

Pliocene Heteropods (Mollusca: Gastropoda) from Miyagi-shima, Okinawa, Japan

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沖縄県宮城島産の鮮新世異足類 (軟体動物: 腹足類)

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(Abstract)

Nine species of heteropods are described from Pliocene strata of the Shinzato Formation of the Shimajiri Group at Miyagi-shima in Okinawa Prefecture. They are *Oxygyrus* sp., *Protatlanta kakegawaensis* Shibata, *Atlanta helicinooides* Souleyet, *A. peroni* Lesueur, *A. plana* Richter, *A. tokiokai* van der Spoel and Troost, *A. sp. 1*, *A. sp. 2* and *Carinaria* sp. All these species are reported from this group for the first time. Three living species, *A. helicinooides*, *A. plana* and *A. tokiokai* from this site constitute their oldest occurrence record.

Introduction

In 1990, 1993 and 1996 we made the survey of pelagic mollusks in the Plio-Pleistocene Shimajiri Group in Okinawa. No or a few specimens of heteropods, holoplanktonic gastropoda, were obtained at most localities sampled. An exposure of the Shinzato Formation of this group at Miyagi-shima, however, exceptionally yielded a large number of heteropod specimens. The heteropod collection from this exposure consists of one species of the genus *Oxygyrus*, one species of the genus *Protatlanta*, six species of the genus *Atlanta* and one species of the genus *Carinaria*. The occurrence of these species from the Shinzato Formation adds on new data for the restoration of the Pliocene heteropod fauna of Japan. This paper describes and illustrates the nine species of heteropods from Miyagi-shima. The only report on heteropods from the Shimajiri Group is description of a new species of *Atlanta* by Noda (1972)

from the Shinzato Formation at the locality near our collection site. We follow Seapy (1990) and Richter and Seapy (1999) for the taxonomic classification of heteropoda. All specimens described herein are housed in Graduate School of Environmental Studies, Nagoya University.

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Locality and geologic setting

The stratigraphy and age of the Shimajiri Group can be found in MacNeil (1960), Natori and Kageyama (1987), Ujiié (1988) and Hanagata (2004). The second publication gives a detailed geologic map of the distribution area of the Shimajiri Group, and so we follow it concerning the stratigraphic subdivision of this group. The collection site of heteropods is the cutting about 1 km east of Yonashirotobaru at Miyagi-shima, Okinawa Prefecture (Fig. 1). This cutting was

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キーワード : 異足類, 巻貝, 鮮新世, 分類, 新里層, 沖縄県.

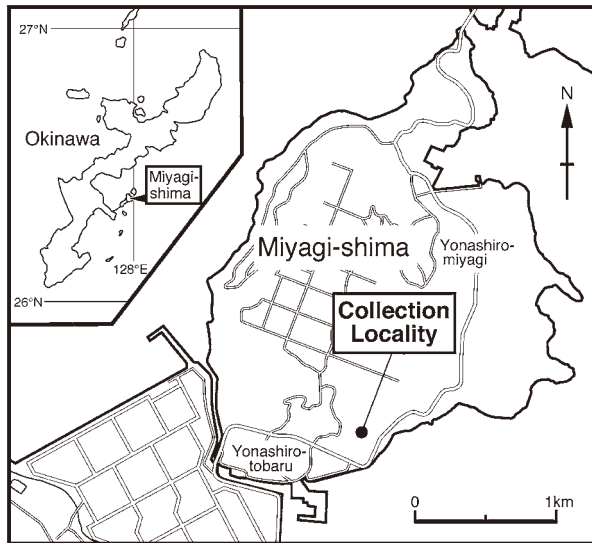


Fig. 1. Map showing the collection site of heteropods at Miyagi-shima, Okinawa.

made as a result of developing a farmland on its south more than twenty years ago, and it has been largely covered with grasses now. There outcrop mudstones of the Shinzato Formation with an thin intercalation of tuff and those of sandstone in the cutting. Heteropods were collected from the interbedded sandstones of 0.5 to 1m thick (Fig. 2) in which benthic mollusks and holoplanktonic gastropoda, pteropods, occur clustered.

