Brackish Water Molluscan Fauna from the Miocene Bihoku Group, Hiroshima Prefecture, Southwest Japan

Keiji MATSUOKA*

備北層群より産出した汽水性貝類群集

松 岡 敬 二*

(要　　旨)

広島県北東部に分布する備北層群より産出した汽水性貝化石を検討した結果，新種 *Batissa bihokuensis* n. sp. を含む *Melanoides* sp., *Terebralia* sp., "*Ostrea*" sp., *Novaculina* sp., *Geloina* cf. *stachi* OYAMA の6種を識別し，記載した．この汽水性貝類群集は，*Batissa bihokuensis* n. sp. が多く含まれることで特徴づけられ，*Batissa* 群集と呼ぶことができる．*Batissa* 群集の生息地は，その群集を構成する種の近縁現生種の資料に基づくと，河口奥部の泥底と考えられる．これまで報告されている中新統の汽水群集のうち，*Geloina* 群集（糸魚川・西川，1976; SHIBATA, 1978），*Geloina–Telescopium* 群集（OYAMA, 1950; IWASAKI, 1970）の生息地は，*Batissa* 群集の生息地に近いことが推定できる．これらの群集は，種の多様度が低く，少数種の個体数が多い特徴を持ち，陸側の汽水環境下の泥底群集としてまとめられる．一方，*Batillaria* 群集（CHINZEI・IWASAKI, 1967）や *Crassostrea–Batillaria* 群集（糸魚川，1971）などは，前者の汽水貝類群集より種の多様度，生息地の塩分濃度が高い海側の泥底群集として一括することができる．この2つの貝類群集群は，備北層群下部の群集遷移において *Batissa* 群集を含む陸側の群集群から，*Batillaria* 群集を含んだ海側の群集群へと変わる．また，これらの群集群には，ともに亜熱帯から熱帯要素が含まれ，陸側群集群に比較して海側群集群のほうが北まで産出地の報告があり，時間的・地理的に南方要素の侵出に段階性があったことが推定される．

(**Abstract**)

The collections of brackish water molluscs from two localities of the Miocene Bihoku Group consist of *Melanoides* sp., *Terebralia* sp., "*Ostrea*" sp., *Geloina* cf. *stachi* OYAMA and a new species of a corbiculid bivalve, *Batissa bihokuensis* n. sp. The *Batissa* assemblage characterized by the abundance of *Batissa bihokuensis* n. sp. is a mudflat molluscan community in the interior part of estuaries, and is discriminated from previously discribed brackish water molluscan assemblages of Japanese Miocene. The brackish water molluscan assemblages known from Japan are parceled out into two groups, the estuarine mudflat assemblages of landward fringe including the *Batissa* assemblage and the coastal mudflat assemblages of seaward fringe.

Introduction

During the stratigraphic and paleontologic work in the northeastern part of Hiroshima Prefecture, the author has collected six brackish water molluscs including

* Department of Earth Sciences, Nagoya University, Nagoya
Received November 8, 1979

one new species from the Jinseki Formation of the Miocene Bihoku Group at locality 1 and locality 2. The localities are shown in the index map (Fig. 1). The brackish water molluscan assemblages from the two localities have much in common, and both of the assemblages are the *Batissa* assemblage which is characterized by the abundance of *Batissa bihokuensis* n. sp.

Among the brackish water molluscan assemblages reported from the Japanese Early Miocene deposits are the Arcid-Potamid fauna (TSUDA, 1965) from areas along the Sea of Japan, the *Geloina-Telescopium* assemblage (OYAMA, 1950) from the Yatsuo Group of Toyama Prefecture of Central Japan, the *Batillaria* assemblage (CHINZEI and IWASAKI, 1967) from the Shiratorigawa and Natori Groups of Northeast Japan, the *Crassostrea-Batillaria* assemblage (ITOIGAWA, 1971), *Crassostrea-Cyclina-Geloina* assemblage (OKAMOTO and TERACHI, 1974), *Crassostrea-Geloina* assemblage (OKAMOTO *et al.*, 1978), and the *Geloina* assemblage (ITOIGAWA and NISHIKAWA, 1976) from the Bihoku Group, and so on. The *Batissa* assemblage, as compared with the habitats of these assemblages, is recognized as a segregated community of the most landward fringe.

This paper also discusses the pattern of appearance and change of the brackish water molluscan assemblages, which contain the subtropical to tropical elements.

Acknowlegements

Special thanks are due to Assistant Prof. Dr. J. ITOIGAWA of Nagoya University for his kind guidance and his reading the manuscript. I am thankful to Dr. H. SHIBATA of Nagoya University for his useful discussion and his reading the manuscript. I thank Mr. I. NISHIKAWA who provided me molluscan specimens available for study. I am grateful to Prof. Dr. A. MORISHITA and Mr. S. MORI of Nagoya University for thier advices.

Geologic setting and localities

Early to Middle Miocene sedimentary rocks in the northern part of Hiroshima Prefecture are divided into two stratigraphic units, the Shiomachi Formation and the Bihoku Group in ascending order (IMAMURA, 1957). He states that the Shiomachi Formation is non-marine deposit marked by the occurrence of the Daishima-type flora; on the contrary he states that the Bihoku Group is the marine one. Although this division has been formally used, it is not well fitted to describe the stratigraphic position of the brackish water molluscan fossils from the two localities. Hence the author makes use of the stratigraphic classification shown in Table 1.

Locality 1

Nogumi, Tojō-cho, Hiba-gun, Hiroshima Prefecture. "Tojō" quadrangle (1975) 1: 25,000. About 1.5 kilometers east-southeast of Tojō.

