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The first records of two species of precious coral (Octocorallia: Coralliidae) from the Ryukyu Archipelago

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Abstract. Two specimens, one each of two species of precious coral collected from the Ryukyu Archipelago, are recorded here for the first time, and identified as *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903) and *Pleurocorallium inutile* Kishinouye, 1902, by applying systematics proposed by recent molecular studies (Ardila et al. 2012; Figueroa & Baco 2014; Tu et al. 2015b). The type locality of *P. inutile* is Kochi Prefecture and that of *H. sulcatum* is Chiba Prefecture, and recently both species have been recorded from Taiwan (Tu et al. 2012). However, until now there have been no other records from any other location for these two species.

Introduction

Species in the family Coralliidae (Octocorallia: Alcyonacea) are known as precious coral because their colorful and hard axial skeletons have been valuable for use as jewelry, medicine, and other products for at least 5,000 years. There are 38 species in Corallidae, including 29 species from the Pacific region (Nonaka & Muzik 2012) and 9 species from the Atlantic and Mediterranean (Tu et al. 2015a).

In Japanese waters, 9 species have been described (Kishinouye 1902; 1903a; 1903b; 1904a; b; Nonaka et al. 2012), but no species were collected from the Ryukyu Archipelago in the original descriptions. Grigg (1974) noted "commercial species of *Corallium*" in the western Pacific (Japan, Okinawa, Taiwan, Bonin Islands) but he did not record scientific names or precise locations. According to Kosuge (1987), fishery activities began in the Okinawa region in 1924, and continued until after World War II, but apparently there were no remarkable harvests. The Okinawan fishermen called the three species they harvested as "Aka-sango" (*Corallium japonicum*), "Momoiro-sango" (*Pleurocorallium elatius*), and "Shiro-sango" (*P. konojoi*), but no formal taxonomic publications were made. The first publication on precious corals collected from Okinawan waters that included scientific identifications was a display record (*Corallium japonicum, Pleurocorallium elatius, P. konojoi,* and *Pleurocorallium* sp.) in the Okinawa Churaumi Aquarium (Nonaka et al. 2006).

In this study, two specimens, one each from Tsukenjima Island and Tanegashima Island are identified as *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903) and *Pleurocorallium inutile* Kishinouye, 1902, respectively. They are the first records of these species in the Ryukyu Archipelago.

Material and methods

In October 1982, one specimen collected by the second author (K. Muzik) from Tsukenjima Is. (Fig. 1), near SE Okinawa Is. was labelled as *Corallium sulcatum,* and preserved in the Smithsonian Institution (USNM 76105). In November 2007, a specimen of Coralliidae off Tanegashima Is. (Fig. 1), northern Ryukyus, Japan, was preserved in Okinawa Churaumi Aquarium (OCA-Cn20071115-016).

In this study, the specimens were examined using traditional morphological characters. The specimens were observed by naked eye and digital microscope (Keyence VHX), and measurements of colony size, diameter of branch section, diameter of autozooids, and thickness of coenenchyme, etc., were made using measurement software accessorized with Keyence VHX. Small samples of coenenchyme were removed from some colony parts (anthocodia, pharynx, coenenchymal mounds, branch tip, base) for observation of the sclerites. For scanning electronic microscope examination, sclerites and axis were separated and cleaned using 5 % sodium hypochlorite solution (household bleach), and details of axial surface and sclerites were observed by Keyence VE–8800. Important taxonomic characters such as polyp dimensions, coenenchyme thickness, and sclerite sizes were measured as many times as possible. Only the size range is presented in the descriptions. Statistical data (average and standard deviation) is reported in respective tables. The sclerites were classified according to standard taxonomic convention (Bayer 1956; Bayer et al. 1983; Nonaka et al. 2012), photographed by SEM, and length and widths measured with the SEM accessory software.

For most of the twentieth century, the family Coralliidae contained only one genus, *Corallium* Cuvier, 1798 [type species: *Madrepora rubra* Linnaeus, 1758], but Bayer & Cairns (2003) divided

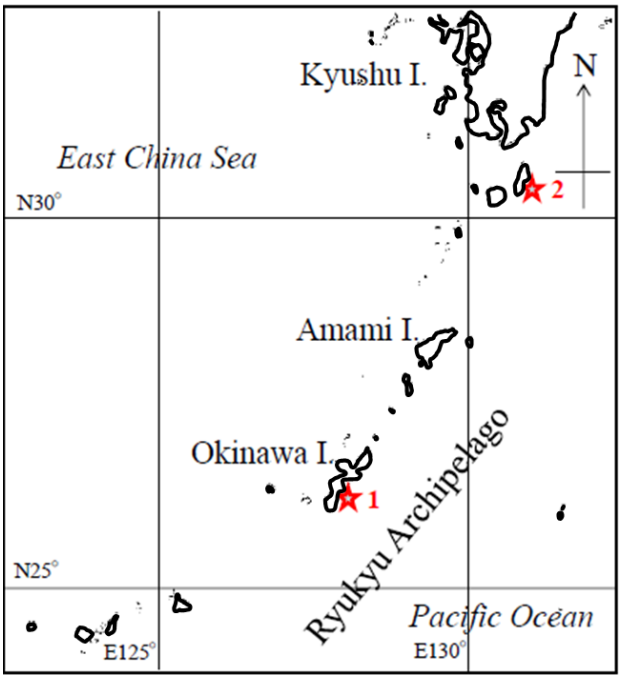

Fig. 1. Sampling sites. Red star 1 indicates Tsukenjima Is. (USNM 76105) and red star 2 indicates Tanegashima Is. (OCA-Cn20071115-016).
図1. 採集場所. 赤星印1は津堅島 (USNM 76105), 赤星印2は種子島 (OCA-Cn20071115-016) を示す.

the family into two genera, *Corallium* and *Paracorallium* Bayer & Cairns, 2003 [type species: *Corallium tortuosum* Bayer, 1956], based on aspects of axial morphology (mainly, presence or absence of beaded pits). Recently, Ardila et al. (2012), using molecular analyses, recognized *Paracorallium* as a junior synonym of *Corallium* and proposed to use the genus *Hemicorallium* Gray, 1867, for species with long rod sclerites, cylindrical autozooid mounds and smooth axes. As well, Figueroa & Baco (2014) concluded that *Paracorallium* should be subsumed into *Corallium* and the genus *Pleurocorallium* Gray, 1867 was resurrected. Tu et al. (2015b) revised the three genera of Coralliidae, *Corallium*, *Hemicorallium* and *Pleurocorallium,* which now consist of 7, 16 and 14 species respectively.

The list below summarizes their hypotheses (the Latin names written in bold type are type species of each genus), with new species, *Pleurocorallium occultum*, n. comb. described by Tu et al. (2015a) from the Atlantic.

Genus *Corallium* Cuvier, 1798; ***C. rubrum* (Linnaeus, 1758)**, *C. japonicum* Kishinouye, 1903, *C. medea* Bayer, 1964, *C. nix* Bayer, 1996, *C. salomonense* (Thomson & Mackinnon, 1910), *C. stylasteroides* Ridley, 1882 and *C. tortuosum* Bayer, 1956. (7 species).

Genus *Hemicorallium* Gray, 1867; ***H. tricolor* (Johnson, 1898)**, *H. abyssale* (Bayer, 1956), *H. bathyrubrum* (Simpson & Watling, 2011), *H. bayeri* (Simpson & Watling, 2011), *H. boshuense* (Kishinouye, 1903), *H. ducale* (Bayer, 1955), *H. halmaheirense* (Hickson, 1907), *H. imperiale* (Bayer, 1955), *H. laauense* (Bayer, 1956), *H. maderense* (Johnson, 1898), *H. niobe* (Bayer, 1964), *H. regale* (Bayer, 1956), *H. reginae* (Hickson, 1907), *H. sulcatum* (Kishinouye, 1903), *H. taiwanicum* (Tu, Dai & Jeng, 2012) and *H. variabile* (Thomson & Henderson, 1906). (16 species).

Genus *Pleurocorallium* Gray, 1867; ***P. secundum* (Dana, 1846)**, *P. borneense* (Bayer, 1950), *P. carusrubrum* (Tu, Dai & Jeng, 2012), *P. elatius* Ridley, 1882, *P. gotoense* (Nonaka, Muzik & Iwasaki, 2012), *P. inutile* Kishinouye, 1902, *P. johnsoni* (Gray, 1860), *P. kishinouyei* (Bayer, 1996), *P. konojoi* (Kishinouye, 1903), *P. niveum* (Bayer, 1956), *P. occultum* (Tu, Altuna & Jeng, 2015), *P. porcellanum* (Pasternak, 1981), *P. pusillum* (Kishinouye, 1904), *P. thrinax* (Bayer & Stefani, 1996), and *P. uchidai* (Nonaka, Muzik & Iwasaki, 2012). (15 species).

Gray (1867) distinguished *Corallium* and his two genera, *Hemicorallium* and *Pleurocorallium*, by the characters of the shape and distribution of the coenenchymal mounds covering the autozooids. For genus *Corallium*; the mounds are slightly elevated from the surface, scattered on all sides of the branches, while for genus *Pleurocorallium*; the mounds are scarcely elevated, confined to one side, and for genus *Hemicorallium*; the mounds are prominent cylindrically, clustered on one side. According to Gray's diagnosis, the present specimen, OCA-Cn20071115-016 belongs to *Corallium* as there are hemispherical mounds on all sides of the colony (Fig. 10). A contrary example is *C. japonicum*, with its hemispherical mounds distributed on one side, thus belonging to *Pleurocorallium*. For avoid such confusion, Tu et al. (2015b) suggested redefining the diagnosis of the genera as follows: genus *Corallium*; the axis with raindrop-shaped pits, with strong longitudinal grooves, 8-radiate sclerites dominant, while for genus *Pleurocorallium*; the autozooids retractable into hemispherical mounds, and genus *Hemicorallium*; the mounds prominent cylindrically, composing non-retractile autozooids, axis smooth.

In this study, we have applied the new systematic of Tu et al. (2015b) as above and identified the specimens using these generic names.

Abbreviations are as follows: OCA: Okinawa Churaumi Aquarium, Okinawa, Japan; USNM: National Museum of Natural History, Smithsonian Institution, Washington, USA.

Results

***Hemicorallium* cf. *sulcatum* (Kishinouye, 1903)**
(Figs. 2–8, Table 1, 2)

Material examined. USNM 76105, Okinawa, off Tsukenjima Is., 800m, given to K. Muzik by a fisherman, October 5, 1982. Dry.

Description. Colony form. The specimen is an almost whole colony with a holdfast. Two main stems arise from the holdfast but some branch tips are missing (Fig. 2). The colony is about 100 mm tall and 90 mm wide, branched in almost one plane, with irregular angles of branching. Branches taper to sharp tips and there are no anastomoses. The diameter of the base of the colony is about 25 mm, that of the two main stems is about 10 mm each and the thinnest branch tip is 1 mm in diameter (Fig. 3). Branch cross-sections are rounded.

Polyps. Autozooids are distributed on one side of the colony (Fig. 3). They are retracted into the coenenchyme beneath tall mounds, 1.01–1.73 mm in diameter and 0.80–1.35 mm in height (Fig. 4, Table 1). The distance between autozooids (from center to center) is 1.91–4.06 mm on the twig tips (Table 1), but they are further apart at the base. Siphonozooids

Fig. 2. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. Entire specimen. Scale bar is 5 cm, scale divisions 1.0 mm.
図 2. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. 群体全体を示す．スケールは長さ 5 cm，目盛は 1.0 mm.

