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Two new species of scale worms (Polychaeta: Aphroditiformia) from deep-sea habitats in the Gulf of Cadiz (NE Atlantic)

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Abstract

Two new species of scale worms are described from the Gulf of Cadiz (NE Atlantic), at depths between 1100 and 2230 m. *Australaugeneria iberica* **sp. nov.** (Polynoidae) was obtained from an alcyonarian colony collected at the flank of Carlos Ribeiro mud volcano; it is characterized by the presence of neuropodial hooks only on segment two and by having the first parapodia not enlarged. This is the first report of the genus for the deep sea. The diagnosis of *Australaugeneria* is emended and a table comparing all species of the genus is provided. *Pholoe petersenae* **sp. nov.** (Pholoidae) was collected from the crater of three mud volcanoes (Darwin, Captain Arutyunov and Carlos Ribeiro) in areas of active seepage. This species is characterized by the presence of prostomial peaks and parapodia stylodes and the absence of eyes.

Key words: Annelida, Polychaeta, Polynoidae, Pholoidae, *Australaugeneria*, *Pholoe*, taxonomy, Gulf of Cadiz, NE Atlantic

Introduction

The Gulf of Cadiz is an extensive cold seepage area located west of the Strait of Gibraltar (NE Atlantic), enclosed by the southern Iberian margin and the northern margin of Morocco. It comprises over 40 known mud volcanoes and adjacent deep-sea habitats (cold water corals, carbonate crusts, gorgonian and sponge aggregations) at depths ranging from 200 to 4000 m. The diverse fauna of this region is greatly promoted by the high habitat heterogeneity of the area (Cordes *et al*. 2010), weak hydrocarbon fluxes, varied biogeochemical settings and complex water circulation, that ensures oceanographic connectivity with the Mediterranean Sea as well as with the Equatorial and North Atlantic regions (Cunha *et al*. 2013a).

The specimens reported here were found during a polychaete study of samples taken over the past 15 years from 27 mud volcanoes and adjacent habitats in the Gulf of Cadiz. Scale worms belonging to the families Acoetidae Kinberg, 1856, Polynoidae Kinberg, 1856, Pholoidae Kinberg, 1858 and Sigalionidae Malmgren, 1867 were recorded from 15 of these mud volcanoes. The new species described here are assigned to the families Polynoidae, genus *Australaugeneria* Pettibone, 1969a, and Pholoidae, genus *Pholoe* Johnston, 1839. The genus *Australaugeneria* was erected by Pettibone (1969a) for the species *Polynoe rutilans* Grube, 1878 and later emended by Pettibone (1969b) to accommodate the species *A. pottsi*. At present, this genus includes only three species—*A. rutilans* (Grube, 1878), *A. michaelseni* Pettibone, 1969a and *A. pottsi* Pettibone, 1969—found in the Indian and Pacific oceans at shelf depths, often associated with alcyonarians and gorgonians (Pettibone 1969a, b). The genus *Pholoe*, although common in marine benthos, is often overlooked due to the small size of their specimens. The NE Atlantic shallow water *Pholoe* species have often been erroneously identified as *P. minuta* (Fabricius, 1780), a NW Atlantic species (Petersen 1998). This is also the reason for the confusion concerning the type species of the genus, *P. inornata* Johnston, 1839, that was subsequently referred to *P. minuta* by Malmgren 1865. Much of the material assigned to *P. minuta* has been re-examined by Pettibone (1992) and Petersen (1998) but a comprehensive revision of the genus is required. The genus includes 15 species of which six are distributed within N Atlantic waters—*P. longa* (O. F. Müller, 1776) from Greenland, *P. inornata* Johnston, 1839, British Isles,

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P. baltica Örsted, 1843, *P. assimilis* Örsted, 1845, Danish waters, *P. fauveli* Kirkegaard, 1983, Bay of Biscay and Azores, *P. pallida* Chambers, 1985, British waters. With the exception of *P. fauveli*, these species are found mainly at shallow depths (Petersen 1998). Other deep-sea species are known, but not yet described (Petersen, unpublished data). A comparison table for all species of *Pholoe* can be found in Padovanni & Amaral (2013).

