A Miocene molluscan fauna from the Owase Group, Kii Peninsula, Southwest Honshu

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紀伊半島南東部，中新統尾鷲層群の貝類化石群

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(要　　旨)

紀伊半島南東部の三重県尾鷲市付近には，下部－上部中新統の尾鷲層群が分布する．尾鷲層群は下位から大曽根層，行野浦層，瀬元鼻層の三層に区分され，行野浦層からは *Nuculana* sp., *Acila* sp., *Portlandia* sp., *Cyclocardia siogamensis* (Nomura), *Lucinoma* sp., *Macoma optiva* (Yokoyama), *Cultellus otukai* Ogasawara and Tanai, *Periploma* sp., *Turritella (Hataiella) sagai* Kotaka, *Cerithium* sp., *Cryptonatica* sp.などの貝類化石を産する．同層の貝類化石群集は下部浅海，暖温帯の要素を含み，瀬戸内中新統東部及び紀伊半島南東部の熊野層群下－中部の貝類化石群集に類似する．さらに群集組成の上から沖合泥底を特徴づける *Acilana tokunagai* フォーナにも類似し、熊野層群分布域を含む本地域に寒流系水塊（親潮潜流）の南限が及んでいたと考えられる。

(Abstract)

A marine transgressive sequence of the Owase Group (late early to earliest middle Miocene) outcrops in the southeastern part of the Kii Peninsula, southwest Honshu, Japan. The group is divided, in ascending order, into the Osone, Yukunoura and Semotobana Formations. The Yukunoura Formation consists largely siltstone (or sandy siltstone), and yields *Nuculana* sp., *Acila* sp., *Portlandia* sp., *Cyclocardia siogamensis* (Nomura), *Lucinoma* sp., *Macoma optiva* (Yokoyama), *Cultellus otukai* Ogasawara and Tanai, *Periploma* sp., *Turritella (Hataiella) sagai* Kotaka, *Cerithium* sp., and *Euspira* sp. The faunas of the Yukunoura Formation indicates a lower sublittoral, warm-temperate environment and correspond to the faunas of the lower and middle parts of the Kumano Group, southeastern Kii Peninsula, and those of the eastern First Setouchi Series and correlative strata, central Honshu. In addition, the fauna of the Owase Group corresponds to the *Acilana tokunagai* Fauna of northern and central Japan. It is inferred that the Owase district had been influenced by the southern limit of the subsurface cold current, which has been called *Oyashio Senryu*.

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Introduction and Acknowledgments

Ogawa (1904) was the first to study the geology of the Owase district, southeastern part of the Kii Peninsula, southwest Honshu. He divided the Cenozoic strata into "Conglomerate", "Shale" and "Sandstone", in ascending order, and recorded *Melania* sp.? from the Shale. Subsequently, Iizuka (1932) studied the geology of the Owase district, and divided the strata into the Matoya (Jurassic) and the Miyai Beds (Paleogene) in upward sequence. Iizuka further divided the Miyai Beds into three units which, in ascending order, are the lower (conglomerate and sandstone, about 100 m in thickness), middle (alternating beds of sandstone and shale, about 200 m), and upper (shale intercalating sandstone and conglomerate, over 600m) units. Iizuka (1932) recorded such mollusks as *Lucina* sp. and *Tellina* sp. from the Miyai Beds.

Suzuki (1934) assigned the Miyai Series a Miocene age, and recorded molluscan fossils from the "Yukunoura Formation": "*Pecten*" n. sp., *Macoma owasensis* (invalid), *Aloides*, n. sp., and *Periploma owasense* Suzuki. Suzuki and Ito (1946) assigned the Miyai Series an early to middle Miocene age, based on the molluscan fossils.

Mizuno (1951) proposed the Miyai Group for the Shimosato and Miyai Series, southeastern part of the Kii Peninsula. Subsequently, Mizuno (1953) proposed the Kumano Group (middle Miocene) for Mizuno's (1951) Miyai Group, and divided the Kumano Group into the Koguchi and Mitsuno Formations in ascending order. Mizuno (1953) also discussed the molluscan assemblages of the Kumano Group, and doubtfully correlated the Miocene of the Owase district with the Koguchi Formation of the Kumano Group.

