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E-mail: hyxbe@263.net

The first record of *Ophioleila elegans* (Echinodermata: Ophiuroidea) from a deep-sea seamount in the Northwest Pacific Ocean

ZHANG Dongsheng[1], LU Bo[1], WANG Chunsheng[1, 2]*, O'HARA Timothy D[3]

[1] Key Laboratory of Marine Ecosystem and Biogeochemistry, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China

[2] State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China

[3] Marine Invertebrates, Science, Museum Victoria, Melbourne 3000, Australia

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Abstract

The rare ophiuroid species, *Ophioleila elegans*, was collected by the submersible *Jiaolong* from 1 660 m depth on the Caiwei Guyot located in the Magellan Seamount Chain in the Northwest Pacific Ocean. This is the first published record of this species since the types were described from similar habitat off Hawaii. We provide more detailed morphologic characteristics of arm skeleton and a phylogenetic analysis based on CO1 sequences. Both morphology and phylogeny results suggest that the genus *Ophioleila* is more closely related to Ophiactids than Hemieuryalids.

Key words: *Ophioleila elegans*, systematics, deep-sea seamount, the Northwest Pacific Ocean

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1 Introduction

Ophioleila with only one species, *Ophioleila elegans* A. H. Clark, 1949, is a rare ophiuroid genus previously reported from deep sea floor (748–1 342 m) habitat in the vicinity of the Hawaiian Islands (Clark, 1949). In this study, we redescribe this species based on two specimens collected from a deep-sea guyot in the Magellan Seamount Chain in the Northwest Pacific Ocean.

Ophioleila was placed in the family Hemieuryalidae by Fell (1960). However, Martynov (2010) and O'Hara et al. (2017) have found the traditional Hemieuryalidae grouping to be a polyphyletic assemblage, and O'Hara et al. (2017) found that the type genus *Hemieuryale* to be related to the genus *Ophioplocus*. O'Hara et al. (2017) also managed to sequence exonic and mitochondrial DNA from one of these new *Ophioleila* specimens, which indicated a phylogenetic relationship with the genera *Ophiothamnus* and *Histampica*. They provisionally placed these three genera in a new family-level lineage, the "Ophiothamnidae" (yet to be officially described), sister to a clade containing the Ophiactidae *sensu stricto*, *Ophiopholis* and Ophiotrichidae.

We provide more detailed information about the morphology of *Ophioleila* in this study, and in particular the arm skeleton which supports the ophiactid affinities of *Ophioleila*.

2 Materials and methods

During the China Ocean Mineral Resources R & D Association (COMRA)'s cruise DY35 in 2014, two specimens in this study were collected by the manned submersible vehicle *Jiaolong* on a glass sponge (Fig. 1) from the Caiwei Guyot located in the Magellan Seamount Chain in the Northwest Pacific Ocean. The two specimens were fixed in 80% ethanol on board and deposited in the sample repository of the Second Institute of Oceanography (RSIO35101), Hangzhou, China.

Photographs were taken on board with a Nikon DSLR and in the laboratory using a dissection-microscope (Leica M205C) equipped with a camera (DFC450). Arm skeletal elements for scanning electron microscope (SEM) were processed as Gondim et al. (2015), which were submerged in commercial bleach (2.5% NaOCl), until all soft issue dissolved, then washed in tap water, air-dired and mounted on aluminum stubs, metalized with gold and imaged using a Hitachi TM1000 scanning electron microscope.

DNA extraction was done with DNeasy blood and tissue kit (Qiagen, CA, USA) following the protocol supplied by the manufacturer. COI sequence was amplified using primers Oph-COI-F and Oph-COI-R (O'Hara et al., 2014a). PCR mixtures contained ddH_2O, 0.8 μmol/L of each primer, 0.5 U of Taq polymerase (TAKARA, China), 2.5 μL of buffer solution (supplied by the polymerase manufacturer), 0.5 μL of 2.5 mmol/L dNTPs solution and 2 μL template DNA in a mixture of total 25 μL. The temperature profile was as follows: 95°C for 5 min, (94°C for 15 s, 50°C for 60 s, 68°C for 60 s) with 35 cycles, and then 68°C for 10 min. PCR products were purified with QIAquick PCR purification kit (Qiagen, CA, USA) following the protocol supplied by the manufac-

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*Corresponding author, E-mail: wang-sio@163.com; wangsio@sio.org.cn

turer. Sequencing was performed by Sangon Biotech (Shanhai, China) on an ABI 3730XL DNA analyser (Applied Biosystems). The new sequence is deposited in NCBI GenBank (MH492319). Alignments were performed using Genious 9.0 with default settings. A maximum likelihood (ML) analysis was conducted by RAxML GUI 1.5 beta (Stamatakis, 2014) with 1 000 replicates.

