Lower Cretaceous Marine Pelecypods of Japan Part I

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Lower Cretaceous Marine Pelecypods of Japan

Part I

By

Itaru HAYAMI

Abstract

This is a serial comprehensive study on the Lower Cretaceous pelecypods of Japan, except for the trigoniids, the pachyodonts and the brackish- and fresh-water species. In the present part 68 species of the Palaeotaxodontida, the Eutaxodontida, the Isofilibranchida, the Pteroconchida and the Colloconchida are described systematically on the basis of the well preserved specimens as plentifully as possible which have been collected from many sedimentary areas by a number of straitigraphers and palaeontologists, including myself. A new subfamily (Pterinellinae), three new subgenera (*Hanaia*, *Neithella* and *Aequineithea*) and 23 new species are proposed. A classification of the genus *Neithea* is also presented.

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The forthcoming Part II of this study will include the description of the Lower Cretaceous marine pelecypods belonging to the Subclass Heteroconchia, the conclusion on the fauna, the locality guide and the bibliography.

1. Introduction

Lower Cretaceous marine deposits are distributed in the Outer Zone of Southwest Japan as a chain of many sedimentary basins and also occur in several limited areas of Northeast Japan. Since the end of the last century Lower Cretaceous stratigraphy and palaeontology have been investigated by a number of workers, but owing to the complicated geologic structure and the

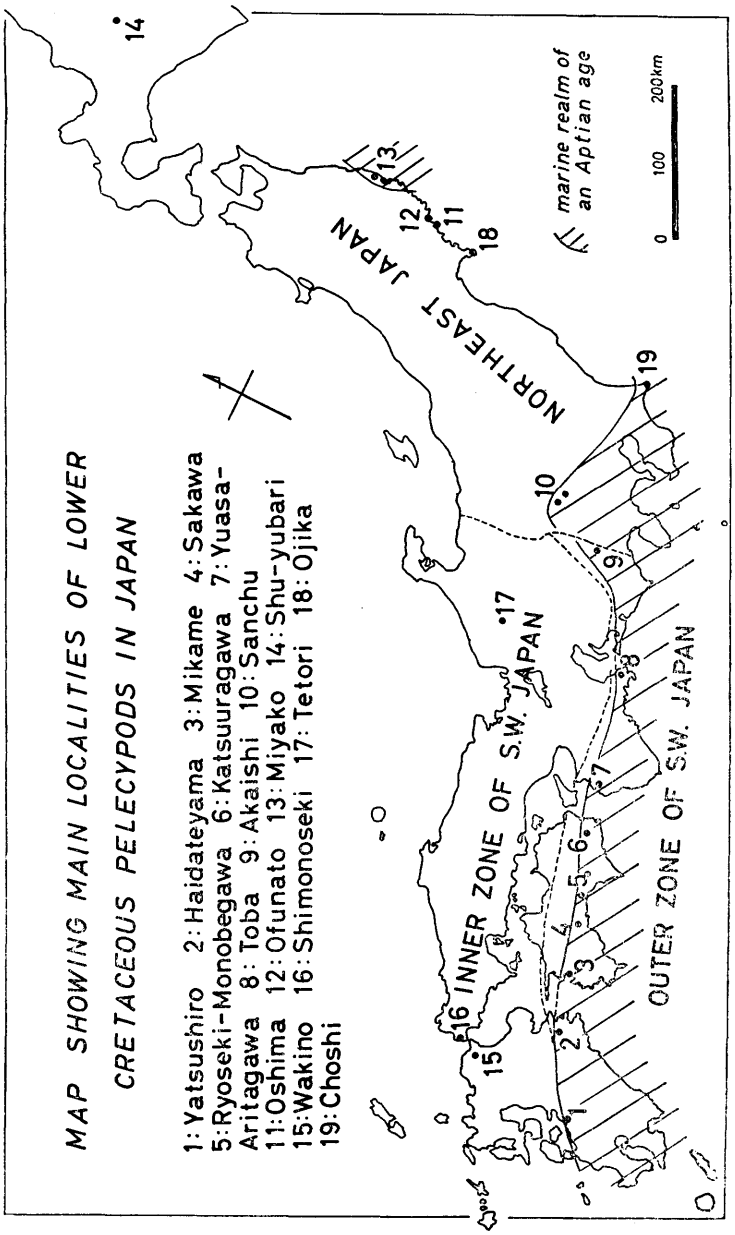

Fig. 1. Index map

rarity of well preserved index fossils our knowledge of these subjects still remains very insufficient in comparison with that of the precisely studied Upper Cretaceous sediments and faunas. Notwithstanding the fact that the Lower Cretaceous was an important epoch in the geologic history of the Japanese islands, no reliable zonation has been established except for its uppermost part.

As shown in Fig. 1, pelecypods are, however, very common in the various outcropping areas of the Lower Cretaceous, namely the Yatsushiro, Haidate-yama, Sakawa, Ryoseki-Monobegawa, Katsuuragawa, Yuasa-Aritagawa areas and some other parts of the Outer Zone of Southwest Japan, and the Sanchu, Choshi, Oshima, Ofunato and Miyako areas of Northeast Japan, offering important data relating to historical geology and biostratigraphy as well as to pure palaeontology. The Lower Cretaceous seems on the whole to be an interesting epoch also for the study of pelecypod evolution. Although abrupt changes affecting generic or higher taxa are scarcely known, many older groups became extinct, while the obvious direct ancestors of Cenozoic and Recent pelecypods are often found first in the rocks of this epoch.

It was 1890 that YOKOYAMA first reported some Lower Cretaceous marine pelecypods from "Kagahara", in the Sanchu area*. In the same year NEUMAYR (in NAUMANN and NEUMAYR, 1890) described *"Cyrena" naumanni* and some other fossils from the Ryoseki group of Shikoku. Since then, the Lower Cretaceous pelecypods have been investigated by many authors. Marine faunas were monographed by YABE, NAGAO and SHIMIZU (1926) from the Sanchu area and by NAGAO (1934) from the Miyako area. The two monographs contain the detailed descriptions of more than 60 Lower Cretaceous pelecypods, and have been a good foundation for subsequent investigations. The abundant Lower Cretaceous trigoniids were described by YOKOYAMA (1891) and YEHARA (1915, 1921, 1923, 1926). Pachyodont pelecypods were reported by YEHARA (1920), YABE and NAGAO (1926a) and NAGAO (1932) from the Miyako area of Kitakami and the Sorachi area of Hokkaido, and recently also by OKUBO and MATSUSHIMA (1959) from the Akaishi area. Cretaceous as well as Cenozoic species of *Pholadomya* were surveyed by NAGAO (1943). The genus *Teredo* was reported by HATAI (1951) from Miyako. Besides these studies, Lower Cretaceous brackish- and fresh-water pelecypods, including *Trigonioides, Plicatounio, Nippononaia* and many interesting genera and species, were investigated by YABE, NAGAO and SHIMIZU (1926), KOBAYASHI and SUZUKI (1936, 1939) and SUZUKI (1941, 1949).

Recent progress has been achieved in the classification of the Trigoniidae and non-marine pelecypods. COX (1952b) and KOBAYASHI (1954) suggested the taxonomic positions of previously known trigoniids in terms of up-to-date taxonomy, and the detailed descriptions of many species were undertaken by KOBAYASHI (1957), KOBAYASHI and NAKANO (1957, 1958), NAKANO (1957, 1958) and MAEDA (1963a). Summarizing the stratigraphic occurrences of the Cretaceous species of the Trigoniidae, NAKANO (1960) discussed their evolution and

* The revision of this fauna has recently been made by MATSUMOTO, HAYAMI and ASANO (in MATSUMOTO, 1963, ed.)

geographic distribution. Lower Cretaceous fresh-water pelecypods, occurrence of which is almost restricted to the Inner Zone of Southwest Japan, were studied by OTA (1959a, b, c, 1960, 1963), HASE (1960) and MAEDA (1959, 1963). These special studies are still in progress.

On the other hand, little revisory work has been done on other marine pelecypods. MATSUMOTO and KANMERA (1952) and MATSUMOTO (1954, ed.) surveyed the pelecypod faunas of the Yatsushiro area of Kyushu, publishing emended lists. They gave new generic and specific identifications to some specimens, but the material remains undescribed except for some trigoniids dealt with by KOBAYASHI and NAKANO (1958). AMANO (1957a) described about 20 marine pelecypods from the Hagino formation of Shikoku, and suggested that their age was Apto-Albian. Berriasian marine pelecypods were described by TAMURA (1959, 1960a, b, c) from the Koyamada formation of the Soma group of Abukuma and by HAYAMI, SUGITA and NAGUMO (1960) from the Isokusa and Nagasaki outcrops of the Shishiori group of Kitakami, together with Upper Jurassic species. As readily recognized from the specific assemblages, these Berriasian faunas are more closely related to the Upper Jurassic ones than to the Lower Cretaceous ones here discussed.

I highly appreciate the above-mentioned preceding works, but the systematic and stratigraphic positions of most species should be further examined from the up-to-date taxonomic and stratigraphic points of view. Since the purpose of most previous works was to describe local faunas and in some cases to apply the result to the biostratigraphy of each sedimentary area, there has been much room for further investigations regarding the identifications, typology, variation, synonymy of the various species and the mutual relationship of the faunas of different areas. Moreover, there were a number of undescribed genera and species (nom. nud.) in the Lower Cretaceous marine beds of Japan.

At the suggestion of Prof. Emeritus T. KOBAYASHI of the University of Tokyo and Prof. T. MATSUMOTO of the Kyushu University, I have undertaken a monographic work on the Lower Cretaceous marine pelecypods. The purpose of this study is to describe these fossils systematically on the basis of the well-preserved material which it has been possible to collect from all the areas of distribution in Japan, and also to contribute to the general classification of pelecypods and knowledge of their evolution, as well as to palaeobiogeography and biostratigraphy. As to their application to biostratigraphy, much further works should be undertaken in cooperation with stratigraphers and ammonite palaeontologists. The life range of each pelecypod species is provisionally shown in this paper, although it should be further checked by careful collecting and by the correct identification of associated ammonites and other index fossils.

Three subdivisions are generally accepted in the Lower Cretaceous of Japan. They are the Kochian (Ryoseki), Aritan (Oshima) and Miyakoan series in ascending order, and may roughly correspond respectively to the Berriasian-Valanginian, Hauterivian-Barremian and Aptian-Albian of the European standard. The detailed palaeontological study of the Kochian pelecypods, which

are mostly brackish-water species, is now being undertaken by Dr. Y. OTA, so that they are not considered in the present study. The characteristic Lower Cretaceous trigoniids and pachydonts have been investigated by Dr. M. NAKANO and some others, but may need further studies.

Except for some non-marine faunas of undermined ages discovered in the upper Tetori and Wakino subgroups, known occurrences of pelecypods in the Aritan and Miyakoan subdivisions are restricted to the Outer Zone of Southwest Japan and to some areas of Northeast Japan. The uppermost part of the Miyakoan, which is sometimes called the Infra-Gyliakian, and is correlated with the Lower Lower Cenomanian (see MATSUMOTO, 1954, p. 63), contains many pelecypods in various areas of Hokkaido and Kyushu. Their detailed study is, however, reserved for further research, since the species of this part seem to be more closely related to those of the fauna of the Gyliakian (main part of Cenomanian and Turonian) than of the Miyakoan proper. The present palaeontological work is, therefore, restricted to the Aritan and the Miyakoan (proper) marine pelecypods of Japan.

2. Acknowledgements

This study was commenced in 1961 in the Geological Institute, University of Tokyo, under the direction of Prof. Emeritus Teiichi KOBAYASHI, and has been continued in the Department of Geology, Kyushu University, under the guidance of Prof. Tatsuro MATSUMOTO. Prof. MATSUMOTO critically read the typescript of this paper. It is a great pleasure to record here my sincere gratitude to these two authorities for their invaluable advice and encouragement. I am especially indebted to Dr. Leslie R. COX of the British Museum (Natural History) for his kind advice and critical reading of this manuscript and to Dr. Koichiro ICHIKAWA of the Osaka City University for his kind and instructive information about pelecypod palaeontology. The fossil material, on which this study is based, was collected by many geologists and palaeontologists during their field surveys. I desire to express my sincere thanks to Dr. Kametoshi KANMERA of the Kyushu University and to Dr. Tetsuro HANAI of the University of Tokyo, who have kindly put their collections at my disposal and have given me instructive information about stratigraphy and other subjects. Acknowledgement is also due to Prof. Toshio KIMURA, Dr. Takashi HAMADA, Dr. Akira TOKUYAMA, Mr. Munemitsu SUGITA and Mr. Takeo ICHIKAWA of the University of Tokyo, Dr. Mitsuo NAKANO of the Hiroshima University, Dr. Masahisa AMANO and Dr. Minoru TAMURA of the Kumamoto University, Prof. Kozo NAGAI of the Ehime University, Dr. Ikuwo OBATA of the Tokyo Science Museum, Dr. Koji FUJII of the Onoda Cement Co., Mr. Makoto OGAWA of the Japan Grout Co., Mr. Takeshi AKATSU of the Yahata Chemistry Co. and the late Mr. Teruyuki AKIYAMA of the Kesennuma High School for the privilege of describing their collections and for field assistance. My sincere thanks are extended to Prof. Ryuzo TORIYAMA, Dr. Tsugio SHUTO and

Dr. Hakuyu OKADA of the Kyushu University and Prof. Yoshihisa OTA of the Fukuoka Gakugei University for their kind help in various ways. Miss Tomoko MIYAZAKI kindly assisted me in preparing the typescript. Thanks are also due to Prof. Fuyuji TAKAI of the University of Tokyo, Prof. Kiyoshi ASANO and Prof. Kotora HATAI of the Tohoku University and Prof. Masao MINATO of the Hokkaido University for permission to examine the collections in those universities. Financial support was given by the Ministry of Education of Japan, the Japan Society for the promotion of Science, the Palaeontological Society of Japan and the Geological Society of Japan.

3. Materials*

The present study is chiefly based on the following collections, which were examined by permission of the curators of a number of institutes or were put at my disposal by the courtesy of various collectors.

1) The collection from the Ishido and Kawarazawa formations of the Sanchu area described by YABE, NAGAO and SHIMIZU (1926). This is now kept in the Institute of Geology and Palaeontology, Tohoku University, and is indicated in this paper by the abbreviation IGPS.

2) The collection from the Miyako group of Iwate Prefecture described by YEHARA (1915), YABE and NAGAO (1926) and NAGAO (1934). It is now partly kept in the Institute of Geology and Palaeontology, Tohoku University, and is indicated by the abbreviation IGPS.

3) The collection from the Miyako group of Iwate Prefecture described by NAGAO (1934, 1943). It is partly kept in the Geological and Mineralogical Institute, Hokkaido University, and is indicated by the abbreviation GH.

4) The collection from the Hagino formation of Kochi Prefecture descibed by AMANO (1957a). It is now kept in the Geological Institute, University of Tokyo, and is indicated by the abbreviation GT.

5) The collection made by MATSUMOTO, KANMERA and FUJII from the Hachiryuzan, Hinagu and Yatsushiro formations of Kumamoto Prefecture, which was listed by MATSUMOTO and KANMERA (1952) and MATSUMOTO (1954, ed.) but remain undescribed. This and the under-mentioned collections are preserved in the Department of Geology, Kyushu University. This repository is indicated by the symbol GK.

6) The collection made by FUJII and KANMERA from the Haidateyama formation in Oita Prefecture, which was listed by MATSUMOTO (1954, ed.).

7) The collection made by AKATSU from the Yatsushiro formation in Kumamoto Prefecture, when he was a student of Kyushu University.

8) The collection made by MATSUMOTO and others from the Arita, Nishihiro and Izeki formations in Wakayama Prefecture.

9) The collection made by AMANO from the Yatsushiro formation in

* Precise information about the localities of the present material will be given in the forthcoming Part II.

Kumamoto Prefecture.

10) The collection made by OGAWA from the Hagino formation in Kochi Prefecture, when he was a student of Kyushu University.

11) The collection made by HANAI and some others from the Miyako group of Iwate Prefecture. The collection is especially important on account of the good preservation of the fossils.

12) The collection made by AKIYAMA from the Oshima formation of Iwate Prefecture.

13) The collections made by NAKANO and OBATA independently from the Miyako group of Iwate Prefecture.

14) The collection made by HANAI from the Choshi formation of Chiba Prefecture.

15) The collection made by ICHIKAWA and SUGITA from the Ishido and Sebayashi formations of the Sanchu area in Nagano and Gumma Prefectures.

16) The collection made by NAGAI and NAKANO from the Nigyu formation of Ehime Prefecture.

17) The collections made by HAMADA and NAKAI independently from the Hanoura and Hoji formations of Tokushima Prefecture.

These collections were further amplified by myself from the Hinagu, Yatsushiro, Haidateyama, Miyako, Oshima and Ofunato formations in 1961, from the Ishido, Sebayashi, Miyako, Hanoura, Arita, Hagino and Choshi formations in 1962, and from the Ishido, Hanoura and Hoji formations in 1963.

4. Systematic Descriptions

Order Palaeotaxodontida
Superfamily Nuculacea
Family Malletiidae
Genus *Mesosaccella* CHAVAN, 1947

Type-species.—*Nucula forsteri* MÜLLER, 1847, Upper Cretaceous, Europe (original designation).

Mesosaccella insignis (NAGAO)
Plate 27, Figure 1

1934. *Nuculana insignis* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 189, pl. 29, figs. 10–12.

Material.—The holotype is a left valve illustrated by NAGAO (1934, pl. 29, fig. 10). It was collected from the Aketo formation at the northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture. It is said that the specimen (GH. no. 6773 or 6853) is kept in the Hokkaido University, but I have not yet been able to find NAGAO's illustrated specimens in the university. Two specimens (GK. H6193, GK. H6194) in the material studied (HAYAMI coll.), on which the following description is based, are undoubtedly identical with

the holotype of *N. insignis*.

Description.—Shell very small, not exceeding 8 mm., elongated, *Saccella*-like in outline, tapering gradually to the posterior end, pointed at the extremity; test moderately thick, translucent; antero-dorsal margin smoothly arcuate, while postero-dorsal margin is concave; ventral margin broadly arcuate; umbo not prominent, placed a little posteriorly from mid-point of length; escutcheon not clearly defined but distinctly excavated; surface marked with 20 or more regular subconcentric grooves which are much narrower than their flat interspaces and become somewhat weaker on anterior and posterior peripheral parts; two or three grooves cut obliquely by postero-ventral margin; internal characters unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK.H6193)	6.5	3.5	2.0	1.86
Left valve (GK.H6194)	6.0	3.0	1.5	2.00

Observations and comparisons.—The characteristic ornamentation is clearly observable in the present specimens. Although the internal structure is not revealed in NAGAO's figures and the present specimens, all of them must be conspecific with the holotype of *N. insignis* NAGAO, 1934, in view of the *Saccella*-like outline and characteristic subconcentric grooves.

Typical species of *Nuculana* LINK, 1807 (type-species: *Arca rostrata* BRUGUIÈRE), are characterized by the elongated posterior rostrum, which is truncated subvertically at its extremity. As shown by the holotype, the outline, with the posterior end not rostrate, suggests this is in any case not a member of *Nuculana*. Since the hinge and ligament structure are as yet unknown, it cannot be readily determined to which of the families Nuculanidae or Malletiidae (or Ctenodontidae) this belongs.

The outline agrees with that of some species of *Neilonella* and *Mesosaccella* of the Malletiidae as well as of *Saccella* WOODRING, 1925, of the Nuculanidae. But, as pointed out by NAGAO (1934) and ICHIKAWA and MAEDA (1958a, p. 81), this species seems to be closely related to *"Nuculana" lineata* (SOWERBY, 1836) in WOODS (1899), from the Lower Greensand of England, which has numerous taxodont teeth of ctenodont-type in an uninterrupted row, and the two species are considered to be congeneric. The generic position of *"N." lineata* has not been sufficiently studied, but COX (1940, p. 5) noted that *Palaeoneilo* of the Ctenodontidae is continued into the Cretaceous by such species as *"N." lineata*. Two Jurassic species, *Nucula phillipsi* MORRIS, 1850, and *N. galatea* D'ORBIGNY, 1850, were referred to *Palaeoneilo* by COX (1937), and subsequently two species from Cutch Jurassic were added to the genus (COX, 1940). *Palaeoneilo* is thus considered to have survived from the Silurian to the Jurassic or later.

On the other hand, several genera which may have been derived from the Ctenodontidae persist in the Cenozoic and in the bathyal regions of Recent seas, constituting the family Malletiidae. The latter family possesses porcellaneous shells, while the Palaeozoic species of *Palaeoneilo* are said to have

more primitive nacreous shells like the Nuculidae.

As seen in the holotype, this species is characterized by the pointed posterior extremity, excavated post-umbonal margin and peculiar subconcentric striae which are cut more or less obliquely by growth-lines and much weakened in the posterior area. In these characters it seems more closely allied to *Neilonella* DALL, 1881 (type-species: *Leda (Neilonella) corpulenta* DALL, 1881) and *Mesosaccella* than to *Palaeoneilo*. Such oblique striae are also known in many species of *Lembulus* LEACH in RISSO, 1826, *Portlandia* MÖRCH, 1857, *Cnesterium* DALL, 1898, and *Hilgadia* HARRIS *in* HARRIS and PALMER, 1946, of the Nuculanidae, but the outline suggests that this species is unrelated to those genera.

The pallial line is distinctly sinuated in Recent *Neilonella*, whereas it is said to be simple in *Palaeoneilo*. Therefore, the shell structure and nature of the pallial line, which are scarcely known in Cretaceous species, are probably important for determining their generic and family positions.

Although there is the possibility of further study of the phyletic relationship between *Palaeoneilo* and *Mesosaccella* and between *Mesosaccella* and *Neilonella*, I provisionally adopt *Mesosaccella* as the generic name of *insignis*, since typical *Palaeoneilo* and *Neilonella* have been scarcely known in the Cretaceous.

AMANO (1957) regarded a Late Cretaceous species with oblique striae as a member of *Neilonella* on the basis of its uninerrupted denticles and the absence of a chondrophore. The present species is clearly different from AMANO's in view of its much smaller dimensions, stronger convexity, transversely elongated and *Saccella*-like outline, and regular subconcentric striae. *Leda angulatostriata* SOKOLOV and BODYLEVSKY, 1931, from the lower Aptian of Spitzbergen has also similar oblique striae, but the umbo is placed more posteriorly in this species.

The outline and ornamentation agree to a great extent with those of *"Nuculana" mariae* (D'ORBIGNY, 1846) from the Gault of England (WOODS, 1899) as well as of *"N." lineata*. However, the ratio of length/height is slightly larger, and the umbo is placed more posteriorly than in the two English species. *Mesosaccella perdita* (CONRAD, 1852) from the Campanian of France (CHAVAN, 1947b) and Cameroun (DARTEVELLE and FRENEIX, 1957) resembles this species in many respects, especially the excavated post-umbonal margin and pointed posterior extremity. In the position of its umbo the Campanian species is still more similar to *"N." mariae* and *lineata* than *M. insignis*. *Nuculana amuriensis* WOODS, 1907, from the Senonian of New Zealand may be also congeneric with this species, but its dimensions seem much larger.

Occurrence.—Lower and upper Miyakoan (Aptian and Albian). Calcareous sandstone belonging to the second cycle of the Miyako group at loc. Hn. 4053, Oshima island and at loc. Hn. 4101, Tairajima island, off the coast of Moshi, Iwaizumi town, Shimohei County, Iwate Prefecture. NAGAO (1934) originaly described this species from the Aketo formation at the northeast of Raga and from the "Hiraiga sandstone" at Moshi.

Mesosaccella sp. indet.
Plate 27, Figure 2

This is represented by an internal mould of a right valve (KANMERA coll.). Shell small, apparently subequilateral, elongate-elliptical, moderately inflated, much longer than high (GK.H 6195, 11 mm. long, 5.5 mm. high, 2.0 mm. thick); antero-dorsal margin nearly straight, postero-dorsal margin slightly concave; apical angle about 140 degrees; anterior and posterior margins rounded; ventral margin nearly straight and horizontal in middle part; umbo broad, incurved, placed near mid-point of length; denticles fairly strong, arranged in an uninterrupted row, about 22 or slightly more in number, about 12 being placed in front of umbo; chondrophore apparently absent; external characters and musculature unknown.

This resembles *Mesosaccella insignis* (NAGAO, 1934) from the Miyako group and its allied species from the European Cretaceous, but the posterior end is more rounded and the dimensions are somewhat larger. This is probably a new species, but its specific determination is deferred until its external characters are known.

Occurrence.—Upper Miyakoan (Albian). Dark grey sandy shale of the Yatsushiro formation at loc. Km. 3096, southwest of Kohara, Tôyô village, Yatsushiro County, Kumamoto Prefecture.

Genus *Malletia* DESMOULINS, 1832

Type-species.—*Malletia chiliensis* DESMOULINS; Recent (monotypy).

Subgenus *Neilo* A. ADAMS, 1854

Type-species.—*Neilo cummingii* A. ADAMS, 1854, Recent (monotypy).

Malletia (*Neilo?*) *higoensis* sp. nov.
Plate 27, Figures 3–5

Material.—The holotype is a left internal mould (GK.H 6196) illustrated in pl. 1, fig. 5 of this paper. It was collected from the Yatsushiro formation at loc. Km. 3096, southwest of Kohara, Tôyô village, Yatsushiro County, Kumamoto Prefecture (KANMERA coll.). Paratypes (GK.H 6197, GH.H 6377) from the type-locality (KANMERA coll.).

Description.—Shell small for genus, inequilateral, semicircular, well inflated, much longer than high; test thin; antero-dorsal margin nearly straight; postero-dorsal margin faintly concave, much longer than antero-dorsal; apical angle almost 180 degrees; ventral margin broadly arcuate; umbo comparatively narrow, risng a little above dorsal margin, and placed at about two-fifths of length from front; a conspicuous angular carina extends from umbo to postero-ventral region, defining an elongate-triangular postero-dorsal slope; surface smooth except for numerous concentric growth-lines; hinge not interrupted below umbo; denticles not much diminished in size towards umbo; about 20

denticles placed in front of umbo and about 18 behind it; chondrophore probably absent; musculature unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6196) left in. mould	11.0	6.5	3.0	1.85
Paratype (GK.H6197) right in. mould	13.0	6.5	2.5	2.00

Observations and comparisons.—The holotype reveals the hinge structure and nearly complete outline, although the test is completely eroded away. The paratype, GK.H 6197, which consists of broken internal and external moulds of a right valve, is slightly deformed, and shows that the surface was smooth. The large apical angle, continuous denticles and general outline suggest that these specimens belong to *Malletia,* and the sharp posterior carination is reminiscent of that of *Neilo.* In typical *Neilo,* however, the anterior denticles are stronger than the posterior ones, while there seems to be no such tendency in this species. This differs from the *Malletia* (*Neilo*) sp. recorded by AMANO (1957) from the Upper Cretaceous of Koshikijima in the broader posterior region and more prominent carina. *Malletia* (*Neilo*) *cymbula* WOODS, 1917, from the Senonian of New Zealand differs in the greater prominence of the concentric lamellae on its surface.

Occurrence.—Upper Miyakoan (Albian). Dark grey sandy shale of the Yatsushiro formation at loc. Km. 3096, southwest of Kohara, Tôyô village, Yatsushiro County, Kumamoto Prefecture.

Family Nuculidae

Genus *Nuculopsis* GIRTY, 1911

Type-species.—*Nucula girtyi* SCHENCK, 1934, Carboniferous, U.S.A. (= *Nucula ventricosa* HALL, 1858, non HINDS, 1843).

Subgenus *Palaeonucula* QUENSTEDT, 1930

Type-species.—*Nucula hammeri* DEFRANCE, 1825, Lower and Middle Jurassic, Europe (original designation).

Nuculopsis (*Palaeonucula*) *ishidoensis* (YABE and NAGAO)

1926. *Nucula ishidoensis* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.,* Ser. 2, Vol. 9, No. 2, p. 41, pl. 13, figs. 46, 47.

Material.—The lectotype, here designated, is a left internal mould (IGPS reg. no. 7125) illustrated by YABE, NAGAO and SHIMIZU (1926, pl. 13, fig. 46). It was collected from the Ishido formation at Ishido, Ohinata village, Minamisaku County, Nagano Prefecture.

Remarks.—The syntypes of *Nucula ishidoensis* are two internal moulds of different valves. They show that the ventral margin is smooth internally, that the umbones are nearly terminal and that the denticles posterior to them somewhat degenerated. All the newly collected specimens, which may be conspecific with *N. ishidoensis,* are fragmentary or ill-preserved, but the characteristic features shown by the syntypes suggest that the species belongs to *Palaeo-*

nucula rather than to *Nuculoma, Ennucula* or some other genus with smooth inner ventral margins. The generic name *Leionucula* QUENSTEDT, 1930 (type-species: *Nucula albensis* D'ORBIGNY) may be applicable to many smooth Cretaceous nuculids. On the other hand, *Palaeonucula* flourished in the Jurassic and has been considered to have become extinct by the early Cretaceous. As suggested by COX (1940) and ICHIKAWA and MAEDA (1958a), there are some transitional species between *Palaeonucula* and *Leionucula* in the Jurassic, and the latter may be considered to have been derived probably from the former. As can be judged from the outline and hinge structure of the syntypes, however, the present species must be more closely related to the type-species of *Palaeonucula* than to that of *Leionucula*.

Occurrence.—Aritan (upper Neocomian). Fine grey sandstone of the Ishido formation at Ishido, Ohinata village, Minamisaku County, Nagano Prefecture. Some identical specimens occurred in the dark grey sandy shale of the Arita formation in the Yuasa area and in the dark grey sandy shale of the Hanoura formation at loc. Hy. 5002, 5011, Hiroyasu, Katsuura town, Katsuura County, Tokushima Prefecture. Hayami coll.

Family Nuculanidae

Genus *Nuculana* LINK, 1807

Type-species.—*Arca rostrata* BRUGUIÈRE, Recent (monotypy).

Nuculana (*s. l.*) *sanchuensis* YABE and NAGAO

1926. *Nucula sanchuensis* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 42, pl. 12, figs. 21–23.

Material.—Right internal mould (IGPS reg. no. 7115) illustrated by YABE, NAGAO and SHIMIZU (1926, pl. 12, fig. 21) is designated here as the lectotype. It was collected from the Ishido formation at Ishido, Ohinata village, Minamisaku County, Nagano Prefecture.

Remarks.—The lectotype is a nearly complete internal mould, but its dimensions are somewhat smaller than those of the other syntypes. Since the dentition and musculature are not clearly observable in those specimens and some which have been newly collected, the generic determination of this species is deferred. It is probably not a typical *Nuculana*, and the rounded, non-carinate posterior end reminds me of *Portlandia* MÖRCH, 1857. All the newly collected specimens are poorly preserved or fragmentary.

Occurrence.—Aritan to ? upper Miyakoan (upper Neocomian to Albian). Besides the type locality, similar specimens are found in the Ishido formation at loc. Hy. 4001, 4002, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture, in the Hanoura formation at loc. 5010, east of Nakagoya, Katsuura town, Katsuura County, Tokushima Prefecture (HAYAMI coll.), in the Yatsushiro formation at loc. Km. 3096, southwest of Kohara, Tôyô village, Yatsushiro County, Kumamoto Prefecture (KANMERA coll.), and in the Arita formation at loc. Ys. 3 and Ys. 8 near Suhara, Yuasa town, Arita County, Wakayama Prefecture (MATSUMOTO coll.).

Order Eutaxodontida
Superfamily Arcacea
Family Parallelodontidae
Genus *Parallelodon* MEEK and WORTHEN, 1866
(=*Macrodon* BUCKMAN, 1844 non MÜLLER, 1842; *Beushausenia* COSSMANN, 1897)

Type-species.—*Macrodon rugosus* BUCKMAN, 1844, Middle Jurassic, England (original designation).

Parallelodon nipponicus (NAGAO)
Plate 27, Figures 6, 7

1934. *Grammatodon nipponica* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 190, pl. 28, fig. 3.

Material.—The holotype by monotypy is a right valve (GH. reg. no. 6787) illustrated by NAGAO (1934, pl. 28, fig. 3). It was collected from the Hiraiga formation at Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. Three specimens (GK. H6601-GK. H6603) from the Haidateyama formation (FUJII and KANMERA coll.) and a specimen (GK. H6604) from the Miyako group (HAYAMI coll.) are referable to the present species.

Description.—Shell comparatively small, transversely elongated, about 2.5 times longer than high, strongly inflated; test fairly thick; hinge-line long, occupying whole shell-length; anterior margin smoothly arcuate, meeting hinge-line with a right angle; posterior margin obiquely truncated; ventral margin broadly concave in middle part; umbo broad, slightly rising above hinge-line, placed at about one-third of shell length from the anterior extremity; a blunt carina extending from umbo to postero-ventral corner, defining a slightly excavated postero-dorsal slope; hinge plate of moderate breadth, provided with three sets of teeth; anterior and posterior teeth subhorizontal, three or four, elongated; median teeth numerous, very small, showing gradually changing inclination; cardinal area very wide, provided with several chevron-like grooves; surface marked with numerous fine radial threads and somewhat irregular concentric lamellae.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left in. mould (GK.H6601)	29.5	13.5	9.0	2.18
Both in. moulds (GK.H6602)	24.0	8.5	12.5	2.82
Left valve (GK.H6604)	44.0	20.0	10.5	2.20

Observations and comparisons.—The holotype of *Grammatodon nipponicus* is a well preserved right valve, revealing the internal and external characters. The dentition and external characters are undoubtedly of *Parallelodon*-type. The newly collected specimens from the Miyako group and the Haidateyama formation are identical with the holotype in the dentition, mode of ventral sinuation and other essential characters, but they are not so well preserved as that specimen.

Parallelodon flourished from Devonian to Jurassic times but is believed to

have declined considerably subsequently. Although Cretaceous species are rather rare, this species possesses all the essential characters of the genus, namely, the transversely elongated outline, ventral sinuation, highly asymmetrical hinge composed of three sets of teeth, broad ligament area and fairly prominent irregular concentric surface lamellae. Since *Parallelodon* is separable at least generically from *Grammatodon,* I transfer this species to the former genus, of which it is probably the youngest known representative. *Nemodon* CONRAD, 1869 (type-species: *Arca conradi* JOHNSON) is generally considered to have been a Cretaceous derivative of *Parallelodon,* but its hinge teeth are stronger and the umbo more nearly terminal than in that genus.

As stated by ALENCASTER (1956), *Grammatodon (Cosmetodon) rataensis* ALENCASTER from the Aptian of Mexico, which is here regarded as a *Parallelodon,* may be close to this species.

Occurrence.—Lower and upper Miyakoan (Aptian and Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. This species occurs also in a weathered sandstone of the Haidateyama formation at loc. U. 1005, between Tamarimizu and Ochiai, Nozu town, Ono County, Oita Prefecture, in the sandstone of the Yatsushiro formation at loc. Km. 1843, north of Shimofukami, Sakamoto town, Yatsushiro County, Kumamoto Prefecture (KANMERA coll.), and in a fine sandstone of the Arita formation at loc. Ys. 103, west of Kumai, Yuasa town, Arita County, Wakayama Prefecture (MATSUMOTO coll.).

Family Cucullaeidae

Genus *Nanonavis* STEWART, 1930

Type-species.—*Arca carinata* SOWERBY, 1813, Aptian to Cenomanian, western Europe, as described and figured by WOODS (1899) (original designation).

Remarks.—Hitherto reported occurrences of *Grammatodon* and related genera and subgenera indicate that there were two distinct lines of descent in the evolutional history of this group. One was *Grammatodon (s. s.)*, characterized by comparatively small size and by weak radial riblets usually confined to the both lateral areas of the surface. As *Macrodon otagoensis* WILCKENS, 1927, which has been believed to have been the earliest species of *Grammatodon (s. s.)* is said to be an upper Middle Jurassic species (SPEDEN, 1960), the true range of the genus may be almost confined to the Jurassic. *Grammatodon (s. s.) takiensis* KIMURA, 1956, ranges from Upper Jurassic to Berriasian in Japan (HAYAMI, SUGITA and NAGUMO, 1960), but no other representative of *Grammatodon (s. s.)* is known from the Cretaceous. The other line of descent is *Indogrammatodon,* the earliest representative of which, for example, *Grammatodon inequivalvis* (GOLDFUSS, 1836) (ARKELL, 1930) and *Grammatodon (Indogrammatodon ?) nakanoi* HAYAMI, 1958a, appeared already in the lower Lias of Europe and Japan. The acme of the development of *Indogrammatodon* is, of course, found in the Upper Jurassic of the Indo-African province, and

most Cretaceous species, including those belonging to *Nanonavis* were, I think, derived from this stem. This phylogenetical consideration would make it easy to explain the presence of intermediate species in the Lower Cretaceous. *Nanonavis* is in any case considered to be closer to *Indogrammatodon* than to *Grammatodon*.

Indogrammatodon was originally established as a subgenus of *Grammatodon*, but CHAVAN (1947, p. 184) treated *Indogrammatodon* as a subgenus of *Nanonavis*. I think CHAVAN's classification is reasonable, unless they are regarded as two distinct genera, as by ICHIKAWA and MAEDA (1958).

Subgenus *Nanonavis s. str.*

Nanonavis (*Nanonavis*) *yokoyamai* (YABE and NAGAO)

Plate 27, Figures 8-13

1890. *Cucullaea* cfr. *striatella* MICHELIN, YOKOYAMA, *Palaeontographica*, Bd. 36, p. 199, pl. 25, fig. 13.
1926. *Grammatodon yokoyamai* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 45, pl. 12, figs. 12, 13, 15.
1926. *Grammatodon yokoyamai*, YABE and NAGAO, *Chikyu*, Vol. 5, p. 436.
1954. *Grammatodon yokoyamai*, MATSUMOTO, Cretaceous System, Japan. Islands, pp. 64, 76, 82, 114, listed.
1958. *Nanonavis yokoyamai*, ICHIKAWA and MAEDA, *Jour. Inst. Polytech. Osaka City Univ.*, Ser. G, Vol. 3, p. 67.
1963. *Nanonavis yokoyamai*, HAYAMI *in* MATSUMOTO (ed.), A survey of the fossils from Japan illustrated in classical monographs, p. 32, pl. 51, fig. 13 (reproduction of YOKOYAMA's figure).

Material.—An internal mould of both valves (IGPS reg. no. 7124) illustrated by YABE, NAGAO and SHIMIZU (1926, pl. 12, fig. 12) is designated here as the lectotype. It was collected from the Ishido formation at Ishido, Ohinata village, Minamisaku County, Nagano Prefecture. This species was originally proposed as *"nom. nov."* for *Cucullaea* cfr. *striatella* in YOKOYAMA (1890), but its lectotype should be selected from the three specimens treated by them, since *G. yokoyamai* can be regarded as YABE and NAGAO's new species. Two other syntypes are also the examples of this species. The following description is based on three specimens (GK. H6139-GK. H6141) from the Yatsushiro area (KANMERA coll.), two specimens (GK. H6138, GK. H6605) from the same area (HAYAMI coll.) and a specimen (GK. H6605) from the Oshima area (AKIYAMA coll.) in addition to the lectotype and syntypes.

Description.—Shell of medium size for a grammatodontid but rather small for *Nanonavis* (*s. str.*), scarcely exceeding 40 mm. in length, subrhomboidal to subtrapezoidal in outline, more or less elongated transversely, about 1.5 times longer than high, strongly inflated; test moderate in thickness; umbo comparatively narrow, slightly prosogyrous, incurved, placed at about one-third of hinge-line from front; dorsal margin gently convex, forming an acute angle of about 80 degrees with dorsal margin; posterior margin straight, meeting

dorsal margin in an obtuse angle; a prominent carina extends from umbo to postero-ventral corner, defining clearly a feebly concave posterior slope; ventral margin gently arcuate but nearly straight and subhorizontal in middle part; hinge plate moderate in width and broadened near both ends; each valve provided with two anterior and three (sometimes two) posterior stout subhorizontal teeth and a number of median denticles, which gradually change their inclination and converge ventrally; second posterior tooth especially long, occupying about two-fifths of hinge-line; surface sculpture slightly different in the two valves; left valve marked with more than 30 irregularly spaced, roof-shaped, stout radial costae and a few subordinate riblets; about 12 primaries present on posterior area behind carina; radials somewhat sparse on anterior part, much narrower than their interspaces; radials much weaker and more numerous in right valve than in left; some of primaries possibly correspond to those of left valve, but their interspaces are marked with one or two riblets of secondary prominence not found on that valve; concentric lamellae somewhat irregular but densely spaced near ventral margin in adult shell; ligament area of moderate height, provided with more than 10 densely spaced cheverons.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left valve (GK.H6138)	35.5	24.5	7.0	1.45
Right valve (GK.H6138)	35.5	21.5	8.0	1.65
Left in. mould (GK.H6140)	23.0	13.0	6.0	1.77
Left in. mould (GK.H6141)	14.5	8.0	3.5	1.81
Left in. mould (GK.H6200)	21.5	13.5	5.5	1.59
Left valve (GK.H6605)	21.5	12.0+	3.5+	1.79−

Observations and comparisons.—Many specimens from the Ishido, Yatsushiro, Hanoura and a few other formations are available for study. Although most of them are internal and external moulds, the surface ornament and hinge characters are clearly reproduced. The first specimen (GK. H6138), though its posterior part is a little broken, is bivalved and the different mode of ornamentation of the two valves can be seen. The dentition, musculature and general outline are best shown in a left internal mould (GK.H 6140) as well as in the lectotype. The position of the umbo and the ratio of length/height are somewhat variable, but this may be partly due to secondary deformation.

Grammatodon yokoyamai YABE and NAGAO, 1926,* which was originally reported from the Ishido formation of the Sanchu area, is a widely distributed species, and is known to occur in the Aritan and Miyakoan deposits of various areas. YABE and NAGAO described the surface ornamentation of the right valve only. The difference of ornamentation of two valves has not yet been observed in the Sanchu specimens, but I believe that the specimens here described are conspecific with typical *N. yokoyamai,* because they agree well with the syntypes

* "*Gammatodon*" and "*Grammmatodon*" in YABE and NAGAO's original description (1926, p. 44) are evidently typographical errors of *Grammatodon*, as pointed out by NICOL (1954).

in the the sharply carinated outline, dentition and ornamentation of the right valve.

As mentioned by YOKOYAMA (1890) and YABE, NAGAO and SHIMIZU (1926), the outline of this species is fairly similar to that of *Grammatodon carinatus* (SOWERBY) from the Gault and the Upper Greensand of England (WOODS, 1899), which is the type-species of *Nanonavis* STEWART, 1930. But the ratio of length/height is somewhat smaller, the carina is less conspicuous and the radials are less flattened at the top. Moreover, the ornament of the right valve is different from that indicated in WOODS' figures (pl. 8, figs. 4b, 5, 7a, b). So far as I can ascertain from the European specimens of *N. carinatus* kept in the Tohoku and Kyushu Universities, the species is not so strongly inequivalve as *N. yokoyamai,* and is more hemi-cylindrical in form.

