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# Euthecosomatous gastropods (Mollusca: Heterobranchia) from Buton (SE Sulawesi, Indonesia), with notes on species from Viti Levu, Fiji; systematics, biostratigraphy

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## Abstract

Pteropoda (Mollusca, Gastropoda, Euthecosomata) described by Beets (1943, 1950, 1953) from the alleged Late Miocene/Early Pliocene asphaltic deposits of Buton (SE Sulawesi, Indonesia) are revised. The following species are distinguished: *Styliola subula* (Quoy & Gaimard, 1827), *Cavolinia bituminata* (Beets, 1953), *Cavolinia mexicana* (Collins, 1934), *Cavolinia vendryesiana* (Guppy, 1873) and *Diacria mbaensis* Ladd, 1934. A comparison with the Fiji pteropod associations suggests a Miocene (Tortonian to Messinian) age for the Indonesian faunules. Pteropod species described by Ladd (1934) from Viti Levu (Fiji Islands), are revised in an appendix. Five species are distinguished, viz. *Creseis acicula* (Rang, 1828) (?), *Cavolinia gypsorum* (Bellardi, 1873), *C. mexicana*, *C. rewaensis* (Ladd, 1934) and *Diacria mbaensis* Ladd, 1934. The presence of *Cavolina gypsorum* dates this association as Miocene (Tortonian–Messinian).

## Introduction

Mollusca from asphaltic sediments outcropping in the southern part of the isle of Buton (Boeton in Dutch spelling) (SE Sulawesi, Indonesia) were described by Martin (1933, 1935) and Beets (1943, 1950, 1953). The geological setting of these deposits is poorly known. In the papers by Martin and Beets data on stratigraphy are lacking, and merely localities are mentioned. Apparently four localities yielded similar material, viz. Waisiu (or Waisioe), Kabungka, Ktolemando and Tesoh (see map in Beets 1943). Tesoh might be another name for one of the other three localities. In the Basel collection material from one of these is indicated to have originated from the 'Sampalokossa Beds', a stratigraphic unit on which I have no information.

The age of the faunas from all these localities was assumed to be identical, and initially was thought to be Oligocene (Martin 1935) or Late Oligocene (Beets 1943). Beets (1953) discussed in detail the age of the asphaltic sediments using molluscs. He recognized the deep water character of the faunas, and realised that the method of using percentages of extant species in age determinations of fossil communities could not properly be applied to deep water faunas. He concluded that the faunas are most probably of Mio/Pliocene age. Skwarko & Sufiati (1994) still accepted this age assignment.

Apart from many benthic species Beets (1943) described also five species of holoplanktonic gastropods, namely:
*Styliola* sp. indet.
*Clio asphaltodes* Beets, 1943
*Diacra kipasiformis* Beets, 1943
*Cavolina limatula* Beets, 1943
*Cavolina (Gamopleura) cranioides* Beets, 1943

These were subsequently (Beets 1950) revised as follows: *Diacra kipasiformis* was synonymised with

*D. mbaensis* Ladd, 1934, a species described from 'Late Miocene' deposits of Viti Levu, Fiji, while *Cavolina cranioides* was considered a subspecies of the extant, mainly Indo-Pacific *C. globulosa* (Gray 1850). In 1953, Beets erected *Cavolina bituminata*, based on material housed in the Naturhistorisches Museum (Basel, Switzerland). The list of Buton species then was:
*Styliola* sp. indet.
*Clio alphaltodes* Beets, 1943
*Cavolina bituminata* Beets, 1953
*Cavolina globulosa cranioides* Beets, 1943
*Cavolina limatula* Beets, 1943
*Diacra mbaensis* Ladd, 1934.

Skwarko & Sufiati (1994) repeated this list and only replaced the incorrect genus name *Diacra* by *Diacria*. Apart from two additional species from the Pliocene of the isle of Seran, viz. *Cavolina moluccana* Fischer, 1927 and *Cavolina* sp., these are the only holoplanktonic molluscs recorded by these authors from the Indonesian Cainozoic.

In the present paper the Buton material is revised, and the age of the association discussed by means of comparison with pteropod faunas described from the Fiji Islands by Ladd (1934).

*Abbreviations:*

| | |
|---|---|
| BM | Bishop Museum (see BPBM) |
| BPBM | Bernice P. Bishop Museum, Honolulu, Hawaii, U.S.A. |
| NMB | Naturhistorisches Museum, Basel, Switzerland. |
| NNM | National Museum of Natural History, Department of Invertebrates, Malacology, Leiden, the Netherlands |
| RGM | National Museum of Natural History, Department of Geology (formerly Rijksmuseum van Geologie en Mineralogie), Leiden, the Netherlands |
| USNM | United States National Museum of Natural History, Smithsonian Institution, Washington DC, U.S.A. |
| UVA | University of Amsterdam, Geological Institute, Amsterdam, the Netherlands. |

Symbols used in the lists of synonyms are those of Richter (1948).

**Systematic part**

Order Thecosomata de Blainville, 1824
Suborder Euthecosomata Meisenheimer, 1905
Family Cavoliniidae Fischer, 1883
Subfamily Creseinae Rang, 1828
Genus *Styliola* Gray, 1850
*Type species*: *Styliola subula* (Quoy & Gaimard 1827) (Recent).

*Styliola subula* (Quoy & Gaimard 1827)
(Plate I, Figures 1a, b)

v. 1943 *Styliola* spec. indet. – Beets, p. 304.

For further synonymy and description see Janssen (1990, p. 32).

