: *Ns. margaritae*, *Vb. verbeeki* *Ns. carticulifera* zone: *Ns. craticulifera*, *Ns. colaniae*, *Vb. verbeeki*	Lower: *Lophophyllidium*?, bryozoans ?		*Neoschwagerina* z.; *Waagenoceras* zone	Guadalupian: *Polydiexodina* z.; *Timorites* zone; *Waagenoceras* z.	Kazanian
NABEYAMAN	Ns. simplex: Paf. kaerim.	KATTISAWA STAGE: Parafusulina Z.	Tateishizawa M.: *Mon. matsubaishi.*, "*Parafusulina*"	Rodai Formation: *Paf. japonica*, *Paf.* cf. *kaerimiz.*, *Pfs. ambigua*, *Pfs. kraffti*, *Nankinella*, *Eoverbeekina*, *Michelinia multitabulata*, *Promytilus*, *Leptodesma*		*Cc. nipponica* zone: *Cc. nipponica*, *Ns. simplex*, *Paf. japonica*			Chisia Ls.: *Parafusulina* zone; *Kufengoceras* zone	Leonardian: *Parafusulina* zone; *Perrinites* zone	Artinskian (incl. Kungarian)
SAKAMOTOZAWAN	Psf. ambigua: Mis. claudiae; Psf. vulgaris: Psf. vulgaris; Pss. morikawai	SAKAMOTOSAW ASERIES, KABAYAMA STAGE: Pseudofusulina Z. (Psf. ambigua, Psf. fusiform.; Psf. vulgaris) KAWAGUCHI STAGE: Pss. Z. (Zellia. Monod.); Sakamotosawa (P1)	Hosoozawa Member: *Psf. kraffti*, *Michelinia multitabulata* Minamisawabe M.: *Pss.* sp.	Nishikori F.: *Pss. schellwieni.*, *Zellia nunosei*, *Pfs. vulgaris*	Motomura F.: *Psf.* cf. *ambigua*, *Psf.* cf. *vulgaris.*, *Psf.* cf. *gran.-avenae* Iriishikura Formation: *Gerthia* sp., *Linoproductus*? sp.				*Pseudohalorites* z. Mapingian, Maping Limestone: *Pseudoschwagerina* zone; *Propopanoceras* zone	Wolfcampian: *Pseudoschwagerina* zone; *Properrinites* z.	Sakmarian (incl. Asselian)

Himalayan species. This is in marked contrast with the brachiopods which have many species in common with those of Tethys. Some facts are noteworthy.

Firstly, several genera of Mesozoic type appear in this fauna. *Neoschizodus* (*Neoschizodus*) and *Costatoria* flourished in the Triassic. *Waagenoperna* (*Permoperna*) appears to be ancestral to *Waagenoperna* (*Waagenoperna*) which ranges from the Upper Triassic to the Lower Cretaceous, and species similar to *Lopha* occur here and in the upper Permian of Japan. This genus is elsewhere characteristic of Triassic and younger rocks.

Secondly, several groups with multivincular and alivincular ligaments appeared simultaneously for the first time in this age. Examples are the multivincular *Waagenoperna* (*Permoperna*) and *Towapteria,* n. gen. and the alivincular *Ensipteria,* n. gen.

In the upper Kanokura Formation bivalves decreased in number in the Kitakami massif because of unfavorable conditions. On the other hand, some bivalves appeared in the Maizuru Belt and central Kyushu, but they are few in number as compared with diverse brachipods. The Maizuru fauna has only two species similar to the succeeding Toyoma epoch: *Aviculopecten* cf. *shiroshitai* and *Astartella* cf. *toyomensis.* On the other hand, the Kashiwadaira fauna in the Abukuma massif tentatively referred to this age is rather similar to the lower Kanokura fauna, suggesting a somewhat lower horizon than the Maizuru fauna.

Toyoma Series (P 3)

The Toyoma Series contains two rather distinctive faunas having affinities with those of older rocks. Both faunas are composed mainly of bivalves. Gastropods are next in prominence. The brachiopods are quite rare, and there are no fusulinids, trilobites or corals. This has important bearing on the great faunal change between the Mesozoic and Paleozoic, because these faunas apparently represent the highest Permian and the pelecypod faunas of this age are very poorly known anywhere in the world.

The Toyoma fauna occurs in black shales, and pebble-bearing muddy sandstones of a relict, inland sea (MINATO, 1944). *Bellerophon* sp. and other gastropods are common recalling the Bellerophonkalk of the southern Alps. Besides *Pseudopermophours uedai,* n. sp., *Astartella toyomensis,* n. sp., *Netschajewia* sp., *Myalina* sp., *Aviculopecten* sp., *Palaeoneilo ogachiensis* HAYASAKA, and *Nuculties kimurai* HAYASAKA, described herein, the following fossils have been recognized.

> *Edmondia* sp., "*Nuculana*" sp., *Allorisma* sp., *Cypricardinia* sp., "*Palaeolucina*" sp., *Leptodus richthofeni, Linoproductus*? sp., *Spirifer*? sp., ramose bryozoans, and others.

In addition, *Protocycloceras* cf. *cyclophourm* WAAGEN was described by HAYASAKA (1942), and a trace fossil, *Notaculites toyomensis* was noted by KOBAYASHI (1945). As noted above, the bivalves are associated with a few brachiopods. Those brachiopods reported are all of Paleozoic rather than Mesozoic aspect, and the bivalves are also of Paleozoic type. It is interesting to find *Pseudopermophorus* in this fauna which heretofore has been known only in the Permian of the United States.

Gujo Fauna

This interesting fauna is found as shell accumulations in greenish-black shales.

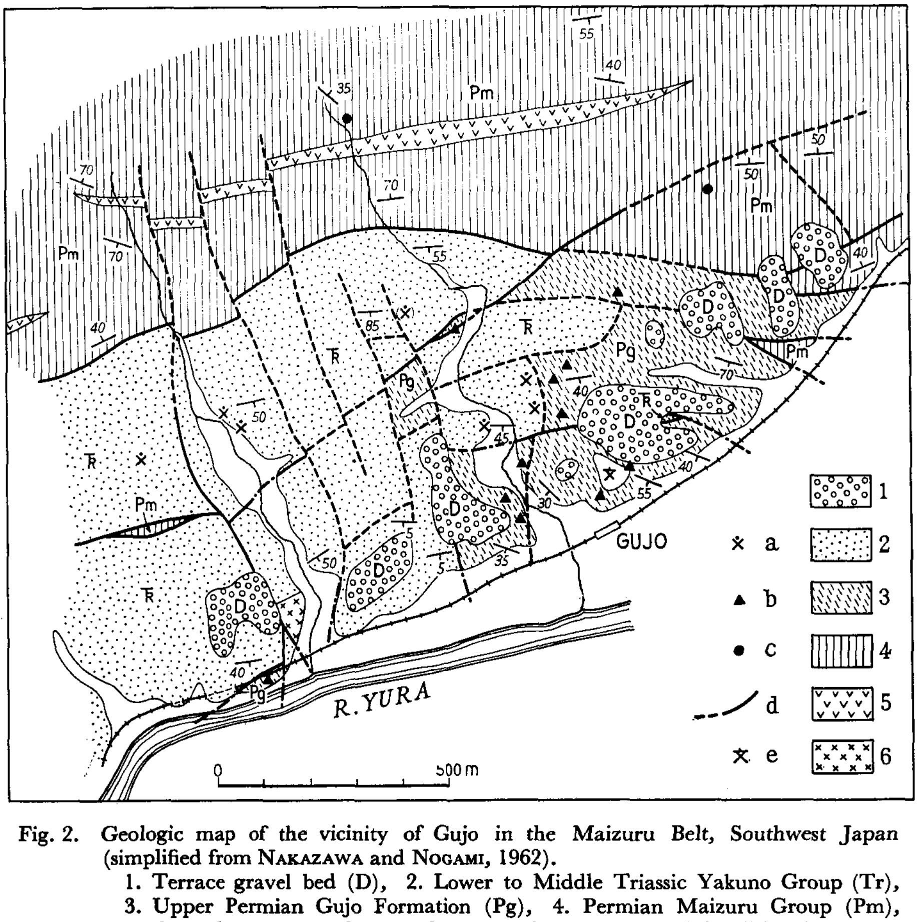

Fig. 2. Geologic map of the vicinity of Gujo in the Maizuru Belt, Southwest Japan (simplified from NAKAZAWA and NOGAMI, 1962).
1. Terrace gravel bed (D), 2. Lower to Middle Triassic Yakuno Group (Tr), 3. Upper Permian Gujo Formation (Pg), 4. Permian Maizuru Group (Pm), 5. sheared quartz-porphyry, 6. meta-gabbro, a-c. fossil localities (a. Lower Triassic molluscs, b. Gujo fauna, c. *Lepidolina-Yabeina* fauna), d. fault, e. campus of Kawanishi Primary School.

Some shells are pyritized but by far the majority are preserved as molds. Some species are found with closed valves in approximately life position. Most shells evidently were distributed somewhat and transported to the present location. However, they are considered to be essentially autochthonous. Twenty-three species of bivalves and four species of brachiopods are distinguished. In addition, *Euphemites* sp., *Bellerophon* sp., a murchisonid and ramose bryozoans are contained in the same beds. Like the Toyoma fauna it lacks fusulinids and corals and is mainly composed of bivalves.

An outstanding feature of the Gujo fauna is the association of Paleozoic and Mesozoic genera. Most genera belong to Paleozoic types. On the other hand, *Neschizodus* (*Neoschizodus*) *permicus* and *Costatoria kobayashii* recall genera that flourished in the Triassic. *Lopha* (?) is also an included genus unknown elsewhere below the Triassic. *Gujocardita oviformis*, n. gen. and n. sp., and *Promytilus* spp., which are commonly found in this fauna, show intermediate characters between Permian and Triassic relatives.

Aviculopectinidae, which were most diverse in the Permian elsewhere, are represented by only two species, *Aviculopecten shiroshitai* n. sp., and *Leptochondria*? sp. The latter genus is also known in the Triassic.

In short, the Gujo fauna is composed of a mixture of forms of Permian and Triassic aspect. Evdently, it represents a transition between Paleozoic and Mesozoic assemblages.

Dr. Roger L. BATTEN of the American Museum of Natural History has examined a little collection of gastropods from the Gujo Formation. His report confirms the bivalve evidence of a Permian fauna containing precocious Triassic elements as listed below.

Triassic only of other regions

Worthenia cf. *toulai* KITTL

Triassic and Permian of other regions

Worthenia cf. *münsteri* KITTL

Permian of other regions

Retispira sp.
Bellerophon sp.
Euphemites sp.
Hypselentoma sp. ?
Trepospira sp. ?

Another interesting fact is the occurrence of *Pyramus planus*, n. sp., and *Chaenomya* (*Vacunella*) *rostrata* n. sp., because these forms resemble species characteristic of the Permian of Australia.

Table 1. Occurrence of the Permian bivalves.

	P1	P21	P2u	P3	Locality
Nuculidae					
Nuculopsis orientalis ICHIKAWA				C	Katsura
N. spp., ICHIKAWA				R	"
Malletidae					
Nuculites kimurai HAYASAKA				VR	Toyoma
N. ichikawai NAKAZAWA & NEWELL, n. sp.				VR	Katsura
Palaeoneilo ogachiensis HAYASAKA				VR	Toyoma
P. sp., ICHIKAWA				VR	Katsura
P.? sp., NAKAZAWA & NEWELL			VR		Maizuru
Nuculanidae					
Phestia (*Polydevcia*)? sp., NAKAZAWA & NEWELL			VR		Maizuru
Edmondiidae					
Edmondia sp. *a*, NAKAZAWA & NEWELL				C	Gujo
E. sp. *b*, NAKAZAWA & NEWELL			VR	R	Gujo, Maizuru
E. sp. *c*, NAKAZAWA & NEWELL		R			Maiya
E. sp., HAYASAKA		R			Kesennuma
E.? sp. *α*, ICHIKAWA				VR	Katsura
E.? sp. *β*, ICHIKAWA				VR	Katsura
Sanguinolitidae					
Sanguinolites cf. *plicatus* PORTLOCK			VR		Abukuma
S. kamiyassensis NAKAZAWA & NEWELL, n. sp.		VR			Kesennuma
S. sp., NAKAZAWA & NEWELL		VR			"
S.? sp., NAKAZAWA & NEWELL		VR			Maiya
Wilkingia sp., NAKAZAWA & NEWELL		VR			Imo
W. sp., (HAYASAKA)		VR			Kesennuma
Solenomorpha elegantissima HAYASAKA			C		Akasaka
Megadesimidae					
Pyramus planus NAKAZAWA & NEWELL, n. sp.				C	Gujo
Parallelodonditadae					
Parallelodon obsoletiformis HAYASAKA			R		Akasaka
P. cf. *longus* MASLENNIKOV		R	R		Maizuru, Kesen.
P. cf. *multistriatus* GIRTY			VR		Abukuma
P. cf. *tenuistriatus* (MEEK & WORTHEN)		VR			Kesennuma
Mytilidae					
Promytilus maiyensis NAKAZAWA & NEWELL, n. sp.		C			Maiya
P. sp. *a*, NAKAZAWA & NEWELL				C	Gujo
P. sp. *b*, NAKAZAWA & NEWELL	VR				Maiya
Pinnidae					
Aviculopinna rectangularis (HAYASAKA)		R			Imo, Kesennuma
A. sp., NAKAZAWA & NEWELL				VR	Gujo
Myalinidae					
Myalina (*Myalina*) sp., NAKAZAWA & NEWELL				VR	Toyoma
M.? sp., ICHIKAWA				VR	Katsura
Septimyalina sp., NAKAZAWA & NEWELL				VR	Gujo
Pterineidae					
Leptodesma (*Leiopteria*) sp., NAKAZAWA & NEWELL		C			Maiya
L. sp., NAKAZAWA & NEWELL	C				Maiya

Table 1. (Continued)

	P1	P21	P2u	P3	Locality
Bakevelliidae					
Bakevellia (*Bakevellia*) *gujoensis* NAKAZAWA				R	Gujo
B. (*B.*) sp., NAKAZAWA				VR	"
Towapteria nipponica NAKAZAWA & NEWELL, n. gen. & sp.		C			Maiya, Kesenn.
T. sp.				VR	Gujo
Isognomonidae					
Waagenoperna (*Permoperna*) *hayamii* N. & N., n. gen. & sp.		R			Maiya, Kesenn.
Tambanella gujoensis N. & N., n. gen. & sp.				R	Gujo
Pteriidae					
Ensipteria onukii N. & N., n. gen. & sp.		C			Maiya
Aviculopectinidae					
Aviculopecten hataii MURATA		R			Kesennuma
A. cf. *hataii* MURATA		R			Maiya
A. shiroshitai NAKAZAWA & NEWELL, n. sp.				C	Gujo
A. cf. *shiroshitai* NAKAZAWA & NEWELL			R		Maizuru
A. hiemalis Salter		VR			Kesennuma
A. sp. *a*, NAKAZAWA & NEWELL		R			Maiya, Kesenn.
A, sp. *b*, NAKAZAWA & NEWELL				VR	Toyoma
Hayasakapecten shimizui N. & N., n. gen. & sp.		C			Maiya
H. sasakii (MURATA)		C			Kesennuma
H. reticularis (HAYASAKA)			VR		Akasaka
H. minoensis (HAYASAKA)			VR		"
Etheripecten? *hayasakai* (MURATA)		C			Imo, Kesennuma
Acanthopecten spinosus HAYASAKA		VR			Kesennuma
A. onukii MURATA		C			Maiya, Imo, Kesennuma
A. cf. *coloradoensis* (NEWBERRY)		VR			Maiya, Kesenn.
Annuliconcha kitakamiensis MURATA		R			Imo, Kessenum.
Leptochondria? sp. *a*, NAKAZAWA & NEWELL				R	Gujo
L.? sp. *b*, NAKAZAWA & NEWELL				VR	"
Guizhoupecten miyamoriensis (MURATA)		VR			Miyamori
G. sp., NAKAZAWA & NEWELL			VR		Maizuru
Streblopteria sp. *a*, NAKAZAWA & NEWELL		R			Maiya, Kesenn.
S.? sp. *b*, NAKAZAWA & NEWELL		VR			Kesennuma
Cyrtorostra cf. *lunwalensis* (REED)		VR			"
Euchondria sp., NAKAZAWA & NEWELL			VR		Mizukoshi
E.? *kesennensis* (HAYASAKA)		VR			Imo
Entoliidae					
Pernopecten spp.		VR	VR	VR	Gujo, Maizuru, Maiya
Ostreidae					
Lopha? *murakamii* NAKAZAWA & NEWELL, n. sp.				A	Gujo
L.? *teranosawensis* NAKAZAWA & NEWELL, n. sp.	R	R			Maiya
Limidae					
Lima takakurayamana KOBIYAMA			VR		Abukuma
Myophoriidae					
Schizodus japonicus (HAYASAKA)			C		Akasaka
S. tobai (HAYASAKA)		C			Imo, Kesennuma
Neoschizodus (*Neoschizodus*) *permicus* NAKAZAWA				A	Gujo

Table 1. (Continued)

	P1	P21	P2u	P3	Locality
N. (*N.*) *kobayashii* (ICHIKAWA)				R	Katsura
N. (*N.*) *kitakamiensis* NAKAZAWA & NEWELL, n. sp.		R			Maiya
Costatoria katsurensis NAKAZAWA				C	Katsura
C. kobayashii (KAMBE)				A	Gujo
Carditidae					
Gujocardita oviformis N. & N., n. gen. & sp.				C	Gujo
Permophoriidae					
Permophorus tenuistriatus NAKAZAWA & NEWELL, n. sp.				C	Gujo
Pseudopermophorus uedai NAKAZAWA & NEWELL, n. sp.				C	Toyoma
Netschajewia cf. *elongata* (NETSCHAJEW)				VR	"
N. sp., NAKAZAWA & NEWELL		VR			Maiya
Stutchburia? sp., NAKAZAWA & NEWELL		VR			"
Myoconcha? sp., HAYASAKA		VR			Kesennuma
Family uncertain					
Actinodontophora katsurensis ICHIKAWA		R		R	Katsura, Kessen.
A. cf. *katsurensis* ICHIKAWA				VR	Gujo
Astratidae					
Astartella toyomensis NAKAZAWA & NEWELL, n. sp.				A	Toyoma
A. sp. *a*, NAKAZAWA & NEWELL			R		Maizuru
A. sp. *b*, NAKAZAWA & NEWELL			VR		Mizukoshi
A. sp. *c*, NAKAZAWA & NEWELL			VR		Maizuru
A.? sp. *d*, NAKAZAWA & NEWELL		VR			Kesennuma
Pholadomyidae					
Chaenomya (*Vacunella*) *rostrata* NAKAZAWA & NEWELL, n. sp.				R	Gujo
Undulomya? sp., (KOBIYAMA)			VR		Abukuma

A. Abundant, C. common, R. rare, VR. very rare.

The Katsura fauna, in Shikoku, also lacks fusulinids, brachiopods, and corals. ICHIKAWA (1951) suggested a shelf sea environment for this fauna. As already stated, this is comparable to the Gujo fauna, although it also has a resemblance to the lower Kanokura fauna.

Comparison of the Permian and Triassic Faunas

The Lower Triassic Fauna in Japan

The Lower Triassic in Japan contains two different kinds of faunas. One occurs in the lower part of the Yakuno Group, in the Maizuru Belt, and in the lower part of the Inai Group, in the southern Kitakami massif. The rocks of both areas are composed mainly of sandstones, conglomerates and subordinate shales.

The contained fauna is characterized by abundant and diverse bivalves.

The second pertains to the outer (Pacific) side of southwest Japan. The beds there are composed of limestones and shales much thinner than those of the former area. The fauna is characterized by the *Eumorphotis multiformis-Pteria ussurica yabei* assemblage, and, in some places cephalopods of the upper Eo-Triassic Owentian (BANDO, 1964).

Pelecypods of the Maizuru Belt were described by KAMBE (1951, 1957) and NAKAZAWA (1959, 1960, 1961) and those of the outer side by YEHARA (1927), OSAKI and SHIKAMA (1954), ICHIKAWA and YABE (1955) and KAMBE (1963). These fossils are tabulated below.

Maizuru Belt (Lower half of the Yakuno Group)

Entolium cf. *discites* (SCHLOTHEIM)
E. cf. *microtis* (BITTNER)
E. spp.
Eumorphotis cf. *maritima* KIPARISOVA
E. cf. *multiformis rudaecosta* KIPARISOVA
E. cf. *tenuistriata* (BITTNER)
Claraia cf. *decidens* DIENER
C. pulchella NAKAZAWA
"*Pecten*" *ussuricus* BITTNER
"*P.*" cf. *sojalis* WITTENBURG
"*P.*" cf. *amuricus* BITTNER
Leptochondria minima (KIPARISOVA)
L. ? cf. *virgalensis* WITTENBURG
L. ? cf. *bittneri* (KIPARISOVA)
Mysidioptera circularis NAKAZAWA
Promyalina minuta NAKAZAWA
"*P.*" spp.
Pinna muikadaniensis NAKAZAWA
Pteria cf. *murchisoni* (GEINITZ)
Unionites cf. *fassaensis bittneri* (FRECH)
U. sp.
Bakevellia (*Maizuria*) *kambei* NAKAZAWA
B. (*M.*) *kambei dannensis* N.
B. (*M.*) *okuyamensis* N.
B. (*M.*) *narawarensis* N.
B. (*Neobakevellia*) *tsuzuradaniensis* N.
Neoschizodus (*Neoschizodus*) cf. *laevigatus* (ZIETHEN)

N. (*N.*) ? *shikii* NAKAZAWA
Nuclana (*Dacryomya*) *nogamii* NAKAZAWA
N. (*D.*) *yakunoensis* N.
Phestia spp.
Palaenoneilo cf. *elliptica* in KIPARISOVA
P. cf. *oviformis* (ECK)
P. spp.
P. cf. *elliptica praecursor* FRECH
Nuculopsis spp.

The Lower Triassic fauna of the Inai Group, in the southern Kitakami massif has not been described yet, but is similar to that of the Maizuru.

Pacific side of southwest Japan

Eumorphotis multiformis (BITTNER)
E. multiformis shionosawensis ICHIKAWA and YABE
E. shikokuensis (YEHARA)
Pteria ussurica yabei NAKAZAWA
Bakevellia (*Neobakevellia*) *rostrata* YABE
Entolium discites (SCHLOTHEIM)
Chlamys kryshtofowichi KIPARISAVA
Leptochondria minima (KIPARISOVA)
L. ? *minima reticulata* (KIPARISOVA)
Unionites canalensis (CATULLO)
Unionites canalensis bittneri (ICHIKAWA and YABE)
Unionites fassaensis (WISSMANN)

In addition to these, *Streblopteria* sp. was collected by MATSUSHITA from the Kurotaki limestone, in Kochi Prefecture of Shikoku.

In spite of the marked contrast of lithofacies, the faunas of the two areas are closely similar, a curious aspect that they share with the cosmopolitan Lower Triassic marine faunas elsewhere in the world. Most genera and even species of the Pacific side of southwest Japan are also found in the Maizuru-Kitakami provinces. Many fossils are cosmopolitan even at a specific level, for example, species of *Entolium, Eumorphotis, Unionites,* and *Neoschizodus* (*Neoschizodus*). Species belonging to *Claraia, Leptochondria, Bakevellia, Palaeoneilo,* and "*Pecten*" are widely distributed, if not world-wide. In considering a strong regional and facies differentiation of the Permian bivalves, as already stated, the homogeneity of the Eo-Triassic forms is quite striking. Strong diversification took place in late Triassic time, especially in the Karnian, which includes 45 genera and 170 species in Japan. The regional and facies differentiation was mostly at the species level.

In all of Japan there are found in the Lower Triassic only forty-five species and eight subspecies of pelecypods belonging to eighteen genera, including indeterminable species. This number is small when we consider the extent of the Triassic deposits and the seemingly suitable conditions of preservation.

As already discussed, the Permian lower Kanokura fauna alone contains 39 species of bivalves belonging to 27 genera, in spite of the predominace of brachiopod fossils, and the Toyoma fauna has 41 species in 26 genera preserved, in rather unsuitable facies. Furthermore, this estimate of the number of Permian bivalves is too small. It will increase much more because many species are left undescribed.

There are no species in common between the latest Permian and early Triassic, but many of the Lower Triassic genera are also found in the Permian. *Nuclopsis*, *Palaeonelio*, *Phestia*, *Bakevellia*, *Leptochondria*, *Streblobteria*, and *Neoschizodus* are examples. *Lopha*?, *Costatoria*, and *Wagenoperna* appeared in the Permian and also occur in the Upper Triassic or later but early Triassic representatives have not been discovered in Japan. *Nuculana*, *Pinna*, *Promyalina*, *Eumorphotis* and *Entolium* of the Lower Triassic are considered to be directly derived from the Permian *Phestia*, *Aviculopinna*, *Myalina*, *Etheripecten* and *Pernopecten* (or "*Pseudamussium*"), respectively.

It is evident from the above that many Paleozoic genera became extinct during late Permian time. Some representatives of Aviculopectinidae, Sanguinolitidae and Myalinidae are outstanding examples. On the other hand, many nuculoids, which are adapted to muddy sea bottom, and some pterioids and trigonioids, survived the later Permian biological revolution (Chart 3).

Clearly, marked changes occurred among the bivalve communities at the close of the Permian. These changes are indicated more by extinction of Permian genera than by introduction of new genera in the early Triassic. After the Permian exinctions a marked expansion did not take place until the late Triassic.

As stressed by NEWELL (1963, 1967) and RUZHENCEV *et al.* (1965), a possible cause of the extinctions in the late Permian was world-wide regression, decrease in area of the epicontinental seas and remarkable changes in paleogeography, changes which progressed through the Permian Period reaching a maximum at the Permo-Triassic boundary.

These paleogeographic changes evidently effected the bivalves less than the other main constituents of the Permian faunas, bryozoans, brachiopods, corals, trilobites and fusulinids.

Chart 3. Range chart of bivalve genera from the later half of the Permian to the early Triassic in Japan.
P2 (Kanokura Epoch), P3 (Toyoma Epoch),
T1 (Skythian)

Order and Superfamily	Family	Genus	P2	P3	T1
Nuculoida	Nuculidae	*Nuculopsis*	- - -	—	—
	Nuculanidae	*Nuculana*			—
		Phestia	- - -	—	—
	Malletiidae	*Nuculites*	- - -	—	
		Palaeoneilo	- - -	—	—
Arcoida	Parallelodontidae	*Parallelodon*	—	- - -	- - -
Praecardioida	Edmondiidae	*Edmondia*	—	—	
	Megadesmidae	*Pyramus*	- - -	—	
	Sanguinolitidae	*Sanguinolites*	—		
		Wilkingia	—		
		Solenomorpha	—		
Mytiloida	Mytilidae	*Promytilus*	—	—	
	Pinnidae	*Aviculopinna*	—	—	
		Pinna			—
Pterioida Ambonichiacea	Myalinidae	*Myalina*	—	—	
		Septimyalina	- - -	—	
		Promyalina			—
Pteriacea	Pteriidae	*Pteria*			—
		Ensipteria	—		
	Bakevelliidae	*Bakevellia*	- - -	—	—
		Towapteria	—	—	
	Isognomonidae	*Waagenoperna*	—	- - -	- - -
		Tambanella		—	
	Pterineidae	*Leptodesma*	—		
Pectinacea	Pectinidae	*"Pecten"*			—
		Chlamys			—
	Aviculopectinidae	*Aviculopecten*	—	—	
		Etheripecten?	—		
		Hayasakapecten	—		
		Acanthopecten	—		
		Annuliconcha	—		
		Leptochondria ?	- - -	—	—
		Cyrtorostra	—		
		Streblopteria	—	- - -	? —
		Guizhoupecten	—		
		Eumorphotis			—
		Claraia			—
	Euchondriidae	*Euchondria*	—		
	Entoliidae	*Pernopecten*	—	—	
		Entolium			—
Limacea	Limidae	*Lima s.l.*	—	- - -	- - -
		Mysidioptera			—
Ostreacea	Ostreidae	*Lopha?*	—	—	- - -
Actinodontoida	?	*Actinodontophora*	—	—	
Unionoida	Anthracosiidae?	*Unionites*			—
Trigonioida	Myophoriidae	*Neoschizodus*	—	—	—
		Costatoria	—	—	- - -
		Schizodus	—		
Veneroida	Carditidae	*Gujocardita*		—	
	Permophoridae	*Permophorus*	- - -	—	
		Pseudopermophorus	- - -	—	
		Stutchburia?	—		
		Netschajewia	—	—	
	Astaridae	*Astartella*	—	—	
Pholadomyoida	Pholadomyidae	*Chaenomya*	- - -	—	
		Undulomya?	—		

Systematic Description of Permian Bivalvia

Order Nuculoida DALL, 1889

Superfamily Nuculacea GRAY, 1824

Family Nuculidae GRAY, 1824

Genus *Nuculopsis* GIRTY, 1911

Type species: *Nucula ventricosa* HALL 1850 (= *Nuculopsis girtyi* SCHENK, new name, 1934, p. 30).

Several generic groups of nuculoids are represented in the Japanese Permian. QUENSTEDT (1930) established *Palaeonucula* as a subgenus of *Nucula*. The type species, *Nucula hammeri* (DEFRANCE) BRONN is a Jurassic species. SCHENK (1934) recognized its close resemblance to the upper Paleozoic *Nuculopsis* GIRTY and referred to the former as a subgenus of *Nuculopsis* in his elaborate study of the classification of nuculids. Since then, many authors followed SCHENK's classification. As pointed out by him the only distinction between the Paleozoic and Jurassic species seems to be in the degree of opisthogyration of the umbo and DRISCOLL (1965, p. 74) did not admit a subgeneric value in this character. We also prefer to treat *Palaeonucula* as a synonym of *Nuculopsis** until distinctive differences in shell structure or in musculature may be demonstrated.

Nuculanella TASCH, 1953 (type species: *Nuculanella piedmontia*, Pennsylvanian of Kansas) is another nuculoid to be considered in connection with the Japanese pelecypods. When TASCH proposed this genus (TASCH, 1953, p. 395) he recognized a close affinity with *Nuculana*, but after reexamining the type specimens DICKINS (1963, p. 30) concluded that *Nuculanella* is more closely related to *Nuculopsis*. He classed *Nuculanella* as a subgenus of *Nuculopsis* and included in *Nuculanella* the following species: *N. bangarraensis* DICKINS from the lower Permian of West Australia (*ibid.*, p. 31, pl. 1, figs. 7–12), *Nucula montipelierensis* GIRTY (1910, p. 38, pl. 4, figs. 1–3) from the lower Permian of the United States, *Nucula ventricosa* of WAAGEN (1881, p. 251, pl. 19, fig. 20) from the Upper Productus Limestone, and *Nucula trivialis* of WAAGEN (*ibid.*, p. 253, pl. 24, fig. 8) of the upper Middle and Upper Productus Limestone of the Salt Range. According to DICKINS, *Nuculanella* is distinguished from *Nuculopsis* s. s. by subtrigonal profile and more or less upright

* DICKINS (1963, p. 28, p. 30) referred to *Palaeonucula* as distinct from *Nuculopsis* because of the absence of chondrophore tooth in the latter, evidently holding a view that *Palaeonucula* has a chondrophore tooth as in *Nucula* s.s. But QUENSTEDT (*op. cit.* p. 112) stated clearly in his diagnosis of *Palaeonucula* that "Hinter der Bandgrube, zwischen Bandgrube und Hinterabschnitt der Zahnreihe, weder Bandgrabenzahn noch ein ebenes Verbindungsstück der Schlossplatte." Futhermore, his figure (*op cit.*, pl. 2, fig. 9) exhibits neither chondrophore tooth nor hinge-plate connecting anterior and posterior rows of denticles.

beaks turned slightly inward and toward the rear. The presence of a distinctly marked lunular area in some species was also considered to be a diagnostic feature by him.