This species may be closer to *Grammatodon securis* (LEYMERIE), which is regarded as another species of *Nanonavis* (*s. s.*), from the Speeton Clay of England and the (?) Neocomian of Argentina, since the right valve of *N. securis* has more densely spaced radials than the left (WOODS, 1899, pl. 7, figs. 14a, b), just as in the present specimen (GK. H6138). I cannot find any criteria for the distinction of *N. yokoyamai* from WOODS' specimens of *N. securis*, but figures of *N. securis* in LEYMERIE (1842) and D'ORBIGNY (1844) seem to suggest that typical specimens of that species from France are more transversely elongated than the present specimens of *N. yokoyamai.* WOODS (1899) noted, "I think it is possible that they (*N. securis* and *N. carinatus*) may prove to be identical". *N. yokoyamai* is here considered to be distinct from *N. carinatus*, and I am inclined to regard it for the time being as distinct also from *N. securis.* Further study on the variation of the species in Europe is needed for a precise comparison.

A difference in the mode of ornamentation of the two valves is known also in some Upper Cretaceous species of *Nanonavis,* namely, *Arca japetica* FORBES as figured by STOLICZKA (1871, pl. 18, figs. 6-11) from the Arriallor (Ariyalur) group of south India, and *Indogrammatodon awajianus* ICHIKAWA and MAEDA, 1958, from the Izumi group of southwest Japan. The shell is, however, much smaller and more elongated and the posterior carina seems stronger in the present species. The radials are much more densely spaced in *N. japetica* than in *N. yokoyamai* and in the right valve of the latter species they are weaker than in *L. awajianus. Nanonavis sachalinensis* (SCHMIDT, 1873) is an ubiquitous grammotodontid in the Senonian of Japan (NAGAO, 1932; NAGAO and OTATSUME, 1938, AMANO, 1957; ICHIKAWA and MAEDA, 1958, etc.). It resembles *N. yokoyamai* in the ornamentation of the left valve and in the dentition, but is clearly distinguishable by its less elongated and much larger shell, subequal ornamentation, broader umbonal region and weaker posterior carina.

It is now recognized that several Cretaceous species of *Nanonavis* possess ornament of the *Indogrammatodon*-type. But they are also very close to typical *Nanonavis* in many characters. Taking these similarities into consideration,

I suggest that *N. yokoyamai* and WOODS' specimens of *Grammatodon securis* are intermediate between *Indogrammatodon* and *Nanonavis*.. Compared with the species of typical *Indogrammatodon* COX, 1937 (type-species: *Cucullaea virgata* SOWERBY, 1840), from the Upper Jurassic of the Indo-African province (HOLDHAUS, 1913; COX, 1937a, 1940), New Zealand (MARWICK, 1953) and Mexico (IMLAY, 1940a), *N. yokoyamai* generally has more densely spaced and less elevated radial ribs on the left valve, and its shell is much smaller. The posterior carination in typical *Indogrammatodon* seems to be less conspicuous than in the present species. The degree of difference in the ornamentation of the two valves is, I think, essentially the same.

The outline of *N. yokoyamai* is somewhat variable. The posterior margin forms an obtuse angle of approximately 110 degrees with the hinge line in many specimens from the Yatsushiro and Ishido formations. But the angle is much smaller in one specimen (GK.H 6605) from the Oshima formation and is somewhat larger in many specimens adhered to a slab (IGPS reg. no. 36562) from the Ofunato group.

Occurrence.—Aritan to upper Miyakoan (upper Neocomian to Albian). Grey fine sandstone of the Ishido formation at loc. Hy. 4011, Ishido, Ohinata village, Minamisaku County, Nagano Prefecture, and at loc. Hy. 4001, 4002, Ichinose-bashi, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture. Ill preserved specimens also from the black shale of the Ishido formation at Hy. 4013, west of Ishido. Dark grey sandy shale of the Yatsushiro formation at loc. Km. 3096, southwest of Kohara, Tôyô village, Yatsushiro County, and at loc. Km. 3037 and loc. Hy. 1016, west of Mt. Jôgûsan, Miyaji, Yatsuhiro City, Kumamoto Prefecture. Dark grey shale of the Hanoura formation at loc. Hy. 5002, Hiroyasu, Katsuura town, Katsuura County, Tokushima Prefecture. Black shale of the Oshima formation at loc. Hy. 0009, Shiraito-hama and loc. Hy. 0004, south of Yokonuma, both in Oshima island, Kesennuma City, Miyagi Prefecture. Grey fine sandstone of the Hiraiga formation at loc. Hn. 0012, southern coast of Hiraiga, and grey sandy shale of the "*Orbitolina* sandstone" at loc. Hn. 6203, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture. Black shale of the Ofunato group at Yakehama of Massaki, Ofunato City, Iwate Prefecture. Dark grey sandy shale of the Arita formation at Ys. 105, west of Kumai, at Ys. 8, near Suhara and at Ys. 53, near Yoshikawa, all in Yuasa town, Arita County, Wakayama Prefecture.

Nanonavis (*Nanonavis*) sp. cf. *N.* (*N.*) *yokoyamai* (YABE and NAGAO)

Plate 27, Figure 14

Represented by two specimens, the internal and external moulds of different left valves. Shell of medium size, subquadrate in outline, apparently not much elongated, strongly carinated (GK.H6201, left internal mould, 26.5+mm. long, 18.0 mm. high, 5.0 mm. thick; GK.H6202, left external mould, 17.5+mm. long, 18.0 mm. high, 5.5 mm. thick); umbo placed at about two-fifths of hinge-line

from front; ligament area (seen in the second specimen) about 1.1 mm. in maximum width, provided with about 13 densely spaced chevrons; anterior margin apparently meeting the hinge-line in a right angle; posterior margin forming an obtuse angle of about 100 degrees with hinge; dentition similar to that of the preceding species; surface (left valve) marked with more than 40 radial ribs, which are simple and somewhat weakened on posterior area.

The two specimens now described are at once seen to differ from the specimens of *N. yokoyamai* with which they are associated in the more mesially placed umbo and more rectangular outline, with less pronouncedly prosocline anterior and posterior margins. The posterior area behind the carina is seemingly narrower than in typical specimens of *N. yokoyamai*, but it is not impossible that this difference may be due to mechanical deformation. I can find no diagnostic criterion in the dentition and surface ornamentation of the left valve, and provisionally compare the specimens to *N. yokoyamai*, until the corresponding right valve is found.

Occurrence.—Upper Miyakoan (Albian). Dark grey sandy shale of the Yatsushiro formation at loc. Hy.1007 (Km. 3096), southwest of Kohara, Tôyô village, Yatsushiro County, Kumamoto Prefecture (HAYAMI coll.).

Genus *Cucullaea* LAMARCK, 1801

Type-species.—*Cucullaea auriculifera* LAMARCK, 1801 (=*Arca labiata* SOLANDER, 1786), Recent, Indo-Pacific (monotypy).

Cucullaea acuticarinata NAGAO

Plate 27, Figure 15; Plate 28, Figures 1–10

1934. *Cucullaea acuticarinata* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 192, pl. 24, figs. 10–14, pl. 30, fig. 5.

non 1957. *Cucullaea* aff. *acuticarinata* NAGAO, AMANO, *Kumamoto Jour. Sci.*, Ser. B, Sec. I, Vol. 2, No. 2, p. 81, pl. 1, figs. 4, 5.

Material—The holotype is a right valve (GH reg. no. 6756) illustrated by NAGAO (1934, pl.24, fig. 11). It was collected from the Hiraiga formation at Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. The following description is based on eleven specimens (GK.H 6203—GK.H 6211, GK.H 6380, GK.H 6381) from the type area (HANAI and HAYAMI coll.) in addition to the holotype and paratypes.

Description.—Shell of small or medium size for genus, inequilateral, obliquely trapezoidal, well inflated, much longer than high; test thick; hinge-line moderate in length, occupying about two-thirds of shell-length; anterior margin forming an obtuse angle with hinge, smoothly arcuate; posterior margin long, nearly straight or feebly concave in dorsal half, forming an obtuse angle of about 120 degrees with hinge axis; ventral margin nearly straight or only slightly convex, with somewhat variable inclination to hinge-line; umbones orthogyrous, incurved, not contiguous, highly salient above hinge-line, placed near center of hinge; posterior carina sharp, persistent from umbo to postero-ventral

ertremity; postero-dorsal area, which is clearly defined by carina, fairly wide, occupying about a third of whole surface, divided subequally into two faintly concave areas by a weak median carina; surface marked with numerous irregular concentric growth-lines and numerous radial riblets; radials apparently similar to those of *Grammatodon* (*s. s.*) and almost effaced on central part; ventral margin not crenulated internally; posterior adductor scar placed on a weak buttress; hinge almost symmetrical, composed of three or four elongated anterior and posterior horizontal teeth and a number of median oblique teeth, although the three series are not clearly demarcated; all teeth apparently divergent from a point at base of hinge plate; anterior horizontal teeth usually slightly shorter than posterior ones; cardinal area fairly wide, slightly concave, obtusely triangular, marked with densely spaced chevrons, which are bordered dorsally by a pair of weak ridges; cardinal angle, which is indicated by the angle between cardinal areas of conjoined valves, about 100 degrees or slightly larger.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK.H6203)	39.0	30.5	15.5	1.28
Right valve (GK.H6204)	42.0	32.5	16.5	1.29
Right valve (GK.H6205)	20.0	14.5	6.5	1.38
Right valve (GK.H6206)	24.5	18.5	8.0	1.32
Right valve (GK.H6207)	26.5	19.5	9.5	1.36
Right valve (GK.H6208)	27.5	21.5	9.5	1.28
Left valve (GK.H6209)	36.0	24.5	12.5	1.47
Right valve (GK.H6210)	25.5	17.5	8.0	1.46
Left valve (GK.H6211)	26.5	21.5	9.5	1.23

Observations and comparisons.—A number of well-preserved specimens are available for study. Two specimens (GK.H6209, 6210) are slightly compressed, but the others are free from secondary deformation. The ratio of thickness/height seems to increase with growth. The sharp posterior carination is seen in all specimens, but the prominence of radial riblets at both ends of the shell seems somewhat variable among individuals.

The specimens at my disposal are in every way identical with the holotype and other illustrated specimens of *Cucullaea acuticarinata* NAGAO, 1934. NAGAO noted on the basis of the holotype, "Ventral margin is subparallel to the dorsal". However, the ventral margin is fairly oblique in his other specimens and frequently forms an angle as large as 30 degrees with the hinge axis in some of the present specimens. The growth-lines show that the inclination of the ventral margin increases gradually during growth, as can be well observed in relatively large specimens (GK.H6203, GK.H6204). It is concluded that the obliquity of the ventral margin is fairly variable among individuals and changes in ontogeny.

NAGAO compared this species with *Cucullaea fittoni* (PICTET and CAMPICHE) and *Cucullaea cornueliana* (d'ORBIGNY) from the Neocomian and Aptian of western Europe. In fact, *Arca robinaldina* PICTET and RENEVIER, 1857 (non

D'ORBIGNY, 1846), which is synonymous with *Cucullaea fittoni* according to WOODS (1899), is similar in the outline of the shell to some of the present specimens. The posterior carina, however, seems always sharper and the shell is generally more obliquely expanded in *C. acuticarinata* than in *C. fittoni*. *Cucullaea cornueliana* probably has a more strongly curved ventral margin and much weaker posterior and median carinae.

This is not a typical *Cucullaea*, and should be taxonomically placed in some category between *Cucullaea* and *Grammatodon* in view of the hinge-structure and surface ornamentation. Several immature specimens (pl. 28, fig. 1) reveal *Grammatodon*-like characters, that is to say, a comparatively less protruding umbonal region, a moderately long hinge-line and radial riblets which are distinctly confined to the two extreme ends. The ornamentation is not much different from that of *Grammatodon* (*s. s.*) *concinus* (PHILLIPS, 1829) (ARKELL, 1930), *G.* (*s. s.*) *andhouensis* COX, 1940 and *G.* (*s. s.*) *takiensis* KIMURA, 1956, from the Middle-Upper Jurassic. The hinge-line, however, is much shorter, the teeth are arranged more symmetrically and the cardinal area is broader than in any species of *Grammatodon*.

NICOL (1954, 1958a) has surveyed the nomenclature of cucullaeids, and has critically listed 24 available generic or subgeneric names, of which 15 has been proposed on the basis of Cretaceous species. Among them *Arcullaea* VOKES, 1946 from the Aptian of the Lebanon, and *Idonearca* CONRAD, 1862, are more or less similar in morphology to the present species. But this differs from *Arcullaea olea* VOKES, 1946, in its narrower hinge plate, broader ligament area, more salient umbo and probably stronger posterior carina, though the arrangement of its hinge teeth is fairly similar. The type-species of *Idonearca*, i.e. *Cucullaea tippana* CONRAD, 1858, is also characterized by a thick test and heavy hinge. But *Cucullaea acuticarinata* is not typical of that genus in view of its longer hinge-line, smaller dimensions and not much effaced central teeth. The riblets are similarly restricted to the two ends of the shell in *Idonearca stephensoni* STOYANOW, 1949, from the Aptian of Arizona, but that species also does not appear to be a typical *Idonearca*.

Cucullaea (*s. l.*) is common also in the Jurassic, and some species from this system, including *Ashcroftia inversidentata* CRICKMAY, 1930, show a similar outline and subsymmetrical hinge. The anterior and posterior teeth of such Jurassic species are usually more elongated and more inclined outwards, and the posterior carination and adductor buttress seem weaker than in *C. acuticarina*. It is uncertain whether such small Cretaceous cucullaeids as this species were derived from Jurassic *Cucullaea* or directly from *Grammatodon* (*s.s.*).

This could be separated subgenerically from any of Jurassic and Cretaceous cucullaeid genera and subgenera hitherto proposed. Recently CASEY (1961) has proposed *Noramya* (type-species: *Cucullaea ovalis*) for certain Cucullaeidae from the Lower Greensand. However, for *Cucullaea fittoni*, *C. cornueliana* and some other species, which appear congeneric with *C. acuticarinata*, CASEY did

not alter their original generic name. I would agree with him in refraining from the proposal of a new subgenus for this group, because there are many Upper Cretaceous species transitional between this group and typical *Cucullaea*.

Occurrence.—Lower and (?) upper Miyakoan (Aptian to Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga, and at loc. Hn. 0912, 0914, 0916, north of Haipe, Tanohata village, Shimohei County, Iwate Prefecture. NAGAO (1934) reported this species also from the sandstone of the (?) 2nd cycle of the Miyako group at Hideshima and the Aketo sandstone at Aketo. *Cucullaea* aff. *acuticarinata* reported by AMANO (1957) from the Hagino formation of Shikoku belongs to another species (see page 246).

Cucullaea transversa NAGAO

Plate 28, Figures 11-13

1934. *Cucullaea transversa* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 193, pl. 25, figs. 1, 3-6.

Material.—The holotype is a left valve (GH reg. no. 6797) illustrated by NAGAO (1934, pl.25, fig.1). It was collected from the Hiraiga formation at Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. The following description is based on three specimens (GK.H6212-GK.H6214) from the type locality (HANAI and HAYAMI coll.) in addition to the holotype and paratypes.

Description.—Shell small for genus, scarcely exceeding 25 mm. in length, usually more or less elongated transversely, subtrapezoidal, much longer than high, moderately inflated; test comparatively thin; umbo not at all prominent, orthogyrous, broad, rising a little above hinge-line, placed at about two-fifths of sell from anterior end; anterior margin rounded, passing into postero-dorsal and ventral margins in uninterrupted curves; postero-dorsal margin distinctly longer than antero-dorsal; posterior margin nearly straight, forming an obtuse angle of about 120 degrees with postero-dorsal margin and a rounded-off acute angle of about 75 degrees with ventral; ventral margin broadly arcuate but nearly horizontal in posterior part; a rounded carina extends from umbo to postero-ventral corner, defining a steep posterior slope; median carina absent; surface marked with numerous faint radial threads in addition to growth-lines; hinge plate very narrow; internal buttress undeveloped.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left valve (GK.H6212)	22.5	14.0	6.5	1.61
Left in. mould (GK.H6213)	24.5	14.0	6.0	1.75
Left valve (GK.H6214)	16.5	11.0	4.0	1.50

Observations and comparisons.—Many specimens are referred to *Cucullaea transversa* NAGAO, 1934, on account of their similarity in outline and surface markings. The test, which is very thin and apt to be exfoliated, is preserved only in two specimens. The ligament and hinge structures are not observable in NAGAO's figured specimen or in the present ones. The characters were, how-

ever, described by NAGAO as follows: "Ligament area elongate, very narrow, with a few inverted V-shaped grooves. Hinge plate provided with numerous small teeth, anterior three and posterior four or five longer than the others and distinctly oblique to the hinge line". The description seems to have based on one of his specimens which was not illustrated. The characters appear to agree with those of normal Cretaceous *Cucullaea*.

However, the resemblance in outline between *Cucullaea transversa* and *Arca aptiensis* PICTET and CAMPICHE, 1866, from the Aptian of France and Lower Greensand of England, which is the type-species of *Aptolinter* CASEY, 1961, cannot be overlooked. CASEY (1961, p.575, text-fig.11a) has shown that the species is not an arcid but a parallelodontid close to *Nanonavis*. Therefore, it is necessary to observe the detailed structure of the hinge in order to determine the taxonomic position of *C. transversa*. Specifically it is distinguishable from *A. aptiensis* and from other species of *Aptolinter* by its weaker radial ornamentation.

As stated by NAGAO, the outline of this species is considerably variable, the ratio of length/height ranging from 1.50 to 1.75. If the outline of two extreme forms alone were compared, they might be taken to belong to different species, but the difference must be due to intraspecific variation, since some specimens with intermediate outline are found in association.

Occurrence.—Lower and (?) upper Miyakoan (Aptian to ? Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga, Tanohata village, Shimonohei County, Iwate Prefecture. NAGAO has also reported this species from the Aketo formation at Aketo and the "*Orbitolina* sandstone" at Hiraiga.

Cucullaea fujii sp. nov.
Plate 28, Figures 14-15

1954. *Cucullaea acuticarinata*, FUJII, *Jour. Geol. Soc. Japan*, Vol. 60, No. 709, p. 421, listed (non NAGAO, 1934)

cf. 1957. *Cucullaea* aff. *acuticarinata* NAGAO, AMANO, *Kumamoto Jour. Sci.*, Ser. B, Sec. 1, Vol. 2, No. 2, p. 81, pl. 1, figs. 4, 5.

Material—The holotype is an internal mould of slightly dislocated valves (GK. H6216) from a sandstone referable to the Haidateyama formation at loc. U. 1005, between Tamarimizu and Ochial, Nozu town, Ono Country, Oita Prefecture (FUJII coll.). Paratype (GK. H6217) from the type locality (FUJII coll.).

Description.—Shell of small-medium size for genus, subtrapezoidal, obliquely expanded but not much elongated, well inflated, longer than high; test comparatively thin; anterior margin well rounded, short; posterior margin nearly straight and forming an obtuse angle of about 110 degree with hinge-line; ventral margin rounded, fairly oblique to hinge; hinge-line moderate in length; umbo comparatively narrow, pointed, placed submesially, rising prominently above hinge-line; posterior carina sharp, clearly defining a wide posterior slope; median carina present but weak; surface marked with numerous faint radial threads,

which become stronger near anterior periphery; internal buttress for posterior adductor distinct but comparatively weak; flattened belt along ventral margin very narrow; marginal crenulations absent; hinge-plate fairly broad at both ends, provided with three or four subhorizontal teeth at each end, which are nearly symmetrically disposed; teeth almost effaced in median portion; weak radial striae impressed on interior of shell; ligament area moderate in width, provided with several densely spaced chevrons.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6216) right in. mould	35.5	28.0	9.0	1.27
Holotype (GK.H6216) left in. mould	34.5+	26.0	9.0	1.33
Paratype (GK.H6217) left in. mould	36.0	29.0	9.5	1.24

Observations and comparisons.—This is represented by three internal and/or external moulds which had formerly been listed by FUJII (1954) as *Cucullaea acuticarinata*. In addition, two left internal moulds described by AMANO (1957a) under the name of *Cucullaea* cf. *acuticarinata* are probably conspecific with the present specimens.

The holotype consists of nearly complete and slightly dislocated internal mould of conjoined valves and of a broken external mould, and the paratype is a left internal mould on which the external mould of an annelid is impressed. Hinge structure of the *Cucullaea* type is shown by the two specimens.. AMANO's specimens are somewhat smaller and have thinner tests, but are similar to the holotype in every essential character.

As was suggested by FUJII and AMANO, this species at first sight is similar to *Cucullaea acuticarinata* NAGAO, 1934, from the Miyako group, but the shell is slightly taller and thinner, the umbo is narrower and the median carina is distinctly weaker than in typical specimens of that species. In outline *Cucullaea fujii* is also similar to *Cucullaea amaxensis* MATSUMOTO, 1938, from the Gosyonoura group of Kyushu, but that species is characterized by its larger dimensions, better developed internal buttress and broader umbo.

The species is dedicated to Dr. Koji FUJII who collected the present material.

Occurrence.—Miyakoan (Aptian to Albian). Weathered brown fine sandstone probably referable to the Haidateyama formation at loc. U. 1005, between Tamarimizu and Ochiai, Nozu town, Ono Country, Oita Prefecture. This species seems to occur also in the weathered sandstone of the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture.

Genus *Trigonarca* CONRAD, 1862
(=*Trigonoarca auct.*)

Type-species.—*Cucullaea maconensis* CONRAD, 1860, Upper Cretaceous, U.S.A. (monotypy).

Trigonarca obsoleta YABE and NAGAO

1926. *Trigonoarca* (?) *obsoleta* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 43, pl. 12, fig. 24.

Material.—The holotype by monotypy is a left valve (IGPS reg. no. 22538) illustrated by YABE, NAGAO and SHIMIZU (1926, pl. 12, fig. 24). It was collected from the Ishido formation at Ishido, Ohinata village, Minamisaku County, Nagano Prefecture.

Remarks.—No specimen of this species is in the present collection. Although the holotype is ill-preserved, its triangular outline and partly exposed hinge teeth indicate the genus *Trigonarca*.

Occurrence.—Aritan (upper Neocomian). This species is known only from the Ishido, Ohinata village, Minamisaku County, Nagano Prefecture.

Trigonarca sp. cf. *T. obliquata* AMANO

Plate 28, Figure 17

cf. 1957. *Trigonoarca* (?) *obliquata* AMANO, *Kumamoto Jour. Sci.*, Ser. B. Sec. 1, Vol. 2, No. 2, p. 82, pl. 1, figs. 6–8.

This form is represented only by a right valve (GK. H6146, 36.5 mm. long, 27.0 mm. high, 11.0 mm. thick), the test of which is exfoliated except for its posterior part. Shell of medium size, subquadrately triangular, obliquely expanded, moderately inflated, much longer than high; umbo not very prominent, fairly strongly opisthogyrous, placed slightly posteriorly to the midpoint of hinge-line; posterior area separated from flank by a sharp carina, subdivided into two slightly concave areas by a weak median carina, and ornamented with numerous radial riblets and concentric lines; ventral margin smooth; hinge and ligament structures unknown.

The outline of *Trigonarca passyana* WOODS, 1899, from the Upper Greensand of England is fairly similar to that of this specimen, in which, however, the median carina and radial riblets of the posterior area are more conspicuous. The present specimen is close to the three specimens from the Hagino formation of Shikoku, upon which the species *Trigonoarca* (?) *obilquata* was founded by AMANO (1957a), because its outline, the position of umbo and its posterior radial riblets are quite similar. The growth-lines are not so distinct in the Hagino specimens, but this may be due to the different state of preservation. I agree with AMANO in referring the Hagino species to *Trigonarca* in view of the trigonal outline, numerous V-shaped continuous numerous teeth, comparatively un-protruding and slightly opisthogyous umbo, and somewhat unevently and widely spaced ligament grooves. The specific distinction of *T. obliquata* from *Trigonarca obsoleta* YABE and NAGAO, 1926, from the Ishido formation, is by no means based on reliable criteria at present, in view of the strong deformation of fossils from the Ishido formation.

Occurrence.—Upper Miyakoan (Albian). Boulder of dark grey hard fine sandstone of the Yatsushiro formation at the south of Bishô, Tôyô village, Yatsushiro County, Kumamoto Prefecture (AKATSU coll.).

Family Arcidae
Genus *Eonavicula* ARKELL, 1929

Type-species.—*Arca quadrisulcata* SOWERBY, 1814, Upper Jurassic, England (original designation).

Eonavicula prolata (AMANO)

1957. *Arca prolata* AMANO, *Kumamoto Jour. Sci.*, Ser. B, Sec. 1, Vol. 2, No. 2, p. 80, pl. 1, figs. 1-3.

Material.—The holotype is a right external mould (GT KML-0017), a plaster cast of which was illustrated by Amano (1957, pl. 1, fig. 1). It was collected from the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture.

Remarks.—No specimen of this species is in the present collection. The dentition is observable in two of the original specimens (GT KML-0015, 0016, AMANO, 1957a, pl. 1, figs. 2, 3). As noted by AMANO, the teeth near the ends of hinge-plate are fairly long and oblique. I agree with him in considering that this species is related to *Arca carteroni* D'ORBIGNY, 1844, from the Lower Greensand of England (WOODS, 1899), the reference of which to *Eonavicula* was suggested by ARKELL (1929, p. 36) and CASEY (1961, p. 60).

Occurrence.—Lower Miyakoan (Aptian). This species is known only from the weathered sandstone of the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture.

Genus *Barbatia* GRAY, 1847

Type-species.—*Arca barbata* LINNAEUS, 1758, Recent, Europe (original designation).

Barbatia sp. indet.
Plate 28, Figure 16

This form is represented by an ill-preserved internal mould of left valve (GK. H6218, 31.5 mm. long, 10.5 mm. high, 6.5 mm. thick). It is strongly compressed in a vertical direction, and the thickness and the ratio of length/height may therefore be exaggerated. Shell elongate-elliptical, well inflated; anterior and posterior margins evenly arcuate without any angulations; umbo placed at about two-fifths of length from front, fairly broad, incurved; hinge comparatively short, provided with numerous denticles, which become slightly oblique towards both ends but are not much elongated; an obscure carina extends from umbo to posterior part; ventral margin parallel to dorsal; byssal gape, if present, very narrow; exterior unknown.

The original outline of this specimen seems to have been close to that of *Barbatia marullensis* (D'ORBIGNY, 1844) from the Lower Greensand and Gault of England (WOODS, 1899), but its posterior carina may be more conspicuous. *Arca shinanoensis* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU (1926), from

the Neocomian "Shiroi formation" of the Sanchu area, may be another allied species, but its dimensions are much smaller than those of the specimen now recorded.

Occurrence—Aritan (upper Neocomian). Grey muddy shale of the lower Monobegawa subgroup at Okuminotani, southwest of Ryoseki, Nangoku City, Kochi Prefecture (KIMURA coll.).

Family Glycymerididae

Genus *Glycymeris* DA COSTA, 1778

Type-species.—*Glycymeris orbicularis* DA COSTA, 1778 (=*Arca glycymeris* (=*Arca glycymeris* LINNÉ, 1758), Recent, Europe (tautonymy).

Subgenus *Hanaia,* nov.

Type-species.—*Glycymeris densilineata* NAGAO, 1934, Aptian-Albian, north Japan.

Diagnosis.—Shell small, well inflated, more or less inequilateral, prosocline; umbo prominent, submesially placed; ventral margin with coarse internal crenulations; ligament area of moderate width, slightly concave, marked with a few chevrons; hinge slightly asymmetrical, with stout and elongated lateral teeth and not much degenerated central teeth; flattened area along periphery of hinge plate unusually narrow; surface nearly smooth except for rounded radial ribs and grooves in which there are numerous fine radial striae.

Remarks.—It has been known that *Glycymeris densilineata* NAGAO, 1934, from the Miyako group, is not typical of the genus. The characteristic ornamentation composed of radials of two different orders of prominence was pointed out by NAGAO, and the hinge structure seems also different from that of *Glycymeris* (*s. s.*). Although nothing was said about the dentition in NAGAO's original description, the holotype of *G. densilineata,* the hinge of which was artificially polished, shows the disposition of hinge teeth. Many newly collected and well preserved specimens, which are undoubtedly identical with *G. densilineata,* enable the hinge structure to be described in detail and the species distinuished at least subgenerically from *Glycymeris* (*s.s.*) and other taxa of the Glycymerididae previously recognized.

Some Cretaceous species of *Glycymeris* are considered to belong to the subgenus *Glycymerita* FINLAY and MARWICK, 1937 (type-species: *Glycymeris concava* MARSHALL, 1917), which is characterized by the subquadrate and well inflated outline of the shell and the strong and elongated hinge-teeth, which are inclined at a low angle to the horizontal. The present species likewise has comparatively long teeth, but the dimensions of the shell are much smaller, the hinge plate is thicker, the teeth are more extended and closer to the periphery of the hinge plate, and the antero- and postero-dorsal shoulders are less pronounced than in that subgenus. In many primitive species of *Glycymeris,* including *Glycymerita,* the beaks are located a little posterior to the centre of

dorsal margin. Such a tendency is, however, unknown in *G. densilineata*. The surface ornamentation of *G. densilineata* is different from that of *Glycymerita*, and is at a glance similar to that of the type-species, *Glycymeris capricornea* HEDLEY, 1906, and related species of the subgenus *Tucetilla* IREDALE, 1939. The hinge teeth of *Tucetilla* are, however, more similar to those of *Glycymeris* (*s. s.*) than to the teeth of *Glycymerita* and of the species now under discussion.

G. densilineata differs both in internal and external characters from all the genera and subgenera of the Glycymerididae, which were listed by NICOL (1945) with nomenclatorial discussions. Broadly rounded radial ribs are known also in *Tucetona*, but the secondary riblets are more distinct and delicate and the umbo is placed more centrally in this type-species. The shell convexity of *G. densilineata* seems much stronger than in normal *Tucetona*, although as a general tendency Mesozoic glycymerids may be more strongly inflated than Cenozoic ones. A small Recent glycymerid, *Tucetona planicostata* HABE, 1961, which is the type-species of subgenus *Tucetonella*, is apparently similar to *G. densilineata* in its small size and inequilateral outline, but in the fossil species the shell convexity is still stronger and the radials are much narrower. A narrow flattened area around the hinge teeth is observable in some species of Tertiary and Recent *Glycymeris* (s. l.), such as *Glycymeris whaleyi* NICOL, 1947, from the Oligocene and Miocene of California, but it is not so well defined as in *G. densilineata*. The present type species is apparently similar to *Glycymeris requierriana* (D'ORBIGNY, 1846) from the Turonian of France, which was referred to the subgenus *Veletuceta* IREDALE, 1931, by FRENEIX (1959, p. 191), but has more triangular outline with truncated anterior and posterior margins, and less numerous ventral crenulations than the type-species of *Veletuceta*, *Glycymeris flammens* REEVE, 1843.

The triangular colour pattern, which is preserved on the postero-central surface of many specimens of *G. densilineata*, reminds me that of some living *Veletuceta*. However, the smaller dimensions, the slightly elevated primary ribs and the peculiar features of the hinge teeth of *G. densilineata* require its subgeneric distinction. So far as I can ascertain from examination of foreign Cretaceous specimens and references, there is no known species consubgeneric with *G. densilineata*.

This subgenus is named after Dr. Tetsuro HANAI, who kindly placed a great number of pelecypod specimens from his magnificient collection at my disposal and gave me much instructive information and many suggestions related to palaeontology and stratigraphy.

Glycymeris (*Hanaia*) *densilineata* NAGAO

Plate 29, Figures 1-15

1934. *Glycymeris densilineata* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 195, pl. 32, figs. 8, 9

Material.—The holotype is a right valve (GH. reg. no. 6759) illustrated by NAGAO (1934, pl. 32, fig. 8). It was collected from the Hiraiga formation

at Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. 15 specimens (GK. H 6219-GK. H 6225, GK. H 6351-GK. H 6358) from the type area (HANAI and HAYAMI coll.) in addition to the holotype and paratypes are concerned with the description below.

Description.—Shell very small for *Glycymeris*, scarcely exceeding 20 mm. in length, trigonally orbicular, nearly equilateral to fairly inequilateral, prosocline, more or less obliquely expanded, although the obliquity varies considerably; length invariably in excess of height though only slightly so; convexity strong; test comparatively thick; posterior margin obliquely truncated but sometimes as rounded as the anterior one; umbo placed near mid-point of length, incurved, rising prominently above hinge, nearly orthogyrous; surface ornamented with about 25 rounded weak radial ribs, which are almost as wide as interspaces and much weakened on anterior and posterior areas; each rib and interspace marked with 5 to 7 microscopic clean-cut radial threads; postero-central surface usually with a dark triangular speck, which may represent original colour pattern; crenulations, which are about 20 in number and become denser and weaker towards the anterior and posterior ends; ligament area of moderate breadth, occupying about two-fifths of hinge-line, slightly concave, marked with 5 or 6 fine chevron-shaped ligament grooves; hinge plate slightly asymmetrical, broader in posterior part than in anterior, provided with 18-22 teeth occupying nearly its whole surface; smooth band along periphery of hinge plate unusually narrow; teeth elongated subhorizontally on anterior and posterior areas, short and subvertical, though never effaced, on median part; no buttress in front of posterior adductor scar.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left valve (GK.H6219)	13.0	12.5	5.0	1.04
Right valve (GK.H6220)	12.5	12.0	4.5	1.04
Right valve (GK.H6221)	15.5	14.0	5.5	1.11
Right valve (GK.H6352)	16.0	14.0	5.5	1.14
Left valve (GK.H6353)	10.0	9.0	3.5	1.11
Right valve (GK.H6354)	19.0	17.5	7.0	1.08
Right valve (GK.H6222)	13.0	12.0	4.5	1.08
Right valve (GK.H6223)	15.0	14.0	5.0	1.07
Left valve (GK.H6224)	14.5	13.5	5.0	1.07
Left valve (GK.H6225)	15.5	15.0	5.5	1.03
Left valve (GK.H6351)	10.0	9.5	3.5	1.05

Observations and comparisons.—As this subgenus includes no other known species, the specific characters cannot be clearly demarcated from the subgeneric diagnosis.

The variation in shell outline seems greater than in living glycymerid species. Most specimens are more or less inequilateral and it is just possible to say which is the posterior margin, but several are nearly equilateral and it is rather difficult to determine whether they are right or left valves. The prominence of secondary radial threads is also variable, but this may partly due to

differences in the state of preservation and to erosion before fossilization.

In every specimen collected from the calcareous sandstones at loc. Hn. 0017, 0018, 6203, etc. near Hiraiga, a large dark grey (or brown) triangular speck exists on the surface. It is somewhat variable in size, but usually occupies about one-third of the whole surface and invariably appears on the postero-central part. The umbonal, ventral and anterior parts are always whitish and free from coloration. In view of the fact that the colour patterns of some gastropods are well preserved at these localities, the specks on these specimens are presumed to be essentially related to the original colour of the shells. It is known that the exterior and interior of some Recent glycymerids, especially of the subgenus *Veletuceta*, are different in colour. The specks on the present specimens may be connected with such a peculiar character of the glycymerids.

As stated by NAGAO (1934), the species now under discussion resembles *Glycymeris hokkaidoensis* (YABE and NAGAO, 1928) from the Middle Yezo group of Hokkaido in the nature of its surface ornamentation. Though the hinge of *G. hokkaidoensis* is not as yet described, it may be related to this species. However, the dimensions are much smaller, the convexity slightly weaker and the general outline is more triangular in *G. densilineata*. *Glycymeris amakesensis* NAGAO, 1930, from the Himenoura group of west Kyushu (including var. *solida* from the Gosyonoura group) is another well-known Cretaceous species. *G. densilineata* is clearly distinguishable from *G. amakusensis* in its smaller dimensions, coarser ventral crenulations and more triangular outline. Moreover, the slightly posterior position of the umbo, the strong convexity, stout and curved teeth and the surface ornamentation suggest that *G. amakusensis* is a member of the subgenus *Glycymerita*.

Glycymeris (*Veletuceta*?) *marrotiana* (D'ORBIGNY) from the Senonian of France resembles *G. densilineata* in outline, but differs in its larger size, less prominent umbo and less elongated teeth on both lateral areas. *Glycymeris marullensis* (LEYMERIE) from the Neocomian of France (D'ORBIGNY, 1844) may be the oldest representative of the Glycymerididae. It is probably not closely related to the present species, since its umbo is not prominent and its radial ornamentation is quite different.

Occurrence.—Lower and upper Miyakoan (Aptian to Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0010, 0017, 0018, southern coast of Hiraiga, at loc. Hn. 0914, 0916, north of Haipe, and at loc. Hn. 1903, south of Haipe, Tanohata village, Shimohei County, Iwate Prefecture. Calcareous sandstone of the 2nd cycle of the Miyako group at loc. Hn. 4053, Oshima island off the coast of Moshi, Iwaizumi town, the same county. Calcareous sandstone of the Aketo formation at loc. Hn. 6201 and fine sandy shale of the "*Orbitolina* sandstone" at loc. Hn. 6203, northeast of Raga, Tanohata village. Dirty mudstone and fine sandstone of the 1st cycle of the Miyako group at loc. Hn. 2065, Hideshima of Sakiyama, Miyako City, Iwate Prefecture. A similar form is also found in the Nigyu formation in the Mikame area of Ehime Prefecture (NAGAI and NAKANO coll.).

Subgenus *Glycymerita* FINLAY and MARWICK, 1937

Type-species. — *Glycymerita concava* MARSHALL, 1917, Wangaloan (Danian), New Zealand (original designation).

Glycymeris (*Glycymerita* ?) *haipensis* sp. nov.
Plate 29, Figures 16, 17

Material.—The holotype is a left valve (GK. H 6226) collected from the Hiraiga formation at loc. Hn. 0914, north of Haipe, Tanohata village, Shimohei Country, Iwate Prefecture (HAYAMI coll.). Paratype (GK. H 6227) from the same area (HAYAMI coll.).

Description.—Shell small, roundly subtrapezoidal, slightly inequilateral, longer than high; convexity comparatively weak; test of moderate thickness; anterior margin rounded, posterior margin obliquely truncated; umbo placed submesially or slightly posteriorly to mid-point of hinge-line, not prominent; hinge-line fairly olng, occupying nearly three-fifths of shell length; radial ornamentation comparatively weak; ventral margin serrated internally by about 30 crenulations which become weaker and denser towards its ends; ligament area long, narrow, slightly concave, provided with several densely spaced chevrons; hinge-plate wide, with wide smooth marginal area; teeth asymmetrically disposed, with gradually changing inclination, about 20 in number, elongated subhorizontally and sometimes with slightly hooked extrimities at each end of hinge plate but small and subvertical on its middle part.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6226) left valve	19.5	17.0	6.0	1.15
Paratype (GK.H6227) right? valve	20.5	17.5	?	1.17

Observations and comparisons.—Only two specimens are available. Their surface ornamentation cannot be observed in detail, but they evidently differ from specimens of the preceding species from the same localities in the following characters: the size is slightly larger, the flattened marginal area around the hinge teeth much broader, the hinge-line longer and the general outline more quadrate than in all the specimens of *Glycymeris* (*Hanaia*) *densilineata.* The hinge structure of the present species is more similar to that of the type-species of *Glycymerita* than of *Glycymeris* (*s. str.*) or of any other subgenus.

If the outline of the shell is compared with that of various species of *Glycymerita,* however, it is seen to be somewhat different. Although a shouldered and quadrate outline is common in the subgenus, the weak convexity, transverse elongation and oblique posterior truncation are reminiscent of some genera of the Cucullaeidae, such as *Dicranodonta* WOODS, 1899 (type-species: *Cucullaea donningtonensis* KEEPING, 1883) from the Aptian of England and *Arcullaea* VOKES, 1946 (type-species: *A. olea* VOKES, 1946) from the Aptian of Lebanon. The former, however, has more elongated side teeth and a more prominent umbo, while the latter has a posterior carination and a smooth

ventral margin. Ventral crenulations are known in *Dicranodonta,* in *Cucullona* FINLAY and MARWICK, 1937, and in a few other groups of the Cucullaeidae*, but the absence of a posterior carina and the dentition suggest that the present species belongs to a certain primitive group of the Glycymerididae. NICOL (1950) discussed the origin of the Glycymerididae, concluding that the ancestor of the family may have belonged to the genus *Idonearca* CONRAD, 1862, of the Cucullaeidae. Although no morphological resemblance between the present species and *Idonearca* is apparent, the outline and dentition of the former may suggest some affinity with the Cucullaeidae.

Glycymeris haipensis appears at first sight similar to *Glycymeris marullensis* (LEYMERIE, 1842) (D'ORBIGNY, 1846; WOODS, 1899) from the Neocomian of Europe on account of its transversely elongated outline and comparatively weak convexity, but its hinge-line is probably still longer than in that species, the teeth more numerous and the posterior truncation more distinct. NICOL (1950) referred *G. marullensis* to subgenus *Glycymerita,* but it seems probable that *G. marullensis* and the present species would be ultimately separated subgenerically from typical Upper Cretaceous species of *Glycymerita.*

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0914, north of Haipe, Tanohata village, Shimohei County, Iwate Prefecture. Calcareous sandstone of the 2nd cycle sediments of the Miyako group at loc. Hn. 4051, Oshima island, off the coast of Moshi, Iwaizumi town, the same county.

Order Isofilibranchida

Superfamily Mytilacea

Family Mytilidae

Genus *Modiolus* LAMARCK, 1799

(=*Volsella* SCOPOLI, 1777, by Opinion 325 of the International Commission of Zoological Nomenclature; *Modiola* LAMARCK, 1801)

Type-species.—*Mytilus modiolus* LINNAEUS, 1758, Recent, northern Atlantic (tautonymy).

Modiolus falcatus AMANO

Plate 30, Figures 1, 2

1957. *Modiolus falcatus* AMANO, *Kumamoto Jour. Sci.*, Ser. B, Sec. 1, Vol. 2, No. 2, p. 91, pl. 2, figs. 3-8.

Material.—The holotype is a left internal mould (GT. KML-0058), illustrated by AMANO (1957a, pl. 2, fig. 4). Collected from the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture. The following

* *Dicranodonta dowlingi* MCLEARN, 1919, from the Albian of Alberta and northern Alaska (MCLEARN, 1945; IMLAY, 1961), is said to have smooth inner ventral margin, but the species appears to belong to an uunamed genus of (?) the Cucullaeidae.

description is based on a specimen (GK. H 6228) from the Miyako area (HAYAMI coll.) and a specimen (GK. H 6589) from the Arita area (MATSUMOTO coll.) in addition to the holotype and paratypes.

Description.—Shell small, mytiliform, elongated postero-ventrally, slightly curved, strongly inflated, much longer than high; hinge-line moderate in length, passing gradually into posterior margin; anterior margin broadly concave; a sharp diagonal carina, which coincides with the line of maximum convexity, defining a moderate-sized anterior bulge; umbo not terminal, not prominent; surface smooth except for weak growth-lamellae; hinge probably edentulous; no umbonal septum.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right in. mould (GK.H6228)	23.5	16.5	6.0	1.42
Both valve (GK.H6589)	25.5	16.0	11.0	1.59

Observations and comparisons.—Two specimens are available for study in addition to six specimens studies by AMANO (1957a). One is a comparatively well preserved bivalved specimen from the Arita formation. The other is an imperfectly preserved specimen consisting of internal and external moulds of a right valve from the Miyako group. The anterior bulge and absence of radial ornament and umbonal septum suggest that these specimens belong to *Modiolus* (*s. l.*). *Cuneolus* STEPHENSON, 1941, which according to VAN DE POEL (1959) includes several so-called species of *Dreissena* such as "*D.*" *lanceolata* (SOWERBY) from England (WOODS, 1900) and Japan (AMANO, 1957), shows a somewhat similarly concave anterior margin and a strong carina, but the anterior bulge is much narrower and the carina is closer to the anterior margin than in the present specimens.