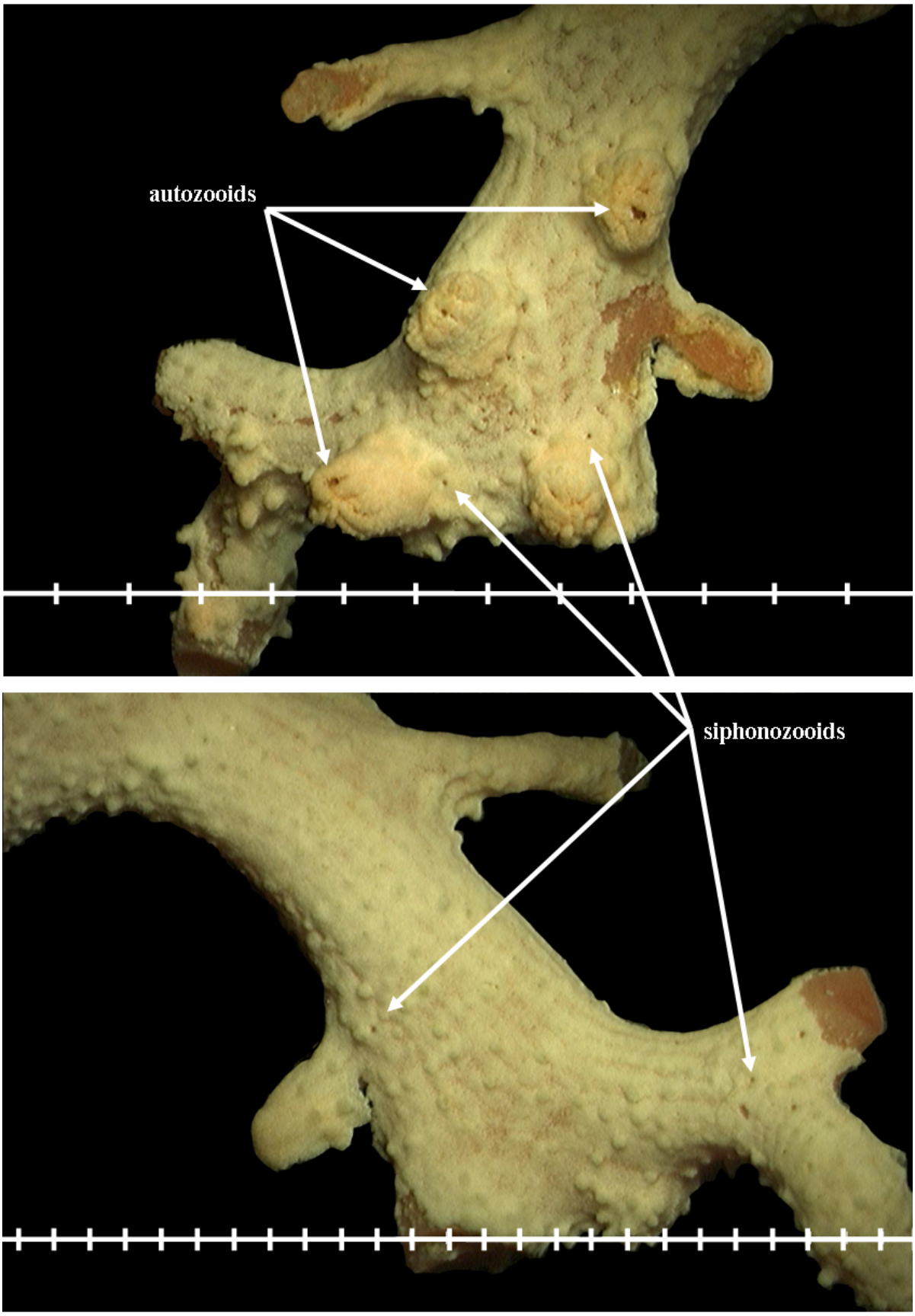

Fig. 3. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. Detail of surface on opposite sides of branch (above and below). Scale divisions are 1.0 mm (above) and 0.5 mm (below).
図 3. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. 群体末端部の詳細. 同じ個所を両面から撮影. スケール目盛は 1.0 mm (上) と 0.5 mm (下) .

Fig. 4. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. Detail of autozooid showing sclerites of anthocodium. Scale divisions are 0.5 mm.
図 4. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. 通常ポリプ先端部の詳細. スケール目盛は 0.5 mm.

are small pits 0.03–0.08 mm in diameter (Table 1), invisible to the naked eye, and distributed randomly all over the colony, 0.35–2.40 mm apart (Fig. 3, Table 1).

Axis. The surface of the axis is almost smooth, indistinctly longitudinally grooved at 0.23–0.35 mm intervals (Table 1), and covered with minute tubercles ornamented with thorny projections (Fig. 6). Pits are absent beneath the autozooids. The axial skeleton has two or three burrows (about 2 mm wide, 5–10 mm long) on each branch tip, likely caused by commensal worms (Fig. 5).

Coenenchyme. Part of the holdfast is damaged and the coenenchyme is missing (Fig. 2). The coenenchyme is only about 0.1 mm thick. There are distinct protuberances 0.15–0.24 mm in diameter (Table 1) on the both sides of the colony, tending to line up with the axial grooves (Fig. 3).

Color. The dry coenenchyme is pale pinkish white (Figs. 1–5). The axis appears slightly deeper pink in color, but the holdfast is almost white in color (Figs. 1, 3).

Shape and size of sclerites (Fig. 7, Table 2). The anthocodia contain mainly 8-radiates 0.056–0.084 mm long and 0.035–0.044 mm wide, rods 0.059–0.127 mm long and 0.021–0.037 mm wide, and rare double-clubs and 7-radiates (Fig. 7A). Pharyngeal sclerites are mainly 8-radiates 0.047–0.093 mm long and 0.030–0.045 mm wide, double-clubs with a rough surface 0.049–0.066 mm long and 0.031–0.043 mm wide, symmetric 6-radiates 0.045–0.061 mm long and 0.031–0.043 mm wide, 7-radiates 0.049–0.063 mm long and 0.033–0.044 mm wide, and rods 0.044–0.083 mm long and 0.016–0.033 mm wide (Fig. 7B). The coenenchymal mounds enclosing the autozooids contain predominantly 8-radiates 0.053–0.087 mm long and 0.032–0.046 mm wide, double-clubs with a rough surface 0.042–0.077 mm long and 0.031–0.052 mm wide, 7-radiates 0.050–0.067 mm long and 0.035–0.042 mm wide, and a few 6-radiates and rods (Fig. 7C). The coenenchyme on the branch tips contains mainly 8-radiates 0.048–0.064 mm long and 0.030–0.040 mm wide, 7-radiates 0.046–0.066 mm long and 0.031–0.038 mm wide, symmetric 6-radiates 0.043–0.061 mm long and 0.030–0.037 mm wide, double-clubs with a rough surface 0.047–0.058 mm long and 0.032–0.039 mm wide, and rare crosses (Fig. 7D). The coenenchyme on the base of the colony contains predominantly 8-radiates 0.043–0.069 mm long and 0.027–0.040 mm wide, along with some 7-radiates 0.045–0.060 mm long and 0.029–0.042 mm wide, a few double-clubs with a rough surface, some symmetric 6-radiates and some crosses (Fig. 7E).

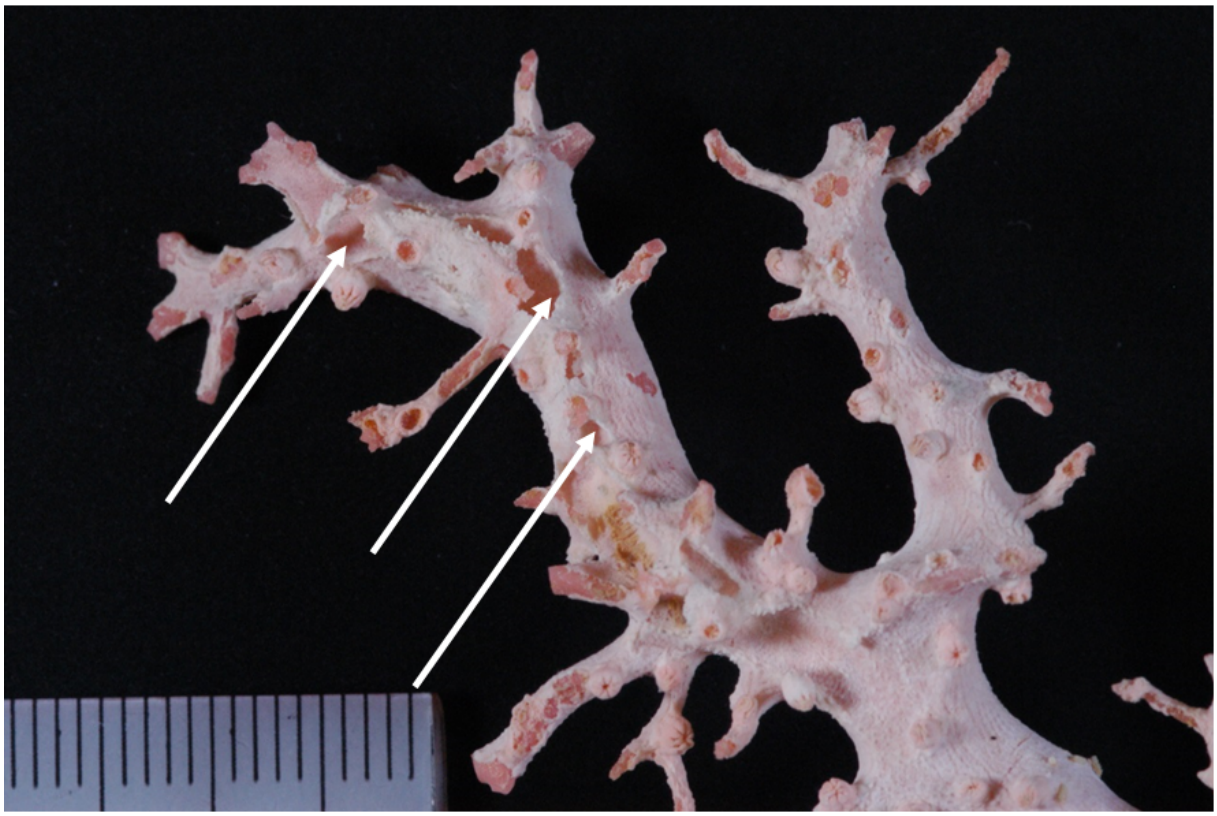

Fig. 5. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. Branch tip. Arrows indicate opening of large burrows. Scale divisions are 1.0 mm.
図 5.　*Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. 群体末端部. 矢印は群体表面の溝構造部を示す. スケール目盛は 1.0 mm.

Table 1. Summary of measurements of taxonomic characters comparing the two specimens examined. Measurements reported are the mean ± standard deviation (n = number of measurements). Statistical data represents measurements of 5 or more samples; for fewer than 5, measurements are reported as "about."
表 1. 各標本の形質データ. 平均±標準偏差 (n＝標本数). 標本数が 5 未満の場合には"about"として平均値のみ表示.

