

Five new species of Arcidae from Brazil with description of new genus: *Paranadara* (Mollusca: Bivalvia)

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New arcid species belonging to the genera Paranadara gen. nov., Acar and Asperarca (new record) are described for the western Atlantic Ocean based on shell morphology. Paranadara taludae sp. nov., Acar naturezae sp. nov., Acar oliveirae sp. nov. and Asperarca tarcylae sp. nov. were collected off north-eastern Brazil between depths of 70 and 690 m, whereas Acar lepidiformis sp. nov. was dredged off the State of Rio Grande do Sul (southern Brazil) at a depth of 141 m. There are no species along the Brazilian coast that are morphologically similar to Paranadara taludae sp. nov. Acar naturezae sp. nov., Acar lepidiformis and Acar oliveirae sp. nov. are similar to this genus due to shape, ligament, presence of concentric lamellae cut by radial threads, a broad dorsal area and a markedly narrowed anterior region in comparison to the posterior region, which is strongly expanded. Asperarca tarcylae sp. nov. is similar to this genus due to the presence of a small edentulous region below the umbo and smooth inner margin.

Keywords: taxonomy, Bivalvia, Arcoidea, *Acar*, *Paranadara*, *Asperarca*, biodiversity

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INTRODUCTION

Arcidae Lamarck, 1809 is a large, diverse family of marine bivalves characteristic of the continental shelf (Allen & Turner, 1974), ranging in size from minute to large (length 4 to 100 mm). These organisms are mostly found in warm, shallow, tropical seas worldwide, inhabiting a wide array of benthic environments from the lower intertidal to sublittoral zones, on coral, rocks, stones, sponges, broken shells, calcareous algae, gravel and grassy bottoms or burrowed in sand or mud and rarely in estuarine or fresh waters (Abbott, 1974; Coan *et al.*, 2000; Mikkelsen & Bieler, 2008). This family is represented by 12 living genera and 200 to 250 species (Coan *et al.*, 2000; Mikkelsen & Bieler, 2008), but few are known for the deep sea (e.g. *Bentharca* Verrill & Bush, 1898; *Bathyarca* Kobelt, 1891).

In the South Atlantic, the family Arcidae is represented by the genera *Arca* Linnaeus, 1758, *Barbatia* Gray, 1842, *Anadara* Gray, 1847 (Rios, 2009), *Acar* Gray, 1857 (Simone, 2009), *Bentharca* Verrill & Bush, 1898 (Prado & Barros, 1994; Passos & Birman, 2009) and *Bathyarca* Kobelt, 1891 (Absalão *et al.*, 2003; Rios, 2009). As might be expected, little systematic work has been conducted on the group and descriptions of taxa are non-existent for the deep sea off Brazil.

Thirteen species of arcids are currently known for the Brazilian coast, all broadly distributed in the western

Atlantic Ocean (Rios, 2009), except *Acar transmar* Simone, 2009, *Bathyarca* sp. (Absalão *et al.*, 2003) and the species described here, four of which probably live exclusively in deep waters.

The genera currently included in the family Arcidae are the object of discussion in the literature (Knudsen, 1970; Kilburn, 1983; Oliver & von Cosel, 1992; La Perna, 1998; Coan *et al.*, 2000; Oliver & Holmes, 2006; Kamenev, 2007a, b; Mikkelsen & Bieler, 2008). The main difficulty in conchological studies on new species is the lack of a consensus on the definition of genera. The disagreement between genus arrangements within the family Arcidae is also a barrier to the positioning of species (Kilburn, 1983; Oliver & von Cosel, 1992; La Perna, 1998; Coan *et al.*, 2000; Oliver & Holmes, 2006; Kamenev, 2007a, b; Mikkelsen & Bieler, 2008).

This paper describes six new taxa of the Arcidae, the first record of *Asperarca* for the South Atlantic and offers a brief discussion on the characteristics considered important to the determination of genera.

MATERIALS AND METHODS

The malacological material used in the present study had the following origins: (1) Saldanha Sul II Expedition, carried out in 1969 off the continental shelf of the State of Rio Grande do Sul by the oceanographic vessel 'Almirante Saldanha' and deposited at the Oceanography Department of the Universidade Federal de Pernambuco (Brazil); (2) oceanographic campaigns performed as part of the Live Resources of the Exclusive Economic Zone Program (REVIZEE/

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North-east) of the Brazilian government between 2000 and 2001 under the coordination of the Research and Management Center for Fishing Resources on the continental slope of north-eastern Brazil by the research vessel 'Natureza'; and (3) dredging performed in December 2004 off the State of Pernambuco by the research vessel 'Sinuelo', which belongs to the Fishery and Aquiculture Department of the Universidade Federal Rural de Pernambuco (Brazil).

The conchological characterization of *Acar* (Bartsch, 1931; Oliver & Allen, 1980; Kilburn, 1983; Oliver & von Cosel, 1992; Coan *et al.*, 2000; Mikkelsen & Bieler, 2008; Simone, 2009) and *Asperarca* (Newell, 1969; La Perna, 1998; Kamenev, 2007a) is based on the respective studies. *Paranadara* nov. gen. was defined based on arguments raised in studies addressing the subfamily Anadarinae Reinhart, 1935 (Newell, 1969; Keen, 1971; Abbott, 1974; Kilburn, 1983; Oliver & von Cosel, 1992; Lutaenko, 1993; Evseev & Lutaenko, 1998; Coan *et al.*, 2000; Lutaenko, 2003; Mikkelsen & Bieler, 2008; Rios, 2009). Identification of the material was carried out comparing the morphology of the shells with original descriptions and illustrations of types of the species and congeners. Comparisons were also made with species pertaining to other genera due to a greater degree of similarity regarding characteristics. Based on both the literature and observations on the material detailed herein, a brief discussion is offered on genus characteristics in order to assist future studies on this family.

Type specimens were photographed and submitted to electronic scanning performed on the JEOL JSM 6360 at the Electron Microscope Laboratory of the Instituto Tecnológico de Pernambuco (Brazil).

Abbreviations used: D, dredging; Lt, length of shell; Wt, width of shell; H, height of shell; m, metres. Institutional abbreviations: Departamento de Oceanografia da Universidade Federal de Pernambuco (DOUFPE Mollusca), Haus Der Natur Cismar, Germany (MHNC); Museu Nacional do Rio de Janeiro (MNRJ), Rio de Janeiro, Brazil; Museu Oceanográfico Prof. Eliezer de Carvalho Rios (MORG), Rio Grande, Rio Grande do Sul, Brazil; Museu de Zoologia da Universidade de São Paulo (MZSP), São Paulo, Brazil.

SYSTEMATICS

Subclass PTERIOMORPHIA Beurlen, 1944

Order ARCOIDA Stoliczka, 1944

Family ARCIDAE Lamarck, 1809

Subfamily Anadarinae Reinhart, 1935

Genus *Paranadara* nov. gen.

TYPE SPECIES

Paranadara taludae sp. nov.

ETYMOLOGY

From the Latin '*Para*'—alongside; *Paranadara* is positioned alongside *Anadara*.

DESCRIPTION

Shell of small size, transversally elongated, strongly inequilateral, white colour, equivalve. Valve outline subrectangular. Umbo small, rounded and incurved. Ligament amphidetic. Anterior region narrower than posterior region.

Ornamented by wide radial ribs of same size as the interspaces, in groove shape. Ventral margin sinuate and slanted. Posterior slope does not form carina. Central area forming small depression with thin axial ribs. Inner margin forming small crenulation; edentulous gap, below the umbo, interrupting the tooth series. Anterior and posterior teeth short and oblique.

REMARKS

The diagnostic characters of *Paranadara* gen. nov. allow including this genus in the subfamily Anadarinae Reinhart, 1935 (Coan *et al.*, 2000). These characters relate it especially to the genus *Anadara* Gray, 1847 as well as other Anadarinae (e.g. *Bathyarca* Kobelt, 1891; *Bentharca* Verrill & Bush, 1898; *Samacar* Iredale, 1936) (Newell, 1969; Coan *et al.*, 2000).