The specific name *falcatus* was formerly used by MÜNSTER *in* GOLDFUSS (1836) for a species of *Mytilus*. But AMANO's name cannot be regarded as a homonym, because *Mytilus falcatus* MÜNSTER has strong divaricated ribs on the surface and has never been referred to *Modiolus*.

Occurrence.—Aritan to Miyakoan (upper Neocomian to Aptian or Albian). Grey sandy shale of the Tanohata formation at loc. Hn. 0220, northern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. Grey sandy shale of the Arita formation at loc. Ys. 103, west of Kumai, Yuasa town, Arita County, Wakayama Prefecture. AMANO reported this species from the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture.

Modiolus sp. aff. *M. subsimplex* D'ORBIGNY

Plate 30, Figure 3

This is represented by an internal mould of closed valves. Shell medium in size, transversely elongated, ensiform, moderately inflated, about three times longer than high (internal mould of closed valves, GK.H 6588, 76.5 mm. long, 27.0 mm. high, 14.5 mm. thick); test probably thin; hinge-line long, passing

gradually into posterior margin; antero-ventral margin nearly straight or a little concave; umbo placed very anteriorly but not terminal; a weak rounded carina extending from umbo to postero-ventral extremity, defining a broad anterior area; surface smooth except for growth-lines; a narrow ridge elongated along dorsal margin; musculature unknown.

This is probably closely related to *Modiolus subsimplex* (D'ORBIGNY, 1843) from the Neocomian and Aptian of France and also from the Neocomian of Argentina (WEAVER, 1931), but the specific identity is not concluded here, because the ratio of length/height is slightly larger in the present specimen than in typical European specimens of *M. subsimplex*. It may remind one of *Inoperna* CONRAD, 1875, but characteristic ornamentation of *Inoperna*-type is absent on the dorsal half of shell. *Modiolus siliquus* MATHERON (D'ORBIGNY, 1844; FRENEIX, 1959) from the Cenomanian of France is also somewhat similar, but the umbo appears to be located more anteriorly in that species. *Amygdalum ishidoense* (YABE and NAGAO, 1926) from the Ishido formation and the Miyako group is different from this in the absence of carina and in the more cylindrical outline.

Occurrence.—Aritan (upper Neocomian). Fine sandy shale of the Arita formation at loc. Ys.103, west of Kumai, Yuasa town, Arita County, Wakayama Prefecture (Matsumoto coll.).

Genus *Amygdalum* MEGERLE VON MÜHLFELD, 1811

Type-species.—*Amygdalum dendriticum* MEGERLE VON MÜHLFELD, 1811, Recent (monotypy).

Amygdalum ishidoense (YABE and NAGAO)

Plate 30, Figures 4–10

1926. *Modiola? ishidoensis* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 63, pl. 13, fig. 42.

? 1934, *Gervillia?* sp., NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 201, pl. 24, fig. 2.

Material.—The holotype by monotypy is a right valve (IGPS, reg. no. 8570) illustrated by YABE, NAGAO and SHIMIZU (1926, pl. 13, fig. 42). It was collected from the Ishido formation at Ishido, Ohinata village, Minami-saku County, Nagano Prefecture. Seven specimens (GK.H 6229-GK.H 6232, GK.H 6359-GK. H 6361) from the Miyako area (HANAI and HAYAMI coll.) are concerned with the description below in addition to the holotype.

Description.—Shell of medium size, elongate-oval, with unusually small obliquity, slightly expanded posteriorly, about 2.5 times longer than high, cylindrically inflated, never carinated; test very thin, somewhat transparent; hinge straight, long, occupying about two-thirds of the shell length; ventral margin straight, long, a little prosocline to hinge; anterior extremity weakly angulated, posterior margin smoothly rounded; umbo not prominent, placed very anteriorly but not terminal; anterior lobe absent; hinge edentulous; a

faint elongated internal ridge runs along hinge-margin; surface shiny, quite smooth except for faint growth-lines.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK.H6229)	31.5	12.5	4.0	2.52
Right valve (GK.H6230)	39.0	15.0	5.0	2.60
Left in. mould (GK.H6231)	37.5	14.5	5.0	2.59
Left valve (GK.H6232)	38.0	15.5	5.0	2.45
Right valve (GK.H6359)	32.5	13.0	4.0	2.50
Right valve (GK.H6360)	20.5	8.0	2.5	2.56
Right valve (GK.H6361)	31.0	11.5	3.5	2.70

Observations and comparisons.—Many specimens are available for study. The test is very thin and apt to be exfoliated, but the shiny surface is observable in some specimens (GK.H6229, GK.H6359). The specimens are commonly characterized by the straight outline, cylindrical inflation and absence of carina. They are fairly uniform in outline, with the ratio of length/height almost invariably from 2.50 to 2.60. They are probably conspecific with the holotype of *Modiola? ishidoensis* YABE and NAGAO, 1926, from the Sanchu area. The latter is rather ill-preserved, but its outline and smooth surface, as described and illusrated by YABE and NAGAO, are identical with those of the present specimens.

Many ensiform species of "*Modiolus*" from the Jurassic and Lower Cretaceous belong to *Inoperna* CONRAD, 1875 (type-species: *I. carolinensis* CONRAD) (=*Pharomytilus* ROLLIER, 1914), but they have a distinct diagonal carina and characteristic subconcentric wrinkles on the postero-dorsal surface. Some Liassic species such as *Modiolus sculptus,* which are generally considered as ancestral to *Inoperna* (COX, 1940, etc.), resemble this species in the straightly elongated outline and smooth surface, but they have a weak carina.

On the other hand, *Amygdalum,* which is represented by a few Recent species, has a similarly cylindrical and not carinated outline and a shiny surface, and the present species seems to be its earliest known member. Some Japanese malacologists have regarded *Amygdalum* as a subgenus of *Brachidontes* SWAINSON, 1840, overlooking the priority of the former. The subgenus *Arcuatula* LAMY, 1919 (type-species: *Modiolus arcuatula* HANLEY), included in *Brachidontes,* often shows a similar outline, but there are distinct radial ribs on the postero-dorsal surface of normal species of *Arcuatula* and *Brachidontes* (*s.s.*). I am here treating *Amygdalum* as a distinct genus.

Specifically *Amygdalum ishidoense* is quite similar to *Modiolus rectior* WOLLEMANN, 1896, from the Hilsconglomerat (approximately upper Neocomian, according to BRINKMANN, 1959) of Germany in the cylindrically inflated and not carinated outline. The former has, however, a slightly longer hinge-line and somewhat larger ratio of length/height than the latter (as understood from the original figure). I presume that *M. rectior* also belongs to *Amygdalum. Modiolus* (*Volsella*) *onoensis* ANDERSON, 1938, from the lowest part of the

Horsetown group (Valanginian or Hauterivian) of California, may be also congeneric, but that species has more expanded posterior part and smaller ratio of length/height.

Occurrence.—Aritan and lower Miyakoan (upper Neocomian to Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. YABE, NAGAO and SHIMIZU (1926) reported this species from the Ishido formation at Ishido, Ohinata village, Minami-saku County, Nagano Prefecture, where a fragmentary specimen resembling this species was recently collected. Furthermore, NAGAO (1934) reported a similar specimen from the "*Orbitolina* sandstone" at Raga, Tanohata village as "*Gervillia* (?) sp."

Genus *Lecompteus* VAN DE POEL, 1959

Type-species.—*Mytilus ornatus* MÜNSTER *in* GOLDFUSS, 1836, Upper Cretaceous, Germany (original designation).

Lecompteus sp. cf. *L. guerangeri* (D'ORBIGNY)

Plate 30, Figures 11-12

Compare.—

1844. *Mytilus guerangeri* D'ORBIGNY, Pal. franç., Terrain crétacé, Vol. 3, p. 282, pl. 342, figs. 7-9.
1862. *Brachidontes guerangeri*, CHENU, Manuel de Conchyl., Vol. 2, p. 154, fig. 762.
1900. *Modiola* (*Brachidontes*) *guerangeri*?, WOODS, Monogr. Cret. Lamell. England, p. 101, pl. 17, figs. 4, 5.
1959. *Lecompteus guerangeri*, VAN DE POEL, *Bull. Inst. roy. Sci. nat. Belgique*, Tom, 35, No. 15, p. 20.

Material.—This species is represented by two specimens from the Miyako area (GK. H 6233, GK. H.6234) (HAYAMI coll.).

Description.—Shell small or medium-sized, subtrigonal, obliquely elongated, well inflated, longer tha nhigh; test of moderate thickness; anterior margin long, nearly straight or slightly concave, angulated at junction with postero-dorsal margin; umbo nearly terminal; a rounded carina runs from umbo to antero-ventral extremity, clearly defining a steep crescentic anterior slope; posterior surface ornamented with characteristic divaricating ribs which are somewhat weakened near ventral margin; anterior area with numerous weaker riblets which are subvertical to growth-lines; growth-lines very irregularly spaced and slightly imbricated; internal characters unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left valve (GK.H6233)	31.0	25.5	6.5	1.22
Right valve (GK.H6234)	20.5+	16.0	4.0	1.28+

Observations and comparisons.—The left valve (GK. H. 6233) shows the general outline and the right valve (GK. H 6234) reveals the characteristic

ornamentation. Although the material is insufficient to allow the external and internal characters to be examined in detail, this form is specifically comparable with *Mytilus guerangeri* D'ORBIGNY, 1844, from the "Cenomanian" of Europe. It is quite similar to WOODS' figures (1900) of *M. guerangeri*?, from the Upper Greensand of England, in the diagonal carination, antero-ventral angulation, divaricating costae and slightly imbricated growth-lamellae, although it has a slightly obliquely elongated outline. WOODS' specimens are probably identical with D'ORBIGNY's, and the present specimens are tentatively compared with *M. guerangeri*.

FRENEIX (1959, p. 197) and some other authors have referred such ornamented mytilids to *Brachidontes*, but VAN DE POEL (1959) has proposed a genus *Lecompteus* and included *M. guerangeri* in it, calling attention to the characteristic ornamentation. A similar ornamentation exists also in the type-species, *Mytilus exustus* LINNAEUS, and certain other species of *Hormomya* MÖRCH, 1853 of Cenozoic age. Therefore, *Lecompteus* is probably more closely related to that genus than to *Brachidontes*. Although there may be a room for further study of the relationship between *Hormomya* and *Lecompteus*, I accept here the latter as a distinct genus to which the present species belongs, because typical *Hormomya* possesses small umbonal teeth which are unknown in the Cretaceous species.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the 2nd cycle of the Miyako group at loc. Hn. 4053, Oshima island, off the coast of Moshi, Iwaizumi town, Shimohei County, Iwate Prefecture.

Genus *Mytilus* LINNAEUS, 1758

Type-species.—*Mytilus edulis* LINNAEUS, 1758, Recent, cosmopolitan (designated by ANTON, 1839).

Mytilus (?) sp. indet.

Plate 30, Figure 23

Only an incomplete right valve (GK. H 6624, 30.0 mm. long, 16.0 mm. high, 5.0 mm. thick) is available for study. The test is well preserved in the postero-ventral part but is exfoliated in the umbonal region. The shell is very obliquely elongated with nearly straight anterior and posterior margins which are subparallel to each other. The apical angle is about 30 degrees, although the umbonal area is fairly rounded. The outline and the absence of anterior lobe indicate that it is a *Mytilus*, but there is a certain possibility that it belongs to *Mytilisepta* HABE, 1951, which can be considered as a subgenus of *Septifer* RECLUZ, 1848. The presence or absence of an umbonal septum cannot be, however, ascertained in the present specimen. Its generic and specific identification is deferred until better material is procured.

Occurence.—Lower Miyakoan (Aptian). Calcareous sandstone of the 2nd cycle of the Miyako group at Loc. Hn. 4053, Oshima island, off the coast of Moshi, Iwaizumi town, Shimohei County, Iwate Prefecture (HAYAMI coll.).

Order Pteroconchida

Superfamily Pteriacea

Family Pteriidae

Subfamily Pterinellinae, nov.

Diagnosis.—A subgroup of the pteriids having numerous oblique pseudotaxodont denticles and multivincular triangular ligament pits which are composed of one large main median pit and several small supplementary pits in both anterior and posterior directions on the elongated ligament area.

Remarks.—This subfamily is represented at present only by one genus *Pterinella* TOULA, 1882. The ligament structure is the most diagnostic character of this subfamily, but it is unfortunately imperfectly known in the type-species, i.e. *Pterinella petersi* TOULA, 1882. In the syntypes of *P. petersi* the anterior wing is broken, and the presence of anterior supplementary pits cannot be ascertained. The present diagnoses of the Pterinellinae and the genus *Pterinella* are based in part on *P. shinoharai* sp. nov., many specimens of which reveal ligament and hinge structure.

In the ligament structure this subfamily is quite different from any other group of the Pteriacea.

It may be at a glance a reminder of the structure of the Bakevelliidae and the Isognomonidae, since most pterioids with multivincular ligament pits are referable to the two families. Pseudotaxodont denticles are also known in a number of species of the Bakevelliidae. This subfamily is, however, clearly distinguishable from any groups of the Bakevelliidae in the following essential characters:

1) Every species of the Bakevelliidae possesses a series of ligament pits, which are added successively at the posterior end of the ligament area during growth. A new term "equivincular" is proposed here for such ligament strctreu. In the present subfamily, on the contrary, the multivinciular pits are composed of one main medium pit and a number of successively added smaller supplementary pits on the anterior and posterior parts of the elongated ligament area. Another new term "inequivincular" is proposed for this structure.

2) In the Bakevelliidae, the first initial pit is subequal to or more commonly rather smaller than subsequent pits, and all the pits are acline of slightly prosocline. In *Pterinella,* however, the initial pit grows much larger than other pits, and anteriorly added pits have more or less opisthocline apices.

3) In Permian and some Triassic species of the Bakevelliidae, ligament pits are usually triangular in outline, but they are subquadrate or subcircular in the adult specimens of Jurassic and Cretaceous species. On the contrary, all the pits of *Pterinella* are triangular throughout the growth.

4) The dorsal margin of the ligament area is nearly straight in the adult specimens of the Bakevelliidae, whereas it forms an obtuse chevron in

Pterinella as usually so in the Pteriidae.

5) The anterior and posterior wings of *Pterinella* are much longer than those of the Bakevelliidae, being analogous to those of *Malleus* of the Isognomonidae.

6) In most species of the Bakevelliidae the pseudotaxodont denticles are differentiated into anterior and posterior series, but the denticles are completely continuous in *Pterinella*.

Gervillaria COX, 1954 (type-species: *Modiola? alaeformis* SOWERBY, 1819) flourished world-widely in the early Cretaceous. The radial ornamentation (especially in the immature shells) and pseudotaxodont denticles are somewhat similar to those of *Pterinella*, but the ligament structure of *Gervillaria* is equivincular and typical of the Bakevelliidae. Incidentally, the left valve is much more strongly inflated and the both wings are not much developed in *Gervillaria*. The apparent resemblance between *Pterinella* and *Gervillaria* should be taken as a case of homoemorphism.

Aguileria WHITE, 1887 (type-species: *Aguileria cumminsi* WHITE, 1887) from the Cenomanian of Gulf Coast and *Bakevelloides* TOKUYAMA, 1959 (type-species: *Gervillia hekiensis* KOBAYASHI and ICHIKAWA, 1952) from the Karnian of Japan have also pseudotaxodont denticles and chevron-shaped dorsal margin. The ligament pits are comparatively few for Mesozoic bakevelliids. They are, however, unrelated to *Pterinella* in view of the undeveloped wings, differentiated denticles and the equivincular pits of *Bakevellia*-type.

Panis STEPHENSON, 1953 (type-species: *Panis cuneiformis* STEPHENSON, 1953) from the Cenomanian of Gulf Coast and (?) France resembles *Pterinella* in the shape of "inner byssal channel" on the interior of the anterior wings, not prominent umbo and excavated anterior margin. But the ligament of *Panis* is equivincular and typical of the Bakevelliidae, and the radial ornamentation and pseudotaxodont denticles are unknown in that type-species.

Isognomon mulleti (DESHAYES, 1842) from the Lower Cretaceous of Europe and Argentina, for which FISCHER (1887) introduced a section name *Mulletia*, is a broadly plicated curious species. It has also unusually anterior margin, but protruded posterior wing and excavated anterior margin, but is essentially different from *Pterinella* in the absence of well-defined anteror wing, terminal umbo and strongly plicated surface.

Recent species of *Malleus* LAMARCK, 1799 (type-species: *Ostrea malleus* LINNAEUS, 1758) are somewhat similar to *Pterinella* in the T-shaped outline with extraordinally elongated wings, although the ligament is commonly alivincular and hinge teeth are absent in them. *Pterinella* is, however, anyhow not referrable to the Isognomonidae, because of the pseudotaxodont denticles and the peculiar way of increase of ligament pits.

An inequivincular ligament structure has been known in a few Palaeozoic pectinoids, especially in the genus *Euchondria* MEEK, 1874 (type-species: *Pecten neglectus* GEINITZ, 1866) from the Carboniferous of United States and from the Permian of Australia (DICKINS, 1963). NEWELL (1937-38) studied many

species of *Euchondria* in detail, and proposed a new family Euchondriidae mainly on the basis of their peculiar ligament structure. According to him, *Euchondria* possesses a large central resilifer and a number of minute supplementary resilifers which are successively added at both ends of hinge. It is, however, almost impossible that *Pterinella* had something to do with the Euchondriidae, since such an inequivincular ligament has not been known in Triassic and later pectinoids. As suggested by NEWELL, the Euchondriidae was a small branch derived from the Aviculopectinidae and became extinct by the end of the Permian.

It has been known in some species of the Cassianellidae from the Triassic that a few ligament pits were produced in both directions from the initial pit (ICHIKAWA, 1958, etc.). Pseudotaxodont denticles are commonly seen in *Cassianella* BEYRICH, 1862, and *Hoernesia* LAUBE, 1865, and radial ribs are known in some species of the family. But the umbonal area of the left valve is strongly inflated and internally provided with a characteristic septum, which is absent at all in *Pterinella*. Moreover, the outline of the Cassianellidae is usually very inequivalve, subquadrate and not pteriform. The Cassianellidae has been known only from the Triassic (Skytian to Rhaetian), and no representative of the family can be found in the Hettangian and later. Therefore, *Pterinella* is believed to have been derived from a certain pteriid independently from the Cassianellidae as well as the Bakevelliidae.

The outline of the main body of *Pterinella* is not much different from that of many genera of the Pteriidae. The morphological resemblance between *Pteroperna* and *Pterinella* was pointed out by TOULA (1882) and GILLET (1924a). If the inequivincular ligament structure and unusually long anterior wing are ignored, *Pterinella* is fairly similar to *Pteroperna* MORRIS and LYCETT, 1853 (type-species: *Gervillia costatula* EUDES-DESLONGCHAMPS, 1824) from the Middle and Upper Jurassic. Pseudotaxodont denticles are almost continuous and an obliquely elongated ligament pit, which may correspond to the initial pit of *Pterinella*, is known in typical species of *Pteroperna* (MORRIS and LYCETT, 1853; COX, 1940). Similar radial ribs can be observed on the umbonal area of left valve in many species of that genus. The posterior wing of *Pteroperna* is characteristically marked with a few subhorizontal ridges, which are also observable in the present specimens of *Pterinella shinoharai* sp. nov. For this reason I presume that the subfamily Pterinellinae nov. was derived from the genus *Pteroperna* and should be taxonomically placed in the Pteriidae. But so far known ligament structure of *Pteroperna* is alivincular, and the difference deserves a distinction of subfamily rank.

Multivincular ligament structure has been also known in some species of *Pseudoptera* MEEK, 1873 (type-species: *Avicula anomala* SOWERBY, 1836). *Pseudoptera* was originally proposed as a subgenus of *Pteria* SCOPOLI 1777, but, subsequently, Meek (1876, p. 29) admitted the possibility that it might be a gervillid. The internal structure is unfortunately scarcely known in the type-species from the Upper Greensand of England (WOODS, 1905), but there

are several species of *Pseudoptera* in the Aptian of Lebanon, the Cenomanian of Texas and some other areas, which show their ligament and hinge structure. WOODS (1913, p. 425) pointed out that the presence of multivincular ligament pits in *Pseudoptera* has been noticed by GUÉRANGER (1867, pp. 17, 20, pl. 22, figs. 9, 10; pl. 25, figs. 10, 11) and by PERON (1890-1891, p. 238) and stated that it should be regarded as a subgenus of *Gervillia*. The opinion was supported also by GILLET (1924a, p. 46). VOKES (1946) treated *Pseudoptera* as a distinct genus of the Isognomonidae (=the Isognomonidae plus the Bakevelliidae in the present usage). He pointed out that some American specimens, which are close to *P. anomala*, have multivincular ligament pits. STEPHENSON (1953) described five species of *Pseudoptera* from the cenomanian of Texas, two (*P. hornensis* STEPHENSON, 1953, and *P. viana* STEPHENSON, 1953) of which show three (or more) widely spaced ligament pits. STEPHENSON, however, did not refer *Pseudoptera* to the Isognomonidae but placed it provisionally in the Pteriidae.

I have not as yet observed the ligament structure of *Pseudoptera*, but think that it is equivincular and that there are no anterior supplementary pits in front of the initial pit. The hinge of *Pseudoptera* probably consists of a few anterior and posterior teeth, and not of pseudotaxodont denticles. The anterior wing is not much elongated in all the species of *Pseudoptera*. Therefore, it is certain that *Pterinella* is not intimate to *Pseudoptera*, even if the latter was derived directly from a pteriid and not from a bakevelliid.

CHAVAN (1950, p. 208; 1952, p. 29) described an interesting pterioid from the Upper Jurassic of Calvados, which was named *Hoernesia munieri* (BIGOT MS) CHAVAN, 1950. Its left valve shows pteriform outline and widely spaced radial ribs. It is probably not a *Hoernesia* but may be intimate to *Pseudoptera*. Although the restored outline of the Jurassic species (CHAVAN, 1950, p. 209,

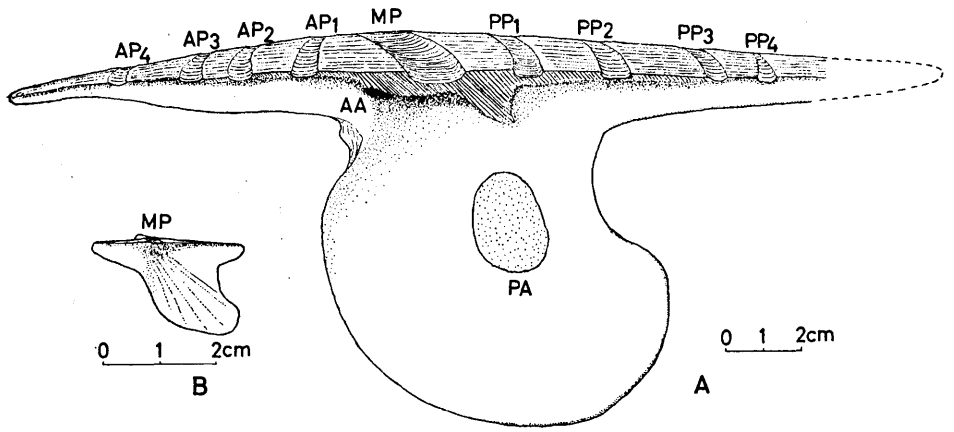

Fig. 2. Interior of the valve of *Pterinella shinoharai* sp. nov. A: adult specimen restored from the holotype (GK.H6235); B: juvenile specimen restored mainly from the paratype (GK.H6616). AA: anterior adductor scar, PA: posterior adductor scar, MP: main (initial) ligament pit, $AP_{1\sim4}$: anterior ligament pits, $PP_{1\sim4}$: posterior ligament pits.

figs. 1,2) resembles that of the immature specimens of *Pterinella shinoharai* sp. nov., the ligament structure appears equivincular and is clearly different from that of *Pterinella*.

Many genera with multivincular ligament pits were undoubtedly derived from alivincular pteriids at many different stages. The resemblance of the ligament structure between *Pterinella* and many genera of the Bakevelliidae, Isognominidae, Cassianellidae and Euchondriidae must be superficial (see Fig. 3).

Genus *Pterinella* TOULA, 1882

Type-species.—*Pterinella petersi* TOULA, 1882, Neocomian, Balkan (monotypy*).

Diagnosis.—Shell large, more or less inequivalve, T-shaped with extraordinarily long hinge-line and elongated wings; left valve more strongly inflated than right; anterior margin deeply excavated, but not widely open; umbo not prominent, not terminal; ligament area triangular with chevron-shaped dorsal margin, occupying whole shell-length, fairly broad in adult stage, horizontally striated, provided with a large prosocline triangular main pit approximately at its mid-length and several smaller supplementary pits in both anterior and posterior directions; hinge provided with numerous oblique pseudotaxodont denticles, which are not differentiated into anterior and posterior series; anterior adductor scar very small, while posterior one is large and subovate; surface of both valves or left valve only marked with radial ribs in juvenile stage, but they become weaker or tend to disappear on ventral area in adult stage.

List of species.—Besides the type-species I refer to this genus the following species:

Pterinella crassitesta TOULA, 1889, from the Aptian of Balkan

Gervillia newcombii WHITEAVES, 1900, from the Lower Cretaceous of Queen Chalotte island.

Pterinella shinoharai sp. nov. from the upper Neocomian and Albian of Japan.

The specimens described by TOULA (1882) as *Pterinella* (?) *crassitesta* and *Pterinella* (?) sp., both from the Neocomian of Balkan, are probably nothing but immature examples of *Pterinella petersi* TOULA.

Pterinella shinoharai sp. nov.

Plate 31, Figures 1-3; Plate 32, Figures 1-6; Plate 33, Figures 1.2; Plate 34, Figures 1, 2; Plate 35, Figures 1, 2

1952. *Bakevellia* (*Aguileria*) *shinoharai* MATSUMOTO and YAMASHITA (MS), in MATSUMOTO and KANMERA, Guide book of the excursion in the lower stream of Kuma river, p. 49, *nom. nud.*

* When TOULA proposed *Pterinella*, he described three species under the generic name: *Pterinella petersi*, *P.* (?) *crassitesta* and *P.* (?) sp. Although he did not designate the type-species, *P. petersi* must be regarded as the type-species by monotype, since other species were referred to *Pterinella* with a query.

1954. *Bakevellia (Aguileria) shinoharai* MATSUMOTO and YAMASHITA (MS), in MATSUMOTO, Cretaceous System, Japan. Islands, pp. 76, 82, 114, *nom. nud.*

Material.—The holotype is a right internal mould (GK. H 6235) collected from the Yatsushiro formation at loc. Hy. 1012, north of Nekodani, Miyaji, Yatsushiro City, Kumamoto Prefecture (AMANO coll.). Three paratypes (GK. H 6148-GK. H 6150) from the Yatsushiro area (KANMERA coll.) and eleven paratypes (GK. H 6362, GK. H 6609-GK. H 6616, GK. H 6382, GK. H 6383) from the Katsuuragawa area (HAYAMI coll.).

Description.—Shell very large for the Pteriidae, inequivalve, pteriform

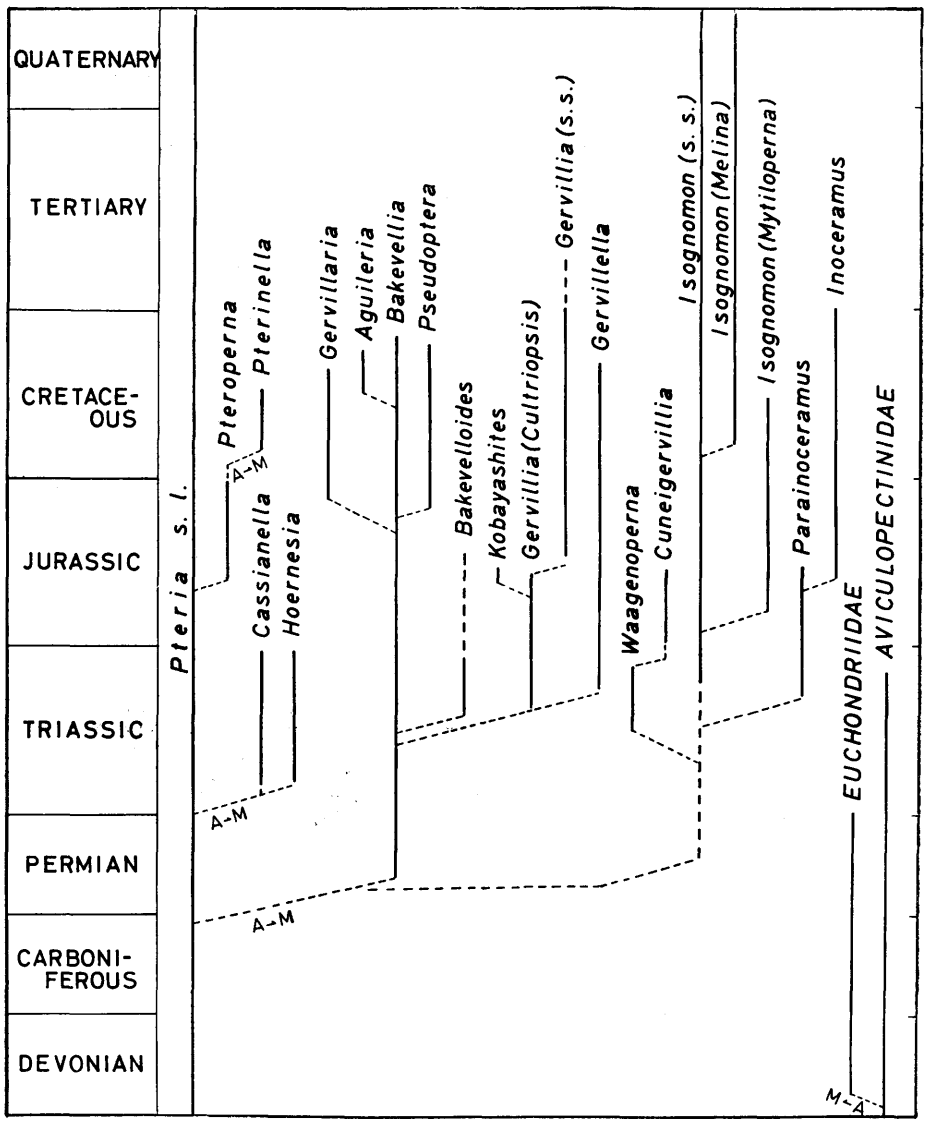

Fig. 3. Evolution of pelecypods with multivincular ligament structure

with an unusually long hinge-line and well-developed wings, highly inequilateral, much longer than high; test of moderate thickness; left valve and umbonal region of right valve convex, while ventral region of right valve is nearly flat or even slightly concave; anterior wing narrow with sharply pointed extremity, about 4 times longer than high in mature stage, but less elongated in immature stage, separated by a shallow sulcus from body of shell; posterior wing also elongated, gradually tapering to its extremity, clearly demarcated; anterior margin deeply excavated below anterior wing; byssal gape, if present, very narrow; posterior margin with a broad and profound sinuation; shell-obliquity, which is measured by the angle between hinge-line and line from umbo to the most distant point on ventral margin 45 to 55 degrees; umbo not prominent, comparatively narrow, scarcely rising above hinge-line; hinge provided with numerous pseudotaxodont denticles, which form angles of 45-55 degrees with hinge-line and are not differentiated into anterior and posterior series; denticles distribute also on both wings, though they are much shorter than on the body of shell; ligament area elongated along whole dorsal margin, with chevron-shaped dorsal margin, marked with numerous horizontal striae, and in mature stage provided with as many as 9 triangular pits; initial pit large, obliquely elongated from umbonal area; in holotype 4 small opisthocline pits exist on anterior wing, while pits placed on shell body and posterior wing are strongly prosocline and are elongated subparallel to the pseudotaxodont denticles; pits generally much narrower than interspaces; anterior adductor scar very small but strongly impressed on interior of umbonal area; posterior adductor scar large, elliptical, placed slightly posteriorly to mid-point of shell-body; pallial line obscure, though its anterior part is indicated by a series of minute scars; surface of shell-body ornamented with about 25 or rather more radial riblets and numerous sinuous concentric striae, though radials seem weaker in right valve and on ventral peripheral part of left valve; posterior wing marked with about 30 finer radial threads and non-sinuous concentric striae.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6235) right in. mould	217.0	68.5+	—	3.17−
Paratype (GK.H6148) right ex. mould	139.5+	124.5	8.5+	?
Paratype (GK.H6149) left in. mould	50.0+	55.0	9.0	?
Paratype (GK.H6150) left in. mould	74.5+	70.0+	8.0	?
Paratype (GK.H6609) left in. mould	131.5	92.0	ca. 13.0	1.43
Paratype (GK.H6610) left valve	97.0+	107.0	ca. 16.5	?
Paratype (GK.H6611) left valve	98.0+	91.0	ca. 10.0	?
Paratype (GK.H6612) right ex. mould	129.0+	101.0	—	?
Paratype (GK.H6613) left in. mould	48.0+	51.5+	ca. 9.0	?
Paratype (GK.H6614) left valve	59.0	45.0	ca. 7.5	1.31
Paratype (GK.H6615) right valve	89.5+	90.0+	—	?
Paratype (GK.H6616) right in. mould	23.0	16.0	ca. 3.5	1.44

Observations and comparisons.—All the available specimens are more or less incomplete. The holotype (GK. H 6235) is fairly well preserved and exhibits

the characteristic ligament, hinge and musculature of an adult right valve, although its ventral and posterior peripheral parts are broken. The paratype (GK. H 6148) is bivalved, but the two valves are much dislocated. The ligament area of the left valve and the exterior of the right valve (anterior part) are impressed on a slab. It is probably a gerontic individual, and the radial ornamentation, which is clearly seen on the umbonal area, is almost effaced near the ventral periphery. Another paratype (GK. H 6149) appears to represent the neanic stage. The characteristic denticles and musculature are observable in this specimen, but the ligament area is proportionally much thinner than in the larger specimens. Another paratype (GK. H 6616) is a juvenile specimen, showing not much elongated wings and *Pteroperna*-like outline.

The ontogenic changes of this species may be summarized as follows:

1) The shell convexity remains almost constant during the growth of the left valve, but the right valve is nearly flat or even slightly concave after the nepionic stage. Consequently the shell is subequivalve in the young stage but becomes more inequivalve in the adult.

2) The outline of this species is fairly similar to that of *Pteroperna* in the juvenile stage, but in the full-grown shell it becomes rather similar to that of *Malleus* owing to the curious and rapid elongation of both wings.

3) Radial ornament is distinct in the nepionic stage of the left valve, but in gerontic valve it is confined to the umbonal region.

Pterinella petersi TOULA, 1882, from the Neocomian of Balkan, has very similar pseudotaxodont denticles and general outline, but the body of shell is narrower than that of this species. The initial pit of *P. petersi* is probably larger than that of *P. shinoharai*. *Pterinella* (?) *crassitesta* and *P.* (?) sp. in TOULA (1882) are seemingly juvenile specimens of *P. petersi*. The juvenile specimens of *P. shinoharai* are similar to them in the outline, but the radial ornament is more delicate in the Japanese species. *Gervillia newcombii* WHITEAVES, 1900, which is to be assigned to *Pterinella*, is related to the present species, but they are distinguished in that the anterior margin is more deeply concave and the shell is more strongly oblique in the latter than in the former.

Occurrence.—Aritan and upper Miyakoan (upper Neocomian and Albian). Dark grey fine sandstone of the Yatsushiro formation at loc. Hy. 1012, north of Nekodani, Miyaji, Yatsushiro City, at loc. Km. 3037, west of Mt. Jôgûsan, Miyaji, and at loc. Km. 1843, north of Shimofukami, Sakamoto town, Yatsushiro County, Kumamoto Prefecture. Dark grey sandy shale of the Hanoura formation at loc. Hy. 5002 and loc. Hy. 5004, Hiroyasu, Katsuura town, Katsuura County, Tokushima Prefecture. Fine grey sandstone of the Arita formation at Ys. 329a, north of Oura, Minamihiro village, Arita County, Wakayama Prefecture (MATSUMOTO coll.)

Family Bakevelliidae

Genus *Gervillaria* COX, 1954

Type-species.—*Modiola? alaeformis* SOWERBY, 1819, Lower Cretaceous, western Europe, South Africa and Argentina (original designation).

Gervillaria haradae (YOKOYAMA)

Plate 35, Figures 3-6; Plate 36, Figure 1; Plate 37, Figure 2

1890. *Avicula haradae* YOKOYAMA, *Palaeontographica*, Vol. 36, p. 199, pl. 25, figs. 12a, b.

1926. *Gervillia haradae*, YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 58, pl. 13, figs. 1-3, 7, pl. 14, fig. 2.

1926. *Gervillia haradae*, YABE and NAGAO, *Chikyu*, Vol. 5, pp. 433, 436, pl. 9, figs. 1-3.

1934. *Gervillia* cf. *haradae* YOKOYAMA, NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 199, pl. 31, fig. 13.

? 1957. *Bakevellia* sp., AMANO, *Kumamoto Jour. Sci.*, Ser. B, Sec. 1, Vol. 2, No. 2, p. 86, pl. 1, figs. 14, 15.

1963. *Gervillaria haradae*, HAYAMI *in* MATSUMOTO, A survey of the fossils from Japan illustrated in classical monographs, p. 32, pl. 51, figs. 12a, b.

Material.—The lectotype is an immature left (erroneously noted as "right" by YOKOYAMA) valve illustrated by YOKOYAMA (1890, pl. 25, figs. 12a, b). It was designated and the figure was reproduced by HAYAMI *in* MATSUMOTO (1963, ed., p. 32, pl. 51, figs. 12a, b). The specimen is said to have come from the Cretaceous deposits near Kagahara and presumably its type occurrence was the Ishido formation of Sebayashi, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture, where this species is rather commonly found. Five specimens (GK. H 6154-GK. H 6158) from the Yatsushiro area (AKATSU coll.), a specimen (GK. H 6236) from the same area (HAYAMI coll.), two specimens (GK. H 6625, GK. H 6627) from the Sanchu area (ICHIKAWA and HAYAMI coll.) and two specimens (GK. H 6626, GK. H 6237) from the Miyako area (HAYAMI coll.) are concerned with the description below.

Description.—Shell very large for a bakevelliid, very inequivalve, subtrigonal in outline, slightly higher than long; test moderately thick, with hinge area much thickened in adult shell. Left valve strongly inflated, pteriform with well-defined wings; umbo strongly prosogyrous, subterminal, rising a little above hinge-line; hinge fairly long, straight, occupying whole shell-length; byssal gape, if present, very narrow; anterior wing comparatively small, pointed forwards; posterior wing compressed, triangular, nearly as wide as shell-body, truncated acutely or subvertically, clearly delimited from shell-body by an angular depression; shell-body comparatively narrow, elongated subvertically, mytiliform, somewhat weakly carinate where it joints posterior wing; shell-obliquity about 70 degrees in adult but somewhat smaller in immature shell; ligament area attaining a considerable breadth in adult shell, horizontally striated, provided with more than six slightly prosocline subquadrangular pits, which are almost as wide as their interspaces; anterior teeth short, six or more in number, obliquely placed near umbo, forming an angle of about 45 degrees; posterior tooth usually single, elongated, forming an angle of 10-20

degrees with hinge-line; surface of shell-body and posterior wing (especially in immature shell) ornamented with numerous fine radial ribs of unequal strength at irregular intervals besides numerous faint concentric lamellae. Right valve subtrigonal, less inflated with umbo not protruding above hinge-line; anterior and posterior margins slightly concave; anterior wing small, pointed; posterior wing not well differentiated from shell-body; hinge with a few short anterior teeth and two elongated posterior ones; surface smooth except for growth-lamellae; other characters similar to those of left valve.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left valve (GK.H6154)	86.5	105.5	25.5	0.82
Left in. mould (GK.H6155)	70.5+	80.0	19.5	0.88+
Left in. mould (GK.H6156)	57.0	48.5+	15.0	?
Left ex. mould (GK.H6157)	45.0	33.5+	12.0	?
Left valve (GK.H6236)	74.5	78.0+	24.0	0.95−
Left valve (GK.H6237)	23.5	20.5+	6.5	1.15−
Right in. mould (GK.H6158)	50.5	55.5	8.0	?

Observations and comparisons.—The material studied consists of many external and internal moulds of left valves and a few moulds of right valves. The test is preserved only in three left valves, the measurements of which are recorded above. One of the left valves (GK. H 6236) is the best preserved and shows the characteristic outline and ornamentation of this species, although the shell-convexity may be slightly emphasized by secondary deformation. In this and other larger specimens radial ribs are seen only on the umbonal area and on the anterior part of the posterior wing. A small specimen from the Miyako group (GK. H 6237) is more oblique and has a rather larger ratio of length/height, a more pteriform outline due to its comparatively large anterior wing and more prominent radial ribs than the larger ones. The carina on the posterior side of the shell-body is weakly developed on some specimens but may be almost imperceptible on others.

Although I have had no opportunity to study the lectotype, which should be in Munich, it is probably an immature left valve, because its size is very small and the radial ribs are strong and persist to the ventral margin.

Possibly the present species could be divided into at least three geographical subspecies. On the average a group of specimens from the Yatsushiro formation has a slightly greater shell-convexity and usually less developed anterior wing than that of typical specimens from the Ishido formation. Several specimens from the Hiraiga formation of the Miyako group, which are undoubtedly identical with *Gervillia* cf. *haradae* in NAGAO (1934), have somewhat weaker convexity and a more rounded end of their anterior wing.

As pointed out by YABE, NAGAO and SHIMIZU (1926), this species is closely related to *Gervillia alaeformis* (SOWERBY, 1819) in WOODS (1905), for which COX (1954) proposed the genus *Gervillaria*. The changes in ontogeny indicated in WOODS' figures seem to agree well with those observable in the present species.

COX (1954, p. 49) defined the generic characters of *Gervillaria*, with which the present species agrees well in many respects. It is, however, specifically distinguishable from *G. alaeformis*, because it has more conspicuous radial ribs, broader and more acutely pointed posterior wing and a less oblique adult shell than that species. Incidentally, the posterior wing is obtuse in the adult specimens of *G. alaeformis* and its posterior margin forms an angle exceeding 110 degrees with the hinge margin.

Gervillaria alaeformis and species allied to it are widely distributed in and outside western Europe. *G. alaeformis*, from the Lower Cretaceous of Argentina (WEAVER, 1931), and *G. alatior* (IMLAY, 1940) from the Neocomian of Mexico, are clearly referable to *Gervillaria*, and resemble the species now described in their posterior outline, which is truncated more acutely than in typical *G. alaeformis* from western Europe as figured by WOODS (1905). The radial ornament, however, is more widely spaced and more persistent on the main shell-body in the two American species than in the present species. *Bakevellia* sp. described by AMANO (1957a) from the Aptian Hagino formation of the Monobegawa area of Shikoku may be conspecific with *G. haradae*. One of his specimens (pl. 1, fig. 14) looks as if it had an obtuse posterior wing, but the original outline of the specimen may be actually similar to that of the present species, since the dorsal part of AMANO's specimen is considerably broken.