Table 1. The correlation table of the Bihoku Group of the previous and present works

IMAMURA, 1953 Northern part of Hiroshima Prefecture		MATSUOKA, (PRESENT PAPER) Around and in Yuki-cho		
BIHOKU GROUP	UPPER SHALE MEMBER	BIHOKU GROUP	KIBI FORMATION	UPPER MUDSTONE MEMBER
	LOWER SANDSTONE MEMBER			LOWER SANDSTONE MEMBER
SHIOMACHI FORMATION			JINSEKI FORMATION	UPPER MEMBER
				LOWER MEMBER
				YUKI CONGLOMERATE

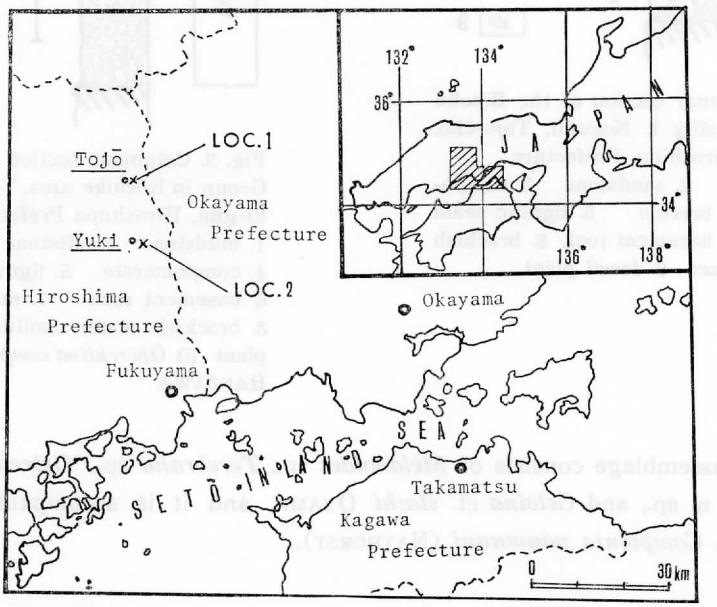


Fig. 1. Index map of the northeastern part of Hiroshima Prefecture showing the two localities of the new brackish water molluscan assemblage

The stratigraphic unit from which the molluscan remains were recovered is that designated by the author as the Jinseki Formation. The Paleozoic Formation of the North-zone (HASE, 1965) unconformably underlies the Jinseki Formation, which in turn is conformably overlain by the Kibi Formation.

The brackish water molluscan assemblage has been collected from the blackish gray mudstone of the Lower Member of the Jinseki Formation (Fig. 2). The

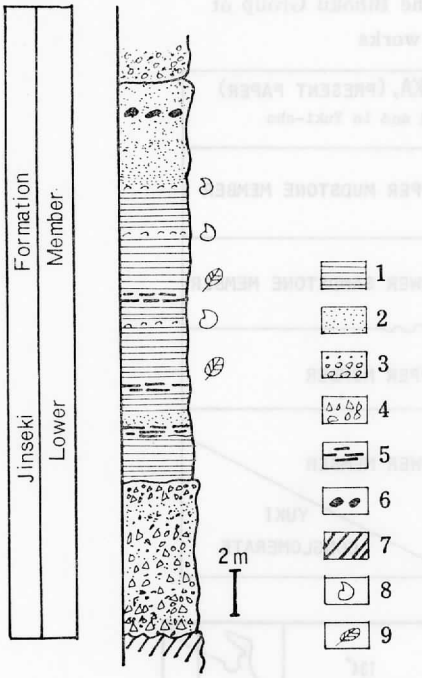


Fig. 2. Columnar section of the Bihoku Group at locality 1, Nogumi, Tojō-cho, Hiba-gun, Hiroshima Prefecture
1. mudstone 2. sandstone 3. conglomerate 4. breccia 5. lignitic seam 6. nodule 7. basement rock 8. brackish water molluscs 9. fossil plant

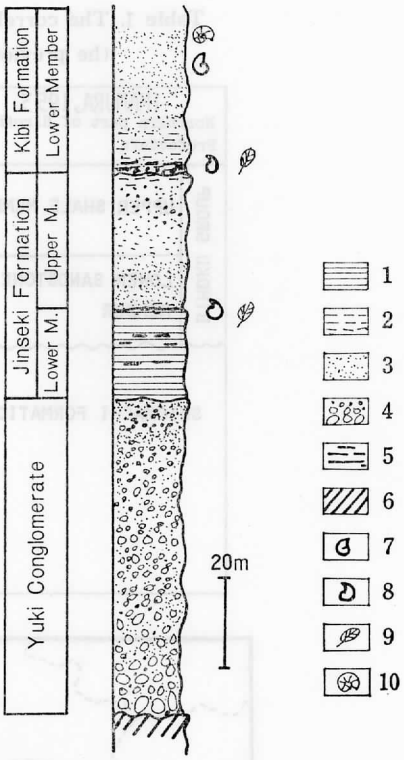


Fig. 3. Columnar section of the Bihoku Group in Kōzuike area, Yuki-cho, Jinseki-gun, Hiroshima Prefecture
1. mudstone 2. siltstone 3. sandstone 4. conglomerate 5. lignitic seam 6. basement rock 7. marine molluscs 8. brackish water molluscs 9. fossil plant 10. *Operculina complanata japonica* HANZAWA

molluscan assemblage consists of *Melanoides* sp., *Terebralia* sp., "*Ostrea*" sp., *Batissa bihokuensis* n. sp., and *Geloina* cf. *stachi* OYAMA, and it is accompanied with the fossil plant, *Comptonia naumanni* (NATHORST).

Locality 2

Kōzuike, Yuki-cho, Jinseki-gun, Hiroshima Prefecture. "Yuki" quadrangle (1976) 1:25,000. Along the southeast-flowing brooklet about 2 kilometers southeast of Yuki.

In this district, the basement rocks which are composed of the Cretaceous Inai Formation and the upper Paleozoic Yoshii Group are covered with the Bihoku Group. The columnar section of the Bihoku Group is summarized in Fig. 3. The brackish water molluscs rich in *Batissa bihokuensis* n. sp. occur in the uppermost part of the Lower Member of the Jinseki Formation. The sediment emtombing *Batissa* is ill-sorted siltstone. Other fossils were *Melanoides* sp., *Novaculina* sp., and fossil plants including *Comptonia naumanni* (NATHORST).

