

Fossil Ophiuroids from the Oligocene Asagai Formation of Iwaki, Fukushima, Japan*

by

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Abstract A new species of fossil ophiuroid, *Amphioplus uchigoensis*, is established. The specimens were found in sandy mudstone of the Oligocene Asagai Formation in Uchigo, Iwaki City, Fukushima Prefecture, Japan. No fossil species of this genus has been reported except a Miocene species, *A. venezuelanus* BERRY, 1941, in Venezuela. The new species is the oldest record of *Amphioplus* in the geological ages. Judging from the associated molluscan fossils, the sedimentary environment where these ophiuroids lived is inferred to be a shallow marine.

Introduction

Two fossil specimens of ophiuroid were collected from the Oligocene Asagai Formation of Uchigo, Iwaki City, Fukushima Prefecture, Japan. They have been preserved at the National Science Museum, Tokyo, and at the Yotsukura Historical Museum, Iwaki City, Fukushima Prefecture. The former was listed by YANAGISAWA (1957) as “*Ophiura? uchigoensis* EGUCHI et YANAGISAWA” but was *nomen nudum*. The same specimen was illustrated as *Macrophiothrix?* sp. by FUJIYAMA (1982). The latter specimen was listed by HAMADA and ITOIGAWA (1983) and by TAKAHASHI (1988) as “an ophiuroid” in their books. The ophiuroid species has not been systematically described in these references.

This paper provides the first systematic description of the species, *Amphioplus uchigoensis*. This is the first record of the fossils of the genus *Amphioplus* in Japan. Only one fossil species of the genus *Amphioplus* has been known (*Amphioplus venezuelanus* BERRY, 1941) from the Miocene of Venezuela. Fossil ophiuroids have been occasionally found in the Tertiary of Japan, but they have not been specifically identified yet. Among them a few specimens were specifically discussed (MASUDA and NAKAGAWA, 1973; OKUBO, 1976; Itsukaichi Basin Research Group, 1983; Palaeontological Subgroup of Itsukaichi Basin Research Group, 1985; ISHIDA, 1988).

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Fossil locality and geology

Two ophiuroid specimens were found at an outcrop of a cliff of the Yasaka Shrine, about 350 meters southeast of the Uchigo Station of the Joban Line (Fig. 1). The strata of this cliff are assigned to the uppermost part of the Asagai Formation of the Oligocene Shiramizu Group (SUGAI *et al.*, 1957). The Asagai Formation is composed mainly of medium to fine sandstone, of which the grain size becomes finer in ascending order. In the uppermost part of this formation, siltstone and shale beds are intercalated.

The outcrop containing the two ophiuroid specimens is about 17 meters in height, and its lithofacies are fine-grained sandstone and sandy mudstone. Some mudstone and fine tuff layers are intercalated in the outcrop (Fig. 2). The country rock of the

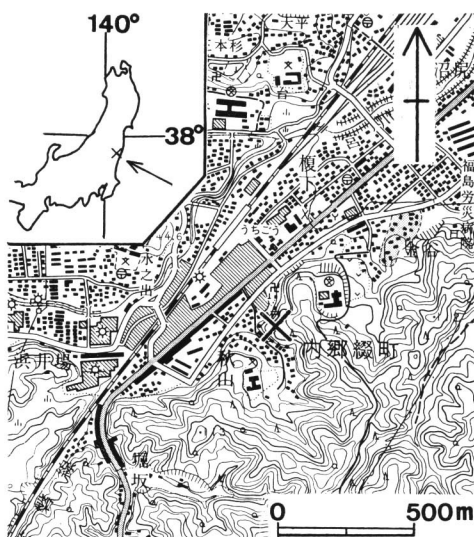


Fig. 1. Locality of fossil ophiuroids. A part of the topographic map of "Joban-Yumoto" on the scale of 1: 25000 by the Geographical Survey Institute. ×: Fossil locality.