Occurrence.—Aritan to upper Miyakoan (upper Neocomian to Albian). Grey fine sandstone of the Yatsushiro formation at loc. At. 828A and at loc. Hy. 1021, south of Bisho, Tôyô village, Yatsushiro County, Kumamoto Prefecture. Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. Fine grey sandstone of the Ishido formation at loc. Hy. 4001, Ichinose-bashi, Sebayashi, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture, and at loc. Hy. 4011, Ishido, Ohinata village, Minami-saku County, Nagano Prefecture. AMANO's specimens from the fine sandstone of the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture, are probably identical with the present species.

Gervillaria miyakoensis (NAGAO)

Plate 36, Figures 2-4; Plate 37, Figure 1

1934. *Gervillia miyakoensis* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 197, pl. 31, fig. 2, pl. 32, fig. 7 (? pl. 31, fig. 1).

Material.—A left valve (GH. reg. no. 6777) illustrated by Nagao (1934, pl. 31, fig. 2 and pl. 32, fig. 7) is here designated as the lectotype. It was collected from the Aketo formation at the northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture. The following description is based on five specimens (GK. H 6238-GK. H 6242) from the type area in addition to the lectotype.

Description.—Left valve large, linguiform, subvertically elongated, slightly alate, much higher than long, not carinate, evenly inflated; thickness of test

considerable in hinge region, moderate in other parts; obliquity with respect to hinge-line approximately 80 degrees; byssal gape widely open below umbo, occupying an upper half of anterior margin; hinge line considerably short; posterior margin broadly concave; both wings well defined; anterior wing very small, pointed in front; posterior wing flattened, large but not much pointed; umbo subterminal, prosogyrous, rising slightly above dorsal margin; ligament area attaining a considerable breadth, horizontally striated, with more than four large, subtrapezoidal pits which are slightly prosocline and slightly wider than their interspaces; hinge plate unusually wide, with many irregularly disposed subvertical denticles, which are sometimes fairly strong and not clearly differentiated into anterior and posterior series; umbonal region bearing weak radial riblets, remaining part only with numerous irregular lines of growth; musculature unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left valve (GK.H6239)	73.5+	115.0+	29.0	?
Left valve (GK.H6240)	58.5	76.0	17.0	0.77
Left valve (GK.H6241)	78.0+	119.0	28.5	0.65+
Left in. mould (GK.H6242)	69.0	89.0	21.5	0.78

Observations and comparisons.—Although nothing is known about the right valve, the external and internal characters of the left valve are well exhibited in the lectotype and the present specimens. The first specimen (GK. H 6239) shows the eroded exterior of the shell and the anterior part of the ligament and hinge areas. The outline of the left valve is shown more completely by two smaller specimens (GK. H 6240, GK. H 6242).

NAGAO (1934, pl. 31, fig. 1) regarded a fragmentary specimen (GH. reg. no. 6760) as a right valve of this species. Since, however, it shows some affinity also to *Gervillaria haradae* (YOKOYAMA), its specific identity is not clear. If it belongs to the present species, it shows that the right valve is slightly less inflated than the left.

The subvertically elongated outline and widely open byssal gape of *G. miyakoensis* may be similar to those of *Isognomon* but the presence of pseudotaxodont denticles on a wide hinge plate and well defined wings preclude it from the assignment to the Isognomonidae.

The linguiform outline, the anteriorly protruded umbo and the comparatively narrow interspaces between the ligament pits are very much like the characters of *Panis* STEPHENSON, 1953, from the Cenomanian of Texas. Its type-species, *P. cuneiformis* STEPHENSON, 1953, however, has not such pseudotaxodont denticles and posterior wing as those in the present species. FRENEIX (1959, p. 208) regarded *Gervillia enigma* (D'ORBIGNY, 1845) as a member of *Panis*, but "*Gervillia enigma*" in GIGOUT (1951, pl. 12, figs. 10-13), from the Cenomanian of Marocco, which has similar pseudotaxodont denticles, was referred by her to *Gervillaria*. The present species is actually close to GIGOUT's, and especially to the left valve represented in his pl. 12, fig. 12, which is very similar in

outline and shell-obliquity to ours. Although a wide byssal gape and a much thickened hinge plate are unusual, the present species can probably be included in *Gervillaria*, since in other essential characters it agrees well with the type-species and other examples of that genus.

It is clearly distinguishable from *Gervillaria haradae* (YOKOYAMA, 1890) by its more vertically elongated outline, broader hinge plate, more elongated denticles, greater obliquity, absence of carina on the body of left valve, and indistinct radial ribs. Moreover, the anterior margin is not so widely gaped as in *G. haradae*.

Occurrence.—Lower and upper Miyakoan (Aptian and Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga and at loc. Hn. 0920, north of Haipe, Tanohata village, Shimohei County, Iwate Prefecture. Grey sandy shale of the "*Orbitolina* sandstone" at loc. Hn. 6203, northeast of Raga, the same village. NAGAO's lectotype occurred from the Aketo formation at the northeast of Raga.

Genus *Bakevellia* KING, 1848, em. COX, 1940

Type-species.—*Avicula antiqua* MÜNSTER *in* GOLDFUSS, 1836, Permian, western Europe and Greenland (original designation).

Bakevellia pseudorostrata (NAGAO)

Plate 37, Figures 3-6

1934. *Gervillia pseudorostrata* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 199, pl. 31, figs. 7-9 (? non pl. 31, fig. 6).

Material.—A left valve (GH. reg. no. 6758) illustrated by NAGAO (1934, pl. 31, fig. 8) is here designated as the lectotype. It was collected from the "Moshi sandstone" (the 1st cycle of the Miyako group) at Moshi, Iwaizumi town, Shimohei County, Iwate Prefecture. Two other syntypes (NAGAO, 1934, pl. 31, figs. 7, 9) are also the examples of this species, although another specimen (NAGAO, 1934, pl. 31, fig. 6) may belong to a different species of *Bakevellia*. The following description is based on five specimens (GK. H 6243-GK. H 6247) from the type area (HANAI and HAYAMI coll.) in addition to the lectotype and two syntypes.

Description.—Shell small for Mesozoic *Bakevellia*, inequivalve, pteriform, distinctly auriculate, much longer than high; test thin; obliquity approximately 50 degrees. Left valve moderately inflated with slightly protruding umbo and broad shell-body; anterior margin nearly straight, scarcely gaping, forming an angle of about 70 degrees or slightly less with hinge-line; posterior margin broadly concave; hinge-line long, occupying whole shell-length; anterior wing acutely triangular, pointed in front; posterior wing also pointed, comparatively narrow, flattened, delimited by an obtuse angle from shell-body; surface neither carinate nor radially ribbed, smooth except for weak growth-lamellae. Right valve only weakly convex, with a less prominent umbo and sharply pointed wings; other characters similar to those of left valve.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left in. mould (GK.H6243)	20.5	16.0	4.5	1.28
Left valve (GK.H6244)	20.5	15.0	4.5	1.37
Right in. mould (GK.H6245)	16.5	10.5	2.5	1.57
Right in. mould (GK.H6246)	14.5	10.5	2.0	1.38
Right valve (GK.H6247)	12.0	9.0	1.5	1.33

Observations and comparisons.—NAGAO (1934) established the species *Gervillia pseudorostrata* on the basis of several left valves from the Miyako group, one of which (pl. 31, fig. 6, GH. reg. no. 6762) apparently belongs to a different species from the lectotype and other specimens. A number of left valves newly collected from the Miyako group agree well with the lectotype in the pteriform outline, with well developed and pointed wings. A few associated right valves are assignable to the same species. In the outline and inequivalveness this species is somewhat similar to the immature specimens of *Gervillaria haradae,* from which, however, it is easily distinguishable by its broader shell-body, its less clearly defined posterior wing and the absence of radial ornament.

Since the test is thin and apt to be exfoliated, the hinge and ligament characters have not as yet been observed clearly in NAGAO's and the present specimens. There is, however, little possibility that this species would prove to belong to any genus of the Pteriidae, inasmuch as it is closely related to *Gervillia rostrata* (SOWERBY) from the Cenomanian of Europe (WOODS, 1905), which was properly referred to *Bakevellia* by FRENEIX (1959, p. 207). Moreover, two ill-preserved internal moulds (GK. H 6159, GK. H 6160) from the Yatsushiro formation, which are most certainly conspecific with the Miyako specimens, reveal a multivincular ligament structure of the *Bakevellia*-type and a few small anterior teeth and two obliquely elongated posterior ones.

The inequivalveness and the other characters are not much different from those of some Jurassic and Lowest Cretaceous *Bakevellia* which are common in the brackish-water faunas of Japan. *Bakevellia shinanoensis* (Y,BE and NAGAO, 1926) (KOBAYASHI and SUZUKI, 1939), from the Kochian Ryoseki series of the Sanchu, Yatsushiro and Yoshimo areas, differs from the present species in the larger dimensions, less pointed wings, narrower shell-body and more numerous denticles.

The present species is distinguishable from *Bakevellia rostrata* (SOWERBY) (=*Avicula cenomanensis* D'ORBIGNY, 1846) by its less conspicuous concentric lines, its smaller anterior wing and its less oblique shell.

Occurrence.—Lower and upper Miyakoan (Aptian and Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. Fine grey sandstone of the Yatsushiro formation at loc. Km. 1843, north of Shimofukami, Sakamoto town, Yatsushiro County, Kumamoto Prefecture (KANMERA coll.) NAGAO reported this species also from the "Moshi sandstone" at Moshi, Iwaizumi town, Shimohei County, Iwate Prefecture.

Bakevellia iwatensis sp. nov.
Plate 35, Figures 7, 8

Compare.—

1934. *Gervillia pseudorostrata* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 199, pl. 31, figs. 6, 6a (non figs. 7–9).

Material.—The holotype is an internal mould of right valve (GK. H 6249) from the Hiraiga formation at loc. Hn. 0018, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture (HANAI and HAYAMI coll.). Paratypes (GK. H 6250, GK. H 6251) from the type area (HANAI and HAYAMI coll.).

Description.—Shell small, inequivalve, obliquely elongated, much longer than high; shell-obliquity approximately 45 degrees; test comparatively thin. Left valve moderately convex, not carinate; anterior margin long, slightly convex, not gaping, forming an angle of about 65 degrees with hinge-line; posterior margin obliquely truncated, not much excavated; both wings obscurely delimited from body of shell; anterior wing pointed in front; posterior one unusually narrow, not protruded backwards; umbo not prominent, placed at about one-fifth of hinge-line from the anterior extremity; hinge composed of a few small anterior teeth and an obliquely elongated posterior tooth; ligament area quite narrow, provided with several shallow pits; surface smooth except for concentric lines of growth; musculature unknown. Right valve less inflated, with unprotruding umbo; postero-dorsal area remarkably flattened and not much auriculate; other characters similar to those of left valve.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6249) right in. mould	22.5	14.5	2.5	1.55
Paratype (GK.H6250) left valve	14.5	9.5	3.0	1.53
Paratype (GK.H6251) left in. mould	20.0+	17.5	5.0	1.14+

Observations and comparisons.—The three specimens, the measurements of which are recorded above, differ from the specimens of *Bakevellia pseudorostrata* (NAGAO, 1934) in their less auriculate outline, narrower shell-body and less concave posterior margin. The shell seems slightly less oblique. The development of a posterior auricle generally varies to some extent in species of *Bakevellia,* but the differences between the present specimens and typical ones of *B. pseudorostrata* are beyond the extent of intraspecific variation. Besides the present material, a left valve illustrated by NAGAO (1934, pl. 31, figs. 6, 6a) under the name of *Gervillia pseudorostrata* may belong to *B. iwatensis* in view of its similar outline.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture.

Genus *Gervillia* DEFRANCE, 1820

(=*Gervilliopsis* WHITFIELD, 1885; *Ensigervillia* DIETRICH, 1910)

Type-species.—*Gervillia solenoides* EUDES-DESLONGCHAMPS, 1820, Maastrichtian, Europe. The syntypes and plesiotypes of *G. solenoides* have been illustrated, the original figures and description reprinted, and some observations added by BIGOT (1906, pp. 95, 95a, 95b).

Subgenus *Gervillia s. str.*

Gervillia (Gervillia) forbesiana D'ORBIGNY

Plate 37, Figures 7, 8; Plate 38, Figures 1–5

1826. *Gervillia solenoides*, SOWERBY, Min. Conch., Vol. 6, p. 14, pl. 510, figs. 1–3 (non fig. 4).
1846. *Gervillia forbesiana* D'ORBIGNY, Pal. franç., Terrain crétacé, Vol. 3, p. 486, pl. 396, figs. 5, 6.
1905. *Gervillia forbesiana*, WOODS, Monogr. Cret. Lamell. England, Vol. 2, p. 85, pl. 11, figs. 26, 27, pl. 12, figs. 1–5.
1926. *Gervillia forbesiana*, YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 57, pl. 12, figs. 36, 37, pl. 14, figs. 8, 9.
1927. *Gervillia forbesiana*, YABE, *Ibid.*, Ser. 2, Vol. 11, No. 1, pl. 5, figs. 5a, b.
1934. *Gervillia forbesiana*, NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 197, pl. 31, figs. 1, 2, pl. 32, fig. 7.
1951. *Gervilliopsis forbesiana*, SHINOHARA, Illustrated handbook for fossils in Shikoku, p. 26, pl. 11, fig. 2.
1952. *Gervillia metaforbesiana* AMANO and MATSUMOTO (*nom. nud.*) *in* MATSUMOTO and KANMERA, Guide book of the geological excursions. The lower valley of the Kuma, p. 49, listed.
1954. *Gervillia metaforbesiana* AMANO and MATSUMOTO (*nom. nud.*) *in* MATSUMOTO, Cretaceous System, Japan. Islands, p. 114 (non *Gervillia metaforbesiana* AMANO and MATSUMOTO *in* AMANO, 1956).

Material.—A specimen (GK. H 6163) from the Yatsushiro formation (AKATSU coll.), four specimens (GK. H 6161, GK. H 6162, GK. H 6164, GK. H 6165) from the same area (KANMERA coll.) and three specimens (GK. H 6252-GK. H 6254) from the Miyako area (HANAI and HAYAMI coll.) and several fragmentary specimens from the Sanchu area (ICHIKAWA and HAYAMI coll.) and from the Katsuuragawa area (HAYAMI coll.) are concerned with the description below.

Description.—Shell medium-sized to large for genus, equivalve, ensiform, elongated postero-ventrally, not strongly inflated, more than four times longer than high; test fairly thick; anterior margin obliquely truncated, more or less gaping; hinge-line straight or a little concave, comparatively short; posterior margin slightly concave behind posterior wing, subparallel to antero-dorsal margin; umbo terminal, scarcely rising above hinge-line; maximum convexity lies near posterior margin of shell body where shell is abruptly compressed; anterior wing not developed; posterior wing obtusely triangular, somewhat variable in width, compressed, delimited clearly from shell-body by an angular sulcus; sur-

face of shell-body and posterior wing smooth except for numerous irregular growth-lamellae which are sometimes weakly corrugated on postero-dorsal slope; ligament area horizontally striated, attaining a considerable breadth in full-grown stage, provided with 3-5 prosocline, deep, slightly rounded pits which are usually wider than their interspaces; hinge teeth fairly irregular both in number and disposition, but usually composed of a few short anterior teeth below umbo and 6-8 obliquely elongated posterior teeth on posterior wing; teeth of both series invade ligament area.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK.H6252)	70.5+	16.5	4.0	4.27+
Right valve (GK.H6253)	79.0+	18.5	4.5	4.27+
Left in. mould (GK.H6254)	68.0+	17.0	4.0	4.00+
Left in. mould (GK.H6163)	67.0+	25.5	5.5	?
Right in. mould (GK.H6161)	55.5+	21.0	4.5	?

Observations and comparisons.—The posterior extremity is broken in every specimen, but the ratio of length/height is thought to be not less than 5.5, judging from the growth-lines. The average obliquity of the shell is a little less than 20 degrees. The posterior wing is variable in breadth and in the inclination of the posterior margin. The wing is generally narrower in the specimens from the Miyako group than in those from the Sanchu and Yatsushiro areas. This character, however, seems also to vary among British specimens of *G. forbesiana,* as described by WOODS (1905), and may not be a criterion for specific distinction. One of the specimens from the Yatsushiro formation (GK. H 6163), composed of left internal and external moulds, is probably a gerontic individual, judging from the much thickened ligament area. The hinge structure of this specimen is quite similar to that of *G. forbesiana* from the Gault of England (WOODS, 1905, pl. 12, fig. 5).

A small anterior rostrum-like projection is distinguishable in some specimens from the Miyako and Yatsushiro areas. Such a projection is well developed in some Upper Cretaceous *Gervillia* (*s. s.*), such as *G. solenoides* as figured by HOLZAPFEL (1889). The development of this projection was the criterion by which AMANO (1956) distinguish *Gervillia metaforbesiana* AMANO and MATSUMOTO, 1956, founded on some specimens from the Gosyonoura group of Shishijima, Kagoshima Prefecture. MATSUMOTO and KANMERA (1952) and MATSUMOTO (1954, ed.) referred some specimens from the Yatsushiro area to the same species. However, the character is fairly variable in the material collected at any one locality, and it is almost impossible that the present rostrate specimens are specifically distinct from normal specimens of *G. forbesiana,* even if typical *G. metaforbesiana* from Shishijima is distinct from this species.

Occurrence.—Aritan to upper Miyakoan (upper Neocomian to Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga and grey sandstone of the "*Orbitolina* sandstone" at loc. Hn. 6203, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefec-

ture. Calcareous sandstone of the 2nd cycle of the Miyako group at loc. Hn. 4053, Oshima island, off the coast of Moshi, Iwaizumi town, the same county. Grey fine sandstone of the Ishido formation at loc. Hy. 4001, Ichinose-bashi, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture, and at loc. Hy. 7002, Ishido, Ohinata village, Minamisaku County, Nagano Prefecture (ICHIKAWA and HAYAMI coll.). Fine grey sandstone of the Yatsushiro formation at loc. At. 828A, south of Bishô, Tôyô village, Yatsushiro County, Kumamoto Prefecture, and at loc. Km. 3096, 3097, southwest of Kohara in the same village, and also at loc. Km. 1843, north of Shimofukami, Sakamoto town, the same county. Dark grey sandy shale of the Arita formation at loc. Ys. 329a, north of Oura, Minami-hiro village, Arita County, Wakayama Prefecture. Several specimens comparable with this species occur in the Oshima formation at the north of Yokonuma, Oshima island, Kesennuma City, Miyagi Prefecture, the Funagawara formation of the Ofunato area of Iwate Prefecture, the Miyama formation of the eastern Sanchu area of Gumma Prefecture, and the Hanoura formation of the Katsuuragawa area of Tokushima Prefecture, but they are too poorly preserved to be precisely identified.

Family Isognomonidae

Genus *Isognomon* LIGHTFOOT, 1786*

(=*Perna* BRUGUIÈRE, 1789; *Pedalion*, DILLWYN, 1817)

Type-species.—*Isognomon lignea* LIGHTFOOT, 1786 (=*Ostrea isognomum* LINNAEUS), Recent (tautonymy).

Subgenus *Isognomon s. str.*

Isognomon (*Isognomon*) *sanchuensis* (YABE and NAGAO)

1926. *Perna sanchuensis* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 57, pl. 12, figs. 1–4.

Material.—A left valve (IGPS reg. no. 22457) illustrated by YABE, NAGAO and SHIMIZU (1926, pl. 12, figs. 3, 3a, 3b) is here designated as the lectotype. It was collected from the "Shiroi formation" (now called Sebayashi formation) at Hachimanzawa, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture. Three other syntypes are also examples of this species. This species is not represented in the subsequent collections, with which I am concerned.

Remarks.—The linguiform outline, ligament structure, edentulous hinge and presence of a wide byssal gape in the lectotype and syntypes suggest that this species belongs to *Isognomon* (*s. str.*), as defined by COX (1940).

Isognomon occasionally occurs in some Jurassic and Cretaceous cyrenoid

* According to Dr. L. R. COX's personal communication, Mr. S. P. DANCE of the British Museum has recently discovered that the "Portland Catalogue", which includes the original description of *Isognomon lignea*, was complied by LIGHTFOOT, and not by SOLANDER, as commonly supposed.

beds of Japan, notwithstanding the fact that all the living species of this genus are marine. The present species was probably a brackish-water species, because it is accompanied by some species of the Neomiodontidae. *Isognomon rikuzenicus* (YOKOYAMA, 1904) is somewhat similar to the present species in outline and ligament structure. The anterior margin of *I. sanchuensis* is, however, more widely open and more broadly concave than that of *I. rikuzenicus*, and the anterior extremity is more sharply pointed in the former species.

Occurrence.—Miyakoan (Aptian or Albian). Black shale of the Sebayashi formation (defined by TAKEI, 1963, p. 137) near loc. Hy. 40055, Hachimanzawa, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture. The fossil bed was originally included in the "Shiroi formation" which was generally assigned to the Kochian Ryoseki series. But the age of the fossil bed is evidently younger than that of the Ishido formation and probably Miyakoan.

Isognomon (*Isognomon*) *choshiensis* sp. nov.

Plate 39, Figure 1

Material.—The holotype is right external and internal moulds (GK. H 6255a, b) collected from the Choshi formation at Ashikajima, Choshi City, Chiba Prefecture (HANAI coll.).

Description.—Shell of medium size, subtrapezoidal, prosocline, nearly as long as high (holotype, right internal mould, GK. H 6255, 66.0 mm. long, 62.0 mm. high, ca. 7.0 mm. thick). Right valve linguiform, weakly inflated, not carinate; test comparatively thin; umbo terminal, prosogyrous, not rising above dorsal margin; byssal margin broadly concave, well delimited from antero-ventral margin; byssal gape probably narrow; dorsal margin moderately long, forming an angle of about 70 degrees with anterior margin; posterior margin slightly concave, forming a postero-dorsal angle of about 100 degrees with hinge; anterior wing absent; posterior area much flattened but not clearly alate; surface marked with several widely spaced irregular concentric lamellae besides closely spaced growth-lines; hinge edentulous; ligament area comparatively narrow, provided with a number of U-shaped pits. Left valve unknown.

Observations and comparisons.—This species is represented only by a specimen consisting of right external and internal moulds. The absence of a wide byssal opening and the prosocline outline are somewhat similar to those of the subgenus *Mytiloperna* IHERING, 1903, but other characters are rather close to those of *Isognomon* (*s. s.*). Judging by the narrow ligament area, this specimen may be a young individual. It is somewhat similar to *Perna rauliniana* D'ORBIGNY, 1846, from the Lower Greensand of England (WOODS, 1905-1906), which seems to belong to *Isognomon* (*s. s.*), in the form of shell, but the ratio of length/height is considerably larger and the posterior margin is more distinctly concave than in that species. *Isognomon sanchuensis* (YABE, NAGAO and SHIMIZU, 1926) from the Sebayashi formation of the Sanchu area has a more quadrate outline, a less oblique shell, a thicker test and a more strongly convex right valve than in the present specimen.

Occurrence.—Miyakoan (Aptian or Albian). Fine grey sandstone of the Choshi formation in a quarry at Ashikajima, Choshi City, Chiba Prefecture.

Subgenus *Mytiloperna* IHERING, 1903

Type-species.—*Perna americana* FORBES, Lower Jurassic, Chile (original designation).

Isognomon (*Mytiloperna*) sp. indet.
Plate 39, Figures 6, 7

Only a broken left valve (GK. H 6256) and a left internal mould (GK. H 6606, 34.0 mm. long, 29.0 mm. high, 5.5 mm. thick) are available. The first specimen reveals a ligament area with more than nine U-shaped subvertical pits which are much broader than their interspaces. The general outline is shown in the second specimen. The apical angle is only 45 degrees. The pointed umbo, mytiliform outline and absence of well-defined byssal opening suggest the subgenus *Mytiloperna*. Since *Mytiloperna* is scarcely known from the Lower Cretaceous, this may represent a new species. Its specific denomination, however, is deferred until more sufficient material is available.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, and the conglomeratic sandstone of the Tanohata formation at loc. Hn. 0803, Koikorobe, both in Tanohata village, Shimohei County, Iwate Prefecture (HAYAMI coll.)

Subgenus *Melina* RETZIUS, 1788

(=*Sutura* MEGERLE VON MÜHLFELD, 1811)

Type-species.—*Ostrea ephippium* LINNAEUS, 1758, Recent, Indo-Pacific (designated by HERRMANNSEN, 1847).

Isognomon (*Melina*) *ichikawai* sp. nov.
Plate 38, Figures 8, 9

Material.—The holotype is a right internal mould (GK.H6257) collected from the Ishido formation at loc. Hy. 4011, Ishido, Ohinata village, Minamisaku County, Nagano Prefecture. Paratypes (GK.H6258, GK.H6259) from the type locality (HAYAMI coll.).

Description.—Shell medium-sized for genus, more or less inquivalve, fairly irregular in outline but usually gibbous, weakly inflated, slightly longer than high; test comparatively thin; both wings absent; hinge-line short, occupying about one-forth of shell-length, passing gradually into posterior margin; anterior margin straight or slightly concave, opisthocline, forming an apical angle of about 115 degrees; antero-ventral part remarkably expanded forwards; byssal gape, if present, very narrow; umbo not prominent, probably prosogyrous, placed at about one-fourth of shell from anterior extremity; ligament area of moderate width, provided with about 11 shallow prosocline ligament pits which

are unusually densely spaced and much broader than their interspaces; hinge edentulous; adductor scar suborbicular, placed near centre of valve; surface marked, as in some Ostreidae, with foliated concentric lamellae; nacreous layer probably narrower than periostracum, because foliated concentric lamellae are clearly seen on marginal part of internal surface.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6257) right in. mould	45.5	40.5	6.0	1.12
Paratype (GK.H6258) right in. mould	22.0	14.5+	?	?

Observations and comparisons.—The holotype consists of a complete internal and a fragmentary external mould of a right valve, revealing the characteristic outline and ligament structure. A fragmentary left valve (GK.H6259) is nearly flat, showing that this species is slightly inequivalve.

Although the outline seems somewhat irregular, the weak convexity of the shell, the anteriorly expanded ventral part, and the foliated surface sculpture seem to characterize the present species, and indicate that it is more closely related to *Melina* than to *Isognomon* (*s.s.*) and other subgenera. In comparison with those of living species of *Melina*, the ligament pits are more numerous and more densely spaced; the anterior margin, moreover, is not so deeply concave below the umbo.

The present species resembles *Perna keuperiana* BLANCKENHORN, 1875, from the Keuper of Germany in the comparatively short hinge-line and general outline, but is distinguishable by its more expanded postero-ventral area. There is no other known species of *Melina* which it can be compared with.

Occurrence.—Aritan (upper Neocomian). Fine greey sandstone of the Ishido formation at loc. Hy 4011, Ishido, Ohinata village, Minamisaku County, Nagano Prefecture.

Superfamily Pinnacea

Family Pinnidae

Genus *Pinna* LINNAEUS, 1758

Type-species.—*Pinna rudis* LINNAEUS, 1758, Recent, West Indies (designated by CHILDREN *in* LAMARCK, 1823).

Pinna sp. cf. *P. robinaldina* D'ORBIGNY

Plate 39, Figures 2, 3

Compare.—

1844. *Pinna robinaldina* D'ORBIGNY, Pal. franç., Terrain crétacé, Vol. 3, p. 251, pl. 330, figs. 1-3.

1858. *Pinna robinaldina*, PICTET and RENEVIER, *Matér. Pal. Suisse*, Ser. 1, p. 117, pl. 16, fig. 5.

1888. *Pinna robinaldina*, CHOFFAT *in* CHOFFAT and DE LORIOL, *Mém. Soc. phys. d'Hist. nat. Genève*, Tom. 30, Fasc. 2, p. 86, pl. 5, figs. 4, 5.

1905-1906. *Pinna robinaldina*, WOODS, Monogr. Cret. Lamell. England, Vol. 2, p. 96, pl. 12, figs. 11-15, pl. 13, fig. 1.

1957. *Pinna* sp., AMANO, *Kumamoto Jour. Sci.*, Ser. B, Sec. 1, Vol. 2, No. 2, p. 85, pl. 1, figs. 10-13.

Material.—A right external mould (GK. H 6261), from the Sanchu area (ICHIKAWA coll.), and a broken internal mould of both valves (GK. H 6607), from the Yatsushiro area (MATSUMOTO and KANMERA coll.), are primarily concerned with the description below. Besides, a few fragmentary specimens from the Sanchu and Yatsushiro areas may be identical with them.

Description.—Shell fairly large, straight, elongated, acutely trigonal in lateral view, subrhomboidal in transverse section, well inflated; posterior margin probably angular and widely gaping; surface divided into two planes by a sharp median carina; dorsal slope nearly flat, provided with several equidistant, moderately strong, radial ribs, interspaces of which are roundly concave and much broader than the ribs; ventral slope weakly concave, broader than dorsal slope, provided with several weak ribs which are slightly oblique to shell-elongation; concentric lamellae prominent especially in intervals between radial ribs on dorsal part of shell. Specimen, incomplete right external mould (GK. H 6261), 175.0+mm. long, 41.0+mm. wide.

Observations and comparisons.—The specimens illustrated are incompletely preserved but reveal the characteristic surface ornamentation. They are very similar to *Pinna robinaldina* D'ORBIGNY, 1844, as described by WOODS (1905-1906) from the Lower Greensand of England. The surface ornamentation of the specimen (GK. H 6261) just agrees with that of the British specimen figured by WOODS (pl. 12, fig. 155), although the slightly oblique riblets on the ventral slope of this specimen are probably slightly coarser. *Pinna* sp. in AMANO (1957a), from the Hagino formation of Shikoku, has more delicate ribs than the present specimens, but must also be closely related to *P. robinaldina*.

Occurrence.—Aritan to lower Miyakoan (upper Neocomian to Aptian). Fine grey sandstone of the Ishido formation at loc. Hy. 4011, Ishido, Obinata village, Minamisaku County, Nagano Prefecture. Black sandy shale of the Hinagu formation at Km. 1832, north of Tsuzura, Sakamoto town, Yatsushiro County, Kumamoto Prefecture. A similar species is known from the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture.

Pinna sp. indet.

Plate 39, Figure 4

1934. *Pinna* sp., NAGAO, *Jour. Fac. Soc. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 196, pl. 26, figs. 9-11.

A small specimen of *Pinna* (right valve, GK. H 6260, 36.0 mm. long, 12.5 mm. wide, 4.5 mm. thick) has been obtained from the Miyako group. It is probably conspecific with the *Pinna* sp. of NAGAO (1934). It resembles *Pinna* sp. cf. *P. robinaldina* D'ORBIGNY from the Sanchu and Yatsushiro areas in the surface ornamentation and median ridge, but probably belongs to another species, because it has much finer radial ribs on the dorsal slope and is much smaller than that species.

Occurrence.—Lower and upper Miyakoan (Aptian to Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0018, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture (HAYAMI coll.). NAGAO (1934) reported that comparable specimens also occur in the Hiraiga formation at Haipe and in the "*Orbitolina* sandstone" at Raga in the same village.

Genus *Atrina* GRAY, 1847

Type-species.—*Pinna nigra* CHEMNITZ, Recent, Indo-Pacific (original designation).

Atrina heiensis sp. nov.

Plate 40, Figure 7

Material.—The holotype is internal and external moulds of closed valves (GK. H 6262a, b) collected from the upper part of the "*Orbitolina* sandstone" of the Miyako group at loc. Hn. 6203, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture (HANAI and HAYAMI coll.).

Description.—Shell of medium size, equivalve, acutely trigonal in lateral view, lenticular in transverse section, not strongly inflated, expanded postero-ventrally; test thin, about 1.5 mm. in maximum thickness, composed almost entirely of fibrous prismatic layer; nacreous layer, if present, very thin; dorsal margin nearly straight, occupying the greater part of length; anterior margin slightly concave near umbo but passing gradually into the broadly arcuate posterior margin; apical angle about 40 degrees; line of maxicum convexity situated near dorsal margin; surface marked with several obscure radial undulations, which are confined to antero-dorsal part, and fairly prominent concentric lines of growth, which form irregular folds on dorsal peripheral region; a weak internal ridge runs longitudinally, dividing umbonal area into two angles. Specimen, holotype (GK. H 6262) internal mould of closed valves, 148.0+mm. long, 94.0+mm. wide, 33.0 mm. thick.

Observations and comparisons.—This species is represented by an incomplete specimen, the apical and posterior parts of which are broken. The fibrous prismatic layer has partly adhered to the external mould. The broadly trigonal and non-carinate outline with a large apical angle remind me of *Atrina* and some of its subgenera. But the radial ribs are much weaker than in the most species of *Atrina* hitherto known. *A. heiensis* may appear to be related to *Plesiopinna atriniformis* AMANO, 1956, from the uppermost Miyakoan (lower Lower Cenomanian) of Shishijima of southwest Kyushu. As noted by AMANO (1956), the closed posterior margin and the presence of an conspicuous internal ridge in the umbonal area are striking characteristics of *Plesiopinna*, by which it is distinguishable from *Atrina*, *Pinna* and other genera of the Pinnidae. Whether the posterior margin is closed or gaping in the present specimen cannot be ascertained, but an internal ridge similar to that of the type-species of *Plesiopinna* is seen on the inner surface of the umbonal area. The specimen is, however, at least specifically distinct from *P. atriniformis*,

because it has a still larger apical angle, weaker shell-convexity and much shorter anterior margin. Moreover, its median carina is more conspicuous than that of *P. atriniformis*. According to AMANO, *Pinna neptuni* D'ORBIGNY, 1844, and *P. ligeriensis* D'ORBIGNY, 1844 from the Cenomanian of France, are referable to *Plesiopinna*. The references were later accepted by FRENEIX (1959). Unfortunately photographic illustrations of the type specimens of those species are not yet available, and precise comparison with them is at present difficult. *Pinna moreana* D'ORBIGNY, 1844, from the Cenomanian of France is somewhat similar to this species, although its apical angle seems distinctly smaller than in the present specimen.

Occurrence.—Lower (?) and upper Miyakoan (? Aptian to Albian). Grey sandy shale of the upper part of the "*Orbitolina* sandstone" of the Miyako group at loc. Hn. 6203, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture. Fragmentary shells composed of similar fibrous prismatic layer are found in the Tanohata and Hiraiga formations at many places (Hn. 0018, Hn. 0220, etc.) in the environs of Hiraiga.

Superfamily Pectinacea

Family Pectinidae

Subfamily Pectininae

Genus Neithea DROUET, 1825

(=*Neitheops* STEWART, 1930)

Type-species.—*Pecten versicostatus* LAMARCK, 1819 (= *Pecten quinquecostatus* SOWERBY, 1814), Aptian-Turonian, Western Europe, Africa and India (designated by HERRMANNSEN, 1847).

Remarks.—*Neithea* is a very characteristic genus of the Pectininae in the Cretaceous. Most species of the genus are plano-convex in outline and provided with six raised primary radial ribs in addition to many secondary riblets on the right (convex) valve. But *Neithea aequicostata* (LAMARCK, 1819) and a few other species have numerous radial ribs of a single order of prominence on the whole surface of right valve. *N. aequicostata* and a few related species to it have been generally considered to constitute a distinct taxonomic group from normal species of *Neithea*. STEWART (1930), who believed HERRMANNSEN's (1847) type designation of *N. quinquecostata* to be invalid and CHENU's (1862) designation of *N. aequicostata* to be the first for the genus, proposed *Neitheops* (type-species: *N. grandicosta* GABB, 1869) for the six-ribbed normal species. NORTH (1951, p. 233), however, stated, "STEWART suggested that these (HERRMANNSEN's and GRAY's) designations were invalid on the ground that *N. quinquecostata* was not cited in DROUET's original list. But neither was *N. aequicostata*, except in synonymy. DROUET's first species was his own *N. pectinoides* (p. 186, pl. 7, figs. 1, 2) and this is quite clearly LAMARCK's *Pecten aequicostatus*, as has never been contested (1819, p. 181). But DROUET also

included in his list *N. versicostata* (*Pecten versicostatus* LAMARCK, 1819, p. 181), and this is equally the same as *N. quinquecostata* (SOWERBY, 1814, p. 122, pl. 56, figs. 4-8). Thus *N. quinquecostata* has exactly the same right as has *N. aequicostata* to receive the subsequent designation as type, and HERRMANNSEN's designation should be upheld."

I agree with NORTH's opinion, and *Neitheops* should be accepted as a subjective synonym of *Neithea s. str.*

Neithea seems to have appeared first in the Neocomian, and flourished in the Aptian and Albian over the world except for the boreal province and South America. In western Europe and Africa Upper Cretaceous species are also common, while in other continents the genus appeared to have become almost extinct in the Cenomanian stage.

The ancestry of *Neithea* should be sought in the Jurassic species of the Pectininae, and probably in Lower Jurassic *"Vola" alata* and allied species to it from South America, for which BOEHM (1920, p. 138) proposed a genus *Weyla* (type-species: *Pecten alatus* BUCH, by monotypy). In California similar Lower Jurassic pectinids were called *Parapecten* by CRICKMAY (1933). However, nothing is known about the Upper Jurassic representative of this lineage which could link *Weyla* with *Neitheea.* I agree with DARTEVILLE and FRENEIX (1957, p. 71) and TAMURA (1959) in excluding *"Neithea" kotsubu* KIMURA, 1951, from the Upper Jurassic of Japan, from true *Neithea,* because it probably belongs to the Chlamydinae.

Numerous Cretaceous species of *Neithea* have been described by many authors. Their classification was attempted by PETHÖ (1882), WOODS (1902), JAWORSKI (1914), BÖHM (1920), GILLET (1924a), STEWART (1930), DARTEVILLE and FRENEIX (1957) and some others. The principal criteria for the classification are found in the development and inequality of auricles, the presence or absence of primary ribs, the number of secondary riblets on each interspace, the ornamentation on the both lateral areas, the shell convexity and the apical angle. The characters of the left (flat) valve have not been so precisely examined as those of the right, but, properly speaking, the same importance should be attached to both valves.

JAWORSKI (1914) suggested that "Kreide-Volen" i.e. *Neithea* can be divided into the following three groups:

> "1. eine Gruppe mit einfacher, gleich starker Berippung der ganzen Klappe,
> 2. eine Gruppe mit ganz geringen Untershieden in der Stärke der Berippung, und
> 3. eine Gruppe, bei denen Rippen verschiedener Grössenordnung auftreten".

The first and third groups may correspond to the *Aequicostata*-group and *Atava*-group of PETHÖ (1882), but it is not clear by what species the second group is actually represented.

Subsequently GILLET (1924) divided *Neithea* into two larger groups on the basis of the inequality of the auricles, and further subdivided them into many smaller subgroups chiefly according to the mode of surface ornamentation of the right valve, as summarized below:

A. Auricles equal or slightly unequal
  a) Group of *N. atava* and derived forms (Neocomian to Senonian)
  b) Group of *N. phaseolina* (=*phaseola*) (Turonian)
  c) Group of *N. decemcosta* (Senonian)
  d) Group of *N. fleurausiana*, *N. roemeri* and *N. lapparenti* ("Middle Cretaceous")
  e) Group of *N. deshayesiana* (Neocomian)
  f) Group of *N. dilatata* (Turonian)
B. Auricles very unequal
  a) Group of *N. quadricostata* (Cenomanian)
  b) Group of *N. acuticostata* ("Middle Cretaceous")
  c) Group of *N. longicauda*, *N. cometa*, *N. digitalis* and *N. notabilis* (Cenomanian to Turonian)

I agree with GILLET (1924) in considering the inequality of the auricles to be an important character for classification, but her classification seems more or less artificial. Her discussion appears to have been based in part on the much restored and schematized figures of D'ORBIGNY (1847), from which many vaxatious typological problems have arisen in other pelecypod groups. In the same year GILLET (1924 a) introduced her classification into her memoir "Etudes sur les lamellibranches néocomiens", and divided the group of *N. atava* into the following three subgroups:

1) Subgroup of *N. atava* including *N. neocomiensis*, *N. valanginiensis*, *N. morrisi*, *N. heberti*, *N. neumanni* and *N. lindiensis*.
2) Subgroup of *N. shawi*
3) Subgroup of *N. aequicostata* including *N. kaufmanni*.

Neithea aequicostata was included in the group of *N. atava*, but as noted before, it differs considerably from *N. atava* and most other species in surface ornamentation. *Neithea cometa* is, according to WOODS (1902), distinguishable from *N. atava* by the smaller number of primary ribs, although the two species are similar in the very unequal development of auricles. *N. morrisi* is clearly different from *N. atava* in surface ornamentation, and should be placed in a different group.

DARTEVILLE and FRENEIX (1957, pp. 72-73) published a diagnostic table of African species of *Neithea*, and the classification proposed in her table may be applicable also to most species from other continents. Their table runs as follows:

I. Ribs sharp
  A. Costation almost uniform ..... *N. aequicostata* (LAMARCK)
  B. Six costae dominant
    a) Three intercalary costae between two principal costae
      1) Form large; wings developed, very unequal, lateral areas striated ..... *N. gibbosa* (PULTENEY)
      2) Form narrow; wings reduced, equal; lateral areas smooth ..... *N. shawi* PERVINQUIÈRE (inclusive of varieties)
    b) Four intercalary costae between two principal costae; lateral areas striated..... *N. quinquecostata* (SOWERBY)
    c) Two intercalary costae between two primary costae; principal costae very feebly subdivided at the base; lateral areas smooth..... *N. ficalhoi* (CHOFFAT)

C. Strong and weak costae alternating; height large .....
.....*N. welwitschi* (CHOFFAT)
II. Costae plain, surface almost smooth; 19 radial striae correspond to the interval of costae.....*N. noutai* RENNIE

It seems most reasonable to classify *Neithea* on the basis of a combination of various characters such as outline of two valves, mode of ornamentation, development of auricles and dimensions. Phylogenetical relationship and geographical distribution should be also taken into consideration. As suggested by DARTEVILLE and FRENEIX, the mode of ornamentation of the right valve may indeed be the most important and convenient criterion for classification, but the extent to which it can be applied depends on the circumstances. The number of secondary ribs is very constant in some species and groups such as IBa and IBc, whereas it is frequently variable in one and the same species in certain other groups.

I am of opinion that *Neithea* can be divided into at least three subgenera. Two of them are equivalent to the groups IA and IB, typified respectively by *N. aequicostata* and *N. quinquecostata*. A new subgeneric name, *Aequineithea*, is proposed here for the former group. The latter group, of course, constitutes *Neithea s. str.* *Neithea atava* and its allies, which were not treated by DARTEVILLE and FRENEIX, seem to constitute another phylogenetical branch. These species have four-six primary ribs and appear at first sight to be similar to the group IB, but their primary ribs are broadly plicated and rounded at their tops and bottoms. The intercalary radials are represented by weak striae which are essentially different from the secondary riblets of *Neithea* (*s. str.*). Since some different opinions have been expressed as to the specific characters of *N. atava*, I propose here a new subgenus *Neithella* for this group, designating *Janira wrightii* SHUMARD, 1860, as the type-species.

There are in addition several aberrant species of *Neithea*, which may require the establishment of more subgenera, but I would refrain from proposing the new names on this occasion.

It is often difficult to recognize the true synonymic relationships among many early described species of *Neithea*, unless it is possible to examine their type specimens. A scheme of classification and synoptic lists of species are presented here, although much remains to be done in the future to establish a natural classification on the basis of phylogenetical relationship.

