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Miocene Molluscs from the Tenguyama Formation, Toyama Prefecture, Hokuriku District, Japan

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Abstract: The molluscan fauna of the Tenguyama Formation, Toyama Prefecture is characterized by a dominance of the pectinids *Kotorapecten kagamianus moniwaensis, Chlamys meisensis, C. arakawai* and *Nanaochlamys notoensis*. This pectinid-dominant fauna is correlatable with the Middle Miocene Iwaya fauna of the Nanao Formation, Noto Peninsula. It is the first discovery of fossils from the Yatsuo area, where the type formations used for the Neogene stages of the Hokuriku district occur. Consequently, the molluscan fossils of the Yatsuo area can be biostratigraphically divided, from older to younger, into the Kurosedani, Higashibessho, Tenguyama, Otokawa and Mita faunas.

Introduction

The Yatsuo area of the Toyama sedimentary basin of the Hokuriku district, west-central Honshu (Fig. 1), is well known because well-preserved Neogene molluscan fossils occur in various strata such as the Kurosedani (then Yatsuo), Higashibessho, and Otokawa (or Otogawa) Formations. These fossils have been divided and assigned to Neogene stages of the Hokuriku district. However, a detailed biochronological study of each stage has not been done. Therefore, each stage has not been defined in terms of the geological age. In addition, the stratigraphic division of the Neogene formations of the area was not settled until recently. Recently, HAYAKAWA and TAKEMURA (1987) clarified the stratigraphic division of the Neogene from a chronological point of view and redefined them the Kurosedani, Higashibessho, Tenguyama, Otogawa and Mita Formations, in ascending order. Their new division is very significant because the stratigraphic range of the Otokawa (or Otogawa) Formation has been controversial among workers.

Since OYAMA (1950) first noted a Miocene mangrove molluscan fauna from the Yatsuo (Kurosedani of the current nomenclature) Formation, the Yatsuo fauna has been thoroughly studied by many paleontologists. However, molluscs of the upper part of the Kurosedani Formation and the Otokawa Formation have not been studied from

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paleoecological and biostratigraphical viewpoints.

During a field survey of the area in 1984, IJIMA, then as a student of the Kanazawa University, collected well-preserved molluscs of the Tenguyama Formation from a river-side cliff at Wada-gawa, Tonami City. This fossil-bearing formation was previously treated as the lower Member of the Otokawa Formation by SAKAMOTO and NOZAWA (1960),

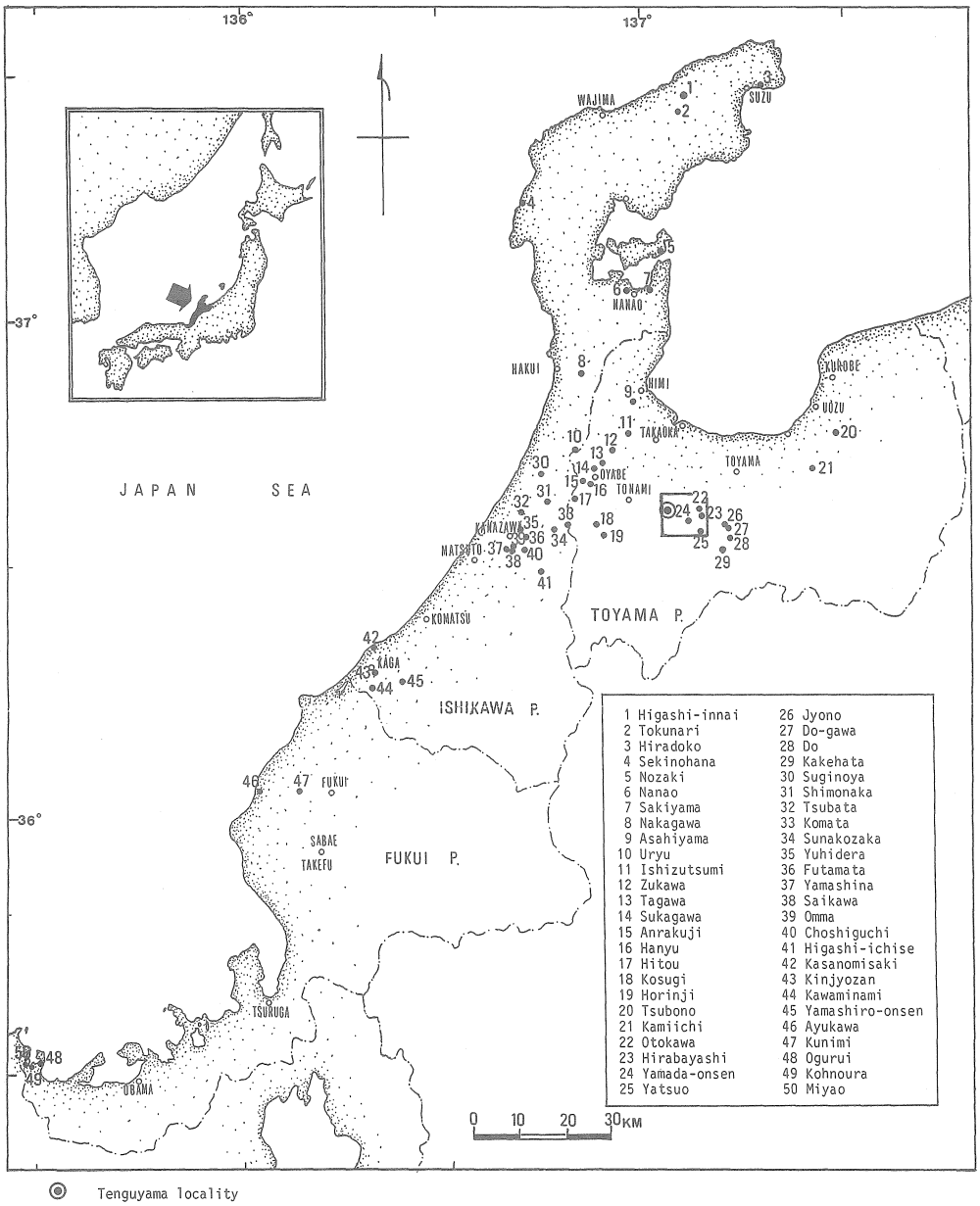


Fig. 1. Index map of the area studied, indicating major localities of Neogene molluscs in the Hokuriku district.

who assigned it to the Middle Miocene. Subsequently, the Tenguyama and Otokawa faunas were separated biostratigraphically from each other.

In the present paper, we describe the characteristics of the Tenguyama fauna and discuss its age, paleoenvironment, and geological significance.

Outline of Geology

The Cenozoic strata of the Yatsuo area have been used as standard units of the Hokuriku district since SAKAMOTO and NOZAWA (1960) summarized the Neogene stratigraphy of the area. However, these stratigraphic divisions have not been well examined from

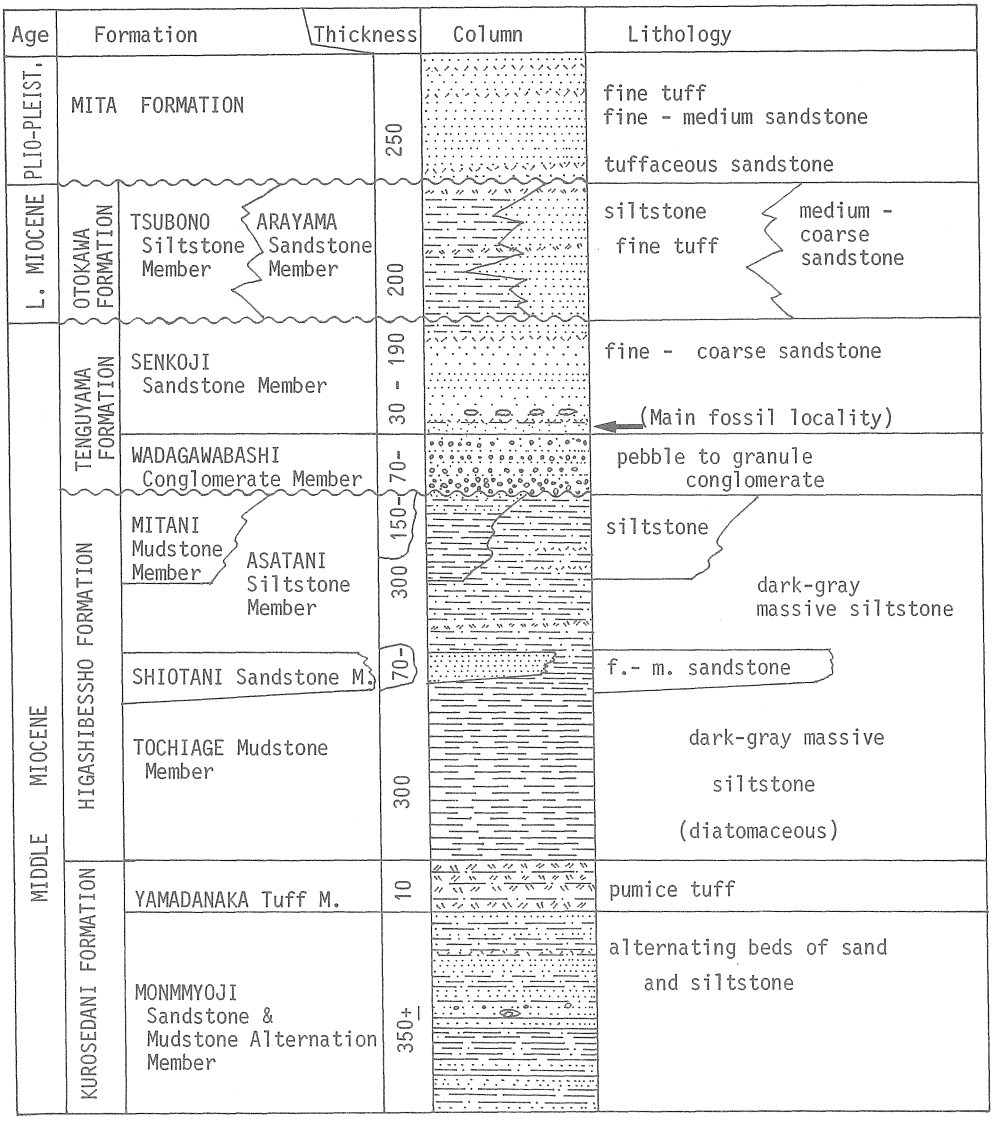


Fig. 2. Neogene stratigraphic division of the studied area.