*Type material* – Neotype NNM 57267 (Recent, Canary Islands, South of Palma, 28–26′N, 17–51W), see Janssen (in press, text Figure 3).

*Material* – A single specimen labelled Boeton (UVA B. 6517, De Roever leg.) is available.

*Discussion* – Beets (1943) referred to two specimens in the Amsterdam collection, but only one could be traced. This specimen agrees in all respects with the Late Oligocene to Recent *Styliola subula*. Beets most probably listed this taxon in open nomenclature in view of its alleged Oligocene age. At that time *S. subula* was only known from the Pliocene onwards.

Subfamily Cavoliniinae van der Spoel, 1967
Genus *Cavolinia* Abildgaard, 1791 (emend. Philippi, 1853)
*Type species*: *Cavolinia tridentata* (Niebuhr 1775) (Recent).

*Cavolinia bituminata* (Beets 1953)
(Plate I, Figures 2a–e)

*v 1953 *Cavolina bituminata* spec. nov., Beets, p. 251, pl. 1, Figures 5–7

v. 1994 *Cavolina bituminata* Beets 1953 – Skwarko & Sufiati, p. y3.

*Type material* – Holotype NMB H 17876 from Waisioe, Buton, SE Sulawesi, Indonesia (leg. F. Weber, don. 24 September 1952), 'Miopliocene': Sampalokossa Beds.

*Description* – Shell with typical cavoliniform outline, slightly less than one and a half times higher than wide. The dorso-ventral diameter equals circa 7/10 of shell width. Maximum shell width situated slightly below mid-height.

The dorsal side of the shell is rather flat, with a convex apertural rim. Its ornament consists of three more or less equally wide and very indistinct radial ribs visible only in the abapical part. These ribs are separated by very shallow interspaces that are slightly narrower than the ribs themselves. At both sides of the set of radial ribs there is a triangular, slightly concave area, a little bulbous where the interlocking mechanisms at the margin of the inner shell wall are situated. Here, the outline of the dorsal shell part is slightly constricted. The anterior part of the dorsal shell wall is the most convex part, strongly curved in ventral direction, overhanging the aperture. The dorsal surface shows very faint concentric growth lines.

The ventral shell part is wider than high and considerably more convex than the dorsal side. The place of the strongest curvature is situated in the anterior shell part, where it is curved to an almost horizontal position in lateral view. Towards the ventral apertural margin the shell wall is very slightly concave. The ventral apertural margin is recurved as a strengthening device, hidden in the aperture. Weak but regular transverse striae are seen, especially on the most convex part. In their centre they are faintly bent in apical direction. The lower portions of the ventral side are smooth or show some faint growth lines only.

Dorsal and ventral shell parts are only fused on the posterior margins, which are slightly excavated. From the posterior corners towards the aperture lateral slits occur, the lower parts of which are visible in straight dorsal view. Where the dorsal shell part shows faint constrictions a catch structure is present on the shell margin, projecting inwards, and hooking over the reflected margin of the ventral shell part (Figures 2d, e), preventing both shell parts to become separated.

The apical spine is flattened dorso-ventrally, with an elliptical transverse section, and two very weak longitudinal carinae along the flat dorsal part. The apical spine is curved in dorsal direction. On both sides of the spine weak wrinkles are present close to the posterior margins.

*Material* – The holotype is the only specimen known.

*Discussion* – Beets (1953) compared this species with *Cavolinia limatula*, and most of his observations are pertinent. However, he did not note the peculiar closing mechanism, which differs considerably from what is normally seen in *Cavolinia* species, i.e., a kind of press-stud, consisting of a cavity on the inner wall of the dorsal shell part, and a knob-like structure on the margin of the ventral shell part (Janssen, in press, pl. 4, Figures 2, 3c). In the present species there is no cavity, and the knob structure is on the dorsal shell part. The margin of the ventral shell part does not show any special structure, apart from a very narrow reflection of the margin where it is secured by the knob of the dorsal margin. This feature makes *C. bituminata* unique among the species of this genus.

*Cavolinia mexicana* (Collins, 1934)
(Plate I, Figures 3a–c, 4a–c)

| | |
|---|---|
| *v 1934 | *Cavolina mexicana* n. sp., Collins, p. 182, pl. 7, Figures 12–15. |
| v. 1934 | *Cavolinia globulosa* Rang – Ladd, p. 235, pl. 42, Figures 2, 3 (non Rang). |
| v. 1943 | *Cavolina (Gamopleura) cranioides* spec. nov., Beets, p. 306. |
| v. 1943 | *Cavolina (Gamopleura) cranoides* (sic !) – Beets, pl. 29, Figures 120–123. |
| v. 1950 | *Cavolina globulosa cranioides* Beets – Beets, p. 336. |
| v. 1953 | *Cavolina globulosa cranioides* Beets – Beets, pp. 251, 252. |
| v. 1974 | *Cavolina (Cavolina) mexicana* Collins – Perrilliat, p. 36. |
| . 1982 | *Cavolinia mexicana* Collins – Bernasconi & Robba, p. 217. |
| 1986 | *Cavolinia globulosa* (Gray, 1850) – Shibata, Ishigaki & Ujihara, p. 50, pl. 8, Figure 9 (non Gray). |
| 1990 | *Cavolinia mexicana* (Collins, 1934). – Ujihara, Shibata & Saito, p. 321, pl. 2, Figures 11–12. |
| v. 1994 | *Cavolina globulosa cranioides* Beets 1942 – Skwarko & Sufiati, p. y3. |
| v. in press | *Cavolinia mexicana* (Collins, 1934) – Janssen, pl. 1, Figures 5–7. |

*Type material* – Holotype USNM 645.206 see Janssen, in press. Holotype of *C. cranioides* (RGM 42.513, Figure 3a–c).

