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New Species of *Nannamoria* from the Pliocene and Miocene of Australia (Caenogastropoda: Volutidae)

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ABSTRACT This study provides the taxonomic description of eight species of *Nannamoria* Iredale, 1929 from Miocene deposits of Victoria and South Australia and Pliocene deposits of Flinders Island Tasmania, Australia. The following new species are described, discussed and compared to their congeners: *Nannamoria costatum* n. sp., *Nannamoria flindersi* n. sp., *Nannamoria hiscocki* n. sp., *Nannamoria gnotuki* n. sp., *Nannamoria alquezae* n. sp., *Nannamoria cadella* n. sp., *Nannamoria malonei* n. sp. and *Nannamoria persimilis* n. sp. Various aspects of *Nannamoria* evolution are discussed.

KEYWORDS Mollusca, Gastropoda, Volutidae, *Nannamoria*, fossil, palaeontology, new species, Australia, Victoria, South Australia, Tasmania, *N. costatum, N. flindersi, N. hiscocki, N. gnotuki, N. alquezae, N. cadella, N. malonei, N. persimilis*

INTRODUCTION

Nannamoria Iredale, 1929 is a genus of predatory marine gastropods belonging to the family Volutidae. They are endemic to Australia and are typically found in deep water in sandy environments. Their shells are generally quite small (20-50 mm) with a short conical spire and multispiral protoconch, which is dome-like or pupiform in shape. The shoulder usually bears nodules or sharply pointed spines and the columella usually has four strong plaits. *Nannamoria* species have an extensive fossil history in southern Australia and first appeared in the early Miocene, although in Darragh's (1988) revision of Tertiary Volutidae of South-Eastern Australia, he states that the oldest species in the genus is *N. weldii* from the upper Oligocene beds of Victoria. However, *N. weldii* appears to be restricted to the early Miocene, suggesting a possible error. This is likely attributed to specimens similar to *A. weldii* from the lower Miocene beds of Torquay being mixed-up with the upper Oligocene beds below. Fossil records indicate that *Nannamoria* experienced a period of radiation during the early Miocene like many other endemic genera of marine gastropods from South Eastern Australia, although the paleoenvironmental reasons for this radiation are uncertain (personal observation). The extinct species reached their peak diversity during the Middle Miocene, when the earth's temperature was considerably warmer than it is today.

There are currently eight extant species in the genus, *N. amicula* Iredale, 1929: *N. breviforma* Bail & Limpus, 2008; *N. bulbosa* Bail & Limpus, 2008; *N. gotoi* Poppe, 1992; *N. inflata* Bail & Limpus, 2008; *N. inopinata* Darragh, 1979; *N. parabola* Garrard, 1960 and *N. ranya* Willan, 1995. The fossil record contains twelve species: *N. ralphi* (Filay, 1930); *N. weldii* (Tenison Woods, 1876); *N. limbata* (Tate, 1888); *N. lundeliusae* Ludrook, 1978; *N. trionyma* Darragh, 1989; *N. stolida* (Johnson, 1888); *N. strophodon* (McCoy, 1876); *N. paraboloides* Darragh, 1989; *N. fasciculata* Darragh 1989; *N.*

deplexa Darragh, 1989; *N. cinctuta* Darragh 1989; and *N. amplexa* Darragh 1989. This study describes an additional eight species of fossil *Nannamoria*.

Fossil records are known from the Bass, Otway, Gippsland and Murray basins of Victoria and South Australia and extant species only occur in eastern Australian overlap (personal observation). It is possible however, that the genus *Paramoria* (Smith, 1886) also belongs to the genus *Nannamoria*, as some species can be readily placed in either genera and this would indicate a much wider distribution. The morphologies of the new species described in this paper differ from those of known species and these differences are discussed, along various aspects of *Nannamoria* evolution.

Abbreviations.
MV = Museum of Victoria, Melbourne
CAH = Collection of Angus Hawke, Melbourne

MATERIALS AND METHODS

The author has examined numerous specimens in museums and private collections in Victoria, New South Wales and South Australia. Additional material was obtained from field research during 2009-2020. In some cases, only a few specimens were available for study. Mature, adult specimens were used for morphometric analysis and to evaluate key characteristics. The following measurements were taken: shell length, width, height and the number of shoulder nodules or spines has been counted for some of the species. In the absence of soft-bodied anatomical characters, molecular data and colour pigmentation, this taxonomic study is primarily based on three types of evidence. These are: a) morphological (*i.e.*, what characters can be used to differentiate between distinct taxa); b) spatial (*i.e.*, to what extent does the geography influence evolutionary relationships); and c), temporal (*i.e.*, to what extent can supposed age differences between deposits inform evolutionary changes). All these lines of evidence were considered *a priori* to the taxonomic decisions made.

SYSTEMATICS

Superfamily : Volutoidea Rafinesque, 1815
Family : Volutidae Rafinesque, 1815
Genus : *Nannamoria* Iredale, 1929
Type species : *Nannamoria amicula* Iredale, 1929 (original designation)

Nannamoria flindersi Hawke, new species
(Plate 2, Figures 1-14; Plate 5, Figure 2)

Holotype: Plate 2, Figures 2a , 2b. MV - P344175.

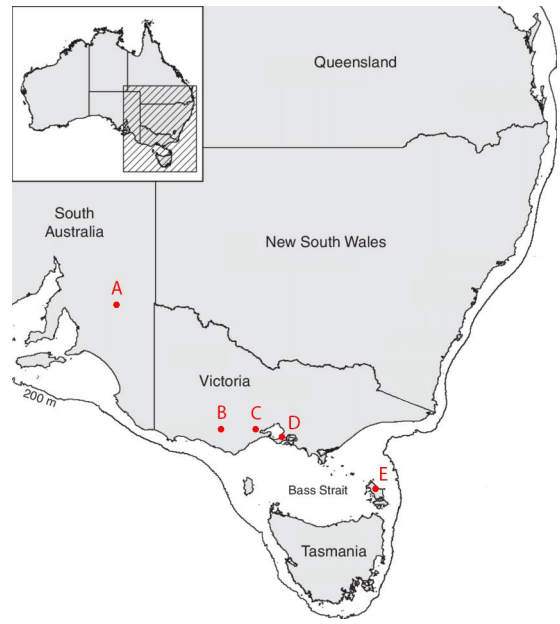
Description. Solid shell, ranging from 25 to 30mm in length; shape somewhat biconic, tapering to narrow anterior end; protoconch with three tumid whorls; moderately short, to short pointed spire; strong prominent sculpture, consisting of approximately 14-16, narrowly spaced axial costae on outer whorl, extending full length of shell; shoulder bearing prominent pointed nodules, which grade into the axial costae of the whorls; outer lip smooth, moderately thickened with slight outward flare; columella with four strong plaits.