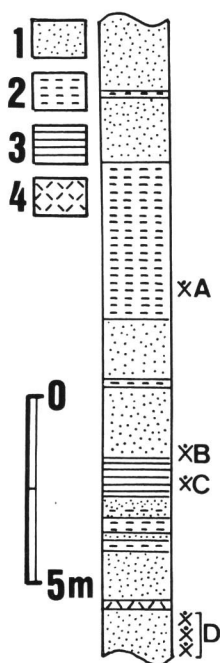


Fig. 2. Columnar section of the outcrop and the site of the fossil ophiuroids. 1: fine sandstone, 2: sandy mudstone, 3: mudstone, 4: tuff, A: *Clinocardium decoratum* (GREWINGK), B: *Clinocardium* sp., *Diodora* sp., C: *Thracia* sp., *Mya* (*Arenomya*) cf. *grewingki* MAKIYAMA, fish scales, D: *Clinocardium* cf. *decoratum* (GREWINGK), *C. asagaiense* (MAKIYAMA), *C.* sp., *Anadara* cf. *chichibuensis* KANNO.

fossil ophiuroids is sandy mudstone, but the exact positions in the cliff where the two specimens occurred are not clear. *Clinocardium decoratum* (GREWINGK), *C. asagaiense* (MAKIYAMA), *C.* sp., *Anadara* cf. *chichibuensis* KANNO, *Thracia* sp., *Mya* (*Arenomya*) cf. *grewingki* MAKIYAMA, *Diodora* sp., and some fish scales were found in this outcrop. The molluscan fossils found herein are well-preserved and are not broken to pieces, so these fossils seem to be autochthonous or quasi-autochthonous.

Systematic description

Class Stellerioidea LAMARCK, 1816

Subclass Ophiuroidea GRAY, 1840

Order Ophiurida MÜLLER & TROSCHEL, 1840

syn. Myophiuroida MATSUMOTO, 1915

Suborder Genathophiurina MATSUMOTO, 1915

Family Amphiuridae LJUNGMAN, 1867

Genus *Amphioplus* VERRILL, 1899

Type-species: *Amphiura tumida* LYMAN, 1878

Diagnosis: Arms are slender, long, and flexible. Arm spines are short and erect. Disk tends to drop off from the jaw apparatus. Having a pair of infradental papillae at a tip of jaw and four or five oral papillae at each side.

Amphioplus uchigoensis n. sp.

(Fig. 3; Table 1A; Plate 1, figs. 1, 2, 4, 5)

Ophiura? uchigoensis EGUCHI & YANAGISAWA, (*nom. nud.*), YANAGISAWA, 1957, p. 88.

Macrophiothrix? sp., FUJIYAMA, 1982, p. 380, pl. 190, fig. 1894.

Materials: Holotype, NSM-PA11745. Stored at the National Science Museum, Tokyo, Japan. The collected site is Akiyama, Tsuzura, Uchigo, Iwaki City, Fukushima Prefecture. Asagai Formation, Oligocene.

A conferred specimen collected from the same locality by the late Gen KOBAYAMA has been stored at the Yotsukura Historical Museum, Iwaki City, Fukushima Prefecture.

Diagnosis: Having two arm spines of the same length. Distal part of the oral frame protrudes from the vertebra and is very pointed.

Measurements: Detailed measurements are shown in Table 1A.

Description: The holotype shows the oral side, and is mostly represented by an impression, but partially its skeletons are preserved. The jaw apparatus is preserved in the holotype, but the disk has dropped off from the jaw apparatus in appearance. The diameter of the jaw apparatus is about 3.5 mm. The jaw apparatus shows V-shape which points to the center of the oral apparatus, but individual parts of the holotype are indistinguishable. The angle of the V-shape is about 45°. The distal part of the oral frame protrudes from the vertebra and is very pointed (Fig. 3, B). The tooth is half oval in shape, not forming the tooth papillae. The oral slits are almost rectangular. At the distal part of the oral slit, the joint part of the vertebra and the oral frame is circular in shape. Part of the oral plate (Fig. 3, B) is a slender rectangle. The arms are very long, about 40 times of the diameter of the jaw apparatus. They are very slender, and their widths are invariable except for the distal parts with abrupt tapering. The arms are flexible along the horizontal plane. Although the arms are quite straight for long length, they also have sharp S-shaped bends that can occur at any place along their length. The ratio of width to length of an arm segment is about 1.7 at the basal part, 1.2 at a distance of 10 cm from the base, and 0.6 at the distal part (Table 1A). Consequently, the width of arm segments exceeds the length except at the distal part. The distal arm segments are trapezoidal in shape, and each segment becomes narrower in the direction of the basal side (Fig. 3, C, d). The lateral arm plates are well developed and protrude from the basal side of each segment. The

Table 1. Measurements of *Amphioplus uchigoensis* and others.