Natori and Kageyama (1987), Ujiié(1988)and Hanagata (2004) referred the Shinzato Formation in age to the N21 to N22 of the planktonic foraminiferal biochronological zones on the basis of planktonic foraminifera. The collection site is in the distribution area of strata of the N22 in the geologic map by Ujiié (1988), whereas Hanagata (2004) assigned strata of this site to the N21. This paper follows the age assignment by Hanagata (2004) as the age of the strata at the collection locality.

Systematic paleontology

Literature on Recent occurrences are excluded from the synonymy for each species.

Superfamily Heteropoda d'Orbigny, 1836
 Family Atlantidae Rang, 1829
 Genus *Oxygyrus* Benson, 1835

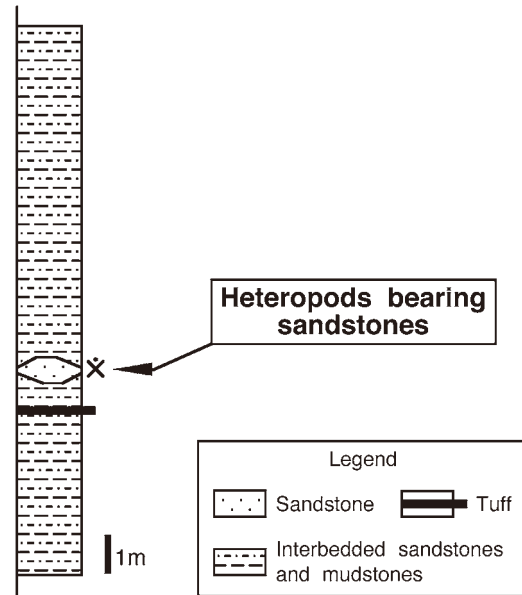


Fig. 2. Columnar section of the Shinzato Formation at the collection site of heteropods at Miyagi-shima, Okinawa.

Oxygyrus sp. (Figs. 3-1-2)

Material: Four specimens. One specimen has the adult shell, but the others lack it.

Description: Shell of moderate size, involute, deeply umbilicated in both the upper and the lower side. The last whorl large, well inflated, extending from larval shell with a sharp boundary. Aperture expanded both in the upper and the lower part of it, lunular, about 0.6 of the shell width in height. Younger whorls ornamented with fine zigzag spiral lines. The last whorl sculptured with densely arranged axial folds and fine spiral striations. Axial folds most developed in the initial part of the last whorl. In addition to these sculptures, the last whorl having a faint spiral band on its periphery, incremental lines being sinuate on this band. Dimensions; KC20301, height 2.0 mm, diameter 3.2 mm.

Discussion: The specimens at hand agree with *O. keraudreni* (Lesueur) in many respects, but they differ from this species in having strong axial folds and fairly distinct spiral striations on the last whorl. In addition, the proportion of the shell height to the shell width is a little smaller in the former than in the latter. They seem to represent a new species, but an examination of additional well-preserved specimens

is needed to establish it.

Genus *Protatlanta* Tesch, 1908

Protatlanta kakegawaensis Shibata, 1984
(Figs. 3-3-4)

Protatlanta kakegawaensis Shibata, 1984, p. 75, pl. 23, figs. 1-3.

Material: 98 specimens. Most of the specimens are imperfect.

Description: Shell of moderate size, the largest specimen reaching a diameter of 5.5 mm, consisting of about 5 whorls. Spire very small, low, convex conical. Spire whorl size very slowly increasing in the first three whorls. Sutures of the first to third whorls shallow, linear. Spire strongly inclined with respect to the axis of the last whorl, the third and fourth whorls being partly hidden by the last whorl. The apex of spire a little below the upper plane of the last whorl in apertural view. The last whorl large, about four times as large as spire in diameter, well inflated. The second and third whorls ornamented with two spiral lines, which are close to the upper and lower sutures, respectively. The fourth whorl with three fine zigzag spiral lines. The last whorl with numerous microscopic spiral striations. In addition to these striations, the last whorl bearing a flattened spiral band in its periphery. Umbilicus deep, narrow. Two or three fine zigzag spiral lines visible on the underside of the fourth whorl in umbilical view.

Dimensions (in mm) -.

	Height	Diameter
KC20305	1.4	3.5
KC20306	1.5	3.0
KC20307	2.2	5.1

Discussion: This species resembles *P. rotundata* (Gabb) described from the Miocene of Santo Domingo. Janssen (1999) redescribed and illustrated the holotype of *P. rotundata* and discussed its synonyms. Janssen (2004) referred *P. kakegawaensis* to a synonym of *P. rotundata*.

