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Notes on the systematics, morphology and biostratigraphy of fossil holoplanktonic Mollusca, 7-9. 7, *Clio lucai* spec. nov. from the Plio/ Pleistocene of northern Italy, with notes on evolutionary lineages of the genus *Clio;* 8, *Cavolinia grandis* (Bellardi, 1873) from the Early Pliocene of New Zealand, a further example of long-distance correlation by means of pteropods; 9, apertural reinforcements in *Limacina atypica* (Laws, 1944) from the Miocene of New Zealand[1]

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7. *Clio lucai* spec. nov. is described from Early Pleistocene deposits in northern Italy. The new taxon is compared with related species, for most of which the subgenus *Balantium* may be revived. Characteristics of other *Clio (Balantium)* species, known from modern faunas as well as from the fossil record, are compared. Most features, however, develop independant of time and seem to be controlled mainly by ecological factors, thus offering little possibilities for the construction of an evolutionary lineage. Some ideas on a further subdivision of the genus *Clio* s.lat. are added.
8. A large species of *Cavolinia* from the Early Pliocene of New Zealand has been found to be assignable to *C. grandis* (Bellardi, 1873), originally described from the Zanclean of northern Italy. The same species is also known from Japan, and thus constitutes a 'first order long-distance correlation tool'.
9. A paratype of *Limacina ferax* (Laws, 1944) in the collection of the Geology Department (Otago University, Dunedin, New Zealand) has now proved to be assignable to *Limacina atypica* (Laws, 1944), described from the same locality and stratigraphic level.. The internal mould of the specimen demonstrates a clear margin-parallel constriction shortly behind the aperture, thus demonstrating the presence of apertural reinforcements in this species, which was hitherto believed to have a simple apertural margin.

Key words: Gastropoda, Euthecosomata, Pteropoda, new species, systematics, evolutionary lineages, palaeogeography, morphology, Cainozoic, Italy, New Zealand, world wide.

7. *CLIO LUCAI* SPEC. NOV. FROM THE PLIO/PLEISTOCENE OF NORTHERN ITALY, WITH NOTES ON EVOLUTIONARY LINEAGES OF THE GENUS *CLIO*

INTRODUCTION

In January 1994 Mr L. Bertolaso (Correggio, Italy) kindly sent me some specimens of a large species of *Clio*, collected from a new outcrop on the Enza River, near the bridge connecting the villages of Traversetolo and San Polo d'Enza (province of Parma).

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[1] For no. 6 in this series see Basteria 63: 111-120, 1999.

Superficially, these specimens resemble the Recent species *Clio recurva* (Children, 1823), which has a circumtropical to -subtropical distribution, but is absent from the Mediterranean (van der Spoel, 1967: fig. 351). A preliminary study of this material, however, soon showed that there are distinct differences between these taxa. The age of the deposits outcropping on the Enza River was initially considered to be Late Pliocene.

In May 1995 I visited the locality myself, accompanied by Mr Bertolaso, and collected additional material at the site. Simultaneously, colleagues from the Istituto di Geologia, Paleontologia e Geografia of Parma University executed a first logging of the section, and took samples for palaeoecological and micropalaeontological analyses. A description of the locality was published in the 'Guida alle escursioni' of the XIIIth Convegno of the Società Paleontologica Italiana, at Parma, September 1996 (Iaccarino & Monegatti, 1996); the age of the sediments now is considered to be Early Pleistocene.

During my visit to the locality I happened to meet Mr E. Borghi (Reggio Emilia), a private collector who later sent me additional material of the same species, but originating from outcrops along the Torrente Stirone, from sediments of Late Pliocene age.

All samples mentioned in this paper are housed at the National Museum of Natural History, Leiden, The Netherlands, and bear RGM (Palaeontology Department) or RMNH (Zoology Department) registration numbers.

LOCALITIES AND AGE INTERPRETATION

1. Traversetolo

The outcrop on the Enza River (Torrente Enza) is situated on the left bank, immediately N of the bridge connecting the villages of Traversetolo and San Polo d'Enza (fig. 1). The river here is the border between the provinces of Parma and Emilia. The section comprises c. 190 m of marine sediments within a regressive succession, capped by terrestrial sediments. The lower part shows an inclination of c. 48°, the upper part c. 25°, indicating that the complete succession is accessible over a relatively short distance. The Early Pleistocene age was determined on the occurrence of the bivalve *Arctica islandica* (Linné, 1767), which was found to occur from c. 10 m above the base of the section upwards. Foraminifera document the *Bulimina marginata* Zone (Iaccarino & Monegatti, 1996: fig. 1).

The new species of *Clio* is found in a very sandy clay, in a rather thin level of 1 m at the most, at the time of my visit outcropping just above water level, at a height of c. 60 m in the section measured by Iaccarino & Monegatti (1996). Associated species are, apart from a variety of benthic invertebrates, two other pteropod species, viz. *Clio pyramidata* Linné, 1767 f. *lanceolata* (Lesueur, 1813) (RGM 429.259) and *Cavolinia tridentata* (Niebuhr, 1775) (RGM 429.257-258). The former was also found but not collected in other levels below and above that which yield the new *Clio*. There is no lithostratigraphical interpretation yet for this section.

2. San Nicomede

The locality from which two specimens of *Clio lucai* spec. nov. were collected is indicated in fig. 2. Along the streambed of the Stirone River outcrops a thick section of Late Miocene to Pleistocene sediments (Papani & Pelosio, 1963). The provenance of the two specimens collected at this section by Mr Borghi indicates that they are of Late

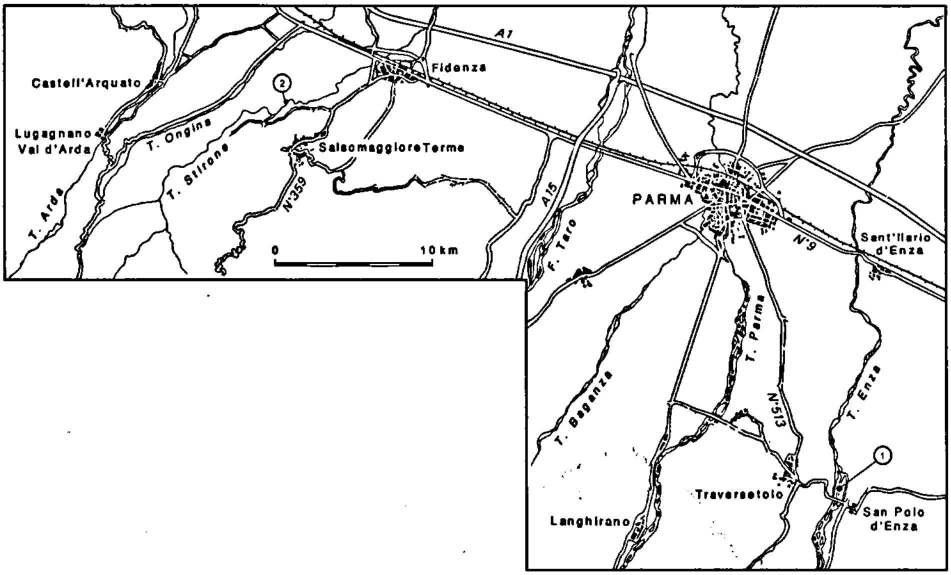


Fig. 1. Map showing localities: 1, Traversetolo, outcrop in streambed of Torrente Enza, type locality of *Clio lucai* spec. nov.; 2, San Nicomede, outcrop in streambed of Torrente Stirone.