biostratigraphic and chronostratigraphic points of view. In particular, microfossils such as diatoms, foraminifers, calcareous nannofossils and radiolarians were scarcely known except for the early Middle Miocene. Combined with this problem, the durations of chronological gaps which were recognizable in and below the Miocene deposits as unconformities were controversial among workers (NAKASEKO, 1954).

Recently, HAYAKAWA and TAKEMURA (1987) and ITOH and HAYAKAWA (1988, 1989) thoroughly revised the stratigraphy of the Yatsuo area from a chronological viewpoint (Fig. 2, 3). According to them, the Neogene in the Yatsuo area is divided into the Nirehara, Iwaine, Iozen, Kurosedani, Higashibessho, Tenguyama, Otokawa and Mita Formations in ascending order (Fig. 3). The Tenguyama Formation is subdivided into the Wadagawabashi Conglomerate and Senkoji Sandstone Members, and the Otokawa Formation is also subdivided into the Ranjonomori Conglomerate, Tsubono Siltstone, Arayama Sandstone and Yoshitani Sandstone Members as shown in Fig. 3.

The Tenguyama Formation thus defined corresponds to SAKAMOTO and NOZAWA (1960)'s Tenguyama Sandstone Member of the Otokawa Formation. The lower part of the formation is mainly composed of turbidite sequence of sandstone and conglomerates (Wadagawabashi Member) and unconformably overlies the Higashibessho Formation which is composed of massive siltstone. The upper part of the formation is composed of massive medium to fine grained sandstone (Senkoji Member) and also unconformably

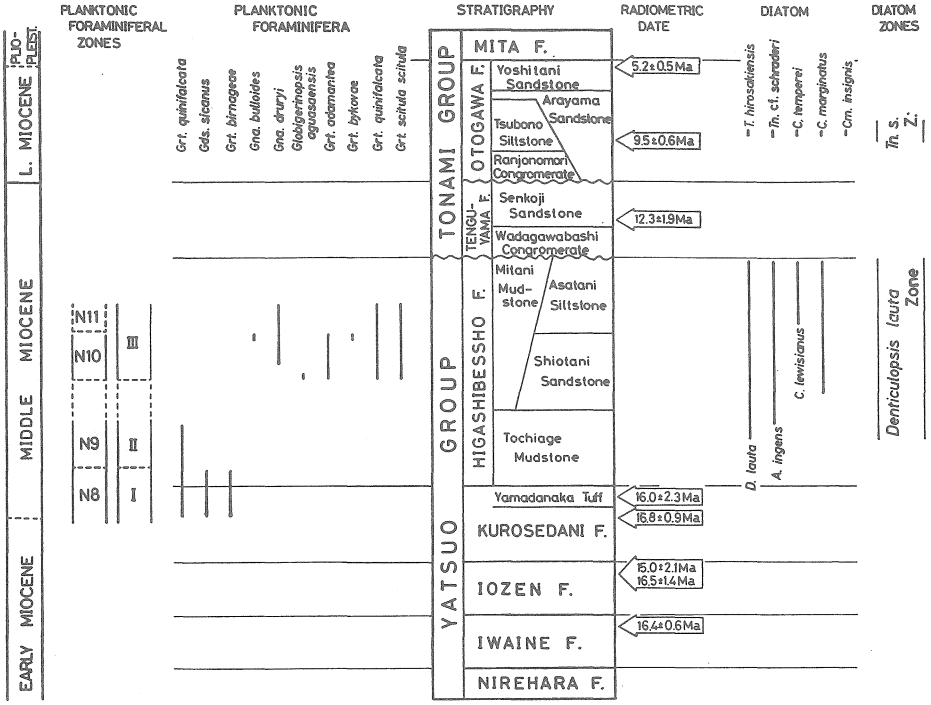


Fig. 3. Compiled table on the Neogene chronological data of the Yatsuo area, Hokuriku District (after HAYAKAWA and TAKEMURA, 1987).

overlain by the Otokawa Formation. According to HAYAKAWA and TAKEMURA (1987), these unconformities related to the Tenguyama Formation were named the Ikahama and Arayama unconformities, respectively.

Geological map of the studied area including the main fossil locality of the Tenguyama Formation is shown in Fig. 4.

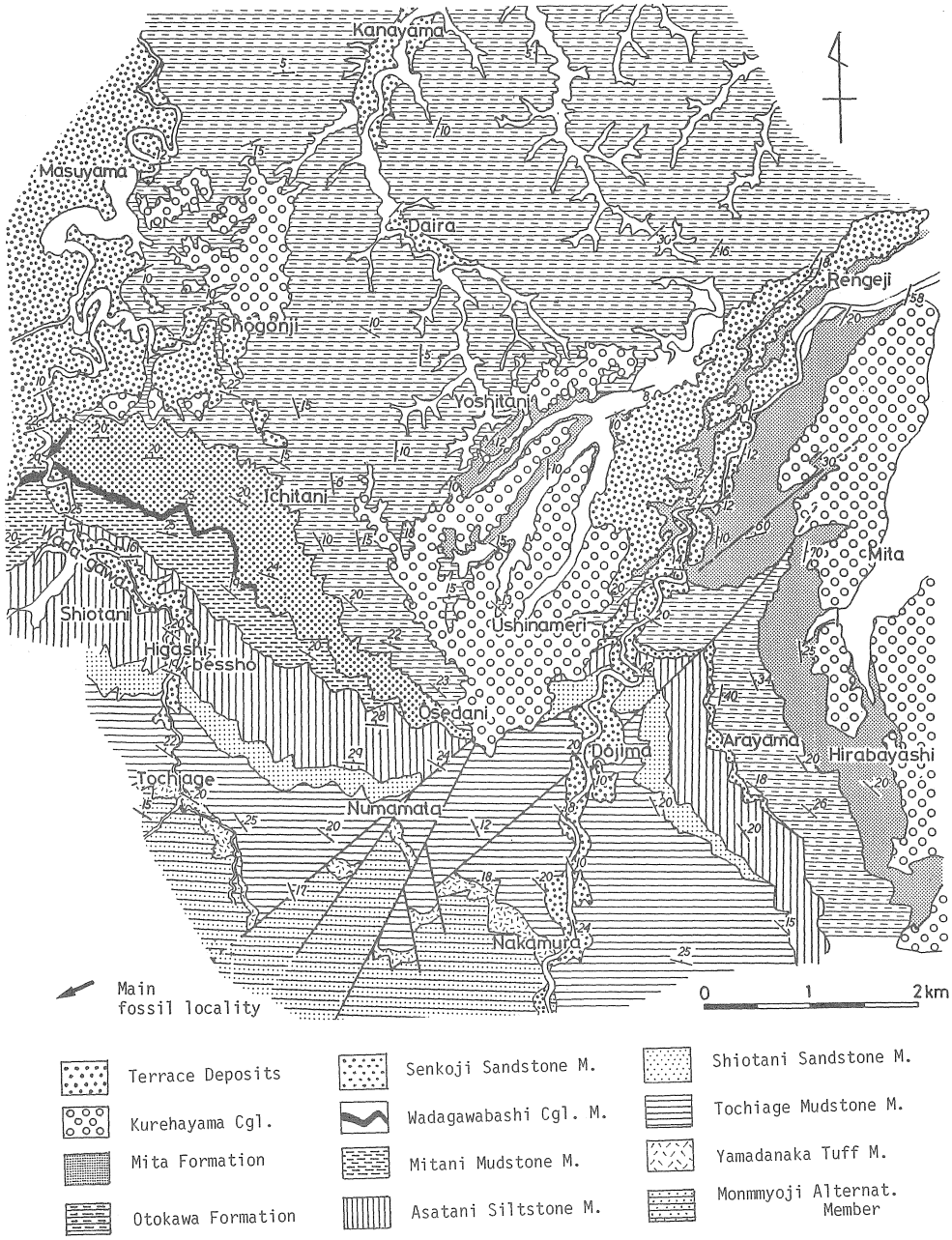


Fig. 4. Geological map of the area showing the main fossil locality in the Tenguyama Formation.