CIRIACKS (1963, p. 38) recognized two groups of *Nuculopsis* in the Permian of the Middle Rockies, in the United States. Group I includes more elongate, subrectangular forms, with posteriorly located beaks, and Group II is characterized by smaller, subtrigonal forms, with more centrally placed beaks. The type species of *Nuculopsis* is undoubtedly included in Group I, while *N. montipelierensis* is in Group II. The latter group is more comparable to *Nuculanella*. However, we find no merit in separating *Nuculanella* as a genus or subgenus because there are intermediate forms connecting the two forms as shown by CIRIACKS. It seems to us to be preferable at present to consider the two groups as members of a single genus, *Nuculopsis*.

Three species of nuculoids have been described from the Permian of Japan. All are from the Katsura Formation in Shikoku:

Nuculopsis (*Palaeonucula*) *orientalis* ICHIKAWA (1951, p. 322, pl. 1, fig. 1)
N. (*P.*) sp., ICHIKAWA (*ibid.*, p. 323, pl. 1, fig. 2)
"*Nucula*" sp., ICHIKAWA (*ibid.*, p. 321, pl. 1, fig. 14)

The first species exhibits an intermediate form between Group I and II. The second species is correctly referred to Group I., while the third species is very similar to *bangarraensis* DICKINS and *montipelierensis* (GIRTY).

Superfamily Nuculanacea MEEK, 1864

Family Malletiidae H. & A. ADAMS, 1858

Genus *Nuculites* CONRAD, 1841

Type species: *Nuculites oblongatus* CONRAD, 1841 (subsequent designation by MILLER, 1889, p. 496).

The characteristic feature of *Nuculites* which distinguishes it from the similar genus *Palaeoneilo* is the presence of an internal myophoric buttress starting from, or in front of, the beak and running ventrally to or near the pallial line. The buttress is variable in both strength and direction. The genus *Nuculites* is generally considered to be limited to the Silurian and Devonian Systems, but HAYASAKA described *Nuculites kimurai* (1924, p. 49, pl. 6, figs. 4–7) from black shale of the upper Permian Toyoma Formation in Kitakami massif, northeast Japan, more than forty years ago. The second occurrence of *Nuculites* described below from the upper Permian in Shikoku confirms the view that the genus survived until the Permian Period in Japan. Thus far, it is unknown anywhere from the Carboniferous.

Nuculites ichikawai NAKAZAWA and NEWELL, new species

Plate 1, Figures 1, 2

Material.—Two left valves, one, represented by an internal mold, and the other by internal and imperfect external molds.

Description.—Shell of medium size, oval, elongate posteriorly; length attaining a little less than twice the height, moderately inflated; ventral margin broadly rounded without sinuation; antero- and posterodorsal margins nearly linear, making a very obtuse angle under the beak; posterior margin rather acutely rounded; beaks low, lying at about the anterior one-third of shell length, and terminating with prosogyrate beak; ligament external, opisthodetic, set in a very slender groove which occupies about two-fifths of the posterodorsal margin; lunule and escutcheon lacking; taxodont denticles not interrupted at beak, consisting of about thirty denticles in posterior row and eight or nine stronger ones in anterior row; a broad, strong but short internal myophoric ridge runs vertically between the beaks and anterior adductor scars; posterior adductor scar weakly impressed close to posterior end of the hinge; pallial line not seen; surface nearly smooth.

Measurements in mm:	Length	Height	1/2 Convexity	Preumbonal length
	22.5+	13.8	4.7	7.7
	25.5	14.4	5.5	7.5

Discussion.—In one specimen a small pedal retractor scar is preserved at the tip of the umbonal cavity and in the other one there are indistinct radial muscle impressions placed near the interior of the beak. These muscle scars are similar to those of Devonian species of *Nuculites*. In the present species the myophoric buttress is shorter and the radial pedal scars are closer to the beak than in the Devonian species. The former character was also noticed in *Nuculites kimurai* by HAYASAKA (1924, p. 50) and this may be a characteristic feature of the Permian species. In external shape, the present species is more like *oblongatus* than *kimurai*, but distiguished from the former by internal characters mentioned above. This species is similar to *Nucula prisca* GOLDFUSS (1834–40, p. 163, pl. 124, fig. 7; BEUSCHAUSEN, 1895, p. 71, pl. 6, fig. 8, *Ctenodonta*) which apparently belongs to *Nuculites*, but differs in a more inflated and robust shell.

Occurrence.—Rare in the upper Permian Katsura Formation (P 3), Shikoku.

Genus *Palaeoneilo* HALL and WHITFIELD, 1869*

Type species: *Nuculites constricta* Conrad, 1841.
Synonym: *Anthraconeilo* GIRTY, 1911 (type species: *A. taffiana* GIRTY)

GIRTY (1911, p. 132) distinguished *Anthraconeilo* from *Palaeoneilo* in lacking an external ligament and in ventral sinuation, but after examining well preserved topotype specimens of the type species, *Anthraconeilo taffiana* GIRTY we find that a ligament groove extends posteriorly from the beak occupying a little less than a half of posterodorsal margin, and the shell is slightly gaping at that place. A chondrophore apparently is absent. GIRTY considered the genus to be more extended anteriorly, and placed it in Nuculidae, but this is obviously erroneous, because the external ligament is set along the longer dorsal margin**. The degree of ventral sinuation of *Palaeoneilo* is variable, and some species are almost lacking in sinuation. So there is no distinct criterion for recognition of *Anthraconeilo*.

Ctenodonta SALTER, 1851 (type species: *Tellinomya nasuta* HALL=*Ctenodonta logani* SALTER) is also similar to *Palaeoneilo*, but the typical forms are distinguished from the latter genus in more central position of the beaks and in medially located ventral sinus and treated here as a distinct genus (see DIRSCOLL, 1965, p. 67; McALESTER, 1964, p. 16).

Two species of *Palaeoneilo* have been described from the Permian of Japan. These are: *P. ogachiensis* HAYASAKA (1924, p. 51, pl. 6, figs. 8–12) from the upper Permian Toyoma Formation in Kitakami massif and *P.* sp. (ICHIKAWA, 1951, p. 320, pl. 1, figs. 3a–b) from the upper Permian Katsura Formation in Shikoku. The third species described below is unusually large and elongate for the genus, and the generic position is somewhat questionable.

Palaeoneilo? sp.

Plate 1, Figure 3

Material.—An incomplete, internal mold of a right valve, a posterior part of which is missing.

Description.—Shell medium in size, strongly elongate, and nearly cylindrical; umbo indistinct, hardly salient above hinge-margin and lying at less than one third of shell-length from anterior end; dorsal and ventral margins almost parallel; anterior margin acutely rounded; posterior not preserved; dentition consisting of

* On the validity of this name the reader refers to SINCLAIR's (1951, p. 411) and McALESTER's (1962, p. 16, footnote) papers.

** GIRTY himself (1911, p. 132; 1914, p. 113, footnote) suspected the presence of pallial sinus and stated "If a sinus is really present, the orientation here employed should be reversed".

eight anterior denticles and more than twenty-eight posterior denticles, arranged in nearly straight linear series; muscle scars and pallial line not preserved; surface unknown.

Measurements in mm.—Estimated length, *ca.* 50; height, 16; preumbonal length, 13; convexity of single valve, 6.

Discussion.—This specimen has been mechanically deformed and its reference to *Palaeoneilo* is somewhat questionable. The elongate form of the Japanese specimen is reminiscent of *Pseudarca* TROMELIN and LEBESCONTE, 1875 (type species: *P. trommeri*) but the former differs in lacking a myophoric butterss.

Occurrence.—Obtained from black shale of the upper member of the Maizuru Group (P 2u) near Matsunoodera Station in Maizuru City where it was associated with ? *Phestia* (*Polidevcia*) sp., bellerophons, crinoids and bryozoans.

Family Nuculanidae H. & A. ADAMS, 1858

Genus *Phestia* CHERNYSHEV, 1951

CHERNYSHEV (1951) proposed two generic names for Carboniferous "*Nuculana*" from the Soviet Union, *Phestia** (type species: *P. inflatiformis* CHERNYSHEV from Donetz Basin) and *Polidevcia** (type species: *P. karagandensis* CHERNYSHEV from southwest Siberia). They are both distinguished from Mesozoic and Cenozoic *Nuculana* in having an internal ridge staring from near beaks and extending ventrally. According to CHERNYSHEV, *Polidevcia* differs from *Phestia* in the strongly elongate form and absence of a chondrophore. ELIAS (1957, p. 750) and DICKINS (1963, p. 36) expressed strong doubts about the absence of the chondrophore in *Polidevcia*, and DICKINS considered the genus to be a synonym of *Phestia*. LUTKEVICH and LOBANOVA (1960, p. 18) placed both under *Nuculana* as subgenera. According to them *Phestia* is represented by short shells at relatively shallow marine deposits, *Polidevcia* has an elongate shell with a straight umbonal keel, and is found in relatively off-shore, deeper sea sediments. KUMPERA *et al.* (1967, p. 17) examined *Polidevcia* in detail and concluded that it has a chondrophore and no external ligament. They erected a new subfamily Polidevciinae founded on *Polidevcia*. The main distinction of *Phestia* from *Polidevcia* is as follows: "Escutcheon and lunule are shallow to indistinct. In case of the escutcheon being distinct no special lanceolate area spearated by the rib is visible in it, which is typical of *Polidevcia*." They also noticed the common association of these genera in the same deposits and confessed that it is not easy to separate the two forms. In this paper *Polidevcia* is treated as a subgenus of *Phestia* following ELIAS. *Phestia* is not limited to the

* For the English translation of the generic diagnosis the reader refers to ELIAS' (1957) and KUMPERA *et al.* (1960) papers.

Paleozoic, but is found also in the Triassic as illustrated by *Nuculana* (*Dacryomya*) sp. of NAKAZAWA (1961, p. 270, pl. 14, figs. 5–7) from the Lower Triassic in the Maizuru Belt, southwest Japan, which we now believe to be a true *Phestia* s. s.

? *Phestia* (*Polidevcia*) sp.

Plate 1, Figures 4 a, b

Material.—A single, univalved specimen, represented by internal and external molds.

Description.—Shell small, falcate, strongly elongate, more than four times as long as high; posterior half tapering backward and curving gently upward; anterior part much shorter than the posterior, with acutely rounded extremity; umbo moderate, orthogyrate and incurved, slightly behind the anterior one-third of the shell length; lunule and escutcheon distinct, escutcheon marked by a sharp carina extending from the umbo to the posterior extremity; ligament external, opisthodetic, set in a rather wide and deep furrow along half of the posterodorsal margin. Dentition and muscular impression not preserved; surface covered by regular, closely set, concentric costae.

Measurements in mm.—Length, 21.5; height, 4.8; preumbonal length, 5.4; convexity of single valve, *ca.* 2.7.

Discussion.—The specimen is considered to be strongly deformed, and it is almost impossible to interpret the original shape. Although the dentition is not preserved, it is probable that the present species belongs to *Phestia* (*Polidevcia*) judging from the slender, arcuate form, distinct lunule and escutcheon. Furthermore, a trace of a depression is recognized near the umbo of the internal mold, which is suggestive of *Phestia.*

Occurrence.—Middle Maizuru Group (P 2u), south of Matsunoodera Station in Maizuru City.

Order Praecardioida NEWELL, 1965

Superfamily Edmondiacea KING, 1850

Family Edmondiidae KING, 1850

Genus *Edmondia* DEKONINCK, 1841

Type species.—*Isocardia unioniformis* PHILLIPS, 1836 (original designation). Two doubtful examples of *Edmondia* were described by ICHIKAWA from the upper Permian Katsura Formation in Shikoku:

Edmondia? *a* sp. (Ichikawa. 1951, p. 324, pl. 1, fig. 9)
Edmondia? *β* sp. (*ibid.*, p. 324, pl. 1, fig. 8)

We found three occurrences of *Edmondia* but specific determination is impracticable because of secondary deformation and poor representation.

Edmondia sp. *a*

Plate 1, Figures 6 a, b

Material.—Many specimens were obtained from the upper Permian Gujo Formation in Kyoto Prefecture, most of which are deformed articulated valves.

Description.—Small, inequilateral, fairly inflated, elongate and quadrangular-ovate in shape; umbo prominent, slightly prosogyrate, very anterior; two rounded ridges start near beaks and run along both sides of the strongly inflated umbones towards antero- and posterodorsal margins, fading away in a short distance; ventral and dorsal margin subparallel; posterior margin gradually curving upward and forward, intersecting dorsal margin at a very obtuse, rounded angle; anterior margin is nearly upright; lunule and escutcheon absent; hinge edentulous; internal hinge plate characteristic of the genus relatively short and projecting ventrally; muscle scars and pallial line not shown; surface covered by concentric irregular wrinkles and close-set, fine, concentric growth lines; shell margin closed; granular texture of the shell surface very minute without regular arrangement, counting about ten granules in each linear mm.

Measurements in mm:	Length	Height	Preumbonal length
	26.8	20.8	2.5
	37.8	13.7	2.0
	27.8	25.5	3.8
	35.0	19.4	2.0
	25.5	15.2	2.2
	32.9	14.4	1.6
	32.1	12.0	4.8
	13.6	15.5	terminal
	20.0	21.0	3.5
	28.0	25.3	2.0

Disucssion.—Some specimens were found in a position with the plane of commissure vertical to the bedding plane, and in this case the hinge axis forms an angle of thirty to fifty degrees with the stratification. These individuals are considered to have been buried in the living position. Other bivalved individuals may have also been buried near where they lived.

All specimens have been secondarily strongly deformed. Some show very elongate form, while other ones are extended vertically. The laterally compressed, tall form is very similar to *Allorisma similis* LUTKEVICH and LOBANOVA (1960, p. 83, pl. 10, figs. 6–8) from the upper Permian of Taimur in Russia, and the laterally elongated form is much like *Edmondia accipiens* (SOWERBY) (HIND, 1889, p. 331, pl. 18, figs. 8–16) from the Carboniferous in England, but these similarities are superficial and are caused by secondary crushing. The species is considered to have an intermediate form between the two, and is more similar to *E. transversa* HIND (*op, cit.*, p. 317, pl. 32, figs. 12–16), but the umbonal slope is more rounded and the umbo is more robust in the latter species. The present form possibly represents a new species, but the poor preservation makes this possibility very uncertain.

Occurrence.—Common in the Gujo Formation, Kyoto Prefecture, west Japan.

There are several specimens of *Edmondia* similar to the preceding, but differing in the development of fairly regular concentric wrinkles. It is not certain whether this modification is an effect of faulty preservation.

Edmondia sp. *b*

Plate 11, Figure 7

Material.—There are three left, one right, and one bivalved specimens in addition to several questionable ones. All are incompletely preserved.

Description.—Shell medium in size, suboval; length about one and a half the height; not so inflated; umbo robust, nearly orthogyrate, beak lying at about anterior one-third of the shell length; lunule and escutcheon absent; internal plate similar to the preceding species; surface covered by strong, regularly arranged, concentric wrinkles which become obsolete near the posterodorsal margin; muscle and pallial impression not preserved.

Discussion.—This form is readily distinguished from the associated *Edmondia* sp. *a* described above in ovate outline, more posteriorly located umbo, more regular concentric sculpture and less convex shell. It is similar to *Edmondia tschernyschewiana* FREDERICK described by LICHAREW (1939, p. 131, pl. 31, figs. 17 a, b) from the lower Permian of the Urals, but differs in more regular ornamentation and more posterior position of the beak.

Occurrence.—Rare in the upper Permian Gujo Formation (P 3) in Kyoto Prefecture, west Japan. Two questionable specimens have been procured from the Upper Member of the Maizuru Group (P 2u) at Kuwanoe pass, Ayabe City, Kyoto Prefecture.

Edmondia sp. *c*

Plate 1, Figures 7, 8

Material.—One left, one right and a matched pair of valves are at our disposal, all of which are represented by molds, and more or less mechanically crushed.

Description.—Shell small, rounded quadrate, somewhat inequilateral, moderately inflated; umbo strong, salient above hinge margin; beak incurved and directed forward, lying at about anterior two-fifths of the shell length; umbonal ridge blunt, running from the beak to the posteroventral extremity; anterior and ventral margins making semicircular curve and suddenly rising up to the arcuate posterior margin; hinge edentulous; internal plate occupying about a hlaf of the shell length and projecting ventrally; muscle scars and pallial line not observed; surface covered by concentric costae, which are relatively sharp and distinct near the anterior margin becoming obscure on flank and posterior areas; lunule and escutcheon absent.

Measurements in mm:	Length	Height	1/2 Convexity	Preumbonal length
	16.8	15.5		6.4
	18.8	*ca.* 15.0		7.8
	6.6	*ca.* 7.0	*ca.* 2.0	2.8
	8.4	7.3	*ca.* 2.5	3.3

Discussion.—In external shape this species is similar to the Upper Carboniferous *Edmondia rudis* M'Coy described by Hind (1899, p. 302, pl. 27, figs. 15, 15a; pl. 28, figs, 8–14; pl. 32, figs. 1, 3–6) from England and *E. nebrascensis* (Geinitz) described by Yakowlev (1903, p. 22, pl. 1, figs. 21), Maslennikov (1935, p. 98, pl. 6, figs. 3a, b) and by Lutkevich and Lobanova (1960, p. 78, pl. 8, figs. 14–17) from the Permian in the Soviet Union. The latter species is somewhat different from the Carboniferous American *nebrascensis* in sculpture and probably is not conspecific with it. The Japanese species is distinguished from these in a somewhat taller outline and different ornamentation which is distinct near the anterior margin and obscure over the main part of the shell. The latter feature is remindful of the diagnostic character of *Sedgewickia* M'Coy (1844, p. 61; Hind, 1899, p. 277), but the presence of internal plate makes it more reasonable to refer the species to *Edmondia.*

Occurrence.—Rare in the Tenjinnoki Formation (P 21), at Tenjinnoki and Teranosawa, Maiya, Towa-cho, Miyagi Prefecture, northeast Japan.

Family Sanguinolitidae

Genus *Sanguinolites* M'COY, 1844

Type species: *Sanguinolites discors* M'COY, 1844 (subsequent designation by STOLICZKA, 1871).

Sanguinolites sp.

Material.—An internal and an external molds of articulated specimen which are considered to suffer from slight secondary deformation.

Description.—Shell inequilateral, subquadrangular, posteriorly extended, 41.3 mm long, 21.4 mm. high with height/length ratio of nearly 1/2 measured on the internal mold; convexity about two-thirds of shell-height; umbo subdued, with slightly prosogyrate beak, lying at less than one-fourth of the length from the anterior margin; dorsal margin nearly straight; anterior margin rounded, curving uniformly into a straight ventral margin which is parallel to the dorsal margin; ventral margin abruptly rising up and forward into truncated posterior margin with a slight gape near dorsal margin; umbonal ridge rounded, prominent, defining a triangular posterodorsal slope; midumbonal depression anterior to the umbonal ridge very shallow and wide leaving no ventral sinus; lunule and escutcheon deep and wide; ligament external, extending along more than one half of the posterior hinge margin; apparently edentulous; posterior surface with a few radiating costellae which die out dorsally; muscle scars and pallial line unknown.

Discussion.—This species recalls the Carboniferous *S. striato-granulosus* KONINCK (1885, p. 84, pl. 15, figs. 14, 15, *tri-costatus*; HIND, 1900, p. 303, pl. 42, figs. 16–22) from Belgium and England and the Permian *S.* ? sp. of CIRIACKS (1963, p. 73, pl. 14, figs. 12, 13) from the Park City formation in the Middle Rockies. It is distinguished from the former in lacking radial carina in the posterodorsal area, from the latter in less elongate form, and from the both in more strongly developed granular texture on the surface. This probably is a representative of an unnamed species.

Occurrence.—Very rare in the fine-grained sandstone of the lower Kanokura Formation (Shegejizawa Member) (P 21) at Kamiyasse, Kesennuma City, Miyagi Prefecture, northeast Japan.

Sanguinolites kamiyassensis NAKAZAWA and NEWELL, new species

Plate 11, Figures 3, 4

Material.—A single, left internal mold with a fragment of the external mold is available for study. The specimen retains original shape, judging from the associated fossils.

Description.—Shell medium in size, very inequilateral, elongate-subquadrangular in outline, 50.3 mm long, 18.5 mm high with H/L ratio of 0.37; umbo moderate, lying at about one-fifth of shell-length from anterior extremity, terminating with prosogyrate and slightly incurved beak; dorsal and ventral margin slightly convex; anterior margin semicircular; posteroventral margin rising abruptly upward and forward into truncated posterior; prominent umbonal ridge running from umbo to posterodorsal extremity defining a depressed posterodorsal area; posterodorsal area a little inflated and provided with two radial carinae, upper of which dies out posteriorly; hinge edentulous; escutcheon long and narrow, lunule small and indistinct; muscle scars and pallial line unknown; surface nearly smooth except for weak concentric rugae, papillate texture not observed.

Discussion.—The strong umbonal ridge and two radial carinae on the posterodorsal area are distinctive. In this respect this species is similar to the Lower Carboniferous *Sanguinolites subplicatus* KIRBY described by KONINCK (1885, p. 80, pl. 15, figs. 5, 6) and *S. tricostatus* PORTLOCK of HIND (1900, p. 391, pl. 42, figs. 11–15, *non* KONINCK, 1885), but differs from the former in less expanded posterior part, more tumid umbo, and from the latter in the more acute umbonal ridge and nearly straight ventral margin. Among Permian species this one is somewhat like *S. modiomorphoides* GRABAU (1931, p. 318, pl. 31, figs. 4a, b) from Mongolia, but readily distinguished by its much longer outline.

Occurrence.—Very rare in the Shegejizawa Memger (lower Kanokura Formation) (P 21) at Kamiyasse, Kesennuma City, Miyagi Prefecture, northeast Japan.

Sanguinolites? sp.

Plate 1, Figure 11

Material.—A single, external mold of a right valve represents this form.

Description.—Shell roundly quadrangular, elongate posteriorly, 38.4 mm long and 18.0 mm. high, H/L ratio of 0.47; very inequilateral, umbo subdued lying at about one-fourth of shell length from anterior end; dorsal margin nearly straight; anterior part of shell somewhat tumid, anterior margin rounded curving uniformly into broadly rounded ventral margin, which rises abruptly to the truncate posterior margin; posterior margin meets dorsal margin at a very obtuse angle; blunt, rounded umbonal ridge runs from the umbo to the posteroventral end; posterodorsal area sculptured by four obscure radial carinae; general surface covered by close-set, fine growth lines; lunule, escutcheon and hinge unknown.

Discussion.—This form recalls *S. tricostatus* (PORTLAND) but the radial carinae are more obscure and the anterior part is a little more tumid than the latter. Externally *Allorisma dubium* WAAGEN (1881, p. 196, pl. 17, fig. 7) fromthe Upper Productus Limestone of Salt Range resembles the present species, but is more inflated and lacks radial carinae.

Occurrence.—Very rare in the Tenjinnoki Formation (P 21) at Tenjinnoki, Maiya, Towa-cho, Miyagi Prefercture, northeast Japan.

Wilkingia sp.

Plate 10, Figure 6

Material.—Incomplete, internal and external molds of a single right valve are at hand. They have been strongly crushed and compressed dorsoventrally.

Description.—Shell large, subcylindrical, more than 98 mm long and 33 mm high, H/L ratio approximately 1/3: strongly inequilateral; umbo robust, a little salient above hinge margin; beak orthogyrate, lying behind the anterior margin approximately one-fifth of the length of shell; dorsal and ventral subparallel margins curving slightly upward; anterior margin rounded, continuing gradually into broadly rounded ventral margin; posterior margin truncated, apparently gaping; rounded obscure umbonal ridge running from umbo to posteroventral direction; surface covered by faint growth lines and somewhat irregular concentric wrinkles; granular texture of exterior surface very minute, about ten granules in one linear millimeter; lunule and esctucheon reflected on the internal mold; muscle scars and pallial line not observed.

Disucssion.—The specimen has suffered some crushing and the original shape cannot be accurately known. *Sanguinolites lunulatus* (KEYSERLING) described by MASLENNIKOV (1935, p. 97, pl. 5, fig. 9) from the upper Permian of Northern Region of USSR is similar to this species, but is less elongate. *Wilkingia waageni* (REED) (1944, p. 298, pl. 56, fig. 1) from the lower Middle and upper Lower Productus Limestone is another allied species, but is distinguished by more anterior position of the umbo and less angulated posteroventral corner.

Occurrence.—Very rare in the sandstone of the lower? Kanokura Formation (P 21) at Imo, Iwate Pref., northeast Japan, collected by KOIZUMI.

Family Megadesmidae VOKES, 1967

Genus *Pyramus* DANA, 1847

Type species: *Pyramus myiformis* DANA (subsequent designation by NEWELL, 1956).

The type species of *Pyramus* and of *Notomya* are so similar that they have been regarded by some students as congeneric or even conspecific (NEWELL, 1956; WATERHOUSE 1965). We are, therefore, treating the latter as a subjective synonym of *Pyramus*.

Pyramus planus NAKAZAWA and NEWELL, new species

Plate 1, Figures 5, 9, 10

Material.—There are ten nearly complete external molds and two internal molds in our collection.

Description.—Shell medium sized, equivalve; a little inequilateral, ovate, longer than high with height/length ratio approximately 1/1.7; a little inflated; umbo subdued, orthogyrate, located anterior to the middle; antero- and posterodorsal margins nearly straight; anterior margin well rounded, continuing to slightly arcuate ventral margin; posterior half is somewhat tumid compared with anterior half, and sometimes obscurely truncated posteriorly; surface covered by numerous, fine, close-set growth lines and rugae which are variable in strength and in arrangement; granular texture of genus not observed; ligament opisthodetic, elongate; lunule and escutcheon weak or absent; hinge consisting of an obscure triangular tooth and linear, weak depression anterior to the tooth in the right valve, with corresponding socket and projection in the left; oval posterior adductor muscle scar impressed near the posterodorsal margin; anterior scar not clearly seen, but located near the anterodorsal border; pallial line distinctly sinuated under posterior adductor scar.

Measurements in mm:	Length	Height	Preumbonal length
RV	20.4	12.3	10.0
RV	21.5	11.3	8.5
RV	20.4	12.4	9.3
RV	19.6	12.4	7.8
RV	17.9	10.2	7.5
RV	17.8	9.4	—
RV	17.9	12.0	8.2
RV	26.0	18.8	9.6
LV	35.9	23.7	15.9
LV	23	15.8	10.0
LV	20.6	12.3	7.6

Discussion.—The hinge of the specimens in our collection is incompletely preserved. Apparently, it consisted of a weak subtrigonal cardinal tooth and posterior socket in the right valve and a corresponding socket and tooth in the left. Thus, the basic pattern coincides with that of *Pyramus*. The presence of a pallial sinus and the lack of distinct lunule, escutcheon and umbonal ridge in the Japanese specimens likewise conform to *Pyramus*, a genus which characterizes the cold-water of the eastern Australian Permian.

From the Australian examples of *Pyramus* the Japanese species is distinguished by shorteroutline, weaker dentition and somewhat more indented pallial sinus.

Occurrence.—Fairly common in the Gujo Formation (P 3) at Gujo, Kyoto Prefecture, west Japan.

Subclass Pteriomorphia BEURLEN, 1944

Order Arcoida STOLICZKA, 1871

Subfamily Arcacea GOLDFUSS, 1820

Family Parallelodontidae DALL, 1898

Genus *Parallelodon* MEEK and WORTHEN, 1868

Type species: *Macrodon rugosus* BUCKMANN, 1845.

Parallelodon cf. *longus* MASLENNIKOV 1935

Plate 1, Figure 12

Material.—There are five incomplete specimens collected from several localities.

Description.—Shell small, elongate, more than twice as long as high, subquadrate, strongly convex; umbo robust, not salient above hinge margin, lying at about anterior one-fourth of shell length; dorsal and ventral margins parallel with each other and nearly straight; posterior margin truncate, intersecting dorsal margin at obtuse angle; anterior part tumid; umbonal ridge strong and well rounded, defining posterodorsal area which is relatively narrow and steeply inclined, dorsally; hinge consisting of several small anterior denticles and long one or two slender posterior teeth nearly parallel with hinge margin; anteriormost three or four teeth curving up and forward becoming nearly horizontal, the succeeding denticles gradually changing their axis to a posteroventral direction; ligament area narrow and not well shown; surface nearly smooth excepting faint growth lines; muscle scars and pallial line not shown.

Discussion.—One specimen (from the Kanokura Formation of Kitakami massif) shows eight anterior denticles, diverging dorsally; anterior individuals of which curve upward and forward, tending to run parallel with cardinal margin, while the remainder dips downward. In another specimen collected from Monobe, Kyoto Prefecture, three anterior denticles and a long, slender posterior tooth are preserved. In a specimen from Oe-cho, Kyoto Prefecture, a circular anterior adductor scar is impressed close to the anterodorsal corner.

These specimens are characterized by elongate shape and smooth shell surface without radial ornaments. In these respects the species is comparable to *P. trimuensis* REED (1944, p. 288 pl. 54, fig. 13) from the Lower Productus Limestone of the Salt Range, *P. politus* GIRTY (1908, p. 424, pl. 9, fig. 25) from the middle part of Capitan Formation in Texas, *P. obsoletus* (MEEK) (1875, p. 334, pl. 19, fig. 9; KEYES, 1894, p. 120, pl. 46, fig. 1, *Macrodon*) from the Upper Carboniferous in Kansas, and *P. obsoletiformis* HAYASAKA (1925, p. 18, pl. 8, figs. 15, 16) from the middle Permian in Japan. This species is distinguished from *obsoletus*, *timuensis* and *obsoletiformis* in the much smaller size, an obscure radial depression in the middle part of the shell, and from *politus* in the narrower posterodorsal area and lack of a posterior auricle. The species most resembles *P. longus* MASLENNIKOV (1935, p. 114, pl. 3, figs. 7, 8) from the upper Permian of northern part of USSR. But materials are insufficient for close comparison.