The Lower Sandstone Member of the Kibi Formation has at least two richly fossiliferous beds. The bed of the lower part of the Lower Sandstone Member is characterized by the *Batillaria* assemblage, which contains *Batillaria tateiwai* MAKIYAMA, *B. yamanarii* MAKIYAMA, *Reticunassa simizui* (OTUKA), *Siratoria siratoriensis* (OTUKA), and others. The bed of the upper part of the Lower Sandstone Member is marked with the *"Vasticardium"-Phacosoma* assemblage.

Elements of the *Batissa* assemblage

The brackish water molluscan assemblage from locality 1 is predominated by the articulated shells of *Batissa bihokuensis* n. sp., and *Melanoides* sp. is the second most common species. This brackish water molluscan assemblage of the predominance of *Batissa bihokuensis* n. sp. is named the *Batissa* assemblage. In addition to the *Batissa* assemblage from locality 1, the author also refers the molluscan assemblage from the uppermost part of the Lower Member of the Jinseki Formation at locality 2 to the *Batissa* assemblage. An interpretation concerning the paleoecologic condition of each constituent species of the *Batissa* assemblage is considered on the basis of its allied modern species.

According to ALLAN (1950), *Batissa triquetra* is found in the Daintree River, Queesland in the North Australia, and it also lives in mangrove areas in the Low Isles. *Batissa violacea* (LAMARCK) lives in sand and mud bottoms from fresh water to slightly brackish water of estuaries that are widely distributed in islands of the Indo-Pacific Archipelago (JUTTING, 1953). The species invades the fresh water area about 14 kilomters inland, the Fage River in Missol Island, New Guinea (JUTTING, 1958).

Geloina in Australia occurs within the range of tidal influence in downstreams (ALLAN, 1950). According to BRANDT (1974), *Geloina coaxans* (GMELIN) lives in estuaries, larger rivers, drainage trenches of mudflats and in nipa palm forest which "occurs in landward and upstream areas (MACNAE, 1968)". He also mentions that *Geloina bengalensis* (LAMARCK) is quite common in mudflats of estuaries in Thailand.

Living *Terebralia palustris* (LINNE) is widely distributed in coastal areas of the Indo-West Pacific oceans from East Africa, India to North Australia, Malay Archipelago, and Philippines (JUTTING, 1956; BRANDT, 1974), where it lives in swampy mudflats of mangrove bushes (ALLAN, 1950; JUTTING, 1956), and in mudflats of estuaries (ALLAN, 1950). *Terebralia sulcata* (BRON) as well as *T. palustris* (LINNE) has a wide specific distribution. *T. sulcata* (BRON) is a mudflat-dwelling species of mangroves and estuaries (ALLAN, 1950; JUTTING, 1956), and often attaches to branches or roots of mangroves, namely *Rizophora* and *Sinneratia* (JUTTING, 1956). *Rizophora mucronata* develops along by rivers, where are situations with a salinity around 20 ‰ (MACNAE, 1968).

Extant *Melanoides* occurs in a wide range of the fresh water condition from

lower reaches of rivers to 10-20 kilometers inland (JUTTING, 1958), ditches with soft mud bottoms (DAVIS and YAMAGUCHI, 1969), and in the situations of estuary (GOODRICH, 1936). A well-known recent species, *Melanoides turberculata* (MÜLLER) is very widely distributed over Africa, south of the Mediterranean, and Indo-West Pacific regions. The species was found at the stations of 24 ‰ salinity (JACOB, 1957).

Novaculina siamensis MORLET has been reported to live in the Pasak River near Saraburi, Thailand (BRANDT, 1974).

Modern *Telescopium telescopium* (LINNE) inhabits mudflats in coasts and in mangrove regions (JUTTING, 1956; BRANDT, 1974).

From the above-mentioned fact, the *Batissa* assemblage seems to have lived mainly in water ranging from oligohaline (salinity range of 0.5-5‰) to mesohaline (5-18‰). It appears to represent a mudflat molluscan community in the interior part of estuaries. The molluscan assemblages paleoecologically similar to the *Batissa* assemblage may be the *Geloina* assemblage (ITOIGAWA and NISHIKAWA, 1976; SHIBATA, 1978) and the *Geloina-Telescopium* assemblage (OYAMA, 1950; IWASAKI, 1970). The *Geloina* assemlage and the *Geloina-Telescopium* assemblage, however, seem to adapt to a salinity from mesohaline to polyhaline (18-30‰). The paleoecology of the principal components of these molluscan assemblages is summarized in Fig. 4.

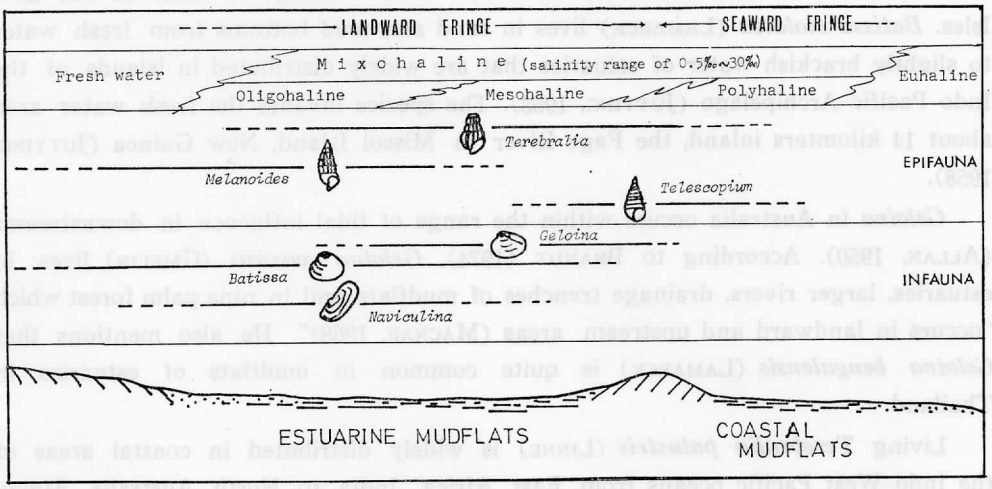


Fig. 4. Suggested habitats of the six species in the *Batissa* assemblage, the *Geloina* assemblage, and the *Geloina-Telescopium* assemblage