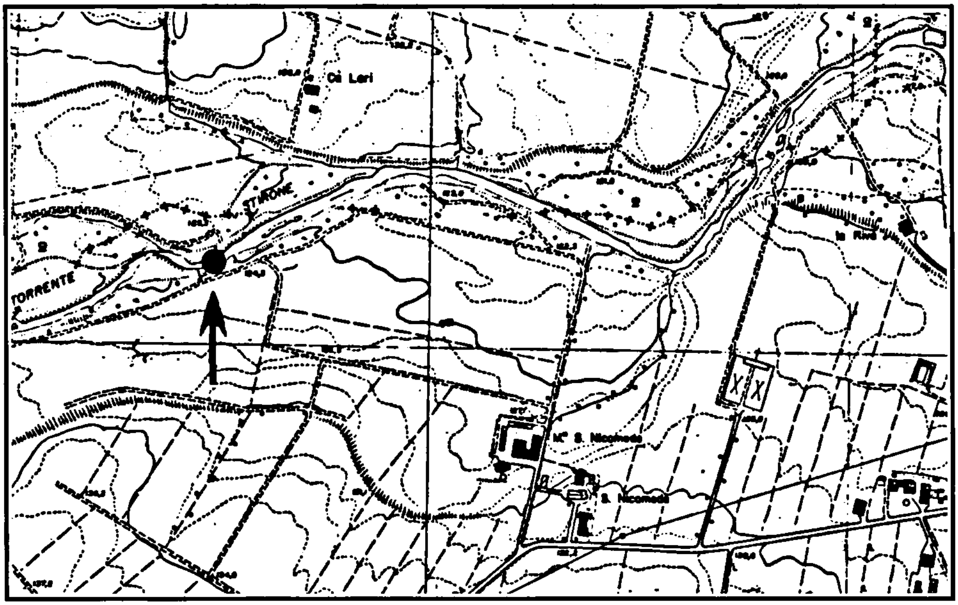


Fig. 2. Provenance of the Torrente Stirone sample.

Pliocene (Gelasian) age (Professor G. Pelosio, in litt., November 1996). The Gelasian deposits here reach a thickness of c. 300 m; the specimens were found above mid-height of this unit, for which no formation name is available either.

SYSTEMATIC PART

Order	Thecosomata de Blainville, 1824
Suborder	Euthecosomata Meisenheimer, 1905
Family	Cavoliniidae Fischer, 1883
Subfamily	Cliinae van der Spoel, 1967 [emended: Rosenberg, 1992]
Genus	*Clio* Linné, 1767

Clio lucai spec. nov. (figs 3-6)

'pteropodi'; Iaccarino & Monegatti, 1996: 65, fig. 1.

Origin of name. – The new species is named after Mr Luca Bertolaso of Correggio (Italy, Emilia), who not only was the first to collect material of this species, but who donated a substantial material to the RGM collections, and has been very helpful in my studies on holoplanktonic molluscs over many years.

Type material. – Holotype (leg./don. L. Bertolaso, fig. 3a-c) RGM 429.249.

Paratypes from the type locality (fig. 1): 17 specimens (leg./don. L. Bertolaso) RGM 429.250; 1 specimen (leg. A.W. Janssen, fig. 4a-b) RGM 429.254; 1 specimen (leg. A.W. Janssen, fig. 8) RGM 429.256; 14 specimens (leg. A.W. Janssen) RGM 429.255; 5 specimens (leg. A.W. Janssen) RGM 429.257; 2 specimens (leg. E. Borghi, figs 5-6) RGM 429.251-252; 1 specimen (leg. E. Borghi) RGM 429.253. Two specimens (SMF 319964) are housed in the Senckenberg Museum, Frankfurt an Main, Germany, two further specimens were donated to the Dipartimento di Scienze della Terra, Torino, Italy.

Paratypes from San Nicomede (fig. 2): 2 specimens (leg. E. Borghi) RGM 429.260.