Type Material.
Holotype: (Plate 2, Figures 2a, 2b) 29.6 mm (L) 20.7 mm (W) Type locality. MV P344175
Paratype: 1 (Plate 2, Figures 4a, 4b) 26.6 mm (L) 17.4 mm (W) 13.3 mm (H) Type locality.
Paratype: 2 (Not illustrated) 28.5 mm (L) 19.0 mm (W) 19.3 mm (H) Type locality.
Paratype: 3 (Plate 2, Figures 6a, 6b) 27.8 mm (L) 15.3 mm (W) 13.5 mm (H) Coll: Paul Southgate
Paratype: 4 (Plate 2, Figures 1a, 1b) 29.4 mm (L) 16.8 mm (W) 13.3 mm (H) Type locality.
Paratype: 5 (Plate 2, Figures 5a, 5b) 25.6 mm (L) 14.2 mm (W) 12.0 mm (H) Type locality.
Paratype: 6 (Plate 2, Figures 7a, 7b) 29.8 mm (L) 18.3 mm (W) 13.2 mm (H) Type locality. CAH
Paratype: 7 (Plate 2, Figures 9a, 9b) 28.4 mm (L) 15.5 mm (W) 13.3 mm (H) Type locality.
Paratype: 8 (Plate 2, Figures 11a, 11b) 30.3 mm (L) 17.1 mm (W) 14.9 mm (H) Type locality.
Paratype: 9 (Plate 2, Figures 13a, 13b) 27.2 mm (L) 17.1 mm (W) 13.3 mm (H) Type locality.
Paratype: 10 (Plate 2, Figures 14a, 14b) 30.3 mm (L) 18.3 mm (W) 19.7 mm (H) Type locality.
Paratype: 11 (Plate 2, Figures 12a, 12b) 28.7 mm (L) 16.8 mm (W) 14.2 mm (H) Type locality.
Paratype: 12 (Plate 2, Figures 10a, 10b) 26.6 mm (L) 16.0 mm (W) 13.3 mm (H) Type locality.
Paratype: 13 (Plate 2, Figures 8a, 8b) 26.4 mm (L) 16.4 mm (W) 13.4 mm (H) Type locality.
Paratype: 14 (Plate 2, Figures 3a, 3 b) 27.7 mm (L) 16.3 mm (W) 13.3 mm (H) Type locality.

Type Locality/Distribution. Known only from the Pliocene deposits of the Cameron Inlet Formation on Flinders Island, restricted to only a few locations (Refer to Map 1).

Etymology. Named in honour of Matthew Flinders, after which Flinders Island, Tasmania is named.

Remarks. This species has been treated as a variant of *N. paraboloides* in the past, (see Goudey, 2018: Page 33, fig. G). although it differs from that species by way of the prominent axial costae. The author has not found the two species in the same area, suggesting they may not have been sympatric, although more fieldwork is needed to confirm. *Nannamoria paraboloides* is the most abundant *Nannamoria* species from Flinders Island, although well-preserved specimens are rare. The pattern is quite often well preserved and comparable to that of other extinct *Nannamoria*. For example, the pattern of *N. malonei* n. sp (described herein) has been revealed using ultraviolet light, which causes the pigmented regions of the shell to fluoresce and this examination has shown similar patterns in both species with some subtle differences. The pattern is also similar to that in a number of *Notovoluta* species; both fossil and extant.



Map 1. (A) Morgan, South Australia (B) Lake Gnotuk, Victoria. (C) Batesford Quarry, Victoria, (D) Gunyoung Creek, Victoria, (E) Cameron Inlet Formation, Flinders Island, Tasmania.

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Nannamoria costatum Hawke, new species
(Plate 4, Figures 1a, 1b; Plate 5, Figure 7)

Holotype: Plate 4, Figures 1a, 1b. MV - P344171.

Description. Solid shell, ranging from 35 to 50 mm in length; shape biconic to subcylindrical, tapering to narrow anterior end; slightly convex protoconch with three whorls; moderately high spire; poorly developed sculpture, consisting of approximately 25-32, narrowly spaced axial costae on outer whorl, extending full length of shell; outer lip is smooth, slightly thickened. columella with four strong plaits.

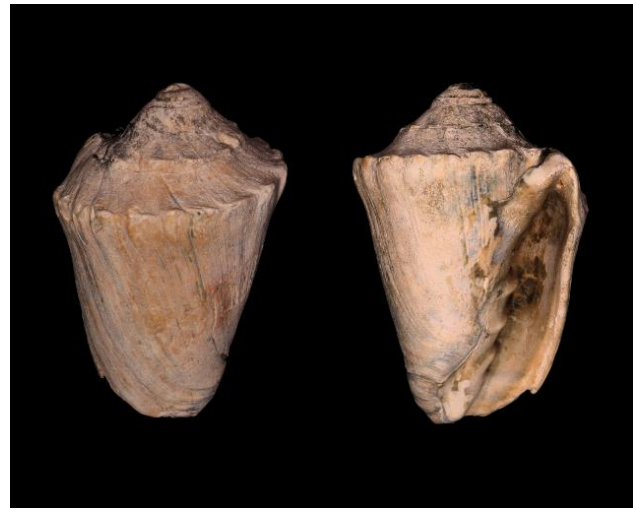
Type Material. Holotype: From type locality (Plate 4, Figures 1a, 1b) 37.6 mm (L) 20.4 mm (W) MV - P344171.

Distribution. Known only from the Pliocene deposits of the Cameron Inlet formation on Flinders Island, Tasmania, where it is restricted to only a few locations (Refer to Map 1).

Etymology. Costatum = Latin for 'ribbed', referring to the numerous distinctive ribs that distinguish this species.

Remarks. This species superficially resembles other species of *Nannamoria* from Flinders Island, although it is very distinctive and cannot be confused with other species. *Nannamoria costatum* n. sp. is quite large for the genus and fairly rare. The conical spire and small protoconch are characteristic of *Nannamoria*. Other specimens of this species were examined by the author but were unable to be included.

Nannamoria gnotuki Hawke, new species
(Plate 1, Figures 3a, 3b; Plate 5, Figure 1)



Holotype: Plate 1, Figures 3a, 3b. MV - P344173.

Description. Solid shell, ranging from 30 to 35 mm in length; shape pyriform, tapering to narrow anterior end; protoconch with three tumid whorls; short, rounded, squat spire; shoulder bearing narrowly spaced, pointed nodules, drawn out into flange or triangular plates; shoulder nodules sometimes form slight axial costae, which taper-out towards anterior end; outer lip smooth, slightly thickened, with minor inward flare; columella with four strong plaits.