The Arcid-Potamid fauna, the *Batillaria* assemblage, the *Crassostrea-Batillaria* assemblage, the hataiarcan fauna associated with vicaryan species (NODA, 1978) that are selected out of the Japanese Early Miocene brackish water molluscan assemblages and faunae seem to have been lived in coastal mudflats of the inner embaymental environment from polyhaline to euhaline (30-40‰). The brackish water molluscan assemblage from the Japanese Early Miocene deposits are divided

into two groups, one is the group of the *Batissa* assemblage, the *Geloina* assemblage, and the *Geloina-Telescopium* assemblage, and the other is the *Batillaria* assemblage, the *Crassostrea-Batillaria* assemblage, and others. The former represents past assemblages of mudflats in the landward fringe, and the latter represents those of mudflats in the seaward fringe. The relationship between the landward molluscan assemblages and the seaward molluscan assemblages is illustrated in Fig. 5.

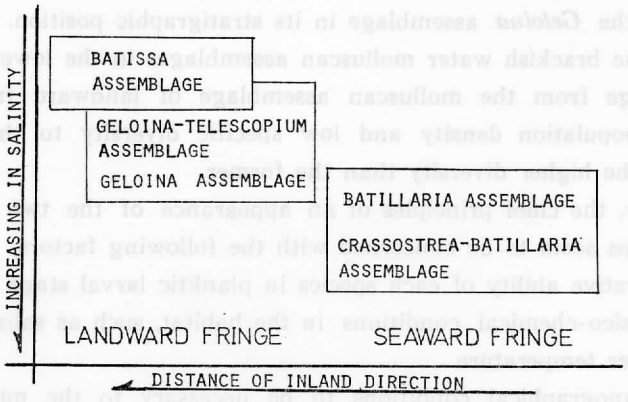


Fig. 5. Diagram showing interrelation of the brackish water molluscan assemblages

Discussion

The brackish water molluscan assemblages of the Bihoku Group are considered to belong to the same paleobiogeographic province with the Early Miocene brackish water molluscan faunae that have been reported from the localities along the Japan Sea borderland. The brackish water molluscan assemblages from the Early Miocene series comprise the subtropical to tropical elements and the strata which yield abundantly these assemblages concentrate in late Early Miocene (15.5—16- m. y. B. P.) in age (ITOIGAWA, 1978). In the Japanese Early Miocene molluscan assemblages, the assemblages of the landward and seaward fringes which have abvanced in the proceding section have respective north limits of their paleobiogeographic distribution. The *Batissa* assemblage has the north limit (ca. lat. 35° N) in Hiroshima Prefecture (present paper). The *Geloina-Telescopium* assemblage has the north limit (ca. lat. 36°30′N) in Toyama Prefecture (OYAMA, 1950), and moreover the *Geloina*-bearing molluscan assemblage has been reported from the Nishitagawa coal-field (ca. lat. 38°30′N) by NISHIDA and CHIHARA in 1966. The *Geloina* assemlage and the *Geloina-Telescopium* assemblage have a lot of occurrences in Southwest Japan, but the number of their localities decrease as the geographic latitude becomes higher. On the other hand, the *Vicarya*-bearing molluscan assemblage that is equal to the *Batillaria* assemblage of the Bihoku Group has been known to the Okushiri Island (ca. lat. 42°N) in Southwest Hokkaido (UOZUMI and FUJIE, 1966). It seems that

the biogeographic spread of the *Vicarya*-bearing molluscan assemblage has reached the most north region in the Early Miocene brackish water molluscan assemblages. From the above-mentioned fact, the geographic graduation of their north limits in Japanese Islands suggests that the subtropical to tropical elements have been moved by the Proto-Tsushima oceanic current (KOBAYASHI and MASATANI, 1955) from the southern regions.

In the Bihoku Group, the *Batillaria* assemblage is higher than the *Batissa* assemblage or the *Geloina* assemblage in its stratigraphic position. Thus the faunal succession of the brackish water molluscan assemblages in the lower Bihoku Group generally change from the molluscan assemblage of landward fringe associated with the high population density and low specific diversity to those of seaward fringe having the higher diversity than the former.

Accordingly, the chief principles of an appearance of the two brackish water molluscan groups seem to be concerned with the following factors,

(1) the migrative ability of each species in planktic larval stage
(2) the physico-chemical conditions in the habitat, such as salinity, substratum, and water temperature
(3) the oceanographical conditions to be necessary to the migration of the subtropical to tropical elements
(4) the prosperity and decay of paleo-oceanic current.

Systematic paleontology

All specimens with ESN numbers are deposited in the molluscan collection of the Department of Earth Sciences, University of Nagoya.

Family Thiaridae
Genus *Melanoides* OLIVIER, 1804
Type species : *Melanoides fusciolata* OLIVIER
Geologic range : Paleoc.-Rec.
Recent distribution : Indo-Pacific region (south of Amami-Oshima), Africa, and Europe

Melanoides sp. indet.
(Pl.5, Figs. 3-5)

Description : Shell small to moderate, 10-20 millimeters long, turriform; whorls about seven, young whorls lost; increasing slowly in size. Apical angle is about 20 degrees. Spire somewhat high, conical, occupying about two-thirds of whorls, separated by suture. Sculpture consists of distinct longitudinal ribs and spiral cords; rib slightly curved, numbering about 18 on the body whorl, with subequal interspaces; spiral cords regular, narrower than their interspaces, about five on the body whorl. On the base of body whorl with three spiral bands.
Remarks : *Melanoides* sp. from locality 1 and 2 is similar to fossil *Melanoides darmavangiensis* MARTIN (MARTIN, 1905, p. 245, pl. 37, figs. 589-590) from Java.

