New records of *Heteropathes* Opresko, 2011 (Anthozoa: Antipatharia) from the Mid-Atlantic Ridge

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Abstract *Heteropathes opreski* de Matos, Braga-Henriques, Santos and Ribeiro, 2014 (Antipatharia: Cladopathidae) was recently described based on a single specimen from northeast of the Oceanographer Fracture Zone, Mid-Atlantic. Several specimens of the same species were recently collected in the vicinity of Semenov and Irinovskoe ore clusters (northern subequatorial Mid-Atlantic Ridge). Based on this new material, a re-description of the species, an emended diagnosis and a comparison with hitherto known species of the genus are provided. Such a diagnosis is needed because two key characters outlined in the original description as distinctive for this species (short lateral pinnules and larger spines at lateral pinnules) appear to be misinterpreted features caused by the poor condition of the holotype, which was damaged and undergoing regeneration. *H. opreski* differs from all other known species of the genus by more densely set lateral pinnules and occasionally anastomosing subpinnules on the anterior primary pinnules. The species is known exclusively from the Mid-Atlantic Ridge (34°46.7’ N to 13°19.43’ N) at depths 1955-2738 m and is considered here as a putative endemic of the area.

Keywords black corals, taxonomy, distribution, ore fields, growth disturbances

Introduction

The black coral fauna of the Mid-Atlantic Ridge is poorly known. In a review of the fauna of the black corals of the North-East Atlantic (Molodtsova 2006), only the northern part of the Mid-Atlantic Ridge including the Azores was studied. The MARECO cruise (Molodtsova et al. 2008) found only one species of black coral *Schizopathes affinis* Brook, 1889 north of the Azores, although more species were expected based on earlier studies (Molodtsova 2006). In the course of prospecting for polymetallic sulphides along the Mid-Atlantic Ridge, the Polar Marine Geosurvey Expedition (PMGRE) collected several specimens of the recently described species *Heteropathes opreski* de Matos, Braga-Henriques, Santos & Ribeiro, 2014 (Fig. 1) at four stations in the vicinity of ore fields Semenov and Irinovskoe. Some morphological aspects of the colonies differ significantly from those described for the holotype (de Matos et al. 2014) and they are close to those of other species of the genus *Heteropathes* Opresko, 2011. The present paper based on newly collected material provides a redescription of *H. opreski* with its growth disturbances and a discussion of its distribution patterns.

Materials and methods

Material used in the present work was collected on the 30th, 32nd and 34th cruises of *RV Professor Logachev* (PMGRE) in the course of prospecting for polymetallic sulphides along the Mid-Atlantic Ridge (Cherkashev et al. 2013). Those cruises were mainly focused on geological tasks and therefore no biologists were on board. Biological samples were photographed on deck and collected material was dried or preserved in 70% alcohol. Three specimens from two different localities and on-deck photographs were available for study (Dobretsova et al. 2013). All corallum measurements were carried out on preserved material or approximated from on-deck photographs. The spines were measured using light microscopy and scanning electron microscopy (SEM) of the skeleton. The distance between spines was chosen as a distance measured between centers of the bases of adjacent spines in the same longitudinal row; the

height of the spine was chosen as a distance between the apex and the center of the base of the same spine. Type specimens of *Heliopathes americana* Opresko, 2003 (USNM 100111, 92591) and *H. pacifica* Opresko, 2005 (USNM 1070758, 1070760) were studied for comparison. The holotype of *Heteropathes opreski* was not available for study.

Results

Heteropathes Opresko, 2011

Heliopathes Opresko, 2003: 531; Opresko 2005: 160;

Heteropathes Opresko, 2011: 67; de Matos et al. 2014: 294

Corallum monopodial or very rarely branched and pinnulate; pinnules arranged in two lateral rows and one or more anterior rows. Lateral pinnules usually simple, elongated; anterior pinnules short and subpinnulated. Rarely lateral pinnule with one or several subpinnules of same morphology as anterior pinnules. Lateral pinnules arranged alternately, the lowermost lateral pinnules subopposite or alternate. Polyps 3 to 6 mm in transverse diameter.

