Two New Species of Awalycaeus (Caenogastropoda: Cyclophoridae: Alycaeinae) from Kochi and Kumamoto Prefectures, Japan

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Abstract: Two new species in the cyclophorid subfamily Alycaeinae, Awalycaeus yanoshokoae Yano & Matsuda n. sp. and A. shiosakimasahiroi Yano, Matsuda & Nishi n. sp. are described from limestone areas in Hidaka-mura, Takaoka-gun, Kochi Prefecture and in Gyokuto-machi, Tamana-gun, Kumamoto Prefecture, respectively. Awalycaeus yanoshokoae n. sp. was firstly reported from fissure deposits in a limestone cave as an undescribed fossil species, but living individuals have since been found near the cave. It can be distinguished from other Awalycaeus species by its large shell, with sparser axial ribs from the earlier whorls to end of the sutural tube, and by its parietal lip being detached from the body whorl. Awalycaeus shiosakimasahiroi n. sp. was previously recorded as "A. akiratai", but it can be distinguished from the latter by having a non-reflexed outer lip margin, many axial ribs along the sutural tube, and a less expanded spire from the beginning of the sutural tube to the aperture.

Keywords: Awalycaeus, new species, land snail, limestone area, taxonomy, Japan

Introduction

The monotypic genus Awalycaeus was proposed by Kuroda (1951) for Awalycaeus abei Kuroda, 1951. Among three genera in the subfamily Alycaeinae in Japan, this genus is characterized by having a small and depressed shell with a very short region between the beginning of the sutural tube and the aperture, and a calcareous operculum that cannot be withdrawn into the aperture, like that of Cyclotus campanulatus Martens, 1865.

Two other species have subsequently been added to the genus, A. okamurai Azuma, 1980 and A. akiratai Minato, 1982 (Azuma, 1980; Minato, 1982). However, the former was later transferred to the genus Cipangocharax Kuroda, 1943 (Azuma, 1982; Minato, 1982). Thus, only two species currently belong in Awalycaeus (Minato, 1988). Their distributions are restricted to Japan and particularly the island of Shikoku: A. abei is recorded from Tokushima and Kochi Prefectures, and A. akiratai from Ko’oge-jima Island in the Seto Inland Sea off Ehime Prefecture (Kuroda, 1951; 1963; Minato, 1982). They basically inhabit limestone areas (Minato, 1975; Minato, 1982; Tada, 2010) though with some exceptions (Abe, 1981).

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http://zoobank.org/urn:lsid:zoobank.org:pub:2D600B12-C337-44F3-8201E6DB70CD
In 2009, fossil shells of a cyclophorid gastropod were collected from fissure deposits below the ground surface in Saruda-do Cave, which is located in Hidaka-mura, Kochi Prefecture (Kawase et al., 2012). This limestone cave is known for fossil land snails, which are rarely found in Japan. Kawase et al. (2012) regarded the cyclophorid to be an undescribed species of the genus *Awalycaeus* and thus to represent the second fossil species of Alycaeinae found in Japan after *Chamalycaeus okinawaensis* Uozumi, Yamamoto & Habe, 1979.

Motivated by this finding, one of the authors (SY) and Mrs. Shoko Yano visited a limestone area located 3 km east of Saruda-do Cave, and found live snails that looked similar to the fossil species (Yano, 2014). SY then also discovered live snails around Saruda-do Cave. Based on careful examination of the morphology of the new material and comparison with the fossil specimens, we concluded that they are conspecific and distinct from the other species in the genus, and therefore describe them herein as a new species.

In addition, we examined another *Awalycaeus* species occurring in Kumamoto Prefecture, Kyushu. It was firstly collected from Ōzu-machi, Kikuchi-gun (a non-limestone area) by Dr. Hiroshi Nishino of Kumamoto University (Yano, 2015), and later found in a limestone area at Gyokuto-machi, Tamana-gun by Mr. Masahiro Shiosaki and one of the authors (KN). It was tentatively identified as “*A. akiratadai*” (Shiosaki & Nishi, 2013; Shiosaki & Nishi, 2014a; Shiosaki & Nishi, 2014b). However, because the localities in Kyushu are situated distantly and discontinuously from the type and sole known locality of *A. akiratadai* (Ko’oge-jima Island, Ehime Prefecture, Seto Inland Sea), additional samples were collected in Kumamoto Prefecture and compared in detail with *A. akiratadai* from the type locality. We concluded that they are morphologically distinguishable, and describe them here as another new species.

