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Research paper

Pirumosphaera armandae nov. sp., a new Southern Ocean polycystine radiolarian genus and species

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ABSTRACT

This paper describes a new monospecific polycystine radiolarian genus and its single species so far, *Pirumosphaera armandae*, found in the Southwest Pacific and Indian sectors of the Southern Ocean. The new spumellarian form is rarely found as a complete specimen, as only its first and second shells are commonly found. However, partially complete specimens suggest that the test of this species is made of four shells. The most diagnostic feature of the species is the peculiar shape of the first shell which protrudes through the second shell, a characteristic that does not conform to any other Quaternary spumellarian genus. Based on the distinct and unique relationship between the first and second shells, the species is assigned to the newly established *Pirumosphaera* genus.

RÉSUMÉ: Cet article décrit un nouveau genre de radiolaire polycystine qui inclut, à ce jour, seulement une espèce: *Pirumosphaera armandae*. Cette nouvelle espèce a été trouvée dans les sédiments des secteurs Sud-Ouest Pacifique et Indien de l'océan Austral. Ce nouveau spumellaire est rarement trouvé entier. En effet, des spécimens incluant seulement la première et deuxième chambres sont le plus souvent observés. Cependant, un spécimen partiellement entier laisse penser que le squelette complet de cette espèce est fait de quatre chambres. La particularité de ce nouveau genre est la forme piriforme de la première chambre, dont la plus petite sous-section ressort de la deuxième chambre. C'est une caractéristique absente des autres spumellaires du Quaternaire. En raison de cette caractéristique, cette nouvelle espèce est assignée au nouveau genre *Pirumosphaera*.

Introduction

Polycystine radiolarians are siliceous micro-zooplankton ranging in size from less than 20 μm to 1–2 mm (Anderson, 2019). They inhabit the marine environment, from the tropics to the high-latitude polar regions (Boltovskoy et al., 2010). A range of depth preferences has also been observed, with some species being surface dwellers, while others dwell in the subsurface and deeper waters. In the Southern Ocean (SO), radiolarian species generally peak in abundance between 100 and 400 m depth (Boltovskoy, 2017), although living radiolarians have been found in waters deeper than 2000 m (Boltovskoy et al., 2010).

The SO hosts several hundred polycystine taxa, many of which are widely distributed, with a few of them endemic to the region (e.g. *Antarctissa* genus, *Actinomma antarcticum, Lithomelissa* sp. A, to cite a few; Nigrini and Moore, 1979; Abelmann, 1992; Renaudie and Lazarus, 2015; Rogers, 2020). The community composition has been found to reflect both the latitudinal gradients of temperature and density of the polar waters and the longitudinal differences in oceanographic conditions between the sectors (Lowe et al., 2022; Civel-Mazens et al., 2023). Because of the sensitivity of their assemblages to environmental conditions, radiolarians are useful indicators of conditions such as temperature, upwelling, and productivity (e.g., Lazarus, 2005; Cortese and Prebble, 2015; Civel-Mazens et al., 2023). In this study, we describe a new polycystine radiolarian monospecific genus found in Late Quaternary sediments in the Southwest Pacific and Indian sectors of the SO.

Sample location and collection

Specimens were identified in three SO sediment cores (Fig. 1). Core MD19-3575CQ (46.047°S, 44.370°E, water depth 2410 m; IGSN IEFRA09CX) was collected using a CASQ corer, a type of large volume gravity corer, on board the *RV Marion Dufresne II* during the 2019 MD218 CROTALE voyage (doi:10.17600/18000886) in the Indian sector of the SO (Crosta, 2019). Two sediment cores TAN1302–96 (59.092°S, 157.050°E, water depth 3099 m) and TAN1302–97 (57.287°S, 161.331°E, water depth 3544 m) were collected using a grav-