Occurrence.—Rare in the Upper Member of the Maizuru Group at Kuwanoe pass, Monobe, Ayabe City, Kyoto Prefecture, and at Nomaru, Oe-cho, Kyoto Pretecture (P 2u). Rare in the lower Kanokura Formation (P 21) at Kamiyasse, Kesennuma City, Miyagi Prefecture, and in the Tenjinnoki Formation (P 21) at Tenjinnoki, Towa-cho, Miyagi Prefecture.

Parallelodon cf. *multistriatus* GIRTY

Plate 2, Figure 1

Material.—Two pairs of valves and a questionable left valve are in our collections. They are more or less mechanically deformed.

Description.—Shell small, moderately inflated, elongate, subtrapezoidal, H/L ratio varying between 0.33 and 0.41; umbo prominent, salient above hinge margin, terminating in orthogyrate beaks which are located at about one-fourth of shell length behind anterior margin; dorsal and ventral margins straight, subparallel, anterior extremity somewhat tumid; posterior margin truncated, intersecting dorsal margin at a very obtuse angle; anterior denticles are as in the species described above, posterior teeth consist of three long, parallel teeth which ventrally become shorter; umbonal furrow absent; surface sculptured by faint radial striae which become obsolete posteriorly; muscle scars and pallial line unknown.

Measurements in mm:	Length	Height	Preumbonal length
RV	22.8	*ca.* 8.8	7.3
LV	26.3	8.8	5.3
LV	*ca.* 22.2	9.1	5.3

Discussion.—In general outline the present species resembles the preceding species but is shorter and easily distinguished by presence of very faint, close-set radial striae. In this respect the Japanese form is much like the Permian *P. multistriatus* GIRTY (1908, p. 423, pl. 31, figs. 13, 14), but the radial striae in the present species are narrower than the interstices and become obscure posteriorly, while those of *multistriatus* are wider than interstices and uniform in strength over the whole surface.

Occurrence.—Rare in sandy shale of the Kashiwadaira Formation, Takakurayama Group (P 2u) at the northern slope of Takakurayama near Tamayama, Yotsukura-machi, Fukushima Prefecture, northeast Japan.

Parallelodon cf. *tenuistriatus* (MEEK and WORTHEN), 1866

Plate 2, Figure 2

Material.—A single incomplete, external mold of a right valve occurs in our collection.

Description.—Shell small, elongate, subquadrangular; 24 mm long and about 12 mm high; umbo prominent, salient above hinge margin; beak not preserved but presumably lying at about anterior one-fifth of the shell length; dorsal and ventral margins straight, subparallel except for a faint indentation of the pedal area under the umbo; anterior margin slightly curved; posterior margin almost straight, intersecting dorsal margin at a right angle; umbonal ridge obscure, defining a relatively broad, depressed, triangular posterodorsal area; hinge, ligament area and musculature unknown; surface ornamented by growth lines and radial striae; some of the growth lines are developed into lamellose concentric sculpture; radial striae very weak, wider than interstices and almost limited on the posterodorsal area.

Discussion.—This species is quite similar externally to *Parallelodon tenuistriatus* (MEEK and WORTHEN) from the Upper Carboniferous of the United States. The former differs in lacking radial ornament over most of the flank, while in the latter species radial striae become obsolete on the flank but are still discernible. Further comparisons of the Japanese material are impracticable because of poor preservation of the material.

Occurrence.—Very rare in fine-grained sandstone of the lower Kanokura Formation (P21) at Kamiyasse, Kesennuma City, Miyagi Prefecture, northeast Japan.

Order Mytiloida FÉRRUSAC, 1822

Superfamily Mytilacea RAFINESQUE, 1815

Family Mytilidae RAFINESQUE, 1815

Subfamily Modiolinae KEEN, 1958

Genus *Promytilus* NEWELL, 1942

Type species: *Promytilus annosus* NEWELL, 1942 (original designation).

Promytilus maiyensis NAKAZAWA and NEWELL, new species

Plate 2, Figures 5, 6

Material.—Many specimens in our collection are referred to this species. All have been more or less crushed, secondarily.

Description.—Shell small, obliquely elongate, length slightly exceeding height by a ratio of about 1.12; dorsal margin slightly convex, dorsally, continuing uniformly to a broadly arcuate posterior margin and well-rounded posterodorsal margin; dorsal margin bears a slender ligament groove similar to that of recent *Modiolus* extending along about two-thirds or three-fourths of hinge margin; anterior margin distinctly sinuated below relatively small but well marked lobe; umbo terminal or subterminal, hardly salient above hinge margin, umbonal carination rather strong with an umbonal angle of about 60 degrees at late growth; surface covered by faint growth lines, and sometimes one or two strong imbrications; oval anterior adductor scar found in the interior of anterior lobe, posterior scar not observed.

Measurements in mm:	L	H	D	dl	a	H/L	hl
LV	14.0	11.0	15.0	8.0	50	0.78	6.0
LV	13.0	13.0	14.5	9.0	75	1.00	5+
LV	*ca.* 14.0	16.0	19.0	12.0	70	1.14	—
LV	18.6	17.3	21.5	11.5	72	0.93	8.3
LV	16.4	12.2	16.4	10.8	53	0.74	9.0
LV	13.0	11.4	14.4	10.0	56	0.88	—
LV	7.5	7.0	9.0	—	90	0.94	—
RV	17.5	17.0	21.0	10.0	65	0.97	6.8
RV	19.0	15.7	20.2	12.0	50	0.83	8.0
RV	10.2	8.5	11.0	7.0	85	0.83	4.5

dl: length of dorsal maigin, hl: length of legament groove, D: umbonal length, a: umbonal angle in degree.

Discussion.—Although most specimens have been somewhat mechanically deformed, the mean value of measurements is considered to approximate the original form. In well-preserved specimens the ligament area tapers forward and terminates at the anterior end, and in several specimens it is provided with a slender ligament ridge or nymph that extends the whole length of the hinge. The prominent umbonal carination and consequently the strong inclination of the anterior slope of the shell, and small but sharply defined anterior lobe are the characteristics which distinguish the Japanese species from other species of the genus such as the Upper Carboniferous *P. priscus* NEWELL (1942, p. 40, pl. 1, figs. 1, 2, 5–7) or *P. swallowi* (MCCHESNEY) (NEWELL, *ibid.*, p. 37, pl. 1, figs. 8, 13). "*Modiola*" *megaloba* (M'COY) described by HIND (1896, p. 60, pl. 2, figs. 5–10, especially figs. 5 and 9) is similar to this species in the feature of anterior lobe, but the shells are more obliquely elongate, and the anterior lobe is larger and the umbonal ridge is more rounded.

There are found two associated variants of the Japanese species. One has a nearly straight anterior margin and more obsoletely defined anterior lobe. This is very similar to *Promytilus maiyensis*? described below, but has a less oblique outline. The other one is represented by small shells having more robust, quadrate shape, and gentle anterior slope.

There are several examples which preserve the imprint of radial prismatic structure in the external molds. These probably indicate fibrous shell structure of the ectostracum (OBERLING, 1964) similar to that of the Pennsylvanian *Promytilus swallowi* NEWELL (1942, p. 33). The large diameter of the "fibers", attaining to 50 microns, is surprising, because in the case of *swallowi* the diameter is less than 2 microns. This disparity might be an effect of diagenetic recrystallization in the Japanese forms.

Occurrence.—Common in the Tenjinnoki Formation (P 21) at Tenjinnoki, Towa-cho, Miyagi Prefecture, northeast Japan.

Promytilus sp. *a*

Plate 2, Figures 7, 8

Material.—Numerous crushed fragments.

Description.—Shell small, obliquely elongate, umbo anterior but not terminal; dorsal margin nearly straight or slightly convex; umbonal carination distinct, rounded, nearly straight, separating steep anterior slope and anterior lobe, umbonal angle about 40 degrees; anterior lobe well developed but not clearly separated from anterior slope; nearly linear with weak or absent sinuation; ligament groove occupying nearly whole hinge margin; anterior adductor scar relatively small, elongately oval; posterior adductor scar and pallial line not observed; surface covered by weak growth lines.

Discussion.—Judging from the growth lines, anterior sinuation is distinct in the early growth stage becoming obscure later. This species recalls *Modiolus* in having a projected anterior lobe anterior to the beak, but some individuals have nearly terminal umbones and a prominent umbonal ridge close to the anterior margin. This is unusual to *Modiolus*. Thus this species possesses some of the attributes of both *Modiolus* and *Promytilus*. This form is similar to *P. maiyensis* described above, but differs from the latter in the more oblique shell, longer ligament, non-terminal umbo, and nearly straight anterior margin. It is more similar to the early Permian *Modiolus koneckii* DICKINS (1963, p. 61, pl. 8, figs. 6–11, text fig. 9) from Western Australia. From that species it is distinguished in a less oblique outline and more pronounced umbonal carination. The Japanese shells may represent an unnamed species, but the preservation is too poor to infer the characters of the living population to which they belonged.

Measurements in mm:	L	H	D	dl	hl	a	H/L
RV	20.8	14.3	24.7	12.5	11.5	32	0.69
LV	18.8	15.3	23.7	12.7	11.6	45	0.84
RV	23.0	16.0	26.5			46	0.70
RV	18.0	14.8	19.7			47	0.80
RV	17.8	14.6	23.3			28	0.82
RV	16.3	11.7	16.7			47	0.71

Occurrence.—Common in the Gujo Formation (P 3) at Gujo, Oe-cho, Kyoto Prefecture, west Japan .

?*Promytilus maiyensis* NAKAZAWA and NEWELL, new species

Plate 2, Figure 9

Discussion.—This form is represented by two specimens in association with the preceding species in the Gujo Formation. It is distinguished by a less oblique shell and smaller, but well demarcated anterior lobe. It is similar to one of the variants of *P. maiyensis*, but differs in the larger size, more posteriorly located umbo, and less prominent umbonal carination.

Measurements in mm:	L	H	D	a	H/L
RV	28.0	30.3	35.8	65	1.08
LV	21.5	22.7	23.0	65	1.06

Promytilus sp. *b*

Plate 2, Figure 10

Discussion.—A single internal mold of a right valve was collected from the Rodai Formation of the Maiya Group (P 1u), at Maiya, Towa-cho, Miyagi Prefecture, northeast Japan. It is 27 mm long and 18.1 mm high, with a maximum dimension of 28 mm, and an umbonal angle of 45 degrees. It is distinguished from *P. maiyensis* in less pronounced umbonal ridge and larger anterior lobe. In these respects it is similar to *P. swallowi* (MCCHESNEY) and *P. priscus* NEWELL. In considering the deformation of associated crinoid stems, the specimen is considered to have been stretched antero-posteriorly by tectonic forces. Probably the original shape was less oblique and less slender.

Superfamily Pinnacea LEACH, 1819

Family Pinnidae LEACH, 1819

Genus *Aviculopinna* MEEK, 1864

Type species: *Solen pinnaeformis* GEINITZ (original designation)

When HIND discussed *Pteronites* M'COY (1844, type species: *P. angustatus* M'COY, subsequent designation by STOLICZKA, 1871) he stated, "I have little or no hesitation in considering *Aviculopinna* of MEEK as a synonym of *Pteronites.* He founded this genus of pinniform shells with non-terminal umbones and a sinuous posterior border, both of which characters are well shown in his type *A. americana.*" (1901, p. 6). But *americana* is neither the type species of *Aviculopinna* nor the usual form of the genus. The type species, *pinnaeformis,* as well as many other species of the genus, is strongly extended posteroventrally and the dorsal margin does not coincide with the shell length except in the questionable species, *A. peracuta* SHUMAD (MEEK, 1872, p. 198, pl. 6, figs. 11a, b; KEYES, 1894, p. 116, pl. 45, figs. 2a, b). The posterior margin of *Aviculopinna* is, in most cases, nearly straight, rising upward and forward from the ventral margin, making an acutely rounded posteroventral angle; the shape is much more elongate than that of *Pteronites* with a small "apical" angle, even in *americana.* Thus, *Aviculopinna* is treated here as a distinct genus. The genus may have been derived from *Pteronites* through some intermediate form like *americana,* and, in turn, may have given rise to *Pinna* or *Atrina**.

* As pointed out by TURNER and ROSEWATER (1958), *Atrina* has a simpler undivided nacreous layer and is more primitive than *Pinna.* Many of the Paleozoic and Mesozoic species of *Pinna* may be transfered to *Atrina,* but in most cases there is no observation concerning the nacreous layer.

It is interesting that the Japanese Permian *Aviculopinna* sp., described below, and *A. timanica* MASLENNIKOV, from the late Permian in the northern region of the USSR have a terminal umbo, as *Pinna* or *Atrina*. It seems to be desirable to separate them subgenerically from *Aviculopinna* in which the umbo does not reach the anterior end. More materials than we have are needed to solve this problem.

Aviculopinna sp.

Plate 3, Figure 1

Material.—There are two specimens in our collection from the Gujo Formation. One is incomplete but well preserved, retaining an apical portion. The other is nearly complete, but severely crushed and its relationship to the former is uncertain.

Description.—Shell of medium size, equivalve, posteriorly very extended, acutely trigonal in shape with an apical angle of 16 to 25 degrees; umbo indistinct, terminal; median transverse ridge rounded, starting from the umbo and running above midheight in the middle part of shell, then gradually shifted ventrally, and flattened; the most inflated medial part forming a rhomboidal cross section with sharp edges of straight dorsal and ventral margins; posterior margin truncate, intersecting the dorsal margin at an obtuse angle, and making an acutely rounded angle with ventral margin; surface covered by weak, regular, close-set growth lines over the dorsal side above the medial ridge, and by growth wrinkles below: ligament area narrow, grooved by several, faint thread-like transverse furrows; radial, narrow depression starting from near anterior end, running posteroventrally, and separating an inflated anteroventral marginal portion which corresponds to the anterior lobe of mytiloids.

Discussion.—The terminal umbo and sharp medial ridges distinguish this form from other Paleozoic species, such as the Carboniferous *A. americana, pinnaeformis* and *peracuta*. *Aviculopinna timanica* MALSENNIKOV (1935, p. 38, pl. 4, figs. 1–4) from the late Permian of Timan is similar to this species. Both are intermediate in form between *Aviculopinna* and the Mesozoic *Pinna* or *Atrina*. The present species differs from *timanica* in a less acute umbonal angle and the anterior lobe is inflated, being bounded by a radial furrow, while that of *timanica* is depressed and defined by radial ridge.

Occurrence.—Rare in the Gujo Formation (P 3) at Gujo, Oe-cho, Kyoto Prefecture, west Japan.

Aviculopinna cf. *rectangularis* (HAYASAKA)

Plate 3, Figure 2

Material.—A single, incomplete, bivalved specimen was found in the lower Kanokura Formation at Kamiyasse, Kesennuma City, Miyagi Prefecture, northeast Japan.

Discussion.—*Conularia rectangularis* was first introduced by HAYASAKA (1920, p. 1, text figs. 1–4) from the Kanokura Formation in Kamiyasse. SUGIYAMA (1942) placed it in his new genus *Neoconularia* by unusual characteristics for *Conularia.* Recently, HAYASAKA (1963a, p. 475, text figs. 1 a–d) examined new materials and stated, "Thus, it seems plausible to suppose that *Conularia rectangularis*, that is, *Neoconularia*, might stand outside the limits of *Conularia*, and perhaps of Conulariidae." We think that this species is regarded as *Aviculopinna.* Our specimen is probably identical with *rectangnlaris*, but the material is too fragmentary, and flattened secondarily for exact comparison.

Order Pterioida NEWELL, 1965

Superfamily Ambonychiacea MILLER, 1877

Family Myalinidae FRECH, 1891

Genus *Myalina* DEKONINK, 1842

Type species: *Myalina goldfussiana* DEKONINCK, 1842.

Myalina (*Myalina*) sp.

Plate 2, Figure 4

Material.—One incomplete, internal mold of a left valve with fragment of the external mold was procured.

Description and discussion.—Shell medium in size, more than 25 mm high and more than 22 mm long, prosocline with an umbonal angle of about 70 degrees; moderately inflated; umbo terminal; anterior lobe obscure; ligament area narrow, provided with three strong grooves, which intersect the lower margin of the area at a very acute angle; small, shallow dental socket observed at the interior of anterodorsal extremity; muscle scars and pallial line unknown.

Apparently, this shell was covered by distinct but not foliated growth lines. The posterior margin is not alate. In these particulars the species is similar to *Myalina wyomingensis thomasi* NEWELL (1942, p. 51, pl. 14, figs. 15, 16) from the upper Permian of Wyoming, but a significant comparison is not practicable.

Occurrence.—Very rare in black, gritty shale of the Toyoma Formation (P 3) at Kitazawa, Toyoma-cho, Miyagi Prefecture, northeast Japan.

Genus *Septimyalina* NEWELL, 1942

Type species: *Myalina peratenuata* MEEK.

Septimyalina sp.

Plate 2, Figure 3

Material.—A single, imperfect, internal mold of a left valve and its fragmental counterpart were collected.

Description.—Shell of medium size, moderately inflated, prosocline, about as long as high; posterior margin nearly straight; anterior margin slightly curved with concave side forward, but as a whole running subparallel with posterior margin; ventral margin rather narrowly rounded; umbo terminal, directed forwrd; umbonal angle, about 65 degrees; posterodorsal angle, about 125 degrees; ligament area, moderately broad and striated transversely by fine, numerous grooves; umbonal septum provided with a shallow slender dental socket; surface nearly smooth, ornamented only by faint growth lines; musculature unknown.

Discussion.—The outline of the adult shell is inferred from growth lines over the younger stages, so it is not certain whether the mature shell was auriculate. Apparently, this shell is somewhat similar to *S. burmai* NEWELL (1942, p. 67, pl. 12, figs. 1–6) from the Wolfcampian of North America in general shape, but is distinguished by a nearly smooth shell without prominent growth lamellae.

Occurrence.—Very rare in the Gujo Formation (P 3) at Gujo , Oe-cho, Kyoto Prefecture, west Japan.

Superfamily Pteriacea GRAY, 1847

Family Pterineidae MILLER, 1877

Genus *Leptodesma* HALL, 1883

Type species: *Leptodesma potens* HALL, 1883 (subsequent designation by MILLER, 1889).

When HALL proposed the genus *Leptodesma*, he distinguished it from the very similar *Leiopteria* HALL (1883, types species: *L. dekayi* HALL) by the nasute and acute anterior ear in the former instead of auriculate and rounded ears in *Leiopteria*. The Devonian *Leptodesma* commonly is more prosocline than *Leiopteria*. In the Permian and Carboniferous species are found that are intermediate so that generic placement has been arbitrary. For example, some species are like *Leptodesma* in general shape, but have an anterior lobe like that of *Leiopteria*. HIND (1901, p. 9) considered *Leptodesma* as possibly a synonym of *Leiopteria*.

In this paper *Leiopteria* is treated as a subgenus of *Leptodesma*, following ELIAS (1957, p. 759) and the intermediate forms are simply classed as *Leptodesma*.

Leptodesma sp.

Material.—Eight specimens were obtained, all of which were severely crushed.

Description.—Shell small, inequilateral, inequivalve, right valve less convex than left, pteriiform, extended posteroventrally, moderately inflated; anterior auricle relatively small, roundly trigonal; not sharply defined from the body; posterior wing depressed and projected posteriorly at posterodorsal corner; ligament area with several, chevron-shaped, transverse grooves below beaks; hinge consisting of one cardinal tooth and a posterior lateral in left valve, and two of each in right valve, all subparallel with hinge margin; surface covered by regular, lamellose, concentric sculptures and weak growth lines.

Comparison.—This species is similar to the Capitanian *Pteria guadalupensis* GIRTY (1908, p. 426, pl. 9, figs. 20, 20a) in shape and ornamentation, but differs in taller and less prosocline outline. The lower Permian *L.*? *corrandibbiensis* DICKINS (1957, p. 30, pl. 4, figs. 13–17, text fig. 4) from West Australia is also very similar to this in shpae and in ornamentation.

Occurrence.—Common in calcareous shale associated with limestone of the Rodai Formation (lower Permian, P 1u) of Maiya Group, where it is associated with *Parafusulina* sp., and *Michelinia*, north of Maiya, Towa-cho, Miyagi Prefecture, northeast Japan.

Leptodesma (*Leiopteria*) sp.

Plate 3, Figures 3, 4

Material.—There are ten specimens more or less deformed secondarily, in our collections.

Description.—Shell small, pteriiform, prolonged posteroventrally; subequivalve, not so inflated, considerably longer than high; umbo subterminal, salient above hinge margin, with prosogyrate beaks; anterior auricle small, roundly trigonal, sharply defined from main body by a sulcus, that of left valve provided with distinct radial depression anterior to the margin of main body; posterior aurcle extended, wing-shaped, with pointed extremity and well marked by posterodorsal umbonal ridge; ligament area very narrow, shorter than shell length, longitudinal ligament grooves not observed; surface marked by weak growth lines; hinge consisting of one lamellar posterior lateral tooth parallel with cardinal margin, in left valve, and two in the right; cardinal tooth not observed; a small circular anterior adductor muscle scar occurs in the interior of the anterior auricle.

Discussion.—This form resembles *Leptodesma* in the strongly prosocline shape but the anterior lobe recalls that of *Leiopteria*. A radial, broad furrow of the anterior auricle of the left valve recalls some Devonian shells of *Leiopteria*, such as the type species *L. dekayi* HALL (1884, p. 164, pl. 90, figs. 16–18). In the elongate shape the present species is similar to "*Pteria*" *guadalupensis* GIRTY and "*P*" *longa* (GEINITZ) (LICHAREW, 1931, p. 34, pl. 3, figs. 12, 13) but distinguished from the former by lacking distinct concentric sculpture and from the latter by the distinct lobation of the anterior ear. "*Pteria*" *richardosoni* GIRTY (1909, p. 427, pl. 28, fig. 14) from Delaware Mountain Formation is another allied species, but it is said to possess closely arranged, squamulose concentric lirae which are absent in this species.

Measurements in mm:	Length	Height	Hinge Length	Angle α
LV	8.0	6.2	4.5	23°
LV	8.0	6.2	—	27
LV	10.0	7.4	8.7	30
RV	8.0	4.8	7.8	25
RV	13.0	6.0	8.0	18
RV	10.5	5.2	8.8	21

Occurrence.—Rare in sandy shale of the Tenjinnoki Formation (P 21) at Teranosawa, Maiya, Towa-cho, Miyagi Prefecture, northeast Japan.

Family Bakevelliidae KING, 1848

One of us (NAKAZAWA, 1959, p. 196) had supposed that the origin of *Bakevellia* KING was in some ancestor similar to *Pteria* and that *Pteria* had diverged from a duplivincular "Pterioid" stock such as *Leptodesma*. NAKAZAWA illustrated (*op. cit.*, p. 196, text fig. 1) an example of *Pteria* s. l. from the Tenjinnoki Formatkon. After further examination of better specimens it is now recognized that the Tenjinnoki form possesses a multivincular ligament of the *Bakevellia* type. This is herein described as *Towapteria nipponica*, new genus and species.

Pterioids with an alivincular ligament have not previously been reported in the Paleozoic and *Ensipteria* NAKAZAWA and NEWELL, n. gen. apparently is the first such pterioid to be recognized in Permian rocks.

Species of *Bakevellia*, of course, pass through a *Pteria* stage (NAKAZAWA, *ibid.*, p. 195) during ontogeny. In the higher Permian of Japan there are several genera with a multivincular ligament, e. g., *Bakevellia, Towapteria* n. gen., *Waagenoperna* (*Permoperna*) n. subgen. and *Tambanella* n. gen. As discussed below, the last two genera belong most probably to the Isognomonidae. Thus the multivincular grade of ligament appeared in different stocks apparently independently but at about the same time near the close of the Paleozoic.

STEPHENSON (1952) has described the Createceous *Phelopteria* which reduced ligament pits to only one in number during ontogeny. Thus it is possible that the Triassic *Pteria* was derived from *Bakevellia* by reduction in number of ligament pits. Discovery of *Ensipteria* n. gen. from the Tenjinnoki Formation has some bearing on this problem. It is quite similar in shape to the multivincular *Angustella* WAAGEN (1907, p. 170, type species: *Gervillia angulata* MÜNSTER) and the Carboniferous to Permian duplivincular *Monopteria* MEEK and WORTHEN (1866, type species: *Gervillia longispina* COX), but has an alivincular ligament. From circumstantial fossil evidence it appears that both multivincular and alivincular ligaments developed independently and nearly simultaneously from duplivincular ancestors as suggested below.

Pterineidae	Bakevelliidae
Actinopteria	*Towapteria*
Leptodesma	*Bakevellia*
	Pteriidae
Leptodesma	*?Pteria*
	Isognomonidae
Leptodesma	*Waagenoperna*
Monopteriidae	Pteriidae
Monopteria	*Ensipteria*
Myalinidae	Inoceramidae
Atomadesma	*Aphanaia*

In the Permian of Japan there are two species of *Bakevellia* described from the Gujo Formation, that is, *Bakevellia* (*Bakevellia*) *gujoensis* NAKAZAWA (1959, p. 198, pl. 1, figs. 5–8; text fig. 3) and *B.* (*B.*) sp. (NAKAZAWA, *op. cit.*, p. 199, pl. 1, fig. 9 a-c)

Towapteria n. gen. described below is superficially like some species of the Devonian *Actinopteria* or *Ptychopteria* and also Triassic *Pteria*. *Towapteria* tentatively is poaced in Bakevelliidae because of its multivincular ligament as discussed below.

Genus *Towapteria* NAKAZAWA and NEWELL, new genus

Type species: *Towapteria nipponica* n. sp., middle Permian (P 21) in northeast Japan.

Diagnosis.—Shell small, pteriiform, inequivalve, inequilateral; left valve more inflated, ornamented by strong radial costae; anterior not lobate, but bounded by strong, broad radial furrow running from the anterior part of the umbo anteroventrally; right valve less convex, ornamented by relatively broad weak radial costae and concentric sculpture, anterior ear lobate, set off by a weak radial furrow; hinge consisting of one or two short cardinal teeth parallel with the hinge margin, and one slender, long, posterior lateral tooth in each valve also parallel with the hinge margin; ligament multivincular, ligament area straight and narrow, provided with several weak trigonal ligament pits.

Discussion.—The anterior part, which is demarcated by a broad radial furrow in the left valve, nearly but not quite complements the anterior lobe of the right valve. This furrow starts from the beak as do other radial ornaments. This genus recalls *Actinopteria* in the developement of radial ornamentation, external shape and posterior lateral dentition. A cardinal tooth is said to be lacking in *Actinopteria*, but the allied genus *Leptodesma* has a cardinal tooth similar to that of the present genus as exemplified by *Leptodesma* (*Springeria*) ELIAS, 1957 (type species: *L.* (*S.*) *natheri* ELIAS). Some radially sculptured Mesozoic species referred to *Pteria* are also very similar to this genus excepting for ligamental differences. The multivincular ligament in this genus recalls *Bakevellia*, but the shell exterior in the latter genus is smooth.

Towapteria nipponica NAKAZAWA and NEWELL, n. gen. and n. sp.

Plate 3, Figures 5–8

1959. *Pteria* sp., NAKAZAWA, p. 196, text fig. 1

Material.—There are many specimens at hand, ten of which are nearly complete and used for description.

Description.—Shell small, inequivalve, inequilateral, pteriiform, strongly extended posteroventrally, longer than high with H/L ratio of about 2/3; moderately inflated, the left valve being more convex and bearing rather prominent and salient umbo above hinge margin; beak slightly prosogyrate curving inward and forward; dorsal margin long and straight, a little shorter than shell length; posterior ear depressed, sharply defined from vaulted body, alate, projecting posteriorly; anterior ear of the right valve small, roundly trigonal, or semicircular, slightly inflated, marked off from main body by shallow radial furrow and with weak auricular sinus; anterior ear of left valve poorly differentiated, limited behind by a deep radial furrow extending downward from the beak; ligament area of both valves narrow, diverging at a very wide angle, multivincular and provided with two to four, very weak, trigonal ligament pits; dentition consisting of a nearly horizontal, subtrigonal cardinal tooth and a slender, lamellar, posterior lateral tooth in the right valve, two cardinals and a lateral in the left valve; the dorsal cardinal rudimentary, the ventral tooth curving downward and continuing to a weak myophoric buttress; surface of left valve sculptured by variable radial costae of two or three orders and concentric fila over shell body and posterior wing, and more uniform over the anterior part; radials more or less scaly or nodose at intersections with concentric fila; surface of right valve covered by weak, relatively broad, costae in the posterior part of the shell body but becoming obsucrue anteriorly and without radial sculpture over anterior ear; ornamentation of posterior wing of the two valves similar; muscle scars and pallial line not observed

Measurements in mm:	Length	Height	Hinge Length
LV	11.8+	9.0	11.0
RV	15.0	8.3	12.1
RV	13.4	8.1	9.8
LV	9.2	7.8	7.8
LV	13.3	7.1	10.6
RV	10.9	7.2	9.0
RV	12.0	6.2	9.4

Discussion.—The ligament area of this species is very narrow and ligament pits are weak, so it is difficult to precisely describe the ligament character. One of us (NAKAZAWA, 1959, p. 196, text fig. 1) misinterpreted it as alivincular ligament and referred the species as *Pteria* s. l. After examining more material we have found several specimens with distinct multivincular ligament, with several weak ligament pits. Radial costae of the body of the left valve are fairly varible, the primary costae vary in number between seven to eleven, the secondaries are in some cases absent in the posterior part of the shell or may become as thick as the primaries. In other examples tertiaries are inserted. The posterolateral tooth of the right valve lies below that of the left.

Externally this species is similar to the Devonian *Actinopteria muricata* HALL (1883, p. 187; 1884, p. 108, pl. 17, figs. 1–3), but the former differs in being more numerous, differentiated radial costae, and in possessing a multivincular ligament. *Avicula* (*Oxytoma*) *wähneri* described by KITTL (1903, p. 687, pl. 22, figs. 9, 10) from the *Bellerophon* Limestone in Sarajevo is similar in the radial ornament and presence of a broad anterior furrow. However, the Yugoslav species is distinguished from this in having a distinctly separated trigonal anterior ear.

Occurrence.—Common in sandy shale of the Tenjinnoki Formation (P 21) at Tenjinnoki, and rare at Teranosawa, Maiya, Towa-cho, Miyagi Prefecture; rare in the lower Kanokura Formation at Kamiyasse, Kesennuma City, Miyagi Prefecture;

questionable specimens are scarcely found in the Gujo Formation at Gujo, Oe-cho, Kyoto Prefecture, west Japan.

Family Isognomonidae WOODRING, 1925

Genus *Waagenoperna* TOKUYAMA, 1959

Type species: *Edentula lateplanata* WAAGEN, 1907 (original designation)

Synonym: *Edentula* WAAGEN, 1907 (*non* NITZSCH, 1820)

Subgenus *Permoperna* NAKAZAWA and NEWELL, new subgenus

Type species: *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL, n. subg. and n. sp.