Material and methods

The *Australaugeneria* specimens were collected during a ROV dive of the cruise JC10-1 (RRS *James Cook*, project HERMES) at Carlos Ribeiro mud volcano (MV). The *Pholoe* specimens were found in sediment samples from Captain Arutyunov and Carlos Ribeiro MVs taken during the cruises TTR14 (RV *Prof. Logachev*, Training Through Research programme, IOC-UNESCO) and MSM01-03 (RV *Maria S. Merian*, project HERMES) and in a wood colonization experiment retrieved two years after deployment at Darwin MV (cruise B09-14b, RV *Belgica*, project CHEMECO). Metadata of the sampling sites are provided in Table 1 and the location of the mud volcanoes is shown in Figure 1. The Darwin MV is located in the Moroccan Carbonate Province, and Captain Arutyunov and Carlos Ribeiro MVs are located in the Deep-water field. Details on the environmental setting of the latter two mud volcanoes can be found in Cunha *et al.* (2013a). An account of the colonization experiments and a brief description of Darwin MV are provided by Cunha *et al.* (2013b).

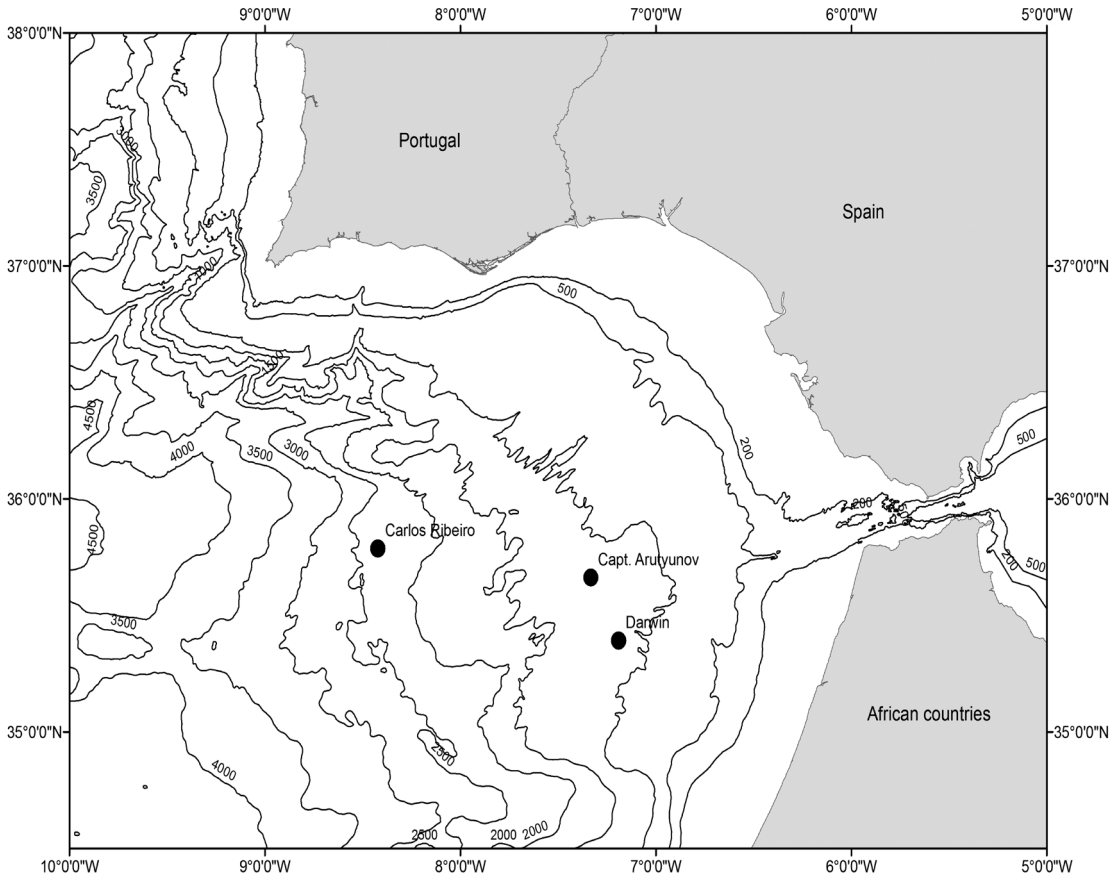

FIGURE 1. Map with the location of the sampling sites.

