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New Scissurellidae and Anatomidae from Manazuru, Sagami Bay, and Okinawa, Japan (Mollusca: Gastropoda: Vetigastropoda)

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Abstract

Three new Scissurellidae and one new *Anatoma* (Anatomidae) are described from Cape Manazuru, Sagami Bay, and Okinawa, Japan. *Sinezona costulata* n. sp. from Sagami Bay has a protoconch with strong axial cords, the apertural varix is not connected to the embryonic cap, and the teleoconch sculpture is initially of strong axials, which are replaced on the shoulder at the apertural margin by fine spiral lines. *Sinezona milleri* n. sp. from Okinawa has a similar protoconch to *S. costulata*, and the teleoconch sculpture gives rise to a reticulate pattern at the apertural margin. The seven described and two new Japanese species of slit-bearing Scissurellidae are compared. *Coronadoa hasegawai* n. sp. from Sagami Bay is the second species in the genus and is characterised by distinct sculpture on the embryonic cap of the protoconch. *Anatoma parageia* n. sp. from Sagami Bay is a rare example of a shallow water anatomid. The shell is covered with numerous very fine axial cords that form minute, spirally-arranged points giving the impression of spiral sculpture (pseudospirals), and has undulating axial cords on the base. Depth preferences of Scissurellidae and Anatomidae are examined on a world-wide scale, but no change in turnover depth with latitude could be detected. The depth preferences of the two families are most likely explained by the extent to which variable food sources can be utilised.

Key words: New species, vertical distribution, radula, food, feeding

Introduction

Scissurellidae and Anatomidae are minute vetigastropods, occurring from the intertidal to the deep-sea of all fully marine oceans (cf. Geiger 2003, 2008a for reviews). The first Japanese species were described by A. Adams (1862) and Watson (1886) with some Japanese workers adding further taxa (Okutani 1964: *Scissurella sagamiana*; Habe 1951: *Schizotrochus soyoae*; Sasaki *et al*. in press: *Anatoma f.* n. sp.). Habe (1951) enumerated the known taxa from Japan at that time. Kuroda *et al*. (1971) illustrated two species [*Anatoma lamellata* (A. Adams, 1862) and *Sukashitrochus carinatus* (A. Adams, 1862)] while Okutani and Hasegawa (2000) figured the described species and two undescribed *Sinezona* species.

Sasaki (2006) illustrated an anatomid collected in the intertidal of Cape Manazuru, Sagami Bay, tentatively identified as *Anatoma* cf. *lamellata*. We made an intensive joint collecting effort at Cape Manazuru in March 2008 and found three undescribed scissurellid and anatomid species, which are described below.

Materials and Methods

Specimens were prepared for and examined by SEM and radulae were extracted and mounted as detailed in Geiger *et al*. (2007). Shell morphological terms are defined in accordance with all previous publications by us on the family (e.g., Geiger 2003, 2006a, b, 2008b, Geiger and Jansen 2004a, b, Geiger and Sasaki 2008, Sasaki *et al*. in press); definitions of the most significant terms as they are used in this publication are provided below:

Axials: Axial sculptural elements. In order of increasing strength: thread/striae, lines, cords, ribs/lamellae.
Base: The portion of the shell from the slit/selenizone to the umbilicus.
Cord: Distinct sculptural elements, easily seen under the light microscope, wider than lines, lower than ribs.
Funiculus: A spiral cord in the wall of the umbilicus.
Lines: Sculptural elements that may barely be seen under the light microscope and are approximately as wide as high. Lines are wider than threads/striae, narrower than cords, and less elevated than riblets.
Shoulder: The portion of the shell from the suture to the slit/selenizone.
Spirals: Spiral sculptural elements. In order of increasing strength: thread/striae, lines, cords, ribs/lamellae, keels.
Teleoconch: Postembryonic part of the shell.
Teleoconch I: Postembryonic shell to the start of the selenizone.
Teleoconch II: Postembryonic shell from the start of the selenizone to the apertural margin.
Whorl counts follow the methodology of Geiger and Jansen (2004b: 5–6).

Abbreviations

AMS: Australian Museum Sydney, New South Wales, Australia.
DLG: Daniel L. Geiger Collection, Los Angeles, California, USA.
SBMNH: Santa Barbara Museum of Natural History, Santa Barbara, California, USA.
UMUT: University Museum, University of Tokyo, Japan.

Taxonomy

Scissurellidae Gray, 1847

Shell small (0.6–3 mm), trochiform to auriform, no nacre. Protoconch 0.75 to 1 whorl; sculpture of axials, spirals, microhexagons, or absent; with or without apertural varix. Teleoconch usually with selenizone (absent in *Coronadoa* Bartsch, 1946, *Ariella* Bandel, 1998); slit open (e.g., *Scissurella* d'Orbigny, 1824), closed to foramen (e.g., *Sinezona* Finlay, 1926), absent (*Coronadoa*), usually umbilicate. Operculum corneous, thin, multispiral, nucleus central. Radula rhipidoglossate; serrated rachidian tooth, triangular cusp; lateral teeth 1–3 similar; lateral tooth 4 reduced, hook-shaped; lateral tooth 5 enlarged by broadening; marginal teeth with spoon-shaped cusps and many denticles.

Sinezona Finlay, 1926

Type species: *Schismope brevis* Hedley, 1904, by original designation.

Scissurellid with selenizone, slit closed to foramen. Protoconch sculpture of axials or spirals, or absent; with or without apertural varix.

Sinezona costulata n. sp.

Figures 1–3

Sinezona sp.: Fukuda, 1993: 17–18, pl. 4, fig. 17.
Sinezona sp.: Sasaki, 1998: fig. 45a–c.
Sinezona sp. 2: Okutani and Hasegawa, 2000: 37, pl. 18, figs 7a,b [see discussion].

Type material

Holotype. SBMNH 83544.

Paratypes. SBMNH 83545, 5 dry shells; SBMNH 83546, 11 complete specimens in ethanol; SBMNH 83547: operculum and radula mounted including shell of source specimen; DLG 1037, ~100 shells; DLG 1038, 9 complete specimens in ethanol. 0–0.5 m: all from type locality. UMUT RM27645, Goshikinohama, Usa, Tosa, Kochi Prefecture, Japan 33.424˚N, 133.457˚E [figured by Sasaki, 1998: fig. 45a–c]. Misaki Field Station, west coast of Miura Peninsula, 50 m to right of field station, Japan, 35.250˚N, 139.667˚E (AMS C.380660, 4). Banda, Tateyama, Chiba Prefecture, Japan, 34.975˚N, 139.770˚E (UMUT RM30022-30033, 1).

Type locality

Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan, 35.141˚N, 139.161˚E. Rock and algal washings from moderately exposed rock and boulder shore in intertidal.

Etymology

Costulata, Latin adjective—ribbed, referring to the many fine axial ribs on the teleoconch.

Description

Shell small for genus (to 0.9 mm), trochiform depressed. Protoconch of 0.75 whorl, with strong axial cords, apertural varix not connected to embryonic cap, apertural margin straight. Teleoconch I of 0.7–0.8 whorl, with 8–10 axial lamellae, in majority of specimens not reaching suture, starting out as axial cords, from mid-shoulder to mid-base as lamellae, fading towards umbilicus. No spiral sculpture. Interstices with fine irregular growth marks. Teleoconch II of 0.7 whorl, suture little impressed. Shoulder with approximately a dozen indistinct axial cords from suture to selenizone, fine spiral lines starting 0.1–0.2 whorl after onset of selenizone, increasing to approximately 12 at apertural margin, irregularly spaced between suture and selenizone. Base with distinct constriction below selenizone, axial lamellae starting abruptly below constriction, fading toward umbilicus. Approximately 11 spirals, below suture as fine spiral lines, towards umbilicus changing to spiral steps. Umbilicus bordered by finely granulated carina, umbilical walls straight with finest axial growth lines, no funiculus. Selenizone above periphery, keels shorter than width of selenizone (usually eroded), slit closed to foramen. Aperture roundly D-shaped, roof overhanging.

Dimensions given in Table 1.

TABLE 1. Dimensions of *Sinezona costulata* n. sp.

Specimen	Overall		Aperture		Protoconch	
	Width	Height	Width	Height	Length	width
Holotype	0.90 mm	0.64 mm	0.45 mm	0.39 mm	206 µm	149 µm
Paratype Figure 2A	0.86 mm	0.67 mm	0.47 mm	0.38 mm	196 µm	150 µm
Paratype Figure 2B	0.88 mm	0.62 mm	0.47 mm	0.38 mm	209 µm	162 µm
Paratype Figure 2C (juvenile)	0.58 mm	0.38 mm	0.29 mm	0.23 mm	210 µm	154 µm

Animal. (From preserved specimen) with distinct eyes and papillate epipodial tentacles (number and additional details not determined due to contracted state of material).

Radula. Rachidian tooth triangular, all denticles of cusp approximately the same size, central denticle, three denticles on each side. Lateral teeth 1–3 similar, 3–4 denticles on outer edge of cusp. Lateral tooth 4 reduced, hook-shaped, with minute point on outer edge of cusp. Lateral tooth 5 enlarged by broadening, apical denticle largest, approximately 7 denticles along inner edge of cusp, decreasing in size from tip, outer edge smooth. Inner marginal teeth with triangular cusp, apical denticle largest, approximately 3 denticles along inner margin, approximately 5 denticles on outer margin. Outer marginal teeth with spoon-shaped cusp, many fine denticles on each side. Radular interlock of central field moderate.

Remarks

Sinezona costulata has previously been collected at Miyanohama, Chichijima, Ogasawara Islands, Japan, 27.105˚N, 142.194˚E (Fukuda 1993), and Hachijô Island, Izu Islands, Japan 33.112˚N, 139.785˚E (Y. Shikano, pers. comm. cited by Fukuda 1993).