The preservation of the present specimens is not sufficient to permit description of species and to distinguish from the former species.

Measurements(in mm):

Specimen〔ESN-40001〕, height=ca. 15.0, width=ca. 6.0

Specimen〔ESN-40002〕, height=9.0, width=3.0

Specimen〔ESN-40003〕, height=11.0, width=4.3

Formation and Locality: Lower Member of the Jinseki Formation. Locality 1. Lower Member (uppermost) of the Jinseki Formation. Locality 2.

Family Potamididae

Genus *Terebralia* SWAINSON, 1840

Type species: *Terebralia palustris* (LINNE)

Geologic range: Upper Cret.-Rec.

Recent distribution: Indo-Pacific region

Terebralia sp. indet.

(Pl.5, Fig. 6)

Description: Shell of medium size, high-conical in outline, thick. Whorls seven, but young whorls eroded, increasing in size slowly and regularly, with even convex side and periphery. Suture is distinct. Shell sculpture consists of three to four spiral striae on the lower part of whorls, and irregular thirteen axial ridges with a varix on the body whorl.

Remarks: Two deformed specimens were obtained only from locality 1. These specimens are closely related to *Terebralia sulcata* (BRON) living in Madagascar to Indo-West Pacific (JUTTING, 1956, pp. 442-444, fig. 110) and to the fossil specimen described as *Potamides (Terebralia) palustris* LINNE var. from Java (MARTIN, 1899, pp. 210-211, pl. 32, fig. 478). *Terebralia* sp. from locality 1, however, is more slender than modern *Terebralia sulcata* (BRON), and is smaller than *Potamides (Terebralia) paustris* LINNE var. of Martin's specimen. In the Japanese Tertiary deposits, *Terebralia makinoi* OYAMA (MS) has been reported from the Miocene Yatsuo Group by OYAMA (1950).

Measurements(in mm):

Specimen〔ESN-40004〕, height=ca. 32.0, width=17.0

Formation and Locality: Lower Member of the Jinseki Formation. Locality 1.

Family Ostreidae

"*Ostrea*" sp. indet.

Remarks: Ostreid shells occur in low density from the Jinseki Formation at locality 1, and owing to their fragmentary specimens the author cannot determine its identity satisfactorily.

Formation and Locality: Lower Member of the Jinseki Formation. Locality 1.

Family Pharellidae (Syn. Novaculinidae)
Genus *Novaculina* BENSON, 1830
Type species: *Novaculina gangetica* BENSON
Geologic range: Mioc. (present paper)-Rec.
Recent distribution: Southeast and South Asia (e.g., India and Thailand)

Novaculina sp. indet.

(Pl.5, Figs. 7a, b)

Description: Shell is elongated, rounded at the anterior end and truncated at the posterior end. Shell sculpture only fine concentric growth lines. Umbo is low, and lies at about anterior one-third of the length. Hinge plate bears three cardinal teeth on the left valve and two cardinal teeth on the right valve.
Measurements (in mm):

Specimen〔ESN-40005〕, length=56.0, height=18.0

Formation and Locality: Lower Member (uppermost part) of the Jinseki Formation. Locality 2.

Family Corbiculidae
Genus *Geloina* GRAY, 1842
Type species: *Cyrena zeylanica* LAMARCK
Geologic range: Eoc. (Oligoc.)-Rec.
Recent distribution: Indo-West Pacific region (south of Amami-Oshima)

Geloina cf. *stachi* OYAMA

1950 *Geloina stachi*, OYAMA; Rep. Geol. Surv. Japan, No. 132, pp. 12, 13, pl. 3, figs. 1, 2a, b.
1953 *Geloina stachi*, TSUDA; Jour. Fac. Sci., Niigata Univ., Ser. Ⅱ, Vol. 1, No. 2, pp. 8, 28.
1955 *Geloina stachi*, TUDA; Jour. Geol. Soc. Japan, Vol. 61, No. 722, pp. 537, 538.
1956 *Geloina stachi*,, TSUDA; Jour. Paleont., Vol. 30, No. 4, p. 977.
1960 *Geloina stachi*, TSUDA; Jour. Fac. Sci., Niigata Univ. Ser. Ⅱ, Vol. 3, No. 4, pp. 179, 193.
1963 *Geloina stachi*, OYAMA and ISHIYAMA; Chishitsu-news (Geological News), No. 104, p. 8, fig. 6.
1965 *Geloina stachi*, TSUDA; Fossils, No. 10, p. 1, table 1.
1976 *Geloina stachi*, ITOIGAWA and NISHIKAWA; Bull. Mizunami Fossil Mus., No. 3, pp. 132, 136, 146, pl.36, figs. 1a, b.
1978 *Geloina* cf. *stachi*, OKAMOTO *et al.*; Bull. Mizunami Fossil Mus., No. 5, p. 4, pl.1, figs. 2, 3.
1978 *Geloina stachi*, ITOIGAWA; Bull. Mizunami Fossil Mus., No. 5, pl. 2, figs. 8a, b.

Remarks: The specimens collected from locality 1 are close valves and fragmentary isolated valves. These specimens have a large and elongate shell, and are similar to *Geloina stachi* OYAMA more than *Geloina yamanei* OYAMA.
Measurements (in mm): Owing to poor preservation the altitude of shells is not determinable.
Formation and Locality: Lower Member of the Jinseki Formation. Locality 1.

Genus *Batissa* GRAY, 1852

Type species: *Cyrena tenebrosa* HINDS

Geologic range: Upper Jur. (Eoc.)-Rec.

Recent distribution: Indo-West Pacific region ; Java, Borneo, Philippine, various Pacific Islands, India, and New Guinea.