Molluscs of the Tenguyama Formation were found from only two localities (Fig. 5). They mainly occurred from calcareous nodule-bearing medium to fine grained sandstone. The major fossil locality (T-1), previously cited by NAKASEKO (1953), is stratigraphically occupied about 7m below the tuff (TG-1), a key bed regionally traceable, of HAYAKAWA and TAKEMURA (1988).

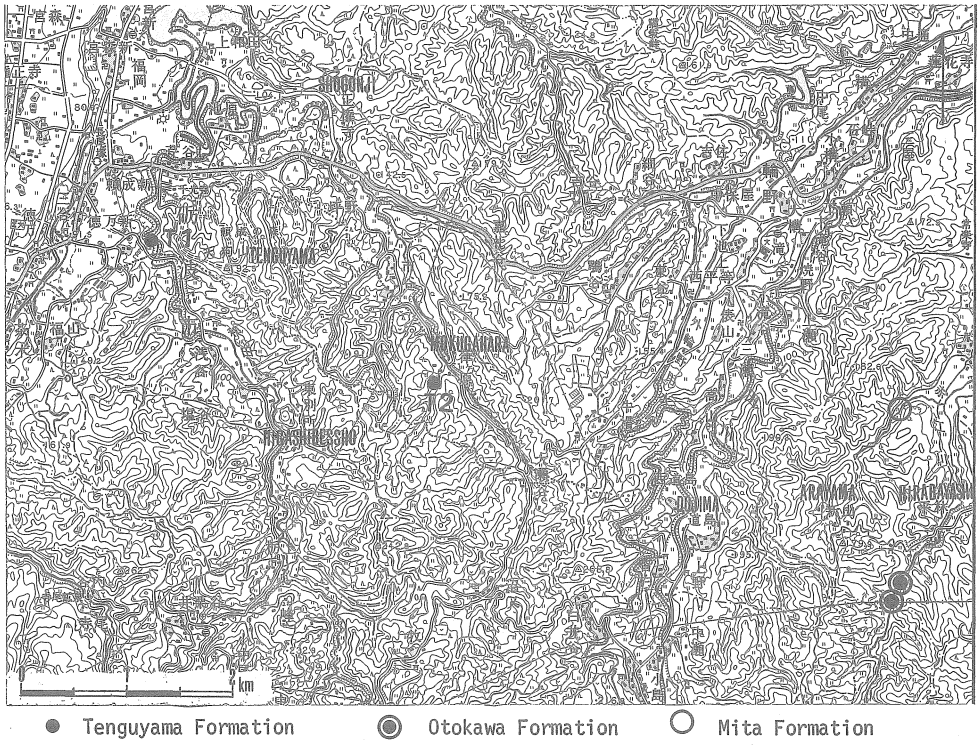


Fig. 5. Index map of the fossil localities of the Tenguyama, Otokawa and Mita Formations. (adapted from Geographical Quadrangle Map "Yatsuo" 1 : 50,000, Agency of Land Survey, Ministry of Construction).

Molluscan Fauna of the Tenguyama Formation

From the two fossil localities, 29 species including 20 bivalves, 8 gastropods and one scaphopod, are identified (Tab. 1). They occurred from sandstone as shell beds (loc. T-1) and a lenticular bed (loc. T-2). Some bivalves have conjoined shells and well preserved fine shell ornamentation, hinge teeth and other fragile portion, however some fragmental shells of pectinids also occurred. From the locality 1, some barnacles and shark's teeth occur with molluscs. The mode of shell occurrences suggests that these shells represent an allochthonous thanatocoenosis.

Among the species, such pectinids are dominant as *Kotorapecten kagamianus moniwaensis, Chlamys meisensis, C.* cf. *ingeniosa, C. arakawai* and *Nanaochlamys notoensis*

Table 1. Molluscan fossils of the Tenguyama Formation.

species	locality	T-1	T-2
Acila sp.		*	
Saccella confusa cf. *kongiensis* Otuka		*	
Anadara sp.		*	
Glycymeris sp.		*	
Chlamys arakawai (Nomura)		*	
C. meisensis (Makiyama)		*	
C. cf. *ingeniosa* (Yokoyama)		*	
Nanaochlamys notoensis notoensis (Yokoyama)		*	
Kotorapecten kagamianus moniwaensis (Masuda)		*	*
Crassostrea cf. *gravitesta* (Yokoyama)		*	
Lucinoma acutilineatum (Conrad)		*	
Cyclocardia cf. *siogamensis* (Nomura)		*	
Vasticardium ? sp.		*	
Mercenaria yokoyamai (Makiyama)		*	
Dosinia (Phacosoma) cf. *tugaruana* Nomura		*	
D. (Kaneharaia) kannoi Masuda		*	
Pitar cf. *itoi* (Makiyama)		*	
Macoma sp.		*	
Mya cuneiformis (Böhm)			*
Myadora sp.		*	
Crepidula cf. *nitadoriensis* Otuka		*	
Sinum yabei Otuka		*	
Euspira meisensis (Makiyama)		*	
Phos cf. *iwakianus fujinaensis* Ogasawara et Nomura		*	
Buccinum sp.		*	
Musashia sp.		*	
Olivella cf. *omurai* Ogasawara		*	
Cancellaria (Sydaphera) sp.		*	
Fissidentalium yokoyamai (Makiyama)			*

T-1: riverside cliff of Wada-gawa at about 200m downstream from the Wadagawa-Bridge, Tonami City
T-2: riverside cliff about 200m SSW from Mokugahara, Fuchu-machi, Nei-gun, Toyama Prefecture

notoensis. A few individuals of *Mercenaria yokoyamai* and *Pitar* cf. *itoi* occur as conjoined shells. Some remains of the small bivalves *Acila, Saccella, Anadara, Glycymeris, Lucinoma* and *Mya* are also common constituents. Among gastropods, large specimens of *Buccinum* sp. and *Musashia* sp. are characteristic and a few small shells such as *Sinum yabei, Phos* cf. *iwakianus fujinaensis, Cancellaria* sp. and *Olivella* cf. *omurai* are present.

From the shell occurrences and taxa cited above, the assemblage evidently is composed of two associations which can be separated into shallow and deep elements. That is, the first is the pectinid-dominant association with some Veneridae, and the second is the *Saccella-Musashia* assemblage in association with *Acila, Lucinoma, Cyclocardia, Myadora, Buccinum* and *Fissidentalium*. Moreover, the allochthonous assemblage may contain

some taxa suggestive of a transitional facies between the shallow and deep associations, based on current knowledge of this fossil assemblage and also based on the ecological data for allied recent genera/species.

Paleoenvironment

The molluscan fauna of the Tenguyama Formation is characterized by a pectinid-dominated assemblage. The occurrence of large pectinids suggests a paleo-depth less than 50-60m and a sandy bottom (OGASAWARA, MASUDA and CHINZEI, 1986). Other cooccurring molluscs such as *Mercenaria* and *Pitar* also suggest nearly the same paleo-depth as the pectinids. However, *Fissidentalium yokoyamai, Acila, Saccella, Lucinoma, Cyclocardia, Buccinum* and *Musashia* species are considered to represent a deeper habitat than that of the pectinids. As cited above, the mode of occurrence of the assemblage and its species composition suggest that taxa from different habitats were mixed after death. Some shallow elements may have been transported into deeper environments by turbidity currents. Consequently, the deep molluscan elements suggest about 100 to 200m in paleo-depth.

The shallow assemblage in turn, is mainly composed of warm-water elements such as *Nanaochlamys notoensis notoensis, Chlamys arakawai* and *Kotorapecten kagamianus*. As described in the latter, these pectinids have been recorded from various localities in association with subtropical and warm-water genera or taxa such as *Turbo, Cypraea, Placopecten, Nipponopecten,* and *Gloripallium*. However, species of *Nanaochlamys* and *Kotorapecten* are warm to mild temperate elements because they have rather wide stratigraphic ranges up to the late Middle Miocene (*Coscinodiscus yabei* zone of diatom biostratigraphy). These evolutionarily advanced species/subspecies such as *Nanaochlamys notoensis otutumiensis* and *Kotorapecten kagamianus kagamianus* are considered to be survival elements adapted to the cooling events of the Miocene (MASUDA, 1962a, b ; OGASAWARA, 1988). Consequently, these data suggest that the shallow elements of the Tenguyama fauna may have flourished under warm-temperate conditions.