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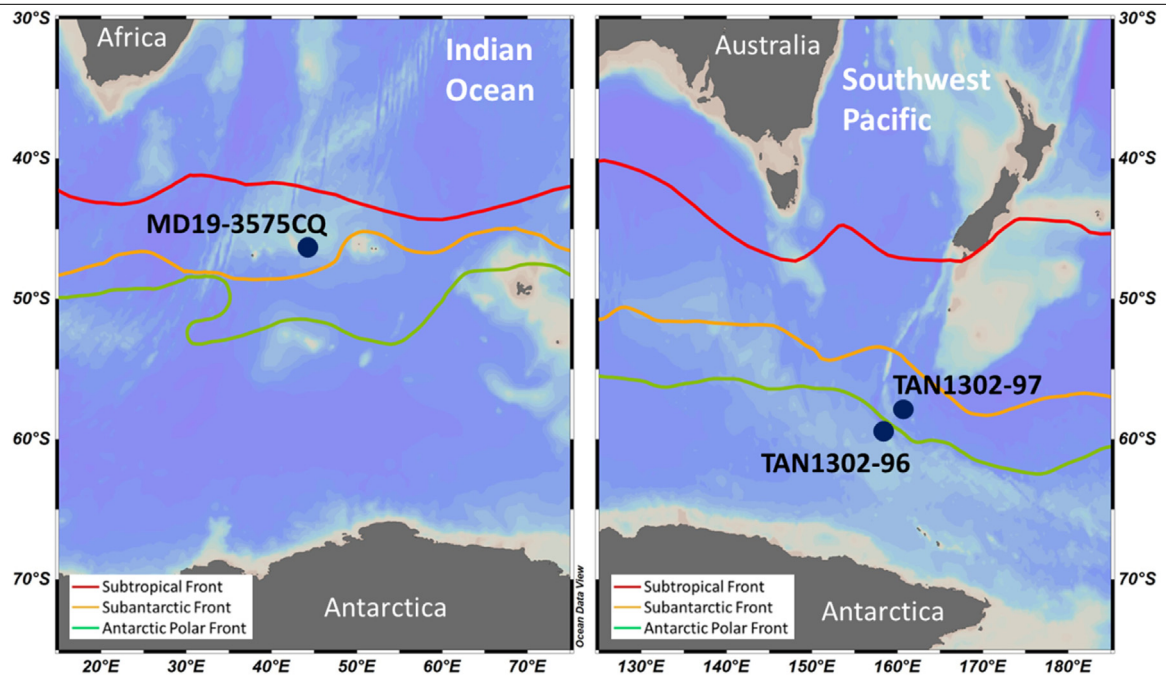

Fig. 1. Sediment core locations where specimens of the newly described species were recorded in the Southwest Pacific and Indian sectors of the SO. Fronts locations according to Orsi, 1995.

ity corer during the 2013 Mertz Polynya voyage on the *RV Tangaroa* in the Southwest Pacific sector of the SO (Williams et al., 2013).

The sediment samples were washed with ca. 20% hydrogen peroxide (and a splash of Calgon, a surfactant) to oxidise the organic matter and breakdown clays, and then soaked with 10% HCl to remove the carbonates. The remaining sediment was sieved at 45 µm, and the residue was used for producing permanent slides using the mounting medium Norland Optical Adhesive 61 (NOA 61), cured with a UV light for about 10 min. Radiolarians were identified and enumerated using a Zeiss Axioskop 40 transmitted-light microscope at 200x magnification. A total of 21 specimens of *Pirumosphaera armandae* were recovered from the study material, 10 from core TAN1302-96, 9 from core TAN1302-97, and 2 specimens, including the Holotype, from core MD19-3575CQ. Slides containing the holotype and paratypes are stored within the National Paleontological Collection at GNS Science, Lower Hutt, New Zealand, accessible here: https://www.gns.cri.nz/data-and-resources/national-paleontological-collection/.

Systematics

Class POLYCYSTINA Ehrenberg, 1838

Order SPUMELLARIA Ehrenberg, 1875

Family ACTINOMMIDAE Haeckel, 1862

Pirumosphaera Lowe et al., nov. gen.

Description. Spumellarian radiolarian with four concentric shells, the first one having a non-spherical shape, but rather in the form of a pear, or pyriform.