COX (1954) introduced *Cuneigervillia* as a new genus with the Lias *Gervillia hagenowi* DUNBAR as the type. *Edentula* WAAGEN, 1907 (type, *E. lateplanata* WAAGEN, U. Triassic) *non* NITZSCH, 1820, was regarded by COX as a subjective synonym of *Cuneigervillia* and an invalid junior homonym. Consequently, *Cuneigervillia* is not a replacement name for *Edentula* since the two genera are based on different type species. WAAGEN had considered his Alpine Triassic species as closely allied with *Perna* (=*Isognomon*) but COX placed *Cuneigervillia* in Bakevelliidae because the type species passes through a *Bakevellia* stage during ontogeny.

After an examination of the Japanese Upper Triassic *Edentula triangularis* (KOBAYASHI and ICHIKAWA, 1952, p. 268, text figs. 1, 2; TOKUYAMA, 1959, p. 153, pl. 16, figs. 8–15) TOKUYAMA came to the same conclusion as WAAGEN that the Triassic forms in question are more akin to *Isognomon* than to *Bakevellia* because they do not have a *Bakevellia* stage in ontogenetic development. TOKUYAMA proposed a new name *Waagenoperna* for the preoccupied *Edentula*, designating *E. lateplanata* as type. He included the genus in Isognomonidae.

Recently, HAYAMI (1960, p. 327, text fig. 6) called attention to the occurrence of an *Isognomon*-like bivalve in the middle Kanokura Series near Kesennuma in Kitakami massif where it is associated with *Monodiexodina matsubaishi* (FUJIMOTO). NAKAZAWA obtained several specimens of the same species from an equivalent horizon at Tenjinnoki.

This species is very similar to Triassic *Waagenoperna* but sufficiently different that it is referred here to a new subgenus *Permoperna*, as discussed below. Our observations support the conclusion of WAAGEN and TOKUYAMA that *Waagenoperna* is phylogenetically independent of *Bakevellia*.

Diagnosis.—Shell cuneiform, nearly acline at full growth, inequilateral, inequivalve, left valve more inflated than right; umbo weak, subdued, prosogyrate with subterminal beak; anterior ear very small, posterior wing not well differentiated;

ligament area long and slender, becoming somewhat obscure at the posterior end, provided with several, subquadrangular ligament pits; hinge consisting of a weak, rudimentary posterior lateral tooth in each valve; muscle scars and pallial line unknown.

Discussion.—This subgenus is closely related to the Mesozoic *Waagenoperna* s. s. in the multivincular ligament, nearly edentulous hinge, subterminal umbo, rudimentary anterior ear and large but obscrurely defined posterior wing. It is distinguished from the latter in having a rudimentary posterior lateral tooth and less prosocline shape. *Waagenoperna* s. s. is said by TOKUYAMA to have no hinge tooth through ontogeny, but NAKAZAWA has collected a few Triassic specimens of *W.* (*W.*) *triangularis* that have an obsolescent posterior lateral tooth. *Permoperna* differs from the Permian *Bakevellia* s. s. in lacking cardinal teeth, less developed anterior auricle and larger size. WAAGEN considered the origin of *Waagenoperna* in *Myalina*, but it may not be so, because none of the Myalinidae has lateral teeth. *Waagenoperna* s. s. more probably was derived from Pterineidae through Permian *Permoperna.*

Waagenoperna (*Permoperna*) *hayamii* NAKAZAWA and NEWELL, n. subg. and n. sp.

Plate 3, Figures 9–11

1925. *Liebea sinensis*, HAYASAKA. p. 14, pl. 8, figs. 11, 12, 13?. not *Liebea sinensis* FRECH (1911, p. 115, pl. 16, figs. 1 a-b)
1960. "*Isognomon*" n. sp., HAYAMI. p. 327, text fig. 6.

Material.—Two complete right valves and three left valves are available.

Description.—Shell relatively small, cuneiform, nearly acline, a little inflated, left valve more convex than the right; higher than long, hinge margin straight, shorter than shell length; posterior margin slightly arcuate; ventral margin well rounded, and anterior margin fairly sinuated below the anterior auricle; umbo weak, almost terminal, not salient above the hinge margin; anterior auricle very small, distinctly separated from main body by a furrow; posterior wing not well differentiated; ligament area narrow becoming obscure near rear margin, provided with three to five ligament pits, among which the first is slender and subtrigonal, and the others are broad, quadrangular and shallow; cardinal teeth absent, a weak, short, posterior lateral tooth originates near the last ligament pit and runs posteroventrally; pallial line and muscle scars unknown.

Measurements in mm:	Length	Height	Hinge Length
RV	12.3	14.6	8.8
RV	18.0	20.6	12.2
LV	*ca.* 10.0	12.6	6.8
LV	20.0	16+	17.6
LV	13.5	15.0	7.9

Discussion.—When WAAGEN (1881, p. 292) established *Liebea* [type, *L. squamosa* (J. de C. SOWERBY), subsequent designation by COX, 1936], he described the genus as having mulitiple lingament pits on the ligament area. NEWELL (1942, p. 73) scrutinized the genus in detail, and clarified that it had a myalinid ligament.

According to FRECH (*op. cit.*) *Liebea sinensis* from the Lopingian in China has several linear ligament grooves on the ligament area similar to *Liebea*, but the ligament grooves are parallel to the hinge margin. Furthermore, the species has five to six denticles below the ligament area. If this is true, *Liebea sinensis* is quite different from type *Liebea*, which has a sort of "dysodont" dentition. *Liebea sinensis* reported by HAYASAKA from southern Kitakami massif has one or two, true ligament pits near the anterior end of ligament area, and the rest of the ligament area is not preserved. Undoubtedly, the Japanese specimens are identical with *Waagenoperna* (*Permoperna*) *hayamii* n. sp. described above.

Genus *Tambanella* NAKAZAWA and NEWELL, new genus

Type species: *Tambanella gujoensis*, new species, Gujo Formation, west Japan.

Diagnosis.—Shell small, ovate-myaliniform, nearly equivalve, strongly inequilateral; umbo terminal; anterior ear absent, posterior wing usually not differentiated; dorsal half of anterior margin strongly inflexed in the byssal region; ligament area very narrow, provided with several quadrate ligament pits; hinge consisting of a strong, oblique, prosocline cardinal tooth and two, slender, lamellar posterior lateral teeth, in the right, and a cardinal socket and one posterior lateral tooth in the left; posterior adductor muscle scar large and oval lying in the posterodorsal part of shell, anterior muscle scar absent or very small, if present; pallial line entire.

Discussion.—In external shape this genus resembles *Selenimyalina* NEWELL (1942, p. 63, type: *Myalina meleniformis* M. and W.) or species of *Myalina* such as *M.* (*Myalinella*) but is distinguished in having a multivincular ligament and posterior lateral teeth. It also differs from *Bakevellia* which has multivincular ligament, in lacking anterior auricle, in a single cardinal tooth and less differentiated posterior wing. It seems to be more allied to *Waagenoperna* (*Permoperna*) described above, although distinguished in the absence of an anterior aurcle and in having a cardinal tooth in the right valve. On the other hand it cannot be overlooked that there is similarity with the Devonian *Mytilarca* (1869, type: *Inoceramus chemungensis* CONRAD) in general outline and in dentition. This suggets some phylogenetical relation between the two genera. It is difficult to decide the relationship of this genus. Tentatively it is placed in Family Isognomonidae by the reason of superficial simiality with *Permoperna* and *Isognomon*. At any rate the genus is an endemic, short-lived off-shoot which has not left any descendents in the Mesozoic.

Tambanella gujoensis NAKAZAWA and NEWELL, n. gen. and n. sp.

Plate 4, Figures 4–9

Material.—We have four complete, two incomplete and several fragmental specimens from the Gujo fauna. Although they have been crushed by crustal movement, an adequate description can be given.

Description.—Shell small, thin-walled, nearly equivalve, inequilateral, prosocline, obliquely ovate, elongate posteroventrally; umbo terminal, weak with an acute beak pointing forward and downward; nearly as long as high; a little inflated; dorsal margin straight, shorter than shell length; anterior and posterior margins nearly parallel with each other; posterior and dorsal margins intersect at a rounded obtuse angle; anterior ear lacking; anterior margin strongly inflexed near the beak apparently leaving a byssal gape; ventral margin well rounded; posterior wing usually not differentiated; ligament area very narrow provided with three or four subquadrangular ligament pits; right hinge consisting of forward inclined slender cardinal tooth below the beak, and two, lamellar posterior lateral teeth; and in the left, one cardinal socket and one lateral tooth; posterior adductor muscle scar large, oval, lying at posterodorsal part of the shell; two very small muscle pits situated at the tip of the umbonal cavity (anterior adductor scar and pedal muscle scar?); pallial line entire; surface nearly smooth excepting weak growth lines.

Measurements in mm:	Length	Height	Hinge Length	Angle α
RV	17.3	17.6	11.0	30°
LV	18.0	15.2	12.6	38
LV	15.5	17.5	8.5	38
LV	17.4	15.3	10.1	43

Discussion.—The lateral sockets are relatively wider than the corresponding teeth. In most individuals, the posterior wing is not clearly marked from the rest of the body, but one specimen shows a distinctly depressed posterior wing bounded by umbonal ridge, and the posterior margin is thickned at the boundary.

Occurrence.—Rare in the Gujo Formation (P 3) at Gujo, Oe-cho, Kyoto Prefecture, west Japan.

Family Pteriidae GRAY, 1847

Genus *Ensipteria* NAKAZAWA and NEWELL, new genus

Type species: *Ensipteria onukii*, new species, Tenjinnoki Formation (P 21) in northeast Japan.

Diagnosis.—Shell medium-sized, nearly equivalve, ensiform, strongly elongate posteriorly; umbo terminal, only slightly salient above hinge margin; anterior auricle very small, lobate, clearly separated by a furrow from main body; posterior wing large, depressed; ligament area very narrow, subtrigonal, provided with large, very broad, triangular, striated ligament pit at the anterior end; main body nearly parallel sided, slightly concave dorsally; hinge consisting of several radial cardinal teeth and one or two slender posterior lateral teeth subparallel with hinge margin; small internal buttress present just in front of the umbonal cavity; surface nearly smooth; muscle scars and pallial line unknown.

Dicussion.—The shape of the species reminds one of the Upper Triassic *Angustella* WAAGEN (1907, p. 170, type: *Gervillia angusta* MÜNSTER) or Jurassic *Cultriopsis* COSSMANN (1904, p. 510, type: *C. falciformis* COSSMANN), but it is readily distinguished by quite different ligament characters. The upper Paleozoic *Monopteria* MEEK and WORTHEN (1866, type: *Gervillia longispina* COX) is another similar genus but the latter is not so elongate, and possesses a duplivincular ligament.

Ensipteria onukii NAKAZAWA and NEWELL, n. gen. and n. sp.

Plate 3, Figures 12–14

Material.—Three complete and several incomplete specimens.

Description.—Shell of medium size, nearly equivalve, ensiform, horizontally very elongate; umbo terminal, slightly salinet above hinge margin; anterior auricle very small, lobate, marked off from main body by furrow; posterior part of hinge wing-shaped, about as long as one-third of shell length, slightly sinuated posteriorly; ligament area occupying entire length of dorsal margin, very narrow, provided with, broad, shallow, triangular, horizontally striated ligament pit near the anterior end; the cardinal area of each valve behind the resilifer diverges outward at a very obtuse angle, striated parallel to the ventral margin of ligament; hinge consists of several, small, radiating cardinal teeth and a lamellar lateral tooth in the right valve, two laterals in the left; hinge plate supported by a septum-like inner ridge delimiting anterior margin of umbonal cavity; muscle scars and pallial line unknown.

Measurements in mm:	Length	Height	Hinge Length
LV	35.7	5.9	12.9
LV	13+	3.0	7.2
RV	51.0	8.6	18.9
RV	35.5	6.0	11+

Discussion.—This species is similar to *Gervillia* (*Angustella*) *praeangusta* FRECH (1911, p. 113, Explanation of plate 19, fig. b) from the Permian Loping Beds in China but the latter is relatively shorter. *Pteria longa* var. *longissima* LICHAREW (1931, p. 10, pl. 3, figs. 13, 15) from the upper Permian in northern Russia is externally much like this species. Close comparison with these species is impossible because of lack of knowledge of the interior characters.

Occurrence.—Common in the Tenjinnoki Formation, Tenjinnoki and Teranosawa, Maiya, Towa-cho, Miyagi Prefecture, northeast Japan.

Superfamily Pectinacea REFINESQUE, 1815

Family Aviculopectinidae MEEK and HAYDEN, 1864

Subfamily Aviculopectininae MEEK and HAYDEN, 1864

Genus *Aviculopecten* M'COY, 1851, em. NEWELL, 1938

Type species: *A. planoradiatus* M'COY (subsequent designation by HIND, 1903, p. 66).

Aviculopecten shiroshitai NAKAZAWA and NEWELL, new species

Plate 4, Figures 1–3

Material.—Many specimens were collected from the Gujo Formation, among which left valves are predominant.

Description.—Shell of medium size, inequivalve, inequilateral, acline with subcircular disc, nearly as long as high; left valve fairly convex, right valve slightly inflated or almost flat; hinge margin straight, shorter than shell length; anterodorsal margin of disc somewhat concave dorsally, posterodorsal border straight or only slightly concave and longer than anterodorsal border; ventral margin well rounded, making angulation with posterodorsal margin; anterior auricle rounded triangular, shorter than posterior auricle, separated from body by distinct sulcus or depression; posterior auricle large, wing-shaped, well sinuated posteriorly with pointed posterodorsal corner; right anterior ear bounded below by a deep byssal notch; ligament area narrow, provided with a shallow, wide, obtuse-trigonal ligament pit extended posteriorly; main body of left valve with numerous radial ribs of as many as five orders; primaries prominent, round-topped, eight to eleven in numger; secondaries starting from very near the beak, alternating with primaries, and in a few cases becoming as strong as primaries; weaker radials of lower orders inserted alternately in flat interspaces between the higher orders; the two ears similarly sculptured by radial ribs of two orders, attaining six to twelve in the anterior ear and twelve to nineteen in the posterior; the whole surface is covered by distinct, close-set, concentric growth lines, projecting adapically on the first and second order radials and making a somewhat scaly appearance on the third and fourth radials; surface of right valve sculptured by approximately ten, flat, weak, radial ribs separated by shallow, narrower interstitial grooves, increasing in number by bifurcation and attaining to more than thirty in number in adults; muscle scars and pallial line not observed.

Measurements in mm:	Length	Height	Hinge Length	Angle a
LV	13.0	16.5	12.5	60°
LV	19.0	19.0	16.0	80
LV	26.0	29.5	23.0	70
LV	25.0	18.0	19.0	110
LV	18.0	22.0	—	60
RV	19.0	15.5	—	60
RV	10.5	9.0	10.5	110

Discussion.—In shape and differentiated radial ornamentation this species, especially the holotype specimen, is similar to the Upper Carboniferous *A. gradicosta* NEWELL (1938, p. 53, pl. 6, figs. 1, 2) from Kansas but our holotype specimen is slightly deformed secondarily and the original shape of the shell probably was more symmetrical. Rib scales are less pronounced than in *A. gradicosta.* Also, *A. mutabilis* LICHAREW (1927, p. 72, pl. 5, figs. 7-10) from the Upper Carboniferous of the Ural is another similar form, but it is distinguished by less regular ribbing of the lower orders, in the more acutely sinuated posterior auricle, and in the relatively large anterior ear. The new species is also similar to the Japanese Permian *A. hataii* MURATA (1960, p. 221, pl. 34, figs. 10 a-d) in ornaments, but the former differs in lacking prominent spinosity on the radials.

Occurrence.—Common in the Gujo Formation (P3) at Gujo, Oe-cho, Kyoto Prefecture, west Japan.

Aviculopecten cf. *hataii* MURATA

Plate 5, Figures 1–3

Discussion.—There are several specimens collected from the Tenjinnoki Formation at Tenjinnoki, and the Kanokura Formation (Shigejizawa Member) at Kamiyasse, Kesennuma City in Miyagi Prefecture, which are similar to and were contemporaneous with *A. hataii* MURATA. The radial costae consist of three, rarely, four orders, and there are eight to nine primaries. Intercalating costae of the second, or rarely the third, order become as strong as the primaries, at maturity. Thus, the present species presents the illusion of having more numerous, and stronger costae than does *hataii*. This may be an effect of infraspecific variation and the population needs numerical analysis of more material to warrant a conclusion. Judging from internal molds the right valve is sculptured by numerous radial costae of nearly equal strength (pl. 5, fig. 2)

Measurements in mm:	Length	Height	Hinge Length
LV	17.5	20.2	*ca.* 17.0
LV	13.5	16.0	12.5
LV	*ca.* 11.0	15.0	7+
LV	14.0	14.0	12.5

Aviculopecten sp. *a*

Plate 5, Figure 5

Material.—Four incomplete and several fragmental specimens are in our collection; all are left valves.

Description.—Shell small, nearly symmetrical excepting auricles, fairly convex; length nearly equal to height; umbo not prominent, a little salient above hinge margin, with orthogyrate beak situated just in front of the middle of the shell; hinge line straight, slightly shorter than the shell length; hinge area narrow, triangular; resilifer not observed; anterior ear subtrigonal, smaller than the posterior ear, sinuated below; posterior auricle comparatively small, wing-shaped, the postero-dorsal extremity not reaching the posterior end of the shell; surface of the shell body sculptured by ten or eleven, strong, keel-like primary ribs, which extend over the shell margin and are separated by wide, flat interspaces; alternating secondaries are introduced some three or four millimeters from beak and usually are conspicuously weaker than the primaries, but rarely some secondaries become as strong as primaries and tertiary ribs are delayed until maturity; anterior ear provided with three to five radial ribs, and the posterior wing with six radials; concentric ornamentation lacking.

Discussion.—This form is characterized by simple, alternating radial ribs of two orders excepting rare tertiaries. It is similar to the Upper Carboniferous *A. alternatoplicatus* CHAO (1927, p. 29, pl. 3, figs. 8, 9) in ornamentation and shape, but seems more equilateral in outline and the tertiary riblets are less developed. The Upper Carboniferous *A. eaglensis* (PRICE) (NEWELL, 1938, p. 54, pl. 4, figs. 15, 16) of North America and the Permian *A. tenuicollis* (DANA) (1849, p. 705, pl. 9, figs. 7, 7a; DICKINS, 1957, p. 45, pl. 6, figs. 6, 7; 1963, p. 82, pl. 11, fig. 5; pl. 13, figs. 12–17; pl. 16, fig. 1) of Australia are also similar to this species, but the former species has more inequilateral outline and more distinct concentric lines, and the latter has more numerous radials, distinct concentric sculpture and different outline.

Occurrence.—Rare in the lower Kanokura Formation (P 21) at Kamiyasse, and common in the Tenjinnoki Formation at Tenjinnoki, Miyagi Prefecture, northeast Japan.

Aviculopecten sp. *b*

Plate 5, Figure 4

Discussion.—A single incomplete left valve, represented by internal and external molds, was collected from black shale of the Toyoma Formation (P 3) at Kitazawa, Toyoma-cho, Miyagi Prefecurte. The specimen has been mechanically compressed. This species is characterized by a relatively large anterior ear, truncated posterior ear and very weak radial ornamentation which consists of eight, weak primaries and four to eight faint intercalated costillae of variable strength in each interspace. Concentric sculpture relatively distinct, making a latticed appearence with the radials. In addition, several weak concentric folds are seen. An obtuse, triangular ligament pit is well preserved.

Genus *Hayasakapecten* NAKAZAWA and NEWELL, new genus

Type species: *Hayasakapecten shimizui*, new species, mid-Permian, northeast Japan (P 21).

Diagnosis.—Shape and ligament as in *Aviculopecten*, acline, inequilateral, subequivalve; left valve a little more inflated than right; nearly equal or greater than height; posterior ear alate, larger than the anterior; both valves ornamented by simple, uniform radial ribs; concentric sculpture usually becoming stronger on ribs producing a scaly or tuberculose appearance and on the interspaces extended ventrally with spinose projection as in *Acanthopecten.*

Discussion.—The most characteristic features of this genus are subequivalved shells in ornamentation as well as in convexity and simple radial sculptures, which do not increase their number by bifurcation nor by insertion. In simplicity of ornamentation this genus resembles *Detlopecten* but is quite different in ligament structure. The former had a ligament of the *Aviculopecten* kind while the latter does not have a distinct resilifer. So the similarity is superficial. On the other hand the ornamentation of the left valve of *Acanthopecten* is comparable with that of this genus. Both genera are ornamented by simple radial ribs and the concentric sculpture is more or less scaly with ventrally directed spines in the intersticial grooves. *Hayasakapecten,* however, does not possess the regular, periodic raised fila of *Acanthopecten* and is less circular in shape.

The right valve of *Acanthopecten* is nearly flat, almost smooth, ornamented by widely spaced, slender radial costae. But there is an undescribed species collected from the Word Formation in Texas, of which right valve is identical with the left in ornaments and differs only in less convexity of the shell. *Aviculopecten derejatensis* WAAGEN (1887, p. 304, pl. 23, figs. 1a, b)* from the Middle Productus Limestone of Salt Range belongs to the same group.

It seems to us desirable to separate this group as a new genus related to *Acanthopecten.*

Aviculopecten sasakii MURATA (1964, p. 218, pl. 34, figs. 1, 2) reported from the mid-Permian of Kitakami massif in Japan belongs to *Hayasakapecten. A. reticulatus* HAYASAKA (1925, p. 6, pl. 8, fig. 2) and possibly *A. minoensis* HAYASAKA (*ibid.*, p. 5, pl. 8, fig. 1) from the "upper middle" Permian (*Yabeina* zone) Akaska Limestone in central Japan is most probably referred to this genus. *A. expoticus* REED, *A. ruklensis* REED and *A. regularis* REED have ornamentation similar to that of *Hayasakapecten,* but the shells are relatively taller and seem to be extended anteriorly. These species probably belong to *Guizhoupecten,* as will be discussed later.

Hayasakapecten shimizui NAKAZAWA and NEWELL, n. gen. and n. sp.

Plate 5, Figures 6, 8, 9

Material.—Seven nearly complete and several fragmentary specimens were

* WAAGEN illustrated the species as lacking the byssal sinus but this may be in error. The actual specimen, as examined by NEWELL, is too incomplete to determine this. The same is true with *Aviculopecten subexoticus* WAAGEN (*op. cit.*, p. 311, pl. 23, figs. 6a–c) which belongs more probably to *Cyrtorostra.*

examined. Among these, five are right valves.

Description.—Shell relatively small, subequivalve, inequilateral, acline, subcircular except for auricles; left valve moderately inflated, right valve slightly flatter than the left; length nearly equal to or a little greater than height; umbo not prominent, salient above hinge margin; beak subcentral and orthogyrate; hinge margin straight, a little shorter than shell length; ligament of *Aviculopecten* type, ligament area very narrow, provided with forward directed triangular resilifer pit; posterior auricle larger than the anterior, wing-shaped not so sharply defined from the body as the anterior ear; right anterior ear subquadrate, deeply sinuated below; left anterior ear subtrigonal with convex anterior margin and a slightly incised anteroventral part; anterodorsal margin of the body slightly concave dorsally; posterodorsal margin almost straight; the rest of the shell margin regularly rounded; surface of the body covered by uniform, simple, round-topped radial ribs, 21–24 in number, which are separated at an early growth stage by broader concave interstitial grooves; with growth the ribs become stronger and slightly wider than the interspaces; posterior wing sculptured by radial ribs which are narrower than interspaces and increase in number by insertion, attaining fourteen to fifteen near the margin; anterior ear provided with five to six radials; whole surface ornamented by close-set, weak, concentric fila, which become scaly on the radial ribs, and on interstitial grooves pointed adapically as with *Acanthopecten*; muscle scars and pallial line not observed.

Measurements in mm:	Length	Height	Hinge Length	Angle a
RV	21.5	18.0	18.0	90°
RV	12.0	11.5	10.5	87
RV	16.0	16.0	12.5	85
RV	15.0	13.5	—	90
LV	*ca.* 20.0	19.0	15+	90
LV	17.0	15.5	14.0	95

Discussion.—The described species is similar in ornamentation to *Aviculopecten regularis* REED (1944, p. 305, pl. 54, figs. 2, 2a) from the Middle Productus Limestone of Salt Range, but judging from the figures the latter species has a smaller apical angle, taller profile and is extended anteriorly. *Hayasakapecten sasakii* (MURATA) is a more closely related species as regards both extenal shape and ornamentation but the radial ribs are angular, not rounded, as in the present species. *Aviculopecten minoensis* HAYASAKA and *A. reticularis* HAYASAKA are also similar to the present species, but the former species is distinguished by more orbicular shape, larger apical angle and longer but narrower posterior wing. The latter species is characterized by the absence of radial ornaments on the posterior wing and by stronger concentric suclpture.

Occurrence.—Common in the Tenjinnoki Formation (P 21) at Tenjinnoki, and rare at Teranosawa, Towa-cho, Miyagi Prefecture, northeast Japan.

Hayasakapecten sasakii (MURATA)

Plate 5, Figures 7, 10

1964. *Aviculopecten sasakii*, MURATA. p. 218, pl. 34, figs. 1, 2, text-fig. 1.

Discussion —There are three, external right valves under examination, collected from MURATA's type locality of *Aviculopecten sasakii.* The specimens in our collection agree with MURATA's description very well except the holotype specimen is longer than high, while the present materials display the reverse. This difference apparently is caused by secondary deformation. As nearly as we can judge, shells of the species had nearly equal length and height. Right valves are moderately inflated, and similar to the left in convexity. The species is characterized by the roof-shaped, sharp, radial ribs bounded by roundly concave interspaces. The concentric sculpture is projected ventrally there making V-shaped spines or scales.

Genus *Etheripecten* WATERHOUSE, 1963

Type species: *E. striatura* WATERHOUSE, upper Permian of New Zealand.

According to WATERHOUSF, *Etheripecten* is intermediate between *Aviculopecten* and *Limipecten.* In general shape and sculpture of left valve *Etheripecten* resembles *Aviculopecten,* but the radial ornaments of the right valve increase in number by insertion not by bifurcation. In this respect the present genus is similar to *Limipecten,* but unlike *Limipecten* the shell is less orbicular, and the concentric sculptures reflex apically in the interspaces. The Triassic *Eumporphotis* is considered to be intimately related to this genus, but the latter is distinguished by more symmetrical shape.

Etheripecten ? hayasakai (MURATA)

Plate 6, Figures 1 a-c.

1925. *Aviculopecten interstitialis* (PHILLIPS), HAYASAKA, p. 7, pl. 8, figs. 3-5
1964. *Aviculopecten hayasakai*, MURATA, p. 219, pl. 34, figs. 3-5

Discussion.—The ornamentation of this species is noteworthy. In the left valve, ornamentation is of the *Aviculopecten* type, but the strong primary ribs are plications rather than costae. In the right valve, low, broad plications are sculptured by finer costae, as with *Fasciculopecten*. The generic position of this species is uncertain, and it is placed in *Etheripecten* tentatively because the finer radials of the right valve are similar to those of *Etheripecten* rather than *Aviculopecten*, and the anterior ear is relatively large as in the former genus.

Genus *Leptochondria* BITTNER, 1891

Type species: *Pecten* (*Leptochondria*) *aeolicus* BITTNER, (original designation), Norian of Anatolia, Turkey.

Discussion.—*Leptochondira* was established as a subgenus of *Pecten*. It was founded on the Upper Triassic, small, inequivalved species, *Pecten aeolicus* BITTNER (1891, p. 101, pl. 2, fig. 13; text fig.). The left valve is convex, nearly equilateral, bearing very obscurely defined, subequal ears, and sculptured by fine radial costae of irregular strength. The right valve is flat, with a deeply sulcate byssal notch and unlike the left valve is nearly smooth or sculptured by only weak radial ribs. *Leptochondria* has an *Aviculopedten*-type ligament, but is distinguished from other aviculopectinids in equilateral shape and obscurely defined, subequal ears. In most cases the right valves are quite rare as compared with left valves.

Pecten alberti GOLDFUSS is a Middle to Lower Triassic representative of *Leptochondria*. The Lower Triassic *Pecten* (*Velopecten*) *minimus* KIPARISOVA, *P.* (*V.*) *bittneri* KIPORISOVA in Siberia, *Leptochondria*? *okuyamensis* NAKAZAWA in Japan, *Monotis*? *thaynesiana* (GIRTY) in the United States all probably belong to this genus. As noticed by CIRIACKS (1963, p. 81) *Monotis*? *thaynesiana* is closely allied to the Permian *M.*? *landerensis* (BRANSON). The latter species as well as Japanese Permian species described below are referred to *Leptochondria*, althoug a definite conclusion must be postponed until a right valve can be obtained.

Leptochondria? sp. *a*

Plate 6, Figures 4–7

Material.—Three complete and one incomplete left valves from the Gujo Formation at Gujo are in hand, all of which are secondarily considerably deformed.

Description.—Shell small, oval, nearly equilateral, acline or slightly prosocline, a little higher than long; umbo subcentral, not prominent, only slightly salient above hinge margin; ears subequal, not clearly defined from main body; dorsal margin short and straight, equal to about one-half of shell length; anterior margin slightly sinuated at the boundary between anterior ear and the main body; posterior margin nearly rectilinear; ventral margin regularly rounded; ligament area obtusely trigonal and narrow, provided with triangular resilifer pit; surface covered by numerous, fine, radial costae of two orders; primaries round-topped, twenty-six to thirty-three in total, somewhat irregular in strength; one or two rarely three, weaker secondaries inserted between the primaries, in general more developed near the anterior margin; radials on ears weaker and more closely set in anterior than in posterior ear; concentric growth lines well developed on both ears and on umbonal half of main body.

Discussion.—The present species is like Triassic species of the genus *Leptochondria* in symmetrical shape, subcentral umbo, subequal, obscurely defined ears and numerous, weak radial ornamentation and *Aviculopecten*-type ligament. The right valve was not observed.

Leptochondria sp. *a* is similar to the Permian *Monotis? langcrensis* (BRANSON) (1930, p. 48, pl. 12, figs. 2, 3; CIRIACKS, 1963, p. 51, pl. 6, fig. 8) from the Middle Rockies, the Lower Triassic *M? thaynesiana* (GIRTY) (1927, p. 440, pl. 3, figs. 27, 28; CIRIACKS, *op. cit.*, p. 81, pl. 15, fig. 16), *Leptochondria? virgalensis* (WITTENBURG) (1909, p. 8, pl. 3, fig. 4; NAKAZAWA, 1961, p. 261, pl. 12, figs. 18 a, b) and *L. alberti* (GOLDFUSS) (1834, p. 138, pl. 120, fig. 6).

The Japanese species differs from the first two in less numerous but more differentiated radial costae, from *virgalensis* in taller shape and smaller ears, and from *alberti* in more numerous radials. The material is too poor, however, for strict comparison.

Occurrence.—Rare in the Gujo Formation (P 3) at Gujo, Oe-cho, Kyoto Prefecture, west Japan.

Leptochondria? sp. *b*.