Batissa bihokuensis n. sp.

(Pl.5, Figs. 8a,b, 9-11, Pl.6, Figs. 1a,b, 2a,b, 3-8)

Description: Shell large, roundly pentagonal in outline, moderately convex, thick-tested; a little longer than high, subequilateral. The anterior margin rounded, the posterior margin rounded or truncated. The postero-dorsal margin nearly straight, sloping backward; the antero-dorsal margin steeply sloping forward, descending to the anterior margin; the ventral margin long, arched. Umbo prominent and well rounded, situated at the point about the middle of the length of shell, somewhat elevated above the hinge margin, but commonly eroded. Ligament external, strong, a little long and elevated above the postero-dorsal margin ; nymph platy. Surface ornamented with fine concentric lines of growth, irregular, and the anterior part in association with concentric lines of growth which are elevated distinctly. The hinge plate is thick, provided with three divergent cardinal teeth and crenulated lateral teeth on both sides of the former, and dentition as formulated below;

$$\frac{\text{AIII, A1, 3a, 1, 3b, PI, PIII}}{\text{AII, 2a, 2b, 4b, PII}}$$

On the left valve the anterior cardinal tooth(2a) slightly oblique forward, bifid; the middle one(2b) slightly oblique backward, also bifurcated, and as large as the former; the posterior one(4b) narrow, much obliquely sloping backward. On the right valve the anterior cardinal tooth(3a) much obliquely sloping forward; middle one(1) nearly vertical, bifid, largest in all; the posterior one(3b) much oblique backward, also bifurcated, a little smaller than the former. The lateral on the both sides, finely crenulated; the anterior one(AII) being about two-thirds as long as the posterior, and more solid than the former. The inner margin of the shell is smooth, and pallial line is simple. The anterior muscle scar is subpentagonal in outline, distinct impressed, and the posterior one is subovate in outline.

Remarks: Twelve specimens were obtained from the type locality, but almost all of them are deformed. Several specimens collected from the locality 2 are internal and external moulds of an isolated valve. This species is closely allied to *Batissa mirabilis* (NAGAO) from the Yoshinotani Formation of the Oligocene Oti Group (NAGAO, 1928b, pp. 52(42)-53(43), pl. 7, figs. 27, 27a, b; SUZUKI, 1941, pp. 50-54, pl. 2, figs. 1-3), but the latter is distinguished from the former by the postero-ventral portion having three broad, low, and rounded radial plications. It is also similer to *Batissa nagaoi* (SUZUKI) from the Hutagojima Formation of the Eocene Takashima Group (NAGAO, 1928a, p. 108 (12), pl. 21 (4), figs. 21, 21a, b), with regard to the surface sculpture of the anterior part and shell outline, while the latter is distinguished from the former by having conspicuously inflated shell and weak cardinal teeth. This new

species is also related to *Batissa violacea* (LAMARCK) living in various islands of the Indo-Australian Archipelago (JUTTING, 1953, pp. 54-57, fig. 13), but the former is distinguished from the latter by its hinge nature, shell size in mature, and weak ridge from beak to postero-ventral corner.

The shell structure of this species is illustrated in the Plate 6 with four pictures.

Measurements (in mm.):

Holotype〔ESN-40006〕, left valve; length=49.8, height=40.5, width=9.8
Paratype 1〔ESN-40007〕, right valve; length=49.9, height=44.8, width=9.7
Paratype 2〔ESN-40008〕, left valve; length=44.9, height= 39.0, width=9.2
Paratype 3〔ESN-40009〕, left valve; length=ca. 39.0, height=ca. 37.0, width=8.8
Paratype 4〔ESN-40010〕, closed valve; height=41.8, width=31.4
Paratype 5〔ESN-40011〕, closed valve; length=48.4, height=ca. 37.0, width=12.0

Formation and Locality: Lower Member of the Jinseki Formation (Type locality : long. 133°17′30″E, lat. 34°53′30″N). Lower Member (uppermost part) of the Jinseki Formation. Locality 2.

References

ALLAN, J. (1950), Australian shells. 487 p. *Georgian house, Melbourne.*

BRANDT, R. A. M. (1974), The non-marine aquatic mollusca of Thailand. *Archiv für Mollusk.*, **105**(1-4), 1—423.

CHINZEI, K. and IWASAKI, Y. (1967), Paleoecology of shallow sea molluscan fauna in the Neogene deposits of Northeast Honshu, Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 67, 93—113.

DAVIS, G. M. and YAMAGUCHI, S. (1969), The freshwater gastropoda of Okinawa. *Jap. Jour. Malac. (Venus)*, **28**(3), 137—152.

GOODRICH, C. (1936), Notes on Philippine freshwater mollusks. *Nautilus*, **49**(3), 73—76.

HASE, A. (1964), Paleozoic era. In UMEGAKI, Y. *et al.* : Geological map of Hiroshima Prefecture 〔scale 1:200,000〕 and its explanatory text (in Japanese). *Hirohima Prefectural Government.*

IMAMURA, S. (1953), In IMAMURA *et al.* : Guide book of geological excursion, Kamine, Funasa, Miyoshi, Mirasaka, Shōbara and Shōkozan (in Japanese). 50 p. *Inst. Geol. Min., Fac. Sci., Hiroshima Univ., Hiroshima.*

ITOIGAWA, J. (1971), Miocene molluscan fauna from the eastern district of Chugoku, Southwest Japan (in Japanese). *Fossils*, no. 22, 29—36.

———(1978), Evidence of subtropical environments in the Miocene of Japan. *Bull. Mizunami Fossil Mus.*, no. 5, 7—21.

ITOIGAWA, J. and NISHIKAWA, I. (1976), A few problems on the Miocene Setouchi Series in the northern part of Okayama-Hiroshima Prefectures, Southwest Japan (in Japanese with English abstract). *Bull. Mizunami Fossil Mus.*, no. 3, 127—149.

IWASAKI, Y. (1970), A Miocene molluscan fauna in the Philippines. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 77, 205—228.