Anadara has a hinge with continuous dentition and no byssal gape on the ventral margin (Newell, 1969; Keen, 1971; Coan *et al.*, 2000; Mikkelsen & Bieler, 2008). According to Newell (1969), *Anadara* groups two subgenera (*Anadara sensu stricto* and *Lunarca*). *Lunarca* has a dentition divided into two sets that may be related to *Paranadara* gen. nov., but the oval shape of *Lunarca* diverges from the antero-posterior elongation of the new genus presented here. Keen (1971) offers a key for the different subgenera included in *Anadara*. *Paranadara* initially falls within the concept of *Anadara sensu stricto*, but in the diagnosis of this subgenus, the set of continuous, uniform teeth excludes *Paranadara*, which has a gap between the sets of teeth. Species of *Anadara* recorded for South Africa and Mozambique may have a byssus, but do not have a byssal gape (Kilburn, 1983). *Anadara geissei* (Dunker, 1891) recorded in shallow waters of western tropical Africa has weak anterior ribs and wider, flatter posterior ribs, a narrow anterior ventral byssal gape and two distinct sets of teeth on the hinge, with no edentulous region (Oliver & von Cosel, 1992). The new species of *Paranadara* described here has wide, rounded, uniform radial ribs, a central ventral byssal gape and an edentulous gap interrupting the sets of teeth.

Anadara is recorded in shallow waters on the coast of Brazil (Abbott, 1974; Rios, 1994), whereas *Paranadara* is typically found on the continental slope off north-eastern Brazil. *Paranadara* resembles *Anadara* in the following aspects: external sculpture with numerous radial ribs; interspaces formed by deep grooves; elongated, amphidetic ligament; and crenulated inner margin of the shell. *Paranadara* differs from *Anadara* in that it has a small umbo and two series of denticles on the hinge separated by an edentulous region divergent at the terminations. *Paranadara* has a narrow byssal gape. *Anadara* has a large umbo, continuous series of denticles on the hinge and denticles of similar size. *Anadara* has no byssal gape (Newell, 1969; Keen, 1971; Kilburn, 1983; Oliver & von Cosel, 1992; Coan *et al.*, 2000; Mikkelsen & Bieler, 2008). The situation on the ventral margin in *Paranadara* is found on the juvenile and adult specimens and likely reflects an epibyssate lifestyle. The evolution from the the epibyssate to endobyssate lifestyle in Arcidae is possible (La Perna, 2006), but the maintenance of the byssal gap in *Anadara* requires further investigation. Juvenile specimens of *Anadara notabilis* (Röding, 1798) from the Brazilian coast do not have a ventral margin with situation or an edentulous gap below the umbo interrupting the tooth series.

Paranadara resembles *Bathyarca* in the following characteristics: small, fragile, elongated shell; anterior umbo; two series of denticles with edentulous region on the hinge and divergent at the termination; and an amphidetic ligament (e.g. *Bathyarca glacialis*) (Coan *et al.*, 2000). The new genus described here differs from *Bathyarca* in the shape of the shell, small umbo size, ribbed outer sculpture and crenulated inner margin. *Bathyarca* has a shorter length in relation to shell height and a large prominent umbo. It does not have radial ribs separated by grooves and the inner margin of the shell is smooth. Together with *Bentharca*, *Bathyarca* represents deep-sea, cold-water Anadarinae (Keen, 1971; Abbott, 1974; Coan *et al.*, 2000).

Paranadara resembles *Bentharca* in the elongated shape of the shell. These genera have a narrowed anterior region, anterior umbo, two series of denticles with an edentulous region on the hinge and divergent at the termination and amphidetic ligament that is sinuate on the ventral margin. These genera differ with regard to the outer sculpture. *Bentharca* has a commarginal sculpture and the inner margin of the shell is smooth (Coan *et al.*, 2000; Kamenev, 2007a). The ecological aspect is the same as that described for *Bathyarca* (Kilburn, 1983; Coan *et al.*, 2000; Kamenev, 2007a).

Paranadara resembles *Samacar* with regard to the following characteristics: inequilateral, elongated shell, anterior umbo, hinge with short anterior series of denticles, edentulous median region, long posterior series of denticles and amphidetic ligament. The genera differ in their outer sculpture. *Samacar* has a low sculpture, commarginal, lamellar ribs crossed by weak radial sculptures and the inner margin is smooth (Kilburn, 1983; Coan *et al.*, 2000; Kamenev, 2007a). *Paranadara* is biogeographically distant from *Samacar*. There are no records of *Samacar* in the Atlantic, only reports of the group in the Indo-Pacific and North Pacific (Kilburn, 1983; Coan *et al.*, 2000; Kamenev, 2007b).

Paranadara taludae sp. nov.
(Figures 1–6)

TYPE MATERIAL

Holotype MNRJ 11127 (Ht 4.0 mm, Lt 7.59 mm, W 1.35 mm)—off the State of Rio Grande do Norte, Brazil, 'Natureza' (D-23, 04°51'S 35°06'W, muddy bottom, 24 November 2001, 375 m).

2 paratypes MZSP 84246; 1 paratype, MHNC 64514—all off the State of Pernambuco, Brazil, 'Natureza' (D-11, 08°46'S 34°44'W, muddy bottom, 18 November 2000, 690 m); 3 paratypes, MORG 50781; 3 paratypes, MNRJ 11134—all off the State of Rio Grande do Norte, Brazil, 'Natureza' (D-23, 04°51'S 35°06'W, muddy bottom, 24 November 2001, 375 m).

COMPARATIVE MATERIAL EXAMINED

Anadara notabilis (Röding, 1798). DOUFPE Mollusca n°5372—8 valves—State of Rio Grande do Norte, Brazil, 'Astro Garoupa' (Station 27A, 4°59'24"S 36°40'51"W, 18 July 2002, 13.5 m).

DESCRIPTION

Shell small (Ht 4.0 mm, Lt 7.59 mm), white, shiny, elongated in contour, transversely elongated. Equivalve, inequilateral,

with numerous ribs (Figures 1 & 2). Dorsal margin truncated with flat hinge. Ventral margin sinuate and weakly slanted. Posterior margin undeveloped, non-sinuate, convex, forming weakly obtuse angle with dorsal margin. Ligament amphidetic. Ligamental area very narrow, longer than high and anteriorly increasing posterior to umbo, ornamented by very thin parallel threads along entire area (Figure 3). Umbo yellow, anterior, translucent, small, prosogyrous, rounded and incurved. Posterior slope triangular, convex, defined by one radial rib with the same appearance as the other ribs, not forming carina, ornamented by 7 strong, smooth, rounded radial ribs with well-marked grooves between them; grooves exhibit fine growth threads with more raised concentric threads. Last rib attached to dorsal margin. Ventral margin entirely crenulated in concordance with terminations of strong outer radial ribs. Central area medially concave, with finer ribs that increase in thickness in antero-posterior direction. Strong radial ribs, separated by deep grooves ornamented by raised, equally spaced concentric threads, forming a fine decussate pattern. Anterior area with 7 strong radial ribs, with interspaces similar to those of central region. Inner margin forming small, raised denticles; pallial scar hardly evident. Inner area white and smooth, with outer ribs evident. Muscle scars rounded, slightly marked, posterior of which is larger. Hinge with 5 to 6 anterior teeth and 13 to 17 posterior teeth, which diverge in final portion (Figure 4). Edentulous area below umbo.

ETYMOLOGY

The specific name *taludae* is in reference to the continental slope where the new species was found, which is *Talude Continental* in Portuguese.

