Miocene mollusks from the Kumano Group of the Ukui area, southeastern part of the Kii Peninsula, southwestern Honshu, Japan

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Abstract. The Shimosato Formation comprises the lower part of the Kumano Group of the southeastern Kii Peninsula, southwestern Honshu. It yields such mollusks as Saccella miensis (Araki), Cyclocardia siogarnensis (Nomura), Macoma (Macoma) izurenis (Yokoyama), Cultellus izumoensis Yokoyama, Dosinia (Phacosoma) nomurai (Otuka), Periploma (Aelga) mitsuganoense Araki, Thracia watanabeli Itoigawa and Shibata, Turritella (Hataeillia) sagai Kataka, and Fulgoraria (Musashia) yanagidaniensis Araki. The Periploma–Saccella–Cyclocardia and Turritella–Dosinia assemblages of the Shimosato Formation are inferred to represent lower subittoral to bathyal and subittoral environments, respectively.

The fauna of the Shimosato Formation is comparable with the subtropical Akeyo Fauna of late Early Miocene age, based on the occurrence of diagnostic species such as Dosinia (Phacosoma) kawagensis Araki, Thracia watanabeli Itoigawa and Shibata, Turritella sagai, and Fulgoraria yanagidaniensis. The assemblages of the middle part of the Shikya Formation and the lower part of the Akiyama Formation are comparable with those of the tropical Kurosedani (subtropical Kadonosawa) Fauna of latest Early to earliest Middle Miocene age.

Key words: Assemblages, fauna, Kumano Group, Miocene, mollusks, systematic description

Introduction

The Miocene Kumano and Owasai Groups of the Nankai Geologic Province are exposed in the southeastern part of the Kii Peninsula, southwestern Honshu (Figure 1). The Kumano Group rests upon the Shimanto Supergroup with clinom–unconformity or is faulted against it and is intruded by the Kumano Acidic Rocks. The age of the Kumano Acidic Rocks is between 14 and 15 Ma (Chijiwa, 1988). The Kumano Group consists largely of mudstone and sandstone from 1,500 to 4,000 m thick and is divided into three lithologic units, in ascending order: the Shimosato (Onuma), Shikya (Koguchi) and Akiyama Formations (Hisatomi, 1984) (Figure 2).

The contemporaneous Setouchi Miocene Series (upper Lower to lower Middle Miocene) of the Setouchi Geologic Province is extensively distributed in central and western Honshu, to the north of the Kii Peninsula (Figure 1). The molluscan paleontology of the Setouchi strata has been studied in detail (vide Itoigawa and Shibata, 1992). For example, Itoigawa (1987, 1988) named and defined the subtropical Akeyo Fauna (late Early Miocene; ca. 18 to 16 Ma) based on mollusks of the Akeyo Formation of the Mizunami Group. Similar fauna has also been recorded from the Ichishi, Ayugawa and Tsuzuki Groups of the Eastern Setouchi Miocene Series in southwestern Honshu; the Kurami Group in central Honshu; the upper part of the Kuniguda Formation, and the Nakayama and Yotsuyaku Formations in northeastern Honshu (Ozawa et al., 1995; Matsubara, 1995a).

On the other hand, the tropical Kurosedani Fauna (Tsuda, 1960) has been recorded from southwestern Japan, and the contemporaneous subtropical Kadonosawa Fauna has been recorded from northeastern Honshu and southern Hokkaido, northern Japan (Itoigawa, 1988). Both faunas are restricted within the N. 8 zone of Blow (1969) of latest Early to earliest Middle Miocene age (Ogasawara and Noda, 1996). The Akeyo Fauna differs from the Kurosedani Fauna by lacking the tropical mollusks of the latter (Itoigawa, 1988). It also differs from the Kadonosawa Fauna by lacking the characteristic species of the latter: Anadara (Hataeillia) kakehataensis Hatai and Nisyama, Vesticardium ogurii (Otuka), Glycydonta itoigawai (Tsuda), Tateiwaia tateiwa (Makiyama), T. yamamari (Makiyama), and Zeeusis minoenesis (Itoigawa) (Itoigawa, 1988).

A Miocene fauna has been reported from several places in the Kii Peninsula (Mizuno, 1953, 1967; Tanai and Mizuno, 1954; Katto and Masuda, 1978; Katto et al., 1976,1980; Ujihara and Shibata, 1982; Chijiwa and Tomita, 1985;
Honda, 1992). However, much data are required to reconstruct the Miocene paleoenvironments in the Nankai Geologic Province.