*Description* (based on the Buton material) – Shell typically cavoliniform, slightly less than one and a half times higher than wide. The dorso-ventral diameter more or less equals the shell width. Maximum shell width is situated at about mid-height.

The dorsal side of the shell is very convex. Its ornament consists of three more or less equally wide and rather indistinct radial ribs developing more clearly in the anterior half of the shell. These ribs are separated by narrow interspaces. At both sides of the set of radial ribs there is a narrow, flat or slightly concave area, slightly bulbous where the interlocking mechanism at the inner shell wall is situated. Here, the outline of the dorsal shell part is slightly constricted. The anterior part of the dorsal shell wall is the most convex part, strongly curved in ventral direction, overhanging the aperture and the anterior portion of the ventral shell part, with a short, recurved apertural lip. The dorsal surface shows very faint concentric growth lines.

Width and height of the ventral shell part are about equal, and the ventral part is considerably more convex than the dorsal side. The place of the strongest curvature is situated in the anterior shell part, which is curved to an almost horizontal position in lateral view. Towards the apertural margin the shell wall is almost flat to slightly concave. The margin itself is recurved as a strengthening device, hidden in the aperture. Quite regular transverse striae are seen, especially on the most convex part. In their centre they are faintly curved in apical direction. The lower parts of the ventral side are smooth or show some faint growth lines.

Dorsal and ventral shell parts are fused on the posterior margins, which are almost straight to slightly excavated. From the posterior corners towards the aperture lateral slits are present, the lower parts of which are visible in straight dorsal view.

The apical spine itself is flattened dorso-ventrally, has an elliptical transverse section, and curved in dorsal direction to such an extent that it almost touches on the dorsal shell part. The protoconch has a rounded apex. On both sides of the spine wrinkles are present close to the posterior margins.

Measurements are given in Table 1.

*Material* – Holotype and one paratype of *Cavolinia cranioides* (RGM 42.513, Figure 3a–c; RGM 231.423, Figure 4a–c) from Waisiu, Buton; one broken paratype (UVA B. 6525), merely labelled 'Buton'.

*Table 1.* Dimensions of *Cavolinia mexicana* (Collins, 1934)

| Sample no. | height | width | dorso-ventral diameter | height of ventral side |
|---|---|---|---|---|
| Buton, Indonesia | | | | |
| RGM 231.432 | 2.58 | 2.17 | 2.00 | 2.17 |
| RGM 42.513 | 3.17 | 2.50 | 2.42 | 2.75 |
| Viti Levu, Fiji | | | | |
| BPBM 208247 | 3.58 | 2.75 | 2.67 | 3.08 |

*Discussion* – The differences between *Cavolinia cranioides* and *C. mexicana* are so small, that I consider them to be conspecific. Beets (1943) compared *C. cranioides* with the Recent Indopacific species *C. globulosa* (Gray 1850). Later (Beets 1950), no doubt influenced by Ladd's (1934) paper in which very similar material was described from Fiji as *C. globulosa*, he even considered *C. cranioides* to be a subspecies of *C. globulosa*. Indeed, these taxa are similar, but there are also considerable differences. In the much larger *C. globulosa* the dorsal shell part is flatter, whereas the ventral part is usually more convex. Furthermore, the apical spine of the Recent species is indeed strongly curved, but apparently not so strong as in *C. mexicana*. This is difficult to estimate in the Recent species, as this shell part is shed in adult specimens, the opening being closed with a calcareous septum (van der Spoel, 1967, Figure 101). This is not the case in *C. mexicana*.

I was able to study the specimen of '*C. globulosa*' from Viti Levu, Fiji, illustrated by Ladd (1934), thanks to the kind co-operation of Dr R.H. Cowie of the Bishop Museum at Honolulu. The shell is re-illustrated here (Figure 9a–c). When compared to the Buton specimens of *C. cranioides* differences are minor. For instance, the posterior margins seem to be less excavated, the ventral shell part is more regularly rounded, and the overall size is slightly larger. The Fiji and Buton material are undoubtedly conspecific.

*Cavolinia mexicana* was studied in detail by Janssen (in press). The holotype, originating from the Early Pliocene Agueguexquite Formation of Santa Rosa (Vera Cruz, Mexico) is a small specimen with a shell height of 3.1 mm. In this respect it resembles the Buton and Fiji specimens (Table 1). Late Miocene specimens from the Dominican Republic reach larger dimensions (Janssen, in press, Table 3) with a shell height of over 6 mm. The same holds true for

the Japanese occurrences, referred to by Shibata et al. (1986), Ujihara et al. (1990) and Janssen (in press). Except for the size, however, there are no significant differences.

*Cavolinia vendryesiana* (Guppy 1873)
(Plate I, Figure 5a–c)

| | |
|---|---|
| * 1873 | *Hyalaea (Diacria) vendryesiana* n. sp., Guppy, p. 74, pl. 2, Figure 2. |
| *v 1943 | *Cavolina limatula* spec. nov., Beets, p. 305, pl. 29, Figures 117–119. |
| v 1953 | *Cavolina limatula* Beets – Beets, p. 251, 252. |
| v 1994 | *Cavolina limatula* Beets 1942 – Skwarko & Sufiati, p. y3. |
| 1998 | *Cavolinia vendryesiana* (Guppy, 1873) – Janssen, pl. 2, Figure 2a-c (with additional synonymy). |

*Type material* – Lectotype, designated by Woodring (1928, p. 115) is USNM 115624 (not studied herein).