Plate 6, Figure 8

Discussion.—Only one specimen is avaliable for study, found in association with the preceding species. The shell is more symmetrical, the ears are smaller, and the secondary costae are much weaker than the primaries in comparison with the preceding form.

Measurements in mm:	Length	Height	Hinge Length
sp. *a*	8.2	12.8	4.5
sp. *a*	11.0	10.6	5.2
sp. *a*	9.5	9.8	4.0
sp. *b*	6.6	8.0	3.0

Subfamily Streblochondriinae NEWELL, 1938

The diagnosis of Streblochondriinae by NEWELL (1938, p. 80) is as follows: "Smooth or sculptured opisthocline shells having a relatively broad and long anterior auricle, and a small or obsolete posterior one, ligament area similar to that of *Aviculopecten*, except that in some of the genera the obliquity of the resilifer is backward; outer ostracum in most genera radial crossed-lamellar in both valves, prismatic structure unknown; inner ostracum concentric crossed-lamellar in some genera; both valves of nearly the same convexity, the right one being only slightly flatter than the left."

He included *Streblochondria, Obliquipecten,* "*Comptonectes*" and *Streblopteria* in this subfamily. In addition, *Guizhoupecten* CHEN (1962) may be included in this subfamily. The Triassic genus *Pleuronectites* SCHLOTHEIM (1820, type species: *Pecten laevigatus* v. SCHLOTHEIM) is also probably closely related to *Streblopteria.* It has a flatter right valve and more symmetrical shell, and its ligament characters are not yet well known. *Cyrtorostra* BRANSON (1930, p. 44) was first placed in Pteriidae and later inadvertently in Monotidae (CIRIACKS, 1963, p. 56), while the synonymous genus *Blanfordina* REED (1944, p. 312) was originally included in the Limidae. It might better be placed in Streblochondriinae of Aviculopectinidae because of its opisthocline shell, subequal convexity and ornamentation of the two valves and the small, ill-defined posterior auricle.

It should be noted that there are two groups in this subfamily separable by ligament characters. The first group, containing *Streblochondria* and *Guizhoupecten,* has a deep but narrow central resilifer pit of a sort usual in aviculopectinids. The ligament areas of both valves diverge at a large angle and the ligament is essentially external.

The resilifer pit of *Cyrtorostra* (see *C. varicostata* BRANSON in CIRIACKS, 1963, pl. 9, figs. 12, 13) is relatively shallow and wide, occupying almost whole width of the ligament area. A very similar type of ligament is observed in well preserved silicified examples of Texas Permian "*Comptonectes*", *Obliquipecten* and *Streblopteria* kept at the American Museum of Natural History. In some cases, the resilifer pit is not clearly defined from the rest of the area. The two ligament areas diverge at a very narrow angle and the ligament is subinternal. This type of ligament is reminiscent of *Deltopecten,* on which DICKINS established the Family Deltopectinidae. "Pectinoid shell characterized by the presence of an elongated ligament area without a distinctly marked-off central chondrophore as in the Aviculopectinidae ETHERIDGE Jr., 1906 *emend.* NEWELL 1937, or the chevron-shaped ligament grooves characteristic of the Pterinopectinidae NEWELL, 1937." (DICKINS 1957, p. 39).

According to NEWELL (1938, p. 90, pl. 8, figs. 5a, b; text fig. 32), *Oblicquipecten* *laevis* HIND, the type species of *Obliquipecten* from the Lower Carboniferous of England has the usual *Aviculopecten*-type ligament. He (*op. cit.*, p. 88) also stated "there is no question that the Pennsylvanian species (of *Streblopteria*) has hinge structure like those of the Aviculopectinidae." On the other hand the Permian species of *Obliquipecten*, *Streblopteria* and "*Camptonectes*" from Texas as well as the Permian *Streblopteria* of Japan have a broad, shallow resilifer pit covering the nearly whole ligament area as mentioned above. This second type of ligament of the Permian species may have been derived from the first type ligament, that is, the Carboniferous aviculopectinid ligament.

We do not have instructive examples of *Deltopecten*, but according to DICKINS (*op. cit.*) the ligament is duplivincular, and the ligament area is provided with distinct, parallel grooves. If so the group of *Streblopteria* is quite different in origin from *Deltopecten*. *Streblopteria, Obliquipecten*, "*Camptonectes*" and possibly *Pleuronectites* form a compact series. Permian representatives of this group are characterized by a smooth or weakly sculptured shell and a wide resilifer pit. In ornamentation *Cytrorostra* constitutes another group. In conclusion, the subfamily Streblochondriinae is divisible into three gorups illustrated by *Streblochondria*, *Streblopteria*, and *Cyrtorostra*.

Genus *Guizhoupecten* CHEN, 1962

Type species: *G. wangi* CHEN (original designation), upper Permian of southwest China.

Discussion.—The genus is very similar to *Streblochondria*, but differs in stronger radial ribs of both valves and bifurcated radials in the right. *Aviculopecten guadalupensis* GIRTY, 1908 (inclunding *A.* sp. *a*, GIRTY, 1908) and *Streblochondria*? *maynci* NEWELL, 1955, are referred to the present genus. *Streblochondria*? *tubicostatus* CIRIACKS (1963, p. 54, pl. 8, figs, 16–22) is also classed in this genus. In this species fine radial ribs are inserted between the bifurcated stronger radials. An undescribed species from Texas is very similar to *tubicostatus* in possessing quite variable ribbing in the right valve. In most individuals the radials increase in number by insertion, in some cases there are no secondaries, and very rare specimens increase by bifurcation. It is expected that the radial ribs of *Guizhoupecten* increase by bifurcation or insertion and rarely are they represented by simple ribbing.

Guizhoupecten miyamoriensis (MURATA)

1964. *Streblochondria miyamoriensis*, MURATA, p. 229, pl. 35, figs. 14 a, b.

This species is very similar to *Streblochondria*? *tubicostata* CIRIACKS (1963, p. 54

pl. 8, figs. 16–21) from Wyoming and both are more properly placed in *Guizhoupecten* than in *Streblochondria*. Mid-Permian, Hiryu-yama Formation, Iwate Prefecture, Kitakami massif, northeast Japan.

Guizhoupecten sp.

Plate 6, Figure 9

Material.—A single incomplete right valve was collected from the Upper Formation of Maizuru Group, in Mikata-cho, Hyogo Prefecture, west Japan. The specimen is severely crushed and distorted.

Description.—Shell relatively small, fan-shaped, exclusive of the auricles; slightly inflated, longer than high, prolonged anteriorly, opisthocline; anterior ear longer and broader than posterior ear, delimited by a deep byssal notch; posterior ear triangular, pointed at posterodorsal corner; anterodorsal and posterodorsal margins of main body nearly straight; ventral margin regularly rounded; hinge margin linear, provided with very narrow ligament area, ligament pit not observed; surface of disc ornamented by twenty-five roof-shaped radials bounded by wider, concave grooves; radial ribs provided with scaly projections which are arranged concentrically and grow stronger toward rear margins; concentric sculpture weak; anterior ear sculptured by several radial ribs and relatively strong concentric lines; posterior ear ornamented only by concentric sculpture; muscle scars and pallial line not preserved.

Discussion.—In simple ribbing this form is similar to *Hayasakapecten*, but the concentric sculpture does not project ventrally in the interstitials, and the anterior ear is larger than the posterior. We do not know of any comparable species.

Genus *Streblopteria* M'Coy, 1851

Type species: *Meleagrina laevigata* M'Coy (subsequent designation by Meek and Worthen, 1866, p. 333).

Discussion.—This is a poorly understood genus as our knoweldge of the type species is still insufficient. The type species has a rounded, opisthocline shell; the posterior ear is broad and larger than the anterior, undefined from the rest of the shell. Hind (1901, p. 48) thought that *Streblopteria* should be limited to shells of that form rejecting the broader interpretation of Meek and Worthen (1866, p. 332). Later authors have used this name in various ways. Anteriorly expanded pectiniform shells which are smooth or very weakly sculptured and have a small posterior ear, such as *Discites pusillus* Schlotheim, *Avicula sericeus* Verneuil or *Aviculopecten* *englehardti* ETHERIDGE and DUN, are variously classed by authors, as *Pecten, Streblochondria, Streblopteria, Pseudamusium, Pleuronectites* or *Euchondria*. Our examples should not be referred to *Pecten, Pseudamusium* or *Euchondria* because of differences in hinge structures. The Japanese shells probably are most closely related to *Streblochondria* or *Streblopteria*. Although NEWELL (1938) referred such forms bearing weak radial ornaments to *Streblochondria* with some question, the generic significance of such a weak scupture remains uncertain. We have not sufficient material to illuminate further this problem. We include here forms without radial ornaments in *Streblopteria* as did NEWELL.

Streblopteria sp. *a*

Plate 6, Figures 2, 3

Material.—Three right valves are under examination. Two specimens from the lower Kanokura Formation are considerably deformed and the other, from the Tenjinnoki Formation, has been weakly deformed.

Description.—Shell small, subcircular, moderately inflated, approximately as long as high, extended anteriorly and a little opisthocline; both auricles subequal in length; posterior ear obtusely triangular, depressed, well defined with slight sinuation; anterior ear subquadrate, inflated, deeply incised below, with dorsal margin curving somewhat up; ligament area narrow; resilifer pit wide, elongate, obscurely defined; surface of main body almost smooth without radial ornament, anterodorsal margin sculptured by distinct concentric lines which continue for only a short distance; anterior ear covered by strong concentric fila; muscle scars and pallial line not observed.

Measurements in mm:	Length	Height	Hinge Line
RV	13.5	11.0	5.8
RV	15.0	22.5	6.0
RV	13.0	12.0	6.0

Discussion.—The specimens are diversely deformed. Reconstructed figures based on oval cross sections of associating crinoid stems sugget that all of these belong to a single species. It is similar to *Streblochondria*? (or *Streblopteria*?) *sericeus* (VERNEUIL) (1845, p. 321, pl. 20, fig. 15 and others) from the Permian of Russia, it differs in lacking radial ornamentation and subequal auricles.

Occurrence.—Very rare in the lower Kanokura Formation at Kamiyasse, Kesennuma City, and in the Tenjinnoki Formation at Tenjinnoki, Towa-cho, Miyagi Prefecture, northeast Japan.

Streblopteria? sp. *b*

Plate 6, Figure 10

Material.—A single left valve is at our disposal. It was collected from sandy shale of the Kanokura Formation (Shigejizawa Member) at Kamiyasse, Kesennuma City, Miyagi Prefecture.

Description.—Shell of medium size, roundly subquadrangular, inequilateral, prosocline, moderately inflated, 29 mm long and 28.2 mm high, depth 6.5 mm; umbo prominent, highly salient above hinge margin with an orthogyrate beak lying at about anterior one-third of the shell length; hinge margin straight, shorter than shell length; posterior margin nearly straight, slightly sinuated near the dorsal margin; ventral margin broadly arcuate rising up suddenly to the slightly curved anterior margin; anterior ear poorly developed; posterior ear broad, depressed, not sharply defined from the body; surface almost smooth in the umbonal region and marked by weak, concentric, growth lines over marginal areas; hinge and musculature unknown.

Discussion.—This species recalls typical *Streblopteria* in possessing a large and ill-defined posterior auricle, but the anterior ear apparently is not developed and the shell is posteriorly expanded. It resembles *Rutotia obesa* DEKONINCK (1885, p. 199, pl. 7, figs. 3, 4) from the Lower Carboniferous of Belgium, but differs in a more anterior position of the umbo, and hence in a more inequilateral shape.

Genus *Cyrtorostra* BRANSON, 1930

Type species: *C. varicostata* BRANSON, Phosphoria Formation (lower Guadalupian), the United States.

Cyrtorostra cf. *lunwalensis* (REED)

Plate 5, Figure 11

Material.—A single internal mold of a right valve is at hand. Judging from the cross-sections of associated crinoid stems the specimen has been slightly compressed dorsoventrally.

Description.—Shell suboval, in plan, slightly higher than long, opisthocline, moderately inflated; umbo moderate, salient above hinge margin, terminating with incurved, prosogyrate subcentral beak; hinge area short, low, resilifer pit not observed; anterior ear quadrate, projecting anterodorsally and bounded by a deep, broad byssal notch below; posterior ear obtusely triangular, not sharply defined from the rest of the body; anterodorsal margin of shell body short and concave upward; anterior margin broadly curved making subrectangular angulation with dorsal margin, but gradually continuing to well rounded ventral margin; posterior margin incomplete; surface with ten, narrow, sharply rounded, primary ribs projecting distally beyond shell margin and separated by broad, low ribs or interspaces; muscle scars and pallial line not preserved.

Discussion.—This species is a characteristic member of *Cyrtorostra* BRANSON. It has the cahracteristic ornamentation, shell outline and deep byssal notch. It differs from the type species, *C. varicostata* BRANSON (1930, p. 44, pl. 11, figs. 16–19; CIRIACKS, 1963, p. 57, pl. 9, figs. 1–14) from the upper Permian of Texas and Wyoming in fewer ribs and more inflated shell. In these respects the Japanese shell is akin to *Blanfordina lunwalensis* REED (1944, p. 313, pl. 55, figs. 4–7) from the top of the Middle Productus Limestone in the Salt Range, but exact comparison is difficult because the avaliable materials from Japan and West Pakistan are incomplete. *Blanfordina* is undoubtedly congeneric with *Cyrtorostra* as pointed by CIRIACKS (1963, p. 57).

Occurrence.—Very rare in Shigejizawa Member of the Kanokura Formation (P 21), Kamiyasse, Kesennuma City, Miyagi Prefecture.

Subfamily Euchondriinae NEWELL, 1938

Genus *Euchondria* MEEK, 1874

Type species: *Pecten neglectus* GEINITZ, Pennsylvanian of Nebraska.

Euchondria sp.

Plate 11, Figures 1, 2

Material.—There is only one left valve represented by internal and external molds. It is strongly deformed, secondarily, and the exact shape cannot be ascertained.

Description.—Shell small, a little inflated, longer than high (14 mm. long and 10.5 mm high), fan-shaped excepting subequal ears; antero- and posterodorsal margins nearly straight, making an apical angle of about 95 degrees; ventral margin broad and regularly rounded, gradually continuing to anterodorsal margin; posteroventral corner somewhat angular; hinge margin straight, 9 mm long; ligament area very narrow, provided with trigonal central resilifer pit and numerous, vertical hinge denticles; anterior ear roundly trigonal, sculptured by regular concentric fila and four feeble radial costae; posterior ear wing-shaped, ornamented by concentric sculpture similar to that of the anterior; surface of the shell body covered by seventeen slender radial costae separated by wide, slightly concave interspaces, very weak secondary radials inserted in each interspace near the shell margin; entire surface covered by concentric lines which cross the radials making weak scaly projection near the peripheral margin; muscle scars and pallial line not observed.

Discussion.—The specimen is mechanically compressed, transversally. The shell must originally have been somewhat taller and more equilateral. In ornamentation this species is similar to *E. neglectus* (GEINITZ) (1886, p. 33, pl. 2, fig. 17; MEEK, 1872, p. 193, pl. 9, figs. 1a, b; NEWELL, 1938, p. 105, pl. 19, figs. 1, 4) from the Pennsylvanian, *E. weiensis* WANNER (1940, p. 378, pl. 1, fig. 2) from the Permian of Timor and *E. callytharrensis* DICKINS (1963, p. 89, pl. 14, figs. 2–8) from the Permian of Australia. Permian species of the genus are distinguished from most Carboniferous species in the more equilateral shape and subequal ears, as pointed out by DICKINS. The Japanese species is distinct from other Permian species in less numerous radials.

Occurrence.—Very rare in muddy conglomerate of the Upper Member of Mizukoshi Formation (about 250 meters above the *Lepidolina*-bearing limestone), Kamiumegi, Mifune-cho, Kumato Prefecture, Kyushu.

Family Entoliidae

Genus *Pernopecten* WINCHELL, 1865.

Type species: *Aviculopecten limaeformis* WHITE and WHITFIELD, 1862

There are four specimens in our collection provisionally assigned to *Pernopecten*. One is from the Upper Formation of the Maizuru Group (P 2u), at Katsuradani, Oe-cho, and one from the upper Permian Gujo Formation (P 3) at Gujo, Oe-cho, Kyoto Prefecture. The other two have been obtained from the Tenjinnoki Formation (P 21). These are too incomplete to be described.

Suborder Ostreina FERRUSAC, 1822

Superfamily Ostreacea RAFINESQUE, 1875

Family Ostreidae RAFINESQUE, 1875

Genus *Lopha* RÖDING, 1798

Type species: *Mytilus cristagalli* LINNÉ, 1758, recent.

Discussion.—The genus *Enantiostreon* (type; *E. hungaricum* BITTNER) was proposed by BITTNER (1901, p. 70) for the Triassic plicated oysters attached by the right valve. Morphologically these are virtually identical with *Lopha* which, however, attaches by the left valve. Thus *Enantiostreon* is generally considered to be more closely related to *Terquemia* or *Plicatula* than to *Lopha* or ther ostreids. COX (1952, p. 67) reported examples of *Enantiostreon cristadifformis* (SCHLOTHEIM) which were attached by the left valve, like "true" oysters, and pointed the possibility that the Triassic plicated oysters may have attached indifferently by either valve. He suggested that the orientation of the attached valve might not be a fundamental criterion of classification. So the genus *Enantiostreon* might be treated as a subjective synonym of *Lopha*, or it could be defined to include plicated oysters attached by either the right valve or left valve.

Plicated oysters found in the upper Permian of Japan are too poorly preserved for us to identify positively the orientation. Dr. Erle KAUFFMAN of the U. S. National Museum regards our species as plicated oysters in which attachment was apparently exclusively by the left valve. Our sample is very small, and not adequate to assert that right attachment did not also occur in some individuals. *Lopha* is unusual among oysters in possessing opisthogyre to orthogyre beaks, as apparently do our specimens.

NEWELL (1960) once considered the origin of the oysters in *Pseudomonotis* by abrupt changes of several fundamental characters. But it now appears that ancestry of at least the plicated oysters should be searched for in equivalved, non-attached shells. In this connection *Lopha*? *teranosawensis* NAKAZAWA and NEWELL, n. sp. from the middle Permian in Japan is worthy of note. This species has a strong resemblance to some *Enantiostreon* and *Lopha* in external shape, and plication, differs in having an internal ridge and an auricle (posterior?) and in the subequivalve shell. In this form there is no evidence of an attachment area. Our material is inadequate for further discussion.

Lapha? *murakamii* NAKAZAWA and NEWELL, new species

Plate 7, Figures 1–4, 6–8

Material.—There are many poorly preserved specimens collected from greenish-black shale of the Gujo Formation. Twenty fairly complete specimens served as a basis for the following description.

Description.—Wide individual variation is observed in both configuration and sculpture; shell small, inequivalve, generally subcircular in profile, more or less extended anteroventrally, sometimes elongate oval; shell consisting of concave unornamented umbonal part and plicated outer part in the attached or lower valve, and convex, smooth umbonal part and plicated outer part in the free or upper valve; shape of umbonal part variable in accordance to attached substances, but circular or ovate to elongate making a meridional depression or rounded inflation; in the upper valve strong constriction marking a boundary between smooth, convex part and plicate, outer part of shell; plication rather strong, radiating from the smooth part, varying in number from twelve to thirty, increasing in number by insertion; ligament area short, provided with a broad, shallow ligament pit, devoid of hinge teeth or crenulation in the cardinal area; growth lines close-set, weak; posterior muscle scar subcircular, lying at the posterior side of the midheight of the shell; pallial line not observed.

Discussion.—It is difficult for us to determine the orientation of these shells. Most of the specimens do not show the muscle scar and are subcircular in outline. But judging from an internal mold preserving a posterior adductor muscle scar and comparing the shell forms of plicated oysters, for instance, *Lopha bellaplicata* (SHUMARD) in KAUFFMAN, 1965, the shell has a tendency to expand more or less anteroventrally. The following table indicates the estimated number of upper and lower valves in a sample of twenty specimens:

Upper	Lower
3+7?=10	5+5?=10

The collection is tantalizingly inadequate, but it seems clear that this species is a true oyster related to the Triassic shells classed as *Lopha* and *Enantiostreon*. The ovate shells are similar to the Triassic *Enantiostreon cristadifformis* (SCHLOTHEIM) (GOLDFUSS, 1838, p. 2, pl. 172, fig. 1) or *E. hungaricum* BITTNER (1901, p. 70, pl. 6, figs. 20–25) but the shell is much smaller and is more distinctly differentiated into two parts in the upper valve. The vertically elongate form (pl. 7, fig. 4) is quite similar to the Upper Triassic *Lopha mediocostata* WÖHRMANN (1889, p. 120, pl. 6, fig. 5) from the southern Alps. But both species are too imperfect for confident comparison.

Occurrence.—Common in the upper Permian Gujo Formation (P 3) at Gujo, Oe-cho, Kyoto Prefecture, west Japan.

Lopha? *teranosawensis* NAKAZAWA and NEWEKL, new species

Plate 7, Figures 5, 9

Material.—Four relatively complete and a few fragmentary specimens from two localities are in our collection.

Description.—Shell small, obliquely elongate, falcate, inequilateral, subequivalve, moderately inflated; umbo not prominent, lying a little anterior to the middle of the hinge margin; ventral margin semicircular convex, abruptly rising up to concave opposite margin; hinge margin straight and short; marginal (posterior?) ear depressed, marked off from main body by an umbonal ridge which runs from beak to posteroventral extremity; body of the shell sculptured by somewhat irregular radial plications diverging from umbonal ridge, seven to twelve in number; ligament area narrow, provided with a relatively broad ligament pit; short internal ridge or buttress runs from under the beak to (posteroventral?) margin; muscle scars and pallial line not observed.

Discussion.—In the general outline this species recalls some falcate species of *Lopha.* It is variable in shape, but we are unable to recognize a scar of attachment. The plications of some specimens of *Lopha? murakamii* described above (see Plate 7, Figure 6) resemble those of this species but general configuration is very different. The lateral ear and internal ridge suggest a different generic position of this species and it may represent an entirely different group of bivalves.

Occurrence.—Rare in the middle Permian Tenjinnoki Formation, at Teranosawa, Towa-cho and in the Rodai Formation at Maiya, Towa-cho, Miyagi Prefecture, northeast Japan.

Subclass Palaeoheterodonta NEWELL, 1965

Order Trigonioida DALL, 1889

Superfamily Trigoniacea LAMARCK, 1819

Family Myophoriidae Cox, 1952

The classification of myophoriids has been considered by many investigators, such as FRECH (1889, 1904), WÖHRMANN (1892), BEUSHAUSEN (1895), L. WAAGEN (1907) and others. In recent years, Cox (1951) gave attention to this problem. He reexamined the type species of *Schizodus* DE VERNEUIL and MURCHISON, 1844 (*Axinus obscurus* SOWERBY) and concluded that the hinge teeth of *Schizodus* are reduced in comparison with those of some other primitive Trigoniacea, consisting of a single strong subumbonal tooth in the right and a strong, more or less, bilobed subumbonal tooth in the left preceded by another weak tooth. So the dentition is formulated by 3a/4a 2. At the same time he introduced the generic name *Eoschizodus* for Devonian smooth myophoriids having full myophorian dentition, that is, 3a 3b/4a 2 4b and *Neoschizodus* for smooth Triassic representatives possessing the same general dentition but also with a distinct myophoric buttress behind the anterior adductor.

However, other authors have attributed to *Schizodus* various species possessing two cardinal teeth in each valve or even three in the left. To resolve this confusion we have examined well-preserved specimens of several kinds of *Schizodus* at the American Museum of Natural History. For example, the hinge of topotype specimens of *Schizodus hurii* MILLER (classed by Cox in *Schizodus*) bears two cardinal teeth in each valve. In the right valve, subumbonal tooth 3a is large and stout, medially ridged and subpyramidal; posterior tooth 3b is short and weak, fused to, but defined from, a relatively strong nymph by a weak depression or furrow; in the left valve, subumbonal tooth 2 is as strong as 3a but with a slightly concave ventral face, bordered on both sides by cardinal sockets receiving 3a and 3b of the opposite valve; anterior tooth 4a is slender and a little shorter than 2, and distinctly separated from anterodorsal shell margin. This hinge may be expressed by 3a 3b/4a 2. The right posterior tooth 3b is so small as to be easily overlooked. Further, it may be noted that the nymph may be mistaken for a tooth, especially if only a single valve is observed.

Many species of collections of the Permian and Pennsylvanian *Schizodus* in this Museum are quite similar to *harii* in dentition and in the character of the nymph. The only exceptions observed were *S. bifidus* and *S.* cf. *texanus* both of which have a weak posterior tooth 4b in the left valve. In this case, 4b is very rudimentary compared with that of *Eoschizodus*, discussed below. So the hinge structure of *Schizodus* seems to have been rather constant through Carboniferous to Permian. SOWERBY's specimens of the type species, *obscurus*, are represented by internal molds, and it is not easy to interpret the hinge character.* However, it appears that the dentition of *Schizodus* is most probably formulated as 3a 3b/4a 2, and 4b is usually asbent; wherever it is present it is very rudimentary.**

In comparison with *Schizodus* the dentition of the type species of *Eoschizodus* (type, *Megalodus truncatus* GOLDFUSS) or *Neoschizodus* (type, *Trigonia laevigata* ZIETHEN) is clearly shown by illustrations in GOLDFUSS (1838, pl. 132, figs. 10a, b) and BEUSHAUSEN (1859, p. 126, pl. 9, figs. 13a–d) or SCHMIDT (1928, p. 184, text figs. a-h). The two genera differ from *Schizodus* not only in the number of teeth but also in the features of teeth and nymph. In *Eoschizodus* and *Neoschizodus* the posterior cardinal tooth 3b in the right valve and 4b in the left are lamellar and resemble lateral teeth.

In most Permian and Triassic species the ridge in the left valve bordering the ventral margin of the posterior cardinal socket is more or less well-developed starting from the posteroventral edge of subumbonal tooth 2, and in this case the nymph may be poorly developed.

Triassic Myophoriidae are of *Eoschizodus* type, as also is the upper Permian

* Dr. A. LOGAN of the University of Leeds kindly examined the type specimens kept at Sedgwick Museum and informed us that *S. obscurus* appears to have two cardinal teeth in each valve, but 3b is not demonstrable, and may be too small to appear on the internal mold. He also sent us a squeeze impression of *S. schlotheimi* (GEINITZ) which has quite similar dentition to that of *S. harii*.

** Recently, DRISCOLL described three cardinal teeth in the left valve of *S. rostratus* (WINCHELL) (DRISCOLL, 1965, p. 101, pl. 16, figs. 6–21) but judging from his illustrations the "posterior tooth 4b" is a nymph. WILSON interpreted *S. taiti* (1962, p. 517, pl. 66, figs. 24–28), based on two left valves, as having a cardinal tooth in the right and two in the left, and referred a "thickening" of posterocardinal margin to be a poor expression of tooth 4b, but the latter is most likely to be a nymph and the species is considered to have two cardinals in each valve. The left valve has two sockets in the both sides of large tooth 2.

Costatoria kobayashii (KAMBE) (NZKAZAWA, 1960, p. 52, pl. 6, figs. 10–20) from Japan. On the other hand, North American species of *Costatoria* display the *Schizodus* type of dentition* although they cannot be distinguished externally from *Costatoria*. So these American Permian species may be separated as a different genus when they are fully described in the future.

Another interesting species is "*Myophoria*" *subelegans tobai* HAYASAKA from the Permian of Japan. This externally resembles the Devonian genus *Hefteria* DAHMER, 1954 (type, *Cardinia arnata* ROEMER, 1889) and the Triassic *Lyriomyophoria* KOBAYASHI, 1954 (type, *Lyriodon elegans* DUNKER, 1849) in concentric sculpture and strong umbonal carina, but the dentition is of the *Schizodus* type. The dentition of *Hefteria* is said to resemble that of *Myophoria*. So future work may require a new generic or subgeneric name for *tobai*, although tentatively it is placed here in *Schizodus*.

From the hinge structure mentioned above it is reasonable to classify the Paleozoic Myophoriidae into two groups, 1) a group of *Schizodus* and 2) a group of *Neoschizodus*. An interesting example of parallelism between the two groups is shown in the next table.

Group of *Neoschizodus*	Group of *Schizodus*
Costatoria (plicate)	. "*Costatoria*" *sexradiata*
Lyriomyophoria (concentric)	. *Schizodus tobai*
Hefteria (concentric)	
Neoschizodus (smooth)	
Eoschizodus (smooth)	. *Schizodus harii*

Cox separated the Triassic *Neoschizodus* as a distinct genus from the Paleozoic *Eoschizodus* in having a distinct myophoric buttress. But typical *Neoschizodus* is also found in the Permian of Japan. The development of the myophoric buttress has many grades and is considered here to have questionable phyletic value. Provisionally, *Eoschizodus* is treated here as a subgenus of *Neoschizodus*.

Group of *Neoschizodus*

Genus *Nesochizodus* GIEBEL, 1856

Subgenus *Neoschizodus* GIEBEL, 1856

Type species: *Trigonia laevigata* ZIETHEN 1830, Lower Triassic.
Synonym: *Middalya* DICKINS, 1956

* There are at least two Permian species of "*Costatoria*" in the collection of the American Museum of Natural History from Texas, one of which is referred to "*C.*" *sexradiata* (BRANSON).

Discussion.—DICKINS (1956, p. 36) proposed a genus *Middalya*, with *M. johnstonei* (*op. cit.*, p. 36, pl. 6, figs. 1–7, text fig. 3), from the lower Permian (Kungurian) of West Australia, as type. He placed the genus in the Family Astartidae assuming affinity with *Astartella*. The dentition of this genus was thought to consist of two cardinal teeth in the left valve, one cardinal and one lateral in the right valve. But judging from his description, figures and from an examination of latex casts of the types at the American Museum of Natural History, the dentition is identical of that of *Neoschizodus* in number and form of the teeth. The lateral tooth in the right valve mentioned by DICKINS is here considered to be a lamellar posterior cardinal tooth, and the dorsal margin of the corresponding socket in the left valve most probably reflects the third cardinal tooth of the opposite valve. The lack of lunule, escutcheon and concentric lamellar sculpture, and the possession of a strong myophoric buttress, strongly suggest that the genus belongs to the Myophoriidae rather than to Astartidae.

Neoschizodus (*Neoschizodus*) *kitakamiensis* NAKAZAWA and NEWELL, new species

Plate 8, Figures 4–6

Material.—There are four complete and several fragmental specimens obtained from the middle Permian of Kitakami massif. The interior is well perserved in the internal molds.

Description.—Shell relatively small, roundly quadrate, equivalve, inequilateral, moderately inflated, longer than high with H/L ratio of 1:1.2–1.3; umbo located at anterior one-third to two-fifths of shell length, not prominent, terminating with prosogyrate beak; anterior margin well-rounded, continuing rather abruptly to broadly rounded ventral margin; posterior margin slightly arcuate; umbonal carina obscure; hinge consists of typical myophorian dentition of formula 3a 3b/4a 2 4b; 2 and 3b, stout and strongly projected; 4b and 3b, long and lamellar, parallel to dorsal shell margin; 3a, lobate, not so projected as 2 and 4a; myophoric buttress well-developed behind anterior adductor muscle scar; pallial line entire; posterior adductor scar usually not impressed; surface covered by very fine regularly disposed, concentric fila or grwoth lines which can be observed with a magnifying glass.

