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PALEOGENE AND EARLY NEOGENE MOLLUSCAN FAUNAE IN WEST JAPAN

By

Atsuyuki Mizuno

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Masatsugu SAITO, Director

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CONTENTS

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Abstract

This paper deals with the pooblems on the Paleogene and early Neogene molluscan faunae in west Japan. The biochronologic division, the characteristics of fauna of each age, the feature of faunal vicissitude and its control factors are discussed, on the bases of the description of stratigraphy and faunal occurrence. The faunal lists of each area and each stage are prepared in detail, according to the writer's observation and partly to the previous contributions. There is shown only the summary of consideration on some important mulluscs of west Japan, concerning the taxonomy; the detailed notes including the descriptions of many new species from the rocks in question are to be given in another paper. The following six stages are discriminated in the rocks in descending order.

Saseboan stage	lower Miocene
Nishisonogian stage	Oligocene
Mazean stage	
Funazuan stage	
Okinoshiman stage	Eocene
Takashiman stage	

The chronologic appearances of the constituents of the fauna including about 230 species were controlled by some factors such as phylogenic evolution and migration owing to the change of climatic and physical conditions of the gulf. The stratigraphic and geographic appearances of molluscs in each age were evidently regulated by the conditions of bottom material, water and topography of the gulf.

I. Introduction

The purpose of this paper is to summarize and clarify the Paleogene and early Neogene biochronology and molluscan faunal development in west Japan, in order to prepare the fundamental data for the molluscan paleontology in Japan, on the bases of the stratigraphic and paleontologic works carried out by the writer the last decade especially in northwest Kyushu and partly based upon the previous works by some authors. Taxonomic detailed notes on new species and known species to be revised and also the discussions on the Paleogene faunae in north Japan or over Japan are going to be given in another paper.

It is more than 30 years since the late Dr. T. NAGAO elaborated his excellent and detailed stratigraphic and paleontologic works in west Japan, which have been respected and improved in high degree as the groundwork of Paleogene biostratigraphy not only of west Japan but of whole Japan. Subsequently, the detailed geologic investigations were carried out by many workers concerning the former area including many important coal fields, and in result we have now far more precise and various stratigraphic and faunal informations than those of his days on each field, but unfortunately they have not yet been summarized by any authors.

I. 1 Materials studied

Of the stratigraphic and paleontologic data on west Japan, those of the Takashima, Isahaya, Sasebo and a part of the Chikuho coal field were taken through the writer's field studies during 1957–1960. Many molluscan fossils from the Hokusho, Karatsu, Sakito, Amakusa, Miike, Hokonoko, Fukuoka and Yuyawan areas were available to him during 1951–1960, awarded for identifications from many geologists of the Geological Survey of Japan and others, and the stratigraphic data of these areas owe to them much. Discussions on the other areas of west Japan are mostly based upon the previous works.

I. 2 Acknowledgments

In preparing this paper, the writer is greatly indebted to Prof. F. TAKAI of Tokyo University for his kind encouragements and advices. Taxonomic and paleoecologic interpretations owe much to critical advices and helps from Dr. K. OYAMA of the Geological Survey of Japan.

The writer's special thanks should be made to many geologists. As to the geology of Takashima and Isahaya of northwest Kyushu, he was kindly offered useful advices from Assist. Prof. Y. KAMADA of Nagasaki University, Mr. M. HOSONO of the Iojima Mine, Mr. S. HINOKUMA of the Takashima Mine, Dr. H. KAMISHIMA and Dr. Y. TAKAI, both of the Geological Survey of Japan. The fossil materials of many other areas of Kyushu were awarded from the following many persons: Mr. H. NAGAHAMA, Dr. I. IMAI, Mr. T. YOSHIDA, Mr. E. INOUE, Dr. Y. TAKAI and Dr. K. SUGAI of the Geological Survey of Japan; Prof. H. TAKEHARA of Nagoya University; Mr. H. ENDO of the Oshima Mine; Mr. S. IESAKA, Mr. M. INOUE and Mr. M. KOMODA of the Mitsubishi Mining Company. Mr. M. OKABE of the Takamatsu Mine offered him much helps in paleontologic research of the Ashiya area, and Prof. S. IMAMURA and Mr. K. OKAMOTO offered him a chance to examine the materials from the Yuyawan area.

The writer is also thankful to Dr. S. UOZUMI of Hokkaido University and Dr. T. KOTAKA of Tohoku University, who kindly offered him a chance to examine some type specimens kept in their institutes.

II. General Accounts on the Paleogene and Lower Neogene Formations in West Japan

The Paleogene and lower Neogene formations are widely distributed in west Japan where many coal fields made of them are developed. This area is largely divided into two, namely, northwest Kyushu and north Kyushu–west Honshu areas, owing to their very different lithologic, stratigraphic and paleontologic features. The detailed geologic aspects of every coal field are referred in NAGAO (1926–1928)'s and MATSUSHITA (1949)'s excellent synthetic works and more recent contributions by many authors.

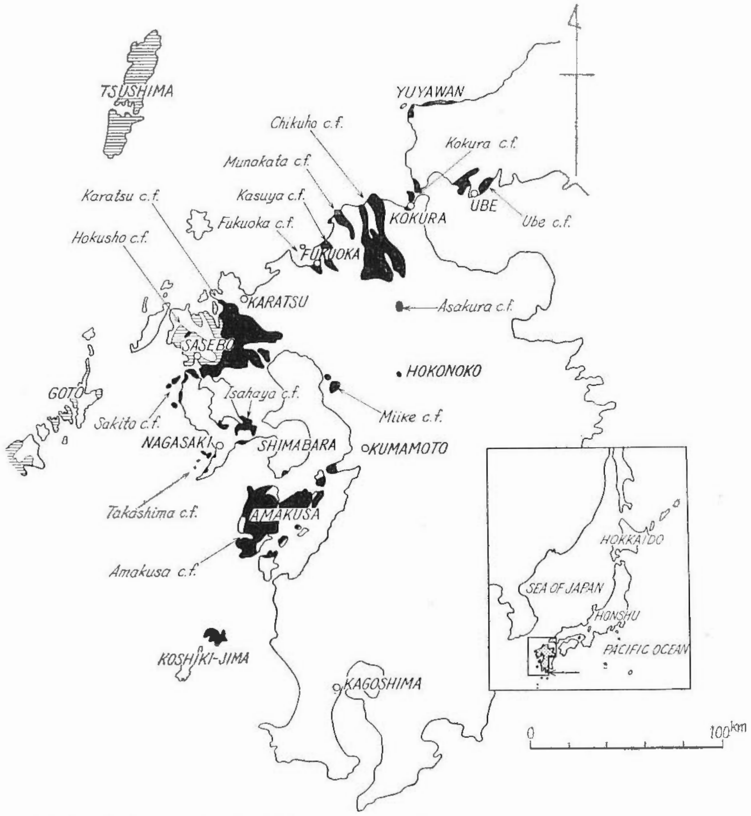


Fig. 1 Distributions of the Paleogene and lower Neogene strata in west Japan
The painted areas show those of the Paleogene and the hatched areas show those of the lower Neogene.

The northwest Kyushu area which is conveniently called the Hokusho-Amakusa district in this article comprises such coal fields as those of Amakusa, Miike, Asakura, Isahaya, Takashima, Sakito, Karatsu and Hokusho. Chronologically somewhat different Tertiary formations with many molluscan fossils are there scattered, broadly speaking, in the manner that the older ones are more south and the younger ones are more north; that is; in the southern Amakusa and Miike coal fields only Eocene rocks are developed, but in the northern Sakito, Karatsu and Hokusho coal fields Oligocene and lower Neogene rocks are widely developed, and in the intermediate Takashima, Isahaya and Asakura coal fields the whole Eocene and lower Oligocene rocks are thickly developed. Accordingly, summarizing the whole formations, nearly perfect stratigraphic and faunal columns of Paleogene and lower Neogene may be established in this district with no time break, and the columns may be available to the studies of the Paleogene biochronology and faunal development in Japan, as formerly pointed out by the writer (MIZUNO, 1956a; OYAMA *et al.*, 1960). Figure 2 shows their stratigraphic columns.

In general, at the basal parts of the Paleogene formations in the abovementioned intermediate and southern coal fields, which covers unconformably the pre-Cretaceous rocks, there are probably mostly terrestrial and nearly non-fossiliferous clastic sediments with the so-called purple shale. They are called the so-called "Akazaki group", and are represented by the Akazaki formation at Amakusa, the Koyagi formation at Takashima, the Ginsui formation at Miike, the Yamanokami formation at Asakura and the Hokonoko formation at Hokonoko. The Fukami formation at west Amakusa has been considered as the equivalent of Akazaki formation; however, according to TAKAI's recent study (TAKAI, 1961), it is probably a member of the Cretaceous rocks. The Eocene rocks other than the above-mentioned basal part consist of sandstone and siltstone with marine, brackish or fresh water molluscan fossils and especially with many coal seams at their lower half parts. They are largely composed of siltstone at Amakusa, but predominant in sandstone and conglomerate at the other areas. The Oligocene rocks developed at the intermediate and northern coal fields are predominant in marine various sediments with many molluscan fossils, being accompanied with remarkable tuff generally called "Honeishi" at their middle parts. The Miocene rocks located only at the northern coal field conformably cover the Oligocene sediments. They are almost wholly composed of sandstone rarely with the shallow marine and non-marine fossils.

The north Kyushu-west Honshu district once called the Chikuho-Asakura district (OYAMA *et al.*, 1960) comprises the coal fields of Chikuho, Kokura, Ube, Fukuoka, Kasuya and Munakata which are made of the Paleogene rocks, and besides, the marine Paleogene rocks paleontologically evidenced are developed near Yuyawan in west Honshu where the Miocene rocks are also found. The Paleogene sequence in the present district so differs from the Hokusho-Amakusa district as a whole that the correct correlation with that of the preceding district is impossible. That is to say, the lower Paleogene is missing there, and the middle (the upper Eocene and the lower Oligocene) is predominant in coal-bearing non-marine coarse-grained sediments, represented by the Nogata and Otsuji groups, while the upper (the upper Oligocene) is composed of fossiliferous marine clastic sediments generally rich in sandstone; the last is represented by the Ashiya group. The Miocene sediments conformably covering the Paleogene are found only in the Yuyawan area.

Biochronologic Division In what way is a biochronologic division available to a stratigraphic work? What biochronologic division is useful for the most precise understanding of faunal development? The subjects have been a focus of discussion for many years. Such divisions as based on the following matters seem to be valid to the writer for the Paleogene deposits of west Japan which are rich in the lateral change of litho- and bio-facies. 1) Any biochronologic units being characterized by a rich fauna including dwellers of various habitats. 2) Phylogenic situations of constituents of the fauna being recognized. 3) There being a correct vertical relationships with no duplication or no hiatus between any stratigraphic columns upon which any biochronologic units are based. 4) Any units having a type column.

The several stages of MATSUSHITA (1949) and IKEBE (1954) have been used in general for the standard divisions of the Paleogene in Kyushu. However, the divisions cannot be always accurately adopted today. One of reasons is laid in that the recent informations on the Paleogene and lower Neogene of Kyushu require some modifications of the stratigraphic and faunal data upon which they were based. Another is in that the above-mentioned matters were not introduced to them by the authors; that is to say; their stages were based upon the columns of the both Miike and Chikuho coal fields, while a part of the type columns of the stages is not quite characterized by the paleontologic evidences. The type columns of the Nogata and Otsuji stages of MATSUSHITA in the Chikuho coal field are very poor in fossil. The large difficulty arises from these matters as to the synthetic understanding of the faunal development during the ages in question in Kyushu under the adoption of their divisions.

Fortunately the Tertiary formations with many fossils developed at the Hokusho–Amakusa district seem to be qualified for the standard section of bio-chronologic division of Paleogene in west Japan, in respect that in summarizing them, nearly perfect stratigraphic and faunal columns are able to be established, as briefly shown in the preceding chapter. The writer once discriminated, in this respect, three faunal "zones" which are chronologically successive at the district and tentatively called them *Venericardia nipponica* zone, *Venericardia yoshidai* zone and *Venericardia vestitoides* zone in ascending order (MIZUNO, 1956a). However, new data on the subject were found through his more recent works and as a result his three divisions were required some modifications. Therefore, six stages shown in Table 1 were anew proposed as a standard bio-chronologic units of the Paleogene and lower Neogene in west Japan. Their type columns were designated to the vertically serial and laterally surely correlated formations at the Takashima, Sakito and Hokusho coal fields (MIZUNO, 1962). The division is based upon a molluscan faunal vicissitude; above all, upon those of turritellids, crassatellids, carditids, pitarinids, which are richly found especially in the Paleogene formations of west Japan.

III. Takashiman Stage

III. 1 Description of type column

The type column is designated to the vertically serial rocks including the Koyagi, Futagojima and Hashima formations in ascending order in the Takashima coal field. The type column has been recently described in detail by SAKAKURA (1953), TAKAHASHI and OHARA (1955), OHARA (1959) and OHARA (1960) and also studied by the writer (HIROKAWA and MIZUNO, 1962; MATSUI and MIZUNO [MS.]).

The lower, Koyagi formation attaining about 1,000 m in thickness is widely distributed in the nearly whole coal field, forming there the basal rocks of the Paleogene, unconformably upon the Mesozoic metamorphic complex. The formation is vertically divided into three parts from their lithologic characteristics, and is as a whole predominant in cross-laminated conglomerate and very coarse-grained sandstone beds intercalating fine sandstone and "purple shale", all of them forming promiscuous alternations. Thin beds of coaly shales are interbedded between them at both the lowest and upper horizons of the formation. The formation has been hitherto considered to be wholly lack in fossil. However, according to the writer's observations, there are some fossil beds bearing molluscan fossils in the part about 110 m below the upper limit, and the beds are recognizable throughout the whole areas of the field. They are shown in Table 2 and these are mostly of brackish and fresh water, common with those of the Futagojima formation.

Table 1 Comparison of the biochronologic division here proposed and various divisions proposed so far

NAGAO, 1926–'28	IKEBE, 1954	MATSUSHITA, 1949	MIZUNO, 1956 a, b	MIZUNO, 1962, '64
	(F1)	Chikushi	C4 (formally unnamed)	Saseboan
Brachiodus japonicus zone	(E)		C3	
Crassatellites yabei zone	D		*Venericardia vestitoides* zone	Nishisonogian
Upper *Pecten sakitoensis* zone			*Venericardia yoshidai* zone	Mazean
	C	Otsuji		Funazuan
Lower *Pecten sakitoensis* zone				
Athleta japonicus zone				
Crassatellites fuscus zone *Athleta nishimurai* zone	B	Nogata	*Venericardia nipponica* zone	Okinoshiman
Upper *Orthaulax japonicus* zone	A	Ariake		Takashiman
Lower *Orthaulax japonicus* zone				
	Ao	Amakusa		

Table 2 Molluscan fossils from the upper part of Koyagi formation in the Takashima coal field

Specific name \ Lithology / Station	cs 162	cs 163	vcs 163'	fs 165	slt 168	slt T-K
Colpospira okadai (NAGAO)	·	c	·	·	·	·
Faunus ? sp.	·	r	·	·	·	·
Bellatara ? sp.	·	a	·	·	·	·
Vicarya n. sp.	·	r	·	·	·	·
"*Epitonium*" sp.	·	·	·	r	·	·
Lunatia ? *utoensis* NAGAO	·	r	·	·	·	r
Nerita subgranulosa NAGAO	·	·	·	r	·	·
Eopleurotoma ? *higoensis* NAGAO	·	a	·	·	·	·
Anomia sp.	a	c	·	a	·	·
Pycnodonta cassis (NAGAO)	a	c	r	a	·	·
Anodonta n. sp.	·	·	·	·	a	·
Cristaria sp.	·	·	·	·	a	·
Corbicula nagaoi SUZUKI	c	·	·	·	·	·
C. sp.	·	·	·	·	r	·
Lentidium ? *kyushuense* (NAGAO)	·	·	·	a	·	a

Remarks: Among the 6 stations, the remainings except St. 168 which is from about 30m below the uppermost of the formation at the Incline No. 3 of Koyagi mine are from about 110m below that at Kaminoshima and gallery of Takashima mine.

Abbreviations: vcs, very coarse-grained sandstone; cs, coarse-grained sandstone; fs, fine-grained sandstone; slt, siltstone.

The middle, Futagojima formation, is 320 m in maximum thickness, consisting of sandstone and siltstone in alternation, together with conglomerate and in the lower and upper parts with some coal seams. The fossils are richly yielded in the lowest part, which was called "lower *Orthaulax japonicus* zone" by NAGAO and extends over the coal field. *Polinices eocenica, Phaxas brevis,* "*Orthaulax*" *japonicus* and *Pitar hinokumai* etc. are very abundant there. Fossils are included also in the upper part, though very rare (St. F-H1 and F-H2).

The upper, Hashima formation of 150–240 m in thickness, consists of sandstone and siltstone intercalating thick workable coal seams. It yields also brackish and fresh water molluscan fossils; in the lowest part *Bellamya koyagiensis, Vicarya yabei,* "*Orthaulax*" *japonicus* and *Lentidium*? *kyushuense* are found, and in the middle part called "upper *Orthaulax japonicus* zone" by NAGAO, *Faunus*? *miikensis, Faunus*? sp., *Polinices eocenica,* "*Orthaulax*" *japonicus, Phaxas brevis, Macoma* sp. etc. are found. *Corbicula nagaoi* is included throughout this formation.

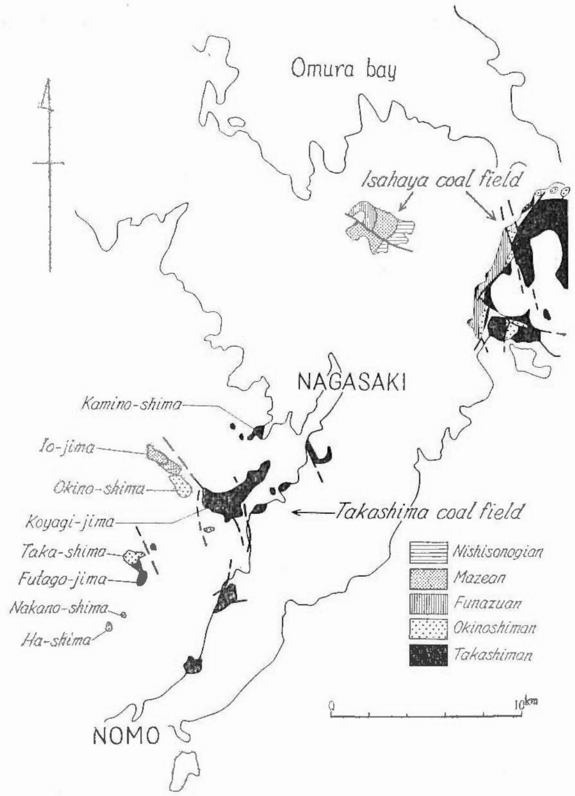


Fig. 3 Index map of the Takashima and Isahaya coal fields with the geologic map after HIROKAWA and MIZUNO (1962) and MATSUI and MIZUNO [MS.]

III. 2 Correlatives

The correlatives with the type column are found only, but widely, in the southern area of the Hokusho–Amakusa district.

The Enoura formation at the Isahaya coal field is stratigraphically correlated with the Futagojima formation, though, in contrast to the latter, the former is rich in siltstone with a lot of marine small foraminifers, and the molluscan fossils have not been yet found (KAMADA, 1957; MATSUI and MIZUNO, MS.). The correlative with the Koyagi foramtion is probably concealed under the ground there. The Keya formation, about 600 m in thickness is correlated with the Hashima formation. It mostly consists of white medium-~coarse-grained sandstone with some coal seams at its upper and lower part. *Corbicula mirabilis* is rarely found in it (SUZUKI, 1941; KAMADA, 1957; MATSUI and MIZUNO, MS.).

The stratigraphic succession of the correlative in Amakusa is somewhat similar to one of Isahaya. It was clarified through the efforts of NAGAO (1926–1928), MATSUSHITA (1949), HATAE (1960) and TAKAI (1961). The Akazaki formation, which occupies the basal facies of the Tertiary of Amakusa, is of some deca metres in thickness and composed of purple coloured shale and sandstone intercalating conglomerate alike the Koyagi formation and is lack at the west part of the field

Table 3 Molluscan fossils from the Futagojima formation at Takashima, Hashima and Koyagijima

Specific name \ Lithology / Station	F-F slt	F-K slt	169 slt	F-H1 slt	F-H2 cs
Colpospira okadai (NAGAO)	r	×	r	·	r
Faunus ? miikensis (NAGAO)	·	×	·	·	·
Polinices eocenica NAGAO	a	×	c	·	·
Calyptraea sp.	r	·	r	·	·
Pseudoneptunea ? sp.	r	·	r	·	·
"*Orthaulax*" *japonicus* NAGAO	c	×	c	·	·
Arcidae, gen. et sp. indet.	r	·	r	·	·
Brachidontes sp.	r	·	·	·	·
Pycnodonta cassis (NAGAO)	r	·	r	·	a
Isognomon tomiyasui (NAGAO)	·	×	·	·	·
Venericardia (*Cardites*) sp.	·	·	·	·	r
Corbicula nagaoi SUZUKI	·	×	·	a	·
"*Lucina*" sp.	r	·	·	·	·
Pitar hinokumai MIZUNO, n. sp.	a	·	a	·	·
P. n. sp. b	r	·	·	·	·
Macoma sp.	r	·	·	·	·
Phaxas brevis (NAGAO)	a	·	r	·	·
Caryocorbula subtumida (NAGAO)	·	×	·	·	·

Remarks: The occurrences marked by × are after NAGAO (1928a)

where the Shiratake formation unconformably covers the Cretaceous group. The Shiratake formation rests upon the preceding in thickness of 100 m or more, and from the Shiratake many littoral or brackish shell fossils are found, according to the cited works. *Nummulites amakusaensis* and *Discocyclina* aff. *pratti* are reported to occur, too (YABE and HANZAWA, 1923). The Kyoragi formation of about 800 m in thickness upon the Shiratake exhibits similar lithology to the Enoura formation, but its uppermost part called the "Tomiya fossil bed" (HATAE, 1960) yields such molluscan fossils as *Crassatellites* and *Venericardia*. On the other hand, the Toishi formation mostly consists of sandstone and siltstone of non-marine, intercalating some coal seams, and *Venericardia* is rarely found at the upper part.

In the Miike coal field, the correlative column including the Ginsui, Komenoyama, Toka and Nanaura formations is wholly composed of littoral or non-marine coarse-grained sediments bearing many coal seams and the molluscan fossils are included at some horizons except the lowest, Ginsui formation which consists of probably terrestrial deposits including purple shale. However, the Toka and Nanaura formations are composed of foraminifers-bearing marine rocks near Nagasu about 10 km of the south of Miike, according to KIHARA (1960).

Table 4 Molluscan fossils of Takashiman stage from Amakusa and Miike coal fields

Locality / Specific name	Amakusa						Miike		
	1	2	3	4	5	6	7	8	9
GASTROPODA									
Lischkeia sp.	×	·	·	·	·	·	·	·	·
Orectospira gemma (NAGAO)	·	×	·	·	·	·	·	·	·
Colpospira okadai (NAGAO)	×	×	×	×	·	·	×	·	·
C. tashiroi KOTAKA	×	·	·	·	×	·	·	·	·
Faunus nipponicus NAGAO	·	×	·	·	·	·	·	·	·
F.? *miikensis* (NAGAO)	·	·	·	·	·	·	×	·	×
F.? sp.	·	·	×	·	·	·	·	·	·
Vicarya n. sp.	×	·	·	·	·	·	·	·	·
Cerithiopsis sp.	·	×	·	·	·	·	·	·	·
Polinices eocenica NAGAO	?	·	·	×	×	·	×	·	×
Lunatia ? *utoensis* NAGAO	·	×	·	·	·	·	·	·	·
Nerita subgranulose NAGAO	·	×	·	·	·	·	×	·	·
"*Orthaulax*" *japonicus* NAGAO	×	×	·	·	×	·	×	·	×
Pseudoneptunea ? sp.	·	·	·	·	×	·	·	·	·
Pseudoperissolax yokoyamai SUZUKI et ITO	·	·	·	·	×	·	·	·	·
Volutospina ? *nishimurai* (NAGAO)	·	·	·	·	×	·	·	·	·
Eopleurotoma higoensis (NAGAO)	·	×	·	·	·	·	·	·	·
Liroa paupercula (NAGAO)	·	×	·	·	·	·	·	·	·
PELECYPODA									
Yoldia sp.	·	·	·	·	×	·	·	·	·
Portlandia sp.	×	·	·	·	·	·	·	·	·
Barbatia sp.	·	·	·	·	·	·	×	·	·
Crassatellites nipponensis YOKOYAMA	·	·	·	·	×	·	·	·	·
Venericardia mandaica (YOKOYAMA)	·	·	·	·	×	·	·	·	·
V. nipponica (YOKOYAMA)	·	·	·	·	×	×	·	·	×
Corbicula nagaoi SUZUKI	·	·	·	·	·	×	·	·	·
Joannisiella problematica (NAGAO)	·	·	·	×	·	·	·	·	·
Vepricardium miikense (NAGAO)	·	·	·	·	·	·	×	·	·
Pitar hinokumai MIZUNO, n. sp.	×	·	·	·	·	·	·	·	·
Callista ariakensis (NAGAO)	·	×	·	×	·	·	·	·	·
Solena sp.	×	·	·	·	·	·	·	·	·
Caryocorbula subtumida (NAGAO)	·	×	·	×	·	·	·	·	·
Lentidium? *kyushuense* (NAGAO)	·	×	·	·	·	·	·	×	·

1. Vicinity of Ushibuka in South Amakusa* (Some stations are mixed)
2. Akase in Uto peninsula**
3. Misumi in Uto peninsula***
4. Mirokudake in North Amakusa**
5. Vicinity of Ushibuka in South Amakusa* (upper part of Shiratake formation)

(1–5: Shiratake formation)

6. Ibid.* (Toishi formation)
7. Komenoyama formation**
8. Toka formation**
9. Nanaura formation**

* Mainly after Y. TAKAI's collection
** Mainly after NAGAO (1928a)
*** After M. HOSHINO's collection

In the vicinity of Hokonoko about 40 km of the east of the Miike coal field, the Hokonoko and Kannondake formations are known to be exposed in about 100 m in thickness (FURUKAWA and URATA, 1960). They are mostly composed of coarse-grained sandstone, and some coal seams are found in the lower part of the Kannondake, from which some molluscan fossils were reported by them. On the other hand, the writer found some fossils as listed in Table 5 in the collection of K. SUGAI who collected them from the Kannondake formation. These molluscs evidence the attribution of the formation to the present stage.