Whenever possible the specimens were sorted on board and preserved in 96% ethanol. Drawings were prepared from preserved specimens with a camera lucida. Measurements of body width were taken from the widest part of the body, excluding chaetae. Body length excludes prostomium appendages and anal cirrus. Type specimens were deposited in the Natural History Museum, London (NHM), and the remaining material was deposited in the Biological Research Collection, Departamento de Biologia, Universidade de Aveiro (DBUA).

TABLE 1. Metadata for the sampling stations in the Gulf of Cadiz. Station code: the label is composed of the cruise name and station number as used in Pangaea database (www.pangaea.de); Code of gear: CHE—colonization devices, Gr—TV-assisted grab, UB—USNEL Boxcorer, MC—Multicorer, BL—BIGO Lander, FL—FLUFO Lander, ROV—ROV (Bibo—Claw/Biobox).

Structure	Station code	Gear	Date dd.mm.yy	Latitude (N)	Longitude (W)	Depth (m)
Gulf of Cadiz – Mud volcanoes						
Darwin	B09/14b_02W	CHE	19.05.09	35°23.523'N	07°11.513'W	1100
Cap. Arutyunov	TTR14_AT546	Gr	06.08.04	35º39.692'N	07º20.046'W	1345
	MSM01/3_180	UB	27.04.06	35º39.740'N	07º19.960'W	1323
	MSM01/3_190.1	MC	28.04.06	35º39.665'N	07º19.970'W	1322
	MSM01/3_218	UB	30.04.06	35˚39.700'N	07˚20.012'W	1318
	MSM01/3_225	BL	04.05.06	35º39.682'N	07º19.882'W	1320
	MSM01/3_274	BL	10.05.06	35º39.738'N	07º20.010'W	1321
Carlos Ribeiro	MSM01/3_184	FL	27.04.06	35º47.124'N	08º25.291'W	2204
	JC10_051-Bibo2	ROV	27.05.07	35˚47.102'N	08˚25.309'W	2230

Results

Systematics

Class Polychaeta Grube, 1850

Order Phyllodocida Dales, 1962

Suborder Aphroditiformia Levinsen, 1883

Family Polynoidae Kinberg, 1856

Genus *Australaugeneria* Pettibone, 1969; emended

Australaugeneria Pettibone 1969a, p. 20; Pettibone 1969b, p. 519.

Type species. *Polynoe rutilans* Grube, 1878.

Diagnosis. Body dorsoventrally flattened, tapering posteriorly, less than 40 segments. Elytra 15 pairs on segments 2, 4, 5, 7, alternating to 23, 26, 29, 32. Elytra soft, translucent, smooth. Prostomium margin rounded without cephalic peaks. Ceratophore of median antenna inserted in anterior notch. Ceratophores of lateral antennae inserted anteroventrally. Palps stout, gradually tapering. Eyes present or absent. Tentacular segment with two pairs of tentacular cirri, without chaetae. Second segment (buccal segment) without nuchal fold, without or with few notochaetae, with hooked neurochaetae. Parapodia of later segments sub-biramous. Notopodia with projecting acicular lobe. Neuropodia long, with well-developed pre- and postchaetal lamellae. Prechaetal lamellae of segments 2 and 3 may be more or less strongly enlarged, hood-like, enclosing hooked chaetae. Notochaetae few, stouter or more slender than neurochaetae, smooth or spinulose, tips unidentate. Neurochaetae present as stout hooks in anteriormost segments, those of following segments curved, smooth or faintly spinulose below more or less strongly hooked tips, sometimes bidentate, with a small secondary tooth.