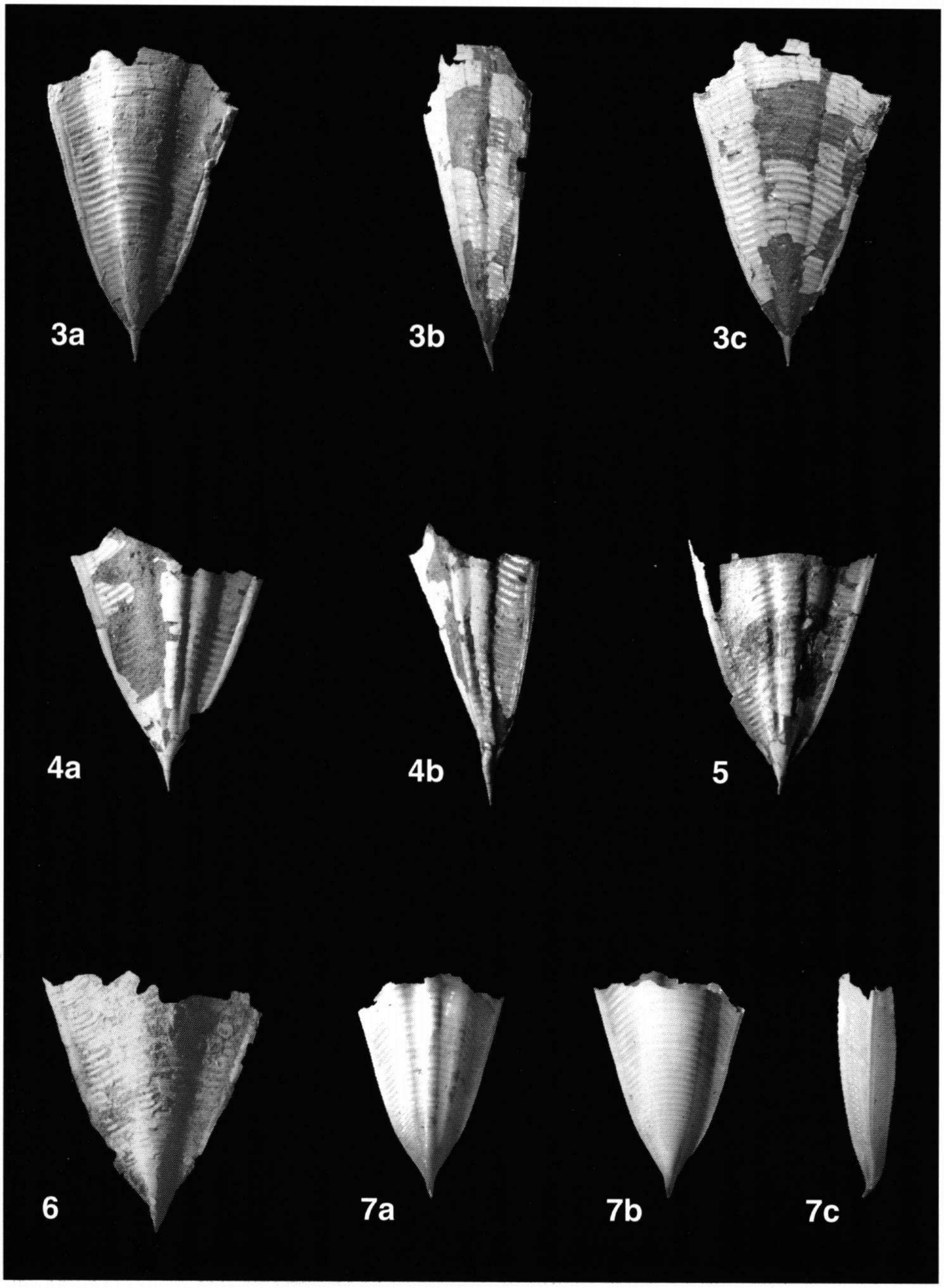
Type locality. – Traversetolo, outcrop on left bank of Enza River, just N of the bridge connecting Traversetolo and San Polo d'Enza (Italy, province of Parma) (fig. 1).

Stratum typicum. – grey, very sandy clay (Early Pleistocene).

Diagnosis. – Large species of *Clio*, resembling the Recent *C. recurva* (Children, 1823), but differing in a number of features, among which especially the straight protoconch (not curving dorsally, as in *C. recurva*), the narrower central rib on the ventral side, the much coarser transverse ornament, especially so in the basal part of the shell, and the angle at which the transverse riblets touch on the lateral carinae, being c. 90° in *C. lucai* and c. 60° in *C. recurva.*

Description. – Large species of *Clio*, reaching more than 30 mm in height, triangular in shape, with in the basal part flexuous sidelines. Maximum width is at the aperture, which equals 6/10th of the total shell height. Dorso-ventral diameter difficult to estimate, as all specimens are preserved in matrix.

Protoconch-1 is elongated spherical with a distinct proximal cusp, somewhat higher than wide and connected to protoconch-2 by a distinct constriction.. Its diameter is c. 0.24 mm. After the constriction the shell is conical, with an apical angle of c. 17°, at the sides distinct wrinkles are seen (fig. 8), the height of protoconch-2 is c. 8 times that



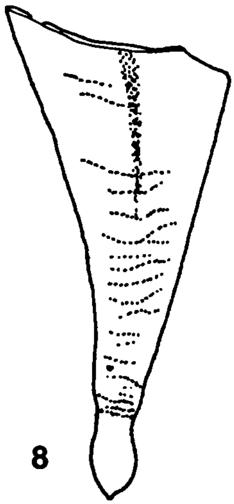
Figs 3-7. *Clio* spec. Figs 3-6. *C. lucai* spec. nov., x 1½. 3, holotype: a, ventral view; b, ventro-lateral view, to demonstrate the straight position of the protoconch; c, same specimen, coated with ammonium chloride (RGM 429.249, leg. & don. L. Bertolaso). 4, paratype: a, dorsal view; b, dorso-lateral view, to demonstrate the straight position of the protoconch (RGM 429.254, leg. A.W. Janssen). 5, paratype, dorsal view (RGM 429.251, leg. & don. E. Borghi). 6, paratype, ventral view (RGM 429.252, leg. & don. E. Borghi). All specimens from the type locality. Fig. 7. *C. recurva* (Children, 1823), x 1½. Recent, Tydeman Cape Verde expedition, 1982. CANCAP-VI, Station 6.049: WSW of Fogo, 14°52' N 24°32' W, depth 1100-1300 m, basalt rocks, sandy clay, 1.2 m Agassiz trawl, 10.vi.1982 (RMNH 2912/6.049).

of protoconch-1. Protoconch-1 and -2 together are in line with the axis of the teleoconch, not curved in dorsal direction, as seen in most species of *Clio.*

The teleoconch starts with a distinct lateral widening to c. 70° in frontal view, and at the same time lateral carinae start to develop. These carinae each consist of two close-set, sharp crests, concave in between, continuing to the aperture, and giving the carinae a squarish transverse section. Gradually the apical angle of the shell decreases, reaching c. 35° in the apertural half of the shell.

Being embedded in matrix the holotype shows its ventral side only. This side is moderately convex, with a narrow smooth area along the carinae, and a convex central rib, running from the early teleoconch to the aperture, equalling c. 1/3 of the shell width. The lateral areas are slightly concave. A regular transverse ornament is seen, consisting of c. 13 riblets per cm (central shell part), which start shortly after the transition between protoconch and teleoconch and almost immediately reach the strength they show all over the teleoconch. From the narrow flat zone along the carinae they start with an angle of c. 90°, curving gently in apertural direction, with their strongest curvature on the central radial rib. Towards the aperture they tend to efface a bit. Growthlines are faint and follow the shape of the riblets. On the narrow lateral zones they are better visible than in between the riblets, where they show a strong upward curvature, touching the carinae at an angle of c. 45°.

