Bull. Natn. Sci. Mus., Tokyo, Ser. C, **27**(3, 4), pp. 89–100, December 22, 2001

First Occurrence of Eocene Nautilids from the Miyaragawa Formation in Ishigaki-jima Island, the Ryukyus, Southwest Japan

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Abstract Two species of Eocene nautilid, *Aturia yokoyamai* Nagao and *Eutrephoceras japonicus* (Shimizu) were first discovered from the Miyaragawa Formation in Ishigaki-jima Island, the Ryukyus. From the associated molluscan species as *Vicarya*, *Terebra* and *Colpospira*, this occurrence shows the tropical shallow sea environment at Eocene. However, the sediments deposited inside of the nautilid specimens together with subangular pebbles in sandstone show off shore and active marine condition.

Key words: Eocene, Miyaragawa Formation, Ishigaki-jima, Okinawa, nautilid, mollusca, *Aturia*, *Eutrephoceras*.

Introduction

After the first systematic research on molluscan fossils from the Eocene Miyaragawa Formation (Nakagawa, *et al.*, 1982) in Ishigaki-jima Island, the Ryukyus by MacNeil (1964), no additional reports have been published from the formation except for the record of *Vicarya* and *Vicaryella* by Masuda (1980). The present writers had a chance to examine the first discovery of two species of Eocene nautilid from the Miyaragawa Formation together with the associated molluscan fossils. The Paleogene nautilid fossils were well known to occur from northern Kyushu as discussed by Kobayashi and Kamada (1959a, b), Kobayashi and Inoue (1961), Tanabe and Chiba (1983) and Nishida and Aoki (1984). The Eocene nautilids discussed herein are the first ones identified to *Aturia yokoyamai* and *Eutrephoceras japonicus* from the Ryukyus. The paleontological discussion of the first cephalopod record from the Ryukyu is thought meaningful for more consideration to the future development of their paleobiogeography and systematic of the species. The co-occurrence of *Aturia*

yokoyamai and *Eutrephoceras japonicus* is significant for the age determination of the late Eocene in Japan.

Occurrence of Eocene Nautilids

Two species of Eocene nautilids identified *Aturia yokoyamai* and *Eutrephoceras japonicus* were first discovered from the Miyaragawa Formation which is the southern most distribution for both species in Japan. Both species of *Aturia* and *Eutrephoceras* were collected from a granular to pebbly sandstone of the Miyaragawa Formation designated by Nakagawa *et al.* (1982, same with the Miyara Formation of MacNeil, 1964) at sea coast, about 500 m west of Ibaruma, northern part of Ishigaki-jima Island (Fig. 1). This locality is probably same or near to MacNeil's (1964) Loc. no. D 366, west coast of Ibaruma. Most of the molluscan species of the formation were recorded from this locality. Two species of nautilid specimens were occurred from the locality in almost parallel to the stratification of the formation, and together with the following molluscan species (Table 1). Most species are duplicated with those of MacNeil's (1964) report. The molluscs including nautilids are tightly preserved in granular to pebbly sandstone in the shape of water worn and in broken shape. However, the preservation is somewhat good on the surface of exposure for identification, but is hard to collect from deep inside of exposure. The dominant specimens of *Colpospira* (*Acutospira*) *kotakai* MacNeil occurred together with nautilids carry their immature whorls in good state of preservation.