Remarks. Pettibone (1969a, b) considered the notochaeta of *A. rutilans* and *A. pottsi* as bidentate, however Wehe (2006) disagreed arguing that the bidentate appearance of the chaetae is due to the long series of spines along the convex notochaetal edge reaching almost to the tip of the chaetae. This feature was confirmed by Dr. Gordon Paterson that examined one syntype of *A. pottsi* (BMNH1924:3:1:77) on our behalf.

***Australaugeneria iberica* sp. nov.**
Figure 2

Type material. Atlantic Ocean. Gulf of Cadiz: **Carlos Ribeiro MV**, St JC10_051, ca. 2230 m, 3 incompl. spms (NHMUK2016.347, holotype; DBUA0001726.01, paratypes).

Description. Examined specimens incomplete, only one specimen with one elytron. Larger fragment with 18 segments, 5.09 mm long and 1.09 / 2.69 mm wide without and with parapodia, respectively. Body without pigmentation pattern or dorsal tubercules, compressed dorsoventrally, gradually tapering anteriorly and posteriorly. Elytra scars on segments 2, 4, 5, 7, alternating to the end of fragment. Elytra large, covering the dorsum, delicate and transparent, without tubercles or papillae. Prostomium rounded, bilobed anteriorly, without cephalic peaks; eyes not visible (Fig. 2A). Median antenna very long (reaching 3rd chaetiger), smooth, gradually tapering distally, ceratophore inserted in anterior notch. Lateral antennae very short, piriform, ceratophores inserted ventrally. Palps stout, smooth, gradually tapering, about half the length of median antenna. First segment not visible dorsally, without chaetae; two pairs of tentacular cirri, dorsal cirri about as long as median antenna with large ceratophore, ventral cirri much shorter, similar in length to palps, with shorter ceratophore. Parapodia of buccal segment (segment 2) not modified (Fig. 2B); ventral cirri similar in length to the following ones; hooked chaetae present. Pharynx not observed. Parapodia of median segments relatively long, sub-biramous. Notopodia with long projecting acicular lobe, extending to near distal end of neuropodial lobes or beyond in posterior parapodia (Fig. 2C, D). Dorsal cirri much longer than parapodia including chaetae, smooth, tapering gradually to filiform tips, present on segments without elytra, attached at the base of notopodia. Neuropodia deeply incised dorsally and ventrally, with longer bilobed prechaetal lobes, and shorter rounded to slightly bilobed postchaetal lobes. Ventral cirri slightly longer than neuropodia, smooth, gradually tapering to filiform tips. Notochaetae stout, spinulose, with entire tips, present from segment three (Fig. 2F–H). Neurochaetae of segment two stout hooks (Fig. 2E); remaining parapodia with two types of neurochaetae: upper group slightly slender, spinulose, with bidentate tips (Fig. 2I, J); lower group stouter, falcate, smooth or faintly spinous (Fig. 2K, L). Pygidium not observed.

Type locality. Gulf of Cadiz (NE Atlantic), Carlos Ribeiro mud volcano, 35˚47.102'N, 08˚25.309'W, 27 May 2007, JC10 Leg1 (RRS *James Cook*).

Distribution. Northeast Atlantic (Gulf of Cadiz).

Habitat. In association with one alcyonarian colony (cf. *Acanella* sp.), collected at the flank (no methane seepage detected) of Carlos Ribeiro MV, at 2230 m water depth.

Etymology. The species name refers to its type locality on the Iberian margin.

TABLE 2. Morphological differences between the four species of the genus *Australaugeneria* (modified from Pettibone 1969a).

	A. rutilans	*A. michaelseni*	*A. pottsi*	*A. iberica* **sp. n.**
Eyes	present	absent	absent	absent
First parapodia	enlarged	strongly enlarged	slightly enlarged	not enlarged
Neuropodial hooks	on segm. 2 and 3 (strongly bent)	on segm. 2, 3 and 4	on segm. 2, 3 and 4	on segm. 2 (slightly bent)
Notopodia	short, about half the length of neuropodial lobes	long, extending to near distal end of neuropodial lobes	short, about half the length of neuropodial lobes	long, extending to near distal end of neuropodial lobes
Notochaetae	present from segm. 3; more slender than stoutest neurochaetae; spinulose	present from segm. 3; as stout as or stouter than stoutest neurochaetae; smooth	present from segm. 2; more slender than stoutest neurochaetae; spinulose	present from segm. 3; more slender than stoutest neurochaetae; spinulose
Body width	2 mm	3–4 mm	2 mm	2.7 mm