*Description* – See Beets (1943, p. 305).

*Material* – Holotype of *C. limatula* Beets, 1943, RGM 42.512 from Waisioe, Buton, SE Sulawesi, Indonesia.

*Discussion* – Beets (1943) gave a detailed description of his *C. limatula*, a taxon only known by its holotype. Beets (p. 306) stated 'Entfernt verwandt ist *C. vendreysiana* Guppy [. . .] letztere ist aber ganz verschieden, obwohl sie ebenfalls eine vollkommen glatt ausgebildete Art ist und sicher mit *C. limatula* einer charakteristischen Untergruppe dieser Gattung angehört'. Beets based his interpretation of *C. vendryesiana* merely on Woodring's illustrations of the lectotype, which, however, is not a very well preserved and representative specimen. Janssen (1998) had abundant material available from the type locality (Bowden, Jamaica). Compared with those samples the Indonesian specimen shows but few differences in proportions and size, insufficient to maintain *C. limatula* as a separate species for the time being. Should more material demonstrating constant differences from typical *C. vendryesiana* become available, then Beets' name might be revived.

Genus *Diacria* Gray, 1847
*Type species*: *Diacria trispinosa* (de Blainville, 1821) (Recent).

*Diacria mbaensis* Ladd, 1934
(Plate I, Figures 6a–c; 7a, b; 13a, b; 14a, b)

| | |
|---|---|
| *v 1934 | *Diacria mbaensis* Ladd, new species, Ladd, pp. 234, 237, pl. 42, Figures 6, 7. |
| v. 1943 | *Clio asphaltodes* spec. nov., Beets, p. 304, Figures 101–103. |
| v. 1943 | *Diacra kipasiformis* spec. nov., Beets, p. 304, Figures 98-100. |
| v. 1950 | *Diacra mbaensis* Ladd – Beets, p. 336. |
| v. 1953 | *Diacra mbaensis* Ladd – Beets, p. 251. |
| 1972 | *Diacria mbaensis* Ladd, 1934 – Noda, p. 479. |
| v. 1994 | *Diacria mbaensis* Ladd 1934 – Skwarko & Sufiati, p. y4. |
| v. 1994 | *Clio asphaltodes* Beets 1942 – Skwarko & Sufiati, p. y4. |

*Type material* – Holotype and paratype (BPBM 208244-5) from 2 1/4 miles South of Na Rarawai, Sta. 306, Viti Levu, Fiji (Late Miocene).

*Description* – The holotype (Figure 13a, b) is incompletely preserved (apical shell part is missing) on a piece of clayey sediment, only showing its dorsal side. The paratype is on another piece of clay, and shows its ventral side. The lozenge-shaped shell is bilaterally symmetrical, flattened dorso-ventrally, with distinct lateral spines at circa 3/4 of the shell height. In between these spines and the apex the dorsal and ventral shell parts are fused to form a squarish carina. Above the lateral spines these shell parts are not fused, but separated by a narrow slit, soon widening to form the aperture. There is no interlocking system. The protoconch (H = 0.36, W = 0.16 mm) is preserved in the paratype (Figure 14b) only. It is elongated elliptical, with a smoothly rounded tip, circa twice as high as wide. The transition to the teleoconch is abrupt, marked by some distinct growth lines and a faint constriction.

The early teleoconch is dorso-ventrally flattened right from the start and has narrow but distinct lateral margins, accompanying the carinae. Clear wrinkles are seen next to the lateral margins of both sides. Initially this shell part is very slender, but towards the

*Table 2.* Dimensions of *Diacria mbaensis* Ladd, 1934

| Sample no. | height | width | dorso-ventral diameter | height of apertural part above spines |
|---|---|---|---|---|
| Buton, Indonesia | | | | |
| RGM 42.510 | 2.88+ | 2.08+ | 1.28 | 1.28 |
| RGM 42.511 | 2.52+ | 2.00 | 1.12 | 1.24 |
| | 3.04+ | 2.08 | 1.16 | 1.24 |
| | 2.16+ | 1.84 | 1.12 | 1.00 |
| UVA B 6524 | 2.76+ | 2.00 | 1.24 | 1.16 |
| UVA B 6519 | 2.84+ | 1.92+ | 2.20+ | – |
| Viti Levu, Fiji | | | | |
| BPBM 208244 | 3.68+ | 3.04 | – | 1.07 |
| BPBM 208245 | 4.68 | 3.20 | – | 1.24 |

lateral spines the width increases rapidly. The ventral side of the shell is more convex than the dorsal, especially so towards the aperture. The ventral apertural margin is truncated and distinctly recurved (Buton specimens). Apart from the slightly widening marginal seams the ventral shell part has no ornament, except for some faint growth lines.

The dorsal shell part is higher, its apertural part overhanging the ventral margin, and thus leaving only a narrow aperture. Between the lateral spines the dorsal apertural margin has a clear external thickening. The ornament consists of five radial ribs, three of which start quite early on the initial teleoconch (occasionally the middle one somewhat later than the other two), whereas the two lateral ones develop later. Between this set of ribs and the lateral margins is a narrow, slightly excavated triangular field.

Growth lines follow the shape of the apertural margin and therefore are much more strongly curved on the dorsal than on the ventral side. Measurements are given in Table 2.

*Material* – Holotype (RGM 42.510), 4 paratypes (RGM 42.511, 3 specimens; UVA B. 6524, 1 specimen) of *Diacria kipasiformis* Beets, 1943. Holotype (UVA B. 6519) of *Clio asphaltodes* Beets, 1943.