Type Material.
Holotype: (Plate 1, Figures 3a, 3b) 30.3 mm (L) 20.9 mm (W) Type locality. MV - P344173.
Paratype 1: (Plate 1, Figures 5a, 5b) 21.8 mm (L) 19.3 mm (W) Type locality. MV - P344174.

Paratype 2: (Plate 1, Figures 1a, 1b) 33.0 mm (L) 21.5 mm (W) 18.8 mm (H) Type locality. CAH.
Distribution. Known only from Lake Gnotuk, Victoria, which is the type location (Refer to Map 1).

Etymology. Named after the type location, Lake Gnotuk, Victoria, Australia.

Remarks. The key characteristic of this species is the narrowly spaced shoulder nodules, which in most specimens are drawn out into flange-like plates. The shape of the spire and spacing of the shoulder nodules, indicate that this species is possibly ancestral *N. amplexa* and the most likely predecessor is *N. strophodon*. Most specimens are slightly eroded. Only known from type location.

Nannamoria alquezae Hawke, new species
(Plate 4, Figures 6a, 6b; Plate 5, Figure 3)

Holotype: Plate 4, Figures 6a, 6b. MV - P344178.

Description. Shell ranging from 35 to 45 mm in length; somewhat biconic to elongate in shape, tapering to narrow anterior end; protoconch with three whorls; high spire; shoulder smooth or bearing weak to moderate subspinose nodules; shoulder nodules usually absent in early whorls; lacks axial costae or prominent sculpture; columella with four strong plaits.

Type Material.
Holotype: (Plate 4, Figures 6a, 6b) 32.8 mm (L) 15.4 mm (W) Type locality. MV - P344178.
Paratype: 1 (Plate 4, Figures 11a, 11b) 31.4 mm (L) 15.0 mm (W) Type locality. MV - P344180.
Paratype: 2 (Plate 4, Figures 7a, 7b) 40.3 mm (L) 17.5 mm (W) 17.3 mm (H) Type locality CAH.
Paratype: 3 (Plate 4, Figures 9a, 9b) 40.7 mm (L) 18.3 mm (W) 16.4 mm (H) Type locality.
Paratype: 4 (Plate 4, Figures 12a, 12b) 33.3 mm (L) 14.4 mm (W) 13.4 mm (H) Type locality.
Paratype: 5 (Plate 4, Figures 8a, 8b) 35.8 mm (L) 16.8 mm (W) 15.2 mm (H) Type locality.
Paratype: 6 (Plate 4, Figures 10a, 10b) 40.1 mm (L) 18.4 mm (W) 17.6 mm (H) Type locality.
Paratype: 7 (Plate 4, Figures 13a, 13b) 36.2 mm (L) 16.4 mm (W) 14.0 mm (H) Type locality.
Paratype: 8 (Plate 4, Figures 5a, 5b) 28.6 mm (L) 14.6 mm (W) 12.4 mm (H) Type locality,

Distribution. Found in several localities of Bairnsdalian age, which is Middle Miocene. The type location is Gunyoung Creek on the Mornington Peninsula, Victoria, Australia.

Etymology. Named in honour of Apple Alqueza, who has often provided extensive assistance in the field.

Remarks. Darragh illustrated *Nannamoria alquezae* n. sp. under the name *N. limbata* in his (1988) revision of Tertiary Volutidae of South-Eastern Australia (Page 284, fig. 9). However, Darragh's specimen differs from the latter by way of the higher spire, more biconical shape, as well as being slightly less robust. The two species appear to be closely related and occur in the same deposits at a number of locations suggesting they were sympatric, although not all sites appear to have both species. *Nannamoria alquezae* n. sp. superficially resembles

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Notovoluta differta, Darragh, 1989, although that species is only found in lower Miocene deposits and lacks shoulder nodules. *N. alquezae* does not exhibit decortication of the suture of the suture, a seen in *N. limbata*.

Nannamoria malonei Hawke, new species
(Plate 3, Figures 1a, 1b; Plate 5, Figure 8)

Holotype: Plate 3, Figures 1a, 1b. MV - P344169.

Description. Solid shell, ranging from 35 to 45 mm in length; shape biconic to obovate, tapering to narrow anterior end; protoconch with three whorls; moderately short rounded spire, strong prominent shoulder nodules, consisting of approximately 7 to 8 broadly spaced nodules on outer whorl, outer lip is smooth, moderately thickened; columella with four strong plaits.

Type Material.
Holotype: (Plate 3, Figures 1a, 1b) 41.5 mm (L) 21.4 mm (W) Type locality. MV - P344169.
Paratype 1: (Plate 3, Figures 2a, 2b) 39.3 mm (L) 22.4 mm (W) 21.4 mm (H) Type locality. CAH.
Paratype 2: (Plate 3, Figures 3a, 3b) 37.6 mm (L) 21.3 mm (W) 20.2 mm (H) Type locality. CAH.
Paratype 3: (Plate 3, Figures 4a, 4b) 41.3 mm (L) 23.2 mm (W) 22.5 mm (H) Type locality.
Paratype 4: (Plate 3, Figures 5a, 5b) 36.7 mm (L) 20.5 mm (W) 19.5 mm (H) Type locality.
Paratype 5: (Plate 3, Figures 6a, 6b) 38.0 mm (L) 20.6 mm (W) 20.8 mm (H) Type locality.
Paratype 6: (Plate 3, Figures 7a, 7b) 33.9 mm (L) 19.6 mm (W) 28.5 mm (H) Type locality.
Paratype 7: (Plate 3, Figures 8a, 8b) 40.4 mm (L) 21.5 mm (W) 21.0 mm (H) Type locality.

Distribution. Most specimens originate from Batesford Quarry in Victoria, Australia, where the type material has been collected. This species also occurs at Fossil Beach, in Victoria, Australia, although it is very rare at this location (Refer to Map 1).

Etymology. Named in honour of Mark Malone, who has provided specimens and supported my fieldwork.

Remarks. This species is most similar to *N. trionyma,* although it differs by way of its larger size, more rounded spire, larger protoconch and stronger shoulder nodules, which are less numerous. *Nannamoria malonei* n. sp. typically has between 7 and 8 shoulder nodules, with an average of 7.8 among the type material, whereas *N. trionyma* typically has between 8 and 13 shoulder nodules, with an average of 10.5. *N. trionyma,* is also a much more variable species. *Nannamoria malonei* n. sp. most likely evolved from *N. persimilis* n. sp. and is found alongside *N. strophodon,* although it can be readily separated from *N. strophodon* by its more robust shell, rounded protoconch and the sharp triangular shoulder nodules. It has a restricted range and most examples are from Batesford Quarry, Victoria.