D: the distance of the measured arms from the base, W: width of the arm segments, L: length of the arm segments, A: length of the arm spines.

A. *Amphioplus uchigoensis*

e-e': part of arm showing in Fig. 3, A and pl. 1, fig. 1. Arm length: 120+ mm.

D (mm)	Base	10	20	40	70	100	e 0	e' 10	e' 20
W (mm)	1.0	1.0	0.9	1.0	0.9	0.8	0.7	0.5	0.3
L (mm)	0.6	0.6	0.7	0.6	0.7	0.6	0.6	0.5	0.5
A (mm)	—	0.5	0.8	0.6	0.8	0.7	0.6	0.5	0.5
W/L	1.7	1.7	1.3	1.7	1.3	1.3	1.2	1.0	0.6
A/W	—	0.5	0.9	0.6	0.9	0.9	0.9	1.0	1.7

B. *Amphioplus* cf. *uchigoensis*

Disk diameter: 10 mm, Arm length: 70+ mm.

D (mm)	Base	20	40	60	70
W (mm)	0.9	0.9	0.9	0.8	0.8
L (mm)	0.7	0.7	0.6	0.6	0.6
A (mm)	0.7	0.7	0.8	0.6	0.6
W/L	1.3	1.3	1.4	1.3	1.4
A/W	0.8	0.8	0.9	0.8	0.8

C. Recent *Amphioplus abditus* (VERRILL)

Locality: Conneticut, USA.

Disk diameter: 8 mm, Arm length: 170 mm.

D (mm)	Base	20	40	80	100	120	140	160	170
W (mm)	1.0	1.0	1.0	0.9	0.8	0.7	0.5	0.4	0.2
L (mm)	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.2
A (mm)	0.5	0.6	0.5	0.5	0.4	0.4	0.3	0.2	0.1
W/L	2.0	2.0	2.0	1.8	2.0	1.8	1.3	1.0	1.0
A/W	0.5	0.6	0.5	0.6	0.5	0.6	0.6	0.5	0.5

D. Recent *Macrophiothrix bell* (DÖDERLEIN)

Locality: Broome, West Australia

Disk diameter: 20 mm, Arm length: 310 mm.

D (mm)	Base	40	80	120	160	200	240	280	310
W (mm)	2.5	2.6	2.5	2.2	2.2	2.2	2.0	1.6	0.9
L (mm)	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.5
A (mm)	0.8	3.0	3.0	3.0	3.0	3.0	3.0	2.8	1.0
W/L	2.5	2.6	2.5	2.2	2.4	2.4	2.4	2.0	1.8
A/W	0.3	1.2	1.2	1.4	1.4	1.5	1.5	1.8	1.1