Specimen No.標本番号	USNM76105	OCA-Cn20071115-016
Diameter of autozooids 通常ポリプの直径	1.16 ± 0.28 mm (n = 16)	1.33 ± 0.35 mm (n = 24)
Height of autozooids 通常ポリプの高さ	About 1.04 mm (n = 3)	0.74 ± 0.07 mm (n = 6)
Interval between autozooids 通常ポリプの分布間隔	3.38 ± 0.85 mm (n = 5)	2.83 ± 0.29 mm (n = 13)
Diameter of siphonozooids 管状ポリプの直径	0.05 ± 0.01 mm (n = 26)	0.25 ± 0.07 mm (n = 21)
Interval between siphonozoids 管状ポリプの分布間隔	1.31 ± 0.70 mm (n = 12)	1.96 ± 0.78 mm (n = 17)
Coenenchyme thickness 共肉の厚み	—	0.17 ± 0.05 mm (n = 15)
Diameter of coenenchymal warts 共肉表面イボ状突起の直径	0.18 ± 0.03 mm (n = 17)	—
Interval between coenenchymal warts 共肉表面イボ状突起の間隔	0.36 ± 0.11 mm (n = 33)	—
Interval between axial grooves 骨軸長軸を通る溝の間隔	0.29 ± 0.04 mm (n = 13)	0.26 ± 0.06 mm (n = 27)

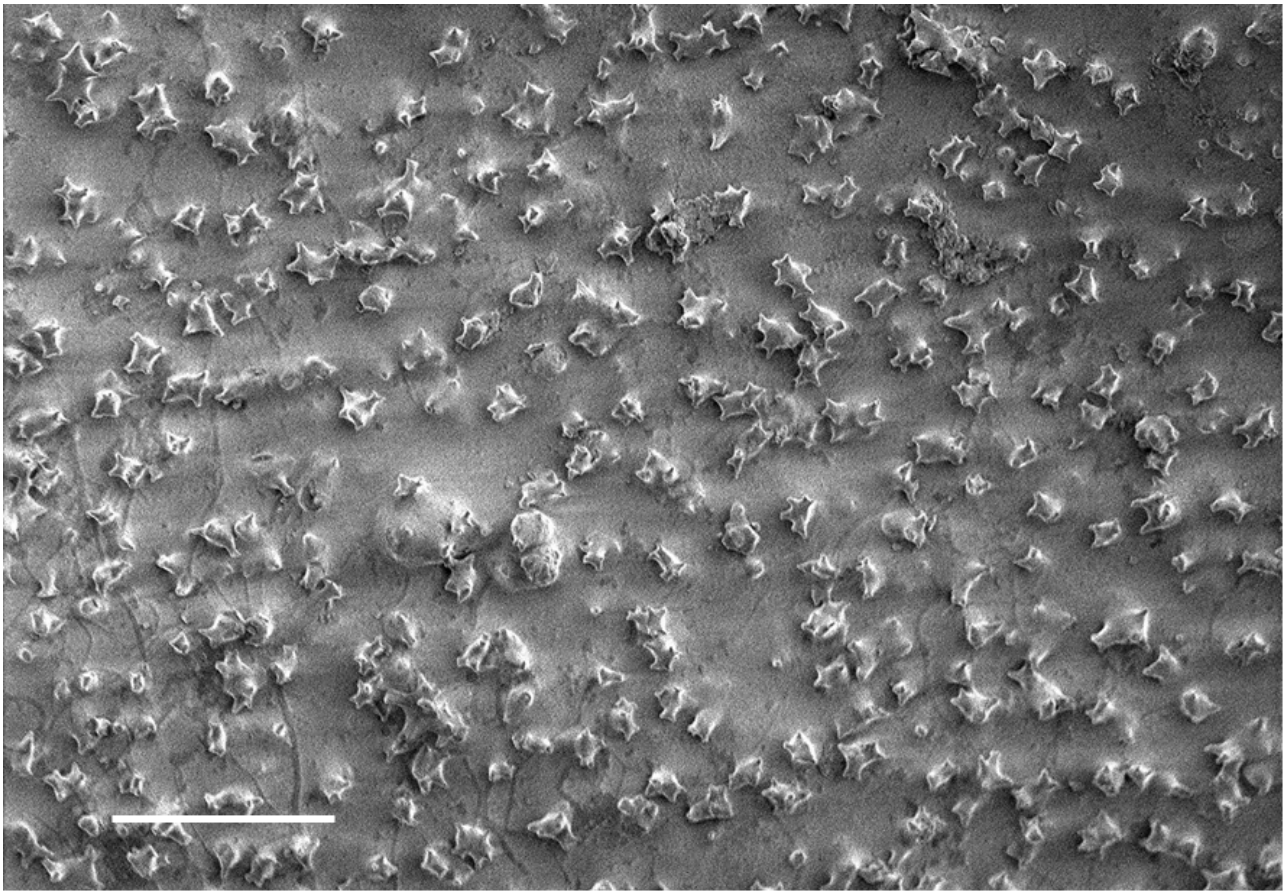

Fig. 6. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. Axis. Detail of surface with thorny projections. Scale bar is 0.1 mm.
図 6. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. 骨軸表面の詳細. スケールは 0.1 mm.

The statistical data for sclerites of this specimen are shown in Table 2.

In the anthocodia, there are long, warty rod-shaped sclerites, which are fewer, shorter, and spiny in the pharynx and coenenchymal mounds (Table 2). The most prevalent sclerites throughout the colony are 8-radiates. Those from the autozooids (the anthocodia including the pharynxes) and coenenchymal mounds are somewhat longer than those from the general coenenchyme at the branch tip and base. The double-clubs with rough surface that are found in this specimen are longer than those of other species of Coralliidae, and they have 8 projections instead of 6.

Relative abundance of sclerites (Fig. 8, Table 2). There are 6 kinds of sclerites in the coenenchyme of the specimen USNM 76105. In the anthocodia, 8-radiates represent 49% of the sclerites, and rods 43%. In the pharynxes, 8-radiates represent 46% of the sclerites and double-clubs 26%. In the coenenchymal mounds, 8-radiates represent 66% of the sclerites and double-clubs 20%. In the branch tips, 8-radiates represent 33% of the sclerites, 7-radiates 29%, symmetric 6-radiates 22% and double-clubs with a rough surface 14%. In the base part, 8-radiates represent 77% of the sclerites, and 7-radiates 13%. The 8-radiates, comprising 33–77%, are the most abundant sclerites in this specimen. Double-clubs with a rough surface are present in all parts of the colony, comprising 4–26%. Seven-radiates are more common than in other species, but 6-radiates are few except in the branch tip.

Remarks. Kishinouye (1903a) described *H. sulcatum* (Kishinouye, 1903) as new, but he did not select a holotype from amongst his material, and none of his specimens have ever been found.

USNM 76105 has several characteristics that agree with Kishinouye's comments; "autozooids cylindrical, with eight longitudinal grooves, and are distributed on the front side only,"; "coenenchyme thin, has longitudinal grooves, and light red in color"; "five kinds of spicules; octoradiate, cruciform, long warty spindles, double clubs, and irregular forms, the octoradiate form is most abundant"; and "axis smooth, pinkish in color." One similar character reported by Kishinouye for this species is having "many large burrows for a commensal worm", like the burrows found on the

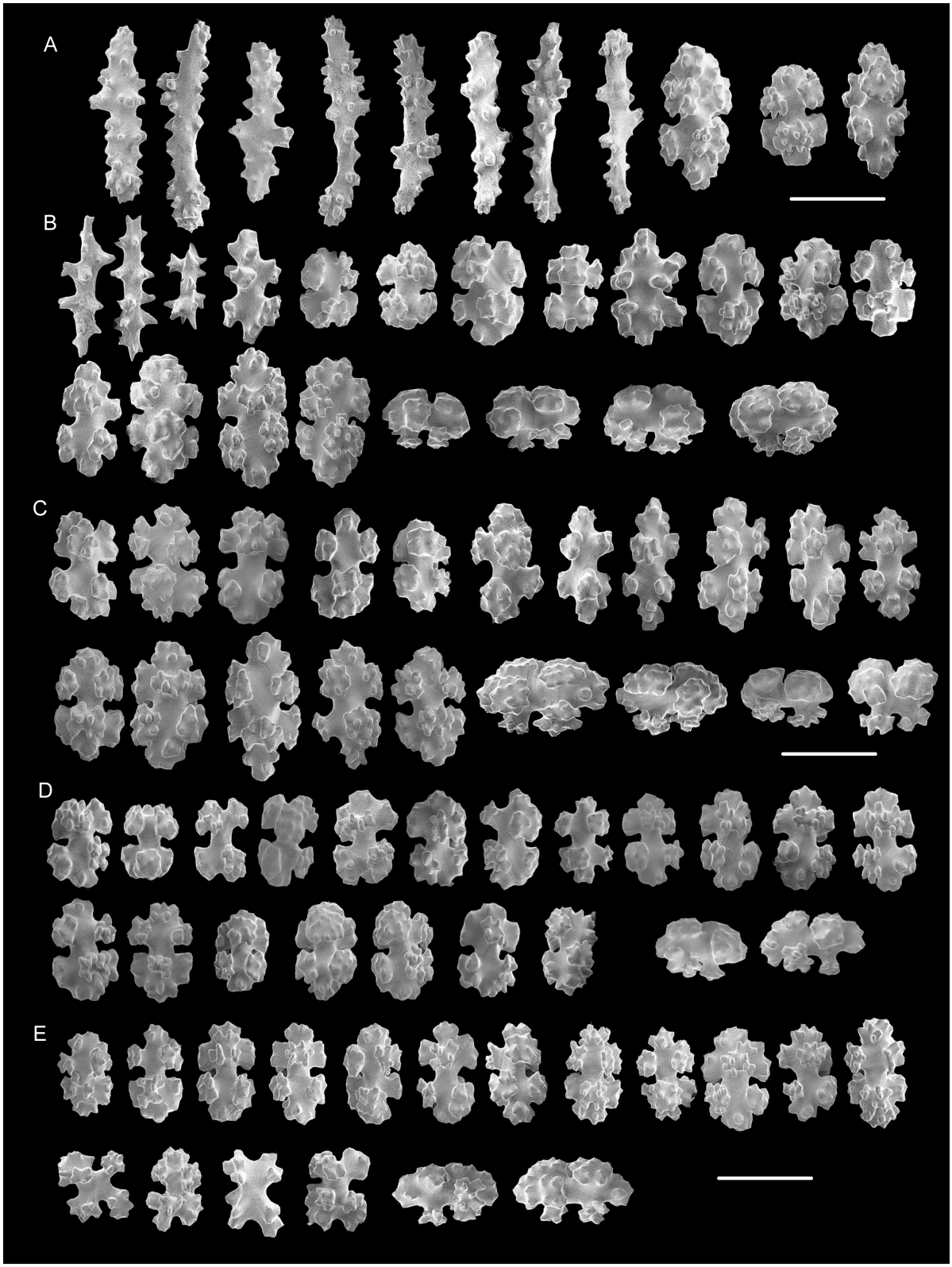

Fig. 7. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. Sclerites. A: from anthocodia. B: from pharynx. C: from coenenchyme mounds. D: from branch tip. E: from base. Scale bars are 0.05 mm.
図 7. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. 骨片. A: 通常ポリプ先端部. B: 通常ポリプ胃腔部. C: 通常ポリプ被覆共肉. D: 枝先端部. E: 群体基部. スケールは 0.05 mm.

Table 2. Sclerites of *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903) (USNM 76105). Mean size (mm) in length (L.) and width (W.) ± standard deviation, number of measured sclerites (n) and composition of total sclerites sampled (%) from the each part, anthocodia, pharynxes, coenenchymal mounds, branch tips and base of colony.
表 2．*Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105 における各種骨片の平均サイズ（mm）（長さ L.と幅 W.）±標準偏差，標本数（n）と各採取部位（ポリプ先端部 Anthocodia，ポリプ胃腔部 Pharynxes，ポリプ被覆共肉 Coenenchymal mounds，枝先端部共肉 Branch tips，群体基部共肉 Base における各種骨片の割合（%）.