In 1976 and 1977, one of us (SU) collected several hundred fossil mollusks from a construction site at Ukui Junior High School (Loc. 2; Figures 3, 4), as well as several tens of specimens from an outcrop on a wave-cut terrace at Loc. 7 on Kitsune-jima (Figure 3). Recently, one of us (YH) obtained more specimens from additional localities in the Ukui area. All of these localities are assigned to the Shimosato Formation and together they contain mollusks such as Saccella miensis (Araki), Cyclocardia siogamensis (Nomura), Macoma (Macoma) izurensis (Yokoyama), Cutellius izumoensis Yokoyama, Dosinia (Phacosoma) nomurai (Ootuka), Periploma (Aelga) mitsuganoense Araki, Thracia watanabei Itogawa and Shibata, Turritella (Hataeilla) saga Kotaka, and Fulgoraria (Musashia) yanagidaniensis Araki (Table 1).

The purpose of this study is to record the molluscan assemblages of the Shimosato Formation, and to describe their characteristic species, including those representative of the Akeyo Fauna. We also wish to clarify the molluscan faunal succession of the Kumano Group of the Nankai Geologic Province of southwestern Japan.

Outline of geology and molluscan fauna

The upper Muro Group (Upper Oligocene to Lower Miocene) of the Shimanto Supergroup and the Shimosato Formation of the Kumano Group are exposed in the Ukui area. The Muro Group consists largely of interbedded gray sandstone and black shale. The Shimosato Formation, on the other hand, is made up of massive, gray, fine- or very fine-grained sandstone, and sandy siltstone. In a wave-cut platform on Kitsune-jima (Loc. 7 in Figure 3), the Shimosato Formation is made up of well-sorted, well-jointed, pale gray, tuffaceous, fine-grained sandstone. The fine-grained sandstone at this locality frequently contains sand-pipes. The Shimosato Formation strikes about N50°E and dips about 10° to 20°SE, and is approximately 200 m thick. Conglomerate of the lowermost Shimosato Formation, which attains a thickness of 30 to 80 cm, rests upon black shale of the uppermost Muro Group with clin- unconformity.

The Kumano Acidic Rocks also crop out in this area. They consist largely of granite porphyry, and intrude into the upper Muro and Kumano Groups. A vertical pyroclastic dike, which is closely related to the Kumano Acidic Rocks (Suzuki, 1976), is exposed in two small cuts at Ukui Junior High School. This dike intrudes into very fine-grained sandstone of the Shimosato Formation, varies in width from approximately 0.5 to 5 m, and trends about N80°E. Figure 3 is a map showing the location of fossil localities in the Shimosato Formation, and Figure 4 shows fossil localities in columnar sections.

Mollusks reported previously from the Shimosato Formation by Ujihara and Shibata (1982) include Neilonella cf. N. isensis Shibata, Saccella miensis, Portlandia (Portlandella)
<table>
<thead>
<tr>
<th>AGE (Ma)</th>
<th>PF</th>
<th>NORTHERN AREA</th>
<th>CENTRAL AREA</th>
<th>SOUTHERN AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>N.9</td>
<td>MITSUNO FORMATION</td>
<td>KD</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>N.8</td>
<td>KOGUCHI F.</td>
<td>SHIKIYA F.</td>
<td>SEMOTOBANA F.</td>
</tr>
<tr>
<td>17</td>
<td>N.7</td>
<td>ONUMA F.</td>
<td>SHIMOSATO F.</td>
<td>YUKUNOURA F.</td>
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<tr>
<td>?</td>
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<td>OSONE F.</td>
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</table>

**Figure 2.** Stratigraphic classification of the Kumano and Owasé Groups, southeastern Kii Peninsula. **AK**, occurrence of the molluscan fauna comparable with the Akeyo Fauna; **KD**, occurrences of the assemblages comparable with those of the Kurosedani (Kadosawa) Fauna. **PF**, zonation by planktonic foraminifera (Blow, 1969).

watasei (Kanehara), Yoldia (Chesnertium) sp., Lucinoma sp., Macoma (Macoma) optiva (Yokoyama), Turricula (Turricula) osawanoensis (Tsuda), Turritella (Turritella) kilensis (Yokoyama), Orectospira sp., and Euspira mitsuganoensis Shibata.

Mizuno (1957) reported mollusks in the Shimosato Formation of the Ukii area (Loc. 7 in Figure 3), including Dosinia (Phacosoma) nomurai Otuka and Turritella (Idaella) tanaguransis Kotaka. Chijiwa and Tomita (1985) noted the following mollusks in the Onuma Formation: Saccella miensis, Portlandia watasei, Cyclocardia siogamensis, Macoma optiva, M. izurensis, Cultellus izumoiensis Yokoyama, and Periploma cf. P. mitsuganoense.