TYPE LOCALITY

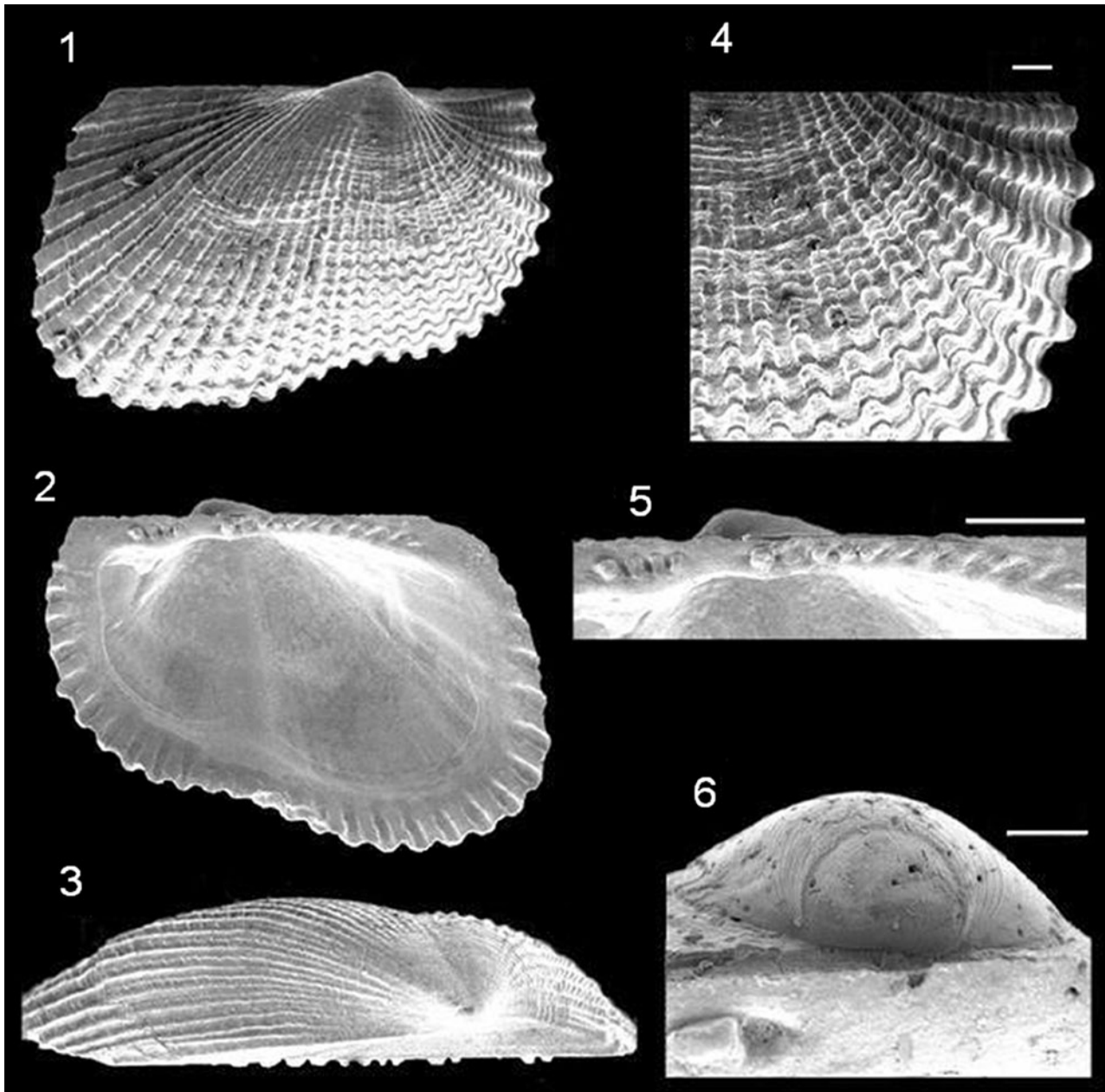
Continental slope off the State of Pernambuco, Brazil.

DISTRIBUTION

Off the States of Rio Grande do Norte and Pernambuco, north-eastern Brazil, at depths between 375 and 690 m.

REMARKS

Paranadara taludae sp. nov is doubtlessly one of the most easily recognized taxa for the Brazilian coast due to its fragile appearance and small dimensions. *Paranadara taludae* resembles *Anadara antiquata* (Linné, 1758) (type species of *Anadara*) in the anterior position of the umbo, prominent ribs separated by deep grooves and crenulations on the inner margin of the shell. The main differences between the species are the small umbo, hinge with edentulous region and presence of a byssal gape on the ventral margin in *P. taludae*, whereas *A. antiquata* has a large umbo, continuous hinge and no byssal gape. The elongated shape of *P. taludae* resembles a miniature *Anadara notabilis* (Röding, 1798) from the Brazilian coast (see Rios, 1994: 232, pl 80, figure 1144; Mikkelsen & Bieler, 2008: 54; Rios, 2009: 474, figure 1335), but the ventral margin is slanted and the anterior region is narrower. The dentition also exhibits important differences, for the teeth of the posterior and anterior terminations are convergent in *A. notabilis* (Röding, 1798), whereas these teeth are strongly divergent in *P. taludae*. *Anadara concinna* (Sowerby, 1833) from the North Pacific (see Keen, 1971: 42, figure 78) is similar to *P. taludae* in its elongated elliptical shape, inner margin forming small similarly raised denticles