Sinezona costulata is the only species in the genus in its known range and easily identified by the slit closed to a foramen and the lack of spiral keels on the teleoconch. *Sukashitrochus carinatus* (A. Adams, 1862) has distinct spiral keels on the teleoconch. *Scissurella staminea* (A. Adams, 1862) has an open slit, is overall more globular and has distinct axials and spiral on the teleoconch forming a wide reticulate pattern, while in *Sin. costulata* the axial lamellae predominate. Note that juvenile *Sinezona* spp. have an open slit that only closes at maturity (Fig. 2C). A common sign of maturity in Scissurellidae is that the last quarter whorl markedly descends along the coiling axis of the shell (Fig. 2A vs. 2C).

Other species of world-wide *Sinezona* that resemble *Sin. costulata* can be distinguished as follows. *Sinezona bandeli* Marshall, 2002, from New Zealand (Marshall 2002) has more strong axial cords on the protoconch (17 vs. 12), and the axial cords on teleoconch I reach the suture while *Sin. costulata* shows a distinct gap. *Sinezona garciai* Geiger, 2006, from the Caribbean (Geiger 2006a) has a protoconch with fine axials (strong in *Sin. costulata*), lacks an apertural varix (present in *Sin. costulata*), and the teleoconch has more (25 vs. 9) axial cords, which however are weaker.

The differentiation of all slit-bearing Scissurellidae known from Japan including Okinawa is given in Table 5.

The radula is of the generic scissurellid type with no exceptional features encountered. Although there are subtle differences in details of radular morphology among scissurellid species such as shape of cusp of rachidian tooth as narrower or broader triangle or number of denticles on lateral teeth 1–3, they do not approach the radical transformations encountered in Anatomidae (see Geiger and Sasaki 2008).

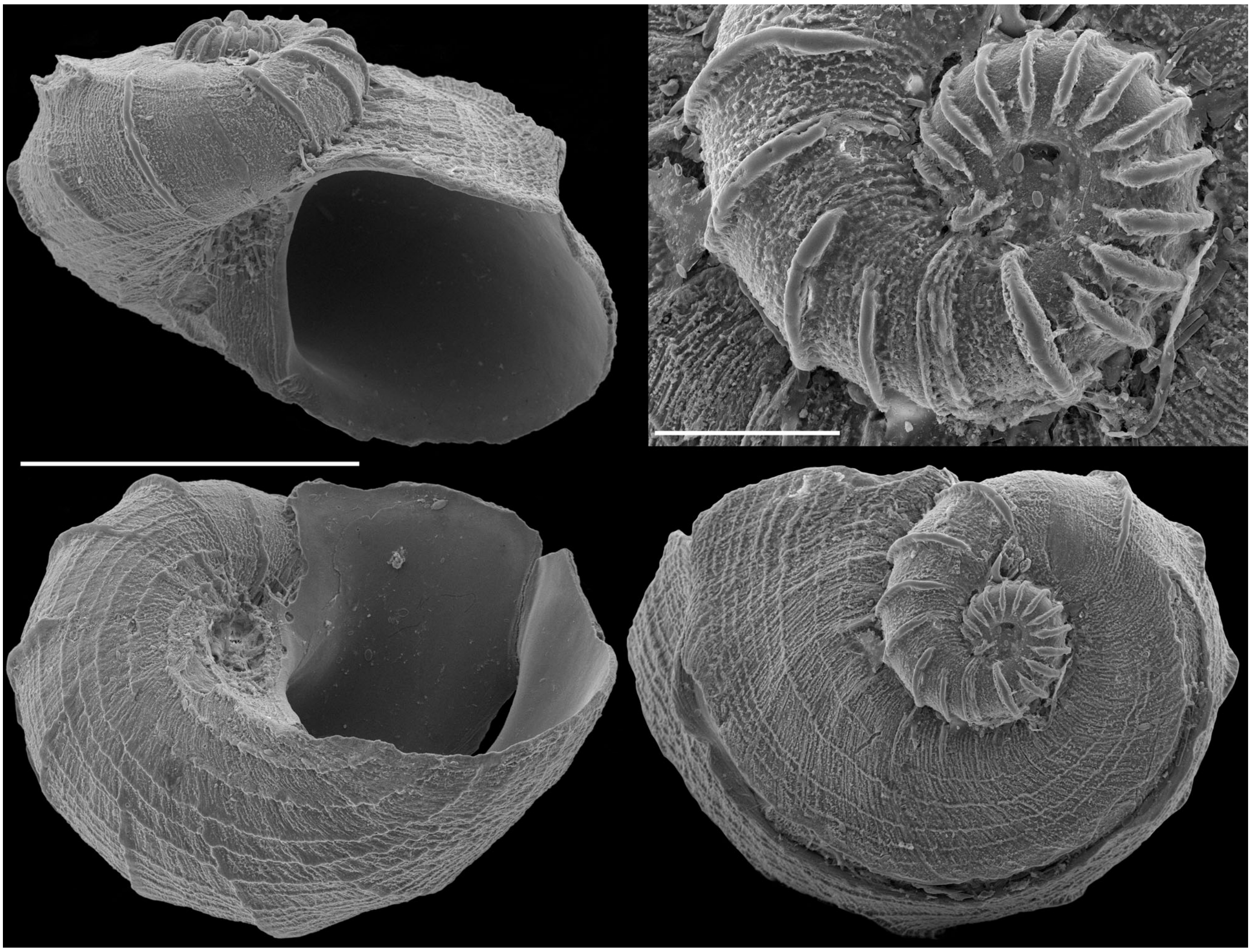

FIGURE 1. Holotype of *Sinezona costulata* n. sp. SBMNH 83544. Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan. Scale bar shell = 500 µm. Scale bar protoconch = 100 µm.

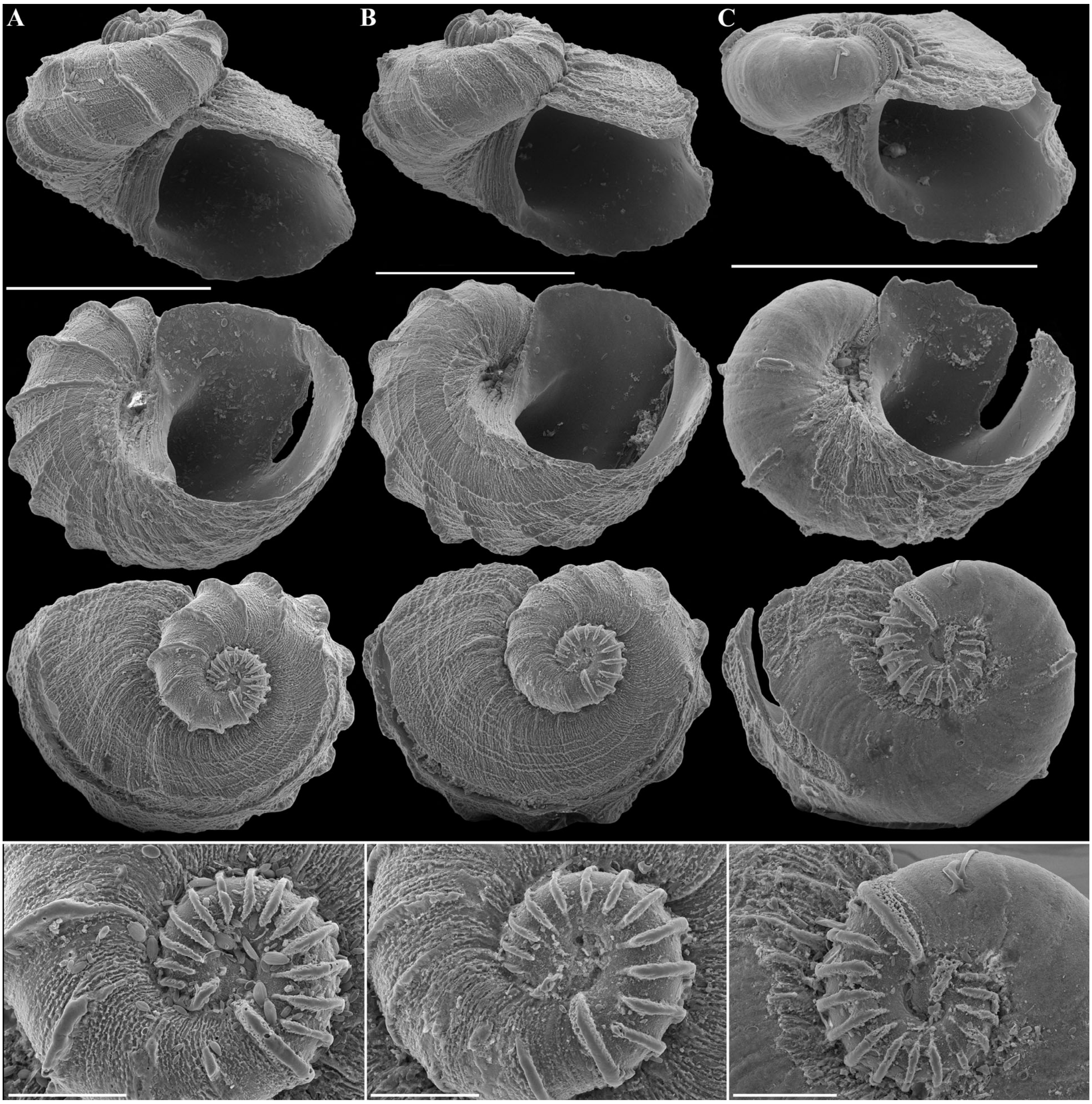

FIGURE 2. Paratypes of *Sinezona costulata* n. sp. **A–C.** SBMNH 83545. Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan. Scale bars shell = 500 µm. Scale bars protoconch = 100 µm.

