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Research article

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Revision of deep-water species in *Granulina* (Gastropoda: Granulinidae) from Mauritania and Western Sahara

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Abstract. Empty shells (thanatocoenoses) have been reviewed of species in the genus *Granulina* (Gastropoda: Granulinidae) from the lower shelf and upper bathyal zones off Mauritania and Western Sahara. We encountered nine species of which four were already known from off Mauritania. Four new species are proposed herein: *Granulina reginae* sp. nov., *G. ronaldi* sp. nov., *G. sandrae* sp. nov. and *G. sigridae* sp. nov. These four sympatric new species lack labial denticles and they probably form a phyletic clade with a common ancestor. Most hitherto known species in *Granulina* from the NE Atlantic Ocean and the Mediterranean possess labial denticles. One additional new species with denticles was left in open nomenclature because the material available was considered inadequate. Species in *Granulina* from Mauritania and Western Sahara have not been found off NW Morocco or the Canary Islands, and the species known from NW Morocco and the Canary Islands have not been found off Mauritania and Western Sahara. The southern extents of the distributions of the Mauritanian species are currently uncertain as additional sampling would be required off Senegal or further South. A key to Mauritanian species in *Granulina* is given.

Keywords. Mollusca, NW Africa, Atlantic Ocean, taxonomy, new species.

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Introduction

Staff at the Senckenberg am Meer Institute (Wilhelmshaven, Germany) studied the marine mollusk fauna from the upper slope and shelf of Mauritania and Western Sahara. In this paper, the gastropod genus *Granulina* Jousseaume, 1888 (family Granulinidae G.A. Coovert & H.K. Coovert, 1995) was studied in more detail. Species in the genus *Granulina* are relatively common in temperate waters around the world. Approximately 130 species are currently known in this taxon (MolluscaBase 2023). To date, there are five species known from Mauritania.

The granulinids from NW Africa have been described by various authors. Orbigny (1840) introduced *Granulina guancha* from Tenerife (Canary Islands). Locard (1897) described many new species from off NW Africa, including *Granulina minusculina* from off NW Morocco. Gofas (1992) reviewed the genus *Granulina* from NW Africa and the Mediterranean, and he described several new species, including *G. africana* from off Goree Island (Senegal) and *G. mauretana* from Baie de l'Etoile, north of Nouadhibou, Mauritania. He also provided colour drawings of living animals of seven species, including *G. mauretana*. Pin & Boyer (1995) described *Granulina pierrepineau* from shallow water in Senegal. Boyer & Rolán (1999) introduced *Granulina fernandesi* from Boa Vista (Cape Verde Islands); this species showed a remarkable granular sculpture and it lacks labial denticles. Smriglio *et al.* (2000) described *Granulina crassa*, *G. cerea*, *G. nofronii* and *G. crystallina* from the shelf off northern Mauritania and Western Sahara. Boyer (2001) described *Granulina canariensis* from off Fuertaventura, Canary Islands. Finally, Boyer (2017) introduced the genus *Granulinopsis* Boyer, 2017 for small highly cylindrical granulinids that were originally placed in *Granulina*. Three species were included in *Granuliopsis*: *G. cylindrata* (Rolán & Boyer, 2004) from Senegal and Cape Verde, *G. zanclea* (Bogi, Boyer, Renda & Giacobbe, 2016) from the southern Tyrrhenian Sea and *G. atlantidea* (Boyer, 2016) from El Hierro, Canary Islands. Only *G. cylindrata* shows labial teeth within *Granuliopsis*, *G. zanclea* and *G. atlantidea* lack labial teeth.

Fossil species in *Granulina* are not well known from NW Africa. La Perna *et al.* (2001) reported on nine Pliocene granulinids from an outcrop near Estepona (western Mediterranean Sea, southern Spain); six species were extinct and three still occur today in the Mediterranean.

We were also able to find new species among our samples and herein expand the knowledge of the genus *Granulina* off Mauritania and Western Sahara. The shells of the new species have no labial denticles but do possess a thickened lip. Labial denticles and a thickened lip are characteristic features in most known adult species of *Granulina* in the NE Atlantic and the Mediterranean Sea. Because of their different morphology, we consider them as adults of several new species. The absence of labial denticles was included as an identification character.

Material and methods

This study focuses on the upper continental slope from Mauritania and Western Sahara. The material was collected using box cores or van Veen grabs during different expeditions. The German R/V *Meteor* cruises M36 (1975), M44 (1977), M53 (1980), and M60 (1982) sampled the lower shelf to the upper bathyal zone from NW Morocco to southern Mauritania. The Dutch CANCAP III (1978; van der Land 1987) and Tyro Mauritania I (1988) expeditions sampled the shelf off northern Mauritania. The German R/V *Poseidon* 346 cruise (2007; Westphal 2007) concentrated on the coral mounds off central and southern Mauritania (Banda and Timiris mound complexes). The German R/V *Maria S. Merian* cruise MSM 16/3 (2010; Westphal *et al.* 2014) sampled the shelf of the Banc d'Arguin and the deep-water coral mound chains off Mauritania.

The sediment samples were sieved on board and all size fractions greater than 0.5 mm were retained. They were subsequently washed with fresh water and dried. Live-collected samples were not available for this study. Therefore, we looked at shells from thanatocoenoses; live-collected yet dried specimens were only encountered occasionally in other genera. Examination of soft parts or genetic analyses could not be done. Judging from dating established on hard coral samples from the sea bottom, we assume that all shells are Recent (Late Holocene) to 90 kaBP (Late Pleistocene) age (Wienberg *et al.* 2018). All translucent shells are considered as Recent.

The material was sorted under a stereo microscope and the determinations were made using literature (particularly Gofas 1992; Smriglio *et al.* 2000). Selected (often translucent) shells were

imaged using a Vega3-Tescan Scanning Electron Microscope (SEM). The shells were gold-coated to enhance the imaging of the micro-sculpture. Imaging was made using both secondary and back-scatter electrons; incident electron energy was 20 keV. Shell measurements were made by using calibrated software in the SEM. All holotype specimens are stored in the Senckenberg Museum Frankfurt (SMF: Frankfurt am Main, Germany). Paratypes are stored in either SMF (Frankfurt am Main) or Naturalis Biodiversity Center (RMNH, formerly Rijksmuseum voor Natuurlijke Historie, Leiden, the Netherlands). All other material is kept in SMF, RMNH or in Senckenberg am Meer (SaM, Wilhelmshaven, Germany).

The descriptions of new species are based on the photos of the type material illustrated herein. All illustrations of full shells have been made using the same magnification. Sampled locations are stated by their coordinates in decimal format and depth in metres.

Abbreviations

Institutes

- RMNH = Naturalis Biodiversity Center, formerly Rijksmuseum voor Natuurlijke Historie (Leiden, the Netherlands)
SaM = Senckenberg am Meer (Wilhelmshaven, Germany)
SMF = Senckenberg Museum Frankfurt (Frankfurt am Main, Germany)

General

- GeoB = Sampling location reference system of Marum, University of Bremen
kaBP = 1000 years before present time
SEM = Scanning Electron Microscope

Results

Class Gastropoda Cuvier, 1795
Subclass Caenogastropoda Cox, 1960
Order Neogastropoda Wenz, 1938
Superfamily Volutoidae Rafinesque, 1815
Family Granulinidae G.A. Covert & H.K. Covert, 1995

Genus *Granulina* Jousseaume, 1888

Type species

Granulina isseli Nevill, 1875 (type by monotypy), from the Red Sea. The species is also known in the eastern Indian Ocean.

Granulina cerea Smriglio, Gubbioli & Mariottini, 2000
Figs 1, 2A–D

Granulina cerea Smriglio, Gubbioli & Mariottini, 2000: 54–55, figs 1, 5–8; type locality: off Mauritania.

The holotype was deposited in the Bologna Zoology Museum (MZB14033). Smriglio *et al.* (2000) reported four shells from off Mauritania without further location details. Three paratypes were retained in private collections.

Material examined (388 shells)

MAURITANIA – **off Banc d'Arguin** • 5 shells; 18.9833° N, 16.8333° W; depth 203 m; 30 Oct. 1978; CANCAP stn 3.140; sandy clay with shells by van Veen grab; RMNH.MOL.351801 • 9 shells; 19.35° N, 16.9333° W; depth 200 m; 31 Oct. 1978; CANCAP III stn 3.154; sandy clay with shells; van Veen grab; RMNH.MOL.351802 • 89 shells; 19.94° N, 17.48° W; depth 85–151 m; 22 May 1988; Tyro Mauritania I stn B5; dredge; SaM • 4 shells; Arguin mud wedge; 20.2353° N, 17.6029° W; depth 111 m; 24 Oct. 2010; MSM16-3 stn GeoB14703; box core in muddy silt; SaM • 1 shell; Baie du Levrier ; 20.8801° N, 16.9922° W; depth 14 m; 31 Oct. 2010; MSM16-3 stn GeoB14782; box core in muddy silt; SaM • 4 shells; Arguin South 3 Canyon; 19.7381° N, 17.1465° W; depth 483 m; 7 Nov. 2010; MSM16-3 stn GeoB14858; bottom grab; SaM. – **Timiris Mud wedge** • 1 shell; 19.5117° N, 16.8618° W; depth 52 m; 8 Nov. 2010; MSM16-3 stn GeoB14865; box core in muddy silt; SaM • 2 shells; 19.5506° N, 16.9731° W; depth 100 m; 8 Nov. 2010; MSM16-3 stn GeoB14866; box core in silty sand; SaM. – **off Nouakchott**; SMF • 61 shells; 17.045° N, 16.7783° W; depth 202 m; 11 Feb. 1977; M44 stn 133-KG613; box core; SMF • 43 shells; 17.045° N, 16.7783° W; depth 208 m; 11 Feb. 1977; M44 stn 133-KG615; box core; SMF • 108 shells; 17.045° N, 16.7783° W; depth 199 m; 11 Feb. 1977; M44 stn 133-KG616; box core; SMF • 46 shells; 17.0967° N, 16.73° W; depth 127 m; 11 Feb. 1977; M44 stn 193-KG626; box core; SMF • 3 shells; 17.0967° N, 16.73° W; depth 126 m; 11 Feb. 1977; M44 stn 193-KG627; box core; SMF • 2 shells; 17.0967° N, 16.73° W; depth 124 m; 17 Feb. 1977; M44 stn 193-KG629; box core; SMF.

WESTERN SAHARA – **North of Dakhla** • 2 shells; 25.1833° N, 15.8033° W; depth 87 m; M36 stn 95-KG6; 22 Feb. 1975; box core; SMF.