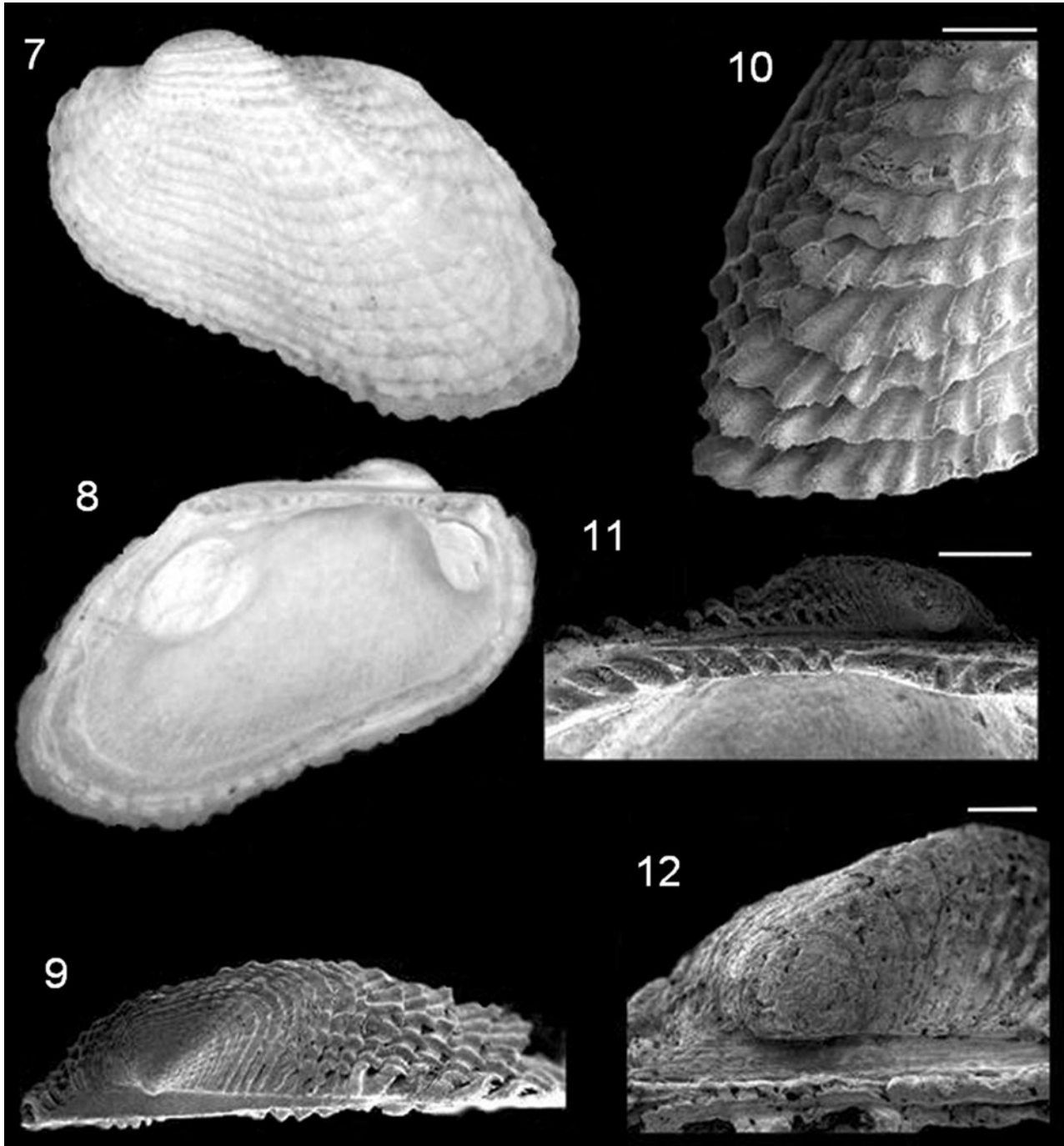


Figs 1–6. *Parnadara taludae*: (1) external view of right valve—holotype (MNRJ 11127; Lt 4.0 mm); (2) Internal view—holotype; (3) dorsal view of umbonal area—holotype; (4) external sculpture—holotype; (5) hinge area—holotype; (6) prodissoconch—holotype. Scale bars: (4) 100 μm ; (5) 500 μm ; (6) 50 μm .

and rounded radial ribs. It can be distinguished from the species described here by the fact that it is more strongly sulcate and by the uniformity of the radial ribs, which in *P. taludae* are thinner in the anterior region and become progressively thicker in the posterior direction. *Barbatia* (*Nipponarca*) *allocostata* Oliver & von Cosel, 1992 from West Africa (see Oliver & von Cosel, 1992: 323, pl IV, figures 1a, b & 2; Oliver & Holmes, 2006: 238, figure 2) is similar to *P. taludae* in the presence of strong radial ribs separated by long grooves, but the species described here has these grooves ornamented, crossed by raised concentric threads, equally spaced and forming a fine reticulum. The location of the umbo, situated one-third from the dorsal margin of the anterior end, and the crenulated ventral margin are also characteristics that bring these two species close together, but the subrectangular contour, nearly parallel

dorsal and ventral margins and the long continuous series of teeth on the hinge of *B. allocostata* distinguish it from the species described here, which exhibits an elliptical, transversely elongated shape, a sinuate ventral margin and the presence of an edentulous area below the umbo. *Barbatia allocostata* is more frequently found offshore at about 15 m (Oliver & von Cosel, 1992), whereas *P. taludae* is typically found on the continental slope off north-eastern Brazil, occurring at depths from 375 to 690 m. The subgenus *Nipponarca* is a subdivision of *Barbatia*, but has kinship with infaunal Anadarinae (Oliver & von Cosel, 1992; Oliver & Holmes, 2006).

Subfamily ARCINAE Lamarck, 1818
Genus *Acar* Gray, 1857



Figs 7–12. *Acar naturezae* sp. nov.: (7) external view of left valve—holotype (MNRJ 11128: Lt 7.5 mm); (8) internal view of left valve—holotype; (9) dorsal view of umbonal area of right valve—paratype (MZSP 84247); (10) external sculpture of right valve—paratype (MZSP 84247); (11) hinge area of left valve—paratype (MZSP 84247); (12) prodissoconch of right valve—paratype (MZSP 84247). Scale bars: (10) 1 mm; (11) 500 μm; (12) 100 μm.

TYPE SPECIES

Arca gradata Broderip and Sowerby, 1829, original designation by Gray, 1857: 369.

DIAGNOSIS

Shell usually small, thick, heavy, inequilateral, quadrate to subtrapezoidal. Periostracum thin, dehiscent. Sculpture with radial riblets and commarginal lirae. Cardinal area narrow laterally; ligament opisthodontic. Posterior keel developed. Byssal gape narrow.

Acar naturezae sp. nov.

(Figures 7–12)

TYPE MATERIAL

Holotype MNRJ 11128 (Ht 7.5 mm, Lt 12.8 mm, W 1.7 mm)—off the State of Sergipe, Brazil, ‘Natureza’ (D-08, 11°58’S 36°49’W, muddy bottom, 1 November 2000, 100 m).
 2 paratypes MNRJ 11135, 2 paratypes MORG 50784, 2 paratypes MZSP 84247, 3 paratypes MNRJ 11136, 2 paratypes,

MORG 50780, 2 paratypes MZSP 84248, 2 paratypes MORG 50779, 2 paratypes MZSP 84249—all off the State of Sergipe, Brazil, 'Natureza' (D-08, 11°58'S 36°49'W, muddy bottom, 1 November 2000, 100 m); 1 paratype, MHNC 64511—off the State of Rio Grande do Norte, Brazil, 'Natureza' (D-22, 04°15'S 37°12'W, muddy bottom, 10 November 2001, 206 m).

DESCRIPTION

Shell small (Ht 7.5 mm, Lt 12.8 mm), subtrapezoidal to elliptical (Figure 7), in some forms more worn, yellowish white, opaque with radial ribs strongly tinged yellow, especially more recent ribs. Shell transversely elongated, valves apparently equivalve, strongly inequilateral. Anterior margin rounded, 1.7 times wider than long. Posterior margin developed and slanted, weakly convex, forming obtuse angle with dorsal margin. Dorsal margin flat, narrow, slightly arched and with strong hinge. Ventral margin irregular, with long byssal gape. Ligamental area more developed below umbo and in anterior region, narrowing in posterior direction, ornamented by fine threads along entire area. Umbo prosogyrous, small, incurved, slightly projected over ligamental area (Figure 12), situated about 1/3 from margin. Posterior slope defined by a carina, projecting small arched lamellae in the posterior direction. Posterior slope ornamented by 8 to 10 strong, nodular radial ribs, sometimes barely evident, forming concentric ridges in this region. These ribs are cut by 10 to 17 slightly elevated, strong, concentric ridges of irregular prominence. Posterior slope developed, slightly triangular and strongly ornamented, forming reticulum or, more rarely, condensed concentric ridges. Ventral and posterior margins more crenulated anteriorly than anterior margin, in concordance with outer radial ribs. Central area with 19 to 24 very condensed radial ribs, cut by 18 to 26 concentric ridges. Anterior area formed by 4 to 6 nodular axial ribs, crossed by continuation of ridges in central area. Inner margin entirely crenulated, less evident in byssal gape. Inner area white, strong entire pallial scar. Muscle scars well marked, posterior of which is larger (Figure 8), with small calcareous projections toward interior of umbo. Dentition variable, generally with 5 to 7 prosocline anterior teeth and no edentulous area. 1 to 2 intermediate teeth between anterior and posterior areas, more typically orthocline (Figure 10).

ETYMOLOGY

The specific epithet '*naturezae*' refers to the name of the research vessel 'Natureza' that dredged in north-eastern Brazil where the new species was found.

TYPE LOCALITY

State of Sergipe, Brazil (11°58.7'00"S 36°49.2'00"W), at a depth of 100 m.

DISTRIBUTION

Off the States of Sergipe and Rio Grande do Norte, north-eastern Brazil, at depths between 100 and 206 m.