The dorsal side is visible only in paratypes. The convexity of this side of the shell almost equals the ventral side. There are three close-set radial ribs, running from close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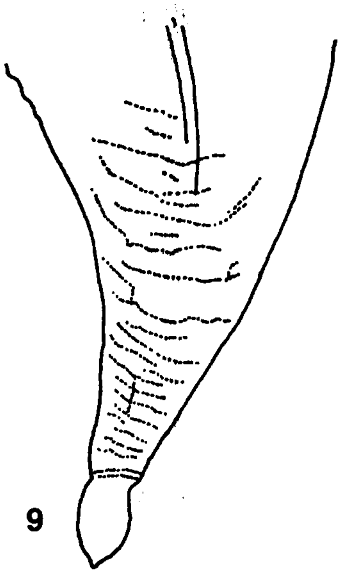
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to the protoconch to the aperture. Together they occupy somewhat more than 1/3 of the shell width, the central one barely wider but more elevated than the two lateral ones. The areas between the set of radial ribs and the carinae are flat to slightly concave. A very similar transverse ornament is seen on this side, differing only by the stronger curvature of the riblets in apertural direction, indicating that in complete specimens the dorsal apertural margin must be higher than the ventral one. The density of the riblets is the same as on the ventral side, and also the growthlines follow the course of the riblets, with a similar upward curvature on the narrow smooth zone close to the carinae.

The apertural margins are not preserved, but were presumably thin and extremely fragile.

Discussion. – The variability of the available material predominantly concerns the apical angle of the shell, which may range between 35 and 41° (apertural half). The three radial ribs of the dorsal side may be separated by furrows of varying width. The strength of the transverse ornament close to the aperture differs from specimen to specimen, but it never disappears completely.

There are four Recent species to be compared with *C. lucai.* Differences to the relatively common *Clio recurva* are obvious: in that species the transverse riblets in the basal part of the shell are weak and close-set, which is not the case in *C. lucai,* where from the start they reach their overall strength. A further significant difference is the fact that in *C. recurva* the protoconch is distinctly curved in dorsal direction, whereas it is straight in *C. lucai.* The course of the transverse riblets is also significant, these are more strongly curved in the Recent species, making an angle with the lateral carinae of c. 60°, whereas they are almost perpendicular in the fossil species. The radial rib on the ventral side of *C. lucai* is relatively narrower that in C. *recurva.*

Similar differences are noted in a comparison with the Recent *Clio chaptali,* which has a more triangular shell, misses a ventral longitudinal rib, has non biangulate carinae, and an utterly different protoconch (see Tesch, 1946: pl. 3 fig. 13c).

Another extant species, of which only few specimens are known from the Antarctic Weddell Sea, is *C. piatkowskii* van der Spoel, Schalk & Bleeker, 1992. This differs from *C. lucai* by its small size, its strongly diverging side lines (c. 70° at a shell height of 13.5 mm), in lacking biangulate carinae, and having wider radial ribs on the dorsal shell surface. The protoconch of *C. piatkowskii* is still unknown (see van der Spoel et al., 1992).

The fourth modern species, rarely recorded, is *Clio scheelei* (Munthe, 1888) , which resembles *C. lucai* in several respects (e.g. its straight shell, shape of the transverse riblets). Important differences with *C. lucai,* however, are the smaller (H = 16 mm) and more slender shell of *C. scheelei,* in which the central radial rib on the dorsal side is significantly wider than the two lateral ones, the transverse riblets increasing gradually in strength from base to aperture, and the protoconch-1 being spherical, without a cusp (compare Munthe, 1888: 18, figs 15-19 and Newman & Greenwood, 1987: 91, figs 2-3).

Recorded from Plio/Pleistocene deposits in Japan is *Clio kakegawaensis* Shibata, 1984. In several respects this species resembles *C. recurva,* e.g. in the finer and more crowded transverse ornament in the basal shell part (Shibata, 1984: 82, pl. 24 figs 6, 7 *'Clio balantium* forma *kakegawaensis'*). It differs clearly, however, by its much wider apical angle of almost 65° (apertural half), approaching the shape of *C. piatkowskii,* which, however, lacks biangulate carinae.

Also similar is a species described by Ujihara (1996) as *Clio hataii* (non Noda, 1972) from Japanese Early Pliocene deposits. In the specimens illustrated by Ujihara de transverse ornament closely resembles that of *C. lucai,* but the sidelines are straight, and the posterior part of the shell is strongly curved in dorsal direction.

OTHER RELATED SPECIES

Here, species of *Clio* which have a more or less elongate-triangular shell, with three more or less well-developed radial ribs on the central dorsal shell part, a single central rib on the ventral side, and distinct transverse riblets on both the dorsal and ventral sides are compared. Placing such species in chronostratigraphical order (Table 1) may shed some light on the evolutionary developments within this group.

Bellardi (1873) subdivided the fossil species known to him into two groups: *Cleodora* Péron & Lesueur, 1810 (shell wider than high, lateral margins more or less concave and enclosing an acute apical angle, apertural margins more or less produced in the centre, the dorsal one more than the ventral, ventral side more or less depressed, the dorsal side angular), and *Balantium* Children, in Gray, 1823 (shell higher than wide, lower lateral margins straight or slightly convex and enclosing a less acute angle, apertural margins similar and curved, usually both sides convex and with transverse ornament present or absent). *Balantium* was again subdivided into three subgenera, viz. *Balantium* s.str. (shell very high, transverse riblets all over, lateral margins slightly convex, curved apertural margins), *Flabellulum* Bellardi, 1873 (less high, wider shell, transverse riblets partly or completely covering the shell, straight lateral margins enclosing a moderately sharp apical angle, longitudinal ribs on dorsal side) and *Poculina* Bellardi, 1873 (wide shell, absence of transverse ornament, and a moderately sharp apical angle). *Cleodora* Péron & Lesueur, 1810 is currently considered a junior objective synonym of *Clio* Linné, 1767. The name *Poculina* is preoccupied according to Zilch (1959: 51).

In 1873 Bellardi did not realise that the subdivision advocated by him is actually supported by protoconch morphology. In *Clio pyramidata* and several related forms the protoconch is more or less pyriform, elongate and pointed, in all other species (as far as we know) it is globular, with a proximal spine present or absent.

In Table 1 all species showing features of Bellardi's *Balantium (Balantium)* group, are listed in chronological order.

Species	Qua		Plio			Mio						Oli	
	R	Pl	G	Pi	Z	M	T	S	L	B	A	C	R
Clio chaptali (Gray, 1850)	x												
Clio piatkowskii van der Spoel et al., 1992	x												
Clio recurva (Children, 1823)	x												
Clio scheelei (Munthe, 1888)	x												
Clio kakegawaensis Shibata, 1984		x	x										
Clio lucai spec. nov.		x	x										
Clio hataii Ujihara, 1996 (non Noda, 1972)				?	x								
Clio shibatai Ujihara, 1996				?	x								
Clio guidottii Simonelli, 1896					x								
Clio hataii (Noda, 1972)								?	?				
Clio ichishiensis Shibata, 1983								?	x	?			
Clio itoigawai (Shibata, 1983)								?	x	?			
Clio lavayssei Rutsch, 1934								?	x	?			
Clio spec. Janssen, 1995[2]										x	x	?	
Clio spec. 1 Zorn, 1991												x	
Clio nielseni Janssen, 1990												x	
Clio berglundorum Squires, 1989										?	x	x	?