The Shikiya Formation contains mollusks such as Acharax tokunagai (Yokoyama), Acila tokunagai (Yokoyama), Conchocele bisecta (Conrad), Lucinoma kamenoensis (Otuka), Macoma optiva, Turritella sagai, and T. (Hataella) kodonosawaensis Otuka (Mizuno, 1953; Tanai and Mizuno, 1954). Katto et al. (1976) proposed the Uematsu Formation for the middle part of the Shikiya Formation (Hisatomi and Miyake, 1981), which crops out in the southernmost part of the Kii Peninsula. The Uematsu Formation yields many warm-water mollusks such as Cucullaea toyamaensis Tsuda, Crassatellites pauxillus (Yokoyama), Miktadotochus sp., and Conus (Chelyconus) tokunagai Otuka (Katko et al., 1976; Katto and Masuda, 1978), in association with larger foraminifers such as Lepidocyclina (Nephrolepidina) japonica (Yabe) and Miogypsina sp. (Nishimura and Miyake, 1973).

The lower part of the Mitsuno Formation also contains many warm-water mollusks such as Glycymeris (Veletuvita) cisshuensis Makiyama, Anadara (Anadara) kilensis Mizuno, Crassatellites naran (Adams and Reeve), and Conus tokunagai (Mizuno, 1953; Tanai and Mizuno, 1954). Katto et al. (1980) also studied mollusks from the lower part of the Mitsuno Formation (vide Saeke and Kato, 1972) and noted the presence of warm-water mollusks such as Anadara cf. A. (Anadara) ogawai (Makiyama), Veremolpa minoensis (Itogawa), Vasticardium ogurai, and Paphia haitai Masuda and Noda.

Honda (1992) studied molluscan fossils of the Owasé Group, which crops out on the southeastern margin of the Kii Peninsula to the north of the Kumano Group. The Yukunoura Formation of the Owasé Group contains mollusks such as Acila sp., Portlandia sp., Cyclocardia siogamensis, Lucinoma sp., Macoma optiva, Cultellus otukai Ogasawara and Tanai, Periploma sp., and Turritella sagai (Honda, 1992). The assemblages of the Yukunoura Formation resemble those of the Shimosato, Shikiya, and Onuma Formations within the lower and middle parts of the Kumano Group; and those of the Eastern Setouchi Miocene Series in central and
Figure 3. Map showing fossil localities in the Shimosato Formation. 1-7, fossil localities.

Figure 4. Columnar sections of the Shimosato Formation. 1-7, fossil localities.
Table 1. Occurrences of fossil mollusks in the Shimosato Formation. VA, very abundant (20 or more individuals); A, abundant (10 to 19 individuals); C, common (5 to 9 individuals); F, few (2-4 individuals); R, rare (one individual). One individual is defined herein as consisting of more than half of a separated valve or an articulated pair of bivalves, and more than half of a gastropod specimen. See also Figure 5 and Tables 2, 3.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>LOCALITY</th>
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<tbody>
<tr>
<td>Bivalves:</td>
<td></td>
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<tr>
<td>Acita cf. A. (Acita) submirabilis Makiyama</td>
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<tr>
<td>Acita sp.</td>
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<tr>
<td>Ennucula sp.</td>
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<td>Sacciella miensis (Araki)</td>
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<td>Solamen sp.</td>
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<tr>
<td>Septifer ? sp.</td>
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<tr>
<td>Chlamys cf. C. iwamurensis Itoigawa</td>
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<tr>
<td>Cycladicama sp.</td>
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<tr>
<td>Cyclocardia siogamensis (Nomura)</td>
<td>C</td>
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<tr>
<td>Cyclocardia sp.</td>
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<tr>
<td>Lucinomea sp.</td>
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<tr>
<td>Mactra sp.</td>
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<tr>
<td>Mactocoma (Mactoma) izurensis (Yokoyama)</td>
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<tr>
<td>Angulus cf. A. kagayamensis Ogasawara and Tanai</td>
<td></td>
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<tr>
<td>Nidiotellina sp.</td>
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<tr>
<td>Cultellus izumoensis Yokoyama</td>
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<tr>
<td>Disinia (Phacosoma) kawagensis Araki</td>
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<tr>
<td>Dosinia (Phacosoma) nomurai (Otuka)</td>
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<tr>
<td>Dosinia sp.</td>
<td></td>
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<tr>
<td>Paphia sp.</td>
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<tr>
<td>Glauconome sp.</td>
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<td>Mya sp.</td>
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<tr>
<td>Aniscocoruba sp.</td>
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<tr>
<td>“Teredo” sp.</td>
<td>C</td>
</tr>
<tr>
<td>Periploma (Aelga) mitsuganoense Araki</td>
<td></td>
</tr>
<tr>
<td>Periploma (Aelga) sp.</td>
<td></td>
</tr>
<tr>
<td>Thracia watanae/i Itoigawa and Shibata</td>
<td></td>
</tr>
<tr>
<td>Thracia sp.</td>
<td></td>
</tr>
<tr>
<td>Gastropods:</td>
<td></td>
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<tr>
<td>Turritella (Hataiella) sagai kotaka</td>
<td></td>
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<tr>
<td>Turritella sp.</td>
<td></td>
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<tr>
<td>Bittium sp.</td>
<td></td>
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<tr>
<td>Euspira sp.</td>
<td></td>
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<tr>
<td>Ancistroplepis sp.</td>
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<tr>
<td>Fulgorania (Musashia) yanagidaniensis Araki</td>
<td></td>
</tr>
<tr>
<td>Eocyllchina sp.</td>
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</tbody>
</table>