ISSN 0738-9388

Nannamoria cadella Hawke, new species
(Plate 1, Figures 10a, 10b; Plate 5, Figure 4)

Holotype: Plate 1, Figures 10a, 10b. MV - P344168.

Description. Solid shell, ranging from 20 to 30mm in length; shape, cylindrical to obovate, tapering to narrow anterior end; small round protoconch with three whorls; short to moderate spire; weak shoulder nodules, consisting of approximately 5 to 7 broadly spaced nodules on outer whorl; outer lip thin and typically looks immature; columella with four strong plaits; indistinct siphonal notch.

Type Material.
Holotype: (Plate 1, Figures 10a, 10 b) 21 mm (L) 13.3 mm (W) Type locality. MV - P344168.
Paratype 1: (Plate 1, Figures 8a, 8b) 27 mm (L) 12.7 mm (W) 12.4 mm (H) Type locality. CAH.
Paratype 2: (Plate 1, Figures 7a, 7b) 26.3 mm (L) 22.7 mm (W) 11.5 mm (H) Type locality.
Paratype 3: (Plate 1, Figures 9a, 9b) 23.4 mm (L) 13.3 mm (W) 12.7 mm (H) Type locality.

Distribution. Known only from the Cadel Formation, 4.8km south of Morgan-Cadell Rd, South Australia (Refer to Map 1).

Etymology. Named after the Cadel Formation.

Remarks. This Middle Miocene species is similar to *N. trionyma,* although it differs by way of its smaller size and more slender, cylindrical shape. It also has less developed shoulder nodules, which are less numerous. *Nannamoria cadella* n. sp. typically has between 5 and 7 shoulder nodules, with an average of 6.4. Whereas, *N. trionyma,* typically has between 8 and 13 shoulder nodules, with an average of 10.5 (Hawke, unpublished data). The unique features are very apparent when compared side by side (see Table 1).

	N. trionyma	***N. malonei***	***N. cadella***
Typical Size (mm)	25 to 35	35 to 45	20 to 30
Shape	biconic to obovate	biconic to obovate	cylindrical to obovate
Spire	moderately short, somewhat pointed	moderately short rounded	moderately short bullet shaped
Expression of shoulder nodules	weak to moderate shoulder nodules	strong prominent shoulder nodules	weak shoulder nodules
Number of shoulder nodules	approximately 8 to 13 moderately spaced nodules on the outer whorl	approximately 7 to 8 broadly spaced nodules on the outer whorl	approximately 5 to 7 broadly spaced nodules on the outer whorl

Table 1. Comparison of *Nannamoria trionyma, N. malonei* n. sp *and N. cadella* n. sp.

ISSN 0738-9388

Nannamoria hiscocki Hawke, new species
(Plate 4, Figures 3a, 3b; Plate 5, Figure 5)

Holotype: Plate 4, Figures 3a, 3b. MV - P344170.

Description. Solid shell, ranging from 35 to 40 mm in length; shape somewhat biconic to pyriform, tapering to narrow anterior end; protoconch with three tumid whorls; short, rounded, subconical spire; moderate sculpture, consisting of approximately 14-16, narrowly spaced axial costae on outer whorl, extending full length of the shell; shoulder bearing prominent pointed nodules, which grade into axial costae of whorls; outer lip smooth, moderately thickened with slight flare. columella with four strong plaits.

Type Material.
Holotype: (Plate 4, Figures 3a, 3b) 36 mm (L) 22.7 mm (W) Type locality. MV - P344170.
Paratype 1: (Plate 4, Figures 4a, 4b) 32.8 mm (L) 19.6 mm (W) 13.5 mm (H) Coll: Paul Southgate.

Distribution. Known only from the Pliocene deposits of the Cameron Inlet formation on Flinders Island, Tasmania. Restricted to a few locations (Refer to Map 1).

Etymology. Named in honour Dr. Martin Hiscock, from Melbourne Australia, who has shown a great deal of kindness over the years and assisted in obtaining specimens for my research.

Remarks. This species closely resembles *Mauithoe insignis* (Marwick, 1926) from the Miocene of New Zealand and it is possible there is a close association between the two species from an evolutionary perspective, especially given the similarity in fauna between Australia and New Zealand. Beu and Maxwell (1990) stated that *M. insignis* has five strong columella plaits, although all the specimens examined by the author have four, which is consistent with *Nannamoria*. Further investigation is needed to establish the relationship between *Mauithoe* and *Nannamoria*. The taxa found in association with this species suggests it is slightly older than *N. flindersi* n. sp, and if this is the case, then it is possible that this species gave rise to *N. flindersi*. n. sp.

Nannamoria persimilis Hawke, new species
(Plate 1, Figures 2a, 2b; Plate 5, Figure 6)

Holotype: Plate 1, Figures 2a, 2b. MV - P344172.

Description. Solid shell, ranging from 40 to 45 mm in length; shape biconic to obovate, tapering to narrow anterior end; large round protoconch with three whorls; high pointed spire, strong prominent shoulder nodules, consisting of approximately 7 to 8 broadly spaced nodules on outer whorl; outer lip smooth, moderately thickened; columella with four strong plaits.

Type Material.
Holotype: (Plate 1, Figures 2a, 2b) 39.8 mm (L) 20 mm (W) Type locality. MV - P344172.
Paratype 1: (Plate 1, Figures 4a, 4b) 42.5 mm (L) 22.7 mm (W) 19.2 mm (H) Type locality. CAH.
Paratype 2: (Plate 1, Figures 6a, 6b) 39.4 mm (L) 19.1 mm (W) 18.9 mm (H) Type locality. CAH.

Distribution. Known only from the type location, which is the lower Miocene beds of Jan Juc beach.

Etymology. Persimilis = Latin for 'very like' in reference to the similarities to *N. weldii*.

Remarks. This species is quite similar to *N. weldii*, which is highly variable and may be represented by more than one species, although more research is needed to determine if this is the case. *Nannamoria persimilis* n. sp. is much less variable and there are a few key differences. For example, *N. persimilis* n. sp. is generally more elongated, with a larger protoconch and has stronger shoulder nodules, when compared to specimens of *N. weldii* with a similar shape. *Nannamoria weldii* is usually wider with a smaller protoconch. *Nannamoria persimilis* n. sp. also bears some resemblance with *N. strophodon,* although the two species are very different and can easily be separated by the taller spire and sharper shoulder nodules. *Nannamoria malonei* n. sp, has a larger, more rounded protoconch, stronger shoulder nodules, heavier shell and usually has 2 to 3 less shoulder nodules. *Nannamoria persimilis* n. sp. is possibly ancestral to *N. malonei* n. sp., by way of flattening of the spire and inflation of the shoulder width.

