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Research article

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***Gibbosaverruca weijiai*, a new verrucid (Crustacea, Thoracica) species from the Weijia Guyot deep-sea seamount in the West Pacific**

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Abstract. A new species of verrucid barnacle, *Gibbosaverruca weijiai* sp. nov., is described and illustrated based on specimens collected from a deep-sea seamount, Weijia Guyot, in the West Pacific. This is the third barnacle species reported from Weijia Guyot. The new species is distinguished from its congeners by its extremely long caudal appendage. In terms of shell morphology, *G. weijiai* sp. nov. is most similar to *G. gibbosa* and *G. sulcata* but differs from them by the intermediate articular ridges of its movable tergum and scutum, which are distinctly wider than the axial ridges. The COI and 16S rRNA sequences of the holotype of *G. weijiai* sp. nov. are presented to support future research, and a key to extant species of the genus *Gibbosaverruca* Young, 2002 is provided.

Keywords. Taxonomy, morphology, barnacle, identification key.

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Introduction

The family Verrucidae Darwin, 1854 is a species-rich group of asymmetrical sessile barnacles mainly inhabiting deep waters. Young (1998, 2002, 2004) performed excellent taxonomic work on a generic revision of the Verrucidae and described new genera and species. Currently, there are 12 extant genera identified in the family. *Gibbosaverruca* Young, 2002 is one of the genera separated from the genus

Altiverruca Pilsbry, 1916 by Young (2002) based on external features of the shells. He placed *G. gibbosa* (Hoek, 1883), *G. nitida* (Hoek, 1883), *G. sulcata* (Hoek, 1883), *G. costata* (Aurivillius, 1898), *G. mitra* (Hoek, 1907), *G. darwini* (Pilsbry, 1907), *G. navicula* (Hoek, 1913), *G. rathbuniana* (Pilsbry, 1916), *G. somaliensis* (Nilsson-Cantell, 1929), *G. laeviscuta* Buckeridge, 1994, *G. montereyi* Young, 2002, *G. robusta* Young, 2002 and *G. mateoi* Young, 2002 in this genus because they are all relatively large and possess opercular plates, a rostrum and a carina with pronounced growth lines and well-developed articular ridges on the surface. Recently, Gale (2020) reported three fossil species of *Gibbosaverruca* from the bathyal Upper Pliocene–Lower Pleistocene strata in the Rodrigues Ridge, Indian Ocean, including one new species, *G. youngi* Gale, 2020. However, many of the verrucid species are poorly described and lack any description of the soft body appendages, especially for the species described in the 19th century. This condition causes some difficulties in the revision of verrucid taxa and results in some species with uncertain statuses.

Weijia Guyot (also known as Ita Mai Tai Guyot) is a Cretaceous–Early Cenozoic seamount located in the northwest Pacific (12°50'0" N, 156°50'0" E), with a minimum depth of approximately 1400 m and a maximum depth of over 6000 m (Wedgeworth & Kellogg 1987; Lee et al. 2003, 2005). Although several scientific expeditions have been executed in Weijia Guyot, only two barnacle species have been reported from the seamount: *Scillaelepas ushakovi* Zevina, 1988 and *Arcoscalpellum angularum* Gan, Xu, Li & Wang, 2020 (Gan et al. 2020). In 2017, an investigation cruise (Voyage Dayang 41B) was carried out at Weijia Guyot and nearby seamounts by the Guangzhou Marine Geological Survey using the research vessel *Haiyangliuhao*. Several verrucid specimens were collected during this cruise. Detailed morphological examination indicates that these specimens represent a new verrucid species.

Material and methods

Specimens were collected from the peak plain of Weijia Guyot by the remotely operated vehicle (ROV) *Haima*. All specimens were preserved in 75% ethanol when taken on board. Morphological examination and molecular experiments were executed in the Department of Marine Organism Taxonomy and Phylogeny, Institute of Oceanology, Chinese Academy of Sciences. The specimens were deposited in the Sample Repository of the Second Institute of Oceanography (SRSIO), Ministry of Natural Resources of the People's Republic of China, Hangzhou.