southwestern Honshu.

Molluscan assemblages and environments

Approximately 400 specimens were collected from 7 localities in the Shimosato Formation. These specimens comprise 22 genera and 28 species of bivalves and 6 genera and 7 species of gastropods (Table 1). Mollusks occur sporadically in the fine- and very fine-grained sandstone and sandy siltstone of the Shimosato Formation. Almost all specimens are complete or nearly so, but all except those from Locality 7 lack original shell material. Two molluscan assemblages are recognized herein: the Periploma–Sacciella–Cyclocardia (Loc. 2) and Turritella–Dosinia assemblages (Loc. 7). Mollusks from Localities 1 and 3–6 are not used for recognition of assemblages, because each yielded fewer than 10 specimens. Table 2 summarizes the molluscan assemblages and characteristic and associated species.

The Periploma–Sacciella–Cyclocardia assemblage

This assemblage occurs in beds of sandy siltstone and overlying very fine-grained sandstone at Locality 2. Both beds are up to about 10 m thick. The assemblage is characterized by the dominant occurrence of Periploma (P.
Molluscan assemblages of the Shimosato Formation. Vfs: very fine sandstone; sdy slt: sandy siltstone; fs: fine sandstone.

<table>
<thead>
<tr>
<th>MOLLUSCAN ASSEMBLAGE</th>
<th>CHARACTERISTIC SPECIES</th>
<th>ASSOCIATED SPECIES</th>
<th>LITHOLOGY LOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turritella-Donisia Assemblage</td>
<td>Turritella sagai Donisia nomurai D. kawagensis</td>
<td>C. siogamensis Acila cf. A. submirabilis</td>
<td>fs 7</td>
</tr>
</tbody>
</table>

*mitsuganoense*: Figures 5-12, 5-13, and P. sp.: Figure 5-8); Saccella miensis (Figure 5-1), and Cyclocardia (C. siogamensis: Figure 5-14, and C. sp.), but also contains Ancistrolepis sp., Bittium sp., Ennucula sp. (Figure 5-2), Mya sp. (Figure 5-10), Culletillus izumoensis (Figure 5-11), Turritella sagai (Figure 5-9), and Macoma izurenisis (Figure 5-7); Table 2). This assemblage typically contains many extant genera that live in upper sublittoral to batalial depths (N, B) off Japan and neighboring countries, including Saccella, Cyclocardia and Turritella (Table 3). However, it also includes Periploma, Ancistrolepis and Musashia, which live in lower sublittoral to bathyal depths (N, B Table 3). Consequently, the Periploma-Saccella-Cyclocardia assemblage is inferred to represent a lower sublittoral to bathyal environment.

Comparison: The Onuma Formation of the Kumano Group contains a number of species known from this assemblage, including Saccella miensis, Cyclocardia siogamensis, Macoma izurenisis, and Culletillus izumoensis (Chijiwa and Tomita, 1985). This assemblage is therefore correlative with those of the Onuma Formation, which represent lower sublittoral environments (Chijiwa and Tomita, 1985).

In addition, the Periploma-Saccella-Cyclocardia assemblage contains many species with common with the Periploma-Acila and Machoma-Lucinoma assemblages in the Eastern Setouchi Miocene Series of central and southwestern Honshu, including Saccella miensis, Periploma sp., M. izurenisis, Culletillus izumoensis, and Cyclocardia siogamensis (Shibata, 1978). This assemblage is therefore also correlative with the Periploma-Acila and Machoma-Lucinoma assemblages, which represent upper sublittoral and sublittoral environments, respectively (Shibata, 1978).