### Materials and Methods

Specimens of *A. yanoshokoae* n. sp. were collected from a limestone area adjacent to Saruda-do Cave, Hidaka-mura, Takaoka-gun, Kochi Prefecture, from 23 March to 15 June, 2014. Those of *A. shiosakimasahiroi* were collected in a limestone area in Gyokuto-machi, Tamana-gun, Kumamoto Prefecture, on 28 April, 2014. Shells and opercula were dried after removing the soft parts. The soft parts were directly fixed and preserved in 99.5% ethanol. For comparison, fossil specimens identified by Kawase et al. (2012) as *Awalycaeus* sp. and preserved in the Mizunami Fossil Museum (MFM) were examined. Two other species in the same genus were also examined: *Awalycaeus abei* collected from Monobe, Kami, Kochi Prefecture, from July to October, 2012 and *A. akiratadai*, collected on Ko’oge-jima Island, Ehime Prefecture, on July 17, 2012. Type and voucher materials are deposited in the National Museum of Nature and Science, Tsukuba (NSMT).

Shell morphology was observed under a stereomicroscope. Measurements of the shell were made on digital images that were taken with an opto-digital microscope (Olympus DSX–100), with the aid of Adobe Photoshop®. The following dimensions were used for the analysis: Shell length (SL), Shell width (SW), and length of the sutural tube (STL). In addition, the number of axial ribs along the sutural tube (No. AR along tube) was counted. Diameter, width and papilla length of the operculum (OD, OW, and PL) were also measured. The radula of *A. yanoshokoae* n. sp. was extracted under a stereomicroscope, cleaned in diluted bleach, and rinsed in distilled water. The morphology of the radula and parts of the shell was observed with a scanning electron microscope (Miniscope, TM3030) with Au coating.

### Taxonomy

Family Cyclophoridae Gray, 1847  
Subfamily Alycaeinae Blanford, 1864
Two New Species of *Awalycaeus*

**Genus *Awalycaeus*** Kuroda, 1951

*Awalycaeus yanoshokoae* Yano & Matsuda *n. sp.*
(Figs 1A–I, 3A–B, 4A)

*Awalycaeus* sp. – Kawase et al., 2012: 85–88.

**Type material:** Holotype, NSMT-Mo 78962 (Fig. 1A–G), March 28, 2014, extended region of limestone area of Saruda-do Cave, Okina, Hidaka-mura, Takaoka-gun, Kochi Prefecture (type locality); 6 paratypes, NSMT-Mo 78963–78964, from March 23–28, 2014; 3 paratypes, NSMT-Mo 78965, June 15, 2014, Saruda; 3 paratypes, MFM-110112–110114, May 27, 2009, Saruda (all in Okina, Hidaka-mura, Takaoka-gun, Kochi Prefecture).

**Description:** Shell large for genus (SW = 3.83–4.47 mm; Table 1), broader than tall, depressed conic in outline, yellowish white in color (Fig. 1A). Whorls 3.5 in number (holotype), well rounded,

![Fig. 1. *Awalycaeus yanoshokoae* *n. sp.* A–G. Holotype, NSMT-Mo 78962, SL = 2.17 mm; A–D, apical (A), basal (B), apertural (C) and lateral (D) views of shell; E–G, lateral (E), inner (F) and outer (G) views of operculum. H–I. Fossil specimen, paratype, MFM-110112, SL = 2.22 mm; apical (H) and apertural (I) views of shell.](image-url)
Table 1. Shell dimensions for four *Awalycaeus* spp.