Type species *Heliopathes americana* Opresko, 2003. Apart of type species three more species are assigned to genus: *Antipathes heterorhodzos* Cooper, 1909, *Heliopathes pacifica* Opresko, 2005 and *Heteropathes opreski* de Matos, Braga-Henriques, Santos & Ribeiro, 2014.

Geographic Distribution. Western Atlantic (the Caribbean Sea off Jamaica, no depth data; off Georgia, 2200 m ─ *H. americana*), Mid-Atlantic Ridge (NE of Oceanographer Fracture Zone; Semenov ore field; Irinovskoe ore field, 1955-2738 m ─ *H. opreski*), Indian Ocean (off Sri Lanka, 1062 m ─ *H. heterorhodzos*), North Pacific (Alaskan seamounts, Derickson Seamount, 3563-4511 m ─ *H. pacifica).*

Bathymetric Distribution: *H. americana* 2200 m*, H. opreski* 1955-2738 m*, H. heterorhodzos* 1062 m, *H. pacifica* 3563-4511 m, *H. opreski* 1955-2738 m.

Heteropathes opreski de Matos, Braga-Henriques, Santos & Ribeiro, 2014

Material studied (Figs. 1-2). *RV Professor Logachev* cruise 30, 30L295g: TVG 13º30,422'N, 44º56,339' W, 2122 m numerous specimens (photographs only); cruise 32, 32L100g: TVG 13º 30.312' N 44º 54.056'W, 2738 m – 2 specimens (photographs only); 32L372g: TVG 13° 30,700'N, 44º56,001' W 2256 m – 1 alcohol preserved specimen (IORAS IV-9-Ant-15-010); cruise 34, 34L201d: rock dredge 13º 19.824´N 44º 57.836´ W, 2221 m (beginning) 13º 19.436´ N 44º 57.903´ W, 1955 m (end) – 2 dry specimens (IORAS IV-9-Ant-15-010).

Diagnosis (after Matos et al. 2014, emended). Small colony monopodial or very rarely and very sparcely branched and pinnulate. Unpinnulated stem is 25–32 mm long. Fluted area begins 9–17 mm above the base and extends vertically up to bases of the lowermost lateral pinnules (Fig. 2 A, C). Pinnules arranged in two lateral rows and one irregular anterior row. Lateral pinnules relatively long, usually simple and arranged alternately (basal pair of lateral pinnules may be subopposite or alternate), inclined and curved distally. Longest lateral pinnules (17–28 mm in studied specimens (Fig. 2 A–C) and ~50 mm based on on-deck photographs can reach (Fig. 1)) in the middle and upper third of pinnulated part of the stem. Density of lateral pinnules 12–14 /cm on lower part of pinnulated portion of the stem and 11–12 / cm near the apex. Anterior pinnules with subpinnules forming a dense row ~5–5.5 mm wide and inserted nearly perpendicularly to the stem just above corresponding lateral pinnules (beginning from 1st to 3d lateral pinnule). Density of anterior pinnules 11–12 pinnules / cm. Each anterior pinnule has two or three orders of densely set subpinnules and forms an arborescent structure with subpinnules originated at almost the same level. Secondary subpinnules arranged in several subopposite pairs or in verticils beginning 0.5–0.6 mm above the base of the primaries. Tertuary pinnules arranged in subopposite pairs or irregularly. Quatenaries when present arranged irregularly. Frequent anastomoses occurring between anterior secondary and/or tertuary

subpinnules of the same and/or adjacent anterior primary pinnules. One or more lateral pinnules can be modified into pinnulated side branch with lateral and anterior pinnules. In forming lateral branches anterior pinnules may be mistaken to lateral subpinnules, however they always have characteristic longer spines.

