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## NOTE ON THE MARINE MOLLUSCAN FAUNA FROM THE PLEISTOCENE KOGASHIRA FORMATION IN KAGOSHIMA CITY, SOUTH KYUSHU, JAPAN

By

Shozo HAYASAKA\* and Kimihiko ÔKI\*

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### Introduction and Acknowledgments

The Kogashira Formation (ÔKI and HAYASAKA, 1970, p. 77), one of the marine formations intercalated in the thick and complicated pyroclastic sequence originated from the Aira and Ata calderas, has long been known to yield molluscan fossils (OTUKA, 1931). Although the detailed stratigraphic relation in the sequence and the general aspect of the associated fauna had been left uncertain, one of the species occurring most abundantly in the Kogashira Formation has been described as a new species named *Mabellarca hiratai*\*\* by Dr. Tadashige HABA (1953) based upon the specimens collected by Prof. Kunio HIRATA of the Kagoshima University.

In 1970, the writers (*op. cit.*) described the stratigraphy of the northern Kagoshima City area (Table 1) including the distribution of the Kogashira Formation in its northwestern part. Through the writers' study, the stratigraphic relations of the present formation with the other stratigraphic units has been clarified and the molluscan fossils occurring there were discriminated specifically and listed up.

Though the number of species discriminated in the present collection is rather scarce, they seem to be worthy of a paleontological note for the following reasons. The faunal characteristics of the Kogashira Formation may be helpful to understand the ecology of the interesting extinct species *Anadara (Scapharca) hiratai* (HABA) on the one hand, and on the other, to compare it with the other faunas from the different horizons in the sequence concerned.

Here the writers thank Professor Kotori HATAI of the Institute of Geology and Paleontology, Tohoku University, for reviewing the manuscript. Particular appreciation is due to Dr. Nobuhiro HATAE, Professor Emeritus of the Kagoshima University, for his valuable suggestions which stimulated the present work. Thanks are also due to Professor Rikizo Imaizumi of the Tohoku University for his information on the crab fossils.

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\*\* The generic position of this species has been revised by NODA (1966) to *Anadara (Scapharca)*.

Table 1. Generalized stratigraphic sequence in the northern part of Kagoshima City (ÔKI and HAYASAKA, 1970)