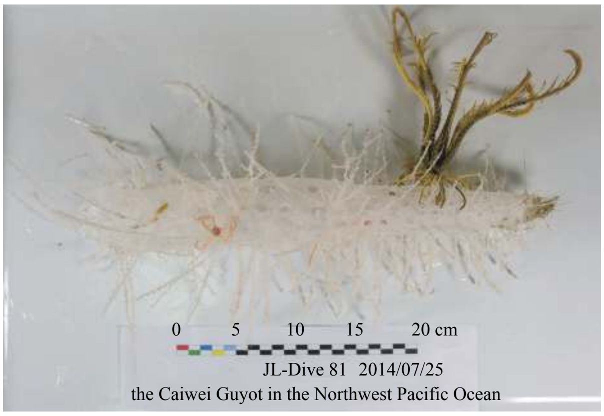

Fig. 1. Two individuals of *Ophioleila elegans* with sponge before they were removed.

3 Results

Systematics

Genus *Ophioleila* A. H. Clark, 1949

Ophioleila elegans A. H. Clark, 1949

***Ophioleila elegans* A. H. Clark, 1949**: Figs 2a–f and 3a–j

Material examined

The Caiwei Guyot of the Magellan Seamount Chain in the Northwest Pacific Ocean; 15°40.98′N, 154°55.80′E; 1 660 m; 2 specimens (RSIO35101); July 25, 2014.

Description

The disc is 9 mm in diameter. Ten enlarged swollen lobes, sack shape, longer than wide, curving around the edge of the disc and expanded more than 2 mm on the aboral side, covering most part of the disc. These lobes, covered by imbricated scales, bearing cylindrical or conical granules with a terminal crown of thorns, which are 0.2 mm high, slightly separated radially, contiguous interradially at the proximal end but separated distally by the arm bases (Fig. 2a).

Primary plates, round or irregular polygons, about 0.5 mm in diameter, covering the center of the disc, with one thorny granule similar to those on the swollen lobes on each plate (Fig. 2a).

Oral shields small and triangular, about 0.4 mm wide, with an acute proximal angle, slightly sunken compared with the adoral shields. Madreporic oral shield larger than the others and convex along the distal side (Figs 2b and c). Adoral shields, enlarged trapezoid shape, longer than wide, contiguous in the proximally, separating the oral shields from the first lateral arm plates, bearing two cylindrical or subconical oral papillae along the proximal side, the distal one protecting the external oral tentacle pore. Oral plates small and as long as wide, slight convex in the middle, bearing a cluster of 3–5 oral or tooth papillae, similar to the papillae on the adoral shields (Figs 2b and c).

Five arms, more than 5 times of disc diameter. The first dorsal arm plates, wider than long, with a straight distal margin, proximal edge rounded with an obtuse apex in the middle, consecutive plates similar to the first plates, slightly reducing in size distally (Figs 2a, e and 3a). The ventral arm plates wider than