DISCUSSION

The close relationship between *Nannamoria*, *Amoria, Paramoria* and *Notovoluta* is quite apparent and at times they can be hard to differentiate. For example, the morphology and preserved pigmentation in *N. lundeliusae* clearly indicate that the closest relative is *Paramoria johnclarki* Bail & Limpus, 1997. If this is the case, then maybe *N. lundeliusae* should be reassigned to *Paramoria* or perhaps *Paramoria* should be lumped with *Nannamoria* and in the opinion of the author, *Paramoria* should never have been reinstated. Darragh (1988) stated that species such as *N. weldii* can be readily placed in either *Paramoria* or *Nannamoria* as defined and preferred to regard the two taxa as synonyms until further anatomical work proves otherwise, with which this author agrees. Unfortunately, the proclivities of taxonomic splitting in recent times have become a contentious issue and often a valid, monophyletic genus has been split into many smaller genera, without fixing any phylogenetic problems with existing taxon. Darragh examined the radula of *N. amicula* and noted that it was similar to that of *Paramoria guntheri* and many other *Amoria.* He also stated that the anatomical morphology was similar, except that the radula was unicuspid (Darragh, 1988).

Climatic and biostratigraphy of Nannamoria.
Paleoclimatic variability has played a large role in shaping the endemic fauna we find in Australia today. Approximately 14.5 million years ago the earth's temperature steadily began to cool, which caused many land and marine species to go extinct. (Sterling 2011) This event is known as the Middle Miocene Disruption and

it triggered a shift in the position of the overlap zones, between the tropical and temperate regions. It is probably the cause for the reduction of many of the endemic taxa of that time, including *Nannamoria*. Many of the lineages, which have survived until the present-day, appear to have either migrated north-east, or west, where the water temperature is slightly warmer (personal observation). Today, there are no species of *Nannamoria* that inhabit the waters of Victoria and Tasmania, where a myriad species once flourished. The most likely reason for this is a Paleoclimatic change, which seems to have pushed many of the species into warmer waters of South Western Australia and particularly towards Northern NSW and southern Queensland. In fact, many endemic species from northern NSW and southern Queensland resemble species that once lived in south-eastern Australia. Below are some examples of extinct taxa and their modern-day counterparts, which are now confined to northern NSW and southern Queensland (see Table 2).

Fossil Species	**Extant species**
Ericusa ancillodes † (Tate, 1889)	*Ericusa sericata* Thornley, 1951
Athleta antipinosa † (Tate, 1889)	*Athleta studeri* (von Martens, 1897)
Nannamoria strophodon † (McCoy, 1876)	*Nannamoria parabola* Garrard, 1960
Athleta bungae † Darragh 1971	*Athleta insperata* Darragh 1979
Nannamoria limbata † (Tate, 1888)	*Nannamoria inopinata* Darragh 1979

Table 2. Extinct taxa and their modern-day counterparts.

Ocean temperature is considered to be one of the most important physical factors affecting the distribution of molluscs and also has a substantial impact on the rate of extinction and evolution. Fossil records in south eastern Australia indicate that evolutionary changes in *Nannamoria* appear to occur more rapidly, when compared to other genera and very few species seem to be long-lasting. Changes in shell morphology can also be quite considerable over a relatively short period of time and this can be seen in some of the species from Flinders Island, which have experienced species radiation as a result of changing ocean temperatures and sea levels. There is substantial evidence showing that sea-levels fluctuated throughout the last ice age and during parts of the Pliocene. The oceans were 20-30 m higher than they are today. As a result, much of the eastern side of Flinders Island was covered by water, which is why there are fossils found on this part of the island. By comparing the habitat of a variety genera that have modern counterparts today, we can surmise that the species of *Nannamoria*, which are found at Flinders Island today would have likely lived in depths below 30 m (personal observation). The assemblages of species can also change quite significantly from one location to another on Flinders Island, despite locations being in relatively close proximity. There are a couple of conceivable ways to interpret this. One could be that the water gradually receded over an extended period of time, allowing the species in this region to evolve slightly or that there is stratification of differing ages. It is possible to get a rudimentary understanding of the slight age differences of the fossil deposits, by looking at the percentage of recent species contained within, as well as the number of species that closely resemble living species. General observations indicate that the older deposits are less likely to contain species with living representatives or species, which closely

resemble extant species. However, different regions have undergone different physical changes and consequently, variation in the rate of extinction and changes in shell morphology must also be considered when applying this ratiocination. *Nannamoria flindersi* n. sp. is generally found at sites with a relatively high proportion of molluscan species that are still living today. In contrast, *N. costatum* is generally associated with fewer living species. This suggests an age difference between the deposits of these two species. Neither of these species have been recorded from the same collection site by the author, despite the collection sites for each species being only a short distance away. Only one or two species of *Nannamoria* appear to have coexisted within the Pliocene deposits of Flinders Island and these species are likely to have evolved into the array of fossil species found on the island today. In order to properly categorize species and determine their evolutionary relationships, it is essential to understand the fossil record. Unfortunately, not enough emphasis is put into research of fossil species, which are often overlooked in favour of their modern counterparts, although this is steadily changing.