Spines on lateral pinnules simple, triangular compressed and distally inclined: polypar spines 0.04–0.08 mm tall, abpolypar spines 0.015–0.03 mm tall. Spines arranged in longitudinal rows with four rows visible in lateral view. Within each row spines 0.2–0.3 mm apart resulting in 4–5 spines per 1 mm. Spines as large as 0.12 mm tall reported on lateral pinnules of the holotype may have been hypertrophied – see discussion below – or belong to forming anterior sibpinnules.

Spines on anterior pinnules mostly simple, conical, acute, often inclined distally 0.08–0.17 mm tall, usually tallest at concave side of subpinnules. Spines at base of subpinnules irregularly arranged, closely set, often inclined proximally and sometimes bifurcated.
Polyps about 3 mm in transversal diameter, as estimated from the photo (Fig. 1 C), spaced about 1.5–2 mm apart, resulting in 2.5 polyps / 1 cm.

Remarks. All specimens at hand (Fig. 2) or photographed on deck (Fig. 1) bear rather long lateral pinnules (up to 28 mm), some longer than the unpinnulated part of the stem. This differs significantly from the condition in the holotype, which had all lateral pinnules broken off with the remaining parts only up to 7 mm long. Furthermore, in the specimens examined in the present study, the spines on the lateral pinnules are not longer than 0.08 mm, whereas in the holotype spines as long as 0.12 mm were found. Undoubtedly the holotype was seriously damaged, consequently the true size of the lateral pinnules cannot be determined. In addition, regeneration may have contributed to the large spines resembling those of anterior pinnules, which were found at the blunt tips of the lateral pinnules. Regeneration may cause spines on the remaining axis to grow abnormally large as new layers of sclerenchyme are added. As shown in the specimens described here, under normal growth conditions the distal end of the lateral pinnules narrows to a hair-like tip and has only minute spines.

The occurrence of anastomoses between the subpinnules of the anterior primary pinnules is not mentioned by de Matos et al. (2014), but can be seen at their Figure 1d, and similar anastomosing is found in the specimens collected at the ore fields. In other antipatharians anastomosing of branches or pinnules can be a natural feature or may result from the presence of symbiotic polychaetes (see e.g. Molodtsova and Budaeva 2007).

The maximum total number of lateral pinnules recorded for this species is 36 (18 at each side) with an approximated total length of the colony of about 65–70 mm and the pinnulated part significantly longer than the unpinnulated stem (Fig. 1A). Preserved specimens studied here are up to 50 mm long with 22–25 lateral pinnules (Fig. 2 A–C). One of the apical lateral pinnules is 19 mm long (in specimen from 32L372g) and is modified into a lateral branchlet with four lateral pinnules (7-8 mm long) and 3 anterior pinnules (Fig. 2 E). The first anterior primary pinnule at the branch is arranged between the first and second lateral. Anterior and lateral pinnules on the side branch have the same morphology as those on the main stem, but are shorter. Matos et al. (2014) reported that on the holotype there were "ramified subpinnules" (also referred to as a "secondary laterals" on some lateral pinnules, which resembled the anterior pinnules on the stem. These lateral pinnules, however, did not show any signs of developing into incipient branches. De Matos et al. (2014) regarded all pinnules arranged at laterals including the branched ones as lateral subpinnules, but in fact it was an early process of formation of a secondary branch.

Ecological notes. All specimens considered in the present paper were collected from the ore clusters (Irinovskoe and Semenov, Mid-Atlantic Ridge). Based on the on-deck photographs (Fig. 1), *H.opreski* occurred in groups of 2–7 specimens per rock fragment, often along with a species preliminary determined as *Umbellapathes* sp. (Schizopathidae) and bryozoans (Fig. 1 A–B). As in case with other taxa (Dobretsova et al. 2013), all colonies were documented from ore or basaltic substrates that were covered by an iron-manganese crust. The colonies were almost upright or with the pinnulated part slightly bent in the direction of the polypar side, beginning

just below the base of the lowermost pinnules. In the latter case, the pinnulated part forms an inner angle of 120–130° with stem. No ecological or geological data are available for the specimen from the Oceanographer Fracture Zone, but the species may belong to the ecological group occurring at non-active vents.