	Anthocodia	Pharynx	Coenenchymal mound	Branch tip	Base
6-radiates (symmetric) L.	0.055	0.051 ± 0.004	0.056 ± 0.003	0.050 ± 0.004	0.047 ± 0.002
6-radiates (symmetric) W.	0.036	0.037 ± 0.003	0.038 ± 0.004	0.034 ± 0.002	0.037 ± 0.002
	(n = 1; 2%)	(n = 14; 12%)	(n = 2; 2%)	(n = 21; 22%)	(n = 2; 2%)
7-radiates L.	0.058	0.056 ± 0.005	0.060 ± 0.006	0.052 ± 0.004	0.052 ± 0.004
7-radiates W.	0.037	0.038 ± 0.004	0.039 ± 0.003	0.035 ± 0.002	0.034 ± 0.004
	(n = 1; 2%)	(n = 10; 9%)	(n = 11; 10%)	(n = 28; 29%)	(n = 16; 13%)
8-radiates L.	0.068 ± 0.009	0.063 ± 0.009	0.066 ± 0.007	0.055 ± 0.004	0.056 ± 0.005
8-radiates W.	0.039 ± 0.003	0.039 ± 0.004	0.040 ± 0.003	0.034 ± 0.002	0.033 ± 0.003
	(n = 25; 49%)	(n = 53; 46%)	(n = 71; 66%)	(n = 32; 33%)	(n = 92; 77%)
Double-clubs (rough) L.	0.065 ± 0.004	0.056 ± 0.005	0.060 ± 0.009	0.053 ± 0.003	0.055 ± 0.009
Double-clubs (rough) W.	0.039 ± 0.0001	0.037 ± 0.003	0.040 ± 0.005	0.035 ± 0.002	0.035 ± 0.003
	(n = 2; 4%)	(n = 30; 26%)	(n = 22; 20%)	(n = 14; 15%)	(n = 7; 6%)
Rods L.	0.096 ± 0.017	0.059 ± 0.014	0.070 ± 0.006	0	0
Rods W.	0.029 ± 0.005	0.025 ± 0.005	0.032 ± 0.002	0	0
	(n = 22; 43%)	(n = 9; 8%)	(n = 2; 2%)		
Crosses L.	0	0	0	0.062	0.049 ± 0.007
Crosses W.	0	0	0	0.055	0.045 ± 0.006
				(n = 1; 1%)	(n = 2; 2%)
	(n = 51; 100%)	(n = 116; 100%)	(n = 108; 100%)	(n = 96; 100%)	(n = 119; 100%)

branch tips of this specimen. However, "autozooids are about 2 mm in height, 1.5 mm in diameter," is larger than the size of the autozooids of the specimen in this report. As well, the original reported "distribution" of this species is "Mera, Boshu," which indicates a location off the shore of southern Chiba Prefecture, central Japan. Our specimen USNM 76105 was collected from near Okinawa Is., very far from the type locality (about 1,500 km). Therefore, we refer this specimen only provisionally to this species.

Tu et al. (2012) also described *H. sulcatum* collected from Taiwan, with photos of a whole colony and SEM image of sclerites. Their description may fit the original description by Kishinouye (1903a, 1904b), but their sclerites were relatively different from our specimen. Moreover, their sampling site was also far away from the original type locality. Collections at the type locality and designation of a neotype specimen are necessary for positive identification of this species.

Ardila et al. (2012) examined this same specimen, USNM 76105, in their molecular analyses, and showed that it belonged to the clade of genus *Hemicorallium*. Accordingly we have classified USNM 76105 in this genus.

Hemicorallium boshuense (Kishinouye, 1903) is very similar to the original description of *H. sulcatum,* differing only in color; *C. sulcatum* is palepink, and *C. boshuense* is white (Kishinouye 1903a). Moreover both were collected in the same place, "Mera, Boshu". It is possible that these are

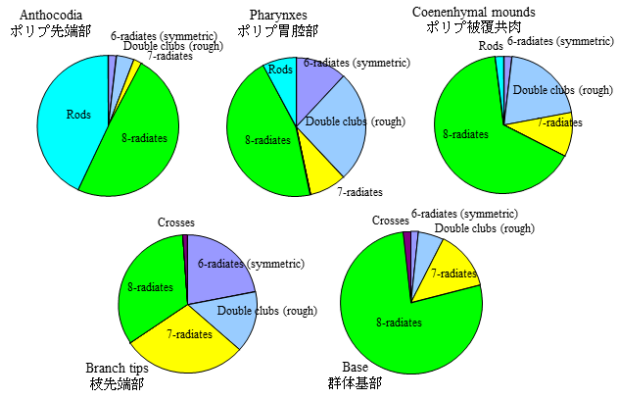

Fig. 8. *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), USNM 76105. Composition of sclerites from each part sampled.
図 8. ミゾサンゴ近似種 *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903), 標本 USNM 76105 における群体各部ごとの骨片形態の構成 (%).

synonyms, but as no original material of either has been found again, it is not possible to verify this at the present time.

***Pleurocorallium inutile* Kishinouye, 1902**

(Figs. 9–20, Table 1, 3)

Pleurocorallium inutile Kishinouye 1902: 419; Tu et al. 2015b: 181, table 1.

Corallium inutile Kishinouye 1903a: 626; Kishinouye 1903b: 105; Kishinouye 1904a: 28, pl. 5, figs. 1, 2; pl. 7, fig. 7; pl. 8, fig. 18; Kishinouye 1904b: 27, pl. 5, figs. 1, 2; pl. 7, fig. 7; pl. 8, fig. 18; Kukenthal 1924: 48; Bayer 1956: 76 (in key); Imahara 1996: 28 (in list).

Paracorallium inutile Bayer & Cairns 2003: 224; Nonaka & Muzik 2010: 98, figs. 23–25; Tu et al. 2012: 4 (in key), fig. 1; Nonaka et al. 2012: 42–50, figs. 35–42, table 11.

Material examined. OCA-Cn20071115-016, southern Kagoshima, Tanegashima Is. at 245 m deep on rock substratum on November 15, 2007.

Diagnosis. Main branches planar, but smaller branches ramify in all directions, often anastomosing, and net-like. Coenenchyme thin but firm and light red. Autozooids small, 1.0–1.5 mm in diameter, slightly elevated and distributed over all parts of the branches. Axis brittle, finely striated. Small but deep

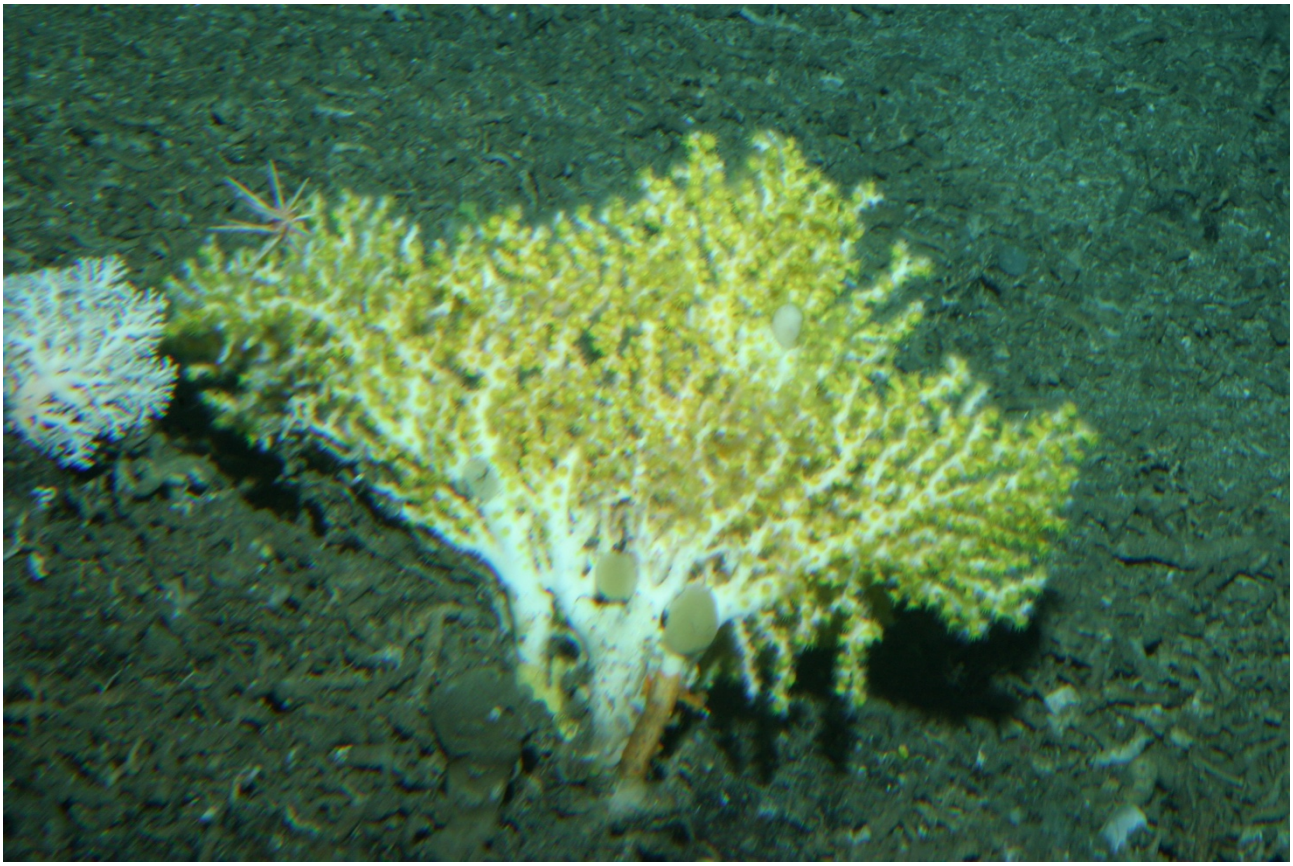

Fig. 9. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Living colony photographed *in situ*, collected from near Tanegashima Is. 245m deep. The yellowish polyps are epibiotic zoantharians (*Corallizoanthus* sp.).
図 9. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 種子島近海水深 245m における生時写真. 黄色く見えるのは着生スナギンチャク類 (*Corallizoanthus* sp.).

Fig. 10. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Specimen viewed on opposite sides of same branch. Scale bar is 5 cm, scale divisions 1.0 mm.
図 10. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 同じ枝を両面から撮影.スケールは 5 cm, 目盛は 1.0 mm.

pits in axis underneath autozooids. Axis entirely white, slightly tinged with yellow. Five kinds of sclerites: 6-radiates, 7-radiates, double-clubs, rods and irregular forms. 6-, 7-radiates few, double-clubs predominant in coenenchyme. Double-clubs mainly smooth. Anthocodia with rods with small projections.

Description of specimen OCA-Cn20071115-016. Colony form. The specimen is formed by two pieces of the same colony (Figs. 10–11). A photograph of the living, still intact colony taken from the manned submersible is shown in Fig. 9. From photographs the base was determined to be about 50 mm thick. The whole colony was about 200 mm tall, 400 mm wide, branched irregularly and not in one plane. Branches of the samples are tapered at the tip, with some anastomoses (Fig. 11), and irregular branch angles. The main stems are 20–40 mm in diameter, and the thinnest tips of the branches are 5 mm in diameter (Fig. 10). Branch cross sections are rounded (Fig. 14). Polyps of a yellowish epibiotic zoantharian (*Corallizoanthus* sp.), about 3.2–3.7 mm in diameter, are distributed on each side of the colony (Figs. 9, 12).