Compared with the holotype of *P. rotundata*

illustrated by Janssen (1999), *P. kakegawaensis* has a large shell and has a more number of whorls. In addition to these differences between the two species, the spire more strongly tilts in *P. kakegawaensis* than in *P. rotundata*. Thus, we regard the two as different species.

Genus *Atlanta* Lesueur, 1817

Atlanta helicinoides Souleyet, 1852
(Figs. 4-1-2)

Atlanta helicinoides Souleyet, 1852, p. 384, pl. 20, figs. 23-30; Shibata and Ujihara, 1983, p. 156, pl. 47, fig. 3; Grecchi and Bertolotti, 1988, p. 121, pl. 2, fig. 4; Janssen, 2007, p.146, pl. 3, figs. 4-6, pl. 4, figs. 1-5.

Material: Five specimens.

Description: Shell small, with 4.5 whorls. Spire small, convex conical, elevated. Sutures of spire whorls slightly canaliculate. The apex of spire projecting beyond the upper plane of the last whorl in apertural view. The second and third whorls shouldered at a little above their middle. The first 1.5 whorls smooth, remaining spire whorls and the initial 1/4 of the last whorl decorated with fine crimped spiral lines; crimped spiral lines four on the third whorl and more on the initial part of the last whorl. The shell base moderately inflated, with deep umbilicus. Fine spiral lines visible on the shell base. Keel low, not inserted between the two last whorls.

Dimensions (in mm) -.

	Height	Diameter
KC20316	0.5	1.4
KC20317	0.5	1.3

Discussion: *A. helicinoides* and *A. inflata* Souleyet both belonging to the *A. inflata* species group (Richter and Seapy, 1999) closely resemble each other, but the last whorl is more inflated in the former than in the latter, and the former has deeper sutures of spiral whorls. *A. helicinoides* is also similar to *A. fusca* Souleyet, but it has a more depressed spire, and the width of spire whorls increases more regularly in *A. helicinoides* than in *A. fusca*.