Subgenus *Neithea s. str.*

Diagnosis.—Right valve with six constant primary costae and several sharp secondary riblets in each interspace; left valve nearly flat or slightly concave; auricles subequal or unequal; lateral areas may or may not be striated; numerous crenules arranged along hinge line.

1. Group of *Neithea quinquecostata* (SOWERBY)

Diagnosis.—Shell small or medium-sized; right valve with three-five

secondary riblets in each interspace, which are fairly irregular in number in any one species; radial ribs of left valve almost uniform in prominence; auricles small, subequal or slightly unequal; both lateral areas may or may not be striated.

List of species.—

Neithea (Neithea) amanoi sp. nov. (= *Pecten (Neithea)* cf. *morrisi*, AMANO, 1957a, p. 88, pl. 1, figs. 17-18, 20 ,25, 27-29) Aptian, Japan.

Neither angoliensis NEWTON, 1916, p. 566, pl. 1, fig. 4 (= *N. shawi*)

Neithea attockensis COX, 1935, p. 20, pl. 2, figs. 17-20, Albian, India.

Janira dutemplei D'ORBIGNY, 1847, p. 646, pl. 447, figs. 8-11 (PERON, 1877, p. 507, pl. 7, fig. 4; BOEHM, 1891, p. 83, pl. 3, fig. 33; CHOFFAT, 1901-1902, p. 149, pl. 3, figs. 8-9) (? = *N. sexcostata*)

Neithea grandicosta GABB, 1869, p. 200, 251, pl. 33, fig. 99a (STEWART, 1930, p. 116, pl. 1, fig.5) Lower Cretaceous, California.

Neithea (Neithea) matsumotoi sp. nov. Albian, Japan.

Janira morrisi PICTET and RENEVIER, 1858, p. 128, pl. 19, fig. 2 (CHOFFAT, 1901-1902, p. 147, pl. 3, figs. 5-6; WOODS, 1902, p. 201, pl. 39, figs. 11-13; PERVINQUIÈRE, 1912, p. 135, pl. 9, fig. 7; DOUVILLÉ, 1916, p. 171, pl. 20, figs. 17, 18; GILLET, 1924 a, p. 53, fig. 30) (? = *Pecten syriaca*) Aptian, Western Europe and North Africa.

Neithea (Neithea) nipponica sp. nov. Albian, Japan.

Pecten quinquecostatus SOWERBY, 1814, p. 122, pl. 56, figs. 4-8 (GOLDFUSS, 1836, p. 55, pl. 93, fig. 1; BRONN, 1937, p. 678, pl. 30, fig. 17; D'ORBIGNY, 1847, p. 632, pl. 444, figs. 1-5; STOLICZKA, 1871, p. 437, pl. 31, figs. 1-6, pl. 37, figs. 4-9; GEINITZ, 1872, Pt. 1, p. 201, pl. 45, figs. 8, 9, pt. 2, p. 36, pl. 10, figs. 17, 18; BAYLE, 1878, pl. 122, figs. 2, 3; MARTIN, 1889, p. 157, pl. 16, figs. 10-11; CHOFFAT, 1907-1902, p. 148, pl. 3, fig. 7; WOODS, 1902, p. 202, pl. 39, figs. 14-17, pl. 40, figs. 1-5; ROMAN and MAZERAN, 1913, p. 88, pl. 9, fig. 12; RENNIE, 1929, p. 17, pl. 1, fig. 13) Aptian-Turonian, Europe, Angola and India.

Pecten sexcostatus WOODWARD, 1833, p. 48, pl. 5, fig. 29 (WOODS, 1902, p. 214, pl. 40, figs. 10-15, pl. 41, figs. 1-10) Senonian, Western Europe.

Neithea shawi PERVINQUIÈRE, 1912, p. 136, pl. 9, figs. 1-6, including var. *atropha* and var. *biatropha* (DARTEVILLE and FRENEIX, 1957, p. 74, pl. 9, figs. 8-11) (= *Neithea tricostata* RENNIE, 1929, p. 67, pl. 1, figs. 10-12, non COQUAND, 1862, non BAYLE, 1849) Albian-Cenomanian, Tunisia, Algeria and Angola.

Pecten striatocostatus MÜNSTER *in* GOLDFUSS, 1836, p. 55, pl. 93, figs. 2 c-e (non figs. 2a, b, f, g) (FAVRE, 1869, p. 156, pl. 13, figs. 12-13; HOLZAPFEL, 1889, p. 239, pl. 26 fig. 19; MÜLLER, 1898, p. 37, pl. 4, fig. 8; RAVN, 1902, p. 95, pl. 2, figs. 8, 9) Senonian-Maastrichtian, Germany.

Janira syriaca CONRAD, 1852, p. 230, pl. 1, fig. 6 (HAMLIN, 1884, p. 61, pl. 5, figs. 4a-c; VOKES, 1946, p. 166, pl. 4, figs. 1-7) Aptian, Lebanon.

Janira tricostata COQUAND, 1862, p. 219, pl. 13, figs. 3, 4, non BAYLE, 1849 (*Pecten coquandi* PERON, 1877, p. 504, pl. 7, fig. 2, non *Pecten coquandianus*

D'ORBIGNY, 1847; non RENNIE, 1929, p. 67, pl. 1, figs. 10-12) Albian-Cenomanian, Algeria.

Pecten triplicatus MANTELL, 1822, p. 128, pl. 25, fig. 9 (= *P. sexcostatus*).

Pecten versicostatus LAMARCK, 1819, p. 181 (DROUET, 1825, p. 187, pl. 7, fig. 4) (= *P. quinquecostatus*).

Remarks.—This group is subdivisible into two subgroups according to the presence or absence of radial riblets on the lateral areas of the right valve. One is the *quinquecostata* subgroup with striated areas, and includes *N. angoliensis, N. matsumotoi, N. nipponica* and *N. sexcostata;* and the other is the *morrisi*-subgroup, including *N. amanoi, N. shawi* and *N. syriaca,* and is characterized by smooth lateral areas and relatively narrow outline.

Vola bellula CRAGIN, 1893, p. 216 (KNIKER, 1919, p. 22, pl. 3, figs. 3-11; ADKINS and WINTON, 1920, p. 69, pl. 11, figs. 3-7; WINTON, 1925, p. 55, pl. 10, fig. 5; ADKINS, 1928, p. 125, pl. 17, fig. 5; STANTON, 1947, p. 42, pl. 42, figs. 3-7), from the Albian of the Gulf Coast, is rather aberrant in the presence of numerous fine secondary riblets on the interspaces between the primaries. Such ornamentation is also found in the figures of *Janira truellei* D'ORBIGNY, 1847, p. 648, pl. 448, figs. 5-8. The reference of these species to this group is doubtful.

2. Group of *Neithea ficalhoi* (CHOFFAT)

Diagnosis.—Shell small or medium-sized; right valve provided with two constant stout secondary ribs in each interspace; primary ribs frequently accompanied by weak subordinate riblets on their anterior and posterior slopes; both lateral areas typically smooth; auricles small, subequal; left valve nearly flat or slightly concave, although its umbonal area is commonly inflated.

List of species.—

Janira alpina D'ORBIGNY, 1847, p. 643, pl. 446, figs. 4-8 (MÜLLER, 1898, p. 37, pl. 4, fig. 7) Turonian or approximately so, Western Europe.

Janira ficalhoi CHOFFAT, *in* CHOFFAT and DE LORIOL, 1888, p. 89, pl. 5, figs. 8-10. Aptian-Albian, Angola and Japan.

Pecten fredericksburgensis CRAGIN, *in* TWENHOFEL, 1924, p. 78, pl. 22, fig. 5 (= *N. occidentalis*)

Neithea georgetownensis KNIKER, 1919, p. 31, pl. 6, figs. 1-3, (ADKINS and WINTON, 1920, p. 70, pl. 12, figs. 5, 6; WINTON, 1925, p. 59, pl. 10, fig. 7; ADKINS, 1928, p. 127, pl. 17, fig. 7; STANTON, 1947, p. 46, pl. 37, figs. 1, 2, pl. 38, fig. 3) Albian, Gulf Coast.

Vola irregularis BÖSE, 1910, p. 78, pl. 15, figs. 10-18 (KNIKER, 1919, p. 18, pl. 2, figs. 1-6; WINTON, 1925, p. 48, pl. 10, fig. 8; ADKINS, 1928, p. 126, pl. 17, fig. 8) (= *N. occidentalis*)

Neithea occidentalis CONRAD, 1855, p. 269 (*Pecten quadricostatus* SOWERBY var., RÖMER, 1852, p. 64, pl. 8, fig. 4; CONRAD, 1857, p. 150, pl. 5, fig. 1; STANTON, 1947, p. 43, pl. 27 figs. 1-4; PERKINS, 1960, p. 66, pl. 17, figs. 22, 23) Albian, Gulf Coast and Mexico.

Vola subalpina BÖSE, 1910, p. 96, pl. 15, figs. 5, 7-9 (KNIKER, 1919, p. 28, pl. 5,

figs. 4-6, including var. *linkii*; ADKINS and WINTON, 1920, p. 68, pl. 11, figs. 1, 2, pl. 12, figs. 3-15; WINTON, 1925, p. 50, pl. 10, figs. 1-3; ADKINS, 1928, p. 127, pl. 17, figs. 1, 3; STANTON, 1947, p. 42, pl. 44, figs. 7, 8; PERKINS, 1960, p. 66, pl. 17, figs. 24, 25) Albian, Gulf Coast and Mexico.

Pecten texanus RÖMER, 1852, p. 65, pl. 8, fig. 3 (CONRAD, 1857, p. 151, pl. 5, fig. 2; SHATTUCK, 1903, p. 17, pl. 5, figs. 7, 8; BÖSE, 1910, p. 93, pl. 15, figs. 2-6, including var. *elongata;* KNIKER, 1919, p. 28, pl. 5, figs. 2, 3; ADKINS and WINTON, 1920, p. 71, pl. 12, fig. 2; ADKINS, 1928, p. 127, pl. 17, figs. 2, 4, including var. *elongata;* STANTON, 1947, p. 45, pl. 38, figs. 2, 4, 5, pl. 39, figs. 3-5, 7; PERKINS, 1960, p. 66, pl. 18, figs. 3-6) Albian, Gulf Coast.

Pecten tricostatus BAYLE, 1849 (PERON, 1877, p. 503, pl. 7, fig. 5; DOUVILLÉ, 1904, p. 268, pl. 39, figs. 9, 10; BOEHM, 1920, p. 130, text-figs. 1, 2) Cenomanian-Turonian, Western Europe, Algeria and Persia.

Remarks.—This is a group well defined by the regular ornamentation. It is probably related to the *quinquecostata*-group, in particular to the species with four secondary riblets in an interval, but has a somewhat different geographical distribution. In some species of this group the subordinate riblets on the both sides of the primaries are fairly strong, but forms transitional to other groups are scarcely known.

3. Group of *Neithea gibbosa* (PULTENEY)

Diagnosis.—Shell large for *Neithea;* right valve typically provided with three secondary riblets in each interspace, but these riblets are sometimes variable even in one species; auricles very unequal; anterior auricle pointed forwards and much larger than posterior one; byssal notch deep; both lateral areas striated; left valve nearly flat, with almost uniform ribs.

List of species.—

Pecten duplicicosta (RÖMER, 1849, p. 398 (RÖMER, 1852, p. 65, pl. 8, fig. 2; KNIKER, 1919, p. 28, pl. 2, figs. 7, 8, pl. 3, figs. 1, 2; STANTON, 1947, p. 43, pl. 39, figs. 1, 2) Albian, Gulf Coast.

Janira faucignyana PICTET and ROUX, 1853, p. 505, pl. 45, fig. 2 (= *P. gibbosa*)

Janira faujasi PICTET and CAMPICHE, 1869, p. 253 (=*Janira quadricostata* D'ORBIGNY, 1847, p. 632, pl. 447, figs. 1-7, non SOWERBY, 1814) Cenomanian, France.

Pecten gibbosa PULTENEY, 1813 (COX, 1940, p. 124, pl. 7, figs. 2, 3) Cenomanian, western Europe, Turkey, Angola and Zululand.

Pectinites gryphaeatus SCHLOTHEIM, in QUENSTEDT, 1852, p. 507, pl. 41, fig. 1.

Pecten (Janira) inconstans SHARPE, 1849, p. 188, pl. 19, fig. 3 (CHOFFAT, 1901-1902, p. 156, pl. 2, figs. 4, 6) Turonian, Portugal.

Neithea (Neithea) kanmerai sp. nov., Aptian, Japan.

Vola lapparenti CHOFFAT, 1901-1902, p. 154, pl. 3, figs. 1, 2, Cenomanian-Turonian, Portugal.

Vola lindiensis KRENKEL, 1910, p. 205, pl. 21, fig. 4 (LANGE, 1914, p. 212, pl. 16, figs. 10-12, pl. 17, figs. 1-3) Lower Cretaceous, East Africa.

Pecten quadricostatus SOWERBY, 1814, p. 122, pl. 56, figs. 1, 2 (GOLDFUSS, 1836, p. 54, pl. 92, fig. 7; BRONN, 1837, p. 680, pl. 30, fig. 16; GEINITZ, 1843, p. 16, pl. 3, figs. 14, 15; GEINITZ, 1872, p. 37, pl. 10, figs. 14-16; DE LORIOL, 1882, p. 103; MÜLLER, 1898, p. 35, pl. 4, figs. 9, 10; NEWTON, 1909, p. 55, pl. 2, figs. 18-21; NEWTON, 1916, p. 568, pl. 1, fig. 8; RENNIE, 1930, p. 241, pl. 31, figs. 10-12) (=*P. gibbosa*)

Vola stefanoi CHOFFAT, 1900, p. 183 (CHOFFAT, 1901-1902, p. 155, pl. 2, fig. 3) ? Albian, Portugal.

Remarks.—This group attains a large size in comparison with other groups of *Neithea* (*s. str.*). The height of right valve scarcely exceeds 60 mm. in the groups of *N. quinquecostata,* and *N. ficalhoi,* while in the present group adult right valves are as tall as 70-100 mm. In the group of *N. quinquecostata* three secondary riblets are sometimes observed in one interspace between primaries but the number is much more irregular than in the present group. Although the unusual development of auricles is known only in a few species of the present group, the above listed species seem to be related to one another in view of the similarity in their size and ornamentation.

Subgenus *Neithella* nov.

Type-species.—*Janira wrightii* SHUMARD, 1860, Upper Albian, Gulf Coast.

Diagnosis.—Shell small, scarcely exceeding 40 mm. in height, comparatively narrow; right valve provided with four, five or six roundly plicated and broad ribs; secondary riblets absent; a number of fine radial striae marked on the bottom of each interspace and the slopes of the primaries; left valve also plicated, with digitated ventral margin; auricles unequal; anterior auricle usually pointed in front, much larger than posterior one.

List of species.—

Pecten atavus RÖMER, 1839, p. 29, pl. 18, fig. 21 (WOODS, 1902, p. 197, pl. 39, figs. 1-5) (non D'ORBIGNY, 1847, p. 627, pl. 442, figs. 1-3, 5; non PICTET and CAMPICHE, 1870, p. 237, pl. 180; non GILLET, 1924 b, p. 51, text-figs. 27-29; non ALENCASTER, 1956, p. 12, pl. 2, figs. 5-7) upper Neocomian-Aptian, Western Europe and (?) Japan.

Janira cometa D'ORBIGNY, 1847, p. 640, pl. 445, figs. 15-20 (WOODS, 1902, p. 200, pl. 39, figs. 6-10) Cenomanian, Western Europe.

Janira johannisboehmi TIESSEN, 1895, p. 473, pl. 17, figs. 5 (? = *J. cometa*)

Pecten (*Neithea*) *hourcqi* COLLIGNON, 1939, p. 13, pl. 1, figs. 16, 17, Cenomanian, Madagascar.

Janira longicauda D'ORBIGNY, 1847, p. 639, pl. 445, figs. 9-14 (GEINITZ, 1872, p. 202, pl. 45, figs. 16, 17) Turonian, Western Europe.

Janira matheroniana DE LORIOL, 1866, p. 65, pl. 2, fig. 9 (? = *P. atavus,* as interpreted by WOODS, 1902).

Janira neocomiensis D'ORBIGNY, 1847, p. 629, pl. 442, figs. 4, 6-9 (DE LORIOL, 1861, p. 105, pl. 14, figs. 2, 3) (= *P. atavus*).

Pecten notabilis MÜNSTER, in GOLDFUSS, 1836, p. 56, pl. 93, fig. 3 (GEINITZ,

1872, p. 202, pl. 45, figs. 10-12) "Greensand", Germany.

Pecten (Neithea) ornithopus KEEPING, 1870, p. 107, pl. 4, fig. 5 (= *P. atavus*, as interpreted by WOODS, 1902).

Janira valanginiensis PICTET and CAMPICHE, 1870, p. 242, pl. 181, figs. 1-3, Neocomian, Switzerland.

Janira wrightii SHUMARD, 1860, p. 607 (CRAGIN, 1893, p. 217, pl. 32, figs. 2, 3; WHITNEY, 1911, p. 13, pl. 1, fig. 4; KNIKER, 1919, p. 23, pl. 4, figs. 1-3; ADKINS and WINTON, 1920, p. 69, pl. 11, figs. 8-11; WINTON, 1925, p. 53, pl. 10, fig. 6; ADKINS, 1928, p. 125, pl. 17, fig. 6; SRANTON, 1947, p. 46. pl. 21, figs. 6, 7) Albian, Gulf Coast.

Remarks.—The unequal auricles have not been observed in all the above-listed species, because of the inadequate state of preservation, but this subgenus is well characterized by the small size of the shell, the broadly plicated primary ribs, and the weak secondary ornament. Many species of this group have six primary ribs as those of *Neithea* (*s. str.*). According to WOODS (1902), *Neithea cometa* (D'ORBIGNY, 1847) has only five primary ribs on the right valve, and *Neithea wrightii* (SHUMARD, 1860), the type-species of this subgenus, is characterized by only four primaries. In all the species of this subgenus with six primaries, however, the 1st and 6th ribs are much weaker than other ribs, and, therefore, the number of primaries may not be a very important character for the classification of this subgenus.

Judging from the stratigraphic occurrences, this subgenus may have constitute a distinct evolutionary stem ranging from Neocomian to Turonian. Species with decreased primaries appeared mainly in the Albian and later, and they were probably derived from six-ribbed species which were common already in the Neocomian.

Subgenus *Aequineithea* nov.

Type-species.—*Pecten aequicostatus* LAMARCK, 1819, Cenomanian, Western Europe and Africa.

Diagnosis.—Shell small to medium; right valve strongly convex, typically with a number of fine ribs of almost equal prominence, although sometimes the surface is nearly smooth except for feeble radial striae; outline subovate; ventral margin not strongly serrated, at times almost smooth; auricles small, subequal; both lateral areas nearly smooth; left valve also with numerous riblets or striae of almost equal prominence.

Remarks.—The group of *Neithea aequicostata* has been considered to constitute *Neithea* (*s. str.*) by some authors, but, as noted above (p. 287), *Neithea* (*s. str.*) should properly consist of *Neithea quinquecostata* and its allies with six prominent primary ribs. The present subgenus corresponds essentially to the group IA of DARTEVILLE and FRENEIX's (1957) diagnostic table of African *Neithea*, but the group II, typifieed by *Neithea laevis*, is also included in it in this paper, since the shell form and auricles are fairly similar.

Group of *Neithea aequicostata* (LAMARCK)

Diagnosis.—Shell small or medium-sized; right valve with about 40 fine radial ribs of almost equal prominence; lateral areas usually smooth.

List of species.—

Pecten aequicostatus LAMARCK, 1819, p. 181 (GOLDFUSS, 1836, p. 54, pl. 92, fig. 6; REUSS, 1845, p. 32, pl. 39, fig. 22, pl. 40, figs. 2, 3; ? D'ORBIGNY, 1847, p. 637, pl. 445, figs. 1-4; GEINITZ, 1872, p. 200, pl. 45, figs. 25, 26; BAYLE, 1878, pl. 122, fig. 4; DE LORIOL, 1882, p. 102, pl. 13; figs. 6-8; CHOFFAT, 1901-1902, p. 152, pl. 3, fig. 10; WOODS, 1902, p. 208, pl. 40, figs. 8, 9; PERVINQUIÈRE, 1912, p. 135; NEWTON, 1916, p. 565, pl. 1, figs. 2, 3; FAVRE, 1918, pl. 10, figs. 24, 25; GILLET, 1924, pl. 24, figs. 3, 4; COLLIGNON, 1939, p. 12, pl. 1, figs. 11-13) Cenomanian, Western Europe and Africa.

Neithea kaufmanni MAYER-EYMAR, 1893, Neocomian, Somaliland.

Neithea pectinoides DROUET, 1825, p. 186, pl. 7, figs. 1, 2 (= *P. aequicostatus*).

Remarks.—Primary ribs of very slight prominence are indicated in the figures of *Janira aequicostata* in D'ORBIGNY (1847, pl. 445, figs. 1, 4), and may suggest that the figured specimen is a transitional species between the present group and that of *N. quinquecostata*.. Judging from the stratigraphical occurrence of the present group, which is almost restricted to the Cenomanian and Turonian, it is highly probable that this group was actually derived from six-ribbed species of *Neithea* (*s. str.*). However, such a transitional ornamentation has not been reported by subsequent authors.

Group of *Neithea laevis* DROUET

Diagnosis.—Shell small or medium-sized, similar to the group of *N. aequicostata* in outline of two valves; right valve without ribs, nearly smooth except for about 20 fine radial furrows which may correspond to the intervals between primaries in normal species of*Neithea* (*s. str.*).

List of species.—

Neithea laevis DROUET, 1825, p. 188, pl. 7, fig. 3 (STOLICZKA, 1871, p. 438, pl. 31, figs. 7, 8; CHOFFAT, 1901-1902, p. 151, pl. 3, figs. 11, 12; GRECO, 1918, p. 204, pl. 3, figs. 4, 6; COLLIGNON, 1939, p. 12, pl. 1, figs. 14, 15) Cenomanian-Turonian, Western Europe, Portugal and Madagascar. (= *Janira phaseola* D'ORBIGNY, 1847, p. 635, p. 444, figs. 6-10, non LAMARCK, 1819).

Pecten decipiens REUSS, 1846, p. 31, no. 28, pl. 45, fig. 3, Upper Cretaceous, Bohemia (? = *N. laevis*)

Neithea noutai RENNIE, 1945, p. 29, pl. 2, figs. 6, 7, Cenomanian, Angola.

Neithea phaseolina GILLET, 1924 a, p. 119 (? misprint of *N. phaseola*) (= *N. laevis*).

Pecten phaseolus LAMARCK, 1819, p. 181, no. 12 (ROGER, 1956, no. 49) Cenomanian-? Turonian, Western Europe.

Subgenus indeterminable

Besides the species classified above, several minor groups characterized

by peculiar characters can be distinguished.

Janira welwitschi CHOFFAT *in* CHOFFAT and DE LORIOL, 1888, p. 90, pl. 3, fig. 11, from the Albian of Angola has large dimensions and an alternation of strong and weak radial ribs on the right valve.

Janira dutrugei COQUAND, 1862, p. 229, pl. 13, figs. 1, 2 (CHOFFAT, 1901-1902, p. 150, pl. 2, figs. 1, 2, including var. *beirensis*) from the Cenomanian of North Africa and Portugal has numerous radial ribs which are not clearly differentiated into two orders. It appears to be transitional between *Neithea* (*s. str.*) and *Aequineithea* and may be related to "*Janira aequicostata*" as figured by D'ORBIGNY (1847).

Janira deshayesiana D'ORBIGNY, 1847, p. 626, pl. 441 (GILLET, 1924 a, p. 54, fig. 31) from the Neocomian of France has a nearly smooth surface except for numerous fine radial striae. Though the exterior recalls that of the group of *N. laevis*, the highly developed and unequal auricles may suggest another group.

Neithea aketoensis sp. nov. from the Albian of Japan is also very aberrant, as the radial ribs of the right valve are very irregular in arrangement and prominence.

Pecten (*Vola?*) *roemeri* HILL, 1889, p. 5, pl. 1 (SHATTUCK, 1903, p. 15, pls. 2-4, pl. 5, fig. 1; KNIKER, 1919, p. 43, pl. 9, figs. 1-3, pl. 10, fig. 1; STANTON, 1947, p. 44, pl. 35, figs. 1, 2, pl. 36, figs. 1, 2) from the Lower Cenomanian of Gulf Coast is large and has well developed auricles, recalling the species of the group of *Neithea gibbosa*. It has six primary ribs, like normal *Neithea* (*s. str.*), but the shell is said to be subequivalve as regards both to convexity and ornamentation. Such an inflated left valve is unknown in other species of *Neithea*.

In *Janira decemcostata* D'ORBIGNY, 1847, p. 649, pl. 449, figs. 1-5, from the Senonian of France, and *Neithea biangulata* IMLAY, 1940, p. 146, pl. 20, figs. 6, 7 from the Neocomian of Mexico, the main ribs are 11 to 13 in number and apparently homologous with the primary and central intercalary ribs of normal species of *Neithea*. These species are at a glance intermediate between *Neithea* (*s. str.*) and *Aequineithea*, although not in the same way as *Janira dutrugei;* they are in any case very different from other species.

Distribution of Neithea.—Aequineithea is known in the Cenomanian-Turonian of Western Europe, Africa, Madagascar and India, but scarcely found in other stages and in other continents. The group of *Neithea ficalhoi*, on the contrary, is comparatively rare in Europe, but is represented by a number of species in the Albian of the Gulf Coast region. *N. ficalhoi* itself is found in the Aptian-Albian of Angola and Japan. The groups of *Neithea quinquecostata* and *Neithea gibbosa* are more widely distributed, and especially common in various stages from Neocomian to Senonian in Western Europe, Africa and India, and also are found from the Lower Cretaceous of Japan. The distribution of *Neithella* is also very wide, but in Africa it seems somewhat rare. In Oceania and South America *Neithea* appears very rare, and in North

America its occurrence is restricted to the Aptian-Lower Cenomanian Comanche series and its correlatives.

Japanese species of Neithea.—In Japan, *Neithea* occurs commonly in the Aritan and Miyakoan (upper Neocomian to Albian) sandy beds of various areas, but Upper Cretaceous species are scarcely known. The restricted occurrence is just comparable with that in North America.

Since YABE, NAGAO and SHIMIZU (1926) described *Neithea* sp. cf. *N. atava* (RÖMER) from the Ishido and Kawarazawa formation of the Sanchu area, various forms have been referred to or compared with *N. atava, N. morrisi* or *N. quadricostata,* but such specific references are not always acceptable. As the result of the present study, it has been found that most specimens so far collected from Japan are closely related to nearly conteemporaneous European or African species, but their specific identity is often doubtful, because of their isolated geographic occurrence and slight morphological differences.

The name *Neithea* sp. cf. *N. atava* is conserved here for a few specimens from the Sanchu area, because they are very similar to the Lower Greensand specimens of *N. atava,* as described by WOODS (1902). Similar specimens are found also in the Miyako group, although only rarely. *Neithea morrisi* as recorded by NAGAO (1934) from the Miyako group invariably has two secondary costae in each interval and nearly smooth lateral areas. Although the name has been used by many subsequent stratigraphers, this species appears to be indistinguishable from *Neithea (Neithea) ficalhoi* (CHOFFAT) from the Albian of Angola.

The group of *Neithea quinquecostata* is well represented in Japan. *Neithea (Neithea) nipponica* sp. nov. from the upper part of the Miyako group resembles *N. quinquecostata* in many respects. The species listed by MATSUMOTO (1954) as*Neithea atava,* from the Yatsushiro and the Haidateyama formations of Kyushu, is a new species and is here named *Neithea (Neithea) matsumotoi.* The *Neithea* sp. cf. *N. morrisi* recorded by AMANO (1957 a) from the Hagino formation of Shikoku is probably close to *Neithea morrisi* and to *Neithea shawi,* but has proved to be a new species, here named *Neithea (Neithea) amanoi.* The species from the Hinagu formation of Kyushu, listed by MATSUMOTO (1954) as *Neithea atava* and here named *Neithea (Neithea) kanmerai,* is a large form and certainly belongs to the group of *Neithea gibbosa* of the present classification. The same species can also be found in the Ishido, Arita and Hanoura formations.

Although the Cenomanian and Turonian pelecypods of Japan are not yet sufficiently studied, *Aequineithea* is probably not represented in this country. An aberrant species of *Neithea* was found in the upper part of the Miyako group, here named *Neithea (s. l.) aketoensis.*

Subgenus *Neithea s. str.*

Group of *Neithea quinquecostata*

Neithea (Neithea) nipponica sp. nov.
Plate 40, Figures 1-6; Plate 52, Figures 1, 2

1934. *Pecten (Neithea)* sp., NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 209, pl. 29, figs. 8, 9.

Material.—The holotype is a right valve (GK. H 6263) collected from the Aketo formation at loc. Hn. 6201, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture (HANAI coll.). Paratypes (GK. H.6264-GK. H 6266, GK. H 6364, GK. H 6365, GK. H 6632, GK. H 6633) from the type area (HANAI, OBATA and HAYAMI coll.).

Description.—Shell medium-sized, plano-convex, polygonally ovate in outline, subequilateral, slightly higher than long; test moderately thick. Right valve strongly inflated, with incurved and prominent umbo; antero- and postero-dorsal margins long, broadly concave, forming an apical angle of about 80 degrees; ventral margin distinctly concave between primary ribs; auricle subequal in size, comparatively small, although anterior auricle is more acutely angulated and has a shallow byssal notch; hinge-line moderate in length, provided with numerous fine internal crenules; six primary ribs nearly straight in perpendicular view, not very strong but clearly distinguishable from secondary ribs; each interval between primary ribs slightly concave, provided with four regular secondary riblets which are subequal to their interspaces in breadth; both lateral areas and auricles marked with a number of still finer riblets; concentric lines comparatively weak. Left valve nearly flat in early stage and weakly concave after mid-growth; apical angle exclusive of auricles approximately 100 degrees; auricles subequal in size, the posterior one right-angled or obtuse, the anterior one acute and demarcated by a deep angular groove; radial ribs about 30 or slightly more in number, slightly narrower than interspaces, increasing gradually in number by irregular bifurcation which occurs on the weak radial ribs corresponding to primary ribs of right valve; both lateral areas marked with several weaker radial riblets; auricles apparently smooth except for growth-lines.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6263) right valve	39.5	41.0	11.0	0.96
Paratype (GK.H6264) left valve	35.0	35.0	—	1.00
Paratype (GK.H6265) left valve	17.5	16.5	—	1.07
Paratype (GK.H6266) right valve	14.5+	21.5	5.0	0.65+
Paratype (GK.H6364) right valve	15.5+	21.0	5.5	0.74+
Paratype (GK.H6365) left valve	16.0	16.0	—	1.00
Paratype (GK.H6632) right valve	38.0	42.5	12.5	0.89
Paratype (GK.H6633) right valve	22.5	25.0	8.0	0.90

Observations and comparisons.—The holotype shows nearly complete outline and ornament of right valve, although the test is partly exfoliated. The paratypes of left valves reveal the interior and exterior, and their specific identity with the holotype can be readily presumed from their association with

it in the same fossil bed and from the correspondence in ornamentation. The striated lateral areas are observable in every right valve. The *Neithea* sp. described by NAGAO (1934) from the Miyako group is probably conspecific with these specimens in view of the similar ornamentation.

This species is clearly distinguishable from *Neithea* (*Neithea*) *ficalhoi* (CHOFFAT), which is sometimes associated with it, by the weaker convexity of the right valve, the larger number of secondary riblets (invariably two in *N. ficalhoi*), the finer primary and secondary ribs, the distinctly striated lateral areas and the larger apical angle of left valve. The height is scarcely in excess of 35 mm. in *N. ficalhoi*, whereas the adult specimens of the present species are as tall as 40 mm.

The ornamentation of both valves of the present species is similar to that of *Neithea quinquecostata* (SOWERBY, 1814), a well-known species from the Aptian-Turonian of Western Europe, Africa and India. In comparison with WOODS' figures (1902) and with the Upper Greensand specimens of typical *N. quinquecostata*, however, the umbo of the right valve is slightly narrower and the umbonal area of the left valve is less concave. The shell convexity is distinctly weaker in *N. niponica* than in *N. quinquecostata*.

Occurrence.—Lower (?) and upper Miyakoan (?) Aptian and Albian). Grey sandy shale of the Aketo formation at loc. Hn. 6201, and grey sandy shale of the upper part of the "*Orbitolina* sandstone" at loc. Hn. 6203 and Hn. 0671, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture. NAGAO's specimens of *Neithea* sp. are said to have come from the Hiraiga formation at Hiraiga in the same village, although I have been unable to find this species in the lower part of the Miyako group.

Neithea (*Neithea*) *matsumotoi* sp. nov.

Plate 41, Figures 1-7

1952. *Neithea atava* (RÖMER), MATSUMOTO and KANMERA, Guide books of the geological excursions. The lower valley of the Kuma, p. 49 (non p. 45), listed.
1954. *Neithea atava* (RÖMER), MATSUMOTO, Cretaceous System, Japan. Islands, p. 114 (non p. 113), listed.

Material.—The holotype is internal and external moulds of a right valve (GK. H 6126) collected from the Yatsushiro formation at loc. Km. 3037, west of Mt. Jôgûsan, Miyaji, Yatsushiro City, Kumamoto Prefecture (KANMERA coll.). Paratypes (GK. H 6125, GK. H 6127—GK. H 6131) from the type area (KANMERA, FUJII and AKATSU coll.).

Description.—Shell small or medium-sized for genus, plano-convex, subequilateral, polygonally ovate. Right valve higher than long to a varying extent, well inflated; umbo incurved, protruding prominently above hinge-line, overhanging that of the other valve; anterior and posterior margins slightly concave when viewed perpendicularly to valve margin; ventral margin frilled, corresponding to radial ribs of two orders; apical angle about 75 degrees; primary ribs six in number, roof-shaped in transverse section, very prominent, giving

rise to digitations of ventral margin, slightly curved outwards; ribs distinctly plicated; interspaces of primary ribs flattened at bottoms, bearing three-five weak secondary riblets, which are of rather unequal prominence, nearly as wide as their interspaces and sometimes bifurcated at various growth-stages; both lateral areas also striated by secondaries of similar strength; faint concentric growth-lines cross radials; auricles subequal, comparatively small. Left valve nearly flat or even slightly concave, suboctagonal, nearly as high as long; hinge-line of moderate length; ventral margin with angular projections corresponding to intervals between primaries and broadly sinuated at primaries; apical angle exclusive of auricles approximately 90 degrees; primary ribs, which correspond to the intervals between primaries of the other valve, five in number, straight, strongly plicated, much broader than interspaces, marked with three-five secondary riblets; primary grooves bearing also a few radial threads, which are, however, much weaker, densely spaced and not impressed on internal surface; concentrics weak; auricles small, subequal, demarcated clearly from main body by a pair of angular sulci; anterior auricle rectangularly truncated; byssal notch shallow; posterior auricle more obtuse; strong internal ridges extend along antero- and postero-dorsal margins, defining a pair of faintly striated marginal areas; musculature unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6126) right in. mould	17.5	18.5	6.5	0.95
Paratype (GK.H6125) right in. mould	20.5	21.5	7.0	0.95
Paratype (GK.H6127) right valve	25.5	27.5	9.5	0.93
Paratype (GK.H6128) left ex. mould	29.5	29.0	—	1.02
Paratype (GK.H6129) left in. mould	21.5	21.0	—	1.00
Paratype (GK.H6130) right in mould	16.5+	19.0	6.0	0.84+
Paratype (GK.H6131) left in. mould	23.0	22.0	—	1.05

Observations and comparisons.—This species is represented by many specimens, seven of which are nearly complete. The test is preserved only in one paratype (GK. H 6127), and all other specimens are composed of internal and/or external moulds. Specimens with both valves in juxtaposition cannot be found, but the two valves certainly belongs to one species in view of their similar frequency and corresponding ornamentation. The variation of outline seems relatively slight, according to my measurements of the ratio of length/height. The secondary riblets, however, are fairly variable in number and prominence.

The present specimens were formerly assigned to *Neithea atava* (RÖMER, 1839), but they are essentially different from every specimens from Europe hitherto referred to *N. atava*. Compared with the Lower Greensand specimens of *N. atava* as described by WOODS (1902), the right valve has narrower ribs, its secondary ornament consists of fine ribs instead of striae of the *Neithella*-type, and the left valve is more weakly plicated and has a much smaller and less projecting anterior wing. The present species is certainly a member of

the group of *Neithea quinquecostata* of the present classification.

In the outline of the right valve this species is somewhat similar to *Neithea morrisi* (PICTET and RENEVIER, 1858) from the Aptian of Western Europe (WOODS, 1902), and allied species to it from Lebanon (VOKES, 1947), but the convexity of the right valve is stronger and the two lateral areas, beyond the outermost primary ribs, are distinctly striated in the present species. In convexity and number the secondary riblets are comparable to those of *Neithea quinquecostata* (SOWERBY, 1819) from the Aptian-Turonian of western Europe, Africa and India (WOODS, 1902; STOLICZKA, 1871; etc.). However, in the right valve the secondary riblets are more delicate than in that species and the left valve is more distinctly plicated than that of *N. quinquecostata.* In the left valve of *N. quinquecostata* radial ornament consists of many ribs which are almost equal in strength, while in the present species it is more complicated, as described above. Such differences also exist between the present species and *Neithea (Neithea) nipponica* sp. nov. from the Miyako group.

Pecten (Neithea) sexcostatus WOODWARD (WOODS, 1902) from the Chalk of England differs from the present species in its weaker outermost primary ribs, more salient umbo and larger size. *Neithea attockensis* COX, 1935, from the Albian of Attock district of India, is related to the present species, in which, however, the lateral areas are more clearly ornamented and the umbonal region of the right valve is more prominent, and the secondary ribs are generally weaker and more numerous.

This species is named after Prof. Tatsuro MATSUMOTO of the Kyushu University, who has given me invaluable advise and encouragement throughout this study.

Occurrence.—Upper Miyakoan (Albian). Dark grey sandy shale of the Yatsushiro formation at loc. Km. 3037, west of Mt. Jôgûsan, Miyaji, Yatsushiro City, Kumamoto Prefecture. Grey sandstone of the same formation at the southwest of Bishô, Tôyô village, Yatsushiro County, Kumamoto Prefecture. This species is known also from the Haidateyama formation at loc. U. 1005, between Tamarimizu and Ochiai, Nozu town, Ono County, Oita Prefecture (FUJII coll.)

Neithea (Neithea) amanoi sp. nov.

Plate 41, Figures 8-10; Plate 42, Figures 1-4

1957. *Pecten (Neithea)* cf. *morrisi* (PICTET and RENEVIER), AMANO, *Kumamoto Jour. Sci.*, Ser. B, Sec. 1, Vol. 2, No. 2, p. 88, pl. 1, figs. 17, 18, 20, 25, 27-29.

Material.—The holotype is a right internal mould (GK. H 6267) collected from the Hagino formation at loc. Hy. 6011, Hagino, Mirafu village, Kami County, Kochi Prefecture (OGAWA coll.). Paratypes (GK. H 6268-GK. H 6274) from the type locality (OGAWA coll.).

Description.—Shell comparatively small, subovate, planoconvex, subequilateral in the main part. Right valve higher than long, comparatively narrow, moderately inflated; umbo prominent, incurved; antero- and postero-dorsal

margins broadly concave when viewed perpendicularly to valve margin; valve margin with weak serrations corresponding to radial ribs of two orders; apical angle about 65-70 degrees; primary ribs six in number, comparatively narrow, not much raised, but clearly distinguishable from secondaries, nearly straight or only slightly curved outwards; each interval of primary ribs not much concave, ornamented with three (sometimes four) secondary riblets which are slightly broader than their interspaces, almost uniform in breadth and prominence; lateral areas quite smooth; auricles well inflated, remarkably unequal; anterior auricle about twice as large as posterior one; hinge-line comparatively long, provided with numerous fine crenulations internally. Left valve flat, suborbicular, slightly higher than long; antero- and postero-dorsal margins straight, forming an apical angle of about 90 degrees; anterior auricle acutely triangular, about twice as large as posterior one; surface weakly plicated; radial ribs about 24 in number, nearly as wide as their interspaces, almost uniform in breadth and prominence; auricles apparently smooth except for growth-lines; ventral margin weakly serrated but never digitated.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6267) right in. mould	19.0	23.5	6.5	0.81
Paratype (GK.H6268) right ex. mould	18.5	22.5	6.0	0.82
Paratype (GK.H6269) right ex. mould	14.5+	18.0	5.5	0.81+
Paratype (GK.H6270) right in. mould	18.0	21.0	6.5	0.86
Paratype (GK.H6271) right in. mould	23.0	25.5	7.5	0.90
Paratype (GK.H6272) left ex. mould	15.5	17.0	—	0.91
Paratype (GK.H6273) left ex. mould	11.0	11.0	—	1.00
Paratype (GK.H6274) left in. mould	19.5	20.0	—	0.98

Observations and comparisons.—All the available specimens are represented only by internal and/or external moulds. No bivalved specimen was obtained, but the right and left valves can be assigned with certainty to the same species, because of the corresponding ornamentation and coexistence in the same fossiliferous bed.

As noted by AMANO (1957a), the present species is characterized by the comparatively small apical angle of the right valve, the narrow primary ribs, the nearly smooth lateral areas, the unequal auricles and the three (sometimes four) persistent secondary riblets in each interspace. These characters indicate that this species belongs to the subgroup of *Neithea morrisi* of the group of *N. quinquecostata* of the present classification.

AMANO compared this species with *Neithea morrisi* (PICTET and RENEVIER, 1858) from the Aptian of Western Europe, citing the references of WOODS (1902) and NAGAO (1934). In fact, *Neithea morrisi* as recorded by WOODS (1902) from the Lower Greensand of England has a similarly tall outline and smooth lateral areas, but the present species has narrower primary ribs, larger anterior auricle and, generally, a smaller number of secondary riblets. The species described as *Neithea morrisi* by NAGAO (1934) from the Miyako group is certainly related neither to *N. morrisi* nor to the present species.

and will be described in this paper as *N. ficalhoi.*

Neithea morrisi has been considered by some authors to be conspecific or closely related to *Neithea syriaca* (CONRAD, 1852) from the Aptian of Lebanon (VOKES, 1946; CASEY, 1961). The present species resembles *N. syriaca* in the outline and ornamentation of both valves. The shape of auricles is, however, somewhat different and more unequal in the present species. The secondary riblets of *N. syriaca* are constantly four in number like *N. morrisi.*

Neithea (Neithea) nipponica sp. nov. from the Miyako group has a larger size, a larger apical angle, a broader outline, less unequal auricles, distinctly striated lateral areas and typically four secondary riblets in each interspace between primaries. *Neithea (Neithea) matsumotoi* sp. nov. from the Yatsushiro formation has a broader outline, broader and more roof-shaped primary ribs, more numerous and delicate secondary riblets, a slightly larger apical angle, distinctly striated lateral areas and less unequal auricles.

