Pteropoda (Gastropoda, Euthecosomata) from the Australian Cainozoic

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All Tertiary euthecosomatous gastropods from the Australian continent known to the author are described. The species introduced by Ralph Tate (1887) are revised. Altogether 18 species are discussed. A new genus, *Spoelia*, and five new species, viz. *Limacina curryi, L. lunata, L. tatei, Spoelia torquayensis* and *Vaginella victoriae*, are introduced. Potential tools in the Australian pteropod fauna for a future biostratigraphical zonation and for long distance correlations are indicated.
In an annex *Vaginella sannicola* sp. nov. is introduced for specimens from the Miocene of Gargano, Italy, which were incorrectly identified as *V. eligmostoma* Tate by d'Alessandro & Robba, 1980.

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Introduction

Planktonic molluscs from the fossil record have recently been demonstrated to be potentially useful for biostratigraphical zonation of Cainozoic deposits and for long distance correlations (King, 1981, 1984; Janssen & King, 1988; Janssen, in press; Janssen, in prep.). An absolute condition for a successful application, of course, is a sound systematic base for the species involved. The fossil forms have been treated rather insufficiently, contrary to the Recent representatives of this mollusc group, on which an extensive literature is available.

Mollusc groups which, because of their planktonic way of life, should be studied in this respect, are especially the Heteropoda and the 'Pteropoda'. The latter denomination is a rather obsolete name for a somewhat heterogeneous group of gastropods, to which both shell-bearing and naked species belong. The shelled species, the only ones of course to be found as fossils, belong to two main groups of the gastropods, respectively indicated as Gastropoda Euthecosomata and Gastropoda Pseudothecosomata. The Gymnosomata have exclusively their embryonic shell calcified, which has been described from sediment or plankton for a very restricted number of species only. Because of the very small dimensions of their shells Gymnosomata are hardly known from the fossil record. Among the Pseudothecosomata only very few fossil representatives are known, and none of them from the Australian continent. The species discussed in the present paper all belong to the Euthecosomata.

While examining material for her study of Recent planktonic gastropods in the collections of the Australian Museum (Sydney) Miss Leslie Newman (University of Queensland, Brisbane) came across a sample of fossil pteropods from the well-known Muddy Creek locality near Hamilton. She asked Professor S. van der Spoel (Institute for Taxonomical Zoology, Amsterdam) his opinion on this sample and he transferred it to me for identification.

Only one paper on the systematics of fossil Australian Pteropoda had appeared (Tate, 1887), but the specimens in Miss Newman's material, belonging to three species, couldn't easily be identified using that paper. Therefore, Tate's type material was located and I started to gather additional Australian pteropod material. A specific search for fossil planktonic gastropods obviously had never taken place in Australia. So the number of available samples remained restricted.

A great help for the present study was the generous gift of a collection of Australian and New Zealand pteropod samples by Mr D. Curry (Itchenor, U.K.) in 1987. When he heard about my intentions he was kind enough to forego the material and to donate it to the RGM collections. The present paper summarizes the information on all known Australian species. Holotypes of new species, chosen from the RGM material, are placed into the collections of the Museum of Victoria, Melbourne. Thus, all primary type specimens of the Australian Cainozoic pteropods are housed in Australian institutions.

Unfortunately many samples from the Australian continent lack detailed information on the levels from which they were collected (for none of them for instance the nannoplankton zone is known!) and sometimes this shortage of information prevents a satisfying taxonomical interpretation. This is especially so for the Muddy Creek locality near Hamilton, where representatives of the genus *Vaginella* cannot properly be evaluated. The only possibility to solve such problems is the detailed sampling of the complete succession.

LOCATION OF MATERIAL AND ABBREVIATIONS USED IN THE TEXT

The pteropod material used for this paper is preserved in the collections listed below and referred to in the text by the following abbreviations:

AMS	The Australian Museum, Department of Malacology, Sydney, N.S.W., Australia
BM(NH)	British Museum (Natural History), Palaeontology Department, London, U.K.
NMV	Museum of Victoria, Department of Invertebrate Palaeontology, Melbourne, Victoria, Australia.
RGM	Rijksmuseum van Geologie en Mineralogie (now forming part of the Nationaal Natuurhistorisch Museum), Department of Cainozoic Mollusca, Leiden, The Netherlands.
SAM	South Australian Museum, Section Palaeontology, Adelaide, South Australia, Australia.
USNM	United States National Museum, Washington, U.S.A.
WAM	Western Australian Museum, Perth, Western Australia, Australia.

In the systematic part the symbols of Richter (1948, p. 54) are used to indicate the degree of certainty with which a synonym is quoted:

* - first valid introduction of a taxon;
. - responsibility for the identification is accepted by the present author;
- (no symbol) responsibility for the identification is not accepted by the present author, but there is no reason for doubt;
? - in the opinion of the present author there is reason to doubt the identification;
v - the original material of this reference was studied by the present author;
( )- (date between brackets) the year of publication is uncertain (or the paper has not been published officially, e.g. thesis).

In the paragraphs 'material studied' in the systematic descriptions below, the localities are only briefly mentioned. Additional information is given in Table 8 in the chapter on Biostratigraphy.

ACKNOWLEDGEMENTS

The compilation of the present paper would have been impossible without the help of numerous colleagues, private and professional palaeontologists and library curators. I would like to thank especially the following persons: Dr W. Backhuys (Oegstgeest, The Netherlands), for information on literature; Dr M. van den Boogaard (Nationaal Natuurhistorisch Museum, Leiden, The Netherlands), for help with the operation of the SEM; Dr M.F. Buonaiuto (Coolbinia, W.A.), for information on various objects and permission to use unpublished data; Mr John Cooper [British Museum (Natural History), Department of Palaeontology, London, U.K.], for the loan of specimens and especially for his highly appreciated dedication in locating essential literature in the

BM(NH) libraries; Mr D. Curry (Itchenor, U.K.), for donating a substantial pteropod collection from Australia and New Zealand to the RGM collections, for valuable suggestions and for critical reading of the manuscript; Dr T.A. Darragh (Museum of Victoria, Melbourne, Vict.), for loan of specimens and critical reading of the manuscript; Professor E. Gittenberger (Nationaal Natuurhistorisch Museum, Leiden, The Netherlands), for donating a sample from the Snellius II expedition; Mr H.-J. von Hacht (Ammersbek, F.R.G.), for putting a large material from the Early Pliocene of SE France at my disposal; Dr D.J. Holloway (Museum of Victoria, Department of Invertebrate Palaeontology, Melbourne, Vict.); for the loan of specimens; Dr R. Janssen (Naturmuseum Senckenberg, Frankfurt am Main, F.R.G.), for information on stratigraphy; Dr Kamps (Zentrales Geologisches Institut, Berlin, D.D.R.), for information on type specimens; Dr G.W. Kendrick (Western Australian Museum, Department of Palaeontology, Perth, W.A.), for the loan of specimens and for diverse information; Mr D.C. Long (Leckhampton, Cheltenham, U.K.), for donating Australian pteropod samples collected by himself to the RGM collections and for extensive information on localities and stratigraphy; Dr P. Lozouet (Morigny, France), for donating pteropod samples from the Aquitaine Basin; Dr E. Martini (Frankfurt am Main, F.R.G.), for a nannoplankton interpretation; Dr P.A. Maxwell (New Zealand Geological Survey, Lower Hutt, N.Z.), for useful discussions and critical reading of the manuscript; Miss Leslie Newman (University of Queensland, St Lucia, Brisbane, Qld.), for initiating my study of Australian pteropods and for the loan of specimens; Dr Pietrzeniuk (Museum für Naturkunde der Humboldt-Universität, Berlin, D.D.R.), for information on type material; Dr N. Pledge (South Australian Museum, Adelaide, S.A.), for the loan of type and other specimens and for valuable information on localities and literature; Dr W.F. Ponder (Australian Museum, Sydney, N.S.W.), for help with the loan of samples, information on stratigraphy and for useful discussions; Dr S. Ritzkowski (Geologisch-Paläontologisches Institut der Georg-August Universität, Göttingen, F.R.G.), for information on type material; Professor E. Robba (Università degli Studi di Milano, Dipartimento di Scienze della Terra, Milano, Italy), for donating indispensable pteropod samples from the Italian Neogene and for the supply of important literature; Mrs L.C. Schekkerman (Karrinyup, W.A.), for donating *Vaginella* samples from Muddy Creek; Professor S. van der Spoel (Instituut voor Taxonomische Zoology, Amsterdam University, Amsterdam, The Netherlands), for sending me my first sample of Australian pteropods, for highly appreciated discussions and suggestions, and for critical notes on the manuscript; Mr C. Tabanelli (Cotignola, Italy), for the donation of Italian pteropod material; Mr J. Timmers (Nationaal Natuurhistorisch Museum, Leiden, The Netherlands), for drawing text-figs. 2 and 3; Mr J. van der Voort (Ostercappeln, F.R.G.), for showing pteropod material from Turkey.