The Turritella-Donisia assemblage

This assemblage occurs in gray, fine-grained sandstone at Locality 7 and is characterized by the dominant occurrence of Turritella (T. sagai: Figure 5-9, and T. sp.) and Donisia (D. nomurai: Figures 5-15, 5-19, D. kawagensis: Figure 5-16, and D. sp.) (Table 2). Cyclocardia siogamensis and Acila cf. A. submirabilis (Figure 5-6) are also present in this assemblage (Table 2). The presence of many intact specimens in this assemblage implies that there was little or no post-mortem transportation. Modern Turritella, Cyclocardia and Acila species live in upper sublittoral to bathyal depths (N, N-B), and Donisia (Phacosa) dwell in the tidal to lower sublittoral zone (N-N) (Table 3). The Turritella-Donisia assemblage is therefore inferred to represent a sublittoral environment.

Comparison: This assemblage contains Turritella sagai.
and Dosinia nomurai in common with the Turritella-Lucinoma assemblage of the Tomikusa Group (upper Lower Miocene) in the Eastern Setouchi Miocene Series of central Honshu (Shibata, 1978). This assemblage is therefore correlative with the Turritella-Lucinoma assemblage, which represents an upper sublittoral environment (Shibata, 1978).

Discussion

Honda (1992) noted that two types of molluscan assemblage are present in the Kumano and Owave Groups. The first type has been recorded from the Shimosato, Shikya, and Onuma Formations within the lower and middle parts of the Kumano Group (Mizuno, 1953; Tanai and Mizuno, 1954; Ujihara and Shibata, 1982; Chijiwa and Tomita, 1985); and the Yukunoura Formation of the Owave Group (Honda, 1992). The type is characterized by Portlandia watasei, Cyclocardia siogamensis, Lucinoma sp., Macoma optica (M. izurensis), Cuitellus izumonoensis, and Turritella sagai (T. kado nosawaensis, T. shatai, T. kiensens)
The Periploma Saecella-Cyclocardia and Turritella-Dosinia assemblages of the Shimosato Formation contain many species in common with those of the first type, including Cyclocardia siogamensis, Macoma izurensis, Cuitellus izumonoensis, and Turritella sagai (Table 2). Both assemblages therefore belong to the first type. In addition, the Shimosato Formation contains Dosinia kawagensis, Thracia watanabei, Turritella sagai, and Fulgoraria yanagidaniensis (Table 1), which characterize the fauna of the Akeyo Formation. The fauna of the Shimosato Formation is therefore comparable with the Akeyo Fauna of late Middle Miocene age (ca. 18 to 16 Ma; Itoigawa, 1987, 1988) (Figure 2).

On the other hand, the second type of molluscan assemblage has been reported from the middle part of the Shikya and the lower part of the Mitsuho Formation within the middle and upper parts of the Kumano Group (Mizuno, 1953; Tanai and Mizuno, 1954; Katso and Masuda, 1978; Itoigawa et al., 1980). The type is characterized by many warm-water mollusks such as Anadara cf. A. ogawai, Cuculnea toymaensi, Crassatelles paucillius, C. nanus, Vasticardium oguri, Mikadotrochus sp., and Conus tokunagai.

Among these species, Cuculnea toymaensi and Conus tokunagai characterize the Kurosedani Fauna of southwestern Japan. Conus tokunagai is also characteristic in the Kadosoawana Fauna of northern Japan. The middle part of the Shikya Formation yields Cuculnea toymaensi and Conus tokunagai (Katso and Masuda, 1978), in association with larger foraminifers such as Lepidocyclina japonica and Miogypsis sp. (Nishimura and Miyake, 1973). In addition, Conus tokunagai has been reported from the lower part of the Mitsuho Formation (Mizuno, 1953; Tanai and Mizuno, 1954; Katto et al., 1980).

Accordingly, the assemblages of the middle part of the Shikya Formation and the lower part of the Mitsuho Formation are comparable with those of the Kurosedani (Kadosoawana) Fauna (Figure 2). The occurrence of the Kurosedani (Kadosoawana) Fauna corresponds to the warm marine climatic episode during the latest Early to earliest Middle Miocene period (ca. 16-15 Ma) (Chinizel, 1986).

Such a different stratigraphic occurrence of the molluscan assemblages suggests a warming of climate and not merely a change in the sedimentary environment. The warming of climate is also recognized in the transition from the subtropical Akeyo to tropical Kurosedani Fauna in the Mizunami Group of the Eastern Setouchi Miocene Series (Itoigawa, 1988, 1989).