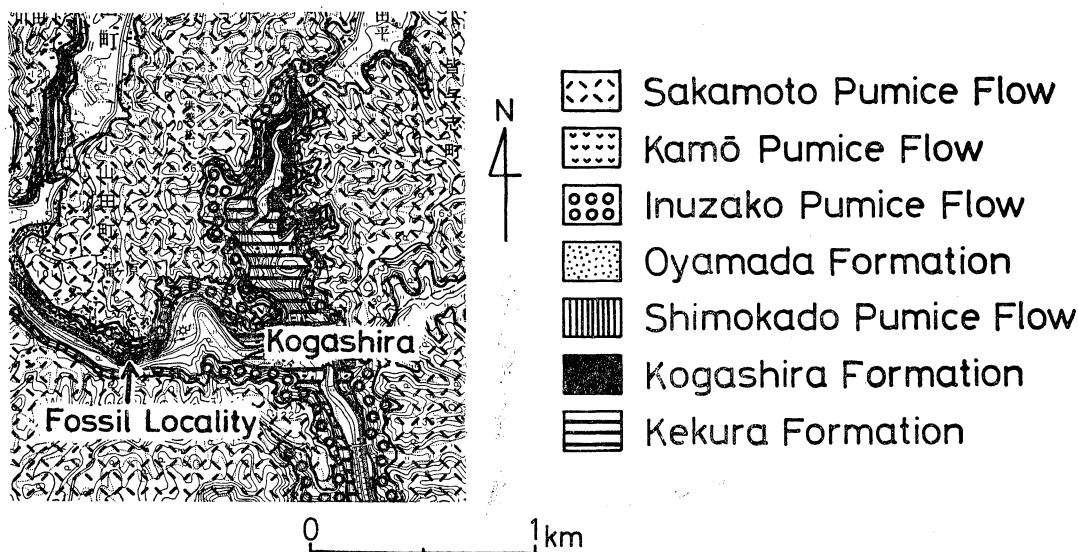
Age	Formation Name	Thickness (m)	Lithology	
Holo- cene	Younger Volcanic Ash and Pumice Bed (新期火山灰および軽石層)	5	yellowish brown volcanic ash bed brown volcanic ash bed thinly laminated volcanic ash and pumice bed pumice fall bed	
	Sakamoto Pumice Flow (坂元軽石流)	100±	grayish white, pumiceous breccia tuff	
Pleistocene	Nagaida Pumice Flow (長井田軽石流)	50±	reddish orange, pumiceous tuff pumice bed (diameter 1cm+)	
	Kamô Pumice Flow (蒲生軽石流)	10	massive black tuff	
	Tatsuo Formation (竜尾層)	25	pumiceous tuff tuffaceous sand (very coarse-very fine grained) and tuffaceous silt	
	Shiroyama Formation (城山層) ×	50±	siltstone unconsolidated coarse grained sand gravel (angular and cobble to boulder sized) tuffaceous sand (coarse-very fine grained) and tuffaceous silt rounded pebble gravel	
	Inuzako Pumice Flow (大迫軽石流)	40	gray-coloured welded tuff	
	Oyamada Formation (小山田層) ×	40	tuffaceous sand (very coarse-very fine grained) and tuffaceous silt	
	Ishide Sand and Gravel Member (石井手砂礫部層)		20±	unconsolidated coarse grained sand
	Shimokado Pumice Flow. (下門軽石流)	10±	dark gray coloured welded tuff	
	Kogashira Formation (河頭層) ×	16+	bluish gray siltstone tuffaceous sand (medium-very fine grained) and tuffaceous silt rounded pebble-granule gravel	
	Terayama Basalt (寺山玄武岩)		dark gray coloured olivine basalt	
	Yoshino Pumice Flow (吉野軽石流)	80±	grayish brown coloured welded tuff	
	Late Pliocene-Early Pleistocene	Iso Tuffaceous Sand Member (礫凝灰質砂部層)	50	grayish white tuffaceous sand reddish orange tuffaceous sand
		Kekura Formation (花倉層) ×	110	pumiceous breccia tuff tuff breccia, pumice bed, breccia tuff tuffaceous sand (fine-very fine grained) and tuffaceous silt
Murêgaoka Andesite (牟礼ヶ岡安山岩)			dark gray coloured two-pyroxene andesite	
Shirahama Basalt (白浜玄武岩)			dark gray coloured olivine basalt	
Hiramatsu Basalt (平松玄武岩)			black coloured compact basalt	
Mifuné Formation (三船層)		20+	tuffaceous sand (coarse-very fine grained) and tuffaceous silt with thin (about 10cm) pumice bed angular pebble gravel pumiceous breccia tuff	
Plio- cene ?		Mifuné Rhyolite ? (三船流紋岩)		rhyolite gray laminated tuff obsidian, spherulite
	Ryûgamizu Andesite (竜ヶ水安山岩)		gray-grayish white coloured two-pyroxene andesite	

(×Marine molluscan fossils)

### Geologic Setting

As stated above, the geology of the northern part of Kagoshima City including the Kogashira Formation was studied by the present writers (ÔKI and HAYASAKA, 1970).

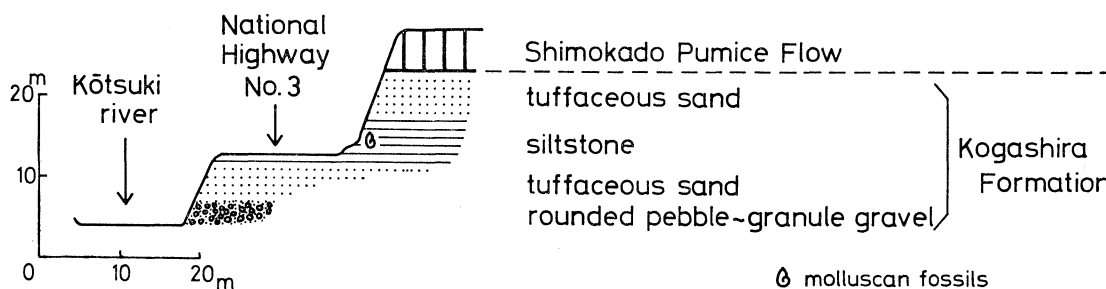
The most remarkable feature of the Kogashira Formation is the extremely limited distribution (Text-fig. 1) in comparison with those of the other 19 stratigraphic units discriminated through the writers' study cited above (Table 1). As shown in Text-fig. 1, the Kogashira Formation crops out in the four limited areas in the northwestern border of the Kagoshima City area. Outside of this area, the Kogashira Formation has been unknown even from the subsurface geologic data (HAYASAKA and ÔKI, 1971). Owing to this unfavourable situation, a few problems on the Kogashira Formation, such as paleogeography, sedimentary environment and so on, have still remained unsolved.