In many characters the present species resembles *Neithea shawi* PERVINQUIÈRE, 1912 (DARTEVILLE and FRENEIX, 1957) and its "varieties" from the Cenomanian of Tunisia, Algeria, Lebanon and the Albian of Gabon. The outline of the main body, the apical angle and the radial ornamentation are especially similar, but the anterior auricle is larger and the umbo may be more salient and narrower than that of *N. shawi.* It may be also close to *Neithea attockensis* COX, 1935, from the Albian of Attock in view of the number of secondary riblets, the smooth lateral areas and the relatively inconspicuous primary ribs, but is distinguishable from the Indian species by its narrower outline, smaller apical angle and weaker shell-convexity.

The specific name is dedicated to Prof. Masahisa AMANO of the Kumamoto University, who previously described this species and kindly gave me valuable specimens of Lower Cretaceous pelecypods.

Occurrence.—Lower Miyakoan (Aptian). Fine weathered sandstone of the Hagino formation at loc. Hy. 6011, Hagino, Mirafu village, Kami County, Kochi Prefecture.

Neithea (Neithea) sp. indet.

Plate 43, Figure 7

An ill-preserved internal mould of a right valve (GK. H 6275, 31.5 mm. long, 35.0 mm. high, 11.5 mm. thick) is almost indistinguishable from *Neithea matsumotoi* sp. nov. from the Yatsushiro formation as regards its radial ornamentation impressed on the mould. The shell-convexity is, however, slightly stronger and the umbonal region is still prominent. Its specific identification is deferred until better material is obtained.

Occurrence.—Aritan (upper Neocomian). Fine grey sandstone of the Ishido formation at loc. Hy. 4001, Ichinosebashi, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture (ICHIKAWA and HAYAMI coll.).

Group of *Neithea ficalhoi*

Neithea (Neithea) ficalhoi (CHOFFAT)
Plate 42, Figures 5–16

1888. *Janira ficalhoi* CHOFFAT, *in* CHOFFAT and de LORIOL, *Mém. Soc. Phys. Hist. nat. Gènève*, Tom. 30, No. 2, p. 89, pl. 5, figs. 8–10.
1934. *Pecten (Neithea) morrisi*, NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 206, pl. 26, figs. 2–6 (non *Janira morrisi* PICTET and RENEVIER, 1858).
1957. *Neithea ficalhoi*, DARTEVILLE and FRENEIX, *Ann. Mus. roy. Congo Belge*, Sér. 8, Vol. 20, p. 76.

Material.—A dozen of specimens (GK. H 6275-GK. H 6280, GK. H 6366-GK. H 6370, GK. H 6617), from the Miyako area (HANAI and HAYAMI coll.), are concerned with the description below.

Description.—Shell small or medium-sized, plano-convex, subequilatera except for auricles, but slightly opisthocline; test fairly thick. Right valve higher than long, strongly inflated, with a prominently projecting, strongly incurved umbo; antero-dorsal and postero-dorsal margin nearly straight; apical angle about 65-70 degrees when viewed perpendicularly to valve margin; six primary ribs which are very prominent, round-toped and not much outcurved, giving rise to digitations of ventral margin; each interspace ornamented with two secondary riblets which are very constant in number and prominence; sometimes weak subordinate riblets are visible on both sides of primary ribs in adult specimens; both lateral areas (beyond the outermost primary ribs) fairly wide, nearly smooth except for a blunt ridge and a shallow furrow; faint concentric lines of growth cross radials; auricles slightly unequal, strongly convex, marked only with growth-lamellae; anterior auricle slightly larger than posterior one. Left valve weakly concave, not plicated, invariably, though only slightly, higher than long; umbonal region well inflated, apparently forming a small tubercle, which probably indicates the biconvex early stage of growth; antero- and postero-dorsal margins nearly straight, forming an apical angle of about 85 degrees; primary grooves, which may correspond to primary ribs of the other valve, six in number, bordered by highly raised riblets on both sides; interval between primaries bearing a single weaker riblets; growth-lines arched forwards in interval between ribs and angularly sinuate on ribs; auricle subequal in size but differing in shape; anterior one acutely triangular, clearly demarcated from main body by an angular furrow; posterior one broadly concave, truncated subvertically with a slightly sinuate margin; radials absent on auricles; inner surface shiny, almost smooth except for posterior and ventral peripheral areas where radial ornament is obscurely impressed; adductor subovate, placed posteriorly to the mid-point of the valve; resilifer triangular, fairly large.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK.H6276)	26.5	31.0	11.0	0.85
Right valve (GK.H6277)	9.5	11.0	4.0	0.86

Right valve (GK.H6278)	21.5	21.0+	9.0	1.02−
Left valve (GK.H6279)	10.0	11.0	—	0.91
Left valve (GK.H6280)	13.5+	16.0	—	0.84+
Left valve (GK.H6368)	17.5+	21.0	—	0.83+
Right valve (GK.H6366)	11.0	13.0	5.0	0.85
Left valve (GK.H6369)	11.0	11.5	—	0.96
Left valve (GK.H6617)	13.0	14.0	—	0.93

Observations and comparisons.—The present species is here represented by more than 12 well-preserved specimens. In the largest of them, a right valve (GK. H 6276), the test is partly exfoliated in the umbonal region but the characteristic ornament, smooth lateral areas and strongly inflated auricles can be observed in detail. In this specimen weak subordinate riblets are separated from the primary ribs laterally by shallow furrows (see Fig. 3). Two secondary ribs constantly cover each interspace in all the right valves. The primary grooves of the left valve seem somewhat irregular in breadth; in most specimens they are clearly distinguishable and distinctly broader than the secondary ones, but in a few specimens the two orders cannot be clearly

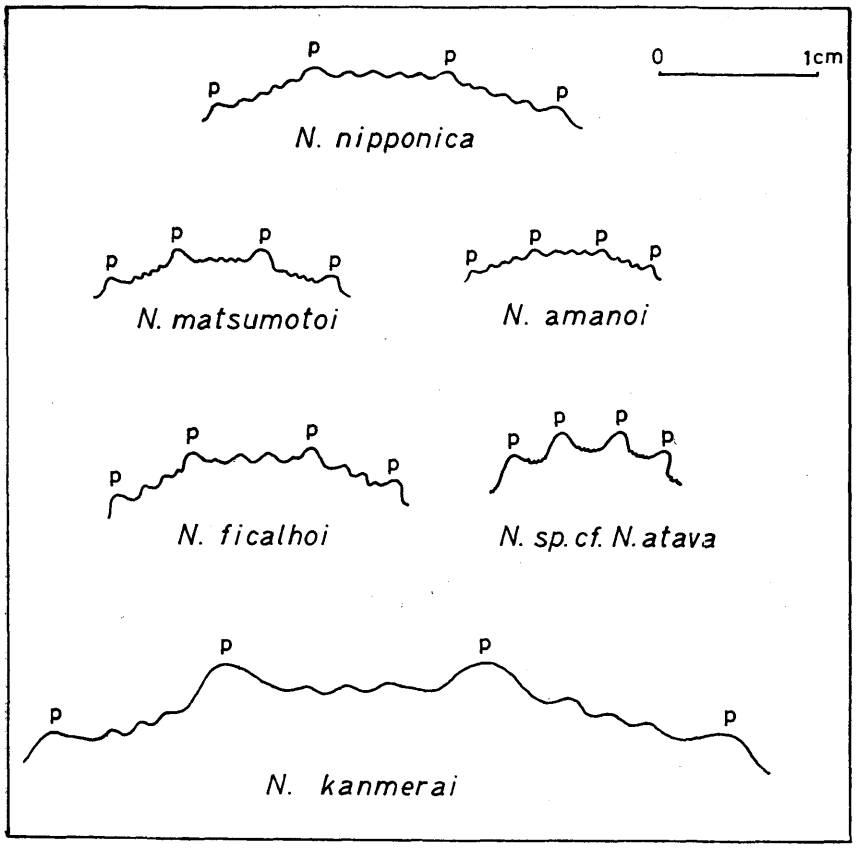

Fig. 4. Radial ornamentation of the Japanese species of *Neithea* (right valve)
p: primary ribs

discriminated. The abrupt change of shell convexity in the early stage of growth can be presumed from every left valve. Muscle impressions, which can be observed on the internal surface of a left valve (GK. H 6281), are not much different from those of living *Pecten*.

NAGAO (1934) assigned several specimens, which were collected from the same localities as the present ones, to *Neithea morrisi* (PICTET and RENEVIER, 1858), originally described from the Aptian of France. However, the specimens which include NAGAO's "*N. morrisi*" are clearly different from typical *N. morrisi* from Western Europe in the following points. According to WOODS (1902, pl. 39, figs. 11 b, 12 b) the ratio of thickness/height is less than 0.30 in the Lower Greensand specimens of *N. morrisi*, while it is about 0.35 or slightly larger in the present specimens. The secondary ribs of the right valve are comparatively narrow and typically four on each interspace in *N. morrisi*, whereas they are stout and invariably two in these specimens. The radials are strongly curved outwards in *N. morrisi* but are nearly straight in the present specimens. Moreover, both of the lateral areas which are free from radial ornament are distinctly broader than in *N. morrisi*.

The present specimens from Japan closely resemble the type-specimens of *Janira ficalhoi* CHOFFAT *in* CHOFFAT and DE LORIOL, 1888, from Angola. The strongly convex shell, the nearly straight radial ribs and the broad smooth lateral areas agree well with those of the African specimens. The radial ornamentation of the right valve of *N. ficalhoi* from Angola similarly consists of six round-topped and feebly subdivided primary ribs and of two stout secondary riblets on each interspace (DARTEVILLE and FRENEIX, 1957). As regards the left valve, the primary and secondary grooves seem slightly more regularly arranged than in the Angolan specimens, but the outline, the apical angle, the shape of auricles and the number of radials are quite similar. I therefore refer the present specimens to *N. ficalhoi*.

Neithea alpina D'ORBIGNY, 1847, is probably related to *N. ficalhoi* in view of the similar radial ribs, but the lateral areas are narrower than in the latter species. In the Comanche series of the Gulf Coast and its comparable strata in Mexico, many species belonging to the group of *N. ficalhoi*, have been described. *Neithea occidentalis* (CONRAD, 1855) (= *Vola irregularis* BÖSE, 1910) seems to be the closest to this species in view of the similar surface ornamentation and the shape of auricles of two valves. Someone might consider *N. ficalhoi* as conspecific with *N. occidentalis*, but the former has broader ribs to a variable extent than the latter. *Neithea texana* (RÖMER, 1852) also resembles *N. ficalhoi*, but the shell is less convex and the radial ribs are more flat-topped in the former.

Occurrence.—Lower and upper Miyakoan (Aptian to Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga, loc. Hn. 0914, north of Haipe and loc. Hn. 0299, northern coast of Hiraiga, all in Tanohata village, Shimohei County, Iwate Prefecture. Fine grey sandy shale of the Tanohata formation at loc. Hn. 0220, northern coast of

Hiraiga in the same village. Fine grey sandstone of the 2nd cycle of the Miyako group (so-called Belemnite zone) at "Ebisudana" of Hideshima, Sakiyama, Miyako City, in the same prefecture. Fine grey sandy shale of the upper part of the "*Orbitolina* sandstone" at loc. Hn. 6203, northeast of Raga, Tanohata village.

Group of *Neithea gibbosa*

Neithea (*Neithea*) *kanmerai* sp. nov.

Plate 43, Figures 1-5; Plate 52, Figure 3

1952. *Neithea atava* (RÖMER), MATSUMOTO and KANMERA, Guide books of the geological excursions. The lower valley of the Kuma, p. 45 (non p. 49), listed.

Material.—The holotype is a right internal mould (GK. H 6132) collected from the Hinagu formation at loc. Km. 3085c south of Kohara, Tôyô village, Yatsushiro County, Kumamoto Prefecture (KANMERA coll.). Three paratypes (GK. H 6133-GK. H 6135) from the type locality (KANMERA coll.) and a paratype (GK. H 6608) from the Yuasa area (MATSUMOTO et al. coll.).

Description.—Shell large, plano-convex, subequilateral exclusive of auricles. Right valve moderately inflated, higher than long, with prominent umbo and slightly sinuate antero- and postero-dorsal margins; apical angle approximately 80 degrees in perpendicular view; anterior wing flattened, large, probably prolonged forwards; primary ribs strongly plicated, roof-shaped in transverse section, invariably six in number, slightly curved outwards; the outermost ribs somewhat weaker than others, and the 1st and 5th interspaces much narrower than others; interspaces deeply concave, each ornamented with three round-topped secondary riblets, which are distinctly plicated in their central part but only weakly impressed on internal surface of anterior and posterior areas; both lateral areas also ornamented with much weakened radial riblets; concentric lines apparently weak. Left valve nearly flat or slightly convex, its length and height differing only slightly, if at all; both auricles clearly demarcated by a pair of deep furrows; primary ribs five in number, broadly rounded; interspaces, which correspond to primary ribs of the other valve, each ornamented with two or three prominent riblets; apical angle probably larger than 90 degrees.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6132) right in. mould	71.0	68.5+	16.5	1.04−
Paratype (GK.H6133) right in. mould	47.5	53.0	15.0	0.90
Paratype (GK.H6134) left in. mould	73.0+	70.5+	—	1.03±
Paratype (GK.H6135) right in. mould	88.5	94.0	21.0	0.94
Paratype (GK.H6608) right in. mould	44.5	43.5	14.5	1.02

Observations and comparisons.—All the available specimens are more or less imperfectly preserved. The holotype (GK. H 6132) shows approximately the original outline, but the auricles and the ventral peripheral area are broken.

The left valve is represented only by an incomplete specimen (GK. H 6134), which shows the radial ornamentation of the central part of a valve.

This large *Neithea*, together with the specimens from the Yatsushiro formation, has been assigned previously to *Neithea atava* (RÖMER), but clearly differs from *N. atava* and *N. matsumotoi* in its much larger size, larger anterior auricle, larger apical angle and generally fewer secondary riblets. The specimens which were referred to *Neithea atava* by D'ORBIGNY (1847, pl. 442, figs. 1, 3-5) from the Neocomian of France and by ALENCASTER (1956, pl. 2, figs. 5-7) from the Lower Cretaceous of Mexico show also large size. However, they are clearly different from the present species in the narrower outline, less roof-shaped primary ribs and narrower secondary ribs.

The large size, well developed auricles and the number of secondary riblets on the right valve (almost invariably three in each interval between primaries) suggest that this species belongs to the group of *Neithea gibbosa* (PULTENEY, 1813). In comparison with *Neithea quadricostata* (SOWERBY, 1814) from the Albian-Cenomanian of Western Europe (D'ORBIGNY, 1847; WOODS, 1902), which has been regarded by COX (1952a) and DARTEVILLE and FRENEIX (1957) as a synonym of *N. gibbosa*, the radial ornament of the right valve is composed of primary ribs which are more roof-shaped and less rounded and of secondary riblets which are finer than in that species. In the right valve of *N. gibbosa* the difference between the ribs of two orders is less conspicuous. The apical angle of the two valves appears slightly larger than in *N. gibbosa*.

Vola stefanoi CHOFFAT, 1901-1902, from the "Bellasien" of Portugal may be a closely allied species to this, but detailed comparison is difficult at present, since that species is represented by more or less deformed specimens. I provisionally regard the present specimens as distinct from *N. stefanoi*, because the size of *N. stefanoi* is still larger than that of these specimens.

The present species is named after Dr. Kametoshi KANMERA, who kindly supply the material upon which it is based, and gave me instructive information about the stratigraphy.

Occurrence.—Aritan and lower Miyakoan (upper Neocomian to Aptian). Conglomeratic sandstone of the Hinagu formation at loc. Km. 3085 c, south of Kohara, Tôyô village, Yatsushiro County, Kumamoto Prefecture. Fine grey sandstone of the Arita formation at loc. Ys. 103, west of Kumai, Yuasa town, Arita County, Wakayama Prefecture. Fragmentary specimens, which probably belong to this species, occur from the Hanoura formation at loc. Hy. 5004, north of Hiroyasu, Katsuura town, Katsuura County, Tokushima Prefecture (NAKAI and HAYAMI coll.) and also from the Ishido formation at loc. Hy. 4001, Ichinose-bashi, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture (ICHIKAWA and HAYAMI Coll.).

Subgenus *Neithella, nov.**

* See also p. 291.

Neithea (Neithella) sp. cf. *N. (N.) atava* (RÖMER)

Plate 44, Figures 1-4; Plate 52, Figure 4

Compare.—

1839. *Pecten atavus* RÖMER, Versteinerungen nord-deutsch. Gebirges, Nachtrag, p. 29, pl. 18, fig. 21.

non 1847. *Janira atava*, D'ORBIGNY, Paléont. franç. Terrain crétacé, Vol. 3, p. 627, pl. 442, figs. 1, 3-5.

1847. *Janira neocomiensis* D'ORBIGNY, *Ibid.*, Vol. 3, p. 629, pl. 442, figs. 4, 6-9.

1902. *Pecten (Neithea) atavus*, WOODS, Monogr. Cret. Lamell. England, Vol. 1, p. 197, pl. 39, figs. 1-5.

non 1924. *Neithea atava*, GILLET, *Mém. Soc. géol. France*, N. S., Tom. 1, Fasc. 3-4, Mém. No. 3, p. 51, text-figs.

non 1924. *Neithea atava*, GILLET, *Bull. Soc. géol. France*, Sér. 4, Tom. 24, p. 116, text-figs.

1926. *Neithea* cf. *atava* (RÖMER), YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 61, pl. 13, figs. 18, 19.

non 1952. *Neithea atava* MATSUMOTO and KANMERA, Guide books of the geological excursions. The lower valley of the Kuma, pp. 45, 49, listed.

non 1954. *Neithea atava*, MATSUMOTO, Cretaceous System, Japan. Islands, pp. 113, 114, listed.

Material.—Two specimens (GK. H 6281, GK. H 6628) from the Miyako area (HANAI and HAYAMI coll.) and three specimens (GK. H 6282, GK. H 6283, GK. H 6371) from the Sanchu area (ICHIKAWA and HAYAMI coll.) are concerned with the description below.

Description.— Shell very small, scarcely exceeding 15 mm. in height, more or less inequilateral. Right valve much higher than long, comparatively narrow, well inflated; umbo highly salient, incurved, comparatively narrow; antero- and postero-dorsal margins broadly concave; apical angle about 60 degrees in young shell but slightly larger in adult; primary ribs six in number, broad, prominent, with rounded tops, curving outwards, giving rise to digitations of ventral margin; outermost primary ribs much weaker than others; secondary riblets absent, but each interspace marked with seven or more faint radial striae; both lateral areas apparently smooth; growth lamellae distinct; auricles probably comparatively large, fairly unequal. Left valve almost as long as high; main body subequilateral, weakly inflated in umbonal region but rather concave in mid-ventral area; apical angle exclusive of auricles about 85 degrees; primary grooves broad, strongly plicated; each groove marked with four or more faint narrow striae; concentric lines overriding radials, arched forwards in grooves and broadly sinuate on their intervals, producing somewhat squamose surface; auricles depressed, well defined by a pair of angular furrows; anterior auricle much larger than posterior one, acutely triangular, protruding forwards; posterior auricle truncated subvertically; resilifer triangular, bounded on both sides by a pair of chevron-shaped ridges.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK.H6281)	12.5	15.0	4.5	0.83

Left in. mould (GK.H6282)	12.5+	14.0	—	0.89+
Left in. mould (GK.H6283)	13.0	12.5	—	1.04
Right ex. mould (GK.H6371)	6.5	9.0	3.0	0.72

Observations and comparisons.—In one of the Miyako specimens (GK. H 6281) the auricular parts are not exposed, but the main body is well preserved, showing the characteristic ornamentation, composed of six broadly plicated primary ribs together with numerous fine radial striae in their interspaces and on their slopes. No left valve has been found in the Miyako group, but this valve is represented by the internal and external moulds of two individuals from the Ishido formation of the Sanchu area. The shell seems to be biconvex in the juvenile stage, then becoming plano-convex. The radial ribbing, composed of broadly plicated primary grooves and of many fine striae, is identical with that of specimens from the same area described by YABE, NAGAO and SHIMIZU (1926) as *Neithea* cf. *atava*.

The specific identity of the Miyako and the Ishido specimens cannot be conclusively decided at present, because the left valve is unknown at Miyako and there is no satisfactory right valve among the specimens from the Ishido formation. All the specimens, however, evidently belong to the subgenus *Neithella*, nov.

Neithea atava (RÖMER, 1839) is an early proposed Neocomian-Aptian species. However, there have been different understandings about the diagnosis of this species, since RÖMER's original figure of *Pecten atavus* from the Hilsconglomerat of Germany is not quite satisfactory. The Lower Greensand specimens illustrated by WOODS (1902) are approximately 26 mm. high, and much smaller than the specimens of *N. "atava"* from France (D'ORBIGNY, 1847; PICTET and CAMPICHE, 1870), from Trinidad (COX, 1954a) and from Mexico (ALENCASTER, 1956). It is rather impossible that WOODS' specimens are conconspecific with such a large form, because the surface ornamentation is also fairly different. On the other hand, several specimens from France (D'ORBIGNY, 1847, pl. 442, figs. 4, 6-9), which was named *Janira neocomiensis*, appear to be conspecific with *N. atava* as interpreted by WOODS.

The present species may be conspecific with *Neithea atava* (RÖMER), because the narrow outline, the surface ornamentation of the *Neithella*-type and other characters are identical with those of the Lower Greensand specimens which were described by WOODS (1902, p. 197, pl. 39, figs. 1-5), although the primary ribs of the right valve may be slightly broader than in WOODS' figures. I provisionally compare this species with *Neithea (Neithella) atava* on the basis of the resemblance.

In the outline this species is also similar to *Neithea (Neithella) cometa* (D'ORBIGNY, 1847) from the Cenomanian of western Europe (WOODS, 1902), and to *Neithea (Neithella) wrightii* (SHUMARD, 1860) from the Albian of Gulf Coast (STANTON, 1947). However, the outermost primary ribs are degenerated or much more weakened in those species.

Occurrence.—Aritan and lower Miyakoan (upper Neocomian to Aptian).

Dirty sandy shale of the Hiraiga formation at loc. Hn. 0013, southern coast of Hiraiga and at loc. Hn. 0299, northern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. Fine weathered sandstone of the Ishido formation at loc. Hy. 7002, Ishido, Ohinata village, Minamisaku County, Nagano Prefecture. YABE, NAGAO and SHIMIZU (1926) reported identical specimens from the Ishido formation at Shiroi, Ueno village, Tano County, Gumma Prefecture.

Subgenus indeterminable

Neithea (*s. l.*) *aketoensis* sp. nov.

Plate 43, Figure 6

Material.—The holotype is a right valve (GK. H 6284) collected from the Aketo formation at loc. Hn. 6201, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture (HANAI coll.).

Description.—Right valve fairly large, trigonally ovate, subequilateral but a little opisthocline, slightly higher than long, moderately inflated; test thin; antero- and postero-dorsal margins nearly straight, forming an apical angle of about 75 degrees; ventral margin weakly serrated at terminations of radial ribs; umbo central, prominent, incurved; surface ornamented with 25 straight radial ribs which are quite irregular in breadth and prominence; no ribs distinguishable as primary ones; radials not increasing during growth either by bifurcation or by intercalation; concentric lines absent except for weak growth-lamellae; both lateral areas, which are well demarcated from main surface by a pair of marginal carinae, nearly smooth except for two or three weak riblets near carinae; auricles and left valve unknown. Holotype (GK. H 6284) right valve, 49.0 mm. long, 51.5 mm. high, 13.5 mm. thick.

Observations and comparisons.—This species is represented only by a well preserved right valve. The ends of both auricles are broken away, and the test is partly exfoliated in the umbonal region.

The irregularly disposed radial ribs seem to characterize this species. In the right valve of normal species of *Neithea* six primary ribs are clearly distinguishable, but the distinction between primary and secondary ribs is impossible in the present specimen. In view of the number of radial ribs it may be presumed that this species is related to the group of *Neithea quinquecostata* in which there are typically four secondary riblets between adjacent primaries.

Neithea welwitschi CHOFFAT *in* CHOFFAT and DE LORIOL (1888) from the Albian of Angola is large and somewhat similar to the present species, but it is characterized by an almost regular alternation of strong and weak ribs. Such a regularity is not recognized in the present specimen.

The new subgenus *Aequineithea* is characterized by a number of radial ribs or furrows of almost the same order of prominence, and the radials are of nearly equal breadth, while the ribs are irregular in breadth and prominence in the present species.

Occurrence.—Upper Miyakoan (Albian). Grey sandy shale of the Aketo formation at loc. Hn. 6201, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture.

Subfamily Chlamydinae

Genus *Chlamys* [RÖDING, 1798]

Type-species.—*Chlamys cinnabarina* [RÖDING, 1798] (= *Ostrea islandica* GMELIN), Recent, northern seas (designated by HERRMANNSEN, 1846).

Chlamys robinaldina (D'ORBIGNY)

Plate 44, Figures 5–7

1842. *Pecten interstriatus*, LEYMERIE, *Mém. Soc. géol. France*, Sér. 1, Tom. 5, p. 10' pl. 13, fig. 1 (non *P. interstriatus* MÜNSTER *in* GOLDFUSS, 1836).
1845. *Pecten obliquus*, FORBES, *Quart. Jour. Geol. Soc. London*, Vol. 1, p. 249 (non *P. obliquus* SOWERBY, 1823).
1847. *Pecten robinaldinus* D'ORBIGNY, Paléont. franç. Terrain crétacé, Vol. 3, p. 587 pl. 431, figs. 1–4.
1847. *Pecten interstriatus*, D'ORBIGNY, *Ibid.*, Vol. 3, p. 594, pl. 433, figs. 1–5 (non *P. interstriatus* MÜNSTER *in* GOLDFUSS, 1836).
1870. *Pecten robinaldinus*, PICTET and CAMPICHE, *Matér. Pal. Suisse*, Vol. 5, p. 188, pl. 170, figs. 1–5.
1900. *Pecten robinaldinus*, WOLLEMANN, *Abhandl. k. preuss. geol. Landes.*, N. F., Heft 31, p. 47.
1902. *Pecten* (*Chlamys*) *robinaldinus*, WOODS, Monogr. Cret. Lamell. England, Vol. 1, p. 181, pl. 34, figs. 7–12, pl. 35, figs. 1–10.
1924. *Pecten* (*Chlamys*) *robinaldinus*, GILLET, *Mém. Soc. géol. France*, N. S., Tom. 1, Mém. No. 3, p. 47.
1931. *Pecten* (*Chlamys*) *robinaldina*, WEAVER, *Mem. Univ. Washington*, Vol. 1, p. 279, pl. 28, figs. 152–154.

Material.—Three specimens (GK. H 6285-GK. H 6287) from the Miyako area (HANAI and HAYAMI coll.) are concerned with the description below.

Description.—Shell small or medium-sized for genus, inequivalve, slightly inequilateral, slightly prosocline, relatively narrow, much higher than long; auricles unequal in size and shape, much compressed. Right valve very weakly convex; antero-dorsal margin feebly concave, postero-dorsal margin nearly straight; apical angle about 75-80 degrees; radial riblets about 45 or rather more in number, rarely bifurcated, slightly sinuous on ventral region, somewhat scaly at intersections with concentric lines which are more or less regularly spaced; anterior byssal auricle proportionally large, with a deep byssal notch, marked with well-defined growth-lamellae but almost lacking radial ornament, connected with main body by a narrow fasciole area; posterior auricle much smaller than anterior one, obtusely truncated, marked with faint radial threads besides concentric ones; ctenolium not observable in the present material. Left valve slightly more convex than the right; antero-dorsal margin slightly concave, postero-dorsal one nearly straight; apical angle 75-80 degrees; surface ornamented with about 40 radial riblets of irregular prominence, which are

usually narrower than their interspaces and more or less scaly, and sometimes increase in number by irregular insertion; concentric lines fairly regular, intersecting radials to form a lattice-like ornamentaton; anterior auricle large, subvertically truncated; posterior one obtuse, much smaller.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK.H6285)	17.0	20.5	2.0	0.83
Left valve (GK.H6286)	17.5	21.0	3.0	0.83
Left valve (GK.H6287)	19.0	23.0	3.5	0.82

Observations and comparisons.—Three complete specimens are available for study; one is a right valve and two are left valves, differing in convexity and in mode of ornamentation. In a left valve (GK. H 6287) the interior of the shell is observable, on which the radial and concentric ribs are freebly impressed.

The lattice-like ornamentation is reminiscent of that of *Camptochlamys* ARKELL, 1933 (type-species: *Pecten intertextus* RÖMER, 1839) from the Jurassic, but the concentric elements are much weaker and less elevated than in that genus. The present species is fairly inequivalve as is usual in Mesozoic *Chlamys*, and possibly belongs to the group of *Chlamys archiacina* of GILLET's classification (1924a). Furthermore, it appears to be conspecific with *Chlamys robinaldina* (D'ORBIGNY, 1847) from the Barremian and Aptian of Western Europe. The comparatively narrow outline, large and unequal auricles, small apical angle, numerous sinuous scaly radial riblets intersect by more or less regular concentric lines and other essential characters agree well with those of *C. robinaldina*, especially the Lower Greensand specimens as described by WOODS (1902). According to him, the number of radial riblets is somewhat variable but generally smaller in the left valve than in the right. WOLLEMANN (1900) noted also that the ribs were finer in the right valve than in the left. It seems to be somewhat curious, since the radial ribs of *Chlamys* generally interlock with those of the opposite valve at ventral margin. However, this discrepancy may be compensated by the unequal intervals of radials of the left valve. Similar tendencies can be recognized also in the present material. The apical angle of adult specimens of *C. robinaldina*, as described by WOODS (1902), may be slightly larger than ours, but the angle at the actual umbo is nearly the same owing to the concave antero-dorsal margin. It should be pointed out that the present specimens are smaller than European specimens of *C. robinaldina*, and the subspecific distinction might be possible if they could be confirmed to be mature.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga and at loc. Hn. 0103, southern coast of Raga, Tanohata village, Shimohei County, Iwate Prefecture.

Chlamys sp. cf. *C. subacuta* (LAMARCK)
Plate 45, Figure 1

Compare.—

1819. *Pecten subacutus* LAMARCK, Anim. sans Vert., Vol. 6, p. 181.
1847. *Pecten subacutus* D'ORBIGNY, Paléont. franç. Terrain crétacé, Vol. 3, p, 605, pl. 435, figs. 5–10.
1872. *Pecten subacutus*, GEINITZ, *Palaeontographica*, Bd. 20, Teil 1, p. 195, pl. 44, fig. 5.
1902. *Pecten (Chlamys) subacutus*, WOODS, Monogr. Cret. Lamell. England, Vol. 1, p. 169, pl. 31, figs. 7–9.

Material.—A bivalved specimen (GK. H 6288) from the Miyako area (HANAI coll.) is concerned with the description below.

Description.—Shell medium-sized, inequivalve, slightly opisthocline, higher than long; test moderate in thickness; right valve weakly convex, left valve more strongly inflated; antero-dorsal margin of both valves slightly concave, postero-dorsal one nearly straight; surface ornamented with about 23 roof-shaped, scaly and prominent ribs which become somewhat weaker on the posterior part and are slightly curved forwards on the anterior part; radials neither bifurcated nor intercalated. Specimen, both valves (GK. H 6288), 31.5 mm. long, 36.5 mm. high, 10.5 mm. thick.

Observations and comparisons.—The test of the right valve of a bivalved specimen is mostly exfoliated and the auricular part is broken off. However, the characteristic roof-shaped radial ribs, which become denser on the posterior area, indicate that this is closely related to *Chlamys subacuta* (LAMARCK) from the Upper Greensand of England (WOODS, 1902).

Occurrence.—Upper Miyakoan (Albian). Grey sandy shale of the Aketo formation at loc. Hn. 6201, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture.

Chlamys (?) *shikokuensis* AMANO
Plate 44, Figure 8

1957. *Chlamys shikokuensis* AMANO, *Kumamoto Jour. Sci.*, Ser. B, Sec. 1, Vol. 2, No. 2, p. 90, pl. 2, fig. 2.

Material.—The holotype is a left external mould (GT. KML-0019) illustrated by AMANO (1957a, pl. 2, fig. 2). It was collected from the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture. A specimen represented by left internal and external moulds (GK. H 6289) from the Ryoseki area (KIMURA coll.) is probably conspecific with the holotype.

Remarks.—The holotype of *Chlamys shikokuensis* shows the nearly complete outline of a left valve, but is rather poorly preserved. A specimen newly collected from the Ryoseki area is very similar to the holotype in view of the radial ornamentation and the outline. These specimens are too strongly inflated for a *Chlamys*, and appear to be more closely related to *Cryptopecten* DALL, BARTSCH and REHDER, 1938, from the Cenozoic and Recent than to

Chlamys. But the radial ribs are too roof-shaped for *Cryptopecten* and rather similar to those of *Spondylopecten* ROEDER, 1882, from the Jurassic. A large number of Jurassic species resembling this have been called "*Aequipecten*", although they are clearly different from living true *Aequipecten* in many characters. This is certainly not a typical *Chlamys*, but the original generic assignment is provisionally accepted with a query, until a more suitable generic name can be defined on sufficient grounds.

Occurrence.—Aritan and lower Miyakoan (upper Neocomian to Aptian). Dark grey sandy shale of the upper Monobegawa subgroup at Okuminotani, southwest of Ryoseki, Nangoku City, Kochi Prefecture. AMANO originally reported this species from the Hagino formation at Hagino, Mirafu village, Kami County, Kochi Prefecture.

Genus *Prohinnites* GILLET, 1921

Type-species.—*Hinnites leymerieri* DESHAYES, 1842, Lower Cretaceous, Western Europe and South America (original designation).

Prohinnites sp. cf. *P. favrinus* (PICTET and ROUX)

Plate 44, Figure 9

Compare.—

1853. *Hinnites favrinus* PICTET and ROUX, *Soc. Phys. d'Hist. nat. Genève*, Tom. 13, No. 1, pp. 503, 547, pl. 43, fig. 2, pl. 44, fig. 1.
1870. *Hinnites favrinus*, PICTET and CAMPICHE, *Matér. Pal. Suisse*, Sér. 5, p. 231, pl. 178.
1903. *Hinnites favrinus*, WOODS, Monogr. Cret. Lamell. England, Vol. 1, p. 220, text-figs. 6, 7.
1924. *Hinnites* (*Prohinnites*) *favrinus*, GILLET, *Mém. Soc. géol. France*, N. S., Mém. No. 3, p. 157.

Material.—A specimen (GK. H 6290) from the Miyako area (HAYAMI coll.) is concerned with the description below.

Description.—Left valve very large for a pectinid, suborbicular in outline, nearly as long as high, moderately inflated; antero- and postero-dorsal margins slightly concave; umbo placed submesially, not prominent; auricles rather ill demarcated from main body, subequal, subvertically truncated; surface ornamented with about 20 radial plications, which are somewhat irregularly disposed; hinge edentulous; resilifer internal, elongate-triangular. Right valve and detailed characters of exterior unknown. Specimen, left internal mould (GK. H 6290), 168.5 mm. long, 163.0 mm. high, 44.0 mm. thick.

Observations and comparisons.—An internal mould of a giant pectinid is referable to *Prohinnites* GILLET, 1921, in view of the edentulous hinge, subvertically elongated resilifer and somewhat irregularly disposed radial plications. It is probably a left valve, because the shell is evenly inflated, lacking an attachment area. In the dimensions, the number of radial plications and the general outline with ill-defined auricles, this specimen seems comparable with

Prohinnites fabrinus (PICTET and ROUX, 1853), from the Aptian of France and the Lower Greensand of England (WOODS, 1903). The test, however, has been completely eroded away in the present specimen, and its specific determination on a firm basis is impossible until further material is collected.

Occurrence.—Lower Miyakoan (Aptian). The present specimen was collected from a boulder of conglomeratic sandy shale at the southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. It was probably derived from the upper part of the Tanohata formation, so far can be judged from the lithology.

Family Amusiidae

Subfamily Entoliinae

Genus *Entolium* MEEK, 1865

(=*Protamussium* VERRILL, 1897)

Type-species.—*Pecten demissus* PHILLIPS, 1829, Middle Jurassic, cosmopolitan (original designation).

Remarks.—Cretaceous species of entoliids are not so numerous as Jurassic ones; most species are much smaller than typical species of *Entolium*, and have a *Camptonectes*-like outline and unequal auricles. Such a small species has often been described under the generic (or subgeneric) name of *Syncyclonema* MEEK, 1864 (type-species: *Pecten rigidus* HALL and MEEK, 1854, non SOWERBY, 1821 = *Pecten halli* Gabb, 1861).

Many authors including PHILIPPI (1900) and WOODS (1902) considered that *Entolium* is a synonym of *Syncyclonema*. STEWART (1930, p. 120) considered that the original specimens of *S. halli* are immature and that this species is probably intimate to *Pecten orbiculars* SOWERBY as described by WOODS (1902).

Pecten orbicularis SOWERBY, 1817, from the Albian-Cenomanian of western Europe, Greenland and east Africa, is a well-known species, attains a fairly large size and has characteristic wide-spaced concentric grooves on the right valve. As I have noted before (1959, p. 156), such grooves are also observed in many species such as *Entolium inequivalve* HAYAMI, 1959, from the Upper Jurassic of Japan, *Pecten nummularis* PHILLIPS *in* MURCHISON, VERNEUIL and KEYSERLING (1845), from the Upper Jurassic and the Lowest Cretaceous of the boreal province (SOKOLOV and BODYLEVSKI, 1931; SPATH, 1936; BODYLEVSKI and SHULGINA, 1958), and *Pecten germanicus* WOLLEMANN, 1900, from the Neocomian of Germany. These species having conspicuous concentric grooves certainly constitute a distinct group, but they are very similar to typical *Entolium* in view of the internal characters.

As noted by COX (1952, p. 35) the characters of the type-species of *Syncyclonema* are still imperfectly known. In the original description and illustration of *P. rigidus* HALL and MEEK, 1854, its surface was said to be marked with

strong concentric undulations, which have been taken by STEWART (1930) as a character showing an intimate relationship between *P. rigidus* and *P. orbicularis*. In the group of *P. orbicularis*, however, the left valve and the umbonal region of the right valve are almost smooth. If the small dimensions of *P. rigidus* are taken into consideration, the ornamentation is probably quite different from that of the immature specimens of *P. orbicularis* and its allies. Moreover, the end of anterior auricle is acutely pointed in *P. rigidus* but is commonly obtusely truncated in the group of *P. orbicularis* and many species of *Entolium*. I am, therefore, of opinion that *Syncyclonema* is distinct from *Entolium* including the group of *P. orbicularis*, even if the original specimens of *P. rigidus* are proved to be immature.

Entolium sanchuense sp. nov.

Plate 45, Figures 12, 13; Plate 52, Figure 5

Material.— The holotype is a bivalved specimen (GK. H 6291) collected from the Ishido formation at loc. Hy. 4001, Ichinose-bashi, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture (ICHIKAWA and HAYAMI coll.). Paratypes (GK. H 6292, GK. H 6293) from the type locality (ICHIKAWA) and HAYAMI coll.).

Description.—Shell very large for genus, usually exceeding 70 mm. in length and height, fairly inequivalve, subequilateral, orbicular, almost as long as high, weakly inflated; test comparatively thick; left valve slightly more strongly inflated than right; antero- and postero-dorsal margins straight; ventral margin smoothly arcuate; hinge-line proportionally long; apical angle approximately 100 degrees; auricles subequal in size; anterior auricle subvertically truncated, while postero-dorsal angle of posterior auricle is obtuse; dorsal margin of both auricles elevated above hinge-line; no byssal notch; surface ornamented with numerous fine concentric striae numbering about 20 to every 10 mm. near ventral margin and more than 30 on umbonal region; concentrics very weak on auricles; main body and auricles marked with numerous faint radial capillae, which are visible only under cross light; a pair of broad internal crural ridges extend from umbonal region to antero- and postero-ventral peripheries; resilifer triangular, fairly deep.

Measurements in mm.

Specimen	Lenth	Height	Thickness	L/H
Holotype (GK.H6291) right valve	79.0	80.5	?	0.98
Paratype (GK.H6292) left in. mould	50.5+	79.5	9.0	?
Paratype (GK.H6293) left ex. mould	74.5	61.0+	8.0	?

Observations and comparisons.—The present species is represented by three specimens. The holotype is a bivalved specimen, but its left valve is only partly exposed and the test is preserved only on the anterior part of the right valve. Two paratypes from the type locality are very incomplete, but the external and internal characters of the two valves are well recognized from these three specimens.

In the essential characters this species is somewhat similar to the type-species of *Entolium*, *E. demissum* (PHILLIPS) (STAESCHE, 1926; DECHASEAUX, 1936a) from the Middle Jurasic of western Europe and some other regions. Its suborbicular outline and fine concentric sculpture are especially similar to those of the latter. Accordingly the present species is definitely referable to typical *Entolium*.

The present species, however, differs from *E. demissum* and its probable Lower Jurassic projenitors by the more rectangularly truncated anterior auricle and generally more prominent concentric ornament. The hinge-line is slightly longer than in the Jurassic species.

The present species is probably unrelated to *Entolium orbiculare* (SOWERBY, 1817) and allied species to it, because the right valve lacks conspicuous wide-spaced concentric grooves as seen in those species. *Entolium utakokense* IMLAY, 1961, from the Albian of north Alaska, is a species more or less related to the present one, since the surface ornamentation of its right valve is fairly similar. The dimensions of the shell of the Alaskan species are also exceptionally large for a Cretaceous *Entolium*. It seems, however, to differ specifically from the present species in view of the stronger convexity of the left valve, the shorter hinge line and the more prominent umbo.

Occurrence.—Aritan (upper Neocomian). Fine grey sandstone of the Ishido formation at loc. Hy. 4001, Ichinose-bashi, south of Kagahara, Nakazato village, Tano County, Gumma Prefecture.

Entolium (?) yatsushiroense sp. nov.

Plate 48, Figure 6

1954. *Pecten (Syncyclonema)* aff. *obovatus* STOLICZKA, MATSUMOTO, Cretaceous System, Japan. Islands, p. 114, listed.

Material.—The holotype is left internal and external moulds (GK. H 6294) collected from the Yatsushiro formation at loc. Km. 1843, north of Shimofukami, Sakamoto town, Yatsushiro County, Kumamoto Prefecture (HAYAMI coll.). Paratypes (GK. H 6373, GK. H 6374) from the type locality (KANMERA coll.).

Description.—Left valve small, not exceeding 10 mm. in length and height, suborbicular, subequilateral except for auricles, nearly as long as high, weakly inflated; antero-dorsal margin slightly concave, postero-dorsal one nearly straight; umbo placed submesially; apical angle approximately 90 degrees; auricles well defined; anterior auricle much larger than posterior, acutely trigonal with more or less prosocline anterior margin; posterior auricle obtusely truncated; dorsal margin of auricles scarcely rising above hinge-line; auricular crura sharp; a pair of internal ridges of *Entolium*-type, if present very weak; surface apparently smooth. Little is known about the right valve.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6294) left in. mould	9.5	9.5	ca. 1.5	1.00
Paratype (GK.H6373) left in. mould	7.5	7.0	ca. 1.0	1.07

Observations and comparisons.—Although the test is not preserved in all the specimens, the internal and external characters of the left valve are exhibited in the holotype. Two other left internal moulds (GK. H 6373, GK. H 6374) are smaller and not so well preserved. A fragmentary specimen from the type locality may represent the right valve of this species, although this is uncertain.