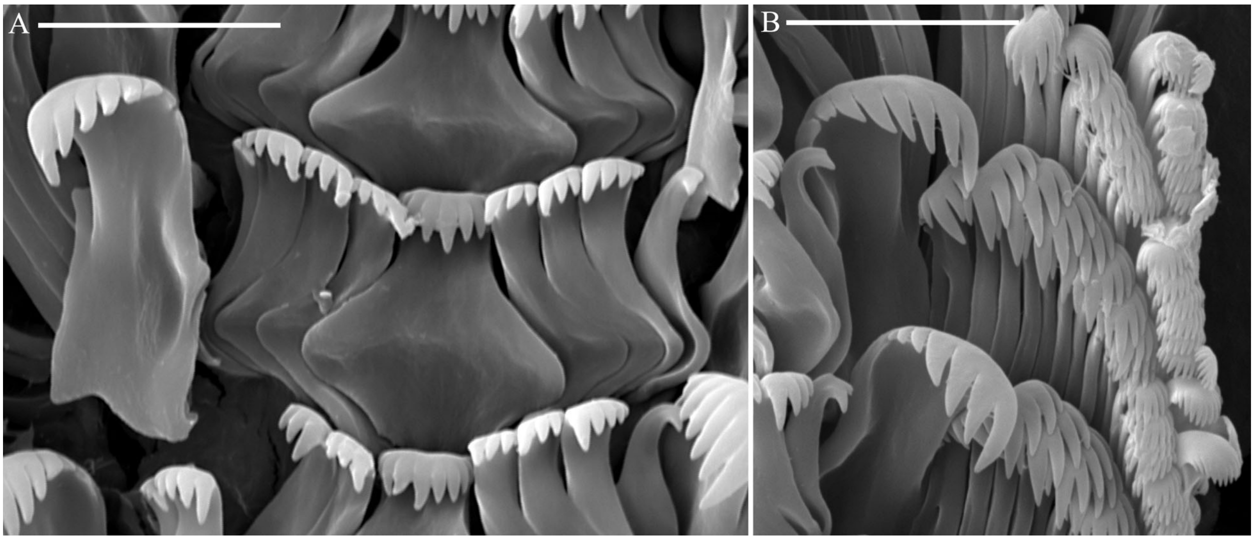

FIGURE 3. Radula of *Sinezona costulata* n. sp. Paratype SBMNH 83547. Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan. **A.** Central field. **B.** Lateral tooth 5 and marginal teeth. Scale bars = 10 µm.

Sinezona milleri n. sp.

Figure 4

Sinezona sp. 1: Okutani and Hasegawa, 2000: 37, pl. 18, figs 6a,b [see discussion].

Type material

Holotype. SBMNH 83548, empty shell.

Paratypes. SBMNH 83549, 2. Both from type locality, empty shells.

Type locality

North side, Ikei Jima, Okinawa, Japan, 26.384˚N, 127.990˚E, 17 m.

Etymology

Named for the collector of the type specimens, Shawn Miller of Nagahama, Okinawa, for his continued support in malacological research by providing marine sediment samples of Okinawa.

Description

Shell trochiform depressed, small for genus (up to 0.9 mm *fide* Okutani and Hasegawa, 2000: 37). Protoconch of 0.75 whorl, strong axials with thickening in apical region, apertural varix not connected to embryonic cap, apertural varix straight. Teleoconch I of 1 whorl, suture moderately impressed, approximately 19 raised axial cords, first spiral line after 0.5 whorl in same position as selenizone. Teleoconch II of 0.25 whorl. Shoulder flat, approximately 20 axials on first 0.5 whorl, decreasing in strength from distinct cords to indistinct cords, spirals increasing in strength from five lines at onset of selenizone to approximately 13 lines and cords at apertural margin of fully grown specimen; axials and spirals forming reticulate pattern towards apertural margin. Base barely constricted below selenizone; axials as on shoulder, approximately 20 spirals, increasing in strength from fine lines below selenizone to cords towards umbilicus, the latter forming small thickenings at intersection with axials. Umbilicus at angle to base, bordered by granulated spiral cord; walls straight, with fine axial growth lines, no funiculus. Selenizone above periphery, keels low, less then 20% of width of selenizone, moderately strong, slit closed anteriorly to foramen. Aperture roundly D-shaped to subquadrate, roof overhanging.

Dimensions given in Table 2.

TABLE 2. Dimensions of *Sinezona milleri* n. sp. *—best estimate from broken shell.

Specimen	Overall		Aperture		Protoconch	
	Width	Height	Width	Height	Length	width
Holotype	0.76 mm	0.51 mm	0.45 mm	0.34 mm	150 µm	108 µm
Paratype SBMNH 83549	0.78 mm	0.54 mm	0.45 mm	0.35 mm	144 µm	112 µm
Paratype SBMNH 83549	0.79 mm	0.59 mm	*0.40 mm	0.40 mm	150 µm	110 µm

Animal. Unknown.

Remarks

Sinezona milleri can be identified by the reticulate sculpture on the later teleoconch. *Sinezona costulata* from the Japanese mainland does not show reticulate sculpture. Among Scissurellidae from Okinawa, *Sin. milleri* can be distinguished as follows. *Sinezona plicata* (Hedley, 1899) of broad Indo-Pacific distribution (see Geiger and Jansen 2004b) has strong axial keels and grows to much larger size (2.3 vs. < 1 mm). *Scissurella staminea* has much wider spacing of the reticulate pattern, which is also developed equally over entire teleoconch. *Scissurella evaensis* Bandel, 1998, of broad Indo-Pacific distribution (Geiger and Jansen 2004b) bears a spiral series of distinct axial tooth-like projections on the mid base. *Scissurella mirifica* (A. Adams, 1862), with broad Indo-Pacific distribution (see Geiger and Jansen 2004b: as *Sci. declinans* Watson, 1886) has a more globular appearance, and a fine reticulate pattern on shoulder and base over entire teleoconch. *Scissurella lorenzi* Geiger, 2006, mainly found in the Indo-Malayan Archipelago, is more globular in shape and shows a distinct color pattern of broad axial rays on the shoulder. *Scissurella spinosa* Geiger & Jansen, 2004, with broad Indo-Pacific distribution is overall more globular and has reticulate sculpture, in which the intersections of axials and spirals are raised to distinct points. *Sukashitrochus carinatus* from the mainland of Japan to Okinawa has distinct spiral keels on the base of the teleoconch. See also remarks under *Sin. costulata* for distinction between juvenile *Sinezona* and adult *Scissurella*, both with an open slit.

Other species of world-wide *Sinezona* that resemble *Sin. milleri* can be distinguished as follows. *Sinezona danieldreieri* Geiger, 2008, from the Indo-Malayan Archipelago (Geiger 2008b) has 0.9 teleoconch I whorl (1 in *Sin. milleri*) and has consistent non-reticulate sculpture on the teleoconch. All other *Sinezona* species show distinct characteristics.

The differentiation of all the slit-bearing Scissurellidae from Japan including Okinawa is given in Table 5.

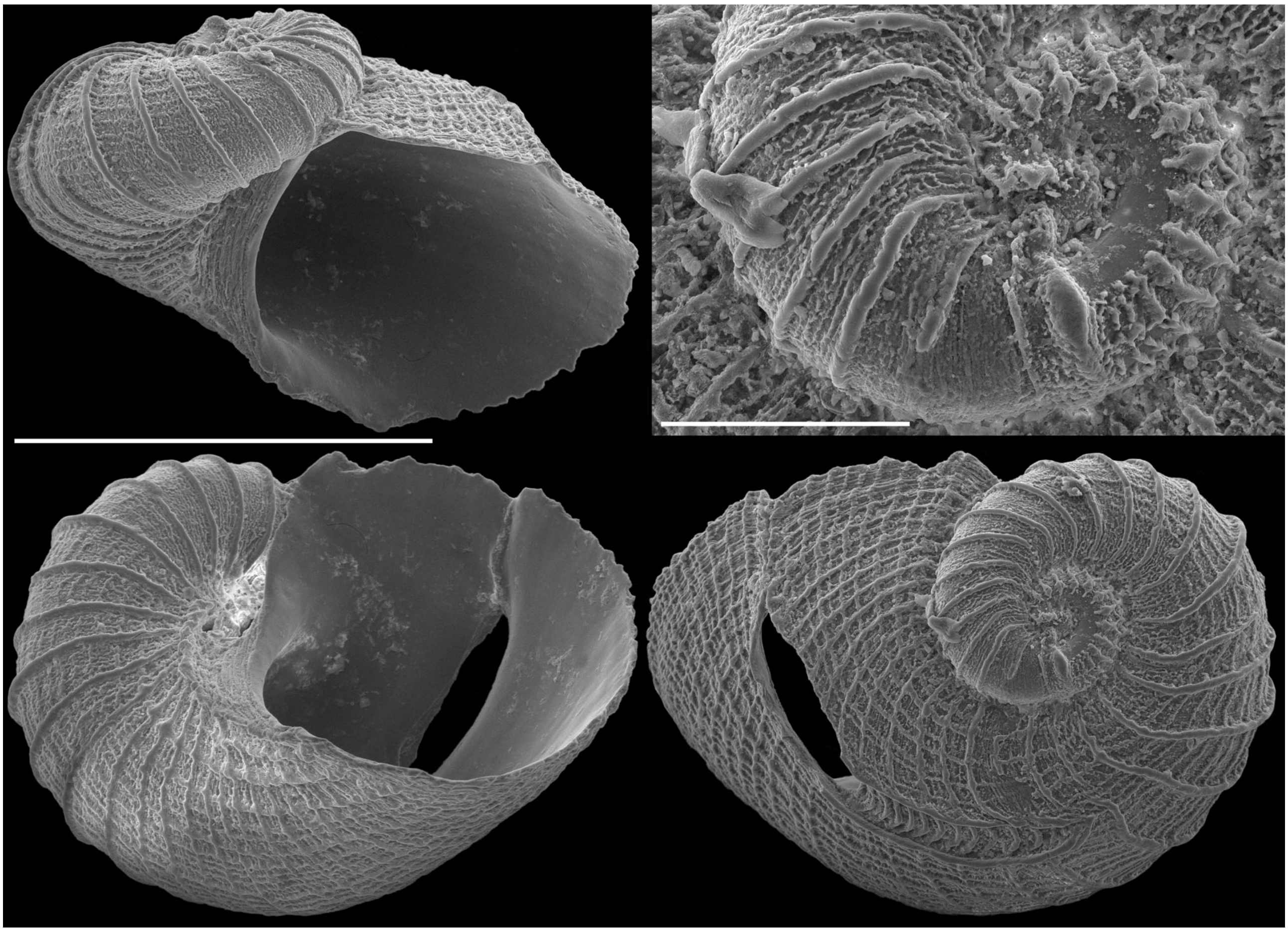

FIGURE 4. Holotype of *Sinezona milleri* n. sp. SBMNH 83548. North side, Ikei Jima, Okinawa, Japan. Scale bar shell = 500 µm. Scale bar protoconch = 100 µm.