Mizuno (1953) and Tanai and Mizuno (1954) recorded the following molluscan fossils from the Koguchi Formation: *Acharax tokunagai* (Yokoyama), *Acilana tokunagai* (Yokoyama), *Lucinoma otukai* Hatai and Nisiyama, *Conchocele bisecta* (Conrad), *Macoma optiva*, *Turritella (Hataiella) sagai*, and *T. (Hataiella) kodonosawaensis* Otuka. In addition, Mizuno (1953) and Tanai and Mizuno (1954) recorded molluscan fossils from the Mitsuno Formation. These are dominated by warm water dwellers such as *Saccella congiensis* (Otuka), *Glycymeris (Veletuceta) cisshuensis* Makiyama, *A. (Anadara) kiiensis* Mizuno, *Crassatellites nanus* (Adams and Reeve), *D. (Phacosoma) nomurai* Otuka, *Timoclea nipponica* Mizuno, *Siratoria siratoriensis* (Otuka), *Macoma (Macoma) tokyoensis* Makiyama, *Turritella (Turritella) kiiensis* Yokoyama, *T. (Hataiella) shataii* Nomura, and *Conus (Chelyconus) tokunagai* Otuka.

Araki (1958) proposed the name Owase Group for the Miocene in the Owase district outcropping to the north of the Kumano Group. He divided it into the Osone Conglomerate and the Yukunoura Formation in upward sequence. Araki (1958) described a total of 12 species of bivalves from the Yukunoura Formation including *Acila* cf. *A. (Acila) oyamadensis* Hirayama, *Lucinoma* cf. *L. acutilineatum* (Conrad), *Tellina matsumotoensis* Araki, *Macoma optiva*, *Cultellus otukai*, *Thracia pertrapezoidea* Nomura, *Turritella* sp., indet., and *Cerithium* sp., indet., from the lower part of the Yukunoura Formation; and *Periploma yokoyamai* Makiyama from the upper part. But there were only three species illustrated

from the Owase Group (Araki, 1958).

Araki, Akamine, and Yamada (1959) divided the Owase Group into the Osone, Yukunoura, and Semotobana Formations in ascending order. The Semotobana Formation corresponds to the upper part of the Araki's (1958) Yukunoura Formation. They recorded *Crassostrea gigas* (Thunberg), *Lucinoma otukai*, *Dosinia (Kaneharaia) kaneharai* Yokoyama, and *Macoma optiva* from the Semotobana Formation. Saeki and Koto (1972) studied the geology and ore deposits of the Miyai Group, and divided it into four units, which in ascending order are the Onuma, Taketo, Itaya, and Okochi Formations. They mapped the Miocene of the Owase district, the Okochi Formation, as a northern extension of the Kumano Group.

Ohe and Hamaguchi (1975) recorded a pleuronectid fossil fish from the Yukunoura Formation, in association with *Macoma optiva, Miogypsina* sp., and *Lepidocyclina* sp. The modern descendant of this fossil fish live in cold to temperate waters at depths of 40 to 300 m around Japan (Ohe and Hamaguchi, 1975). Katto, et al. (1980) recorded molluscan fossils from the lower part of the Shiko Formation of the Kumano Group. The Shiko Formation is correlated with the Mitsuno Formation (Saeki and Koto, 1972). Hisatomi (1981) studied the geology of the Kumano Group, and divided it into the Shimosato, Shikiya and Mitsuno Formations in ascending order. He assigned the Kumano Group an late early to middle Miocene.

Ujihara and Shibata (1982) recorded molluscan fossils from the Shimosato and Shikiya Formations of the Kumano Group, and assigned the Koguchi Formation a late early to early middle Miocene age. Hisatomi (1984) divided the Kumano Group into three units which in ascending order are the Onuma (or Shimosato), Koguchi (or Shikiya), and Mitsuno Formations. Chijiwa and Tomita (1985) studied the geology of the Kumano Group, and recorded molluscan fossils from the Onuma Formation of the Kumano Group. Although the lower and upper limits are indeterminable, Chijiwa (1988) made a sedimentological study of the Kumano Group, and assigned the Kumano Group to the late early to earliest middle Miocene.