Age and Correlation

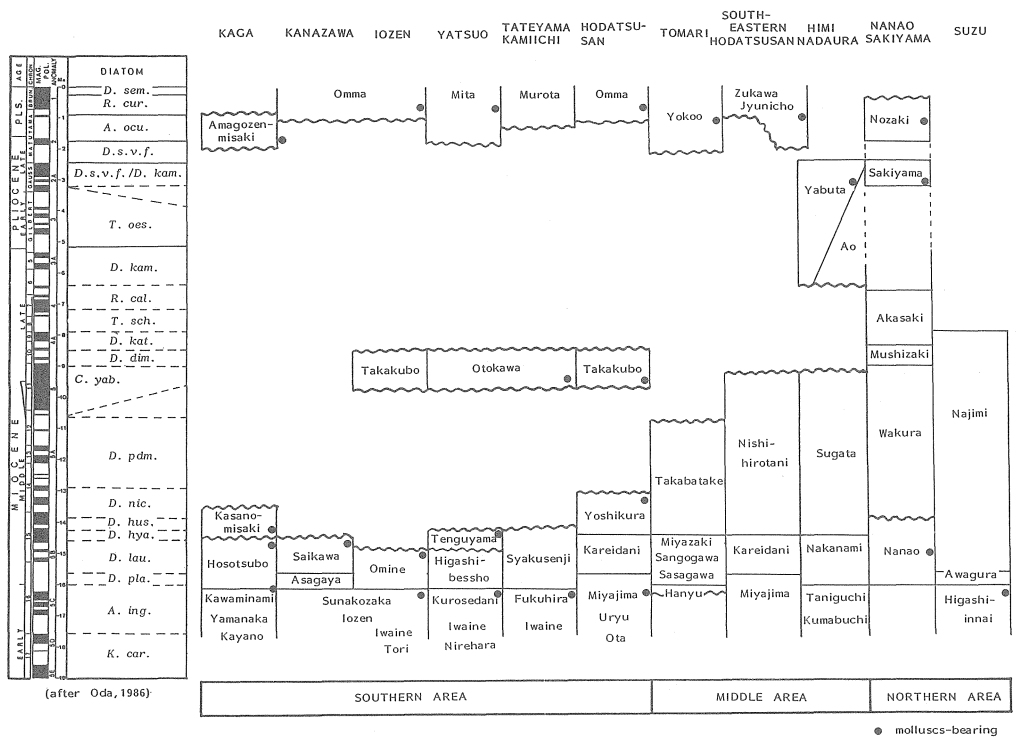
The molluscan assemblage of the Tenguyama Formation is quite similar to that of the Nanao Formation. In particular, it is very comparable to the Iwaya fauna of the Nanao Formation, Noto Peninsula (KASENO, 1964). Based on calcareous nannofossils, the Nanao Formation is allocated into the CN4 to CN5a zones, that is, about 14 Ma (KAMI *et al.*, 1981).

Among the Tenguyama molluscan taxa, *Nanaochlamys notoensis notoensis, Kotorapecten kagamianus moniwaensis* and *Chlamys* cf. *ingeniosa* are useful for correlation and age assignment. These species have been recorded from Middle Miocene strata of Central to Northern Honshu. On the basis of co-occurring microfossils (ODA, 1986 ; SAITO *et al.*, 1986), these species are assignable to the early to middle Middle Miocene, N8-N9 zones of the planktic foraminiferal zonation, or to the *Denticulopsis praelauta-D. lauta* zones of

diatom biostratigraphy.

The Tenguyama Formation can be correlated with the Kinjyozan Sandstone, Saikawa, and Omine (Kurahara) Formations in the Hokuriku district based on molluscan and microfossil data (Tab. 2), as shown by OGASAWARA *et al.* (1989). The Tenguyama fauna is different from the Otokawa (Otogawa) fauna, which is characterized by pectinids such as *Mizuhopecten matumoriensis* (OGASAWARA, KASENO and SHIMOKAWA, 1988 ; OGASAWARA *et al.*, 1989).

Table 2. Correlation table of the Upper Cenozoic strata (mainly shallow-sea molluscs bearing-formations) in the Hokuriku District (after OGASAWARA, SASAKI and NEMOTO, 1989).



Except for *Nanaochlamys notoensis notoensis*, the Tenguyama fauna is not directly comparable with those of the upper part of the Kurosedani Formation, which contain *Placopecten osawanoensis, Gloripallium osawanoensis*, and *Chlamys ishidae* (TSUDA, 1959 ; MASUDA, 1962a ; OGASAWARA, 1987MS).

The assemblage is also closely allied to those of the Miocene of North Korea. According to MAKIYAMA (1926, 1936), the Neogene of the Kisshu and Meisen districts, North Korea, is divided into the Heiroku Conglomerate (200-240m thick), Inan Sandstone (50-300m), Kantin Shale (80-200m), Lower Banko Sandstone (70-100m), Middle Banko Sandstone (60-110m) and Upper Banko Sandstone (200-400m), in ascending order. The tropical and/or subtropical molluscan fauna which is characterized by *Vicarya* and *Tateiwaia*

species is recorded from the Heiroku Conglomerate, while the overlying Inan Sandstone has not yielded any kind of molluscs. The molluscs of the Kantin Shale are closely allied to those of the upper part of the Kurosedani and Higashibessho Formations of the Yatsuo area, because those formations yielded such deep water genera as *Yoldia, Nuculana, Conchocele* (= *Thyasira*), *Lucinoma*, and *Periploma*.

Subsequently, a *Chlamys meisensis*-bearing molluscan assemblage which is very comparable to the present Tenguyama fauna, has been recorded from the Lower Banko Sandstone, which is equivalent to the Mankodo Formation of MAKIYAMA (1926). Some molluscs originally described by MAKIYAMA as new species from the Lower Banko Sandstone have been recorded from the Japanese Miocene. They are *Anadara ogawai, Glycymeris cisshuensis, Diplodonta ferruginata, Pitar itoi, Protothaca tateiwai, Neverita koticazae,* and *Surculites cryptoconoides* (see p. 201 of MAKIYAMA, 1936). Among the reported species from the Lower Banko Sandstone, *Dosinia kaneharai* was examined by MASUDA (1962), who considered it to be synonymous with *Kaneharaia kannoi* MASUDA ; other molluscs, such as *"Cardium" shiobarense, Phos meisensis* and *Dosinia sirakii* of the Lower Banko Sandstone need to be reexamined from a systematic viewpoint. The fossils from the overlying Middle and Upper Banko Sandstone is characterized by fresh-water molluscs and mastodon-like teeth (MAKIYAMA, 1936).

The Tenguyama fauna contains the first record of *Chlamys meisensis* in the Japanese Islands and is very comparable to the MAKIYAMA's Lower Banko assemblage of North Korea. Consequently, both molluscan assemblages can be assigned to the Middle Miocene (ca. 15-14 Ma), as cited above.

In general, the Middle Miocene molluscan faunal succession tends to change from tidal assemblages through shallow open-sea to more deep water assemblages in the Japanese Islands, as pointed by TSUDA (1965). These assemblages are represented by the Arcid -Potamid fauna, the pectinid fauna of the Kurosedani Formation (TSUDA, 1965) and the Higashibessho fauna in the Yatsuo area, respectively. However, it must be added to the just cited environmental history that the shallow molluscs-bearing Tenguyama Formation unconformably overlies the Higashibessho Formation. Subsequently, it can be assumed that the Tenguyama stage became a shallow environment just after the Higashibessho Formation was accumulated. Such a paleo-environmental succession is also recognizable in the Miocene sequences of the Kaga and Iozen areas in the Hokuriku district, and the Kisshu-Meisen area of North Korea as noted above. That is, during the Middle Miocene the southwest Japan Sea, as represented by the deposits of the Hokuriku district and North Korea, contained such environmental conditions as terrestrial, subtidal, shallow sea, deep sea and shallow sea, in ascending order. These environmental changes might correspond to world-wide sea-level changes as shown by HAQ *et al.* (1987).

Remarks on Characteristic Species

Saccella confusa cf. *kongiensis* (OTUKA)

Pl. 1, figs. 1, 2, 3.

Compared with : *Nuculana confusa kongiensis* OTUKA, 1935, p. 608-609, pl. 47, fig. 14.

Remarks : Some poorly-preserved specimens were examined. They are characterized by a rather symmetrical high form with fine concentric striae. This form is most allied to *Saccella confusa kongiensis* OTUKA described from the Kadonosawa Formation. The species resembles *S. confusa toyomaensis* KAMADA, but is distinguished from the latter in having finer concentric striae.

Anadara sp.

Pl. 1, fig. 7.

Remarks : The present form is allied to *Anadara makiyamai* and *A. ogawai* in its dichotomous radials. However, the number of radials is not distinct due to ill-preserved specimens

Chlamys arakawai (NOMURA)

Pl. 3, fig. 1.

Pecten (*Pecten*) *arakawai* NOMURA, 1935, p. 41, pl. 4, figs. 1, 2.

Pecten (*Chlamys*) *arakawai* NOMURA, NOMURA, 1940, p. 17, pl. 2, figs. 1-3.

Coralichlamys shigemai HIRAYAMA, 1954, p. 51, pl. 3, fig. 2.

Chlamys arakawai (NOMURA), MASUDA, 1954, p. 150, pl. 19, figs. 1-6. ; MASUDA, 1962a, p. 161.

Remarks : A few specimens are at hand. They are characterized by a high form with slightly concave anterior dorsal margin, narrow apical angle (ca. 78°) and about 22 bifurcated radial ribs.

The species is allied to *Chlamys iwamurensis* ITOIGAWA which was originally described from the Miocene of Gifu Prefecture. However, it can be distinguished from *C. iwamurensis* because it has small ears, a narrow apical angle and distinct ctenolium.

Chlamys meisensis (MAKIYAMA)

Pl. 1, figs. 9, 10, 11 ; Pl. 3, figs. 2, 3, 5, 6.

Pecten (*Chlamys*) *meisensis* MAKIYAMA, 1926, p. 156, pl. 13, fig. 4.

Chlamys meisensis MAKIYAMA, MAKIYAMA, 1936, p. 206.

Chlamys meisensis (MAKIYAMA), MASUDA, 1962a, p. 187-188, pl. 23, fig. 2.