Comparison. After examination of the new material and the type material of *H. americana* Opresko, 2003 (USNM 92592, USNM 100111) and *H. pacifica* Opresko, 2005 (USNM 1070758), it can be concluded that two of the key characters mentioned by de Matos et al. (2014) as distinctive for the new species (short lateral pinnules only 0.7 cm long and spines on the lateral pinnules as high as 0.12 mm) appear to be artifacts related to the damaged condition of the type, and subsequent regeneration of the skeletal axis, which often causes hypertrophic development of the spines (Table 1). Nevertheless *H.opreski* can be distinguished from *H. americana* and *H. pacifica* by differences in the location of the fluted area at the stem (in *H. opreski* it stops at the level of the lowermost lateral pinnules, whereas in the other two species it extends further vertically). No data are available on the length of the fluted area in *H. heterorhodzos* and the location of the type specimen is unknown (Opresko 2003). *H.opreski* can also be distinguished from all its congeners by slightly shorter densely subpinnulated anterior pinnules (Fig. 3 G) with occasionally anastomosing subpinnules, and from *H. heterorhodzos* and *H. pacifica* by more densely set lateral pinnules.

Distribution. The species is known exclusively from the northern subtropical and subequatorial Mid-Atlantic Ridge (34°46.7’N to 13°19.43’N) from 1955–2738 m depth and can be a putative endemic of the area. *H. opreski* was reported both from the east (de Matos et al. 2014) and the west (present study) flank of the Mid-Atlantic Ridge (Fig. 4).

Growth disturbances and colony morphology

It is not uncommon for deep-sea species to be described based on a single specimen, because they are usually rare and difficult to collect. Black corals are not an exception. Thus descriptions of 30 among 39 new species and subspecies of black corals in the Challenger Expedition (Brook 1889) were based on a single specimen or even a fragment, and 19 species described by Brook (1889) are known only from material used in the original description. On the other hand, in cases where an aberrant form is described as a type specimen of a species, it is difficult to attribute new findings properly.

Little is known about patterns of colony formation in black corals. Specimens collected can be damaged or modified by symbionts (Molodtsova and Budaeva 2007) or may represent an abnormal colony form due to ecological conditions. There are some literature records that can be attributed to growth disturbances. Thus, *Bathypathes seculata* Opresko, 2005 collected in the North Pacific off Hawaii was described based on a single specimen of 9 cm length with six pairs of subopposite pinnules (Opresko 2005:130-133, Fig. 1). Based on the fact that the upper pair of pinnules was the longest with a stem projecting above, the author suggested that the specimen had attained the maximum colony size of the species. Meanwhile even colonies of the same genus of moderate and giant size usually have slightly shorter pinnules near the apex apparently due to the apical dominance. The phenomenon of apical dominance was never considered for black corals but it was reported for other Cnidaria (see e.g. Shaish and Rinkevich 2009 for Scleractinia). Apparently the unique growth form seen in *B. seculata* with the longest upper pinnules occured as a result of injury to the upper part of the young colony that led to more extensive growth of the upper pair of pinnules without formation of the next apical pair.

Symbiotic polychaetes can also seriously alter morphology of antipatharian colonies. Thus symbiotic polynoids can induce numerous anastomoses between adjacent pinnules and, depending on the species of the host and associate polychaete, can even induce a formation of characteristic reticulated worm run (Totton 1923). There are some indications that the presence of symbiotic polynoids can induce a brush-like colony forming along the ‘worm run’

(Molodtsova and Budaeva 2007). Anastomoses between adjacent pinnules or subpinnules have not, until now, been reported for the genus *Heteropathes,* therefore doubts remain if anastomoses encountered in *H. opreski* are characteristic for the species or were induced by symbiotic organisms.

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Figure Captions

Fig. 1 On-deck photographs of *Heteropathes opreski*. A-B. Station 30L295g (arrowheads indicate position of colonies). C-E. Station 32L100g. Scale bars: A: 3 cm, B: 2 cm, C-D: 1 cm.