Itoigawa (1988) divided the Miocene "Kadonosawa fauna" of Southwest Japan into two faunas: the subtropical Akeyo (ca. 18 to 16+ Ma) and tropical Kurosedani (ca. 16+ to 15 Ma) faunas. The two faunas reflect the difference in the paleocurrent during late early to earliest middle Miocene times (Itoigawa, 1988). The Akeyo fauna is represented by the Akeyo Formation of the Mizunami Group (Itoigawa, 1988). Recently, Karasawa (1990) recorded the *Carcinoplax antiqua-Trachycarcinus huziokai* assemblage from the Koguchi Formation, which indicates a subtropical, lower neritic (over 120 m in depth) environment.

The purpose of the present study is to discuss and to clarify the characters of the molluscan fauna of the Owase Group. The author expresses his deep gratitude to Professor Tamio Kotaka, Tohoku Gakuin University for his continuous encouragement during the study, and to Professor Kenshiro Ogasawara, Institute of Geoscience, University of Tsukuba for his helpful advice during the study and helpful criticism of the manuscript. Thanks are also extended to Dr. Fred J. Wicks, Royal Ontario Museum, Canada for his

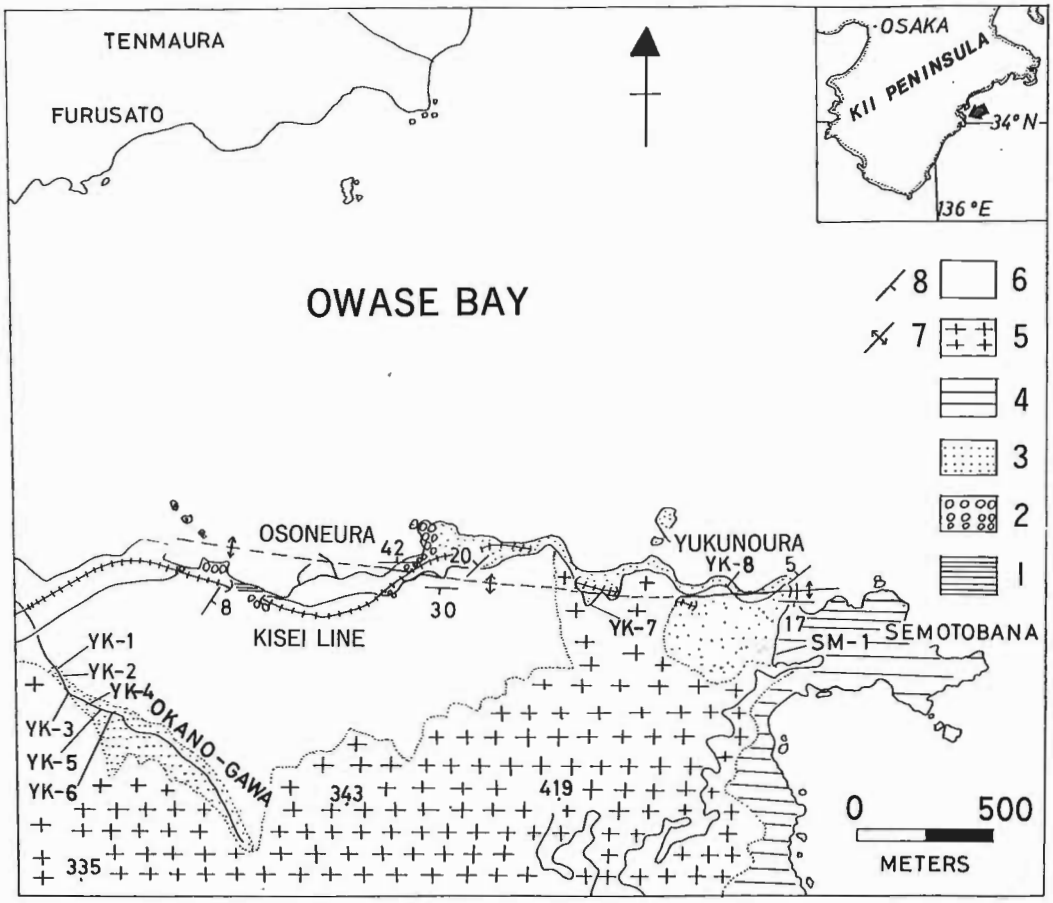


Fig. 1. Geological map of the southern coastal area of the Owase Bay. 1, Matoya Group. 2-4, Owase Group; 2, Osone Formation; 3, Yukunoura Formation; 4, Semotobana Formation. 5, Kumano Acidic Rocks. 6, Elevated Alluvial fan deposits. 7, Anticline. 8, Strike and dip. YK- and SM- are sample locations.

valuable assistance to improve this manuscript.