Table 5 Molluscan fossils from the Kannondake formation (Collected by SUGAI and FURUKAWA)

Specific name	A	B	C	D
Vicarya n. sp.	×	·	·	·
Cerithiopsis sp.	×	·	×	·
"Orthaulax" japonicus NAGAO	×	·	·	·
Acila (Truncacila) sp.	·	·	×	·
"Ostrea" sp.	·	×	·	·
Venericardia nipponica YOKOYAMA	·	×	·	×
V. sp.	·	·	×	·
Joannisiella problematica (NAGAO)	·	·	×	·
Lucina sp.	·	·	×	·
Callista ariakensis (NAGAO)	·	·	×	·
Phaxas brevis (NAGAO)	·	·	×	·
Solen sp.	×	·	·	·
Lentidium ? kyushuense (NAGAO)	×	·	·	·

Lithology: A, poorly sorted medium-grained sandstone; B, coarse-grained sandstone; C, sandy siltstone; D, medium-grained sandstone (the horizon correctly unknown)

Besides the listed species, *Faunus nipponicus*, *F.? miikensis*, *Lunatia? utoensis*, *Venericardia* aff. *mandaica* etc. were reported by FURUKAWA and URATA (1960)

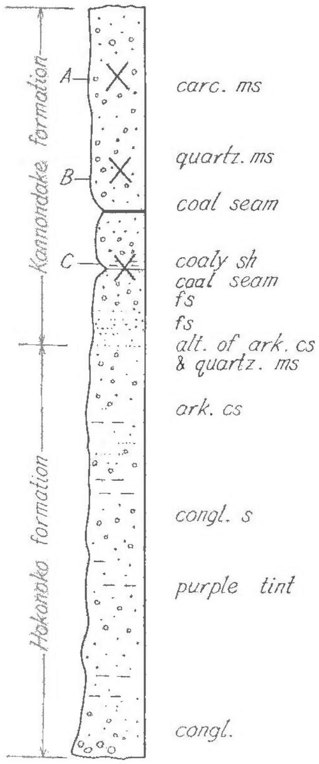


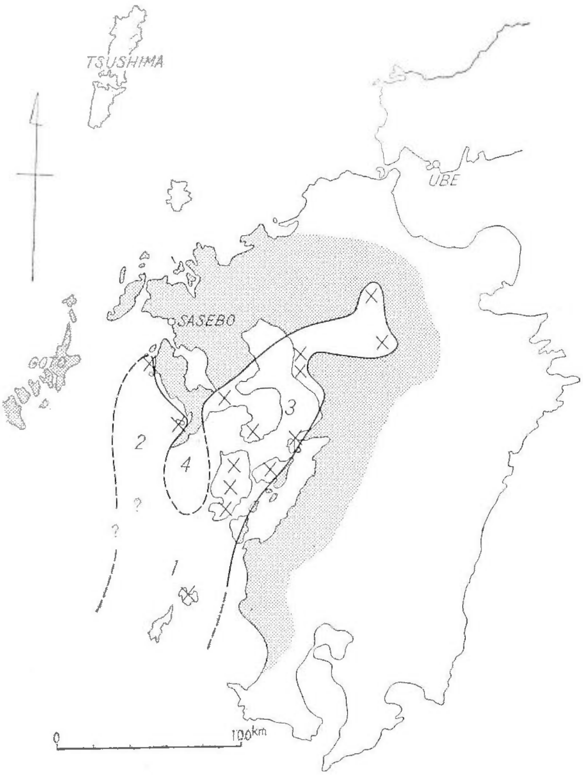
Fig. 4 Columnar section of the Paleogene at the area of Hokonoko, showing the stratigraphic situation of each station (column after FURUKAWA and URATA, 1960)

The Yamanokami and Hoshuyama formations of Asakura, about 120 m in thickness, have been considered to be the correlatives with the type column, but they yield no fossil.

III. 3 Paleontologic remarks

After the regression of the Cretaceous sea, the wide area including the nearly whole part of northern Kyushu was suffered from subsidence again in the time of Paleogene and in the result the thick deposits of various environments were formed there.

Paleogeography and Sedimentation The Takashiman stage is of the earliest among them. Summarizing the characteristics of stratigraphy and litho-facies of each area, the stage is roughly divided into the three; the lower including the Koyagi, Akazaki, Ginsui formations etc., the middle including the Futagojima, Enoura, Kyoragi formations etc. and the upper including the Hashima, Toishi, Keya formations etc. Moreover, the detailed lithology of each part varies in every area and the bio-facies also somewhat varies in every area and formation. Through the Takashiman age there were probably the two areas in the depositional basin of the Paleo-gulf of Shiranuhi of KOBAYASHI (1941). One is called here the Paleo-Ariake bay of which head was in the vicinity of Asakura and mouth was to the south of Amakusa. The other is called the Paleo-Takashima bay which was to the west of the preceding and probably was combined with the preceding on the south.



1. Paleo-gulf of Shiranuhi, 2. Paleo-Takashima bay, 3. Paleo-Ariake bay, 4. Paleo-Nomo peninsula, ×. Distribution of the Takashiman stage

Fig. 5 Shore lines of the Paleo-gulf of Shiranuhi at the middle Takashiman age

The two bays were separated by the Paleo-Nomo peninsula running from north to south probably at the northern half of the gulf. The discrimination of the two bays can be easily inferred from the stratigraphic, lithologic and faunal great differences between the Takashima and Isahaya coal fields which are distant only 15 km at the part of neck of the peninsula to each other.

The early time of the Takashiman age: In this time, probably fluvial coarse-grained deposits very rarely having unionid fossils were formed nearly in the whole area, at some places intermitted by the deposition of purple shale, but the later time only the Takashima area was temporally suffered from the marine invasion by which some shells of Tertiary tropic brackish or littoral fauna including *Bellatara* ?, *Colpospira*, *Vicarya* etc. were first brought into west Japan. The subsidence of the basement at the time was especially remarkable near Takashima, where the thick non-marine deposits of about 1,000 m thick were formed, while there were only the nearly insignificant ones in every area of the Paleo-Ariake bay, represented by deposits of some deca-metres in thickness everywhere.

Hitherto, the lower part of the Takashiman stage has been discriminated from the middle and upper parts, called as the "Amakusa stage", from the view-point of the peculiar litho-facies, without no fossil evidence. But the writer is in the opinion that it is biochronologically better to unite them, so far as the upper Koyagian fossils and those of the "lower *Orthaulax* zone" are concerned, though there remains some problem on the attribution of the non-fossiliferous, middle and lower parts of the Koyagi formation.

The middle time of the Takashiman age: The marine water was first widely invaded in the gulf region in the earliest of the present time, but most areas were not so deep in the sea and more or less influenced also by the fresh water except a part of Amakusa. The conditions produced the characteristic littoral or brackish fauna of the so-called "lower *Orthaulax japonicus* zone" or near it, everywhere.

Just subsequently, the differentiation took place on the sedimentation of the both bays. That is to say, in the paleo-Takashima bay at Takashima sandstone and siltstone intercalating coal seams were formed in the brackish environment and at Sakito of the head of the bay probably fresh water rocks were formed. On the other hand, concerning the Paleo-Ariake bay, the marine thick siltstone attaining about 700–800 m thick was deposited in the large areas including Isahaya, Shimabara and Amakusa, while rather thin coarse-grained rocks containing coal seams alike those of Takashima were only formed in the brackish area of remainings, namely, Miike and Hokonoko, and moreover in the northern head (Asakura) probably fresh water sediments were deposited in small amount. The above-cited siltstone is generally poor in large animal fossils, but bears small foraminifers represented by abundant arenaceous forms (MURATA and MORINAGA, 1957). The fact may suggests that the areas occupied by the siltstone were not so intervened in the bottom current, where the molluscan faunae were more or less impoverished probably owing to their enclosed environment in the rather deep sea bottom.

The later time of the Takashiman age: The greater parts of the two bays changed as a whole to the environment of non-marine. There, deposits including many good coal seams were formed probably in the fresh water or oligohaline brackish estuary where *Corbicula* and *Bellamya* dwelled, but very rarely polyhaline forms such as *Faunus* ?, *Polinices*, "*Orthaulaux*", corbiculid etc. appeared in the result that the marine water was introduced.

Molluscan Fauna The molluscan fossils of the present stage number about 43 genera and about 50 species, and include most of genera of which species are represented in every stage of the Paleogene in west Kyushu and which are of

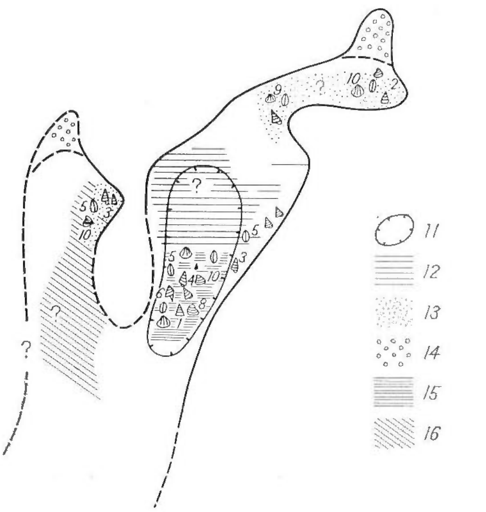
Table 6 Molluscan faunal list of the Takashiman stage (indetermined species very rarely occurred are excluded from this list)

Specific name \ Area	Takashima	Amakusa	Miike	Isahaya	Hokonoko
GASTROPODA					
Bellamya koyagiensis MIZUNO, n. sp.	H	·	·	·	·
Orectospira gemma (NAGAO)	·	S	·	·	·
Colpospira okadai (NAGAO)	K,F	S	Ko	·	·
C. tashiroi KOTAKA	·	S	·	·	·
Faunus nipponicus NAGAO	·	S	·	·	(×)
F.? miikensis NAGAO	F,H	·	Ko,N	·	(×)
F.? sp.	K,H	S	·	·	·
Bellatara ? sp.	K	·	·	·	·
Vicarya n. sp.	K	S	·	·	×
V. yabei KAMADA	H	·	·	·	·
Cerithiopsis sp.	·	S	·	·	×
Lunatia ? utoensis NAGAO	K	S	·	·	(×)
Polynices eocenica NAGAO	F,H	S,Ky	Ko,N	·	·
Nerita subgranulosa NAGAO	K	S	Ko	·	·
"*Orthaulax*" *japonicus* NAGAO	F,H	S,Ky	Ko,N	·	×
Pseudoneptunea ? sp.	·	Ky	·	·	·
Pseudoperissolax yokoyamai SUZUKI et ITO	·	Ky	·	·	·
Volutospina ? nishimurai (NAGAO)	·	Ky	·	·	·
Eopleurotoma higoensis (NAGAO)	K	S	·	·	·
Liroa paupercula (NAGAO)	·	S	·	·	·
PELECYPODA					
Yoldia sp.	·	Ky	·	·	·
Portlandia sp.	·	S	·	·	·
Acila sp.	·	·	·	·	×
Isognomon tomiyasui (NAGAO)	F	·	·	·	·
Anomia sp.	K	S	·	·	·
Pycnodonta cassis (NAGAO)	K,F	·	·	·	·
Cristaria sp.	K	·	·	·	·
Anodonta n. sp.	K	·	·	·	·
Crassatellites nipponensis YOKOYAMA	·	Ky	·	·	·
Venericardia nipponica YOKOYAMA	·	Ky	·	·	×
V. mandaica (YOKOYAMA)	·	Ky	·	·	(×)
Corbicula nagaoi SUZUKI	K,F	T	·	·	·
C. mirabilis NAGAO	·	·	·	Ke	·
C. sp.	K	·	·	·	·
Joannisiella problematica (NAGAO)	·	S	·	·	×
"*Lucina*" sp.	F	·	·	·	×
Vepricardium miikense (NAGAO)	·	·	Ko	·	·
Pitar hinokumai MIZUNO, n. sp.	F	S	·	·	×
P. n. sp.	F	·	·	·	·
Callista ariakensis (NAGAO)	·	S	·	·	×
Macoma sp.	F,H	S	·	·	·
Phaxas brevis (NAGAO)	F,H	·	·	·	×
Solena sp.	·	S	·	·	·
Caryocorbula subtumida (NAGAO)	F	S	·	·	·
Lentidium ? kyushuense (NAGAO)	K,H	S	T	·	×

Marks:
K ···Koyagi formation
H ···Hashima formation
Ky ···Kyoragi formation
Ko ···Komenoyama formation
N ···Nanaura formation
× ···Kannondake formation
F ···Futagojima formation
S ···Shiratake formation
T ···Toishi formation
To ···Toka formation
Ke ···Keya formation

importance for the Paleogene molluscan fauna of the area. The majority of the molluscs seems to be of very shallow marine and polyhaline brackish water and poor in the open sea element. Fresh water or oligohaline forms are only represented by several species of corbiculid, unionid and viviparid. The stratigraphic ranges of some species are more or less restricted to the certain horizon: for example: *Bellatara*? sp., *Anodonta* n. sp. etc. are to the upper part of the lower Takashiman; *Faunus nipponicus*, *Colpospira tashiroi*, *Cerithiopsis* sp., *Lunatia*? *utoensis*, *Pitar hinokumai* etc. are to the lower part of the middle; and *Vicarya yabei* and *Bellamya koyagiensis* are to the lower part of the upper. On the contrary, *Faunus*? *miikensis*, "*Orthaulax*" *japonicus*, *Polinices eocenica* etc. occur in nearly all parts, and the remainings occur mostly in the two adjoining parts. Among them, the first type may be not so important for the fauna of this stage, as they are also only represented by very small populations. The species which range to the above-lying Okinoshiman are represented only by those of *Venericardia*, *Crassatellites*, *Volutospina*?, *Pseudoperissolax*, "*Orthaulax*" etc., the other forms than the last being found rarely only in the marine siltstone of the Shiratake formation of Amakusa which also includes large foraminifers and in the "Tomiyama fossil bed" of the Kyoragi formation of the area.

It is more or less difficult to infer their paleo-ecologic features, because the informations of the ecology on recent animals can not be nearly adopted to them and also in many cases the molluscs of various habitats occur in fossils to be united at one locality. And only the followings may be noticeable, roughly speaking. The vertically widely ranged forms cited above are more or less ubiquitous and euryhaline, presented as facies breaking fossils.



1. *Vicarya*, 2. *Cerithiopsis*, 3. *Colpospira okadai*, 4. *C. tashiroi*, 5. "*Orthaulax*", 6. *Pseudoperissolax*, *Volutospina*, 7. *Venericardia*, 8. *Crassatellites*, 9. *Vepricardium*, 10. *Pitar*, 11. Area of large amounts of subsidence at the middle Takashiman age, 12. Area mostly of sandy silt bottom (probably poor in oxigen in neritic environment) at the middle Takashiman age, 13. Area mostly of sand bottom (mostly in brackish environment), 14. Area of fresh water at the middle Takashiman age, 15. Area where large foraminifers dwelled at the early and middle Takashiman ages (before the area was covered by silt of 12), 16. Area invaded by the marine water at the later time of the early Takashiman age

Fig. 6 Distributions of molluscs in the Paleo-gulf of Shiranuhi at the middle Takashiman age

Colpospira okadai and *Venericardia nipponica* are also found in variously grained rocks. The former was widely distributed in the various environments of the gulf, especially in the time when the "lower *Orthaulax* zone" was formed, but it probably flourished to grow large shells exclusively in the coarse-grained sand bottom somewhat influenced by fresh water at Amakusa where vicaryan shells also dwelled, and it was somewhat impoverished in quantity and also in growth in the rather fine-grained materials of shallow bottom under the polyhaline or marine water at Takashima and Miike.

On the other hand, another form of the genus, *C. tashiroi* was narrowly restricted in horizontal distribution. It is only found in Amakusa, never showing the co-existence with *C. okadai*, and there it occurs always from fine-grained sandstone together with "*Orthaulax*", *Portlandia* etc. The sandstone is situated at the transitional horizon between the lower, *C. okadai*-bearing coarse-grained sandstone of probably polyhaline brackish and the upper, marine siltstone poor in fossil. This may suggest that the optimum environment for the species was only that of marine fine sand bottom not nearly influenced by fresh water.

The other species restricted to certain bottom material, though rather widely distributed in the gulf, are shown by corbulids, vicaryds, *Phaxas* etc. The corbulids and *Phaxas* are abundantly found in the very fine-grained sand or sandy silt facies. *Vicarya yabei* is also so, but *V.* n. sp. is found in the medium- or coarse-grained sand facies.

IV. Okinoshiman Stage

IV. 1 Description of type column

The type formation is designated to the Okinoshima and the Lower Iojima formations lying conformably upon the former in the Takashima coal field.

The lower half of the type column, Okinoshima formation is found at Okinoshima, Takashima and Nakanoshima as a field exposure, besides it is exposed at the sea bottom near the islands and also in the galleries of Takashima and Iojima coal mines. Its lithology and molluscan fossils have been described in detail by many authors (SAKAKURA, 1953; TAKAHASHI and OHARA, 1955; KAMADA, 1957; OHARA, 1959; KOBAYASHI and KAMADA, 1959; OHARA, 1960), together with those of the type column of the Takashiman stage and of the Lower Iojima formation. According to the writer's observation (in HIROKAWA and MIZUNO, 1962; MATSUI and MIZUNO, MS.), it varies from 150 m to 300 m in thickness; nevertheless it is mostly composed of green-coloured, glauconite-bearing and fine-~medium-grained sandstone rich in sand pipe in general, exceptionally in the lower part with frequent intercalations of conglomerate, white-coloured medium-~coarse-grained sandstone and thin coaly shale, the part exhibiting remarkable lateral facies change. The fossils are especially rich in the upper part, but are also found in the basal or lower part, though rather rare. The fauna is characterized by much occurrences of large *Venericardia* represented by two species, *Volutospina? nishimurai*, *V. japonica*, *Nucula hizenensis* and *Pitar kyushuensis*.

The upper half of the type column, Lower Iojima formation is poor in fossils in contrast to the Okinoshima formation. It attains 380 m in maximum thickness at Okinoshima, bearing remarkable conglomerate bed at the lowest part. The rock changes upwards to sandstone of which most parts of the formation are composed and the uppermost part consists of coal-bearing sandstone. These rocks seem to present the soul sedimentary cycle as a whole. Molluscan fossils are very poor in this formation; that is, *Venericardia nagaoi* n. sp., *V. nipponica* (in the lower sandstone) and *Pseudoperissolax yokoyamai* (in the middle sandstone) have been only found (MATSUI and MIZUNO, MS.), but their occurrences seem to assure to unite the formation to soul stage with the Okinoshima formation.

IV. 2 Correlatives

The Kirimiya formation in the Isahaya coal field just northeast of the Takashima coal field is surely the correlative of the Okinoshima formation as considered by KAMADA (1957). The former is very similar to the latter in lithology and molluscan fauna except its lowest Saburaishi member which is composed of sandy siltstone. The Nagayo formation lying upon the Kirimiya is probably partly the correlative with the Lower Iojima formation from the stratigraphic viewpoint. Its lower part consists of coal-bearing alternation, far different from the Kirimiya, and no occurrence of fossil makes the correlation somewhat uncertain. But the occurrence of the fossils younger than this stage from its upper part (see the next chapter) will lead the above conclusion.

The Sakasegawa group in the Amakusa coal field is also of the present stage. It is mostly composed of siltstone called the Sakasegawa formation with large *Venericardia*, *Crassatellites nipponensis*, *Pseudoperissolax yokoyamai*, *Lima*, *Ctenamusium* etc. The glauconite-bearing sandstone similar to that of the Okinoshima formation is only at the basal 10 m or so in thickness. It is called the Itchoda formation and bears the same fossils as above.

The Manda group in the correlative is the Miike coal field, and it wholly consists of sandstone rich in marine fossils.

The total column of Kawamagari and Doshi formations in the Asakura coal field is somewhat similar to the type one of this stage; that is, according to NAGAO (1926–1928) and MATSUSHITA (1949), the Kawamagari formation consists of green-coloured sandstone with glauconite grains and yields many marine molluscan fossils, some of them being common to those of the Okinoshima formation, and in contrast to it the above-lying (with slight unconformity) Doshi formation is made of sandstone and siltstone with several coal seams, barren of fossil. Thus, the stratigraphic and lithologic relationship of the two formations roughly corresponds with that of the Okinoshima and Lower Iojima formations.

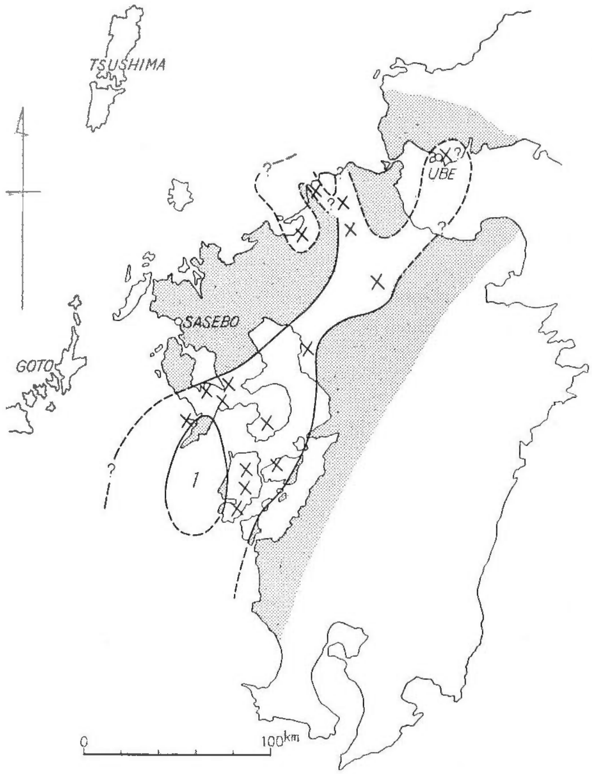
The rocks considered as the correlatives in the north Kyushu–west Japan district are the Nogata, Munakata, Kasuya and Fukuoka groups as discussed by MATSUSHITA (1949). These groups bear workable coal seams in some horizons and exhibit very different stratigraphic column, in addition of poorness of molluscan fossils. According to the previous contributions (NAGAO, 1926–1928, 1928b and MATSUSHITA, 1949), some fossil beds are recognized in the groups, but it is *prima facie* that the majority of the fossils is uncommon to those of Okinoshiman stage in the Hokusho–Amakusa district except some species of the lowest, "Yoshikuma fossil bed" of Nogata group. From the "Yoshikuma fossil bed", *Volutospina*? *nishimurai*, *Pinna asakuraensis* and *Eomiltha* sp. are reported; from the "Namazuta fossil bed", *Modiolus* sp., *Brachidontes* sp., *Ostrea kahoensis*, "*Cardita*" *katsumatai*, *Callista kahoensis*, *Cyclina nodai* etc. are reported; and from the "Kamiyamada fossil bed", *Brachidontes* sp., *Melanatria*? *kahoensis*, "*Cardita*" *katsumatai*, *Eomiltha* sp. and *Callista kahoensis* are reported.