Remarks. The genus *Australaugeneria* includes three species, *A. rutilans* (Grube, 1878) and *A. michaelseni* Pettibone, 1969a, both from southwest Australia, 11–16 m depth, and *A. pottsi* Pettibone, 1969b from the Maldives Islands. Recently, *A. rutilans* was also reported from the Red Sea (Wehe, 2006). *Australaugeneria iberica* **sp. nov.** differs from the other three species in having neuropodial hooks on segment two only (instead of two and three)

and prechaetal lobes of the first parapodia are not enlarged or hood-like. Both characters are diagnostic of the genus and its diagnosis is emended here. Further differences between the four species are highlighted in Table 2. This is the first deep-sea species of the genus, as well as the first record for the Atlantic Ocean.

Family Pholoidae Kinberg, 1858

Genus *Pholoe* Johnston, 1839

Pholoe Johnston 1839, p. 437.

Type species. *Pholoe inornata* Johnston, 1839.

Diagnosis. Body small, with up to 90 segments. Elytra on segments 2, 4, 5, 7, alternating to 23, then on every segment to end of body. Elytra delicate, with border and sometimes also surface papillae. Dorsal cirri and branchiae absent. Prostomium triangular or rounded to bilobed. Median antennae inserted on anterior notch without auricles. Lateral antennae present or absent. Palps stout, emerging ventrolaterally to tentaculophores. Eyes present or absent. Tentacular segment fused to prostomium, with two pairs of subequal tentacular cirri, without chaetae. Parapodia biramous; acicular lobes conical with or without papillae, ventral much longer than dorsal. Notochaetae capillary, lightly spinulose, straight or geniculate. Neurochaetae compound, with subdistally spinose shafts and falcate blades. Pygidium with a pair of anal cirri.

Pholoe petersenae sp. nov.

Figure 3

Type material. Atlantic Ocean. Gulf of Cadiz (MV): Captain Arutynov MV, St MSM01-3_274, 1321 m, 1 spm (NHMUK2016.348, holotype); St MSM01-3_180, 1323 m, 3 spms (NHMUK2016.349-351); St MSM01-3_190.1, 1322 m, 3 spms (DBUA0001727.03); St MSM01-3_218, 1318 m, 13 spms (DBUA0001727.04); St. MSM01-3_225, 1320 m, 1 spm (DBUA0001727.05); St TTR14_AT546, 1345 m, 3 spms (DBUA0001728.01); **Darwin MV**, St B09-14b_02W, 1100 m, 1 spm (DBUA0001729.01); **Carlos Ribeiro MV**, St MSM01-3_184, 2204 m, 1 spm (DBUA0001727.06).

Additional material. *Pholoe anoculata*, Atlantic Ocean, off New England, W of Atlantis Canyon, St S1 4, 39º56'30''N, 70º3954''W, 400 m, 28-08-1962, 1 spm (LACM-AHF Poly 0069; paratype).

Description. The holotype measures 2.13 mm long and 0.30 / 0.91 mm wide without and with parapodia respectively, for 26 segments. Body of uniform width, compressed dorsoventrally, without pigmentation pattern or dorsal tubercules. Globular papillae present on parapodia and ventral surface. Fifteen (?) pairs of elytra on segments 2, 4, 5, 7, alternating to 23, then on every segment to end of body; completely covering dorsum and parapodia. All elytra oval, transparent, delicate, with smooth dorsal surface and a few cirriform papillae with blunt expanded tip bearing cilia on outer border (Fig. 3D, E). Prostomium subsphaerical, bilobed anteriorly; without eyes (Fig. 3A). Anterior lobes with terminal conical peaks protruding lateroventrally to median antenna. Median antenna long, smooth, gradually tapering, with large ceratophore inserted in median notch of prostomium. Palps smooth, stout, gradually tapering, inserted ventrolaterally on prostomium and much longer than median antenna. First segment fused to prostomium, achaetous; tentacular cirri inserted between lateral antennae and palps, subequal and similar in length to median antenna, smooth. Facial tubercle very small (Fig. 3B). Pharynx with 16 terminal papillae and two pairs of light brown jaws. Ventral cirri of buccal segment large, tapering into filiform tips, displaced medially. Parapodia relatively long, biramous, covered by globular papillae and stylodes. Notopodia much smaller than neuropodia, enlarged basally and distally pointed; neuropodia conical (Fig. 3C). Notochaetae long spinulose capillaries, straight or geniculate (Fig. 3F). Neurochaetae long, compound, stouter than notochaetae; shafts with three subdistal rows of spines; blades very long and thin, minutely spinulated, with slightly falcate tips (Fig. 3G). Pygidium with a pair of anal cirri.