JACOB, J. (1957), Cytological studies of Melaniidae (Mollusca) with special reference to parthenogenesis and polyploidy. I. Oögenesis of the parthenogenetic species of Melanoides (Prosobranchia-Gastropoda). *Trans. Roy. Soc. Edin.*, **63**, 341—352.

JUTTING, W. S. S. VAN BENTHEM (1953), Systematic studies on the non-marine mollusca of the Indo-Australia Archipelago. *Treubia*, **22**, 19—73.

———(1956), *ditto. ibid.*, **23**, 259—477.

———(1958), Non-marine mollusca of the island of Misool. *Nova Guinea, new ser.*, **9**, 293—338.

KOBAYASHI, T. and MASATANI, K. (1955), On the occurrence of *Aturia* in provinces of Etchu and Iwami and their bearing on the palaeoflumenology in the Miocene of Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 17, 1—4.

MACNAE, W. (1968), A general accunt of the fauna and flora of mangrove swamps and forests in the Indo-West Pacific region. *Adv. Mar. Biol.*, **6**, 73—270.

MARTIN, K. (1899), Die Fossilien von Java. *Samm. Geol. Reichs-Mus. Leiden*, **1**(6-8), 133—221.

———(1905), *ditto. ibid.*, **1**(39-41), 221—281.

NAGAO, T. (1928a), Palaeogene fossils of the Island of Kyushu, Japan, part 1. *Sci. Rep. Tohoku Imp. Univ.*, 〔2〕, **9**(3),97(1)—128(32)

———(1928b), *ditto*, part 2. *ibid.*, **12**(1), 11(1)—140(130).

NISHIDA, S. and CHIHARA, K. (1966), Neogene Tertiary stratigraphy in the Nishitagawa coal-field, Yamagata Prefecture, North Japan (in Japanese with English abstract). *Contr. Dep. Geol. and Min., Niigata Univ.*, **1**, 31—57.

NODA, H. (1978), Neogene anadaran distribution in Japan and Southeast Asia. *Ann. Rep., Inst. Geosci., Univ. Tsukuba*, no. 4, 33—37.

OKAMOTO, K. and TERACHI, M. (1974), Miocene molluscs from the Bihoku Group at Miya-uchi-chō, Shōbara City, Southwest Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 95, 341—352.

———, IMADA, T., EMA, M. and TAMAYAMA, N. (1978), Discovery of *Geloina* from the Miocene Bihoku Group in Kimita-mura, Futami-gun, Hiroshima Prefecture (in Japanese with English abstract). *Bull. Mizunami Fossil Mus.*, no. 5, 1—5.

OYAMA, K. (1950), Studies of fossil molluscan biocoenosis, No. 1. Biocoenological studies on the mangrove swamps, with descriptions of new species from the Yatuo Group. *Rep. Geol. Surv. Japan*, no. 132, 1—16.

SHIBATA, H. (1978), Molluscan paleoecology of the Miocene First Setouchi series in the eastern part of Setouchi, geologic province, Japan. *Bull. Mizunami Fossil Mus.* no. 5, 23—100.

SUZUKI, K. (1941), The palaeogene corbiculids of Northwestern Kyushu. *Jour. Fac. Sci., Imp. Univ. Tokyo*, 〔Ⅱ〕, **6**, 39—62.

TSUDA, K. (1965), Neogene molluscan assemblages in the inner zone of Northeast Japan —with special reference to the middle Miocene assemblages (in Japanese). *Fossils*, no. 10, 20—23.

UOZUMI, S. and FUJIE, T. (1966), Description of the Okushiri fauna associated with *Vicarya*, from Okushiri Island, Southwest Hokkaido. *Jour. Fac. Sci., Hokkaido Univ.*, 〔4〕, **13**, 139—163.

Hiba (比婆)
Jinseki (神石)
Kibi (吉備)
Kōzuike (高水池)
Nogumi (野組)
Tojō (東城)
Yuki (油木)

Plate 5

Fig. 1. *Comptonia naumanni* (NATHORST)
Lower Member of the Jinseki Formation. Locality 1. ×1

Fig. 2. *Comptonia naumanni* (NATHORST)
Lower Member of the Jinseki Formation. Locality 2. ×1

Fig. 3. *Melanoides* sp.
external mould, specimen [ESN−40002]
Lower Member of the Jinseki Formation. Locality 2. ×2

Fig. 4. *Melanoides* sp.
external mould, specimen [ESN−40001]
Lower Member of the Jinseki Formatiom. Locality 2. ×2

Fig. 5. *Melanoides* sp.
specimen [ESN−40003]
Lower Member of the Jinseki Formation. Loc. 1. ×2

Fig. 6. *Terebralia* sp.
specimen [ESN−40004]
Lower Member of the Jinseki Formation. Loc. 1. ×1

Figs. 7a, b. *Novaculina* sp.
a, external mould of left valve of articulated shell, specimen [ESN−40005] ×1
b, hinge mould of the same specimen showing in Fig. 7a. ×2
Lower Member of the Jinseki Formation. Locality 2.