Remarks

Smriglio *et al.* (2000) indicated a shell height of 2.3 mm; the shells in our material show a height range for adult shells of 2.3–2.8 mm. The species is a member of the four coffin-shaped species from Mauritania. It has weak labial denticles, an angular outline and it lacks an (ab-)apical rostration.

All species reported by Smriglio *et al.* (2000) as well as all other NE Atlantic and Mediterranean species investigated in this study show a micro-sculpture (ab-)apically, near the columellar folds, the parietal area and the outer lip. Smriglio *et al.* (2000) stated that his specimens did not show any micro-sculpture, even at high magnification using a SEM. We note that the outline of a micro-sculpture is visible in some of their SEM images and colour photographs.

The species is known from empty shells in the latitudinal range between 17.0° N and 25.2° N. The full bathymetric range is 14–483 m; it is commonly found on the lower shelf at depths of 80–210 m in silty sand.

Gofas (1992: fig. 14) shows a small (height 2.15 mm) specimen from a depth of 50 m off Gorée Island (Senegal) under the name *Granulina* sp. which could belong to *G. cerea*. If confirmed, then this would extend the southern distribution range significantly.

***Granulina crassa* Smriglio, Gubbioli & Mariottini, 2000**

Figs 1, 3

Granulina crassa Smriglio, Gubbioli & Mariottini, 2000: 55, figs 2, 9–12; type locality: off Mauritania, 80–100 m.

Smriglio *et al.* (2000) reported 14 type specimens, of which some empty shells from off Mauritania (80–100 m) and off Western Sahara (50 m) without further details. The holotype was deposited in Bologna Zoology Museum (MZB14030). Thirteen paratypes were retained in private collections.

Material examined (509 shells)

MAURITANIA – **Banc d’Arguin** • 5 shells; 20.3667° N, 17.6667° W; depth 200 m; 28 Oct. 1978; CANCAP stn 3.120; sandy clay with shells; van Veen grab; RMNH.MOL.351803 • 12 shells;

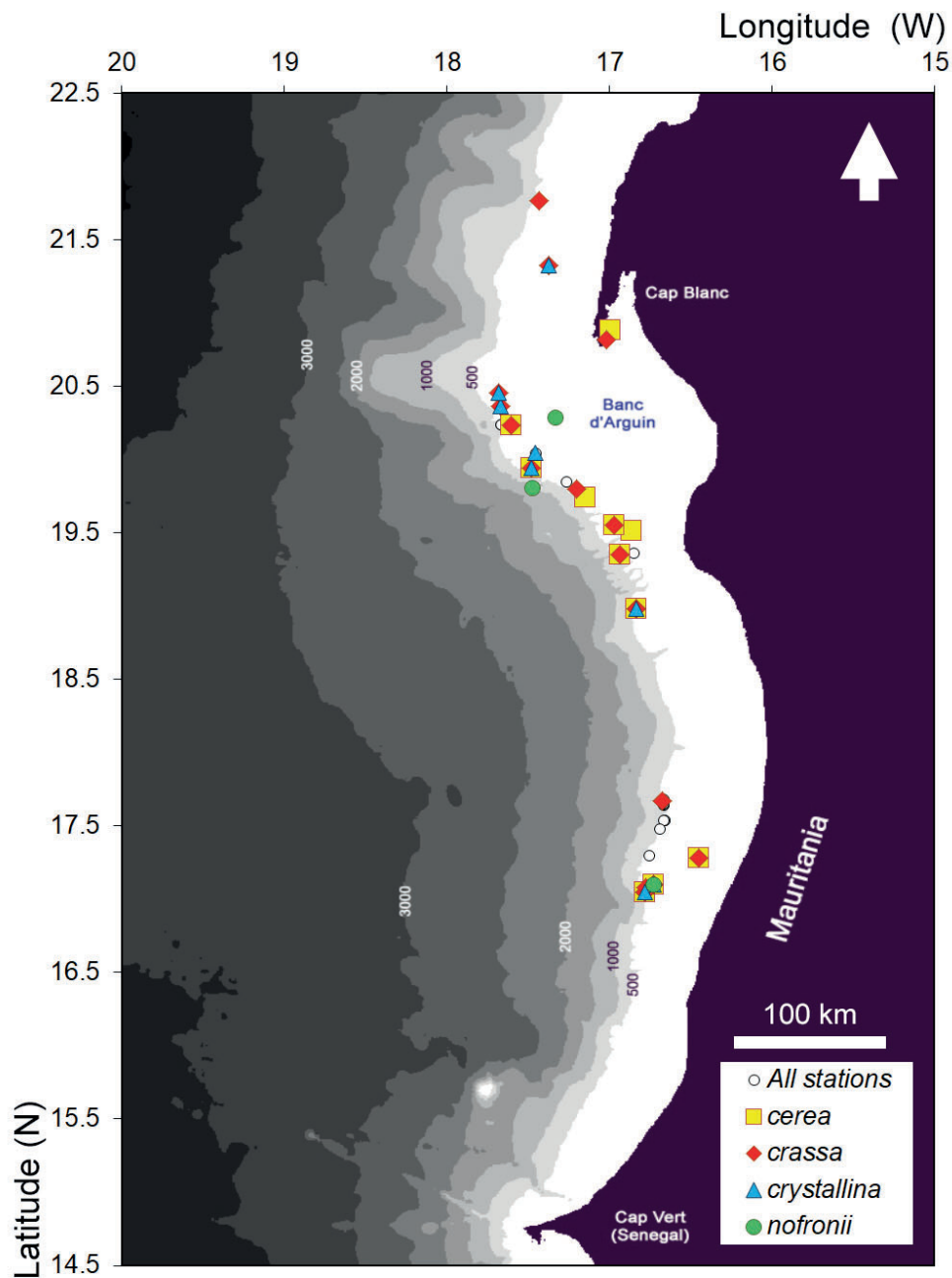


Fig. 1. Location map of the known species of *Granulina* Jousseume, 1888 found off Mauritania and Western Sahara. All investigated stations are shown by white circles; specimens of *Granulina* were only found at locations indicated by colour symbols. *Granulina cerea* Smriglio, Gubbioli & Mariottini, 2000 is presented as yellow squares, *G. crassa* Smriglio, Gubbioli & Mariottini, 2000 as red diamonds, *G. crystallina* Smriglio, Gubbioli & Mariottini, 2000 as blue triangles and *G. nofronii* Smriglio, Gubbioli & Mariottini, 2000 as green circles. Bathymetric data from GEBCO, contours at 500 m intervals.

18.9833° N, 16.8333° W; depth 203 m; 30 Oct. 1978; CANCAP stn 3.140; sandy clay with shells; van Veen grab; RMNH.MOL.351804 • 3 shells; 18.9833° N, 16.8333° W; depth 203 m; 30 Oct. 1978; CANCAP stn 3.140; sandy clay with shells by van Veen grab; RMNH.MOL.351805 • 28 shells; 19.35° N, 16.9333° W; depth 200 m; 31 Oct. 1978; CANCAP stn 3.154; sandy clay with shells; van Veen grab; RMNH.MOL.351806 • 60 shells; 19.94° N, 17.48° W; depth 151 m; 22 May 1988; Tyro Mauritania I stn B5; SaM • 2 shells; Arguin mud wedge; 20.2353° N, 17.6029° W; depth 111 m; 24 Oct. 2010; MSM16–3 stn GeoB14703; box core in muddy silt; SaM • 40 shells; Arguin mud wedge; 20.4569° N, 17.6795° W; depth 142 m; 24 Oct. 2010; MSM16–3 stn GeoB14706; box core in muddy silt; SaM • 1 shell; Baie du Levrier; 20.8169° N, 17.0186° W; depth 13 m; 31 Oct. 2010; MSM16–3 stn GeoB14780; bottom grab in muddy silt; SaM • 1 shell; southern Banc d'Arguin; 19.7967° N, 17.2034° W; depth 105 m; 6 Nov. 2010; MSM16–3 stn GeoB14850; box core in muddy silt; SaM. – **Timiris mud wedge** • 2 shells; 19.5506° N, 16.9731° W; depth 100 m; 8 Nov. 2010; MSM16–3 stn GeoB14866; box core in silty sand; SaM. – **Banda Mound Complex** • 1 shell; 17.6699° N, 16.6736° W; depth 505 m; 14 Nov. 2010; MSM16–3 stn GeoB14898; bottom grab in muddy silt; SaM. – **off Nouakchott** • 3 shells; 17.045° N, 16.7783° W; depth 202 m; 11 Feb. 1977; M44 stn 133–KG613; box core; SMF • 5 shells; 17.045° N, 16.7783° W; depth 208 m; 11 Feb. 1977; M44 stn 133–KG615; box core; SMF • 1 shell; 17.0817° N, 16.775° W; depth 312 m; 12 Feb. 1977; M44 stn

