New genus *Arxellia* with new species of Solariellidae (Gastropoda: Trochoidea) from New Caledonia, Papua New Guinea, Philippines, Western Australia, Vanuatu and Tonga

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Abstract

A new genus, *Arxellia*, is described in the family Solariellidae. Nine species are referred to this taxon, eight of which are new and are described in this paper (*Arxellia trochos* n. sp., *Arxellia boucheti* n. sp., *Arxellia herosae* n. sp., *Arxellia helicoides* n. sp., *Arxellia tracheia* n. sp., *Arxellia thaumasta* n. sp., *Arxellia maestratii* n. sp. and *Arxellia erythrea* n. sp.). The previously described species *Bathymophila tenorioi* Poppe, Tagaro & Dekker, 2006 is reassigned to *Arxellia*.

Key words: Gastropoda, Trochoidea, Solariellidae, central Indo-West Pacific, new genus, new species

Introduction

Trochoidean gastropods currently referred to the Solariellidae remained poorly known until the latter part of the nineteenth century when a number of contributions were published discussing the solariellid fauna of several different parts of the world, as well as the morphology and biology of the group as a whole (Quinn 1979, 1991; Herbert 1987; Hickman & McLean, 1990; Warén, 1993; Marshall 1999). At this time solariellids were treated as a subfamily of the Trochidae, but these studies revealed that the group constituted a well-defined assemblage of genera exhibiting perhaps the highest number of apomorphic character states within the Trochoidea (Hickman 1996). Subsequently, Bouchet & Rocroi (2005) treated the group as a family in its own right and speculated that it might belong within the Seguenzioidea rather than the Trochoidea. However, broad-scale molecular work on the Trochoidea has since demonstrated the trochoidean affinities of solariellids and has confirmed that they cluster as a well-supported monophyletic entity warranting recognition as a distinct family (Williams et al. 2008; Williams 2012; see also WoRMS).

In recent years, large-scale, deep-sea expeditions undertaken by the Muséum national d'Histoire naturelle, Paris have provided new material for both molecular and taxonomic studies (Bouchet et al. 2008). The first molecular phylogeny for Solariellidae was recently published (Williams et al. 2013), in which several new clades were identified, each thought to represent an undescribed genus-level taxon. In this study we present shell, radula and anatomical data for one of these clades (Clade A), which we here describe as the new genus *Arxellia* (Figs 1–9). We also describe eight new species. Other new solariellid genera and species from these samples are described elsewhere (e.g. Vilvens 2009; Vilvens & Williams 2014). Collectively, these studies comprise an important contribution toward the documentation of solariellid diversity—a diversity that is considerably higher than previously recognised.

As a group we are working towards better understanding of solariellid diversity and several projects are currently underway. Studies in preparation include a generic level monograph of the family (the authors and A.
Warén, Y. Kano, B. Marshall), new species descriptions for *Ilanga* Herbert, 1967 (the authors), a description of seven new species and a new genus corresponding to Clade C in Williams et al. 2013 (Vilvens & Williams, 2014), a study of *Minolia* A. Adams, 1860 (Y. Kano, T. Takano, K. Hasegawa & S. T. Williams) and a study of solariellid eyes (L. Sumner-Rooney, J. Sigwart & S. T. Williams). Some of these studies will include molecular phylogenies with new samples, including *Microgaza* Dall, 1881, which is one of only two genera missing from the phylogeny in Williams et al. (2013).

Future studies would profit from sampling the molecular diversity of areas that are poorly sampled to date; for instance the western Atlantic, East Pacific, northwest Africa, southern Africa, Japan, Australia and New Zealand.

**Material and methods**

The material studied in this paper was mainly collected by French IRD-MNHN expeditions covering a large area of the Indo-Pacific, focusing in particular on New Caledonia, Fiji, Vanuatu, Philippines, Solomon Islands, Tonga and Marquesas Islands (Table 1, Fig. 10). Additional material, stored in WAM, was collected during the Australian 'Southern Surveyor' campaign, prospecting in a wide area off Western Australia (28°S to 35°S, 113°E to 117°E).

For species descriptions, the main conchological features used are illustrated in Figure 11 and comprise:

- general shape of the shell and relative height of the spire
- size and shape of the protoconch
- shape of the whorls: convex, concave, straight; with or without shoulder (subsutural ramp), with or without carina
- spiral cords on the whorls: ontogeny, number, beaded (granular), smooth (no beads) or subgranular (intermediate state between smooth and clearly beaded: horizontally elongated, poorly defined beads), features of the subsutural cord in particular, distance between cords
- axial sculpture of the whorls
- shape of the aperture, and features of the outer and inner lips
- shape of the base and its spiral sculpture: number of spiral cords, beaded or smooth, distance between cords
- features of the umbilicus: open or obscured by columellar callus, relative size, margin rounded or carinate, with a smooth or beaded carina, axial threads around umbilical area, shape and number of axial pleats (counted around the last whorl), spiral cords around or inside umbilicus
- columella: thickened or not
- colour: pattern, iridescence; note that when colour is due to the nacreous shell rather than pigment, it is more pronounced in live-collected specimens and such specimens are also often more greenish in colour.

Regarding ridges and wrinkles on the whorls and on the base, we use the following terms and definitions:

- cords: strong ribs
- threads: fine axial ridges (most commonly on the early whorls)
- folds: much larger wrinkles, developing from 3rd whorl
- subsutural folds: beaded wrinkles below the suture
- basal pleats: strong, relatively thick wrinkles produced by axial sculpture around the umbilicus
- basal threads: thinner ridges produced by axial sculpture around the umbilicus
- axial lines: incised lines producing a low axial sculpture around the umbilicus

The known bathymetric range of the species is given as the interval between the two extreme values of all the recorded depth ranges (i.e. MIN depth is the shallowest of the minimum values of all the recorded ranges and MAX depth is the deepest of the maximum values of all the recorded ranges, thus the final bathymetric distribution interval is the shallowest MIN depth—deepest MAX depth).
TABLE 1. List of the Indo-Pacific MNHN expeditions mentioned in this work.

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Prospecting area</th>
<th>Date (m/y)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>5/1993</td>
</tr>
<tr>
<td>BATHUS 3</td>
<td>New Caledonia, Norfolk Ridge</td>
<td>11/1993</td>
</tr>
<tr>
<td>BIOCAL</td>
<td>Southern New Caledonia and Iles Loyauté</td>
<td>8–9/1985</td>
</tr>
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<td>BIOPAPUA</td>
<td>Papua New Guinea</td>
<td>9–10/2010</td>
</tr>
<tr>
<td>BORDAU 1</td>
<td>Fiji Islands</td>
<td>2–3/1999</td>
</tr>
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<td>BORDAU 2</td>
<td>Tonga</td>
<td>6/2000</td>
</tr>
<tr>
<td>CHALCAL 2</td>
<td>Southern New Caledonia and Norfolk Ridge</td>
<td>10–11/1986</td>
</tr>
<tr>
<td>EXBODI</td>
<td>Eastern New Caledonia</td>
<td>9/2011</td>
</tr>
<tr>
<td>LITHIST</td>
<td>Southern New Caledonia</td>
<td>8/1999</td>
</tr>
<tr>
<td>MUSORSTOM 6</td>
<td>Loyalty ridge</td>
<td>2/1989</td>
</tr>
<tr>
<td>MUSORSTOM 7</td>
<td>Wallis et Futuna Islands</td>
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<td>MUSORSTOM 8</td>
<td>Vanuatu</td>
<td>9–10/1994</td>
</tr>
<tr>
<td>NORFOLK 1</td>
<td>New Caledonia, Norfolk Ridge</td>
<td>6/2001</td>
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<td>1–2/1993</td>
</tr>
<tr>
<td>VOLSMAR</td>
<td>Loyalty Ridge</td>
<td>5–6/1989</td>
</tr>
</tbody>
</table>

Abbreviations

Repositories

MNHN          Muséum national d'Histoire naturelle, Paris, France
NHMUK         Natural History Museum of the United Kingdom, London, England
SMNH          Swedish Museum of Natural History,
WAM           Western Australian Museum, Perth, Western Australia

Shell features and dimensions

H             height
HA            height of the aperture
P1, P2,...   primary cords (P1 is the most adapical)
S1, S2,...   secondary cords (S1 is the most adapical)
T1, T2,...   tertiary cords (numbered in order of appearance)
TW           number of teleoconch whorls
W             width

Other abbreviations

stn           station
lv            live-taken specimens present in sample
dd            no live-taken specimens present in sample
sub           subadult specimen
juv           juvenile specimen
Systematics

Superfamily: Trochoidea Rafinesque, 1815


Genus: Arxellia new genus

Clade A, Williams et al., 2013
Type species: Arxellia trochos n. sp.—Recent, New Caledonia.