Discussion.—Possession of myophorian dentition, myophoric buttress, prosogyate beak and nearly smooth shell the present species is properly referable to *Neosdhizodus* as defined by Cox. The only Permian species of *Neoschizodus* heretofore described is *N. permicus* NAKAZAWA (1960, p. 55, pl. 4, figs. 4–9, text fig. 1) from the upper Permian Gujo Formation, and intimately related *N. kobayashii* (ICHIKAWA) (1951, p. 325, pl. 1, figs. 5, 6) from upper Permian in Shikoku. The present species occurs in the middle Permian, hence the range of *Neoschizodus* is lowered.

In comparison with the Triassic *Neoschizodus* the myophoric buttress is wider and lower, and the ventral margin of posterior cardinal socket of the left valve is not so developed as that of the upper Permian *N. permicus* or the Lower Triassic *N.* cf. *laevigatus* in Japan. The present species is similar to "*Schizodus*" *subquadratus* GRABAU (1931, p. 311, pl. 31, figs. 1a–d), and "*S.*" *dubiformis* WAAGEN (1881, p. 238, pl. 19, figs. 15, 16) in roundly quadrate rather than trigonal shape, but the last two apparently lack the myophoric buttress. "*Myophoria*" *praecox* WAAGEN (*op. cit.*, p. 243, pl. 19, figs. 16–19) is close to the present species in having a myophoric buttress and weak concentric sculpture, but it is distinguished by a taller and more inflated shell and more strongly angular umbonal carina. Externally, this species is similar to *Schizodus subovatus* CIRIACKS (1963, p. 60, pl. 10, figs. 1–6) from the Permian of the Middle Rockies of Wyoming, but the latter lacks a buttress and has different dentition. Most intimately related form is found in *N. johnstonei* (DICKINS) mentioned above. The latter slightly differs from Japanese species in a little taller shape.

Measurements in mm:	Length	Height	H/L
LV	15.7	14.5	0.92
RV	15.6	12.2	0.78
RV	15.5	12.4	0.80
RV	9.0	6.5	0.72

Occurrence.—Rare in the Tenjinnoki Formation (P 21) at Teransowa, Maiya, Towa-cho, Miyagi Prefecture, northeast Japan.

Genus *Costatoria* WAAGEN, 1907

Type species: *Donax costatus* ZENKER, 1833 (subsequent designation by NAKAZAWA, 1960).

Costatoria katsurensis NAKAZAWA, 1967

Plate 8, Figures 1a–c

1951. *Schizodus? radiatus*, ICHIKAWA, p. 326, pl. 1, fig. 7, *non Myophoria radiata* LOCZI 1899, p. 155, pl. 9, figs. 21, 22.

1967. *Costatoria katsurensis*, NAKAZAWA, p. 170, pl. 6, fig. 11.

Discussion.—This species was established on a single internal mold of a left valve. Subsequently, several specimens have been obtained from the type locality.

Unfortunately, all excepting one nearly complete right valve are very small and fragmentary. The dentition of both valves is essentially like that of *Costatoria kobayashii* (KAMBE). The main part of the flank is ornamented by eight, acute, roof-like radial plications separated by broad, concave interspaces. The antero-dorsal margin is covered by seven close-set, weak, radial costae. The siphonal area is bounded by a strong umbonal carina and marked by two radial constae and one intercalated secondary costa. These radial ribs are very similar to NAKAZAWA's "type B" ornamentation of *C. kobayashii* (NAKAZAWA, 1960, p. 53, pl. 6, fig. 10). The other five small specimens show the same type of ornamentation, too, but one right valve bears "type A" ornamentation. So the ornamentation of this species is somewhat variable, as with *C. kobayashii*. The two species have much in common. The present form differs slightly in having a more acute umbonal ridge and the posterior radial costae do not become obsolete towards the ventral margin in contrast to *kobayashii*. More and better specimens may reveal that the two species are distinguishable only subspecifically. As the specific name is preoccupied by *C. radiata* (LOCZI) (1899, p. 155, pl. 9, figs. 21, 22) from the Upper Triassic of China, a substitution name, *C. katsurensis* was proposed by NAKAZAWA (1967).

Occurrence.—Rare in coarse-grained sandstone of the Katsura Formation (P3, upper Permian) in Shikoku.

Group of *Schizodus*

Genus *Schizodus* DE VERNEUIL and MURCHISON, 1844

Type species: *Axinus obscurus* SOWERBY, 1821.

Schizodus tobai (HAYASAKA)

Plate 8, Figures 2, 3

1923. *Myophoria subelegans* var. *tobai*, HAYASAKA. p. 190, pl. 15, figs. 4–8
1925. *Myophoria subelegans* var. *tobai*, HAYASAKA. p. 17
1960. *Myphoria subelegans* var. *tobai*, NAKAZAWA. p. 51, pl. 6, figs. 2, 3.

Discussion.—The dentition of this species was briefly interpreted by NAKAZAWA (1960), but additional observations on the same specimens are given here. In the right valve there are two cardinal teeth, the anterior one (3a) of which is trigonal, directed forward and strongly projected outward; the posterior one (3 b) is short and weak, running subparallel to the dorsal shell margin. Posterior to 3b there is a short, shallow furrow, bounded dorsally by a weak internal ridge. Anterior cardinal, 4a is trigonal, weak, small and united with the dorsal margin; the posterior cardinal, 2, is trigonal, strong, erect, and projected outward. Posterior to 2, and separated from it by a deep, oblique socket (equivalent to 3b) there is a weak marginal thickening formerly regarded as posterior cardinal tooth, 4b. But, considering the fact that there is no corresponding socket in the right valve and it does not project beyond the commisure plane of the shell, this probably is not a tooth. So the dentition may be represented by 3a 3b/4a 2 as in *Schizodus* and the general character of the hinge conforms to that of *Schizodus*.

The slender trough behind the posterior cardinal tooth in each valve is considered here to be a posterior pedal retractor muscle scar. A similar incision, considered to be an anterior pedal muscle scar, is impressed near the anterior cardinal tooth of each valve.

The concentric sculpture and strong marginal carina of this species recalls the Devonian *Hefteria* and Triassic *Lyriomyophoria*, as mentioned above. But the different dentition of the Permian species suggests a separate phylogenetic series. It may belong to a new member of the *Schizodus* group, possibly a subgenus.

S. tobai was first considered as a subspecies of "*Myophoria*" *subelegans* WAAGEN (1877, p. 246, pl. 19, figs. 14a–e) from the Upper Productus Limestone, but it differs from the latter in being longer in outilne, in possessing stronger and more closely spaced concentric sculpture and in absence of an anterodorsal ridge. The dentition of *elegans* is not known.

Occurrence.—Rare in the lower Kanokura Formation (P 21), at Imo, Iwate Prefecture, and at Kamiyasse, Kesennuma City, Miyagi Prefecture.

Subclass Heterodonta NEUMAYR, 1884

Order Veneroida ADAMS and ADAMS, 1858

Superfamily Carditacea FLEMING, 1828

Family Carditidae FLEMING, 1828

Genus *Gujocardita* NAKAZAWA and NEWELL, new genus

Type species: *G. oviformis*, new species, upper Permian (Gujo Formation), Japan.

Diagnosis.—Shell small, elongate-oval, equivalve, inequilateral, moderately inflated; umbo very anteriorly located, prosogyrate, lunule small, ill defined; escutcheon well developed, long and deeply excavated; hinge in right valve two cardinal teeth and one posterior lateral; in the left, three cardinals and one lateral; anterior cardinal of left valve represented by marginal thickening of lunule, posterior cardinal poorly developed, fused to nymph; posterior lateral of left valve lies below that of right valve; anterior adductor scar deep, bounded posteriorly by myophoric buttress extending from hinge plate; posterior adductor scar lying close to end of the posterior lateral tooth; pallial line entire; inner shell margin not crenulated; surface covered by radial costae.

Discussion.—The dentition of this genus is represented by the formula: 3a 3b III/(4a) 2 (4b) II. The dentition is closely comparable with that of the Triassic genus *Palaeocardita* CONRAD, 1867 (type species: *Cardium austriacum* v. HAUER, 1853). According to BITTNER (1895, p. 36), *Palaeocardita* has three cardinals in the left and two in the right, but the anterior cardinal of the left is usually not well developed, represented by marginal thickening of the lunule. It seems that there are two cardinals in each valve of the Triassic genus as in *Gujocardita*. The posterior cardinal, 4b, of the left valve of *Palaeocardita* is well developed, while that of *Gujocardita* is rudimentary and in many individuals cannot be observed; the anterior cardinal tooth of the right valve of *Gujocardita* is more developed than in *Palaeocardita*. Furthermore, *Gujocardita* is distinguished from *Palaeocardita* in lacking marginal crenulation of the shell and elongate ovate outline. The genus is somewhat similar to some of Permophiidae, especially to *Stutchburia* which has relatively strong radial ribs but differs in strong development of 3a and obscure 4b. *Gujocardita* may be a transitional form between *Stutchburia* and *Palaeocardita*.

Gujocardita oviformis NAKAZAWA and NEWELL, n. gen. and n. sp.

Plate 9, Figures 1–6

Material.—Many specimens were obtained from the Gujo Formation, all of which are more or less deformed secondarily.

Description.—Shell small, elongate oval, about 1.7 times longer than high, equivalve, inequilateral, moderately inflated; umbo very anterior, with prosogyrate, incurved beak; somewhat tumid anteriorly and a little extended posteriorly; ventral margin broadly arcuate without ventral sinuation; most inflated axis running from beak to posteroventral extremity; escutcheon long and deeply excavated; lunule small, deep, not clearly defined from the rest: ligament external, inserted on a narrow, relatively long nymph; hinge of right valve consists of two cardinals and one posterior lateral; among these the posterior cardinal is trigonal, strongly projected, and directed backward; anterior cardinal weak, lying close to the lunule; between the two cardinals lies a deep trigonal socket and above the posterior cardinal a shallow slender socket; posterior lateral tooth formed by marginal thickening of shell margin; hinge of left valve consists of three cardinals and one posterior lateral; anterior cardinal weak, represented by marginal projection of lunule, medial one trigonal and strongly projected, posterior cardinal very weak, and slender, fused to slender nymph, and in most specimens not well defined; posterior lateral tooth originating behind ligament and bounding a lateral socket with the projected shell margin; anterior adductor scar oval, lying close to anterior shell margin, delimited behind by strong buttress; posterior scar obscrue, larger than the anterior, situated close to the posterior lateral tooth; pallial line entire; surface sculptured by radial ribs except for the anterior part of the shell; radial ribs low, roof-shaped, twelve in number.

Measurements in mm:	Length	Height	H/L
LV	12.3	9.6	0.78
LV	9.0	4.6	0.51
LV	10.8	5.2	0.48
LV	9.4	5.1	0.54
LV	13.3	7.2	0.54
RV	10.8	5.1	0.47
RV	13.0	9.4	0.72
RV	16.7	8.0	0.48
RV	11.7	9.0	0.75

Discussion.—*Palaeoneilo*? *parviradiatus* CIRIACKS (1963, p. 37, pl. 4, figs. 7–11) from the Permian of Wyoming differs from *Palaeoneilo* in having a distinct escutcheon, faint lunule and radial ornament, and is most probably a representative of *Gujocardita*, n. gen. It differs from the Japanese species in character of the ribbing, that is, the radial costae are stronger in the anterior part and grow weaker posteriorly while those of *G. oviformis* grow weaker anteriorly. *Pleurophorus acutiplicatus* WAAGEN (1881, p. 223, pl. 18, figs. 10a–e) from the top bed of the Upper Productus Limestone in Salt Range and *Stutchburia* n. sp. ETHERIDGE (1919, p. 190, pl. 30) from the Permian in New South Wales, are comparable in the elongate-oval shape, distinct escutcheon, and radial ribs. These are all distinguished from the Japanese species by stronger radial ornamentation. Further discussion is impossible as the interior of these shells is unknown.

Family Permophoridae VAN DER POEL, 1959
(*pro* Pleurophoridae DALL, 1895)
Subfamily Permophorinae VAN DER POEL, 1959
Genus *Permophorus* CHAVAN, 1954

Type species: *Arca costata* BROWN, 1851, Permian.

Permophorus tenuistriatus NAKAZAWA and NEWELL, new species

Plate 9, Figures 7–9

Description.—Shell medium sized, elongate, subquadrangular, equivalve, strongly inequilateral, more than two and a half times longer than the height; umbo subdued, prosogyrate, subterminal; dorsal margin slightly convex; posterior margin truncate; ventral margin weakly sinuate and nearly parallel with the dorsal margin; umbonal ridge low and rounded, extending from beak to posteroventral extremity, in front of which there is a weak radial depression; cardinal dentition poorly preserved, in the left valve lies a very shallow, oblique, subtrigonal socket below the beak bounded laterally by weak teeth; in the right valve, an oblique cardinal tooth corresponds to the median socket of the left; one posterolateral tooth in each valve originates some distance from beak and runs parallel to the hinge margin, that of the left valve being below the marginal thickening of the right; lunule very small, escutcheon long and slender; ligament opisthodetic, set in slender nymph; surface sculptured by very feeble radial costellae on the posterodorsal area; anterior adductor muscle scar strongly impressed near the anterior end, delimited posteriorly by myophoric ridge; posterior scar not impressed; pallial line entire.

Discussion.—Although the cardinal teeth are not well shown, but apparently are appreciably reduced in size and, in this respect, recall *Stutchburia*, but the general shape suggests *Permophorus*. Externally, the Japanese species is similar to the Upper Carboniferous *P. subcostatus* (MEEK and WORTHEN, 1866, p. 347, pl. 27, figs. 2, 2a; FEDOTOV, 1932, p. 66, pl. 7, figs. 10–13), but the costellae are weaker and more numerous. It may also be distinguished from the American Permian *P. albequus longus* (BEEDE) (1908, p. 162, pl. 6, fig. 9) in the sinuated ventral margin and rather flattened anterior part of the shell.

Occurrence.—Common in the upper Permian Gujo Formation (P 3) at Gujo, Oe-cho, Kyoto Prefecture.

Genus *Pseudopermophorus* CIRIACKS, 1963

Type species: *P. annettae* CIRIACKS, Permian, Montana.

When CIRIACKS introduced *Pseudopermophorus*, he indicated (1963, p. 69) that "Characteristic differences are found in the dentition and anterior region of the cardinal plate. *Pseudopermophorus* possesses a slender, but well-defined, second cardinal tooth, 5b, on the right valve which is posterior to 4b of the left valve." But we could not confirm 5b in any of CIRIACKS' type specimens in the National Museum in Washington, or in silicified examples from Texas in the American Museum of Natural History or in the Japanese specimens. So we feel that the dentition of *Pseudopermophorus* should be emended to 3b PIII/2 4b PII, which is the dental formula of the Upper Triassic *Curionia* RONCHETTI, 1965 (type species, *Myoconcha curionii* HAUER, 1857). The characteristic feature of *Pseudopermophorus*, is a gaping depression in front of beak occupying the position of a lunule. CIRIACKS noted the similarity of this opening to the pedicle foramen of some brachiopods and suggested that it might have some mechanism for temporary attachment of the anterior end of this bivalve.

Pseudopermophorus uedai NAKAZAWA and NEWELL, new species

Plate 9, Figures 10, 11

Description.—Shell medium sized, nearly equivalve, strongly inequilateral, subquadrate, strongly elongate; beak subdued, subterminal; dorsal margin broadly convex; ventral margin slightly concave and nearly parallel with dorsal margin; anterior margin rounded, posterior obliquely trucate; escutcheon long and deep, occupying nearly the entire dorsal margin; nymph about as long as one-third of hinge margin; circular depression in front of beak occupying the position of lunule; hinge consists of one cardinal tooth 3b, in the right, two cardinals 2, 4b in the left, and one posterolateral tooth in each valve; 2 and 3b relatively long, subtrigonal, very oblique to the hinge axis; 4b, slender and longer than 2, or 3b; posterolateral tooth PII long, and lamellar, lying below lateral socket; PIII represented by marginal thickening; anterior adductor scar rounded, deeply impressed below the lunular depression and bounded posteriorly by myophoric buttress extending from the cardinal plate; posterior scar and pallial line not observed; surface poorly preserved.

Measurements in mm:	Length	Height	H/L
RV	42.4	13.7	0.32
RV	37+	16.2	—
RV	20.9	8.7	0.52
RV	28.0	8.0	0.29
RV	45.0	ca 17.0	0.38
RV	13.7	7.0	0.51
LV	11.5+	4.5	—

Discussion.—There are seven specimens in our collection from black shale of the Toyoma Formation (upper Permian) at Nagahata, Towa-cho, and at Kitazawa, Toyoma-cho, in Miyagi Prefecture. Mainly they represent right valves. In comparing with the type species of *P. annettae* CIRIACKS (1963, p. 70, pl. 13, figs. 6–14) the Japanese species is shorter and possesses weaker ventral sinuation.

Genus *Netschajewia* LICHAREW, 1925

Type species: *Mytilus pallasi* VERNEUIL, 1845 (subsequent designation by NEWELL, 1957).

Netschajewia was introduced by LICHAREW for the Permian *Mytilus pallasi* VERNEUIL and *M. teplowi* VERNEUIL, and as replacement for *Modiolodon* NETSCHAJEW, 1894, which had been preoccupied by the Silurian clams. NEWELL (1957) indicated its affinity with *Stutchburia* ETHERIDGE, 1900 and referred to the former as a subgenus of the latter. DICKINS (1963) considered the main difference between the two to be the strength of the lateral tooth, and did not admit even subgeneric value for *Netschajewia*. But *Netschajewia* differs from *Stutchburia* in the complete absence of cardinal dentition. This is clear from the statements of LICHAREW (1925, p. 120; 1939, p. 143) and NEWELL (1956). Well-preserved, silicifed specimens from the Texas Permian also prove this fact. Mytiloid profile of *Netschajewia* is another distinctive character. This genus is considered to be an offshoot of Permophoriidae, characterized by reduction of the hinge, and it is treated here as a distinct genus.

Rimmyjimina CHRONIC, 1952 (type species, *R. arcula* CHRONIC) was referred to the subjective synonymy of *Netschajewia* by NEWELL (1957, p. 7) with some question, but the former has dentition of the *Permophorus* type. So it may be that the *Rimmyjimina* was based on juveniles of *Permophorus*.

Netschajewia cf. *elongata* (NETSCHAJEW)

Plate 11, Figures 5, 6

Description.—Shell medium sized, mytiliform, prolonged and expanded posteriorly, moderately inflated; umbo subdued, with obscure beak; dorsal margin slightly convex; posterior margin broadly rounded; venter slightly sinuated at the middle; lunule and escutcheon not clearly marked; hinge plate developed along anterior margin and anterior half of dorsal margin lacks cardinal tooth; posterior lateral tooth of right valve represented by marginal thickening; anterior adductor muscle scar circular, located close to the anterior end, rather deeply impressed and delimited posteriorly by low, broad myophoric buttress; posterior adductor scar and pallial line not preserved; surface nearly smooth.

Discussion.—Among the species of *Netschajewia, N. elongata* (NETSCHAJEW) (MASLENNIKOV, 1935, p. 80, pl. 3, figs. 5a–c; LICHAREW, 1939, p. 143, pl. 35, fig. 9) from the upper Permian of the Soviet Union is most related to the present species in general shape. The Japanese species differes slightly from the latter in the smaller size and obscure posterior adductor scar. Fibrous microstructure of the shell surface is considered to show crossed-lamellar texture of ecto- or mesectostracum.

Occurrence.—Only one right valve has been obtained from the upper Peirmian Toyoma Formation at Nagahata, Towa-cho, Miyagi Prefecture in association with *Astartella toyomensis*, *Pseudopermophorus uedai* and others.

Netschajewia sp.

Plate 10, Figure 1

Another species of *Netschajewia* is represented by a single right valve of external and internal molds from the Tenjinnoki Formation (P 21).

This form is similar to *N. pallasi* (VERNEUIL) (1845, p. 316, pl. 19, figs. 16a–i) from the Permian in the USSR but is larger in size and the anterior lobe is better developed and projects forward more than in the latter.

Genus *Stutchburia* ETHERIDGE, 1900

Type species: *Orthonota? costata* MORRIS, 1845, Permian of southeastern Australia.

Stutchburia? sp.

Plate 10, Figure 2

Description.—Shell small, elongate-oval, equivalve, strongly inequilateral, moderately inflated, about twice longer than high; umbo subdued, subterminal; lunule and escutcheon not shown; nymph narrow, extending behind beak about one-fourth of the dorsal margin; cardinal teeth obscure, apparently consisting of one amorphous cardinal in each valve; posterolateral tooth of left valve lying below lateral socket, occupying posterior half of hinge; right posterolateral tooth represented by marginal thickening; anterior adductor muscle scar reinforced behind by an internal buttress; posterior scar and pallial line not impressed; external surface unknown.

Discussion.—One of the three specimens has a quadrangular ovate shape, while the other two are somewhat tumid anteriorly, as is more usual in *Stutchburia*. This form is referred to *Stutchburia* with some doubt because the external surface is unknown. It is somewhat like *S. hoskingae* DICKINS (1963, p. 96, pl. 15, figs. 16–23) from the Permian in west Australia, but is less expanded posteriorly and displays no trace of radial ornamentation.

Occurrence.—Rare in the Tenjinnoki Formation, Maiya, Towa-cho, Miyagi Prefecture, northeast Japan.

Family Uncertain

Genus *Actinodontophora* ICHIKAWA, 1951

Type species: *A. katsurensis* ICHIKAWA, Permian, Japan.

Actinodontophora katsurensis ICHIKAWA, 1951

Plate 10, Figures 8a, b

1951. *Actinodontophora katsurensis*, ICHIKAWA. p. 327, pl. 1, figs. 15–18.

Descritpion.—This genus was introduced by ICHIKAWA for several incomplete specimens from the Permian of Shikoku. Recently Mr. KOIZUMI discovered a more complete individual and several incomplete specimens from dark colored sandstone of the Kanokura Formation, at Nabekoshi-yama, Kesennuma City, northeast Japan. A description is given below, based on these and the type specimens.

Shell medium sized, equivalve, inequilateral, strongly extended posteriorly, more than twice as long as high; umbo subdued lying at one-fourth or one-fifth of shell length from anterior end; ventral margin broadly arcuate, dorsal margin nearly straight, anterior and posterior margins short and well rounded; hinge consists of a fan of radiating cardinal and subcardinal teeth situated below beak, and a weak posterior lateral tooth and socket; two (in one case, three?) cardinal teeth run anteroventrally in each valve, subcardinal teeth of five to seven in number relatively weak, directed posteroventrally; posterior to the subcardinals there is a short but strong nymph; in the left valve posterolateral socket and underlying tooth start from just behind the nymph, running parallel to the dorsal margin; socket bounded marginally by dorsal edge of the shell while ventral edge of the socket is bordered by the lateral tooth; posterolateral tooth of right valve made by marginal thickening of dorsal margin; lunule apparently absent; escutcheon well developed, deeply incised, marked off from flank of shell by sharp ridge extending to near posterior end of hinge; anterior adductor muscle scar subcircular deeply impressed close to anterodorsal margin but without buttress, posterior scar oval, obscure; pallial line entire; suface covered by growth lines.

Discussion.—General shape and ligament character suggest possible affinity with *Permophorus* and its allies on the one hand, and on the other actinodont-type cardinal teeth recall some lower Paleozoic modiolopsoids. The Upper Triassic "*Palaeopharus*" *maizurensis* and its allies in Japan (KOBAYASHI and ICHIKAWA, 1951, p. 19, pl. 1, figs. 1–6; NAKAZAWA, 1955, p. 256, pl. 16, figs. 4–6, 8) show close resemblance with *Actinodontophora* in the elongate form of the shell and actiondont teeth. The former is distinguished from the latter in having distinct radial ornamentation and in the detalis of dentition. Possibly, *Actinodontophora* may be related to the unionoids but the posterolateral tooth does not extend below the ligament nymph, as it does in Unionidae.

Superfamily Crassatellacea MENKE, 1830

Family Astartidae D'ORBIGNY, 1844

Genus *Astartella* HALL, 1868

Type species: *Astartella vera* HALL, Pennsylvanian of Iowa.

Discussion.—NICOL (1955) noted similarities between the dentition of *Astartella* and recent *Astarte* and he considered the astartids to have cyrenoid rather than lucinoid dentition, but HAFFER (1959) referred Astartidae to lucinoid group after examining a young shell of the recent *Astarte elliptica* from the Skagerrak Sea. According to BOYD and NEWELL (in press) the Palaeozoic *Astartella* differs from the later *Astarte* in lacking 5a in the right valve and in having 2 fused to the anterior lateral tooth in the left. The dentition is formulated as below:

$$\frac{\mathrm{I} \qquad \mathrm{III} \qquad 3b \qquad 5b \qquad \mathrm{III}}{\mathrm{II} \qquad 2 \qquad 4b \qquad \mathrm{II}}$$

In the Permian species 5b is sometimes fused to the nymph and hardly discernible.

Astartella toyomensis NAKAZAWA and NEWELL, new species

Plate 10, Figures 3–5

Materials.—Many individuals of the species were found in the upper Permian Toyama shale. Most are more or less mechanically deformed.

Description.—Shell medium sized, ovate, equivalve, inequilateral, moderately inflated; umbo prosogyrate, lying a little more than one-third of the length from anterior extremity; posterodorsal margin long and nearly straight, anterodorsal margin shorter and a little convex, anterior margin well rounded, continuing to the broadly arcuate ventral margin, which rises abruptly up to the posterior margin without sharp angulation; escutcheon long, occupying nearly entire posterodorsal margin and deeply excavated; lunule deep and sharply defined from the rest of shell; hinge of typical *Astartella* type set on a stout hinge plate, consisting of two cardinal teeth in each valve, two posterolaterals and one anterolateral in the left, two anterolaterals and one posterolateral in the right; 2 and AII not clearly differentiated, 4b separated from the nymph by a shallow groove, but 5b usually fused to nymph and hardly discernible or marked off from the latter by a feeble furrow, PIII represented by marginal thickening; both adductor muscle scars oval in shape situated close to the ends of the laterals; pallial line entire; pedal retractor scar visible at center of umbonal cavity; shell margin weakly crenulated; surface covered by closely set growth lines and stronger concentric fila which are somewhat more widely spaced in the medial part of the shell.

Measurements in mm:	Length	Height	H/L
LV	13.3	10.5	0.80
LV	27.o	21.6	0.80
LV	24.0	16.7	0.70
RV	19.3	16.7	0.87
RV	19.4	15.8	0.81
RV	28.0	21.4	0.76
RV	19.7	17.0	0.86

Discussion.—As stated above, the posterior cardinal tooth 5b, in the right valve, is variable in development; usually it is fused to the nymph, from which it is bounded by a very weak furrow. But the corresponding socket of the opposite valve is generally more clearly developed. The anterior cardinal tooth 2, of the left valve, continues into the anterior lateral tooth AII without interruption but becomes angulated at the junction. In one specimen, tooth 2 is striated by a weak radial furrow. Judging from the concentric sculpture, the umbo is located in a more central position at an early growth stage, and later the shell expands posteroventrally and the umbo moves anteriorly.

The ovate rather than quadrangular outline of this species recalls the Upper Carboniferous *A. vera* HALL, as interpreted by FEDOTOV (1932, p. 63, pl. 7, figs. 1–8) from the Soviet Union, but our shell has a more tumid anterior portion and deeper, narrower lunule. The Japanese form is distinguished from the type specimen of *vera,* from the United States, by weaker concentric sculpture. *A. vallesneriana* (KING) from the Permian of Greenland (NEWELL, 1955, p. 30, pl. 1, figs. 11–14) is another allied species, but shorter in outline and much smaller.

Occurrence.—Common in the upper Permian Toyoma Formation (P 3), at Kitazawa, Toyoma-cho, Miyagi Prefecture.

Astartella sp. *a*

Discussion.—Several specimens of an *Astartella* were collected from coarse-grained sandstone of the Upper Formation of the Maizuru Group. These are similar to the preceding species in outline, dentition and sculpture. Unfortunately, the preservation in the coarse matrix is not good and close comparison is difficut. Judging from the materials before us the present species differs slightly from *toyomensis* in weaker dentition and more closely set concentric ridges.

Occurrence.—Rare in the Upper Maizuru Group (*Lepidolina* zone) at Nomaru, Okuyama, Oe-cho, Kyoto Prefecture.

Astartella sp. *b.*

Plate 11, Figure 9

Material.—A single right valve, represented by incomplete internal and external molds is at hand. It is strongly flattened.

Description.—Shell medium sized, a little inflated, inequilateral, longer than high with H/L ratio about 0.8, roundly subquadrate; posterodorsal margin long and nearly straight; anterodorsal margin short and concave; anterior margin well rounded, gradually continuing to a broadly rounded ventral margin and truncated posteriorly, so as to make a rounded angulation at the posteroventral corner; umbo moderately prosogyrate, lying at anterior one-third of shell length; escutcheon distinct and long, occupying nearly the whole length of the posterodorsal margin, delimited from the rest of the shell by sharp angulation; lunule short, deeply incised; hinge consists of two cardinal teeth, two anterior laterals, and one posterior lateral; anterior cardinal 3b strong, subtrigonal, and nearly vertical; posterior cardinal fused to nymph; posterior lateral tooth obscure; anterior adductor muscle scar close to the anterior end of anterior lateral tooth; posterior scar and pallial line not impressed; surface ornamented by strong, regularly arranged and rather broadly spaced concentric fila and intercalating feeble growth lines; marginal crenulation seemingly absent.

Discussion.—The specimen is strongly deformed secondarily. Probably it was more convex and taller in shape than at present. Judging from the dental sockets, the anterior cardinal tooth of the left valve is not separated from the anterior lateral tooth as in the preceding *Astartella* sp. *a.* The quadrate shape of this species recalls the Guadalupian *A. nasuta* GIRTY (1908, p. 445, pl. 23, figs. 6, 7a; pl. 31, figs. 12, 12a and *A. subquadrata* GIRTY (1909, p. 94, pl. 10, figs. 10–13), but our form differs in being more elongate, in having more widely spaced fila and in the less-expanded posterior part of the shell. Probably this form represents an unnamed species, but the material is inadequate for characterization.

Occurrence.—Very rare in the Upper Member of the Mizukoshi Formation (*Lepidolina* zone or later) at Kamiumegi, Mifune-cho, Kumamoto Prefecture, Kyushu.