Remarks. The new monospecific genus described in this paper shares some characteristics with several other genera within the family Actinommidae (e.g., *Druppatractus* due to the pyriform first shell, *Actinomma* due to having concentric shells, *Stylatractus* due to the presence of multiple shells). However, it does not strictly conform to the characteristics of any other genus and requires the establishment of a new genus for classification. This is due to the pyriform shape of the first shell, and the protrusion of this first shell's smaller subsection out of the secondary cortical shell (see Plate 1).

Pirumosphaera armandae Lowe et al., nov. sp.

Plate 1

Description. The species consists of four concentric shells, the first shell is pyriform in shape, and the outer three shells are spherical. The first shell is made of two unequally sized, subspherical sections separated by a stricture. The larger section is central to the specimen (central section), and the smaller section is peripheral to the centre (peripheral section) and partially protrudes through the second shell (Fig. 2b). The pores on the first shell are sub-circular to polygonal; usually 6 to 8 of them are visible across the equatorial plane of the central section, and 3 to 4 are visible across the peripheral section. The pores on the central section are slightly bigger than the pores on the peripheral section. Simple spines are semiregularly spaced over the surface of the central section, usually 8 to 15 visible across the equatorial plane (Fig. 2c). There are 4 to 5 spines present on the portion of the peripheral section that is protruding through the second shell (Fig. 2c). The second shell is spherical to sub-spherical. Pores are sub-circular with hexagonal framing and larger than the pores on the first shell. The third shell is spherical with sub-circular pores that are larger than those on the second shell. The distance between the second and third shells is slightly larger than between the third and fourth shells. The outer, cortical fourth spherical shell has numerous semi-regularly spaced bristle-like byspines and semi-regularly spaced pores that are similar in size to those on the third shell. The primary spines are simple and extend from the inner shell to the exterior of the cortical fourth shell. The primary spines protrude through the fourth shell only by a few microns, possibly with some secondary spines or beams between the second and fourth shell (Fig. 2a).

Remarks. The first shell of *P. armandae* bears a superficial resemblance to the pyriform-shaped first shell of some species belonging to the genus *Druppatractus*, most notably *D. variabilis* and *D. irregularis*. The size of the first shell is most similar to the one in *D. variabilis*. However, *P. armandae* differs by not having distinct polar spines on the first shell and a more marked constriction between the central and peripheral sections than in the pyriform-shaped *Druppatractus* first shell. The second shell of *P. armandae* is spherical, while it is sub-spherical to elongated