Diagnosis. Shell small to moderate (height up to 11.8 mm, width up to 13.0 mm), more or less conical in shape, spire moderate to high. Protoconch diameter 300–350 µm, with up to 6 thin spiral threads (in one species only abapical threads visible) and a thin, straight terminal lip without varix. Early teleoconch whorls usually with 5 or 6 beaded spiral cords of equal strength; adapical cord P1 rapidly strengthening and becoming beaded; one abapical primary cord (P5 or P4 according to species) forming a low suprasutural carina starting from third whorl; carina may weaken or disappear on last whorl. Peristome incomplete; columella thickened in some species, with callus lobes at base and mid-point; granular deposition of calcium carbonate occurs where columella is thickened. Base convex to almost flat, with beaded cords on whole surface or with an intermediate smooth area, but always with at least one strong beaded spiral cord bordering umbilicus. Umbilicus open, narrow to moderately wide. The pink, green and opalescent shell colour of most species is largely due to a nacreous shell layer, rather than pigment. However, in some species shells do appear to be pigmented (e.g. the brown colour in A. boucheti, A. herosae, A. helicoideas, A. maestrati and A. erythrea).

Radula of type species with well-developed latero-marginal plates; formula (5–6)+1+4+1+4+1+(5–6).

External anatomy typical of family; eyes pigmented (where known; see Williams et al. 2013); left neck lobe in the form of two short, non-papillate tentacles, the right one a tringual lobe just behind eye-stalk; three papillate epipodial tentacles of more or less equal size present on each side, and additional smaller tentacle-like projection between the anterior pair on both sides. Operculum corneous, straw-brown, shallowly concave, multispiral with central nucleus; growing margin short.

Remarks. Diagnosis of the new genus is based on the nine species discussed herein. Live specimens collected at 242–650 m.

Discussion. The new genus Arxellia corresponds to "Clade A" in the recent molecular phylogeny of the Solariellidae published by Williams et al. (2013). Seven of the new species and many of the specimens photographed were included in that study. The type species was not included, but unpublished molecular data confirm that it belongs in this clade (Williams, unpub. data). Genetic studies place Arxellia as the sister taxon to Archiminolia Iredale, 1929 with strong support. The two genera can be separated by shell shape (Archiminolia species have turban-shaped shells whereas Arxellia species have conical shells) and by the ontogeny of teleoconch spiral cords. In Arxellia there are numerous beaded spiral cords and a suprasutural carina on the intermediate whorls, whereas in Archiminolia there are at most a few subsutural cords on these whorls.

Arxellia and Archiminolia form a well supported clade with Spectamen Iredale, 1924, Solariella Wood, 1842, Bathymophila Dall, 1881, Minolia A. Adams, 1860, Hazuregyra Shikama, 1962, Zetela Finlay, 1926 and an as yet undescribed genus (Clade B) in the molecular tree (Williams et al. 2013). Although relationships between genera within this larger clade are not well resolved, the first five genera comprise a poorly-supported clade in the MrBayes tree. The presence of well-developed latero-marginal plates in the radula of Arxellia is consistent with the radula morphology of other members of this latter clade, such plates having been reported in Bathymophila, Spectamen, Archiminolia and at least some species of Solariella (Herbert 1987; Wären 1993; Marshall 1999). In other solariellid genera outside this clade, namely Ilanga Herbert, 1967, Clade C (new genus, Vilvens & Williams 2014) and Minolia but also Zetela, this plate is either not present or only weakly developed, retaining a flimsy shaft and cusp. The presence of strong, elongate-rectangular latero-marginal plates may thus be an apomorphic character state shared by most genera comprising this broader clade.

Etymology. Stronghold, citadel (Latin: arx)—referring to the strong columella of some species of the new genus (feminine).
FIGURES 1–9. Arxella new species, all holotypes except *A. tenorioi*. 1, *A. trochos*, n. sp., type species of *Arxella* n. gen. 2, *A. boucheti* n. sp. 3, *A. herosae* n. sp. 4, *A. helicoides* n. sp. 5, *A. tenorioi* n. sp. 6, *A. tracheia* n. sp. 7, *A. maestratii* n. sp. 8, *A. thaumasta* n. sp. 9, *A. erythrea* n. sp. Scale bar = 5 mm.
FIGURE 10: Approximate locations of MNHN and WAM expeditions discussed in this paper: ⋆: PANGLAO 2005; ○: BIOPAPUA; □ MUSORSTOM 8, VOLSMA; ○: BORDAU 1; ◆: BORDAU 2; ⋆: BIOCAL, MUSORSTOM 6, VOLSMA, SMIB 8, BATHUS 1, BATHUS 2, LITHIST, NORFOLK 1, NORFOLK 2, EXBODI; ☼: CHALCAL 2, SMIB 8; ☉: MUSORSTOM 7; ♦: 'Southern Surveyor'.

Key to *Arxellia* species (based on conchological features).

1. Later whorls with at least 3 beaded or subgranular spiral cords .................................................. A. thaumasta
- Later whorls smooth .................................................................................................................. 2
2. Later whorls mostly covered with beaded or subgranular spiral cords ........................................ A. tenorioi
- Later whorls with only 3, widely spaced, beaded or subgranular spiral cords ............................... 3
3. Shell much higher than wide ......................................................................................................... A. helicoides
- Shell height and width more or less equal ................................................................................ 4
4. Shell height attaining 12 mm, periphery more or less rounded ..................................................... A. boucheti
- Shell height less than 9 mm ........................................................................................................ A. erythrea
5. Columella callus with two lobes extensively covering umbilicus .................................................. A. herosae
- No columella callus or expansion slightly covering umbilicus ...................................................... 6
6. Peripheral carina on P5 .................................................................................................................. 7
- Peripheral carina on P4 ................................................................................................................ 8
7. Intervals between spiral cords narrower than cords, carina relatively weak .............................. A. trochos
- Intervals between spiral cords wider than cords, carina stronger ............................................. A. maestrati
8. Intervals between spiral cords wider than cords ........................................................................ A. tracheia
- Intervals between spiral cords narrower than cords ................................................................... A. erythrea
FIGURE 11. Principal conchological features of Arxellia shells utilised in species descriptions: H: height; W: width; HA: height of the aperture (shell: Arxellia trochos n. sp., holotype MNHN IM-2009-23092, New Caledonia, Banc de l’Orne/Walope, EXBODI, stn DW3862, 5.9 x 5.3 mm).

Arxellia trochos n. sp.
(Figs 1, 12–24, Table 2)

Type material. Holotype (5.9 x 5.3 mm) MNHN IM-2009-23092. Paratypes: 3 MNHN IM-2009-23109, IM-2009-23094, IM-2009-23089, 1 NHMUK 20140006.

Type locality. New Caledonia, Banc de l’Orne/Walope, EXBODI, stn DW3862, 22°20’S, 169°01’E, 400–520 m.

Material examined. South-western New Caledonia. BIOCAL: stn DW08. 20°34’S, 166°54’E, 435 m. 16 dd. 8 dd sub. 8 dd juv.—Stn DW83. 20°35’S, 166°54’E. 460 m. 4 dd. 1 dd juv.—BATHUS 2: stn DW730, 23°03’S, 168°58’E, 397–400 m, 2 dd (one exceptionally large: 6 whorls, 8.4 x 7.0 mm).—EXBODI: stn CP3851, 22°19’S, 168°45’E, 471–510 m, 1 lv (paratype MNHN IM-2009-23109).—Stn DW3861, 22°19’S, 169°01’E, 425–490 m, 1 lv (paratype MNHN IM-2009-23094).—Stn DW3862, 22°20’S, 169°01’E, 400–520 m, 3 lv (holotype, paratypes MNHN IM-2009-23089 and NHMUK 20140006).

Loyalty Islands. MUSORSTOM 6: stn DW410, 20°38’S, 167°07’E, 490 m. 3 dd.—Stn DW413, 20°40’S, 167°03’E, 463 m. 1 dd.