The present species is somewhat similar to *Entolium kimurai* TAMURA, 1959, from the Upper Jurassic Torinosu series of the Yatsushiro, Soma and Kitakami areas, but its internal ridges of *Entolium*-type are less conspicuous and the ratio of length/height is slightly larger. *Pecten (Syncyclonema) inconspicuus* CRAGIN, 1895, from the Washita group (upper Albian) of the Comanche series of Texas (ADKINS, 1920; STANTON, 1947), seems to be closely related to this species, but the inequality of its auricles is probably less marked. *Pecten (Syncyclonema) obovatus* STOLICZKA, 1871, from the Upper Cretaceous of southern India and comparable specimens from the Mikasa formation of Hokkaido (YABE and NAGAO, 1928) have a taller outline and subequal auricles.

The present species might belong to *Syncyclonema* MEEK, 1864, but is provisionally referred to *Entolium* owing to the uncertainties of the characters of the type-species of *Syncyclonema* and the absence of concentric ribs on the surface.

Occurrence.—Upper Miyakoan (Albian). Grey sandstone of the Yatsushiro formation at loc. Km. 1843, north of Shimofukami, Sakamoto town, Yatsushiro County, Kumamoto Prefecture.

Genus *Pectinella* VERRILL, 1897

Type-species.—*Pecten (Pseudamussium) sigsbeei* DALL, Recent, Caribbean Sea (original designation).

Remarks.—In the outline and many other characters *"Camptonectes" miyakoensis* NAGAO, 1934, and a few other Cretaceous pectinids, which show a *Chlamys*-like outline but lack external and internal radial ribs and a wide intermediate fasciole area, seem to be congeneric with *Pecten (Pseudamussium) sigsbeei* DALL, from the Caribbean Sea near Havana, a species for which VERRILL (1897) proposed the section *Pectinella*. VERRILL (1897) and THIELE (1935) treated *Pectinella* as a section of *Palliolum*, which they considered to be a subgenus of *Propeamussium*. Their classification, however, cannot be accepted here, because the three groups are at least generically distinct.

Crural ridges of *Entolium*-type are not developed in the type-species of *Pectinella* and *P. miyakoensis*, but a pair of shallow depressions on the antero- and postero-dorsal parts of the left valve of the latter species are comparable with those of *Entolium*. Therefore, I regard here *Pectinella* as a distinct genus of the Entoliinae, presuming the genus as a descendant of *Entolium*. *Pectinella* is considered to be related also to *Syncyclonema* MEEK, 1864, in view of the similar outline of the anterior auricle. However, prominent concentric ornamentation, which were reported to exist on the surface of the type-species of *Syncyclonema*, is absent in *Pectinella*. The precise characters of *Syncyclonema*

are not as yet clarified, and the phylogenetic relationship between the two is an unsolved problem.

Some authors have considered that *Pectinella* and *Syncyclonema* are more closely related to *Pseudamussium* H. and A. ADAMS, 1858 (type-species: *Pecten hybridus* GMELIN, 1792*) and *Palliolum* MONTEROSATO, 1884 (type-species: *Pecten testae* PHILLIPPI) including subgenus *Delectopecten* STEWART, 1930. These genera are also founded on small pectinids with nearly smooth internal and external surface and a more or less developed byssal auricle, although they are generally regarded as the members of the Pectinidae instead of the Amusidae. But the ratio of length/height and the apical angle are much larger and the byssal auricle is never salient above the hinge-line in these two genera. Moreover, in *Palliolum* the ctenolium is distinct and concentric undulations are developed on the surface.

Pectinella miyakoensis (NAGAO)

Plate 45, Figures 2-11; Plate 52, Figure 5

1934. *Pecten (Camptonectes) miyakoensis* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.* Ser. 4, Vol. 2, No. 3, p. 209, pl. 31. figs. 11, 12.

Material.—A right valve (GH reg. no. 6784) illustrated by NAGAO (1934,, pl. 31, fig. 12) is here designated as the lectotype. It was collected from the Hiraiga formation at Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. Another specimen illustrated by NAGAO (1934, pl. 31, fig. 11) and 11 specimens (GK. H 6295-GK. H 6300, GK. H 6375, GK. H 6618-GK. H 6622) at hand (HAYAMI coll.) from the type area are also the examples of this species.

Description.—Shell small, scarcely exceeding 15 mm. in height, subovate, inequivalve, subequilateral exclusive of auricles, slightly higher than long, weakly inflated; test thin, shiny, translucent; antero- and postero-dorsal margins nearly straight, subequal in length; apical angle about 85 degrees. Right valve provided with a *Chlamys*-like bysal auricle, which, however, is connected directly with shell-body without an intermediate fasciole area; byssal notch angular, moderately deep; posterior auricle obtusely truncated, much smaller than anterior one; dorsal margin of anterior auricle frequently protruded above hinge-line, that of posterior auricle subhorizontal; ctenolium not observed; surface smoth except for numerous fine concentric lines and faint (sometimes hidden) radial capillae; inner surface quite smooth without ribs; crural ridges indistinct; resilifer triangular, small. Left valve more strongly inflated than right; average ratio of length/height is slightly smaller than that of right valve; anterior and posterior parts of shell body slightly concave, but the umbonal and central parts broadly inflated; anterior auricle large, acutely triangular, marked with strong growth-lamellae; posterior auricle much smaller, truncated obtusely; their dorsal margins nearly horizontal or only a little elevated above hinge-line; other characters similar to those of

* NORTH (1951) discussed the nomenclatural problems concerning *Pseudamussium*, and stated that the genus was formally established by H. and A. ADAMS (1858) and its valid type designation was first made by SUTER (1913).

right valve.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK.H6295)	11.0	13.0	ca. 1.0	0.85
Right valve (GK.H6296)	11.5	13.0	ca. 1.5	0.89
Right valve (GK.H6297)	13.5	16.5	ca. 1.5	0.82
Right valve (GK.H6298)	9.5	11.0	ca. 1.0	0.86
Right valve (GK.H6299)	10.5	12.0	ca. 1.0	0.88
Left valve (GK.H6618)	10.5	12.5	ca. 1.5	0.84
Left valve (GK.H6619)	6.5	8.0	ca. 1.0	0.81
Left valve (GK.H6620)	7.0	8.5	ca. 1.0	0.82

Observations and comparisons.—More than 10 specimens exhibiting external features are available for study. In addition, numerous individuals are adhered to several slabs of the present collection. The protruded part of byssal auricle is very thin and seems liable to be damaged before fossilization. The ratio of length/height is somewhat variable among NAGAO's and the present specimens, but it is generally larger in the right valve than in the left. Although both valves in juxtaposition are not available at present, the anterior and posterior perhipheral parts of the right valve were probably not covered by the left valve. It is presumably also from the anterior and posterior peripheral areas of the left valve, which are slightly but distinctly concave. The faint radial capillae are seemingly more distinct in the left valve than in the right, but the converse applies to the concentric lines. The apical angle of two valves is almost constant.

NAGAO (1934) assigned the present species to *Camptonectes* MEEK, 1864 (type-species: *Pecten auritus* SCHLOTHEIM, 1820), a well-defined Mesozoic pectinid genus of the Chlamydinae. It is, however, obviously different from *Camptonectes* and other genera of the Chlamydinae in view of the absence of a fasciole area at the base of the byssal auricle, the absence of *Camptonectes*-striations, its dorsal margin extending well above hinge axis, its translucent shell and the presence of weakly concave areas on the anterior and posterior parts of the left valve.

In the general outline and smooth test this species apparently resembles some species of *Entolium* MEEK, 1865, especially the group of *Entolium hehli* in DECHASEAUX's (1936a) classification, which includes several Lower Juraassic species having very unequal auricles. The byssal auricle of this species is protruded upwards and is fairly similar to that of *Entolium*. In Middle Jurassic and later species of *Entolium*, however, auricles are generally subequal or only slightly unequal. Crural ridges of *Entolium*-type are almost invisible in the present species.

In the Cretaceous there are several small pectinids which are comparable with the present species in many characters, but no suitable generic name has been given to them. *Pecten conradi* WHITFIELD and *Pecten simplicius* CONRAD from the Upper Cretaceous of U.S.A. may be congeneric with the present

species, but the auricular protrusion in such species is less striking and the apical angle is much larger than in the present species. *Pecten nilssoni* GOLDFUSS, 1836 (WOODS, 1903) from the Upper Cretaceous of western Europe resembles the present species in the shape of the byssal auricle and some other characters. However, the apical angle of the Japanese species is much smaller than in GOLDFUSS' figure and the antero-dorsal margin is not so deeply concave as in the specimens figured by WOODS. This differs from *Pecten* (*Syncyclonema*) *inconspicuus* CRAGIN, 1895, from the Albian of the Comanche series of Texas (ADKINS, 1920; STANTON, 1947) by the more unequal auricles, the more profound byssal notch and the longer antero- and postero-dorsal margins.

Occurrence.—Lower and (?) upper Miyakoan (Aptian to ? Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0016, 0017, 0018, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. Besides, NAGAO (1934) reported this species from the "*Orbitolina* sandstone" at Raga and the Aketo formation at Aketo, the same village.

Subfamily Propeamussiinae

Genus *Variamussium* SACCO, 1897

Type-species.—*Amusium cancellatum* SMITH, 1885, Recent, Atlantic (original designation).

Variamussium kimurai sp. nov.

Plate 46, Figures 1-4

Material.—The holotype is a right external mould (GK. H 6301) collected from the lower part of the Monobegawa group at loc. Hy. 6002, mouth of Okuminotani, southwest of Ryoseki, Nangoku City, Kochi Prefecture (HAYAMI coll.). Paratypes (GK. H 6302-GK. H 6305) from the type locality (HAYAMI coll.).

Description.—Shell of medium size for genus, suborbicular, very inequivalve, subequilateral except for auricles, nearly as long as high or a little higher than long, weakly inflated; right valve distinctly smaller than left; in both valves antero- and postero-dorsal margins slightly concave, forming an apical angle of approximately 100 degrees and obtuse angles with both extremities of rounded ventral margin; auricles of moderate size, well defined; anterior one about twice as large as posterior, subvertically truncated in left valve but separated from body of shell by a distinct byssal notch in right valve; posterior auricle obtusely truncated, with a slightly concave posterior margin; dorsal margins of auricles scarcely rising above hinge-line; auricular crura short but stout in right valve; about seven internal ribs diverge from umbonal area; several short internal ribs of secondary order inserted irregularly between primaries; ribs of two orders similar in strength, not much broadened towards ventral extremities, strongly curved outwards, reaching ventral peripheral area in each valve; surface of shell-body of right valve marked with regular con-

centric lines which become weaker on anterior and posterior areas; auricles marked with similar concentric lines; left valve, on the contrary, ornamented with radial ribs of three orders, namely, about 13 stout primary ribs, weaker secondaries of about the same number, and numerous faint tertiary threads; primaries and secondaries alternating almost regularly; numerous fine concentric lines crossing radials, forming a delicate network with tertiary threads; auricles marked with numerous radial threads of tertiary strength.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6301) right ex. mould	9.5	9.5	ca. 1.0	1.00
Paratype (GK.H6302) left ex. mould	12.0	13.5	ca. 1.5	0.89
Paratype (GK.H6303) left ex. mould	12.0+	14.5	ca. 1.5	0.83+
Paratype (GK.H6304) right ex. mould	11.5	12.0	ca. 1.5	0.96
Paratype (GK.H6305) left in. mould	12.5	12.0+	ca. 2.0	1.04−

Observations and comparisons.—The essential characters of the two valves are well exhibited on the internal and external moulds. The difference in the dimensions and ornamentation of the two valves is well shown in one of the paratypes (GK. H 6304) which represents the exterior of the smaller right valve and the peripheral part of the larger left valve. The presence of a distinct byssal notch throughout the ontogeny is shown by the growth-lines on the anterior auricle of the holotype.

The presence of characteristic radial ornamentation on the left valve indicates that this species is a member of the genus *Variamussium*. In fact, all its essential characters are not very different from those of *Variamussium habunokawense* (KIMURA, 1951) from the Upper Jurassic Torinosu series (TAMURA, 1959a, 1960). Furthermore, *V.* cf. *habunokawense* is known to occur in the Berriassian of south Kitakami (HAYAMI, SUGITA and NAGUMO, 1960). In *V. habunokawense* and the comparable species to it, however, the length and height scarcely exceed 8 mm. and the internal ribs are almost of a single order of prominence.

The present species is readily distinguishable from *Propeamussium yubarense* (YABE and NAGAO, 1928), from the Upper Cretaceous of various areas of Japan, by its unequal and better defined auricles and stout radial ribs on the left valve, although some specimens from the Lower Cretaceous of Japan have been compared with that species. *P. yubarense* was originally described as a variety of *Propeamussium cowperi* (WARING) from the Upper Cretaceous of California, but, as suggested by ICHIKAWA and MAEDA (1958), it should be treated as a distinct species of *Pseudopalliolum* OYAMA, 1944, a subgenus of *Propeamussium*. The concentric ribs of the holotype is somewhat similar to that of the left valve of *Propeamussium awajiense* ICHIKAWA and MAEDA, 1958a, from the Upper Cretaceous of Awaji island, but the present species is certainly unrelated to that species, because its internal ribs are more numerous and longer, the left valve posseses much stouter radial ribs and the antero- and postero-dorsal margins are more distinctly concave.

It is better to consider that this species is a direct descendant of Jurassic *Variamussium* rather than the ancestral form of Upper Cretaceous *Propeamussium (s. l.)*. In the presence of short inserted secondary internal ribs it is somewhat similar to some species of *Parvamussium* SACCO, 1897 (type-species: *Pecten duodecim lamellatus* BRONN), but such strong ornamentation as seen in this species is quite unknown in that genus.

The specific name is dedicated to Prof. Toshio KIMURA of the University of Tokyo, who kindly put his collection at my disposal and informed me the occurrence of the present species.

Occurrence.—Aritan (upper Neocomian). Black shale of the lower Monobegawa subgroup at loc. Hy. 6002, mouth of Okuminotani valley, southwest of Ryoseki, Nangoku City, Kochi Prefecture. Besides, a poorly preserved specimen, which is probably conspecific, was collected from the Arita formation at Ys. 8, southeast of Suhara, Yuasa town, Arita County, Wakayama Prefecture (HAYAMI coll.).

Family Plicatulidae

Genus *Plicatula* LAMARCK, 1801

Type-species.—*Plicatula gibbosa* LAMARCK, 1801, Recent (monotypy).

Plicatula hanaii sp. nov.

Plate 47, Figures 1-3

Material.—The holotype is a left valve (GK. H 6311) collected from the Tanohata formation at loc. Hn. 0803, Koikorobe, Tanohata village, Shimohei County, Iwate Prefecture (HAYAMI coll.). Paratypes (GK. H 6312-GK. H 6314) from the type area (HANAI and HAYAMI coll.).

Description.—Left valve of medium size for genus, fairly variable in outline, but commonly subovate, nearly acline or slightly oblique, higher than long, weakly inflated; test of moderate thickness; valve margin irregularly undulating; umbo submesially placed, rising a little above dorsal margin; radial ribs irregularly spaced, comparatively weak, not plicated, slightly curved outwards, almost invisible on dorsal and central surface, giving rise to weak crenulations of ventral margin; hinge plate fairly broad, with a pair of deep subvertical crural sockets and bordering teeth; resilifer deeply sunk between two closely spaced central ridges; adductor scar comparatively large, subcircular, placed posteriorly to centre of valve, usually more darkly tinted than remainder of internal surface; pallial line clearly impressed. Right valve unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6311) left valve	15.0	15.5	4.5	0.97
Paratype (GK.H6312) left valve	12.5	15.5	3.5	0.81
Paratype (GK.H6313) left valve	14.5	21.5	3.5	0.67
Paratype (GK.H6314) left in. mould	17.5	20.0	2.5+	0.88

Observations and comparisons.—All the specimens studied are left valves, and the rarity of the right valve seems to have been connected with the mode of life of this species. The surface of shells from the type-locality, Koikorobe, is more or less eroded and the radial ornamentation is almost effaced. The ratio of length/height varies to a great extent, and the shell inclination is also variable.

This species is characterized by the comparatively inconspicuous radial ribs, numerous fine crenules on the ventral margin and heavy hinge teeth. It is somewhat similar to *Plicatula asperrima* D'ORBIGNY, 1847, from the upper Neocomian of France as regards its weak ornamentation and general outline, but its radials are not so numerous and persistent in the present species. As regards the internal structure comparison is at present difficult, since the internal structure of *P. asperrima* is undescribed.

The present species is named after Dr. Tetsuro HANAI of the University of Tokyo, who assisted me in the field and laboratory works in various ways and put his large collection at my disposal.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga and conglomeratic sandstone of the Tanohata formation at loc. Hn. 0803, Koikorobe, Tanohata village, Shimohei County, Iwate Prefecture.

Plicatula kiiensis sp. nov.

Plate 46, Figures 6-8

1954. *Plicatula* aff. *asperrima* D'ORBIGNY, MATSUMOTO, Cretaceous System, Japan. Islands, pp. 76, 113, 114, listed.

Material.—The holotype is a left external mould (GK. H 6590) from the Arita formation at loc. Ys. 103, west of Kumai, Yuasa town, Arita County, Wakayama Prefecture (MATSUMOTO et al. coll.). A paratype (GK. H 6591) from the type area (MATSUMOTO et al. coll.) and another paratype (GK. H 6592) from the Yatsushiro area (KANMERA coll.).

Description.—Shell of medium size, very irregular in outline, but commonly subovate, weakly inflated, more or less higher than long; umbo not prominent, placed submesially, a little prosogyrous; umbonal area of left valve more strongly inflated than that of right, possessing a small attachment area; surface ornamented with more than 35 radial ribs and a number of concentric lines; small spiny tubercles produced at intersections; radials curved outwards on anterior and posterior areas, increasing their number by irregular bifurcation in left valve and by irregular insertion in right valve; spines apparently stronger and concentrics weaker in left valve than in right; internal structure unknown in detail, but probably of typical *Plicatula*.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK.H6590) left ex. mould	18.0	23.0	ca. 5.5	0.78

Paratype (GK.H6591) right ex. mould	24.0	29.0	?	0.83
Paratype (GK.H6592) left ex. mould	22.5	22.5+	?	1.00−

Observations and comparisons.—Three specimens and a few fragments are available for study. Although their hinge structure is unknown in detail, this species undoubtedly belongs to *Plicatula* in view of the characteristic ornament. In the holotype the umbonal area is unusually strongly inflated and the attachment area is also convex. It is, however, doubtful that the characters constitute specific criteria.

As suggested by MATSUMOTO (1954) and some others, this species resembles *Plicatula asperrima* D'ORBIGNY, 1844, from the Neocomian of France, but the radial ribs are probably much stronger and the spines more conspicuous in the present species. *Plicatula ferryi* COQUAND, 1862, from the Cenomanian of Africa (PERVINQUIÈRE, 1912; DARTEVILLE and FRENEIX, 1957; BARBER, 1958) is similar to the present species in view of the surface ornamentation, but the concentric lines are not so crowded in the right valve as those of the present species.

Occurrence.—Aritan and lower Miyakoan (upper Neocomian to Aptian). Dark grey sandy shale of the Arita formation at loc. Ys. 103, west of Kumai and at Ys. 8, between Yuasa and Suhara, both in Yuasa town, Arita County, Wakayama Prefecture. Grey conglomeratic sandstone of the Hinagu formation at loc. Km. 3085 c, south of Kohara, Tôyô village, Yatsushiro County, Kumamoto Prefecture. A similar species occurs also from the Ofunato group and the Yatsushiro formation, but its specific identity with this species is not very clear.

Family Spondylidae

Genus *Spondylus* LINNAEUS, 1758

Type-species.—*Spondylus gaederopus* LINNAEUS, 1758, Recent (designated by ANTON, 1839).

Spondylus decoratus NAGAO

Plate 47, Figures 4–9; Plate 52, Figure 6

1934. *Spondylus decoratus* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 210, pl. 27, figs. 2, 5–7.

1934. *Spondylus* sp. aff. *decoratus* NAGAO, *Ibid.*, Ser. 4, Vol. 2, No. 3, p. 211, pl. 27, fig. 8.

Material.—A left valve (GH. reg. no. 6818) illustrated by NAGAO (1934, pl. 27, fig. 6) is here designated as the lectotype. It was collected from the 1st cycle of the Miyako group at Hideshima, Sakiyama, Miyako City, Iwate Prefecture. The following description and discussion are based on eight specimens (GK. H 6306-GK. H 6310, GK. H 6376, GK. H 6388, GK. H 6399) from the type area in addition to the lectotype and syntypes.

Description.—Shell small or medium-sized, suboval, highly inequivalve, slightly inequilateral, slightly prosocline; test of moderate thickness, not porous;

hinge teeth not observed. Left valve moderately inflated, slightly higher than long, comparatively regular in outline; postero-dorsal margin straight, much longer than antero-dorsal; umbo pointed, rising a little above dorsal margin; apical angle exclusive of auricles about 90-95 degrees; surface marked with numerous radial ribs of two orders of prominence; primary ribs about seven in number, not much broader than secondaries but prominent in middle ventral part, roof-shaped in transverse section, provided with a few irregularly disposed short spines; secondary ribs about seven in number in each interspace between primaries, not bifurcate, without spines; auricles of moderate size, subequal in length but posterior one much higher than anterior; dorsal periphery of two auricles forming a chevron, bounded by a pair of narrow marginal thickenings. Right valve more irregular in outline and convexity, but usually trigonally ovate, strongly inflated, much higher than long; umbonal region pointed, highly protruded above hinge-line; attachment area rather variable in width, often provided with irregular concentric erect lamellae, more or less concave; radial ribs numerous, corresponding to secondary riblets of left valve, all nearly equally prominent, without spines, much weakened on attachment area; cardinal area much higher than that of left valve, triangular, occupying about one-fourth of shell-height, and provided with a few subvertical grooves.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left valve (GK.H6306)	28.0	31.5	6.5	0.89
Left valve (GK.H6307)	26.5	30.5	6.0	0.87
Left valve (GK.H6308)	27.5	31.0	6.0	0.89
Right valve (GK.H6309)	50.0	67.5	23.0	0.74
Right valve (GK.H6310)	35.5	49.0	18.0	0.72

Observations and comparisons.—Many well preserved specimens exhibiting the external features of two valves are referable with certainty to *Spondylus decoratus* NAGAO, 1934, although the outline, ornamentation and width of attachment area vary considerably in the right valve. The difference in ornamentation of the two valves are seen also in NAGAO's syntypes and probably constitute a specific character. An imperfect right valve, which was figured by NAGAO (pl. 27, fig. 8) as *Spondylus* aff. *decoratus*, has many erect subconcentric lamellae on its surface. Such lamellae are also well developed in some of the right valves at hand, and their prominence seems to be fairly variable in this species.

As stated by NAGAO (1934), the present species resembles *Spondylus roemeri* DESHAYES, 1842, from the Neocomian and Aptian, and *Spondylus gibbosus* D'ORBIGNY, 1847, from the Aptian of western Europe, in the outline of two valves. The radial ribs of these species are, however, not so clearly differentiated in two orders as those of the present species . The umbonal region is not so sharply pointed in *S. roemeri*, and the primary ribs of *S. gibbosa* are much weaker than in the present species. Spines are probably less developed in *S. gibbosus*.

Several Cretaceous species with magnificient spines, such as *Spondylus spinosus* (SOWERBY, 1814) (non *S. spinosus* SCHREIBERS, 1793), are easily distinguishable from the present species by the subequivalve shell and simple radial ribs. *Spondylus japonicus* AMANO *in* AMANO and MARUI (1958) (non *S. japonicus* KURODA, 1932) is another Cretaceous spondyliid found in Japan, but it has much larger dimensions and its left valve is not spinose.

Occurrence.—Lower Miyakoan (Aptian). Dirty grey sandy shale of the 1st cycle of the Miyako group at loc. Hn. 2065, Hideshima, Sakiyama, Miyako City, Iwate Prefecture. A boulder of calcareous sandstone from the northern coast of Moshi, Iwaizumi town, Shimohei County, Iwate Prefecture. NAGAO reported this species also from the Hiraiga formation at the south of Hiraiga, Tanohata village, the same county.

Superfamily Limacea
Family Limidae
Genus *Plagiostoma* SOWERBY, 1814

Type-species.—*Plagiostoma giganteum* SOWERBY, 1814, Lower Jurassic, western Europe (designated by STOLICZKA, 1871).

Subgenus *Plagiostoma s. str.*
Plagiostoma (Plagiostoma) sanrikuense sp. nov.
Plate 48, Figure 2

Material.—The holotype is a right valve (GK. H 6315) collected from the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture (HAYAMI coll.).

Description.—Shell fairly large for genus, broadly gibbose in outline, nearly as high as long, moderately inflated; test unusually thick; anterior margin nearly straight, but not very long, forming an obtuse angle with ventral margin; posterior margin gently arcuate, passing gradually into venter; umbonal angle about 100 degrees; anterior umbonal ridge blunt, rounded, nearly straight; "lunule" in front of it obscurely defined, of moderate width, subvertical to valve margin, slightly excavated, nearly smooth except for faint radial striae near anterior umbonal ridge; surface marked with about 65 simple radial costae and faint concentric lines of growth; radials somewhat irregularly spaced on middle part of surface, slightly sinuous, non-punctate, flattened at tops, slightly narrower than their interspaces, not impressed on internal surface but giving rise to weak crenulations of inner ventral margin; auricles and ligament structure unknown. Holotype (GK. H 6315) right valve, 75.5 mm, long, 69.5+mm. high, 21.5 mm. thick.

Observations and comparisons.—This species is represented only by a right valve. It is well preserved but the test is exfoliated in the auricular and umbonal parts. The thickness of the test attains about 4 mm. in the anterior part and about 2.5 mm. in the posterior part. Considering that intraspecific variation is generally small in limids, this species can be regarded as being characterized

by the unusually thick test and broadly gibbous outline.

Plagiostoma (*s. s.*) seems to have flourished in the Jurassic and declined somewhat in the Cretaceous. Some of Cretaceous species appear to be intermediate between *Plagiostoma* (*s. s.*) and *Plagiostoma* (*Acesta*). The broad outline and stout radial ornamentation of the present specimen are, however, not much different from those of typical Jurassic *Plagiostoma* such as *P. cardiiforme* and *P. semicirculare*, and there is no resemblance to *Acesta*. Its exterior resembles that of *Lima vectensis* WOODS, 1904, which should be assigned to *Plagiostoma* (*s. s.*), from the Upper Greensand of England, but its radial ribs are more numerous and flat-topped than in the species in question.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture.

Subgenus *Acesta* H. and A. ADAMS, 1858

Type-species.—*Ostrea excavata* FABRICIUS, Recent, Atlantic (monotypy).

Remarks.—*Acesta* may be rightly considered to have been derived from *Plagiostoma* (*s. s.*). The former is typically distinguishable from the latter by its more elongated shell, prosocline ligament pit and les conspicuous anterior umbonal ridge. *Lima* (*s. s.*) may also be a group descended from *Plagiostoma*, but *Acesta* seems more closely related to *Plagiostoma* (*s. s.*) than to *Lima* (s. s.). Several Jurassic and Cretaceous species have been referred to *Acesta*, and their inclusion in that subgenus seems to have been based chiefly on such external features as a narrow outline, a greater obliquity and finer ribs than in normal species of *Plagiostoma* (*s. s.*). However, *Plagiostoma* (*s. s.*) includes many species characterized by various kinds of outline and ornamentation (COX, 1943), in some of which the surface is nearly smooth as in many species of *Acesta*. The distinction between the two subgenera for Mesozoic species would often be difficult from external features only. FRENEIX (1959, p. 219) regarded *Lima simplex* D'ORBIGNY, 1847, as a member of *Plagiostoma* (*s. s.*), but I think that it may be an intermediate species between *Plagiostoma* (*s. s.*) and *Acesta*, as suggested by CHELOT (1909). The gradual transformation of the ligament pit from an acline *Plagiostoma*-type to a prosocline *Acesta*-type can be expected to have taken place during Cretaceous times. *Plagiostoma* (*Acesta*) *goliathiforme* sp. nov. is probably the earliest known species, the subgeneric reference of which to *Acesta* can be based on ligament characters.

Plagiostoma (*Acesta*) *goliathiforme* sp. nov.

Plate 48, Figures 3, 4

Material.—The holotype is a right valve (GK. H 6316) collected from the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture (HAYAMI coll.). Paratype (GK. H 6317) from the type area (HANAI coll.).

Description.—Shell moderately large, elongate-oval, opisthocline, much

higher than long, fairly inequilateral, moderately inflated; test unusually thick for the subgenus, especially in anterior and umbonal regions; anterior margin nearly straight except for a concavity in front of anterior auricle; posterior margin broadly concave behind posterior auricle but passing gradually into ventral margin; umbo not salient above dorsal margin, placed at about one-third of hinge-axis from front; byssal gape, if present, very narrow, although in its usual position the shell is remarkably thickened and rounded at margin; anterior auricle large for *Acesta* but much narrower than posterior one, elongated along anterior margin, only slightly excavated, ill-defined from body of shell, marked with lamellose growth-lines; posterior auricle also ill-demarcated, obtusely triangular, nearly smooth; anterior umbonal ridge obscure; "lunule" not clearly impressed; surface nearly smooth, without prominent ribs; weak sinuous radial furrows impressed on anterior and posterior areas; cardinal area flat, fairly wide, obtusely triangular, forming an angle of about 30 degrees with commissure plane; ligament pit large, fairly deep, acutely triangular, strongly prosocline to hinge-axis and rounded at base; crural teeth, which often appear in *Lima* (*s. s.*) and *Plagiostoma* (*s. s.*), not developed; adductor scar subovate, placed posteriorly to centre; umbonal cavity shallow.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK. H6316) right in. mould	95.0	129.0	19.0	0.73
Paratype (GK. H6317) left valve	34.0+	36.0+	8.0	?

Observations and comparisons.—The internal characters of the present species are well exhibited in the holotype, the complete outline of which can be recognized from its internal mould. The surface of the umbonal region and of both ears is observable on the rear side of the holotype. There is another specimen (GK. H 6317), the ventral part of which is broken away. It is much smaller than the holotype and may have a proportionally larger posterior auricle, but is here considered to be an immature individual of the same species.

On account of the large size and weak radial sculpture of the holotype, the present species is apparently similar to *Lima* (*Ctenoides?*) *subrapa* NAGAO, 1934, another large limid from the Miyako group. It is, however, clearly distinguishable from that species by its more inequilateral outline and its thicker test. As suggested by Nagao, his species probably belongs to *Ctenoides* MÖRCH, 1853, but the present species seems essentially different from that genus on account of its narrower byssal gape, oblique shell, highly unequal auricles and large prosocline ligament pit.

According to these characteristics it should be included in *Acesta* H. and A. ADAMS, 1858, which now survives on the outer neritic and bathyal sea bottom of the Pacific and the Atlantic. In the essential structure of the hinge, ligament, musculature and surface ornamentation I can find no marked difference between the present species and *Plagiostoma* (*Acesta*) *goliath* (SOWERBY, 1883), a well-known Miocene-Recent species in Japan. In the former, however,

the test of the anterior area is much heavier, and the anterior auricle is more developed and less excavated than in the latter and also many other Cenozoic and Recent species of *P.* (*Acesta*).

The present species is closely related to *Lima simplex* D'ORBIGNY, 1847, from the Cenomanian of France, and *Lima* (*Plagiostoma*) *meyeri* WOODS, 1904, from the Upper Greensand of England, both of which are considered to be intermediate between *Plagiostoma* (*s. s.*) and *Acesta*. However, it is distinguishable from the holotype of the first species, which was clearly refigured by CHELOT (1909), by its longer hinge-axis and more prosocline ligament pit, and from the second species by its more vertically elongated outline and the absence of well-marked growth-rings. *Pecten* (*Camptonectes*) *euplocus* LANGE, 1914, from the Tendaguru formation of east Africa, which is assignable to *Plagiostoma*, may resemble the present species in outline and surface markings. But the present holotype is more gibbous in outline and the ratio of length/height is somewhat smaller than in the African species.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. A boulder of calcareous sandstone probably derived from the Hiraiga formation at the north of Haipe, in the same village.

Genus *Antiquilima* COX, 1943

Type-species.—*Lima antiquata* SOWERBY, 1821, upper Lower Jurassic, western Europe (original designation).

Antiquilima ultima sp. nov.

Plate 49, Figure 6

Material.—The holotype is a left valve (GK. H 6318) collected from the 2nd cycle sediments of the Miyako group at loc. Hn. 4053, Oshima island, off the coast of Moshi, Iwaizumi town, Shimohei County, Iwate Prefecture (HAYAMI coll.).

Description.—Shell of medium size, opisthocline, elongated, highly inequilateral, much higher than long, weakly inflated; test thin; umbo low, placed anteriorly to mid-point of hinge-axis; anterior umbonal ridge inconspicuous; "lunule" not defined; anterior margin broadly concave, posterior margin gently convex and passing gradually into venter; anterior auricle narrow, concave, with slightly thickened periphery; byssal gape fairly wide, occupying about one-fourth of anterior margin of main body; posterior auricle larger than anterior one but not clearly demarcated; surface of main body marked with numerous fine wavy radial riblets of two orders of prominence, although the distinction is not always clear; primary riblets about 30 in number, provided with irregularly spaced scales; secondary riblets about 4-6 in number in each interspace between primaries, very narrow; concentric lines irregularly spaced, present also on anterior auricle; internal and ligament structure

unknown. Holotype (GK. H 6318) left valve, 29.0 mm. long, 39.5 mm. high, 4.5 mm. thick.

Observations and comparisons.—The only specimen studied is a left valve exhibiting exterior. The ventral portion of the periphery is slightly crushed and the test is exfoliated in part.

The mode of byssal opening is somewhat similar to that of *Ctenoides,* but the outline and ornamentation of the shell are closer to those of *Antiquilima* COX, 1943, which was previously thought to be restricted to the Lower Jurassic and Bajocian of western Europe and Japan. *Antiquilima* was originally proposed as a subgenus of *Lima,* but is regarded here as a distinct genus. It has been thought that the benus became extinct after the Middle Jurassic. COX (1943) regarded its extinction as a fact which justified its separation from *Ctenoides* and suggested that the superficial similarity between the two constituted a case of parallel evolution. The existence of *Antiquilima* in the Lower Cretaceous was quite unexpected, but the new occurrence does not make its distinctness less apparent, because the present species clearly differs from *Ctenoides* in its more inequilateral and opisthocline shell, unequal auricles and characteristic ornamentation consisting of radial riblets of two orders. Undoubted *Ctenoides* appeared already in the Upper Jurassic (BOEHM, 1883; KIMURA, 1951) and it is presumed that *Antiquilima* constituted an independent trunk from *Ctenoides* in Jurassic-Cretaceous times.

Specifically, the present species is distinguishable from the Lower Jurassic and Bajocian ones of *Antiquilima,* such as *A. cubiferens* (WHILDBORNE, 1883), *A. antiquata* (SOWERBY, 1821), and *A. nagatoensis* HAYAMI, 1959, by the more delicate radial riblets, narrower anterior wing and presence of more or less widely spaced concentric lines. In the last mentioned character it is similar to *Lima tecta* GOLDFUSS, 1836, from the Upper Cretaceous of Europe and India, but the concentric lamellae of *L. tecta* are more stout and more regularly spaced than those of the present species or of Jurassic species of typical *Antiquilima.* The taxonomic position of *L. tecta,* whether the species belongs to *Antiquilima* or to *Ctenoides,* is not determinable at present, although it resembles the former in outline.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the 2nd cycle sediments of the Miyako group at loc. Hn. 4053, Oshima island, off the coast of Moshi, Iwaizumi town, Shimohei County, Iwate Prefecture.

Genus *Ctenoides* MÖRCH, 1853

Type-species.—*Lima scabra* BORN, 1778, Recent (designated by KOBELT, 1881).

Ctenoides subrapa (NAGAO)

Plate 48, Figure 5; Plate 52, Figure 7

1934, *Lima (Ctenoides?) subrapa* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.,* Ser. 4, Vol. 2, No. 3, p. 212, pl. 30, figs. 9, 10.

Material.—A left valve illustrated by NAGAO (1934, pl. 30, fig. 9) is designated here as the lectotype. It was collected from the Hiraiga formation at Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. NAGAO's other specimen (pl. 30, fig. 10) is also an example of this species. The two specimens are now missing, though they are to be preserved in the Hokkaido University (GH. reg. no. 6774, 6989). The following description is based on two specimens (GK. H 6319, GK. H 6320) newly collected from the type area (HANAI coll.).

Description.—Shell very large for genus, exceeding 100 mm. in height, suboval, subequilateral but a little prosocline, much higher than long, not strongly inflated; test thin except for somewhat thickened byssal area; anterior margin broadly arcuate, passing gradually into venter; umbo submesially placed, not prominent, with an apical angle of about 80 degrees; auricles obtusely triangular; anterior one slightly larger than posterior, marked with more prominent growth-lamellae; surface of shell-body marked with numerous fine radial riblets which are very sinuous, curving outwards; growth-lines very irregular as regards both spacing and prominence; byssal gape comparatively narrow; internal structure unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Both valves (GK. H6319)	89.0	110.0	21.5	0.81
Right valve (GK. H6320)	70.5+	64.0+	?	?

Observations and comparisons.—Two specimens at hand are referable to *Lima (Ctenoides) subrapa* NAGAO, 1934, as shown by the similarly elongate-oval outline and weak radial ornamentation. The first of these specimens shows the nearly complete outline of the shell-body and fine sinuous radial ribbing resembling those of the lectotype, although the auricular parts are incomplete and the shell is slightly compressed secondarily.

As noted by NAGAO (1934), this species may be closely allied to *Ctenoides rapa* (D'ORBIGNY, 1844) (GEINITZ, 1872; WOODS, 1904; FRENEIX, 1959) from the Cenomanian of western Europe. D'ORBIGNY's type specimens were fortunately refigured by CHELOT (1909). The radial riblets are, however, probably finer in the present species and its size is somewhat larger.

Occurrence.—Lower and upper Miyakoan (Aptian to Albian). Calcareous sandstone of the Hiraiga formation at the north of Haipe, and grey sandy shale of the Aketo formation at loc. Hn. 6201, northeast of Raga, Tanohata village, Shimohei County, Iwate Prefecture. NAGAO also reported the present species from the Hiraiga formation at Moshi and Hideshima, and from the "*Orbitolina* sandstone" at Hiraiga.

Genus *Limatula* WOOD, 1839

Type-species.—*Pecten subauriculatus* MONTAGU, Recent, north Atlantic and north Pacific (designated by GRAY, 1847).

Limatula sp. cf. *L. tombeckiana* (D'ORBIGNY)
Plate 52, Figure 8

Compare.—

1847, *Lima tombeckiana* D'ORBIGNY, Pal. franç., Terrain crétacé, Vol. 3, p. 534, pl. 415, figs. 13-17.
1904, *Lima (Limatula) tombeckiana*, WOODS, Monogr. Cret. Lamell. England, Vol. 2, p. 45, pl. 7, figs. 7-9.

This species is represented only by an ill-preserved specimen (GK. H 6634, 12.0+mm. long, 18.0+mm. high, 4.5 mm. thick) from the Miyako area. It is probably a left valve, but the body of shell is nearly equilateral. The test is almost exfoliated, but about 12 regular radial ribs are clearly impressed on the middle part of the internal surface. The ornamented area is subequal to the anterior and posterior smooth areas in breadth. The auricular parts are broken away.

The specimen closely resembles *Lima (Limatula) tombeckiana* D'ORBIGNY from the Lower Greensand of England (WOODS, 1904) in the dimensions and the restricted radial ornament, and is probably closely related to that species, if not identical. The present material is, however, too poorly preserved to be specifically identified.

Occurrence.—Lower Miyakoan (Aptian). Grey sandy shale of the Tanohata formation at loc. Hn. 0220, north of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture (OBATA coll.).

Limatula ishidoensis (YABE and NAGAO)
Plate 49, Figure 5

1926, *Lima (Limatula) ishidoensis* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 60, pl. 14, figs. 7, 16.
non 1934, *Lima (Limatula) ishidoensis*, NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 213, pl. 27, figs. 9, 10. (=*Limatula nagaoi* sp. nov.)

Material.—An external mould of a (?) right valve (IGPS reg. no. 22539) illustrated by YABE, NAGAO and SHIMIZU (1926, pl. 14, fig. 7) is here designated as the lectotype. It was collected from the Ishido formation at Ishido, Ohinata village, Minami-saku County, Nagano Prefecture. The other specimen illustrated by YABE, NAGAO and SHIMIZU (1926, pl. 14, fig. 16) and a newly collected specimen (GK. H 6325) from the Sanchu area (HAYAMI coll.) are also examples of this species.

Remarks.—YABE, NAGAO and SHIMIZU (1926) proposed the present species on the basis of two specimens. Recently a specimen (GK. H 6325, 3.0 mm. long, 5.5 mm. high, 1.5 mm. thick) consisting of external and internal moulds was obtained at the type locality. They are nearly equilateral and it cannot be decided whether they are right or left valves. The outline of the auricular part, especially the slightly concave margins of auricles, which are shown in the present internal mould, is similar to that of *Limatula tombackiana*

(D'ORBIGNY, 1846) from the Neocomian-Aptian of western Europe (WOODS, 1904). The size of the shell, however, is much smaller in *L. ishidoensis*.

The present species have been reported to occur from many other formations than the Ishido, such as the Miyako group, the Yatsushiro formation and the Hanoura formation. But the specimens from those formations mostly belong to another species, here named *Limatula nagaoi*.

Occurrence.—Aritan (upper Neocomian). Fine grey sandstone of the Ishido formation at loc. Hy. 4011, Ishido, Ohinata village, Minami-saku County, Nagano Prefecture.

Limatula nagaoi sp. nov.

Plate 49, Figures 1–4

1934, *Lima* (*Limatula*) *ishidoensis*, NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 213, pl. 27, figs. 9, 10. (non *Lima* (*Limatula*) *ishidoensis* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, 1926).

1954, *Limatula ishidoensis*, MATSUMOTO, Cret. System, Japan. Islands, pp. 82, 114, listed.

Material.—The holotype is a left valve (GK. H 6321) collected from the Hiraiga formation at loc. Hn. 0018, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture (HANAI and HAYAMI coll.). Paratypes (GK. H 6322-GK. H 6324) from the type locality (HAYAMI coll.). Two specimens illustrated by NAGAO (1934, pl. 27, figs. 9, 10) from the Miyako area are also the examples of this species.

Description.—Shell small, unusually narrow, elongate-oval, nearly acline, slightly inequilateral with the posterior margin more rounded than the anterior; height about twice the length; shell-convexity strong; test thin; no "lunule", no anterior umbonal ridge; umbo comparatively narrow, slightly rising above dorsal margin, placed submesially; auricles subequal, obtusely truncated, ill-demarcated from main body; median ridge observable only near umbo; central-ventral area evenly inflated; ornamentation consisting of 15-17 fine simple rdial riblets which are confined to the median part of surface; anterior and posterior unornamented areas subequal in breadth; riblets roof-shaped in transverse section, densely spaced near centre, becoming somewhat weaker and more sparse towards anterior and posterior areas; growth-lines very weak; muscle and ligament structures unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK. H6321) right valve	5.5	10.0	2.5	0.55
Paratype (GK. H6322) left valve	5.0	9.5	2.5	0.53
Paratype (GK. H6323) right valve	4.5	9.0	2.0	0.50
Paratype (GK. H6324) left valve	4.5	8.5	2.0	0.53

Observations and comparisons.—Four well preserved specimens and a few ill-preserved ones are available for study. The ornamentation and outline of the present specimens are fairly constant. In typical Recent *Limatula* (*s. s.*) *a*

pair of more or less stout radial ribs are present on the central surface (OYAMA, 1943), but these are unknown in most Cretaceous species of *Limatula* including the present one. The character suggests that these species may belong to the subgenus *Stabilima* IREDALE, 1939.