Measurements in mm :

IGPS coll. cat. no.	Length	Height	Depth	Hinge Length	Apical Angle	No. rib.	Valve
99978	35.80	39.40	8.9	21.0	90	19+	R
	42.50	49.30	8.4	—	93	23	R
	43.20	50.35	—	—	87	20+	R
	47.50	—	—	—	93	22	R
	63.20	—	13.2	34.0	94	20	R
	67.40	72.70	14.0	—	97	22	R
	83.60	(81.5+)	—	—	98	24	R
	(ca.35.0)	41.90	—	—	93	20	L
	45.20	50.5	—	—	91	22	L
	(52.0+)	62.50	—	—	—	22	L
	66.80	72.90	13.5	38.4	89	23	L

Remarks: The species was originally described from the upper part of the Mankodo Formation at Kinshodo, North Korea by MAKIYAMA (1926). Subsequently, he redefined the name of the formation to the Lower Banko Sandstone (MAKIYAMA, 1936) and reported the presence of such co-occurring species as *Megasurcula cryptoconoides, Polinices coticazae, Glycymeris cisshuensis, Anadara ogawai, Diplodonta ferruginata* and *Chione tateiwai*.

According to the original description, the species is characterized by 23 to 27 equal, equidistant, flat-topped, round-edged and dichotomous ribs, and intercalating ribs first appear when the shell reaches about 30 mm in height.

The species from the Tenguyama Formation is characterized as follows: Shell moderate to large, largest one attains 83.60 mm in length, high, thick and moderately inflated; Both valves nearly equal in inflation that ranges 0.20 to 0.25 in the ratio of Depth/Length; Apical angle ranges from 87° to 98°, and 93° is most common; Surface sculptured with bifurcated, squarish, well elevated, 20 to 24 radial ribs that are not distinct on the shell extremities; mostly about 22 in number with one intercalated riblet in each interspace; width of ribs nearly equal to that of interspaces or slightly narrow; dichotomous ribs appear at a distance of 28 to 35 mm from the beak in general, although a few dichotomous ribs occur at earlier stages; earliest one is at about 7 mm length; not divided into three; Ear ornamentation shows some variant; anterior ear of the right valve sculptured with radials; uppermost radial rib rather broad and subdivided into three by very shallow furrows, and 4 distinct radials; posterior ear of the right valve with 7 to 8 fine radials; anterior ear of the left valve sculptured with about 11 radials of which upper 6 appear to have branched from two radials at an early stage; that is, two ribs become subdivided into three by a furrow during ontogeny; posterior ear sculptured with 8 or 9 fine and distinct radials; ctenolium distinct, about 4 or 5 in number.

The above cited characters comparable well with the original description. However the number of radial ribs of the Tenguyama specimens are rather small compared to the type specimens, but this can be ascribed to intraspecific variation because the type specimen illustrated by MAKIYAMA shows more or fewer than 23 in number by the authors' observation. Moreover, the number of first-order radial ribs of the topotype specimens preserved at IGPS (coll. cat. nos. 74345, 64691, 90654) is 22 or 23 by the authors' examina-

tion.

The present specimens resemble *Chlamys hataii* MASUDA and SAWADA reported from the Miocene Nagaoka Formation, Tochigi Prefecture in general features, in particular dichotomous ribs, intercalating riblets and number of ribs. But it can be distinguished from *C. meisenis* in having a small shell, ribs which are subdivided into three by shallow furrows and fewer radial ribs. However it is quite difficult to separate these species in their younger stages. Therefore, these two species can be considered to be strongly related to each other phylogenetically.

Chlamys otukae MASUDA and SAWADA, reported from the Oido Formation, Miyagi Prefecture also is closely allied to the *C. meisensis* and *C. hataii*, but *C. otukae* can be distinguished from these two species in having a small and thin shell. It is necessary to study these species from a phylogenetic viewpoint in the future, including *Chlamys akitana* YOKOYAMA reported from the Sugota Formation, Akita Prefecture, *Chlamys ishidae* MASUDA reported from the upper part of the Kurosedani Formation and its allied species.

Since MAKIYAMA described the species from North Korea, this Tenguyama record is only the second known occurrence.

Chlamys cf. *ingeniosa* (YOKOYAMA)

Pl. 2, fig. 12.

Compared with:

Pecten (*Chlamys*) *hastatus* SOWERBY var. *ingeniosa* YOKOYAMA, 1929, p. 5, pl. 6, fig. 2.

Chlamys ingeniosa (YOKOYAMA), MASUDA, 1962a, p. 170-171, pl. 22, fig. 13.; ITOIGAWA in ITOIGAWA, SHIBATA and NISHIMOTO, 1974, p. 64, pl. 9, figs. 1a-b.

Remarks: A few fragmental shells were examined. They are characterized in having 20-23 bifurcated radial ribs which are subdivided into two by shallow furrows and 3 intercalated ribs in their interspaces. These characters are similar to those of *Chlamys ingeniosa* described from the Nanao Formation. However, the latter species is known only from fragmental shells.

Nanaochlamys notoensis notoensis (YOKOYAMA)

Pl. 2, figs. 4, 6.

Pecten notoensis YOKOYAMA, 1929, p. 4, pl. 13, figs. 1-4, pl. 4, figs. 1, 2, pl. 5, fig. 1.

Pecten natoriensis MATSUMOTO, 1930, p. 104, pl. 40, figs. 10-11.

Pecten natoriensis var. *inequilateralis* MATSUMOTO, 1930, p. 105, pl. 40, figs. 13-14.

Pecten natoriensis var. *subovalis* MATSUMOTO, 1930, p. 105, pl. 40, fig. 12.

Velopecten survivanus MATSUMOTO, 1930, p. 106, pl. 40, figs. 16-18.

Pecten (*Pecten*) *notoensis* YOKOYAMA, NOMURA and ZINBO, 1935, p. 161, pl. 15, fig. 27.

Pecten (*Chlamys*) *notoensis* YOKOYAMA, NOMURA, 1940, p. 18, pl. 1, figs. 4-7.

Nanaochlamys notoensis (YOKOYAMA), HATAI and MASUDA, 1953, p. 77, pl. 7, figs. 1-7; MASUDA, 1960, p. 373, pl. 39, figs. 1-5; MASUDA, 1962a, p. 199, pl. 20, fig. 11; KANNO, 1962,

pl. 3, fig. 4 ; SAWADA, 1962, p. 74, pl. 3, fig. 1 ; MIZUNO, 1965, p. 331, pl. 1, figs. 1, 2.

Nanaochlamys notoensis setanaensis KANNO, 1962, p. 56, pl. 3, figs. 1-4 ; SATO, 1982, p. 42-53, pl. 1, figs. 1-11, pl. 2, figs. 1-8, pl. 3, figs. 1-2.

Measurements in mm :

IGPS coll. cat. nos.	Length	Height	Depth	Apical Angle	Valve
99975-1	69.40	75.05	13.25	80	right
-2	72.50	—	—	ca. 81	right
-3	65.60	69.70	13.85	79	right

Remarks : The present form differs from *N. notoensis otutumiensis* described from the middle Middle Miocene Otsutsumi Formation in the environs of Sendai. As well studied by MASUDA (1963) and SATO (1982), the species can be distinguished from *N. otutumiensis* in having trifurcated radial ribs while *N. otutumiensis* has a large, thick and heavy shell with secondarily branched radials.

Kotorapecten kagamianus moniwaensis (MASUDA)

Pl. 3, figs. 4, 7.

Pecten (*Patinopecten*?) *kagamianus* YOKOYAMA, 1929, p. 2, pl. 1, fig. 1.

Pecten (*Vola*) *kagamianus* YOKOYAMA, NOMURA and ZINBO, 1936, pl. 20, fig. 3.

Patinopecten kagamianus moniwaensis MASUDA, 1958, p. 276-277, pl. 41, figs. 3-6. ; MASUDA, 1962a, p. 217-218.

Kotorapecten kagamianus moniwaensis (MASUDA), MASUDA, 1963b, p. 149.

Measurements in mm :

IGPS coll. cat. no.	Length	Height	Depth	Hinge L	H/L	D/L	HL/L	Apical Angle
99976-1	80.20	79.40	10.9	41.6	0.99	0.14	0.52	107
-2	112.20	106.20	16.50	54.3	0.95	0.15	0.48	105
-3	110.20	109.15	15.40	54.7	0.99	0.14	0.50	105

Remarks : According to MASUDA (1962a), this species ranges from 100° to 105° in apical angle and 0.35 to 0.62 in the HL/L (ratio of Hinge length/shell length). The above cited measured data comparable well with those of the type specimens.

The Tenguyama species is characterized by 9 to 11 main radial ribs some of which are subdivided into 8 or 9 fine radials by shallow furrows at the marginal of the disk.

Dosinia (*Phacosoma*) cf. *tugaruana* NOMURA

Pl. 1, fig. 14.

Compared with : *Dosinia tugaruana* NOMURA, 1935, p. 58, pl. 6, fig. 6 ; MASUDA, 1963a, p. 32-33, pl. 6, figs. 8, 9, 10a-b.

Remarks : According to MASUDA's examination on the present species and related species (MASUDA, 1963a), *Dosinia tugaruana* can be considered to be synonymous with *D. odosensis* NOMURA. We agree with this opinion.