*Discussion* – The dorsal side of *Diacria mbaensis* closely resembles the Recent *D. trispinosa* (de Blainville 1821), which also has 5 radial ribs. In the considerably larger (H up to over 10 mm) extant species, however, the central rib is the strongest, developing on the apical spine, while the lateral ribs develop later. In *D. mbaensis* the central rib is not stronger than the adjacent ones and develops simultaneously or even slightly later. Much more important differences, however, are found in the protoconch and in the ornament of the ventral shell part. The protoconch of *D. trispinosa* is globular (see van der Spoel 1967, Figure 76c), whereas in *D. mbaensis* it is elongated elliptical and much more closely resembles that of the extant *D. quadridentata* (de Blainville 1821). The ventral shell part of *D. trispinosa* has a well-developed ornament of two radial ribs, separated by a wide and smooth central area (Janssen 1995, plate 9, Figure 3d). Thus, there is no doubt that *D. mbaensis* does indeed represent a separate species. Beets (1950) was absolutely correct in synonymising his *D. kipasiformis* with the species described from Fiji.

The holotype and only specimen of *Clio asphaltodes* Beets, 1943 (Figure 7a–b) is a broken specimen of *D. mbaensis*, with the apical and apertural shell parts missing. Its smooth central side clearly demonstrates its conspecifity with *D. mbaensis*, of which it represents a relatively large specimen.

## Conclusions

The present revision of pteropod material from the asphaltic deposits of Buton (SE Sulawesi, Indonesia) as described by Beets (1943) and revised by Beets (1950, 1953) has resulted in the following corrections detailed in Table 3.

Of these species, *Styliola subula* ranges from the Late Oligocene to Recent. *Diacria mbaensis* (see Ap-

*Table 3.* Revision of pteropod species from asphaltic deposits at Buton, SE Sulawesi, Indonesia

| Beets (1950, 1953) | present paper |
|---|---|
| *Styliola* sp. nov. | *Styliola subula* (Quoy & Gaimard, 1827) |
| *Clio alphaltodes* Beets, 1943 | *Diacria mbaensis* Ladd, 1934 |
| *Cavolina bituminata* Beets, 1953 | *Cavolinia bituminata* (Beets, 1953) |
| *Cavolina globulosa cranioides* Beets, 1943 | *Cavolinia mexicana* (Collins, 1934) |
| *Cavolina limatula* Beets, 1943 | *Cavolinia vendryesiana* (Guppy, 1873) |
| *Diacra mbaensis* Ladd, 1934 | *Diacria mbaensis* (Ladd, 1934) |