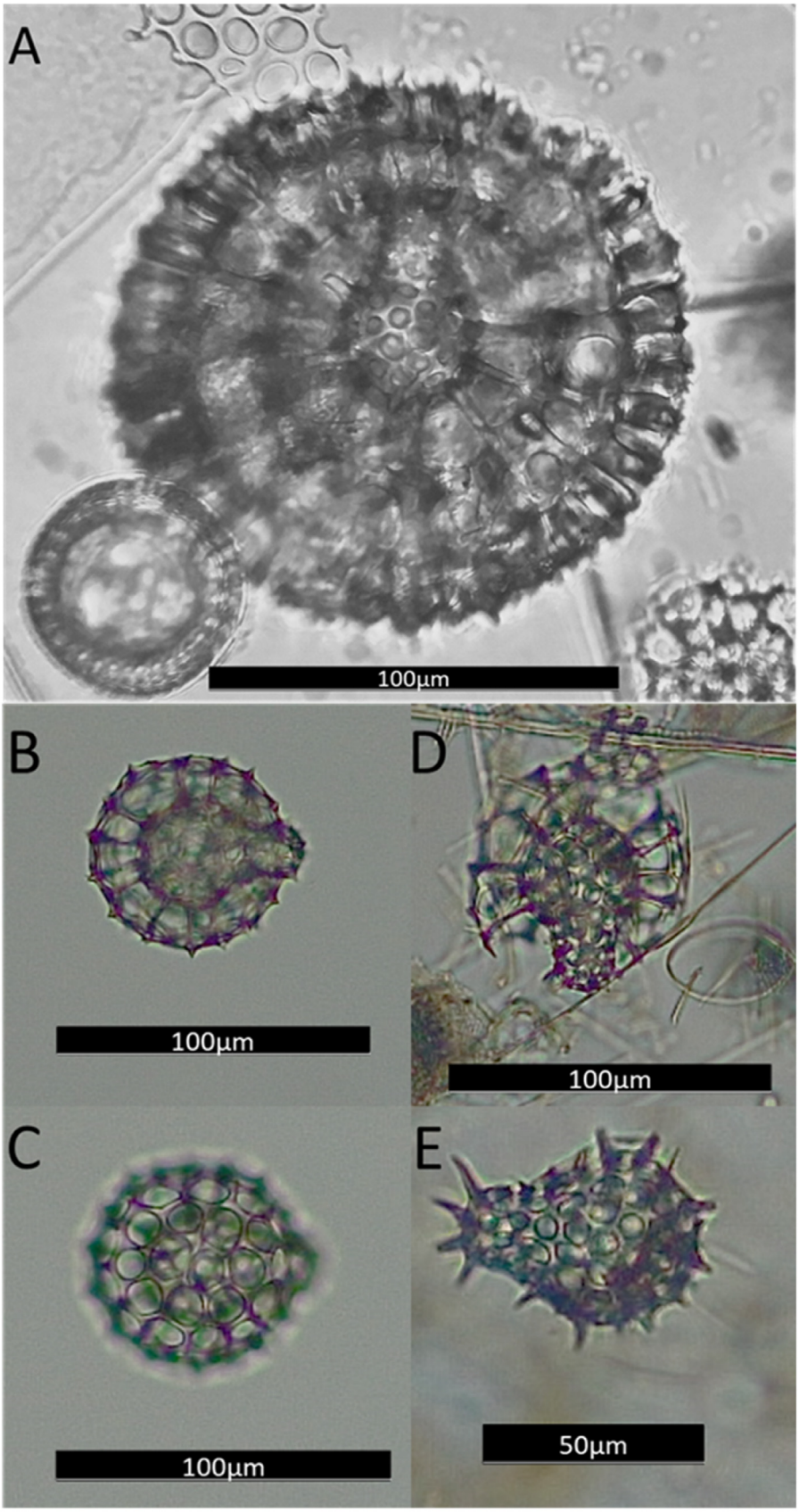

Plate 1. *Pirumosphaera armandae* A) holotype (core site MD19-3575CQ, 299-300 cm), most complete specimen; B & C) paratype 1 (core site TAN1302-97, 21–22 cm), same specimen at two focus levels, inner and 2nd shell present, 3rd and 4th shells missing; D) specimen with second shell broken (core site TAN1302-97, 171-172 cm); E) paratype 2, Specimen consisting of inner shell only with spines, all other shells missing (core site TAN1302-97, 191-192 cm).