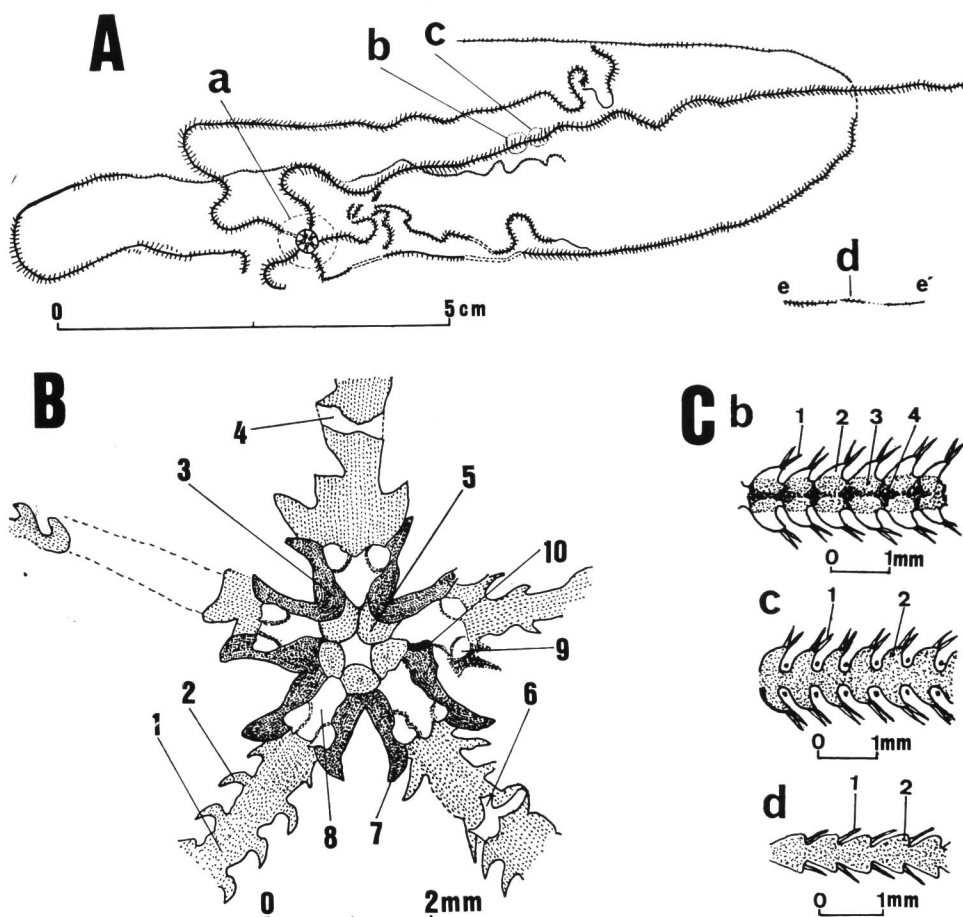


Fig. 3. *Amphiplus uchigoensis* n. sp., oral side.

- A. Parts a, b, c, d are enlarged in B, C.
 B. Jaw apparatus and basal arm. Showing part a in A. 1: arm, 2: lateral arm plate, 3: jaw apparatus, 4: lateral arm plate, 5: parts of the tooth, 6: vertebra, 7: distal part of the oral frame, 8: oral slit, 9: joint of vertebra and oral frame, 10: a part of the oral plate.
 C. Arms. Showing parts b, c, d in A. Part d showing segments of distal part of arm. 1: arm spine, 2: lateral arm plate, 3: vertebra, 4: articulation of vertebra.

lateral arm plates seem to contact each other in the center of the oral side. They are narrow at the central part of the arm segment but wider at the outer part. The ventral arm plates in the holotype are indiscernible because of poor preservation. The arm spines are slender, short, almost equal to the length of the corresponding arm segment, and pointed at the tip. At the distal part of the arm, the length of the arm spines is 1.7 times the width of the arm segments, and it ranges from 0.5 to 0.9 times at the other parts (Table 1A). The lateral arm plate carries two arm spines of equal length.

The angles of the arm spines to the arm segments range from 45° to 90° . The shape of the ventral furrow appears to be semi-circular in the vertical cross-section. The form of the articular umbo is indistinct in the holotype (Fig. 3, C, b).

Comparison: Recent *Amphioplus* species have more than three arm spines (MATSUMOTO, 1917), whereas the *Amphioplus uchigoensis* has only two. The length of arm of the fossil species *Amphioplus venezuelanus* BERRY is only 3 cm, whereas that of *Amphioplus uchigoensis* is about 12 cm. The number of arm spines of *A. venezuelanus* is three. That of the new species is two.

Remarks: Oral papillae, which are necessary for precise identification of Amphiuridae (CLARK, A. M., 1970), are invisible in the holotype. Nevertheless, the