A similar scenario has also been proposed for another taxonomic group in the Kumano Group. For instance, Nishimura and Miyake (1973) reported larger foraminifers such as Lepidocyclina japonica and Miogypsis sp. from the middle part of the Shikya Formation. Using planktonic foraminifers, Ibaraki (1990) assigned the Lepidocyclina-Miogypsis-bearing horizon to the N8.b zone of Blow (1969). From the occurrence of Orburlina universa d’Orbigny (Ikebe et al., 1975), the uppermost part of the Shikya Formation and the Mitsuho Formation correlate with the N9.9 zone of Blow (1969) (Hiasatomi, 1987) (Figure 2).

As was discussed in the aforementioned lines, the molluscan assemblages of the lower part of the Mitsuho Formation (Mizuno, 1953; Tanai and Mizuno, 1954; Katso et al., 1980) are comparable with those of the Kurosedani (Kadosoawana) Fauna. The fauna, however, is restricted within the N.8 zone of Blow (1969) of latest Early to earliest Middle Miocene age (Ogasawara and Noda, 1996). Further studies are needed to clarify the molluscan faunal succession of the Kumano Group of the Nankai Geologic Province of southwestern Japan.

Summary of faunal discussion

1) The Periploma Saecella-Cyclocardia and Turritella-Dosinia assemblages of the Shimosato Formation are inferred to represent lower sublittoral to bathyal and sublittoral environments, respectively.

2) The fauna of the Shimosato Formation is comparable with the subtropical Akeyo Fauna of late Early Miocene age.

based on the occurrence of diagnostic species such as
Dosinia kawagensis, Thracia watanabei, Turiteilia sagai, and
Fulgoraria yanagidaniensis.

3) The assemblages of the middle part of the Shikiya
Formation and the lower part of the Mitsuio Formation are
comparable with those of the tropical Kurosedani (subtropi-
cal Kadonoawawa) Fauna of latest Early to earliest Middle
Miocene age.

**Systematic notes on some important species**

Phylum Mollusca
Class Bivalvia
Family Veneridae
Subfamily Dosiniinae
Genus **Dosinia** Scopoli, 1777
Subgenus **Phacosoma** Jukes-Browne, 1912

**Dosinia (Phacosoma) kawagensis** Araki, 1960

Figure 5-16

Dosinia nomurai Otuka; Itoigawa, 1956, pl. 2, fig. 3 (non Otuka,
1934).

Dosinia japonica kawagensis Araki, 1960, p. 95, pl. 7, fig. 3.

Dosinia (Phacosoma) kawagensis Araki; Masuda, 1963, p. 22, pl.
4, figs. 1-8 (fig. 1, reproduced from Araki, 1960); Yoon, 1979,
p. 15, pl. 2, figs. 7, 9, 10; Matsubara, 1995b, p. 330, pl. 4, figs.
9-11.

Dosinia kawagensis Araki; Hayashi and Miura, 1973, pl. 2, fig. 12;
Hayashi, 1973, pl. 1, figs. 2, 3; Ishida et al., 1980, pl. 3, fig. 12.

Dosinorbis kawagensis (Araki); Itoigawa in Itoigawa et al., 1974,
p. 87, pl. 23, figs. 1-6.

Phacosoma kawagensis (Araki); Itoigawa et al., 1981 (1982, p. 80),
pl. 14, figs. 6a-b; Shibata and Ina, 1983, p. 48, pl. 5, fig. 12;
Itoigawa and Shibata, 1986, pl. 15, fig. 13; Muramatsu, 1992,
pl. 49, fig. 10.

Dosinia (Phacosoma) chikuzenensis nomurai Otuka; Hayashi,
1986, p. 5, pl. 1, figs. 2, 3 (reproduced from illustration of
Dosinia kawagensis in Hayashi (1973)).

Remarks.—Two incomplete closed valves were obtained
from fine-grained sandstone of the Shimosato Formation.
The present species was originally described by Araki (1960)
(as D. japonica kawagensis) from the Kaisekizan Formation
(upper Lower Miocene; vide Yoshida, 1991; Shibata, 1967)
of the Ichishi Group, Mie Prefecture, southwestern Honshu.
Itoigawa (1956) had earlier cited "D. nomurai" from the Tszuku-
ki Group (upper Lower Miocene) of Kyoto Prefecture, but
Masuda (1963) later assigned this occurrence to D. kawagen-
sis.

The present species resembles D. (Phacosoma) nomurai
Otuka, 1934, which was originally described from the
Kadonoawawa Formation (uppermost Lower to lowest Miocene;
irizuki and Matsubara, 1994) of Iwate Prefecture, northeastern Honshu. However, D. (P.) kawagensis differs by having a more anteriorly expanded anterodorsal margin. The present species also resembles D. (P.) japonica (Reeve), which is living in Japan, but differs from the latter by
having a smaller and somewhat more inequilateral shell.
The present species has also been recorded from the
upper Lower to lowest most Middle Miocene formations of
Honshu and Korea. These include the Akeyo Formation of
the Mizunami Group, and other strata of the Eastern Setou-
chi Miocene Series in central and southwestern Honshu
(Itoigawa et al., 1981); the Shiode, Ajiro, and Yotsuyaku
Formations of northeastern Honshu (Masuda, 1963; Mat-
subara, 1995b); and the Sinhyeon Formation of Korea (Yoon,
1970).