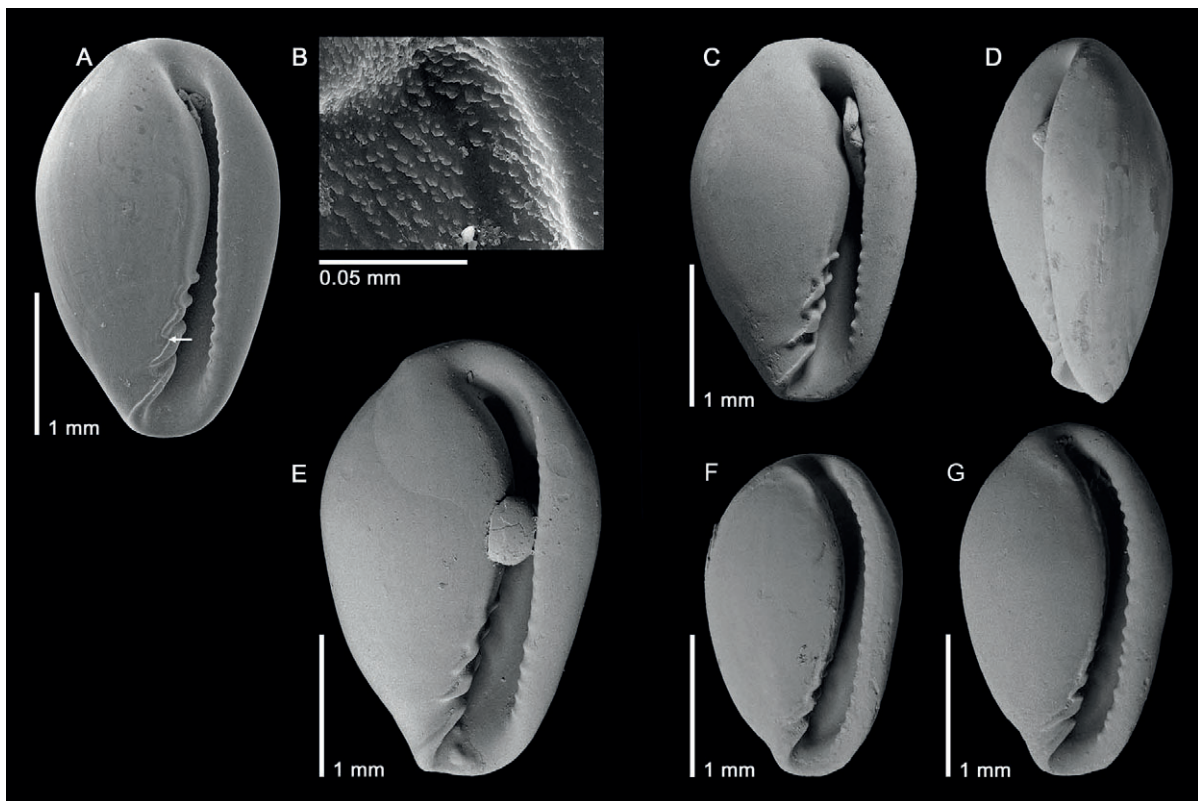


Fig. 2. *Granulina* Jousseume, 1888 from Mauritania. **A–D.** *Granulina cerea* Smriglio, Gubbioli & Mariottini, 2000, off Banc d'Arguin, CANCAP/3.120. **A–B.** Shell. **A.** Ventral view, height 2.8 mm, width 1.7 mm. **B.** Micro-sculpture above second columellar fold, see arrow in **A.** **C–D.** Shell, ventral view and side view, height 2.6 mm, width 1.6 mm, tumidity 1.3 mm. **E.** *Granulina crystallina* Smriglio, Gubbioli & Mariottini, 2000, off Nouakchott, M44/193–KG626, ventral view, height 3.1 mm, width 2.0 mm. **F–G.** *Granulina nofronii* Smriglio, Gubbioli & Mariottini, 2000, MSM16–3/GeoB14714. **F.** Ventral view, height 2.3 mm, width 1.4 mm. **G.** Ventral view, height 2.5 mm, width 1.6 mm

135–KG625; box core; SMF • 25 shells; 17.0967° N, 16.73° W; depth 127 m; 17 Feb. 1977; M44 stn 193–KG626; box core; SMF • 5 shells; 17.0967° N, 16.73° W; depth 126 m; 17 Feb. 1977; M44 stn 193–KG627; box core; SMF • 72 shells; off Nouakchott; 17.2783° N, 16.4483° W; depth 87 m; 13 Feb. 1982; M60 stn 77–KG960; box core; SMF • 85 shells; 17.2783° N, 16.4483° W; depth 88 m; 13 Feb. 1982; M60 stn 77–KG961; box core; SMF • 55 shells; 17.2783° N, 16.4483° W; depth 87 m; 13 Feb. 1982; M60 stn 77–KG965; box core; SMF.

WESTERN SAHARA – off Cap Blanc • 62 shells; 21.325° N, 17.37° W; depth 81 m; 25 Feb. 1977; M44 stn 235–KG649; box core; SMF • 1 shell; 21.7683° N, 17.4333° W; depth 125 m; 20 Feb. 1982; M60 stn 88–KAD268; SMF. – North of Dakhla • 39 shells; 25.0000° N, 15.5167° W; depth 53 m; 21 Feb. 1975; M36 stn 94–KG2; box core; SMF • 1 shell; 25.18333° N, 15.80333° W; depth 87 m; 22 Feb. 1975; M36 stn 95–KG6; box core; SMF.

Remarks

Smriglio *et al.* (2000) indicated a holotype height of 1.9 mm; our set indicates a maximum height of 2.1 mm. The species is the smallest member of the four coffin-shaped species from Mauritania. It has very weak labial denticles that occasionally may be absent, even though these specimens may be sub-adult. *Granulina crassa* lacks an (ab-)apical rostration.

The species is known from empty shells in the latitudinal range 17.0–25.2° N. The full bathymetric range is 13–505 m; it is commonly found on the lower shelf at depths of 80–210 m in silty sand.

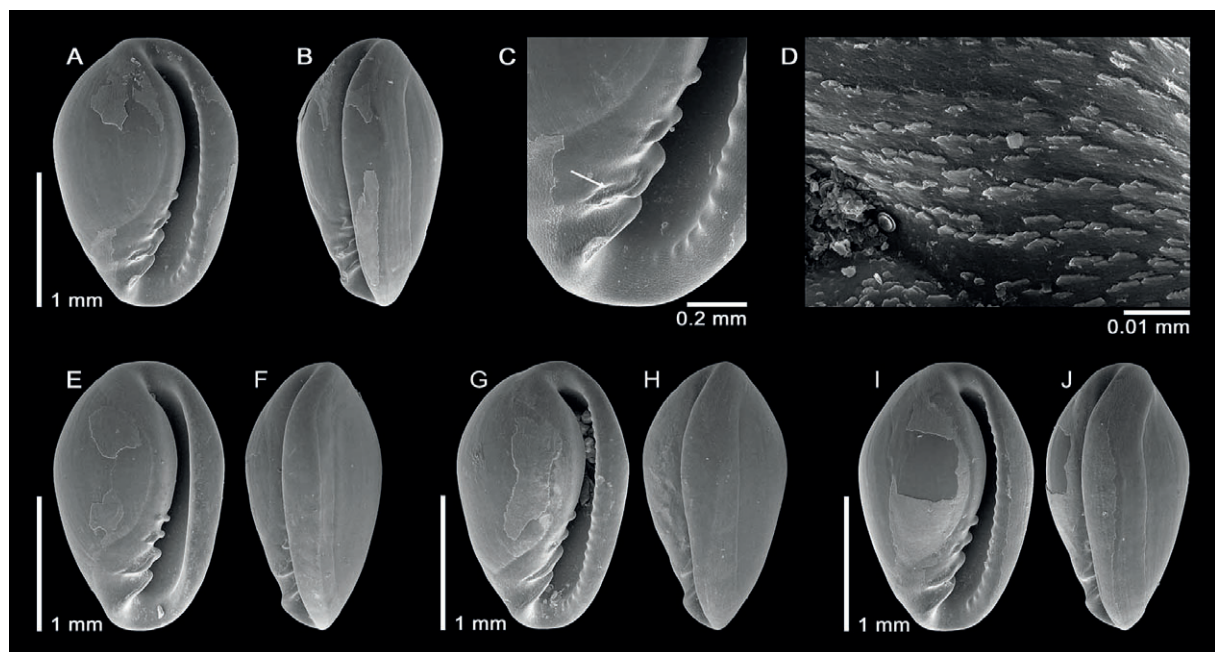


Fig. 3. *Granulina crassa* Smriglio, Gubbioli & Mariottini, 2000, Western Sahara, off Cap Blanc, M44/235–KG649. **A–D.** Ventral and side views, height 2.1 mm, width 1.3 mm, tumidity 1.0 mm. **C.** Columellar folds. **D.** Micro-sculpture above second columellar fold, see arrow in C. **E–F.** Ventral and side views, height 2.1 mm, width 1.3 mm, tumidity 1.0 mm. **G–H.** Views and dimensions as E–F. **I–J.** Views and dimensions as E–F.

Granulina aff. *crassa*

Fig. 4

Diagnosis

Small shell, height maximum 2.0 mm, width maximum 1.3 mm, tumidity maximum 1.0 mm, pear-shaped; labial denticles on interior of external lip, weakly rostrated apically and abapically, widely channelled abapically; 4 separated columellar folds; colour white.

Material examined (3 shells)

MAURITANIA – off **Nouakchott** • 1 shell; 17.045° N, 16.7783° W; depth 208 m; 11 Feb. 1977; M44 stn 133–KG615; box core; SMF373043 • 2 shells; 17.2783° N, 16.4483° W; depth 87 m; 13 Feb. 1982; M60 stn 77–KG960; box core; SMF373044.

Description

Abapical end highly convex, blunt, widening channel; apical end less convex; external lip thick, angular above periphery, thickened from apex to base, protruding and maximum convexity slightly above periphery, reclining towards apex and base, widely channelled at highly convex base, internally smooth, weak to strong labial denticles. Four spiral folds at base of straight columella, lower two strongest extending across base, upper two folds small yet separated. Parietal area widely convex and smooth. Macroscopic sculpture smooth with microscopic irregular growth lines; microscopic sculpture of flakes oriented towards exterior on broad callus on external lip, columella and columellar folds, base and apex, callus reclining in parietal area; internally smooth. Aperture curved, elongated, narrowest slightly above periphery, wide at base.

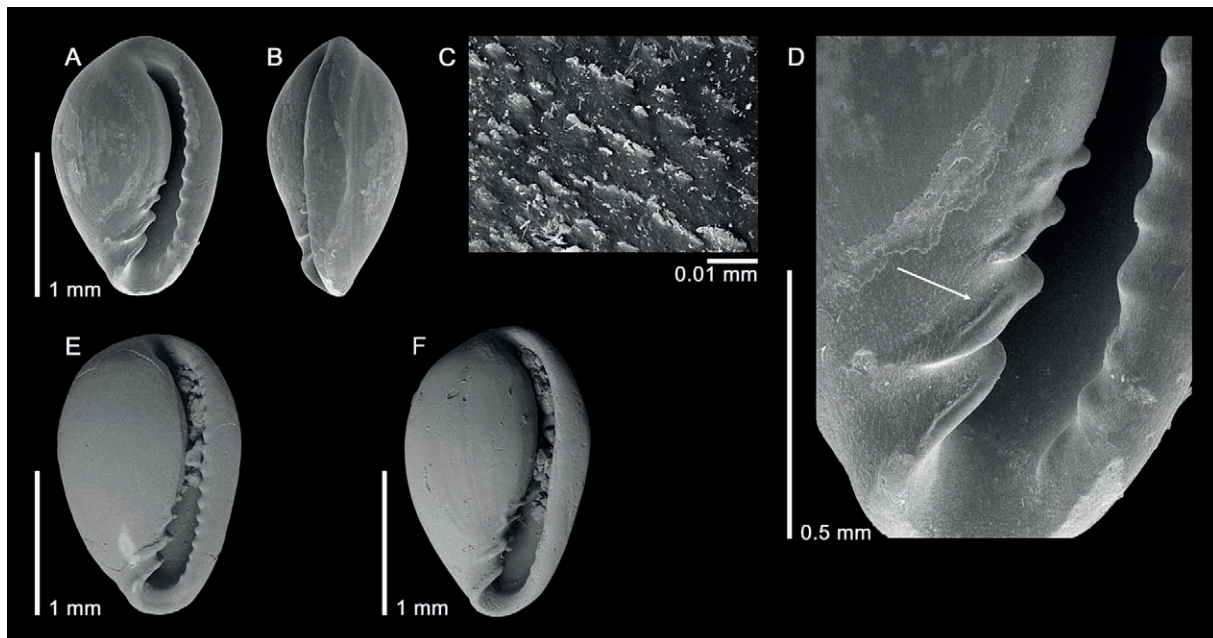


Fig. 4. *Granulina* aff. *crassa*, off Nouakchott, Mauritania. **A–D.** M44/133–KG615. **E–F.** M60/77–KG-960. **A–B.** Ventral and side view, height 1.8 mm, width 1.2 mm, tumidity 1.0 mm. **C.** Micro-sculpture above second columellar fold, see arrow in **D**. **D.** Columellar folds and labial denticles. **E.** Ventral view, height 2.0 mm, width 1.3 mm. **F.** Ventral view, height 2.0 mm, width 1.3 mm.