NOTES ON THE ILLUSTRATIONS

All specimens illustrated in Plates 1-9 were drawn by the author, with a WILD M5 or M8 binocular with camera lucida device. The original drawings were reduced by half for printing.

Each figure represents various views of one specimen (indicated a, b, c, etc.), taken at right angles (projections). In the limacinids sometimes an oblique apical view is given, to obtain an impression of the height of the apex in more or less planorboid species. Specimens are represented as individuals, so injuries and damage are shown in the drawings. This makes specimens easily recognizable afterwards and prevents an undesired schematizing of the illustrations.

On plates 10-13 scanning electron micrographs are given of several species. They were made by the author with the Jeol JSM 840A SEM of the Nationaal Natuurhistorisch Museum, Leiden (gold coating).

Note on R. Tate's 1887 paper

The only earlier paper exclusively dedicated to the study of Australian fossil Euthecosomata is Ralph Tate's 1887 contribution of nearly two pages in the Transactions and Proceedings of the Royal Society of South Australia, volume 9, entitled 'The Pteropods of the Older Tertiary of Australia'. This paper comprises five pteropod species, all introduced as new to science, from four different localities (Muddy Creek, Schnapper Point, Adelaide, and Blanche Point). The paper was illustrated (pl. 20) with drawings made by W.J. Chidley. The magnification of his figures, unfortunately, was not indicated. In Fig. 1 the drawings of the pteropods on Tate's plate 20 are reproduced, somewhat enlarged and re-arranged.

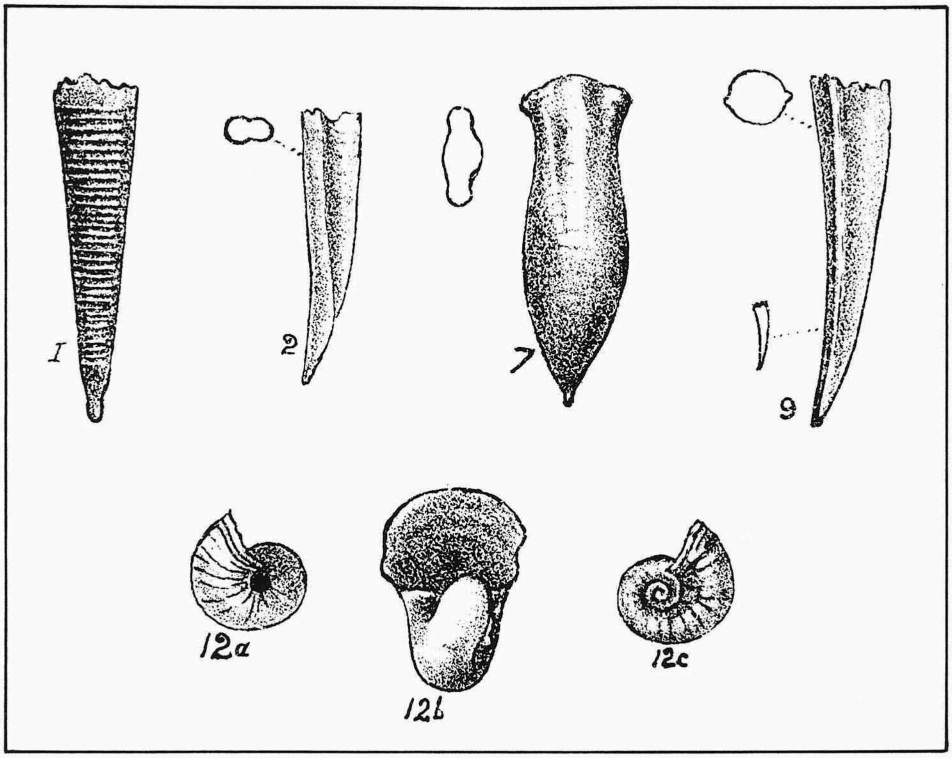


Fig. 1. Illustrations of pteropod species introduced by Tate (1887, pl. 20), drawn by W.J. Chidley. Magnification not indicated, the drawings are re-arranged and magnified × 1.4 from the original plate.
1. *Styliola annulata* Tate (Aldinga, enlarged).
2. *Styliola Rangiana* Tate (Muddy Creek, much enlarged).
7. *Vaginella eligmostoma* Tate (Muddy Creek, much enlarged, aperture in outline).
9. *Styliola bicarinata* Tate (Muddy Creek, enlarged, natural size and section in outline).
12a-c. *Spiralis tertiaria* Tate (Muddy Creek, much enlarged); a: base; b: front view; c: apical aspect.

Fortunately Tate's type material is still present in the collection of the South Australian Museum. It was made available to me by Drs N. Pledge and B. McHenry of that museum, to whom I am very grateful indeed for their co-operation and patience.

A critical revision of Tate's samples is included in the systematic descriptions of the species below. My conclusions are summarized in Table 1.

Table 1. Interpretation of Tate's pteropod species in the present paper.

Tate's 1887 identifications	this paper
Spiralis tertiaria Tate, 1887	*Limacina tertiaria* (Tate, 1887) and *L. inflata* (d'Orbigny, 1836)
Styliola rangiana Tate, 1887	*Styliola subula* (Quoy & Gaimard, 1827)
Styliola annulata Tate, 1887	*Praehyalocylis annulata* (Tate, 1887)
Styliola bicarinata Tate, 1887	*Vaginella bicarinata* (Tate, 1887)
Vaginella eligmostoma Tate, 1887	*Vaginella depressa* Daudin, 1800

Systematic descriptions

Phylum MOLLUSCA
Classis GASTROPODA
Ordo THECOSOMATA
Subordo EUTHECOSOMATA
Familia LIMACINIDAE

Genus *Limacina* Bosc, 1817

Type species — 'le Clio hélicine' = *Limacina helicina* (Phipps, 1774) by monotypy.

Discussion — Biologists working on this group are used to the application of the genus name *Limacina*, in preference of the equally old (December 1817!) name *Spiratella* de Blainville (monotype: '*clio helicina*'!), which has been more popular among palaeontologists. A decision of the I.C.Z.N. would be necessary to declare one of the two names a nomen conservandum by putting it on the official list, but pending such a decision, which as far as I know has not yet been applied for, I chose to use *Limacina*. I decided to do so as this name has been used more frequently than *Spiratella*.

There are good reasons to try and subdivide the genus *Limacina* in several subgenera, as has also been done for the Recent representatives, e.g. by van der Spoel (1967). There has been some discussion on the subject (Wells, 1978), but the problems become, of course, more severe, as soon as the fossil forms are also drawn into the discussion. Still, there are indications that especially the construction of the apertural reinforcements may be applied for a responsible and useful subdivision. A discussion on this subject is beyond the scope of the present paper; it will extensively be treated elsewhere (Janssen, in prep.). For the time being the name *Limacina* is used in a broad sense.

Limacina atypica (Laws, 1944)
Pl. 1, figs. 1-2; Pl. 10, figs. 1, 3.

* 1944 *Spiratella atypica* n.sp., Laws, p. 312, pl. 44, figs. 21, 23.
1966 *Spiratella atypica* Laws, 1944 - Fleming, p. 84.
1982 *Spiratella atypica* Laws - Bernasconi & Robba, p. 215.

Description — Only juvenile specimens are available. Shell very small, sinistral, with up to 2 3/4 convex whorls, regularly and rather quickly increasing in diameter. The shell is c. 1.5 to 1.6 times wider than high and has a flat apical side. The whorls are coiled in a plane spiral and only produced downward. The periphery is evenly rounded, with a gradually convex transition into the base and the umbilicus, which occupies somewhat less than 15% of the shell diameter. The aperture is obliquely ovoid, very slightly indented by the penultimate whorl. None of the more or less complete specimens demonstrates apertural reinforcements.