Among these species, the dominant occurrence of *Colpospira* (*Acutospira*) *kotakai* is interesting to note that there are two morphological forms in external spiral ribs, as mono-carinated form (Fig. 5; 1–5) and bi-carinated form (Fig. 4; 3, Fig. 5; 6–8) as mentioned by MacNeil (1964). Beside of the morphological interest, the genus *Colpospira* has originated from Australia at Eocene and distributed toward Southeast Asia and also up to southern Kyushu (Kotaka, 1959, 1986). The other turritellid species of *Colpospira* as *C. okadai*, *C. tashiroi*, *C. yabei* are all restricted to occur from the middle to late Eocene in Kyushu (Kotaka, 1959). The occurrence of *Pseudoliva japonica* as previousely known under the name of *Orthaulax japonicus* and *Vicarya yabei* indicate the formation to be Eocene in age. *Ampullinopsis hahazimensis* recorded from the formation by MacNeil (1964) is a species originally recorded from the Eocene formation in Hahajima Island (Bonin Islands) in association with a larger foraminifer *Nummulites boninensis*. The other species are of all duplicated with the species from the Miyaragawa Formation recorded by MacNeil (1964) except for only one species of *Euspira*. Previousely, the fauna associated with *Orthaulax japonicus*, was an markable fauna of Eocene in the northern part of Kyushu (Nagao, 1928) as like the species of *Vicarya yabei* and *Colpospira* (*Acutospira*) *kotakai*.

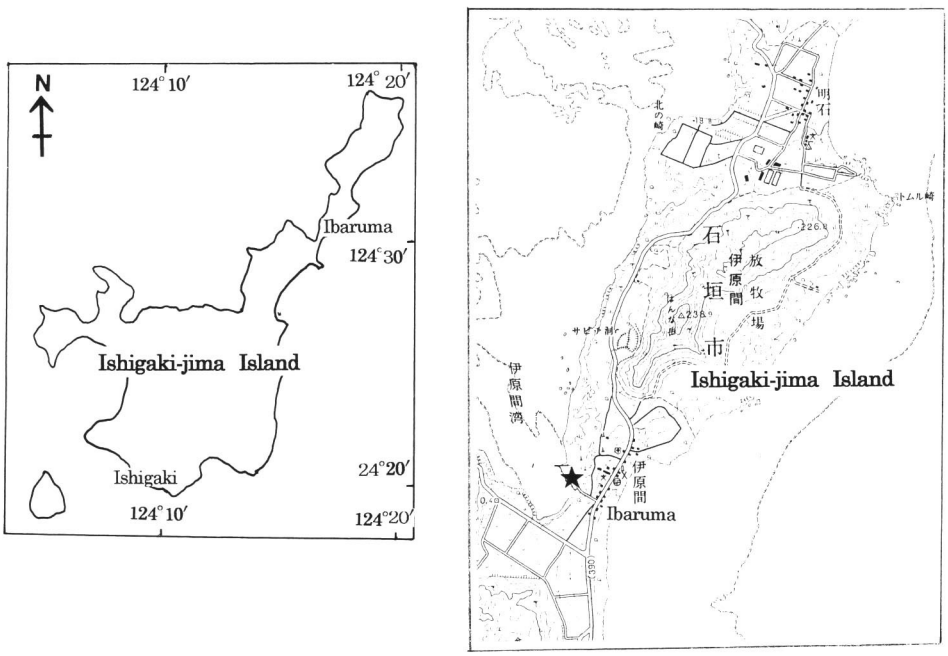


Fig. 1. Locality map of Eocene nautilids in Ishigaki-jima Island, the Ryukyus.

Table 1. Molluscan fossils from the Miyaragawa Formation at Sea coast of Ibaruma.

Pelecypoda	
Ostrea sp.	(rare)
Lima sp.	(rare)
Venerid gen. et sp. indet.	(rare)
Gastropoda	
Lunella miyarensis MacNeil	(rare)
Euspira sp.	(few)
Pseudoliva japonica (Nagao)	(few)
Terebra miyarensis MacNeil	(few)
Scaphander sp.	(few)
Caricella fosteri MacNeil	(rare)
Buccinid gen. et sp. indet.	(rare)
Vicarya yabei Kamada	(rare)
Colpospira (*Acutospira*) *kotakai* (MacNeil)	(dominant)

(rare=1–3 specimens, few=4–10 specimens, dominant=more than 10 specimens)

Systematic Description

Family Nautilidae d'Orbigny, 1840

Subfamily Nautilinae d'Orbigny, 1840

Genus *Eutrephoceras* Hyatt, 1894

Eutrephoceras japonicus (Shimizu, 1926)

Fig. 2; 1a–b

1926, *Nautilus* (s.s.) *japonicus* Shimizu, p. 26–27, pl. 8, figs. 1–6.