Thus, it is highly probable that the lower part of the Nogata group and its correlatives at the district are at least of the Okinoshiman stage from the faunal evidence, but it is unfortunately doubtful whether its upper part including the "Namazuta" and "Kamiyamada fossil beds" is also of the stage or not, because their faunae are quite different from those of the type column. Nevertheless, here, the writer tentatively designates the whole Nogata group to the whole

Table 7 Molluscan fossils of the Okinoshiman stage at the Hokusho-Amakusa district

Occurrence / Specific name	Type column: Okinoshima formation: lowest part	Type column: Okinoshima formation: lower part	Type column: Okinoshima formation: upper part	Type column: lower Iojima formation	Kirimiya formation: glauconite-bearing sandstone	Kirimiya formation: Saburaishi member	Amakusa: Itchoda formation	Amakusa: Sakasegawa formation	Miike: Kachidachi and Yotsuyama formations	Asakura: Kawamagari formation
GASTROPODA										
Lischkeia sp.	·	·	·	·	·	·	·	·	×	·
Orectospira sp.	·	·	·	·	·	·	·	×	·	·
Colpospira yabei KOTAKA	·	·	c	·	·	·	·	·	·	·
Turritella sp.	·	·	·	·	·	a	·	·	·	·
"*Epitonium*" sp.	·	·	·	·	r	·	·	·	·	·
Polinices nomii NAGAO	·	n	·	·	·	·	·	·	·	·
Calyptraea sp.	·	·	r	·	·	·	·	·	·	·
"*Orthaulax*" *japonicus* NAGAO	·	n	·	·	·	·	·	·	·	n
"*Rimella*" sp.	·	·	·	·	·	·	·	·	·	n
Siphonalia asakuraensis (NAGAO)	·	·	·	·	·	·	·	·	·	n
Pseudoperissolax yokoyamai SUZUKI et ITO	·	·	r	r	·	·	·	·	×	·
Mazzalina ? *miikensis* (NAGAO)	·	·	kk	·	·	·	·	·	×	·
Volutospina ? *nishimurai* (NAGAO)	·	·	a	·	r	·	·	·	·	n
V. japonica (NAGAO)	·	n	c	·	k	·	·	·	·	·
Eocylichna takashimensis (NAGAO)	·	·	kk	·	·	·	·	·	·	·
PELECYPODA										
Saccella sp.	·	·	·	·	·	r	·	·	·	·
Nucula hizenensis (NAGAO)	·	·	a	·	r	·	·	·	·	n
Acila (*Truncacila*) sp.	·	·	·	·	r	·	·	·	·	·
Glycymeris sp.	·	·	·	·	c	·	·	·	·	·
G. cfr. *altoumbonata* NAGAO	·	n	·	·	·	·	·	·	·	·
Brachidontes sp.	·	·	·	·	r	·	·	·	·	·
Crenella striatocostata NAGAO	·	·	·	·	·	·	·	·	·	n
Lima amaxensis YOKOYAMA	·	·	·	·	·	·	×	·	·	·
L. kumasoana NAGAO	·	·	·	·	·	·	×	·	·	·
L. nishiyamai (YOKOYAMA)	·	·	·	·	·	·	×	×	×	·
Ctenamusium amakusense OMORI	·	·	·	·	·	·	·	×	·	·
C. inouei OMORI	·	·	·	·	·	·	·	×	·	·
Pinna asakuraensis NAGAO	·	·	·	·	·	·	·	·	·	n
Crassostrea sp.	c	·	·	·	·	·	·	·	·	·
Pycnodonta cassis (NAGAO)	·	n	·	·	·	·	·	·	·	·
Crassatellites nipponensis YOKOYAMA	·	·	·	·	·	·	×	×	×	·
Venericardia nipponica YOKOYAMA	·	c	c	r	k	·	×	×	×	·
V. nagaoi MIZUNO, n. sp.	·	·	·	a	·	·	×	·	·	n
V. okinoshimensis MIZUNO, n. sp	·	·	c	·	c	·	·	·	·	·
V. mandaica (YOKOYAMA)	·	·	·	·	k	? r	×	·	×	·
Eomiltha sp.	·	·	·	·	·	·	·	·	·	n
Pitar kyushuensis (NAGAO)	r	·	c	·	a	r	×	·	·	n
Callista mitsuiana (YOKOYAMA)	·	·	·	·	·	·	·	·	×	·
Mactra sp.	·	·	r	·	·	·	·	·	·	·
Angulus sp.	·	·	r	·	·	·	·	·	·	·
Psammotaea equideclivis (NAGAO)	·	n	·	·	·	·	·	·	·	·
Solena sp.	·	·	kk	·	·	·	·	·	·	·
Pholadomya "*margaritacea* SOWERBY"	·	·	kk	·	·	·	×	×	×	·
P. takashimensis NAGAO	·	·	kk	·	·	·	·	·	·	·
Periploma sp.	·	·	·	·	·	r	·	·	·	·
Teredo sp.	r	·	·	·	·	·	·	·	·	·

Marks: a……abundant, c……common, r……rare, n……after NAGAO (1928a and b), k……after KAMADA (1957), kk……after KOBAYASHI and KAMADA (1959). ×……after previous works and the writer's



×. Distribution of the Okinoshiman stage
1. Paleo-Nomo island

Fig. 7 Shore lines of the Paleo-gulf of Shiranuhi at the early and middle Okinoshiman ages

Okinoshiman stage, from the reasons that the upper part of the latter contains non-marine rocks with coal seams alike the former, and the lower part of the Otsuji group exhibits a transgressive facies alike the Funazuan.

IV. 3 Paleontologic remarks

Paleogeography and Sedimentation After the regression shown by the upper Takashiman prevailing in a large amount of non-marine facies, the marine water was invaded again in the region of Paleo-gulf of Shiranuhi. In this time, the shore lines were suffered from some modifications, though the geographic situation of the gulf in Kyushu was, roughly speaking, similar to that of the Takashiman age. The paleogeography of this time was reasonably presumed by KOBAYASHI and KAMADA (1959). That is to say, the Paleo-Takashima bay which was put into Sakito via Takashima from south in the preceding time disappeared for the upheaval of its northern half area. Moreover, the northern neck of the Paleo-Nomo peninsula which formed an available barrier for sedimentation in the Takashiman age subsided in the sea, and in the result, the peninsula changed to the island called the Paleo-Nomo island by KOBAYASHI and KAMADA (1959). This can be adequately inferred from the similarity of lithofacies, molluscan fauna, thickness etc. of the Okinoshiman stage in the both areas of Takashima and Isahaya. The third important modification was undergone at the head part of the gulf. The north Kyushu–west Honshu district was first invaded by the sea from southwest, and the gulf was extended to the north, Chikuho area and probably also to the northeast, Ube area. And moreover the areas in the vicinity of Fukuoka subsided possibly in the fresh water, sometimes connected with the Chikuho area.

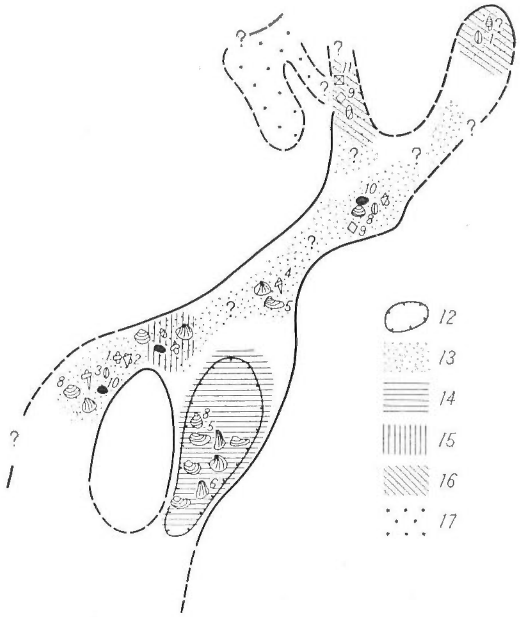
From the characteristics of sedimentation, three sedimentary areas are roughly recognizable in the whole area of the Okinoshiman stage. They are the Amakusa–Shimabara area, the remaining areas of the gulf including Takashima, Isahaya, Miike and Asakura, and the area of north Kyushu–west Honshu.

In the earliest time of the Okinoshiman age, nearly the whole area was submerged in the shallow sea and glauconite-bearing variously grained sand was deposited in the bottoms where many molluscs especially of large shells of pelecypods dwelled. Just subsequently the differentiation of sedimentation took place especially between the first and second areas. At the Amakusa–Shimabara was deposited the very thick siltstone of Sakasegawa formation, very similar to that of the Kyoragi formation, nearly having no mega-fossil but abundant small foraminifers. While, on the contrary, at the remaining most parts of the gulf, successively the glauconitic sand was deposited in the neritic bottom alike the earliest time. At the later time the coarse-grained materials including many gravels were brought into the majority of the area just mentioned and at the latest, these areas changed to the lagoonal environments forming coal seams. Nevertheless, through the times, in the Amakusa–Shimabara area fine-grained sediments were prevailing in the sea bottom, where animals probably could not dwell except smaller foraminifers.

The head part of the gulf was, through the whole times, probably influenced by fresh water, but sometimes invaded by marine water.

Molluscan Fauna The molluscan fossils of the stage number about 40 genera and about 50 species. In contrast to the Takashiman fauna, they are mostly represented by marine forms and the non-marines are only represented by some brackish water forms. The common species to the preceding stage are shown by *Pycnodonta cassis, Pseudoperissolax yokoyamai, "Orthaulax" japonicus, Volutospina? nishimurai, Crassatellites nipponensis* and *Venericardia nipponica* and the last three were more prevailing than in the preceding time. The common genera except the above-mentioned forms are not conspecific with Takashiman species. They are shown by *Colpospira yabei* which was considered by KOTAKA (1959) as the descendant of *C. tashiroi, Polinices nomii, Pitar kyushuensis, Callista mitsuiana* etc. A special notice should be given to the appearances of *Eomiltha, Mazzalina?, Nucula, Ctenamusium, Pholadomya, Lima* etc. in marine forms and the additional appearances of another species in *Volutospina* and large *Venericardia.*

The distributions of these molluscs were more or less regulated by the environmental factors. Marine shells are found from the nearly whole area especially at the lower horizon of the stage, except the fresh water basin near Fukuoka. Their majority is included in glauconitic medium-~fine-grained sandstone and their modes of occurrences in rocks show, roughly speaking, that the areas where shells buried after death were in their biotopes as suggested by KOBAYASHI and KAMADA (1959) as to the shells of *Pitar kyushuensis* and *Eosolen.*



1. *Volutospina japonica*, 2. *V.* ? *nishimurai*, 3. "*Orthaulax*", 4. *Pseudoperissolax*, 5. *Crassatellites*, 6. *Lima*, 7. *Venericardia*, 8. *Pitar*, 9. *Eomiltha*, 10. *Nucula*, 11. *Macoma yamadai*, *Brachidontes*, *Ostrea kahoensis*, *Callista kahoensis*, *Melanatria* ? *kahoensis*, 12. Area of large amount of subsidence in the Okinoshiman age, 13. Area mostly of sand bottom nearly throughout the age, where coal seams were formed in the latest time, 14. Area mostly of sandy silt bottom throughout the early-middle time, but of sand bottom in the earliest time, 15. Area of sandy silt bottom in the earliest time, 16. Area prevailed by the non-marine environment, 17. Area possibly of fresh water

Fig. 8 Distributions of molluscs in the Paleo-gulf of Shiranuhi at the early and middle Okinoshiman ages

The very prevailing sand dwellers throughout the gulf were large *Venericardia* and *Pitar kyushuensis*, but *Crassatellites nipponensis* and *Lima* were predominant only at Amakusa and Miike.

In sandy silt facies at Isahaya nearly simultaneously deposited with the sand facies of Amakusa, small shells of *Turritella* sp. (small form), *Saccella* sp. *Pitar kyushuensis*, *Periploma* sp. etc. dwelled together with abundant benthonic small foraminifers. On the other hand, in the sandy silt facies deposited in the long time just after the deposition of the sand at Amakusa *Lima*, *Venericardia*, *Crassatellites* etc. dwelled in the earliest time, but *Orectospira* sp. and *Ctenamusium* only rarely inhabited instead of them in its main time.

Brackish forms were rather rare in the Okinoshiman age. Majority of them did not dwell in the main part of the gulf, probably throughout the age, but dwelled in the head part of the gulf, especially as the Chikuho area. Brackish fauna of this age is characterized by the disappearances of *Bellatara* ?. *Vicarya*, *Faunus* etc. which flourished in the preceding age and also by the appearances of *Macoma*, *Brachidontes*, *Melanatria* ? etc.

Thus, the characteristic species and the rough communities may be given as follows.

Brackish forms....poorly represented only by *Melanatria? kahoensis*, *Modiolus* sp., *Brachidontes* sp., *Ostrea kahoensis* etc.

Marine fine-~medium-grained sand bottom forms....abundantly represented especially by *Pseudoperissolax yokoyamai*, *Volutospina? nishimurai*, *V. japonica*, *Nucula hizenensis*, *Crassatellites nipponensis*, *Lima nishiyamai*, *Venericardia nipponica*, *V. okinoshimensis*, *V. nagaoi*, *V. mandaica*, *Pitar kyushuensis*, *Pholadomya "margaritacea"* etc.

Marine sandy silt bottom forms....very poorly represented by *Turritella* sp., *Saccella* sp., *Ctenamusium amakusaense* etc.

V. Funazuan Stage

V. 1 Description of type column

The type column, the Funazu sandstone of the lower half of Upper Iojima formation at Iojima in the Takashima coal field, was studied by KAMADA (1957) and the writer (MATSUI and MIZUNO, MS.). According to them, the Funazu sandstone is 70–90m in thickness conformably upon the Lower Iojima formation, and its lowest part consists of conglomeratic sandstone with *Ostrea* bed, which gradually changes upwards to silty fine-grained sandstone or very fine-grained sandstone including many sand-pipes. The molluscan fossils as shown in Table 8 are richly comprised in this part, the majority of them being rather large pelecypods, and among them *Nucula hizenensis*, *Crassatellites matsuuraensis*, *Venericardia hizenensis* and *Pitar kyushuensis* are predominant.

V. 2 Correlatives

The Matsushima group in the Sakito coal field and the Ochi group in the Karatsu coal field can be considered to be synchronous with the Funazu sandstone from the faunal similarity, though the upper parts of the both groups bear non-marine rocks called Sakito and Yoshinotani formations poor in fossil, with workable coal seams. But, whether the parts are surely of the present stage or not is doubtful.

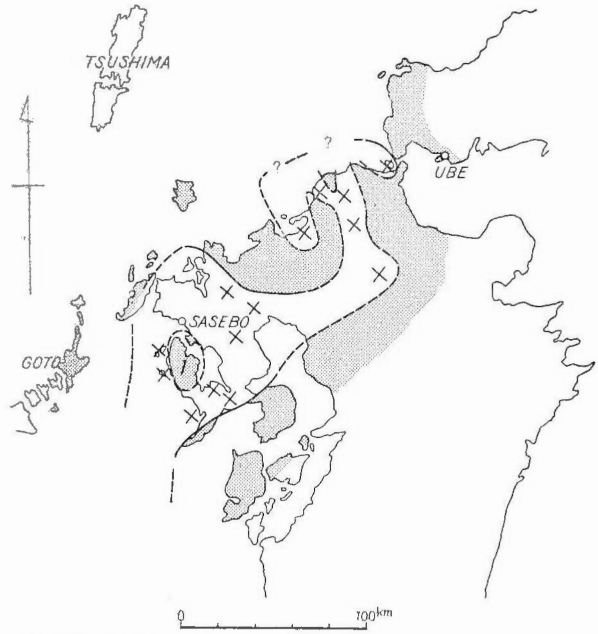
The Ichigojima formation, lower part of the Matsushima group, mostly consisting of sandstone and siltstone, is rich in the areal change of thickness. At Matsushima, attaining more than 100m in thickness, its lower half is composed of conglomerate and its upper half is of fine-~medium-grained sandstone (partly shell sandstone), from which the writer found the following fossils (St. MM01); *Clathrus submaculosus* (rare), *Glycymeris* cfr. *altoumbonata* (very abundant), *Chlamys sakitoensis* (abundant), *Crassostrea sakitoensis* (very abundant), *Venericardia hizenensis* (several) and *V. yoshidai* (rare). At Oshima, it is only 20m in thickness, with the basal shell conglomerate about 1m in thickness (NAGAO's lower *Pecten sakitoensis* zone), in which *Chlamys sakitoensis*, *Ostrea lunaeformis* and *Crassostrea sakitoensis* are crowded (St. OM02) and besides them *Pitar* cfr. *matsuraensis* and *Pitar yokoyamai* are found in the formation (St. H25). While, non-fossiliferous alternation of sandstone and siltstone is very predominant at Sakito. From the Sakito formation including workable coal seams, no marine

Table 8 Molluscan fossils of the Funazuan stage

Locality (lithology) / Specific name	Funazu sandstone (Takashima)				Nagayo formation (Isahaya)			Ichigojima formation (Sakito)		Kiuragi formation			Doshiyama formation (Asakura)	Yoshitani formation Sakito formation
	St. 160	St. 161 (vfs)	St. 154 (fs)	St. 157 (ms)	St. 45 (ms)	St. 41 (slt)	St. 46 (slt)	St. MM01 (cs)	St. OM02 (cg)	Lower-middle (fs)	Upper (vfs)	Uppermost (cs)		
GASTROPODA														
Turritella karatsuensis NAGAO	·	·	·	k	·	·	·	·	·	·	r	·	·	·
Clathrus submaculosus (NAGAO)	·	·	·	·	·	·	·	r	·	·	·	·	·	·
Ampullina nagaoi HATAI et NISHIYAMA	·	·	·	·	·	·	·	·	·	n	·	·	·	·
"*Orthaulax*" *japonicus* NAGAO	·	·	·	k	k	·	·	·	·	n	·	·	n	·
Rimella ? sp.	·	·	·	·	·	·	·	·	·	·	·	·	n	·
Cophocara sp.	·	·	·	·	·	·	·	·	·	·	·	·	n	·
Neptunea altispirata (NAGAO)	·	·	·	·	·	·	·	·	·	·	·	·	n	·
Siphonalia asakuraensis (NAGAO)	·	·	·	?k	·	·	·	·	·	·	·	·	n	·
S. ? sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Volutospina ? *nishimurai* (NAGAO)	·	·	·	·	·	·	·	·	·	·	·	·	n	·
V. japonica (NAGAO)	·	·	r	·	·	·	·	·	·	c	·	n	·	k
Volutilithes ? sp.	·	·	·	·	·	·	·	·	·	·	·	·	n	·
"*Turris*" sp.	·	·	·	·	·	·	·	·	·	·	·	·	n	·
SCAPHOPODA														
Dentalium sp.	·	r	·	·	·	·	·	·	·	·	·	·	·	·
PELECYPODA														
Nucula hizenensis NAGAO	·	a	c	·	·	·	·	·	·	·	·	n	·	·
N. mazeana MIZUNO, n. sp.	·	·	c	·	·	·	·	·	·	·	·	·	·	·
Glycymeris altoumbonata NAGAO	·	·	·	k	k	·	·	a	·	·	·	·	n	·
Cucullaea nipponica NAGAO	·	·	·	k	·	·	·	·	·	·	·	·	·	·
Noetia nagaoi MACNEIL	·	·	·	k	·	?c	?r	·	·	·	·	·	n	·
Brachidontes sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	r
Chlamys sakitoensis NAGAO	·	·	·	r	·	·	·	a	a	·	·	a	·	·
Crassostrea sakitoensis (NAGAO)	·	·	·	·	?c	·	·	a	a	·	·	a	·	r
Ostrea lunaeformis NAGAO	·	·	·	·	·	·	·	·	a	·	·	a	·	·
Crassatellites matsuuraensis NAGAO	·	·	c	·	·	·	·	·	·	n	·	·	·	·
C. asakuraensis NAGAO	·	·	·	·	·	·	·	·	·	·	·	·	n	·
Venericardia hizenensis NAGAO	·	a	a	·	·	·	·	c	·	c	·	?n	?n	·
V. yoshidai NAGAO	·	·	·	·	·	·	·	r	·	·	·	·	·	·
V. kondoi (NAGAO)	·	·	·	·	r	·	·	·	·	·	·	·	·	·
Corbicula mirabilis NAGAO	·	·	·	·	·	·	·	·	·	·	·	·	·	c
Fragum ? *kishimaense* (NAGAO)	r	r	r	·	·	·	·	·	·	·	c	n	·	·
Pitar matsuraensis (NAGAO)	·	r	·	·	·	·	·	·	·	?r	·	n	·	·
P. kyushuensis (NAGAO)	·	·	a	·	·	·	·	·	·	·	·	·	·	·
P. yokoyamai NAGAO	·	·	·	·	k	·	·	·	r	·	·	·	·	·
"*Tellina*" *tricarinata* NAGAO	·	·	·	·	·	·	·	·	·	c	·	·	·	·
Macoma yamadai NAGAO	·	·	?r	·	·	·	·	·	·	·	·	·	·	·
M. sp.	·	r	·	·	r	·	·	·	·	·	·	·	·	·
Angulus maximum (NAGAO)	·	·	·	·	·	r	a	·	·	·	·	·	·	·
Psammotaea ? *equideclivis* (NAGAO)	·	c	·	·	·	a	·	·	·	r	·	·	·	·
Panope sp.	·	r	r	·	·	·	·	·	·	·	·	·	·	·
Phaxas leguminoides NAGAO	·	?r	·	·	·	·	·	·	·	?r	·	·	·	·
Caryocorbula sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	r
"*Corbula*" sp.	·	·	r	·	·	·	·	·	·	·	·	·	·	·
Pholadomya "*margaritacea* SOWERBY"	·	·	r	·	·	·	·	·	·	·	·	·	·	·

Besides the listed species, in the Sakito formation *Phaxas*? sp. and *Modiolus* sp. are rarely comprised and in the middle part of Ichigojima formation at Oshima, *Pitar* cfr. *matsuraensis* is yielded.

Marks: a···abundant, c···common, r···rare, k···after KAMADA (1957), n···after NAGAO (1928b)



×. Distribution of the whole Funazuan stage

Fig. 9 Shore lines of the Paleo-gulf of Shiranuhi at the Funazuan age

fossil is found, but *Corbicula mirabilis* is rarely found (ref. figure 11).

Another fossiliferous correlative, Kiuragi formation is the lower half of the Ochi group in the Karatsu coal field. According to YAMAZAKI (1953), it tends to range from coarse-grained to fine-grained in litho-facies and from thin to thick southwards in its distributed area. It is mostly made up of variously grained sandstone with intercalation of thin siltstone at some places, and workable coal seam called the "Kiuragi-goshaku coal seam" are interbedded in its lower horizon. Some remarkable fossiliferous beds are recognizable in the formation, though the fossils such as *Venericardia hizenensis, Chlamys* sp. and *"Ostrea"* sp. are scattered in the parts between them, according to the writer's observation on the core of the bore hole near Kogayama by the Mitsubishi Mining Company. From the bed called *"Athleta japonica* zone" by NAGAO just above the cited coal seam, the writer discriminated in the core *Psammotaea? equideclivis, Venericardia hizenensis, Volutospina japonica, "Tellina" tricarinata, Pitar* cfr. *matsuraensis, Phaxas* cfr. *leguminoides* etc., besides them *"Orthaulax" japonicus, Ampullina nagaoi* and *Crassatellites matsuuraensis* have been reported from this bed by NAGAO (1928b). At the part about 100m above the bed (about 100m below the upper limit of this formation), *Fragum? kishimaense, Turritella karatsuensis* and cerithiid small fossil are yielded in green-coloured very fine-grained sandstone in the core just cited. Another fossil bed is near the uppermost part of the formation, in which the writer observed the crowded occurrence of *Ostrea lunaeformis, Crassostrea sakitoensis* and *Chlamys sakitoensis* at Kiuragi, and also NAGAO (1928b) reported *Volutospina japonica, Nucula hizenensis, Fragum? kishimaense, Pitar matsuraensis* and *Venericardia* cfr. *hizenensis* in the bed.

From the Yoshinotani formation such marine molluscs as *Volutospina japonica*, *Callista* and *Crassatellites* were reported near Kawako (KIHARA, 1960) and moreover *Crassostrea sakitoensis*, *Brachidontes* sp., *Caryocorbula* sp. were found in the above-mentioned core by the writer.

The correlative at the Isahaya coal field is considered to be the upper part of the Nagayo formation, though the boundary between the Funazuan and Okinoshiman stages is not defined precisely as formerly said. The molluscan fossils, as shown in Table 8 are reported from the part (KAMADA, 1957 and MATSUI and MIZUNO, MS.) and they seem to present a faunal evidence for the correlation.

The Doshiyama formation discriminated by MATSUSHITA (1949) from the NAGAO (1926-1928)'s Doshi formation is also of the Funazuan stage. It comprises many fossils according to them; they are related to those of the Funazu sandstone.

The appropriate correlation between the column of Chikuho coal field and the Funazu sandstone is difficult, owing to the remarkable difference of lithology at the both areas and poorness of fossil in the former. As briefly cited in the preceding chapter, the lower sandy part of the Otsuji group may be at least correlated with the Funazuan.

V. 3 Paleontologic remarks

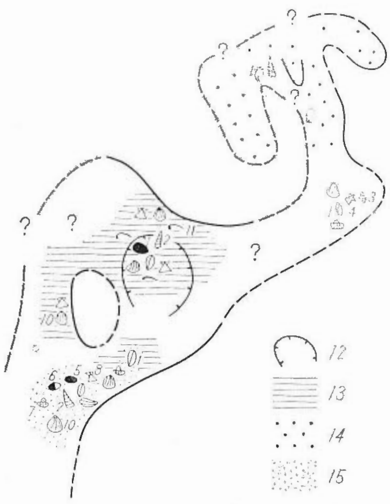
Paleogeography and Sedimentation At the latest time of the Okinoshiman age accompanied with the regression, the wide area of Amakusa which was successively under the sea through the preceding ages probably rose to land. On the other hand, in this age, the areas of Sakito and Karatsu far north of the area were first invaded by the marine water, but the area of the Nishisonogi peninsula remained probably as the island here called the Paleo-Nishisonogi island. In the result, the Paleo-gulf of Shiranuhi shifted northwards as a whole. The marine invasion especially shown by the appearances of new subsidence areas at the above-mentioned areas reached to the head part of the gulf, near Asakura and Chikuho, where the marine sand of this age was deposited upon the non-marine facies of the former age.

The Takashima area was at the earliest time a littoral bottom and was at the main time a neritic bottom where sand was deposited and many molluscs dwelled and the amount of subsidence was somewhat small, compared with those of the other areas as far as considered from the total thickness of rocks of this age. The Isahaya area just east of area and the Asakura area were also so.

On the other hand, the features at Sakito and Karatsu were considerably different from those just mentioned. There, in the early-middle times of the age, the sand was deposited in the littoral and neritic bottoms where many common species to those of the preceding areas inhabited, while in the later time, the areas changed to lagoonal environments where many good coal seams were formed and only some brackish water forms could dwell.

In the brackish head area of the gulf, including the coal fields of north Kyushu, marine water sometimes invaded, accompanying some molluscs conspecific to those of the other areas.

Molluscan Fauna The molluscan fossils of this stage number about 40 species. The majority of them is of marine, including littoral and neritic forms. Turritellid, pitarinid, carditid and crassatellitid are well represented as like as in the other stages. The characteristic species to this stage number only some among them. They are *Ampullina nagaoi, Neptunea asakuraensis, Cucullaea nipponica, Noetia nagaoi, Crassatellites asakuraensis, Venericardia hizenensis, "Tellina" tricarinata;* among them, the species other than *V. hizenensis* which was widely distributed in the gulf were more or less restricted to the certain area in their geographic ranges. The other forms are clearly conspecific to those of the lower, Okinoshiman and the upper, Mazean. The former is shown by *Siphonalia asakuraensis, Volutospina? nishimurai, Nucula hizenensis, Pitar kyushuensis, Psammotaea? equideclivis, Corbicula mirabilis* etc. and the latter is by *Turritella karatsuensis, Nucula mazeana, Chlamys sakitoensis, Ostrea lunaeformis, Crassatellites matsuuraensis, Venericardia yoshidai, Fragum? kishimaense, Pitar matsuraensis, P. yokoyamai* etc. Thus the present stage is paleontologically characterized by the coexistence of fossils exclusively yielded in it, those of the relics of the Okinoshiman fauna and those of the outriders of the Mazean fauna, and the fauna of the stage may be regarded as the transitional between the upper and lower faunae.