Text-fig. 1. Geological map showing the distribution of the Kogashira formation and the fossil locality.

The fossil locality from where the specimens treated in the present article were collected, the type locality of the Kogashira Formation, is an about 16 meters high river side cliff, cut in its middle part for the national highway No. 3 (Text-fig. 2) and situated at about 1 km west of the Kogashira spa.

The vertical sequence of rock facies observed at the type locality is as shown in Text-fig. 2. The molluscan fossils are richly but rather sporadically contained in the massive siltstone bed. Most of the specimens preserve the original shell material and even their detailed sculptures. Many pelecypod specimens preserve their valves conjoined. The massive siltstone entombing these molluscan fossils may imply a calm shallow water condition during the deposition of the pyroclastic sediments.



Text-fig. 2. Schematic profile of the Kogashira formation and the overlying Shimokado pumice flow at the fossil locality shown in the Text-fig. 1.

**Remarks on the molluscan fossils**

The molluscan fossils collected from the present locality and discriminated by the senior writer are shown in the following list (Table 2).

Table 2. List of molluscan fossils from the Kogashira formation.

Species	Number of Specimens
<i>Barbatia (Savignyarca) obtusoides</i> (NYST)	1
<i>Barbatia (Savignyarca) virescens</i> (REEVE)	1
<i>Anadara (Scapharca) broughtonii</i> (SCHRENCK)	1
<i>Anadara (Scapharca) hiratai</i> (HABE)	50+
<i>Anadara (Tegillarca) sp.</i>	1
<i>Atrina sp.</i>	1
<i>Chlamys (Mimachlamys) nobilis</i> (REEVE)	1
<i>Pecten albicans</i> (SCHRÖTER)	3
<i>Ostrea (Ostrea) denselamellosa</i> LISCHKE	5
<i>Lucina stearnsiana</i> OYAMA	8
<i>Fulvia bullata</i> (LINNÉ)	3
<i>Fulvia mutica</i> (REEVE)	1
<i>Cyclina orientalis</i> (SOWERBY)	3
<i>Paphia euglypta</i> (RHILIPPI)	1
<i>Lutraria sp.</i>	2
<i>Arcopagia (Merisca) subtruncata</i> (HANLEY)	1
<i>Macoma (Psammacoma) awajiensis</i> SOWERBY	1
<i>Macoma (Pseudometis) praerupta</i> (SALISBURY)	1
<i>Moevella sp.</i>	1
<i>Barnea (Umitakea) japonica</i> (YOKOYAMA)	1
<i>Dentalium (Paradentalium) octangulatum hexagonum</i> GOULD	1
<i>Lunella granulata</i> (GMELIN)	2
<i>Turritella (Kurosoioia) fascialis</i> MENKE	37
<i>Batillaria zonalis</i> (BRUGUIÉRE)	2
<i>Theridium kobelti</i> (DUNKER)	1
<i>Proclava pfefferi</i> (DUNKER)	1
<i>Natica vitellus spadicea</i> (GMELIN)	7
<i>Rapana thomasi</i> CROSSE	1
<i>Purpura (Mancinella) clavigera</i> KÜSTER	3
<i>Coralliophila hataii</i> HAYASAKA	2
<i>Siphonalia cassidariaeformis</i> (REEVE)	6
<i>Hemifusus tuba</i> (GMELIN)	1
<i>Tritia (Reticunassa) acutidentata</i> (SMITH)	1
<i>Nassarius (Zeuxis) kiiensis</i> KIRA	3
<i>Nassarius (Niotha) livescens</i> (PHILIPPI)	9
<i>Mitropifex collinsoni</i> (A. ADAMS)	1
<i>Adamnestia sp.</i>	1
<i>Ringicula doliaris</i> GOULD	1