Fiji. BORDAU 1: stn DW1486, 19°01’S, 178°26’W, 395–540 m, 34 dd, 16 dd juv.—Stn DW1492, 18°43’S, 178°23’W, 430–450 m, 4 dd, 1 dd juv.—Stn DW1496, 18°43’S, 178°23’W, 392–407 m, 4 dd.

Distribution. South-western New Caledonia, 400–471 m (living at 471–490 m); Loyalty Islands, 463–490 m (dead); Fiji, 407–430 m (dead).

Description. Shell: Size moderate for genus (height up to 6.8 mm, width up to 6.7 mm), conical, slightly higher than wide; height 1.0–1.1x width, 3.1–3.5x aperture height; periphery subangular. Protoconch paucispiral,
diameter approx. 300 µm, rounded, with 5 thin, unequally spaced spiral threads; terminal lip straight, without varix. Teleoconch of up to 5.5 whorls; first two whorls convex, subsequent whorls almost straight-sided; shoulder oblique with angulate rim, except on last whorl where shoulder horizontal; whorls with 8–10 spiral cords; cords thin and nearly smooth on first two whorls, thicker and beaded on subsequent whorls, beads of adapical cords much stronger, intervals between cords narrower than width of cords. Suture canaliculate on early whorls, not so on final whorl. First whorl sculptured by 6 thin, more or less equally spaced, spiral cords; cords arising immediately after protoconch; P1 at rim of shoulder; P6 sometimes partially covered by suture; faint, close-set axial threads between cords. On second whorl, P1 rapidly becoming stronger than other cords; P3 and P4 faint, difficult to distinguish; P2 and P5 of intermediate strength; axial threads evanescing by middle of whorl. Prosocline axial folds develop at start of third whorl, stronger on subsutural area and adapical part, rendering P1 and P2 subgranular; P1 and P5 the strongest cords, P5 stronger than P1, smooth, producing suprasutural (peripheral) carina; P6 totally covered by suture; secondary cord S3 arising at end of whorl, soon attaining size of P3 and P4. On fourth whorl, P1 and P2 strongly beaded, other cords subgranular; P6 partially visible on some samples, weakly subgranular. On fifth whorl, T1 arising at beginning of whorl, between suture and P1; shoulder more or less horizontal, suture not canaliculate; axial folds much weaker, but still visible. On final whorl, P6 arising at periphery; T2 arising above P5, rapidly resembling P4; T3 arising later between P1 and P2, beaded. Aperture subcircular; peristome incomplete; edge of outer and inner lips somewhat thickened; columella vertical, weakly concave, its edge slightly reflected at mid-point and overlapping umbilicus, a small flange at its base. Base weakly convex, almost flat, with 9–10 spiral cords; 3–4 outer cords smooth, relatively strong, their intervals similar to width of cords; cords of median area much weaker, their intervals approx. 1.5x width of cords; 2–3 inner cords much stronger and beaded; innermost cord at rim of umbilicus, twice as wide as penultimate cord and with strong, axially elongate beads. Umbilicus deep, comparatively wide (diameter ca. 17–21% of shell width), with angulate rim; internal wall almost straight, with 3–5 equally spaced, spiral cords of varying strength, crossed by axial grooves; intervals between cords approx. 0.5–1.0x width of cords.

**TABLE 2.** *Arxellia trochos* n. sp.: shell dimensions for type specimens.

<table>
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<th></th>
<th>TW</th>
<th>H</th>
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<th>HA</th>
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<td>1.9</td>
<td>1.07</td>
<td>3.21</td>
<td>1.17</td>
</tr>
</tbody>
</table>

Colour: Teleoconch whors nacreous, white to greyish-blue, varying between samples; early teleoconch whors white to deep grey, later whors and base white to greyish-blue; protoconch white.

Radula (Figs 23, 24): Rhipidoglossate; formula (5–6)+1+4+1+4+1+(5–6), with approx. 30 transverse rows of teeth; rows broadly M-shaped; rachidian cusp trigonal, with finely denticulate lateral margins and a somewhat larger central denticle; two inner lateral teeth similar to rachidian, but asymmetrical, their inner margin straight, the outer one curved; third lateral tooth more slender, fourth lateral tooth elongate and curved, with finer, more irregular denticles; interaction of base-plates complex; a well-developed, elongate-rectangular latero-marginal plate present; marginals 5–6, sickle-shaped, gradually tapering to a sharp point, lacking side denticles.

**Remarks.** *Arxellia trochos* cannot be confused with any known Solariellidae species belonging to other genera. Within *Arxellia*, it is closest to *A. maestratii* (Figs 7, 85–93) from Vanuatu and Wallis Island area, but the latter species is smaller, has stronger carina and the intervals between the spiral cords are wider (not narrower) than the width of the cords. The new species may also be compared to *A. tracheia* (Figs 70–74) from Papua New Guinea and *A. erythrea* (Fig. 94–103) from Tonga, but in these two species the peripheral carina is formed by P4 (not on P5).

The radula exhibits characteristic solariellid features (Herbert 1987; Hickman & McLean 1990), especially the reduced number of rows (approx. 30), highly differentiated lateral teeth (2 inner teeth similar to rachidian tooth, fourth tooth elongate and curved) and relatively few marginal teeth per row; the well-developed latero-marginal plate is similar to that found in *Archiminolia*, *Bathymophila*, *Spectamen* and some species referred to *Solariella*.
FIGURES 12–24. Arxellia trochos n. sp., New Caledonia. 12–14, holotype MNHN IM-2009-23092, Banc de l’Orne/Walope, 400–520 m [EXBODI, stn DW3862], 5.9 x 5.3 mm. 15–18, paratype MNHN IM-2009-23109, Banc Sur Durand, 471–510 m [EXBODI, stn CP3851]. 15–16, shell, 6.8 x 6.7 mm. 17, details of protoconch and early whorls; 18, details of columella, umbilicus and aperture. 19, paratype MNHN IM-2009-23094, Banc de l’Orne/Walope, 425–490 m [EXBODI, stn DW3861], 6.6 x 6.0 mm. 20–22, MNHN, 435 m [BIOCAL, stn DW08], 6.3 x 5.8 mm. 23–24, paratype MNHN IM-2009-23089, radula. 23, entire width of radula ribbon. 24, central field. Scale bar = 5 mm, except figs. 17, 23: 100 µm, fig. 18: 200 µm, fig. 24: 20 µm.
This species was not included in the molecular phylogeny of Williams et al. (2013), but unpublished molecular studies confirm that it belongs in Clade A with the other species here referred to *Arxella*.

**Etymology.** Trochos (Greek: τροχζ), a potter's wheel; used as a noun in apposition—with reference to the shape of the shell, the regular whorls of which are reminiscent of a piece of hand-made pottery.

*Arxella boucheti* n. sp.

(Figs 2, 25–41, Table 3)

Clade A, sp. 4—Williams et al., 2013.


**Type locality.** Southern New Caledonia, Norfolk Ridge, NORFOLK 2, stn DW2057, 24°40'S, 168°39'E, 555–565 m.

**Material examined.** Southern New Caledonia and Norfolk Ridge. CHALCAL 2: stn DW73, 23°40'S, 168°38'E, 573 m, 19 lv, 1 dd juv.—Stn DW74, 22°40'S, 168°3, 650 m, 17 lv, 1 dd sub.—Stn DW75, 24°39'S, 168°40'E, 600 m, 20 lv.—BATHUS 2: stn CP760, 22°19'S, 166°11'E, 455 m, 1 dd sub.—BATHUS 3: stn DW838, 23°01'S, 166°56'E, 400–402 m, 5 lv sub.—NORFOLK 1: stn DW1693, 24°55'S, 168°21'E, 564–1144 m, 7 lv, 3 sub lv, 3 juv lv.—Stn DW1694, 24°40'S, 168°39'E, 575–589 m, 25 lv, 40 sub lv.—Stn DW1695, 24°40'S, 168°39'E, 562–587 m, 25 lv, 10 sub lv.—Stn DW1697, 24°39'S, 168°38'E, 569–616 m, 15 lv, 15 sub lv, 17 juv lv.—Stn DW1699, 24°40'S, 168°40'E, 581–600 m, 2 lv, 6 sub lv.—Stn DW1700, 24°40'S, 168°40'E, 572–605 m, 3 lv, 3 sub lv.—Stn DW1701, 24°40'S, 168°39'E, 564–586 m, 7 lv, 6 sub lv.—Stn DW1704, 23°45'S, 168°16'E, 400–420 m, 1 lv.—Stn DW1707, 23°43'S, 168°16'E, 381–493 m, 5 lv.—NORFOLK 2: stn DW2056, 24°40'S, 168°39'E, 573–600 m, 3 dd, 2 sub lv, 5 juv lv.—Stn DW2057, 24°40'S, 168°39'E, 555–565 m, 8 lv (holotype and paratypes MNHN IM-2009-17851, IM-2009-17849, IM-2009-17852, IM-2009-31844, NHMUK 20140007, coll. C. Vilvens CV2014-18220).—Stn DW2058, 24°40'S, 168°40'E, 591–1032 m, 12 lv.—Stn DW2060, 24°40'S, 168°38'E, 582–600 m, 12 lv, 8 sub lv, 4 juv.—Stn DW2067, 25°16'S, 168°56'E, 614–690 m, 1 dd.—Stn DW2073, 25°24'S, 168°19'E, 609 m, 7 dd.—Stn DW2074, 25°24'S, 168°20'E, 623–691 m, 5 dd.—Stn DW2075, 25°23'S, 168°20'E, 650–1000 m, 5 dd.—Stn DW2077, 25°21'S, 168°19'E, 666–1000 m, 1 dd.—Stn DW2084, 24°52'S, 168°22'E, 586–730 m, 2 lv, 2 juv lv.