Fig. 2 *Heteropathes opreski* colony morphology. A-C. Specimens from station 34L201d; scale bar: 1 cm. D-E. Specimens from station 32L372g; scale bar: 5 mm; large arrowhead indicates side branch, small arrowheads indicate unusually long anterior subpinnule, dotted line: beginning of the fluted area at the stem.

Fig. 3 *Heteropathes opreski*. SEM of spines. A-D. Lateral pinnules. E-J, Anterior pinnules. Scale bars: 0.1 mm.

Fig. 4 Distribution map for *Heteropathes opreski*: type locality (de Matos et al. 2014) (open circle: ○), new locations (solid circles: ●); 8-radiate solid star (✸): seamounts; open 5-radiate star (☆): ore fields, FZ: Fracture Zone

Table 1. Comparison of hitherto known species of the genus *Heteropathes* (Cooper 1909; Opresko 2003, Opresko 2005; de Matos et al. 2014): (*lp*) lateral pinnules, (*ap*) anterior pinnules

	H. americana (Opresko, 2003)	*H. pacifica* (Opresko, 2005)	*H. heterorhodzos* (Cooper, 1909)*	*H. opreski* Matos et al., 2014
Colony size, mm	100–105	220–320	105	50–60
Ratio of pinnulated section to lower unpinnulated stem	4/1 (stem shorter than lowermost pinnules)	2.6/1 (stem longer than lowermost pinnules)	3/1 (stem shorter than lowermost pinnules)	2/3–5/1 (stem longer than lowermost pinnules)
Stem	Fluted area begins 2 mm above the base and stops below the 3rd lateral	Fluted area begins 3 cm above the base and stops at the 7th pair of laterals	NA	Fluted area begins 9–17 mm above the base and reaches lowermost lateral pinnules
Arrangement of lateral pinules	Lowermost pair subopposite, others alternate	Lowermost pair subopposite, others alternate	Alternate (? including lowermost)	Alternate (lowermost can be subopposite)
Arrangement of anterior pinnules	In a single irregular row	In a single irregular row	In a single irregular row	In a single irregular row, anastomosing
Anterior pinnules anastomoses	Absent	Absent	Absent	Present
Lateral pinnules length, mm	70–90+ (all broken off at tip in holotype)	60+ (all broken off at tip in holotype, 140 in paratype)	Up to 60	Up to 30 [...50**]
Lateral pinnules density, cm^{-1}	9–10 [4]***	5	4	10–11
Anterior pinnules length, mm	6–8	6–7	<10	4–6
Anterior pinnule density, cm^{-1}	6–11	6–10	4–5	9–11

Anterior subpinnules	Secondaries, rarely tertaries	Secondaries or tertaries	Secondaries (?)*	Mostly tertaries or quartics
Secondary branching	Not reported	Simple subpinnule at upper lateral (USNM 1070758)	Not reported	Branchlets with simple *lp* and subpibnnulated *ap* originated from laterals
Spines (*lp*)	Triangular, compressed, slightly inclined	Triangular, compressed, nearly at right angle	Minute	Triangular, compressed, slightly inclined
Spines (*ap*)	Conical, strongly inclined distally	Similar to *lp*; slightly larger and more acute and inclined at subpinnules	thin-pointed, needle-like	Conical, strongly inclined distally
Spine size (*lp*), mm	0.03–0.05	0.03–0.06	<0.05	0.02–0.05 up to 0.08
Spine size (*ap*), mm	0.05–0.13 (a)	≤ 0.07 (a)	≤ 0.2 (a)	0.05–0.15
Number of rows of spines in lateral view	5–6... 8****	4–5	4	4
Spine density, mm^{-1}	5–8(l)	4		4–5 (l)
Polyps, transversal diameter, mm	5–6	5–6	NA	3 (l)**
Polyps, cm^{-1}	NA	< 2–3	NA	1.5–2 (l)**

* estimated from illustrations of holotype (Cooper 1909: Pl. 41, 4a–c), assuming the longest lateral pinnules to be 6 cm