Outline of Geology

In the area studied, the strata are divided into the Matoya and Owase Groups, and the elevated Alluvial fan deposits (Fig. 1). The Kumano Acidic Rocks intrude into the Owase Group. The Matoya Group was proposed by Iizuka (1929), and outcrops in a small area of the southern coast of the Owase Bay. The group consists largely of alternating sandstone and shale, with nearly vertically dip. No megafossils were found in the Matoya Group, although, abundant radiolarian fossils of a Cretaceous age have been recorded from the equivalent Shimanto Group in the Nanto-Nansei area, southern part of Mie Prefecture (Mizutani, Nishiyama, and Ito, 1982).

The Owase Group clinounconformably covers the Matoya Group and outcrops in the

northern and southern coast of the Owase Bay (Iizuka, 1932 ; Araki, Akamine and Yamada, 1959). The group shows a marine transgressive, sequence from conglomerate, through sandstone, to shale. It is divided into the Osone, Yukunoura, and Semotobana Formations in ascending order (Fig. 2). The rocks of the Group strike about N 10° to 30° E and dip 10° to 20° north or south and form a E-W trend, anticlinal structure called the Osone Anticline (Araki, Akamine and Yamada, 1959).

The Osone Formation is composed mainly of poorly stratified, pebble to cobble, subrounded conglomerate. The pebbles and cobbles are composed of chert and sandstone derived from the Matoya Group. The Formation attains a thickness of about 100 m. No megafossils were recovered from the Osone Formation.

The Yukunoura Formation is composed of massive or stratified, dark gray siltstone (or sandy siltstone) frequently intercalated with thin sandstone layers. The formation attains a thickness of approximately 200m. The upper part of the Yukunoura Formation is intercalated with a conglomerate layer several meters thick. The formation frequently