Specimens were dissected using a stereo microscope (SMZ1500, Nikon, Japan) and photographed using a microscope integrated with an electronic imaging system (AZ100, Nikon, Japan). The measurement of each specimen is given as the basal rostro-carinal diameter (BD).

Total genomic DNA was extracted from the muscle of the thorax with the QIAamp DNA Mini Kit (QIAGEN, Hilden, Germany) following the manufacturer's instructions. Primers L1490/H2198 (Folmer et al. 1994) were used to amplify mitochondrial cytochrome oxidase subunit I (COI) gene fragment from the extracted genomic DNA, and primers 16S-AR/16S-1472 (Crandall & Fitzpatrick 1996) were used to amplify mitochondrial 16S rRNA gene fragment via polymerase chain reaction (PCR). The PCR was carried out in a 50-μl volume containing 25 μl Premix Taq (TransGen, Beijing, China), 1 μl each of the forward and reverse primers (10 μM), 3 μl DNA template, and 20 μl ultrapure water. The PCR procedure was performed by initial denaturation at 94°C for 5 min, 35 cycles of denaturation at 94°C for 30 s, annealing at 50–52°C for 40 s, elongation at 72°C for 50 s, and a final extension at 72°C for 10 min. The PCR products were purified using the QIAquick Gel Extraction Kit (Qiagen, Hilden, Germany) and bidirectionally sequenced with the same primers by an ABI 3730xl Analyzer (Applied Biosystems, Foster City, USA). Chromatograms and sequences were checked and proofread by ContigExpress 6.0 (LifeTechnologies, Carlsbad, United States). Final sequences were submitted to GenBank (<https://www.ncbi.nlm.nih.gov/>).

Results

Subphylum Crustacea Brünnich, 1772
Superorder Thoracica Darwin, 1854
Order Sessilia Lamarck, 1818
Family Verrucidae Darwin, 1854
Genus *Gibbosaverruca* Young, 2002

Gibbosaverruca weijiae sp. nov.

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Figs 1–4; Table 1

Diagnosis

All plates with prominent growth lines. External surface of rostrum with four ridges, uppermost largest, upper margin of rostrum sloping down to base of movable scutum, faint ridge between them. Movable