Among the species listed above, *Anadara (Scapharca) hiratai* (HABE) and *Turritella (Kurosoioia) fascialis* MENKE are most abundant in number of specimens. The subordinate species are *Lucina stearnsiana* OYAMA, *Natica vitellus spadicea* (GMELIN), *Siphonalia cassidariaeformis* (REEVE) and *Nassarius (Niotha) livescens* (PHILIPPI); and the other 21 species are each represented by only a single specimen. Four species could not be determined specifically, because of their unfavorable state of preservation, caused by the original ill preservation of them and by the breaking at the time of collection.

Besides these molluscs, echinoid and crab fossils were also collected and the latter has been recognized to be new to science and tentatively named *Macrophthalmus kogashiraensis* n. sp. by Prof. Rikizo IMAIZUMI of the Tohoku University. Further, it has also been known that the formation contains abundant fossil foraminifers, of which paleontological note will be given at another opportunity.

*Barbatia (Savignyarca) obtusoides* (NYST)

A single internal mold of the left valve is in the present collection. Dimensions (in mm) of the specimen are 42 in length and 30 in height. The present species ranges from the Pliocene to the Recent, and is now living in the euneritic fascia (OYAMA, 1952) (between the lowest tide mark and the depth of about 20–30 m) chiefly of embayments on the Pacific and the Japan Sea sides of Honshu, Japan, and southwards to the equatorial region.

*Barbatia (Savignyarca) virescens* (REEVE) [Pl. 1, fig. 1]

A single, rather small right valve is in the collection. The present species resembles the preceding one in general outline, but differs in having more convex and elongate shell with much coarser arrangement of radials on the posterior dorsal surface. The present species lives in the euneritic fascia of the open sea condition on the Pacific and the Japan Sea sides of Honshu, Japan, and southwards to the Philippines.

*Anadara (Scapharca) broughtonii* (SCHRENCK)

An imperfect right valve was identified as the named species from its characteristic features such as the number of radial ribs (41) and rather narrow ligamental area provided with two ligamental grooves. The present species ranges from the Pliocene to the Recent, and lives in the euneritic and mesoneritic (between 20–30 and 50–60 m) in the Japanese waters (Southern Hokkaido, Honshu, Shikoku and Kyushu), Korea and North China.

*Anadara (Scapharca) hiratai* HABE [Pl. 1, figs. 2a-d]

Numerous, well-preserved specimens mostly conjoined are in the collection. The present species was originally described by HABE (1953) based upon the specimens collected from the present locality. The generic position of the present species originally referred to the genus *Mabellarca* has been revised by NODA (1966) to *Anadara (Scapharca)*. The morphological features of the present species are so peculiar that we can not point out any species allied to the present one among the species hitherto recorded from Japan. There have been no records of the present species, either fossil or living, other than the one from the present formation. This peculiar species is most abundant in occurrence and characterizes the present fauna. The common and

sporadic occurrence of the conjoined valves of the present species in the massive mudstone of the formation indicates the autochthonous origin of them.

*Anadara (Tegillarca) sp.*

Only a single, imperfect external mold of the right valve is referable to *Anadara (Tegillarca)* based on its narrowly elevated, nodal structure of the radial ribs which are 19 in number. Owing to its unfavorable state of preservation, specific identification is reserved.

*Atrina sp.*

Only a single, imperfect specimen is in the collection.

*Chlamys (Mimachlamys) nobilis (REEVE)*

An intact, average sized specimen retaining the minute sculpture on its surface was examined. The present species ranges from the Late Pliocene to the Recent and lives in the euneritic and mesoneritic fasciae of the Pacific (23°–35°N) and the Japan Sea (37°N).