Remarks

The present species is similar to *Granulina crassa* but its outline is less elongated and less angular and its callus is very well developed across the apex, base and the parietal area. The three shells show a great variability in outline; possibly we deal with more than one species.

We refrain from proposing a new species as we identified only three shells, two of which are eroded. The bathymetric range is 87–208 m; the latitudinal range is 17.0–17.3° N, off Nouakchott.

Granulina crystallina Smriglio, Gubbioli & Mariottini, 2000
Figs 1, 2E

Granulina crystallina Smriglio, Gubbioli & Mariottini, 2000: 55, 58, figs 3, 13–16; type locality off Mauritania (80–90 m).

Smriglio *et al.* (2000) reported 22 specimens, of which some empty shells from off Mauritania (80–90 m) without further details. The holotype was deposited in the Bologna Zoology Museum (MZB14031). Twenty-one paratypes were retained in private collections.

Material examined (48 shells)

MAURITANIA – off **Banc d’Arguin** • 11 shells; 20.3667° N, 17.6667° W; depth 200 m; 28 Oct. 1978; CANCAP stn 3.120; sandy clay with shells; van Veen grab; SaM • 3 shells; 18.9833° N, 16.8333° W; depth 203 m; 30 Oct. 1978; CANCAP stn 3.140; sandy clay with shells; van Veen grab; RMNH.MOL.351807 • 7 shells; Arguin mud wedge; 20.4569° N, 17.6795° W; depth 142 m; 24 Oct. 2010; MSM16–3 stn GeoB14706; box core in muddy silt; SaM; box core in muddy silt; SaM • 1 shell; 19.94° N, 17.48° W; depth 151 m; 22 May 1988; Tyro Mauritania I stn B5; RMNH.MOL.351808. – off **Nouakchott** • 1 shell; off Nouakchott; 17.0967° N, 16.73° W; depth 127 m; 17 Feb. 1977; M44 stn 193–KG626; box core; SMF • 3 shells; 17.045° N, 16.7783° W; depth 199 m; 11 Feb. 1977; M44 stn 133–KG616; box core; SMF.

WESTERN SAHARA – off **Cap Blanc** • 22 shells; 21.325° N, 17.37° W; depth 81 m; 25 Feb. 1977; M44 stn 235–KG649; box core; SMF.

Remarks

Smriglio *et al.* (2000) indicated a holotype height of 2.4 mm; our set indicates a maximum height of 3.1 mm. The species is a largest member of the four coffin-shaped species from Mauritania. It has weak labial denticles, a clear angular outline and it shows a weak (ab-)apical rostration.

The species is known from empty shells in the latitudinal range 17.0–21.4° N. It is commonly found on the lower shelf at depths of 52–210 m in silty sand.

Granulina nofronii Smriglio, Gubbioli & Mariottini, 2000
Figs 1, 2F–G

Granulina nofronii Smriglio, Gubbioli & Mariottini, 2000: 58, figs 4, 17–20; type locality off Mauritania, 80–100 m.

Smriglio *et al.* (2000) reported 24 shells from off Mauritania (80–100 m) and from Western Sahara (50 m) without further details. The holotype was deposited in the Bologna Zoology Museum (MZB14032). Twenty-three paratypes were retained in private collections.

Material examined (23 shells)

MAURITANIA – **Banc d’Arguin** • 20 shells; outer shelf off Banc d’Arguin; 20.0438° N, 17.457° W; depth 52 m; 25 Oct. 2010; MSM16–3 stn GeoB14714; SaM • 1 shell; central outer Banc d’Arguin; 20.2832° N, 17.3335° W; depth 30 m; 2 Nov. 2010; MSM16–3 stn GeoB14788; box core in muddy silt; SaM. – **off Nouakchott** • 2 shells; 17.0967° N, 16.73° W; depth 127 m; 17 Feb. 1977; M44 stn 193–KG626; box core; SMF.

Remarks

Smriglio *et al.* (2000) indicated a holotype height of 2.4 mm; our set indicates a maximum height of 2.5 mm. The species has an elliptical or weak coffin-shaped outline; it has strong labial denticles, and it lacks rostration.

A similar species is *Granulina choffati* La Perna, Landau & da Silva, 2003 from the Atlantic Pliocene in Portugal. It is differentiated from *G. nofronii* by a finer labial denticulation.

The species is known from empty shells in the latitudinal range 17.0–20.3° N. It was found at depths of 30–1252 m in silty sand or mud. We could not confirm the species occurring off Western Sahara.

Granulina reginae sp. nov.

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Figs 5–6

Diagnosis

Small shell, height maximum 2.2 mm, width maximum 1.4 mm (width/height ratio 0.64), tumidity maximum 1.2 mm; ovoid shape, external and columellar lip without denticles, widely channelled and rostrated at apical and abapical ends; colour white, translucent.

Etymology

The name (feminine) of the species acknowledges the late Regina Albert, formerly a technical assistant at Senckenberg, who washed and sieved the raw *Meteor* samples and partly performed the preliminary sorting.

Type material

Holotype

MAURITANIA – **Timiris Mound Complex** • 1 shell; 18.9833° N, 16.8656° W; depth 482 m; 9 Jan. 2007; POS346 stn GeoB11587; box core in coral rubble with mud; SMF359019.

Paratypes (12 shells)

MAURITANIA – **Timiris Mound Complex** • 1 shell; 18.9832° N, 16.8636° W; depth 474 m; 9 Jan. 2007; POS346 stn GeoB11588; box core in coral rubble with mud; SMF359021 • 1 shell; 18.9634° N, 16.8688° W; depth 498 m; 11 Nov. 2010; MSM16–3 stn GeoB14877; box core in coral rubble with mud; SMF359022. – **Banda Mound Complex** • 3 shells; 17.6668° N, 16.6721° W; depth 440 m; 8 Jan. 2007; POS346 stn GeoB11569; box core in coral rubble with mud; SMF359023 • 1 shell; 17.6699° N, 16.6736° W; depth 505 m; 14 Nov. 2010; MSM16–3 stn GeoB14898; bottom grab in muddy silt; SMF359024. – **off Banc d’Arguin, Tanoudert Canyon** • 2 shells; 20.2429° N, 17.6681° W; depth 490 m; 3 Nov. 2010; MSM16–3 stn GeoB14799; box core in coral rubble with mud; SMF359025 • 4 shells; same collection data as for preceding; RMNH.MOL.351809.

Description

Apex with widely convex, sharp, wide channel; outer lip smooth, thickened from apex to base, protruding and somewhat bevelled at periphery, reclining towards apex and base, internally smooth (without

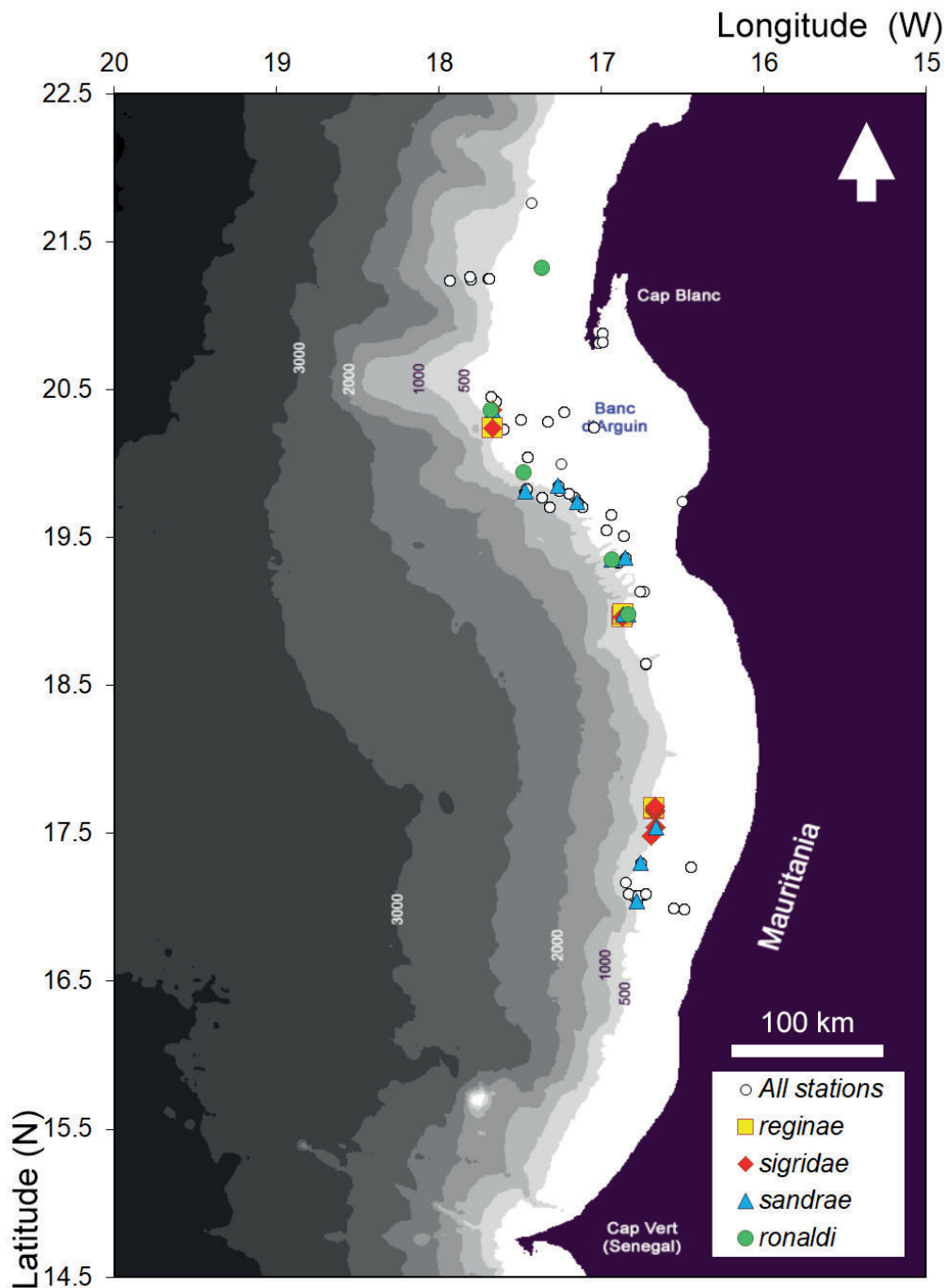


Fig. 5. Location map of the new species in *Granulina* Jousseume, 1888 off Mauritania and Western Sahara. White circles show all investigated stations; colour symbols show locations of shells from new species. *Granulina reginae* sp. nov. is presented by yellow squares, *G. sigridae* sp. nov. as red diamonds, *G. sandrae* sp. nov. as blue triangles, and *G. ronaldi* sp. nov. as green circles. Bathymetric data from GEBCO; contours 500 m