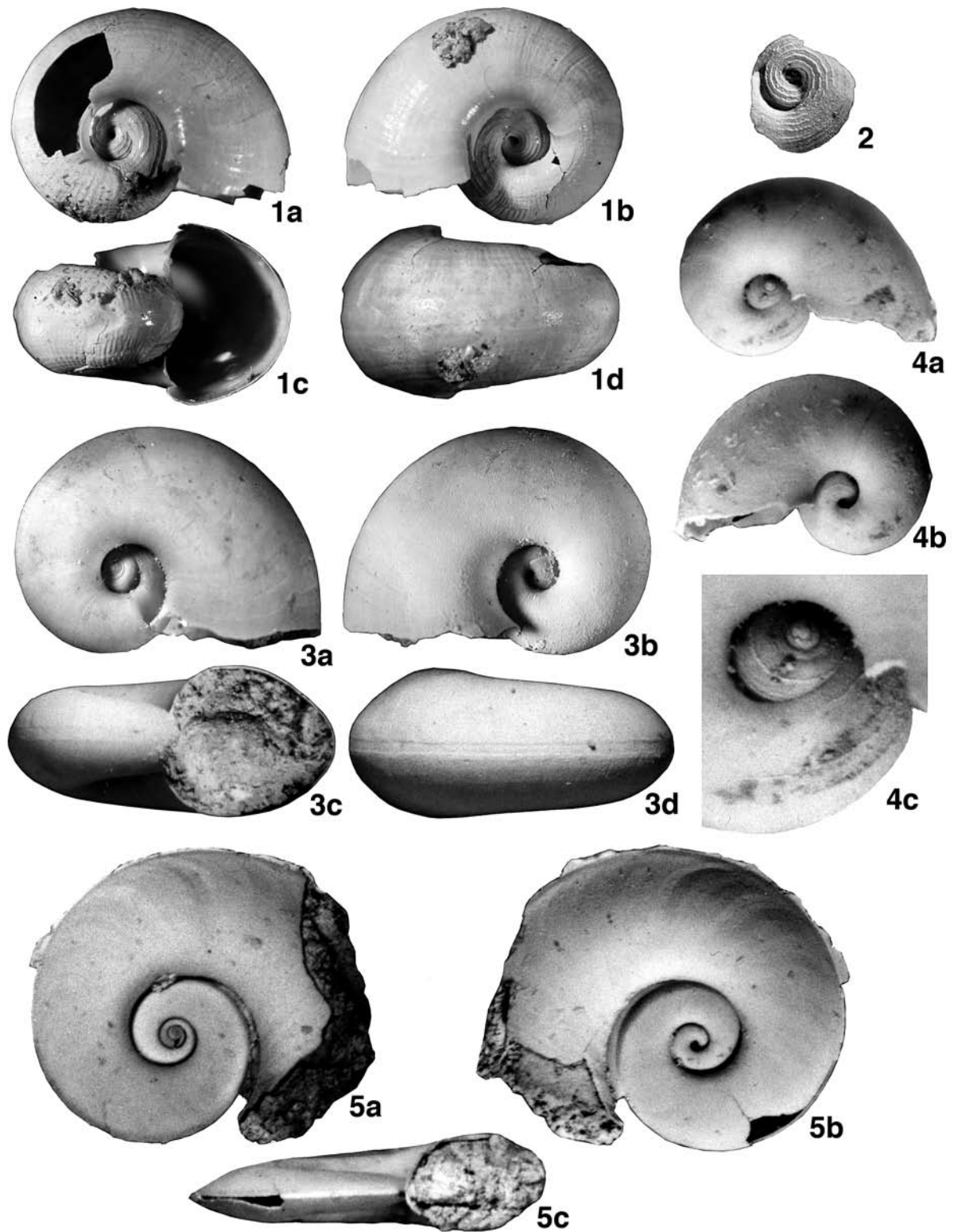


Fig. 3. Heteropods from the Shinzato Formation at Miyagi-shima, Okinawa.
 1-2. *Oxygyrus* sp. 1a, apical, 1b, umbilical, 1c, apertural, 1d, posterior view, $\times 15$, KC20301; 2, apical view, $\times 15$, KC20302.
 3-4. *Protatlanta kakegawaensis* Shibata. 3a, apical, 3b, umbilical, 3c, apertural, 3d, posterior view, $\times 15$, KC20305;
 4a, apical, 4b, umbilical view, $\times 15$, 4c, spire whorls of same specimen, enlarged, $\times 40$, KC20306.
 5. *Atlanta peroni* Lesueur. a, apical, b, umbilical, c, apertural view, $\times 12$, KC20320.