REMARKS

Acar naturezae sp. nov. exhibits morphological similarities to *Acar domingensis* (Lamarck, 1819) from the Caribbean to the Brazilian coast, especially in shape, with the ornamentation forming a reticulum and the posterior end dipping slightly downward with a sharp termination. *Acar naturezae* differs

from *A. domingensis* in that it is more elongated transversely (Figures 7 & 8), the radial ribs are more strongly tinged yellow, the posterior slope has 8 to 10 strong nodular radial ribs (Figure 10) and 10 to 17 strong concentric ridges with the formation of a long byssal gape. *Acar domingensis* has 7 to 9 strong nodular radial ribs in the posterior slope and 15 to 21 concentric ridges (see Rios, 1994: 232, pl 80, figure 1144; Simone & Chichvarkhin, 2004: 363, figures 15–19; Mikkelsen & Bieler, 2008: 54; Rios, 2009: 472, figure 1328). *Acar transmar* Simone, 2009, recently described for the South Atlantic and endemic to the São Pedro/São Paulo Archipelago (Brazil), exhibits similarities to *A. naturezae* in the trapezoidal shape and entirely crenulated inner margin. *Acar transmar* has convex valves, reticulated marked external sculpture, smaller size (up to 5 mm in length) and uniform teeth, whereas *A. naturezae* has compressed valves (Figure 9), lamellar external structure (Figure 4), large size (7 mm in length) and clearly separated, differently sized teeth (Figure 5). *Asperarca secreta* La Perna, 1998 (see La Perna, 1998: pl. 2, figures 5–8) from the central Mediterranean, is one of the species from this genus that could be similar to *A. naturezae*, exhibiting a subtrapezoidal contour and a concentric lamellar sculpture, but the species described differs in its dimensions as well as in not exhibiting a thin hinge-plate with an edentulous gap, the posterior keel is not as pronounced and ventral and posterior margins are crenulated interiorly.

Acar lepidiformis sp. nov.

(Figures 13–18)

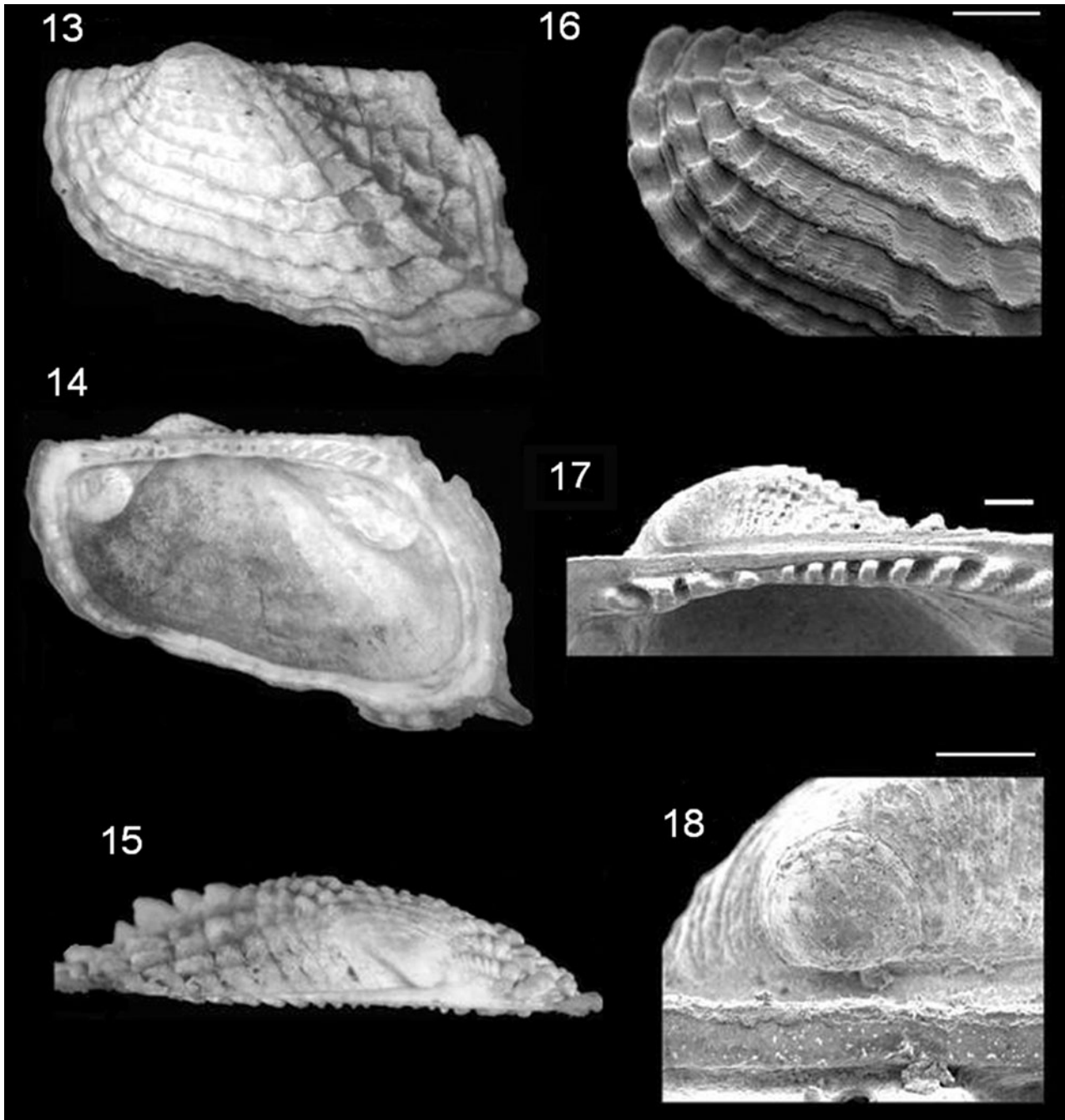
TYPE MATERIAL

Holotype MNRJ 11124 (Ht 6.5 mm, Lt 11.7 mm, W 1.8 3 mm)—off the State of Rio Grande do Sul, Brazil, 'Almirante Saldanha' (2233A, 30°41'S 49°31'W; muddy bottom, 18 October 1969, 141 m).

1 paratype, MNRJ 11129, 1 paratype MZSP 84240, 2 paratypes MZSP 84239, 3 paratypes MORG 50778, 6 paratypes MZSP 84241, 1 paratype MHNC 64510—off the State of Rio Grande do Sul, Brazil, 'Almirante Saldanha' (2233A, 30°41'S 49°31'W; muddy bottom, 18 October 1969, 141 m).

DESCRIPTION

Shell small (Ht 6.5 mm, Lt 11.7 mm), white, opaque, normally subtrapezoidal and transversely elongated (Figures 13 & 14). Equivalve, strongly inequilateral. Anterior margin thin. Posterior margin developed, weakly convex, forming obtuse angle with dorsal margin. Dorsal margin truncated. Hinge approximately straight. Ventral margin irregularly slanted, with short byssal depression. Ligamental area very narrow, increasing anteriorly, ornamented by fine parallel threads along entire area (Figure 15). Umbo prosogyrous, small, incurved, sharp at extremity, situated about one-fifth from dorsal margin from the anterior end (Figure 16). Posterior slope well defined by a carina, strongly ornamented by spine-shaped lamellae projecting posteriorly, ornamented by 3 to 4 strong radial ribs, finely crossed by 7 to 10 raised, concentric lamellae of subequal prominence, producing byssal depression. Central area with strong concentric ridges, marked by about 11 short small irregular projections. Posterior slope slightly convex, triangular and sharp.



Figs 13–18. *Acar lepidiformis*: (13) external view of left valve—holotype (MNRJ 11124; Lt 6.5 mm); (14) internal view of the right valve—paratype (MNRJ 11129); (15) dorsal view of umbonal area of left valve—holotype; (16) external sculpture of left valve—paratype (MZSP 84239); (17) hinge area of right valve—paratype (MZSP 84239); (18) prodissoconch of right valve—paratype (MZSP 84239). Scale bars: (17) 200 μ m; (18) 100 μ m.