** estimated from on-deck photograph based on the length of anterior pinnules (Fig. 1)

*** in holotype all lateral pinnules are more densely set and restricted to 1.2 cm

**** rows at abpolypar side are more numerous than at polypar side

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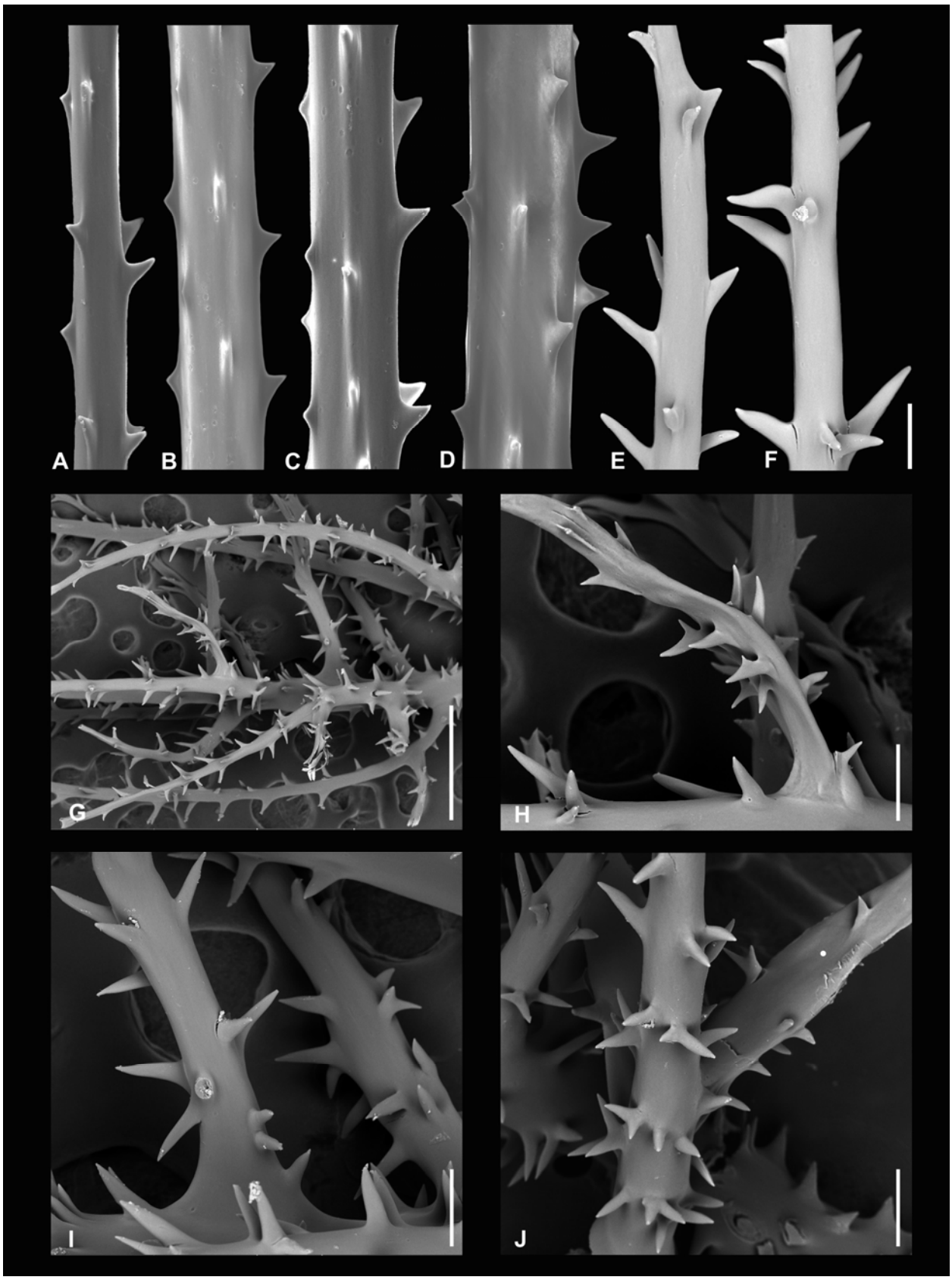