1. "*Orthaulax*", 2. *Turritella*, 3. *Volutospina japonica*, 4. *V.? nishimurai*, 5. *Nucula hizenensis*, 6. *N. mazeana*, 7. *Noetia*, 8. *Chlamys*, 9. *Crassatellites matsuuraensis*, 10. *Venericardia hizenensis*, 11. "*Tellina*", 12. Area of large amounts of subsidence, 13. Area where coal seams were deposited in the later time, 14. Area strongly influenced by the fresh water throughout the age, 15. Area only influenced by the marine water throughout the age

Fig. 10 Distributions of molluscs in the Paleo-gulf of Shiranuhi at the Funazuan age

The *Venericor*-type large venericards, *Pseudoperissolax, Crassatellites nipponensis* and *Colpospira* disappeared from the neritic sea bottom this age. Instead of them, *Venericardia hizenensis* which belongs to another stock of large venericard and *V. yoshidai* which is considered as the descendant of *V. mandaica* dwelled there, and *Crassatellites matsuuraensis* having Cretaceous anthonyan form and *Turritella karatsuensis* which is probably a migrative from the Indian region appeared.

The marine molluscan fossils of this stage are mostly included in sand facies alike in the Okinoshiman stage.

The fauna of gravel or coarse-grained sand bottom is represented by many individuals of *Chamys, Crassostrea, Ostrea* etc. and that of medium- to very fine-grained sand bottom of neritic is represented by Turritella, "*Orthaulax*", *Volutospina, Nucula, Crassatellites, Venericardia, Fragum?, Pitar* etc. *Glycymeris* is probably of medium- to coarse-grained sand bottom. The fauna of silt bottom is very poorly shown by *Psammotaea?, Angulus* etc. The brackish or fresh water shell is also very poorly represented by *Brachidontes, Caryocorbula, Corbicula* etc.

VI. Mazean Stage

VI. 1 Description of type column

The Maze formation (NAGAHAMA and MATSUI, 1958), the type column of this stage, once called Itanoura and Kakinoura formations by NAGAO (1926–1928) and MATSUSHITA (1949), is distributed at Matsushima, Seto, Sakito and on the east coast of Oshima, conformably covering the Sakito formation. It is divided into two parts (upper and lower parts), the upper part almost consisting of sandstone, poor in fossil. The lower half keeps conglomerate and coarse-grained sandstone at its lowest part which proves the abrupt change of environment from the non-marine coal-producing estuary to the littoral sea accompanied with the subsidence of basement. The lower half part mostly consists of very fossiliferous sandy siltstone and silty very fine-grained sandstone at Sakito, but is predominant in medium- and coarse-grained sandstones closely similar to those of the upper half part at Oshima, Matsushima and Seto. The molluscan fossils of the formation numbering about 25 species are characterized by the rich occurrences of *Turritella karatsuensis*, *Tropicolpus sakitoensis*, *Nucula mazeana*, *Crassatellites matsuuraensis*, *Venericardia yoshidai*, *V. subnipponica*, *Fragum*? *kishimaense* and *Pitar matsuraensis* generally in fine-grained rocks, but in general coarse-grained sediments bear many valves of *Glycymeris*, *Chlamys*, *Crassostrea*, *Barbatia* and *Crassatellites komodai*.

Fig. 12 Index map of the Sakito coal field

VI. 2 Correlatives

Correlative formations are found in the Karatsu, Isahaya and Takashima coal fields in the Hokusho–Amakusa district.

According to the previous many contributions, the Kishima formation, generally about 170–240 m in thickness conformably upon the Yoshinotani formation, consists of sandstone and siltstone rich in molluscan fossils, and there is the remarkable fossil bed called "upper *Pecten sakitoensis* zone" by NAGAO. The molluscan fossils of the bed number about 20 as shown in Table 9, according to the materials in hand, and their majority is common to the Maze formation.

The correlative formations in the Isahaya coal field are called the Yamaguchi and Araikiri formations (MATSUI and MIZUNO, MS.). The Yamaguchi lies upon

Table 9 Molluscan fossils of the Mazean stage

Locality / Specific name	Maze formation (Sakito)							Daimyoji member (Takashima)				Kishima formation (Karatsu)			Isahaya	
	St. M624 (ss)	St. M01 (vfs)	St. M04 (vfs)	St. M71 (vfs)	A	B	C	St. 159 (fs)	St. 156 (vfs)	St. 158 (sdy slt)	St. 155 (shell ss)	St. 541036 (sft)	St. Kuromuta	St. Monzen	Yamaguchi f.	Araikiri f.
GASTROPODA																
Orectospira takaii MIZUNO, n. sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	c	·
Turritella karatsuensis NAGAO	·	×	×	·	×	×	·	·	·	×	k	×	×	×	a	·
Tropicolpus sakitoensis (NAGAO)	·	×	·	·	·	·	·	·	·	·	·	·	×	·	?r	r
Mammilla insignis (NAGAO)	·	·	·	·	·	·	·	·	·	·	·	·	×	·	r	·
"*Orthaulax*" *japonicus* (NAGAO)	·	·	·	·	·	×	·	·	·	·	k	·	·	·	·	·
Siphonalia ? *nipponica* OYAMA et MIZUNO	·	·	·	·	·	·	·	·	·	·	·	·	×	·	·	r
Volutospina japonica (NAGAO)	·	·	·	·	·	·	·	·	·	·	·	·	×	×	r	·
Lyria endoi MIZUNO, n. sp.	×	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Turridae gen. et sp. indet.	·	·	·	·	·	×	·	·	·	×	·	·	×	·	a	r
SCAPHOPODA																
Dentalium ashiyaense NAGAO	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	r
D. n. sp.	×	×	·	·	·	·	·	×	·	×	·	·	·	×	c	·
PELECYPODA																
Saccella sp.	·	·	·	·	·	·	·	×	·	·	·	·	×	·	r	·
Yoldia sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·
Portlandia scaphoides (NAGAO)	·	×	·	·	×	·	·	·	·	·	·	·	·	·	·	·
Nucula mazeana MIZUNO, n. sp.	·	×	·	·	×	×	·	×	×	×	k	·	×	×	a	r
Acila nagaoi OYAMA et MIZUNO	·	·	×	·	·	×	·	×	·	×	·	·	×	×	r	c
Barbatia iesakai MIZUNO, n. sp.	×	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Glycymeris altoumbonata NAGAO	·	·	·	·	·	·	×	·	·	·	k	·	·	·	·	·
G. sp.	×	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Solamen subfornicatum (NAGAO)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·
Chlamys sakitoensis (NAGAO)	×	×	·	×	·	·	×	·	·	·	a	·	·	·	·	·
Crassostrea sakitoensis (NAGAO)	×	·	·	·	·	·	×	·	·	·	·	·	·	·	·	·
Crassatellites komodai OYAMA et MIZUNO	×	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
C. matsuuraensis NAGAO	×	×	·	·	×	×	·	·	·	·	k	·	×	×	·	·
Venericardia yoshidai NAGAO	×	×	×	×	×	·	×	×	·	×	k	·	×	·	a	a
V. subnipponica NAGAO	×	·	×	×	×	·	·	·	·	·	·	·	×	·	c	·
V. kondoi (NAGAO)	×	·	·	·	·	·	×	·	·	·	·	·	·	·	·	·
Fragum ? *kishimaense* (NAGAO)	·	×	·	×	×	×	·	·	·	×	×	·	×	×	a	c
Pitar matsuraensis (NAGAO)	·	·	×	·	×	×	·	×	·	×	k	×	×	·	a	c
Pitar yokoyamai (NAGAO)	×	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r
P. matsumotoi (NAGAO)	·	·	·	·	·	·	·	·	·	·	·	·	?×	·	·	·
Cyclina compressa NAGAO	·	·	·	·	·	·	·	·	·	·	·	×	·	×	r	r
Macoma sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·
Angulus maximus (NAGAO)	·	·	·	·	·	×	·	·	×	·	·	·	·	×	c	·
Panope sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r
Solen sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r
Pholadomya "*margaritacea* SOWERBY"	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	r
Thracia sp.	·	·	·	·	·	·	·	·	·	×	·	·	·	·	·	·
Periploma n. sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	c	r

Marks:

Stations: A…upper part of lower Maze formation at Oshima (from bore hole of the Nishiwata-uchi boring by the Oshima mine) (mainly very fine-grained sandstone-sandy siltstone)
B…middle and lower parts of lower Maze formation at Oshima (mainly sandstone)
C…upper Maze formation at the whole Sakito coal field (sandstone)

Occurrence: a…abundant, c…common, r…rare (marked rarely on shells of Isahaya coal field), k…after KAMADA (1957)

×. Distribution of the Mazean stage
1. Pale-Nishisonogi island

Fig. 13 Shore lines of the Paleo-gulf of Shiranuhi at the Mazean age

the Nagayo formation and consists of fossiliferous very fine-grained sandstone or sandy siltstone very similar to those of the main part of the Maze formation throughout the formation, attaining about 100 m in thickness. The molluscan fossils numbering about 30 in species are also common to those of the Maze formation, and alike the latter, *Fragum*?, *Pitar*, *Turritella* and *Venericardia* which are all conspecific with the Mazean species are very rich. The Araikiri formation covers the former and mostly consists of medium-grained sandstone. The molluscs are contained in its lower part. Their detailed occurrences from the about 30 stations are accounted in MATSUI and MIZUNO (MS.).

The Daimyoji member of the upper part of Upper Iojima formation is also correlated with the Maze formation. It rests upon the Funazu member, the type of the Funazuan stage, consisting of siltstone and sandstone with 15 species of molluscs all of them common to those of the above-mentioned formations (MATSUI and MIZUNO, MS.). Its uppermost limit is unknown below the sea level.

The present stage in the north Kyushu–west Honshu district seems to be represented by the Onga formation of the upper part of Otsuji group in the Chikuho coal field. Recently, the writer (MIZUNO and TAKAHASHI, 1962) discovered the molluscan fossils numbering 13 species from the vicinity of Katsuki, Wakamatsu city. Amongst them, the specifically determined fossils are all conspecific with those of the Mazean at the Hokusho–Amakusa district, being represented by *Nucula mazeana*, *Venericardia subnipponica*, *V. yoshidai*, *V. kondoi* and *Cyclina compressa*. The authors concluded that the Onga formation is the correlative of the Mazean, on the bases of the faunal similarity and the stratigraphic relationship between the Onga and Yamaga formations, the latter of which is characterized by the Nishisonogian fauna.

VI. 3 Paleontologic remarks

Paleogeography and Sedimentation There is no evidence to prove that the eastern internal part of the gulf at the preceding age was also extensively submerged below the sea at the Mazean age, and the area probably rose to land from the end of the preceding age to the present age. The marine sedimentary basin of this age was nearly restricted to the northwest area of Kyushu, and the shore lines of the gulf were probably similar to those of the preceding age except the above-cited area. In the early time of the age, the deposition of very fine-grained sand or sandy silt was prevailing at the most bottoms of the gulf, but variously grained sand was deposited at the area ajoining to the shore especially at Sakito and Karatsu. While, at the later time sand was deposited all over the bottom of gulf.

Nearly throughout the age, the north Kyushu district including the areas of Chikuho and Fukuoka was under the fresh water and coal seams were formed there, sometimes invaded by marine water which brought there some molluscs, as shown by the marine fauna of the Onga formation. The marine invasion probably took place from west, but not from south as in the case of the preceding age.

Molluscan Fauna The molluscan fossils number about 40 species in this stage. They are nearly all of marine. The species shown as a outrider in the preceding age dwelled abundantly in the gulf in this age, and adding to them, the followings appeared as the important member of fauna; *Tropicolpus sakitoensis, Mammilla insignis, Lyria endoi, Siphonalia? nipponica, Acila nagaoi, Portlandia scaphoides, Crassatellites komodai, Venericardia subnipponica, Cyclina compressa* etc. Also, the much occurrence of turrid molluscs, though their genera and species are indeterminable, are noticeable.

Among the molluscs, *Turritella karatsuensis, Nucula mazeana* which is considered as the descendant of *N. hizenensis, Acila nagaoi, Crassatellites matsuuraensis, Venericardia yoshidai, Fragum? kishimaense* and *Pitar matsuraensis* were very abundant at the nearly whole area of the gulf showing their much occurrences everywhere in the both sand and silt facies.

In the fauna, the forms exclusively abundantly yielded in coarse-grained facies and considered originally as the sand or gravel dweller are represented by "*Orthaulax*", *Barbatia, Glycymeris, Chlamys, Crassostrea, Venericardia kondoi* etc. While, the other most species are found in the both fine-grained sand and more fine-grained rocks as shown in Table 9.

VII. Nishisonogian Stage

VII. 1 Description of type column

The type column is designated to the Nishisonogi formation at Sakito and Oshima in the Sakito coal field. The name, Nishisonogi formation, is given for several formations of "Nishisonogi group" proposed by NAGAHAMA and MATSUI

Table 10 Molluscan fossils of the Nishisonogi formation

Locality / Specific name	Tokuman member														Yuritake member		Shioda member					Higire member
	M5	MM1, slt	MM2, slt	M10, sltyss	M7, ms	M1, ftf	M2, slt	M3, tf	M3, sltyvfs	M03, sdyslt	IN50, ss	IN157, tf	IN179, ss	M50	M67, vfs	O105, fs	M52	M64	M618	M08	M685 ms	M30, vfs-sdyslt
GASTROPODA																						
Bathybembix sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	×	r	·	·	·	·	·
Turritella infralirata NAGAO	·	·	r	·	·	r	·	·	·	r	·	·	·	·	·	·	r	·	·	·	·	·
T. tokunagai YOKOYAMA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·
Clathrus submaculosus (NAGAO)	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·
Euspira ashiyaensis (NAGAO)	·	·	·	·	r	·	·	·	·	r	·	·	·	·	·	·	·	·	·	c	·	r
Calyptraea sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	r	·	r	·
Ancistrolepis chikuzenensis (NAGAO)	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	r	·	·	r
A. cfr. *modestoideus* (TAKEDA)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·
Neptunea cfr. *dispar* TAKEDA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·
Siphonalia? supragranulata NAGAO	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r
Molopophorus sp.	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·
Pseudoperissolax iesakai OYAMA et MIZUNO	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	c	·	·	·	·	·
Fusinus sp.	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	×	·	·	·	·	·	·
Fulgoraria sp.	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	×	·	·	r	·	·	·
"*Turris*" sp.	·	·	·	·	·	·	·	r	·	r	·	·	·	·	·	·	·	·	·	·	·	·
SCAPHOPODA																						
Dentalium ashiyaense NAGAO	·	·	·	·	r	·	·	·	·	r	·	·	·	·	·	·	r	·	·	·	·	·
PELECYPODA																						
Saccella sp.	·	·	r	·	·	·	·	·	·	r	·	·	·	·	·	·	r	·	·	·	·	·
S. n. sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	c	·	·	·	·	·
Yoldia laudabilis YOKOYAMA	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	r	r	·	·
Portlandia scaphoides (NAGAO)	·	·	·	·	·	·	·	·	·	c	·	·	·	r	·	·	·	·	·	·	·	·
Acila nagaoi OYAMA et MIZUNO	·	·	c	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
A. ashiyaensis NAGAO	·	·	·	·	·	·	·	·	·	·	·	·	·	c	·	·	a	·	·	c	·	r
A. hirayamai MIZUNO, n. sp.	·	·	·	·	·	·	r	r	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Clycymeris sp.	a	a	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Septifer nagaoi OYAMA	·	·	·	·	a	·	·	·	·	·	×	·	·	·	·	·	·	·	·	·	a	·
Solamen subfornicatum (NAGAO)	·	·	·	·	r	·	·	·	·	r	×	r	·	·	·	·	·	·	·	r	·	r
Ctenamusium takaii MIZUNO, n. sp.	·	·	·	·	·	·	·	·	·	r	·	a	·	·	·	·	·	·	·	·	·	·
Chlamys ashiyaensis (NAGAO)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	×	·	·	·	·	·	·
C. cfr. *rutteni* (MARTIN)	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lima nagaoi OYAMA	·	·	·	·	·	·	·	·	·	r	·	·	a	·	r	·	r	·	·	a	·	·
Ostrea lunaeformis NAGAO	·	·	·	·	·	·	·	·	·	r	×	·	·	·	·	·	·	·	·	·	·	·
O. sp.	a	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Crassatellites n. sp.	·	×	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
C. inconspicuus NAGAO	·	·	·	·	a	c	·	a	·	r	·	·	·	·	·	·	·	r	a	·	r	c
Venericardia vestitoides MIZUNO	·	·	·	r	a	a	r	a	r	·	·	·	·	·	r	·	·	·	·	·	·	·
V. yoshidai NAGAO	×	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
V. subnipponica NAGAO	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	a
V. harukii OYAMA et MIZUNO	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·
V. japonica MIZUNO	·	·	·	·	r	·	·	·	r	·	·	·	·	·	r	·	·	·	·	·	·	·
Lucinoma nagaoi OYAMA et MIZUNO	·	·	·	·	r	·	·	·	·	r	·	·	·	·	·	·	r	·	·	·	·	·
Pitar yokoyamai (NAGAO)	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
P. matsumotoi (NAGAO)	·	·	·	c	·	·	·	r	·	r	·	·	·	·	·	·	·	·	·	·	·	·
Callista hanzawai (NAGAO)	·	·	·	a	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	c	·	r
Macoma cfr. *asagaiensis* MAKIYAMA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	r	·	·	·
Periploma iesakai OYAMA et MIZUNO	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·
Pandora sp.	·	·	·	·	·	·	·	·	·	r	·	·	·	·	·	·	·	·	·	·	·	·

(1958) except its lowest part, Maze formation. The present formation lies generally conformably upon the Maze, type formation of the Mazean stage, but in the northwestern coastal area of the Nishisonogi peninsula it covers the Pre-Tertiary metamorphic complex with unconformity, where the Paleogene stages lower than this stage are lacking for non-deposition.

The Nishisonogi formation, attaining 400–500 m thick consists of marine, fossiliferous deposits of sandstone and siltstone, being accompanied with thin hard tuff called "Honeishi" in its lower part. The following five members in upper and lower relationship, each of which was named by NAGAHAMA and MATSUI (1958) or NODA and SUJAKU (1955) in a qualification of "formation", are discriminated in it, in ascending order, although they are very rich in the lateral change of litho-facies and in result an appropriate subdivision is rather difficult. The molluscan fossils richly comprised in them are shown in Table 10; they number about 50 species.

Tokuman tuffaceous alternation — Having thickness of 100–150 m in general, its lower part mainly consists of sandstone and its upper part consists of siltstone; however, its middle part is predominant in the "Honeishi" which was qualified as a silicified and carbonatized quartz-andesitic crystal vitric tuffite by YAMAZAKI, MATSUMOTO and TOMITA (1959). In this member, the molluscan fossils are found in large amount, among them the following being representatives; *Septifer nagaoi, Lima nagaoi, Ctenamusium takaii, Crassatellites inconspicuus, Venericardia vestitoies, Pitar matsumotoi, Callista hanzawai* and *Turritella infralirata*. Besides, such calcareous algae as *Archaeolithothamnium* sp. *Lithothamnium* sp. and *Lithoporella melobesioides* are yielded especially in the lower and middle parts (NODA and SUJAKU, 1955).

Yuritake alternation — Consisting of irregular alternation of sandstone and siltstone, it attains about 130 m thickness. Shell fossils are rather rare.

Shioda sandstone — Consisting of massive sandstone with an intercalation of tuff, it attains about thickness of 50 or 60 m, and includes many molluscan fossils, the representatives being as follows; *Acila ashiyaensis, Lima nagaoi, Chlamys ashiyaensis, Crassatellites inconspicuus* and *Pitar matsumotoi*; rarely *Septifer nagaoi* is crowded in some parts of this member with *Crassatellites inconspicuus* alike in the lower part of Tokuman member.

Higire siltstone—Mostly consisting of dark gray siltstone rich in foraminiferal fossils and numerous thin beds of fine sandstone, it attains a thickness more than 90 m. Shell fossils are rather rare in this member but at some places they are crowded in siltstone or very fine-grained sandstone gradually changed from the former. *Venericardia subnipponica, Crassatellites inconspicuus* are very abundant amongst them.

Katashima alternation — Found only in submarine exposures northwest of Oshima, it consists of alternation of white sandstone and siltstone of about 150 m thickness, according to NODA and SUJAKU (1955). Fossils are not yet found from this member.

VII. 2 Correlatives

The Karatsu formation in the Karatsu coal field and the Hirakoba formation in the Isahaya coal field are surely correlated with the Nishisonogi formation in the Hokusho–Amakusa district from lithologic and paleontologic evidences.

Table 11 Molluscan fossils from the Karatsu formation
(after previous works and data at hand)

Specific name \ Occurrence	Sari			Yukiaino		Hatatsu ss			Hatatsu sh
	l	m	u	l	u	l	m	u	l
GASTROPODA									
Turritella infralirata NAGAO	×	×	·	·	·	·	·	·	·
Euspira ashiyaensis (NAGAO)	·	·	·	×	·	·	·	·	·
Ancistrolepis ? sp.	·	·	·	·	×	·	×	·	·
Siphonalia ? *supragranulata* NAGAO	×	·	·	·	·	·	·	·	·
Fulgoraria sp.	·	·	·	·	·	×	·	·	·
PELECYPODA									
Yoldia laudabilis YOKOYAMA	·	·	·	·	·	×	·	·	·
Y. sobrina TAKEDA	·	·	·	·	·	·	×	·	·
Portlandia scaphoides (NAGAO)	·	·	·	·	·	×	·	·	×
P. thraciaeformis (STORER)	·	·	·	·	·	·	·	·	×
Acila ashiyaensis (NAGAO)	·	·	·	×	·	×	×	·	·
Glycymeris sp.	×	·	·	·	·	·	·	·	·
Solamen subfornicatum (NAGAO)	·	×	·	×	×	×	·	·	·
Septifer nagaoi OYAMA	×	·	·	·	·	·	·	·	·
Lima nagaoi OYAMA	·	·	×	×	·	·	·	·	·
Chlamys ashiyaensis (NAGAO)	×	·	·	·	×	×	·	·	·
Palliolum sp.	·	·	·	·	×	·	·	·	·
Ctenamusium sp.	·	·	·	·	·	·	·	·	×
Ostrea lunaeformis NAGAO	·	·	·	×	·	·	·	·	·
Crassatellites inconspicuus NAGAO	×	·	×	·	·	·	·	·	·
Venericardia vestitoides MIZUNO	×	·	·	×	×	·	·	×	·
V. japonica MIZUNO	·	·	·	·	·	×	·	·	·
V. yoshidai NAGAO	?	·	·	·	·	·	·	·	·
Lucinoma nagaoi OYAMA et MIZUNO	·	·	·	·	×	·	×	·	·
Callista hanzawai (NAGAO)	×	·	·	×	×	·	·	·	·
Pitar matsumotoi (NAGAO)	×	·	·	×	·	·	·	·	·
Periploma iesakai OYAMA et MIZUNO	·	·	·	×	×	·	·	×	·

Abbreviations: l, lower part; m, middle part; u, upper part

The Karatsu formation* exhibits its wide distribution in the Karatsu coal field, conformably overlying the Kishima formation and attaining the thickness more than 1,000 m. Its molluscan fossils at hand and hitherto reported are very similar to those of the Nishisonogi formation, predominant in *Turritella infralirata*,

* The remaining thick part of the Kishima group except its lowest, Kishima formation, is rich in the lateral change of litho-facies and stratigraphic sequence, and in result its subdivision was hitherto proposed by many authors in so various ways that a synthetic discussion on the Kishima group is made rather difficult. Therefore the name of Karatsu formation was proposed to the part for the convenience to discuss the geohistory and biochronology of the Kishima group.

Acila ashiyaensis, Solamen subfornicatum, Septifer nagaoi, Chlamys ashiyaensis, Crassatellites inconspicuus, Venericardia vestitoides, Pitar matsumotoi and *Callista hanzawai*; they are listed in Table 11. The formation has been up to today investigated in detail by many authors; NAGAO (1926–1928), MATSUSHITA (1949), YAMAZAKI (1953), YAMAZAKI and MORINAGA (1954), NODA and SUJAKU (1955), KOBAYASHI *et al.* (1956), TAKAHASHI *et al.* (1957), IMAI *et al.* (1958), INOUE 1958); besides them, YAMAZAKI (1959) published his opinion on the correlation between it and Nishisonogi formation in detail, to which the writer's view on the subject largely owes. According to their contributions, the formation can be subdivided into four members throughout the whole Karatsu coal field, though they are fairly different at some places in their litho-facies.

Sari alternation — This is the counter part of the Tokuman member of the Nishisonogi formation from its lithologic and paleontologic evidences; at the area typically developed, it consists, in ascending order, of sandstone with *Septifer, Crassatellites, Pitar* and *Callista*, of the "Honeishi" and of siltstone. The total thickness attains more than 200 m, and among the three members the last tends to become thick southwards.

Yukiaino sandstone — Conformably overlying the preceding member, it consists of massive sandstone which also yields many molluscan fossils and is almost correlated with the Yuritake member.

Hatatsu sandstone — It consists of muddy sandstone and siltstone with tuffaceous intercalation and remarkably yields two species of *Yoldia*.

Hatatsu shale — At the uppermost part of the Karatsu formation, it is rather poor in fossil; its main part is composed of siltstone alike the Higire member which is almost the correlative of this member, but its upper part of about 70 m thickness consists of alternation of ripple-marked sandstone and siltstone, showing the gradual transition to the above-lying Sasebo group at the top.