*Pecten albicans (SCHRÖTER)*

This species is represented by an intact, juvenile specimen, an imperfect left valve and an internal mold of the left valve. The present species ranges from the Early Pliocene to the Recent, and is now living in areas with sandy bottom in the euneritic fascia in the Pacific (30°–42°N) and the Japan Sea (42°N).

*Ostrea (Ostrea) denselamellosa LISCHKE*

Fragments of a few large right valves and two small left valves are in the collection. The present species ranges from the Pliocene to the Recent, and lives on sandy, gravelly or rocky bottoms between one to ten meters below the low tide mark (euneritic fascia) in the waters of the Pacific coast of Japan (southern Hokkaido to Kyushu), Ryukyu Islands, Formosa, Korea and China.

*Lucina stearnsiana OYAMA [Pl. 1, fig. 3]*

Seven, rather small intact specimens and an intact, internal mold specimen are in the collection. This species ranges from the Pleistocene to the Recent and is known to live in Honshu, Japan and southwards to the Ryukyu Islands. The present species inhabits the muddy bottom of the intertidal (between the highest tide and the lowest tide levels) and euneritic fasciae.

*Fulvia bullata (LINNÉ)*

Two conjoined, but water-worn specimens and an external mold specimen were examined. The present species is now living in the euneritic fascia on the Pacific coast



of central Honshu, Japan and southwards to the equatorial region.

*Fulvia mutica* (REEVE)

An imperfect external mold of the right valve is in the collection. The present species ranges from the Pleistocene to the Recent, and is known to live in the euneritic fascia of northern (excluding Hokkaido), central and western Japan and the Philippine Islands.

*Cyclina (Cyclina) orientalis* (SOWERBY) [Pl. 1, fig. 4]

A well-preserved right valve, an internal mold of the left valve and an external mold of the left valve are in the collection. This species ranges from the Miocene to Recent and its geographic distribution is from Mutsu Bay, Aomori Prefecture, southwards along the Pacific coast to Kagoshima and Nagasaki Prefectures in Kyushu, and along the Japan Sea northwards to Mikata, Fukui Prefecture and also on the west coast of Korea (KAMADA, 1952). This species lives in the muddy bottoms of the intertidal and euneritic fasciae.

*Paphia euglypta* (PHILIPPI)

Only a single internal mold specimen is in the present collection. The characteristic features of the surface ornamentation and general outline are identical with those of the named species. The present species lives in the water below the lower tide line (euneritic fascia) both in the Pacific (31–39°N) and the Japan Sea (40°N).

*Lutraria* sp.

An imperfect right valve and an imperfect internal mold of the left valve are referable to *Lutraria*.

*Arcopagia (Merisca) subtruncata* (HANLEY)

An internal mold specimen of the right valve is in the collection. The present species ranges from the Pleistocene to the Recent and is known to live on the Pacific side of northern (excluding Hokkaido), central and western Japan, Formosa and the Philippines. This species inhabits a fine-grained sandy bottom and bathymetrically ranges from 10 to 300 meters (euneritic to bathyal fascia).

*Macoma (Psammacoma) awajiensis* SOWERBY [Pl. 1, fig. 5]

A single left valve is at hand. This species lives below the lowest tide line (euneritic fascia) both in the Pacific (33°–35°N) and the Japan Sea (37°N).

*Macoma (Pseudometis) praerupta* (SALISBURY) [Pl. 1, fig. 6]

A rather well-preserved right valve is in the collection. The present species ranges

from the Pleistocene to the Recent, and lives on the muddy bottom of the shallow inland sea or embayment ranging from 10 to 50 meters in depth. The geographic distribution of this species is from Kii Peninsula in western Japan to the Philippine Islands.

*Moerella* sp.

Only a single, imperfect left valve is in the collection.

*Barnea (Umitakea) japonica* (YOKOYAMA) [Pl. 1, fig. 7]

An intact specimen with a little fractured periphery is in the collection. The present species, ranging from the Pliocene to the Recent, is known to live along the Kii Peninsula on the Pacific and Wakasa Bay on the Japan Sea side and southwards to Kyushu, Japan.

*Dentalium (Paradentalium) octangulatum hexagonum* GOULD

An imperfect specimen is in the collection. The present species ranges from the Pliocene to the Recent and is known to live below low tide line in Honshu, Shikoku and Kyushu, Japan to China, the Philippine Islands and Singapore.