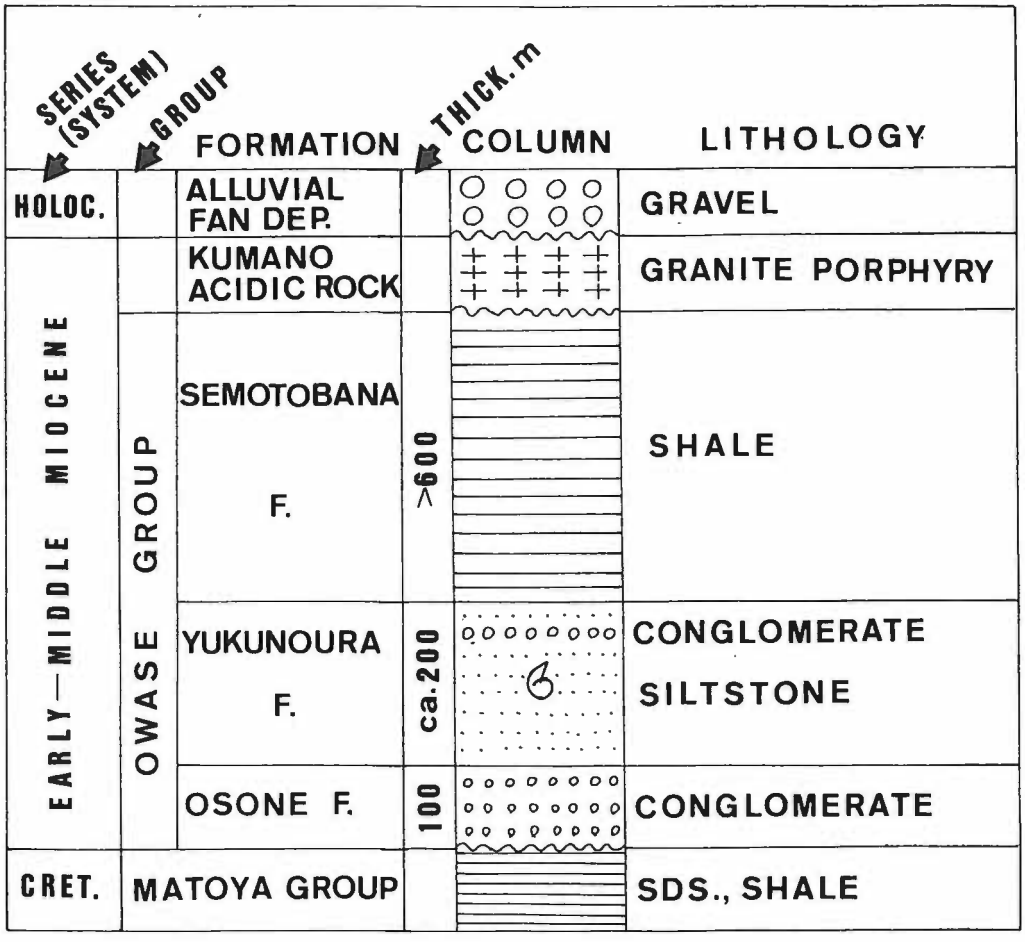


Fig. 2. Stratigraphic classification of the Owase district.

yields molluscan fossils, including *Acila* sp., *Nuculana* sp., *Portlandia* sp., *Cyclocardia siogamensis* (Nomura), *Macoma optiva*, *Cultellus otukai*, *Turritella (Hataiella) sagai* Kotaka, *Cerithium* sp., and *Euspira* sp. (Table 1).

The Yukunoura Formation frequently contains carbonized plant remains. An annelid tube was recovered from siltstone of the formation and a pteropod fossil, *Clio itoigawai* (Shibata) has been recorded from the Yukunoura Formation (Shibata and Ujihara, 1990).

The Semotobana Formation consists largely well-bedded, well-jointed gray shale, and attains a thickness of over 600 m. Only one specimen of a scaphopod was obtained from the Semotobana Formation.

The Kumano Acidic Rocks outcrop extensively in the Owase district and southward. They are largely composed of granite porphyry and are surrounded by Miocene strata. The absolute age of the Kumano Acidic Rocks is between 14 to 15 Ma (*vide* Chijiwa, 1988, p. 365). The elevated Alluvial fan deposits (Mii and Araki, 1959) are unconsolidated, and composed of irregularly arranged, poorly sorted, angular, granite porphyry boulders derived from the Kumano Acidic Rocks. The deposits unconformably cover the underlying strata.

Table 1. Occurrences of mollusks from the Yukunoura and Semotobana Formations. YK, Yukunoura Fm. SM, Semotobana Fm., R, rare (one individual); F, few (2 to 4 individuals); A, abundant (10 to 19 individuals).

SPECIES	YK-								SM-
	1	2	3	4	5	6	7	8	1
Bivalves:									
Acila sp.							F		
Nuculana sp.							R		
Portlandia sp.		R							
Cyclocardia siogamensis (Nomura)					R				
Cyclocardia sp.					F		R		
Macoma (Macoma) optiva (Yokoyama)							R		
Macoma sp.				A	R	F			
Lucinoma sp.								R	
Cultellus otukai Ogasawara and Tanai					R				
Periploma sp.			A	R	F		R	R	
Gastropods:									
Turritella (Hataiella) sagai Kotaka		R							
Turritella sp.		R							
Cerithium sp.	F				R				
Cryptonatica sp.			R						
Scaphopods:									
Dentalium sp.									R
Dentalium? sp.		R							

Fauna and Correlation

About 50* specimens were collected at eight localities in the Yukunoura Formation and one specimen at one locality in the Semotobana Formation (Fig. 1). These specimens comprise eight genera and eight species of bivalves, three genera and three species of gastropods, and one genera and one species of a scaphopod (Table 1). These genera found in the Yukunoura Formation still live today in upper (or lower) sublittoral to bathyal, or sublittoral environments (Higo, ed., 1973 ; Habe, 1977). Those found in the former are *Acila*, *Nuculana*, *Portlandia*, *Cyclocardia*, *Macoma*, *Periploma*, and *Dentalium*, and those in the latter are *Lucinoma*, *Cerithium*, and *Cryptonatica*.

In general, the fossils occur sporadically in gray siltstone (or rarely in very fine-grained sandstone) of the Yukunoura Formation. Although, original shell material has been dissolved after their burial, a large number of the specimens are nearly complete. This mode of occurrences suggests that they are autochthonous or only slightly allochthonous assemblages. On the basis of the above discussions, it is concluded that the molluscan assemblages of the Yukunoura Formation indicate a lower neritic environment.