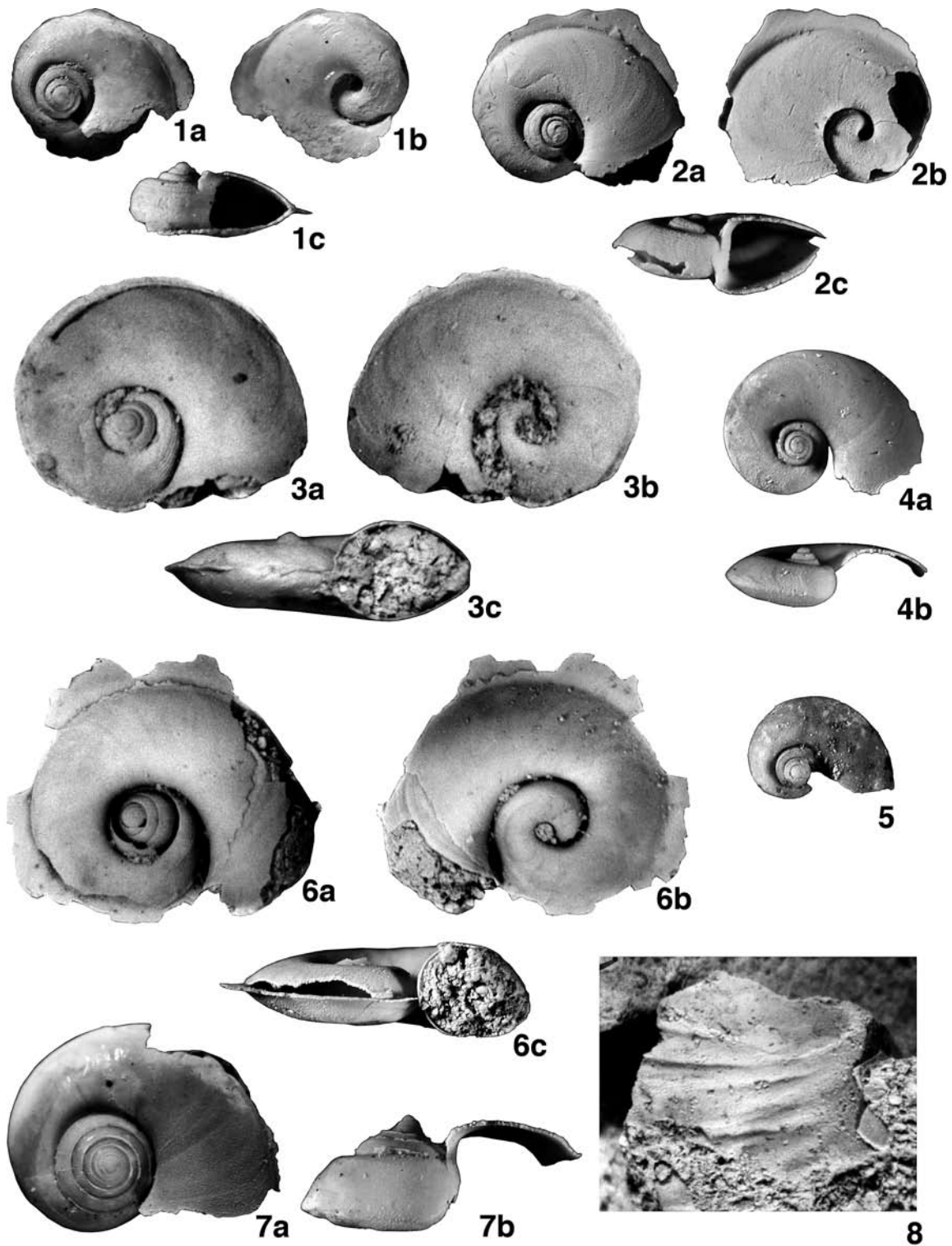


Fig. 4. Heteropods from the Shinzato Formation at Miyagi-shima, Okinawa (continued).

- 1-2. *Atlanta helicinoides* Souleyet. 1a, apical, 1b, umbilical, 1c, apertural view, $\times 24$, KC20317; 2a, apical, 2b, umbilical, 2c, apertural view, $\times 24$, KC20316. 3. *Atlanta* sp. 1. a, apical, b, umbilical, c, apertural view, $\times 24$, KC20342. 4-5. *Atlanta plana* Richter. 4a, apical, 4b, apertural view, $\times 24$, KC20335; 5, apical view, $\times 24$, KC20336. 6. *Atlanta tokiokai* van der Spoel and Troost. a, apical, b, umbilical, c, apertural view, $\times 18$, KC20337. 7. *Atlanta* sp. 2. a, apical, b, apertural view, $\times 24$, KC20344. 8. *Carinaria* sp. lateral view, $\times 12$, KC20346.

Atlanta peroni Lesueur, 1817
(Fig. 3-5)

Atlanta peroni Lesueur, 1817, p. 390, pl. 2, figs. 1, 2;
Shibata and Ujihara, 1983, p. 154, pl. 46, fig. 2;
Grecchi, 1984, p. 19, pl. 1, fig. 19, pl. 2, figs. 1,
2; Shibata, 1984, p. 76, pl. 23, fig. 4; Grecchi and
Bertolotti, 1988, p. 120, pl. 2, fig. 3.

Atlanta peronii Lesueur. Buccheri, 1978, p. 124, pl. 1, fig. 1.
non *Atlanta peroni* Lesueur. Shibata, Ujihara and Ichihara, 2006,
p. 17, figs. 3-5, 3-6.

Material: 158 specimens.

Description: Shell large for the genus, the largest specimen attaining a diameter of 5.5 mm. Whorls 5, separated by moderately deep sutures. Spire low, not visible in apertural view. The last whorl large, depressed. The underside of the last whorl flattened. Aperture large, with a slit in outer lip. Keel tall, penetrated between the last two whorls. Shell surface smooth. Umbilicus narrow.