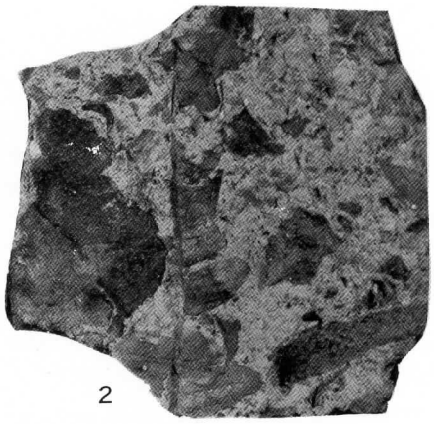
Figs. 8a, b. *Batissa bihokuensis* n. sp.
a, external view of left valve, paratype 3 [ESN−40009]
b, internal view of left valve, the same specimen.
Lower Member of the Jinseki Formation. Loc. 1. ×1

Fig. 9. *Batissa bihokuensis* n. sp.
hinge mould of right valve, specimen [ESN−40012]
Lower Member of the Jinseki Formation. Loc. 2. ×1

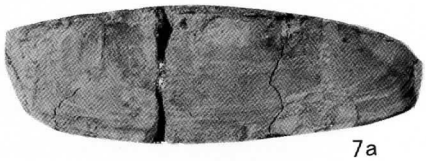
Fig. 10. *Batissa bihokuensis* n. sp.
umbonal view of articulated shell, paratype 4 [ESN−40010]
Lower Member of the Jinseki Formation. Loc. 1. ×1

Fig. 11. *Batissa bihokuensis* n. sp.
internal mould of right valve, specimen [ESN−40013]
Lower Member of the Jinseki Formation. Loc. 2. ×1


1


2


3


7a


4

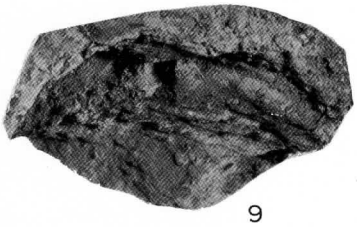

5


6


7b


8a


8b


9


10

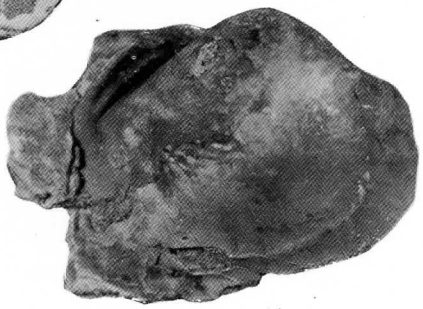

11

Plate 6

Figs. 1a, b. *Batissa bihokuensis* n. sp.
external views of articulated shell, paratype 5 [ESN−40011]
Lower Member of the Jinseki Formation. Locality 1. ×1

Figs. 2a, b. *Batissa bihokuensis* n. sp.
a, external view of left valve, holotype [ESN−40006]
b, internal view of left valve, the same specimen.
Lower Member of the Jinseki Formation. Locality 1. ×1

Fig. 3. *Batissa bihokuensis* n. sp.
external view of right valve, paratype 1 [ESN−40007]
Lower Member of the Jinseki Formation. Locality 1. ×1

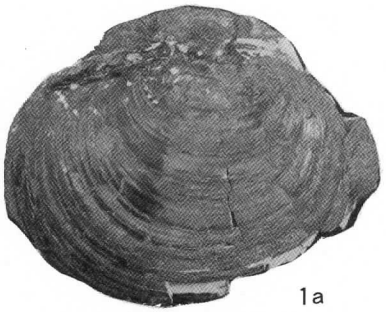
Fig. 4. *Batissa bihokuensis* n. sp.
external view of left valve, paratype 2 [ESN−40008]
Lower Member of the Jinseki Formation. Locality 1. ×1

Fig. 5. Microstructure of *Batissa bihokuensis* n. sp.
outer and inner crystalline layers, radial thin section near the center of left valve.
Lower Member of the Jinseki Formation. Locality 1. × about 22

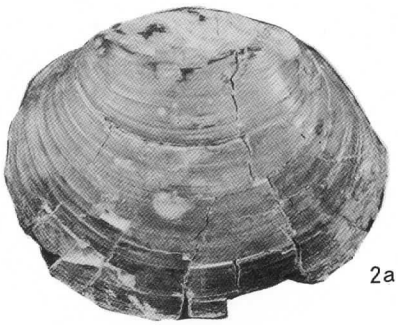
Fig. 6. Microstructure of *Batissa bihokuensis* n. sp.
outer and inner crystalline layers, tangential thin section near the ceter of left valve.
Lower Member of the Jinseki Formation. Locality 1. × about 32

Fig. 7. Microstructure of *Batissa bihokuensis* n. sp.
tangential thin section near the anterior margin of left valve.
Lower Member of the Jinseki Formation. Locality 1. × about 22

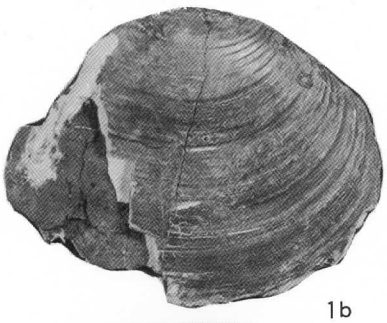
Fig. 8. Microstructure of *Batissa bihokuensis* n. sp.
outer crystalline layer, radial thin section near the ventral margin of left valve.
Lower Member of the Jinseki Formation. Locality 1. × about 34



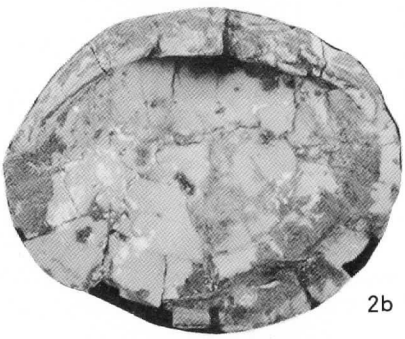
1a



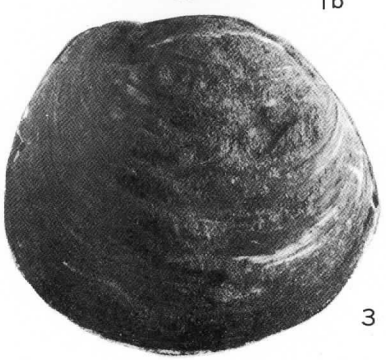
2a



1b



2b

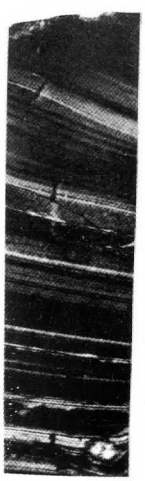


3

4

5

6



7

8