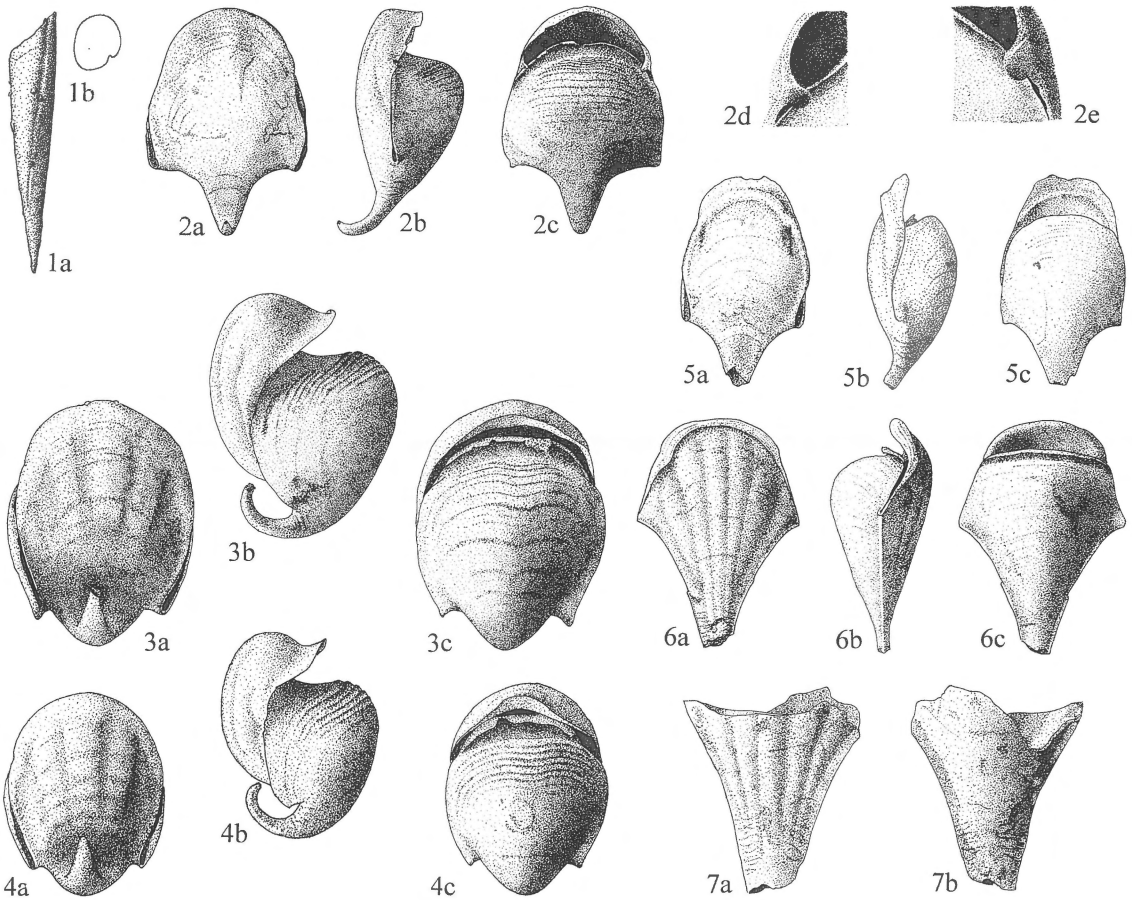


*Plate I.* Species from Buton. *Figure 1a, b. Styliola subula* (Quoy & Gaimard 1827). Buton, SE Sulawesi, Indonesia; UVA B. 6517 (de Roever leg.); a: dorsal view, b: apertural view, X 6. *Figure 2a–e. Cavolinia bituminata* (Beets 1953), holotype. Waisioe, Buton, Sulawesi, Indonesia; NMB H 17876 (F. Weber leg., B. 11); a: dorsal, b: right lateral, c: ventral views, X 12 1/2; d and e: detail of closing mechanisms, X 50. *Figure 3a–c, 4a–c. Cavolinia mexicana* (Collins 1934), holotype and paratype of *Cavolina cranioides* Beets, 1943. Locality see Figure 2a–e; 3: RGM 42.513, 4: RGM 231.432 (both K. Martin Collection); a: dorsal, b: right lateral, c: ventral views, X 12 1/2. *Figure 5a–c. Cavolinia vendryesiana* (Guppy, 1873), holotype of *Cavolina limatula* Beets, 1943. Locality see Figure 2; RGM 42.512 (K. Martin Collection), a: dorsal, b: right lateral, c: ventral views, X 6. *Figure 6a–c. Diacria mbaensis* Ladd, 1934, holotype of *Diacria kipasiformis* Beets, 1943. Locality see Figure 2; RGM 42.510 (K. Martin Collection), a: dorsal, b: left lateral, c: ventral views, X 12 1/2. *Figure 7a, b. Diacria mbaensis* Ladd, 1934, holotype of *Clio asphaltodes* Beets, 1943. Locality see Figure 1a–b; UVA B. 6519 (de Roever leg.), a: dorsal, b: ventral views, X 12 1/2

pendix) is known from the Late Miocene (Tortonian–Messinian). *Cavolinia mexicana* occurs during the Late Miocene–Early Pliocene. Thus, all these species do not conflict with a Tortonian–Messinian age. *Cavolinia bituminata* is exclusively known from Buton. *Cavolinia vendryesiana* is known only from the Pliocene (Caribbean, Mediterranean and Japan). From Buton just a single specimen has been assigned to this taxon. It might be a precursor of the Pliocene form. The relatively common occurrence of *Diacria mbaensis* makes a Tortonian–Messinian age more probable.

## Appendix – Notes on species from Viti Levu, Fiji Islands

Among many benthic species Ladd (1934, pp. 234-237) described several species of euthecosomatous gastropods from various localities at Viti Levu (Fiji Islands). He discussed the following taxa:
*Styliola acicula* (Rang)
*Cavolina telemus rewaensis* Ladd
*Cavolina globulosa* Rang
*Cavolina osoica* Ladd
*Cavolina* sp.
*Diacria mbaensis* Ladd.

Since Beets (1950, 1953) referred to *Cavolina globulosa* and *Diacria mbaensis* in the context of his study of Buton material I re-examined the original material of these taxa, kept in the Bishop Museum at Honolulu. At the same time, I decided to include also the other species mentioned by Ladd. This has led to the following observations.

*Creseis acicula* (Rang, 1828) ?

? 1934 *Styliola acicula* (Rang) – Ladd, p. 234, pl. 41, Figure 10.

*Material* – The material on which this record was based is no longer extant in the Bishop Museum. Recorded by Ladd from his Sta. 306 (Mba Valley Marl).

*Discussion* – Ladd mentioned the absence of protoconchs on his specimens, which makes the identification of these tubes as *Creseis acicula* (Rang, 1828) doubtful.

*Cavolinia rewaensis* (Ladd, 1934)
(Plate II, Figure 8)

*v 1934 *Cavolina telemus rewaensis* Ladd, new subspecies, Ladd, p. 235, pl. 41, Figure 11; pl. 42, Figure 1

*Material* – Holotype (BPBM 208241) from Sta. 158 in the Suva area, Viti Levu, Fiji. Ladd (1934) also referred to specimens from his Sta. 295, 306 and, with some doubt, Sta. 320.

*Discussion* – The holotype (only specimen seen) was adequately described and illustrated by Ladd. It differs clearly from the Recent *Cavolinia tridentata* (Niebuhr 1775) (nomen conservandum = *telemus* Linné, 1767), as stated by Ladd. Especially striking is the complete absence of lateral spines, the upward sloping posterior margins being in line with the lower parts of the lateral slits.

Three strong and narrow radial ribs occur on the dorsal side also in *Cavolinia grandis* (Bellardi 1873), from the Mediterranean Pliocene, but in that species the transition between posterior margins and lateral slits is angular. The apertural margin of the dorsal side is not triangular as in *C. rewaensis*, but regularly curved as in the Recent species. Faint oblique undulations, weaker than in *C. grandis*, can be made out in the Fiji specimen in low angle light.

Since the age of the Fiji material is apparently Tortonian to Messinian (as demonstrated by the co-occurrence of *Cavolinia gypsorum*) it seems appropriate to consider *C. rewaensis* (Ladd 1934) a precursor in the lineage *C. rewaensis* – *C. grandis* – *C. tridentata*. This agrees with the known range of *C. grandis*, i.e., Zanclean.