**Distribution.** Southern New Caledonia and Norfolk Ridge, 402–666 m, living at 402–650 m.

**Description.** Shell: Size relatively large for genus (height up to 11.8 mm, width up to 13.0 mm), slightly wider than high, conical; height 0.9x width, 2.6–3.2x aperture height; periphery weakly angular to almost rounded. Protoconch paucispiral, diameter approx. 330 µm, rounded, with 5 thin, equally spaced spiral threads; terminal lip straight, without varix. Teleoconch of up to 6.2 whorls; first two whorls convex, subsequent whorls almost straight; shoulder oblique with angulate rim, except on last whorl where shoulder horizontal; whorls with up to 20 spiral cords; cords thin and nearly smooth on first two whorls, thicker and beaded on subsequent whorls, beads of adapical cords stronger. Suture canaliculate on early whorls, not so on later whorls. First whorl sculptured by 6 thin, more or less equally spaced, cords; cords arising immediately after protoconch; P1 and P2 slightly stronger than other cords; P1 forming rim of shoulder; close-set axial threads between cords. On second whorl, axial threads hard to distinguish and evanescing at end of whorl; P6 at suture. Prosocline subsutural axial folds develop at start of third whorl, rendering P1 and P2 subgranular; P1 and P2 the strongest with secondary cord S2 arising and rapidly reaching strength of P3; P5 thickening after middle of whorl, smooth and forming a weak suprasutural carina. On fourth whorl all adapical cords beaded, abapical cords subgranular; S4 and S1 arising; P1 stronger than other cords; P5 almost as strong as P1, forming prominent carina above suture; shoulder more or less horizontal, suture not canaliculate; axial folds weaker, but still visible. On fifth whorl, P6 emerging from suture; tertiary cords arising by intercalation between P1 and S1 and/or between S4 and P5. On last whorl, numerous additional tertiary cords arising, resulting in a total of up to 20 cords; carina on P5 weaker than on penultimate whorl. Aperture subcircular; peristome incomplete; outer and inner lips thin; columella vertical, concave, the middle portion slightly reflected and overlapping umbilicus; a small flange at columella base. Base moderately convex, with 15–18 spiral cords; peri-umbilical region with approx. 30 axial pleats, rendering 5–8 most inner cords beaded; cord...
FIGURES 25–40. *Arxellia boucheti* n. sp., New Caledonia, Norfolk Ridge. 25–26, holotype MNHN IM-2009-17850, 555–565 m [NORFOLK 2, stn DW2057], 11.5 x 12.7 mm. 27–30, paratype MNHN IM-2009-17849, 555–565 m [NORFOLK 2, stn DW2057], 27–28, shell, 10.4 x 11.3 mm. 29, details of protoconch and early whorls. 30, details of columella, umbilicus and aperture. 31–33, paratype MNHN IM-2009-17851, 555–565 m [NORFOLK 2, stn DW2057], 11.8 x 13.0 mm. 34–35, paratype NHMUK 20140007, 555–565 m [NORFOLK 2, stn DW2057], 10.8 x 12.3 mm. 36–37, MNHN, 573 m [CHALCAL 2, stn DW73], 12.1 x 13.2 mm. 38–39, MNHN, juvenile specimen, 569–616 m [NORFOLK 1, stn DW1697], 4.2 x 5.2 mm. 40, operculum, MNHN, 575–589 m [NORFOLK 1, stn DW1694]. Scale bar = 5 mm, except fig. 29: 100 µm, fig. 30: 200 µm, fig. 40: 2 mm.
at umbilical rim 1.5–2.0x wider than penultimate cord and strongly beaded with coarse, pointed beads; outer basal cords thin, smooth, becoming weakly beaded in central part of base, intervals between cords 1.5–2.0x width of cords. Umbilicus deep, relatively narrow (diameter ca. 9–13% of shell width), with angulate rim; internal wall almost straight, with 6–8 strong, subgranular to beaded spiral cords; cord closest to rim coarsely beaded; intervals between cords approx. 0.5–1.0x width of cords.

**TABLE 3. Arxellia boucheti n. sp.:** shell dimensions for type specimens.

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<td>holotype MNHN IM-2009-17850</td>
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<td>11.5</td>
<td>12.7</td>
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<td>0.91</td>
<td>3.11</td>
<td>1.92</td>
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<td>13.0</td>
<td>3.7</td>
<td>0.91</td>
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<td>5.9</td>
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<td>11.3</td>
<td>3.5</td>
<td>0.92</td>
<td>2.97</td>
<td>1.76</td>
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<tr>
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<td>2.9</td>
<td>0.88</td>
<td>3.07</td>
<td>1.56</td>
</tr>
<tr>
<td>paratype MNHN IM-2007-18220</td>
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<td>11.2</td>
<td>3.7</td>
<td>0.92</td>
<td>2.78</td>
<td>1.78</td>
</tr>
<tr>
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<td>3.3</td>
<td>0.96</td>
<td>3.15</td>
<td>1.73</td>
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<tr>
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<td>4.1</td>
<td>0.88</td>
<td>2.63</td>
<td>1.86</td>
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<tr>
<td>paratype CV2014-18220</td>
<td>6.0</td>
<td>11.5</td>
<td>12.0</td>
<td>3.9</td>
<td>0.96</td>
<td>2.95</td>
<td>1.92</td>
</tr>
</tbody>
</table>

Colour: Teleoconch whorls nacreous, pinkish to orange; base white to grey; protoconch white.

External anatomy (based on observation of rehydrated bodies removed from dry shells) (Fig. 41): Typical of the family. Propodium with prominent lateral lobes; snout broad with lips modified into a fringe of digitiform processes; cephalic tentacles well-developed, papillate; eyes black, situated on short stalks fused to outer side of tentacle base; right eye-stalk with a small subocular tentaculiform process; left neck lobe present as two short, non-papillate tentacles, the right one as a trigonal outgrowth just behind eye-stalk; three papillate epipodial tentacles present on each side, of more or less equal size; between the anterior pair on both sides is a smaller tentacle-like projection, that on the right appearing to arise from the underside of an epipodial flap. Preservation of material inadequate to determine presence and position of any epipodial sense organs. Operculum corneous, straw-brown, shallowly concave, multispiral with central nucleus; growing margin short.
Remarks. The shell of *Arxellia boucheti* is distinctive on account of its large size, numerous spiral cords and rounded periphery. The external anatomy is almost identical to that illustrated by Warén (1993) for *Solariella obscura* and *S. varicosa*, and is also close to that of *Spectamen* (Herbert 1987). In the molecular analysis of Williams et al. (2013), this species forms a clade with *A. tracheia* and *A. helicoides*.

Etymology. Named after Philippe Bouchet (MNHN), whose dynamic leadership of Indo-Pacific expeditions and skilful management of malacological human resources have led to great advances in systematics and the discovery of many species new to science.

*Arxellia herosae* n. sp.
(Figs 3, 42–51, Table 4)

Clade A, sp. 7—Williams et al., 2013.

Type material. Holotype (7.0 x 7.2 mm) MNHN IM-2009-28739. Paratypes: 2 MNHN IM-2009-31843, IM-2009-28740, 1 NHMUK 20140008.