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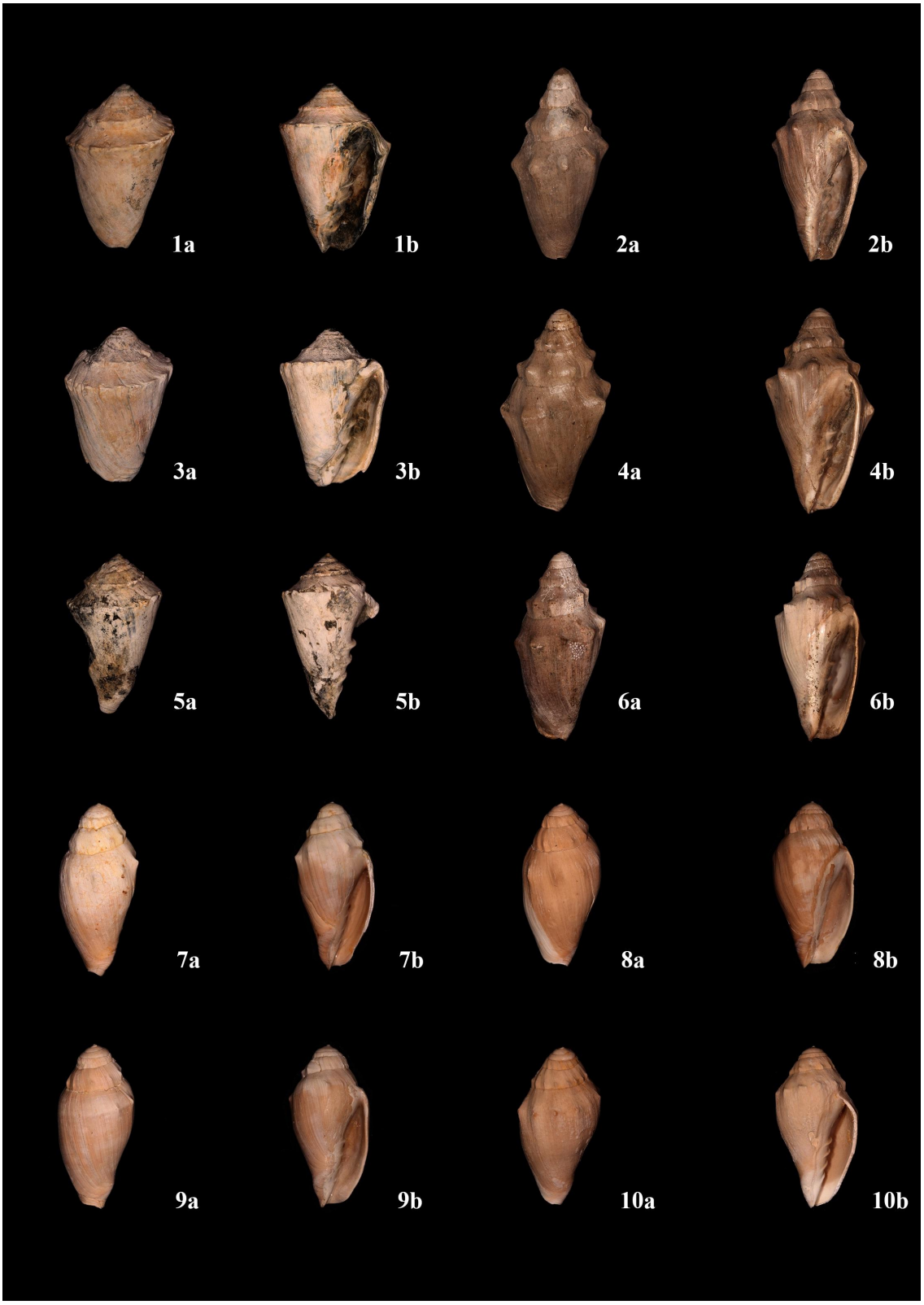

Plate 1. Figures 1, 3, 5 = *Nannamoria gnotuki* n. sp. (Holotype Figure 3, P344173); Figures 2, 4, 6 = *Nannamoria persimilis* n. sp. (Holotype Figure 2, P344172); Figures 7, 8, 9, 10 = *Nannamoria cadella* n. sp. (Holotype Figure 10, P344168).

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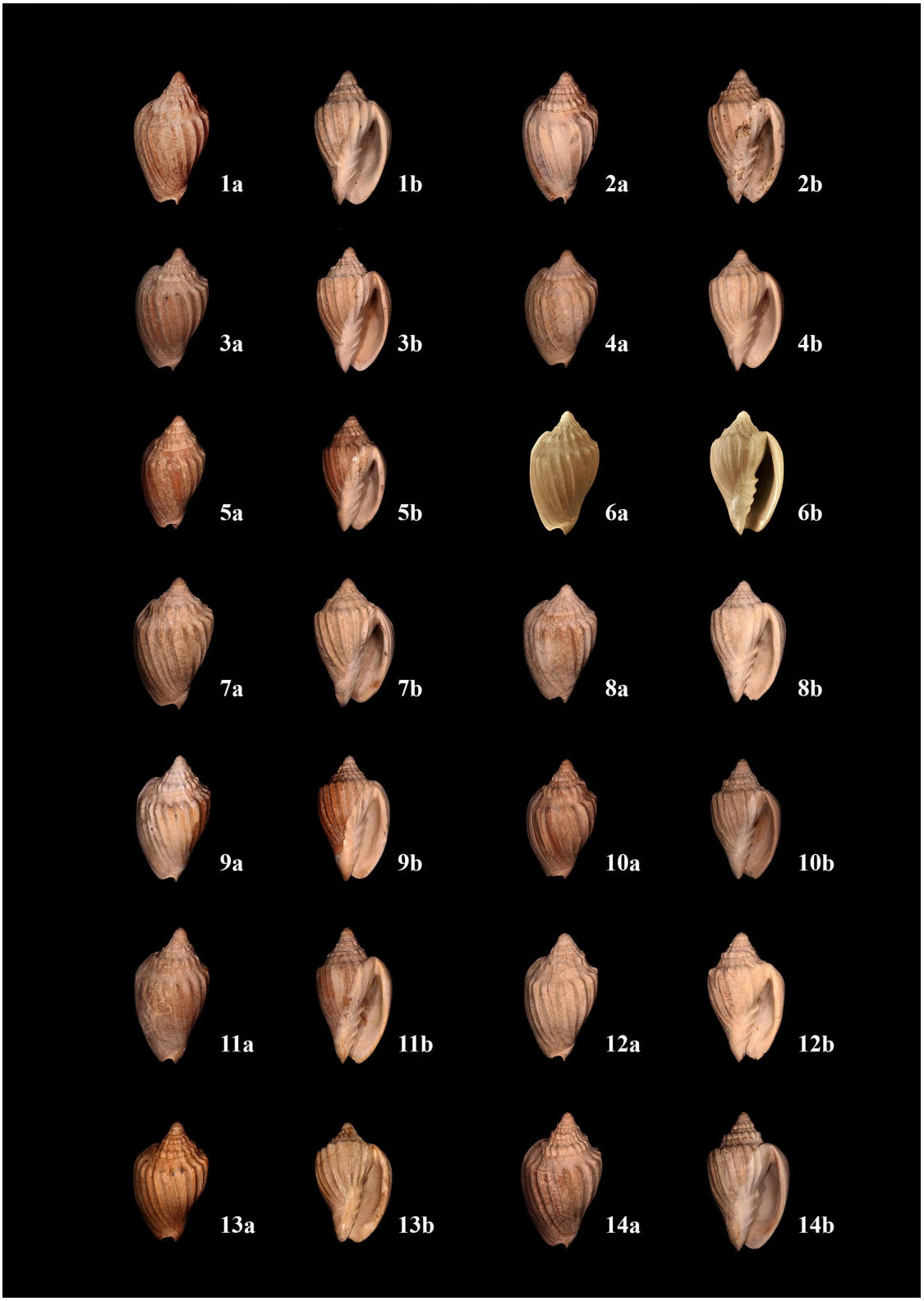

Plate 2. Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 = *Nannamoria flindersi* n. sp. (Holotype Figure 2, P344175).