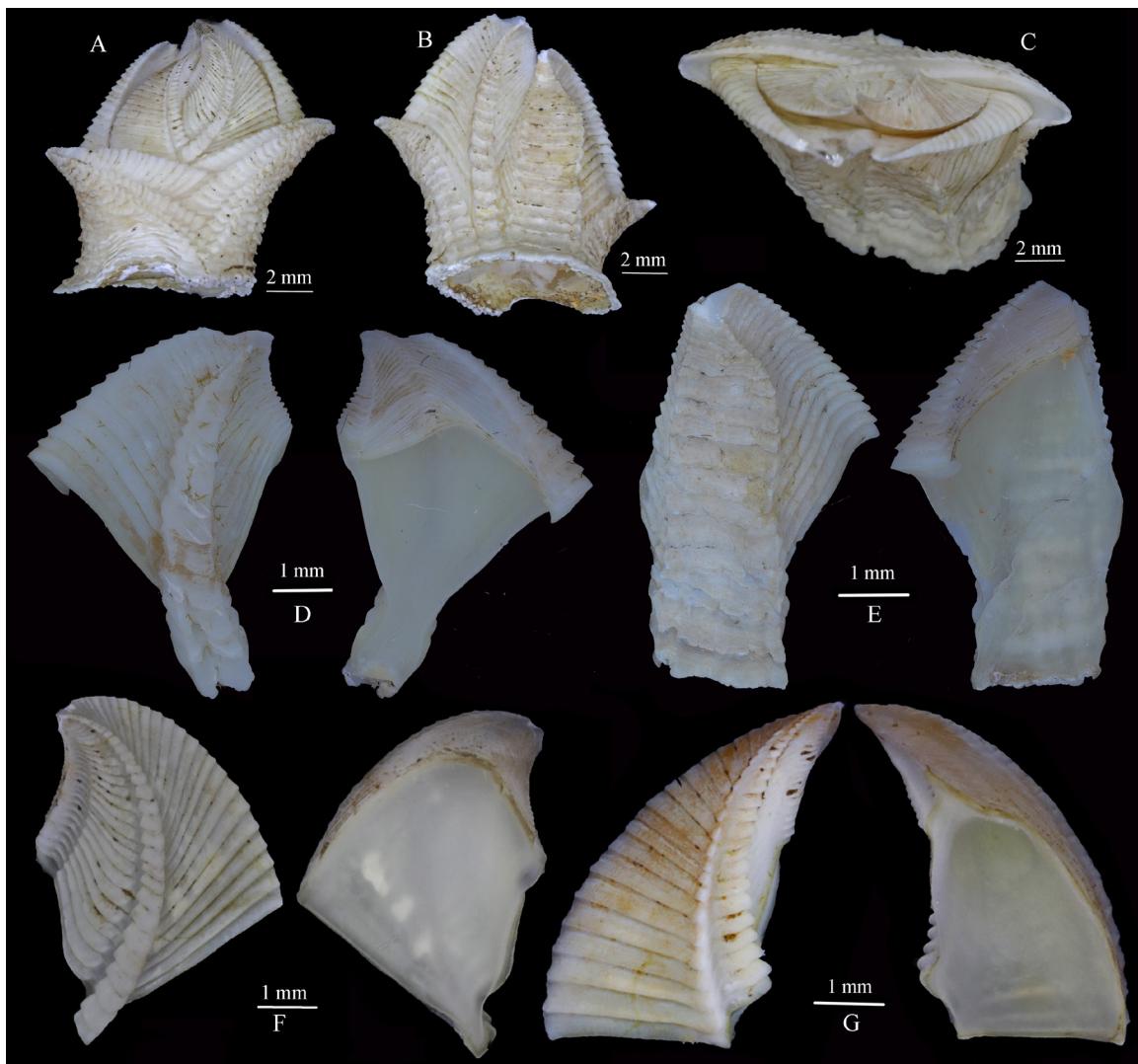


Fig. 1. *Gibbosaverruca weijiae* sp. nov., holotype, SRSIO17090313. **A.** Opercular plates. **B.** Fixed tergum and scutum. **C.** From above. **D.** Fixed tergum. **E.** Fixed scutum. **F.** Movable tergum. **G.** Movable scutum.

tergum with three articular ridges, axial ridge strongly prominent, intermediate ridge widest. Movable scutum with three articular ridges, axial ridge thin, second ridge prominent, wider than axial ridge. Cirrus I and cirrus II with anterior rami no more than half length of posterior rami. Intermediate segments of cirrus VI with three pairs of setae on anterior margin. Caudal appendage very long, more than five times as long as protopodite.

Etymology

The new species is named after its type locality, Weijia Guyot, the West Pacific.

Material examined

Holotype

WEST PACIFIC • measurements BD = 10.29 mm; roof deck of Weijia Guyot; 156°41'15.72" E, 12°47'22.20" N; depth 1935 m; 21 Sep. 2017; crews of ROV *Haima* leg.; Stn MCROV06; Dayang 41B cruise; attached to sponge remains; GenBank: MW033972 (COI), MW033931 (16S rRNA); SRSIO17090313.

Paratype

WEST PACIFIC • 6 specimens, measurements BD = 7.82–10.36 mm; same collection data as for holotype; attached to sponge remains; SRSIO17090314 • 3 specimens, measurements BD = 8.05–9.12 mm; roof deck of Weijia Guyot; 156°17'13.56" E, 12°22'37.92" N; depth 1995 m; 22 Sep. 2017; crews of ROV *Haima* leg.; Stn MCROV02; Dayang 41B cruise; attached to sponge remains; SRSIO17090314.