Type locality. Southern New Caledonia, Norfolk Ridge, Kaimon Maru Bank, NORFOLK 1, stn DW1679, 24°43’S, 168°10’E, 298–324 m.


Description. Shell: Size moderate for genus (height up to 7.0 mm, width up to 7.7 mm), conical, only very slightly wider than high; height 0.9–1.0x width, 2.7–3.1x aperture height; periphery subangular. Protoconch paucispiral, diameter approx. 350 µm, rounded, with microscopic, crisp granules, and 5 thin, equally spaced, spiral threads; terminal lip straight, without varix. Teleoconch of up to 5.2 whorls; first two whorls convex, subsequent whorls almost straight, but final whorl more convex; shoulder oblique, becoming horizontal on later whorls, with angulate rim on early whorls; whorls with up to 8 spiral cords; cords thin and almost smooth on first two whorls; on subsequent whorls, adapical cords beaded to subgranular, abapical cords smoother. Suture canaliculate on early whorls, not so on final whorl. First whorl sculptured from start by 6 thin, more or less equally spaced spiral cords; P1 develops rapidly at rim of shoulder; P6 close to abapical suture; faint, close-set axial threads between cords. On second whorl, P1 stronger than other cords, P6 at abapical suture and axial threads evanescing. Prosocline axial folds develop at start of third whorl, stronger below suture, rendering P1 subgranular; secondary cord S1 (holotype) or S4 (paratype MNHN IM-2009-28740) arising at start or at end of whorl, remaining weak and thin at end of whorl; P1 strongest; P5 strengthening but still weaker than P1, subgranular, forming supersutural carina. On fourth whorl, cords other than P1 and P5 of similar in strength, weakly subgranular; P6 emerging from suture, smooth to weakly subgranular, rapidly approaching strength of P5; shoulder more or less horizontal, suture not canaliculate. On fifth whorl, S1 when present (if not then P2) stronger than other intermediate cords, subgranular. On last whorl, S6 arises, smooth, together with P5 and P6 forming a tricarinate periphery; T2 arising above P5, rapidly resembling P4; T3 arising later between P1 and P2, beaded. Aperture subquadrate; peristome incomplete; edge of inner lip somewhat thickened; outer lip thinner, fusing almost at a right angle with thickened base of columella. Columella vertical, weakly concave adapically; basally with a small flange and with two callus lobes, one basal the other at mid-point, partially overlapping umbilicus. Base weakly convex, almost flat; outer part with 9–15 faint spiral cords, difficult to discern in some specimens, resulting in a smooth appearance; 4 strong, close-set, beaded cords surrounding umbilical rim, innermost cord twice as thick as penultimate cord, pleated by thick, axially elongate nodules. Umbilicus deep, narrow (diameter ca. 6–10% of shell width), rim angulate; inner wall weakly concave to almost straight, with 3 thick axial folds within.
FIGURES 42–51. *Arxellia herosae* n. sp., southern New Caledonia, Norfolk Ridge. 42–46, holotype MNHN IM-2009-28739, Banc Kaimon Maru, 298–324 m [NORFOLK 1, stn DW1679]. 42–44, shell, 7.0 x 7.2 mm. 45, details of protoconch and early whorls. 46, details of columella and aperture. 47–49, paratype NHMUK 20140008, Banc Eponge, 509–513 m [NORFOLK 1, stn DW1691], 5.2 x 5.9 mm. 50–51, MNHN, New Caledonia, 505–515 m [BIOCAL, stn DW66], 7.3 x 6.7 mm. Scale bars = 5 mm, except figs. 45, 46: 100 µm.
Colour: First two teleoconch whorls nacreous white; subsequent whorls nacreous pinkish-white; base nacreous white; protoconch white.

**Remarks.** *Arxellia herosae* is a distinctive species characterised by its bi-lobed columella callus, relatively depressed spire, tricarinate periphery and few beaded to subgranular spiral cords.

**Etymology.** Named after Virginie Héros (MNHN) whose enthusiasm, kindness and efficiency are highly appreciated by all malacologists collaborating with the MNHN.

### Arxellia tenorioi (Poppe, Tagaro & Dekker, 2006)
(Figs 5, 52–62)


**Material examined.** Philippines. PANGLAO 2005: stn CP2394, 9°29’N, 123°40’E, 470–566 m, 4 lv (MNHN 200718423, MNHN 200718424, MNHN 200718425, MNHN 200718429).—Stn CP2399, 9°32’N, 123°42’E, 309–342 m, 1 lv juv (MNHN 200718394).

**Distribution.** Philippines, 342–679 m, living at 242–470 m (including data from Poppe et al. 2006).

**Description (supplementary).** Shell: Size small for genus (height up to 6.1 mm, width up to 5.9 mm), height and width more or less equal; spire moderately elevated, conical, periphery markedly bicarinate. Protoconch paucispiral, diameter approx. 340 µm, rounded, smooth adapically but with crisp granules and 5 thin, equally spaced, spiral threads on abapical half; terminal lip straight, without varix. Teleoconch of up to 5.7 whorls; first two whorls convex, subsequent whorls straight to weakly concave; shoulder horizontal. Early whorls with 6 spiral cords with thin, close-set axial threads in intervals; from third whorl onward, P1 and P5 strong and nodular, P1 strongest; other cords and axial threads evanescing; P5 close to suture; last whorl with 2 subsutural (P1 and S1), 1 suprasutural (P5) cord and 1 cord emerging from suture (P6), P5 and P6 forming 2 carinas and making a bicarinate periphery; nodules of cords adapically oriented. Columella concave, with a small basal flange fused with a strong callus to form one lobe, partially overlapping umbilicus. Base virtually flat, smooth except for two subperipheral spiral cords and one coarsely beaded spiral cord at umbilical rim, sometimes dividing into two cords. Umbilicus wide (diameter ca. 25–28% of shell width) but funnel-shaped and thus narrowing internally; rim angulate and nodular.

Colour: Early teleoconch whorls white, subsequent whorls nacreous bluish-white, variable between specimens; base nacreous turquoise, umbilical area bluish-white; protoconch white. Non-live collected shell is likely completely white.

**Remarks.** *Arxellia tenorioi* clearly exhibits the conchological features distinctive of *Arxellia*. (e.g. conical profile, prominent P1 and P5, weakly reflected columella overlapping umbilicus, beaded spiral cord at rim of umbilicus). Our assignment of *Arxellia tenorioi* to this genus is confirmed by molecular data (Williams et al. 2013).

### Arxellia helicoides n. sp.
(Figs 4, 63–69, Table 5)

Clade A, sp. 1—Williams et al., 2013.
FIGURES 52–62. Arxellia tenorioi (Poppe, Tagaro & Dekker, 2006); Philippines, off Balicasag Island. 52–57, MNHN (200718429), 470–566 m [PANGLAO 2005, stn CP2394], 52–54, shell, 4.9 x 5.3 mm. 55–56, details of protoconch and early whorls. 57, details of columella and umbilicus. 58–59, MNHN (200718424), 470–566 m [PANGLAO 2005, stn CP2394], 5.1 x 5.3 mm. 60, MNHN (200718425), 470–566 m [PANGLAO 2005, stn CP2394], 6.1 x 5.9 mm. 61, subadult specimen MNHN (200718423), 470–566 m [PANGLAO 2005, stn CP2394], 4.3 whorls, 3.2 x 3.3 mm. 62, juvenile specimen MNHN (200718394), 309–342 m [PANGLAO 2005, stn CP2399], 1.5 x 1.8 mm. Scale bars = 1 mm, except figs. 55, 56: 100 µm, fig. 57: 1 mm.

Type material. Holotype (8.2 x 6.3 mm) MNHN IM-2009-15188. Paratypes: 1 MNHN IM-2009-15189, 1 NHMUK 20140009.
Type locality. Papua New Guinea, southern seamount of Manus Island, BIOPAPUA, stn DW3687, 3°04′S, 147°32′E, 305–579 m.

Material examined. Papua New Guinea. BIOPAPUA: stn DW3687, 3°04′S, 147°32′E, 305–579 m, 2 lv (holotype and paratype MNHN IM-2009-15189).—Stn DW3688, 3°04′S, 147°32′E, 402–640 m, 1 lv (paratype NHMUK 20140009).