Coronadoa Bartsch, 1946

Type species: *Coronadoa simonsae* Bartsch, 1946, by original designation.

Scissurellid of small size (< 0.8 mm) without selenizone or slit. Protoconch with axial sculpture, no apertural varix.

Coronadoa hasegawai n. sp.

Figures 5–7

Scissurellidae gen. et sp.: Sasaki, 1998: fig. 45d–f.

Type material

Holotype. SBMNH 83550, empty shell.

Paratypes. SBMNH 83551, 5 (Figs 6A–C, 7A–B); DLG 1041, 15: from type locality, all empty shells. UMUT RM27646 Goshikinohama, Usa, Tosa, Kochi Prefecture, Japan, 33.424˚N, 133.457˚E [figured by Sasaki, 1998: fig. 45d–f]. 0–0.5 m, Misaki Field Station, W. coast Miura Peninsula, 50 m to right of field station, Japan, 35.250˚N, 139.667˚E (AMS 380664, 3: two examined by SEM). Misaki Field Station, west coast Miura Peninsula, Japan, 35.250˚N, 139.667˚E (AMS 380665, 1). Banda, Tateyama, Chiba Prefecture, Japan, 34.975˚N, 139.770˚E (UMUT RM30034-30043, 1).

Type locality

Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan, 35.141˚N, 139.161˚E. Rock and algal washings from moderately exposed rock and boulder shore in intertidal.

Etymology

The species is named for Kazunori Hasegawa of the National Museum of Science and Technology in recognition of his many contributions to Japanese malacology.

Description

Shell small, trochiform globular. Protoconch of 0.9 whorl, embryonic cap with irregular elevated sculptural elements, of same height as subsequent axial cords; approximately 25 axial cords from inner third to suture (some starting more outward up to inner half), no apertural varix, apertural margin straight to slightly prosocline. Teleoconch up to 1.5 whorls, suture deeply impressed, approximately 6 distinct axial cords on first half whorl, density subsequently increasing approximately 2–3 fold, interstices with irregular growth lines, no spiral sculpture. Base with same sculpture as on shoulder, distinct angle at border to umbilicus, adorned with thickenings of axial cords. Umbilicus deep, walls with axials. Aperture D-shaped, lower adumbilical corner flared, giving rise to angled border between base and umbilicus.

TABLE 3. Dimensions of *Coronadoa hasegawai* n. sp.

Specimen	Overall		Aperture		Protoconch	
	Width	Height	Width	Height	Length	width
Holotype	0.64 mm	0.54 mm	0.30 mm	0.28 mm	163 µm	132 µm
Paratype Figure 6A	0.56 mm	0.49 mm	0.28 mm	0.28 mm	167 µm	128 µm
Paratype Figure 6B	0.60 mm	0.49 mm	0.27 mm	0.25 mm	192 µm	136 µm
Paratype Figure 6C	0.42 mm	0.33 mm	0.18 mm	0.19 mm	175 µm	118 µm
Paratype Figure 7A	0.61 mm	0.47 mm	0.29 mm	0.24 mm	172 µm	127 µm
Paratype Figure 7B	0.52 mm	0.44 mm	0.25 mm	0.28 mm	183 µm	122 µm
Paratype Figure 7C (juvenile)	0.54 mm	0.43 mm	0.27 mm	0.27 mm	182 µm	136 µm

Dimensions given in Table 3.

Operculum thin, round, multispiral, nucleus central. Further data on animal not available.

Remarks

Coronadoa hasegawai is very similar in overall shell morphology to *C. simonsae* from the Panamic and Northeast Pacific provinces (Geiger and McLean, unpubl. data). They consistently differ in the sculpture on the early portion of the protoconch (embryonic cap), which bears some irregular but distinct granules and ridges in *C. hasegawai*, which are absent in *C. simonsae*. This feature is consistent for all specimens examined by SEM (*C. hasegawai*: 11; *C. simonsae*: 20). Additionally, the apertural margin of the protoconch is prosocline in *C. simonsae*, but is mostly straight in *C. hasegawai*.

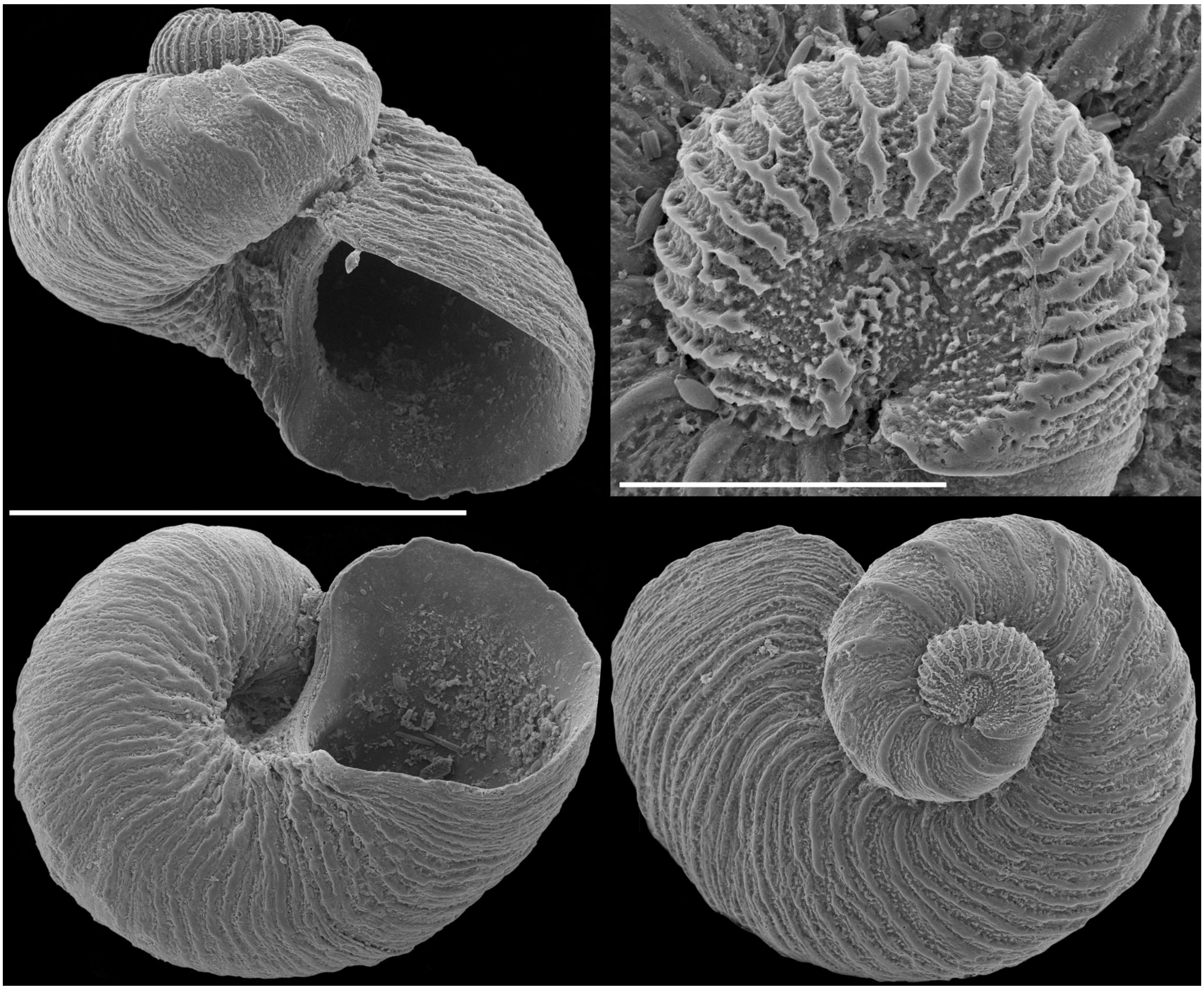

FIGURE 5. Holotype of *Coronadoa hasegawai* n. sp. SBMNH 83550. Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan. Scale bar shell = 500 µm. Scale bar protoconch = 100 µm.