Type locality. Gulf of Cadiz (NE Atlantic), Captain Arutyunov mud volcano, 35º39.740'N, 07º19.960'W, 27 April 2006, MSM01 Leg 3 (RV *Maria S. Merian*).

Distribution. Northeast Atlantic (Gulf of Cadiz).

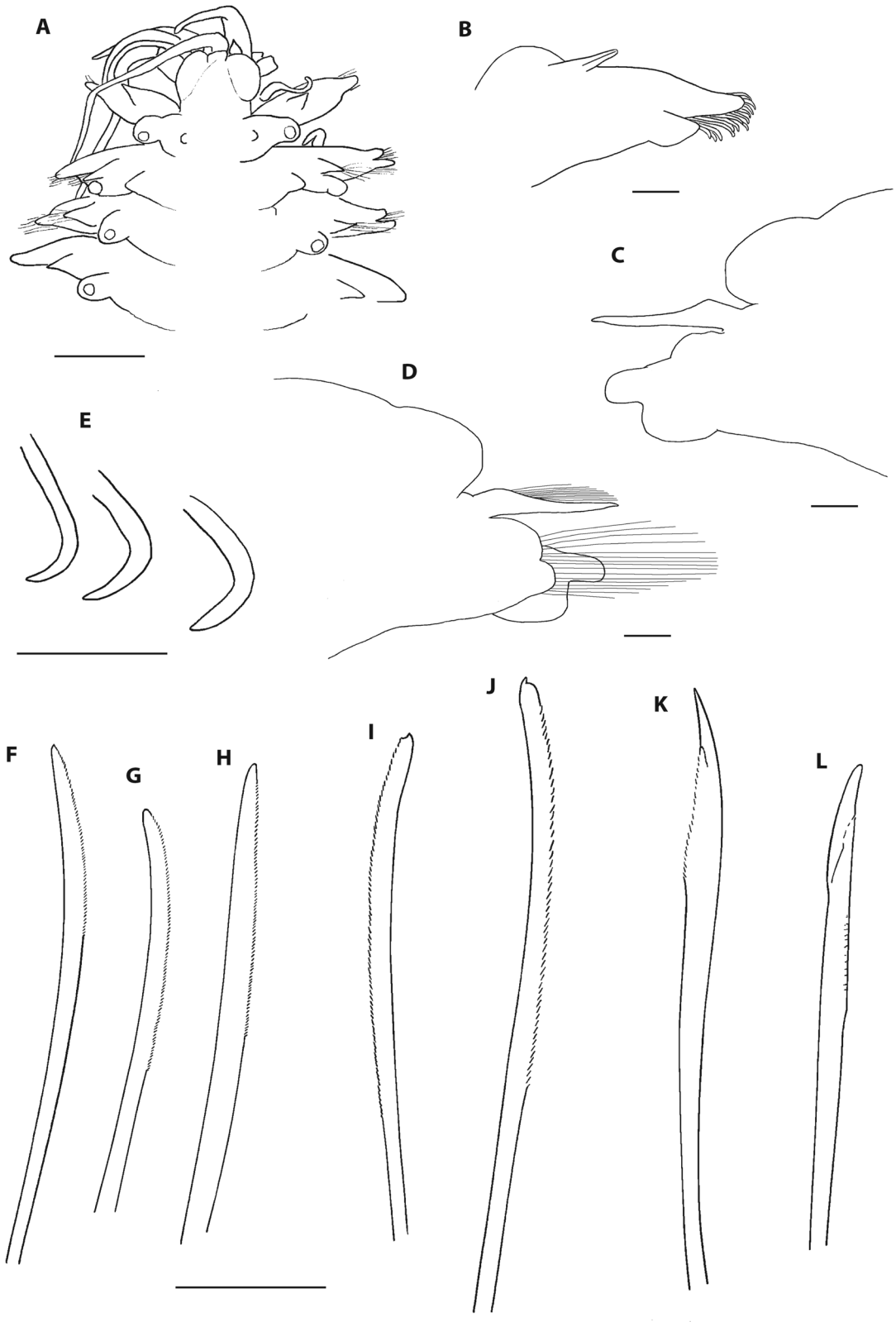

FIGURE 2. *Australaugeneria iberica* **sp. nov.** Holotype. A—Anterior end, dorsal view B—First parapodium, dorsal view C—Posterior parapodium, anterior view D—same, posterior view, with representation of chaetae E—Neurochaeta, first parapodium F—Notochaeta, third parapodium G—Notochaeta, fourth parapodium H—Notochaeta, posterior parapodium I—Upper neurochaeta, fourth parapodium J—Upper neurochaeta, posterior parapodium K—Lower neurochaeta, fourth parapodium L—Lower neurochaeta, posterior parapodium. Scale bars (μm): A=500, B–D=100, E–L=50.