**Occurrence**.—As characteristic species of **Turiteilla-
**Dosinia ass. at Locality 7.

Family Periplomatidae
Genus **Periploma** Schumacher, 1817
Subgenus **Aelga** Slodkewitsch, 1935

**Periploma (Aelga) mitsuganoense** Araki, 1959

Figures 5-12a-b, 13

Periploma mitsuganoense Araki, 1959, p. 163, pl. 18, figs. 2a-b;
Araki, 1960, p. 85, pl. 5, figs. 13a-b (reproduced from Araki,
1959); Shibata in Itoigawa et al., 1974, p. 108, pl. 34, figs. 12-
17; Ishida et al., 1980, pl. 4, fig. 21; Itoigawa et al., 1981
(1982, p. 115), pl. 22, figs. 14a-b; Itoigawa and Shibata, 1986,
pl. 17, fig. 13; non Hayashi, 1973, pl. 5, fig. 1.

Remarks.—Approximately 80 slightly deformed specimens
were collected from sandy siltstone of the Shimosato Forma-
tion. Araki (1959) based this species on specimens from the
Kaisekizan Formation (upper Lower Miocene) of the Ichishi
Group, Mie Prefecture, southwestern Honshu. It closely
resembles Periploma (Aelga) besshoense (Yokoyama, 1924),
which was originally described from the Asagai Formation
(upper Oligocene) of the Joban coal field, northeastern
Honshu, but is distinguished from the latter in having a more
348, text-fig. 4), described from the Owase Group (upper
Lower to lowest most Middle Miocene) of Mie Prefecture,
 southeastern Kii Peninsula, is allocated here to Periploma sp.
indet., owing to the poor preservation of the specimen.
Periploma mitsuganoense has also been recorded from the
Akeyo Formation of the Mizunami Group, and other strata of
the Eastern Setouchi Miocene Series (Itoigawa et al., 1981).

**Occurrence**.—As characteristic species of **Periploma** Sac-
ceLLa—**Cyclocardia** ass. at Locality 2 and also from Loc. 4.

Family Thracicidae
Genus **Thracia** Leach, 1824

**Thracia watanabei** Itoigawa and Shibata, 1975

Figures 5-3, 5a-b

Thracia sp. (n. sp.); Itoigawa in Itoigawa et al., 1974, p. 108, pl. 34,
figs. 10-11.

**Thracia watanabei** Itoigawa and Shibata, 1975, p. 31, pl. 8, figs. 21-
24; Itoigawa et al., 1981 (1982, p. 116), pl. 22, fig. 16.

Remarks.—Only four specimens were obtained from gray,
very fine-grained sandstone at two localities in the
Shimosato Formation. The present species was proposed
by Itoigawa and Shibata (1975) from the Yamanouchi Mem-

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ber of the Akeyo Formation of the Mizunami Group. *Thracia watanabei* has also been recorded from the Tomikusa, Iwamura and Ayugawa Groups of the Eastern Setouchi Miocene Series in central and southwestern Honshu (Itoigawa et al., 1981).

**Occurrence.**—Localities 2, 6.

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**Class Gastropoda**

**Family Turritellidae**

**GenusTurritella** Lamarck, 1799

**Subgenus Hataiella** Kotaka, 1959

*Turritella (Hataiella) sagai* Kotaka, 1951

**Figure 5-9**

*Turritella s-hataii sagai* Kotaka, 1951, p. 87, pl. 12, figs. 13-17.

*Turritella (Hataiella) sagai* Kotaka; Kotaka, 1959, p. 89, pl. 9, figs. 6-8, 10, 12, 13; Yoon, 1979, p. 21, pl. 5, fig. 11; Marinovich and Kase, 1986, p. 61, pl. 2, figs. F-H (in part); Honda, 1992, pl. 58, fig. 8.

*Non Turritella (Hataiella) sagai* Kotaka; Marinovich and Kase, 1986, pl. 2, figs. A-E (in part); Marinovich, 1988, pl. 5, fig. 3, figs. 3, 5-9 (3, 5-7, 9; reproduced from Marinovich and Kase, 1986, pl. 61, pl. 2, figs. A-E); Zhikov and Saidnikov, eds., 1992, p. 248, pl. 46, figs. 3a-b.