<table>
<thead>
<tr>
<th></th>
<th><em>Awalycaeus yanoshokoae</em> n. sp.</th>
<th><em>A. shiosakimasahiroi</em> n. sp.</th>
<th><em>A. abei</em></th>
<th><em>A. akiradai</em></th>
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<tbody>
<tr>
<td><strong>Shell</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SL (mm)</td>
<td>2.02 ± 0.16 1.78 – 2.22</td>
<td>1.91 ± 0.11 1.79 – 2.06</td>
<td>1.70 ± 0.08</td>
<td>1.92 ± 0.06</td>
</tr>
<tr>
<td>SW (mm)</td>
<td>4.17 ± 0.21 3.83 – 4.47</td>
<td>3.52 ± 0.21 3.26 – 3.76</td>
<td>3.57 ± 0.17</td>
<td>3.63 ± 0.15</td>
</tr>
<tr>
<td>SW/SW</td>
<td>0.48 ± 0.03 0.44 – 0.55</td>
<td>0.54 ± 0.01 0.53 – 0.55</td>
<td>0.48 ± 0.01</td>
<td>0.53 ± 0.03</td>
</tr>
<tr>
<td>STL (mm)</td>
<td>0.94 ± 0.07 0.85 – 1.08</td>
<td>0.95 ± 0.07 0.84 – 1.00</td>
<td>0.80 ± 0.14</td>
<td>0.66 ± 0.07</td>
</tr>
<tr>
<td>No. AR along tube (a)</td>
<td>32.8 ± 2.53 29 – 38</td>
<td>28.0 ± 3.16 25 – 32</td>
<td>31.0 ± 4.47</td>
<td>22.1 ± 2.12</td>
</tr>
<tr>
<td>(a)/STL</td>
<td>34.5 ± 1.81 31.8 – 37.8</td>
<td>29.7 ± 4.25 25.0 – 34.4</td>
<td>39.0 ± 4.59</td>
<td>33.5 ± 3.63</td>
</tr>
<tr>
<td>No. protoconch whorl</td>
<td>1.7 ± 0.06 1.6 – 1.8</td>
<td>1.8 ± 0.06 1.7 – 1.8</td>
<td>1.8 ± 0.04</td>
<td>1.7 ± 0.08</td>
</tr>
<tr>
<td>No. whorl</td>
<td>3.6 ± 0.11 3.5 – 3.8</td>
<td>3.6 ± 0.15 3.4 – 3.7</td>
<td>3.6 ± 0.11</td>
<td>3.6 ± 0.14</td>
</tr>
<tr>
<td><strong>Operculum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OD (mm)</td>
<td>1.23 ± 0.06 1.12 – 1.29</td>
<td>1.06 ± 0.03 1.01 – 1.09</td>
<td>1.10 ± 0.07</td>
<td>1.09 ± 0.04</td>
</tr>
<tr>
<td>OW (mm)</td>
<td>0.31 ± 0.05 0.24 – 0.39</td>
<td>0.30 ± 0.02 0.28 – 0.33</td>
<td>0.27 ± 0.04</td>
<td>0.35 ± 0.05</td>
</tr>
<tr>
<td>PL (mm)</td>
<td>0.10 ± 0.02 0.07 – 0.13</td>
<td>0.07 ± 0.02 0.05 – 0.09</td>
<td>0.05 ± 0.01</td>
<td>0.10 ± 0.03</td>
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gradually increasing in diameter towards aperture. Protoconch of 1.7 whorls, smooth, yellowish white to pale red in color. Demarcation between protoconch and teleoconch indistinct but slightly ridged. Teleoconch of 1.8–2.0 whorls, ornamented with densely set axial ribs. Sutural tube long (STL = 0.85–1.08 mm), running backwards along suture. Axial ribs less distinct on earlier whorls, becoming sharper and denser along sutural tube, where color also becomes paler. Umbilicus widely perforate, umbilical walls visible inside (Fig. 1B). Aperture round in shape, proscincline (Fig. 1D), outer margin thin, sharp, expanded and slightly reflexed; inner margin almost simple. Parietal lip detached from body whorl (Figs 1C, 3B). In apical view, region between beginning of sutural tube and aperture slightly expanded with no constriction (Fig. 1A). In lateral view, basal region of body whorl constricted just anterior to beginning of sutural tube.

Operculum thick, calcareous, orbicular (OD = 1.12–1.29 mm, OW = 0.24–0.39 mm); inner side covered by thin chitinous membrane, glossy, whitish yellow in color, with circular ridge at periphery and nipple-like elevation at center, resembling collapsed caldera-topped mountain (Figs. 1E, F). Outer side multispiral, covered by horny membrane (Fig. 1G).