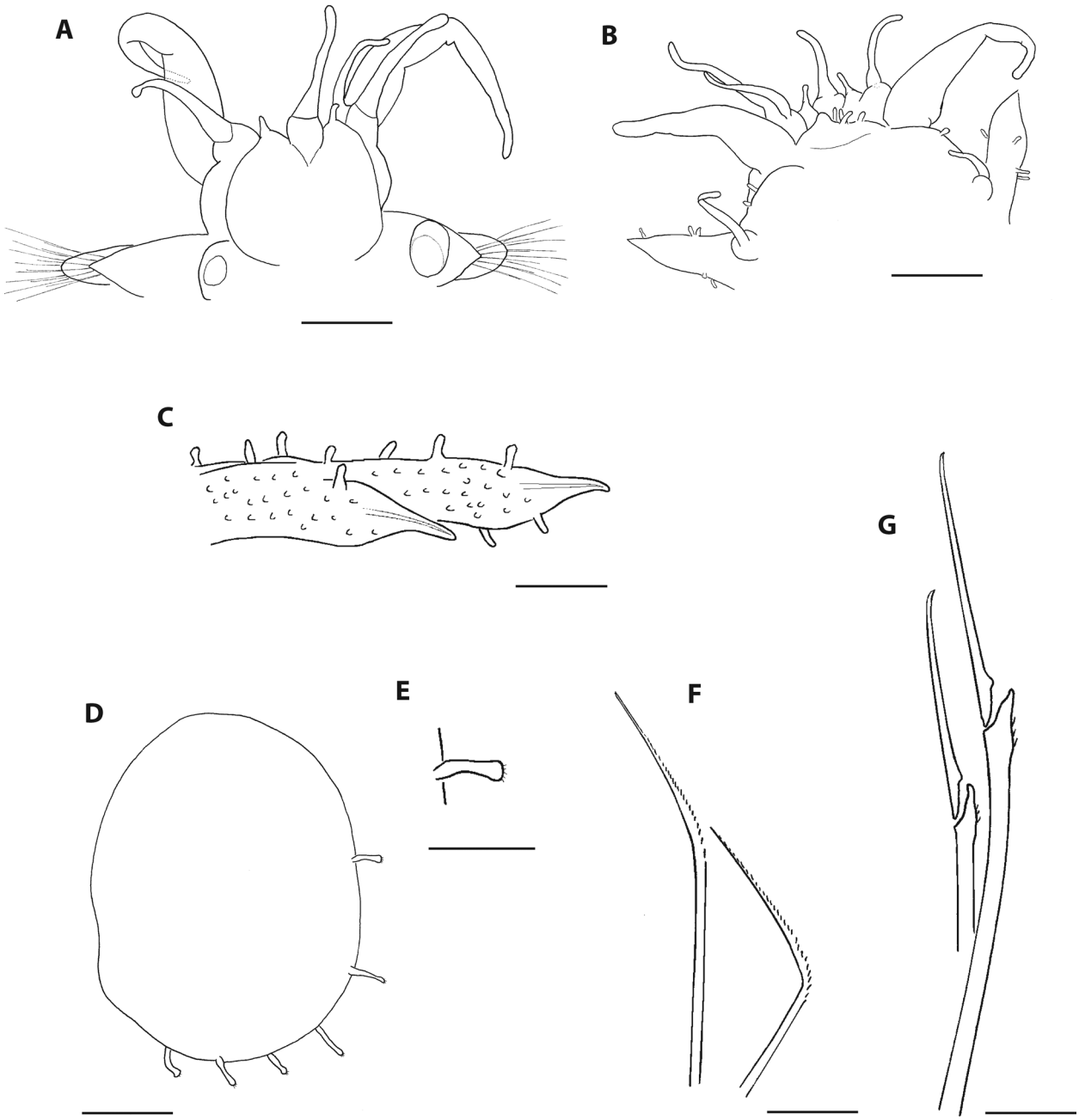

FIGURE 3. *Pholoe petersenae* **sp. nov.** Paratype (NHMUK2016.349). A—Anterior end, dorsal view B—Same, ventral view C—Median parapodium, dorsal view, showing stylodes and globular papillae D—Posterior elytron, dorsal view E—Detail of elytral fringing papilla F—Notochaetae G—Neurochaetae. Scale bars (μm): A, B, D=100, C, E=50, F, G=25.

Habitat. Found in sediment samples taken from active methane seepage sites in the craters of Captain Arutyunov MV and Carlos Ribeiro MV, sympatric to diverse assemblages of chemosymbiotic species (Siboglinidae tubeworms, Thyasiridae, Vesicomyidae and Solemyidae bivalves; see Rodrigues *et al.* 2013 for a complete species list). An additional specimen was retrieved from wood colonization experiments which were deployed for about two years on the crater of Darwin MV typically covered by carbonate slabs and clumps of bathymodiolin mussels. Water depth range from 1100 to 2204 m.

Etymology. The species epithet is given in memory of Dr. Mary Petersen who gathered a large amount of information on *Pholoe* species while revising the genus for an unpublished monograph.

Remarks. Besides *P. petersenae* **sp. n.**, there are presently four described species of *Pholoe* lacking eyes, two of which are recorded from the Atlantic Ocean, *P. pallida* Chambers, 1985 and *P. anoculata* Hartman, 1965. *Pholoe pallida* was first described from off St. Abbs (Scotland) and it is only known from the North Sea area at near-shore

depths (Chambers & Muir 1997; Petersen 1998), although Chambers (1985) refers to a possible confusion between this species and *P. minuta*, and that all records of the latter require revision. The specimens examined herein were collected in the Gulf of Cadiz at deeper waters, and differ from *P. pallida* mainly by having prostomial peaks and neuropodia stylodes (both absent on *P. pallida*), neurochaetae with longer blades, and cirriform instead of flask-shape papillae on the elytra margins. *Pholoe anoculata* is a western Atlantic species occurring from 400 to 5000 m depth, which like the specimens examined here, have nearly smooth elytra with scattered slender fringing papillae and neurochaetae with longer blades (Hartman & Fauchald 1971). Our specimens seem to be morphologically closer to this latter species, but differ from it again by having prostomial peaks and neuropodia stylodes and also neurochaetae shafts with subdistal rows of spines instead of being smooth as stated by Hartman and Fauchald (1971). Previous records of *P. anoculata* from off Northumberland (UK) (Christie 1982) were erroneous and were later ascribed to *P. pallida* (Chambers 1985). A review of these and other species, preferably with the inclusion of molecular data, is required to evaluate their phylogenetic relationships and to define their morphological differences.

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