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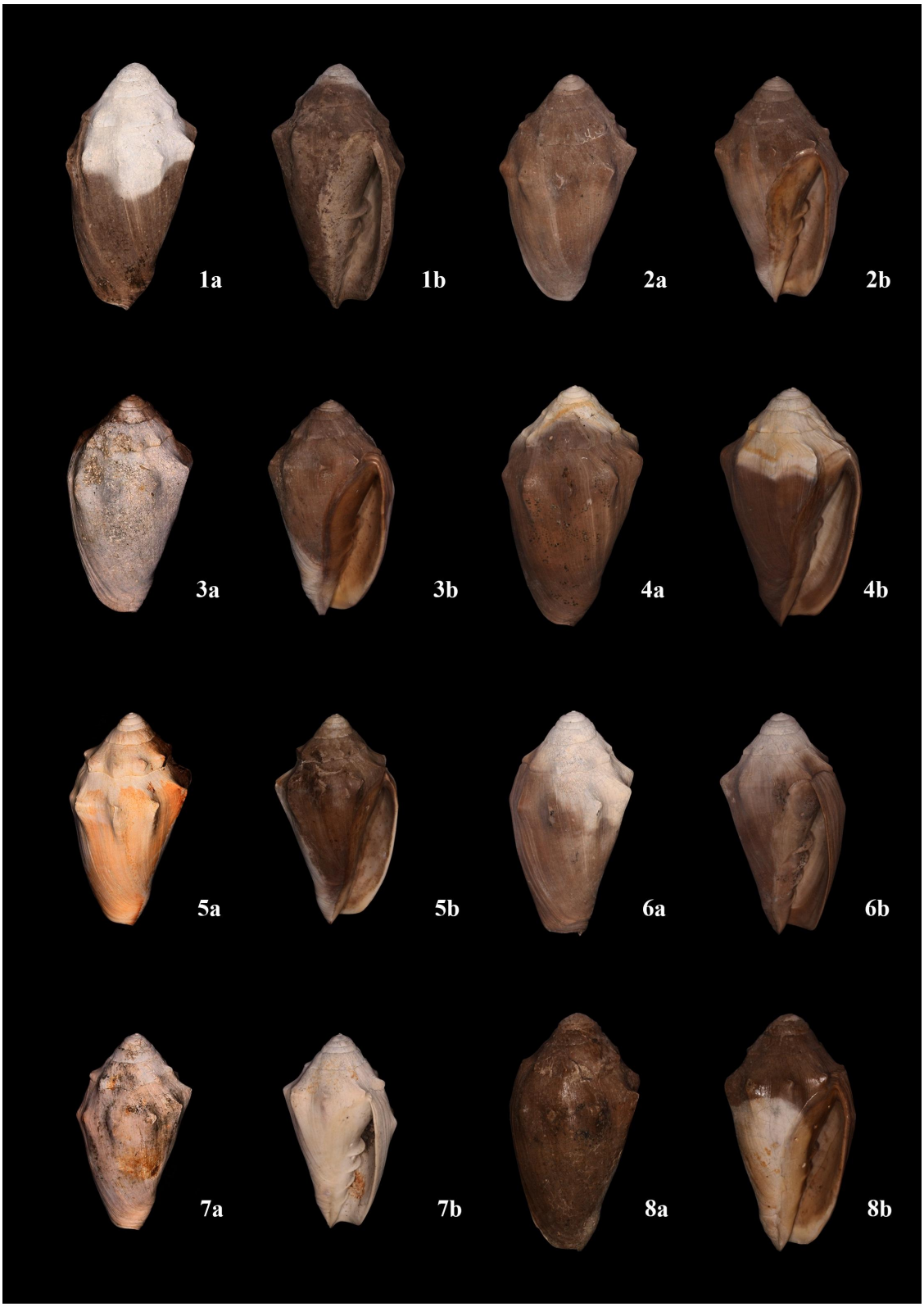

Plate 3. Figures 1, 2, 3, 4, 5, 6, 7, 8 = *Nannamoria malonei* n. sp. (Holotype Figure 1, P344169).

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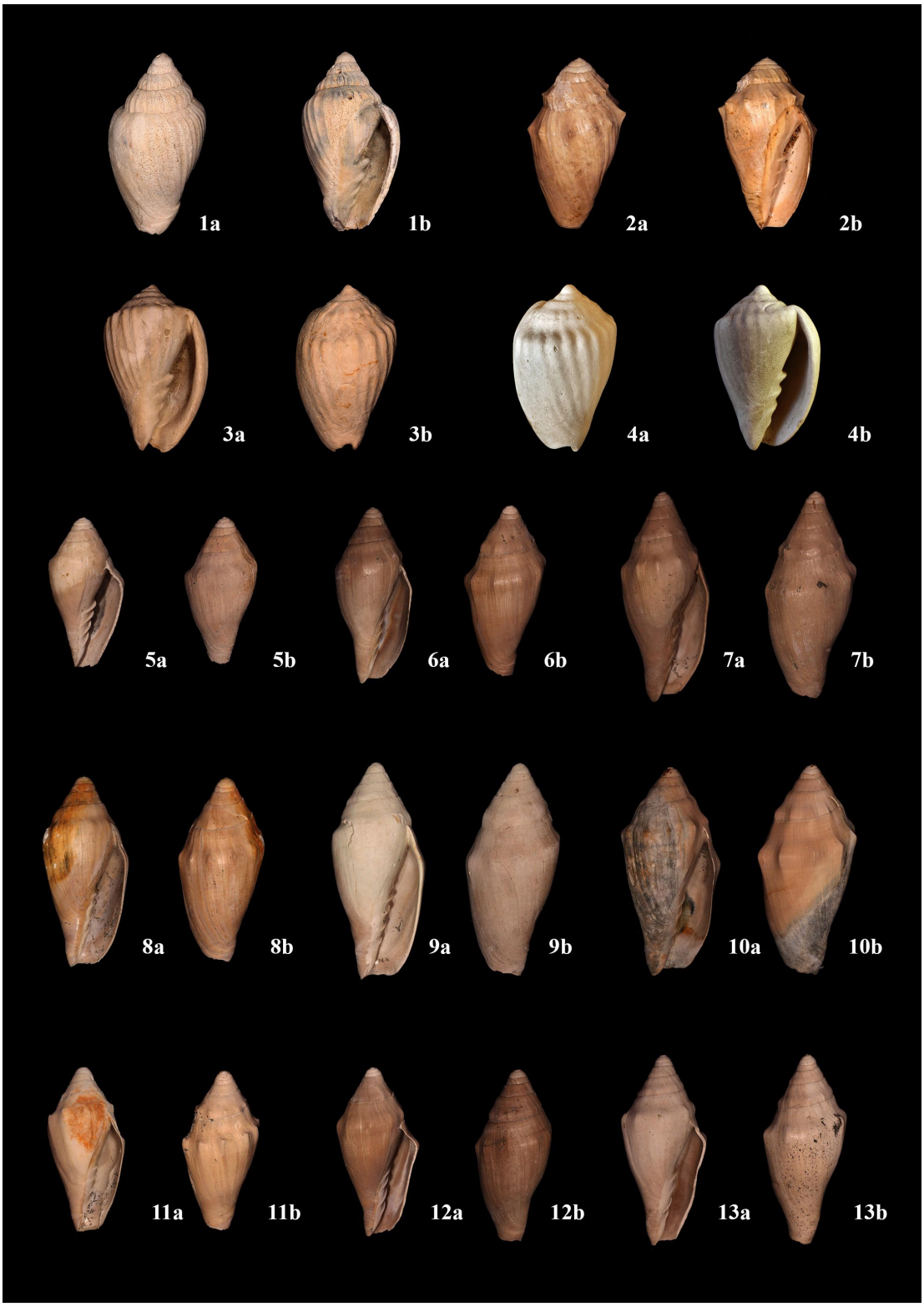