*Lunella granulata* (GMELIN) [Pl. 1, figs. 8a, b]

Two specimens of which apertures are slightly fractured were examined. The present species resembles the common Japanese species *L. coronata coreensis* (RÉCLUZ) in general outline, but differs from the latter in having the spirals with stronger tubercles and deep umbilicus. The geographic distribution of the present species is Amami-Oshima, Kagoshima Prefecture and southwards. The present species lives on gravelly and rocky bottoms in the intertidal fascia.

*Turritella (Kurosioia) fascialis* MENKE [Pl. 1, fig. 9]

Thirty seven, well-preserved specimens of various sizes were examined. The specimens are rather small in size, and the dimensions (in mm) of the largest specimen are about 13 in height and about 3 in maximum diameter. The present species is now living in areas with sandy to sandy mud bottom bathymetrically ranging from 50 to 150 meters (subneritic to bathyneritic fasciae) on the Pacific and the Japan Sea sides of Honshu and in Shikoku and Kyushu. According to KOTAKA (1959), the optimum temperature of the present species is from 10° to 20°C. and the bathymetric range in which the present species occurs commonly is between 70 and 80 meters.

*Batillaria zonalis* BRUGUIÉRE [Pl. 1, figs. 10a, b]

A rather well-preserved and an imperfect specimens are in the collection. The present species ranges from the Pliocene to the Recent, and its geographic distribution is from Australia (type locality), the Philippines, China, Formosa to northern Honshu,

Japan. This is one of the common, widely ranging species in Japan, and usually inhabits the mudflats within the intertidal zone or estuaries of rivers.

*Thericium kobelti* (DUNKER) [Pl. 1, figs. 11a, b]

A rather well-preserved specimen is in the collection. The present species lives below the lowest tide line in the Pacific (26°–35°N) and the Japan Sea (41°N).

*Proclava pfefferi* (DUNKER) [Pl. 1, figs. 12a, b]

A single, water-worn specimen was examined. The present species lives on sandy mud bottom in the euneritic fascia of embayments, and its geographic distribution is from central Honshu, Japan and southwards to the equatorial region and in Japan Sea (37°N).

*Natica vitellus spadicea* (GMELIN) [Pl. 1, figs. 13a, b]

Seven, well-preserved specimens of rather small sizes. The present subspecies is discriminated from the species by its larger ratio of D/H due to increasingly developed body whorl (KIRA, 1959). The present form is known to live in sandy mud in the euneritic fascia.

*Rapana thomasi* CROSSE

An imperfect specimen is in the collection. The present species lives in the euneritic fascia of the Pacific (southern Hokkaido to Kyushu) and ranges from the Pleistocene to the Recent

*Purpura (Mancinella) clavigera* KÜSTER [Pl. 1, figs. 14a, b]

Three specimens are at hand. The present species lives in the intertidal fascia and immediately below the lowest tide line in the Pacific (25°–41°N) and the Japan Sea (41°N).

*Coralliophila hataii* HAYASAKA [Pl. 1, figs. 15a, b, 16a,b.]

Two, large and small specimens were examined. The present species was originally described by the senior writer (1961) from the Pleistocene Toyohashi Group in Atsumi Peninsula, Aichi Prefecture, Japan. There are no subsequent records of the present species, and therefore, this is the second one. It is interesting that the second occurrence of the present species is known also from the Pleistocene formation on the Pacific side of southwest Japan where it had been under the influence of the warm water Kuroshio current at the time of its deposition.

*Siphonalia cassidariaeformis* (REEVE) [Pl. 1, figs. 17a, b]

Six, well-preserved specimens of various sizes are in the collection. This species is now living in central and western Japan (Pacific, 31°–35°N; Japan Sea, 41°N), and ranges from the Pleistocene to the Recent.

*Hemifusus tuba* (GMELIN)

An imperfect, rather small specimen is in the collection. This species lives in the euneritic fascia in the central Honshu, Japan and southwards to the Philippines.