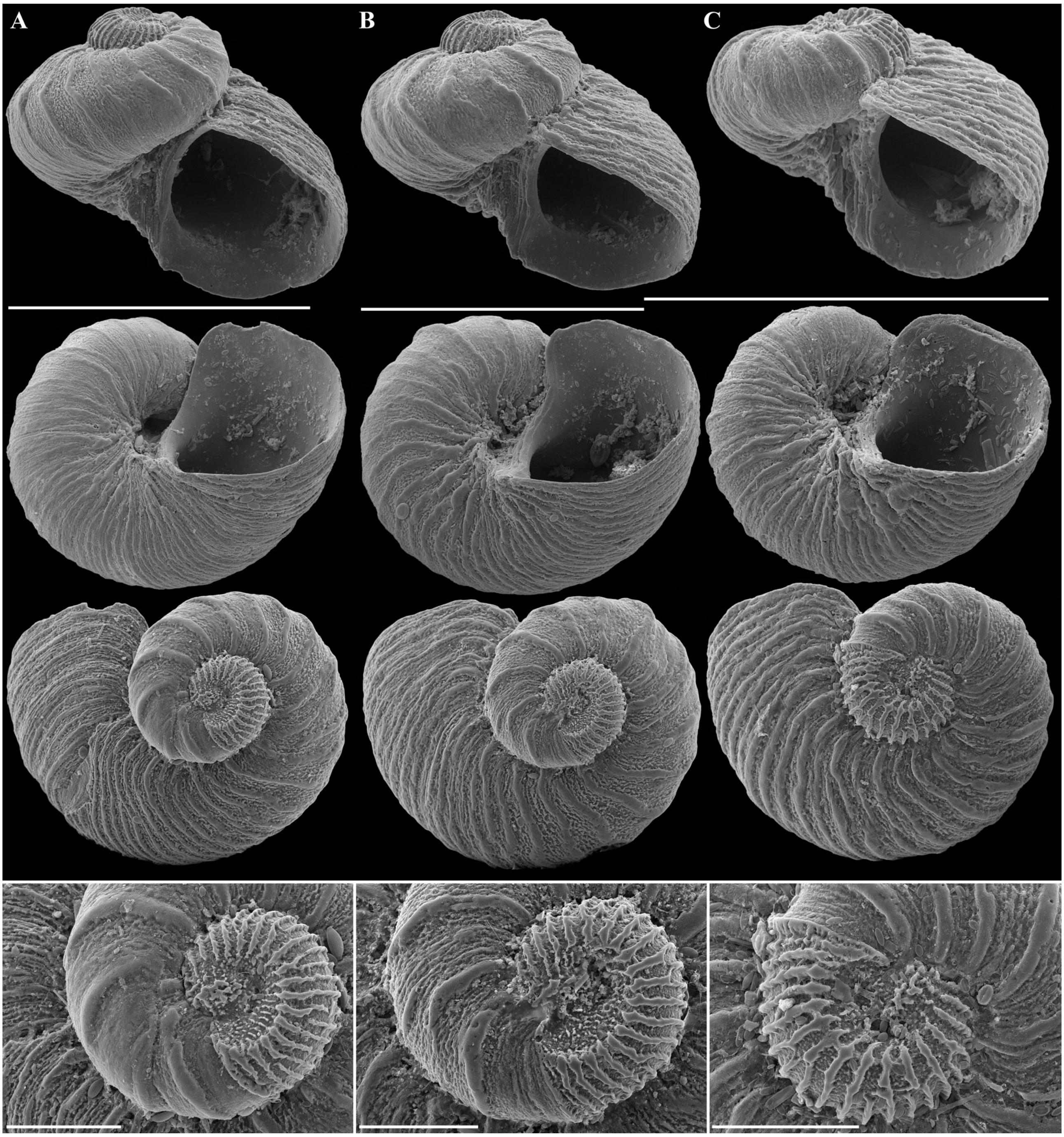

FIGURE 6. Paratypes of *Coronadoa hasegawai* n. sp. **A–C.** SBMNH 83551. Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan. Scale bars shell = 500 µm. Scale bars protoconch = 100 µm.

Although the radula could not be obtained for this species, the similarities in the shells of *C. hasegawai* and *C. simonsae* make us confident of the generic placement of *C. hasegawai*. The trochoid protoconch (see Geiger *et al*. 2008 for discussion), the very similar protoconch and teleoconch sculpture make the placement straightforward. The distinct dip of the last quarter whorl and the tendency to show some separation of the peristome from the previous whorl indicates that the specimens are fully grown and not juveniles of another, larger species. The more than one teleoconch whorls without a slit indicate that this is not a juvenile slit-bearing scissurellid which has not yet developed the slit.

The species is commonly found in southwestern Japan (H. Fukuda, pers. comm. 1/2009).

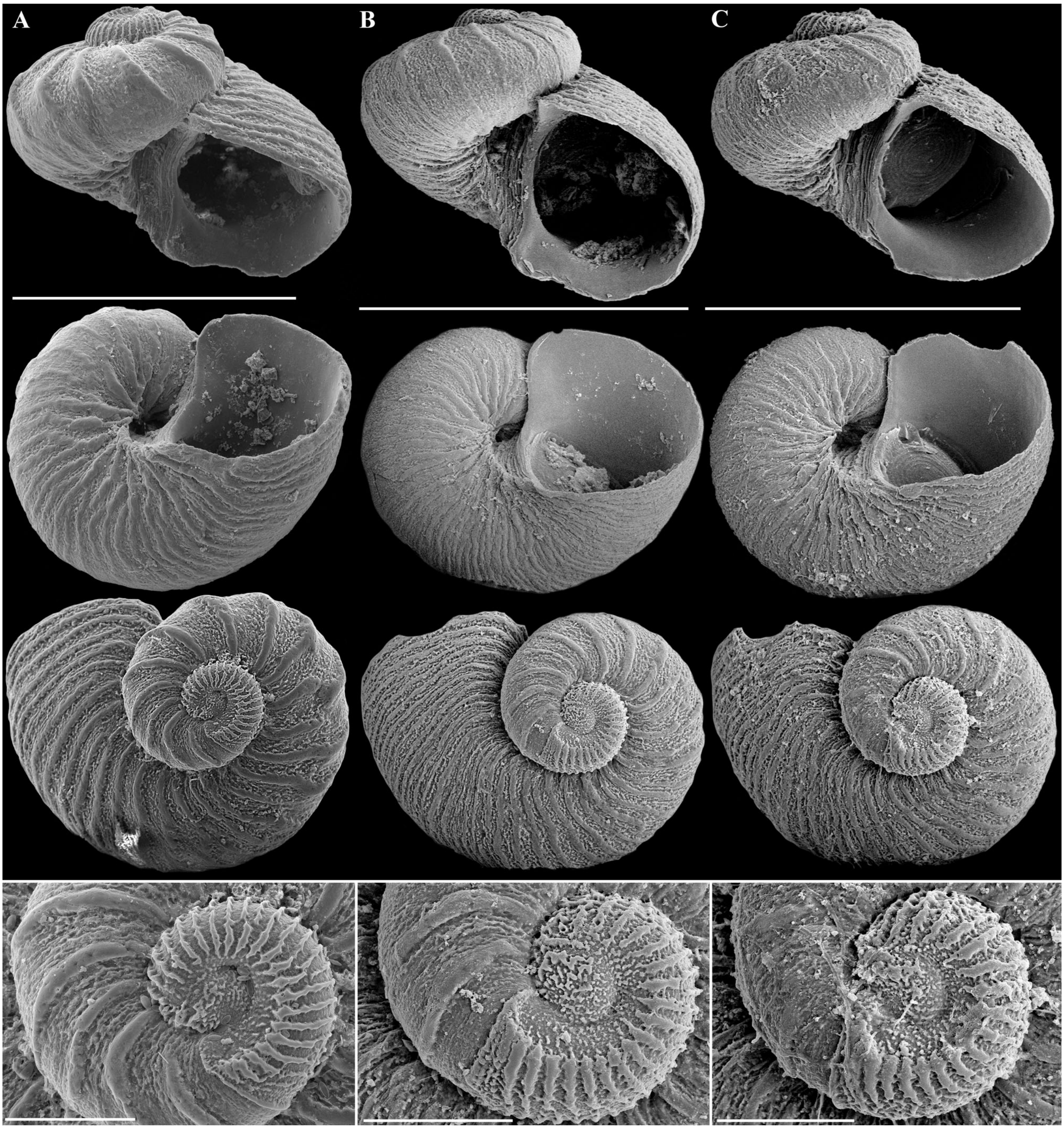

FIGURE 7. Paratypes of *Coronadoa hasegawai* n. sp. **A–B.** SBMNH 83551. Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan. **C.** AMS C.380665. Misaki Field Station, W. coast Miura Peninsula, Japan. Scale bars shell = 500 µm. Scale bars protoconch = 100 µm.

Anatomidae McLean, 1989

Small to medium size (1–11 mm), trochiform globular to binconical (*Anatoma* Woodward, 1859, *Thieleella* Bandel, 1998), naticiform (*Sasakiconcha* Geiger, 2006), no nacre. Protoconch of 0.1–1 whorl, sculpture flocculent, hexagonal, absent; apertural varix present or absent. Selenizone at periphery, slit open (*Anatoma*, *Thieleella*) or closed (*Sasakiconcha*). Umbilicate, with or without funiculus, *Sasakiconcha* with umbilical trough. Operculum corneous, thin, multispiral, central nucleus. Radula variable; if similar to Scissurellidae, then with fifth lateral tooth enlarged by elongation.

Anatoma Woodward, 1859

Type species: *Scissurella crispata* Fleming, 1828, by monotypy.

Anatomid with open slit; protoconch sculpture other than hexagonal.

***Anatoma parageia* n. sp.**
Figures 8–9

Anatoma japonica: Sasaki, 1998: fig. 44c–d. Not *Anatomus japonicus* A. Adams, 1862.

Type material

Holotype. SBMNH 83552, empty shell.

Paratypes. SBMNH 83553, 3 (2 shown in Fig. 8A–B); DLG 1036, 11; UMUT RM 29235 (Fig. 9C), all from type locality, all empty shells. UMUT RM 27644, off Shimoda, Ize Peninsula, Japan [figured by Sasaki, 1998: fig. 44c–d].

Type locality

Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan, 35.141˚N, 139.161˚E. Rock and algal washings from moderately exposed rock and boulder shore in intertidal.

Etymology

Parageios, Greek - pertaining to shallow water, in reference to the intertidal or shallow subtidal habitat, which is rather unusual for an anatomid.