1959a, *Eutrephoceras japonicum* (Shimizu, 1926), Kobayashi and Kamada, p. 105–114, pl. 9, figs. 1a–2b, text-figs. 2 (Holotype), 3.

1959b, *Eutrephoceras japonicum* (Shimizu, 1926), Kobayashi and Kamada, p. 115–124, pl. 10, figs. 1a–2, text-figs. 2a–c.

1960, *Eutrephoceras japonicum* (Shimizu, 1926), Oyama *et al.*, p. 216, pl. 67, figs. 1a–c.

1971, *Nautilus* (s.s.) *japonicus* Shimizu, Tan, p. 44–46, pl. 8, figs. 1 (Holotype) –2.

Remarks; The present species was originally described from the Ashiya Formation in Fukuoka Prefecture by Shimizu (1926). After the description of the species (Shimizu, 1926), the depositional situation was discussed in detail by Kobayashi and Inoue (1961), and Kobayashi and Kamada (1959a, b). The present species is defined by large and swollen shell with shallow and gently curved suture lines, and 14 septal shell. Body chamber is wide and nearly half in shell size. Umbilicus is rather large and deeply sunk. Dorsal side is smooth and swollen. The specimen collected at hand is 168 mm in shell height, 122 mm in shell width and ca. 61 mm in shell thickness (slightly missing at cutting the specimen).

The Formosan specimen previousely reported by Hayasaka (1936) under the name of *Nautilus* sp. from the Kokuseisho Formation (correlated with the Shukkoko Formation) is quite similar with *Eutrephoceras japonicus* but remained unnamed because of preservation and detail of the shell are unknown. But Tan (1971) reported the species from the Eocene Dotitan Shale. According to Nishida and Aoki (1984), the co-occurrence of *Eutrephoceras japonicus* and *Aturia yokoyamai* is quite variable to correlate the formatuon to Eocene in age. Then the distribution of both species had been confirmed the distribution from northern Kyushu to Formosa via Ryukyu. Kobayashi and Kamada (1959 b) mentioned that those cephalopod species at the Eocene time might have been flourished in the area discovered as supported by Tanabe and Chiba (1983). The original or their home region should be traced toward

Fig. 2. *Eutrephoceras japonicus* (Shimizu) ×0.8.
1a. External surface showing suture lines. 1b. inner septal shells on the profile. Locality; Sea coast about 0.5 km west of Ibaruma, Ishigaki City, Okinawa Prefectute, Eocene Miyaragawa Formation, NSM PM 14828.

1b

1a

south, through SE Asia to Mediterranean district.

The Cretaceous *Eutrephoceras* described from Hokkaido (Matsumoto, 1967) is distinguished from the Eocene species in having more swollen shell with crowded septa and sinuous smooth suture lines.