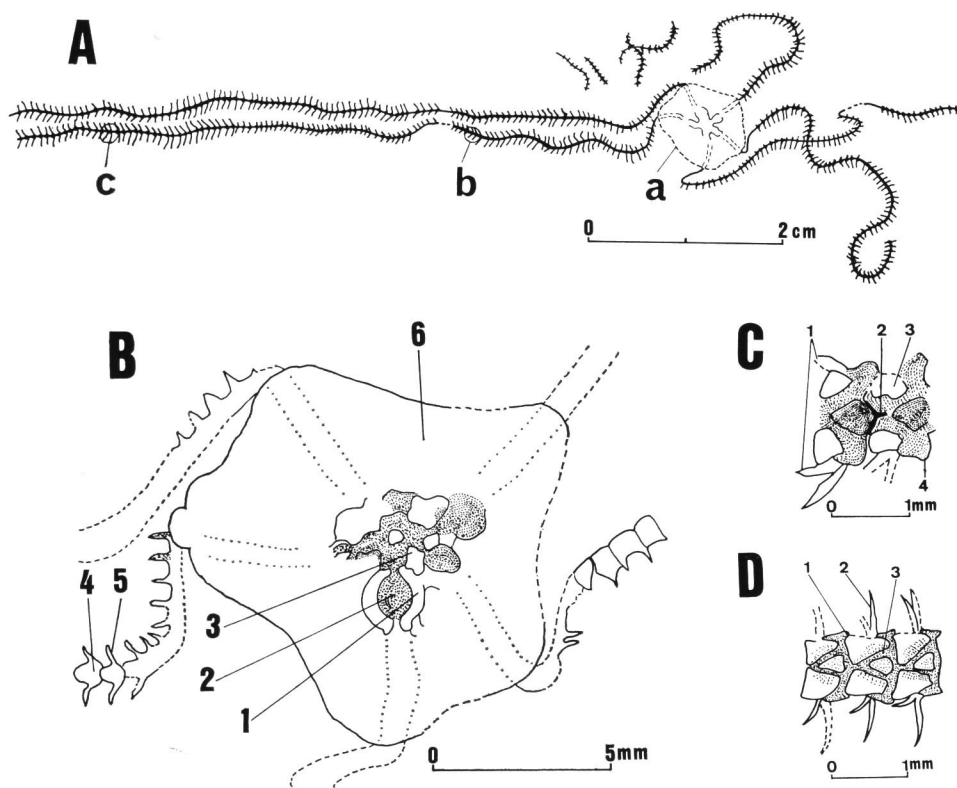


Fig. 4. *Amphioplus* cf. *uchigoensis*, oral side.

- A. Parts a, b, c are enlarged in B, C, D.
- B. Disk. Showing part a in A. 1: oral frame, 2: oral slit, 3: parts of tooth, oral plate and dental plate, 4: arm, 5: arm spine, 6: disk.
- C. Vertebra. Showing part b in A. 1: arm spine, 2: articular umbo, 3: space between lateral arm plate and vertebra, 4: lateral arm plate.
- D. Inside of aboral side of the arm. Showing part c in A. 1: lateral arm plate, 2: arm spine, 3: vertebra.

writer assigns the fossil to the genus *Amphioplus* (s.l.) based on the following features. The features of the specimen are similar to those of the genus *Amphiura*. The arms of the fossil (Table 1A) are slender, long, flexible, and the arm spines are short and erect. The specimen is, however, different from those belonging to the genus *Amphiura* because the disk of the specimen has a tendency to drop off from the jaw apparatus. The disk of the living *Amphioplus* tends to drop off from the jaw apparatus (by personal communication of Dr. Seiichi IRIMURA; Pl. 1, fig. 3). The species of *Macrophiiothrix* (Table 1D) have long arms which are slightly wider than those of *Amphioplus uchigoensis*, and have longer arm spines than *A. uchigoensis*. Judging from the above mentioned features, the present species differs from the species of *Macrophiiothrix*.

A specimen from the same locality, where the holotype of *Amphioplus uchigoensis* was found, is conferred to *A. uchigoensis*. Most features of the conferred specimen are similar in many aspects to the holotype of *Amphioplus uchigoensis* (Fig. 4; Table 1B; Plate 2). However, the conferred specimen retains its disk but is not well-preserved, instead of dropping off from the jaw apparatus as in the holotype. The conferred specimen shows the oral side, and its measurements are shown in Table 1B. The disk is pentagonal with slightly notched interradian edges. One tooth is discernible at a distance of 1 mm from the center of the disk. The diameter of the jaw apparatus is 2.5–3.0 mm, and $2/5$ – $1/2$ times the radius of the disk. The oral slits are elliptical (Fig. 4, B). The arms are about seven times the disk diameter. In each vertebra, the isosceles triangle which points to the distal part is discernible (Fig. 4, D). Considering these features, the conferred specimen probably belongs to the same species as the holotype.