The molluscan fauna of the Yukunoura Formation is characterized by *Acila* sp., *Nuculana* sp., *Portlandia* sp., *Cyclocardia siogamensis*, *Lucinoma* sp., *Macoma optiva*, *Cultellus otukai*, *Periploma* sp., *Turritella sagai*, *Cerithium* sp., and *Euspira* sp. In addition, the Semotobana Formation has yielded a molluscan fauna which is similar to that of the Yukunoura Formation and includes *Lucinoma otukai*, *Periploma yokoyamai*, and *Macoma optiva* (Araki, 1958 ; Araki, Akamine, and Yamada, 1959). At the present these genera live exclusively in the temperate waters of Japan (Higo, ed., 1973 ; Honda, 1989). Therefore, the molluscan fauna of the Yukunoura and Semotobana Formations are assumed to also have lived in a temperate environment.

From the Koguchi Formation, the middle part of the Kumano Group, Mizuno (1953) and Tanai and Mizuno (1954) recorded mollusks such as *Acharax tokunagai*, *Acilana tokunagai*, *Lucinoma otukai*, *Conchocele bisecta*, *Macoma optiva*, *Turritella sagai*, and *T. kadonosawaensis*. This assemblage, as a whole, indicates a lower sublittoral to bathyal, temperate environment. In addition, Ujihara and Shibata (1982) recorded molluscan fossils, including pteropods and heteropods from the Shimosato and Shikiya Formations. They recorded such species as *Acharax tokunagai*, *Acila* sp., and *Portlandia (Portlandella) watasei* (Kanehera) from the Shimosato Formation, and *Macoma optiva* and *Periploma owasense* from the Shikiya Formation. Ujihara and Shibata considered that the molluscan assemblages of the Shimosato and Shikiya Formations indicate a lower sublittoral or upper bathyal environment.

Furthermore, Chijiwa and Tomita (1985) recorded molluscan fossils at 10 localities of the Onuma Formation forming the lower part of the Kumano Group. From the locality

* One individual is considered herein to consist of more than half of a separated valve or a conjoined pair of bivalves, and more than half of a complete gastropod or scaphopod specimen.

7, it yields *Acila* sp., *Portlandia watasei*, *Cyclocardia siogamensis*, *Macoma optiva*, *Cultellus izumoensis* Yokoyama, and *Periploma* sp. Chijiwa and Tomita (1985) considered that this assemblage is autochthonous and indicates a lower neritic environment.

All these molluscan assemblages of the Kumano Group are characterized by the occurrence of *Acila* sp., *Portlandia watasei*, *Cyclocardia* sp, *Lucinoma* sp., *Macoma optiva*, *Cultellus izumoensis*, *Periploma* sp., and/or *Turritella* sp. There are species (or genera) in the Yukunoura Formation that are common or closely related to those of the Kumano Group.

On the other hand, Shibata (1978) recognized a total of 53 molluscan assemblages in the eastern First Setouchi Series (late early to earliest middle Miocene) of central Honshu. These include the *Macoma-Lucinoma*, *Periploma-Acila*, and *Turritella-Lucinoma* assemblages from the First and Second phases of the First Setouchi Series, which indicate an upper, or upper to lower, sublittoral environment (Shibata, 1978).

The molluscan assemblages of the Yukunoura Formation are characterized by the frequent occurrences of *Macoma* and *Periploma*. Also there is a similarity in the composition of the molluscan assemblages amongst the Yukunoura, Koguchi, Shimosato, Shikiya, and Onuma Formations, and the eastern part of the First Setouchi Series so that they all correspond to one another.

In addition, the Morozaki Group of the Chita Peninsula, central Honshu is characterized by the occurrence of *Acilana tokunagai*, and yields such genera as *Solemya*, *Acila*, *Malletia*, *Portlandia*, *Cyclocardia*, *Lucinoma*, and *Periploma* (Shikama and Kase, 1976). The fauna of the Yukunoura Formation, on the whole, corresponds to the Morozaki Group in faunal composition. The occurrence of *Acilana tokunagai* indicates the influence of subsurface cold current (*Oyashio Senryu*; Chinzei, 1981) during early to middle Miocene time.