Radula of typical taenioglossate type, composed of one rachidian tooth flanked by one pair of lateral and two pairs of marginal teeth, with formula 2 + 1 + 1 + 1 + 2 (Fig. 3A). Lateral teeth longer than rachidian tooth, with one large triangular main denticle flanked by one smaller cusp at outer side and two cusps at inner side. Inner and outer marginal teeth with four pointed cusps.

**Habitat:** Most individuals were found in leaf litter of bamboo forest where limestone fragments are scattered.

**Etymology:** The specific name refers to Mrs. Shoko Yano, who collected the first live individuals.

**Remarks:** In comparison between fossil and extant specimens, there is no significant difference in shell size (SW = 3.83–4.47 mm [extant specimens, n = 10] and 4.00–4.45 mm [fossil shells, n = 3]) (Fig. 1A–D, H–I). In both fossil and extant specimens axial ribs are evenly spaced from the earliest teleoconch whorl to the sutural tube but they become very dense along the sutural tube to the aperture. In addition, the parietal lip of the extant specimens was detached from the body whorl, as in the fossil specimens. Although there is a slight difference in the coloration of the shell, the region along the sutural tube being paler only in extant specimens, this can be due to fossilization. Based on these similarities, the extant and fossil specimens are considered to be conspecific.

Kawase et al. (2012) estimated the age of the fossil land snail community in the Saruda-do Cave to be 32,750 ± 140 yr B. P. based on Carbon-14 dating analysis of a vertebrate bone in the same layer, and mentioned that the majority of the fossil land snails in the cave are identifiable as...
Recent species.

The new species is similar to *A. abei* and *A. akiratadai* in general shape. However, as Kawase *et al.* (2012) suggested, *A. abei* can be distinguished from the new species by having a smaller shell (SW = 3.37–3.83 mm [abei, n = 5] vs. 3.83–4.47 mm [yanoshokoae, n = 10]) and denser axial ribs from the earlier whorl to the sutural tube (Fig. 4). *Awalycaeus abei* can also be distinguished by its parietal lip adhering to the penultimate whorl, its less prosocline outer lip margin, and a shorter region between the beginning of the sutural tube and the aperture. *Awalycaeus akiratadai* differs from the new species by its smaller shell (SW = 3.32–3.76 mm [akiratadai, n = 7] vs. 3.83–4.47 mm [yanoshokoae, n = 10]) and coarser axial ribs in the region along the sutural tube (No. AR along tube = 19–26 [akiratadai, n = 7] vs. 29–38 [yanoshokoae, n = 10]). The operculum of the new species is similar in shape to those of the other two species of *Awalycaeus* (Fig. 4).

Radula morphology of the Alycaeinae has been examined for several species (Venmans, 1956; Kano & Goto, 1996; Yano *et al.*, 2013). The general morphology of the radula in the present new species is identical to those of previously reported Japanese species in the genera *Chamalycaeus* and *Cipangocharax*, whereas it differs from species in *Alycaeus*, which have additional cusps on outer marginal tooth (*Al. conformis* Fulton, 1902), seven cusps on the rachidian tooth (*Al. thieroti* de Morgan, 1885) or five cusps on the lateral and inner marginal teeth (*Al. kapananensis* de Morgan, 1885) (Venmans, 1956).

*Awalycaeus shiosakimasahiroi* Yano, Matsuda & Nishi n. sp.

(Figs 2A–G, 3C–D, 4B)

**Type material:** Holotype, NSMT-Mo 78959 (Fig. 2), April 28, 2014; 3 paratypes, NSMT-Mo 78960, April 28, 2014; 1 paratype, NSMT-Mo 78961, August 2, 2015. All specimens were collected from Mt. Konoha, Gyokuto-machi, Tamana-gun, Kumamoto Prefecture, Japan (type locality).

**Description:** Shell small for genus (SW = 3.26–3.76 mm; Table 1), broader than long, depressed conic in form, but relatively long for genus (SL/SW = 0.53–0.55), yellowish white to pale pink in color (Fig. 2A). Whorls 3.7 in number (holotype), gradually increasing in diameter towards aperture. Protoconch of 1.8 whorls, smooth, yellow to pale red in color. Demarcation between protoconch and teleoconch whorls visible but indistinct (Fig. 3C). Teleoconch of 1.8–1.9 whorls, ornamented with densely set axial ribs (Fig. 2C). Axial ribs ambiguous and dense on earlier whorls, but becoming sharper and sparser on adapical whors, except for region along sutural tube where ribs are more densely set (No. AR along tube = 25–32). Sutural tube long (STL = 0.84–1.00 mm), running backwards along suture. Umbilicus widely perforate (Fig. 2B). Aperture round in shape; outer margin thick, inner one almost simple. Parietal lip slightly detached from penultimate whorl (Figs 2C, 3D). Aperture slightly prosocline in lateral view (Fig. 2D).