Astartella sp. *c*

Plate 11, Figure 8

Discussion.—This form is represented by a single complete internal right mold and imperfect external counterpart found in the Upper Maizuru Group, at Katsuradani, Oe-cho, Kyoto Prefecture. The shell is subcircular in outline, small, 7.7 mm long and 8.2 mm high with H/L ratio of 1.07, and weakly inflated. The hinge bears two cardinal teeth. The existence of lateral teeth is not confirmed because of the poor preservation, but judging from the internal mold the anterior cardinal tooth of the right valve seems to continue into a short anterior lateral tooth without interruption, as in other species of *Astartella.* The surface is covered by weak, close-set growth lines and three widely spaced concentric fila. In the tall form and subcentral umbo, this species resembles the Permian *A.* sp. of CIRIACKS (*op. cit.*, p. 65, pl. 12, fig. 10) from Montana and "*Astarte*" *ambiensis* WAAGEN (1881, p. 211, pl. 19, figs. 4a–d) from the Upper Productus Limestone but the Japanese shell is distinguished from the first in lacking strong concentric fila and from the second in the different outline of the shell.

Astartella? sp. *d*

Plate 11, Figure 10

Description.—Shell medium sized, moderately inflated, roundly subtrigonal, subequilateral; 20.5 mm long and 18.4 mm high; umbo moderate, prosogyrate, lying a little anterior to the middle; lunule and escutcheon deeply incised; surface covered by strong, lamellose concentric fila; interstitial concentric growth lines almost absent; interior unknown.

Discussion.—The form is represented by a single right external mold, and the generic placement is uncertain. In external shape and concentric sculpture it resembles certain *Edmondia* such as *E. multilamellosa* GEMMELLARO 1892 (GEMMELLARO, 1895, p. 185, pl. 20, figs. 1–3) from Sosio, but the Japanese shell, unlike *Edmondia,* has a lunule and escutcheon. It differs from *A. toyomensis* in the more symmetrical outline and from *A.* sp. of CIRIACKS in the longer shape and larger size.

Occurrence.—Very rare in the Shigejizawa Member of the Kanokura Formation, (P 21) at Shigejizawa, Kamiyasse, Kesennuma City, Miyagi Prefecture.

Subclass Anomalodesmata DALL, 1889
Order Pholadomyoida NEWELL, 1965
Superfamily Pholadomyacea FLEMING, 1828
Family Pholadomyidae GRAY, 1841
Genus *Chaenomya* MEEK, 1864

Type species: *Allorisma? leavenworthensis* MEEK and HAYDEN, 1858 (original designation), Pennsylvanian of Kansas.

Subgenus *Vacunella* WATERHOUSE, 1965

Type species: *Allorisma curvatum* MORRIS, 1845, upper Permian of New South Wales (Australia).

Discussion.—According to WATERHOUSE (1965, p. 377), *Chaenomya leavenworthensis* differs considerably from *Vacunella curvatum* in having subparallel dorsal and ventral margins, a huge posterior gape, coarse pustules over the shell surface and a lower position of the anterior adductor muscle scar. He treated the two as distinct genera, but there are many intermediate forms and this problem requires further examination on many species. *Vacunella* is here treated as a subgenus of *Chaenomya.*

Chaenomya (Vacunella) rostrata NAKAZAWA and NEWELL, new species

Plate 10, Figure 7

Material.—There are two, somewhat crushed and flattened specimens in our collection from the upper Permian Gujo Formation.

Description.—Shell medium sized, equivalve, inequilateral, hatchet shaped, tumid and posteriorly truncated; umbo robust, with incurved, orthogyrate beak lying at one-third to two-fifths of shell length from anterior end; anterior margin well rounded continuing to broadly arcuate ventral margin, posterior part of which rises making an obscure angulation with anterior part; posterior margin short, truncated, slightly gaping; lunule probably absent; postumbonal carina rounded, extending from beak to posterodorsal extremity, making escutcheon-like depression; hinge edentulous; ligament external, opisthodetic, ligament groove only partly preserved; muscle scar and pallial line not preserved; surface covered by concentric lines and several sporadic wrinkles; fine granular surface texture well-preserved, pustules 5–8 per millimeter, with tendency to parallel the concentric rugae.

Measurements in mm:	Length	Height	H/L
LV	47.4	21.7	0.46
LV	44.3	23.2	0.52

Discussion.—This species recalls *Chaenomya* in having a posteriorly extended shape, concave dorsal margin, posterior gape and edentulous hinge. The dorsal and ventral margins are not parallel. In these respects the present species is more akin to *Vacunella* than to *Chaenomya* s. s.

Occurrence.—Very rare in the upper Permian (P 3) Gujo Formation at Gujo, Oe-cho, Kyoto Prefecture, west Japan.

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Explanation of Plates

Explanation of Plate 1

Figs. 1, 2. *Nuculites ichikawai* NAKAZAWA and NEWELL, n. sp. ....p. 35
1, Holotype, left valve, internal mold, ×2, showing impression of myophoric buttress; 2, latex cast of left valve, ×2. Both from upper Permian Katsura Formation at Katsura, Kochi Prefecture, Shikoku, west Japan.

Figs. 3. ?*Palaeonielo* sp. ....p. 36
Internal mold, ×1, Upper Maizuru Group, Matsunoodera, Maizuru City, Kyoto Prefecture, west Japan.

Figs. 4a, b. ?*Phestia* (*Polidevcia*) sp. ....p. 38
4a, Dorsal view, deformed internal mold, ×3; 4b, right valve, deformed latex cast of the same specimen, ×3, Upper Maizuru Group, Matsunoodera, Maizuru City.

Fig. 5. *Pyramus planus* NAKAZAWA and NEWELL, n. sp. ....p. 45
Right valve, latex cast of the holotype, ×3, Gujo Formation, Gujo, Kyoto Prefecture.

Fig. 6a, b. *Edmondia* sp. *a*. ....p. 39
Left and dorsal views of internal mold, ×2, strongly deformed, dorsoventrally, Gujo Formation, Gujo.

Fig. 7. *Edmondia* sp. *c*. ....p. 39
Left valve, latex cast, ×3, Tenjinnoki Formation Teranosawa, Towa-cho, Miyagi Prefecture, notheast Japan.

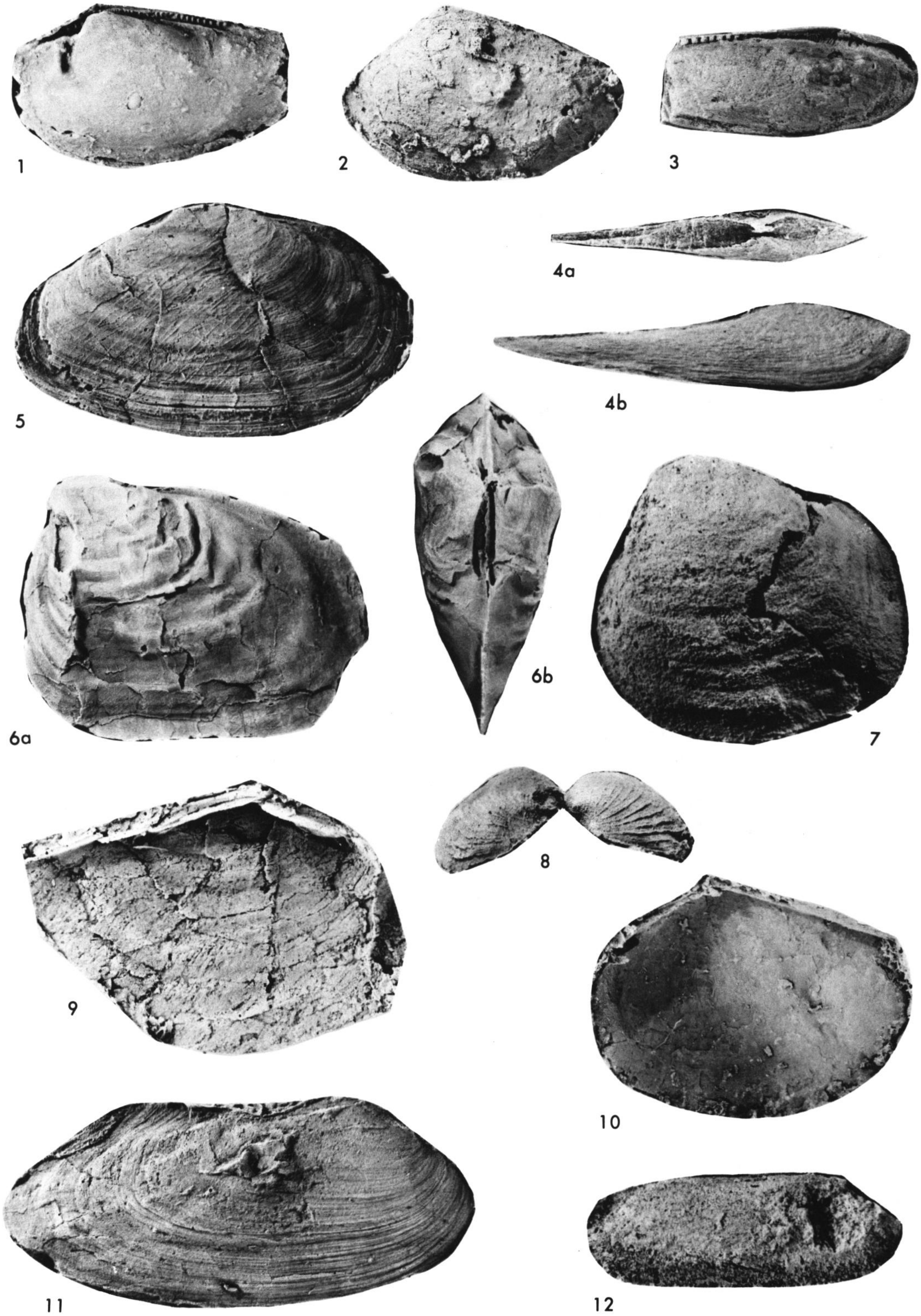
Fig. 8. *Edmondia* sp. *c*. ....p. 39
Both valves, latex cast, ×3, Tenjinnoki Formation, Tenjinnoki, Towa-cho.

Fig. 9. *Pyramus planus* NAKAZAWA and NEWELL, n. sp. ....p. 45
Interior of left valve, latex cast, ×3, showing nymph and dental socket below beak, Gujo Formation, Gujo.

Fig. 10. *Pyramus planus* NAKAZAWA and NEWELL, n. sp. ....p. 45
Internal mold of left valve, ×2, showing pallial sinus, Gujo Formation, Gujo.

Fig. 11. *Sanguinolites*? sp. *a*. ....p. 43
Right valve, latex cast, ×2, Tenjinnoki Formation, Tenjinnoki.

Fig. 12. *Parallelodon* cf. *longus* MASLENNIKOV. ....p. 46
Internal mold of right valve, ×2, Upper Maizuru Group, Kuwanoe, Ayabe City, Kyoto Prefecture.



NAKAZAWA and NEWELL; Permian Bivalves

Explanation of Plate 2

Fig. 1. *Parallelodon* cf. *multistriatus* GIRTY. ....p. 47
Latex cast of both valves, ×4, Takakurayama Formation, near Tamayama, Yotsukura, Fukushima Prefecture, northeast Japan.

Fig. 2. *Parallelodon* cf. *tenuistriatus* (MEEK and WORTHEN). ....p. 48
Latex cast of right valve, ×3, Kanokura Formation (Shigejizawa Member), Kesennuma City, Miyagi Prefecture, northeast Japan.

Fig. 3. *Septimyalina* sp. ....p. 55
Latex cast of left valve, ×2, Gujo Formation, Gujo, Kyoto Prefecture, west Japan.

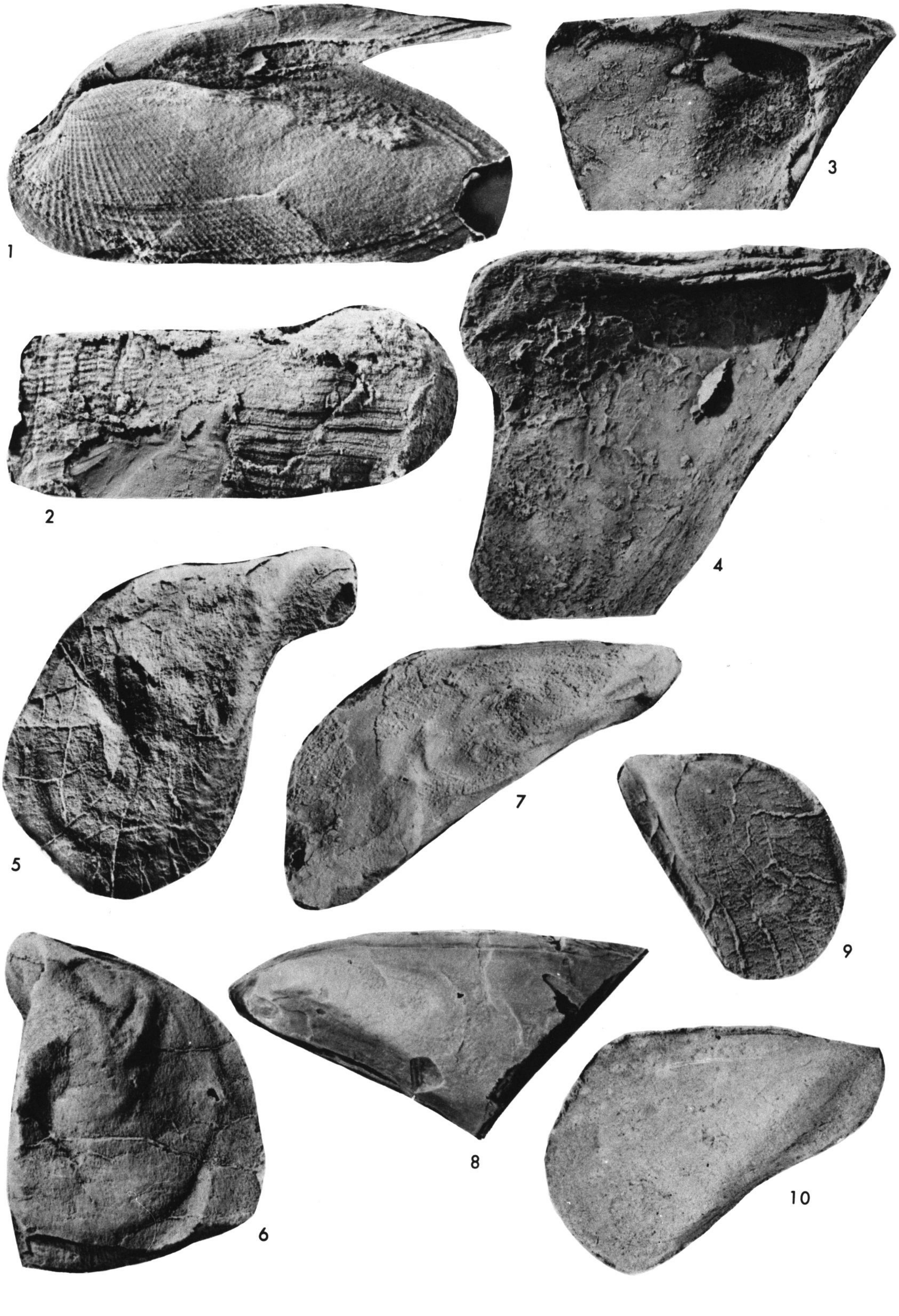
Fig. 4. *Myalina* (*Myalina*) sp. ....p. 54
Latex cast of left valve, ×2.5, Toyoma Fm., Kitazawa, Miyagi Prefecture.

Figs. 5, 6 *Promytilus maiyensis* NAKAZAWA and NEWELL, n. sp. ....p. 49
Internal molds, ×3.5; 5, the holotype, right valve; 6, left valve, Tenjinnoki Formation, Tenjinnoki, Miyagi Prefecture.

Figs. 7, 8 *Promytilus* sp. *a*. ....p. 50
Internal molds of right and left valves, ×3, Gujo Formation, Gujo.

Fig. 9. ?*Promytilus maiyensis* NAKAZAWA and NEWELL, n. sp. ....p. 51
Internal mold, left valve, ×3, Tenjinnoki Formation, Tenjinnoki.

Fig. 10. *Promytilus* sp. *b*. ....p. 52
Internal mold, ×2, Rodai Formation, Maiya, Towa-cho, Miyagi Prefecture.



NAKAZAWA and NEWELL; Permian Bivalves

Explanation of Plate 3

Fig. 1. *Aviculopinna* sp. ....p. 53
Latex cast of part of right valve, ×2, Gujo Formation, Gujo, Kyoto Prefecture, west Japan.

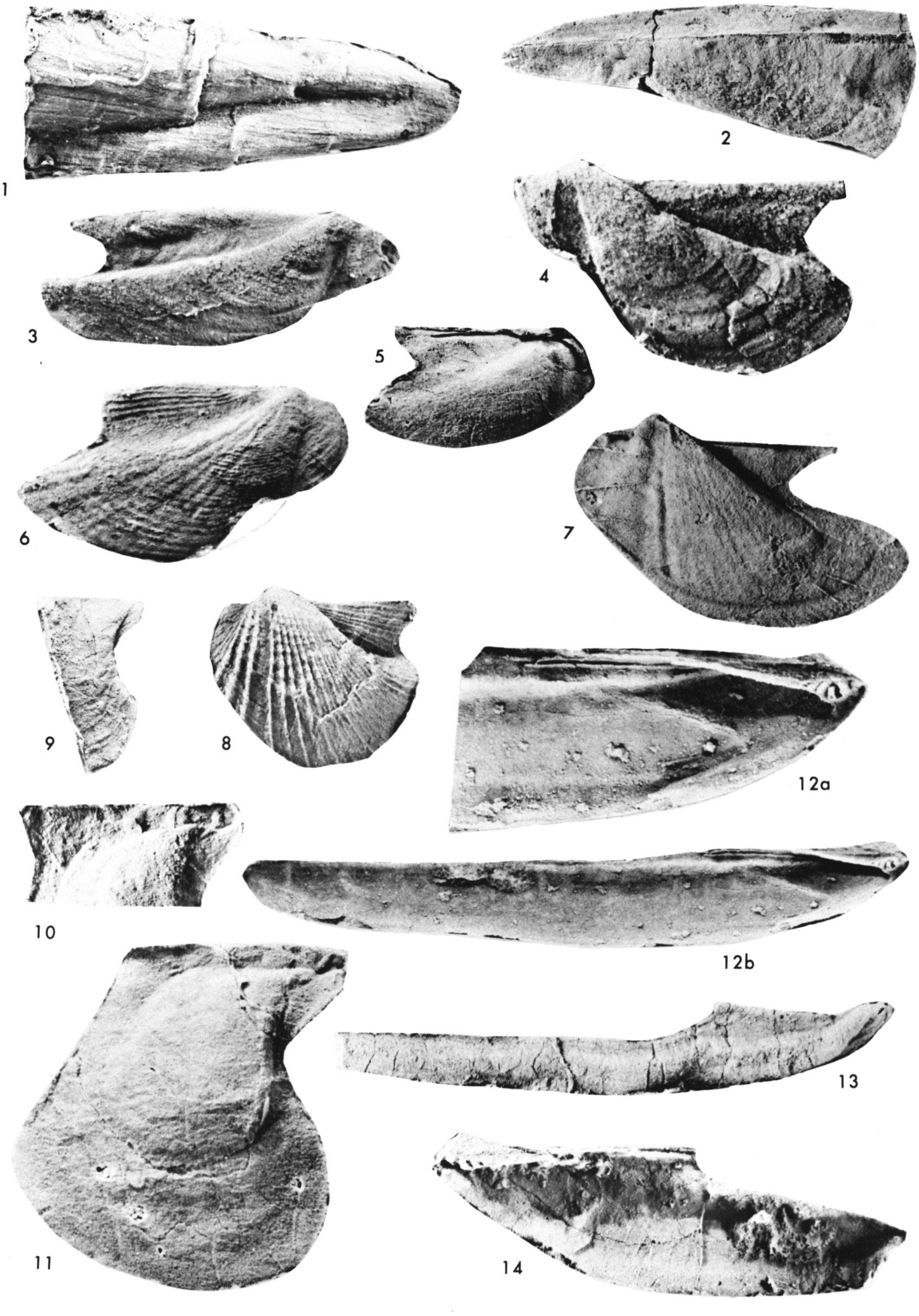
Fig. 2. *Aviculopinna* cf. *rectangularis* (HAYASAKA). ....p. 54
Left side of internal mold of bivalved individual, ×1, Kanokura Formation (Shigejizawa Member), Kesennuma City, Miyagi Prefecture, northeast Japan.

Figs. 3, 4. *Leptodesma* (*Leiopteria*) sp. ....p. 56
Right and left valves, ×5, Tenjinnoki Formation, Maiya, Miyagi Prefecture.

Figs. 5–8. *Towapteria nipponica* NAKAZAWA and NEWELL, n. gen. and n. sp. ....p. 62
Tenjinnoki Formation, Tenjinnoki, Miyagi Prefecture, 5, Internal mold of right valve, ×3; 6, latex cast of right valve, ×4; 7, composite mold of left valve, ×4; 8, latex cast of left valve, the holotype, ×3.

Figs. 9–11. *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL, n. subg. and n. sp. .... p. 62
Tenjinnoki Formation, Tenjinnoki. 9, latex cast of right valve, ×2; 10, internal mold of the same, ×3; 11, internal mold of right valve, the holotype, ×3.

Figs. 12–14. *Ensipteria onukii* NAKAZAWA and NEWELL, n. gen. and n. sp. ....p. 65
Tenjinnoki Formation, Tenjinnoki. 12a, b, Latex cast of the holotype, a left valve, ×5, ×3, respectively; 14, latex cast of right valve, ×2; 15, latex cast of another right valve, ×4.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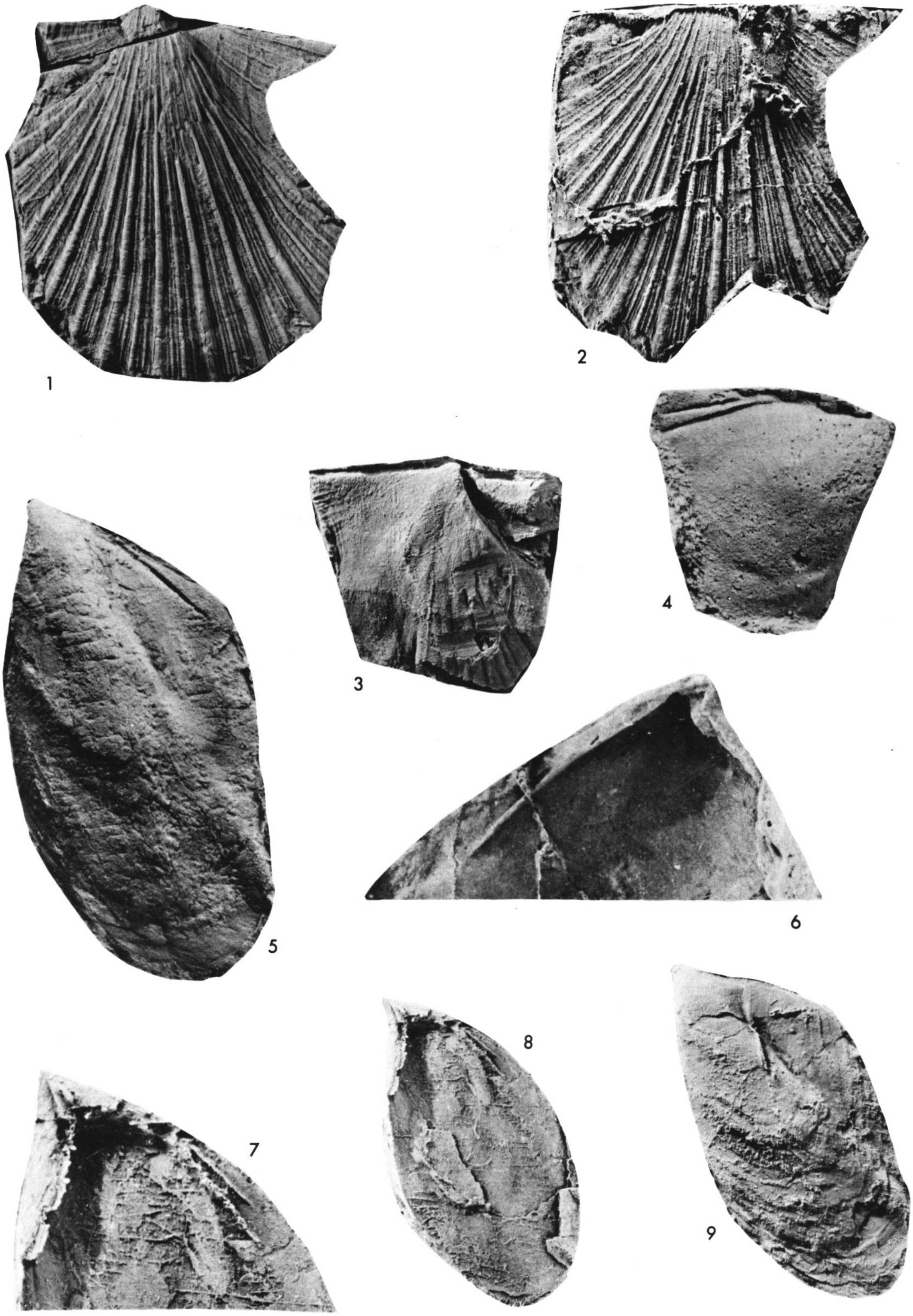
Explanation of Plate 4

Figs. 1–3. *Aviculopecten shiroshitai* NAKAZAWA and NEWELL, n. sp. ....p. 66
Gujo Formation, Gujo, Kyoto Prefecture, west Japan. 1, The holotype, left valve, ×2; 2, latex cast of the same, ×1; 3, internal mold of right valve, ×4.

Figs. 4–9. *Tambanella gujoensis* NAKAZAWA and NEWELL, n. gen. and n. sp. ....p. 64
Gujo Formation, Gujo. 4, Internal mold, right valve, ×5, showing impressions of several resilifers; 5, internal mold, left vlve, ×4; 6, latex cast of left valve, ×4; 7, latex cast of right valve, the holotype, ×4; 8, the same, ×2; 9, latex cast of left valve same, specimen as figure 5, ×3.



NAKAZAWA and NEWELL; Permian Bivalves

Explanation of Plate 5

Figs. 1–3. *Aviculopecten* cf. *hataii* MURATA. ....p. 68
Latex casts, ×3, Kanokura Formation (Shigejizawa Member), Kesennuma City, Miyagi Prefecture, northeast Japan. 1, Left valve, in which the inner ostracum has been dissolved away over most of the shell; 2, right valve; 3, latex cast of left valve.

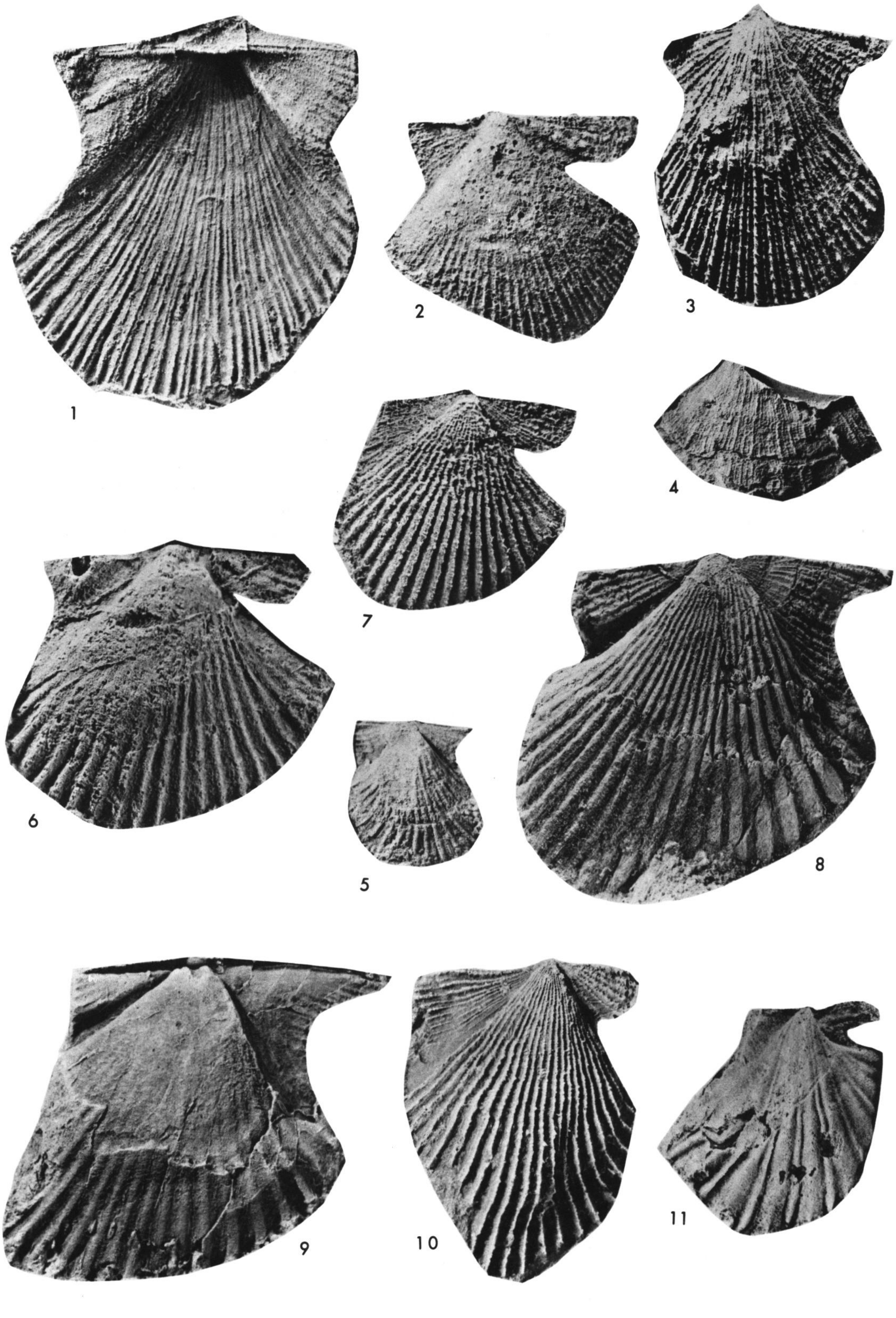
Fig. 4. *Aviculopecten* sp. *b*. ....p. 69
Latex cast of left valve, Toyoma Formation, Toyoma-cho, Miyagi Prefecture.

Fig. 5. *Aviculopecten* sp. *a*. ....p. 68
Composite cast of left valv, ×2, Tenjinnoki Formation, Tenjinnoki, Miyagi Prefecture.

Figs. 6, 8, 9. *Hayasakapecten shimizui* NAKAZAWA and NEWELL, n. gen. and n. sp. ....p. 70
Tenjinnoki Formation, Tenjinnoki. 6, Internal mold of right valve, ×4; 8, the holotype, latex cast of left valve, ×3; 9, internal mold of the same, ×3.

Figs. 7, 10. *Hayasakapecten sasakii* (MURATA). ....p. 72
Latex casts of right valves, ×3, topotypes from Kanokura Formation (Shigejizawa Member), Kamiyasse, Miyagi Prefecture.