Dimensions (in mm) -

	Height	Diameter
KC20320	1.4	5.0
KC20321	-	5.0
KC20322	1.0	4.4
KC20330	1.0	4.1

Discussion: *A. peroni* is the most abundant species in the heteropoda collection from Miyagi-shima. *A. peroni* most resembles *A. fragilis* Richter, but it has a thicker test than *A. fragilis*. This species is also similar to *A. gaudichaudi* Souleyet, but it differs from *A. gaudichaudi* in its depressed protoconchs, and the size of spire whorls more regularly increases in the former than in the latter. The two specimens from the Pleistocene Atsumi Group illustrated by Shibata and others (2006, figs. 3-5 and 3-6) under the name of *A. peroni* are not this species. The revised specific names of the specimens in figs. 3-5 and 3-6 are *A. sp.* and *A. gaudichaudi*, respectively.

Atlanta plana Richter, 1972
(Figs. 4-4-5)

Atlanta plana Richter, 1972, p. 90, figs. 4, 6, 8; Janssen,
2007, p. 148, pl. 7, fig. 4, pl. 8, figs. 1-4, pl. 9, fig. 1.

Material: Two specimens.

Description: The basal part of the shell is destroyed in both specimens at hand. Shell width of the larger specimen 1.3 mm, consisting of about 4 whorls. Spire small, conical, fairly elevated, slightly tilted with respect to the axis of the last whorl. Sutures of spire whorls moderately deep. The apex of spire projecting beyond the upper plane of the last whorl in apertural view. The last whorl large, moderately inflated. The second to third whorls ornamented with two fine crimped spiral lines. Surface of the last whorl smooth. Keel around the last whorl missing, not penetrated between the last two whorls. Dimensions; KC20335, diameter 1.3 mm, KC20336, diameter 1.0 mm.

Discussion: The specimens from Miyagi-shima have stronger spiral lines on spire whorls than the specimen of *A. plana* illustrated by Seapy (1990), and the spire is a little higher in the former than in the latter. They are identified with *A. plana* with some doubt. This species is similar to *A. echinogyra* Richter, but the spiral sculpture is weaker in it than in *A. echinogyra*. It differs from *A. helicinoides* in its slender spire.

Atlanta tokiokai van der Spoel and Troost, 1972
(Fig. 4-6)

Atlanta tokiokai van der Spoel and Troost, 1972, p. 2, figs.
1-3.

Atlanta inclinata Souleyet. Shibata and Ujihara, 1983, p.
155, pl. 47, fig. 1 (non *Atlanta inclinata* Souleyet,
1852).

Material: 12 specimens.

Description: Shell of moderate size, 3.0 mm in diameter, consisting of about 5.5 whorls. Spire low, slightly convex conical, inclined dorsally. The apex of spire visible in apertural view. Spire whorls slightly inflated, separated by shallow linear sutures. The last whorl large, well inflated. Keel tall, penetrated between the two last whorls. Shell surface smooth. Worn surface of the third and fourth whorls having the internal wall structure consisting of numerous microscopic radially-arranged lines. Umbilicus narrow.

Dimensions (in mm) -.

	Height	Diameter
KC20337	0.9	2.8
KC20340	0.8	2.8
KC20341	0.8	3.0

Discussion: The shell surface of *A. tokiokai* is ornamented with spirally-arranged rows of minute tubercles (Seapy, 1990, Seapy and others, 2003), but no such tubercles are observed on the surface of specimens at hand. Their absence on these specimens seems to be due to wearing the shell surface after death. *A. tokiokai* belongs to the *A. inclinata* species group (Richter and Seapy, 1999), and it closely resembles *A. inclinata* Souleyet, another species in this group, but it has a larger shell and a larger apical angle. *A. tokiokai* also resembles *A. meteori* Richter in shape, but it differs from *A. meteori* in having the internal wall structure bearing microscopic radially-arranged lines. The Pleistocene specimens reported under the name of *A. inclinata* by Shibata and Ujihara (1983) have a depressed spire, and they are identified with this species.

Atlanta sp. 1
(Fig. 4-3)

Material: Two specimens.

Description: Shell small, 2 mm in diameter, with 4.5 whorls. Spire small, conical, elevated. The apex of spire visible in apertural view. Spire whorls rather regularly increasing in width, separated by moderately deep sutures. The last whorl large, moderately depressed. Spire whorls with very fine, slightly crimped spiral lines, which number eight on the third whorl. The last whorl smooth. Keel tall, not penetrated between the second last and last whorls. Two spiral lines visible on the underside of the second last whorl in umbilical view. Dimensions; KC20342, height 0.7 mm, diameter 2.0 mm.