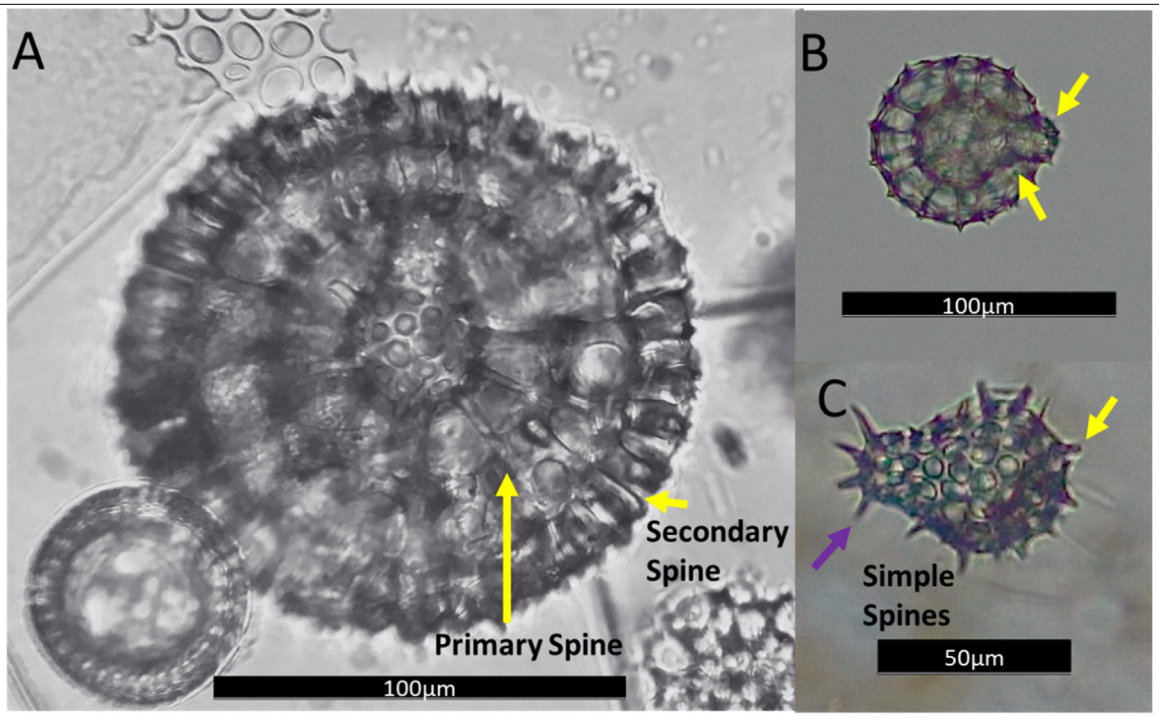

Fig. 2. Characteristics of *Pirumosphaera armandae* A) Primary and secondary spines visible on most complete specimen of *P. armandae*; B) Characteristic protrusion of the peripheral section of the first shell through the second shell, and the stricture between the central and peripheral sections of the first shell; C) the first shell, with simple spines arranged in a semi-regular pattern extending from the surface across the central section and 4 to 5 spines on the peripheral section.

in *D. variabilis* and *D. irregularis*. Unlike *P. armandae*, the first shell of all species in the genus *Druppatractus* is entirely contained within, and does not protrude through, the second shell. Furthermore, the two genera are clearly distinct based on their body plan, with *Druppatractus* having distinct polar spines.

Within Spumellaria, the presence of a non-spherical shaped first shell is not a unique character for the newly proposed genus *Pirumosphaera*, as such a feature is also observed in other genera (both extinct and extant), such as *Druppatractus* and *Entapium* (Sanfilippo and Riedel, 1973; O'Connor, 1999; De Wever et al., 2001; Dumitrica, 2019), although this is not an exhaustive list. Additionally, the presence of a non-spherical first shell has been used to propose different genus assignments (Levyikina, 1986; Matsuzaki et al., 2015; Dumitrica, 2017) for species formerly belonging to the genus *Actinomma*, with *A. medianum, A. arcadophorum* and *A. antarcticum* being suggested to belong to the genus *Rhizosphaera*. Other variations of the central shell include a spicular form, such as observed in *Gonosphaera* (Dumitrica, 2001) and *Joergensenium* (Bjørklund et al., 2007).

The protrusion of the first shell through the second shell observed in *P. armandae* is also observed in the genus *Suttonium*. The migration of the *Suttonium* central shell occurred over the evolution of the genus (Dumitrica, 1983). However, the first shell is spherical in all *Suttonium* species while pyriform in *P. armandae*. We are not aware of any genera with a pyriform first shell that protrudes through the second, spherical shell.

The characteristic features of *P. armandae* were consistent across all specimens observed and do not appear to be the result of reproductive or developmental deviations of another form (Afanasieva and Amon, 2016). Their consistent appearance also indicates that the shape is not the result of a physical trauma to the individual during development, nor the result of reparative rebuilding of the structure after a trauma event.