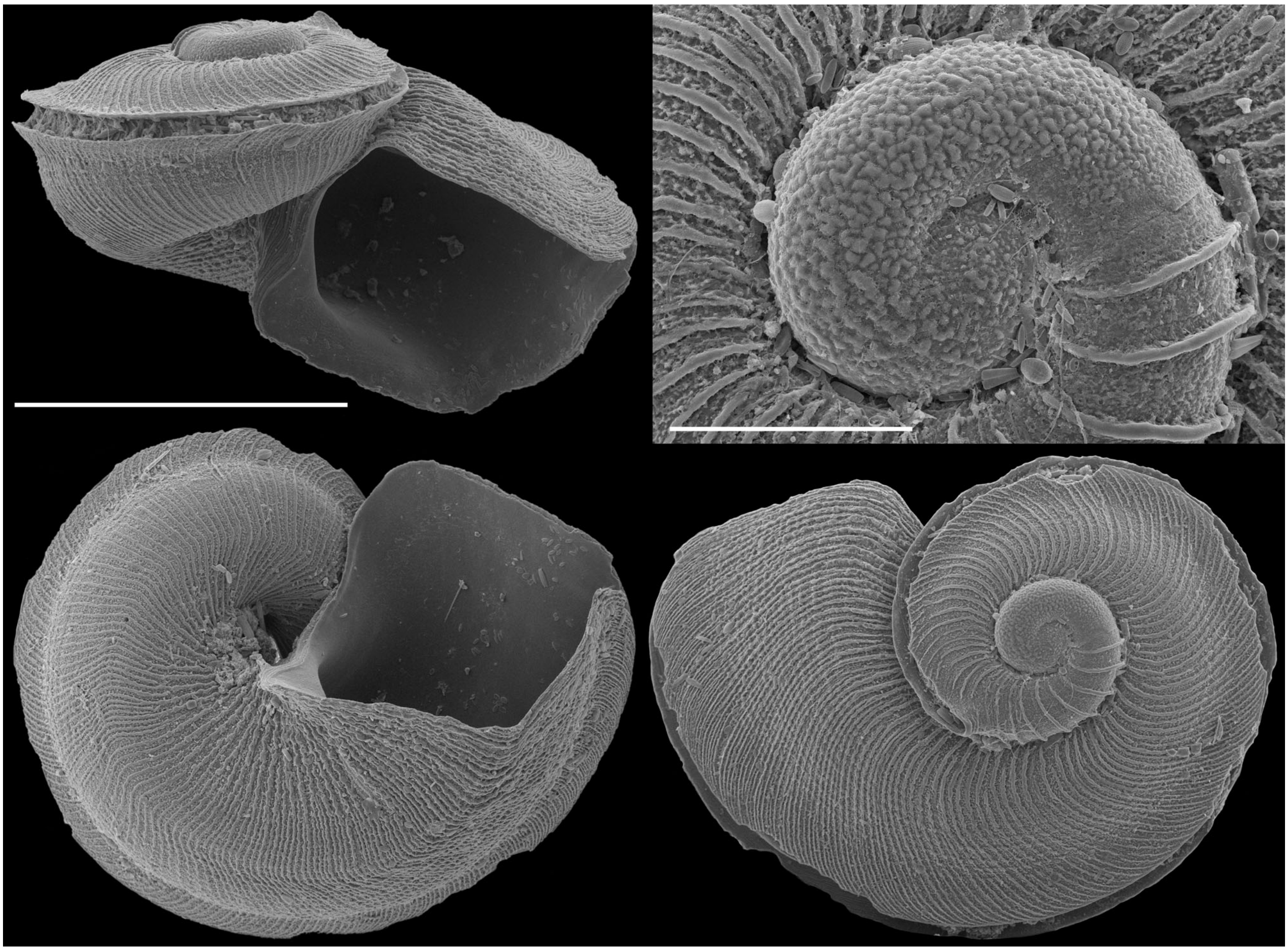

FIGURE 8. Holotype of *Anatoma parageia* n. sp. SBMNH 83552. Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan. Scale bar shell = 500 µm. Scale bar protoconch = 100 µm.

Description

Shell trochiform biconical, small for genus, of 0.75 whorl, flocculent sculpture, no apertural varix, apertural margin straight. Teleoconch I of 0.3 whorl, approximately 10 distinct axial cords, crowded towards onset of selenizone, no spirals. Teleoconch II up to 1.3 whorls. Shoulder slightly convex, suture deeply impressed, many fine axial cordlets, regularly spaced and developed in first half of teleoconch-II-whorl, subsequently either extending from suture to keel (full axials), or starting up to one fifth away from suture (short axials), or arising as bifurcation of full-width axial in adsutural third; most frequent pattern of alternating full axials and short axials. Spirally arranged small points on axials looking like spiral sculpture (pseudospirals), starting after 0.5 teleoconch II whorl increasing variably to 6–12 rows in absutural half of shoulder, giving overall impression of rough surface, dull under light microscope. Base not constricted below selenizone, with more or less distinct spiral angulation in middle of base; axials similar to those on shoulder, slightly undulating in region of angulation; pseudospirals from below selenizone to umbilicus omitting area of spiral angulation. Umbilicus open, with funiculus. Selenizone at periphery, its keels about as wide as selenizone, moderately strong; slit open, margins converging. Aperture rounded with basal adumbilical corner flared, forming funiculus.

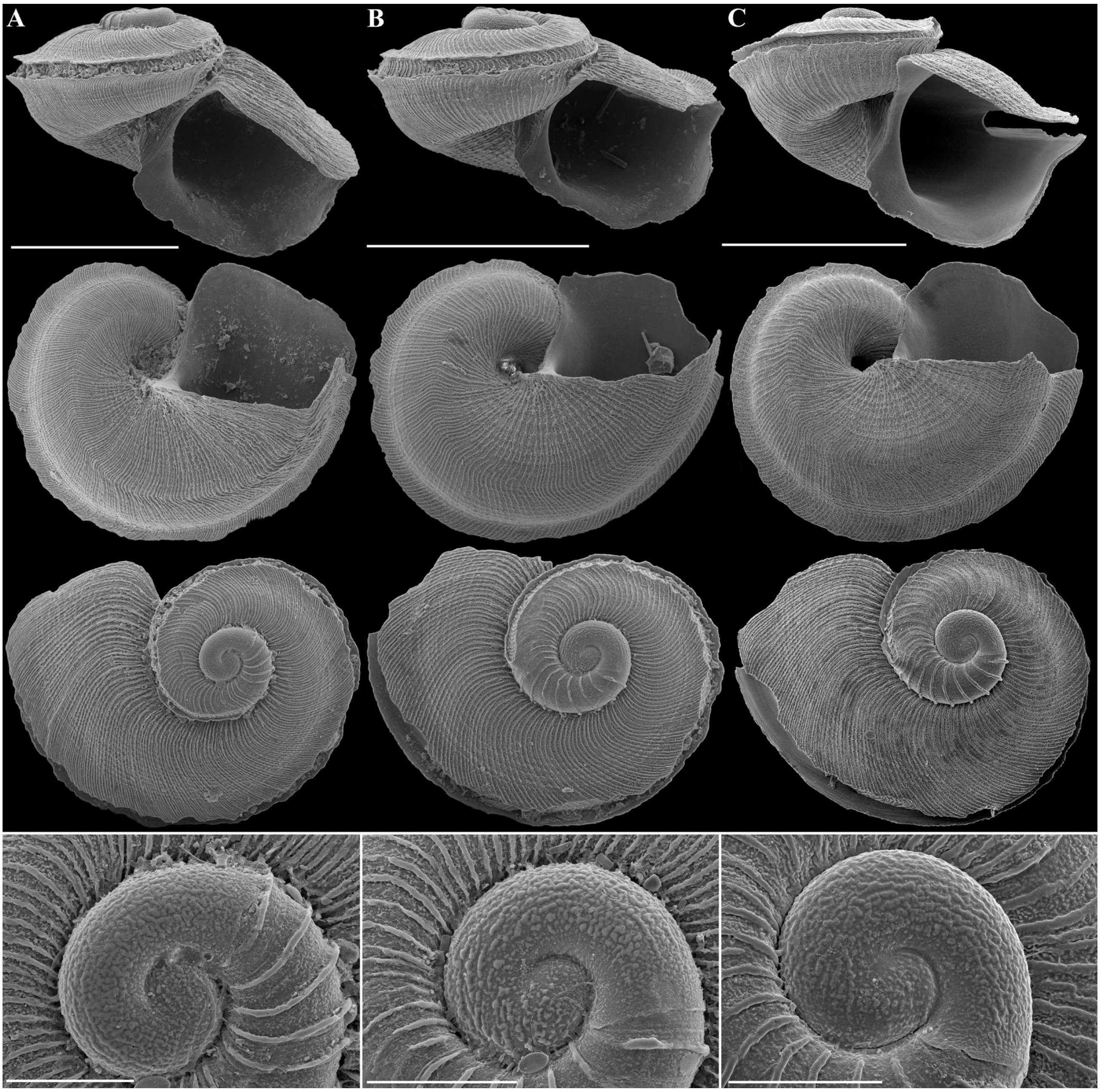

FIGURE 9. Paratypes of *Anatoma parageia* n. sp. **A.–B.** SBMNH 83553. **C.** UMUT RM29235. Peninsula towards shrine, Cape Manazuru, Kanagawa Prefecture, Japan. Scale bars shell = 500 µm. Scale bars protoconch = 100 µm.

TABLE 4. Dimensions of *Anatoma parageia* n. sp.