NAGAO (1934) referred some specimens from the Miyako group, which are certainly identical with the present species, to *Lima* (*Limatula*) *ishidoensis* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU, 1926, originally described from the Ishido formation of the Sanchu area. NAGAO pointed out that the radial riblets are relatively narrower than in typical specimens of *L. ishidoensis*, being separated from one another by much broader interspaces. Although he attributed this distinctive feature to the different state of preservation, such a tendency is clearly recognizable in all the newly collected specimens and can be regarded as a criterion for specific distinction. Moreover, the shell is somewhat larger and taller than the typical specimens of *L. ishidoensis*, which are about 6 mm. in maximum height, with an average ratio of length/height of about 0.60. *L. ishidoensis* has more equilateral outline and more distinctly concave anterior and posterior margins of auricles than the present species.

The present species differs from *Limatula tombeckiana* (D'ORBIGNY, 1846) from the Neocomian-Aptian of western Europe (WOODS, 1904) and its comparable species from the Miyako group in the narrower outline and more numerous radial riblets. *Limatula subaequilateralis* (D'ORBIGNY) as figured by WOODS (1904, pl. 7, figs. 16 a, b) seems close to the present species in the ratio of length/height and radial sculpture, but the shell is much larger than the present specimens. D'ORBIGNY's original figure of *L. subaequilateralis* differs from the present species both in outline and ornamentation.

The present species is named after late Prof. Takumi NAGAO of the Hokkaido University, who was a pioneer in studying Cretaceous pelecypods from Japan and previously described this species.

Occurrence.—Lower and upper Miyakoan (Aptian to Albian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga and sandy shale of the Tanohata formation at loc. Hn. 0220, northern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture. NAGAO reported this species also from the "Hiraiga sandstone" at Haipe and Hideshima, the "Moshi sandstone" at Hiraiga, "*Orbitolina* sandstone" at Hiraiga and the "Aketo sandstone" at Aketo. A similar specimen was found in the Yatsushiro formation at loc. Km. 1843, north of Shimofukami, Sakamoto town, Yatsushiro County, Kumamoto Prefecture (Kanmera coll.).

Superfamily Anomiacea
Family Anomiidae
Genus *Monia* GRAY, 1850

Type-species.—*Anomia zelandica* GRAY, Recent, southern Pacific (designated by KOBELT, 1881).

Monia sp. cf. *M. pseudotruncata* (YABE and NAGAO)
Plate 48, Figure 1

Compare.—

1926, *Anomia pseudotruncata* YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 62, pl. 12, figs. 26, 27, pl. 13, figs. 27, 28, 36, 37.

1939, *Anomia pseudotruncata*, KOBAYASHI and SUZUKI, *Japan. Jour. Geol. Geogr.*, Vol. 16, Nos. 3-4, p. 219, pl. 13, fig. 19.

This species is represented by an internal mould of a left valve (GK. H 6328, 20.0 mm. long, 17.5+mm. high, 4.5 mm. thick). It is almost indistinguishable from the syntypes of *Anomia pseudotruncata* YABE and NAGAO, 1926, from the Neocomian "Shiroi formation" of the Sanchu area and from the Yoshino formation of the Toyonishi grup of the Shimonoseki area. The shell convexity is, however, slightly stronger than the syntypes and weaker than the Yoshimo specimen. Although the exterior of this species is unknown, it is provisionally compared with *A. pseudotruncata,* which probably belongs to *Monia* in view of the weak radial ornament in some specimens of the syntypes.

Occurrence.—Upper Miyakoan (Albian). Fine grey sandstone of the Yatsushiro formation at loc. Km. 3035, west of Jôgûsan, Miyaji, Yatsushiro City, Kumamoto Prefecture (KANMERA coll.).

Monia aptiana sp. nov.
Plate 47, Figures 10, 11

Material.—The holotype is a left valve (GK. H 6326) collected from the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture (HAYAMI coll.). A paratype (GK. H 6327) from the type locality (HAYAMI coll.).

Description.—Left valve of small-medium size, subequilateral, suboval, higher than long, weakly inflated; valve margin irregularly undulating, not lying in one plane, gently arcuate but somewhat shouldered antero- and postero-dorsally; umbo submesially placed, mammillated, a little separated from dorsal margin; surface marked with a number of irregular concentric undulations and numerous sinuous radial riblets which are of a single order of prominence and apparently not granulated. Right valve and inner structures unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK. H6326) left valve	9.5	10.5	ca. 1.5	0.90
Paratype (GK. H6327) left valve	25.0	26.5	ca. 3.5	0.94

Observations and comparisons.—This species is represented only by two left valves. The paratype is much larger than the holotype and has a somewhat water-worn surface. The two specimens are, however, probaly conspecific, because other characters are quite similar.

The outline of the shell and the numerous sinuous radial riblets are similar to those of *Anomia pseudoradiata* D'ORBIGNY, 1850, from the Lower Greensand of England (WOODS, 1899). In particular, a Gault specimen which was figured by WOODS (1899, pl. 5, fig. 11) as *Anomia* cf. *pseudoradiata* may be close to these specimens. However, the convexity of the left valve is apparently weaker, the radial threads much finer and the antero- and postero-dorsal margins more strongly angulated than in the European specimens. Moreover, no granules can be observed on the radials of the present species. *Anomia pseudotruncata* YABE and NAGAO, *in* YABE, NAGAO and SHIMIZU (1926) from the Neocomian "Shiroi formation" of the Sanchu area, may be another related species, but the radial ribs are distinctly granulated and the umbo is placed more closely to the dorsal margin. Although the musculature of these three species is as yet unknown, the presence of distinct radial riblets on the whole surface suggest that they belong to *Monia* instead of *Anomia*.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hy. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture.

Order Colloconchida
Superfamily Ostreacea
Family Ostreidae

Remarks.—VIALOV (1936) divided the Ostreidae into four subfamilies, namely, the Ostreinae, the Lophinae, the Gryphaeinae and the Exogyrinae. STENZEL (1959) emended the diagnoses of these subfamilies and proposed a more subfamily, the Pycnodonteinae, stating that the major groupings of the family Ostreidae should be based on the shell structure, the adductor muscle and its imprint, the hinge and the shell commissure. This classification is here adopted.

Subfamily Ostreinae
Genus *Liostrea* DOUVILLÉ, 1904

Type-species.—*Ostrea sublamellosa* DUNKER, 1846, Lower Jurassic, Europe (original designation). "*Ostrea lamellosa*" in the original description of the genus was corrected by DOUVILLÉ (1904, p. 546).

Liostrea sp. ex gr. *L. cunabula* (SEELEY)
Plate 49, Figure 7

Compare.—

1861, *Ostrea cunabula* SEELEY, *Ann. Mag. Nat. Hist.*, Ser. 3, Vol. 7, p. 117, pl. 5, fig. 1.
1861, *Ostrea lagena* SEELEY, *Ibid.*, Ser. 3, Vol. 7, p. 117, pl. 5, fig. 2.
1913, *Ostrea cunabula*, WOODS, Monogr. Cret. Lamell. England, Vol. 2, p. 358, text-figs. 141-142.
1961, *Ostrea* (*Liostrea*) *cunabula*, CASEY, *Palaeontology*, Vol. 3, Pt. 4, p. 607, listed.

Several left valves forming two clusters are referable to *Liostrea* on account of the general outline, uncoiled umbo and strong convexity. The largest individual (GK. H 6329, left valve, 38.5 mm. long, 42.5 mm. high) from the Miyako group (HANAI coll.) is strongly inflated, with a thick test; the ligament area is broad, subtriangular, and provided with an elongated groove, the apex of which is pointed forwards. In the other smaller left valves, which are adhered to the same cluster, the ligament grooves, however, are nearly acline or curved slightly backwards. The ratio of length/height seems considerably variable in this species. The surface of the marginal area is marked with weak radial plicae and numerous foliated concentric lamellae. The attachment area is generally wide, occupying the greater part of the exterior.

Although its right valve is unknown, this species appears to be closely related to *Ostrea cunabula* SEELEY, 1861, from the Lower Greensand and Upper Greensand of England, which was satisfactorily investigated by WOODS (1913). COX (1952, p. 69) regarded that species as an early representative of *Ostrea* (*s. s.*), but CASEY (1961) included it in *Liostrea*.

The Japanese species is probably distinct from *L. cunabula*, because the shell is much smaller and has a more asymmetrical ligament area. Its specific determination is deferred until a right valve is found.

Occurrence.—Lower Miyakoan (Aptian). Conglomeratic sandstone of the Tanohata formation at loc. Hn. 0803, Koikorobe, Tanohata village, Shimohei County, Iwate Prefecture. A similar specimen was collected from the 2nd cycle sediments of the Miyako group at loc. Hn. 4051, Oshima island, off the coast of Moshi, Iwaizumi town, the same county.

Genus *Gryphaeostrea* CONRAD, 1865

Type-species.—*Gryphaea eversa* MELLEVILLE, 1843, Palaeocene, France (monotypy).

Gryphaeostrea sp. ex gr. *G. vesicularis* (LAMARCK)

Plate 51, Figure 8

A small left valve is available for study. It is strongly inflated, inequilateral, subquadrate in outline, and nearly as long as high; test comparatively thin; anterior slope very steep, posterior area somewhat flattened, delimited by a shallow posterior sulcus, and a little auriculate; umbo comparatively low, orthogyrous, incoiled; surface smooth except for many lamellose concentric lines; interior unknown. Specimen (GK. H 6350), left valve, 21.0 mm. long, 18.0+mm. high, 11.5 mm. thick.

This specimen is fairly similar to *Ostrea vesicularis* LAMARCK, 1806, from the Aptian to Senonian of western Europe (WOODS, 1913, etc.) in outline and in the nature of its concentric lamellae. Its size is, however, much smaller and its umbo is less salient than in *O. vesicularis*. *Gryphaea canaliculata* (SOWERBY, 1813), from the Lower Greensand, Gault and Upper Greensand of England, has a taller outline and a more produced postero-ventral margin.

The strongly inflated left valve and clearly defined posterior area are apparently similar to those of *Gryphaea* LAMARCK, 1801. But the umbo is less strongly coiled and the outline is more transversely elongated than every species of the Gryphaeinae. Some authors include such a irregular and weakly coiled Cretaceous species as *"G." canaliculata* in *Gryphaeostrea,* regarding it as a subgenus of *Gryphaea.* According to STENZEL (1959), however, the ligament area of typical *Gryphaeostrea* consists of three subdivisions as in many species of *Ostrea,* and it is not an intermediate group between *Gryphaea* and *Ostrea.* Although the ligament structure of the present species and related European species are not as yet precisely known, the former is provisionally referred to *Gryphaeostrea,* which is treated here as a distinct genus of the Ostreinae in agreement with STENZEL.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, Tanohata village, Shimohei County, Iwate Prefecture (HAYAMI coll.).

Subfamily Lophinae

Genus *Lopha* [RÖDING, 1798]

(=*Alectryonia* FISCHER DE WALDHEIM, 1807)

Type-species.—*Mytilus cristagalli* LINNAEUS, 1758, Recent, Indo-Pacific (designated by DALL, 1898).

Remarks.—Jurassic and Cretaceous species of *Lopha* can be generally, though not very sharply, divided into two groups according to the outline and surface ornament. One is the group of *Lopha marshii* with a broad outline and irregularly radiating strong plications, and the other is the group of *Lopha eruca* with a narrowly elongated and curved outline and ribs divaricating from a median parting (COX, 1952). *Lopha semiplana* and *Lopha carinata* are the respective Cretaceous representatives of the two groups. I include the former group tentatively in *Lopha* (*s. s.*), although the Recent type-species of *Lopha* has more conspicuous fine wrinkles on the surface and more strongly angulated and fewer plications than the most Mesozoic species. A subgeneric name *Arctostrea* PERVINQUIÈRE, 1910, is applicable to the latter group.

Subgenus *Lopha s. str.*

Lopha (*Lopha*) *nagaoi* sp. nov.

Plate 49, Figures 8-11; Plate 50, Figures 1, 2

1934, *Exogyra yabei* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 202 (pars).

Material.—The holotype is a left valve (GK. H 6330) collected from the Tanohata formation at loc. Hn. 0803, Koikorobe, Tanohata village, Shimohei County, Iwate Prefecture (HAYAMI coll.). Paratypes (GK. H 6331-GK. H 6334) from the type locality (HANAI and HAYAMI coll.).

Description.—Shell of medium size, inequivalve, variable in outline but usually subovate, not much elongated, higher than long to a varying extent.

Left or attached valve moderately inflated; line of maximum convexity lying near anterior margin, often located along a strong carina which corresponds to anterior margin of attachment area; posterior area much flattened; umbo sometimes orthogyrous but commonly more or less opisthogyrous, never coiled; radial plications 12 or a little more, sometimes increasing in number by irregular insertion, roof-shaped but slightly rounded at top and bottoms; attachment area very wide, nearly smooth; valve margin with strong frills corresponding to surface plications; concentric lamellae comparatively weak; ligament area wide, subtrigonal, provided with a triangular groove in the middle; adductor scar subovate, placed posteriorly to centre, usually more darkly tinted than remainder of shell. Right valve nearl yflat or only weakly convex; umbo much depressed; ligament area very thin; surface ornamented with 12 or slightly more radial plications; a median parting may or may not be present; valve margin strongly plicated as in left valve.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK. H6330) left valve	43.5	52.5	19.5	0.83
Paratype (GK. H6331) left in. mould	54.0	61.5	ca. 12.5	0.88
Paratype (GK. H6332) left valve	36.0	44.0	ca. 11.0	0.82
Paratype (GK. H6333) right valve	38.0	49.5	ca. 7.0	0.77
Paratype (GK. H6334) right valve	29.5	43.5	ca. 5.5	0.68

Observations and comparisons.—The outline is variable to a considerable extent, but this species seems to be characterized by the wide attachment area and the *Exogyra*-like appearance i.e. the steep anterior slope and flattened posterior area in the left valve. Clusters with many individuals are rather rare.

The present species is, in fact, somewhat similar to *Exogyra yabei* NAGAO, 1934, from the same locality. However, as seen in the present type specimens the ligament area consists of three well-developed subdivisions as in a normal ostreid and never coiled as in the Exogyrinae. In the left valve of *E. yabei* the postero-dorsal margin in finely crenulated, whereas such a tendency is not found in the present species.

Some of NAGAO's specimens of *E. yabei,* which were not illustrated in his monograph (1934) but are now preserved in the Hokkaido University, have the same ligament structure as this new species.

Specifically the present species resembles some specimens of *Lopha semiplana* (SOWERBY, 1825), which were fully described by WOODS (1913). The radial plications are, however, more prominent and numerous on the anterior part and the adductor scar is slightly larger and placed more posteriorly than in the European species. *Lopha lombardi* FRENEIX, 1957, from the Cenomanian of west Africa, has a more equilateral outline. *Ostrea (Alectryonia) diluviana* as figured by BASSE (1931) from the Upper Cretaceous of Madagascar resembles the present species in many respects, but the typical *L. diluviana,* as figured by PERVINQUIÈRE (1910), has a more narrowly elongated outline and is referable

to *Arctostrea*.

The present species is named after late Prof. Takumi NAGAO of the Hokkaido University, a great pioneer in the study of the Cretaceous pelecypods of this country.

Occurrence.—Lower Miyakoan (Aptian). Conglomeratic sandstone of the Tanohata formation at loc. Hn. 0802, 0803, Koikorobe, Tanohata village, Shimohei County, Iwate Prefecture. Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga, the same village. Calcareous sandstone of the 1st cycle sediments of the Miyako group at loc. Hn. 4024, northern coast of Moshi, Iwaizumi town, the same county. A similar specimen was collected from a dirty mudstone of the 1st cycle sediments of the Miyako group at Hideshima of Sakiyama, Miyako City, the same prefecture.

Subgenus *Arctostrea* PERVINQUIÈRE *in* DOUVILLÉ, 1910

Type-species.—*Ostrea carinata* LAMARCK, 1806, Cretaceous, cosmopolitan (original designation). The holotype of *O. carinata* was refigured by PERVINQUIÈRE (1910, pp. 197 a, b).

Lopha (*Arctostrea*) *carinata* (LAMARCK)

Plate 49, Figure 13

1806, *Ostrea carinata* LAMARCK, Ann. de Muséum, Vol. 8, p. 166.
1822, *Ostrea carinata*, SOWERBY, Min. Conch., Vol. 4, p. 89, pl. 365.
1869, *Ostrea* (*Alectryonia*) *carinata*, COQUAND, Monogr. du genre *Ostrea*, terrain crétacé, p. 129, pl. 49, figs. 3-9.
1871, *Ostrea* (*Alectryonia*) *carinata*, STOLICZKA, *Palaeont. Indica*, Ser. 4, Vol. 3, Pelecypoda, p. 468, pl. 48, fig. 5, pl. 49, figs. 1, 2.
1890, *Alectryonia* cf. *carinata* LAMARCK, YOKOYAMA, *Palaeontographica*, Bd. 36, p. 198.
1910, *Alectryonia* (*Arctostrea*) *carinata*, PERVINQUIÈRE, *Palaeontologia Universalis*, Sér. 3, Fasc. 2, pls. 197a, b.
1910, *Ostrea* (*Alectryonia*) *carinata*, BÖSE, *Bol. Inst. geol. Mexico*, Vol. 25, p. 104, pl. 16, figs. 13, 14.
1913, *Ostrea diluviana*, WOODS, Monogr. Cret. Lamell. England, Vol. 2, p. 342 (pars).
1926, *Ostrea diluviana*, YABE, NAGAO and SHIMIZU, *Sci. Rep. Tohoku Imp. Univ.*, Ser. 2, Vol. 9, No. 2, p. 62, pl. 13, figs. 4-6.
1927, *Ostrea diluviana*, YABE, *Ibid.*, Ser., 2, Vol. 11, No. 1, pl. 5, fig. 4.
1934, *Ostrea diluviana*, NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.* Ser. 4, Vol. 2, No. 3, p. 201.
1947, *Ostrea* (*Arctostrea*) *carinata*, STANTON, *U. S. Geol. Surv., Prof. Paper*, No. 211, p. 18, pl. 7, figs. 8-13.
1954, *Alectryonia diluviana*, MATSUMOTO, Cretaceous System, Japan. Islands, pp. 48, 55, 64, 82, 86, 87, 106, listed.
1954, *Alectryonia* cf. *carinata* LAMARCK, MATSUMOTO, *Ibid.*, p. 114, listed.

Remarks.—Cretaceous specimens of *Lopha* with an elongated and posteriorly curved outline and plications divaricating from a median ridge have been described by many authors under various names, such as *Ostrea pectinata* LAMARCK, 1806, *O. carinata* LAMARCK, 1806, *O. frons* PARKINSON, 1811, *O.*

plicatissima SCHLOTHEIM, 1820, *O. macroptera* SOWERBY, 1824, *O. prionota* GOLDFUSS, 1836, *O. rectangularis* RÖMER, 1839, etc. WOODS (1913) made a comprehensive study of this group and included all the forms in one species, *Ostrea diluviana* LINNAEUS, 1767, which was originally described from the Upper Chalk of Sweden and figured first by NILSSON (1827).

In Japan such a form occurs fairly commonly in the upper Neocomian and Aptian-Albian beds of the Miyako, Oshima, Sanchu, Katsuuragawa, Monobegawa, Haidateyama and Yatsushiro areas. A few specimens from the Miyayko and the Sanchu areas were described by YOKOYAMA (1890), YABE, NAGAO and SHIMIZU (1926) and NAGAO (1934), and many fragmentary specimens from other areas are preserved in the collections of the University of Tokyo and the Kyushu University. All the Japanese specimens have a narrowly elongated and posteriorly curved outline, and the shell does not taper much towards its postero-ventral end. In these respects, the Japanese specimens are more similar to *O. carinata, O. frons* and *O. macroptera* than to *O. diluviana* as figured by WOODS (1913, text-figs. 98-138). LAMARCK's holotype of *O. carinata* was fortunately illustrated by PERVINQUIÈRE (1910, pls. 197 a, b) and it can be said that these Japanese specimens are probably conspecific with it. In North America such a form has been reported from the Lower Cretaceous (mainly Albian) of Texas and Mexico by many authors, and the present specimens are especially similar to STANTON's (1947) specimens of *O. carinata* from the Upper Albian of Texas.

Although the synonymy of this group, which is now much complicated, should be studied in future on the basis of type-specimens as far as possible, I agree with STANTON (1947) in considering that *O. carinata* cannot be included in the range of variation of *O. diluviana,* as thought by WOODS (1913).

Since the present material is mostly fragmentary, only a right valve (GK. H 6335, 15.0 mm. long, 41.5 mm. high) from the Miyako group (HANAI coll.) is illustrated as an example.

Occurrence.—Aritan to upper Miyakoan (upper Neocomian to Albian) in Japan. Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, southern coast of Hiraiga and at loc. Hn. 0480, southern coast of Raga, Tanohata village, Shimohei County, Iwate Prefecture. Grey sandy shale of the "*Orbitolina* sandstone" of the Miyako group at loc. Hn. 6203, northeast of Raga, in the same village. Grey sandstone of the Ishido formation at loc. Hy. 4001, Ichinosebashi, south of Kagahara, Nakazato village, Tano County, Guma Prefecture. Grey sandy shale of the Oshima formation at Yokonuma of Oshima, Kesennuma City, Miyagi Prefecture. Grey sandstone of the Yatsushiro formation at loc. Km. 1843, north of Shimofukami, Sakamoto town, Yatsushiro County, Kumamoto Prefecture (KANMERA coll.). In addition, identical specimens have been reported by many authors as *Ostrea diluviana* from the "Kawarazawa formation" of the Sanchu area, the Hanoura formation of the Katsuuragawa area, the lower Monobegawa subgroup of the Monobegawa area and the Haidateyama formation of the Haidateyama area.

Subfamily Exogyrinae

Remarks.—STENZEL (1959) redefined the diagnosis of the Exogyrinae VIALOV, 1936, as follows: "Exogyrinae have the ligamental area so modified that one of the three subdivisions of the ligamental area is reduced in width or suppressed; the valves are consistently spirogyrate."

The phylogenetic relationship among many groups of the Ostreidae is thought to be much complicated, and many different opinions have been expressed as to their evolution (see COX, 1952; STENZEL, 1959, etc.).

Strongly plicated ostreids are generally grouped as *Lopha,* but several Cretaceous species such as *"Exogyra" flabellata* GOLDFUSS, 1836, *"Exogyra" matheroniana* (D'ORBIGNY, 1847), *"Exogyra" minos* (COQUAND, 1869) and *"Exogyra" yabei* NAGAO, 1934, have *Lopha*-like strong radial plications and a planispiral umbo, may appear to be transitional between *Lopha* and *Exogyra.* But in view of their evolutional history, they may have been derived from non-ribbed exogyroids instead of the Lophinae. Because many species of typical *Exogyra,* such as *E. costata* SAY (STEPHENSON, 1914, etc.), have numerous and relatively fine radial ribs on the strongly inflated left valve and a much narrower attachment area, *Ceratostreon* BAYLE, 1878, is applicable to such strongly plicated species.

On the other hand, many of Cretaceous exogyroids with *Haliotis*-like oblong outline, not much inequivalve shell, and no radial ornament, such as *Amphidonta humboldti* FISCHER DE WALDHEIM, 1829, *"Exogyra" walkeri* WHITE, 1879, *"Exogyra" haliotoidea* (SOWERBY, 1813), *"Exogyra" conica* (SOWERBY, 1813) and *"Exogyra" subhaliotoidea* NAGAO, 1934, can be referred to *Amphidonta* FISCHER DE WALDHEIM, 1829 (? = *Rhynchostreon* BAYLE, 1878), which has been treated as a distinct genus or subgenus by some authors (ORLOV et al., 1960, etc.).

The Cretaceous species of *"Exogyra"* can be thus classified into the following groups:

1) *Exogyra* SAY, 1820, characterized by the relatively large size, the opercular right valve, and the strongly convex left valve which has a weak or obsolete spiral keel, narrow attachment area and numerous radial ribs which are often cancellate or spinose. Mainly Albian to Maastrichtian.

2) *Ceratostreon* BAYLE, 1878, characterized by the not very inequivalve shell, the conspicuous spiral keel and *Lopha*-like surface plications with strongly frilled valve margin. Mainly Neocomian to Albian, though some species survived until Senonian in Europe and Africa.

3) *Amphidonta* (*s. s.*) FISCHER DE WALDHEIM, 1829, characterized by the absence of strong radial ornament, and the *Haliotis*-like outline with a fairly conspicuous spiral keel. Mainly Middle Jurassic to Cenomanian.

COX (1952, p. 89) noted, "It is doubtful if *Exogyra costata,* the type-species of *Exogyra,* is to be regarded as a descendant of the Jurassic forms referred to the genus." *E. costata* and a number of Cretaceous species of typical *Exogyra*

possess very inequivalve shell and numerous radial ribs on the surface of the left valve. In many characteristics Cretaceous species of *Amphidonta* appear to be more closely related to the group of *"Exogyra" nana*, from the Middle and Upper Jurassic, and to its probable descendants in the Lower Cretaceous than to typical *Exogyra*. The Jurassic exogyroids lack radial ornament and can be regarded as ancestral to Cretaceous *Amphidonta*.

STENZEL (1959) regarded the external and ornamental features of ostreids to be rapidly evolving characters. He referred several species of *Haliotis*-like exogyroids from the Comanche series of Texas, which may or may not be radially ribbed, to *Ceratostreon* BAYLE, 1878. *"Exogyra" walkeri* WHITE, 1879, seems to be a typical *Amphidonta*, but *"Exogyra" hilli* CRAGIN, 1893, shows weak radial plications and appears to be an intermediate species between *Amphidonta* (*s. s.*) and *Ceratostreon*. Because the two groups may not be always sharply separated, it seems to be most reasonable that *Ceratostreon* is treated as a subgenus of *Amphidonta*. *Amphidonta* (*Ceratostreon*) may have been derived from *Amphidonta* (*s. s.*).

The phyletic relationship between *Amphidonta* and true *Exogyra* is not very clear, because intermediate species are scarcely known. As pointed out by STENZEL (1959), the early species of *Exogyra* such as *Exogyra plexa* CRAGIN, 1893, from the Albian of Texas, are comparatively small, and gigantism and shell-thickening are probably a general tendency in the evolutionary history of *Exogyra*.

Since the radial ribs of typical *Exogyra* are fairly similar to those of *Ostrea* (*s. s.*), some authors have considered typical *Exogyra* and Jurassic—Lower Cretaceous species now grouped as *Amphidonta* may have been derived from independent sources of the Ostreinae. But I am of opinion that the Exogyrinae, like every other subfamily, cannot be polyphyletic, because a "polyphyletic" taxon would be inconstent with the concept of natural classification. The ligament and other internal structures of *Exogyra* and *Amphidonta* are too essentially similar to consider that they were phylogenetically unrelated.

Genus *Amphidonta* FISCHER DE WALDHEIM, 1829

Type-species.—*Amphidonta humboldti* FISCHER DE WALDHEIM, 1829, Upper Cretaceous, western Europe (monotypy).

Subgenus *Amphidonta s. str.*

Amphidonta (*Amphidonta*) *subhaliotoidea* (NAGAO)

Plate 50, Figures 6–9; Plate 51, Figures 1, 2

1934, *Exogyra subhaliotoidea* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 203, pl. 30, figs. 1–4.

Material.—The holotype is a left valve (GH. reg. no. 6622) illustrated by NAGAO (1934, pl. 30, fig. 3). It was collected from the "Hiraiga sandstone" at Hideshima, Miyako City, Iwate Prefecture. Three paratypes illustrated by

him are also the examples of this species. Six more specimens (GK. H 6242-GK. H 6245, GK. H 6623, GK. H 6628), from the type area (HANAI and HAYAMI coll.), are also concerned with the description below.

Description.—Shell medium-sized or large, inequivalve, inequilateral, *Haliotis*-like in outline, much higher than long; test fairly thick, neither plicated nor radially ribbed. Left valve moderately inflate, sharply edged, with a more or less concave attachment are of moderate width; anterior margin broadly arcuate, highly elevated; posterior margin subvertical, not raised; umbo strongly coiled backwards for one and a half volutions in plane of valve, usually truncated by attachment area; a blunt carina extends crescentically from umbonal region, defining a very steep or nearly vertical marginal belt, which is marked with numerous subvertical striae; surface marked with irregularly foliated concentric growth-lamellae; inner valve margin marked with numerous faint crenules; ligament area elongated along dorsal margin, with incoiled apex, forming a deep groove, the boundary of which forms a tooth-like projection over umbonal cavity. Right valve also *Haliotis*-like but more weakly inflated and even slightly concave in posterior area; anterior margin raised to form a rounded rim, posterior margin nearly flat; umbo strongly coiled, operculiform; ligament area close to and elongated along dorsal margin, very narrow, only slightly concave, provided with a conical tooth-like projection; exterior of anterior rim marked with numerous subvertical striae; adductor scar subcentral, well marked, usually more darkly tinted than the remainder of shell; inner marginal crenules obscure.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Right valve (GK. H6342)	66.5	105.0	27.0	0.63
Left valve (GK. H6343)	54.0	82.5	26.0	0.65
Right valve (GK. H6344)	35.5	51.0+	10.5	0.70−
Right valve (GK. H6345)	43.5	56.0+	11.5	0.78−
Left valve (GK. H6623)	60.0	62.5	30.5	0.65

Observations and comparisons.—The outline of this species is somewhat variable, but is usually *Haliotis*-like with a highly rimmed anterior margin; this character and the absence of radial ribs except for numerous striae on the anterior slope seems to define this species. The exogyroid umbonal coiling is well recognized in the present material and in NAGAO's specimens. Two large specimens (GK. H 6342, GK. H 6343) are the best preserved and show the detailed structure of the umbonal area, the exterior of the left valve and the interior of the right valve. Judging from the shape of the valve margin, which is sharply edged in the left valve and remarkably rounded in the right valve, and also from the position of inner ventral crenules of the left valve, the right valve may be somewhat smaller than the left, the former fitting in the latter.

NAGAO referred this species to *Exogyra*, but the absence of radial ribs and other characters indicate that it belongs to *Amphidonta* (*s. s.*) in the present

classification. This species is distinguishable from *Amphidonta humboldti* FISCHER DE WALDHEIM, 1829, by its broader attachment area and the more abruptly elevated anterior margin of the left valve. *Exogyra haliotoidea* (SOWERBY, 1813) as figured by STOLICZKA (1871) from the Ootatoor group of southern India may be a close ally, as pointed out by NAGAO (1934). But typical *E. haliotoidea* from the Aptian-Cenomanian of Europe, which was considered to be conspecific with *Exogyra conica* (SOWERBY, 1813) by WOODS (1913), has a more planispiral umbo and a more inequivalve shell, i.e. its left valve more strongly convex and the outline of its right valve more operculiform. The original figure of *Ostrea rauliniana* D'ORBIGNY, 1846, is similar to the present species in outline, ligament structure and in the high raised anterior margin. D'ORBIGNY's species was, however, also synonymized with *E. conica* by WOODS (1913). The present species is somewhat similar to *Exogyra parasitica* GABB, 1864 (STEWART, 1930, p. 132, pl. 1, fig. 1) from the "Chico group" of California, which is probably also a member of *Amphidonta* (*s. s.*), as regards the outline of right valve, but differs in dimensions and the shape of adductor scar. *Exogyra walkeri* WHITE, 1879, from the Albian of Texas (STANTON, 1947) (= *Exogyra americana* in ADKINS, 1928), seems closest to the present species among a number of American species of *Amphidonta*. The umbonal coiling of *A. subhaliotoidea* is, however, more conspicuous when viewed from the interior, and the right valve is probably more strongly convex than in the American species.

Occurrence.—Lower and upper Miyakoan (Aptian to Albian). Calcareous sandstone of the Tanohata formation at loc. Hn. 0310, northern coast of Hiraiga and conglomeratic sandstone of the same formation at loc. Hn. 0802, Koikorobe, Tanohata village, Shimohei County, Iwate Prefecture. Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0023, southern coast of Hiraiga, the same village. Grey mudstone of the 1st cycle of the Miyako group at loc. Hn. 2058, Hideshima of Sakiyama, Miyako City, the same prefecture. NAGAO reported this species also from the "Aketo sandstone" near Raga and the "*Orbitolina* sandstone" at Raga, Tanohata village.

Subgenus *Ceratostreon* BAYLE, 1878

Type-species.—*Ostrea matheroniana* D'ORBIGNY, 1848, Senonian, France.

Amphidonta (*Ceratostreon*) *yabei* NAGAO

Plate 49, Figure 12; Plate 50, Figures 3-5

1934, *Exogyra yabei* NAGAO, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, Ser. 4, Vol. 2, No. 3, p. 202, pl. 25, fig. 7, pl. 26, fig. 1, pl. 27, fig. 1, pl. 28, figs. 1, 2, pl. 29 figs. 1, 14.

Material.—A right valve illustrated by NAGAO (1934, pl. 29, fig. 1) is designated here as the lectotype. It was collected from the "Moshi sandstone" (the 1st cycle of the Miyako group) at Moshi, Iwaizumi town, Shimohei County,

Iwate Prefecture. Three syntypes illustrated by NAGAO are also good examples of this species, although some of his specimens, which were not illustrated but are now preserved in the Hokkaido University, are referable to *Lopha nagaoi* sp. nov. Seven more specimens (GK. H 6336-GK. H 6341, GK. H 6390) were collected from the Miyako area (HANAI and HAYAMI coll.). Since NAGAO's original specimens are now missing, the following description is based chiefly on the seven present specimens.

Description.—Shell fairly large, inequivalve, inequilateral, subovate to pyriform in outline, not much elongated, curved posteriorly, higher than long to a varying extent; test fairly thick. Left valve moderately inflated; region of maximum convexity located near anterior margin, coinciding with a sharp spiral carina; anterior margin strongly convex, coarsely frilled; posterior margin concave near umbo, only weakly undulating; umbo placed posteriorly to centre, strongly opisthogyrous, horizontally incoiled; radial plications 12 or rather more, obscurely impressed on attachment area but very conspicuous and angular on anterior slope, which is nearly perpendicular to commissure plane; attachment area very wide, occupying about half the surface; numerous growth-lines cross radial plications, forming, as in *Lopha*, numerous chevrons in anterior and ventral views; ligament area elongated, strongly curved backwards along pre-umbonal margin, provided with a deep ligament groove of *Exogyra*-type; a tooth-like projection produced near incoiled umbo, supporting ligament area; adductor scar large, suborbicular, placed just below tooth-like projection; valve margin finely crenulated internally; umbonal cavity fairly deep. Right valve weakly convex in anterior part and even slightly concave in posterior part, provided with narrow ligament area and planispiral umbo; anterior margin strongly serrated, interlocking with that of opposite valve; radial plications present on whole surface but comparatively weak except on anterior peripheral part; other characters similar to those of left valve.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Left valve (GK. H6336)	56.5	79.0	ca. 23.0	0.72
Left valve (GK. H6337)	89.5	106.0	?	0.84
Right valve (GK. H6338)	63.5	70.0	ca. 10.0	0.91
Right valve (GK. H6339)	31.0	41.5	ca. 8.0	0.75
Left valve (GK. H6340)	30.0	42.5	?	0.71
Left valve (GK. H6341)	45.0	62.0	22.0	0.73

Observations and comparisons.—Many well preserved specimens showing the external and internal characters in the present material are specifically identical with *Exogyra yabei* NAGAO, 1934, although their outline and convexity vary considerably. Multiple clusters are, if present, very rare.

NAGAO (1934) dealt with several specimens in the original description of *E. yabei*, but confused the two valves in the explanation of plates. One specimen, represented in his pl. 25, fig. 7 and pl. 28, fig. 1 (non pl. 26, fig. 1) is evidently a right valve instead of a left one, and another specimen, represented

in pl. 26, fig. 1 and pl. 27, fig. 1 actually a left valve.

The type of radial plication is similar to that of *Lopha*, but the umbo is evidently coiled in the plane of the valve, as seen in the figure of the lectotype and also in the present material. The similarly plicated valves indicate that this belongs to *Amphidonta* (*Ceratostreon*). If the umbonal area is not exposed, it may be hard to distinguish this species from *Lopha nagaoi* sp. nov. Its outline, however, is more regular and the radial plications are generally more weakened on the posterior peripheral part than in *L. nagaoi*.

As noted by NAGAO (1934) and DIETRICH (1936), the present species may be related to *Exogyra minos* COQUAND, 1869, from the Neocomian and Aptian of Europe and South America (SOMMERMEIER, 1913; WEAVER, 1931). I have had no opportunity of comparing it with any photographic illustration of the type specimens of that species, but the South American specimens have generally heavier tests. *Exogyra texana* RÖMER, 1852, from the Albian of Texas (STANTON, 1947) and Mexico (BÖSE, 1910) also resembles the present species but has somewhat weaker radial plications and probably heavier test.

Occurrence.—Lower Miyakoan (Aptian). Calcareous sandstone of the Hiraiga formation at loc. Hn. 0017, 0018, southern coast of Hiraiga and loc. Hn. 0920, north of Haipe, Tanohata village, Shimohei County, Iwate Prefecture. Conglomeratic sandstone of the Tanohata formation at loc. Hn. 0802, 0803, Koikorobe, the same village. A boulder of calcareous sandstone at the northern coast of Moshi, Iwaizumi town, the same county, which was certainly derived from the 1st cycle sediments of the Miyako group. NAGAO reported this species also from the "Hiraiga sandstone" of Hideshima and the "*Orbitolina* sandstone" of Raga.

Subfamily Gryphaeinae

Genus *Gryphaea* LAMARCK, 1801

Type-species.—*Gryphaea arcuata* LAMARCK, 1801, Lower Jurassic, western Europe (designated by ANTON, 1839).

Remarks.—Cretaceous *Gryphaea* is common in the Gulf Coast region and western Europe. The phyletic relationship among many groups of the genus has been regarded as a complicated one, and many authors (KITCHIN, 1912; TRUEMAN, 1922; ARKELL, 1932, etc.) have considered *Gryphaea* to be a "polyphyletic group". However, STENZEL (1959) concluded that the Cretaceous Gryphaeas of the Gulf Coast region have much in common with those of the Jurassic of Europe in shell shape as well as in internal features and shell structure. He established a subgenus *Texigryphaea* (type-species: *Gryphaea roemeri* MARCOU, 1862) for such Cretaceous species of the Gulf Coast region, regarding the subgenus as a descendant from *Gryphaea* (*s. s.*). *Gryphaeostrea* CONRAD, 1865 (type-species: *Gryphaea eversa* MELLEVILLE, 1843, from the Palaeocene of France), which had been regarded by some authors as transitional between *Gryphaea* and the Ostreinae, was proved to be unrelated to the Gryphaeinae and inclusive in the Ostreinae, according to STENZEL. *Odonto-*

gryphaea VON IHERING from the Upper Cretaceous and Tertiary of Baluchistan is said also to be clearly distinguishable from the Gryphaeinae. Therefore, it is presumable that the Gryphaeinae formed an independent lineage from the Ostreinae during the Jurassic and Cretaceous and their evolution was not polyphyletic.

In Japan, true representatives of *Gryphaea* (*s. s.*) and *Texigryphaea* have been scarcely known in the Jurassic and Cretaceous sediments. Only a species from the Lower Cretaceous can be referred to *Gryphaea*, but it differs from *Gryphaea* (*s. s.*) and *Texigryphaea* in some characters.

Gryphaea (*s. l.*) *oshimensis* sp. nov.

Plate 51, Figures 3–7; Plate 52, Figure 9

Material.—The holotype (GK. H 6346) is a bivalved specimen collected from the Oshima formation at loc. Hy. 1009, Yokonuma of Oshima, Kesennuma City, Miyagi Prefecture (OBATA and HAYAMI coll.). Paratypes (GK. H 6347-GK. H 6349, GK. H 6635-GK. H 6639) from the type locality (OBATA and HAYAMI coll.).

Description.—Shell very small for genus, scarcely exceeding 20 mm. in height, highly inequivalve, subequilateral, subovate, much higher than long; test of moderate thickness. Left valve moderately inflated; antero- and postero-dorsal margins slightly concave; anterior and posterior areas not much flattened, not auriculated; no posterior sulcus; umbo placed near mid-point of length, subvertically incoiled, nearly orthogyrous, rising high above dorsal margin; surface marked with *Plicatula*-like, often bifurcating radial ribs and foliated concentric growth-lamellae; attachment area, if present, very narrow. Right valve nearly flat or even slightly concave, suborbicular, marked with somewhat roughly spaced foliated concentric growth-lamellae; radial ribs absent. Internal structure of two valves unknown.

Measurements in mm.

Specimen	Length	Height	Thickness	L/H
Holotype (GK. H6346) both valves	10.0	15.5	6.5	0.65
Paratype (GK. H6347) both valves	10.5	15.0	6.0	0.67
Paratype (GK. H6348) both valves	11.0	15.0	7.0	0.73
Paratype (GK. H6349) both valves	12.0	15.5	5.0	0.77
Paratype (GK. H6635) both valves*	15.5	18.5	7.0	0.84
Paratype (GK. H6636) both valves*	14.5	16.5	5.5	0.88
Paratype (GK. H6637) both valves*	15.5	16.5	4.5	0.94
Paratype (GK. H6638) both valves*	13.0	16.0	5.0	0.81
Paratype (GK. H6639) both valves*	12.0	13.0	5.0	0.92

Observations and comparisons.—A number of secondarily deformed specimens are available for study. The original outline and inequivalveness seem to be retained in the four specimens (GK. H 6346-GK. H 6349), the measurements of which are recorded above. Since all the available specimens are

* More or less strongly compressed specimen.

bivalved and closed, their internal structure cannot be observed. The plano-convex outline and subvertically incoiled umbo of the left valve suggest the reference of these specimens to *Gryphaea*. The orthogyrous umbo, the presence of bifurcating radial ribs and the absence of well-defined posterior flange are characters apparently similar to those of *Fatina* VIALOV, 1936 (type-species: *Ostrea esterhazyi* PÁVAY var. *beldersaiensis* GORIZDRO, 1915) from the Palaeogene, which was treated as a subgenus of *Gryphaea* by ORLOV et al. (1960). But the systematic positions of the present species and that subgenus remains uncertain. In the species of *Gryphaea* (*s. s.*), chiefly from the Jurassic, and of *Texigryphaea*, from the Cretaceous, there is a conspicuous sulcus clearly defining a more or less flattened posterior flange. In the present species, however, there is no trace of such a sulcus.

The present species resembles *Gryphaea newberryi* STANTON, 1893, from the Upper Cretaceous of south Western Interior, in the outline of the left valve, but the shell is of much smaller dimensions and the umbo is much narrower than in that species. So far as I am aware, there is no comparable species in the Lower Cretaceous.

Occurrence.—Aritan (upper Neocomian). Black shale of the Oshima formation at loc. Hy. 1009, Yokonuma of Oshima, Kesennuma City, Miyagi Prefecture.

(to be continued)