Type material — Holotype in the Laws collection (Laws, 1944, p. 297), now in the collection of the New Zealand Geological Survey (Dr P.A. Maxwell, pers. comm.). Five paratypes from the type locality are in the RGM collection (RGM 229 415, 229 729, 229 735, see Pl. 10, fig. 1), donated by Mr D. Curry, who received these specimens from C.R. Laws. Type locality is Pakaurangi Point, Kaipara, New Zealand (Early Miocene, ?Late Otaian). Laws (1944) indicated the age of the sample as 'Altonian'. The lithostratigraphical provenance was not given in the original publication. Dr P.A. Maxwell (in litt., 1.8.1988) supplied the following additional information:

'Although Laws did not give locality details for *Spiratella ferax* or *S. atypica*, I am reasonably certain that both came from a bed with abundant pteropods at Holland's Point (near Pakaurangi Pt, Kaipara harbour). This bed (informally known as the 'pteropod bed' or the '*Vaginella* bed') is near the top of the Waiteroa Member of the Pakaurangi Formation and is dated as late Otaian rather than Altonian. Both species occur higher in the Pakaurangi section in beds of early Altonian age, [.....].'

Material studied — Spring Creek near Torquay, Australia (probably Late Oligocene to Early Miocene, Janjukian-Longfordian): 3 juvenile specimens, 36 juvenile and more or less defective specimens and some fragments, RGM 229 413-415, 229 736.

Discussion — Unfortunately the sample yielding this species is incompletely labelled. Not only the locality is just roughly indicated, but also the stratigraphic level is unknown. The state of preservation of the type sample of *Limacina curryi* (from Torquay, Bird Rock) is very much the same as the Spring Creek sample and therefore these two samples most probably do not differ strongly in age. This is furthermore suggested by the fact that some juvenile specimens from the Spring Creek sample belong undoubtedly to *L. curryi*, as is clearly indicated by their raised apices.

The present material exclusively contains immature specimens, which were compared with the few paratypes of *Limacina atypica* (Laws) in the RGM collection. Judging from the original publication the illustrated type specimen is also a juvenile specimen or a shell with a damaged aperture. In the explanation of the plate it was indicated as the holotype, but on p. 312 Laws wrote 'The figure is that of a paratype'. None of the specimens has an indication of apertural reinforcements and also Dr P.A. Maxwell (in litt., 1.8.1988) noted: 'I have examined numerous specimens of *S. atypica* and have seen nothing to suggest that the outer lip is other than simple (i.e. without obvious reflection, internal thickening or processes)'.

There seems to be hardly any morphological difference between the Australian and the New Zealand form, and therefore Laws's name is applied for the Australian form as well.

Surprisingly the *L. atypica* specimens studied here demonstrate a close resemblance with juvenile specimens of *L. tertiaria* (compare Pl. 1, fig. 1 and Pl. 3, fig. 8). The New Zealand species reaches larger dimensions: the specimen illustrated by Laws has a diameter between 1.6 and 1.7 mm, whereas the *L. tertiaria* specimens remain below 1.2 mm diameter.

Limacina curryi sp. nov.
Pl. 1, figs. 3-5; Pl. 11, fig. 3.

Holotype — Pl. 1, fig. 3, leg./don. D. Curry, NMV P 123 405.
Type locality — Torquay, Bird Rock, Otway Basin, Victoria, Australia.
Stratum typicum — The type sample was collected from the *Glycymeris* Beds', as described in Singleton (1941, p. 39), belonging to the Torquay Group, Jan Juc Formation (Late Oligocene, Janjukian; see Ludbrook, 1967, p. 14; 1973, p. 248).
Derivatio nominis — It is an honour to name this species after Mr Dennis Curry (Itchenor, U.K.), in recognition of his contributions to the study of fossil pteropods and in appreciation of his donation of an important series of samples discussed in this paper.

Description — Rather small, sinistral shell with up to 3 1/2 whorls, regularly and rather quickly increasing in diameter. Together the whorls form a depressed cone with an apical angle of c. 150-155°. The adult shell is c. 1.4 times wider than high. The point of attachment of each volution lies just above the periphery of the preceding one, so there is only a very small overlap of whorls in an apical view. The body whorl is large with a perfectly rounded periphery and a gradual transition of the base into the umbilicus, which is rather wide, occupying c. 15% of the shell diameter (straight umbilical view).

Plate 1

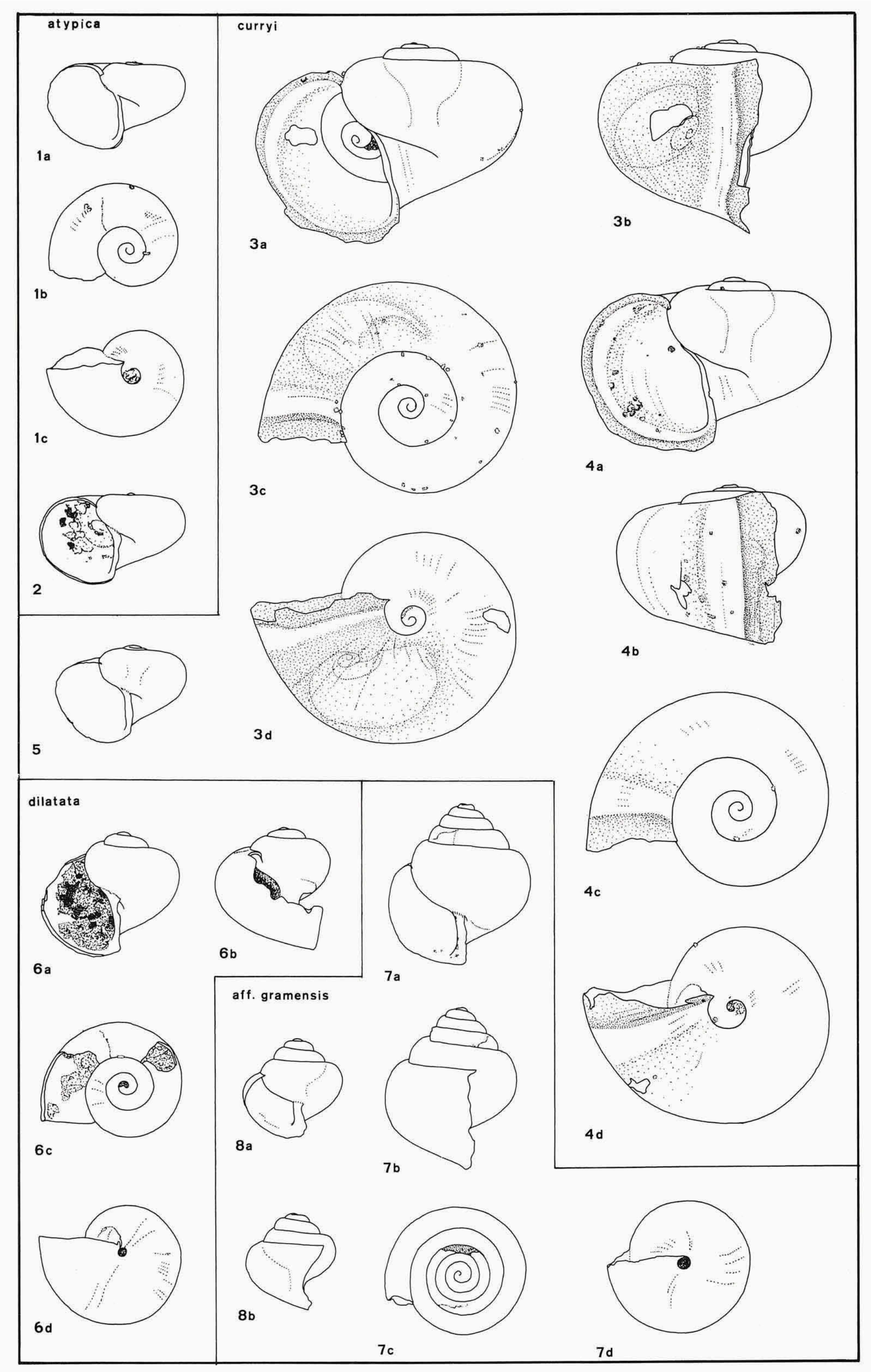
Figs. 1-2. *Limacina atypica* (Laws, 1944)
Spring Creek near Torquay; ?Late Oligocene to Early Miocene, Janjukian-Longfordian.
1a-c: Juvenile specimen, RGM 229 414, × 22.
2: Juvenile specimen, RGM 229 415, × 22.