*Tritia (Reticunassa) acutidentata* (SMITH)

A single, well-preserved specimen is in the collection. The present species lives below the lowest tide line (euneritic fascia) of the Pacific (28°–43°N) and the Japan Sea (43°N).

*Nassarius (Zeuxis) kiiensis* KIRA [Pl. 1, fig. 18]

Two, well-preserved and an imperfect specimens are in the collection. This species is now living in the euneritic fascia on the Pacific side of the central Honshu, Japan.

*Nassarius (Niotha) livescens* (PHILIPPI) [Pl. 1, figs. 19a, b]

The present species, represented by nine, well-preserved specimens in the collection, is now living from the lowest tide line to the depth of about 10 meters in the Pacific (0°–41°N) and in the Japan Sea (41°N).

*Mitropifex collinsoni* (A. ADAMS) [Pl. 1, figs. 20a, b]

A single specimen lacking the basal extremity of the shell was identified as the named species. The present species inhabits muddy sand bottom ranging from 5 to 30 meters in depth in the central Honshu, Shikoku and Kyushu, Japan.

*Adamnestia* sp.

Four juvenile specimens are referable to *Adamnestia*.

*Ringicula (Ringiculina) doliaris* GOULD

Only a single, but well-preserved specimen is in the collection. The present species has been regarded as one of the elements of the "Asiatic Continental Fauna" (MIYADI *et al.*, 1954). This lives on the muddy bottom of embayments on the coasts of northern, central and southwestern Japan and of the Chinese Continent.

**Concluding Remarks**

From the foregoing remarks on each species included in the present collection, the general biotic aspect of the fauna can be summarized as follows.

All the species determined specifically are known to live in the south Kyushu region except *Lumella granulata* (GMELIN), which is known as living in the south of the Amami Islands, about 300 km south of the present area. No cold current elements are included in the present fauna. Based on the geographic distribution of each species, the following four species-groups can be recognized in the present fauna.

1) The species living in central Japan (both Pacific and Japan Sea sides) and southwards, being under the influence of the warm current. This group includes most of the species identified.

2) The species of which living distribution seems to be restricted to around the Japanese Islands, such as *Pecten albicans* (SCHRÖTER), *Rapana thomasi* CROSSE, *Siphonalia cassidariaeformis* (REEVE), *Nassarius (Zeuxis) kiiensis* KIRA and *Mitropifex collinsoni* (A. ADAMS). Among these, the first named two species are now living in Hokkaido, Honshu, Shikoku and Kyushu irrespective of the current system and the latter three live in central and western Japan.

3) The species having their northern limits of distribution in the cold current area, such as, *Anadara (Scapharca) broughtonii* (SCHRENCK), *Ostrea (Ostrea) denselamellosa* (LISCHKE), *Batillaria zonalis* (BRUGUIÉRE), *Purpura (Mancinella) clavigera* (KÜSTER), *Tritia (Reticunassa) acutidentata* (SMITH) and *Nassarius (Niotha) livescens* (PHILIPPI).

4) The elements of the "Asiatic Continental Fauna" (MIYADI *et al.*, 1954) living in the embayments on the coasts of Japan and the Chinese Continent, such as, *Barnea (Umitakea) japonica* (YOKOYAMA) and *Ringicula (Ringiculina) doliaris* GOULD.

It is noticeable that the present fauna comprises two Pleistocene species, *Anadara (Scapharca) hiratai* (HABE) and *Coralliophila hataii* HAYASAKA, which are not known to be living at present. The species in the present collection other than the foregoing two are all living ones. Of these species, the geologic ranges are summarized as follows.

Number of the species

ranging from the Miocene to the Recent	.....2
ranging from the Pliocene to the Recent	.....6
ranging from the Pleistocene to the Recent	.....12
known only from the Pleistocene	.....2

The remaining species have not been known as fossil.