Operculum thick, calcareous, orbicular (OD = 1.01–1.09 mm, OW = 0.28–0.33 mm), and doubly lapped (Fig. 2E). Inner side covered by thin chitinous membrane, glossy, whitish yellow in color, and with small torus-shaped papilla at center (Fig. 2F). Outer side multispiral, covered by horny membrane (Fig. 2G).

**Distribution and habitat:** The present species is usually found in limestone areas covered with fallen leaves. In addition to the type locality, this species was recorded from Izumi-machi, Yatsushiro City (Shiosaki & Nishi, 2014a), Misato-machi, Shimomashiki-gun (Shiosaki & Nishi, 2014b), and Mt. Kitamuki, Ōzu-machi, Kikuchi-gun (Kumamoto Prefecture, 2014; Yano, 2015), all in Kumamoto Prefecture. Ōzu-machi is the sole non-limestone area among previously known localities.

**Etymology:** The specific name is dedicated to Mr. Masahiro Shiosaki, who discovered the present new species at the type locality.

**Remarks:** The present new species is most similar to *A. akiratadai* in shell size (SW =
Fig. 2. *Awalycaeus shiosakimasahiroi* n. sp., holotype, NSMT-Mo 78959, SL = 1.91 mm. A–D. Apical (A), basal (B), apertural (C) and lateral (D) views of shell. E–G. Lateral (E), inner (F) and outer (G) views of operculum.

Fig. 3. *Awalycaeus yanoshokoae* n. sp., and *A. shiosakimasahiroi* n. sp., scanning electron micrographs of radula and shells. A–B. *Awalycaeus yanoshokoae* n. sp.; A, radula, paratype, NSMT-Mo 78962; B, aperture, paratype, NSMT-Mo 78965c. C–D. *Awalycaeus shiosakimasahiroi* n. sp.; C, apical view of protoconch, paratype, NSMT-Mo 78961, allowhead indicates a demarcation between protoconch and teleoconch whorls; D, aperture, paratype, NSMT-Mo 78961.
Two New Species of Awalycaeus

3.26–3.76 mm [shiosakimasahiroi, n = 4] vs. 3.32–3.76 mm [akiratadai, n = 7]) and in the sutural tube being further from the aperture relative to other species in the genus. However, the latter can be distinguished by having sharper and more reflexed outer lip margin, fewer axial ribs along the sutural tube (No. AR along tube = 25–32 [shiosakimasahiroi, n = 4] vs. 19–26 [akiratadai, n = 7]), and a more expanded spire from the beginning of the sutural tube to the aperture. 

A. yanoshokoae n. sp. resembles the present new species in the parietal lip being detached from the body whorl, but can be distinguished by its larger size and the downward-pointing aperture.

Discussion

Four species are now recognized in the genus Awalycaeus: A. abei, A. akiratadai, A. yanoshokoae n. sp. and A. shiosakimasahiroi n. sp. (Kuroda, 1951; Minato, 1982; present study). Among them, A. abei shows a relatively wide geographical distribution in Tokushima and Kochi Prefectures, but the other three are so far restricted to very limited areas. Although A. yanoshokoae n. sp. is distributed in a small area adjacent to the distribution area of A. abei, it can be clearly distinguished from not only A. abei but also the other two species in morphological features, including its large size and coarser sculpture, as discussed above. On the other hand, A. akiratadai and A. shiosakimasahiroi n. sp. are distributed in geographically remote areas, on a small island in the Seto Inland Sea and in Kumamoto Prefecture in Kyushu, respectively. The distribution area of A. shiosakimasahiroi n. sp. is especially distant from those of other species, and it is possible that undiscovered populations of this or related species are present between these localities, probably in limestone areas (Yano et al., 2013). In order to understand the relationship between the distribution patterns of Awalycaeus spp. and the geological history, additional surveys in these areas and
phylogeographic studies are needed.