Figs. 3-5. *Limacina curryi* sp. nov.
Torquay, Bird Rock, Otway Basin; Oligocene, Janjukian, Torquay Group, Jan Juc Formation, *Glycymeris* Beds.
3a-d: Holotype, NMV P123405, × 25.
4a-d: Paratype, RGM 229 421, × 25.
5: Paratype, juvenile, RGM 229 422, × 25.

Fig. 6. *Limacina* ? *dilatata* (von Koenen, 1892)
NW of Cape Otway, N of Pt. Flinders; Late Eocene/Early Oligocene, Aldingan, Glenn Aire Clay Formation. Juvenile specimen with damaged aperture, AMS C149.279, × 25.

Figs. 7-8. *Limacina* aff. *gramensis* (Rasmussen, 1968)
7a-d: Batesford, new quarry; Miocene, Batesfordian to Bairnsdalian, Fyansford Formation, grey clays. Subadult specimen, RGM 229 441, × 25.
8a-b: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation. Juvenile specimen, RGM 229 469, × 25.

Plate 1


atypica
curryi
1a
1b
1c
2
3a
3b
3c
3d
4a
4b
4c
4d
5
dilatata
6a
6b
6c
6d
7a
7b
7c
7d
aff. gramensis
8a
8b

The aperture is large, almost vertical in a lateral view, but somewhat obliquely situated in a frontal view. Its form is semicircular, with an almost straight columellar part and a very slight indentation by the preceding whorl. Sometimes there is an indication of a notch on the columella. In adult shells the apertural margin is very slightly widened (lateral view), not thickened externally. The apertural margin is reinforced internally by a slightly thickened ridge, running parallel to the growth-lines at a short distance from the actual margin, which therefore is always sharp and thin. In the very well preserved type sample the shell material is hardly recrystallized (still transparent!) and the internal ridge is visible externally as a vertical opaque belt, which demonstrates a sharper delimitation anteriorly than posteriorly.

The surface of the shell is smooth and shiny with only poorly visible growth-lines, running downward from the upper suture with a very slight backward curvature.

Material studied — Holotype NMV P123405; 1 paratype (Pl. 1, fig. 4), 1 juvenile paratype (Pl. 1, fig. 5), 1 paratype (Pl. 11, fig. 3), 59 paratypes from the type-locality, RGM 229 420-422, 229 740.

Torquay, Bird Rock, Australia (Oligocene, Janjukian), 2 specimens, RGM 229 430.

Spring Creek near Torquay (probably Late Oligocene to Early Miocene, Janjukian-Longfordian), 4 juvenile specimens, RGM 229 416.

Discussion — *Limacina curryi*, of which abundant material is available from the type-locality, demonstrates only a slight variability, mainly restricted to the height/width ratio. In its type-locality this species co-occurs with *L. lunata* sp. nov., from which it is easily distinguished by its different proportions.

The only further sample yielding this species unfortunately is insufficiently labelled. The only indication is 'Spring Creek, Victoria', indicating that the material originated from a locality pretty close to the type-locality of *L. curryi*. Its age may be estimated as 'probably Late Oligocene to Early Miocene'. This very sample, however, contained a far more abundant material of yet another species, identified as *Limacina atypica*, whereas the species *L. lunata* sp. nov., co-occurring with *L. curryi* in its type-locality, is absent here. So, apparently this 'Spring Creek' sample was collected at a stratigraphic level different from the type-level of *L. curryi*. Considering the distribution of *L. atypica* in New Zealand, a somewhat younger age seems to be the more probable. Although the vertical range of *L. curryi* is only known from the restricted material discussed here, it may be presumed that the difference in age of the two samples is not very large.

There seem to be no other species, inside or outside Australia, closely related to *L. curryi*. The European species *Limacina hospes* Rolle, 1861, known from Rupelian and Chattian deposits, has a similarly (but stronger) widened apertural margin without an internal strengthening device, a relatively higher shell and a much narrower umbilicus.

Limacina ? *dilatata* (von Koenen, 1892)
Pl. 1, fig. 6.

* 1892 *Spirialis dilatata* v.Koenen, von Koenen, p. 994, 995, pl. 62, figs. 3a-b, 4a-c.
1912 *Spirialis dilatata* v.K. - Gripp, p. 24.
1940 *Spirialis dilatata* v.Koenen - Sorgenfrei, p. 60, 113.
1955 *Planorbella dilatata* Koenen - Korobkov, p. 427, pl. 115, figs. 5a-b, 6 (illustrations copied from von Koenen, 1892).

1966 *Spiratella (Spiratella) dilatata* Koenen - Korobkov, p. 74, 78, 79.
. 1984a *Spirialis dilatata* Von Koenen - Janssen, p. 69.
v.1986 *Spiratella dilatata* - Janssen, p. 149, fig. 1.
v.1988 *Limacina dilatata* - Janssen & King, p. 361, fig. 188.

Description – Shell forming a rather raised, conical spire, slightly wider than high. The initial whorl is missing, but it can be determined that c. 3 1/2 convex whorls were present, rather quickly increasing in diameter, resulting in an oblique suture line (lateral view). The whorls attached a short distance above the periphery of the preceding whorl. The body whorl is large, strongly and regularly convex, without any marked transition to the base of the shell. A very narrow umbilical pit is present, occupying less than 6% of the shell's diameter.

The ultimate part of the body whorl is strongly damaged in the only available specimen, which anyway would have been too juvenile to expect a fully developed apertural margin. The columellar side of the aperture is slightly concave. In a lateral view it can still be seen that the aperture had an oblique position with respect to the shell's axis, the upper part reaching somewhat beyond the base.

Syntypes – Over forty specimens from Unseburg and two from Latdorf (both localities nowadays in the G.D.R.) were described by von Koenen (1892). The latter specimens belonged to the Berlin Museum ('Mus. Berolini'), but both the Museum für Naturkunde der Humboldt-Universität zu Berlin (Dr Pietrzeniuk, in litt., 11.11.1987), and the Zentrales Geologisches Institut in Berlin (Dr Kamps, in litt., 8.2.1988) informed me that no type specimens of this species are present in their collections. No specimens are available in the von Koenen collection at Göttingen, F.R.G. (Dr S. Ritzkowski, pers. comm.). The age of the syntype material is stated as 'Unter-Oligocän' = Lower Oligocene, Latdorfian, probably Upper Schönewalde Formation. Various authors consider this interval as Late Eocene.

Material studied – NW of Cape Otway, N of Pt. Flinders, Australia (Late Eocene or Early Oligocene, Aldingan): 1 defective specimen AMS C149.279.

Discussion – The up to now exclusively European species *L. dilatata* is easily recognized, when adult, by its widened apertural margin. Juvenile or damaged specimens, however, may closely resemble the somewhat younger species *Limacina hospes*, which generally has a lower spire and consequently less oblique suture lines. Furthermore, the age of the North Sea Basin material (exclusively known from the Latdorfian, compare Janssen, 1989, p. 95) agrees conveniently with that of the Australian sample. The fact that various authors consider the Latdorfian to be Late Eocene makes the two age indications almost identical.

The presence of *L. dilatata* in the Australian faunas gains in probability by the occurrence of what equally seems to be this species in the 'Late Eocene' of New Zealand (Dr P.A. Maxwell, pers. comm.).

Limacina aff. *gramensis* (Rasmussen, 1968)
Pl. 1, figs. 7-8; Pl. 2, figs. 1-4.

?v* 1968 *Spiratella gramensis* nov. sp., Rasmussen, p. 244, pl. 27, figs. 4-7 (partim).
(For an extensive list of synonyms for the European occurrences of *L. gramensis* the reader is referred to Janssen, in prep.).

Description – Shell conical, higher than wide (H/W-ratio in full-grown specimens over 110), with just over five convex whorls, slowly and gradually increasing in diameter. Each whorl is attached to the periphery of the preceding one and therefore the suture is deep and conspicuous. The apex is slightly flattened. The outline of the spire is truly conical, with almost straight tangents. The base of the body whorl is evenly rounded and has a narrow, but distinct umbilicus. In a straight basal view the umbilicus occupies less than 10% of the shell's diameter. The aperture has an equally curved abaxial margin, which is sharp and thin, neither widened nor reinforced. The columellar part of the aperture is straight to very slightly concave. Growth-lines are only visible on the basal part of the largest available specimen (compare Pl. 1, fig. 7d).