Polyps. Autozooids are distributed uniformly on all sides of the colony (Fig.10) and are mostly retracted with low, hemispherical, coenenchymal

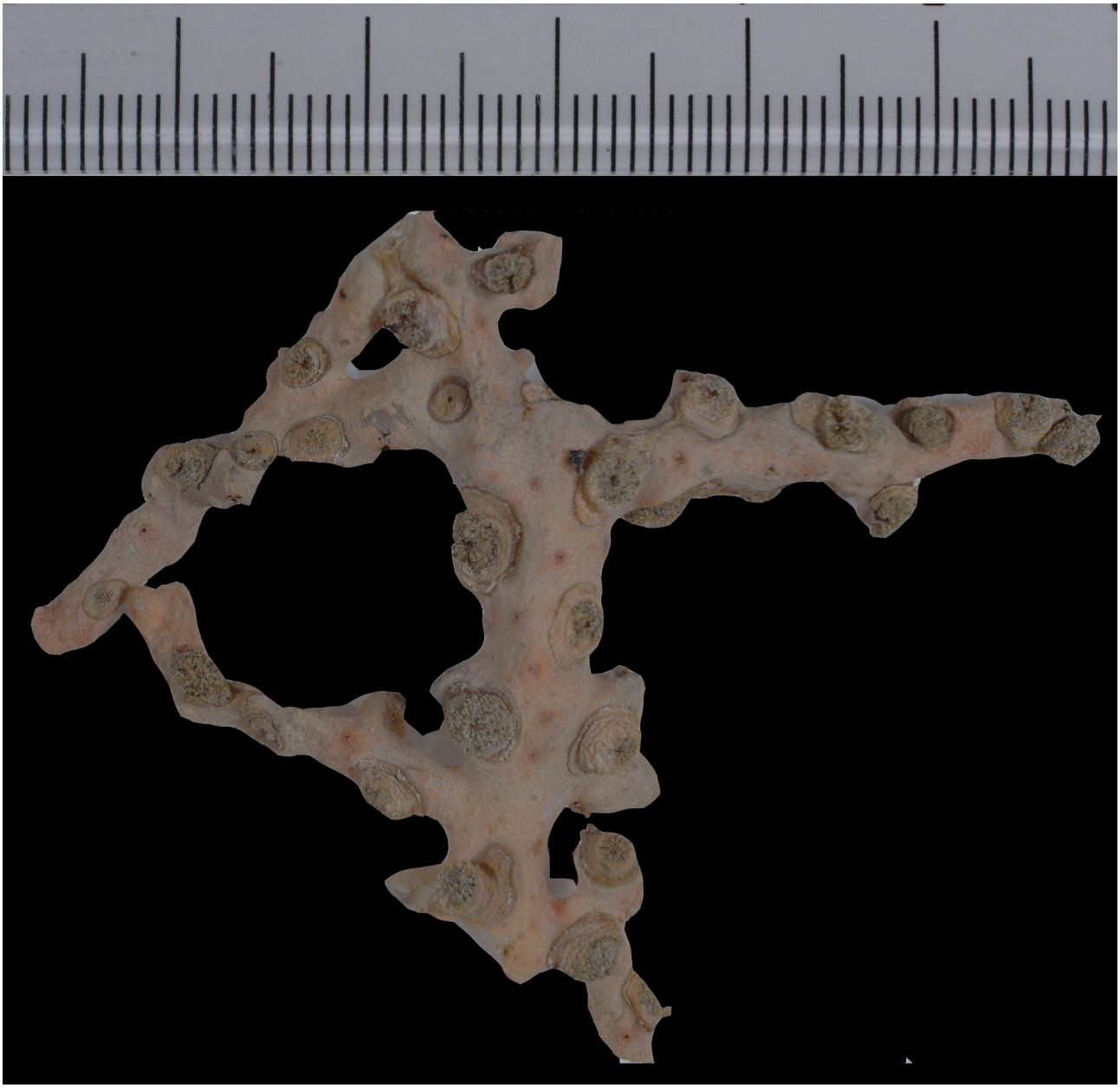

Fig. 11. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Detail of anastomosing branchlets. The scales divisions are 1.0 mm.
図 11. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 枝癒着部の詳細．スケール目盛は 1.0 mm.

mounds, 0.80–2.04 mm in diameter (Table 1) and 0.63–0.82 mm in height (Table 1), with an 8-lobed summit (Fig. 12). Some autozooids are extended and tiny sclerites are observable in the tentacles on the abaxial side (Fig. 13). The distance between autozooids (center to center) is 2.46–3.61 mm (Table 1). Siphonozooids are present as small pits, 0.05–0.34 mm in diameter (Table 1), invisible to the naked eye, and distributed all around the colony, at intervals of 1.06–4.31 mm (Fig. 12, Table 1).

Axis. The surface of the axis is almost smooth, indistinctly longitudinally grooved (Fig. 15), at intervals of 0.16–0.38 mm (Table 1), and covered with minute tubercles ornamented with thorny projections (Fig. 17). The axis of the branch tip has conspicuous pits (0.9–1.5 mm in diameter), with beaded margins underneath the autozooids (Fig. 16). Pits are present in basal parts of the axis, but they are not conspicuous and lack beaded margins (Fig. 15).

Coenenchyme. This is thin (Fig. 14), 0.08–0.26 mm (Table 1) and the surface is smooth as there are no distinct warts (Fig. 12).

Color. The live colony was pure white with many yellow zoantharians polyps. The preserved coenenchyme is pale ocherous white, the autozooids slightly darker, and the axis is white (Fig. 14).

Table 3. Sclerites of *Pleurocorallium inutile* Kishinouye, 1902, (OCA-Cn20071115-016). Mean size (mm) in length (L.) and width (W.) ± standard deviation, number of measured sclerites (n) and composition of total sclerites sampled (%) from the each part, anthocodia, coenenchymal mounds, branch tips and base of colony.
表 3．*Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016 における各種骨片の平均サイズ（mm）（長さ L.と幅 W.）±標準偏差，標本数（n）と各採取部位（ポリプ先端部 Anthocodia，ポリプ被覆共肉 Coenenchymal mounds，枝先端部共肉 Branch tips，群体基部共肉 Base における各種骨片の割合（%）

	Anthocodia	Coenenchymal mound	Branch tip	Base
6-radiates (symmetric) L.	0.045 ± 0.002	0.047 ± 0.007	0.055 ± 0.005	0.052 ± 0.004
6-radiates (symmetric) W.	0.031 ± 0.003	0.036 ± 0.003	0.039 ± 0.006	0.037 ± 0.0001
	(n = 4; 8%)	(n = 4; 2%)	(n = 5; 6%)	(n = 2; 1%)
6-radiates (small) L.	0.034 ± 0.006	0.034 ± 0.007	0.035 ± 0.003	0.045
6-radiates (small) W.	0.024 ± 0.003	0.024 ± 0.005	0.026 ± 0.005	0.024
	(n = 9; 18%)	(n = 26; 16%)	(n = 3; 3%)	(n = 1; 1%)
6-radiates (asymmetric) L.	0.043 ± 0.004	0.045 ± 0.004	0.042	0.045 ± 0.007
6-radiates (asymmetric) W.	0.031 ± 0.002	0.030 ± 0.002	0.032	0.037 ± 0.005
	(n = 8; 16%)	(n = 3; 2%)	(n = 1; 1%)	(n = 5; 3%)
7-radiates L.	0	0.051 ± 0.010	0	0.062
7-radiates W.	0	0.036 ± 0.006	0	0.040
		(n = 3; 2%)		(n = 1; 1%)
Double-clubs (rough) L.	0.044 ± 0.003	0.049 ± 0.006	0.055 ± 0.006	0.055 ± 0.004
Double-clubs (rough) W.	0.033 ± 0.003	0.039 ± 0.005	0.040 ± 0.006	0.042 ± 0.004
	(n = 16; 32%)	(n = 44; 27%)	(n = 3; 3%)	(n = 25; 17%)
Double-clubs (smooth) L.	0.056 ± 0.005	0.054 ± 0.006	0.051 ± 0.004	0.055 ± 0.005
Double-clubs (smooth) W.	0.048 ± 0.005	0.046 ± 0.006	0.041 ± 0.004	0.045 ± 0.004
	(n = 8; 16%)	(n = 80; 50%)	(n = 78; 87%)	(n = 111; 77%)
Rods L.	0.038 ± 0.001	0	0	0
Rods W.	0.015 ± 0.001	0	0	0
	(n = 2; 4%)			
Multi-radiates L.	0.045 ± 0.005	0.049	0	0
Multi-radiates W.	0.025 ± 0.003	0.031	0	0
	(n = 3; 6%)	(n = 1; 1%)		
	(n = 50; 100%)	(n = 161; 100%)	(n = 90; 100%)	(n = 145; 100%)

Shape and size of sclerites (Fig. 18, Table 3). In this specimen, some of the autozooids could be dissected and examined in detail. The anthocodia contain mainly double-clubs with a rough surface 0.040–0.050 mm long and 0.030–0.040 mm wide, some small 6-radiates 0.025–0.042 mm long and 0.019–0.030 mm wide, asymmetric 6-radiates 0.036–0.048 mm long and 0.029–0.034 mm wide, and double-clubs with a smooth surface 0.049–0.064 mm long and 0.038–0.055 mm wide, and a few symmetric 6- radiates, rods and multi-radiates (Fig. 18A). No sclerites were found in the pharynx. The coenenchymal mounds enclosing the autozooids contain mainly double-clubs; those with a smooth surface were 0.042–0.066 mm long and 0.033–0.059 mm wide, those with a rough surface were 0.034–0.063 mm long and 0.031–0.048 mm wide. There were also some small 6-radiates 0.023–0.048 mm long and 0.013–0.031 mm wide, and a few 6-radiates (both symmetric and asymmetric), and 7-radiates