Paleo-environment

The arms of the fossil ophiuroids described in this paper are well preserved, being almost autochthonous. Recent ophiuroids of the genus *Amphioplus* live on the sea bottom at 7 meters to 4000 meters depth (Table 2). Some Japanese species such as *Amphioplus glaucus*, *A. megapomus*, *A. ancistrotus*, *A. japonicus* (endemic species in Japan) are known to live in the shallow sea with depth of a few to a hundred meters in Suruga Bay and others in Japan.

Various well-preserved bivalves such as *Anadara*, *Clinocardium*, *Mya*, *Thracia* and *Diodora*, are associated with *Amphioplus uchigoensis*. *Clinocardium decoratum* and *C. asagaiense* are the most abundant among them. Both valves of each *Clinocardium* contact each other and their axial planes cross the bedding plane at steep angle. These features indicate that the fossils are autochthonous or quasi-autochthonous. The living species of the bivalves corresponding to the fossil species mentioned above live at a depth of about 10 to 150 meters (Table 3).

The range of habitable depths of the Recent *Amphioplus* species is wider than that of bivalves such as *Clinocardium*. Therefore, the writer suggests that the paleo-environment in which *Amphioplus uchigoensis* lived is shown by the habitat of the

Table 2. Living environment of Recent *Amphioplus*. B.M.: bottom material, M: mud, FS: fine sand, S: sand. ①–⑩: references: ① CLARK (1911), ② D'YAKONOV (1954), ③ IRIMURA (1968), ④ IRIMURA (1981), ⑤ IRIMURA (1982), ⑥ KOEHLER (1922), ⑦ MATSUMOTO (1917), ⑧ MURAKAMI (1942), ⑨ MURAKAMI (1966), ⑩ ISHIDA (unpublished).

Species	Localities	Depth (m)	B.M.	
<i>Amphioplus</i>	34°09'20"N, 138°40'15"E, Suruga Gulf	920	M	①
<i>rhadinobranchius</i>	34°52'45"N, 138°42'20"E, Suruga Gulf	516	M	①
CLARK	35°11'25"N, 139°28'20"E, Sagami Bay	675–741	M	①
	Off Aziro, Sagami Sea	366		⑧
	Azuro Bay	458		⑧
	Sagami Bay, Sagami Sea, Suruga Bay	155–1050		⑤
	13°51'30"N, 120°51'30"E, China Sea	291	M	⑥
	Okinose, Sagami Sea	155		⑦
<i>A. acanthinus</i>	Off Tsuragi Saki Light, Honshu Island	201–474	M, FS	①
CLARK	34°46'N, 138°21'50"E, Suruga Gulf	271	M	①
<i>A. hexacanthus</i>	37°59'45"N, 123°08'35"W, off California	92	M	①
CLARK	35°04'42"N, 139°38'20"E, Uraga Strait	161	S	①
<i>A. megapomus</i>	35°05'30"N, 134°56'40"E, off Kii	68	S, M	①
CLARK	Tanabe Bay etc.	—		④
<i>A. cernuus</i> (LYMAN)	Eastwards from Honshu	4209		⑦
<i>A. ancistrotus</i>	Okinose, Sagami Sea	156		⑦
(CLARK)	Off Misaki, Sagami Sea	657		⑦
	Uraga Channel	128–361		⑦
	Off Manazuru Zaki, Sagami Sea	280		⑦
	Off Ose Zaki, Suruga Gulf	82–119		⑦
	Off Kii, Kitan Channel	350		⑦
	Sea of Japan	112		⑦
	Sagami Bay (14 localities)	70–250		⑤
	Off Aziro, Sagami Sea	366		⑧
	Off Shimizu, Suruga Bay	40–80		⑩
	Near Sado Island, Sagami Bay	90–280		②
<i>A. macraspis</i>	Otaba, Sagami Sea	915		⑦
(CLARK)	Off Honshu	916–1371		⑦
	Suruga Gulf	110–494		⑦
	Sagami Sea	1138		⑦
	Off Korea	337		⑦
	Gulf of Tartary	582		⑦
	Off Washington	210		⑦
	Widespread in the North Pacific	7–1400		②
<i>A. japonicus</i>	Off Hayama, Sagami Bay	11	M	⑤
(MATSUMOTO)	Tanabe Bay, west of Mutsu Bay etc.	—		④
	Bays of the Japanese Pacific coast	—		③
<i>A. miyadai</i>	Tanabe Bay, Gokasho Bay etc.	—		⑨
MURAKAMI				③
<i>A. asterictus</i> CLARK	Gokasho Bay, Matoya Bay etc.	—		⑨