The present fauna consists entirely of the normal marine water species including the four embayment species such as *Barbatia (Savignyarca) obtusoides* (NYST), *Macoma (Pseudometis) praerupta* (SALISBURY), *Proclava pfefferi* (DUNKER) and *Ringicula (Ringiculina) doliaris* GOULD. Most of the species in the collection live in the euneritic fascia (between the lowest tide and 20–30 m), and some of them extend their living ranges into the intertidal fascia [*Lucina stearnsiana* OYAMA, *Paphia euglypta* (PHILIPPI) and *Purpura (Mancinella) clavigera* KÜSTER]. Further, there are two intertidal species in the present collection, namely, *Lunella granulata* (GMELIN) and *Batillaria zonalis* (BRUGUIÉRE). On the other hand, the species inhabiting the deeper bottom are *Anadara (Scapharca) broughtonii* (SCHRENCK) (20–60 m: euneritic and mesoneritic fasciae), *Chlamys (Mimachlamys) nobilis* (REEVE) (euneritic and mesoneritic fasciae), *Arcopagia (Merisca) subtruncata* (HANLEY) (10–300 m: euneritic to bathyal fascia) and *Turritella (Kurosoia) fascialis* MENKE (50–150 m: subneritic and bathyneritic fasciae).

As already stated, the most abundant species in the collection are *Anadara (Scapharca) hiratai* (HABE) and *Turritella (Kurosoioia) fascialis* MENKE, of which the former has not been known as living and the latter is the species having the deepest habitat among the present fauna. The depth ranges of the four subordinate species, *Lucina stearnsiana* OYAMA, *Natica vitellus spadicea* (GMELIN), *Siphonalia cassidariaeformis* (REEVE) and *Nassarius (Niotha) livescens* (PHILIPPI) are in the intertidal and the euneritic fasciae, and many other species are also known to live in the euneritic fascia.

Judging from the good state of preservation of the specimens in the present collection, it may be reasonable to say that it is difficult to infer that they had been transported for a great distance before deposition. As a whole, the environmental condition under which the present fauna lived is inferred to be of the deeper part of the euneritic or the shallower part of the mesoneritic fascia along the open sea coast neighbouring an embayment. The sea water temperature assumed from the living distribution of each species of the present fauna is nearly the same as that of this area at present.

The mode of occurrence of *Anadara (Scapharca) hiratai* (HABE) which is represented mostly by well-preserved conjoined shells in the present collection, indicates their autochthonous origin, and therefore, it is reasonable to consider that the environmental condition stated above is nothing but the ecological condition for this extinct species.

The fact that the present fauna has only six species common to the rich molluscan fauna of the Shiroyama Formation in this area (Table 1) suggests considerable difference in faunal characters between them. However, the detailed comparison between the two is reserved until the study on the fauna of the Shiroyama Formation will be accomplished.

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Explanation of Plate 1

(Natural size unless otherwise stated)

- Fig. 1. *Barbatia (Savignyarca) virescens* (REEVE)  
Fig. 2a-d. *Anadara (Scapharca) hiratai* (HABE)  
Fig. 3. *Lucina stearnsiana* OYAMA. Two specimens showing external and dorsal surfaces respectively.  
Fig. 4. *Cyclina (Cyclina) orientalis* (SOWERBY)  
Fig. 5. *Macoma (Psammacoma) awajiensis* SOWERBY  
Fig. 6. *Macoma (Pseudometis) praerupta* (SALISBURY)  
Fig. 7. *Barnea (Umitakea) japonica* (YOKOYAMA). Dorsal view of conjoined valves  
Figs. 8a, b. *Lunella granulata* (GMELIN)  
Fig. 9. *Turritella (Kurosoioia) fascialis* MENKE.  $\times 2.5$   
Figs. 10a, b. *Batillaria zonalis* BRUGUIÈRE  
Figs. 11a, b. *Theridium kobelti* (DUNKER)  
Figs. 12a, b. *Proclava pfefferi* (DUNKER)  
Figs. 13a, b. *Natica vitellus spadicea* (GMELIN)  
Figs. 14a, b. *purpura (Mancinella) clavigera* KÜSTER  
Figs. 15a, b, 16a, b. *Coralliophila hataii* HAYASAKA  
Figs. 17a, b. *Siphonalia cassidariaeformis* (REEVE)  
Fig. 18. *Nassarius (Zeuxis) kiiensis* KIRA  
Figs. 19a, b. *Nassarius (Niotha) livescens* (PHILIPPI)  
Figs. 20a, b. *Mitropifex collinsoni* (A. ADAMS)