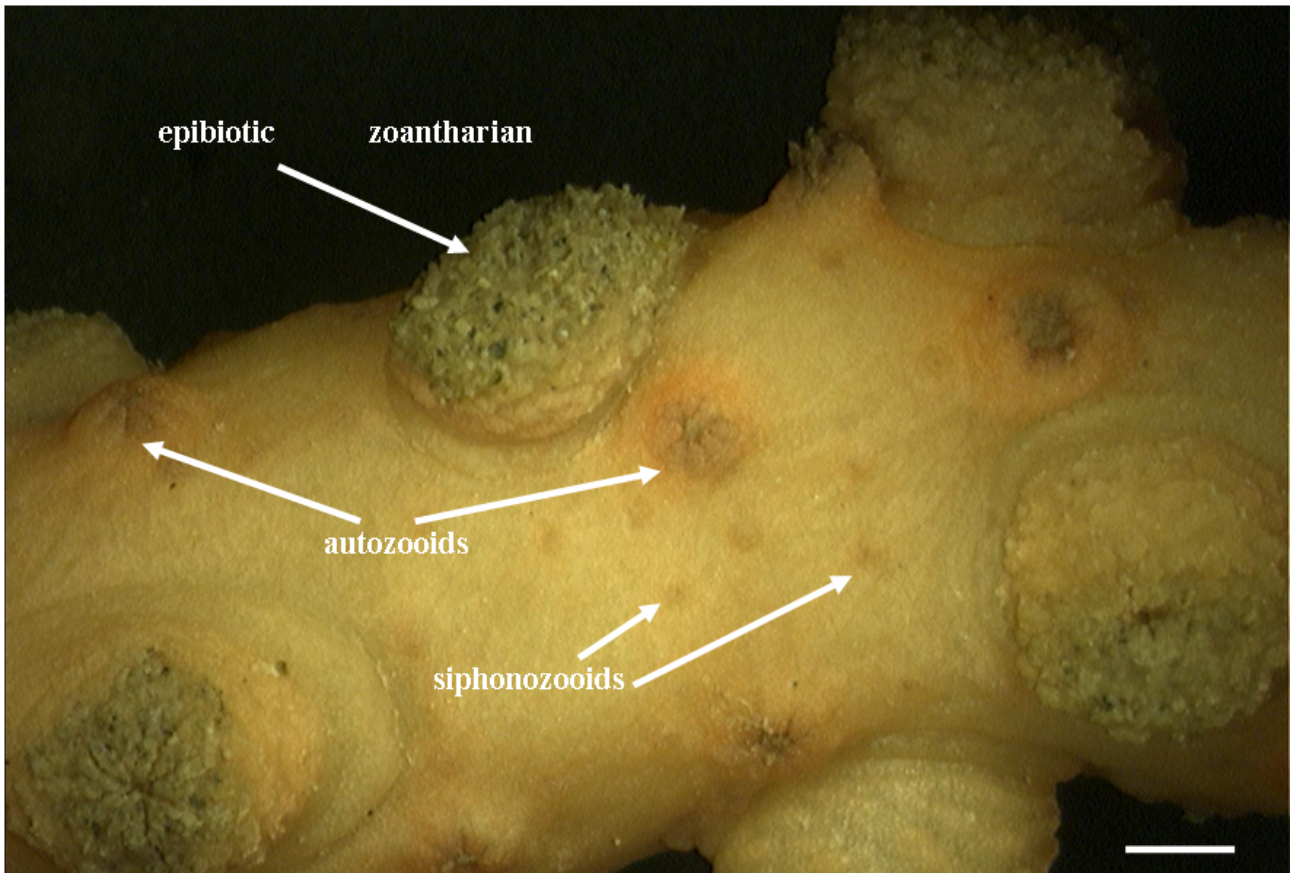

Fig. 12. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Details of autozooids, siphonozooids and epibiotic zoantharians on branchlet. Scale bar is 1.0 mm.
図 12. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 枝先端部表面の通常ポリプ autozooids, 管状ポリプ siphonozooids, 着生スナギンチャク epibiotic zoantharians. スケールは 1.0 mm.

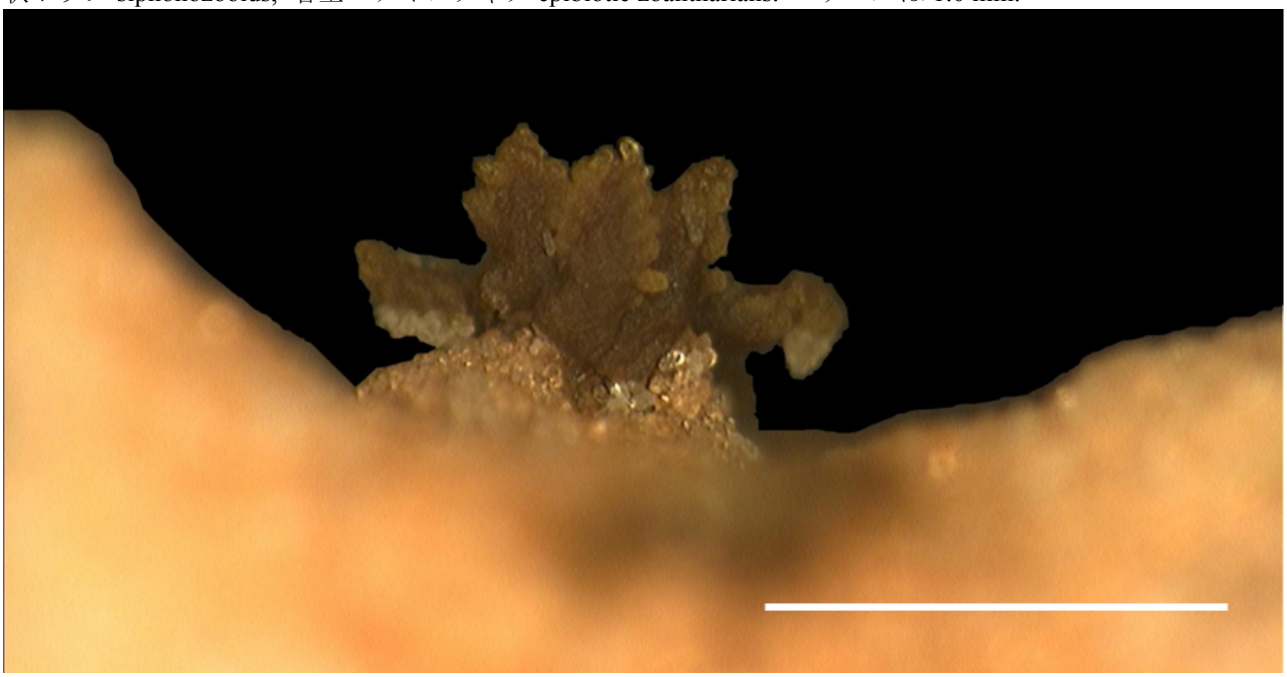

Fig. 13. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Detail of autozooid (anthocodium) showing tentacular sclerites. Scale bar is 1.0 mm.
図 13. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 通常ポリプ触手骨片の詳細. スケールは 1.0 mm.

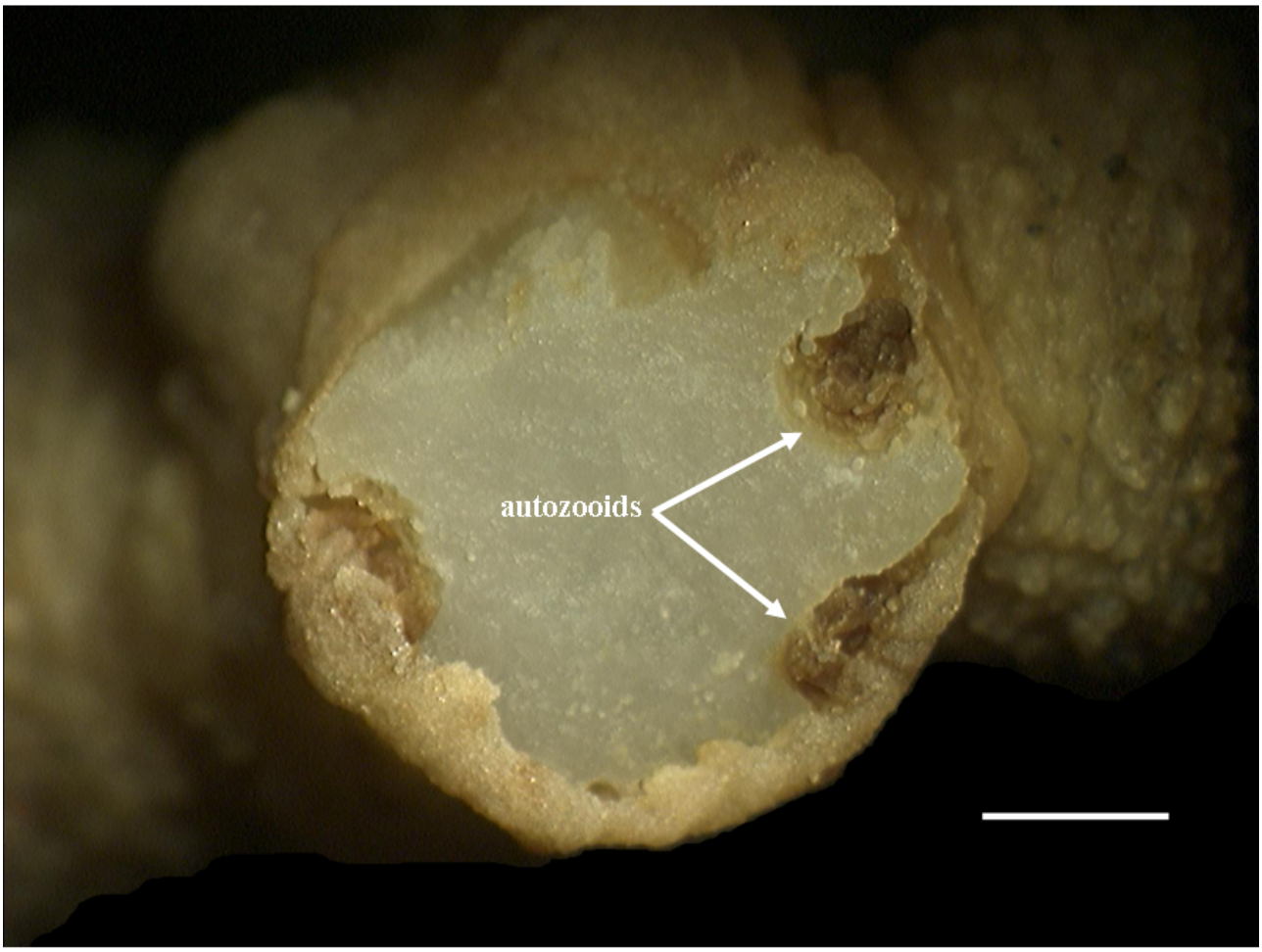

Fig. 14. *Pleurocorallium inutile* Kishinouye, 1902, USNM 19935. Section of axis and autozooid pits on a branchlet. Arrows indicate locations of autozooids.
Scale bar is 1.0 mm.
図 14. *Pleurocorallium inutile* Kishinouye, 1902, USNM 19935. 通常ポリプ部の骨軸断面. 矢印が通常ポリプ下に存在する凹み. スケールは 1.0 mm.

(Fig. 18B). The coenenchyme on the branch tips contains mostly double-clubs those with a smooth surface were 0.043–0.060 mm long and 0.031–0.047 mm wide. There were also a few 6-radiates (both small, symmetric and asymmetric) and rough double-clubs (Fig. 18C). The coenenchyme at the base of the colony contains mainly double-clubs with a smooth surface, 0.043–0.064 mm long and 0.034–0.054 mm wide, some rough double-clubs 0.047–0.061 mm long and 0.033–0.049 mm wide, and a few 6-radiates (small, symmetric and asymmetric) and 7-radiates (Fig. 18D). The statistical data for sclerites of this specimen are shown in Table 3.

Double-clubs with a smooth surface are of almost similar sizes in all four regions sampled. Rough double-clubs in the anthocodia are much smaller than those in the tips of the branches and in the base. Relative abundance of sclerites (Fig. 19, Table 3). There are 8 kinds of sclerites in the coenenchyme of specimen OCA-Cn20071115-016. In the anthocodia there are more kinds of sclerites than in other parts of the colony. There, double-clubs with a rough surface represent 32% of the sclerites, small 6-radiates 18%, asymmetric 6-radiates and smoothed double-clubs 16%. In the coenenchymal mounds, double-clubs with a smooth surface represent 50% of the sclerites, double-clubs with a rough surface 27%, and small 6-radiates 16%. The most abundant sclerites are double-clubs with a smooth surface both in the branch tips (87%) and at the base (77%).

Remarks. Specimen OCA-Cn20071115-016 here identified as *P. inutile* is the third record of this species. In the first report of this species (Kishinouye 1902), the specimens were collected from seas off mainland Japan (Kochi, Kashiwajima Is.). The second record was sampled from Taiwan (Tu et al. 2012). These records indicate that distribution of *P. inutile* may extend south at least as far as Taiwan, about 1,200 km away from the type locality.