Type material – Holotype (reg. no. 1968-LBR-159) and 75 paratypes are housed in the collections of Danmarks Geologiske Undersøgelse, at Copenhagen, Denmark. Only 8 specimens, however, are actually considered to belong to *L. gramensis* (cf. Janssen, in prep.).

The type locality is Gram, Jylland, Denmark; well DGU 141.277 at Gram Teglvaerk, depth 21.00-21.50 m below surface; Gram Clay, Langenfeldian, Late Miocene (for more litho- and chronostratigraphical details see Janssen, in prep.).

Material studied – South side of Lake Costin, Australia (Miocene, ?Longfordian): 1 juvenile specimen, RGM 229 432.

Plate 2

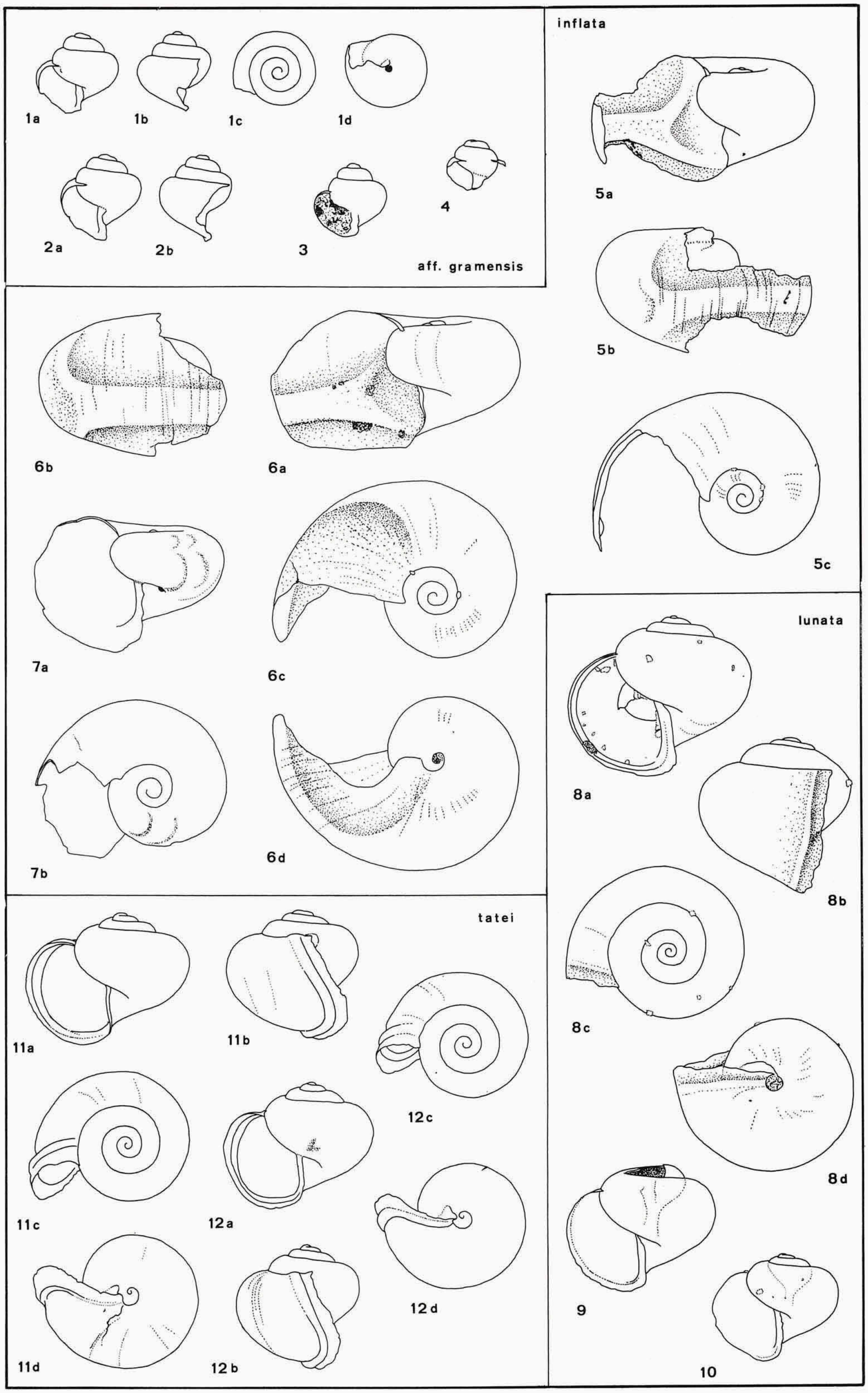
Figs. 1-4. *Limacina* aff. *gramensis* (Rasmussen, 1968)
Altona Bay, SW of Newport, near Melbourne on Port Phillip Bay; Miocene, ?Balcombian, Fyansford Formation.
1a-d: Juvenile specimen, RGM 229 433, × 25.
2a-b: Juvenile specimen, RGM 229 434, × 25.
3a-b: Juvenile specimen, RGM 229 435, × 25.
4: Juvenile specimen, RGM 229 436, × 25.

Figs. 5-7. *Limacina inflata* (d'Orbigny, 1836)
5-6: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation, from interior of *Ancillaria pseudaustralis* Tate.
5a-c: Adult specimen with well-developed 'rostrum', fragile shell-wall broken above and below rostrum, RGM 229 492, × 25.
6a-d: Adult specimen, with fragile shell-wall above and below rostrum for the greater part preserved, RGM 229 491, × 25.
7a-b: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, 'lower beds' (= Muddy Creek Formation). Juvenile specimen, syntype of *Spiralis tertiaria* Tate, SAM T 239, × 25.

Figs. 8-10. *Limacina lunata* sp. nov.
Torquay, Bird Rock, Otway Basin; Oligocene, Janjukian, Torquay Group, Jan Juc Formation, *Glycymeris* Beds.
8a-d: Holotype, NMV P123406, × 25.
9: Paratype, subadult specimen, apex broken, RGM 229 424, × 25.
10: Paratype, juvenile, RGM 229 425, × 25.

Figs. 11-12. *Limacina tatei* sp. nov.
Locality data as for figs. 5-6.
11a-d: Holotype, NMV P123407, × 25.
12a-d: Paratype, RGM 229 496, × 25.

Plate 2


1a
1b
1c
1d
2a
2b
3
4
aff. gramensis
inflata
5a
5b
5c
6b
6a
7a
6c
7b
6d
lunata
8a
8b
8c
8d
9
10
tatei
11a
11b
12c
11c
12a
12d
11d
12b

Altona Bay, Australia (Miocene, ?Balcombian): 4 juvenile specimens (Pl. 2, figs. 1-4), RGM 229 433-436.

Muddy Creek, Hamilton, Australia (Miocene, Balcombian to Bairnsdalian): 1 specimen (Pl. 1, fig. 8), 8 juvenile specimens, RGM 229 469-470.

Batesford, Australia (Miocene, Batesfordian to Bairnsdalian): 1 specimen (Pl. 1, fig. 7), 2 juvenile specimens, RGM 229 441-442.

Balcombe Bay, Mornington, Australia (Miocene, Balcombian): 1 juvenile specimen, RGM 229 450.

Discussion – This species has not been mentioned before frome the Australian Tertiary. Still, it does not seem to be a very rare fossil, as it is present in five different samples. Unfortunately, the material does not contain completely full-grown specimens and only one subadult shell (Pl. 1, fig. 7), the spire of which regretfully was damaged after drawing. According to Dr P.A. Maxwell (pers. comm.) a similar species is present in the New Zealand Miocene.

Some of the samples (e.g. those from Batesford and from Altona Bay, Pl. 1, fig. 7 and Pl. 2, figs. 1-4, respectively) have slightly different apices, caused by the fact that the second whorl is relatively high. The material is too poor, however, to allow a sound discrimination of more than one taxon.

Judging from this admittedly insufficient material it must be concluded that there is a close resemblance to the European Late Miocene representatives of *Limacina gramensis*. In the old world this latter form is part of a supposed evolutionary lineage going from the Late Oligocene and Early to Middle Miocene *Limacina valvatina* (Reuss, 1867), through the Late Miocene *Limacina gramensis* (Rasmussen, 1968) and a *Limacina* sp. nov. (see details in Janssen, in prep.) to the Quaternary and Recent *Limacina retroversa* (Fleming, 1823).