*Cavolinia mexicana* (Collins, 1934)
(Plate II, Figure 9a-c)

v 1934 *Cavolina globulosa* Rang – Ladd, p. 235, pl. 42, Figures 2, 3.

*Material* – BPBM 208247 illustrated by Ladd, from 2 1/4 miles South of Na Rarawai, Viti Levu, Fiji (Sta. 306).

*Discussion* – As stated in the description of *Cavolinia mexicana*, the specimen referred to and illustrated by Ladd undoubtedly belongs to this species. In Fiji, Ladd recorded it from his Sta. 306 only.

*Cavolinia gypsorum* (Bellardi, 1873)
(Plate II, Figure 10a, b; 11a–c; 12)

*v 1934 *Cavolina osoica* Ladd, new species, Ladd, p. 234, pl. 42, Figures 4, 5.
v 1934 *Cavolina* species – Ladd, p. 236.

*Material* – Holotype of *Cavolina osoica* Ladd (BPBM 208243) from 5 1/2 miles Southeast of Na Rarawai, Viti Levu, Fiji (Sta. 304). The paratype sample (BPBM 208245) of *Diacria mbaensis*, originating from Sta. 306, appeared to include a second specimen, showing its ventral shell part (Figure 12).

The specimen referred to by Ladd as *Cavolina* sp. (BPBM 208246, old number BM Geol. 1203), was collected at Sta. 158, an abandoned quarry 6 1/4 miles from Suva on Prince's Road to Nausori, Viti Levu, Fiji, from 'conglomeratic limestone'.

*Discussion* – The holotype of *Cavolina osoica* is a rather poorly preserved specimen, characterized by a relatively flat dorsal shell part, with five radial ribs on a central triangular elevation, and a very convex ventral part, bearing two oblique furrows and, in its most convex part, fairly well-developed growth lines that centrally are slightly curved in apical direction. The shapes of dorsal and ventral lips cannot be observed.

In its relatively narrow outer radial ribs on the dorsal shell part *Cavolinia osoica* agrees with a Late Miocene form from the Dominican Republic, referred to as *Cavolinia* aff. *gypsorum* (Bellardi 1873) by Janssen (in press). As this form co-occurs there with typical *C. gypsorum* it presumably represents nothing more than a forma, which makes *C. osoica* a junior synonym of *C. gypsorum.*

The specimen referred to by Ladd as *Cavolina* sp., preserved as an internal mould, is characterized by 5 radial ribs and a slightly thickened apertural rim on the dorsal shell part. The ventral side is very convex and smooth but for two vague oblique furrows visible in the basal part. No growth lines can be observed. The apertural lips are not preserved. The remaining part of the apical spine demonstrates a clear curvature in dorsal direction.

Specimens of this type were described by Ladd (1934, p. 236) as follows: '... except for their uniformly small size, strikingly resemble Recent specimens of *C. telemus*, ...'. However, he failed to observe the obvious differences in the curved apical spine and the weak but distinct oblique furrows on the ventral part of the shell. In fact, the specimen studied, agrees in all respects with the Late Miocene (Tortonian to Messinian) *Cavolinia gypsorum* (Bellardi 1873).

*Diacria mbaensis* Ladd, 1934
(Plate II, Figures 13a, b; 14a, b)

*v 1934 *Diacria mbaensis* Ladd, new species, Ladd, p. 237, pl. 42, Figures 6, 7.

*Type material* – Holotype and paratype (BPBM 208244-5) from 2 1/4 miles South of Na Rarawai, Sta. 306, Viti Levu, Fiji (Late Miocene); according to Ladd (1934) the species also occurs at Sta. 304.

*Discussion* – Differences between this species and the Recent *Diacria trispinosa* (de Blainville 1821) have been given above.

## Conclusions

Considering these notes, the Fiji material, as described by Ladd (1934) can be revised as summarized in Table 4. These results lead to the following age assignment: *Cavolinia rewaensis*, a presumed precursor of *C. grandis*, may be assumed to be of pre-Zanclean age. *Cavolinia mexicana* is known from the Late Miocene of the Dominican Republic and from the 'Early' Pliocene of Mexico. *Cavolinia gypsorum* is restricted to the Late Miocene (Tortonian–Messinian). *Diacria mbaensis* is of a similar age because of its co-occurrence with *Cavolinia gypsorum.*

These data indicate a Tortonian–Messinian age for stations 158, 304, 306, and probably also for station 298. The stations 295 and 320 can be dated only roughly as 'probably pre-Zanclean'.