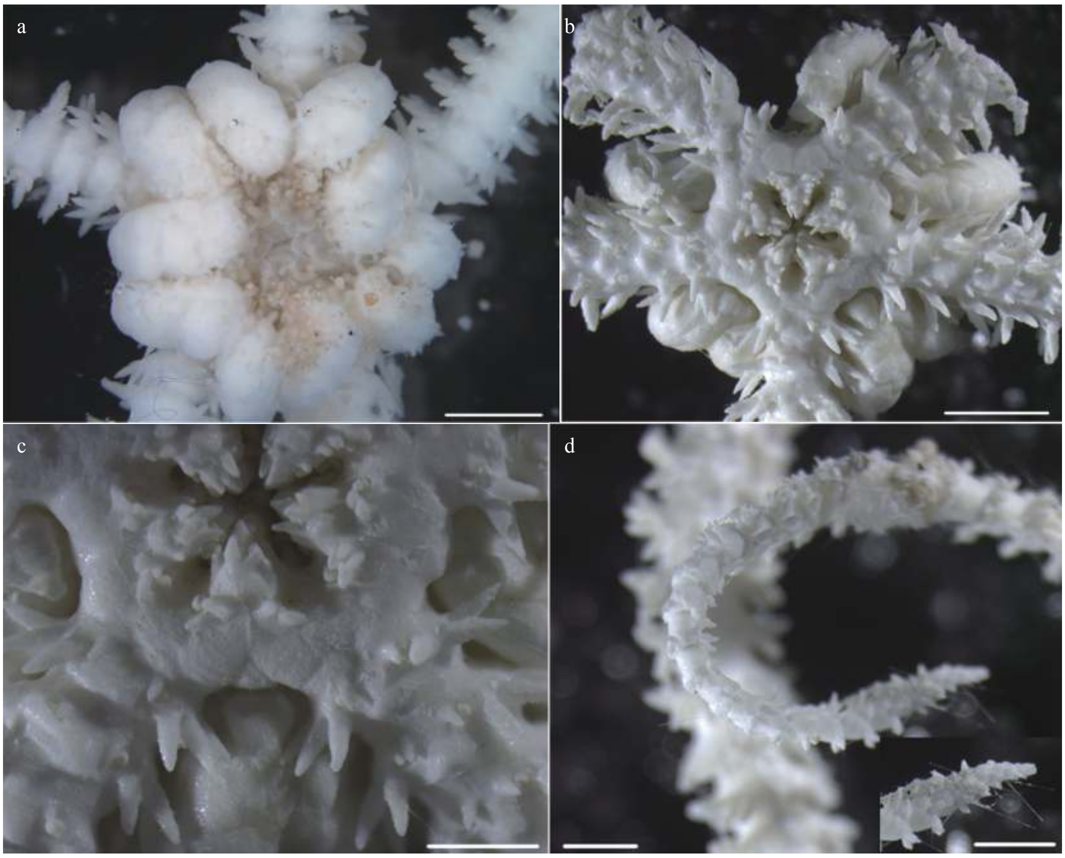

Fig. 2.