denticles); base somewhat flared wide open. Four oblique folds at base of straight columella, folds unconnected and with rounded margins when young, upper two folds coalescent, forming vertical rim when adult. Parietal area widely convex and smooth. Macroscopic sculpture smooth with microscopic irregular growth lines; microscopic sculpture of flakes oriented towards exterior on callus of external lip, columella and columellar folds, base and apex, callus reclining in the middle part; internally smooth. Aperture curved, elongated, narrowest above periphery, wide at base and at apex. Protoconch not visible, convolved inside shell.

Remarks

All described species of *Granulina* from north of Senegal have labial denticles and none have a wide apical channel in the aperture. Therefore, the present species cannot be confused with *Granulina nofronii*, *G. crassa*, *G. crystallina* or *G. cerea* (Smriglio *et al.* 2000), even though they have a relatively

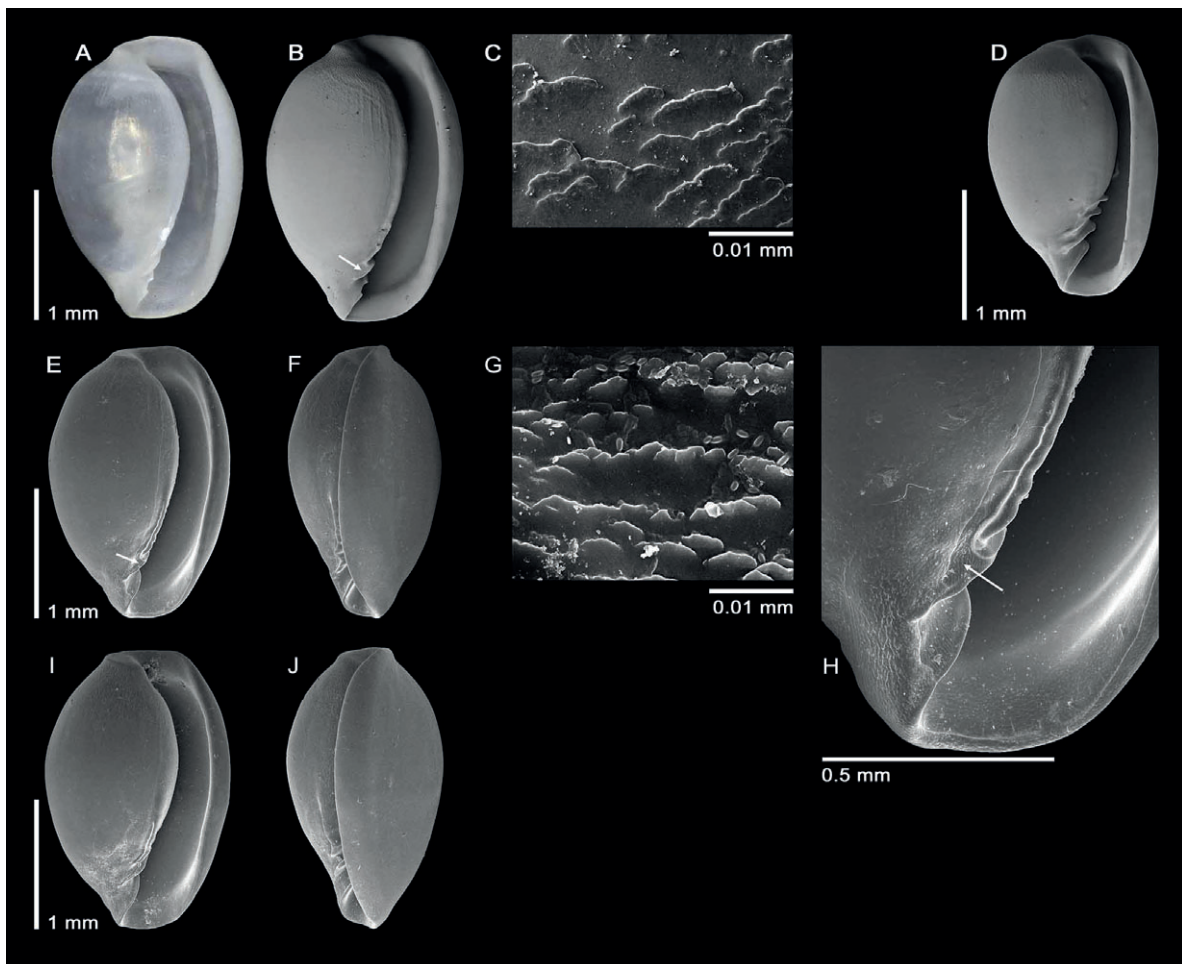


Fig. 6. *Granulina reginae* sp. nov., Mauritania. **A–D.** Timiris Mound Complex. **A–C.** Holotype, POS346/GeoB11587 (SMF359019). **A–B.** Ventral view, height 2.2 mm, width 1.4 mm, **C.** Micro-sculpture above second fold, see arrow in **B.** **D.** Paratype, POS346/GeoB11588 (SMF359021), ventral view, height 2.0 mm, tumidity 1.2 mm. **E–J.** Paratypes (SMF359025), off Banc d’Arguin, MSM16–3/GeoB14799. **E–F.** Ventral and side view, height 2.1 mm, width 1.3 mm, tumidity 1.1 mm. **G.** Micro-sculpture above second fold, see arrows in **E.** **H.** Columellar folds. **I–J.** Ventral and side view, height 2.2 mm, width 1.4 mm, tumidity 1.1 mm.

similar form. The new species *Granulina reginae* sp. nov. lacks labial denticles as do the other three new species: *Granulina ronaldi* sp. nov., *G. sigridae* sp. nov. and *G. sandrae* sp. nov. Compared to these species, *G. reginae* is smaller and somewhat broad (width/height ratio 0.64), clearly more rostrated and has a wide channelized apex, which the other new species do not have. *Granulina sandrae* is pear-shaped and inflated (width/height ratio 0.69), and *G. ronaldi* and *G. sigridae* are more elongated (width/height ratio 0.56–0.59).

Shells from juveniles are identified by their sharp convolving lip and four separated columellar folds; adults have a thickened, bevelled lip and the upper columellar folds are coalescent. Coalescent folds probably are a gerontic character.

Many samples containing these new species were taken in coral rubble and mud. Most likely, they live in upper bathyal coral-associated habitats. Bathymetric range is 440–505 m; their latitudinal range is 17.6–20.3° N.

***Granulina ronaldi* sp. nov.**

urn:lsid:zoobank.org:act:38316ACE-B8E8-4743-8F4D-59785DA8AED2

Figs 5, 7

Diagnosis

Small shell, height maximum 2.9 mm, width maximum 1.7 mm (width/height ratio 0.59), tumidity maximum 1.4 mm, ovoid-angular shape, rather narrow shape; no labial denticles on interior of external lip, tapered and weakly rostrated apically and abapically, widely channelled abapically, colour white, translucent.

Etymology

The name (masculine) of the species acknowledges Ronald Janssen, retired curator of the Mollusca collection in the Senckenberg Museum Frankfurt who salvaged the *Meteor* material when it was about to be discarded and who initiated the preservation and sorting process. He also allowed us to study the *Meteor* samples.

Type material

Holotype

MAURITANIA – **Banc d’Arguin** • 1 shell; 19.35° N, 16.9333° W; depth 200 m; 31 Oct. 1978; CANCAP stn 3.154; SMF359026.

Paratypes (40 shells)

MAURITANIA – **Banc d’Arguin** • 3 shells; same collection data as for holotype; SMF359020, SMF359027, SMF359029 • 25 shells; same collection data as for holotype; RMNH.MOL.351810 • 8 shells; 19.94° N, 17.48° W; depth 151 m; 22 May 1988; Tyro Mauritania I stn B5; box core; SMF359028 • 4 shells; 18.9833° N, 16.8333° W; depth 203 m; 30 Oct. 1978; CANCAP stn 3.140; sandy clay with shells; van Veen grab; RMNH.MOL.351811.

Other material examined (159 shells)

MAURITANIA – **Banc d’Arguin** • 12 shells; 20.3651° N, 17.6834° W; depth 246 m; 24 Oct. 2010; MSM16–3 stn GeoB14704; box core in muddy silt; SaM.

WESTERN SAHARA – **off Cap Blanc** • 6 shells; 21.325° N, 17.37° W; depth 81 m; 25 Feb. 1977; M44 stn 235–KG649; box core; SMF. – **North of Dakhla** • 2 shells; 25.3333° N, 16.1533° W; depth

411 m; 5 Feb. 1982; M60 stn 49–KG921, box core; SMF • 1 shell; 25.3333° N, 16.1533° W; depth 407 m; 5 Feb. 1982; M60 stn 43–KG922; box core; SMF • 10 shells; 25.1833° N, 15.8033° W; depth 87 m; 22 Feb. 1975; M36 stn 95–KG6; box core; SMF • 128 shells; 25.0000° N, 15.5167° W; depth 53 m; 21 Feb. 1975; M36 stn 94–KG2; box core; SMF.