Table 2. (Continued)

Species	Localities	Depth (m)	B.M.	
<i>A. glaucus</i> (LYMAN)	Off Shimizu, Suruga Bay	40	M, FS	⑩
<i>A. legatus</i> KOEHLER	13°45'05"N, 120°30'30"E, Balayan Bay etc	721	M, S	⑥
<i>A. conductus</i> KOEHLER	10°28'45"N, 124°05'30"E, Sebu etc.	704	M	⑥
<i>A. impressus</i> (LJUNGMAN)	13°48'00"N, 121°43'00"E, Marinduque Is.	194	S	⑥
<i>A. lucidus</i> KOEHLER	05°10'15"N, 119°53'00"E	29	FS	⑥
	13°49'40"N, 121°40'15"E, Marinduque Is.	152	M	⑥
<i>A. luctator</i> KOEHLER	11°22'00"N, 119°E, Palowan Passage	95	M	⑥
<i>A. relictus</i> (KOEHLER)	11°31'40"N, 124°42'40"E	58	M	⑥
	11°38'05"N, 124°40'45"E	64		⑥
	06°52'05"N, 126°14'15"E, Pujada Bay	313		⑥
	10°56'55"N, 119°17'24"E	26-46	M	⑥
<i>A. multispina</i> KOEHLER	13°38'00"N, 121°58'00"E, San Andreas Is.	91	M	⑥
	13°38'15"N, 121°48'15"E, San Andreas Is.	353	M	⑥
	13°38'30"N, 121°42'45"E, San Andreas Is.	357	M	⑥
	13°42'15"N, 121°50'15"E, Marinduque Is.	196		⑥

Table 3. Living environment of Recent bivalves, according to HIGO (1973), KURODA and HABE (1952).

Genus	Depth (m)	Latitude (°)
<i>Anadara</i>	0-20	-0-42 N
<i>Clinocardium</i>	10-150	34-72 N
<i>Mya</i>	0-20	31-72 N
<i>Thracia</i>	10-100	32-46 N
<i>Diodora</i>	0-200 (mostly 0-20)	-0-36 N

bivalves to be 10-150 meters in depth.

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Explanation of Plates

Plate 1

- fig. 1. *Amphioplus uchigoensis* n. sp., oral view. e-e' corresponding to e-e' in Table 1A and Fig. 3, A.
- fig. 2. *Amphioplus uchigoensis* n. sp., Jaw apparatus and basal parts of arms. The disk is indiscernible.
- fig. 3. *Amphioplus ancistrotus* (H. L. CLARK), aboral view. Recent species from Suruga Bay in 40-80 m depth.
- fig. 4. *Amphioplus uchigoensis* n. sp., a part of arm. Indicated by X in plate 1, fig. 1. The arm is curved flexibly in the shape of S along the horizontal plane. The arm spines are slender and pointed at the tip.
- fig. 5. A part of arm, indicated by Y in pl. 1, fig. 1 (parts b to c in Fig. 3, A). The arm spines and the lateral arm plates are discernible.

Plate 2

- fig. 1. *Amphioplus* cf. *uchigoensis*, oral view. The arms are slender and are bent flexibly along the horizontal plane.
- fig. 2. *Amphioplus* cf. *uchigoensis*, disk. Slightly notched with interradian edges. The oral slits are elliptical in shape.
- fig. 3. *Amphioplus* cf. *uchigoensis*, a part of arm. Indicated by X in pl. 2, fig. 1. A part is sketched in Fig. 4, C. There are two arm spines. Vertebrae are discernible.
- fig. 4. *Amphioplus* cf. *uchigoensis*, a part of arm. Indicated by Y in pl. 2, fig. 1. A part is sketched in Fig. 4, D. Inside of aboral side. At the middle of the vertebral ossicles, the isosceles triangle is discernible.