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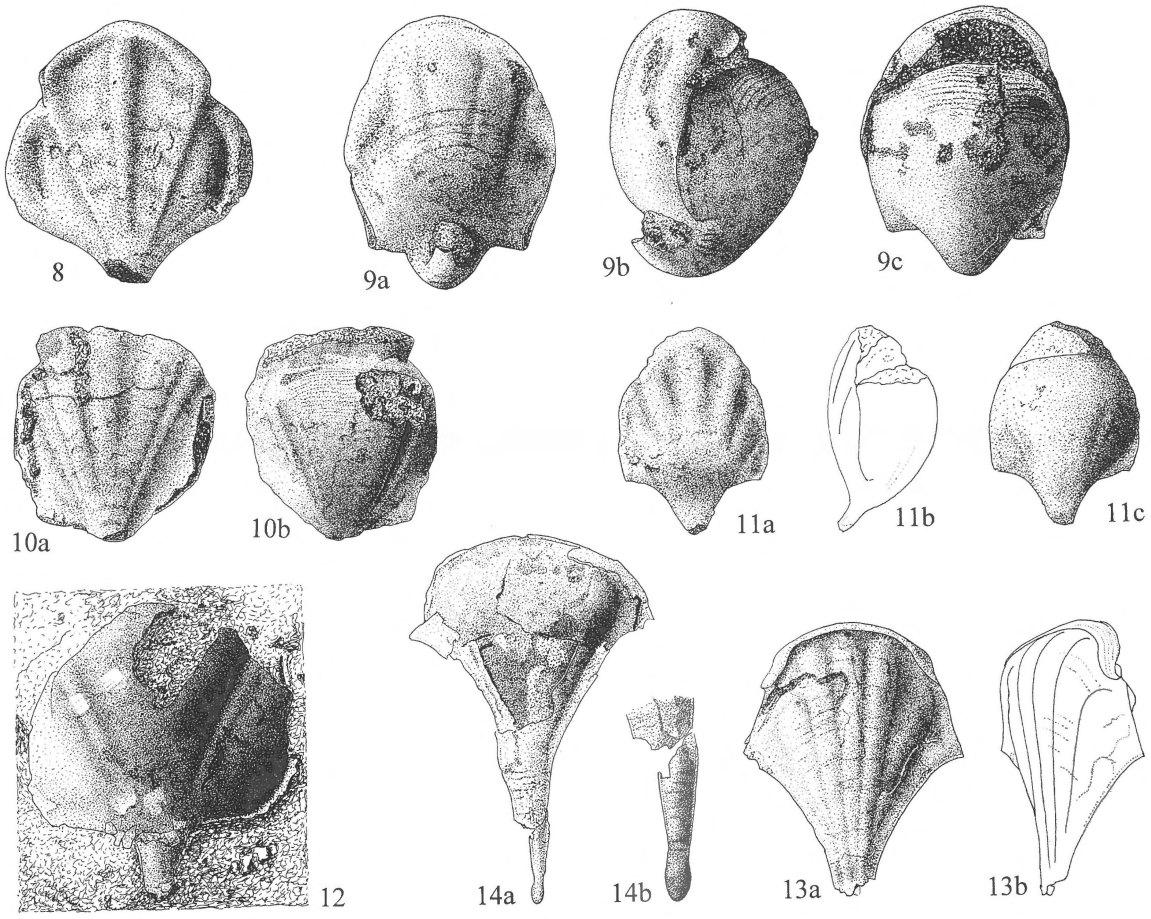


*Plate II.* Species from Fiji. *Figure 8. Cavolinia rewaensis* (Ladd, 1934), holotype. Sta. 158, abandoned quarry 6 1/4 miles from Suva on Prince's Road to Nausori, Viti Levu, Suva area, Fiji; BPBM 208241 (old number BM Geol. 1198; Ladd Collection), dorsal view, X 3. *Figure 9a–c. Cavolinia mexicana* (Collins 1934). Sta. 306, 2 1/4 miles south of Na Rarawai, Viti Levu, Fiji; BPBM 208247 (old number BM Geol. 1204; Ladd Collection). Specimen described and illustrated by Ladd, 1934, as *Cavolina globulosa* Rang; a: dorsal, b: right lateral, c: ventral views, X 12 1/2. *Figure 10a, b. Cavolinia gypsorum* (Bellardi, 1873), holotype of *Cavolina osoica* Ladd, 1934. Sta. 304, 5 1/2 miles southeast of Na Rarawai, Viti Levu, Fiji; BPBM 208243 (old number BM Geol. 1200; Ladd Collection); a: dorsal, b: ventral views, X 6. *Figure 11a–c. Cavolinia gypsorum* (Bellardi, 1873). Locality see Figure 8; BPBM 208246 (old number BM Geol. 1203, Ladd Collection); a: dorsal, b: right lateral, c: ventral views, X 6. *Figure 12. Cavolinia gypsorum* (Bellardi 1873). Locality see Figure 9a–b; BPBM 208245 (old number BM Geol. 1202, Ladd Collection), ventral view, X 12 1/2; same sample contains paratype of *Diacria mbaensis* (see Figure 14). *Figures 13–14. Diacria mbaensis* Ladd, 1934, holotype and paratype. Locality see Figure 9a–b; BPBM 208244-5 (old numbers BM Geol. 1201-2); 13a: dorsal view of holotype, 13b: oblique right lateral view of holotype, X 12 1/2; 14a: ventral view of paratype, X 12 1/2; 14b: protoconch of paratype, X 25.

*Table 4.* Revision of euthecosomatous gastropods from Viti Levu. Fiji Islands and distribution of the species according to Ladd's (1934) station numbers (between brackets when no material was seen by the present author)

| Ladd, 1934 | this paper | Ladd's station numbers | | | | | |
|---|---|---|---|---|---|---|---|
| | | 158 | 295 | 298 | 304 | 306 | 320 |
| *Styliola acicula* (Rang) | *Creseis acicula* (Rang, 1828) ? | – | – | – | (+) | – | |
| *Cavolina telemus rewaensis* Ladd | *Cavolinia rewaensis* (Ladd, 1934) | + | (?) | – | – | + | (?) |
| *Cavolina globulosa* Rang | *Cavolinia mexicana* (Collins, 1934) | – | – | – | – | + | – |
| *Cavolina osoica* Ladd | *Cavolinia gypsorum* (Bellardi, 1873) | – | – | – | + | (+) | – |
| *Cavolina* sp. | *Cavolinia gypsorum* (Bellardi, 1873) | + | – | (+) | – | – | – |
| *Diacria mbaensis* Ladd | *Diacria mbaensis* Ladd, 1934 | – | – | – | (+) | + | – |

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