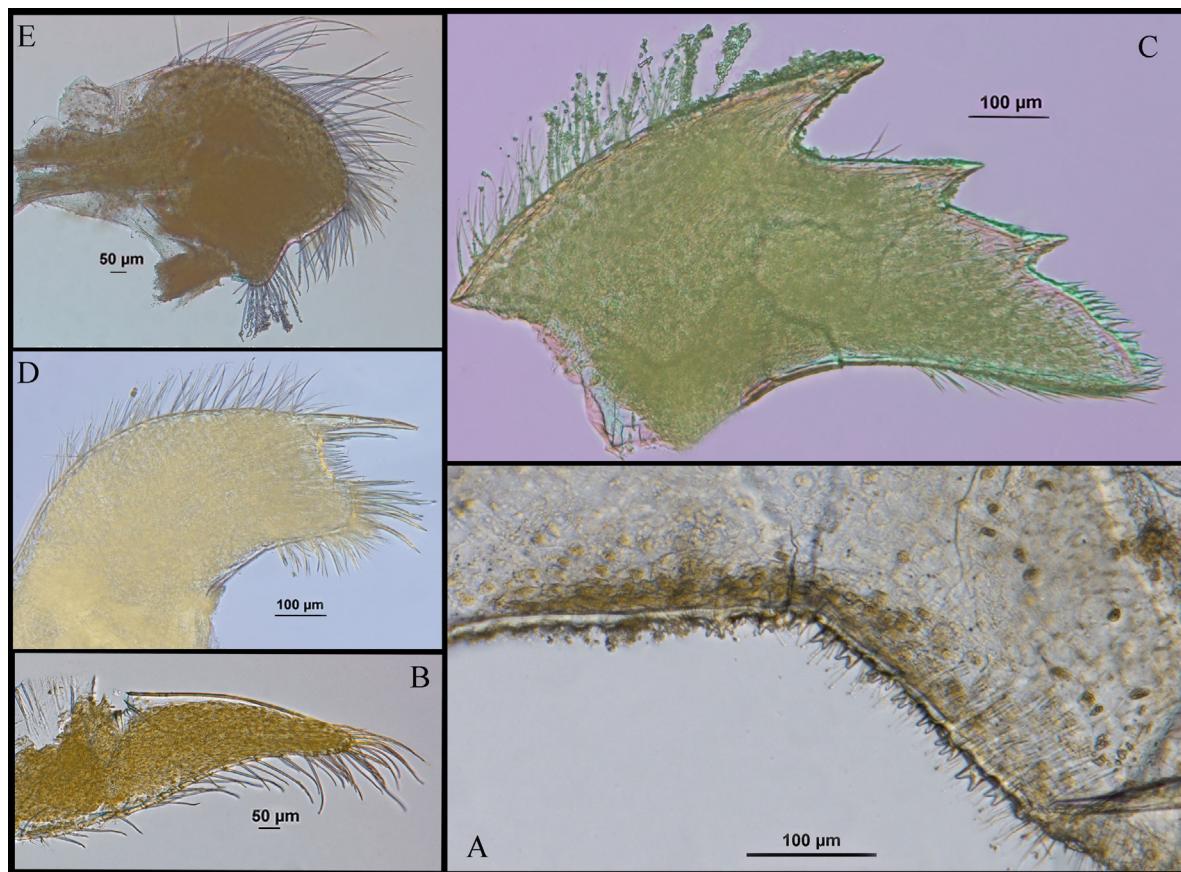


Fig. 2. *Gibbosaverruca weijiae* sp. nov., holotype, SRSIO17090313. **A.** Inner edge of labrum. **B.** Palp. **C.** Mandible. **D.** Maxillule. **E.** Maxilla.

Description

Large-sized verrucid species. Shell white, growth lines prominent on all plates. Apices of rostrum and carina projecting well beyond margins of fixed tergum and fixed scutum (Fig. 1A–C). Rostrum and carina interlocking by four articular ridges (Fig. 1A), with narrow grooves between them on rostro-carinal articulation. Rostrum lower but longer than carina; anterior surface with four ridges, uppermost largest, as wide as following three ridges combined, lowest ridge faint; upper margin of rostrum sloping down to base of movable scutum, faint ridge between them terminating at end of axial ridge of carina. Carina with four articular ridges, first two similar in width, larger than following two; lowest ridge feebly developed.