The Hirakoba formation is another correlative with the Nishisonogi formation. It is located near Nagayo in the northwestern part of the Isahaya coal field and also is, according to H. KAMISHIMA's oral communication, found at Hikishima near Isahaya. According to the writer's survey (MATSUI and MIZUNO, MS.), it covers conformably the underlying formation of the Mazean stage, and mostly consists of siltstone with intercalations of thin tuff beds identified to the "Honeishi", attaining more than 300 m thick. The fossils are poor in this formation, however the followings, the majority of which is not comprised in the Mazean stage but in the Nishisonogian, are rarely included in a sporadical occurrence; *Clathrus submaculosus, Orectospira wadana, Turris* ? sp., *Dentalium ashiyaense, Acila ashiyaensis, Portlandia* cfr. *scaphoides, P.* n. sp., and *Ctenamusium takaii* n. sp. From the above-mentioned stratigraphic and paleontologic evidences, it is no doubt that the present formation is of the Nishisonogian.

The Ashiya and Meinohama groups in the north Kyushu–west Honshu district are also considered to be of this stage. The Ashiya group is found in the Chikuho and Kokura coal fields and in the Yuyawan area. The type Ashiya group at the northern area of the Chikuho coal field conformably overlies the Mazean Otsuji group and is divided into three parts, namely, the Yamaga, Sakamizu and Waita formations in ascending order. These consist mainly of marine fossiliferous sandstone intercalated with thin siltstone beds, attaining about 600 m in thickness. The molluscan fossils collected and identified by the writer at the coastal area

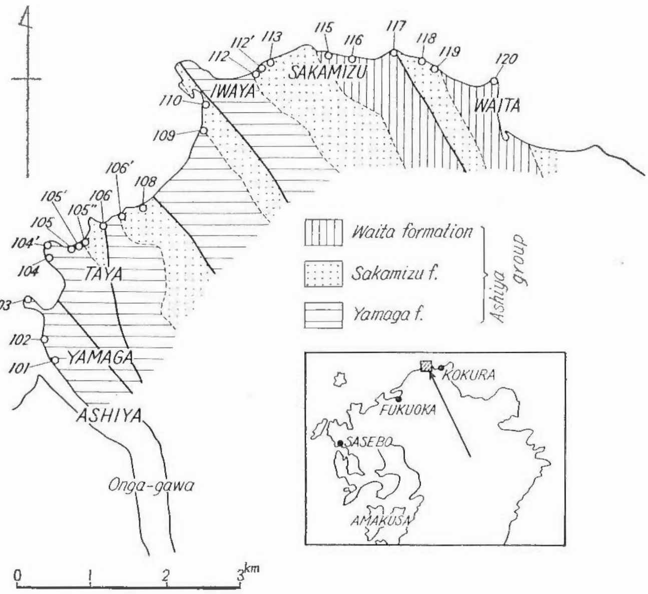


Fig. 14 Sampling localities at the type Ashiya area, with geologic map after MATSUSHITA (1949)

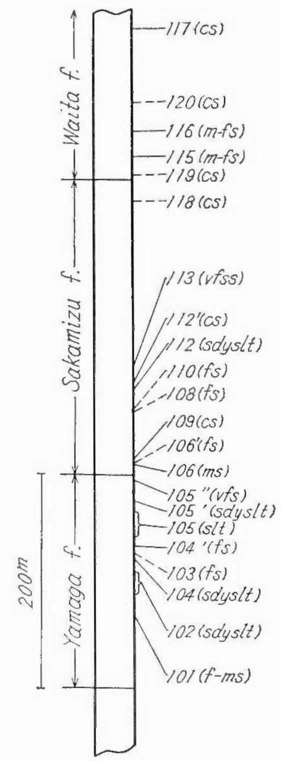


Fig. 15 Rough stratigraphic situation of each locality in the Ashiya group

near Ashiya are shown in Table 12, together with those reported by NAGAO (1928b) and those from the Ashiya group at Hikoshima of the Kokura coal field and the Yuyawan area.

The Yamaga formation has been considered as the correlative of the Maze formation (NAGAO, 1926–1928; MATSUSHITA, 1949), but its fossils suggest that it should be correlated to the Nishisonogi formation.

At the Kokura coal field which is east of the Chikuho coal field, the fossiliferous Asiya group of marine is also developed conformably upon the Otsuji group, mainly consisting of sandstone of about 500 m thickness (IWAHASHI and OHARA, 1959). Its molluscan fossils were reported by HIRAYAMA (1955) (on those at Hikoshima) and MURATA and MOKUDAI (1959) (on those at Ainoshima). According to the former, among 31 species from Hikoshima, 22 species are specifically determined and among the latter the remaining species except the following 6 species are common to the type Ashiya group (especially with the Sakamizu and Waita formations); *Yoldia hikoshimensis, Crassatellites pauxillus, Macoma nagaoi, Semicassis kanmoensis, "Nassarius" shojii* and *Antillophos fusiforme.*

The Ashiya group is also found near Yuyawan at the west extremity of Honshu (IMAMURA and OKAMOTO in OKAMOTO, 1960). According to the writer's observation who had once a chance to study IMAMURA and OKAMOTO's collection, its marine molluscan fossils rich in Sakaigawa formation and Taoyama formation exhibit a strong similarity to the type Ashiya fauna.

In M. INOUE's collection from the green sandstone of Meinohama formation near Fukuoka city, the following molluscan fossils were found; *Euspira ashiyaensis, Fulgoraria* sp., *Glycymeris compressa, Septifer nagaoi, Solamen subfornicatum,*

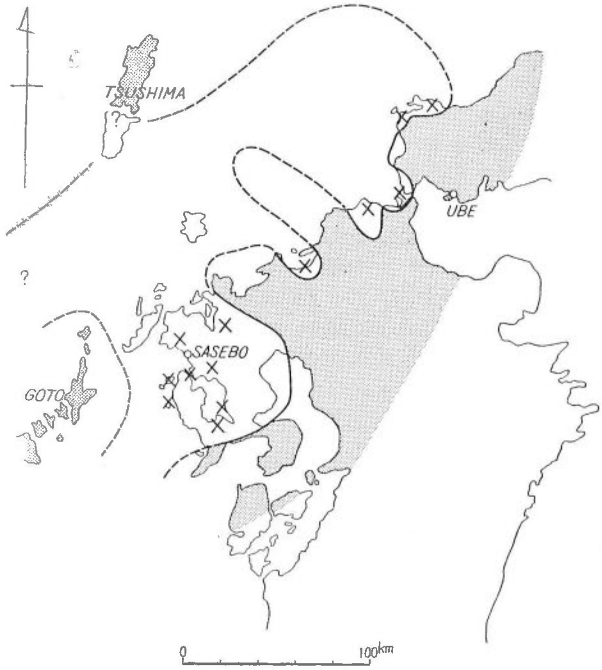
Table 13 Stratigraphic sequence at the Yuyawan area after IMAMURA and OKAMOTO in OKAMOTO (1960)

Yuyawan group		(middle Miocene)
Hitomaru formation		......fs, sh, tuff with molluscan fossils, 450 m th.
Ashiya group	Taoyama formation	......sh, fs, with molluscan fossils, 390 m th.
	Ouchiyama formation	......tuff, 180 m th.
	Sakaigawa formation	......cg, cs, sh with molluscan fossils, 240 m th.

Crassatellites inconspicuus, *Venericardia vestitoides*, *Diplodonta confusa*, *Lucinoma nagaoi*, *Pitar matsumotoi*, *Callista hanzawai*, *Spisula* sp., *Parapholas satoi* and so on. These fossils evidence its Nishisonogian age.

VII. 3 Paleontologic remarks

Paleogeography and Sedimentation The remarkable feature of paleogeography of this age was the large extension of the sea at the north Kyushu–west Honshu. The Chikuho, Kokura and Fukuoka areas which had been predominant in the non-marine environment in the preceding ages were extensively invaded by the sea and subsided under the marine water, and also the Yuyawan area which had been the land throughout the preceding ages was first suffered from the



×. Distributions of the Nishisonogian stage

Fig. 16 Shore lines of the Paleo-gulf of Shiranuhi at the Nishisonogian age marine invasion. The transgression shown by these features has been called the so-called "Ashiya marine invasion". On the other hand, the shore lines in the northwest Kyushu area were almost similar to those of the preceding age, but accurately speaking, the Paleo-Nishisonogi island was subsided below the sea to make rather uniform deposits around the area especially at the early time of the present age. Thus the Paleo-gulf of Shiranuhi at this age was much extended roughly from southwest to northeast on the northwest of Kyushu.

In spite of the wide marine invasion of this age, the Hokusho-Amakusa district was significantly different in sedimentation from north Kyushu-west Honshu districts throughout the whole age. In the Hokusho-Amakusa district is found a remarkable lateral change of litho-facies of the Nishisonogian stage, which has been summarized recently by YAMAZAKI (1959). However, roughly speaking, as a whole throughout the whole area in the earliest time, medium-~coarse-grained sand at some places accompanied with pebble was deposited, and nearly simultaneously and continuously just afterwards quartz andesitic tuff shown by the "Honeishi" was deposited. Next, silt was deposited mainly in the central and southern parts. In the medial time of the age the depositions of sands of various types were prevailing in the whole area. However, its certain type tended to be restricted in certain area; for example, "Komanaki type" sand was deposited only in the northern part. The sediments of the last time of the age are represented by siltstone, and those of the latest time are shown by sand and silt often showing a slumping structure.

On the other hand, in the north Kyushu-west Honshu district, the deposition of sand was very prevailing throughout the age, though it was at some places intermitted by that of silt or sandy silt especially in the time of the Yamaga.

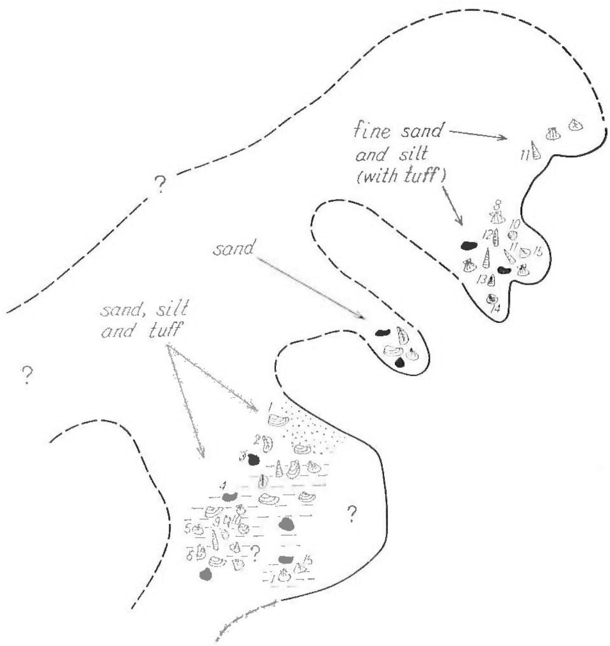
Molluscan Fauna The molluscs of this stage number about 50 genera and 90 species in total, and are the most abundant among the whole stage of the west Japan. They consist mostly of marine species, with a few brackish forms, and no fresh water form is found. The composition of the fauna is considerably different from that of the Mazean, though some species of the latter such as *Acila nagaoi, Venericardia yoshidai* etc. are rarely comprised in the lowermost of the present stage at Sakito and Karatsu. The remarkable features of the present fauna are as follows.

1. Extinctions of some genera and subgenera. The stage is first characterized by the non-occurrences of some genera and subgenera which occupy the important part in the stages lying below. They are shown by "*Orthaulax*" and *Volutospina* among gastropods and by *Venericardia* s. str. and large *Venericardia*, or by some of the other "Eocene" genera.
2. Appearances of new genera or subgenera to the west Japan or more abundant occurrence of them than in the below lying stages. They are indicated by *Hataiella, Fulgoraria, Ancistrolepis, Neptunea,* etc. among gastropods and by *Yoldia, Portlandia, Acila* s. str. *Septifer, Chlamys, Pecten, Cyclocardia, Lucinoma, Clinocardiam, Dosinia, Spisula,* etc. The majority of them is abundantly found in the Neogene fauna of Japan, and some of them are evidently of the northern Pacific form.
3. The remaining most genera or subgenera show remarkable replacements

of species with those of the Mazean. For example, in *Crassatellites*, *C. inconspicuus* and *C. yabei* are found, instead of *C. matsuuraensis*; in *Pitar*, *P. matsumotoi* is found, instead of *P. matsuraensis*; in *Truncacila*, *A. hirayamai* is found, instead of *A. nagaoi*; in *Periploma*, *P. besshoense* and *P. iesakai* are found, instead of *P.* sp. of the Mazean; and in *Orectospira*, *O. wadana* is found, instead of *O. takaii*. Also, the allied form of the Mazean *Angulus maximus* is found as *A. maximus submaximus* in the Nishisonogian. Even in species, i.e. *Venericardia subnipponica*, some differences are recognizable between the individuals of the Mazean and those of the Nishisonogian (MIZUNO, 1956a).

Roughly speaking, some relationships are recognized between the occurrences of genera and species and litho-facies represented especially by the grain-size of rocks. As shown in Tables 10 and 12, in general, in siltstone or sandy siltstone *Turritella*, *Acila*, *Ancistrolepis*, *Portlandia* etc. are abundantly found throughout the gulf, though among them *Turritella* and *Acila* are also found in fine-grained sandstone.

In fine-~medium-grained sandstone, *Euspira*, *Solamen*, *Lima*, *Pitar*, *Callista* etc. tend to be abundantly found at some places, associated with *Acila*, *Yoldia*, *Lucinoma* and *Periploma*, while in the same rock of the Yamaga formation,



Legend for figs. 17 and 18

1. *Crassatellites inconspicuus*, 2. *Septifer*, 3. *Pitar matsumotoi* and *Callista hanzawai*, 4. *Portlandia* and *Yoldia*, 5. *Venericardia*, 6. *Lima*, 7. *Ctenamusium*, 8. *Chlamys*, 9. *Pseudoperissolax*, 10. *Lucinoma*, 11. *Turritella*, 12. *Fulgoraria*, 13. *Molopophorus denselineatus*, 14. *Glycymeris*, 15. *Acila*, 16. *Ancistrolepis*, 17. *Crassatellites yabei*, 18. *Solen* and *Phaxas*, 19. *Pitar ashiyaensis*

Fig. 17 Distributions of the molluscs in the Paleo-gulf of Shiranuhi at the early Nishisonogian age

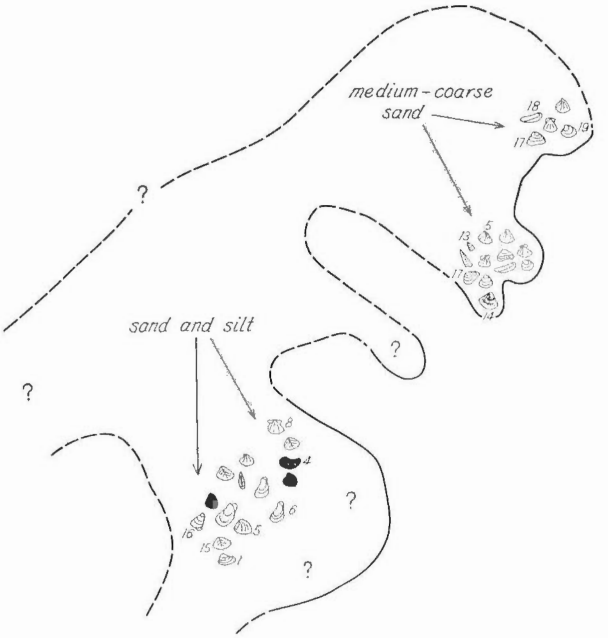


Fig. 18 Distributions of molluscs in the Paleo-gulf of Shiranuhi at the middle and late Nishisonogian ages

north Kyushu and west Honshu *Chlamys* is abundantly yielded, instead of *Lima*, and in the rock of the Sakamizu and Waita of the district *Dosinia*, *Phaxas*, *Pitar ashiyaensis*, *Angulus* etc. are abundant, but there *Chlamys*, *Pitar matsumotoi* etc. are very few. The abundant forms in the medium-~coarse-grained tuffaceous sandstone near "Honeishi" of the Hokusho–Amakusa district are presented by *Crassatellites inconspicuus*, *Venericardia vestitoides*, *Pitar matsumotoi*, and *Callista*, all of them being of ubiquitous, and by *Septifer nagaoi*. Of them, the last is restricted to the present district and the Fukuoka area (the Meinohama formation) of another district. At last, the coarse-grained sandstone of the Sakamizu and Waita formations yields peculiar assemblage of fossils, namely, *Crassatellites yabei*, large form of *Venericardia vestitoides* and *Glycymeris compressa* are exclusively abundant there, associated with *Dosinia chikuzenensis* and rarely *Phyllonotous*.

It is a very remarkable feature for the fauna of the gulf that there are recognizable two different faunal provinces in it. The one is the whole Hokusho–Amakusa district and the Fukuoka area of the north Kyushu–west Honshu district. Another is the Chikuho–Kokura–Yuyawan areas of the latter. Among about 90 species in total, about 50 species are restricted to certain province, and the remainings are found commonly. Their representatives are as follows.

Common forms: *Euspira*, *Ancistrolepis chikuzenensis*, *Fulgoraria*, *Dentalium*, *Acila* (two species), *Yoldia laudabilis*, *Portlandia scaphoides*, *Solamen*, *Venericardia vestitoides*, *Lucinoma nagaoi*, *Pitar matsumotoi*, *Callista* etc.

Restricted forms to the former district: *Pseudoperissolax*, *Septifer*, *Lima*, *Ctenamusium*, *Crassatellites inconspicus*, *Venericardia harukii*, *V. japonica* etc.

Restricted forms to the latter district: *Turritella infralirata, T. ashiyaensis, Phyllonotus ashiyaensis, Molopophorus denselineatus, Nucula, Glycymeris compressa, Pecten kyushuensis, Chlamys ashiyaensis, Crassatellites yabei, Clinocardium, Pitar ashiyaensis, Dosinia, Angulus, Solen, Phaxas* etc.

It is generally accepted in many students that the distributions of recent marine molluscs in certain area tend to be regulated by the character of bottom materials, and it is true as a whole also as to the Paleogene molluscs in Japan as often shown in this paper. Concerning the present fauna, the fact may explain some cases of faunal similarity and difference between the two districts. However, some cases may not be explained only by it and probably some other factors would give the faunal differentiation. For example, in the molluscs of fine-~medium-grained sandstone the three types are recognized as shown formerly. Comparing them to each other, the assemblage with *Chlamys* and that with *Lima* of nearly simultaneous are regionally differentiated, roughly speaking, to the two districts, associated with the fact that *Crassatellites inconspicuus* and *Septifer* are remarkably restricted to its one district (Fig. 17). Moreover, the assemblage of *Dosinia, Phaxas, Angulus* and *Pitar ashiyaensis* was restricted to the Chikuho-Kokura-Yuyawan district in the middle late Nishisonogian age, when in another district the assemblage with *Lima* dwelled in the bottom material. These features were probably caused from the geographic or ecologic isolation, and the difference of depth of habitat or mode of bottom current would play a role in the differentiation.

Then, nearly throughout the age, probably the Sakito-Isahaya-Karatsu-Fukuoka areas would be affected rather strongly by the oceanic current, while the Chikuho-Kokura-Yuyawan areas would not be so affected by it and be in a somewhat enclosed bay at the head part of the gulf.

VIII. Saseboan Stage

VIII. 1 Description of type column

The whole Sasebo group and the Kase formation, lowest division of Tsukumojima group are designated to the type column of this stage.

The Sasebo group is distributed in the Hokusho coal field just west of the Karatsu coal field, conformably overlying the Nishisonogi formation and unconformably underlying the Tsukumojima group.

There have been some problems as to the stratigraphic relationship between the present group and the Nishisonogi and Karatsu formations. TAKEHARA (1953) discussed the subject and concluded its unconformable relationship throughout the whole coal field. However, subsequent contributions which disproved his conclusion were successively published after him, and in the present day, no positive data proves its unconformable relationship, but many data show its conformable and gradually transitional relationship; that is, the conformable one was confirmed at the Imari area (IMAI *et al.*, 1958), Karatsu area (KOBAYASHI *et al.*, 1956), Mimasaka area (OHARA, 1958), Haiki and Hariojima area (NODA and SUJAKU, 1955) and Sasagawa area (SAWADA, 1958), and moreover it was clarified by NODA and SUJAKU (1955), that the "Ushigakubi formation" considered as the basal part of the Sasebo group unconformably overlying the former (MATSUSHITA, 1949) was the uppermost member of the Nishisonogi formation.

The Tsukumojima group named by SAWADA (1958) and once called Nojima group (NAGAHAMA, 1954) lies unconformably upon the Sasebo group. It mostly consists of very thick (more than 1400 m) non-fossiliferous sandstone and siltstone except its lower part; from the basal Kase formation consisting of sandstone and siltstone of about 100 m thickness, *Cerithium* sp., *Portlandia* sp., *Glycymeris* cfr. *matsumoriensis*, *Crassostrea gravitesta*, *Pitar itoi*, *Cyclina japonica*, *Protothaca tateiwai*, *Tapes siratoriensis*, *T. nagahamai*, *Cerithidea* sp., etc. are yielded, some of them being common to the molluscs of below-lying Fukui formation, and moreover from the lower part of Oya formation, the following fresh water molluscan fossils are yielded; *Bellamya kozasana*, *Cuneopsis* n. sp., *Lamprotula nojimensis*, *Lepidodesma uejii* and *Hyriopsis matsuraensis*.

The stratigraphy of the Sasebo group was clarified by the efforts of UEJI (1938), NAGAHAMA (1954), SAWADA (1958) and the other many authors, and the group, attaining about 1300 m thickness, is lithologically divided into five members, namely, Ainoura, Nakazato, Yunoki, Sechibaru and Fukui formations, in ascending order. Every formation is predominant in medium- or fine-grained sandstone and many interbedded siltstone and coal seams. Paying attention to minor sedimentary cycles exhibited by these rocks, Sawada (1958) discriminated 45 cyclothems in the present group and moreover he assumed its depositional environment to be an large estuary called Paleo-Kitamatsuura estuary by him from its litho-facies. Plant fossils are found in many parts of the group, however, molluscan fossils are rather few as a whole. Amongst the latter, marine or brackish water forms, other than the *Ostrea* sp. *Corbicula hizenensis*, *C. matsushitai* and *Lamprotula nojimensis* which are included more or less much, are rare, and they are only yielded in the two horizons; the one is generally called "Masaru fossil bed" in the upper Ainoura formation and another is called "Yadake fossil bed" in the Fukui formation. As shown in Table 14, in which the fossils obtained from the vicinity of Sasebo city are listed, they are mostly of littoral and partly of inner bay.

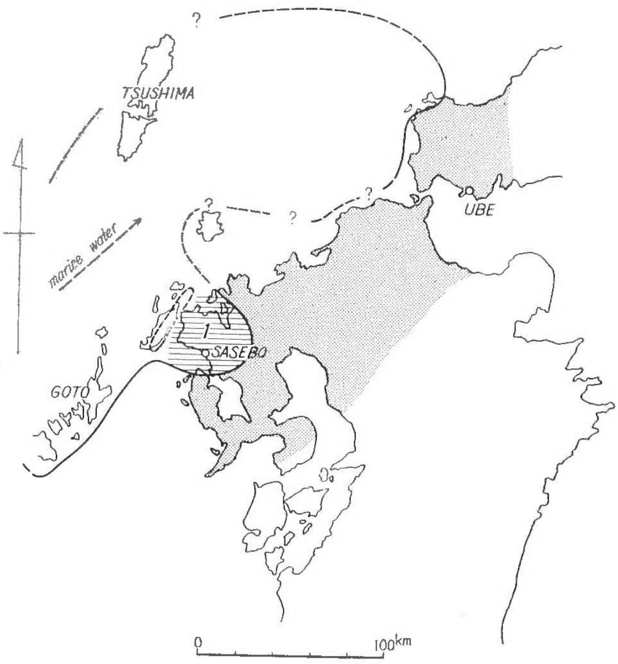
VIII. 2 Correlatives

In the Hokusho-Amakusa district a part of the Goto group in the islands of Goto far west of the district (UEDA and TAKAHASHI, 1956) is the correlative of the Sasebo group. The Saseboan age of it can be evidenced by the occurrences of *Glycymeris*, *Crassatellites* and viviparid fossils from Hirashima and by its litho-facies.

Another very doubtful correlative is a part of the Taishu group at Tsushima. The Taishu group is composed of sandstone and siltstone and attains more than 6,000 m in thickness. The many plant fossils including *Sabalites* and others are rather richly contained in its middle-lower part (UEDA and TAKAHASHI, 1956), while, the molluscan fossils are only rarely included in the group. According to KANNO (1955), some fossils such as *Nucula*, *Anadara*, *Chlamys*, *Patinopecten*, *Venericardia*, *Dosinia*, "*Tellina*", *Phaxas*, etc. are found in the shale near the Taishu mine. And he presumed that the geologic age is late Paleogene or early Miocene. Unfortunately, they are ill-preserved, and the precise determination of their species seems to be very difficult to the writer. However, the occurrences of *Patinopecten* and *Dosinia* are noteworthy; the former is absent in every stage of west Japan and the Paleogene in north Japan, but is included in the lower Miocene "Akahirian" of central Japan, and the latter first appears in the Nishisonogian stage

Table 14 Molluscan fossils from Sasebo group

"fossil bed" / Station number / Specific name	"Masaru fossil bed"										"Yadake fossil bed"		
	N608	N589	N602	N748	F1	T1	T2	T3	T4	H231	T5	T6	T7
Batillaria takeharai MIZUNO n. sp.	·	×	·	·	·	×	·	×	·	·	×	·	×
Cerithium sp.	·	·	·	·	·	×	×	×	·	·	×	·	×
Euspira ashiyaensis NAGAO	×	·	·	·	×	·	·	×	×	·	·	·	·
Calyptraea sp.	·	·	·	·	·	·	·	·	·	·	·	·	×
Chicoreus tiganouranus (NOMURA)	·	·	·	·	·	·	·	·	·	·	×	·	·
Molopophorus denselineatus (NAGAO)	×	·	·	·	×	·	·	·	·	·	·	·	·
Acila ashiyaensis (NAGAO)	·	·	·	·	×	·	·	·	·	×	·	·	·
Glycymeris cfr. *cisshuensis* MAKIYAMA	×	×	×	·	·	×	×	·	·	×	·	·	·
Septifer sp.	·	·	·	·	·	·	·	·	·	·	·	·	×
Crassostrea sp.	·	·	·	·	·	·	×	·	·	×	·	·	·
C. gravitesta (YOKOYAMA)	·	·	·	·	·	·	·	·	·	·	·	·	×
Crassatellites nagahamai MIZUNO, n. sp.	·	×	·	·	·	·	·	·	·	·	·	·	·
C. yabei saseboensis MIZUNO, n. subsp.	·	·	×	×	·	×	×	×	·	×	·	·	·
Pitar matsumotoi (NAGAO)	·	·	×	×	·	×	·	·	·	·	·	·	·
Callista hanzawai (NAGAO)	·	?	·	×	·	×	·	·	·	·	·	·	·
Meretrix sp.	·	·	·	·	·	·	·	·	·	·	×	×	·
Cyclina japonica KAMADA	×	×	×	×	×	×	·	×	·	·	×	×	×
Tapes nagahamai MIZUNO, n. sp.	·	·	·	·	·	·	·	·	·	·	·	×	×



1. Paleo-Kitamatsuura estuary where many coal seams were formed. The gulf area was strongly influenced by the fresh water throughout the age, though sometimes invaded by the marine water.