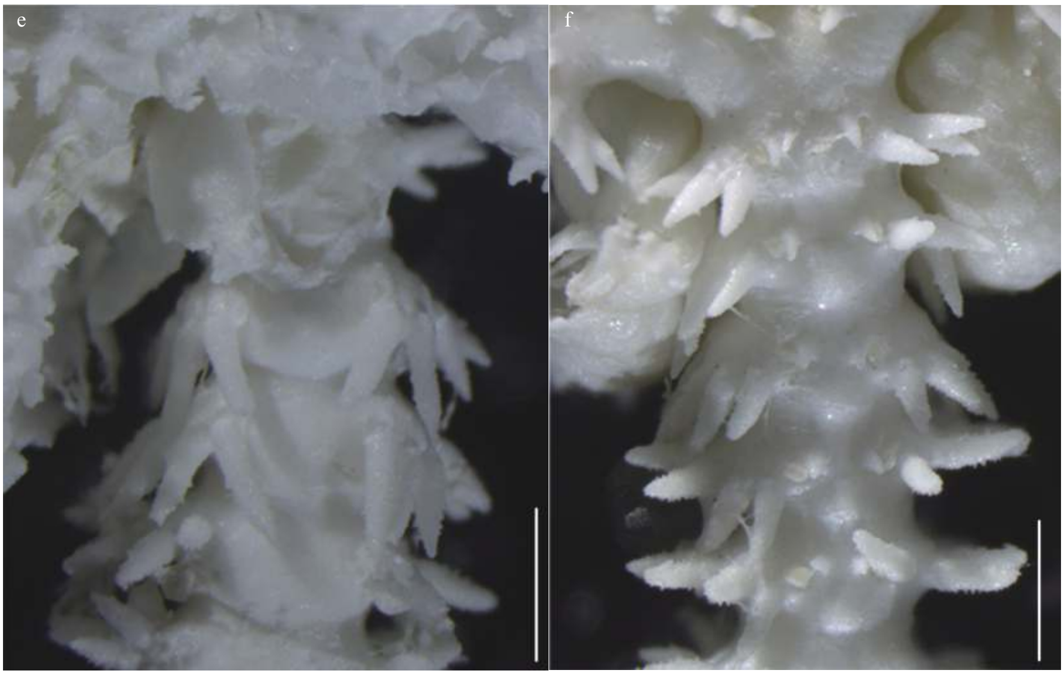

Fig. 2. Morphological characters of *Ophioleila elegans* (RSIO35101). a. Dorsal view; b. ventral view; c. ventral view of plates; d. distal part of arm; e. dorsal view of arm, proximal part; and f. ventral view of arm, proximal part. Scale bars: 2 mm (a, b), 1 mm (c, d, e, f).