Ventral, posterior and anterior margins interiorly crenulated in accordance with terminations of outer ribs, stronger on ventral margin behind continuous radial ribs over lamellae to ventral margin. Anterior area with 3 to 4 strong radial ribs crossed by continuation of lamellae of central area. Entire pallial scar well marked. Inner area white, of irregular aspect, with outer axial ribs visible. Muscle scars well marked, posterior of which is larger and anterior of which with dorsal fold that extends to interior of umbonal area (Figure 14). Hinge with teeth of moderate size, 4 to 6 anterior teeth and 8 to 12 opisthocline posterior teeth, with no edentulous area (Figure 17).

ETYMOLOGY

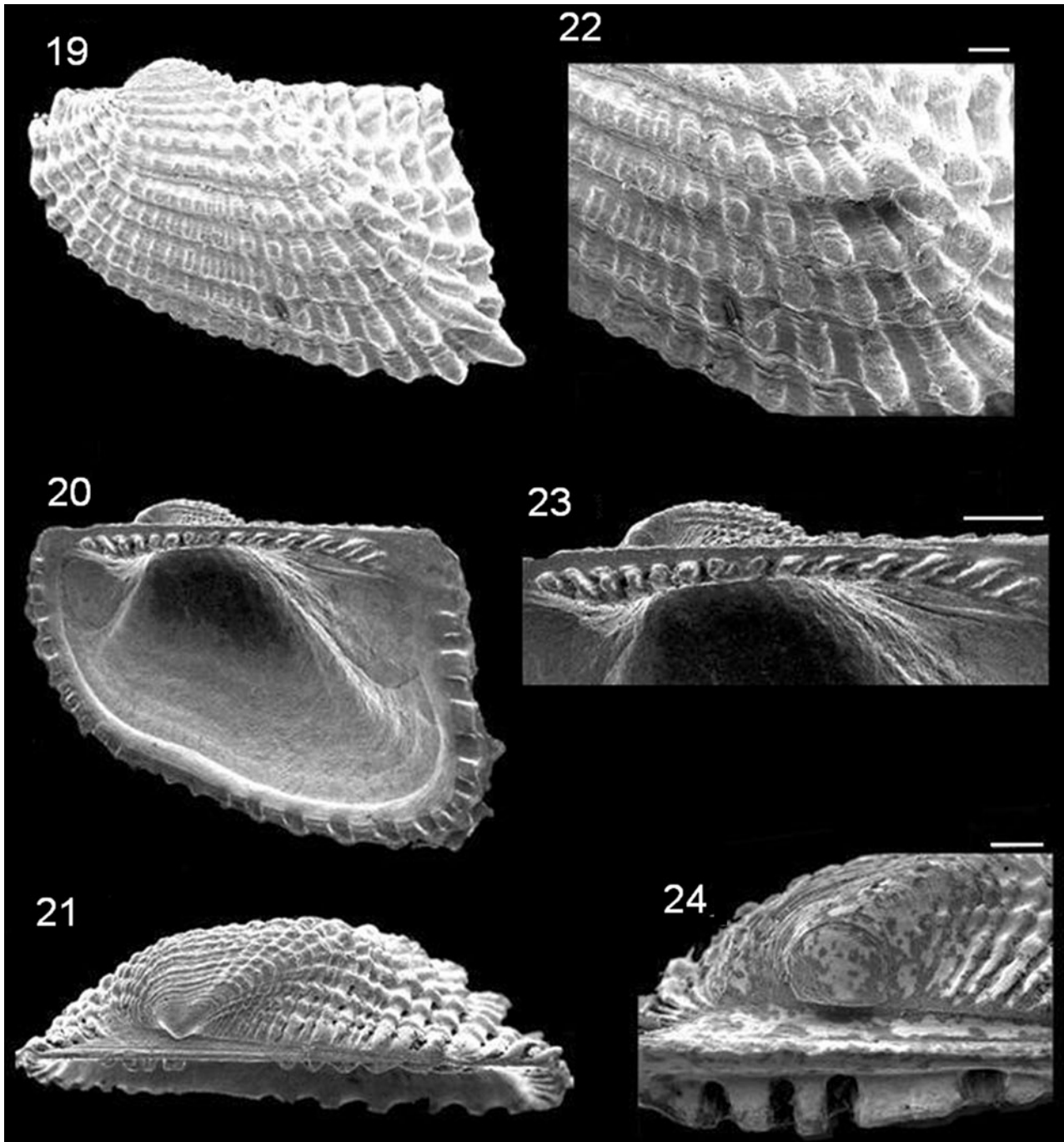
The specific name '*lepidiformis*' refers to the aspect of scales on the external sculpture of the valves (Greek *lepidus* = scale).

TYPE LOCALITY

Off the State of Rio Grande do Sul, Brazil (30°41'S 49°31'W), at a depth of 141 m.

DISTRIBUTION

Restricted off the State of Rio Grande do Sul, Brazil, at a depth of 141 m.

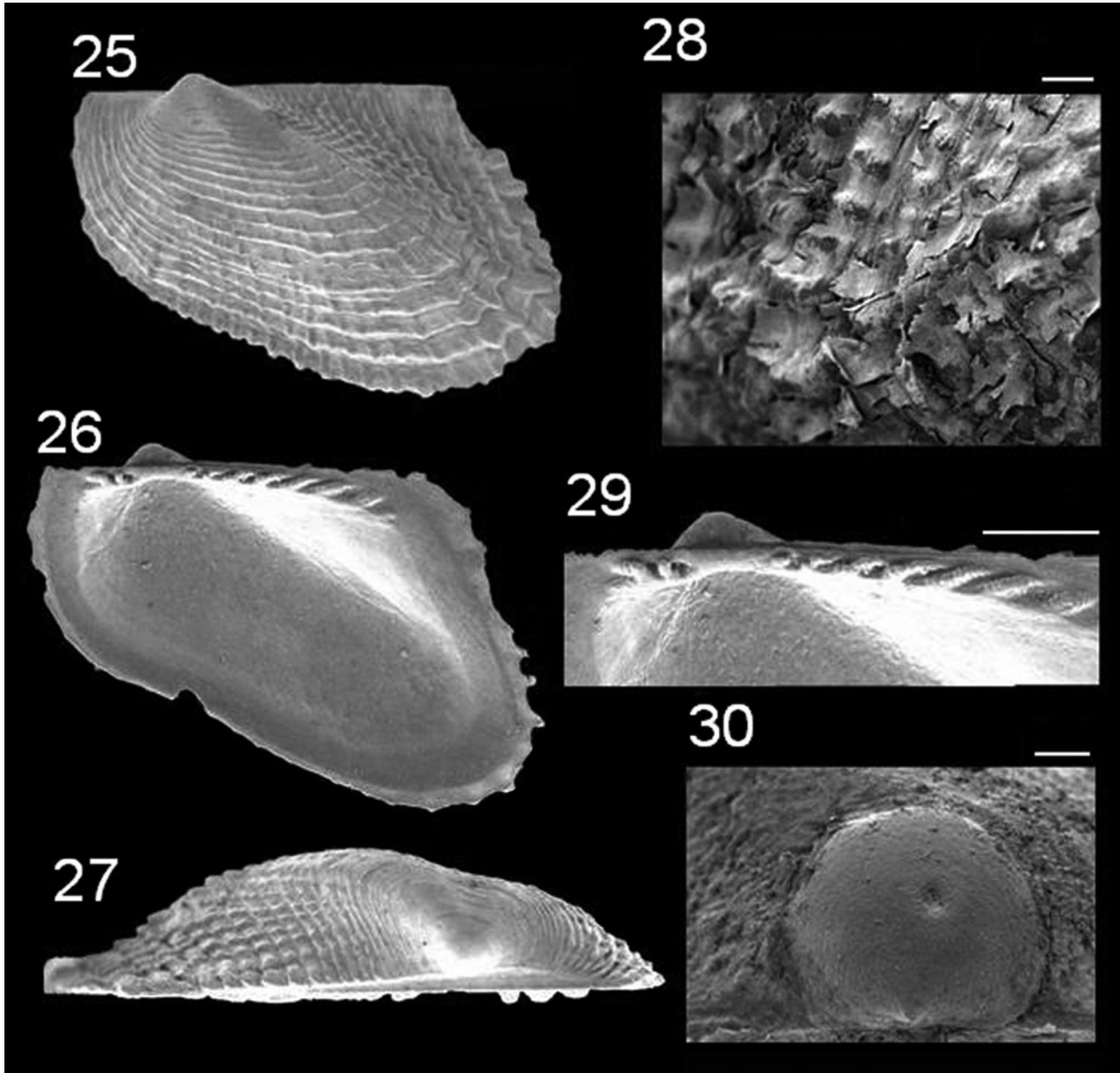


Figs 19–24. *Acar oliveirae*: (19) external view of left valve—holotype (MNRJ 11125; Lt 3.0 mm); (20) internal view of right valve—paratype (MNRJ 11131); (21) dorsal view of umbonal area of right valve—paratype (MNRJ 11131); (22) external sculpture—holotype; (23) hinge area of right valve—paratype (MNRJ 11131); (24) prodissoconch of right valve—paratype (MNRJ 11131). Scale bars: (22) 200 μm ; (23) 500 μm ; (24) 100 μm .