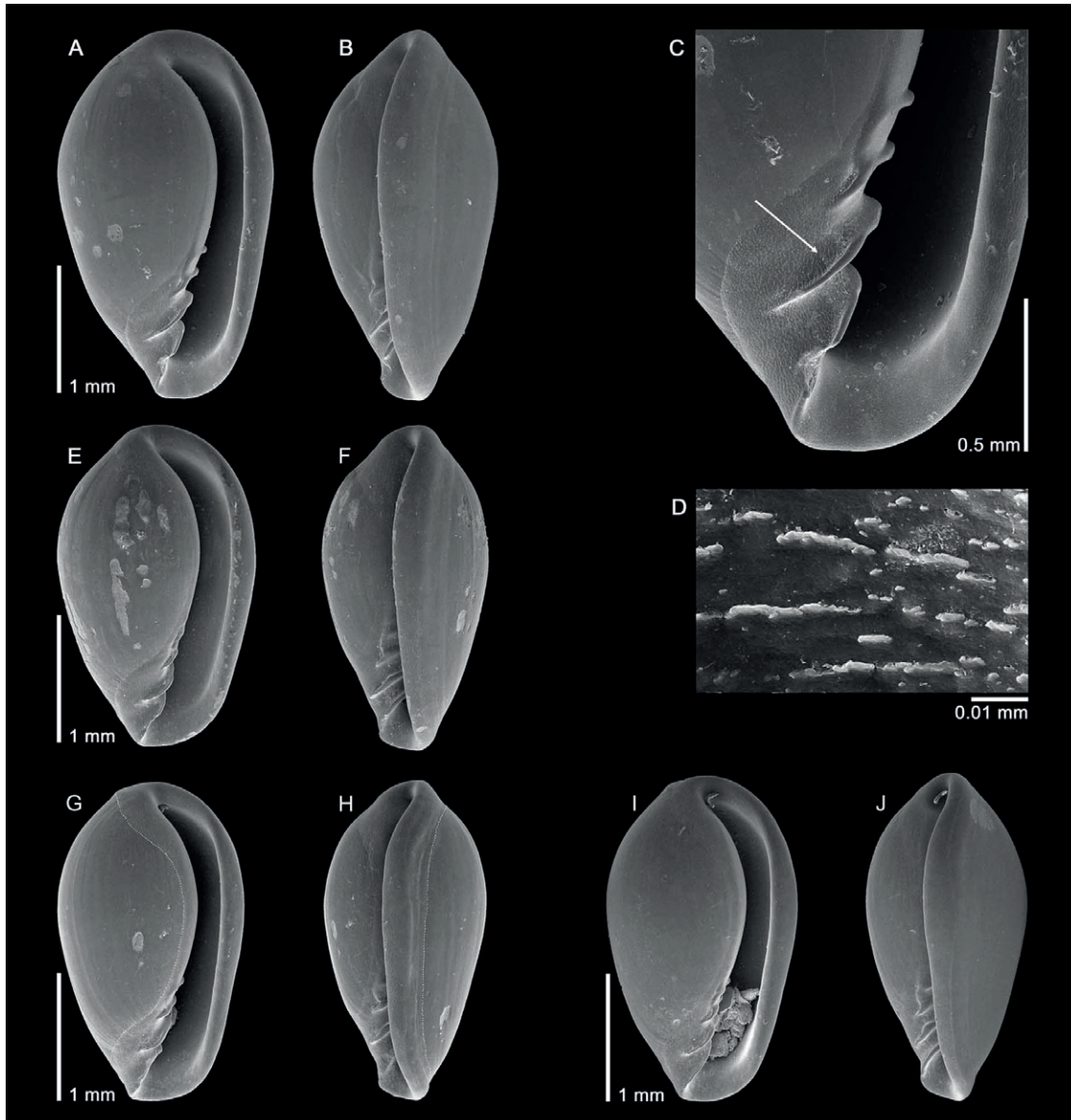


Fig. 7. *Granulina ronaldi* sp. nov., Mauritania, off Banc d'Arguin, CANCAP/3.154. **A–D.** Holotype (SMF359026). **A–B.** Ventral and side views, height 2.9 mm, width 1.7 mm, tumidity 1.4 mm. **C.** Columellar folds. **D.** Micro-sculpture above second columellar fold, see arrow in C. **E–F.** Paratype (SMF359020), ventral and side views, height 2.5 mm, width 1.5 mm, tumidity 1.3 mm. **G–H.** Paratype (SMF359027), ventral and side views, height 2.5 mm, width 1.4 mm, tumidity 1.3 mm, callus line indicated by white dots. **I–J.** Paratype (SMF359029), ventral and side views, height 2.5 mm, width 1.5 mm, tumidity 1.2 mm.

Description

Apex with highly convex, blunt, narrowing channel. External lip smoothly rounded, strongly thickened from apex to base, maximum convexity slightly above periphery, reclining towards apex and base, widely channelled at highly convex base, pointed at base columella, internally smooth (without labial denticles). Four discrete oblique folds at base of straight columella, with round edges, third fold longest. Parietal area widely convex and smooth. Macroscopic sculpture smooth with microscopic irregular growth lines; microscopic sculpture of flakes oriented towards exterior on callus of external lip, columella, columellar folds, base and apex, callus reclining in the middle part; internally smooth. Aperture curved, elongated, wide at base. Protoconch invisible, convolved inside shell.

Remarks

Because of the missing labial denticles, this species cannot be mistaken for any hitherto known species found north of Senegal. The morphology is similar to *Granulina occulta* but that species has labial denticles. The outline of the present species is not as broad (width/height ratio 0.59) as in *Granulina sandrae* sp. nov. (width/height ratio 0.69) and it has a narrow aperture. *Granulina reginae* sp. nov. has a wide, notched apical channel and its last whorl is widely rounded at the periphery.

Granulina ronaldi sp. nov. could be mistaken for *G. sigridae* sp. nov. but that species has different columellar folds; the two upper ones are often coalescent and the third one is not as long as the fourth one. The micro-sculpture in the present species covers a wider area at the base of the callus and apex and is not as retracted in the parietal area as in *G. sigridae* either. The outer lip of the present species is more thickened, with weaker convexity and slightly angular. The (ab-) apical outlines are more convex than in *G. sigridae*.

La Perna *et al.* (2001) described the similar *Granulina longa* La Perna, Landau & Marquet, 2001 from the Pliocene near Estepona (western Mediterranean, Spain). *Granulina longa* differs from the present species by a well-rounded oval outline, a wide aperture and a thin lip with fine labial denticles. La Perna *et al.* (2003) described another similar species: *Granulina choffati* La Perna, Landau & da Silva, 2003 from the Atlantic Pliocene in Portugal. It is differentiated from the present species by fine labial denticulations, and a more oval outline.

The bathymetric range is 81–411 m. The latitudinal range is 18.9–25.4° N, which is the northernmost occurrence of the new species. Some shells were found in sandy or muddy silt occasionally with other shells. The habitat of the species is uncertain.

Granulina sandrae sp. nov.

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Figs 5, 8

Diagnosis

Small shell, height maximum 3.6 mm, width maximum 2.5 mm (width/height ratio 0.69), tumidity maximum 2.0 mm; colour white; outline pear-shaped, apex slightly pointed and weakly rostrated, base widely channelled.

Etymology

The name (feminine) of the species acknowledges Sandra Müller, technical assistant at the Senckenberg Museum Frankfurt, who has been the key person incorporating the SaM samples into the SMF collection.

Type material

Holotype

MAURITANIA • Banc d'Arguin; 19.35° N, 16.9333° W; depth 200 m; 31 Oct. 1978; CANCAP stn 3.154; sandy clay with shells; van Veen grab; SMF359030.

Paratypes (10 shells)

MAURITANIA – **Banc d'Arguin** • 2 shells; same data as type locality; SMF359031 • 1 shell; same collection data as for holotype; RMNH.MOL.351812 • 1 shell; 20.3667° N, 17.6667° W; depth 200 m; 28 Oct. 1978; CANCAP stn 3.120; sandy clay with shells; van Veen grab; RMNH.MOL.351813 • 1 shell; 18.9833° N, 16.8333° W; depth 203 m; 30 Oct. 1978; CANCAP stn 3.140; sandy clay with shells; van Veen grab; RMNH.MOL.351814 • 2 shells; 19.3667° N, 16.85° W; depth 200 m; 31 Oct. 1978; CANCAP stn 3.155; sandy clay with shell gravel; van Veen grab; RMNH.MOL.351815 • 1 shell; deep mound chain off Banc d'Arguin; 19.8107° N, 17.4705° W; depth 1310 m; 7 Nov. 2010; MSM16–3 stn GeoB14852; box core; SMF359035 • 1 shell; Arguin South 3 Canyon; 19.7381° N, 17.1465° W; depth 483 m; 7 Nov. 2010; MSM16–3 stn GeoB14858; bottom grab; SMF359032. – **Timiris Mound Complex** • 2 shells; 19.8524° N, 17.2636° W; depth 369 m; 6 Nov. 2010; MSM16–3 stn GeoB14847; box core in muddy silt; SMF359033.

Other material examined (21 shells)

MAURITANIA – **Timiris Mound Complex** • 1 shell; 18.9832° N, 16.8636° W; depth 474 m; 9 Jan. 2007; POS346 stn GeoB11588; box core in coral rubble with mud; SaM. – **Tamxat Mounds** • 2 shells; 17.5427° N, 16.6634° W; depth 510 m; 15 Nov. 2010; MSM16–3 stn GeoB14904; box core in coral rubble with mud; SaM • 7 shells; 17.3017° N, 16.76° W; depth 411 m; 10 Feb. 1982; M60 stn 65–KG946; box core; SMF • 5 shells; 17.045° N, 16.7783° W; depth 208 m; 11 Feb. 1977; M44 stn 133–KG615; box core; SMF • 6 shells; 17.045° N, 16.7783° W; depth 199 m; 11 Feb. 1977; M44 stn 133–KG616; box core; SMF.

Description

Apex with highly convex, blunt, narrowing channel. External lip smoothly rounded, thickened from apex to base, protruding and maximum convexity well above periphery, reclining towards apex and base, internally smooth, without labial denticles. Four spiral folds at base of straight columella, upper two folds coalescent but still distinct. Parietal area widely convex and smooth. Macroscopic sculpture smooth with microscopic irregular growth lines; microscopic sculpture of flakes oriented towards exterior on callus of external lip, columella and columellar folds, base and apex, callus reclining in the middle part; internally smooth. Aperture curved, elongated, narrowest at periphery, wide at base and narrower at apex. Protoconch invisible, convolved inside shell.