Fig. 19 Shore lines of the Paleo-gulf of Shiranuhi at the Saseboan age

there. These features may suggest that their age is at least younger than the Nishisonogian, and here the writer tentatively considers their age as the Saseboan respecting the occurrence of *Patinopecten* which is included in the "Akahirian".

The Hitomaru formation of about 450 m in thickness, lying upon the Ashiya group at the Yuyawan area of west Honshu is probably correlated with the Sasebo group from its stratigraphic situation and yields *Chlamys* spp., *Lucinoma* sp. *Turritella* sp. *Lima* sp. and *Corbicula* sp., but these fossils are not qualified as the indicating fossil for the Saseboan stage.

VIII. 3 Paleontologic remarks

Paleogeography and Sedimentation The general regression was undergone at the gulf area of the Nishisonogian age at its end and through the present age. In consequence, the shore lines in the north and northwest Kyushu somewhat shifted as a whole northwards. Moreover, the area of islands of Goto first subsided in the water probably mostly non-marine water, and the water was combined with that at the Hokusho area. From the characteristics of litho-facies, SAWADA (1958) considered the environment of the Hokusho area as the estuary as formerly cited. Such environments were probably prevailing not only in the area, but also in the most part of the gulf including the areas of Goto, Tsushima, Yuyawan etc. and the marine water was rarely invaded there.

Molluscan Fauna The molluscan fossils hitherto known from this stage are not so many. Unionids, corbiculids and viviparids are rather rich, but the marine molluscs are represented by about 20 species of littoral or neritic.

There are found the common species to the Nishisonogian, the species peculiar to this stage and also the species found in the many strata of middle Miocene in Japan. The first is represented by *Euspira, Molopophorus, Acila, Pitar* and *Callista*; the second is by *Batillaria, Cerithium,* the two species of *Crassatellites, Tapes* and *Meretrix*; and the third is by *Chicoreus, Crassostrea gravitesta, Glycymeris* and *Cyclina.*

In connection with the stratigraphic situation of their occurrences, it is pointed out that generally the fossils of the first type are restricted to the "Masaru fossil bed" in the Hokusho coal field, and in this respect the fauna of latter akins to that of the Kase formation of the above-lying Tsukumojima group. Respecting in these features, the writer's division of "C_3-" and "C_4 zones" was once given concerning the present stage (MIZUNO, 1956b). However, from the reasons that the faunal evidences are yet poor for the division and the boundary of division can be hardly actually delimited in the column, in this paper both the "zones" are dealt with as a united soul stage.

The molluscan fossils of this stage are all yielded in medium-~coarse-grained sandstone in the crowded manner and it is clear that the shells after death were more or less swept up by the bottom current, but nevertheless, ecological aspects of their recent allies and fossil allies suggest that they dwelled in the sandy bottom.

Among them *Batillaria, Cerithium, Glycymeris, Crassatellites yabei saseboensis* and *Cyclina* are most abundant. They are found out only in the Hokusho area, but also in the area of Goto or Yuyawan, and these may be qualified as representative molluscs of this stage. Of them, *Crassatellites yabei saseboensis* of large crassatellitid is considered as the descendant of *C. yabei* of the preceding stage from the characteristics of shell.

IX. Summary of Considerations on Some Taxonomic Groups

In this chapter, summary of the biochronologic, taxonomic or paleo-ecologic considerations on some important molluscs of west Japan are briefly given, though detailed taxonomic notes including the description of new species are to be presented in another paper. Biochronologic ranges of characteristic species are summarized in Table 15.

Among the molluscs, the followings are here taken into consideration.

GASTROPODA
Turritellidae
Thiaridae
Potamididae
Strombidae
Buccinidae
Busyconidae
Nassariidae
Vasidae
Volutidae

PELECYPODA
Nuculanidae
Nuculidae
Glycymeridae
Mytilidae
Pectinidae
Limidae
Crassatellitidae
Carditidae
Lucinidae
Cardiidae
Veneridae
Tellinidae

Table 15 Biochronologic ranges of the characteristic molluscs of each stage in west Japan

Specific name	Taka-shiman	Okino-shiman	Funa-zuan	Mazean	Nishi-sonogian	Sase-boan
GASTROPODA						
Viviparidae						
Bellamya koyagiensis MIZUNO, n. sp.	×	·	·	·	·	·
Turritellidae						
Orectospira gemma (NAGAO)	×	·	·	·	·	·
O. takaii MIZUNO, n. sp.	·	·	·	×	·	·
O. wadana (YOKOYAMA)	·	·	·	·	×	·
Colpospira okadai (NAGAO)	××	·	·	·	·	·
C. tashiroi KOTAKA	×	·	·	·	·	·
C. yabei KOTAKA	·	×	·	·	·	·
Tropicolpus sakitoensis (NAGAO)	·	·	·	×	·	·
Turritella karatsuensis NAGAO	·	·	×	××	·	·
T. infralirata NAGAO	·	·	·	·	×	·
T. ashiyaensis MIZUNO	·	·	·	·	×	·
T. tokunagai YOKOYAMA	·	·	·	·	×	·
Thiaridae						
Faunus nipponicus NAGAO	×	·	·	·	·	·
F. ? *miikensis* (NAGAO)	××	·	·	·	·	·
Melanatria ? *kahoensis* (NAGAO)	·	×	·	·	·	·
Cerithiidae						
Bellatara ? sp.	×	·	·	·	·	·
Cerithium sp.	·	·	·	·	·	×
Potamididae						
Vicarya yabai KAMADA	×	·	·	·	·	·
V. n. sp.	×	·	·	·	·	·
Batillaria takeharai MIZUNO, n. sp.	·	·	·	·	·	×
Epitoniidae						
Cirsotrema hospitum NAGAO	·	·	·	×	·	·
C. nagaoi OYAMA et MIZUNO	·	·	·	·	×	·
Clathrus submaculosus (NAGAO)	·	·	×	×	×	·
Naticidae						
Euspira ashiyaensis (NAGAO)	·	·	·	·	×	×
Lunatia ? *utoensis* NAGAO	×	·	·	·	·	·
Polinices eocenica NAGAO	××	·	·	·	·	·
P. nomii NAGAO	·	×	·	·	·	·
Ampullina nagaoi HATAI et NISIYAMA	·	·	×	·	·	·
Mammilla insignis (NAGAO)	·	·	·	×	·	·
Strombidae						
"*Orthaulax*" *japonicus* NAGAO	××	×	×	×	·	·

Specific name	Taka-shiman	Okino-shiman	Funa-zuan	Mazean	Nishi-sonogian	Sase-boan
Muricidae						
Phyllonototus ashiyaensis (NAGAO)	·	·	·	·	×	·
Chicoreus tiganouranus (NOMURA)	·	·	·	·	·	×
Buccinidae						
Ancistrolepis chikuzenensis (NAGAO)	·	·	·	·	×	·
A. cfr. *modestoideus* (TAKEDA)	·	·	·	·	×	·
Neptunea altispirata (NAGAO)	·	·	×	·	·	·
Pseudoneptunea ? sp.	×	·	·	·	·	·
Siphonalia asakuraensis (NAGAO)	·	×	·	·	·	·
S. ? *nipponica* OYAMA et MIZUNO	·	·	·	×	·	·
S. supragranulata NAGAO	·	·	·	·	×	·
Busyconidae						
Mazzalina ? *miikensis* (NAGAO)	·	×	·	·	·	·
Nassariidae						
Molopophorus denselineatus (NAGAO)	·	·	·	·	×	×
Vasidae						
Pseudoperissolax yokoyamai SUZUKI et ITO	×	×	·	·	·	·
P. iesakai OYAMA et MIZUNO	·	·	·	·	×	·
Volutidae						
Lyria endoi MIZUNO, n. sp.	·	·	·	×	·	·
Volutospina ? *nishimurai* NAGAO	×	××	×	·	·	·
V. japonica NAGAO	·	×	××	××	·	·
Fulgoraria sp.	·	·	·	×	××	·
Turridae						
Eopleurotoma ? *higoensis* (NAGAO)	×	·	·	·	·	·
Atyidae						
Liroa paupercula (NAGAO)	×	·	·	·	·	·
Scaphanderidae						
Adamnestia takashimaensis (NAGAO)	·	×	·	·	·	·
SCAPHOPODA						
Dentaliidae						
Dentalium n. sp.	·	·	·	××	·	·
D. ashiyaense NAGAO	·	·	·	×	×	·
PELECYPODA						
Nuculanidae						
Yoldia laudabilis YOKOYAMA	·	·	·	·	×	·
Y. sobrina TAKEDA	·	·	·	·	×	·
Portlandia scaphoides (NAGAO)	·	·	·	×	××	·
Nuculidae						
Nucula hizenensis NAGAO	·	××	××	·	·	·
N. mazeana MIZUNO, n. sp.	·	·	×	××	·	·
N. karatsuensis NAGAO	·	·	·	×	·	·

Specific name	Taka-shiman	Okino-shiman	Funa-zuan	Mazean	Nishi-sonogian	Sase-boan
Nucula okabei MIZUNO, n. sp.	·	·	·	·	×	·
Acila nagaoi OYAMA et MIZUNO	·	·	·	××	·	·
A. ashiyaensis (NAGAO)	·	·	·	·	××	×
A. hirayamai MIZUNO, n. sp.	·	·	·	·	×	·
Glycymeridae						
Glycymenis altoumbonata NAGAO	·	(×)	×	×	·	·
G. compressa NAGAO	·	·	·	·	××	·
G. cfr. *cisshuensis* MAKIYAMA	·	·	·	·	·	××
Arcidae						
Cucullaea nipponica NAGAO	·	·	×	·	·	·
Noetia nagaoi MACNEIL	·	·	×	·	·	·
Barbatia iesakai MIZUNO, n. sp.	·	·	·	×	·	·
Mytilidae						
Crenella striatocostata NAGAO	·	×	·	·	·	·
Solamen subformicatum (NAGAO)	·	·	·	×	×	·
Septifer nagaoi OYAMA	·	·	·	·	××	·
Pectinidae						
Ctenamusium inouei OMORI	·	×	·	·	·	·
C. amakusense OMORI	·	×	·	·	·	·
C. takaii MIZUNO, n. sp.	·	·	·	·	××	·
Chlamys sakitoensis (NAGAO)	·	·	××	××	·	·
C. ashiyaensis (NAGAO)	·	·	·	·	××	·
C. hirayamai MIZUNO, n. sp.	·	·	·	·	×	·
Limidae						
Lima nishiyamai (YOKOYAMA)	·	×	·	·	·	·
L. amaxensis NAGAO	·	××	·	·	·	·
L. nagaoi OYAMA	·	·	·	·	××	·
Ostreidae						
Pycnodonta cassis (NAGAO)	×	×	·	·	·	·
Ostrea lunaeformis NAGAO	·	·	×	×	×	·
Crassostrea sakitoensis (NAGAO)	·	·	×	×	·	·
C. gravitesta (YOKOYAMA)	·	·	·	·	·	××
Crassatellitidae						
Crassatellites nipponensis YOKOYAMA	×	××	·	·	·	·
C. asakuraensis NAGAO	·	·	×	·	·	·
C. matsuuraensis NAGAO	·	·	×	××	·	·
C. komodai OYAMA et MIZUNO	·	·	·	×	·	·
C. n. sp.	·	·	·	(×)	(×)	·
C. inconspicuus NAGAO	·	·	·	·	(×)	·
C. yabei NAGAO	·	·	·	·	×	·
C. pauxillus YOKOYAMA	·	·	·	·	×	·
C. yabei saseboensis MIZUNO, n. subsp.	·	·	·	·	·	××

Specific name	Takashiman	Okinoshiman	Funazuan	Mazean	Nishisonogian	Saseboan
Crassatellites nagahamai MIZUNO, n. sp.	·	·	·	·	·	×
Carditidae						
Venericardia nipponica YOKOYAMA	×	××	·	·	·	·
V. mandaica (YOKOYAMA)	×	××	·	·	·	·
V. nagaoi MIZUNO, n. sp.	·	××	·	·	·	·
V. okinoshimensis MIZUNO, n. sp.	·	×	·	·	·	·
V. hizenensis (NAGAO)	·	·	××	·	·	·
V. kondoi (NAGAO)	·	·	×	××	(×)	·
V. yoshidai NAGAO	·	·	×	××	(×)	·
V. subnipponica NAGAO	·	·	·	××	××	·
V. vestitoides MIZUNO	·	·	·	·	××	(×)
V. japonica MIZUNO	·	·	·	·	×	·
V. harukii OYAMA et MIZUNO	·	·	·	·	×	·
V. n. sp.	·	·	·	·	×	·
Ungulinidae						
Joannisiella problematica (NAGAO)	×	·	·	·	·	·
Diplodonta confusa NAGAO	·	·	·	·	×	·
Lucinidae						
Eomiltha sp.	·	×	·	·	·	·
Lucinoma nagaoi OYAMA et MIZUNO	·	·	·	·	××	·
Cardiidae						
Clinocardium okabei MIZUNO, n. sp.	·	·	·	·	×	·
Vepricardium miikense (NAGAO)	×	·	·	·	·	·
Fragum ? kishimaense (NAGAO)	·	·	×	××	·	·
Veneridae						
Pitar hinokumai MIZUNO, n. sp.	××	·	·	·	·	·
P. kyushuensis (NAGAO)	·	××	×	·	·	·
P. matsuraensis (NAGAO)	·	·	×	××	·	·
P. yokoyamai (NAGAO)	·	·	×	××	(×)	·
P. matsumotoi (NAGAO)	·	·	·	(×)	××	×
P. ashiyaensis (NAGAO)	·	·	·	·	×	·
Callista ariakensis (NAGAO)	×	·	·	·	·	·
C. mitsuiana (YOKOYAMA)	·	×	·	·	·	·
C. kahoensis (NAGAO)	·	×	·	·	·	·
C. hanzawai (NAGAO)	·	·	·	·	××	×
Dosinia chikuzenensis NAGAO	·	·	·	·	××	·
Cyclina nodai NAGAO	·	×	·	·	·	·
C. compressa NAGAO	·	·	·	×	·	·
C. japonica KAMADA	·	·	·	·	·	××
Tapes nagahamai MIZUNO, n. sp.	·	·	·	·	·	×
Meretrix pseudomeretrix NAGAO	·	·	·	·	×	·
Meretrix n. sp.	·	·	·	·	·	××

Specific name	Taka-shiman	Okino-shiman	Funa-zuan	Mazean	Nishi-sonogian	Sase-boan
Tellinidae						
Macoma yamadai NAGAO	·	×	·	·	·	·
M. cfr. *asagaiensis* MAKIYAMA	·	·	·	·	×	·
Angulus maximus (NAGAO)	·	·	×	××	·	·
A. maximus submaximus MIZUNO n. subsp.	·	·	·	·	××	·
"*Tellina*" *tricarinata* NAGAO	·	·	×	·	·	·
Mactridae						
Spisula sp.	·	·	·	·	××	·
Solenidae						
Phaxas brevis (NAGAO)	××	·	·	·	·	·
P. leguminoides (NAGAO)	·	·	×	·	·	·
P. rectangulus KANNO	·	·	·	·	×	·
P. izumoensis (YOKOYAMA)	·	·	·	·	×	·
Solen connectens OYAMA	·	·	·	·	×	·
Corbulidae						
Caryocorbula subtumida (NAGAO)	×	·	·	·	·	·
Lentidium ? kyushuense (NAGAO)	×	·	·	·	·	·
Pholadomyidae						
Pholadomya "*margaritacea* SOWERBY"	·	×	×	×	×	·
P. takashimaensis NAGAO	·	×	·	·	·	·
Periplomatidae						
Periploma n. sp.	·	·	·	×	·	·
P. besshoense (YOKOYAMA)	·	·	·	·	×	·
P. iesakai OYAMA et MIZUNO	·	·	·	·	×	·

× rare-common ×× abundant (×) very rare or uncertain

Turritellidae KOTAKA (1959)'s recent contribution is very useful for the study of Tertiary turritellids in Japan. He revised the generic attributions of Paleogene "turritellas" which are useful biochronologic markers in west Japan and discussed their phylogenic relationships.

Among them, *Colpospira okadai* and *C. tashiroi* are both only yielded in the Takashiman stage. The former is much found widely in the stage and considered to be more or less ubiquitous, found in the variously grained rocks, but it is only very large in size in rather coarse-grained sandstone, showing the crowded occurrence, and is small and few in siltstone, found together with many brackish or shallow marine shells. The occurrences suggest that the optimum environment for the species was rather coarse-grained sand bottom. While the latter is only found in Amakusa where it is comprised in fine-grained sandstone or sandy siltstone that represents the transitional facies between the lower, coarse-grained *C. okadai*-bearing sandstone and the upper, siltstone of Kyoragi formation. Thus, the both species show no co-existence in the Shiratake formation, and the fact seems to suggest the original differences of their ecologic requires. *Colpospira yabei* of the Okinoshiman stage seems to be a sand dweller of shallow sea, found in glauconitic sandstone of the stage, and is considered as the descendant of *C. tashiroi*, according to KOTAKA, from the characteristics of shape and ornamentation of shell. The above-cited three species are attributed to his new subgenus, *Acutospira*, and their ancestral form is said the Malayan *Turritella krooni* DOLLFUS (Cretaceous and Eocene of Celebes) (KOTAKA, 1959).

The Funazuan *Turritella* is represented only by *T. karatsuensis* which ranges to the Mazean stage. The species is very similar to Indian *T. hollandi* COSSMANN et PISSARRO of Ranicot which is probably its ancestral form. In the Mazean, it is more abundant and is found from the nearly whole rocks of the Hokusho-Amakusa district. Another species of the Mazean is *Tropicolpus sakitoensis* of which similar form is found in the Ranicot (*Turritella halensis* COSSMANN et PISSARRO). Its biozone is more restricted than the former species as shown by KOTAKA (1959) and its geographic range is also smaller than it.

Turritella infralirata is restricted to the Nishisonogian and is richly included especially in the deposits of north Kyushu-west Honshu. It was considered by KOTAKA (1959) as the ancestral form of Miocene *T.* (*Hataiella*) *s-hataii* stock. Another species of the stage is *T. ashiyaensis* and *T. tokunagai*. The former was anew found by the present writer from the middle part of Ashiya group at the type Ashiya area. It is characterized by rather low whorls decorated by only two prominent and narrow ribs, somewhat resembling *T. karatsuensis* which is considered as the ancestral form of the present species. *T. karatsuensis* of HIRAYAMA (1956, pl. 8, fig. 13) from Hikoshima may be referable to *T. ashiyaensis*. *T. tokunagai* is much found in the Asagai sandstone elsewhere, and it is rarely comprized in west Japan in the Nishisonogi formation of Sakito coal field.

Another turritellid genus *Orectospira* is generally found in Paleogene siltstone of west Japan, though rather rare except that *O. gemma* of which biozone is found in the Takashiman stage is included in the brackish or littoral coarse facies of Amakusa. In the Okinoshiman, *O.* sp. is included in siltstone of the Sakasegawa formation, and Mazean species is *O. takaii* which is anew proposed. *O. wadana* which is a very common species of the Poronai fauna later cited is rarely found in the Nishisonogian stage at the Hokusho-Amakusa.

Thiaridae Four species of brackish inhabitants of the Indo-Pacific elements are known from the Paleogene in west Japan. *Faunus? miikensis* and *F.?* sp. are abundant in the Takashiman stage; they are commonly yielded in the brackish facies of the stage, while another Takashiman *F. nipponicus* is geographically restricted to Amakusa and its individuals are rather few, though its occurrence is also reported from Hokonoko (FURUKAWA and URATA, 1960). Their biozones almost correspond to each other. *Melanatria? kahoensis* is known only from the so-called "Kamiyamada fossil bed" and it is evidently of younger age than the precedings.

Potamididae Paleogene species of *Vicarya* in Japan was first reported by KAMADA (1960) as *V. yabei* from the lowest part of Hashima formation of Takashima. On the other hand, the writer found successively another species of the genus, here named *V.* n. sp., from Hokonoko, Takashima and Amakusa, where it was found in the so-called "lower *Orthaulax* zone" of NAGAO or near it. *Vicarya* has been hitherto known only from the Miocene rocks in Japan, and it is commonly found in the Miocene of the Indo-Pacific region. The occurrence of Paleogene *Vicarya* is universally poor, and only few species have been known. One is *V. eocenica* COX of the Laki in west India. The species was respected as the oldest form of *Vicarya* by DAVIES (1934) and NEAVERSON (1955). One of anothers is *V. jogjacartensis* MARTIN from the upper Eocene Nanggulan of Java. KAMADA (1960) discriminated two stocks of *Vicarya* s. str. and *Shoshiroia* in vicaryan shells. He kept his *V. yabei* in the former of which type is *V. verneuili* d'ARCHIAC, but *V. eocenica* and *V.* n. sp. in the latter established by him, designated the type to *V. callosa* JENKINS. Thus the occurrences of two stocks in Japan both in the Paleogene and Neogene is very interesting for the paleozoogeography of the sea and the historical development of *Vicarya.*

Bellatara is another Eocene potamidid. The genus is said to range from middle Eocene to lower upper Eocene according to RICHARDS and PALMER (1953). The biozone of *Bellatara*? sp. of Kyushu is similar to that of *Vicarya* n. sp.

Batillaria is yielded in the Saseboan stage. *B. takeharai* is somewhat similar to *Vicinocerithium* of European Eocene in outline rather than to the Miocene batillarian shells in Japan.

Strombidae "*Orthaulax*" *japonicus* is very abundant species in the Takashiman stage, but it ranges up to the Mazean, though its occurrence is rather few there. The species seems to be of somewhat ubiquitous, brackish or littoral marine in the Takashiman, but probably littoral and sand dweller at the later age. The species was designated by NAGAO (1924) to *Orthaulax* which is an important guide fossil of American Oligocene and Miocene (COOKE, 1921; WOODRING, 1928). However, according to KAMADA (1960)'s observation, it belongs probably *Pseudoliva.* He compared the specimens of Kyushu with the genotype of *Pseudoliva* and concluded that WOODRING (1928)'s suggestion of the attribution of the species to *Pseudoliva* was quite reasonable. If KAMADA's conclusion is acceptable, the occurrence of the genus in Japan that shows its epibole in the Takashiman stage is well harmonious with the universal tendency of *Pseudoliva* having crest of occurrence at the Eocene though it ranges from the upper Cretaceous to the Recent (GARDNER, 1945).

Buccinidae The buccinid shells which are especially abundant in the upper Paleogene of north Japan are represented by several species in west Japan. Of them, siphonalian fossils of which generic attribution is somewhat doubtful are the good indicators of the middle and upper Paleogene in west Japan, as shown in Table 15. *Ancistrolepis* and *Neptunea* are also present, but they don't play an important role in west Japan.

Busyconidae Doubtful *Mazzalina* of which genotype is from the Eocene of Alabama is yielded in the Okinoshiman stage, but the species (*Mazzalina*? *miikensis*) is reported only from the Miike coal field, though besides, its occurrence is also reported from the Takashima coal field (KOBAYASHI and KAMADA, 1960).

Nassariidae *Molophorus denselineatus* occurs in the Nishisonogian and Saseboan stages. Although the Paleogene and lower Neogene of west coast of North America have in their many horizons many species of the genus that is only found in the circum Pacific region, the Paleogene of west Japan has only soul species in the uppermost part, which is more similar to the Miocene *M. anglonana* Anderson than to the upper Oligocene *M. newcombei* (MERRIAM) of Pacific coast of North America.

Vasidae *Pseudoperissolax* is the Pacific genus alike the preceding, forming the important guide fossil of the Tertiary on the Pacific coast of North America. In west Japan, *P. yokoyamai* that resembles *B. blakei* (CONRAD) of upper Eocene has its biozone in the Takashiman and Okinoshiman. Another Japanese species, *P. iesakai,* similar to the Blakeley *P. trophonoides* TEGLAND is found in the Nishisonogian.

Volutidae Of the family, *Volutospina* abundantly occurring in the foreign Paleogene warm faunae is rich in the lower and middle Paleogene also in west Japan, but is quite absent in the upper Paleogene of the area. Each species recognized there has rather long chronologic range; namely; *V.* ? *nishimurai* ranges from the Takashiman to the Funazuan, but is most abundant in the middle, Okinoshiman, and *V. japonica* ranges from the Okinoshiman in which it is rather rare in the Mazean, and in the latter only *V. japonica* is only richly comprised.

Lyria was first recognized in the Paleogene of Japan. The genus suggests the warm climate alike the preceding genus.

Another genus *Fulgoraria* is very abundant only in the Nishisonogian in which it occurs throughout the west Japan.