Table 1. Chronostratigraphic distribution of species. Abbreviations are: Qua = Quaternary, Plio = Pliocene, Mio = Miocene, Oli = Oligocene, R = Recent, Pl = Pleistocene, G = Gelasian, Pi = Piacentian, Z = Zanclean, M = Messinian, T = Tortonian, S = Serravallian, L = Langhian, B = Burdigalian, A = Aquitanian, C = Chattian, R = Rupelian.

[2] This species was supposed to be closely related to *C. lavayssei* Rutsch, 1934 (see Janssen, 1995: 72, pl. 6 figs 2-4). A direct comparison, however, with Rutsch's specimens (housed in the Naturhistorisches Museum, at Basel, Switzerland) has demonstrated in the meantime that these are utterly different species. So, most probably the Italian material will have to be introduced as a new species.

The chronological succession of these taxa is the only 'safe' basis we have for the construction of an evolutionary lineage. Features such as the presence of longitudinal ribs on ventral and dorsal sides, the wavy transverse ornament, or even the development of biangulate carinae contribute to the solidity of the very thin-walled shells, and thus might develop or change in the course of time, or according to ecological influences and are not necessarily synapomorphic characters. Similar characters occur in still other representatives of '*Clio*'.

If characteristics of the above mentioned species (Table 1) are compared their irregularity in the course of time shows up clearly (Table 2).

Name	shell characteristics												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Clio chaptali	–	+	–	+	+	–	+	+	14	+	–	–	–
Clio piatkowskii	+	–	–	+	?	–	+	+	18	+	–	+	+
Clio recurva	–	+	–	+	+	+	+	–	14	+	–	+	+
Clio scheelei	–	–	+	–	–	–	+	+	14	+	+	+	+
Clio kakegawaensis	+	–	–	+	?	+	+	+	16	+	–	+	+
Clio lucai	–	+	–	–	+	+	–	+	13	+	–	+	–
Clio'hataii'	–	+	–	+	?	+	–	+	12	+	–	+	–
Clio shibatai	–	+	–	+	?	?	–	+	8	+	–	+	+
Clio guidottii	–	–	+	–	?	–	–	–	11	+	+	+	–
Clio hataii	–	+	–	?	?	?	?	+	16	+	–	+	–
Clio ichishiensis	–	+	–	+	?	–	–	+	26	+	+	+	+
Clio itoigawai	–	+	–	+	?	+	+	+	24	+	–	+	+
Clio lavayssei	–	+	–	?	?	?	+	+	18	+[3]	–	+	+
Clio spec.	–	+	–	+	?	+	+	+	16	+	+	+	+
Clio spec. 1	–	+	–	?	?	?	–	+	22	+	+	?	?
Clio nielseni	–	+	–	+	+	+	+	+	25	+	–	+	+
Clio berglundorum[4]	+	–	–	+	?	–	–	+	24	+	+	–	–

Shell characteristics: 1. wide shape; 2. normal shape (= similar to *C. recurva*); 3. slender shape; 4. apex curved dorsally; 5. proximal spine on protoconch present; 6. biangulate carinae; 7. transverse riblets more crowded near base; 8. transverse riblets perpendicular to side lines; 9. number of transverse riblets per cm (anterior half); 10. three dorsal radial ribs present; 11. middle radial rib on dorsal side considerably wider than lateral ones, 12. ventral radial rib present; 13. ventral radial rib wider than 1/3 of shell width.

Table 2. Comparison of various shell characteristics (species are listed in chronological order)

[3] This species has a single, rather narrow but strong, central rib, flanked on both sides by a slightly convex and only vaguely indicated lateral rib, gradually fading towards the margins.

Most characteristics demonstrate a distribution independent of time, and only the density of the transverse ornament seems to show a reduction in the course of time: mean values: Oligocene 24.5, Miocene 23.3, Pliocene 12, Quaternary (incl. Recent) 14.8, but even here the irregularity is quite obvious.

Three species are excluded from this list, viz. *Clio fallauxi* (Kittl, 1886), because of the absence of radial ribs on both sides and the presence of a secondary transverse ornament (compare Janssen & Zorn, 1993: 195), *C. pedemontana* (Mayer, 1868), by the lack (or the reduction ?) of both ventral and dorsal radial ribs (compare Zorn, 1996: 746), and *C. goedertorum* Squires, 1989[4], which has two radial ribs on its dorsal side, instead of the usual three.

The irregularity of most morphological characteristics in the course of time might indicate that, although belonging to just one lineage, the various taxa developed their distinguishing characteristics mainly as a result of environmental influences. I am inclined to refer to all species considered in Tables 1 and 2 as *Clio (Balantium)* spp., and to the three mentioned exceptions as *Clio* (? *Balantium*) spp.

Using the subgeneric name *Balantium* suggests of course that other subgeneric names for the remaining species of *Clio* should be used. To *Clio (Clio)* the type species and related forms, viz. *C. pyramidata* Linné, with *C. antarctica* Dall, 1908, *C. convexa* (Boas, 1886), *C. excisa* van der Spoel, 1963 and *C. sulcata* (Pfeffer, 1879) should be assigned. In the fossil record there is *C. pyramidata* forma *lanceolata* (Lesueur, 1813), which ranges from the Late Miocene to Recent.

Other Recent representatives of '*Clio*', neither corresponding to *Clio* s.str. nor to *C. (Balantium)* are: *C. andreae* (Boas, 1886), *C. campylura* (Tesch, 1948), *C. cuspidata* (Bosc, 1802) and *C. orthotheca* (Tesch, 1948). In addition there is a considerable number of fossil taxa, some of which fit Bellardi's subgenera *Flabellulum*, such as *C. sinuosum* (Bellardi, 1873) and *C. pulcherrima* (Mayer, 1868), or *Poculina*, e.g. *C. multicostata* (Bellardi, 1873) or *C. calix* (Bellardi, 1873).

None of the remaining Recent species, however, fit these subgenera, and there is quite a number of fossil taxa not fitting them either. For instance, for *C. cuspidata* (Recent), and its alleged predecessors *C. carinata* Audenino, 1897 (Middle Miocene), and *C. braidensis* (Bellardi, 1873) (Pliocene) no subgeneric name is available. These three species are all characterised by widely triangular shells, with a high dorsal apertural margin, curved transverse ornament on both dorsal and ventral sides, and the carinae protruding as long lateral spines. They differ from *Clio* s.str. also by their globular protoconch bearing a proximal spine, and thus more closely resemble *Balantium*. As more or less typical *Balantium* species occur distinctly earlier it might be assumed that *C. carinata* and its successor species, as well as *Clio* s.str. are offshoots of *Balantium*, rather than vice versa.