The present form from the Tenguyama Formation is characterized by very fine

concentric lines on the disk and a pointed beak that is anteriorly protruded.

Dosinia sirakii MAKIYAMA from the Meisen Miocene of North Korea is very similar to the present form. Although more detailed study is necessary, *D. sirakii* can be considered as a junior synonym of the present species.

Dosinia (*Kaneharaia*) *kannoi* MASUDA

Pl. 1, figs.,5 8, 13 ; Pl. 2, fig. 8.

Dosinia (*Kaneharaia*) *kaneharai* YOKOYAMA, MAKIYAMA, 1936, p. 213-214, pl. 4, fig. 2 ; KANNO, 1960, p. 272, pl. 40, fig. 9 ; IWAI, 1961, pl. 1, fig. 1.

Dosinia kaneharai YOKOYAMA, NOMURA and ZINBO, 1936, p. 339, pl. 20, fig. 1 ; OTUKA, 1935, p. 443, pl. 30, fig. 3 ; NOMURA, 1940, p. 26, pl. 1, figs. 15, 16.

Dosinia (*Kaneharaia*) *kannoi* MASUDA, 1963a, p. 35-37, pl. 6, figs. 6a-b, 7a-b.

Dosinia (*Kaneharaia*) *kaneharai kannoi* MASUDA, MASUDA, 1967, p. 22-23, pl. 1, figs. 7, 8, pl. 2, figs. 5, 7-9.

Remarks : Some inner and outer molds were examined. They are characterized by a medium size shell with rather broad concentric ribs (about 35 or more in number within 22 mm of the beak). The species is allied to *D.* (*K.*) *kaneharai,* but differs in having regularly sculptured concentrics, as noted by MASUDA (1963a, 1967).

Pitar cf. *itoi* (MAKIYAMA)

Pl. 2, fig. 11.

Compared with : *Pitaria itoi* MAKIYAMA, 1926, p. 159, pl. 13, fig. 7.

Pitar cf. *itoi* (MAKIYAMA), ITOIGAWA in ITOIGAWA, SHIBATA and NISHIMOTO, 1974, pl. 21, figs. 17-18.

Remarks: Poorly-preserved specimens of inner molds are at hand. They are characterized by a medium sized shell (49.20 mm length, 40.40 height, ca. 11.5 depth) and a well marked pallial sinus which reaches to about the center of the shell. Although hinge structures cannot be observed, they may be identified with the present species. According to original description, the species was described under the genus *Pitaria*, and it compared with *P. clarki* DICKERSON. The hinge, which has 3 stout cardinals, suggests that it belongs to another genus of Veneridae such as *Neogeneralla* SLODOKEVICH, 1936. However, it is assigned herein to genus *Pitar* until well preserved specimens are obtained.

Sinum yabei OTUKA

Pl. 4, figs. 2a-b.

Sinum yabei OTUKA, 1935, p. 627-628, pl. 49, figs. 74, 75 ; KAMADA, 1962, p. 161, pl. 19, figs. 6-8 ; MASUDA and TAKEGAWA, 1965, pl. 2, figs. 20a-b ; IWASAKI, 1970, p. 418, pl. 1, fig. 15 ; ITOIGAWA in ITOIGAWA, SHIBATA and NISHIMOTO, 1974, p. 149, pl. 45, figs. 20-21 ; OGASAWARA, 1976, p. 64, pl. 13, fig. 16, pl. 15, fig. 11 ; OGASAWARA, SASAKI and NEMOTO, 1989, pl. 3, fig. 10.

Remarks : One specimen of the Tenguyama Formation is 11.3 mm in maximum diameter, 8.85 mm in minimum diameter and 8.3 mm in height. It is characterized in having about

25 spiral striae on the body whorl. The topotype specimens from the Kadonosawa Formation show 0.8-0.87 in the ratio of Minimum diameter/Maximum diameter although it is given as about 0.65 in the original description. The Tenguyama specimen shows 0.78 in that ratio, which can be assigned to intraspecific variation. Their differences may be caused by ontogenetic changes.

Sinum ineptum (YOKOYAMA) differs from the present species in having a more planispiral volution and low shell.

Phos cf. *iwakianus fujinaensis* OGASAWARA and NOMURA

Pl. 4, figs. 4, 5.

Compared with : *Phos iwakianus fujinaensis* OGASAWARA and NOMURA, 1980, p. 92-93, pl. 12, figs. 5a-b.

Remarks : A few poorly-preserved specimens were examined. They are characterized in having four to five spirals and more than 20 transverse costae on the periphery and/or whorls, and about 13 bead-like nodules on the body whorl. This form is allied to *Phos iwakianus* (YOKOYAMA) described from the Tanagura Bed and *Phos* (*Coraephos*) *meisensis* MAKIYAMA, described from the Lower Banko Sandstone of North Korea. But it can be distinguished from these two species in having finer surface sculpture. This form also is allied to *Phos iwakianus* (YOKOYAMA), reported from the Otokawa Formation by OGASAWARA, SASAKI and NEMOTO (1989), in general shape and spirals. However it is distinguished from Otokawa specimens in having finer spirals and a large number of longitudinal costae. The present form is most allied to *Phos iwakianus fujinaensis* described from the Fujina Formation, Shimane Prefecture.

Olivella cf. *omurai* OGASAWARA

Pl. 4, figs. 1a-b.

Compared with : *Olivella omurai* OGASAWARA, 1976, p. 69, pl. 15, figs. 2, 3, 4.

Remarks : The species resembles *Olivella iwakianus* NOMURA and HATAI described from the Tanagura Bed, Fukushima Prefecture in shell outline but it is distinguishable from the latter in having more numerous columellar folds. One Tenguyama specimen bears more than 6 columellar folds although it is poorly-preserved. This character suggests that it is identical with the present species.

Acknowledgments

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Explanation of Plate 1

(all figures natural size, unless otherwise stated)

Figs. 1, 2, 3. *Saccella* cf. *confusa kongiensis* OTUKA, IGPS coll. cat. no. 99979, Loc. no. T-1.

Fig. 4. *Glycymeris* sp., IGPS coll. cat. no. 99980, Loc. no. T-1.

Figs. 5, 8, 13. *Dosinia* (*Kaneharaia*) *kannoi* MASUDA, figs. 5, 8. IGPS coll. cat. no. 99981, Loc. no. T-1 ; fig. 13, IGPS coll. cat. no. 99983, Loc. no. T-2.

Figs. 6a-b, 12. *Acila* (*Truncacila*) sp., IGPS coll. cat. no. 99983, Loc. no. T-1.

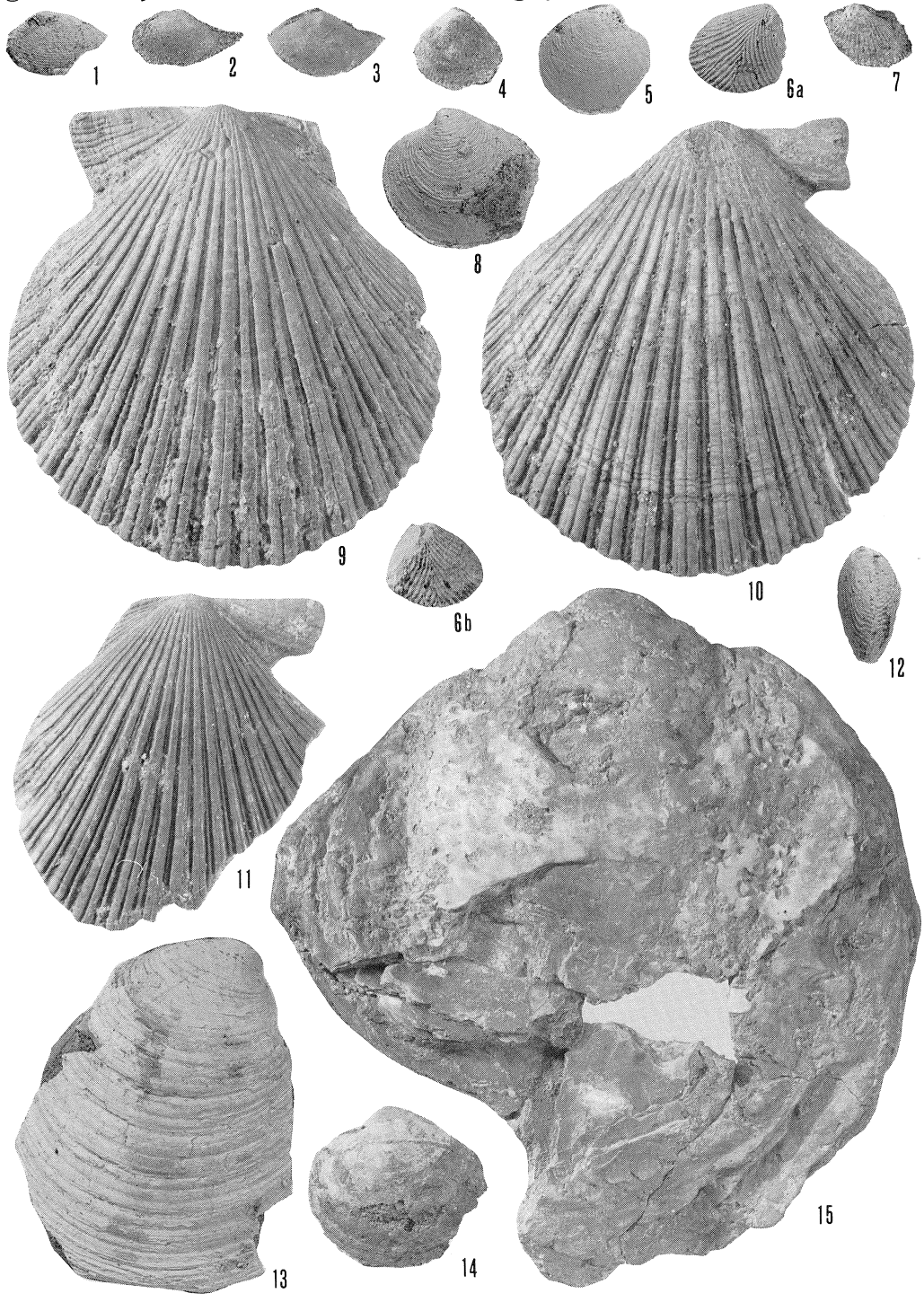
Fig. 7. *Anadara* sp., IGPS coll. cat. no. 100001, Loc. no. T-1.