If the Australian material indeed belongs to *L. gramensis*, and if the supposed European evolutionary lineage of this group is correct, there is a discrepancy with respect to the age of the material. It is highly unlikely that in Australia a *L. gramensis* form has developed in Early to Middle Miocene times and only considerably later in Europe. There are, however, various possibilities to explain this paradox. First of all more material, comprising really adult individuals, will be necessary to check the present identification. Also it cannot be excluded that the suggested evolutionary lineage *L. valvatina* - *L. gramensis* - *L.* sp. nov. - *L. retroversa* in reality is composite. It might very well be that the Recent (cold-water!) species *L. retroversa* in fact has another origin than supposed here. In that case the Australian form might as well be a predecessor of *L. retroversa*, without any relation to the Miocene European forms. For all these reasons it seems advisable to proceed with caution concerning the identification of the Australian material, which is therefore assigned only tentatively to this species.

Limacina inflata (d'Orbigny, 1836)
Pl. 2, figs. 5-7; Pl. 3, fig. 11; Pl. 10, fig. 2.

* 1836 *Atlanta inflata* d'Orb., d'Orbigny, p. 174, pl. 12, figs. 16-19.
1840 *Spirialis rostralis.*, Eydoux & Souleyet, p. 236.
? 1873a *Planorbella imitans*, Gabb, n. sp., Gabb, p. 201.
? 1873b *Planorbella imitans* - Gabb, p. 270, pl. 11, fig. 2.
? 1876 *Embolus rostralis*, Soul. sp. - Seguenza, p. 48, pl. 1, figs. 13, 13a-b (the illustrations are mentioned in the text, but seem to have never been actually published).
? 1878 *Protomedea rostralis (Spirialis)*, Souleyet - Tiberi, p. 77.
. 1880 *Embolus rostralis* Souleyet (*Spirialis*) - Seguenza, p. 277.

? 1882 *Planorbella imitans* - Guppy, p. 175 (reprinted in Harris, 1921, p. 244).
? 1883 *Valvatella imitans*, Gabb - Fischer, p. 430.
v.1887 *Spiralis tertiaria*, spec. nov. - Tate, p. 196, pl. 20, fig. 12a-c (partim, see also *L. tertiaria*).
? 1892 *Planorbella imitans*, Gabb - Cossmann, p. 8.
? 1893 *Planorbella imitans* Gabb - Dall, p. 430.
? 1903 *Valvatella imitans*, Gabb - Lörenthey, p. 475, 523.
? 1905 *Protomedea rostralis*, Soul. sp. - Bellini, p. 30.
? 1922 *Limacina inflata* (Orbigny) - Pilsbry, p. 308, fig. 1.
? 1934 *Limacina inflata* (d'Orbigny) - Collins, p. 179, pl. 7, figs. 3-8 (partim).
? 1979 *Spiratella inflata* (d'Orbigny, 1836) - d'Alessandro et al., p. 82, pl. 15, fig. 11a-b.
? 1979 *Spiratella inflata volhinica* Stancu - Stancu, p. 1390 (nomen nudum).
? 1982 *Spiratella inflata* (d'Orbigny) - Bernasconi & Robba, p. 217, tab. 4.
(For further references of Quaternary and Recent occurrences the reader is referred to the relevant literature).

Description — Very small, sinistral shell with up to three whorls,which quickly and somewhat irregularly increase in diameter. The first whorl is spired, but the second and third whorl reach beyond the highest level of the preceding one, resulting in a planorboid shell with a somewhat concave apical plane, in which the apex forms a small elevation. In a straight frontal view the apex is projecting above the last whorl in very juvenile shells only. The whorls are more produced towards the basal side of the shell, convex on their periphery, slightly flattened above and on the base. The point of attachment onto the preceding whorl lies quite high, so there is a distinct overlap of whorls in an apical view. The base has a distinct umbilicus, occupying c. 10-12% of the shell diameter (measured just behind the apertural reinforcements). The aperture is large, wider than high. Below the small indentation of the preceding whorl the columella is almost vertical, hardly notched. Internally the ultimate part of the body whorl is reinforced by a falciform thickening of the shell-wall (Pl. 10, fig. 2b), about a quarter of a whorl behind the actual aperture. This thickening is produced into a conspicuous opaque, ribbon-like belt of shell-material, running just below the periphery of the body whorl towards the apertural margin. Below and above this belt the shell-wall is much thinner and more transparent, usually broken because of its extreme fragility. In such cases the thickened shell-part projects forward as an anterior apertural rostrum. This 'rostrum' is hardly or not projecting beyond the apertural margin in undamaged shells, as is distinctly indicated by the growth-lines: first the shell-wall is built and subsequently the thickening is formed on the internal shell-wall.

Type material — Syntypes (c. 82 poorly preserved, Recent specimens) are kept in the BM(NH), reg. no. 1854.12.4.38, catalogue 61 (see van der Spoel, 1976a, p. 188); their type locality is indicated as Atlantic and Pacific Oceans, 36° N - 6° (S? or W?) (see van der Spoel, 1976a, p. 188).

Material studied — Muddy Creek, Hamilton, Australia (Miocene, Balcombian to Bairnsdalian): 1 juvenile specimen (Pl. 2, Fig. 7), SAM P29787 (syntype of *Spiralis tertiaria* Tate, 1887); 1 specimen, NMV P122061; 1 specimen (Pl. 10, fig. 2), 43 specimens, RGM 229 471, 229 737; 4 specimens from interior of *Harpa pulligera* Tate, RGM 229 485; 2 specimens (Pl. 2, figs. 5- 6), 1 juvenile specimen (Pl. 3, fig. 11), 15 specimens from interior of *Ancillaria pseudaustralis* Tate, RGM 229 491-494.

Altona Bay, Australia (Miocene, ?Balcombian): 40 immature specimens, RGM 229 437.

Discussion — The very fine and sometimes unusually complete specimens from Muddy Creek were compared with several lots of Recent specimens from various parts of the globe. The only difference seems to be that the Miocene specimens have a regularly curved body whorl (apical view), whereas in most Recent shells the internal thickening is accompanied by an externally visible inflation. The Recent material has a wide range of variability in size of the full-grown shells. With almost 1.5 mm diameter the Miocene form is relatively large. These characteristics are in my opinion insufficient to consider the fossil species different from the living one.

It is striking that the presence of this species at Muddy Creek has not been noticed up to now. Still the species is not a rare constituent of the pteropod fauna: together with c. 200 specimens of *L. tertiaria* 69 shells of *L. inflata* were found.

Miocene records of *L. rostralis* (Eydoux & Souleyet, 1840) (a recognized junior synonym of *L. inflata*) from Western Europe usually refer to the species *Limacina miorostralis* (Kautsky, 1925) or other planorboid species, never to *L. inflata*. This is the first time that Miocene specimens of *L. inflata* have been recognized with certainty. All other records mentioned above in the list of synonyms lack the proof of the apertural reinforcements. Still, it seems at least probable that *Planorbella imitans* Gabb, 1873 indeed is the same as *L. inflata*, as was suggested by Pilsbry (1922, p. 308, fig. 1). The illustrations given by this author of the 'type' of *P. imitans* demonstrate the form and the proportions of juvenile *L. inflata*, only the umbilicus seems to be somewhat wider. Considering, however, the extreme resemblance of juvenile limacinids I prefer to maintain a certain degree of caution, not the least because I haven't yet had the possibility to study the *P. imitans* material myself.

The material published by Collins (1934, p. 180, pl. 7, figs. 3-5), from the Miocene of Santa Rosa, Vera Cruz, Mexico (USNM 645 188, ex Johns Hopkins University collection) might indeed belong to *L. inflata*, but again the apertural characteristics are not (yet?) developed. The specimen recorded by Collins from the Late Miocene (nannoplankton zone NN 11, see Saunders et al., 1986) Cercado Formation, Rio Mao, Dominican Republic (USNM 483 145) does not belong to *L. inflata*, because of its slightly different proportions and, especially, by the presence of a very weak microsculpture on the body whorl.

The specimens described by d'Alessandro et al. (1979) from southern Italy (Gargano Peninsula) are juvenile (diameter c. 0.8 mm) and rather poorly illustrated. Material in the RGM collection from the same locality also is too juvenile and insufficiently preserved (internal moulds) for a reliable identification.