It is inferred that the present area was the southern margin of subsurface cold current flow, as was suggested by Noda, Kikuchi, and Nikaido (1989). Hisatomi (1984) also concluded that this current possibly had flowed into the Kumano basin, based on paleocurrent direction studies, as well as the occurrence of *Acilana tokunagai* from the Kumano Group.

In contrast, Mizuno (1953) and Tanai and Mizuno (1954) recorded molluscan fossils from the Mitsuno Formation in the upper part of the Kumano Group. The Formation is characterized by a large number of the warm water genera including *Saccella*, *Glycymeris*, *Anadara*, *Dosinia*, *Siratoria*, *Turritella*, *Nassarius*, *Conus*, and *Dentalium*. These genera, as a whole, indicate upper neritic, subtropical or warm-water environments. The molluscan fauna of the Yukunoura Formation are different from those of the Mitsuno Formation, because there are only a few genera in the Yukunoura Formation that are common with those of the Mitsuno Formation.

In addition, Katto, et al. (1980) recorded the mollusks from the Shiko Formation of the Kumano Group, which is correlative with the Mitsuno Formation (Saeki and Koto, 1972). The assemblage is represented by such warm water species as *Anadara* cf. *A. (Anadara) ogawai* (Makiyama), *Leucoma (Veremolpa) minoensis* Itoigawa, and *Callista* sp.

The Yukunoura Formation is also distinguished from the Shiko Formation in faunal composition, because there are only a few genera in the Yukunoura Formation in common with those of the Kumano Group.

Furthermore, a large number of subtropical or warm-water mollusks has been recorded from the Uematsu Formation of the Kumano Group. These includes *Acila (Acila) submirabilis* Makiyama, *Cucullaea toyamaensis* Tsuda, *Crassatella pauxillus* (Yokoyama), *Lucinoma annulata* (Reeve), *Cyclocardia siogamensis, Mikadotrochus* sp., and *Conus (Chelyconus) tokunagai* (Katto and Masuda, 1978). The formation has also yielded *Nephlolepidina japonica* (Yabe) and *Miogypsina* sp. (Nishimura and Miyake, 1973). The Uematsu Formation is correlated with the Shikiya (Hisatomi, 1981) or Koguchi Formations (Chijiwa and Tomita, 1985) in the middle part of the Kumano Group.

Accordingly, it is noted that there are two types of molluscan assemblages in the Kumano and Owase Groups: 1) those of the Onuma, Shimosato, Koguchi, and Shikiya Formations forming the lower and middle parts of the Kumano Group and the Yukunoura and Semotobana Formations; and 2) those of the Uematsu and Mitsuno (Shiko) Formations, forming the middle and upper parts of the Kumano Group, respectively. The former indicates a temperate environment, and the latter a tropical or subtropical one. It is highly probable that this stratigraphic difference is the result of a change in climate and not a change in the sedimentary environment. This climatic change seems to be a correspondence to the warming trend from subtropical (or warm temperate) to tropical (or subtropical) that occurred in the late early to earliest middle Miocene age Mizunami Group (Itoigawa, 1989).

In contrast, pteropod and/or heteropod faunas, which indicate the influence of oceanic warm water, have been recorded from the Shimosato and Shikiya (Ujihara and Shibata, 1982), Koguchi (Shibata and Ujihara, 1989), and Yukunoura (Shibata and Ujihara, 1990) Formations. Moreover, a decapod crustacean assemblage which indicates a lower neritic, subtropical environment has been recorded from the Koguchi Formation (Karasawa, 1990). These occurrences are restricted to the lower and middle parts of the Kumano Group and it is inferred that warm oceanic water was also flowing to the Kumano (and Owase) basins during these times.

The faunal composition of the Yukunoura Formation also resembles that of the eastern First Setouchi Supergroup. Therefore, it is correlated with the eastern part of the

Table 2. Stratigraphic classification of the Kumano and Owase Groups.