Acknowledgements

We would like to thank Mr. Masahiro Shiosaki for providing us with information and accompanying us to the sampling site. Thanks are also due to Dr. Yusuke Ando of Mizunami Fossil Museum for his assistance with examination of specimens, Dr. Hiroshi Nishino of Kumamoto University for providing us with meaningful information and for his assistance with examination of specimens, and Dr. Tatsuo Hamano and Mr. Minoru Saito of Tokushima University for valuable comments on the manuscript. One of the authors (SY) owes gratitude personally to Ms. Shoko Yano, in supporting his study of land snails.

References


(Received February 2, 2016 / Accepted April 12, 2016)
Two New Species of *Awalycaeus*

高知県猿田洞周辺および熊本県で発見されたツプラマシオイ属
（新生腹足上目ムシオイガイ亜科）の2新種

矢野重文・松田春業・西 邦雄・川瀬基弘・早瀬善正

要 約

高知県日高村の猿田洞に流入した裂縫堆積物よりツプラマシオイ属の化石個体が発見され、サルダツプラマシオイとして報告されたことをきっかけに、猿田洞を形成している石灰岩層の延長部を調査したところ、同属の生痕が発見され、その後猿田洞周辺でも生痕が見つかった。詳しく調べた結果、殻の特徴が化石個体と一致し、同一種であることが判明した。本種は既知種とは形態的に区別できたため、新種として記載した。また、九州の熊本県北部の玉名郡の石灰岩地において見つかっていたツプラマシオイ属の一種を確認したところ、これまで同定されてきたダリソアツプラマシオイとは形態的に区別できると判断されたため、新種として記載した。

*Awalycaeus yanoshokoae* Yano & Matsuda n. sp. サルダツプラマシオイ（新種）

殻長2.17 mm、殻幅4.32 mm（ホロタイプ）。同属では大型。殻は扁平な円錐形で黄白色を呈し、後生殻に成長脈が認められる。係器は虫構管基端の前方で螺層から離れ、殻底がくびれた後、下方に曲がって殻口を形成する。殻口は円く、殻口縁は二重になり、外側は外方に広がってやや反曲する。殻は石灰質で、直径1.2 mmの円形で、内側はキチン質の膜で覆われ光沢を持ち、中央部には複式火山のような形状の起伏（周辺が外輪山のように高まり、中央部にかけてはやや低く、さらに中央には火山丘のような高まりがある）が見られる。外側は多旋型で角質の膜で覆われる。本種は同属の他種に比べて殻が大きく、成長脈は虫構管基端の前方で螺層から離れる。殻口は円く、殻口縁は二重になり、外側は肥厚する。係器は虫構管基端の前方で螺層から離れる。殻は石灰質で、直径1.0 mmの円形で、内側はキチン質の膜で覆われ光沢を持つ。中央部はサルダツプラマシオイと同様の、それよりもやや小さな起伏が見られる。一方、外側は多旋型で、角質の膜に覆われる。本種は従来タダツプラマシオイと同種とされてきたが、タダツプラマシオイに比べて殻口がおり反曲しないこと、虫構管基の成長脈がより多く現れること、殻口にかけて螺層がやや細くなる傾向があることにより区別できる。タイプ産地は高知県日高村沖。

*Awalycaeus shiosakimasahiroi* Yano, Matsuda & Nishi n. sp. クマモトツプラマシオイ（新種・新称）

殻長1.91 mm、殻幅3.57 mm（ホロタイプ）。殻は円錐形で黄白色〜やや赤褐色があった白色を呈する。同属ではやや殻長が長い。後生殻には成長脈が認められ、最初は密に現れるが徐々に粗くなり、虫構管基端の前方で螺層から離れる。殻は石灰質で、直径1.0 mmの円形で、内側はキチン質の膜で覆われ光沢を持ち、中央部にはサルダツプラマシオイと同様の、それよりもやや小さな起伏が見られる。一方、外側は多旋型で、角質の膜に覆われる。本種は従来タダツプラマシオイと同種とされてきたが、タダツプラマシオイに比べて殻口がより反曲しないこと、虫構管基の成長脈がより多く現れること、殻口にかけて螺層がやや細くなる傾向があることにより区別できる。タイプ産地は熊本県玉名郡玉東町。