Family Aturidae Hyatt, 1894

Genus *Aturia* Bronn, 1838

Aturia yokoyamai Nagao, 1926

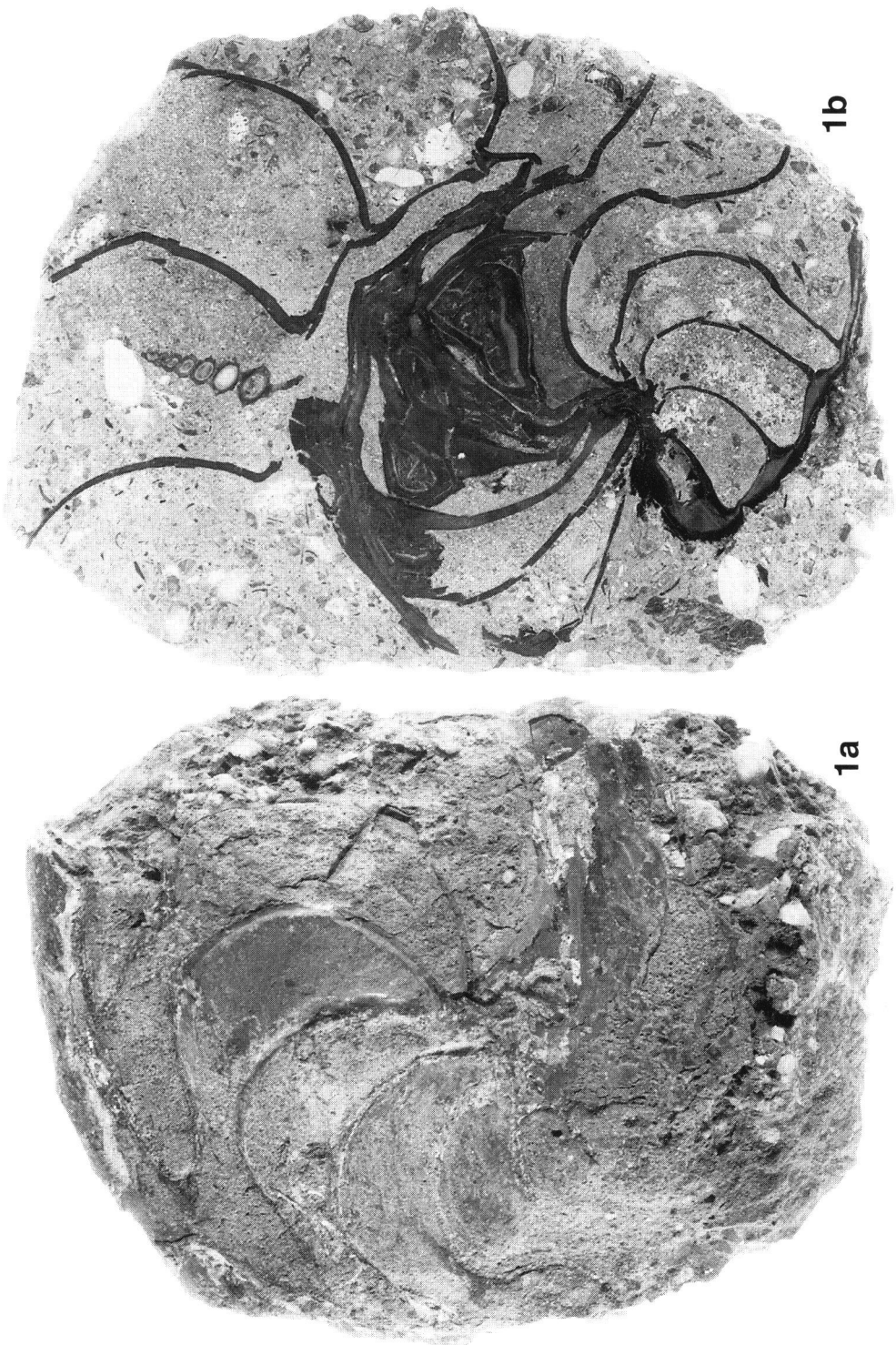
Fig. 3; 1a–b, Fig. 4; 1

1911, *Aturia zigzag* Yokoyama, p. 11, pl. 3, figs. 1a–b, 8a–b.
1926, *Aturia yokoyamai* Nagao, p. 29–32, pls. 9–11.
1957, *Aturia yokoyamai* Nagao, Kobayashi, p. 75–78, pl. 13 and text-figs. 1–2. (reproduced from Nagao, 1926)
1960, *Aturia nagaoi* Kobayashi, Oyama *et al.*, p. 217–218, pl. 68, figs. 1a–b. (reproduction of *Aturia ziczac* of Yokoyama, 1911)
1960, *Aturia yokoyamai* Nagao, Oyama *et al.*, p. 218–219, pl. 69, figs. 2a–b, pl. 70, figs. 1a–b.
1961, *Aturia yokoyamai* Nagao, Kobayashi and Inoue, p. 421–433, pl. 11, figs. 1–2.
1983, *Aturia yokoyamai* Nagao, Tanabe and Chiba, p. 252–253, pl. 2, fig. 2.
1984, *Aturia yokoyamai* Nagao, Nishida and Aoki, p. 69–85, pl. 1, figs. 1–3, pl. 2, figs. 1a–1b, pl. 3, figs. 1a–1c, pl. 4, figs. 1–3, pl. 5, figs. 1–2.
?1992, *Aturia nagaoi* Kobayashi, Tomita *et al.*, pl. 15, fig. 4.
?1993, *Aturia* sp., Schmidt and Jung, p. 349–351, fig. 4–4.

Remarks; The shell is large and discoid in form but not so swollen. The largest shell at hand is measured as 135 mm in shell height, 97.8 mm in shell width and ca. 45 mm in shell thickness. Thin 10 septal sutures through the medial cut (Fig. 3; 1a–1b) are counted. The most part of body chamber was missing. The suture line is typical aturiid in form as having wide and flat ventral saddle with narrow umbilical seam sinuous and broad lateral lobe being slightly lower than ventral saddle. Body chamber is broad and wide.

The present species had described first from Asakura and Meinohama both in Fukuoka Prefecture by Nagao (1926). Additionally the present species was reported from the Late Eocene Okinoshima Formation in Nagasaki Prefecture (Kobayashi and Kamada, 1959a, b; Tanabe and Chiba, 1983), Itsuki Formation and Sari Sandstone

Fig. 3. *Aturia yokoyamai* Nagao, ×1.
1a. External surface showing smooth suture lines. 1b. inner septal shells on the profile. Locality; Sea coast about 0.5 km west of Ibaruma, Ishigaki City, Okinawa Prefecture, Eocene Miyaragawa Formation, NSM PM 14829.