OCA-Cn20071115-016 has some morphological

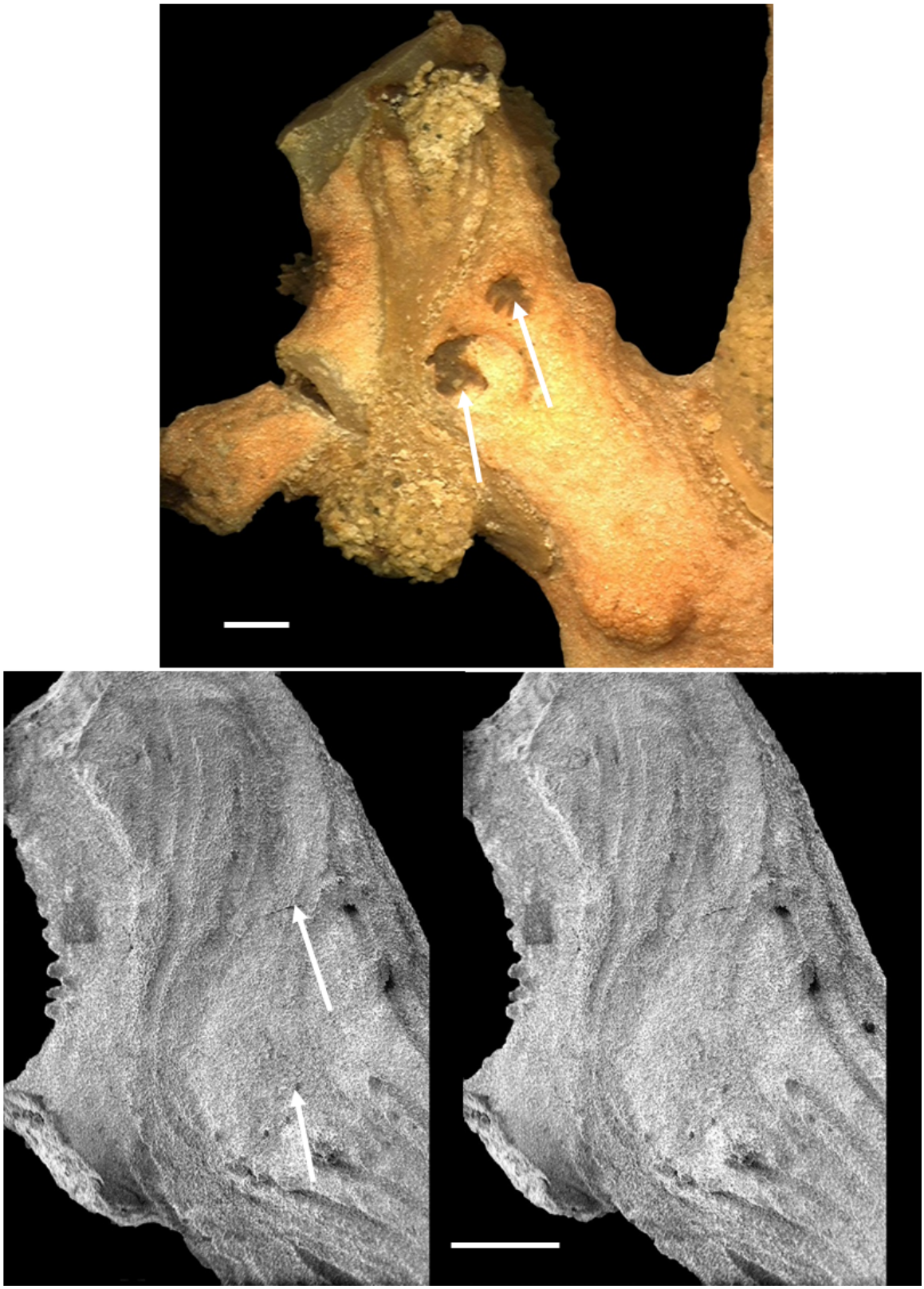

Fig. 15. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Detail of the surface of mid branch and autozooid with coenenchyme (above) and without coenenchyme (below: stereo pairs). The arrows indicate location of autozooids. Scale bars are 1.0 mm (above) and 0.5 mm (below).

図 15. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 群体中央部における通常ポリプ周辺の詳細. 上: 共肉の付いた状態. 下: 共肉を除去した骨軸 (ステレオペア). 矢印は通常ポリプの位置. スケールは 1.0 mm (上), 0.5 mm (下).

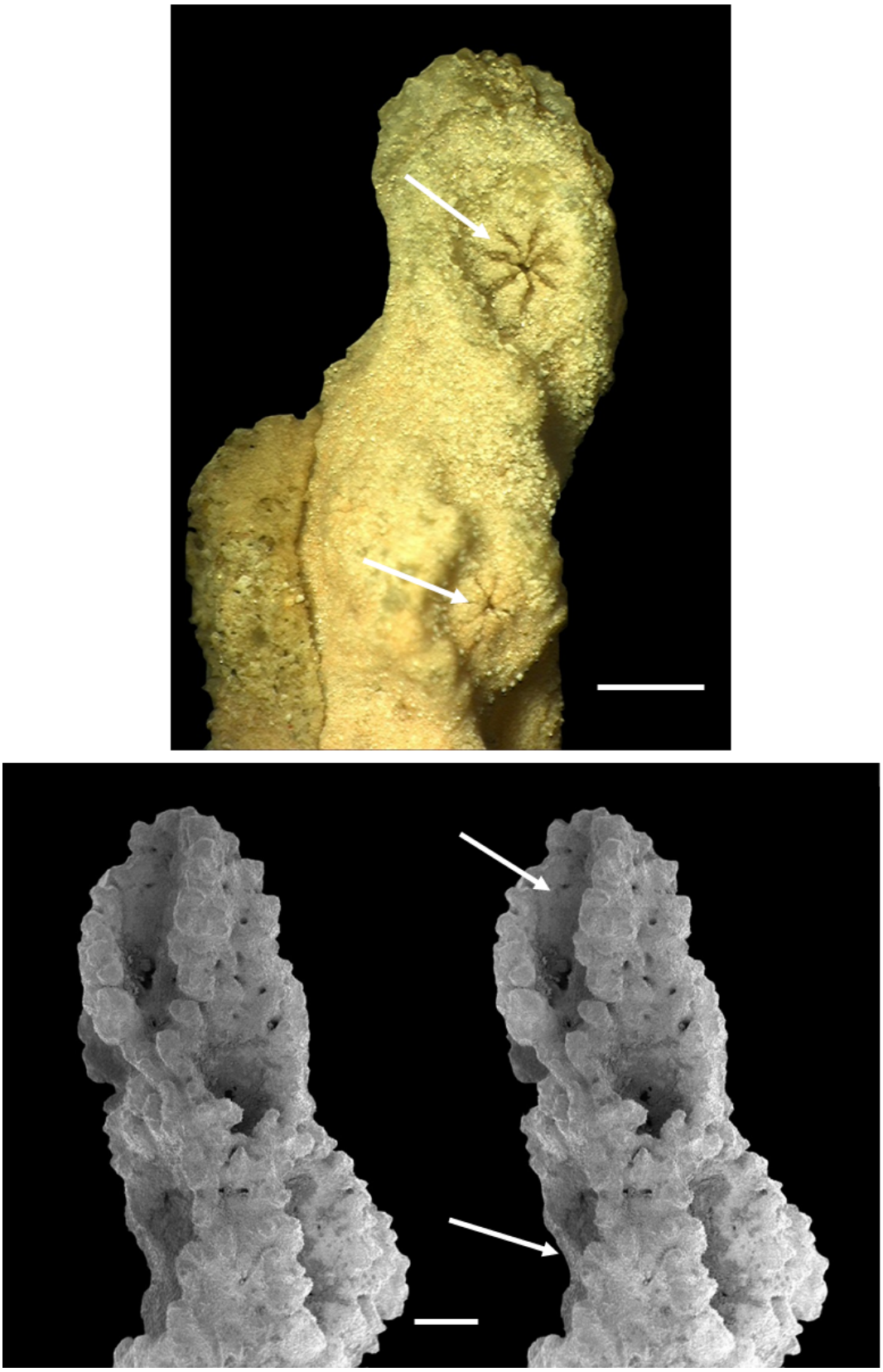

Fig. 16. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Detail of branchlet surface around autozooids with coenenchyme (above) and same part of denuded axis (below: stereo pairs). Arrows indicate autozooids. Scale bars are 1.0 mm (above) and 0.5 mm (below).
図 16. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 枝先端部における通常ポリプ周辺の詳細. 上: 共肉の付いた状態. 下: 共肉を除去した骨軸 (ステレオペア). 矢印は通常ポリプの位置. スケールは 1.0 mm (上), 0.5 mm (下).

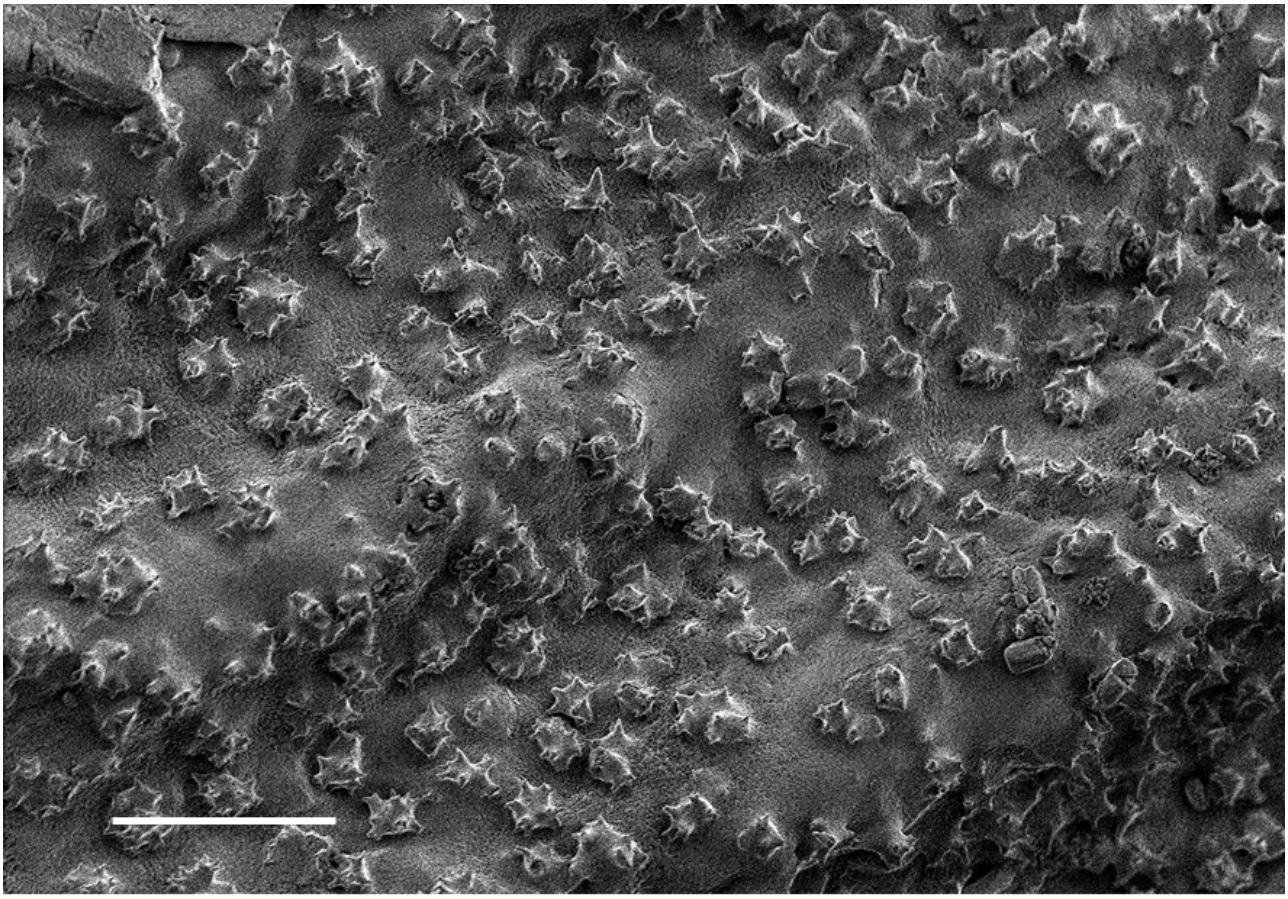

Fig. 17. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Axis. Detail of surface with thorny projections. Scale bar is 0.1 mm.
図 17. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 骨軸表面の詳細. スケールは 0.1 mm.

characteristics, such as thin coenenchyme, autozooid distribution, axis color and surface ornament, similar to the colony of *P. inutile* described by Kishinouye (1902, 1903a, b, 1904a, b). He reported that the main branches were planar and the smaller branches extended in all directions, often anastomosing. Specimen OCA-Cn20071115-016 does have branches extended in all directions (Fig. 9) and some anastomoses (Fig. 11). Autozooids in original description were present as small elevations, 0.8–1.0 mm in diameter, and in OCA-Cn20071115-016, they are 0.80–2.04 mm in diameter (Figs. 12, 13).