Remarks

Granulina boucheti Gofas, 1992 shows a morphological similarity to the new species; it has a similar size and outline but it differs by its labial denticles on the inside of the external lip; the present species lacks labial denticles. *Granulina sigridae* sp. nov. has a wide channel with less convex margin apically, and it is more elongated (width/height ratio 0.56 versus 0.69 in *G. sandrae* sp. nov.) with an even convexity in the outer lip.

The Pliocene *Granulina iberica* La Perna, Landau & Marquet, 2001 has a similar outline as the present species but it differs by the presence of fine labial teeth, a widely notched apical channel and an obliquely truncated apical outline. The present species shows a tapered apex.

Bathymetric range 199–1310 m; latitudinal range 17.0–20.4° N. Some shells were found in sandy clay with other shells. Other shells were found in coral rubble with mud.

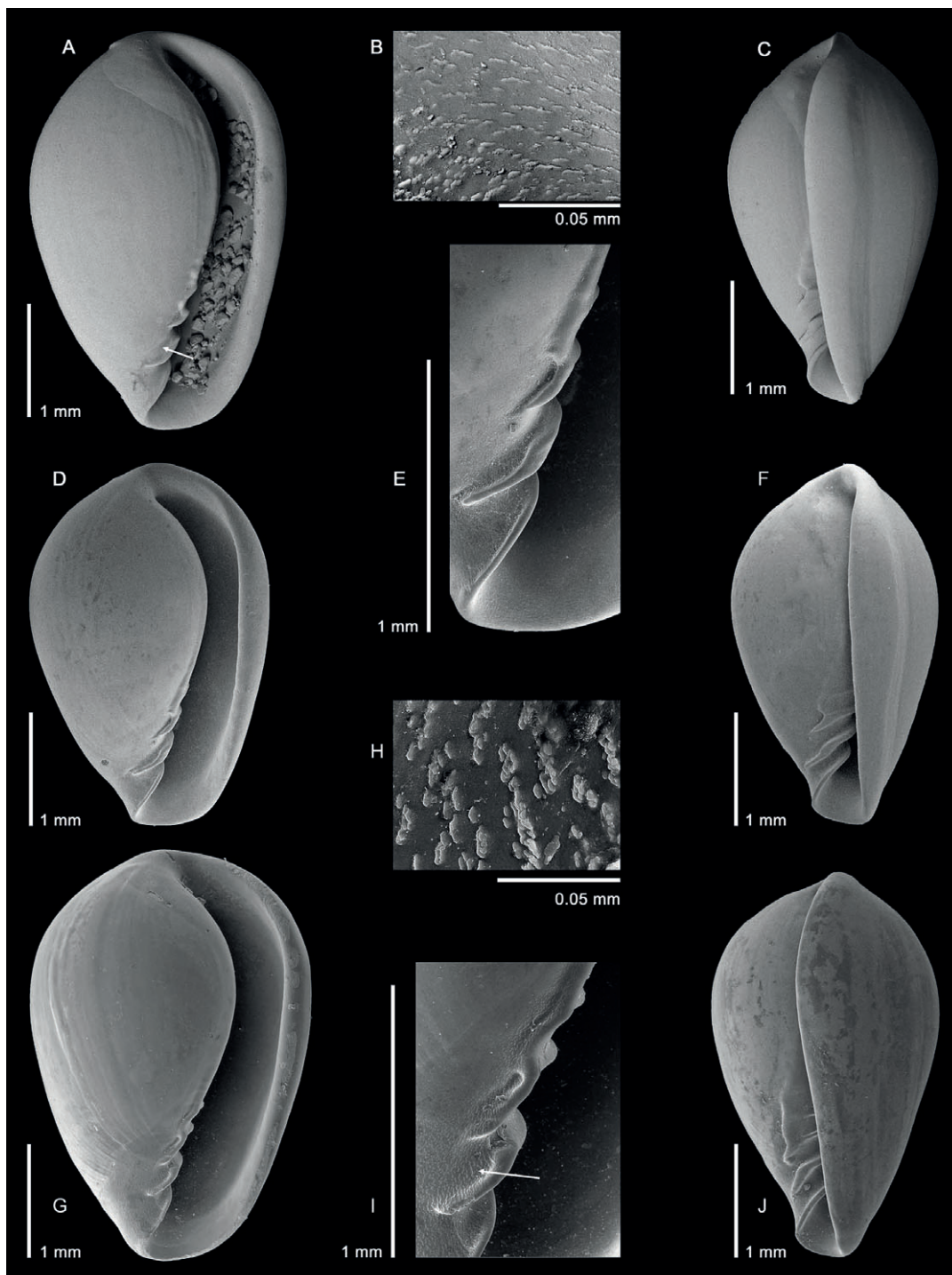


Fig. 8. *Granulina sandrae* sp. nov., Mauritania. – **A–F.** OffCap Timiris, CANCAP/3.154. **A–B.** Holotype (SMF359030), ventral view, height 3.5 mm, width 2.2 mm, micro-sculpture above second columellar tooth, see arrow in A. **C.** Paratype (SMF359031), side view with thickened lip, height 3.2 mm, tumidity 1.8 mm. **D–F.** Paratype (SMF359031). **D, F.** Ventral and side views, height 3.2 mm, width 2.1 mm, tumidity 1.8 mm. **E.** Columellar view with teeth. – **G–J.** Southern Banc d'Arguin, MSM16-3/GeoB14847. **G–I.** Paratype (SMF359033). **G.** Ventral view height 3.6 mm, width 2.5 mm. **H.** Micro-sculpture above second columellar fold, see arrow in I. **I.** Columellar folds. **J.** Paratype (SMF359033), side view with thickened lip, height 3.4 mm, tumidity 2.0 mm.

Granulina sigridae sp. nov.

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Figs 5, 9

Diagnosis

Small shell, height maximum 3.2 mm, width maximum 1.8 mm (width/height ratio 0.56), tumidity maximum 1.6 mm, ovoid oblong shape with convex labial bulge at apex; no labial denticles on interior of external lip, weakly rostrated apically and abapically, widely channelled abapically, colour white, translucent.

Etymology

The name (feminine) of the species acknowledges Sigrid Hof, technical assistant at the Senckenberg Museum Frankfurt, who performed the preliminary sorting of the *Meteor* samples.

Type material

Holotype

MAURITANIA – **Timiris deep coral mound chain** • 1 shell; 18.9624° N, 16.8704° W; depth 548 m; MSM16–3 stn GeoB14876; box core in coral rubble with mud; SMF359034.

Paratypes (8 shells)

MAURITANIA – **Timiris deep coral mound chain** • 6 shells; same collection data as for holotype; SEM, SMF373040 • 11 shells same collection data as for holotype; SMF373042 • 2 shells; 18.9634° N, 16.8688° W; depth 498 m; 11 Nov. 2010; MSM16–3 stn GeoB14877; box core in coral rubble with mud; RMNH.MOL.351816.

Other material examined (61 shells)

MAURITANIA – **Banc d'Arguin** • 1 shell; 20.3667° N, 17.6667° W; depth 200 m; 28 Oct. 1978; CANCAP stn 3.120; sandy clay with shells; van Veen grab; RMNH.MOL.351817 • 2 shells; Tanoudert Canyon; 20.2429° N, 17.6681° W; depth 490 m; 3 Nov. 2010; MSM16–3 stn GeoB14799; box core in coral rubble with mud; SaM. – **Banda Mound Complex** • 1 shell; 17.6459° N, 16.6665° W; depth 442 m; 7 Jan. 2007; POS346 stn GeoB11564; box core in mud with coral rubble; SaM • 3 shells; 17.6501° N, 16.6681° W; depth 441 m; 7 Jan. 2007; POS346 stn GeoB11566; box core in mud with coral rubble; SaM • 1 shell; 17.6585° N, 16.6678° W; depth 428 m; 7 Jan. 2007; POS346 stn GeoB11567; box core in coral rubble with mud; SaM • 1 shell; 17.6668° N, 16.6721° W; depth 440 m; 8 Jan. 2007; POS346 stn GeoB11569; box core in coral rubble with mud; SaM • 1 shell; 17.6794° N, 16.6684° W; depth 450 m; 8 Jan. 2007; POS346 stn GeoB11579; box core in coral rubble with mud; SaM • 1 shell; 17.684° N, 16.668° W; depth 481 m; 8 Jan. 2007; POS346 stn GeoB11580; box core in mud with coral rubble; SaM • 34 shells; Banda Slide; 17.541° N, 16.6666° W; depth 486 m; 15 Nov. 2010; MSM16–3 stn GeoB14905; box core in coral rubble with mud; SaM. – **Tamxat Mound Complex** • 11 shells; C–Tamxat Mounds; 17.5427° N, 16.6634° W; depth 510 m; 15 Nov. 2010; MSM16–3 stn GeoB14904; box core in coral rubble with mud; SaM • 5 shells; S–Tamxat Mounds; 17.4833° N, 16.6941° W; depth 535 m; 15 Nov. 2010; MSM16–3 stn GeoB14910; box core in mud; SaM.

Description

Apex with weakly convex, blunt, narrowing channel. External lip smoothly rounded, thickened from apex to base, protruding and maximum convexity slightly above periphery, reclining towards apex and base, widely channelled at highly convex base, pointed at base columella, internally smooth (without labial denticles). Four spiral folds at base of straight columella, upper two folds are coalescent yet distinct. Parietal area widely convex and smooth. Macroscopic sculpture smooth with microscopic