Fixed tergum (Fig. 1B, D) higher than fixed scutum, axial ridge prominent, narrow, both sides with well-developed alar-like projections; apex flexed towards fixed scutum. Axial ridge of fixed scutum (Fig. 1B, E) wide, about three times width of fixed tergum; alar-like process directed toward rostrum, wide, about two times width of radius-like process, directed toward fixed tergum; apex straight.

Movable tergum (Fig. 1A, F) quadrangular, with three articular ridges; axial ridge prominent, narrow groove between it and intermediate ridge; intermediate ridge very wide, triangular, about three times width of axial ridge; broad groove between intermediate ridge and upper ridge; upper ridge thin, sub-marginal; internal surface smooth. Movable scutum (Fig. 1A, G) triangular, smaller than movable tergum; three articular ridges, axial ridge narrow, low, intermediate ridge largest, prominent, upper ridge short, sub-marginal; area between intermediate ridge and upper ridge smooth, without growth line; internal surface smooth.

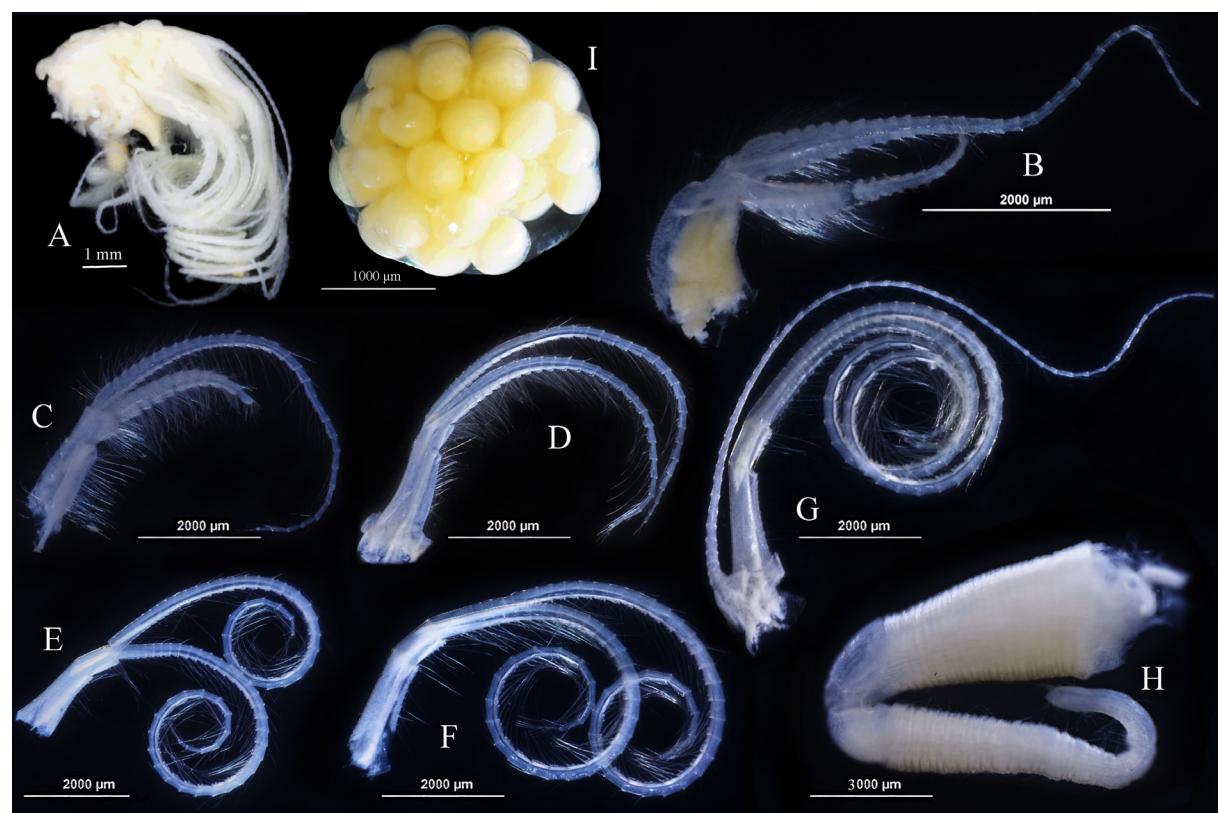


Fig. 3. *Gibbosaverruca weijiae* sp. nov., holotype, SRSIO17090313. **A.** Soft body. **B.** Cirrus I. **C.** Cirrus II. **D.** Cirrus III. **E.** Cirrus IV. **F.** Cirrus V. **G.** Cirrus VI. **H.** Penis. **I.** Eggs.

Labrum (Fig. 2A) with line of bifid or trifid teeth. Palp (Fig. 2B) narrow, with simple setae on terminal and inner margin. Mandible (Fig. 2C) with three teeth, first larger than following two; inferior angle acute, superior border armed with series of spinules. Cutting edge of maxillule (Fig. 2D) inflected; upper angle with large spine and some cuspidate setae; lower region projecting, furnished with cuspidate setae. Anterior margin of maxilla (Fig. 2E) with small notch, upper and anterior margins covered by long setae.

Soft body (Fig. 3) without filamentary appendage. Cirrus I separated from, and shorter, sturdier than cirri II–VI (Fig. 3B), coxopodite inflated; anterior ramus slightly shorter than half length of posterior ramus; both rami with wide basal segments tapering distally. Cirrus II (Fig. 3C) with anterior ramus slightly shorter than half length of posterior ramus. Cirri III–VI (Fig. 3D–G) with rami subequal; intermediate segments of cirrus VI with two pairs of long setae and one pair of short setae on anterior margin. Caudal appendage (Fig. G) very long, more than five times length of protopodite, with more than 50 segments.