1b
1a

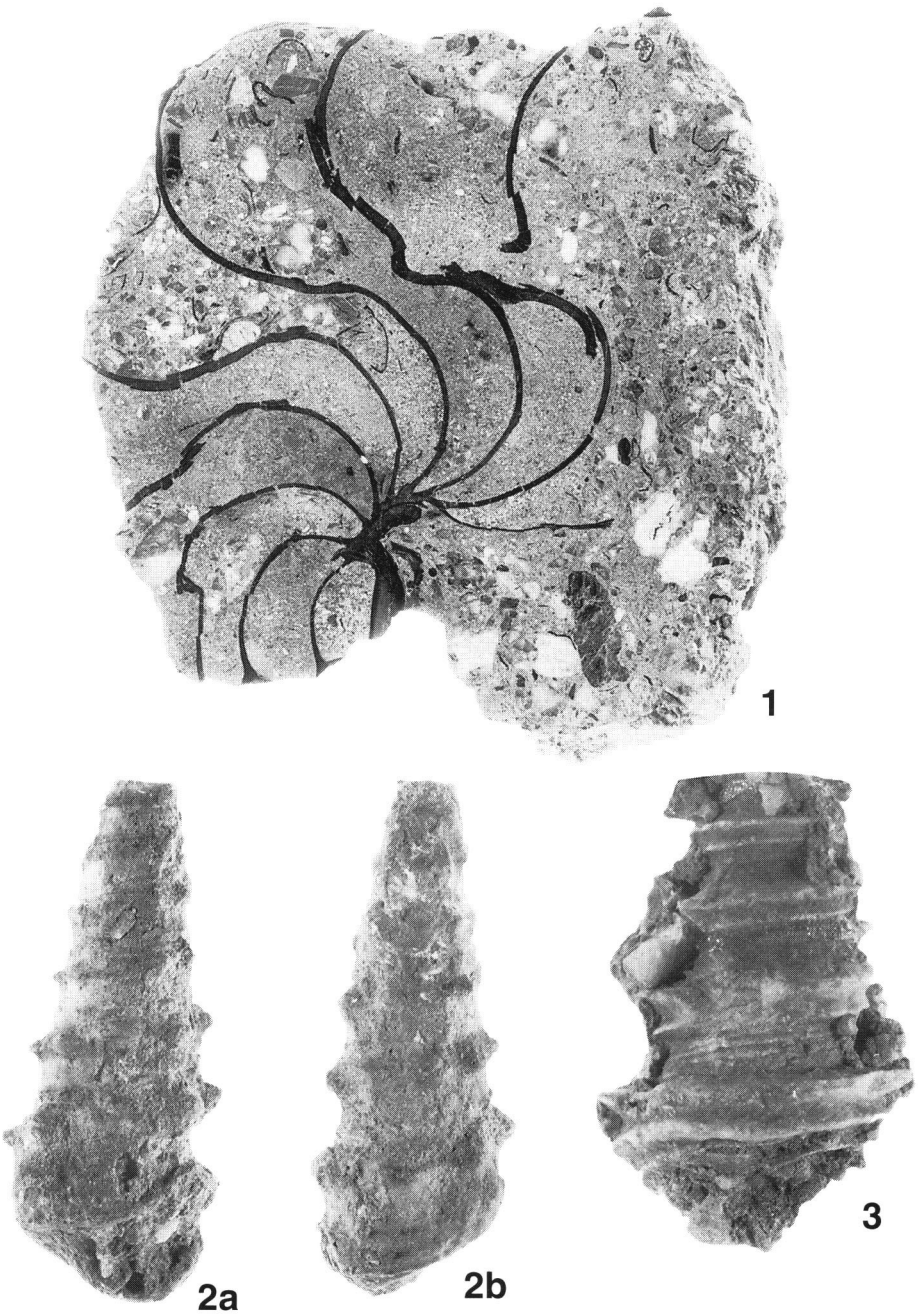


Fig. 4. 1. *Aturia yokoyamai* Nagao, ×0.8.
Locality; Sea coast about 0.5 km west of Ibaruma, Ishigaki City, Okinawa Prefecture, Eocene Miyaragawa Formation, NSM PM 14830. 2a–2b, *Vicarya yabei* Kamada, ×1.5. Loc. same with above. NSM PM 14831. 3. *Colpospira* (*Acutospira*) *kotakai* MacNeil, ×2, Loc. same with above. NSM PM 14832.

(Kobayashi and Inoue, 1961; Nishida and Aoki, 1984) in Saga Prefecture. Okinoshima Island of Nagasaki Prefecture is a quite well known fossil locality of Paleogene nautilids and aturids as already mentioned by Kobayashi and Kamada (1959a, b) and Nishida and Aoki (1984). From and around the type locality of the species, many specimens of cephalopods were recorded by Tanabe and Chiba (1983), and Nishida and Aoki (1984). *Aturia nagaoi* (pl. 15, fig. 4) illustrated from the Kattachi Formation in Omuta, Fukuoka by Tomita *et al.* (1992) is probably same with the present species by having similar suture lines. But the other species illustrated by Tomita *et al.* from the same formation under the name of *A. matsushitai* is distinguished from the present species by its slender shell but suture lines are quite similar with the present species. The occurrence of present species in association to occur with *Eutrephoceras japonicus* is significant to expand the geographical distribution of the species, because the co-occurrence in association is limited in Eocene. The present species from the Miyaragawa Formation is of moderate in size, but the largest specimen as 70 cm had recorded by Nishida and Aoki (1984). The large or gigantic specimens of *Aturia* are often recorded from Eocene to Oligocene as introduced by Kobayashi and Inoue (1961).