Complete forms of *P. armandae* are rarely seen, and only one complete specimen was found in the Indian Sector core MD19-3575CQ (Plate 1a). More commonly, the first shell alone is observed, and occasionally some specimens have the spherical-shaped second shell as well (Plate 1b & c). When only the first shell is present, the stricture does not always appear as pronounced as when the second shell is present (Fig. 2b & c). These specimens may represent a less developed, juvenile form. The distinct form of the inner shell makes this species distinguishable from other similar forms, even when only one shell is present. When *P. armandae* is found as a more complete specimen, with 3 or 4 shells present, it bears a resemblance to species of the *Actinomma* or *Rhizosphaera* genera, possessing multiple spherical shells and primary spines that extend from the inner to outer shell. However, no species belonging to these two genera display the characteristic first shell of the new genus *Pirumosphaera*.

Measurements. When present, the fourth shell is ~135 µm in diameter (only one specimen measured). The more frequently observed second shell (n = 5) is ~68 ± 6.4 µm in diameter. The primary axis of the first shell (n = 12) is ~ 54 ± 3.4 µm long. The diameter of the central section is ~35 ± 2.5 µm and the one of the peripheral section is ~16 ± 1.5 µm.

Occurrence. This species was observed in late Quaternary sediments from the Southwest Pacific and Indian Sectors of the Southern Ocean. The cores were located within the Antarctic to Subantarctic Zone. The Holotype was recovered from core MD19-3575CQ (Tables 1 & 2).

The identification of *P. armandae* in previously counted material from core site E27-23 indicates that specimens may have been counted at a higher taxonomic level (i.e., Unidentified Spumellaria) or misidentified as a similar species such as those of the *Druppatractus* genus where only the first shell is present, or species of the *Actinomma* genus where the second to fourth shells are present. While no occurrences of this species have been reported in the Southern Ocean Radiolarian Dataset (Lawler et al., 2021), it may be of benefit to revisit the core-top material to determine is this is an extant species and, if so, improve the information on the geographic distribution of *P. armandae* in the modern assemblage.

Type Specimens. The reference slides are stored at GNS Science, New Zealand. The holotype and two paratypes are permanently archived

and stored at the National Paleontological Collection at GNS Science. Their England finder positions are as follows: Holotype (MD19-3575CQ, 299-300 cm, Collection reference number: RT 645, England Finder: O-25-3), Paratype 1 (TAN1302-97, 21-22 cm, Collection reference number: RT 646, England Finder: S-48-4), Paratype 2 (TAN1302-97, 171-172 cm, Collection reference number: RT 647, England Finder: O-30-3).

Derivation of name. The genus name, *Pirumosphaera*, meaning "pear sphere", refers to the pear shape of the first shell that protrudes through the second shell. The species name is dedicated to Professor Leanne Armand to honour her memory and her many contributions to the field of micropaleontology.

Table 1
Location of core sites with recorded occurrences of *Pirumosphaera armandae*. SWP – Southwest Pacific Sector, IND – Indian Sector.

Core	*Latitude (°)*	*Longitude (°)*	*Depth (m)*	*Sector*	*Core Type*
TAN1302–96	−59.092	157.050	3099	SWP	Gravity
TAN1302–97	−57.287	161.331	3544	SWP	Gravity
MD19–3575CQ	−46.047	44.370	2410	IND	Gravity

Table 2
Depth and estimated age of samples containing specimens of *P. armandae* in cores MD19-3575CQ, TAN1302-96 and TAN1302-97.

Core	*Depth (cm)*	*Age (kyr)*
MD19–3575CQ	299–300	83.3
	394–395	121.8
TAN1302–96	81–82	12.5
	151–152	43.1
	251–252	107.6
	261–262	115.2
	271–272	118.8
	291–292	125.5
	311–312	134.7
	321–322	139.9
	331–332	144.6
TAN1302–97	21–22	7.8
	91–92	44
	121–122	55.8
	131–132	59.6
	161–162	83.8
	171–172	89.7
	191–192	104.5
	221–222	129.6
	281–282	198.3
	321–322	224.3
	341–342	234.8

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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