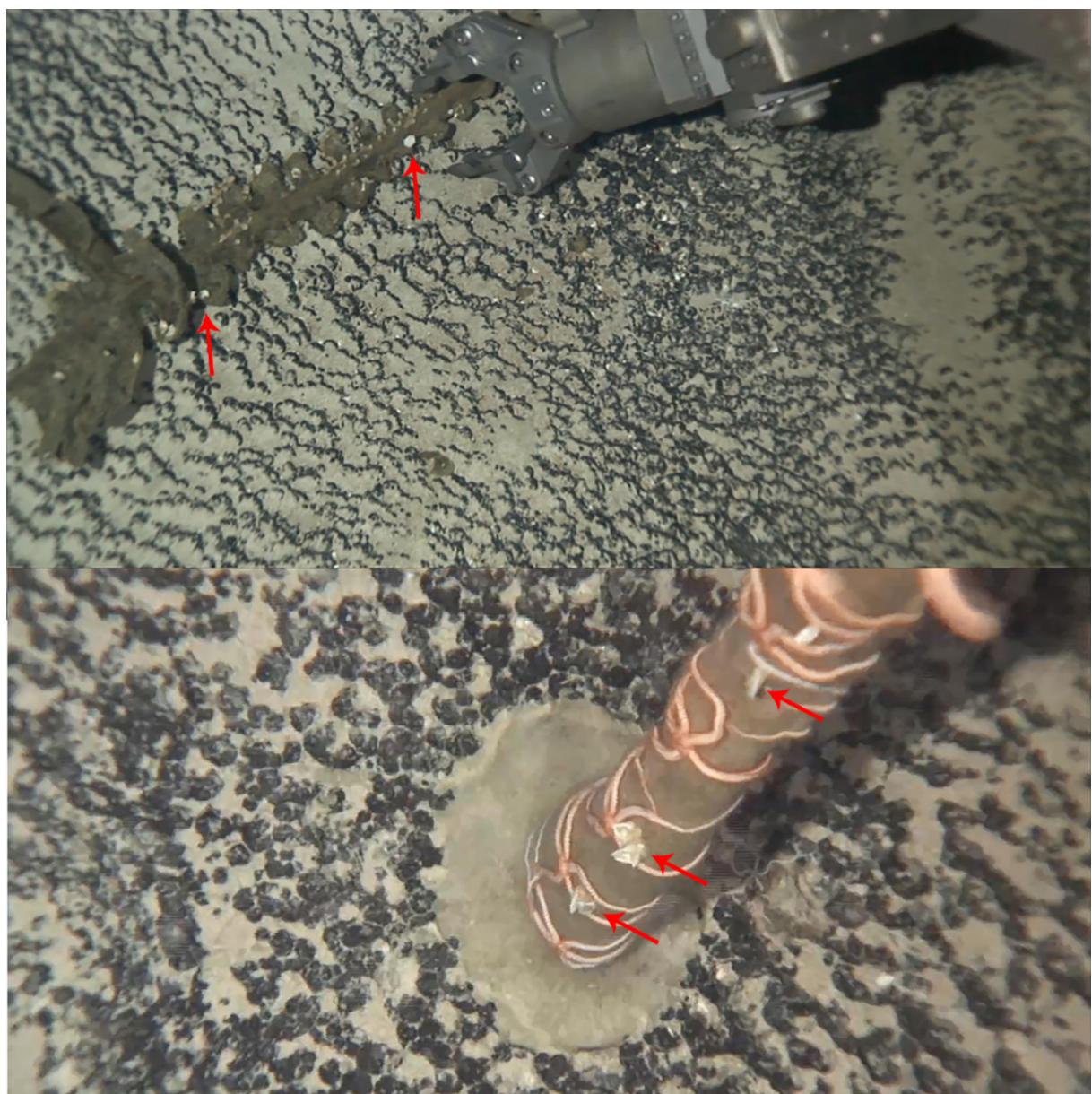


Fig. 4. In situ figures of *Gibbosaverruca weijiae* sp. nov. (red arrows).

Table 1. Number of segments on cirri I–VI and caudal appendage of the holotype of *Gibbosaverruca weijiae* sp. nov.

	Cirri						Caudal appendage
	I	II	III	IV	V	VI	
left	18/29	12/32	27/31	36/40	41/45	48/49	51
right	18/30	13/31	29/32	35/38	43/45	47/50	50

Number of segments of cirri I–VI and caudal appendage are presented in Table 1. Penis (Fig. 3H) robust, tapering, surface with annular wrinkles. Eggs (Fig. 3I) globular, encompassed by transparent film capsule.

Habitat and distribution

Roof deck of Weijia Guyot, depth 1935–1995 m, attached to sponge remains (Fig. 4). Currently only known from the type locality, Weijia Guyot.

Key to the extant species of the genus *Gibbosaverruca* Young, 2002.

1. Movable scutum not flat, with distinct articular ridges 2
- Movable scutum flat, apico-basal line defined by growth-line deflection *G. laeviscuta* Buckeridge, 1994
2. Movable scutum with three or more articular ridges 3
- Movable scutum with two articular ridges 7
3. Movable scutum with three articular ridges 4
- Movable scutum with four articular ridges *G. navicula* (Hoek, 1913)
4. Movable tergum with three articular ridges 5
- Movable tergum with four articular ridges *G. robusta* Young, 2002
5. Intermediate ridge of movable tergum about three times width of axial ridge, caudal appendage extremely long, more than five times length of protopodite *G. weijiae* sp. nov.
- Intermediate ridge of movable tergum about same width of axial ridge, caudal appendage short .. 6
6. Radius-like process of fixed scutum well-developed, apices of rostrum and carina strongly projecting *G. sulcata* (Hoek, 1883)
- Radius-like process of fixed scutum small, apices of rostrum and carina slightly or not projecting *G. gibbosa* (Hoek, 1883)
7. Movable tergum with three articular ridges, caudal appendage short, no more than two times as long as protopodite 8
- Movable tergum with two articular ridges, caudal appendage long, more than two times as long as protopodite *G. nitida* (Hoek, 1883)
8. Rostrum with flat surface from upper margin to basal margin of scutum 9
- Rostrum without flat surface from upper margin to basal margin of scutum 10
9. Rostrum upper surface with one small ridge turned toward scutum *G. mateoi* Young, 2002
- Rostrum upper surface without ridge *G. darwini* (Pilsbry, 1907)