Specimen	Overall		Aperture		Protoconch	
	Width	Height	Width	Height	Length	width
Holotype	0.93 mm	0.66 mm	0.47 mm	0.69 mm	182 µm	122 µm
Paratype Figure 9A	1.05 mm	0.74 mm	0.51 mm	0.48 mm	199 µm	131 µm
Paratype Figure 9B	0.80 mm	0.50 mm	0.37 mm	0.33 mm	175 µm	120 µm
Paratype Figure 9C (juvenile)	0.97 mm	0.64 mm	0.47 mm	0.46 mm	191 µm	133 µm

Dimensions given in Table 4.

Animal. Unknown.

Remarks

The most similar species is *Anatoma pseudoequatoria* Kay, 1979, from Hawaii. It shares the small overall size, the discoidal shape, and the undulating axials on the base. It is distinguished by its very short teleoconch I of 0.25 whorl (0.3 in *A. parageia*). The sculpture on the shoulder of *A. pseudoequatoria* consists of strong axial cords from the suture to the mid shoulder, frequently followed by a narrow interval from the mid shoulder towards the selenizone; *A.*

parageia does not show such a gap in axial sculpture on the shoulder. In *A. pseudoequatoria*, fine axial cords are found on the outer surfaces of the keels of the selenizone, which extend up to one third the width of those keels onto the shoulder and base, respectively; *A. parageia* lacks those additional fine axials on the keels of the selenizone; it is covered by similar sculpture on the entire width of the shoulder and over the entire base.

TABLE 5. Comparison of slit-bearing scissurellid species occurring in Japan. For detailed descriptive accounts, see the text accompanying the cited illustrations.

Species	*Sinezona costulata*	*Sinezona milleri*	*Sinezona plicata*	*Scissurella staminea*	*Scissurella evaensis*	*Scissurella mirifica*	*Scissurella lorenzi*	*Scissurella spinosa*	*Sukashitrochus carinatus*
Protoconch sculpture	Strong axials	Strong axials	absent	Fine axials	Fine axials	Fine axials	Fine axials	Fine axials	Flocculent
Protoconch varix connected to embryonic cap	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Protoconch apertural margin	Straight	Straight	Sinusoid	Sinusoid	Sinusoid	Sinusoid	Sinusoid	Sinusoid	Sinusoid
Teleoconch I whorls	0.6–0.8	1	0.9–1.25	1.1–1.25	1.1–1.25	1.1–1.25	1.1–1.3	1–1.25	1–1.1
Constriction below selenizone	Weak	Barely	Strong	Weak	Strong	Weak	Barely	Moderate	Strong
Border of umbilicus	Angled, not ornamented	Angled with granules	Angled, weakly orna-mented	Angled with carina	Angled with carina	Angled with carina	Continu-ous with base	Angled weak carina	Angled, weakly granulated
Sculpture of shoulder, early teleoconch	Strong axial cords no spirals	Strong axial cords, fine spiral lines	Axial lamellae, fine spiral lines	Strong axial cords	Raised axial cords	Strong axial cords, fine spiral lines	Axial cords, fine spiral lines	Strong axial cords	Indistinct axial cords
Sculpture of shoulder at apertural margin	Fine spiral lines	Reticulate	Axial lamellae fine spiral lines	Axial cords, fine spiral lines	Axial cords, finest spiral lines	Axial and spiral lines	Axial cords, stronger spiral lines	Axial cords, fine spiral lines	Indistinct axial cords and fine spiral lines
Sculpture base	Axial cords fine spiral lines	Axial cords, spiral lines	Axial lamellae fine spiral lines	Axial cords, finer spiral cords or steps	Strong axial cords, periumbilic al spiral lines	Axial lines, spiral steps	Reticulate	Strong axial cords, fine spiral lines	Strong spiral keels
Additional autapo-morphies	—	Spiral sculpture increasing, axial sculpture decreasing in strength with growth	—	—	Axials form elevated projections on periphery of base	—	Narrow umbilicus, axial colour bands on shoulder	Intersec-tions of spirals and axials form elevated points	—
Distribution	Honshu, Ize	S of Amami Islands	IP to Okinawa	Okinawa to Honshu	IP to Okinawa	IP to Okinawa	IP to Okinawa	IP to Okinawa	Okinawa to S Hokkaido
Illustrations	this study, Sasaki, 1998: fig. 45a–c); Fukuda (1993: pl. 4, fig. 17); Okutani and Hasegawa (2000: pl. 38, figs 7a,b)	this study, Okutani and Hasegawa (2000: pl. 38, figs 6a,b	Geiger and Jansen (2004b: figs 21–23)	Okutani and Hasegawa (2000: pl. 38, fig. 9); Geiger (unpubl. data: SEM of types)	Geiger and Jansen (2004b: fig. 13)	Geiger and Jansen (2004b: figs 10–12, as *S. declinans*)	Geiger (2006a: figs 5–6)	Geiger and Jansen (2004b: figs 18–20)	Sasaki (2008: fig. 2F); Okutani and Hasegawa (2000: fig. 8); Geiger (unpubl. data: SEM of types)

Anatoma aupouria (Powell, 1937) from New Zealand shares the undulating sculpture on the base with *A. parageia*. The shoulder is ornamented with strong axial cords close to the suture in *A. aupouria* (only slightly stronger in *A. parageia*), and the base has distinct spiral lines in the adumbilical half (not present in *A. parageia*). Geiger and Jansen (2004a) provided additional details about *A. aupouria*.

Anatomids tend to occupy deeper habitats and are rarely collected in the intertidal or shallow subtidal. The only other known shallow water species is *Anatoma pseudoequatoria* Kay, 1979, from Hawaii. Although *A. parageia* was not collected alive in the intertidal, the relatively large number of empty shells, several in excellent state of preservation, suggests that it occupies a very shallow water habitat. It is unlikely that this may be due to a rare storm event because, firstly the species has been collected there repeatedly, and secondly, no other anatomids known to occur in deeper water of Sagami Bay were collected.

Discussion

The present study demonstrates that even such a well-studied area as Japan, which has recently received one of the best faunal treatments anywhere in the world (Okutani 2000), new species of micromolluscs can be discovered, even in the intertidal of a world-famous locality such as Sagami Bay (cf. Kuroda *et al*. 1971).

The two Japan-mainland scissurellids were figured by Sasaki (1998) and the two *Sinezona* species described herein were previously figured by Fukuda (1993) and Okutani and Hasegawa (2000). While the descriptions of the two species agree with the figures and with the species described here, the distributional pattern indicated by Okutani and Hasegawa (2000) seem to have been switched. *Sinezona* sp. 1 of Okutani and Hasegawa (2000) = *S. milleri* n. sp. is placed at Honshu and Izu Islands, whereas it in fact occurs in more tropical waters. Conversely, *Sinezona* sp. 2 of Okutani and Hasegawa (2000) = *S. costulata* is reported by Okutani and Hasegawa (2000: 37) from “South of Amami Islands” [~28.5˚N], i.e., the tropics, it is in fact a temperate species we collected on Honshu in Sagami Bay (35.2˚N) and around Tosa (33.5˚N) in large numbers and alive.

Anatoma parageia represents a rare case of an intertidal or very shallow subtidal anatomid. Examination of world-wide collection data clearly show that Scissurellidae are more commonly encountered in shallow water, while Anatomidae are more common from a depth of >100 m. Depth records of 4452 samples of Scissurellidae and Anatomidae were analyzed, based on the slightly expanded data-set of Geiger (2008a) for the geographic pattern analysis. One implicit assumption in our analysis is that the sampling procedure by itself does not favor one family over the other with depth. We are confident that no such systematic bias skews the available data, and that the utilization of over 50 different collection resources (see Geiger 2008a for details) balanced out any potential sorting or collecting bias.

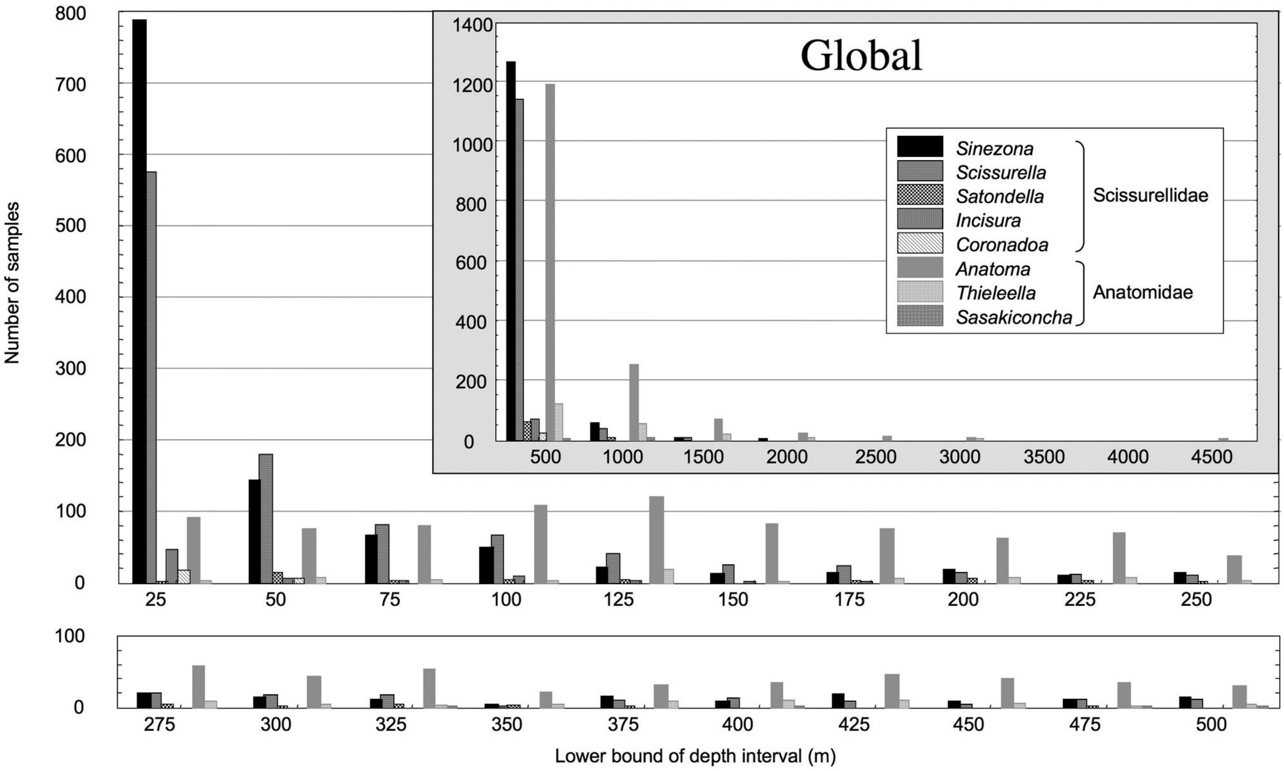

FIGURE 10. Depth records of 4452 Scissurellidae and Anatomidae lots. Insert bar graph shows overall exponential decline in available samples. Main bar graph shows more detailed examination of upper 500 m. Note switch in preponderance of families at 100–125 m. Sequence of genera from left to right as in key from top down.