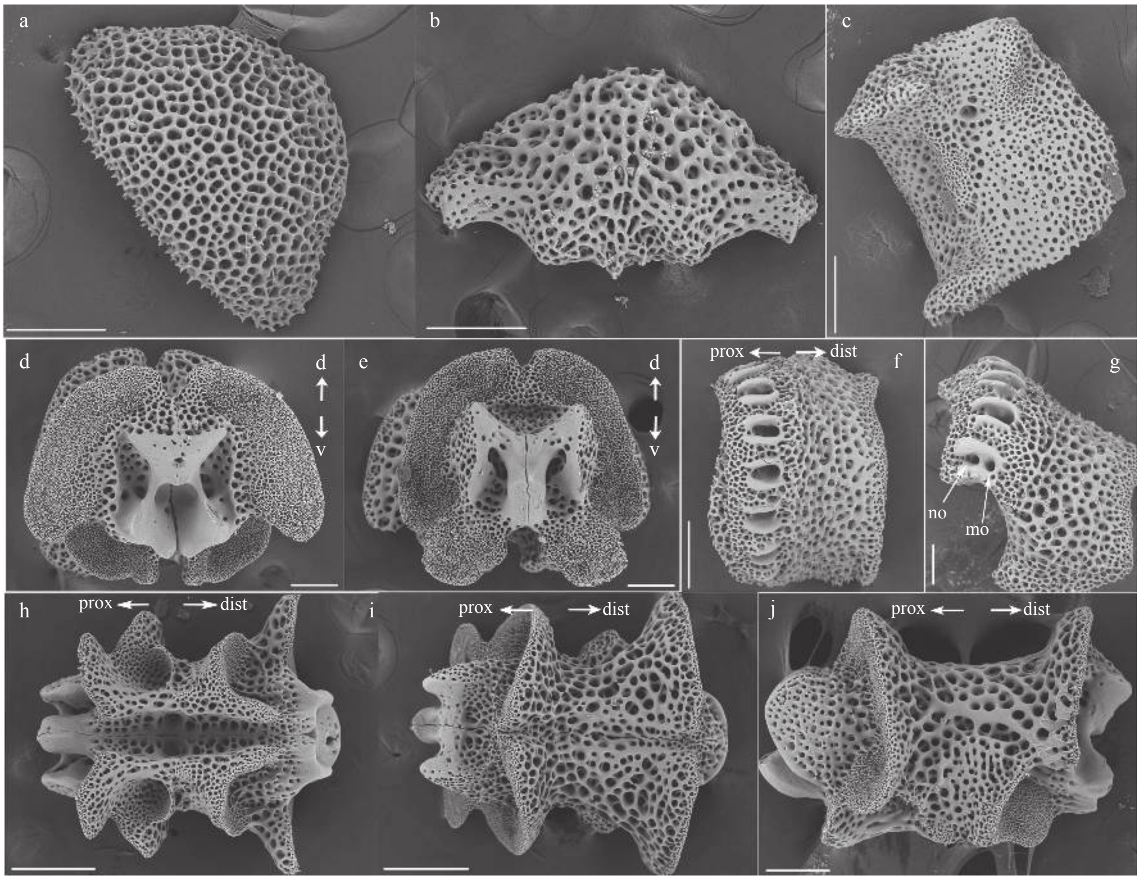

Fig. 3. SEM photographs of arm skeletal characters of *Ophioleila elegans*. a. Dorsal arm plate; b. ventral arm plate; c. internal view of lateral arm plate; d. distal view of vertebrae; e. proximal view of vertebrae; f. external view of lateral arm plate; g. ventral view of lateral arm plate; h. ventral view of vertebrae; i. dorsal view of vertebrae; and j. lateral view of vertebrae. mo represents muscle opening and no nerve opening. Scale bars: 200 μm (a, b, c, f, h, i, j), 100 μm (d, e, g).

long, widely separated by lateral plates, size progressively reducing towards the arm tip. The basal ventral arm plates triangular, with an acute proximal angle and flat distal margin, the second ventral arm plates triangular, similar to the basal plates, but with an obtuse proximal apex and slightly convex distal margin, succeeding plates fan-shaped, rounded distal margin, with a small elevation in the middle of the distal margin (Figs 2b, c, f and 3b).

Lateral arm plates, meeting ventrally and dorsally, with single perforation on the inner side, bearing up to 7 thorny arm spines on the proximal half arm (Figs 2d and 3c). On the first two segments, the uppermost arm spines longest, the lowest spines shortest, most spines slightly longer than one segment except the lowest ones. From the third segment, the lateral spines longest, about one segment in length (Figs 2e and f), the uppermost arm spines become similar to the lowest spines in length. The spine lengths decreasing distally, become shorter than one segment (Fig. 2d). One tentacle scale, enlarged basally, oval or triangular, with an obtuse tip, curving around the tentacle pore from inside, permanently erect, 1/2 as long as the ventral arm plate (Fig. 2f).

The arm spine articulations well developed, with two parallel ridges, of equal length, one or two large openings except the ventral articulation with two smaller openings (Figs 3c, f and g). The vertebrae zygospondylous articulation, as long as wide in the proximal segments and slightly longer than wide from the middle to the distal segments, not keeled, with distinct suture line in dorsal and ventral view (Figs 3d, e, h, i and j).

Remarks

Ophioleila elegans was first described on the basis of two specimens collected from deep sea bottom near the Hawaii. The two specimens examined in this study are similar to the description of the holotype. However, there are some slight differences also, such as the number of arm spines reach up to 7 on the first three segments, and there are more oral papillae on the edge of the oral plate and adoral shields, all of which are considered here as intra-species variations. With only two specimens at our disposal, we did not dissect out the dental, oral or genital plates.

Phylogeny

The maximum likelihood (ML) tree based on COI sequences, though support values are not very high, suggested that *Ophioleila elegans* falls into a separated lineage from the other hemieuyalids including the type genus *Hemieuyale* and another genus *Sigsbeia* (Fig. 4). Instead, *O. elegans* was closely related to *Ophiothamnus*, *Ophiactis* and *Ophiopholis*, which from Ophiacanthidae and Ophiactidae, respectively.

4 Discussion

Ophioleila is probably one of the least known genera of Ophiuroidea, with respect to their ecology and morphology, and