REMARKS

Acar lepidiformis is represented in the material examined by numerous valves and only one complete specimen. *Acar lepidiformis* resembles *Acar congenita* (Smith, 1885) from the Philippines (see Smith, 1885) in its equally strong radial ribs of the posterior slope delimited by a prominent carina, discontinuous radial ribs and a shoulder forming a carina, as in *A. congenita*, which also develops external structure, imbricate lamellae and concentric grooves. It resembles *Acar sagrinata* Dall, 1886 from the North Atlantic (see

Dall, 1886: 245; Dall, 1902: 508, pl. 31, figure 2), especially in its trapezoidal shape, central area with strong concentric ridges and equally strong radial ribs of the posterior slope delimited by a prominent carina. *Acar sagrinata* differs from the species described here in that it exhibits a slight depression over the median area, the ventral margin is regularly slanted, the posterior slope is not delimited by as strong a shoulder as in *A. lepidiformis* and the central area is marked by well-delineated concentric ribs separated by strong grooves.



Figs 25–30. *Asperarca tarcylae*: (25) external view of left valve—holotype (MNRJ 11126; Lt 5.7mm); (26) internal view of right valve—paratype (MZUSP 84244); (27) dorsal view of umbonal area—holotype (MNRJ 11126); (28) external sculpture of right valve—paratype (MZUSP 84244); (29) hinge area of right valve—paratype (MZUSP 84244); (30) prodissoconch of right valve—paratype (MZUSP 84244). Scale bars: (28) 200 µm; (29) 500 µm; (30) 50 µm.

Acar oliveirae sp. nov.
(Figures 19–24)

TYPE MATERIAL

Holotype MNRJ 11125 (Ht 3.0 mm, Lt 4.6 mm, W 1.25 mm)—off the State of Sergipe, Brazil, ‘Natureza’ (D-06, 10°41’S 36°18’W, muddy bottom, 28 November 2000, 365 m).

2 paratypes MNRJ 11132—off the State of Sergipe, Brazil, ‘Natureza’ (D-08, 11°58’S 36°49’W, muddy bottom, 1 November 2000, 100 m); 1 paratype MNRJ 11131—off the State of Pernambuco, Brazil, ‘Natureza’ (D-11, 08°46’S 34°44’W, muddy bottom, 18 November 2000, 690 m); 1 paratype MNRJ 11130—off the State of Rio Grande do Norte, Brazil, ‘Natureza’ (D-22, 04°15’S 37°12’W, muddy bottom,

10 November 2001, 206 m); 3 paratypes MZSP 84242—off the State of Rio Grande do Norte, Brazil, ‘Natureza’ (D-23, 04°51’S 35°06’W, muddy bottom, 24 November 2001, 375 m); 1 paratype MHCN 64515—off the State of Bahia, Brazil, ‘Natureza’ (D-30, 12°02’S 37°36’W, muddy bottom, 14 December 2001, 500 m); 4 paratypes MZSP 84243—off the State of Pernambuco, Brazil, ‘Sinuelo’ (D-04, 08°09’S 34°34’W, muddy bottom, 17 December 2004, 70 m).

DESCRIPTION

Shell very small (Ht 3.0 mm, Lt 4.6 mm), yellowish white, opaque, subtrapezoidal and transversely elongated (Figures 19 & 20). Equivalve and inequilateral. Anterior margin very thin. Posterior margin developed, flat and slightly slanted in older specimens. Dorsal margin truncated and hinge straight.

Ventral margin convex, with barely evident byssal situation. Ligamental area more developed below umbo and ornamented by microscopic threads (Figure 21). Umbo prosogyrous small (Figure 24). Posterior slope defined by a carina ornamented by spine-shaped projections and by 4 to 5 non-continuous, strong radial ribs cut by 5 to 9 raised concentric ridges. Posterior slope triangular and thin near umbo. Margins finely crenulated, especially the ventral margin. Central area with 11–13 strong nodular axial ribs, cut by 5 to 9 concentric ridges. Anterior area with 2 to 3 nodular radial ribs cut by continuation of ridges from central area; in some specimens, nodules in this area are larger and closer than those of other areas. Inner margin crenulated (Figure 20). Interior white, polished. Muscle scars inconspicuous, posterior of which is more evident and has circular aspect (Figure 20). Teeth taxodont, 5 to 7 anterior teeth followed by 8 to 10 opisthoclinal posterior teeth, progressively increasing in size (Figure 22).

ETYMOLOGY

In honour of Professor Deusinete Tenorio de Oliveira, Oceanography Department, Universidade Federal de Pernambuco (Brazil).

TYPE LOCALITY

Off the State of Sergipe, Brazil (10°41'S 36°18'W), at a depth of 365 m.

DISTRIBUTION

Off the States of Rio Grande do Norte, Pernambuco and Bahia (north-eastern Brazil) at depths between 70 and 690 m.

REMARKS

Acar oliveirae sp. nov. resemble *Acar congenita* (Smith, 1885) from the Philippines in the following aspects: sharper anterior area (typical of the genus), a barely evident byssal depression, discontinuous radial ribs and a shoulder forming a carina with spines instead of nodules. *Acar congenita* also develops less-evident crenulations, strong, concentric, imbricate lamellae and radial grooves. *Bentharca asperula* (Dall, 1881) is the only species cited for the Brazilian coast. However, it differs from *A. oliveirae* in exhibiting a posteriorly rounded ventral region, a central area slightly curved by the byssal gape, an inner margin without crenulations, the absence of a carina and weakly developed ornamentation.

Genus *Asperarca* Sacco, 1898

TYPE SPECIES

Arca nodulosa Müller, 1776, original designation by Sacco, 1898: 10.

DIAGNOSIS

Shell small, moderately thick, moderately inflated, trapezoidal to subrectangular, equivalve or slightly inequivalve, strongly inequilateral. Umbo strongly anterior, prosogyrate. Periostacum thin, sometimes slightly hirsute, with short setae along posteroventral margin. Sculpture of slightly imbricated commarginal lamellate ridges, made crenulated or nodulose by closely spaced, wide radial riblets. Cardinal area wide; Ligament external, opisthodontic. Byssal sinus faint to moderate. Hinge plate narrow, slightly curved. Teeth divided into anterior and posterior sets by an edentulous

gap; anterior teeth short, subvertical or oblique; posterior teeth longer, more oblique. Adductor scars slightly raised.

Asperarca tarcylae sp. nov.

(Figures 25–30)

TYPE MATERIAL

Holotype MNRJ 11126 (Ht 5.7 mm, Lt 9.7 mm, W 1.7 mm)—off the State of Alagoas, Brazil, 'Natureza' (D-32, 09°20'S 34°59'W, muddy bottom, 18 December 2001, 452 m).