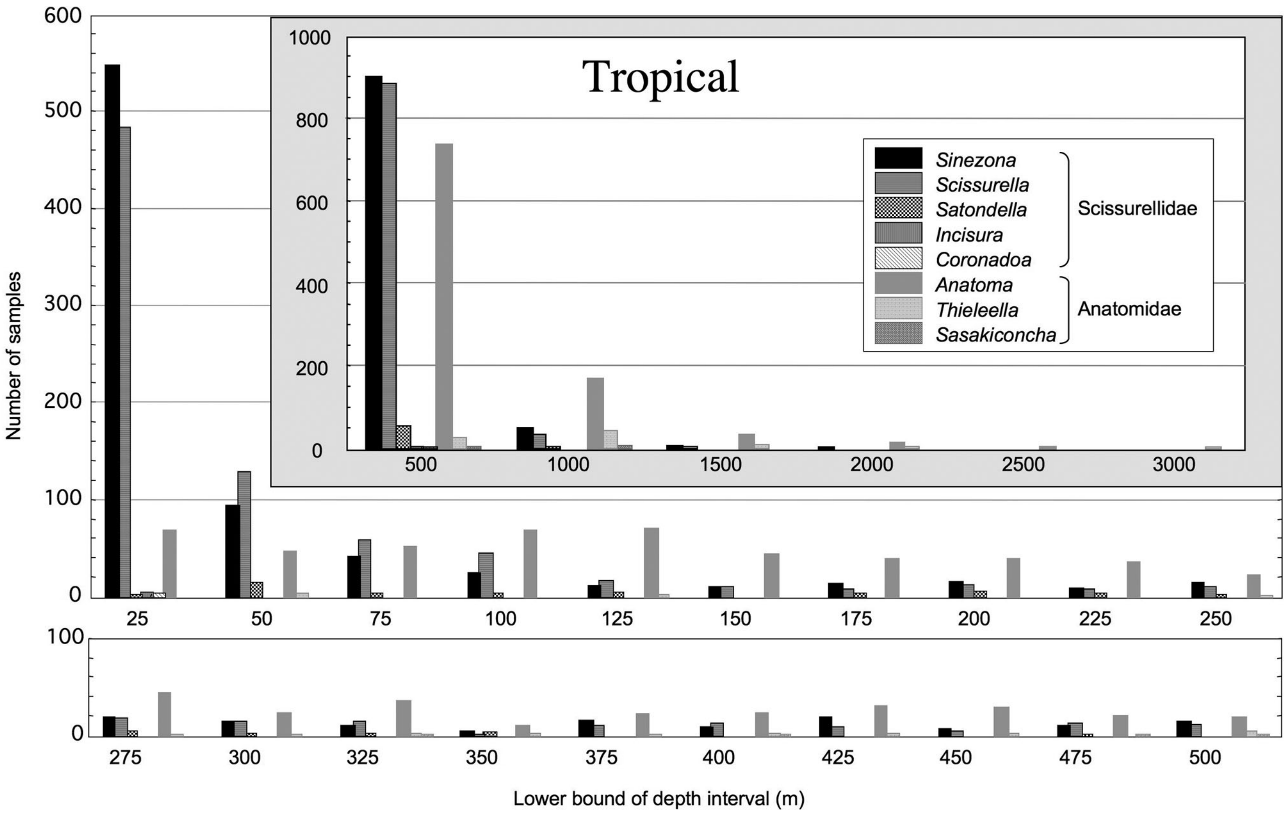

FIGURE 11. Same graph as in Figure 10, but restricted to tropical region (<30˚N/S).

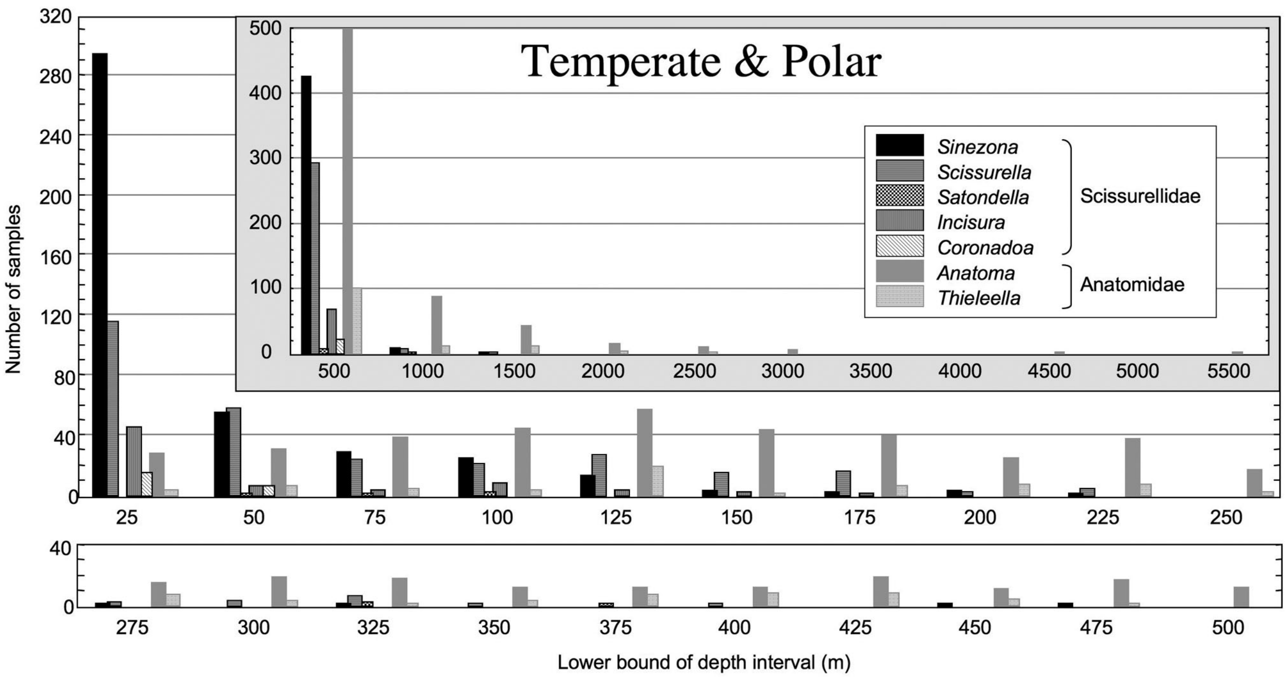

FIGURE 12. Same graph as in Figure 10, but restricted to temperate and polar regions (>30˚N/S). Switch in preponderance of families occurs at approximately 125 m.

At a coarse-grained level with depth intervals of 250 m the faunal switch occurs at 250 m, i.e., the classical shelf break. A more fine-grained analysis of the upper 500 m with depth intervals of 25 m showed, however, that the switch actually occurs at 100–125 m (Fig. 10).

Bouchet *et al*. (2008) pointed out, that the classic shelf concept with a shelf-slope transition at approximately 200–300 m does not apply to tropical settings. In the latter, there is already a faunal turnover at approximately 100–150 m with additional turnover points along the continental slope. To explore this observation, we executed separate analyses for the tropical corridor from 30˚N to 30˚S, and for the remainder of the globe encompassing the temperate and polar biomes.

All three analyses revealed more or less the same pattern (Figs 10–12). The switch of relative dominance occurs at approximately 100–125 m at the global level as well as in the tropical and temperate plus polar subsets. We could not detect any further turnover point at around 300 m in any of our analyses; the bar height from 200–500 m remains very similar. Only a slight decrease in overall sampling density can be noted, which reflects the increasing difficulty of sampling with increasing depth. This overall pattern is even clearer in the insert bar graph covering the entire depth range from the intertidal to the abyssal plain (see also Geiger 2008a for discussion).

Scissurellidae and Anatomidae seem not to fit either of the faunal turnover models with depth. While the classical shelf model would predict a switch at 200–300 m, here a consistent change at 100–125 m was detected. However, we were not able to find the differences in turnover in tropical vs temperate plus polar regions noted by Bouchet *et al*. (2008) either, as both show the turnover at identical depth. Accordingly, the depth distribution patterns found in these families remain to be explained.

The most likely explanation involves food availability and feeding preference. Scissurellidae seem to be more stenoecological with a narrow and shallow habitat preference, probably also tied to the availability of live plant matter. The radular pattern in Scissurellidae is quite fixed, with only minor modification of a common ground pattern. Anatomidae, on the other hand, show a wide depth range from the intertidal to the deep-sea plain. Recently, a number of surprisingly different anatomid radular patterns have come to light (Geiger 2006b, Geiger and Sasaki 2008; Sasaki *et al*. in press, Geiger unpubl. data) without any notable alteration in the shells, supporting the interpretation of Anatomidae as euryphagous.

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