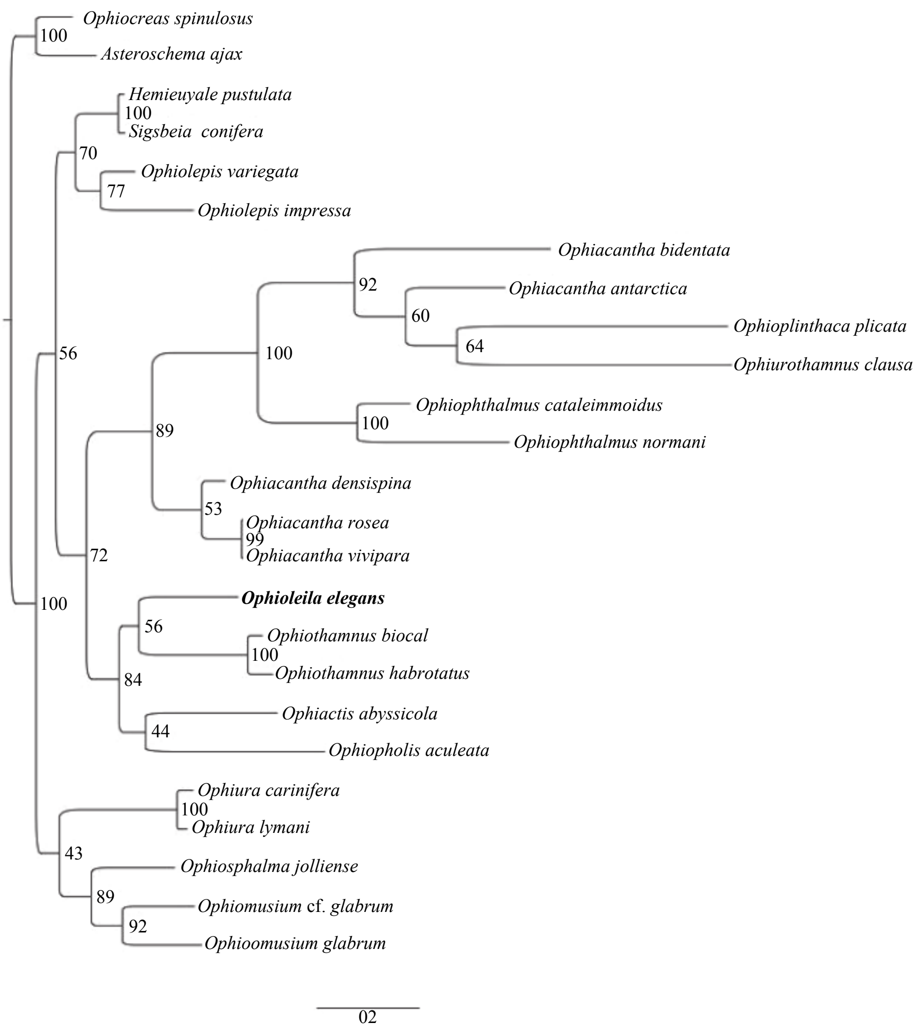

Fig. 4. Maximum likelihood tree based on COI sequences. Bootstrap support values were generated with a rapid bootstrapping algorithm for 1 000 repilcates.

phylogeny. *Ophioleila elegans*, the only species of the genus *Ophioleila*, is so rare that it has not been reported for almost 70 years since its first record around the Hawaiian Islands (Clark, 1949).

The shape of the lateral arm plate and in particular the arm spine articulation surface has emerged as one of the key diagnostic characters for higher-level taxonomy within the Ophiuroidea (O'Hara et al., 2014b; Thuy and Stöhr, 2016). The arm spine articulation shown here, with two parallel ridges surrounding two large pores for nerve and muscle connections, is very similar to that described for the Ophiactidae, and in particular to the related genus *Histampica*, and not at all similar to *Hemieuryale*, the type genus of Hemieuryalidae (Martynov, 2010; Gondim et al., 2015; Thuy and Stöhr, 2016). Thus we demonstrate the ophiactid affinities of *Ophioleila*, and support for molecular data that places this genus in a separate family-level lineage with *Histampica* and *Ophiothamnus*. We also note the similarity of the oral frame (tiny oral shield surrounded by enlarged adoral shields) to that found in the genus *Ophiothamnus* (O'Hara and Stöhr, 2006).

Our observation extends the distributional range of *O. elegans* across the central Pacific Ocean from Hawaii to the Magellan Seamounts. The new specimens were found on a glass sponge (Fig. 1). The rocky habitat recorded from both our samples and the types indicates that this species might be epizoic at depths of 1 300–1 800 m. Water depth has been considered as one of the most important factors that drives biogeographic patterns of benthic species on seamounts (O'Hara, 2007). With most of the seafloor occurring at abyssal depths across the central Pacific Ocean, the most likely dispersal mechanism of *O. elegans* is to use the scattered seamounts as "stepping-stones" between the Hawaiian Islands and the Magellan Seamount Chain. This suggests a possibility that *O. elegans* may also be found on other seamounts in the North Pacific Ocean in future. More sampling is required to determine whether this species is endemic to the north central Pacific Ocean.

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