*Turritella sagai* Kotaka; Shibata and Itoigawa et al., 1974, p. 132, pl. 40, figs. 11, 12; Ishida et al., 1980, pl. 5, fig. 10, 11; Itoigawa et al., 1981 (1982, p. 164), pl. 28, figs. 13-14; Itoigawa and Shibata, 1986, pl. 17, fig. 2; Muramatsu, 1992, pl. 50, fig. 9.

**Remarks.**—A total of 26 specimens are to hand. The present species was originally described by Kotaka (1951, p. 87, pl. 12, figs. 13-17) from the Togari Member of the Akeyo Formation of the Mizunami Group. As noted by Kotaka (1951), *T. (Hataiella) sagai* resembles *T. (H.) shatii* Nomura, originally described from the "Shigogama" Formation (Lower Miocene; Ishii et al., 1982, p. 14, 20) of Miyagi Prefecture, northeastern Honshu. The present species also resembles *T. (H.) belogolovaensis* Ilyina, originally described from the Kulven Formation (Lower Miocene) of western Kamchatka (vide Titov, 1994, p. 7), but it differs from the latter in having a more slender shell.

Marinovich and Kase (1986, p. 61, pl. 2, figs. A-H) cited *Turritella sagai* from the Bear Lake Formation (lowermost Middle Miocene, in part) of southwestern Alaska (figs. A-E), and the Akebighara Sandstone of the Ayugawa Group (upper Lower Miocene) of southwestern Honshu (figs. F-H). Specimens from the Bear Lake Formation are assigned here to *T. belogolovaensis*, as was done by Titov (1994). Zhikov and Saidnikov, eds., (1992, p. 248, pl. 46, figs. 3a-b) cited *T. (H.) sagai* from the Neveliskaya Formation (Lower Miocene) of southern Sakhalin, and this occurrence is also assigned here to *T. belogolovaensis*.

*Turritella sagai* has been recorded from the Akeyo Formation of the Mizunami Group and other strata of the Eastern Setouchi Miocene Series (Itoigawa et al., 1981), and the Hwabongri Formation (lower Middle Miocene) of Korea (Yoon, 1979).

**Occurrence.**—As characteristic species of *Turritella-Do sina* as at Loc. 7, and as associated species of *Periploma-Saccella-Cyclocardia* ass. at Loc. 2.

**Family Volutidae**

**Subfamily Fulgoriniae**

**Genus Musashia** Schumacher, 1817

**Subgenus Musashia** Hayashi, 1960

*Fulgoria (Musashia) yanagidaniensis* Araki, 1959

**Figure 5-17**

*Fulgoria hirasei yanagidaniensis* Araki, 1959, p. 165, pl. 18, fig. 6; Araki, 1960, p. 104, pl. 8, fig. 5 (reproduced from Araki, 1959).

*Musashia (Neopsepheaa ?) yanagidaniensis* (Araki); Shikama, 1967, p. 115, text-fig. 20, pl. 13, figs. 5-8.

*Musashia (Neopsepheaa) yanagidaniensis* (Araki); Shikama, 1967, pl. 14, fig. 1 (same specimen as Shikama, 1967, pl. 13, fig. 8).

*Musashia yanagidaniensis* (Araki); Hayashi, 1973, pl. 3, fig. 8; Shibata and Ina, 1983, p. 62, pl. 9, fig. 6.

*Psepheaa ? yanagidaniensis* (Araki); Shibata and Itoigawa et al., 1974, p. 167, pl. 51, figs. 1-3, pl. 52, figs. 1-2, pl. 53, figs. 1-3, pl. 54, figs. 5a-c.

*Fulgoria yanagidaniensis* (Araki); Ishida et al., 1980, pl. 6, figs. 34a-b.

*Musashia (s. s.) yanagidaniensis* (Araki); Itoigawa et al., 1981.

*Musashia ? yanagidaniensis* (Araki); Itoigawa et al., 1982, p. 239, pl. 40, figs. 1-2.

*Fulgoria (Psepheaa ?) cf. ashiyaensis* Shikama; Hayashi, 1988, p. 7, pl. 3, fig. 8 (reproduced from Musashia yanagidaniensis; Hayashi, 1973).

**Remarks.**—Seven specimens were collected from gray, very fine-grained sandstone at one locality in the Shimosato Formation. Araki (1959) proposed the present species under the name of *Fulgoria hirasei yanagidaniensis* from the Kazekizan Formation (upper Lower Miocene) of the Ichishi Group. The present species has also been recorded from the Akeyo Formation of the Mizunami Group and other strata of the Eastern Setouchi Miocene Series (Itoigawa et al., 1981).

**Occurrence.**—Locality 2.

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