1 paratype MZSP 84244, off the State of Bahia, Brazil, 'Natureza' (D-30, 12°02'S 37°36'W, muddy bottom, 14 December 2001, 500 m); 2 paratypes MORG 50782; 2 paratypes MZSP 84245; 2 paratypes MNRJ 11133—all off the State of Alagoas, Brazil, 'Natureza' (D-32, 09°20'S 34°59'W, muddy bottom, 18 December 2001, 452 m).

DESCRIPTION

Shell small (Ht 5.7 mm, Lt 9.7 mm), white, slightly translucent, subtrapezoidal, strongly convex, equivalve, inequilateral and transversely elongated (Figures 25 & 26). Dorsal margin with square extremities. Ventral margin strongly oblique, with visible but small long narrow byssal gape. Anterior margin small, rounded. Posterior margin straight, forming obtuse angle with dorsal margin. Posterior slope triangular, obtuse, delimited by rounded shoulder marked by radial rib with spines or nodules, barely visible on juvenile specimens. Posterior slope ornamented by 7 to 9 radial ribs and 24 more evident concentric ridges, forming elevated nodules in intersections, separated by short interspaces (Figure 29). Non-continuous radial ribs, distributed nearly throughout entire shell. Nodules progressively increasing in number with age of animal. Anterior ornament with 6 to 8 ribs. Central shell with 17 to 25 ribs and about 25 to 30 low concentric ridges developing shallow grooves. Inner margin smooth (Figure 26). Ligamental area narrow, with fine threads parallel to dorsal margin (Figure 27). Umbo rounded, prosogyrous, slightly projecting over ligamental area. Prodissoconch smooth and delimited by well-marked fold (Figure 30). Hinge slightly arched in median portion and anteriorly narrowed. Dentition divergent, with 3 to 5 prosoclinal anterior teeth and 7 to 14 opisthoclinal posterior teeth, separated by small edentulous region below umbo (Figure 28). Muscle scars well marked, anterior of which is rounded and smaller and posterior of which is trapezoid.

ETYMOLOGY

In honour of Ms Tarcyla C. Arruda da Silva, the first author's niece.

TYPE LOCALITY

Off the State of Bahia, Brazil (12°02'S 37°36'W), at a depth of 500 m.

DISTRIBUTION

Off the States of Alagoas and Bahia (north-eastern Brazil) at depths between 452 and 500 m.

REMARKS

Asperarca tarcylae sp. nov. resemble *Asperarca nodulosa* (type species) from the north-eastern Atlantic (Oliver & Allen, 1980: 64, figures 18 and 21; Kamenev, 2007a: 353, figures 17–

29) and Mediterranean (La Perna, 1998: 14, pl. 2, figures 1–4) in its trapezoidal shape, narrow ligamental area, smooth inner margin and small edentulous region below the umbo as well as the small, rounded anterior margin, the straight posterior margin forming an obtuse angle with the dorsal margin and the ovate–roundish, polished prodissoconch and a pointed apex. In *A. tarcylae*, the margin is entirely smooth, resembling that of *A. nodulosa*. All species named by La Perna (1998) and Kamenev (2007a) for *Asperarca* have a smooth inner margin. *Asperarca tarcylae* differs by exhibiting a much broader posterior region than *A. nodulosa*. The latter exhibits a sinuate margin, whereas the species described here exhibits regularity in the ventral region. *A. tarcylae* is morphologically close to *A. sagrinata* Dall, 1886 (see Mikkelsen & Bieler, 2008: 56) from the northern Atlantic in the ornamentation of the central area formed by broad concentric ribs, marked by thin radial ribs, with no evident nodules on the central area or anterior. In *A. tarcylae*, there are more evident radial ribs and concentric ridges, forming raised nodules at the intersections; the ventral margin is less slanted, the shoulder is more rounded and sharp, marked by a radial rib that forms small spines or nodules. The angle formed between the posterior slope and the dorsal margin does not exceed 130° and the scar of the adductor muscle has a trapezoidal shape. *Acar sagrinata* can be separated from *A. tarcylae* by the presence of a more rounded umbo and a shoulder more strongly marked with robust nodules on the posterior slope; the angle formed between the posterior slope and the dorsal margin reaches 135° and the scar of the anterior adductor muscle is more rounded. In *A. tarcylae*, the margin is entirely smooth, resembling that of *A. sagrinata*.

DISCUSSION

An analysis of the descriptions and illustrations presented by Bartsch (1931), Newell (1969), Knudsen (1970), Abbott (1974), Oliver & Allen (1980), Kilburn (1983), Oliver & von Cosel (1992), Hayami & Kase (1993), Lutaenko (1993), La Perna (1998), Coan *et al.* (2000), Lutaenko (2003), Simone & Chichvarkhin (2004), Oliver & Holmes (2006), Kamenev (2007a, b), Mikkelsen & Bieler (2008) and Simone (2009) reveals that it is possible to separate the genera *Paranadara*, *Acar* and *Asperarca* based on a small number of non-overlapping characters.

Historically, the family Arcidae has been defined with a large number of genera and subgenera (Newell, 1969; Kilburn, 1983), many of which are inconsistent and depend upon more in-depth revisions. The poor use of genus names reflects the lack of a consensus regarding the definitions and morphological limits for each genus, which has contributed toward an increase in taxonomic confusion in this group. A more objective path would be to reduce the number of characteristics evaluated, such as shape, sculpture, periostracal elements, ligament, hinge teeth and ventral byssal gape, in an attempt to establish a clear genus identity (Kilburn, 1983; Coan *et al.*, 2000; Simone & Chichvarkhin, 2004). These characters are used in a practical manner as follows:

(1) *Acar* shares its trapezoidal–retangular shape and more developed posterior plateau with *Bentharca*, *Samarcar* and *Asperarca*, which is much more expanded in *Bentharca*. As nothing described thus far fits perfectly with the pattern exhibited

by *Bentharca asperula* (type species), it may be presumed that this is a monotypic genus and all species allocated in *Bentharca* should probably undergo a generic revision. *Acar* is considered more distant from *Bentharca* and *Asperarca* and therefore the most easily distinguished among the three inequilateral genera;

(2) the position of the ligament may be used to define genera (Thomas, 1978; Oliver & Holmes, 2006). An opisthodontic ligament is shared by *Acar*, *Samarcar*, *Asperarca*, *Bentharca* and *Bathyarca*, but *Bathyarca glacialis* has an amphidetic ligament (Coan *et al.*, 2000). *Anadara*, *Paranadara*, *Arca* and *Barbatia* share the amphidetic ligament; and

(3) genera with a smooth margin or partial crenulations are generally associated with the presence of a byssal gape and a sinuous ventral margin. For instance, the species described by Hayami & Kase (1993) appear to pertain better to *Acar* than *Bentharca*. The smooth inner margin is shared by *Asperarca*, *Samarcar* and *Bentharca*. *Anadara* and *Paranadara* have an inner margin with strong rectangular crenulations. At first glance, *Paranadara taludae* seems completely inserted in *Anadara*, but the straight byssal gape, situation of the ventral margin and presence of an edentulous region on the hinge are not characteristics incorporated by *Anadara*.

The characteristics discussed above are considered in the literature (Bartsch, 1931; Newell, 1969; Oliver & Allen, 1980; Kilburn, 1983; Oliver & von Cosel, 1992; Lutaenko, 1993; Evseev & Lutaenko, 1998; La Perna, 1998; Coan *et al.*, 2000; Lutaenko, 2003; Simone & Chichvarkhin, 2004; Kamenev, 2007a; Mikkelsen & Bieler, 2008; Simone, 2009) as important for the taxonomic arrangement of genera in the family Arcidae. These characteristics may offer a sufficient basis for determining genera. The exclusive use of sculpture in genus differentiation is not practical, as there appears to be considerable overlap in the ornamentations and these characteristics can also vary within a single species throughout its growth. Sculpture should be used together with dentition, which is a more constant character for the distinction and characterization of genera and species.

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