Description. Shell: Size moderate to large for genus (height up to 9.1 mm, width up to 7.2 mm), conical, higher than wide; height 1.3x width, 3.9–4.6x aperture height; periphery angulate; umbilicus funnel-shaped. Protoconch paucispiral, diameter approx. 300 µm, rounded, smooth adapically, but with crisp granules and two thin, equally spaced, spiral threads on abapical half; terminal lip straight, without varix. Teleoconch of up to 6.8 whorls; first two whorls convex, subsequent whorls almost straight; shoulder horizontal on early whorls, disappearing on later whorls; whorls sculptured by 8–12 spiral cords on last whorl. Suture not canalicate but
clearly visible. First whorl with 5 thin spiral cords arising in middle of whorl, cords of equal size and spacing; P1 marking rim of horizontal shoulder at end of whorl, close-set axial threads clearly visible in intervals at end of whorl. On second whorl, P1 strongest; P3 weakening and almost vanishing at middle of whorl; axial threads fading at end of whorl; prosocline axial folds developing at beginning of whorl, stronger on subsutural area and adapical part, rendering P1 and P2 nodular. On third whorl, P1 and P5 strongest, coarsely beaded; P5 forming weak suprasutural carina; axial folds spanning entire whorl. On fourth whorl, nodes of P1 and P5 adapically oriented; carina on P5 more marked; all cords beaded; P6 emerging from suture, beaded, weaker than other cords; shoulder oblique. On fifth whorl, P2, P3 and P4 stronger; axial folds much weaker; S4 arising, equalling P4 in strength between end of fourth whorl (holotype) and sixth whorl (paratype 189), beaded. On sixth whorl, P5 carina less prominent; shoulder evanescing; S6 arising on fifth (paratype 189) or sixth (holotype) whorl, subgranular. On last whorl, all cords similar in size, except P1 stronger and P5 slightly stronger; carina on P5 possibly weaker (paratype 189); tertiary cords may appear between S4 and P5 (holotype) or under P5, under P6 or between P3 and P4 (paratype 189). Aperture roundly quadrate, weakly oblique; peristome incomplete; outer and inner lips thin at rim; angle at base of columella weak. Columella vertical, concave, with a small basal flange fused to callus forming one lobe at mid-point, slightly overlapping umbilicus. Base flat, smooth except for 2 outer and 1 inner spiral cords; outer cords thin and smooth, inner cord forming rim of umbilicus, strongly beaded; weak axial threads on intermediate area. Umbilicus wide (diameter ca. 21–26% of shell width), but funnel-shaped and thus narrower internally; rim angulate, sometimes with 2 beaded spiral cords just inside rim (holotype).

**TABLE 5.** *Arxellia helicoides* n. sp.: shell dimensions for type specimens.

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<td>2.3</td>
<td>1.30</td>
<td>3.91</td>
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<td>2.1</td>
<td>1.26</td>
<td>4.33</td>
<td>1.34</td>
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</table>

Colour: Early teleoconch whorls white, subsequent whorls brownish-grey; base nacreous green, umbilical area white; protoconch white.

**Remarks.** *Arxellia helicoides* superficially resembles *Lamellitrochus pourtalesi* (Clench & Aguayo, 1939) from the tropical western Atlantic, but although of similar size, that species has three strong nodular spiral cords on the last whorl, numerous spiral threads on the base, and a more rounded aperture. Among other *Arxellia* species, *A. helicoides* is distinctive on account of its particularly high spire (having the highest H/W ratio of ca. 1.30). In the molecular analysis of Williams *et al.* (2013) this species forms a clade with *A. tracheia* and *A. boucheti*.

**Etymology.** Helical, helicoid (Greek: ειξ: helix and εδο: figure)—with reference to the generation of the shell, following a mathematical conical helix.

*Arxellia tracheia* n. sp.

(Figs 6, 70–74)

Clade A, sp. 3—Williams *et al.*, 2013.

**Type material.** Holotype (6.7 x 6.4 mm) MNHN IM-2009-15183.

**Type locality.** Papua New Guinea, Vitiaz Strait, BIOPAPUA, stn CP3721, 6°03’S, 147°37’E, 542–554 m.

**Material examined.** Papua New Guinea, Vitiaz Strait. BIOPAPUA: stn CP3721, 6°03’S, 147°37’E, 542–554 m, 1 lv (holotype).

**Distribution.** Only known from the type locality.

**Description.** Shell: Size moderate for genus (height 6.7 mm, width 6.4 mm), conical, slightly higher than wide; height 1.05x width, 2.9x aperture height; periphery subangular. Protoconch paucispiral, diameter approximately 350 µm, rounded, with minute, crisp granules and 6 thin, more or less equally spaced spiral threads, adapical threads arising at half whorl; terminal lip straight, without varix. Teleoconch of up to 5.4 whorls; first two whorls moderately convex, subsequent whorls almost straight; shoulder horizontal on first three whorls, evanescing on later whorls; whorls sculptured with up to 9 spiral cords; cords thin and nearly smooth on first two
whorls, thicker and beaded on following whorls; beads of adapical cords much stronger. Suture shallowly canaliculate on early whorls, not so on final whorl. First whorl convex, sculptured by 5 thin, more or less equally spaced spiral cords arising immediately except P1 appearing a little later; P1 at rim of shoulder, P5 just above suture; faint, close-set axial threads in cord intervals. On second whorl, all cords similar in size; P5 partially covered by suture; axial threads evanescing in middle of whorl. Prosocline axial folds arise during third whorl, stronger on subsutural area and adapical part, rendering P1 beaded; P1 and P4 strongest, both beaded, P1 stronger than P4; P4 forming supersutural carina; P3 weakening; secondary cord S3 arising in middle of whorl, rapidly equalling P3 in strength. On fourth and fifth whorls, P1 and P4 strongest, P2, P3 and S3 weakest, P5 of intermediate strength. On last whorl, T1 arising at start of whorl, between P1 and P2; T2 arising at same time, between S3 and P4, both subgranular; S5 arising at periphery. Aperture roundly quadrate, weakly oblique; peristome incomplete; outer and inner lips moderately thick at rim; angulation at base of columella weak. Columella vertical, shallowly concave, with small basal flange fused to strong callus and forming one lobe at midpoint, partially overlapping umbilicus. Base almost flat, with 4 thin, smooth outer cords, intervals between cords twice width of cords; median area smooth; a single strong cord with coarse, axially elongated beads marking angulate rim of umbilicus. Umbilicus superficially wide (diameter ca. 23% of shell width), but funnel-shaped and thus narrowing internally, its wall sculptured with thin axial threads.

Colour: Early teleoconch whorls greyish-blue, later whorls pinkish; base nacreous white; suture white; protoconch brownish-pink.

Remarks. Arxellia tracheia most closely resembles A. trochos (Figs 1, 12–24) from southern New Caledonia, but though of similar size, that species has a more rounded periphery and differs in numerous sculptural features, namely: P5 (not P4) forms the supersutural carina, all the teleoconch spiral cords are more or less similar in size, the shoulder is still present on the last whorl, there are 2–3 (rather than one) strong, beaded cords around the umbilicus. In the molecular analysis of Williams et al. (2013), A. tracheia forms a clade with A. boucheti and A. helicoides.

Etymology. Uneven, rough (Greek: ταχζεια, εια, οι, adjective)—with reference to the different size of the spiral cords on the shell whorls.

FIGURES 70–74. Arxellia tracheia n. sp., holotype MNHN IM-2009-15183, Papua New Guinea. 70–72, shell, 6.7 x 6.4 mm. 73, details of protoconch and early whorls. 74, details of columella, umbilicus and aperture. Scale bar = 5 mm, except fig. 73: 100 µm, fig. 74: 1 mm.
**Arxellia thaumasta n. sp.**
(Figs 8, 75–82, Table 6)

Clade A, sp. 6—Williams *et al.*, 2013.

**Type material.** Holotype (7.2 x 6.2 mm) WAM S25773. Paratypes: 1 WAM S32251, 1 NHMUK 20140010.

**Type locality.** Western Australia, Perth Canyon, CSIRO RV ‘Southern Surveyor’, stn SS1005/012, 31.92–31.92°S, 115.01–115.02°E, 479–484 m.

**Material examined. Western Australia.** CSIRO RV ‘Southern Surveyor’: stn SS1005/012, 31.92°S, 115.02°E, 479–484 m, 1 lv (holotype WAM S25773).—Stn SS1005/095, 28.49°S–28.50°S, 113.42°E–113.43°E, 416–431 m, 2 dd (paratypes WAM S32251 and NHMUK 20140010).