Discussion: *A. sp. 1* is represented by one nearly perfect specimen and one imperfect one. This species most resembles *A. inflata*, but it differs from *A. inflata* in its more depressed last whorl and the absence of spiral lines on the initial part of the last whorl. *A.*

sp. 1 is distinguished from *A. plana* by its stronger spiral lines. It is not identified with any previously described species, and seems to be very likely a new species.

Atlanta sp. 2
(Fig. 4-7)

Material: One specimen.

Description: The basal part of the shell is missing in the specimen. Shell small, 1.9 mm in diameter, consisting of 5.5 whorls. Spire convex conical, elevated, faintly inclined with respect to the last whorl axis. The first whorl swollen. The apical part of spire visible in apertural view. The last whorl large, inflated. Width of the last whorl about 3 times of that of spire. Sutures of spire whorls deep, slightly imbricate. Surface of spiral whorls smooth, without spiral arrays of microscopic tubercles. Spiral whorl walls appear to have the same internal radial line structure as that of *A. tokiokai*. The initial part of the last whorl with a fine spiral line on its shoulder. Keel destroyed, not inserted between the last two whorls.

Discussion: This species closely resembles *A. tokiokai* and *A. inclinata*, but it has a less tilted spire. The width of the spire is larger in it than in *A. inclinata*. The presence of the internal radial line structure in whorl walls seems to indicate that *A. sp. 2* is grouped into the *A. inclinata* species group (Richter and Seapy, 1999). Additional specimens are needed for further identification of this species.

Family Carinariidae de Blainville, 1818
Genus *Carinaria* Lamarck, 1801

Carinaria sp.
(Fig. 4-8)

Material: Two specimens.

Description: This species is represented by two fragments of the anterior part of the adult shell. Shell small, conical, slightly bent, depressed laterally. Aperture ovate. The surface ornamented with transverse folds. The width of the aperture about 3.7 mm.

Discussion: The specimens are too poor to determine their specific name.