Plate 4. Figure 1 = *Nannamoria costatum* n. sp. (Holotype Figure 1, P344171); Figure 2 = *Nannamoria N. trionyma* (Included for reference); Figures 3, 4 = *Nannamoria hiscocki* n. sp. (Holotype Figure 1, P344170); Figures 5, 6, 7, 8, 9, 10, 11, 12, 13 = *Nannamoria alquezae* n. sp. (Holotype Figure 6, P344178).

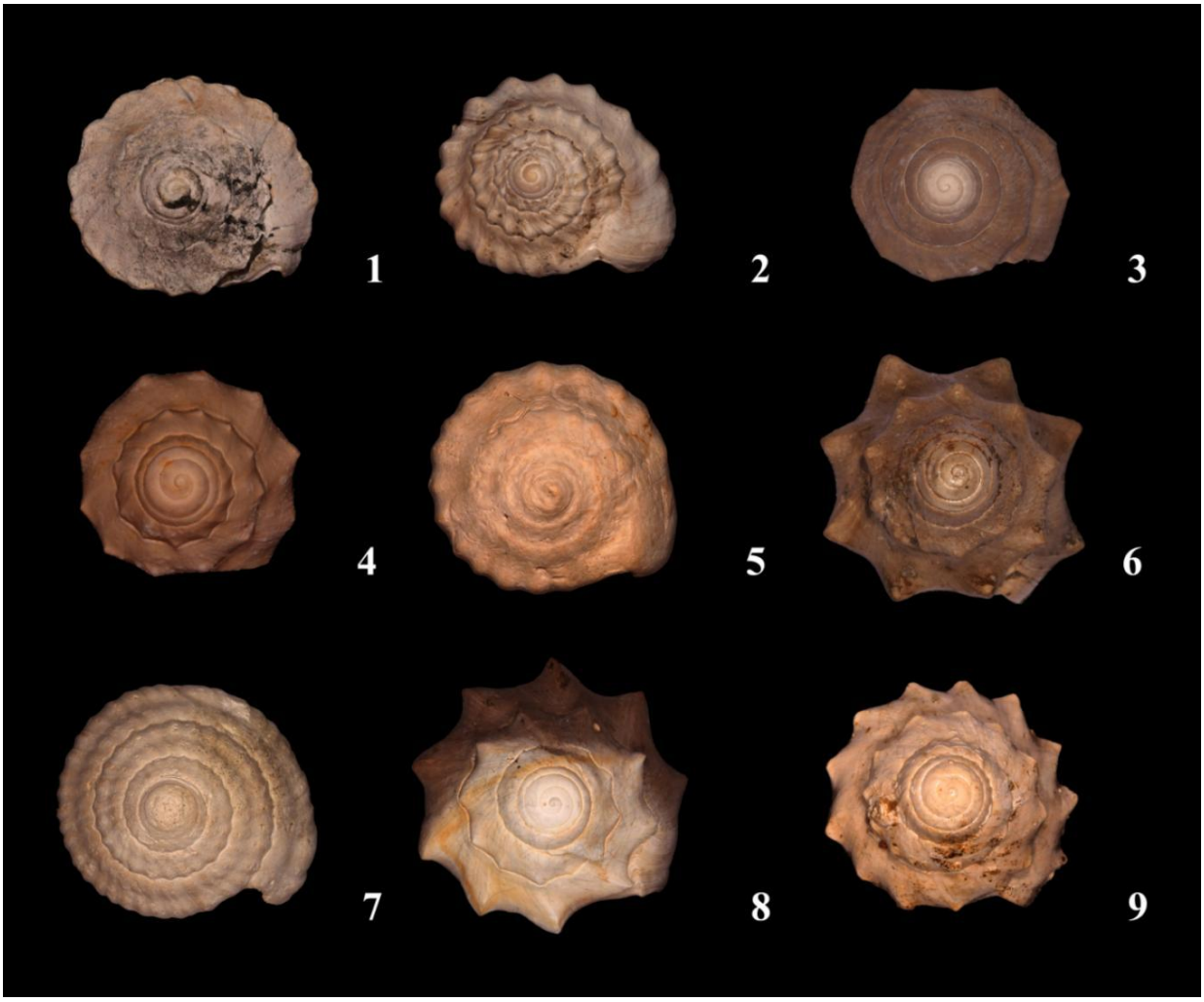

Plate 5. Figure 1 = *Nannamoria gnotuki* n. sp.; Figure 2 = *Nannamoria flindersi* n. sp.; Figure 3 = *Nannamoria alquezae* n. sp.; Figure 4 = *Nannamoria cadella* n. sp.; Figure 5 = *Nannamoria hiscocki* n. sp.; Figure 6 = *Nannamoria persimilis* n. sp. ; Figure 7 = *Nannamoria costatum* n. sp.; Figure 8 = *Nannamoria malonei* n. sp.; Figure 9 = *Nannamoria N. trionyma* (Included for reference).