**Distribution.** Western Australia, 431–479 m, living at 479–484 m.

**Description.** Shell: Size moderate for genus (height 7.2 mm, width 6.3 mm), conical, slightly higher than wide; height 1.2x width, 3.9x aperture height; periphery subangular. Protoconch paucispiral, diameter approx. 320–330 µm, rounded, with minute, crisp granules on first quarter and 5 thin spiral threads; terminal lip straight, without varix. Teleoconch of up to 5.5 convex whorls; shoulder oblique with angulate rim on 3 first whorls, weaker and horizontal on later whorls; early whorls with up to 7 smooth to subgranular spiral cords, last whorl smooth. Suture canaliculate on first two whorls, not so on subsequent whorls. First whorl sculptured by 5 spiral cords present from start, the most abapical one close to suture; P1 forming rim of shoulder; microscopic axial threads between cords; intervals between threads approximately 1.5–2.0x width of threads. On second whorl, P1 slightly stronger than other cords; secondary cord S2 arising between middle (holotype) and end (paratype) of whorl; P5 level with suture. On third whorl, P1 and P4 strongest of which P1 clearly stronger than P4; P4 forming suprasutural carina; secondary S1 and/or S3 possibly arising between start and middle of whorl; all cords except P1 and P4 evanescing and hard to distinguish at end of whorl; prosocline axial folds developing at beginning of whorl, stronger on subsutural area and adapical part, rendering P1 beaded and P4 subgranular; axial threads fading. On fourth whorl, all cords evanescing, P1 the last visible. Last whorl smooth. Aperture subelliptic to almost rounded, sometimes fractionally oblique; peristome incomplete; outer and inner lips moderately thick at rim; inner lip slightly projecting into umbilicus. Columella concave, its edge slightly reflected and overlapping umbilicus; a small flange at its base. Base moderately convex, essentially smooth, but with faint, thin axial threads, stronger nearer to umbilicus and producing beads on a strong spiral cord at rim of umbilicus. Umbilicus deep, relatively wide (diameter ca. 18% of shell width), its rim angulate; internal wall weakly convex, lacking spiral cords, but with numerous, very thin axial threads.

**TABLE 6. Arxellia thaumasta n. sp.: shell dimensions for type specimens.**

<table>
<thead>
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<th>W</th>
<th>HA</th>
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<td>1.10</td>
<td>3.83</td>
<td>1.25</td>
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<tr>
<td>paratype NHMUK 20140010</td>
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<td>6.3</td>
<td>5.7</td>
<td>1.6</td>
<td>1.11</td>
<td>3.94</td>
<td>1.17</td>
</tr>
</tbody>
</table>

Colour: Early teleoconch whorls nacreous grey to whitish-grey; subsequent whorls greyish-blue to greyish-white; protoconch white.

**Remarks.** Molecular data clearly show that this species belongs to *Arxellia* (Williams *et al.*, 2013), but given the morphology of the shell this seems surprising, particularly in view of the reduced sculpture and almost smooth last adult whorl. However, the ontogeny of the spiral cords, with a strong abapical peripheral cord (P4) and a strong subsutural spiral cord (P1) are in fact features consistent with those of *Arxellia*.

In the abovementioned molecular phylogeny, *A. thaumasta* was shown to be genetically very similar to a species known only from a single specimen from the Philippines. We have kept the two as separate species given that they differ morphologically and come from widely disjunct localities. The other species (Clade A, sp. 5 in Williams *et al.* 2013) has the beaded spiral cords typical of other *Arxellia* species. This species is not described here, as it is known only from a single specimen, which has been misplaced. In molecular analyses *A. thaumasta* and Clade A sp. 5 form the sister group to all other *Arxellia* species (Williams *et al.* 2013).
Another specimen (WAM S25779, Figs 83–84), from off Point Hillier, Western Australia (CSIRO RV 'Southern Surveyor', stn SS1005/020, 35.3818°S, 117.2030°E to 35.3822°S, 117.1920°E, 419–460 m), is conchologically close to *A. thaumasta*, but differs most notably in that P1 remains present on the last whorl as a beaded subsutural cord. In addition, S2 arises much earlier (middle of first whorl), and the protoconch is slightly larger (diameter 380 µm). We have no molecular data for this specimen. Thus, it is impossible, based on a single specimen, to assert whether this is an aberrant form of *A. thaumasta* or a distinct species and therefore we refer to it...
here as *A. cf. thaumasta*.

**Etymology.** Surprising, unexpected, extraordinary (Greek: θυμστζ, ον, adjective)—with reference to the smooth whorls of this unusual *Arxellia* species.

**Arxellia maestratii** n. sp.  
(Figs 7, 85–93, Table 7)

**Type material.** Holotype (4.8 x 4.8 mm) MNHN (IM-2000-27389). Paratypes: 4 MNHN (IM-2000-27390), 2 NHMUK 20140011, 1 coll. C. Vilvens (CV2009-DW972).

**Type locality.** Vanuatu, MUSORSTOM 8, stn DW972, 19°22'S, 169°28'E, 487–507 m.

**Material examined.** Vanuatu. VOLSMAR: stn DW51, 20°59'S, 170°03'E, 450 m, 3 dd, 1 dd juv.—MUSORSTOM 8: stn DW972, 19°22'S, 169°28'E, 487–507 m, 30 dd, 5 dd juv (with holotype, paratypes IM-2000-27390, paratypes NHMUK and paratype C.Vilvens).—Stn DW777, 19°25'S, 169°29'E, 410–505 m, 2 dd.—Stn CP963, 20°20'S, 169°49'E, 400–440 m, 1 dd, Western Pacific, Wallis Island. MUSORSTOM 7: stn DW604, 13°21'S, 176°08'W, 415–420 m, 17 dd, 20 dd sub, 6 dd juv.

**Distribution.** Vanuatu, 440–487 m (dead); Wallis Island, 415–420 m (dead).

**Description.** Shell: Size small for genus (height up to 5.7 mm, width up to 5.2 mm), conical, slightly higher than wide; height 1.0–1.1x width, 3.2–3.9x aperture height; periphery subangular, tricarinate. Protoconch paucispiral, diameter approx. 320 µm, rounded, with 5 thin, unequally spaced spiral threads; terminal lip straight, without varix. Teleoconch of up to 5.5 whorls; first two whorls convex, subsequent whorls straight; shoulder oblique with angulate rim on first two whorls, horizontal thereafter; whorls with up to 8 spiral cords; cords smooth and thin on early whorls, subsequently adapical cords becoming beaded and abapical cords subgranular. Suture moderately canaliculate on early whorls, not so on final whorl. First whorl sculptured from start by 5 thin, more or less equally spaced, spiral cords; P1 forming rim of shoulder at end of whorl; P5 very close to suture; no axial threads visible. On second whorl, all cords remaining similar in strength. On third whorl, proscloine axial folds develop at start of whorl, stronger on subsutural area and adapical part, rendering P1 and P2 subgranular; secondary cord S1 arising and rapidly equalling P2 and P3 in strength; P1 strongest; P4 strengthening but remaining weaker than P1, subgranular, forming supersutural carina. On fourth whorl, P1 and P4 strongest, P2 and P3 weakest, P5 covered by suture; S3 may arise on some specimens; shoulder more or less horizontal, suture not canaliculate. On fifth whorl, S1 only slightly weaker than P1, clearly beaded. On last whorl, S5 arising and P5 emerging from suture, almost smooth, in combination with P4 forming a tricarinate periphery; adapical cords more strongly beaded than abapical one; sometimes with additional tertiary cords on large specimens (e.g. specimens from Wallis Is.). Aperture subcircular; peristome incomplete; inner and outer lips thin at rim; angulation at base of columella obtuse. Columella concave, with small basal flange, weakly reflected. Base almost flat, with one subperipheral cord (sometimes two in large specimens) and two strong, close-set, beaded cords bordering umbilicus, innermost of which is strongest; both peri-umbilical cords with coarse nODULES; intermediate portion of base nearly smooth. Umbilicus deep, narrow (diameter *ca. 6–10%* of shell width), funnel-shaped, with angulate rim; interior wall with 4–6 thick spiral cords.