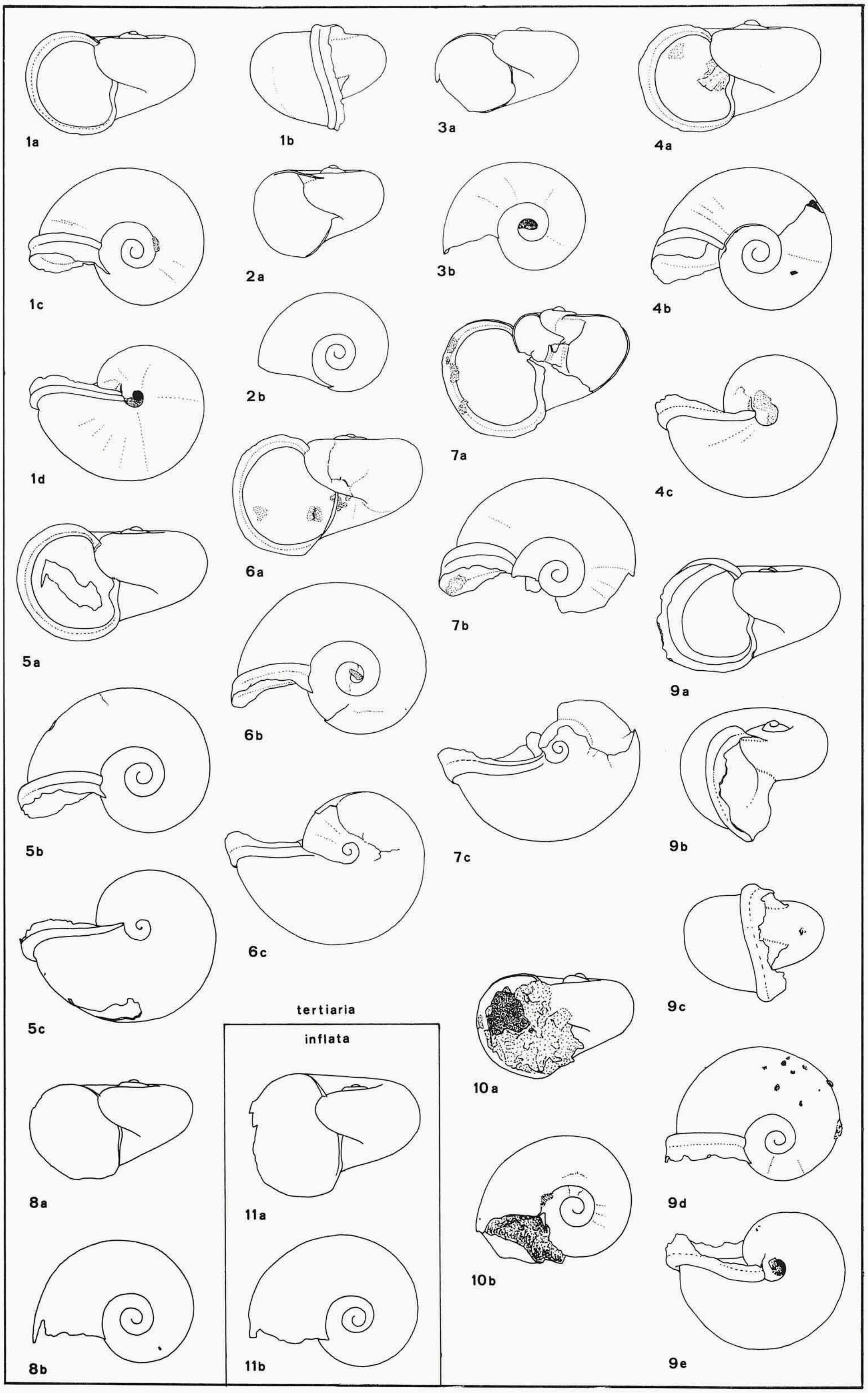
The subspecies *Spiratella inflata volhinica* Stancu, 1979, reported from the Late Miocene of the Romanian Paratethys, was neither described nor illustrated.

Plate 3

Figs. 1-10. *Limacina tertiaria* (Tate, 1887)
1-7: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, 'lower beds' (= Muddy Creek Formation).
1a-d: Lectotype, SAM T 239, × 25.
2-7: Paralectotypes, SAM T 239, × 25.
8: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation, from interior of *Ancillaria pseudaustralis* Tate. Juvenile specimen, RGM 229 498, × 25.
9a-e: Muddy Creek, Hamilton; ?Miocene (no level indicated). Adult specimen, AMS C143.929, × 25; fig. 9b is an oblique view to demonstrate the elevation of the apical whorls.
10a-b: Schnapper Point near Mornington; Miocene, Balcombian or Bairnsdalian ('blue clays'). Paralectotype, SAM T 239, × 25.

Fig. 11. *Limacina inflata* (d'Orbigny, 1836)
Locality data as for fig. 8. Juvenile specimen, RGM 229 493, × 25. Note that figs. 8 and 11 compare about equal-sized juveniles of *L. tertiaria* and *L. inflata*.

Plate 3


1a
1b
3a
4a
1c
2a
3b
4b
2b
1d
7a
4c
6a
5a
7b
9a
6b
5b
9b
7c
6c
5c
tertiaria
inflata
9c
10a
8a
11a
9d
10b
8b
11b
9e

Quite recently (May 1989) an unmistakable specimen of *L. inflata* was collected from the 'Middle Miocene' of Karaman, Turkey, by Mr J. van der Voort (Ostercappeln, F.R.G.).

From the Italian Pliocene *L. inflata* has repeatedly been recorded, usually sub nomine '*rostralis*'. Among them only the observation of Seguenza (1880, p. 277) seems to be quite certain, as this author mentioned the presence of the 'caratteristico rostro'. Several specimens present in the RGM collections donated by Mr C. Tabanelli at Cotignola, Italy, from the 'Middle Pliocene' of Rio Terme near Ravenna (Italy) also seem to belong to *L. inflata*, as indicated by the presence of an opaque subperipheral belt on the body whorl. Additional material is present in the Tabanelli collection.

Limacina lunata sp. nov.
Pl. 2, figs. 8-10.

Holotype — Pl. 2, fig. 8, leg./don. D. Curry, NMV P123406.
Type locality — Torquay, Bird Rock, Otway Basin, Victoria, Australia.
Stratum typicum — The type sample was collected from the so-called '*Glycymeris* Beds', as described by Singleton (1941, p. 39), belonging to the Torquay Group, Jan Juc Formation (Oligocene, Janjukian; see Ludbrook, 1967, p. 14; 1973, p. 248).
Derivatio nominis — The name '*lunata*' refers both to the semicircular shape of the aperture and to the Half Moon Bay in the Bass Street, on which the type locality of this species is located.

Description — Very small sinistral shell with c. 4 moderately convex whorls that slowly and regularly increase in diameter. The point of attachment of the whorls onto the preceding ones lies just above the periphery in juvenile shells and on the periphery in adults. Thus, there is only a very narrow overlap of whorls in an apical view. The shell has a low conical spire, the tangents of which are somewhat convex. The body whorl is large, uniformly convex with a distinctly umbilicate base. The umbilicus is small, occupying less than 10% of the shell's diameter.

The aperture is wide and semicircular. The columella below the base of the penultimate whorl is somewhat inflected around the umbilicus, downward almost straight until the angular transition into the basal part of the margin. Internally, at a short distance from the border, the apertural margin is strengthened with a thickened ridge, which is only visible from outside by transparency of the shell wall before and behind the ridge. In a lateral view (Pl. 2, fig. 8b) the apertural margin is situated obliquely with respect to the shell's axis, the upper part somewhat overhanging the base. The growth-lines are very indistinct. From the upper suture they proceed slightly backwards, but on the base they demonstrate a weak forward curvature.

Material studied — Holotype, NMV P 123406; 2 juvenile paratypes (Pl. 2, figs. 9-10), 5 juvenile paratypes, all from the type locality, RGM 229 424- 426.

Discussion — This new species occurs together with the much more common and equally new species *Limacina curryi*, from which it is easily distinguished by its spired shell, the number of whorls related to the shell's width and the H/W-ratio. In its general outline *L. lunata* resembles closely the species *L. tatei* sp. nov., described in this paper from the Miocene at Muddy Creek. In this latter species, however, the tangents of the whorls are slightly concave instead of convex, the position of the aperture is flexuous opisthocline instead of prosocline, and the apertural reinforcements are completely different.

From European species with a similar shell-form, like *L. valvatina* (Reuss, 1867) or *L. hospes* (Kittl, 1886), the new species can easily be distinguished by the internally thickened apertural margin, but juveniles are extremely similar, especially those of *L. valvatina*.

Limacina tatei sp. nov.
Pl. 2, figs. 11-12.