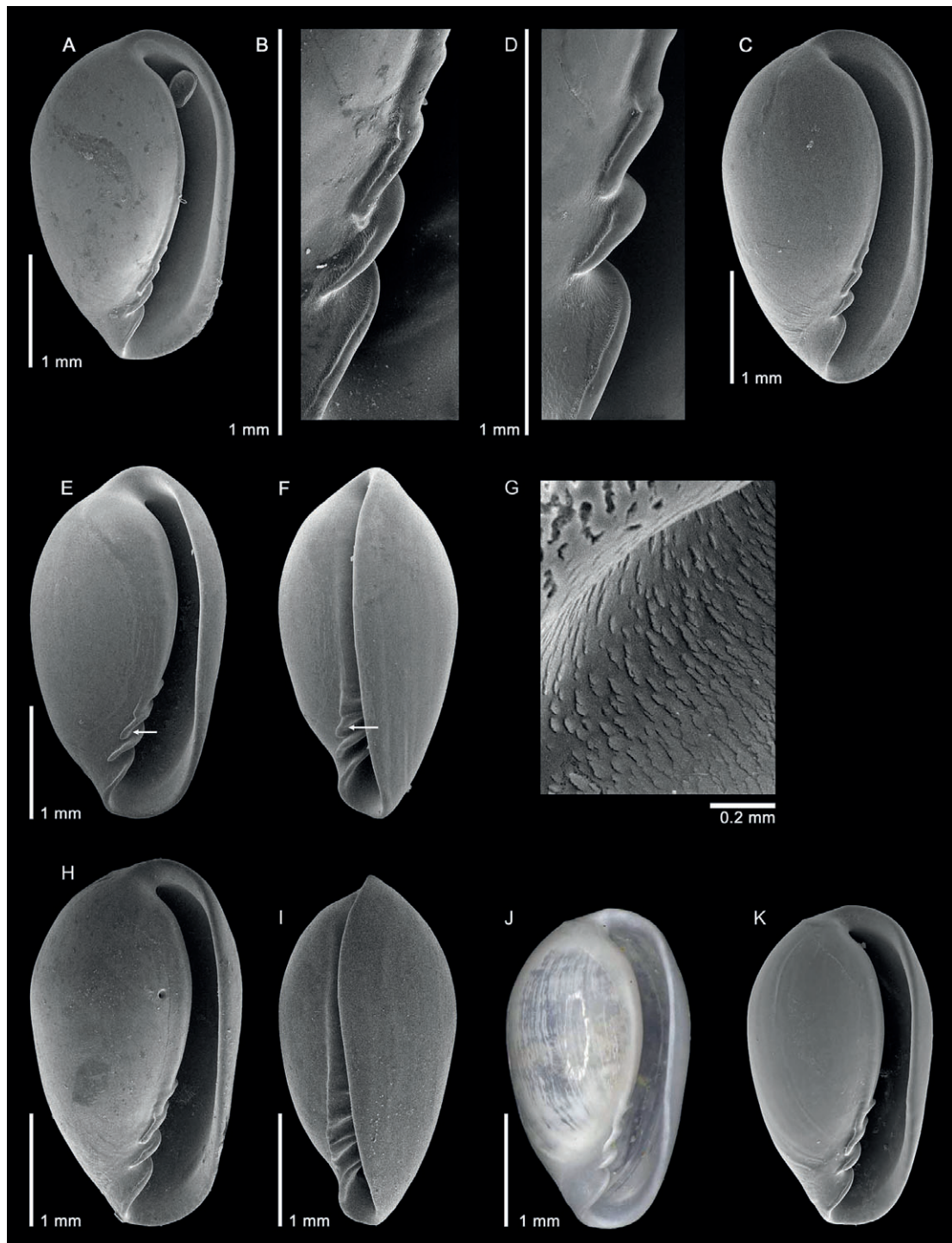


Fig. 9. *Granulina sigridae* sp. nov., Mauritania. **A–I.** Timiris coral mound chain, MSM16–3/GeoB14876. **A–B.** Paratype (SMF373040). **A.** Ventral view, height 2.9 mm, width 1.8 mm. **B.** Columellar folds. **C–D.** Holotype (SMF359034). **C.** Ventral view, height 3.1 mm, width 1.9 mm. **D.** Columellar folds. **E–G.** Paratype (SMF373040). **E–F.** Ventral and side views, height 3.2 mm, width 1.8 mm, tumidity 1.6 mm. **G.** Micro-sculpture above second columellar tooth, see arrow in E–F. **H.** Paratype (SMF373040), ventral view, height 3.0 mm, width 1.8 mm. **I.** Paratype (SMF373040), side view, height 3.1 mm, tumidity 1.6 mm. **J–K.** Tamxat Mounds, MSM16–3/GeoB14904, ventral view, height 2.8 mm, width 1.7 mm.

irregular growth lines; microscopic sculpture of flakes oriented towards exterior on callus of external lip, columella and columellar folds, base and apex, callus reclining in parietal area; internally smooth. Aperture curved, elongated, narrowest and maximum curvature at apex, wide at base. Protoconch invisible, convolved inside shell.

Remarks

Similar to the other new species, *Granulina sigridae* sp. nov. has no labial denticles, but the shell morphology is different. The shell is not as wide (width/height ratio 0.56) as in *G. sandrae* sp. nov. (0.69) and it lacks the widely flared apical channel like in *G. reginae* sp. nov. *Granulina sigridae* is similar to *G. occulta* but that species has labial denticles and it lacks the wide channel at the base. *Granulina ronaldi* sp. nov. has separated columellar folds, an apex with more convexity, a base that is more tapered, and has a thicker lip.

The bathymetric range is 200–548 m; the latitudinal range is 17.4–20.4° N. Most of the specimens were found in coral rubble with mud and an association with upper bathyal coral-related habitats is likely.

Key to Mauritanian species in *Granulina*

This key is for small (< 5 mm) ovoid convolved shell with an internal protoconch.

1. Shells with denticles on inside external lip..... 2
 - Without labial denticles 6
2. Shell very small (height < 2.1 mm) 3
 - Shell larger (height > 2.1 mm)..... 4
3. Broad triangular-rounded outline..... *G. mauretunica* Gofas, 1992
 - Oval outline *G. aff. crassa*
 - Angular elongated (coffin)..... *G. crassa* Smriglio, Gubbioli & Mariottini, 2000
4. Oval outline, even labial denticles..... *G. nofronii* Smriglio, Gubbioli & Mariottini, 2000
 - Angular (coffin) outline 5
5. Weak rostration (ab-)apically..... *G. crystallina* Smriglio, Gubbioli & Mariottini, 2000
 - No rostration *G. cerea* Smriglio, Gubbioli & Mariottini, 2000
6. Wide open apical channel *G. reginae* sp. nov.
 - Apical channel curved and narrow 7
7. Broad outline (width/height 0.69) with weakly pointed apex *G. sandrae* sp. nov.
 - Elongated outline (width/height less than 0.6) 8
8. Rounded apically, thin lip, coalescent upper columellar teeth *G. sigridae* sp. nov.
 - Tapered (ab-)apically, thicker lip, separate columellar teeth *G. ronaldi* sp. nov.

Discussion

Nine species of *Granulina* were present in our samples, of which four are new: *G. reginae* sp. nov., *G. ronaldi* sp. nov., *G. sigridae* sp. nov. and *G. sandrae* sp. nov. One species was left in open nomenclature (*G. aff. crassa*) because the available material was inadequate. Four species were already described by Smriglio *et al.* (2000): *G. cerea*, *G. crassa*, *G. crystallina* and *G. nofronii*.

Over 300 shells of the four newly described species have a thickened outer lip and lack labial denticles. Therefore, the argument for referring these shells as subadult without denticles is rejected. All four new species are clearly part of a radiation in *Granulina* that was overlooked in the past; this radiation is currently only known from upper bathyal and lower shelf depth zones, often related to deep-water corals found off Mauritania. Three species were found off central Western Sahara. We can only speculate about their habitats, as we have not been able to do any research on any living species and their functional traits. The presence of four sympatric species without labial denticles on the lower shelf and upper bathyal depth range off Mauritania and Western Sahara probably suggests a phyletic clade with a common ancestor.

The absence of labial denticles is not uncommon in genera of Granulinidae and this character has not been used to erect a new genus. The genera *Granulinopsis* Boyer, 2017 and *Pugnus* Hedley, 1896 in Granulinidae contain species with and without labial denticles. In *Granulina*, *G. fernandesi* from Senegal and Cape Verde lacks labial teeth although its granular sculpture and oblong shape does not indicate a relationship to the Mauritanian species.

All four species described by Smriglio *et al.* (2000) were confirmed in our large set. Their identification is more difficult when compared to the newly described species. These four species showed a great variability in size, outline and other morphological features and we are uncertain whether we deal with exactly four species with a coffin-shaped outline and with labial denticles. As a lower limit, we identify clearly three species: the smaller *Granulina crassa*, *G. cerea* and the elliptical *G. nofronii* with its stronger labial denticles. In this classification, *G. crystallina* is a synonym of *G. cerea*. In contrast, one could define a set of giants or oval specimens as additional species. Without additional genetic analyses, further lumping or splitting of this group is not expedient. Currently, we lack suitable soft tissue to perform these analyses.

All nine deep-water species seem to be sympatric, occurring on the lower shelf and upper bathyal depth range off Mauritania and most of them also off Western Sahara. It is likely that more Mauritanian species are present off Western Sahara because the latter area has been undersampled.

We looked at the micro-sculpture of various NE Atlantic and Mediterranean species using a scanning electron microscope. For this, we concentrated on the same shell surface between the second and the third columellar folds. No differences between the species could be detected; most species have a similar micro-sculpture. Hence, we were unable to use the micro-sculpture for specific differentiation. Possibly, a future study of the micro-sculpture across the full shell surface area of different species leads to an improved specific differentiation. An exception is *Granulina vanhareni* (van Aartsen, Menkhorst & Gittenberger, 1984), which shows a more granular micro-sculpture on the callus as well as on the entire ultimate whorl. Future research, e.g., using genetic sequencing, may prove that van Aartsen *et al.* (1984) were correct by not placing this species in *Granulina*.

A missing species in our study is *Granulina mauretana* Gofas, 1992, we clearly did not sample its littoral habitat. Also, other species found off western Africa in Senegal or further south were not found in our material: for example, *Granulina africana* Gofas, 1992 or *Granulina pierrepineaui* Pin & Boyer, 1995.

Caballero Herrera *et al.* (2022) made a detailed chorotype analysis of the bio-geographic regions of western Africa using bivalve distribution data. They confirmed the empirical observations of Le Loeuff & Cosel (1998) who observed a break in distributions of NW African benthic fauna near the border between southern Morocco and Western Sahara. The benthic fauna of Morocco and to a lesser extent the Canary Islands resembles that of NW Europe whereas Senegal, Mauritania and Western Sahara form a transition zone to the proper West African fauna. South of Senegal they indicated a biotic region with tropical

West African fauna. Ekman (1953) placed the interface between the European and western African biotic regions further South at Cap Vert. Briggs (1974) placed the interface further north at Cap Blanc, his bioregions were based on fish distribution data. Costello *et al.* (2017) studied global bioregional zones on a very large faunal data set. Their analyses provided insufficient resolution to distinguish the NW African biotic regions. Our distribution data show Mauritanian species in *Granulina* extending north to Western Sahara but not extending into NW Morocco. Additionally, species in *Granulina* known from NW Morocco or the Canary Islands have not been found off Mauritania or Western Sahara. The distributions of species of *Granulina* adhere to the biotic regions shown in Caballero Herrera *et al.* (2022). The southern limits of the distribution ranges are currently poorly defined as we did not have access to deep-water samples south of Mauritania.

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