Figs. 9, 10, 11. *Chlamys meisensis* (MAKIYAMA), IGPS coll. cat. no. 99978, Loc. no. T -1.

Fig. 14. *Dosinia* (*Phacosoma*) cf. *tugaruana* NOMURA, IGPS coll. cat. no. 100002, Loc. no. T-1.

Fig. 15. *Crassostrea* cf. *gravitesta* (YOKOYAMA), IGPS coll. cat. no. 100003, Loc. no. T-1.

Ogasawara, K. et al.:Miocene Tenguyama molluscs Plate 1



Otomo photo.

Explanation of Plate 2

(all figures natural size, unless otherwise stated)

Figs. 1, 2. *Macoma* sp., IGPS coll. cat. no. 100004, Loc. no. T-1.

Figs. 3a-b. *Mercenaria yokoyamai* (MAKIYAMA), IGPS coll. cat. no. 100005, Loc. no. T-1.

Figs. 4, 6. *Nanaochlamys notoensis* (YOKOYAMA), IGPS coll. cat. no. 99975, Loc. no. T-1.

Fig. 5. *Vasticardium*? sp., IGPS coll. cat. no. 100006, Loc. no. T-1.

Figs. 7a-b. *Lucinoma acutilineatum* (CONRAD), IGPS coll. cat. no. 100007, Loc. no. T-1.

Fig. 8. *Dosinia* (*Kaneharaia*) *kannoi* MASUDA, IGPS coll. cat. no. 99981, Loc. no. T-1.

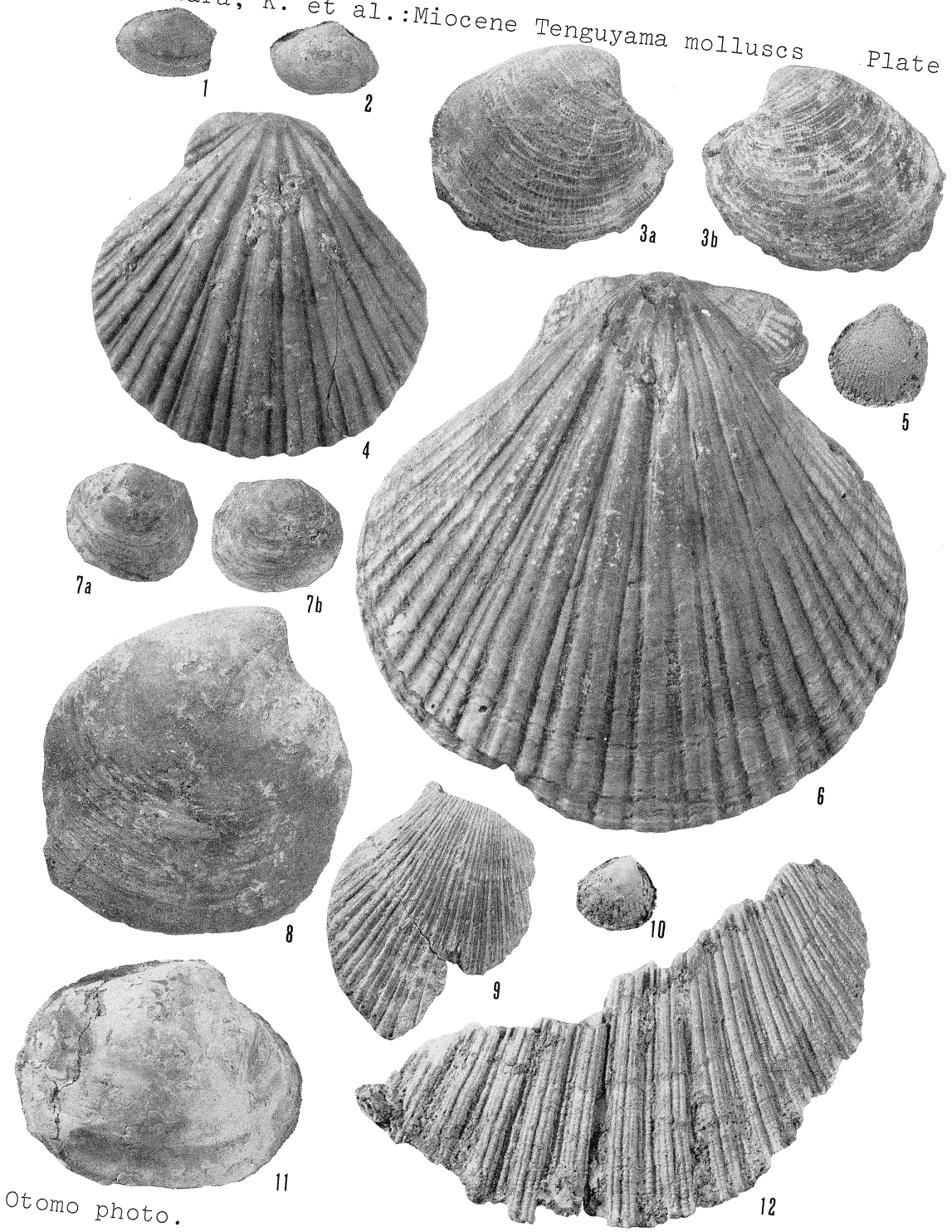
Fig. 9. *Chlamys* sp., IGPS coll. cat. no. 100008, Loc. no. T-1.

Fig. 10. *Cyclocardia* cf. *siogamensis* (NOMURA), IGPS coll. cat. no. 100009, Loc. no. T-1.

Fig. 11. *Pitar* cf. *itoi* (MAKIYAMA), IGPS coll. cat. no. 100010, Loc. no. T-1.

Fig. 12. *Chlamys* cf. *ingeniosa* (YOKOYAMA), IGPS coll. cat. no. 100011, Loc. no. T-1.

Ogasawara, K. et al.:Miocene Tenguyama molluscs Plate 2



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Explanation of Plate 3

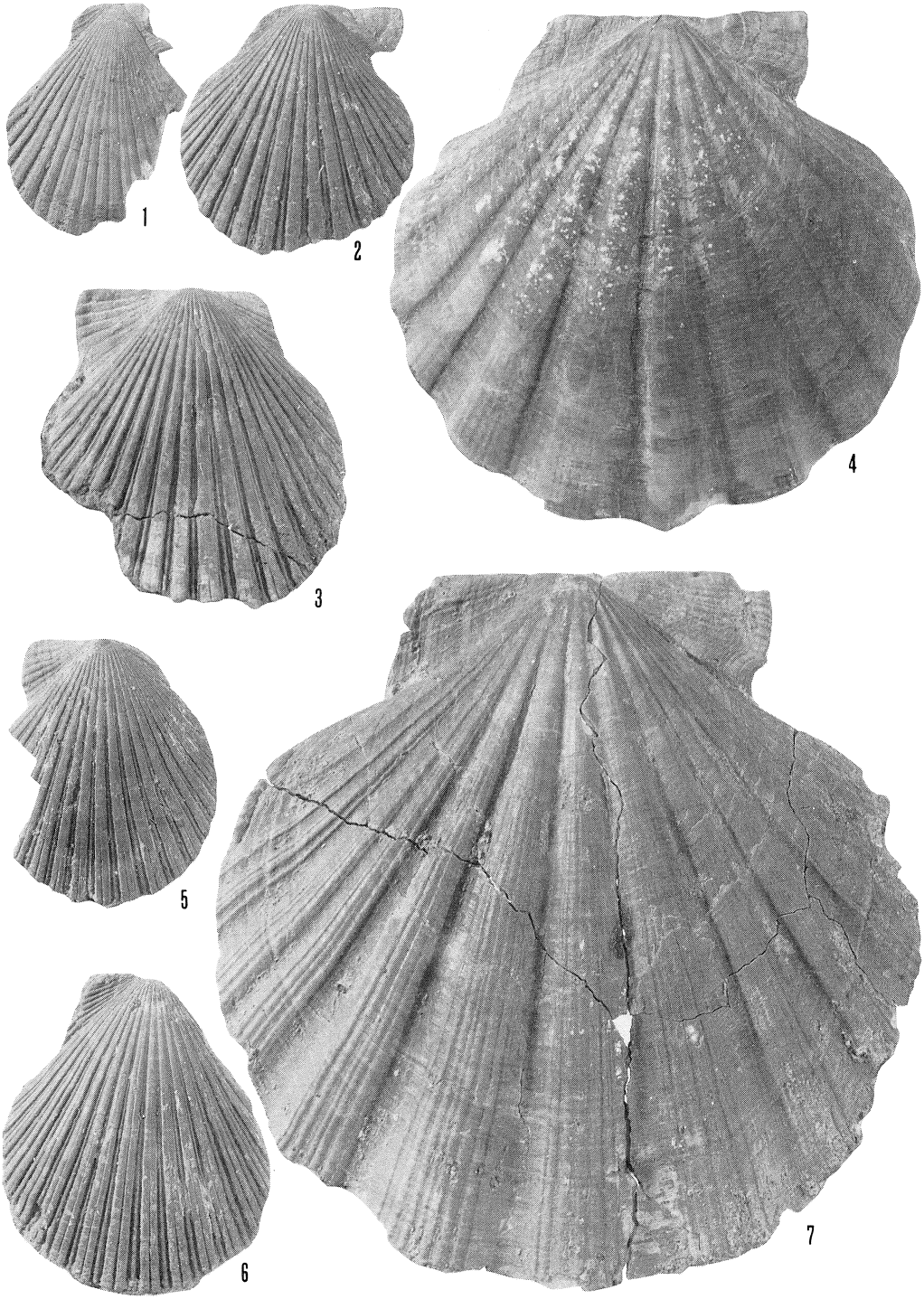
(all figures natural size, unless otherwise stated)