References

- Benson, W. H., 1835. Account of *Oxygyrus*, a new genus of pelagian shells allied to the genus *Atlanta* of Lesueur, with a note on some other pelagian shells lately taken on board the ship Malcolm. *Jour. Asiatic Soc. Bengal*, 4: 173-176.
- Blainville, M. H. de, 1818. Dictionnaire des Sciences naturelles, 12: Paris and Strasbourg, 564p.
- Buccheri, G., 1978. Pteropoda Euthecosomata ed Heteropoda (Mollusca, Gastropoda) in sedimenti batiali pleistocenici della East Yukatan Scarp (Mar dei Caraibi). *Boll. Soc. Paleontol. Ital.*, 17: 118-141.
- Grecchi, G., 1984. Molluschi planctonici e bentonici in sedimenti sapropelatici del Quaternario della Dorsale Mediterranea. *Boll. Malacol.*, 20: 1-34.
- Grecchi, G. and Bertolotti, M., 1988. Interpretazione paleoclimatica della carota CG18-BAN82 basata sull'analisi di Thecosomata Euthecosomata del Quaternario del Mediterraneo Orientale. *Boll. Mus. Reg. Sci. Nat. Torino*, 6: 73-132.
- Hanagata, S., 2004. Pliocene-Pleistocene planktonic foraminiferal biostratigraphy in the Miyagijima and adjacent islands, off Katsuren Peninsula, east of Okinawa-jima, Japan. *Bull. Mizunami Fossil Mus.*, (31): 37-48 (in Japanese with English abstract).
- Janssen, A. W., 1999. Neogene Paleontology in the Northern Dominican Republic 20. Holoplanktonic Mollusks (Gastropoda: Heteropoda and Thecosomata). *Bull. Amer. Paleont.*, 358: 5-40.
- Janssen, A. W., 2004. Holoplanktonic Molluscan Assemblages (Gastropoda, Heteropoda, Thecosomata) from the Pliocene of Estepona (Spain, Málaga). *Palaeontos*, 5: 103-131.
- Janssen, A. W., 2007. Holoplanktonic Mollusca (Gastropoda) from the Gulf of Aqaba, Red Sea and Gulf of Aden (Late Holocene-Recent). *The Veliger*, 49: 140-195.
- Lamarck, J. B. P. A. de, 1801. Système des animaux sans vertebres. Deterville, Paris, 432p.
- Lesueur, C. A., 1817. Mémoire sur deux nouveaux genres de mollusques Atlante et Atlas. *J. Phys. Chim. Hist. nat. Arts*, 85: 390-593.
- MacNeil, F. S., 1960. Tertiary and Quaternary Gastropoda of Okinawa. *U. S. Geol. Surv. Prof. Paper*, 339: 1-148.
- Natori, H. and Kageyama, K., 1987. Geological Map of Oil and Gas Field of Japan (12). Central-southern Part of Okinawa-jima (1:50,000 colored map). Geol. Surv. Japan (in Japanese).
- Noda, H., 1972. Some Fossil Pteropoda from Miyazaki and Okinawa Prefectures, Southwest Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, (88): 472-484.
- Orbigny, A. D., 1836. Mollusques, p. 49-184. In *Voyage dans l'Amerique méridionale exécuté pendant les années 1826-1833*. Bertrand, Paris.
- Rang, P. C. A. L., 1829. Manuel de l'histoire naturelle des mollusques et leurs coquilles. Roret, Paris, 390p.
- Richter, G., 1972. Zur Kenntnis der Gattung *Atlanta* (Heteropoda: Atlantidae). *Arch. Moll.*, 102: 85-91.
- Richter, G. and Seapy, R. R., 1999. Heteropoda. In D. Boltovskoy (ed.), *South Atlantic Zooplankton*, p. 621-647. Backhuys Publishers, Leiden, The Netherlands.
- Seapy, R. R., 1990. The pelagic family Atlantidae (Gastropoda: Heteropoda) from Hawaiian waters: a faunistic survey. *Malacologia*, 32: 107-130.
- Seapy, R. R., Lalli, C. M. and Wells, F. E., 2003. Heteropoda from Western Australian waters, p. 513-546. In Wells, F. E., Walker, D. I. and Jones, D. S. (eds.), *The marine flora and fauna of Dampier, Western Australia*. Western Australia Museum, Perth.
- Shibata, H., 1984. Pteropods and Heteropods from the Upper Cenozoic of Kakegawa, Shizuoka Prefecture, Japan. *Bull. Mizunami Fossil Mus.*, (11): 73-91.
- Shibata, H., and Ujihara, A., 1983. Middle and Late Pleistocene Heteropods and Pteropods from Chiba, Noto Peninsula and Kikaijima, Japan. *Bull. Mizunami Fossil Mus.*, (10): 151-170.
- Shibata, H., Ujihara, A. and Ichihara, T., 2006. Pelagic Mollusks from the middle Pleistocene Takamatsu Silty Sandstone of the Atsumi Group in the Atsumi Peninsula, central Japan. *Sci. Rep. Toyohashi Mus. Nat. Hist.*, (16): 15-30.
- Souleyet, F. L. A., 1852. Zoologie, 2. In F. Eydoux and F. L. A. Souleyet (eds.), *Voyage autour du monde exécuté pendant les années 1836 et 1837 sur la corvette "La Bonite"*. A. Bertrand, Paris, 664p.
- Spoel, S. van der and Troost, D. G., 1972. *Atlanta tokiokai*, a new heteropod (Gastropoda). *Basteria*, 36: 1-6.
- Tesch, J. J., 1908. Systematic monograph of the Atlantidae

(Heteropoda) with enumeration of the species in the Leyden Museum. *Not. Leyden Mus.* 30: 1-30.

Ujiié, H., 1988. Geological Map of Central to Southern Okinawa Islands: Based on Planktonic Foraminiferal Zonation (1:50,000 colored map). Kuniken, Naha (in Japanese).

(要 旨)

柴田 博・氏原 温：沖縄県宮城島産の鮮新世異足類（軟体動物：腹足類）。

沖縄県宮城島の島尻層群新里層の鮮新世の地層から9種の異足類を記載する。それらは *Oxygyrus* sp., *Protatlanta kakegawaensis* Shibata, *Atlanta helicoides* Souleyet, *A. peroni* Lesueur, *A. plana* Richter, *A. tokiokai* van der Spoel and Troost, *A. sp. 1*, *A. sp. 2*, *Carinaria* sp. である。これらのすべての種は島尻層群からははじめて報告される種である。この地点産の3現生種, *A. helicoides*, *A. plana* と *A. tokiokai* は、それらの最も古い時代からの産出記録をなす。