Taphonomical Discussion of Eocene Nautilids

Total 4 specimens of nautilid were collected from sea shore at Ibaruma, Ishigaki-jima Island (Fig. 1) in association with several species of gastropods and pelecypods as shown in Table 1. At a glance of the occurrence of those molluscan species, the specimens carrying distinct spines as *Vicarya yabei* (Fig. 4; 2a–b) and distinct spiral ribs as mono-carinate form (Fig. 5; 1–5) and bi-carinate form (Fig. 4; 3, Fig. 5; 6–8) of *Colpospira* (*Acutospira*) *kotakai* are well preserved. But the specimens having smooth and round shell as *Lunella miyarensis*, *Psudoliva japonica*, and *Caricella fosteri* become more rounded in shape by erosion. Other cylindrically elongated species as *Terebra miyarensis* and *Scaphander* sp. are more smashed to be cylindrically rounded. The pelecypod specimens, as *Ostrea* sp., *Lima* sp. and venerid are well water worn to be difficult for identification into the species level.

The cooccurrence of mixed elements of blackish muddy bottom dweller as *Vicarya*, shallow sandy bottom dwellers as *Lunella*, *Pseudoliva*, *Terebra*, *Scaphander*, *Caricella*, and slightly off shore dweller as *Colpospira*, and both species of nautilids with missing apertural parts probably tell us; 1) their original living place is probably more south (subtropical to tropical sea) as *Eutrephoceras japonicus* was reported from Taiwan by Tan (1971). 2) co-occurrence with typical blackish species as *Vicarya* and shallow marine benthic molluscs living on and in muddy bottom indicate allochothonous occurrence. 3) specimens collected at hand (Fig. 2; 1b, Fig. 3; 1b, Fig. 4; 1) show some 3 or 4 different phase to be buried inside of specimens. 4) internal thin septa are well preserved but inner part of shell is completely filled by matrix-free