Fig. 1. *Chlamys arakawai* (NOMURA), IGPS coll. cat. no. 100013, Loc. no. T-1.

Figs. 2, 3, 5, 6. *Chlamys meisensis* (MAKIYAMA), IGPS coll. cat. no. 99978, Loc. no. T-1.

Figs. 4, 7. *Kotorapecten kagamianus moniwaensis* (MASUDA), IGPS coll. cat. no. 99976, Loc. no. T-1.

Ogasawara, K. et al.: Miocene Tenguyama molluscs Plate 3



Otomo photo.

Explanation of Plate 4

(all figures natural size, unless otherwise stated)

Figs. 1a-b. *Olivella* cf. *omurai* OGASAWARA, IGPS coll. cat. no. 100013, Loc. no. T-1.

Figs. 2a-b. *Sinum yabei* OTUKA, IGPS coll. cat. no. 100014, Loc. no. T-1.

Figs. 3a-b, 11a-b. *Euspira meisensis* (MAKIYAMA), IGPS coll. cat. no. 100015, Loc. no. T-1.

Figs. 4, 5. *Phos* cf. *iwakianus fujinaensis* OGASAWARA and NOMURA, IGPS coll. cat. no. 100016, Loc. no. T-1.

Figs. 6a-b, 7a-b. *Crepidula* cf. *nitadoriensis* OTUKA, IGPS coll. cat. no. 100017, Loc. no. T-1.

Figs. 8a-b. *Cancellaria* sp., IGPS coll. cat. no. 100018, Loc. no. T-1.

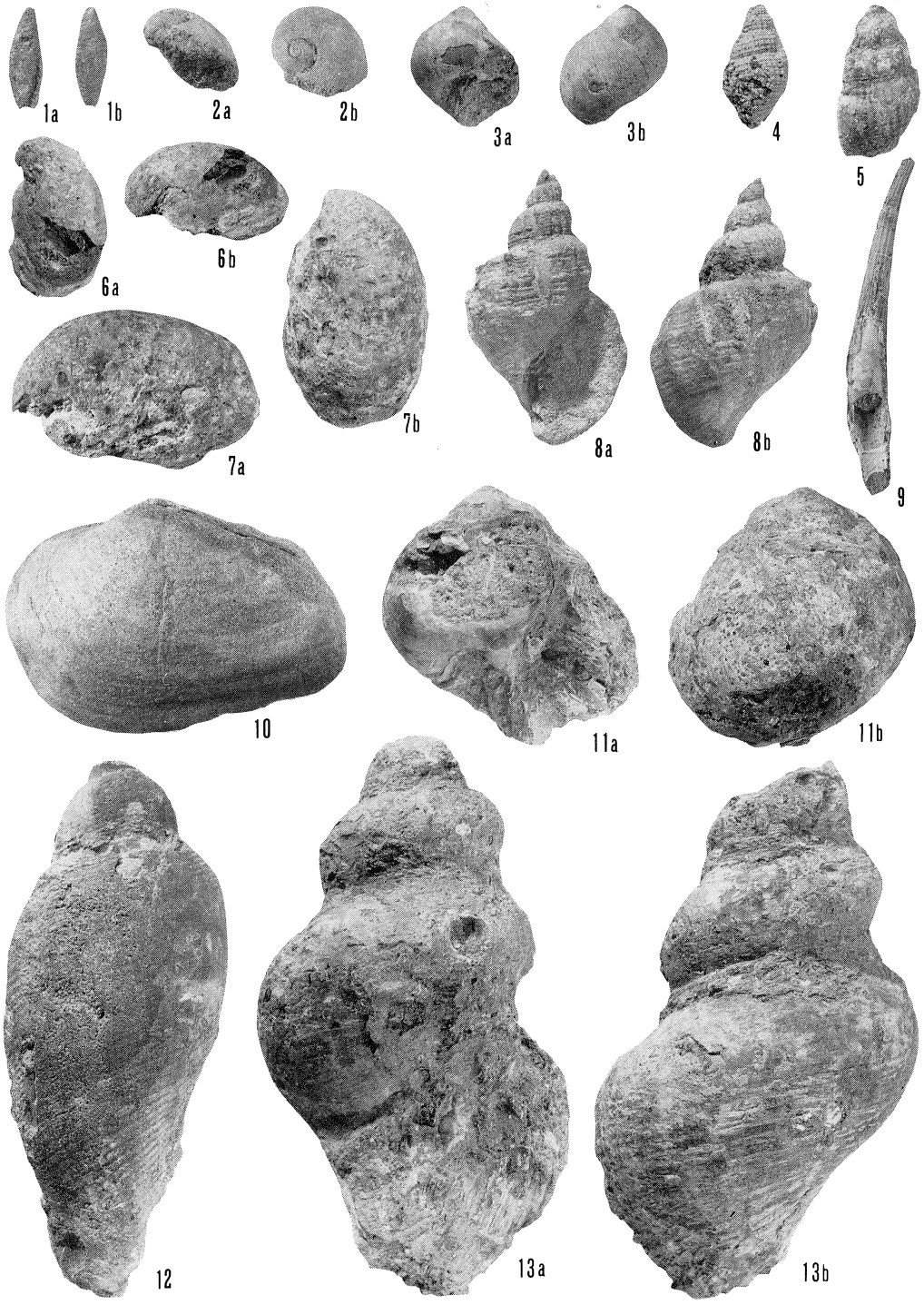
Fig. 9. *Fissidentalium yokoyamai* (MAKIYAMA), IGPS coll. cat. no. 100019, Loc. no. T-1.

Fig. 10. *Mya cuneiformis* (BÖHM), IGPS coll. cat. no. 100020, Loc. no. T-2.

Fig. 12. *Musashia* sp., IGPS coll. cat. no. 100021, Loc. no. T-1.

Figs. 13a-b. *Buccinum* sp., IGPS coll. cat. no. 100023, Loc. no. T-1.

Ogasawara, K. et al.:Miocene Tenguyama molluscs Plate 4



Otomo photo.

Errata

Hiroaki KARASAWA : Late Cenozoic Elasmobranchs from the Hokuriku district, central Japan. No. 1, Vol. 34, 1989.

page	line	read	for
1	18	Akahane	Akabane
5	8	prepared	prepered
5	9	arranged	arraged
5	13	Kaminiikawa	Kaminikawa
5	24	Hosotsubo	Hosokubo
22	36	VII	VIII
24	16	VII	VIII
25	2	VII	VIII
25	23	VII	VIII
26	11	VII	I
27	6	VII	VIII
28	2	VIII	IX
29	11	Akahane	Akabane
29	17	giant	grait
29	44	Ocean,	Ocean.
30	13	Natural	Natual
30	16	*Association*	*Assotiation*
30	16	*Collaboration*	*Coraborarion*
30	18	tectonic	tectonical
30	19	northwestern	northweatern
30	24	Australia	Austtaria
30	43	Molasse	Mollasse
31	1	ichthyologiques	ichthyologuques
31	6	Echinodermata	Echinodelmata
31	23	Randgebiete	Randgebite
31	27	*the Nanao Calcareous*	*The Nanao calcareous*
34	(read)	Faunal list of elasmobranchs from the late Cenozoic formations in the Hokuriku district.	
	(for)	Faunal Hst of clasmobranchs from the Late Cenozoic formatlons in the Hokurlku district.	
37	1	elasmobranch	elastmobranch
37	2	formations	forma tions
39	(read)	Late Cenozoic elasmobranch assemblages and inferred paleoenvironments of the Hokuriku district	
	(for)	Late Cenozoic Elasmobranch Assemblages and Inferred Paleoenvironments of the Hokuriku District	