**Table 7. Arxellia maestratii** n. sp.: shell dimensions for type specimens.

<table>
<thead>
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<th>TW</th>
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<td>4.9</td>
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</table>
FIGURES 85–93. *Arxellia maestratii* n. sp., southern New Caledonia, Norfolk Ridge. 85–89, holotype MNHN IM-2000-27389, Vanuatu, 487–507 m [MUSORSTOM 8, stn DW972], 4.8 x 4.8 mm. 85–87, shell. 7.0 x 7.2 mm. 88, details of protoconch and early whorls. 89, details of columella and umbilicus. 90–91, MNHN, Vanuatu, 410–505 m [MUSORSTOM 8, stn DW977], 5.6 x 5.2 mm. 92–93, MNHN, Wallis Island, 415–420 m [MUSORSTOM 7, stn DW604], 4.8 x 4.8 mm. Scale bars = 5 mm, except fig. 88: 100 µm, fig. 89: 500 µm.

Colour: Early teleoconch whorls and base nacreous white; subsequent whorls nacreous pinkish-white (Vanuatu specimens) to completely white (Wallis Is. specimens); protoconch white.

Remarks. *Arxellia maestratii* resembles *A. trochos* from southern New Caledonia (Figs 1, 12–24) but the former species has fewer, thinner and more widely spaced spiral cords, a greater H/HA ratio, a smooth median area on the base, a narrower umbilicus and peri-umbilical granules that are not elongated. *Arxellia maestratii* also
resembles *A. herosae*, likewise from southern New Caledonia (Figs 5, 42–51), but the present species is smaller and slightly more elevated, and has P4 (instead of P5) forming the characteristic suprasutural carina of *Arxellia*. Furthermore, it has a flatter base with an umbilicus that is not appreciably occluded by any callus deposit. Since only dry material was available, there are no molecular data for this species.

**Etymology.** Named after Philippe Maestrati (MNHN) whose availability, helpfulness and efficiency are highly appreciated by all malacologists collaborating with the MNHN.

**Arxellia erythrea** n. sp.  
(Figs 9, 94–103, Table 8)

**Type material.** Holotype (5.5 x 5.4 mm) MNHN IM-2000-27391. Paratypes: 4 MNHN IM-2000-27392, IM-2000-27393, 2 NHMUK 20140012, 1 coll. C. Vilvens (CV2014-DW1586).

**Type locality.** Tonga, Vava'u group, BORDAU 2, stn DW1586, 18°34'S, 173°55'W, 440–487 m.

**Material examined.** Tonga. BORDAU 2: stn DW1518, 21°21'S, 175°07'W, 336–347 m, 1 dd.—Stn DW1544, 21°18'S, 175°18'W, 441–443 m, 8 lv, 4 dd sub (with 1 paratype MNHN IM-2000-27393 and 2 paratypes NHMUK 20140012).—Stn DW1585, 18°33'S, 173°57'W, 578 m, 1 dd sub (paratype CV2014-DW1586).—Stn DW1586, 18°34’S, 173°55'W, 440–487 m, 13 lv (with holotype and 3 paratypes MNHN IM-2000-27392). Wallis and Futuna Islands area. Wallis Island, MUSORSTOM 7: stn DW523, 13°12'S, 176°16'W, 455–515 m, 1 dd.—Stn DW608, 13°22'S, 176°08'W, 440–458 m, 2 dd sub.—Waterwitch Bank, MUSORSTOM 7: stn DW535, 12°30'S, 176°41'W, 340–470 m, 1 dd sub.—Stn DW537, 12°30'S, 176°41'W, 325–400 m, 1 lv.

**Distribution.** Tonga, 347–578 m (living at 441–443 m); Wallis and Futuna Islands area, 400–455 m (living at 325–400 m).

**Description.** Shell: Size small for genus (height up to 5.7 mm, width up to 5.4 mm), conical, slightly higher than wide; height 1.0–1.2x width, 3.6–3.9x aperture height; periphery subangular. Protoconch paucispiral, diameter approx. 300–310 µm, rounded, with 5 thin, equally spaced spiral threads; terminal lip straight, without varix. Teleoconch of up to 5.2 whorls; first two whorls moderately convex, subsequent whorls almost straight; shoulder oblique, with angulate rim on early whorls, horizontal on later whorls; whorls sculptured by up to 12 spiral cords, with peripheral cord forming a carina; adapical cords beaded, other cords subgranular to nearly smooth. Suture canaliculate on early whorls, not so on final whorl. First whorl sculptured from start by 5 thin, more or less equally spaced, spiral cords; P1 rapidly forming rim of shoulder; P5 soon level with suture; faint, close-set axial threads evanescing. On second whorl, P1 stronger than other cords; S1 arising in middle of whorl and axial threads evanescing. On third whorl, prosocline axial folds develop, stronger on subsutural area and adapical part, rendering P1 subgranular; P1 and P5 strongest, P5 smooth, forming weak suprasutural carina; P3 and P4 very weak; P6 emerging from suture. On fourth whorl, P1 and P2 coarsely beaded, other cords nearly smooth; P5 forming strong carina; P3 and P4 stronger; S3, S4 and S5 arise near end of whorl or at beginning of next whorl. On fifth whorl, additional tertiary cords may arise, especially one cord between suture and P1, rapidly becoming beaded; shoulder more or less horizontal, suture not canaliculate; axial folds much weaker, but still visible. On last whorl, S6 arising at periphery, number of spiral cords reaching 12. Aperture subcircular; peristome incomplete; outer and inner lips slightly thickened at rim; columella vertical, shallowly concave, its edge weakly reflected; a small flange sometimes present at columella base. Base almost flat, with 3–4 thin, smooth spiral cords below periphery, a nearly smooth median area and 2–3 strong, beaded, peri-umbilical cords; innermost cord forming rim of umbilicus, at least twice as thick as penultimate cord, with coarse, weakly pointed beads. Umbilicus deep, wide (diameter ca. 22–32% of shell width), funnel shaped, with angulate rim, interior wall almost straight, bearing 6–7 equally spaced, strong, smooth spiral cords; intervals between spiral cords 0.5–1.0x width of cords.

Colour: First three teleoconch whorls white; subsequent whorls reddish or pinkish with a whitish subsutural area; base nacreous pinkish-white to white; protoconch white.

**Remarks.** *Arxellia erythrea* resembles the type species *Arxellia trochos* from southern New Caledonia (Figs 1, 12–24) but the present species is a little smaller and more depressed, has thinner and more numerous spiral cords on the whorls, of which P5 forms a more prominent suprasutural cord. In addition, it has a greater H/HA ratio and the colour is predominantly reddish (instead of white to greyish-blue). Since only dry material was available, there are no molecular data for this species.
FIGURES 94–103. Arxellia erythrea n. sp. 94–95, holotype MNHN IM-2000-27391, Tonga, Vava'u group, 440–487 m [BORDAU 2, stn DW1586], 5.5 x 5.4 mm. 96–100, paratype MNHN IM-2000-27392, Tonga, Vava'u group, 578 m [BORDAU 2, stn DW1585], subadult. 96–98, shell, 4.1 x 4.1. 99, details of protoconch and early whorls. 100, details of columella and umbilicus. 101–103, MNHN, Waterwitch Bank, 325–400 m [MUSORSTOM 7, stn DW537], 5.2 x 5.1 mm. Scale bars = 5 mm, except figs. 99, 100: 100 µm.

**Etymology.** Red (Greek: ερυθρός, α, ov adjective)—referring to the red background colour of the adult shell whorls.
TABLE 8. Arxellia erythrea n. sp.: shell dimensions for type specimens.

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<td>1.00</td>
<td>3.82</td>
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Acknowledgements

We thank P. Bouchet (MNHN) for reading the manuscript, constructive advice and access to the malacological resources of the MNHN and Carole Hickman and Bruce Marshall for valuable comments that resulted in an improved manuscript. We are also grateful to V. Héros, B. Buge, P. Maestrati and N. Puillandre (MNHN) for sorting samples and providing locality data, and B. Buge, V. Héros and A. Salvador (NHMUK) for providing registration numbers. Special thanks go to A. Warén (SMNH) for his careful analysis and sorting of the huge MNHN collection of solariellid material and to H. Taylor (NHMUK photo unit) for taking photos of holotypes. We also gratefully acknowledge S. Slack-Smith, C. Whisson and J. Fromont (WAM) for the loan of type material from their institution.

References

http://dx.doi.org/10.1111/j.1463-6409.2012.00552.x
http://dx.doi.org/10.1002/ece3.513