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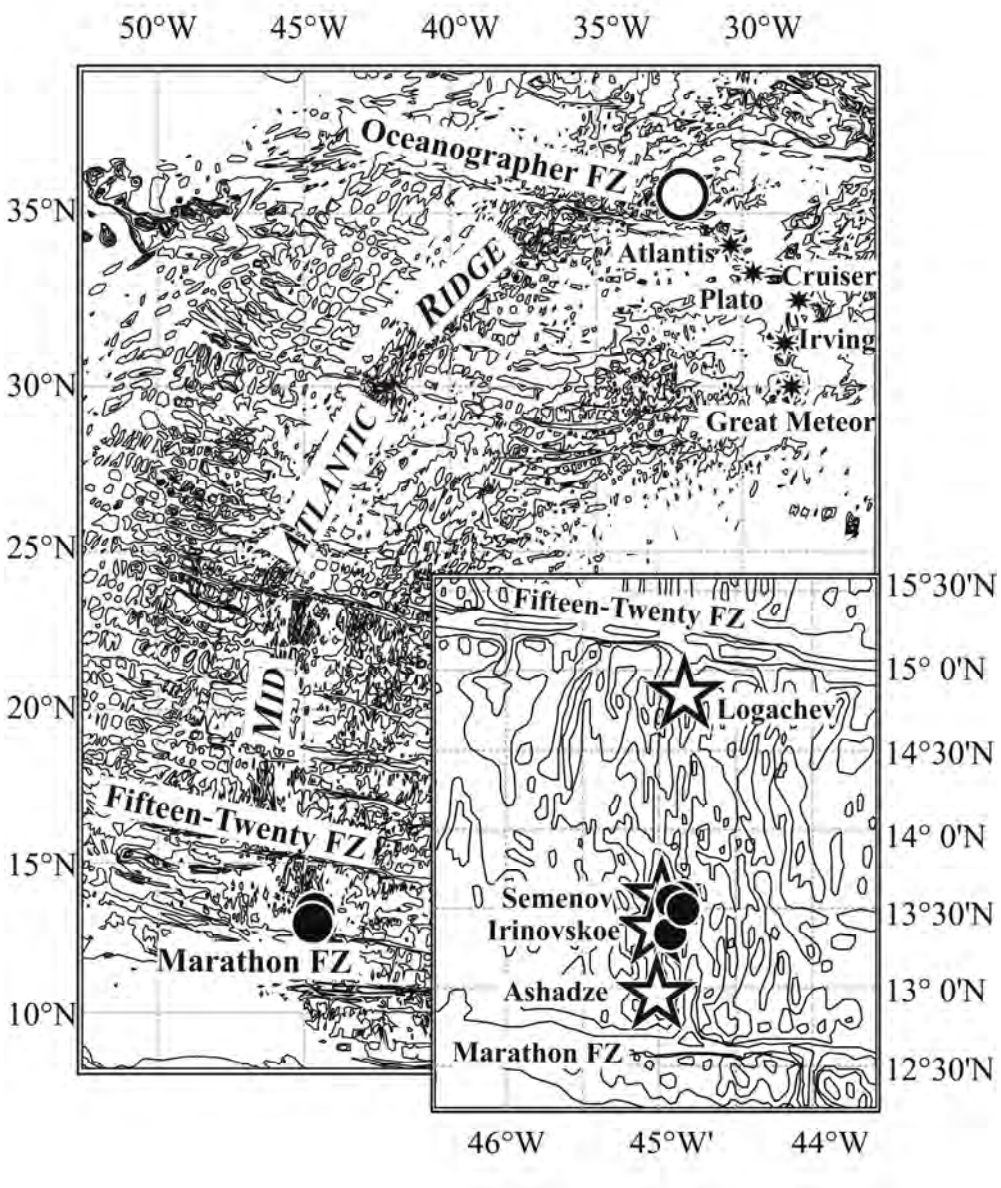

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