- 10. Rostrum and carina each with no more than four articular ridges 11
 - Rostrum and carina each with five articular ridges *G. montereyi* Young, 2002
- 11. Uppermost ridge of carina terminating at end of axial ridge of movable tergum 12
 - Uppermost ridge of carina exceeding end of axial ridge of movable tergum
..... *G. costata* (Aurivillius, 1898)
- 12. Intermediate ridge of movable scutum about same width as axial ridge 13
 - Intermediate ridge of movable scutum about two times wider than axial ridge
..... *G. somaliensis* (Nilsson-Cantell, 1929)
- 13. Rostrum with two articular ridges of same width *G. mitra* (Hoek, 1907)
 - Rostrum with three articular ridges, second largest *G. rathbuniana* (Pilsbry, 1916)

Discussion

Based on its robust appearance and the multiple strong ridges articulating the rostrum and the carina, the new species is easily placed in the genus *Gibbosaverruca*, despite the overlapping diagnostic characters of the genera *Altiverruca* and *Gibbosaverruca* (the suture of the rostrum and carina) (Pilsbry 1916; Gruvel 1920; Young 2002). *Gibbosaverruca weijiae* sp. nov. is distinguishable from all extant species of *Gibbosaverruca* by having relatively long caudal appendage (more than 50 segments), which are unique in the genus. *Gibbosaverruca navicula* and *G. nitida* also have a relatively long caudal appendage compared with those of other species of *Gibbosaverruca*, but both have caudal appendages with no more than 35 segments. The numbers and profiles of the articular ridges of the movable tergum and movable scutum are also very different from those of *G. weijiae* sp. nov. (Buckeridge 1994).

In terms of external shell morphology, *Gibbosaverruca weijiae* sp. nov. is most similar to *G. gibbosa* and *G. sulcata*. All three species have three articular ridges on the movable tergum and movable scutum, and their rostrum and carina united by two or more strong ridges. However, *G. weijiae* sp. nov. differs from *G. gibbosa* by the strongly projecting apices of the rostrum and carina (not or only slightly projecting in *G. gibbosa*) and the relatively wide intermediate ridge of the movable tergum (three times as wide as the axial ridge vs the same width as the axial ridge) (Hoek 1883; Young 1998, 2002). *Gibbosaverruca weijiae* sp. nov. is distinguished from *G. sulcata* by the intermediate ridges of the movable tergum and movable scutum (distinctly wider than the axial ridge vs the same width as the axial ridge) and by the radius-like process of the fixed scutum (vestigial and small vs well-developed and large) (Hoek 1883; Young 2002). Based on fossils of the fixed scutum and fixed tergum, Gale described one new species (*G. youngi*) and two unnamed species (*Gibbosaverruca* sp. 1 and *Gibbosaverruca* sp. 2) from the Indian Ocean (Gale 2020), and these three species are also different from *G. weijiae* sp. nov. First of all, *G. youngi* and *Gibbosaverruca* sp. 2 have a fixed scutum bearing a well-developed radius-like process and a narrower occludent wing compared with *G. weijiae* sp. nov. Secondly, the imbricate flanges on the exterior surface of the fixed scutum of *G. youngi* are furnished with short pustules (see Gale 2020). Furthermore, *Gibbosaverruca* sp. 1 has a fixed tergum presenting strongly convex occludent and carinal margins, which is very unusual in the verrucid species (Gale 2020). In terms of internal soft body morphology, *G. weijiae* sp. nov. differs from *G. gibbosa* and *G. sulcata* by the very unequal lengths of the anterior and posterior rami of cirrus I and the extremely long caudal appendages (Young 2002).

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