Fig. 11. *Cyrtorostra* cf. *lunwalensis* (REED). ....p. 79
Internal mold of left valve, ×2, Kanokura Formation (Shigejizawa Member), Kamiyasse, Miyagi Prefecture.



NAKAZAWA and NEWELL; Permian Bivalves

Explanation of Plate 6

Figs. 1a–c. *Etheripecten? hayasakai* (MURATA). ....p. 72
Internal mold of bivalved individual, left, right, and dorsal views, ×1, Kanokura Formation (Shigejizawa Member), Kamiyasse, Miyagi Prefecture, northeast Japan.

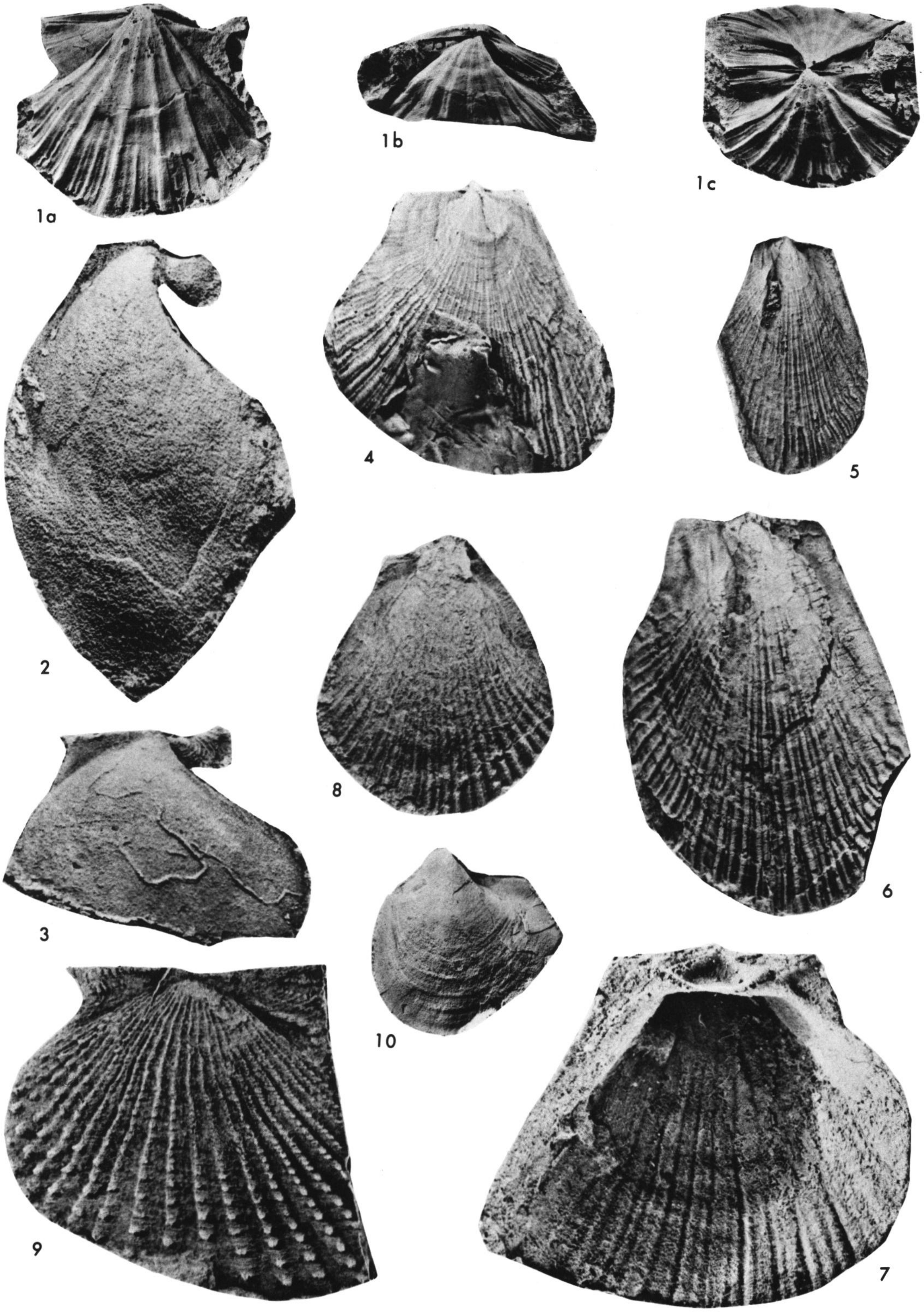
Figs. 2,3. *Streblopteria* sp. *a*. ....p. 78
Right valves from Kanokura Formation (Shigejizawa Member), Kamiyasse. 2, Internal mold, considerably stretched dorsoventrally by rock flowage, ×3; 3, latex cast of another specimen that probably illustrates better the original form, ×4.

Figs. 4–7. *Leptochondria*? sp. *a*. ....p. 73
Latex casts of left valves from Gujo Formation at Gujo, Kyoto Prefecture, west Japan. 4, magnified, ×4; 5, ×3; 6, ×5; 7, interor, ×5, displaying poorly preserved hinge.

Fig. 8. *Leptochondria*? sp. *b*. ....p. 74
Latex cast of left valve, ×5. Gujo Formation at Gujo.

Fig. 9. *Guizhoupecten* sp. ....p. 77
Latex cast of deformed right valve, ×3, from the Upper Maizuru Group at Mikata-cho, Hyogo Prefecture, west Japan.

Fig. 10. *Streblopteria*? sp. *b*. ....p. 79
Internal mold of left valve, ×1, from Kanokura Formation (Shigejizawa Member) at Kamiyasse.



NAKAZAWA and NEWELL; Permian Bivalves

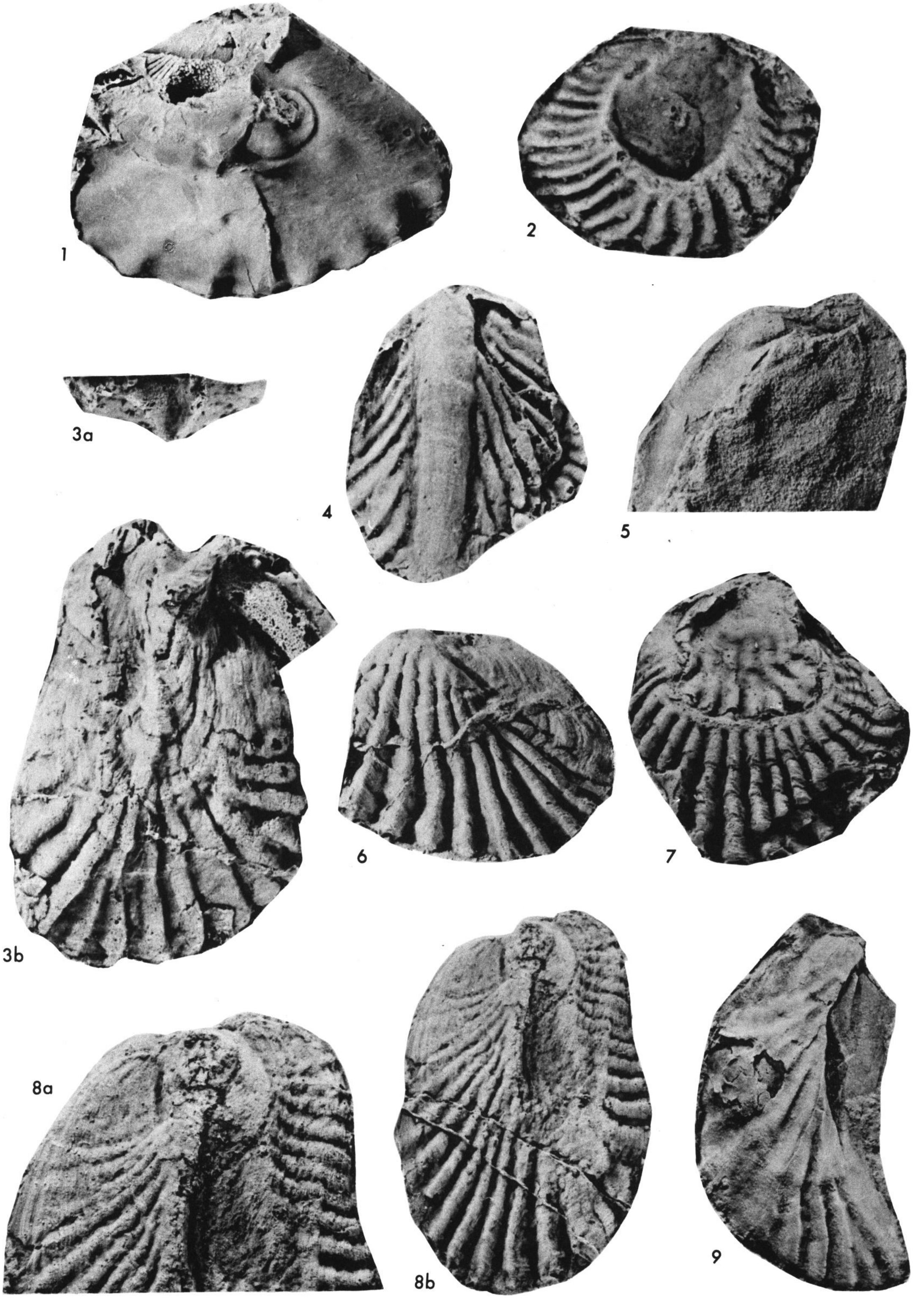
Explanation of Plate 7

Figs. 1–4. *Lopha? murakamii* NAKAZAWA and NEWELL, n. sp. ....p. 82
Gujo Formation, Gujo, Kyoto Prefecture. 1, Natural composite mold of the interior of left (attached) valve, ×3; 2, latex cast of left (attached) valve, ×4; 3a, b, latex cast of left (attached) valve; 4, latex cast of right? valve corresponding to opposite valve which adhered to a cylindrical object of unknown affinities, ×3.

Fig. 5. *Lopha? teranosawensis* NAKAZAWA and NEWELL, n. sp. ....p. 83
Natural mold of hinge area showing outline of a triangular resilifer, right? valve, ×5. Tenjinnoki Formation, Teranosawa, Miyagi Prefecture, northeast Japan.

Figs. 6–8a, b. *Lopha? murakamii* NAKAZAWA and NEWELL, n. sp. ....p. 82
Gujo Formation, Gujo, latex casts. 6, Right (free)? valve, ×2; 7, left (attached) valve, ×3; 8a, b, left (attached)? valve, the holotype, ×3, ×2.

Fig. 9. *Lopha? teranosawensis* NAKAZAWA and NEWELL, n. sp. ....p. 83
Natural internal mold of left? valve, the holotype, ×2, Tenjinnoki Formation, Teranosawa.

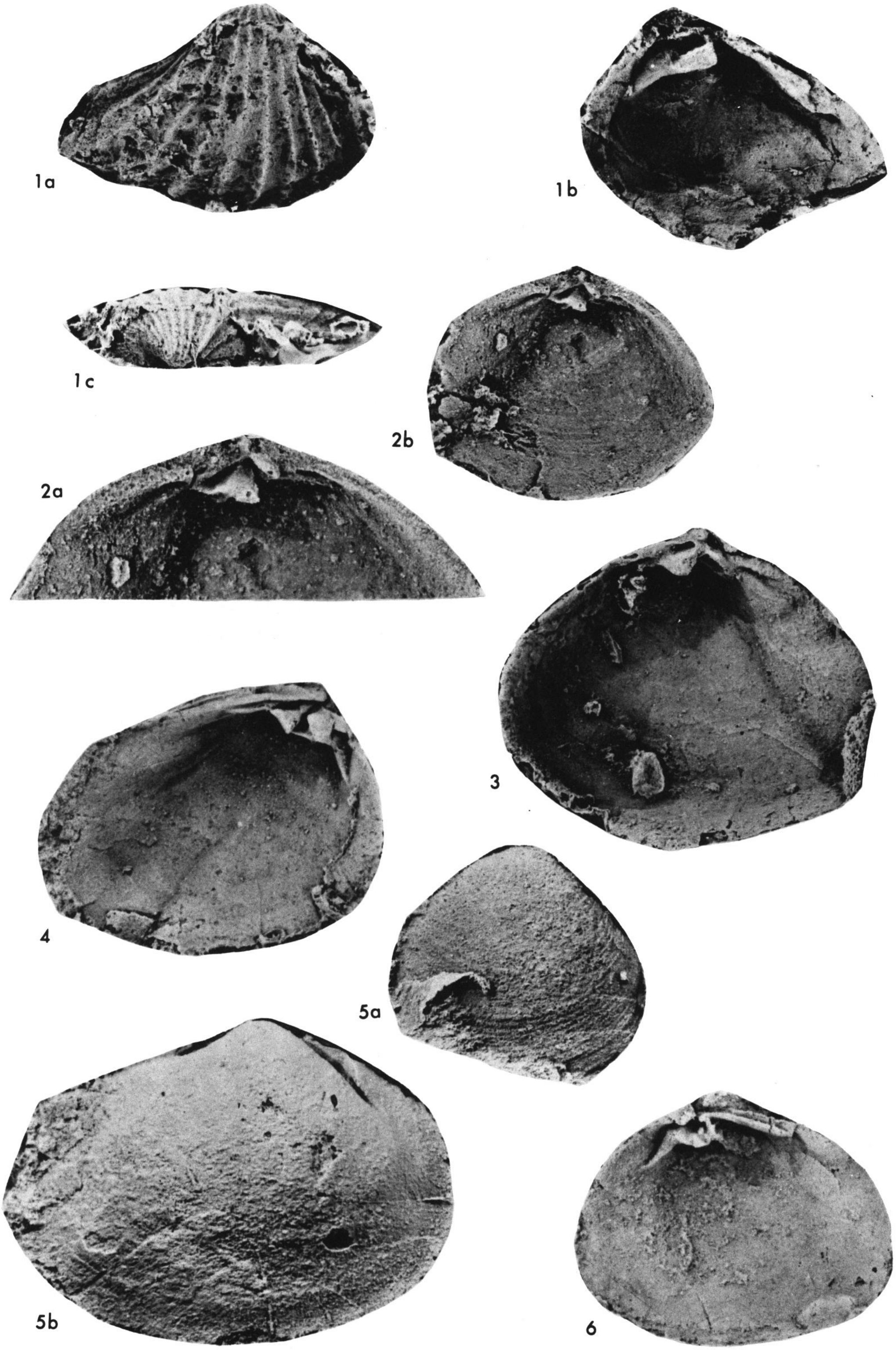

1
2
3a
4
5
3b
6
7
8a
8b
9

Explanation of Plate 8

Figs. 1a–c. *Costatoria katsurensis* NAKAZAWA. ....p. 88
Latex casts of right valve, ×3, Katsura Formation, upper Permian, Shikoku, Japan. 1a, Exterior, side view; 1b, interior; 1c, dorsal view.

Figs. 2a, b, 3. *Schizodus tobai* (HAYASAKA). ....p. 89
Interior views of latex casts, Kanokura Formation (Shigejizawa Member) at Kamiyasse, Kessennuma City, northeast Japan. 2a, Hinge view of left valve, ×5; 2b, same, ×3; 3, internal view of right valve, ×3.

Figs. 4–6. *Neoschizodus* (*Neoschizodus*) *kitakamiensis* NAKAZAWA and NEWELL, n. sp. ....p. 87
Tenjinnoki Formation, Teranosawa, Miyagi Prefcture, norhteast Japan. 4, Left valve, interior, ×3; 5a, exterior view, latex cast of the holotype, right valve; 5b, internal valve of the same, ×4: 6, internal view of latex cast of right valve, ×3.

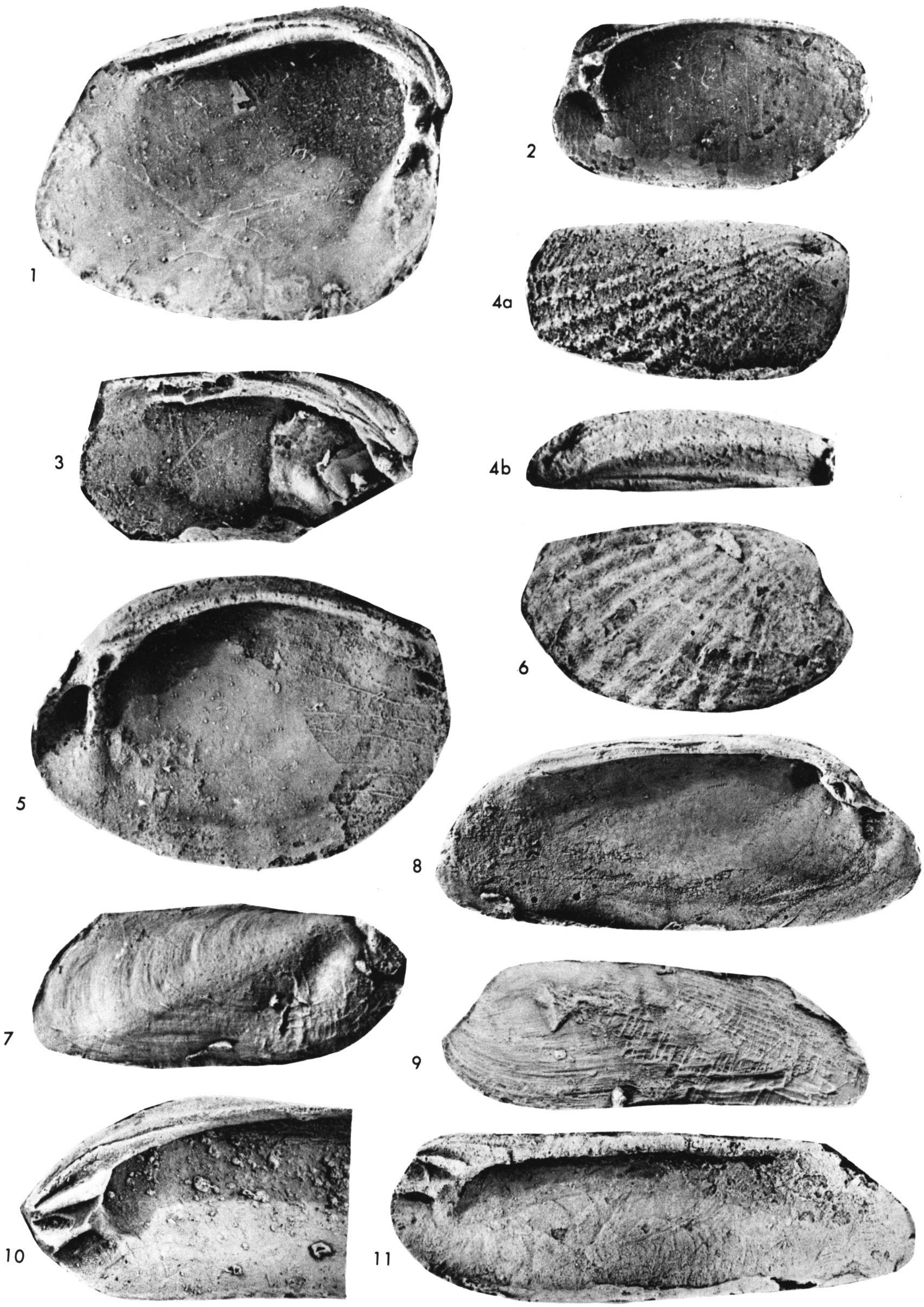

1a
1b
1c
2a
2b
3
4
5a
5b
6

Explanation of Plate 9

Figs. 1–6. *Gujocardita oviformis* NAKAZAWA and NEWELL, n. gen. and n. sp. ....p. 91
Latex casts, Gujo Formation, at Gujo, Oe-cho, Kyoto Prefecture. 1. The holotype, left valve, $\times 5$; 2, right valve, $\times 5$; 3, hinge of left valve, $\times 5$; 4a, b, exterior of right valve, $\times 4$; 5, interior of right valve, $\times 5$; 6, exterior of right valve, $\times 5$.

Figs. 7–9. *Permophorus tenuistriatus* NAKAZAWA and NEWELL, n. sp. ....p. 92
Latex casts, Gujo Formation, Gujo. 7, external view of right valve, $\times 3$; 8, internal view of left valve, $\times 2$; 9, external view of the same, $\times 1.8$.

Figs. 10, 11. *Pseudopermophorus uedai* NAKAZAWA and NEWELL, n. sp. ....p. 94
Latex casts, right valves, $\times 2$, Toyoma Formation, Toyoma-cho, Miyagi Prefecture, northeast Japan. The specimen of Figure 10 is badly deformed by rock flowage.



NAKAZAWA and NEWELL; Permian Bivalves

Explanation of Plate 10

Fig. 1. *Netschajewia* sp. ....p. 96
Latex cast of right valve, ×3, Tenjunnoki Formation, Tenjinnoki, Miyagi Prefecture, northeast Japan.

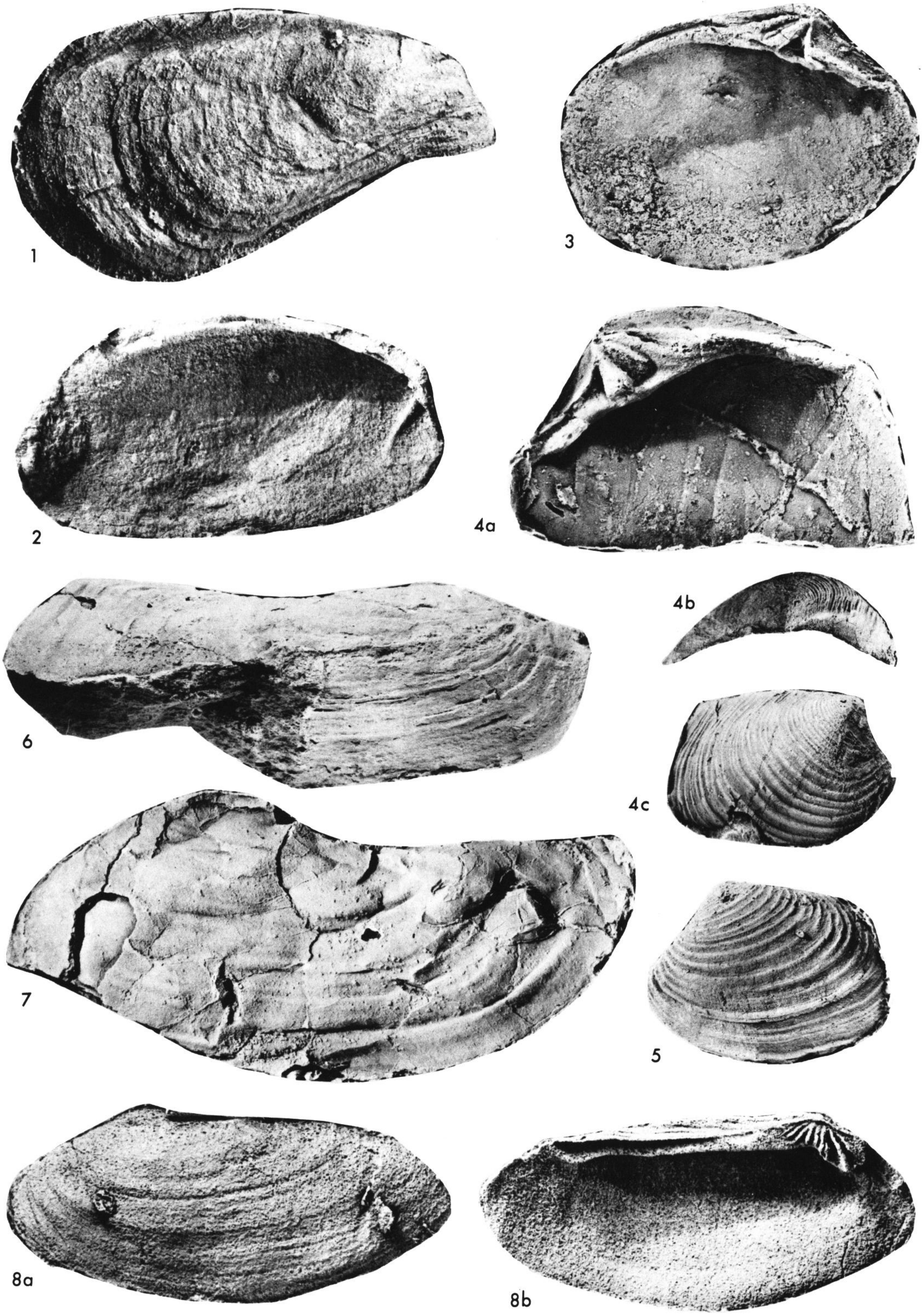
Fig. 2. *Stutchburia*? sp. ....p. 96
Latex cast of left valve, ×4, Tenjinnoki Formation, Tenjinnoki.

Figs. 3–5. *Astartella toyomensis* NAKAZAWA and NEWELL, n. sp. ....p. 98
Toyoma Formation, Kitazawa, Miyagi Prefecture, all latex casts. 3, The holotype, left valve, ×2; 4a–c, right valve, ×3, ×2, ×2, respectively; 5, left valve, ×2.

Fig. 6. *Wilkingia* sp. ....p. 44
Composite mold of right valve, ×1, lower (?) Kanokura Formation, Imo, Iwate Prefecture.

Fig. 7. *Chaenomya* (*Vacunella*) *rostrata* NAKAZAWA and NEWELL, n. sp. ....p. 102
Composite mold of left valve, ×2, Gujo Formation, Gujo, Kyoto Prefecture, west Japan.

Figs. 8a, b. *Actinodontophora katsurensis* ICHIKAWA. ....p. 97
Latex casts of left valve, ×1.5, Kanokura Formation, Nabekoshi-yama, near Kesennuma City, northeast Japan.



NAKAZAWA and NEWELL; Permian Bivalves

Explanation of Plate 11

Fig. 1, 2. *Euchondria* sp. .... p. 80
Mizukoshi Formation, Kamiumegi, Mifune-cho, Kumamoto Prefecture, Kyushu. 1a, b, Internal mold of left valve, ×2, ×5; 2, external latex cast of the same, ×2.

Figs. 3, 4. *Sanguinolites kamiyassensis* NAKAZAWA and NEWELL, n. sp. .... p. 42
Kanokura Formation (Shigejizawa Member), Kamiyasse, Kesnnuma City, Miyagi Prefecture, northeast Japan. 3, The holotype, left valve, internal mold, ×1.5; 4, latex cast of the same, ×1.

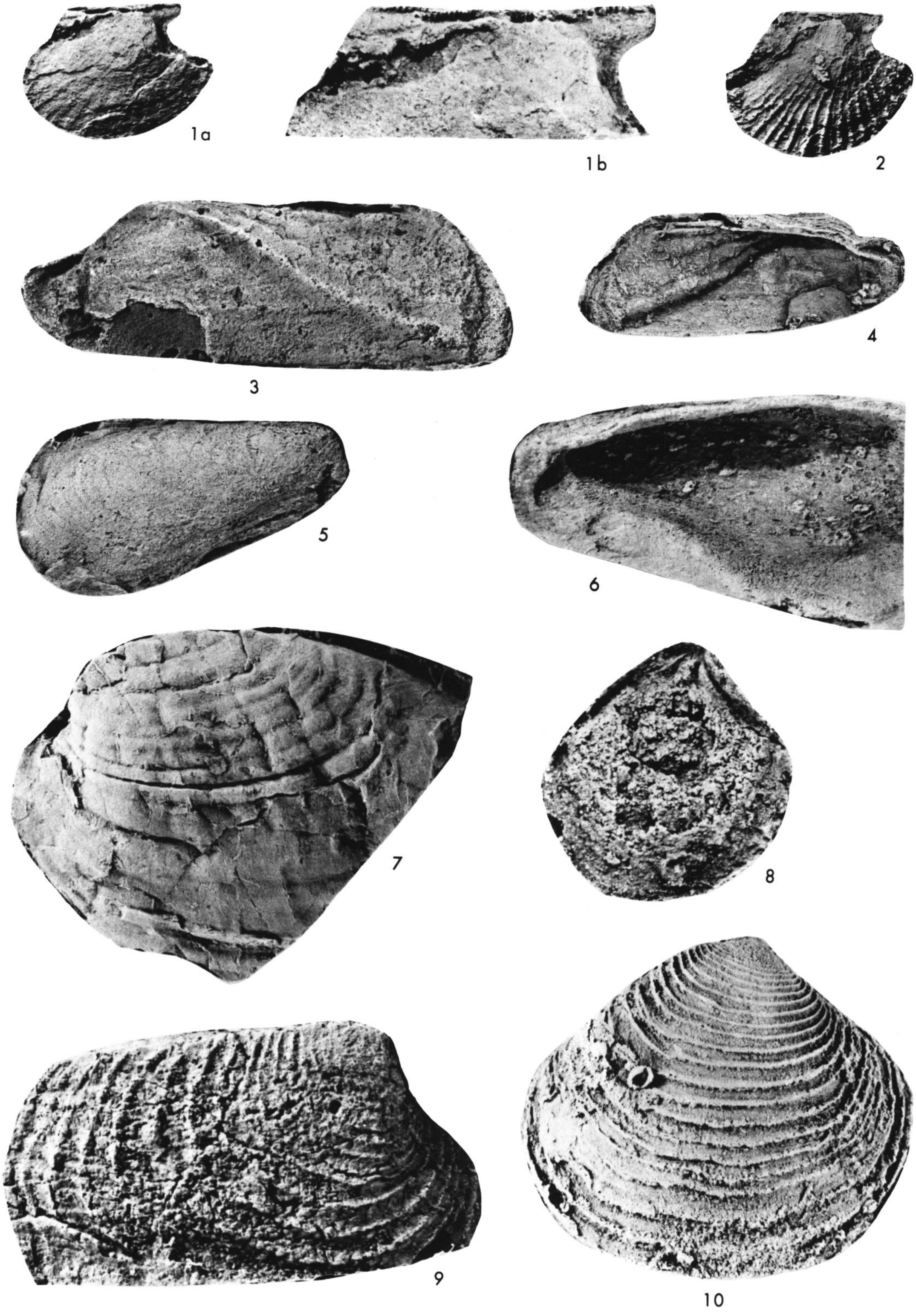
Figs. 5, 6. *Netshajewia* cf. *elongata* (NETSCHAJEW). .... p. 95
Toyoma Formation, Nagahata, Towa-cho, Miyagi Prefecture. 5, Right valve, latex cast, ×2; 6, internal latex cast of the same, ×3.

Fig. 7. *Edmondia* sp. *b*. .... p. 40
Left valve, internal mold, ×2, Gujo Formation, Gujo, Oe-cho, Kyoto Prefecture, west Japan.

Fig. 8. *Astartella* sp. *c*. .... p. 101
Right valve, internal mold, ×5, Upper Maizuru Group, Katsuradani, Oe-cho, Kyoto Prefecture.

Fig. 9. *Astartella* sp. *b*. .... p. 100
Right valve, Latex cast ×3, Mizukoshi Formation, Kamiumegi.

Fig. 10. *Astartella*? sp. *d*. .... p. 101
Right valve, latex cast, ×3, Kanokura Formation, Kamiyasse.



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