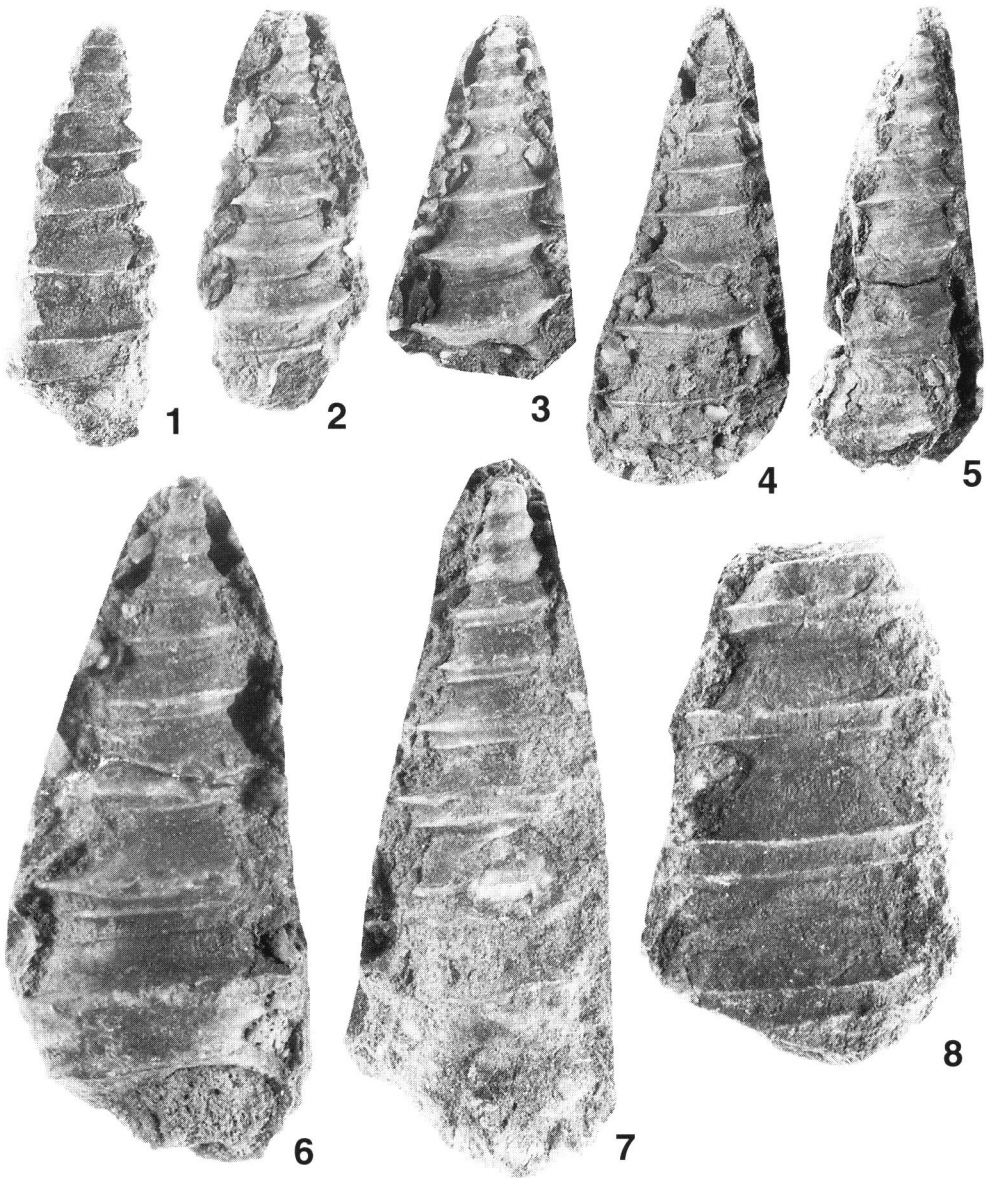


Fig. 5. 1–5, *Colpospira* (*Acutospira*) *kotakai* MacNeil, ×1.
Locality; Sea coast about 0.5 km west of Ibaruma, Ishigaki City, Okinawa Prefecture, Eocene Miyaragawa Formation, NSM PM 14833.
6–8. *Colpospira* (*Acutospira*) *kotakai* MacNeil, ×2.
Locality; Sea coast about 0.5 km west of Ibaruma, Ishigaki City, Okinawa Prefecture, Eocene Miyaragawa Formation, NSM PM 14834.

coarse grained sandstone or pebbly sandstone which is probably due to the rapid breaking of the main part of shell.

According to these observation, the shells collected herein are explained at least as following; After the specimens dead in more southern home sea, the empty shells are drifted toward the blackish to shallow marine coast of the present Ishigaki-jima Island as post-mortal transportation as like discussed by Kobayashi and Inoue (1961) and Kobayashi and Kamada (1959a, b). Then, at coarse grained sandy sea bottom, nautilid shells get fractures to allow sediments insided rapidly. One specimen of *Turritella* was caught in inside of *Aturia yokoyamai* in good shape (Fig. 3; 1b) show the sedimentation as squeezed rapidly from shallow bottom at sea shore. Most of molluscan specimens are well water worn probably due to repeated transportation at near coarse sandy sea bottom. The inner side of the sea coast, mangrove-swamp is expected to be developed by occurrence of *Vicarya*.

This occurrence of two nautilids from the Ryukyus was happen realized as predict by Kobayashsi and Inoue (1961), who had expected the nautiloid species from the Karatsu Coal-field lived around the Ryukyu islands and had been driven into the Paleo-Shiranui Bay (Kyushu) by monsoon or typhoon. More data of occurrence of the nautilid species from more southern territory should be necessary.

Acknowledgements

We are deeply indebted to Dr. Koichiro Masuda, Professor Emeritus of Miyagi University of Education for his many suggestions about the molluscan fauna of the Miyaragawa Formation. We appreciate deeply to Dr. Yasuji Saito of National Science Museum for his kind suggestions and making a chance to publish the present paper. We are also due to Mr. Makoto Miyamoto of Institute of Geoscience, University of Tsukuba for making the cut and polished specimens discussed herein.

The specimens photographed herein are all preserved at National Science Museum, Tokyo with the catalogued number of the abbreviation of NSM PM.

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