Nuculanidae *Yoldia* and *Portlandia* are commonly found in the upper Oligocene and Neogene deposits especially in northern Japan. They are, however, represented by rather few species with rather few individuals in the Paleogene of west Japan. Concerning *Yoldia, Y.* sp. is included in siltstone of the Takashiman stage at Amakusa. In the Nishisonogian, *Yoldia laudabilis* which is abundant in the Poronaian fauna of north Japan is included; at the Hokusho-Amakusa district it is rather commonly found in sand facies, together with *Ancistrolepis, Acila, Venericardia, Callista* etc., while at the north Kyushu-west Honshu it is only included in sandy siltstone of the Yamaga and Sakamizu formations together with *Turritella, Venericardia, Lucinoma* etc.

Concerning *Portlandia* which is comprised in the upper Cretaceous and commonly in the upper Paleogene of north Japan, *P.* sp. is found in the Takashiman stage at Amakusa; it is of small type alike the Cretaceous *P. hakobutsuensis* (NAGAO). *P. scaphoides* of *Portlandella* is rather commonly found in sandy silt facies of the Mazean and Nishisonogian, and it is more abundant in the latter; the species is closely similar to *P. watasei,* the most common species in the upper Oligocene of north Japan. It may be possible that the both species are essentially related to each other, and also to *P. blakeleyensis* DURHAM of the Blakeley.

Nuculidae Concerning the nuculids, *Nucula hizenensis* and *N. mazeana* are abundantly found in the middle Paleogene of west Japan and they show noticeable inter-relationship to each other. The former ranges from the Okinoshiman to Funazuan and the latter is especially rich in the Mazean, though its outrider appears in the Funazuan. According to the writer's observation on their specimens from the Hokusho-Amakusa including those kept in the Tohoku University, they seem to be in a series of progressive evolution.

The group appears first in the Okinoshiman, and ranges to the Mazean, but it is wholly absent in the younger, Nishisonogian. Broadly speaking, chronologically older individuals exhibits the lower ratio of L/H and smaller apical angle and the chronologically youngers provide the higher ratio and larger apical angle.

Comparing the shell of each stage, the followings are clearly recognizable.

The Okinoshiman shells including the holotype of *N. hizenensis* exhibits L/H of 1.23–1.43, apical angle of 100–102° and convex antero-dorsal border though the data on them are very few. Other shells of St. 150 than those figured also show the same dimensions, and those from the Kawamagari formation kept in the Tohoku University do so, too. The shell of this type is referable to typical *N. hizenensis*.

The latest of the group, the Mazean shells provide L/H of 1.32–1.79 and apical angle of 120–134° (among them the commons are of 1.4–1.7 and 125–130°) and nearly straight antero-dorsal border, according to the data of shells from St. 8030402, St. 52, St. 8030401 of the Yamaguchi formation at Isahaya, from St. 156

A B C

A and B. *Nucula mazeana* MIZUNO (MS.), × 1. Loc. Arita, Kishima-gun, Saga Prefecture (Kishima formation). Figured originally.
C. *Nucula hizenensis* NAGAO, × 1. Loc. Okinoshima, Nishisonogi-gun, Nagasaki Prefecture (Okinoshima formation). Holotype (photo. by Mizuno).

Fig. 20 Figures of *Nucula hizenensis* and *N. mazeana*

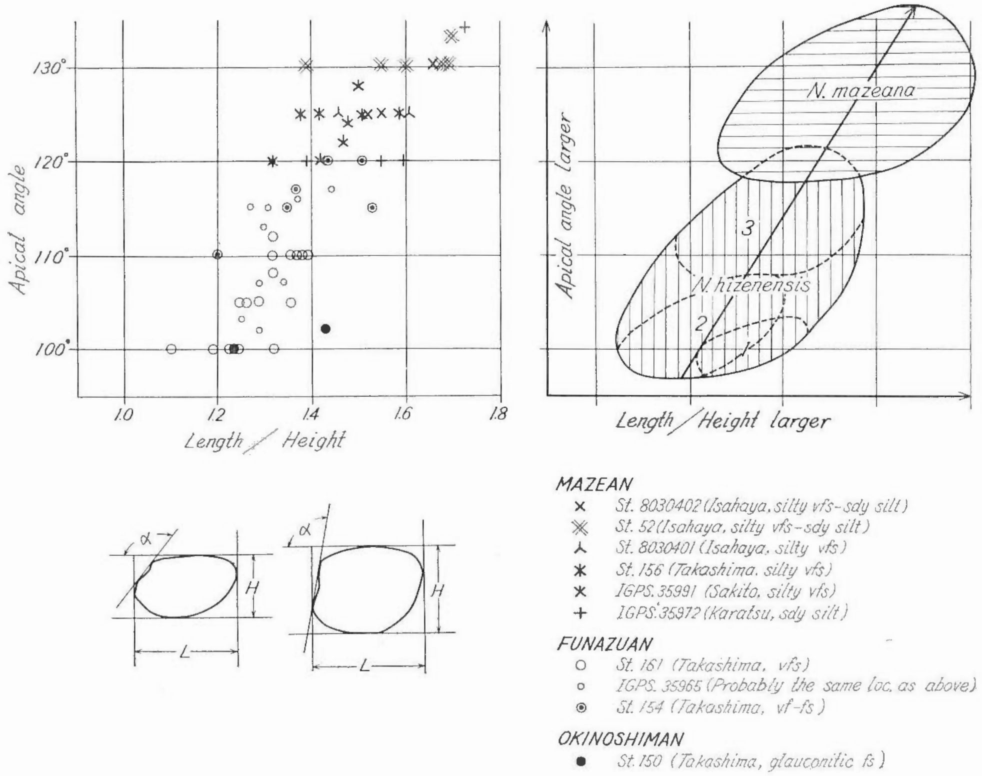


Fig. 21 Orthogenetic chronocline of *Nucula hizenensis*–*N. mazeana*

of the Daimyoji member at Takashima and from Obo-toge near Arita of the Kishima formation at Karatsu. Thus, the type is clearly distinguished from the preceding, and is given the name *mazeana*.

Concerning the shells of Funazuan stage, those from St. 161 which is probably the same as the locality where NAGAO's paratypes were collected from include the Okinoshiman type with lower L/H and smaller apical angle, but the latter of them ranges to about 115°. While those from St. 154 which is of slightly lower horizon than the preceding, distanced about 900 m to each other show apical angle of 110–120° and L/H of 1.35–1.5 and are more similar in outline to *N. mazeana* than the precedings. Roughly speaking, the Funazuan shells include the two forms which are obscurely separated by the line lying at about 107° on apical angle, and the shells of St. 154 include only the type 3 in Figure 21, while those of St. 161 includes the both forms. The form 2 is very similar to the Okinoshiman shells (type 1 in the figure), and probably that both are wholly conspecific. The form 3 approaches the Mazean shells, filling up the gap which lies between the forms 1 and 2 and the Mazean shells, and also including partly the same shells as the latter (shells with apical angle of about 120° and L/H of 1.43–1.51 from St. 154).

The facts seem to suggest that the Funazuan shells include the two intra-breeding communities; in other words, the form 3 can be ragarded as the sub-species of *N. hizenensis* and also as the intermediate form between *N. hizenensis* and *N. mazeana*. Another interesting fact, the overlapping* of the form 3 and the Mazean form suggests the gradual change of shape of nuculid shells from the Funazuan age to the Mazean age.

Summarizing the above discussions, the following formula is given as to the gradation of the nuculid forms. The gradation can be qualified

Okinoshiman	Funazuan	Mazean
? ⟶ *H. hizenensis* (s. str.) ⟶	*N. hizenensis* (s. str.)	
↘	*N. hizenensis* (subspecies)	
	↘ *N. mazeana* ⟶	*N. mazeana*

as the "orthogenetic chronocline" in appearance. It is unfortunately obscure why such a transformation took place in the animals. The question must await further detailed studies. However, concerning the problem, the noticeable feature is that some relations are found between the form of shell and grain-size of rock in which the shells are yielded, as shown in Fig. 21; namely; the shells with smaller apical angle and L/H are found in fine or very fine-grained sandstone while those with larger apical angle and L/H are found in more fine-grained rocks than the former.

It seems highly probable that the modification was undergone in the animals, accompanied with the chronological change of the bottom condition especially represented by the grain-size of bottom material.

Another nuculid, *Acila* which is characteristic in the Pacific region, is represented

* For this respect the discrimination between *N. hizenensis* (its subspecies, the form 3) and *N. mazeana* becomes very difficult. Tentatively, *N. mazeana* is defined as the shell with apical angle more than about 120°, and then a part of the form 3 is brought into *N. mazeana*.

by several species in the rocks in question. In the Takashiman and Okinoshiman, small *Truncacila* is found, but it is specifically indeterminable owing to the ill-preservation of shell. In the Mazean, *nagaoi* of *Truncacila* is richly found, but in the Nishisonogian, *ashiyaensis* of *Acila* s. str. and *hirayamai* of *Truncacila* are both comprised, the former ranging to the Saseboan. The fact is very interesting in the respect that SCHENCK (1936)'s statement on the time of appearance of *A.* s. str. is adoptable in the Paleogene of west Japan. *A. hirayamai* was anew named for the Nishisonogian shell which has large angle of bifurcation of ribs. *Acila* sp. reported by HIRAYAMA from the Ashiya group at Hikoshima (HIRAYAMA, 1956, p. 102, pl. 6, figs. 2–4) is surely referable to this new species.

Glycymeridae Of the family, the Nishisonogian *Glycymeris "cisshuensis"* cited by NAGAO (1928b) is never conspecific with that of MAKIYAMA (1926) from the Miocene of Korea. It is clearly more strongly inflated and in general an upper margin of hinge plate does not smoothly continue to the posterior border of shell, but the part between them show rather strong concavity. On the other hand, *G. "cisshuensis* var. *compressa"* of NAGAO seems to be conspecific with his *G. "cisshuensis"*, according to the writer's observation on their type specimens kept in the Tohoku University, though the former is slightly less inflated than the latter. Thus in this paper G. *compressa* NAGAO is used for NAGAO's *G. "cisshuensis"* of the Nishisonogian very convex type. It is especially much included in medium-∼coarse-grained sandstone of the Ashiya group. In many cases, it is associated by *Turritella, Chlamys, Venericardia, Dosinia* etc. Concerning the Saseboan shell, the glycymerid having less convex shell seems to be referable to *G. cisshuensis* of MAKIYAMA, but the identification is somewhat doubtful owing to the ill-preservation of shell. And it occurs in coarse-grained sandstone including many shells of *Batillaria, Crassatellites, Cyclina* etc.

Mytilidae *Septifer nagaoi* which seems to be related with *S.* cfr. *denticulatus* LAMARCK of Pondaung sandstone of Burma (COTTER, 1923) is very abundant especially in the tuffaceous coarse-grained sandstone just below the "Honeishi" in the Nishisonogian stage of the Hokusho–Amakusa district, though it is rarely found also in the coarse facies of its upper horizons. However, it is quite absent in the area other than the Meinohama near Fukuoka in the north Kyushu–west Honshu.

Pectinidae *Chlamys sakitoensis* is abundantly crowded in the conglomeratic or coarse-grained sand facies together with *Crassostrea* and *Ostrea* in the Funazuan and Mazean. The Nishisonogian *Chlamys* is represented by *C. ashiyaensis* which is larger and provides more complicated radial ribs than the former, and moreover it is found in fine-∼medium-grained sandstone, together with *Venericardia, Dosinia* etc., and is probably the dweller in more calm bottom. It is considered to be the outrider of the Neogene large *Chlamys* in Japan.

Ctenamusium takaii decorated by about twenty inner ribs was anew found by the writer. This is the important guide of the Nishisonogian stage, though it is only found so far in the lower part of the stage of the Hokusho–Amakusa district.

Limidae This family is rather rare in the Paleogene of west Japan, and it is interesting that its each species has a restricted chronologic range and is very steno-topic. For example, some species of the Okinoshiman which are abundantly found in the Sakasegawa group of Amakusa cannot be found elsewhere, and

Lima nagaoi is rather common species throughout the Nishisonogian at Sakito, but it is quite absent in the north Kyushu–west Honshu district.

Crassatellitidae The family which is represented by many species in the Paleogene and lower Neogene in west Japan is one of what should be given a special attention, together with turritellids, venericards, pitarinids. Its shells are yielded abundantly throughout the rocks in question.

Of the ten species, those other than *Crassatellites komodai, C. nagahamai* and *C. pauxillus* belong to the group with smooth inner margin of shell. Hitherto, the two subgenus, *Eucrassatella* and *Spissatella* have been recognized in *Crassatellites* of such type, and the Japanese forms are mostly rather similar to the former in their characters. Neither fossil nor recent records of the type have not been known near Japan, but are now flourishing in the sea near Australia (*Eucrassatella;* IREDALE, 1924) and on the western coast of North America (*Eucrassatella;* ABBOTT, 1955) and are known in New Zealand, Australia and on the eastern coast of North America as Neogene fossils (*Eucrassatella* and *Spissatella;* SUTTER, 1914; IREDALE, 1924; MARWICK, 1931; DAVIS, 1934; PALMER, 1958). In the Paleogene in which crassatellitid are abundantly comprised in general universally, in spite of their similarities of outline to the above-mentioned two subgenera, any species have crenulated shells in the inner margins and clearly represent a quite different group from those above-discussed, except a rare case of the Matan fauna of New Zealand in which *Spissatella* cfr. *australis* ((HUTTON) is included (FINLAY and MARWICK, 1937).

Thus the allied forms of the Japanese Paleogene without marginal crenulation cannot be found in the Paleogene elsewhere at least in the northern hemisphere, but they are presented in the Danian "*Cardita beaumonti* beds" of northwest India; namely; the Japanese Eocene *Crassatellites nipponensis* seems to be related with *C. macrodonts* (SOWERBY) in outline, and also *C. yessoensis* of north Japan, with *C. austriaca* ZITTEL. This may prove that the Japanese *Eucrassatella* originated from the Danian forms and that the shallow sea of the west Pacific was a peculiar faunal province for the development of *Crassatellites* where *Eucrassatella* was enable to flourish in Paleogene–early Neogene and it wholly disappeared in the end of early Neogene.

Among the Japanese *Eucrassatella, C. nipponensis* ranges from the Takashiman to the Okinoshiman; and it is very abundant in the basal sand facies of the Sakasegawa group at Amakusa, showing the crowded occurrence together with many shells of large *Venericardia.*

The Funazuan forms are represented by the two of *C. asakuraensis* and *C. matsuuraensis;* the occurrence of the former is only known from its type locality, Asakusa area, and the latter is included in the fine-grained sand facies of the Funazu member of the Takashima coal field. Concerning the latter which is very abundant in the Mazean stage throughout the Hokusho–Amakusa, its subgeneric position is somewhat doubtful; that is to say; its *Anthonya*-like transversely elongated shape may be not of *Eucrassatella* and its hinge is somewhat different from that of *C. nipponensis,* though it has no marginal crenulation, and then it belongs possibly to other subgenus which is yet unknown. *C.* n. sp. is of *Eucrassatella.* It is only found in the coarse-~medium-grained sand facies of the upper Maze formation and lower part of the Nishisonogi formation of Sakito.

The Nishisonogian *Eucrassatella* is represented by *C. inconspicuus* and *C.*

yabei, the latter of which is only found in the coarse-~medium-grained sand facies of the Ashiya group. On the contrary, the former is a very common species of the stage throughout the whole west Japan and exhibits an interesting polymorphism, of which details will be presented in another chance.

C. yabei saseboensis newly established and once figured by the writer (MIZUNO, 1956a, pl. 2, figs. 8a, b) as *C. yabei*, var. is abundantly included in the so-called "Masaru fossil bed" of the Ainoura formation of the Seaseboan stage, It is considered as the chronologic subspecies of *C. yabei* from the characteristic of shell and represents the last form of the Japanese *Eucrassatella*.

Among the remaining species of *Crassatellites*, the Saseboan *C. nagahamai* is probably the ancestral type of Pliocene and recent species of *Crenocrassatella*, and it is somewhat similar to NOETLING (1899)'s figure (pl. 10, fig. 4) of *Crassatellites rostratus* (LAMARCK). *C. pauxillus* which is abundant in the "Akahirian" of north Kwanto somewhat similar to the immature shell of *C. inconspicuus*, but provides finely crenated inner margin of shell. It is only found in the Nishisonogian stage of the Kokura area in west Japan.

Carditidae The genus *Venericardia* includes twelve species in the Paleogene of west Japan and they are biochronologically most useful together with other some forms. The large *Venericardia* represented by *Venericor* is generally available for the inter-continental correlation of the Eocene beds and it has been hitherto investigated in datail by some authors (HANNA, 1925; GARDNER and BOWLES, 1939; VERASTEGUI, 1953; STENZEL, KRAUSE & TWINING (1957) and others). It is presented in west Japan, too, as *V. nipponica*, *V. nagaoi*, *V. okinoshimensis* and *V. hizenensis*.

Among them *V. nagaoi* and *V. okinoshimensis* are new species, discriminated from NAGAO (1928a, b)'s *V. nipponica*. According to the writer's observations, the so-called *V. nipponica* which is the soul species hitherto recognized as a large *Venericardia* in Japan has three different forms, which are discontinuous in shape, size and number of ribs. The holotype of *V. okinoshimensis* is designated to the specimen figured in NAGAO's pl. 13, fig. 15 (NAGAO, 1928b). It is very large and much inflated, with inflated predominant beaks. Its number of ribs is more than thirty, exhibiting narrowly inverted U-shape. The species is commonly found in the Okinoshiman at Takashima and at Isahaya. While, the holotype of *V. nagaoi* is designated to the specimen from the Kawamagari formation figured in NAGAO (1928b)'s pl. 13, fig. 11. It has the similar form to the preceding, though its beak is less inflated and its size is smaller. Radial ribs number about 18 to 20 and are more or less noded, wide and broadly round-topped. The species is also restricted to the Okinoshiman stage, being found in the lowest part of the lower Iojima, Kirimiya and Kawamagari formations. The remaining, *V. nipponica*, ranges from the Takashiman to Okinoshiman, but is only presented by few specimens comprised in siltstone of Shiratake formation and siltstone of the uppermost part of the Kyoragi formation of Amakusa in the former. According to its original author (YOKOYAMA, 1911), the species has about 23 ribs, but the writer numbered about 25 ribs on YOKOYAMA's holotype specimen, and moreover the 25 ribs are generally recongnizable in other many specimens at hand. The ribs exhibit a clear progressive change in accordance to growth stages: that is to say; concerning those on the middle portion of shell, immature ribs are sharply crested and rather strongly tuberculated, then they gradually change downwards to weakly corrugated and inverted U-shape, separated by deep and narrow furrows. The ribs are generally narrower than those of the species of *Venericor*.

Another large *Venericardia* is represented by *V. hizenensis*, which was referred to *Cardium* by NAGAO (1928b), but its hinge is evidently of carditid, according to the writer's observation on the probable topotype specimens from Iojima. This species is characterized by very narrowly high ribs with rather sharp crest numbering 23–29. In outline and stage of ribs it is most similar to *Claibornicardia* of the Stone City bed at Taxas (STENZEL *et al.*, 1957) among all forms of *Venericardia*, but it is clearly different from it by having no tripartite ribs.

Venericardia mandaica ranging from the Takashiman to Okinoshiman and *V. yoshidai* of the Funazuan and Mazean form are thickly tested small another forms with rather narrow, prominent and strongly nodulous ribs of rather sharp crest. These shells may be of *Venericardia* s. str. and their forms suggest the phylogenic relationship with *Baluchicardia* (RUTSCH and SCHENCK, in RUTSCH, 1944) of the earliest Tertiary and latest Cretaceous including *V. beaumonti* (d'ARCHIAC), *V. elliptica* DOUVILLÉ etc. in some characteristics of shell, though tripartite ribs of *Baluchicardia* is not presented in the present two species.

V. subnipponica ranging from the Mazean to Nishisonogian was established by NAGAO (1928b), based upon many shells, whence he unfortunately confused some specimens (pl. 14, figs. 6, 14–18, 30) with the present species. According to writer's study, on the shell from the Maze, Yamaguchi and Nishisonogi formations of Hokusho–Amakusa and from the Ashiya group of north Kyushu, the present species exhibits a polymorphism as partly cited in his previous work (MIZUNO, 1956a); that is to say; characteristics of shell including outline and state of ribs somewhat varies at every locality or every horizon, being associated with the difference of litho-facies and associated fauna. The detailed aspects of them are to be shown in another paper. As a whole, the shell of the species is inflated and rather small, except some cases of the Ashiya group, with variable shape usually providing a faint ridge from beak to postero-ventral corner. Its ribs are characterized by having round top and being wrinkled or granulated crossing with the concentric elevation periodically arranged on the surface of shell; but rib's number is very variable, ranging from 22 to more than 30, though the prevailing is about 24–27. The species is easily distinguished from *V. nipponica* in the dimensions of shell in mature stage of the latter, but the younger of the latter is very similar in outline and states of ribs and in some places the discrimination is nearly impossible. The fact seems to suggest a phylogenic relationship between them.

V. vestitoides is a common species in the Nishisonogian stage throughout west Japan. It includes a part of NAGAO (1928b)'s *V. subnipponica* (pl. 14, figs. 6, 14–16, 30, ?17, ?18). This species is characterized by trigono-oval shell with the ribs broadly rounded and wide, numbering about 14–about 20, those of the middle part of shell showing progressive change that the immature ribs have sharp crest, gradually varying to widely round-topped downwards. Morever, it shows more or less different form in the both area of west Japan. Generally speaking, the shells of north Kyushu tends to be larger than those of Hokusho–Amakusa. The writer once considered that the species is of *Cyclocardia*, but the characters of shell seem to reject the attribution, and it seems to somewhat relate with *V. nagaoi.*

V. harukii and *V. japonica* are both rather rare elements in the Nishisonogian stage. The latter is of *Megacardita* and the former is of *Cyclocardia* that is very abundant in the upper Paleogene of northern Japan.

V. kondoi characterized by its elongated form is useful guide fossil of sandy or coarser facies of the Mazean stage, though it occurs rarely in the Funazuan.

In summary, the followings are given concerning the venericardian phylogeny. In the Paleogene venericards of west Japan, the three main phylogenic stocks are recognizable. The first is represented by *V. mandaica–V. yoshidai* stock of *V.* s. str.; this is regarded as a direct descendant of *Baluchicardia* group. The second is shown by *V. nipponica–V. subnipponica* stock; they are similar to *Venericor*, but strictly speaking they should be discriminated from the subgenus in having round-topped, narrower and nodulous ribs. The features are different also from other venericards of the Tertiary and probably they represent the unique stock of west Pacific in the time of Paleogene. The last is *V. nagaoi–V. vestitoides* stock, of which phylogenic relation and subgeneric position are some what doubt. They are rather similar to *Pacificor* than *Venericor*, but have no tripartite ribs in young stage; also they resemble *Leuroactis* in outline and ornamentation. The question on the attribution of the present stock to subgenus must await further study.

The remaining species are yet unknown in their phylogenic situations. *V. okinoshimensis* is probably of the same subgenus with *V. nipponica–V. vestitoides* stock, but it seems to be phylogenically accidental in the data of today; *V. hizenensis* also of large venericard probably represents the certain group which is not yet known abroad, though it seems to somewhat relate to *Clairbornicardia*; *V. harukii* is the soul representative of *Cyclocardia* in west Japan; *V. kondoi* is of *Cardites*, but the occurrence in west Japan in quite accidental phylogenically.

Lucinidae The *Eomiltha* of which genotype is of the Thanētian is presented by one indeterminable species (=NAGAO (1928b)'s *Phacoides* aff. *pullensis*) of the Kawamagari formation, "Yoshikuma fossil bed" and "Kamiyamada fossil bed" in west Japan. The genus is, according to GARDNER (1945), also included in the Domengine and Claiborne formations of north America.

Another form of the family, *Lucinoma* which is a common form in the Japanese Neogene deposits, is only shown by the Nishisonogian *L. nagaoi.* The species having rather small shell with rather fine concentric ornamentation is much found in the both sand and silt facies of the stage throughout the west Japan, and it is very similar in outline to *L. columbiana* (CLARK and ARNOLD) of the Sooke formation in the Vancouver Island.

Cardiidae The cardiid shell is rather rare in west Japan. In the Takashiman stage, *Vepricardium* is only found in the restricted horizon of the Miike area. *Fragum*? *kishimaense* is very useful as a guide fossil of Funazuan and Mazean (especially in the latter), and it is richly comprised in the nearly whole area of Hokusho-Amakusa. The remaining, *Clinocardium*, which is shown by many species with many individuals especially in the Paleogene sand facies of north Japan, is only represented by the Nishisonogian *C. okabei* newly found, which is restricted to the sand facies of Ashiya group.

Veneridae The pitarinid shell of the family is especially an useful biochronologic marker throughout the Paleogene deposits of west Japan. However, their phylogenic situations are yet unknown. The Takashiman stage is characterized by small and well inflated *Pitar hinokumai* anew found and *Callista ariakensis*; the former is found in many places, but the latter is only from Amakusa; the both are probably of littoral in the sea of somewhat low salinity, considering from their associated fauna. The Okinoshiman is represented by *P. kyushuensis*, *C. mitsuiana* and *C. kahoensis*; the first is much larger than *P. hinokumai* with less inflated and elliptical form, and it seems to be sand dweller in shallow sea, commonly occurring in the glauconitic sandstone together with many shallow other shells. It ranges to the above-lying Funazuan stage, though it is rather rare there. In the said-stage, *P. matsuraensis* and *P. yokoyamai* newly appeared; they are richly found especially in the Mazean. According to the writer's observation on the former species of Hokusho–Amakusa district, *Macrocallista matsuraensis* of NAGAO which was once cited as *Callista* by some author including the writer surely has the hinge of *Pitar*. In the Mazean, *P. kyushuensis* does not appear, but *P. matsuraensis* and *P. yokoyamai* are much found besides them, *P. matsumotoi* is rarely found. The Nishisonogian pitarinids are everywhere represented by *P. matsumotoi* and *Callista hanzawai* which ranges to the above-lying stage. And *P. ashiyaensis* also included in this stage is only much found in north Kyushu.