Bellardi (1873) did not mention *C. cuspidata*, but following the diagnoses given by him that species fits his '*Cleodora*' concept. Still, the differences in protoconch morphology justify a separate subgenus for this group. *C. braidensis* was included in *Flabellulum* by Bellardi, presumably because he only had a damaged specimen at hand. Van der Spoel (1967: 73) referred to anatomical characteristics in *C. cuspidata* that might equally point to a separate taxonomical position for this and related species.

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[4] The names *Clio berglundi* Squires, 1989, and *C. goederti* Squires, 1989, are adjusted here to *C. berglundorum* and *C. goedertorum*, according to ICZN Art. 31.1.2., as Squires (1989: 447) distinctly stated that the species were named after 'Ross and Marion Berglund' and 'James and Gail Goedert', respectively.

Considerably more data are needed on fossil species before an attempt can be made to reconstruct the evolutionary lineages for all species of *'Clio'*.

8. *CAVOLINIA GRANDIS* (BELLARDI, 1873) FROM THE EARLY PLIOCENE OF NEW ZEALAND, A FURTHER EXAMPLE OF LONG-DISTANCE CORRELATION BY MEANS OF PTEROPODS

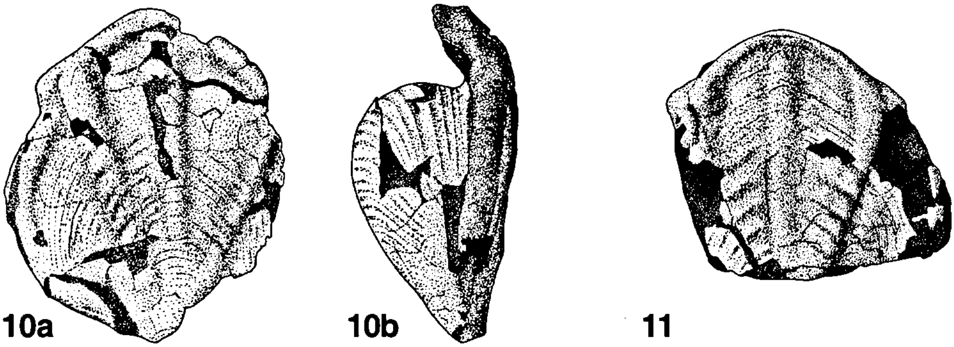
In recent years, examples of long-distance correlation of fossiliferous deposits by means of holoplanktonic Mollusca have been mentioned at various occasions (Janssen, 1990a, 1995). One of the best examples is the distribution of the euthecosomatous species *Sphaerocina formai* (Audenino, 1897), originally described from the Langhian (Middle Miocene) of northern Italy, but subsequently recognised in the Caribbean (Jung, 1971), in southern Italy (Salentina and Sicily), and in Malta (RGM collections, partly yet unpublished). Furthermore, *Lornia marwicki* Powell, 1935, described from the Miocene of New Zealand, was later synonymised (Janssen, 1995: 162) with *S. formai*, which considerably extended the known distribution of that species (fig. 12). The holoplanktonic character of such species allows a direct correlation between the various deposits.

In May 1999 pteropod material housed at the Otago University (Dunedin, New Zealand) was made available to me by Mr Andrew Grebneff. In addition to some paratypes of two species of *Limacina* species described by Laws (1944), viz. *L. atypica* (Laws, 1944) and *L. ferax* (Laws, 1944) the shipment included several lots of a large species of *Cavolinia*, from various localities of Early Pliocene age (Bluebottom Formation) in the West Coast area of South Island, New Zealand. The geology of those localities was the subject of a master's thesis by C.S. Almond, 1980 (Otago University), who collected the material 1974-1976.

In her thesis (p. 231) Ms Almond decided, after deliberation with Professor E. Robba (Milano), that the large species of *Cavolinia* from the Bluebottom Formation had to be considered an undescribed form of *C. tridentata* (Niebuhr, 1775) which she described (p. 232) as *Cavolinia tridentata* forma *zelandica* n. forma. Since her thesis was never formally published the name *zelandica* is not available.

My study of the New Zealand material soon revealed that the specimens undoubtedly are conspecific with a form described from Zanclean (Early Pliocene) sediments in northern Italy, viz. *Cavolinia grandis* (Bellardi, 1873), the true characteristics of which have been recognised only recently (Janssen, 1995: 97, pl. 8 fig. 8). The original illustration by Bellardi (1873: pl. 3 fig. 4) does not show the most important features which allow distinction between this species and Recent *C. tridentata*. The holotype of *C. grandis*, and additional material collected from several Italian localities by myself, demonstrate a peculiar, oblique transverse ornament on the dorsal shell part, which is never seen in *C. tridentata*. The typical form of *C. grandis* is known exclusively from sediments of Zanclean age. The New Zealand material (compare figs 10 and 11) convincingly demonstrates the oblique transverse ornament, and agrees also in other respects with the Italian samples, e.g. the straight apical spine which is not curved dorsally, or barely so.

Thus, the New Zealand Bluebottom Formation has to be dated as Zanclean. In the local New Zealand chronostratigraphy the samples are indicated to have originated from sediments of so-called Waipipian and Opoitian age. According to Carter & Naish (1998: fig. 2) the Waipipian stage correlates approximately with the Early Piacenzian, and the



Figs 10-11. *Cavolinia grandis* (Bellardi, 1873), x 3. New Zealand, South Island, West Coast, McKay Creek, Kaniere Valley, J33/f022; Pliocene, Waipipian, Bluebottom Formation (Otago University, Geology Department, Dunedin, New Zealand). 10, sample OU11913 (*Cavolinia tridentata* f. zelandica Almond ms, 'holotype'); a, dorsal view; b, left lateral view. 11, sample OU42200 (*Cavolinia tridentata* f. zelandica Almond ms, 'paratype'), dorsal view.

Opoitian with the Zanclean. The presence of *Cavolinia grandis* dates both occurrences, however, as Zanclean. During the Piacenzian the species *C. tridentata* is already found. As in some specimens the oblique ornament is not very clear, or has almost vanished, it may be that the samples originate from a younger portion of the Zanclean, thus approaching the indication 'Early Piacenzian'.