<table>
<tr><th rowspan="2">TANAI AND MIZUNO (1954)</th><th rowspan="2">SAEKI AND KOTO (1972)</th><th colspan="3">HISATOMI (1984)</th><th rowspan="2">THIS STUDY</th></tr>
<tr><th>NORTHERN AREA</th><th>CENTRAL AREA</th><th>SOUTHERN AREA</th></tr>
<tr><td>MITSUNO F.</td><td>OKOCHI F.
ITAYA F.</td><td colspan="3">MITSUNO F.</td><td></td></tr>
<tr><td rowspan="2">KOGUCHI F.</td><td>TAKETO F.</td><td colspan="2">KOGUCHI F.</td><td>SHIKIYA F.</td><td rowspan="2">SEMOTOBANA F.
YUKUNOURA F.
OSONE F.</td></tr>
<tr><td>ONUMA F.</td><td>ONUMA F.</td><td></td><td>SHIMOSATO F.</td></tr>
</table>

First Setouchi Supergroup (late early to earliest middle Miocene), which includes the Mizunami and Morozaki Groups; and the other early Miocene strata of Shizuoka Prefecture: the Kamohka Formation (Watanabe, 1988), and the Oga Formation and the Kurami Group (Shibata and Kato, 1988). The Kurami Group yields the Akeyo fauna of late early Miocene (about 18 to 16 Ma) age (Itoigawa, 1988). It seems that the fauna of the Yukunoura Formation also corresponds to the Akeyo fauna.

Conclusions

The faunas of the Yukunoura Formation indicates a lower sublittoral, warm-temperate environment and correspond to the faunas of the lower and middle parts of the Kumano Group, southeastern Kii Peninsula, and those of the eastern First Setouchi Series and correlative strata, central Honshu. In addition, the fauna of the Owase Group corresponds to the *Acilana tokunagai* Fauna of northern and central Japan. It is inferred that the Owase district had been influenced by the southern limit of the subsurface cold current, which has been called *Oyashio Senryu*.

The Owase Group is correlated with the Onuma (Shimosato) and Koguchi (Shikiya) Formations forming lower and middle parts of the Kumano Group, respectively(Table 2), and the eastern part of the First Setouchi Supergroup and the early Miocene of Shizuoka Prefecture, central Honshu, on the basis of the molluscan faunal features. The Owase Group, therefore, indicates a late early to earliest middle Miocene age.

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Plate 58

Figs. 1-2. *Acila* sp. 1. MES* coll. cat. no. 1001, Loc. YK-7, rubber cast, x1 ; 2, MES coll. cat. no. 1002, Loc. YK-7, rubber cast, x1.1.

Fig. 3. *Cyclocardia siogamensis* (Nomura). MES coll. cat. no. 1003, Loc. YK-5, x2.

Fig. 4. *Portlandia* sp. MES coll. cat. no. 1004, Loc. YK-2, x3.3.

Figs. 5a-b. *Nuculana* sp. MES coll. cat. no. 1005, Loc. YK-7, x3.

Figs. 6a-b. *Macoma (Macoma) optiva* (Yokoyama). MES coll. cat. no. 1006, Loc. YK-7, x1.

Fig. 7. *Cerithium* sp. MES coll. cat. no. 1007, Loc. YK-1, rubber cast, x1.7.

Fig. 8. *Turritella (Hataiella) sagai* Kotaka. MES coll. cat. no.1008, Loc. YK-2, rubber cast, x1.5.

Fig. 9. *Cryptonatica* sp. MES coll. cat. no. 1009, Loc. YK-3, x1.

Figs. 10-12. *Periploma* sp. 10, MES coll. cat. no.1010, Loc. YK-4, rubber cast, x1.5 ; 11, MES coll. cat. no.1011, Loc. YK-5, rubber cast, x2.0 ; 12, MES coll. cat. no. 1012, Loc. YK-7, rubber cast, x1.5.

Fig. 13. *Cultellus otukai* Ogasawara and Tanai. MES coll. cat. no. 1013, Loc. YK-5, x1.

Fig. 14. *Lucinoma* sp. MES coll. cat. no. 1014, Loc. YK-8, x2.7.

* Abbreviation for the Department of Earth Sciences, Mie University.


1


2


3


4


5a


5b

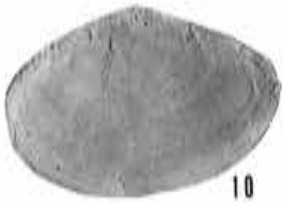

6a


7


8


9


6b


10


11


12


13


14