Of Dosiniinae, *Cyclina nodai* and *C. compressa* are included in the stages as shown in Table 15. *Dosinia* is present only at the Ashiya group of north Kyushu–west Japan; it was considered to be conspecific with *D. nomurai* of Neogene and based on the identification HATAI (1938) once designated the Ashiya group to early Miocene. On the Saseboan stage, *Cyclina japonica* is especially much comprised; shells of the species is commonly included in the Neogene deposits with many shells of southern element in Japan.

Tellinidae Of the tellinids, *Angulus maximus submaximus* was newly discriminated from *Tellina maxima* of NAGAO (1928b). It is only included in fine-~medium-grained sandstone of the Ashiya group, and differs in outline from *A. maximus* in having more rounded and higher shell. Among NAGAO's specimens, those of figs. 8 and 11 of pl. 4 (NAGAO, 1928b) are referable to the new subspecies.

X. Faunal Development in West Japan

The faunal development during Paleogene and early Neogene in west Japan can be well accounted by the biochronologic division here proposed having the type columns in its Hokusho–Amakusa district. The division is first based upon the joined occurrence of the molluscan species, above all those of turritellids, crassatellitids, carditids and pitarinids which are much comprised in the rocks in question. Besides them are taken in consideration the occurrences of another some genera and species of which vertical ranges are more or less restricted to certain horizon. The division may be also available to the actual procedures of stratigraphy and correlation in west Japan, and also useful to appropriately denote the biochronologic situation of certain molluscan fauna at certain area.

Summary of the faunal aspect of each stage The type column and characteristic molluscs of each stage are summarized in Table 16. The Takashiman

Table 16 Paleogene and lower Neogene biochronologic division in west Japan

Age	European Standard	Stage of* West Coast of North America	Stage in west Japan	Type column	Characteristic molluscs ( ) showing the abundant species in each zone, also included in other zones.
MIOCENE	Helvetian	Temblor	Unnamed		
MIOCENE	Burdigalian	Vaqueros	Saseboan	*Sasebo group and Kase formation* at Hokusho coal field	*Batillaria takeharai*, (*Molopohorus denselineatus*), *Glycymeris* cfr. *cisshuensis*, *Crassatellites yabei saseboensis*, *C. nagahamai*, (*Cyclina japonica*), *Tapes nagahamai*, *Meretrix* n. sp.
OLIGOCENE	(Aguitanian) Chattian	Blakeley	Nishisonogian	*Nishisonogi formation* at Sakito coal field	*Turritella infralirata*, *T. ashiyaensis*, (*Molophorus denselineatus*), (*Portlandia scaphoides*), (*Acila ashiyaensis*), *A. hirayamai*, *Glycymeris compressa*, *Ctenamusium takaii*, *Chlamys ashiyaensis*, *Lima nagaoi*, *Crassatellites inconspicuus*, *Venericardia vestitoides*, (*V. subnipponica*), *Lucinoma nagaoi*, (*Pitar matsumotoi*), *P. ashiyaensis*, (*Callista hanzawai*), *Dosinia chikuzenensis*
OLIGOCENE	Rupelian	Lincoln	Mazean	*Maze formation* at Sakito coal field	*Tropicolpus sakitoensis*, (*Turritella karatsuensis*), *Siphonalia ? nipponica*, *Nucula mazeana*, *Acila nagaoi*, (*Crassatellites matsuuraensis*), *C. komodai*, (*Venericardia yoshidai*), (*V. subnipponica*), (*Fragum ? kishimaense*), (*Pitar matsuraensis*), *Cyclina compressa*, (*Angulus maximus*), (*Volutospina japonica*), *Chlamys sakitoensis*
OLIGOCENE / EOCENE	Tongrian Bartonian	Keasey	Funazuan	*Funazu member* at Takashima coal field	*Ampullina nagaoi*, *Neptunea altispirata*, *Siphonalia asakuraensis*, (*Volutospina japonica*), (*Nucula hizenensis*), *Cucullaea nipponica*, *Noetia nagaoi*, *Chlamys sakitoensis*, *Crassatellites asakuraensis*, *Venericardia hizenensis*, "*Tellina*" *tricarinata*
EOCENE	Bartonian Auversian	Tejon "Transitional"	Okinoshiman	*Okinoshima and lower Iojima formations* at Takashima coal field	*Colpospira yabei*, *Polinices nomii*, *Mazzalina ? miikensis*, (*Pseudoperissolax yokoyamai*), (*Volutospina nishimurai*), (*Nucula hizenensis*), *Lima amaxensis*, (*Crassatellites nipponensis*), (*Venericardia nipponica*), (*V. mandaica*), *V. nagaoi*, *V. okinoshimensis*, (*Pitar kyushuensis*), *Cyclina nodai*,
EOCENE	Lutetian Ypresian	Domengin Capay	Takashiman	*Koyagi, Futagojima and Hashima formations* at Takashima coal field	*Bellamya koyagiensis*, *Colposira okadai*, *C. yabei*, *Faunus ? miikensis*, *Vicarya yabei*, *V.* n. sp., *Polinices eocenica*, ("*Orthaulax*" *japonicus*), *Eopleurotoma ? higoensis*, *Joannisiella problematica*, *Vepricardium miikense*, *Pitar takashimaensis*, *Callista ariakensis*, *Phaxas brevis*, *Caryocorbula subtumida*, *Lentidium ? kyushuense*
PALEOCENE	Landenian Montian	Meganos Martinez	Lack in west Japan ?		

* after Western Cenozoic Subcommittee (1944)

stage, which includes the deposits of the Paleo-Takashima and Paleo-Ariake bays in the Paleo-gulf of Shiranuhi, yields about 50 species of molluscs. They consist mostly of very shallow sea and brackish water dwellers, and neritic forms are poorly presented. Their distributions in the gulf were remarkably regulated by the environmental factors such as salinity, bottom materials throughout the age. Hypohaline brackish molluscs were represented by many species including *Phaxas*, corbulid, *Pitar hinokumai*, *Callista ariakensis* and *Vicarya yabei* which probably dwelled in sandy silt bottom and by *Vicarya* n. sp. and *Colpospira okadai* probably of medium-∼coarse-grained sand bottom. "*Orthaulax*", *Polinices* and *Faunus* were also most prevailing in the brackish environment, but they seem to be more or less ubiquitous or euryhaline. Neritic forms are represented by *Crassatellites*, *Venericardia* (two species), *Yoldia* sp., *Volutospina*? *nishimurai* etc. Their majority probably dwelled in the shallow neritic sandy silt bottom, where larger foraminifers of *Nummulites* and *Discocyclina* were prevailing (only in the early–middle time of the age). The chronologic vicissitudes of the environments of the gulf in the age also regulated the faunal distribution.

The Okinoshiman fauna is mostly shown by the fossils comprised in the glauconitic sandstone, and it numbers about 50 species. Some of them including *Venericardia*, *Crassatellites*, *Volutospina*?, "*Orthaulax*" *Pseudoperissolax* etc. are conspecific to the Takashiman shells, but their most parts are occupied by newcommers or relieves. In contrast to the Takashiman fauna, the present fauna is mostly represented by marine forms of probably sand dwellers, and the non-marine is poorly represented by some brackish water forms. In the latest Okinoshiman age, the large parts of the gulf were influenced by the fresh water, but the non-marine mollusc is not nearly found in the deposits of the time. The most characteristic aspect of the fauna is the abundant appearances of many large pelecypods represented by *Lima*, *Eomiltha*, *Pitar kyushuensis*, *Venericardia*, *Crassatellites*, *Pholadomya* etc. The distributions of some of them are remarkably restricted to certain area, as shown in Fig. 8.

The Funazuan fauna numbers about 40 species. They mostly dwelled in the variously grained sand marine bottoms of gulf which shifted northwards from geographic situation at the preceding age. Their majority is occupied by the newcommers, some of which range up to the Mazean age and by the survivers from the preceding age; the characteristic forms are rather few. The first is represented by *Turritella karatsuensis*, *Volutospina japonica*, *Nucula mazeana*, *Chlamys*, *Crassatellites matsuuraensis*, *Venericardia yoshidai*, *Pitar matsuraensis* and so on; the second is represented by *Volutospina*? *nishimurai*, *Nucula hizenensis*, *Pitar kyushuensis*; and the last is by *Venericardia hizenensis*, *Noetia*, *Cucullaea*, "*Tellina*" and other some forms. The non-marine form of the Karatsu and Sakito areas at the later time of the age is represented by *Corbicula mirabilis*. Of the marine forms, *Venericardia hizenensis* and "*Orthaulax*" were most widely distributed in the gulf, but majority of others was more or less restricted to some areas.

The Mazean fauna also mostly consists of marine forms, numbering about 40 species. They dwelled mainly in the neritic sand and sandy silt bottoms of the gulf, considerably lessened, comparing to that of the preceding age. The most abundant forms everywhere were *Turritella karatsuensis*, *Crassatellites matsuuraensis*, *Venericardia yoshidai*, *Fragum*? *kishimaense* and *Pitar matsuraensis*, found in the variously grained rocks. The abundant forms in the very fine-grained sand and sandy silt bottom were *Nucula mazeana* and *Venericardia subnipponica*.

The remarkable feature of the fauna is shown by the absence of large *Venericardia* of which representatives were presented in the preceding each age, and by the last appearance of "*Orthaulax*" and *Volutospina* which ranged from the Takashiman.

The Nishisonogian stage and its fauna show the most remarkable marine invasion in the Paleogene in west Japan. The gulf of this age which was extended roughly from southwest to northeast in the northwest of Kyushu was differentiated to two sedimentary and faunal provinces. The molluscs number about 90 species in total. The fauna is characterized by the lack of some genera or subgenera such as "*Orthaulax*", *Volutospina*, *Venericardia* s. str. and others and by the new appearance or much increasing of species or individuals of the Neogene type genera or subgenera in Japan such as *Hataiella*, buccinid, *Fulgoraria*, *Molophorus*, nuculanid, *Acila* s. str., *Septifer*, pectinid, *Cyclocardia*, *Lucinoma*, *Clinocardium*, *Dosinia*, *Spisula* etc. Concerning the remaining most forms, remarkable replacements of species were undergone. Their distributions were regulated by those of bottom materials as a whole and some assemblages can be recognized on them. Also, among the about 90 species, about 50 species are restricted to or very abundant in certain province out of the two, Karatsu–Sakito–Isahaya–Fukuoka and Chikuho–Kokura–Yuyawan, probably in the result of geographic or ecologic isolation, owing to the difference of some marine conditions.

The Saseboan fauna is rather poorly represented by about 20 species of shallow marine and brackish water and also by some non-marine species. The former forms include the relics of the preceding age (especially of Ashiya–Kokura–Yuyawan area) such as *Molopophorus*, *Euspira*, *Pitar* and *Callista* and the newcommers of *Batillaria*, *Cerithium*, *Chicoreus*, *Cyclina*, *Crassatellites nagahamai*, *C. yabei saseboensis* and *Glycymeris* cfr. *cisshuensis*, the last of which was probably derived from the forms of the preceding age.

Thus, the total species of the whole stage number about 230 species, of which about 30 species are new species or subspecies. Their majority is of marine-hypohaline brackish water.

As a whole, the faunal vicissitude is characterized by the abrupt changes of the constituents, and also the non-marine forms are rather poorly presented except in some stages.

When the rough characteristics of six faunae are taken in consideration, disregarding some difference to each other, the Takashiman and Okinoshiman are characterized by the occurrence of *Venericor*-like large *Venericardia*, *Crassatellites nipponensis*, *Colpospira*, *Volutospina*? *nishimurai*, *Pseudoperissolax yokoyamai* etc. The Okinoshiman and Mazean are characterized by the common occurrences of *Crassatellites matsuuraensis*, *Venericardia yoshidai*, *Pitar matsuraensis*, *Volutospina japonica*, *Turritella karatsuensis* etc. But another type of large *Venericardia* or some Okinoshiman species such as *Nucula hizenensis* and others are restricted to the Funazuan, and on the other hand many species are only included in the Mazean. Then, the Funazuan stage shows the transitional features as to the faunal vicissitude. The Nishisonogian forms another faunal "horizon" and it is also true concerning the Saseboan. Thus, roughly speaking, the writer's three divisions of *V. nipponica*-, *V. yoshidai*- and *V. vestitoides* zones which were preliminarily given (MIZUNO, 1956a) can be accepted to the faunal vicissitude, except the problem of Funazuan.

Comparison with the foreign faunae and chronologic situation of each stage The faunae in question are considerably different from the foreign faunae as a whole and consequently it is very difficult to surely designate each stage to certain chronologic situation. However, fortunately there are found some similarities between them as to the generic or specific composition and the modes of faunal vicissitude. They are summarized as follows.

First, a special attention should be given to the existence of large venericard in the lower stages of west Japan. The large *Venericardia* is qualified as the most important Eocene indicator in many regions of the world. Although the Japanese forms probably belong to other subgenera than those known so far, it will be possible to designate the lower three stages to Eocene, so far as the large venericards are concerned.

The similarity to the tropic-subtropic fauna of "Tethyan provinces" is suggested, though the common species are quite absent, by *Colpospira, Tropicolpus, Bellatara, Lyria, Vicarya, Faunus, Volutospina, Noetia, Septifer, Eucrassatella, Venericardia* s. str., large venericards etc., and besides, by *Nummulites* and *Discocyclina*, of large foraminifers. Among them, *Colpospira* is related to its species of Malayan Cretaceous-Eocene. *Noetia* and *Septifer* are related to their species of Burman upper Eocene. *Vicarya* n. sp. is closely similar to *V. eocenica* of the Laki. *Eucrassatella* and *Venericardia* s. str. was probably directly derived from the Danian forms of Northwest India. The similarity is stronger in the lower stages, and very weak especially in the Nishisonogian. On the other hand, the similarity to the Northeast Paleogene fauna is shown by many genera especially much included in the Nishisonogian, though the common genera are more or less found in the whole stages. They are of temperate-cool elements, especially represented by *Acila, Yoldia, Portlandia Pseudoperissolax*, buccinid, *Molopophorus, Cyclocardia, Clinocardiun, Lucinoma, Peniploma* etc. Comparing the rough faunal vicissitudes in the both west Japan and the area above cited, some similarities are also found. Though they are very different to each other in detail, the Nishisonogian fauna is somewhat similar to the upper Oligocene fauna including those of the Blakeley and Sooke in having *Acila* s. str., *Pseudoperissolax, Portlandella, Lucinoma* and *Monia*, of which latter four are only slightly different to each other. The Mazean fauna has no *Acila* s. str., but includes only *Truncacila* and in this respect it coincides with the lower-middle Oligocene Lincoln fauna. The Funazuan fauna does not nearly show the similarity of faunal constituents with the area in question, but it seems to show the similarity of faunal composition to that of the fauna of Keasey ("Gaviota stage") in consisting of elements of lower and upper horizons (Clark and Vokes, 1936). The Okinoshiman and Takashiman faunae are similar to those of the lower horizon than the Tejon in having large venericards and *Pseudoperissolax.*

Another faunal similarity is given between the gulf coast region as to the lower stages of the west Japan, though poorly.

In considering the chronologic situations of the stages of west Japan, their detailed correlation with the European standard division is nearly impossible, owing to the absence of the common species and to the difference of faunal vicissitude. However, roughly speaking, large venericards of *Venericor*-like in the

Takashiman and Okinoshiman suggest their sure attributions to Eocene. The view is also maintained by *Eomiltha*, abundant occurrence of "*Orthaulax*" (?=*Pseudoliva*), *Mazzalina* ?, *Bellatara* ? and large type *Pseudoperissolax*. Moreover, the occurrence of *Vicarya* n. sp. from the middle part of the Takashiman seems to suggest its attribution to the lower Eocene to which the Laki of India belongs, and this inference is harmonious with the foraminiferal viewpoint. The correlations of the two stages with the European standard and the stages of Pacific Coast of North America are tentatively given in Table 16. In this connection, the occurrence of the mammalian *Amynodon* from the west Japan, which is said to be of the Bartonian (TAKAI, 1950), is noticeable. While, unfortunately the sure correlation of the Ube group, in which it is yielded, with the type column of the Hokusho-Amakusa district, is yet somewhat obscure, though the writer considers it as of the Okinoshiman as discussed before. On the other hand, the Nishisonogian and Mazean are correlated to the Blakeley and Lincoln stages as formerly said and are probably designated to the Oligocene. Concerning the Funazuan, respecting the existences of many newcommers of the Mazean forms, here the writer tentatively disignates it to the lowest Oligocene, although some Eocene forms range to the stage and it is probable that the true boundary between Eocene and Oligocene is put into the formation. The uppermost, Saseboan, is probably designated to lower Miocene (Burdigalian)–? middle Miocene (Helvetian), yielding some newcommers of warm water, which are abundantly represented in the middle Miocene fauna in Japan. The view is maintained by the floral (TANAI, 1955) or mammalian evidences (TAKAI, 1952).

Controlling factors of the faunal vicissitude The faunal vicissitude in west Japan was controlled by some factors as discussed below.

The diversity of habitat in each age brought the diversity of molluscan fauna in each age. The diversity of habitat is shown in each age by salinity (marine, brackish or fresh water), depth (littoral or neritic), bottom material (coarse-grained or fine-grained), hydrographic situation in the gulf and shape of the gulf. The stratigraphic and geographic distributions of every genera and species were regulated by these factors in general, and also the paleo-ecologic inferences are made inevitably very rough and sometimes the procedures are based upon the modes of field occurrences of shells, as the result that the detailed ecologic informations on recent animals cannot be nearly directly adopted.

For the cause which brought the faunal difference of each age, some are pointed out. Its most remarkable feature is shown by the replacement of species in certain genus or subgenus. Although it cannot be appropriately explained in many cases in the present time, some cases can be considered to owe to the phylogenic evolution. For example, the "orthogenetic chronocline" is evidently recognizable in the change of nuculid species from the Okinoshiman to the Mazean, and the change is probably owe to the chronologic change of environmental condition especially represented by the bottom materials. Also, some of turriterid, crassatellitid, venericard and tellinid show the phylogenic evolutions, though the majority of their detailed processes is nearly unknown, owing to the poorness of materials. The phylogenic evolution can be expected for other taxon, but it must await further studies. Among the above-cited forms, some of crassatellitid (represented by *Eucrassatella*) and venericard (represented by *Venericardia* s. str. and *Venericor*-like large *Venericardia*) were probably suffered from the quite endemic developments throughout the Paleogene.

Another important factor for the faunal vicissitude is shown by the immigration and emigration of shells, probably associated with the change of general climate and marine climate. Roughly speaking, the fauna of each age is divided into two forms; the one is the tropic-subtropic Indo-Pacific form especially represented by the molluscs of middle-lower stages, and the other is the temperate-cool Northern Pacific form especially represented by the molluscs of the Nishisonogian, though it is poorly represented in the middle-lower stages, too. The immigration and emigration of shells thus more or less introduced the faunal similarity to the foreign fauna in every age and also the faunal difference of each age.

The faunal vicissitude seems to be somewhat harmonious with the historical change of paleo-geography mainly represented by the geographic situation of the gulf. They were related to each other probably through the change of marine conditions in the result of the change of the paleo-geography.

XI. Summary and Conclusion

1. The area of the Paleo-gulf of Shiranuhi in Kyushu, where many coal fields are developed, is divided into the Hokusho-Amakusa and north Kyushu-west Honshu districts, based upon the manners of developments of the Paleogene and lower Neogene strata.
2. The 6 stages were proposed on them, based upon the molluscan assemblages and their type columns were designated to the strata of the former district where nearly perfect stratigraphic and faunal column of the rocks in question can be obtained. Their sequence, type columns and characteristic molluscs are shown in Table 16.
3. The precise correlations of the 6 stages with the European standard and the stages of the Pacific Coast of North America are very difficult as a whole, owing to the large differences of faunal aspects. The rough correlations are given in Table 16, based upon some similarities of constituents and aspects of faunal vicissitude.
4. The Eocene-Oligocene boundary may be kept in the Funazuan stage, but tentatively and conveniently the Funazuan is here assigned to the lowest Oligocene. The Oligocene-Miocene boundary is kept between the Nishisonogian and Saseboan.
5. The total molluscs of the 6 stages number about 230 species, of which 30 species are new species or subspecies. Their majority is of marine-hypohaline brackish water.
6. Respecting the rough aspect of faunal vicissitude, the three divisions of "*Venericardia nipponica*-", "*V. yoshidai*-" and "*V. vestitoides* zones" preliminarily proposed by the writer (1956a) can be adopted, with some modifications especially on the boundary between the former two.
7. The Takashiman and Okinoshiman faunae are characterized by many Eocene genera and subgenera represented by *Venericar*-like large *Venericardia*. Their most parts are of tropic-subtropic. The Funazuan and Mazean faunae are roughly united to the assemblage characterized by *Turritella karatsuensis, Pitar matsuraensis, Venericardia yoshidai,* but

in the Funazuan fauna the Eocene forms are also found. The Nishisonogian fauna is characterized by many genera abundantly found in the Neogene of Japan, most of them being of temperate-cool in northern Pacific. The Saseboan fauna is characterized by the co-occurrence of the Nishisonogian species and typically Neogene species of warm element.

8. The causes of faunal vicissitude imply some factors. Stratigraphic and geographic distributions of molluscs in each age were evidently regulated by the various conditions of bottom material, water, topography etc. in the gulf. Appearances of molluscs in each age were partly regulated by their phylogenic evolutions (clearly recognizable in some of turritellid, nuculid, crassatellitid, venericard and tellinid), and the immigration owing to the changes of climatic and physical conditions of the gulf also probably played an important role for the faunal vicissitude.
9. The Eocene molluscan fauna of west Japan was once cited by DAVIES (1934) as "showing the obvious overlap of Tethyan and Californian forms", based upon NAGAO (1928a, b)'s work. His conclusion seems to be roughly true in the light of the informations of today, though its mode varies considerably in each age. Also it should be noticed that there were endemic developments of some stocks, too, in Japan, especially represented by *Eucrassatella* (Eocene-early Miocene) and venericardian stocks including *Venericor*-like large venericards (Eocene-late Oligocene) and *Venericardia* s. str. (Eocene-early Oligocene). The fact suggests the peculiarity of the marine condition around Japan during the ages.

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西日本地域における古第三紀—初期新第三紀の貝類群の時代的変遷

水野　篤行

要　旨

この論文は筆者がいままで行なってきた，本邦の古第三紀貝類群の諸問題についての研究の結果の1部である。西日本地域の古第三系は浅海棲貝類化石を多量にふくむ海成層および汽水～淡水棲貝類化石をふくむ夾炭非海成層からなり，貝類群の変遷の問題についての好材料を提供している。また，その層序断面から得られた結果は，本邦他地域ならびに全域にわたる同時代の貝類群に関する考察（別に発表の予定）の基礎的資料となるものである。

西日本地域のうちでも，とくに北西九州（北松—天草地域とよんだ）地方には，下部始新統から中新統にわたる地質系統が，各地域でその発達状況は多少ことなるが，分布し，綜合すれば，ほとんど時間的間隙がない一連の層序断面をうることができる。この地域の高島炭田および崎戸炭田に発達するものを模式断面として，次の6階が識別される。

階	統
佐世保階	下部中新統
西彼杵階	漸新統
間瀬階	漸新統
船津階	漸新統
沖ノ島階	始新統
高島階	始新統

各階の貝類群の特徴をのべ，またくわしい地域ごとの産出化石の表を付した。そしてこれらの古生態，古地理との関係についてもふれている。次に，主要属種の分類，系統関係を考察している。しかし，ここでは，その結果の要約だけをのべた。約230種がみられ，そのうちの30種は新種であるが，新種の記載をふくむ分類学的考察については，別にくわしく報告する予定である。

最後に，貝類群の時代的変遷を総括し，その要因をかんたんに考察した。時代的変遷は属種の系統進化および気候的変化（厳密にいえば，marine climate の）にもとずいたものと考えられる。

地質調査所報告は1報文について報告1冊を原則とし，その分類の便宜のために，次のようにアルファベットによる略号を付ける。

- A. 地質およびその基礎科学に関するもの
  - a. 地　質
  - b. 岩石・鉱物
  - c. 古生物
  - d. 火山・温泉
  - e. 地球物理
  - f. 地球化学
- B. 応用地質に関するもの
  - a. 鉱　床
  - b. 石　炭
  - c. 石油・天然ガス
  - d. 地下水
  - e. 農林地質・土木地質
  - f. 物理探鉱・化学探鉱および試錐
- C. そ の 他
- D. 事業報告

As a general rule, each issue of the Report, Geological Survey of Japan will have one number, and for convenience's sake, the following classification according to the field of interest will be indicated on each Report.

- A. Geology & allied sciences
  - a. Geology
  - b. Petrology and Mineralogy
  - c. Paleontology
  - d. Volcanology and Hot spring
  - e. Geophysics
  - f. Geochemistry
- B. Applied geology
  - a. Ore deposits
  - b. Coal
  - c. Petroleum and Natural gas
  - d. Underground water
  - e. Agricultural geology, Engineering geology
  - f. Physical prospecting, Chemical prospecting & Boring
- C. Miscellaneous
- D. Annual Report of Progress

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Tanemura, M.: Geological and mineralogical studies of clay and silica sand deposits in Seto district, Aichi prefecture, 1963 (in Japanese with English abstract)

Mizuno, A.

Paleogene and Early Neogene Molluscan Faunae in West Japan

Atsuyuki Mizuno

Report, Geological Survey of Japan, No. 204, p. 1~72, 1964
21 illus., 16 tab.

This paper clarifies the molluscan faunal developments during Paleogene and early Neogene in the areas of coal fields mainly in northern Kyushu.
Based on the stratigraphic and faunal sequence at Takashima, Sakito and Sasebo areas, the six stages, namely, Takashiman, Okinoshiman, Funazuan, Mazean, Nishisonogian and Saseboan, in ascending order, are established, of which lithologic and paleontologic characteristics are discussed. The faunal developments were resulted from such factors as phylogenic evolution and migration owing to the change of climatic and physical conditions of the water.

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