The following samples have been studied:

McKay Creek, Kaniere Valley, J33/f022 (New Zealand, South Island, West Coast) Pliocene, Waipipian, Bluebottom Formation; samples OU11913, OU11913a-c, OU42200-42201, OU42228-42230; 9 specimens of *Cavolinia grandis.*

Kaniere Road near McKay Creek, J33/f19A (New Zealand, South Island, West Coast), Pliocene, Waipipian, Bluebottom Formation; samples OU42204-42227; 26 specimens of *Cavolinia grandis* (on 23 slabs of sediment), 2 of these (OU42218-42219) are housed in the RGM collections (RGM 429.262). Furthermore 1 specimen of *Cavolinia* spec. (OU42227).

Greek's Creek, J33/f35 (New Zealand, South Island, West Coast), Pliocene, Opoitian Bluebottom Formation; samples OU42193-42199; 5 specimens of *Cavolinia grandis,* 2 specimens of *Clio pyramidata* f. *lanceolata.*

Greek's Creek, Arahura V, J33/f40 (New Zealand, South Island, West Coast), Pliocene, Waipipian, Bluebottom Formation; sample OU42192; 1 specimen of *Cavolinia grandis.*

The *Cavolinia* spec. in sample OU42227 is not conspecific with *C. grandis.* It has a dorsally curved apical spine and is much smaller (preserved height is c. 4 mm) than the specimens of *C. grandis.* Its dorsal apertural lip is missing, the dorsal shell part has three wide radial ribs. The moderate preservation of the specimen, however, precludes a specific assignment. The only other associated species is *Clio pyramidata* Linné, 1767 f. *lanceolata* (Lesueur, 1813), the known range of which is Late Miocene to Recent.

Cavolinia grandis is also known from Japan (Kyushu) from the Miyazaki Group (Kawabaru and Tsuma members), also of Early Pliocene age, as described by Ujihara (1996:

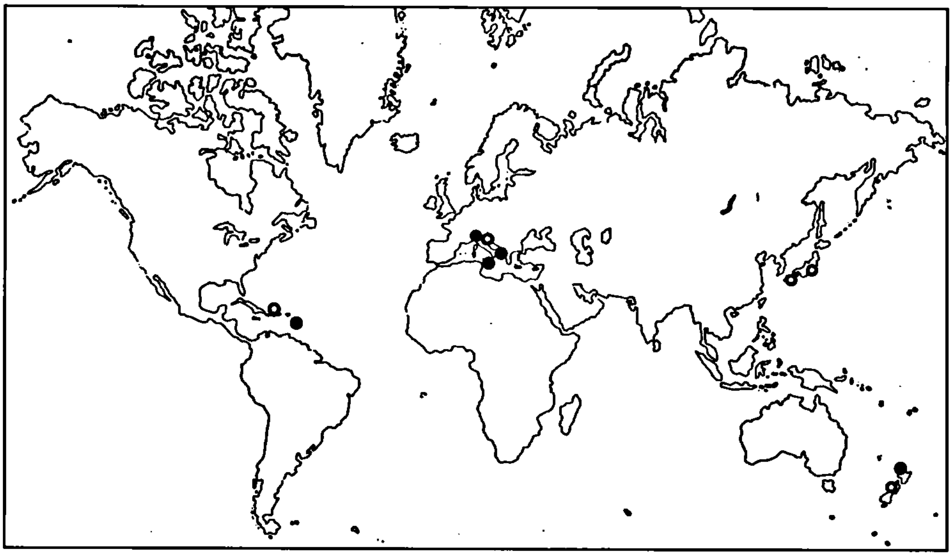


Fig. 12. Distribution of the Miocene *Sphaerocina formai* (Audenino, 1897) (closed circles) and Pliocene *Cavolinia grandis* (Bellardi, 1873) (open circles).

783, figs 7.10-14), who referred to it as *Cavolinia rattonei* Simonelli, 1896, a junior subjective synonym of *C. grandis*. An earlier Japanese reference (Ujihara et al., 1990), as *C.* cf. *angusticostata* (Blanckenhorn, 1901), was synonymised by Ujihara (1996). For a few notes on this still enigmatic taxon the reader is referred to Janssen (1995: 99). Judging from the illustration and description given by Blanckenhorn (1901: 392, fig. 21a-c), *C. angusticostata* might belong to *C. tridentata* (Niebuhr, 1775).

Janssen (1999) referred to specimens from the Early to Middle Pliocene of the Dominican Republic which were considered transitional forms between *C. grandis* and *C. tridentata.*

9. APERTURAL REINFORCEMENTS IN *LIMACINA ATYPICA* (LAWS, 1944) FROM THE MIOCENE OF NEW ZEALAND

In the pteropod shipment received on loan from the Otago University, Geology Department (Dunedin, New Zealand) courtesy of Mr Andrew Grebneff (see above) there are two paratype samples of *Limacina atypica* (Laws, 1944) and *Limacina ferax* (Laws, 1944), consisting of 2 and 6 specimens, respectively. The accompanying labels apparently are in C.R. Laws' handwriting. Both samples originate from the type locality, i.e. Pakaurangi Point, Kaipara (New Zealand, North Island) (registration numbers OU4648 and OU4649, respectively).

Limacina atypica is a species with a very low spire, and a relatively flat shell, whereas *L. ferax* usually has a sunken spire, and a comparatively higher shell. The specimen of *L. atypica* illustrated by Laws (1944: figs 21, 23), has a damaged apertural margin. Laws (1944: 312) wrote 'In apertural features *atypica* seems to agree fairly well with *S. australis* Eydoux and Souleyet'. This latter taxon is nowadays interpreted as a forma of the extant

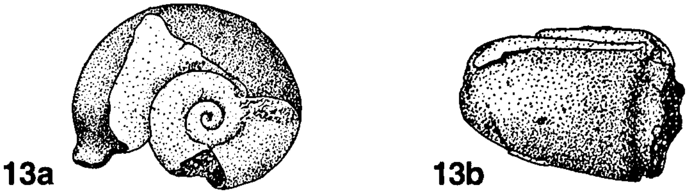


Fig. 13. *Limacina atypica* (Laws, 1944), x 25. a, apical view; b, left lateral view. Paratype of *Limacina ferax* (Laws, 1944). New Zealand, North Island, Pakaurangi Point, Kaipara; Miocene, Late Otaian, probably Pakaurangi Formation, Waiteroa Member (Otago University, Geology Department, Dunedin, New Zealand; sample OU4649A).

species *Limacina retroversa* (Fleming, 1823) (compare van der Spoel, 1967: 48), a species without any reinforcements along the apertural margin.