The most important character of this species species appears to be the abundance of double-clubs with a smooth surface (Nonak et al. 2012), and the present specimen has also smooth double-clubs dominantly (Figs. 18, 19). Kishinouye (1902) did not designate a holotype when he described *Pleurocorallium inutile*, and Nonaka et al. (2012) designated USNM 19935 as the neotype of this species. Although Kishinouye did not describe the size of the double-clubs in his description, the double-clubs of the neotype and present specimen examined are similar in size (Fig. 20). As well, the presence of commensal zoantharians may be an important identifying character for *P. inutile* (Nonaka et al. 2012), and both the neotype and the specimen OCA-Cn20071115-016 hosted zoantharians on their coenenchymal surface (Figs. 9–12).

There are indeed distinct pits with a beaded margin underneath each autozooid, but only on the branch tips (Fig. 16), and not remarkable on the basal part of the axis (Fig. 15). This character is diagnostic of genus *Paracorallium* (Bayer & Cairns 2003), but it is not a stable character in specimen OCA-Cn20071115-016. Ardila et al. (2012) synonymized the genus *Paracorallium* with *Corallium* in their molecular analyses of family Coralliidae. In this study, we also agree to abandon the genus *Paracorallium*.

Tu et al. (2015b) showed that there were the three clades in the family Coralliidae in their phylogenetic tree, and the sample labelled *Paraorallium inutile* collected from Taiwan belongs to the clade "*Pleurocorallium*." Moreover, Kishinouye (1902) described this species as "*Pleurocorallium inutile* n. sp." in the original description. For the time being, in

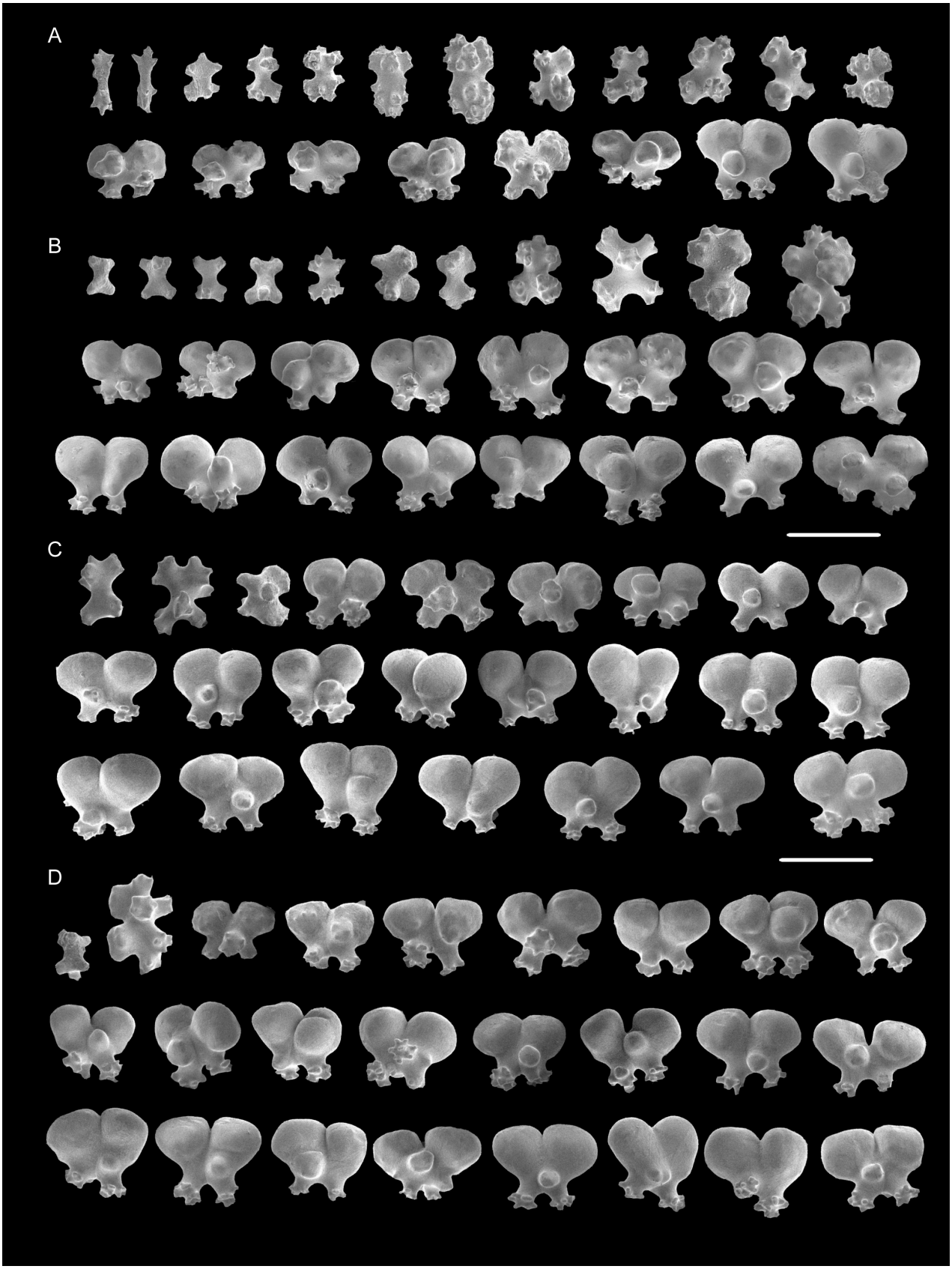

Fig. 18. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Sclerites: A from anthocodia. B from coenenchyme mounds. C from branch tip. D from base. Scale bars are 0.05.
図 18. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. 骨片. A: 通常ポリプ先端部. B:通常ポリプ被覆共肉. C: 枝先端部. D: 群体基部. スケールは 0.05 mm.

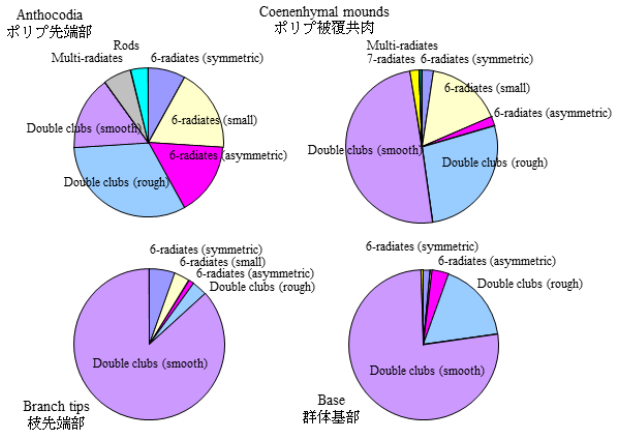

Fig. 19. *Pleurocorallium inutile* Kishinouye, 1902, OCA-Cn20071115-016. Composition of sclerites from each part sampled.

図 19. ダメサンゴ *Pleurocorallium inutile* Kishinouye, 1902, 標本 OCA-Cn20071115-016 における群体各部ごとの骨片形態の構成 (%).

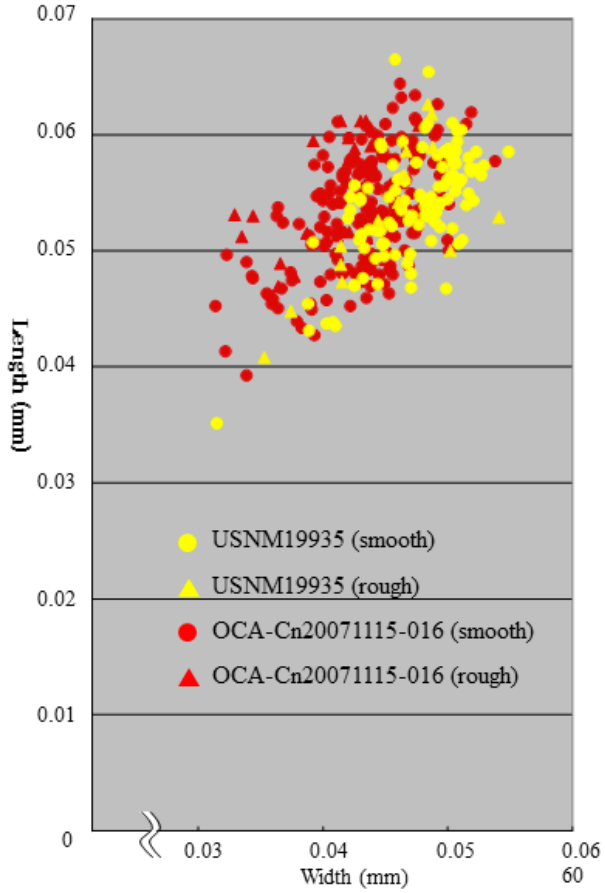

Fig. 20. Comparison of sizes of double club sclerites from branchlets and bases of two specimens of *Pleurocorallium inutile* Kishinouye, 1902, USNM 19935 (neotype) and OCA-Cn20071115-016.

図 20. ダメサンゴ *Pleurocorallium inutile* Kishinouye, 1902 の 2 標本についての, 枝先端部共肉における double club 型骨片のサイズ比較. 黄: USNM 19935 (ネオタイプ), 赤: OCA-Cn20071115-016.

this study we tentatively identify *inutile* to the genus *Pleurocorallium*.

However, this identification is still problematical: Gray (1867) designated the type species of the genus *Pleurocorallium* as *secundum* [*Corallium secundum* Dana, 1956], but unfortunately, there was incomplete information in Dana's original description, furthermore, the type specimen (USNM600) is now just an axial skeleton without autozooids, coenenchyme or sclerites (Nonaka et al. 2015). The taxonomy of this species remains unresolved.

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琉球列島初記録の宝石サンゴ類（八放サンゴ亜綱：ウミトサカ目サンゴ科）２種

野中正法[1]・キャサリン=ミュジック[2]

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要旨. 琉球列島にて採取された宝石サンゴ 2 標本がそれぞれ，ミゾサンゴ近似種 *Hemicorallium* cf. *sulcatum* (Kishinouye, 1903)，及びダメサンゴ *Pleurocorallium inutile* Kishinouye, 1902 と同定された．それぞれのタイプ産地は千葉県 (*H. sulcatum*) と高知県 (*P. inutile*)であるにも関わらず，これまで台湾での記録 (Tu et al., 2012) があり，今回は琉球列島と比較的遠方での記録となった．なお，最近の分子系統学的な研究により，サンゴ科を 3 属に分ける体系が提唱されており (Ardila et al. 2012; Figueroa & Baco 2014; Tu et al. 2015b)，本研究もそれらに倣った．

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