Janssen (1990b: 7, pl. 1 figs 1-2), when discussing Australian specimens of *L. atypica*, also concluded that any special apertural features were absent, a conclusion supported by Dr. P.A. Maxwell's (Waimate, New Zealand) observations. The paratypes of *L. atypica* in the Otago collection similarly have no special structures and appear to be damaged or not yet fully grown.

Among the 6 paratypes of *L. ferax*, however, one specimen stands out in shell shape and number of whorls. This is undoubtedly a specimen of *L. atypica*. The shell (fig. 1a-b) is badly damaged, the body whorl is broken and only its internal mould is preserved. That Laws included it in a paratype sample of *L. ferax* is probably due to the fact that the specimen demonstrates a clear constriction just behind the apertural margin, more or less as found in *L. ferax*. It is difficult to decide whether this constriction was caused by an internal thickening of the margin, or by a margin-parallel fold of the shell wall; the latter seems more probable.

According to Laws *L. atypica* is a common species; seen in this light, it would appear surprising that a genuinely fully-grown specimen is here recorded for the first time. This, however, occurs more often. A similar example is the Miocene North Sea Basin species *Limacina miorostralis* (Kautsky, 1925). Among the thousands of specimens of that species I have seen only very few had their apertural reinforcements completely developed. It must be concluded that in such populations the animals were sexually mature, reproduced and died before their shells are fully grown.

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REFERENCES

ALMOND, C.S., 1980. The Pliocene-Early Pleistocene geology of the Kaniere District, Hokitika. –Master's thesis, University of Otago, Dunedin, New Zealand (not published).

BELLARDI, L., 1873. I molluschi dei terreni terziari del Piemonte e della Liguria, 1. Cephalopoda, Pteropoda, Heteropoda, Gastropoda (Muricidae et Tritonidae). – Memorie della Reale Accademia di Scienze di Torino (2)27: 1-264.

BLANCKENHORN, M., 1901. Neues zur Geologie und Palaeontologie Aegyptens, 4. Das Pliocän- und Quartärzeitalter in Aegypten ausschliesslich des Rothen Meergebietes. – Zeitschrift der deutschen geologischen Gesellschaft 53: 307-502.

CARTER, R.M., & T.R. NAISH, 1998 Have local stages outlived their usefulness for the New Zealand Pliocene-Pleistocene ? – New Zealand Journal of Geology and Geophysics 41: 271-279.

IACCARINO, S., & P. MONEGATTI, 1996. La successione pleistocenica del T. Enza. In: Società Paleontologica Italiana (Ed.), XIII Convegno, Parma, 10-13 settembre 1996, Guida alle escursioni: 63-67.

JANSSEN, A.W., 1990a. Long distance correlation of Cainozoic deposits by means of planktonic gastropods ('pteropods'); some examples of future possibilities. – Tertiary Research 11: 65-72.

——, 1990b. Pteropoda (Gastropoda, Euthecosomata) from the Australian Cainozoic. – Scripta Geologica 91(1989) : 1-76.

——, 1995. Systematic revision of holoplanktonic Mollusca in the collections of the 'Dipartimento di Scienze della Terra' at Torino, Italy. – Monografie, Museo regionale di Sciienze naturale, Torino 17: 1-233.

——, 1999. Neogene paleontology in the northern Dominican Republic, 20. Holoplanktonic mollusks (Gastropoda: Heteropoda and Thecosomata). – Bulletins of American Paleontology 358: 5-40.

——, & I. ZORN, 1993. Revision of Middle Miocene holoplanktonic gastropods from Poland, published by the late Wilhelm Krach. In: A.W. Janssen & R. Janssen (Eds), Proceedings of the Symposium Molluscan Palaeontology, 11th International Malacological Congress, Siena, Italy, 30th August-5th September 1992. – Scripta Geologica, Special Issue 2: 155-236.

JUNG, P., 1971. Fossil mollusks from Carriacou, West Indies. – Bulletins of American Paleontology 61 (269): 147-262.

LAWS, C.R., 1944. The molluscan faunule at Pakaurangi Point, Kaipara, 3. –Transactions and Proceedings of the royal Society of New Zealand 73: 297-312.

MUNTHE, H., 1888. Pteropoder i Upsala Universitets Zoologiska Museum samlade af Kapten G. von Schéele. – K. Svenska Vet.-Akad. Handlingar 13(4)2 (Bihang): 1-33.

NEWMAN, L.J., & J.G. GREENWOOD, 1987. First records of the pteropods *Clio scheelei* (Munte, 1888) and *Clio andreae* (Boas, 1886) (Opisthobranchia: Thecosomata) from the Western Pacific Ocean. – Veliger 30: 90-94.

PAPANI, G., & G. PELOSIO, 1963. La serie plio-pleistocenica del T. Stirone (Parmense Occidentale), 2° Contributo alla conoscenza dei nuovi affioramenti fossiliferi del Calabriano nel Preappennino parmense. – Bollettino della Società Geologica Italiana 81 (1962): 293-335.

SHIBATA, H., 1984. Pteropods and heteropods from the Upper Cenozoic of Kakegawa, Shizuoka Prefecture, Japan. – Bulletin of the Mizunami Fossil Museum 11: 73-91.

SPOEL, S. VAN DER, 1967. Euthecosomata, a group with remarkable developmental stages (Gastropoda, Pteropoda): 1-375. Gorinchem.

——, P.H. SCHALK & J. BLEEKER, 1992. *Clio piatkowskii*, a mesopelagic pteropod new to science (Gastropoda, Opisthobranchia). – Beaufortia 43: 1-6.

SQUIRES, R.L., 1989. Pteropods (Mollusca: Gastropoda) from Tertiary formations of Washington and Oregon. – Journal of Paleontology, 63: 433-438.

TESCH, J.J., 1946. The thecosomatous pteropods, 1. The Atlantic. – Dana Report 28: 1-82.

UJIHARA, A., 1996. Pteropods (Mollusca, Gastropoda) from the Pliocene Miyazaki Group, Miyazaki Prefecture, Japan. – Journal of Paleontology 70: 771-788.

UJIHARA, A., H. SHIBATA & T. SAITO, 1990. Pteropods from the Sagara Group (Mio-Pliocene), Shizuoka Prefecture, Japan. – Venus 49: 306-329.

ZILCH, A., 1959. Euthyneura 1. In: W. Wenz, Handbuch der Paläozoologie 6 (2) Gastropoda: 1-200.

ZORN, I., 1995. Planktonische Gastropoden (Euthecosomata und Heteropoda) in der Sammlung Mayer-Eymar im Naturhistorischen Museum in Basel. – Eclogae geologicae Helvetiae 88: 743-759.