Holotype – Pl. 2, fig. 11, don. D. Curry, NMV P123407.
Type locality – Muddy Creek, Hamilton, Otway Basin, Tyrendarra Embayment, Victoria, Australia.
Stratum typicum – Muddy Creek Formation (Miocene, Balcombian to Bairnsdalian), see Ludbrook (1973, p. 252).
Derivatio nominis – This species is named after the well-known palaeontologist Ralph Tate, the first author to describe fossil pteropods from the Australian continent.

Description – Very small sinistral shell, comprising c. 3 3/4 rather convex whorls that gradually and slowly increase in diameter. Each whorl is attached just above the periphery of the preceding one, resulting in a low conical shell-form with slightly concave tangents. The body whorl is relatively large and regularly rounded with a convex base. The umbilicus occupies c. 12% of the shell diameter (measured just behind the apertural reinforcement). The aperture is large with a regularly circular abaxial side and a straight columella below the base of the penultimate whorl. The opisthocline apertural margin carries a distinct, somewhat swollen ridge, flexuous in a lateral view, followed by a very thin and slightly widened apertural edge. The growth-lines are very inconspicuous, and only visible in low-angle light. They run from the upper suture slightly forward and straight downward from the periphery.

Material studied – Holotype, NMV P123407, and 1 paratype (Pl. 2, fig. 12), RGM 229 496, both from the type locality, from interior of *Ancillaria pseudaustralis* Tate.

Discussion – *Limacina tatei* has the general outline of a very well-known species from the Miocene of Europe, viz. *Limacina valvatina* (Reuss), but differs clearly by the possession of apertural reinforcements. Also *Limacina hospes* (Kittl) is rather similar to *L. tatei*, but in the former species the apertural margin is just slightly widened, without any further strengthening devices. *L. hospes* is, by the way, of Late Oligocene age.

The two available specimens are both adults. They are very similar indeed, with almost no difference in the height/width-ratio. The general outline and the apertural characteristics are identical.

Limacina tertiaria (Tate, 1887)
Pl. 3, figs. 1-10; Pl. 4, figs. 1-6; Pl. 11, figs. 1-2.

v* 1887 *Spiralis tertiaria*, spec. nov., Tate, p. 196 (partim, non pl. 20, fig. 12a-c = *Limacina inflata*).
v. 1897 *Limacina tertiaria*, Tate (sp.) - Harris, p. 19 (partim?).
v. 1899 *Limacina tertiaria*, Tate - Tate, p. 260.
1903 *Limacina tertiaria*, Tate - Dennant & Kitson, p. 94.
1965 *Spiratella tertiaria* - Curry, p. 368.
1981 *Spiralis tertiaria* Tate - Curry, p. 38.
1982 *Spiratella tertiaria* (Tate) - Bernasconi & Robba, p. 215.

Description – Very small, sinistral shell with c. 2 3/4 whorls, that rather quickly and regularly increase in diameter. The first whorl is turreted, but subsequently the volutions become more and more planorboid, resulting in a shell with an almost flat apical plane and downward produced whorls. In juvenile shells the apex protrudes beyond the body whorl in straight frontal view (Pl. 3, fig. 8a), in completely adult specimens the body whorl may or may not rise above the apex. The whorls are very convex, with a regularly rounded periphery. The point of attachment to the preceding whorl lies somewhat above the periphery. The base of the shell is convex, distinctly umbilicate. Diameter of umbilicus in full-grown shells (measured just behind the apertural reinforcements) c. 12-15% of shell diameter.

The aperture is almost circular, only slightly indented by the preceding whorl. The columella is almost straight to distinctly notched. The apertural margin is reinforced by a strong ridge, followed by a distinctly widened final part of the body whorl. The ridge is somewhat sigmoid in a lateral view (Pl. 4, fig. 1b). The widened part before the ridge has an extremely thin shell-wall and therefore the ultimate part of the shell is usually damaged. Only very few shells are available in which the extreme margin is still complete (Pl. 4, fig. 1). In a very restricted number of specimens the flexuous ridge of the apertural margin is preceded by a narrow but distinct groove, which makes the body whorl slightly bulbous just behind the thickened margin (Pl. 4, fig. 6b). The margin and the shell-wall just behind the margin are granulated, which is especially well-visible on the periphery at a magnification of × 100.

The growth-lines are extremely faint and only locally visible in low-angle light. From the upper suture they run with a slight backward curvature, almost straight on the periphery and the base, becoming somewhat flexuous on the second half of the body whorl.

Syntypes — Collection of the South Australian Museum, Adelaide, reg. nos. SAM T 239, P29782-29788. The material described by Tate originates from the 'Lower beds at Muddy Creek and blue clays at Schnapper Point'. Specimens from both localities are preserved in the South Australian Museum. They were kept in a glass vial, glued to a wooden tablet, bearing a label with the text:

> Name: Spiralis tertiaria Tate. Pl. XX fig. 12
> Hab.: Eocene. Schnapper Pt., Muddy Creek
> T 239

In the vial a small strip of cardboard, with a hand-written indication 'Schnapper Pt.', was present, on which five specimens were glued. I removed these shells from the cardboard strip by immersion in water.

Furthermore ten isolated specimens (two of which are strongly defective) were hidden below the cardboard strip in the glass-tube. Apparently these are the syntypes from Muddy Creek.

Four shells from Schnapper Point and five from Muddy Creek are full- grown, as is evident from their remarkably expanded and thickened apertural margin. The remaining specimens lack such an apertural margin, they may be either juveniles or damaged adults. Two specimens from Muddy Creek are too severely damaged to be of much use. The eight more or less complete syntypes from Muddy Creek are illustrated here in Pl. 2, fig. 7, Pl. 3, figs. 2-3 (juveniles) and Pl. 3, figs. 1, 4-7 (adults).

Lectotype designation — Tate's description and illustration distinctly refer to a form from Muddy Creek (see explanation of his plate 20) in which the apertural margin is not widened or thickened: 'Peristome thin, simple, a little reflexed at the umbilicus'. Especially his fig. 12b fits very well the specimen here illustrated in Pl. 2, fig. 7. The general outline of this shell, as well as the number of whorls (compare Tate's fig. 12c) match the illustrations almost perfectly, albeit that they represent a shell with an undamaged aperture. This, however, might be an improvement by the artist, or the specimen may have been damaged afterwards. The measurements of the species are indicated by Tate as: 'Diameter, one millimetre', which more or less agrees with the actual 1.18 mm of the syntype illustrated in Pl. 2, fig. 7. Therefore it would have been logical to designate this juvenile specimen as the lectotype of *Spiralis tertiaria.*

However, additional material available from the same locality proves that in the 'lower beds' at Muddy Creek two species occur, the juveniles of which are extremely similar. The fully grown forms are easily distinguished by the very different development of the apertural reinforcements. In one of these species the body whorl is distinctly widened just before the apertural margin, with a conspicuous ridge at the posterior side of the widening. All adult *Spiralis tertiaria* syntypes belong to this form. The second species, not represented among the adult syntypes, has an internal thickening, which is produced into a long anterior rostrum lying just below the periphery of the ultimate part of the body whorl. In undamaged specimens (compare Pl. 2, fig. 6) it is seen that both below and above this rostrum an extremely thin, membrane-like shell-wall is present, but usually this part of the whorl is broken, with only the more solid rostrum left. This form agrees almost completely with the Recent species *Limacina inflata* (d'Orbigny, 1836), as described above.

Obviously juvenile specimens of both species can be expected among the immature syntypes of *Spiralis tertiaria.* Sufficient additional material was available to find distinguishing characteristics for the very similar juvenile shells. In juvenile specimens of *L. inflata* the apex does not protrude beyond the body whorl in a straight frontal view and the sutural spiral is narrower (apical view) because of the fact that the outer lip attaches rather high onto the preceding whorl. Also the height/width-ratio of the shell has a somewhat higher value. These differences are clearly illustrated by two juvenile specimens from the additional material from Muddy Creek (see Pl. 3, figs. 8 and 9).

From these differences it is clear that the juvenile syntype of Pl. 2, fig. 7 is an immature specimen of *Limacina inflata.* Designating this specimen as the lectotype of *Spiralis tertiaria* would make this latter taxon a synonym of *L. inflata.* At the same time, however, the introduction of a new taxon would be necessary for the remaining syntypes. In these circumstances I think it preferable to choose as lectotype one of the full-grown syntypes, which offers the best guarantee for nomenclatural stability and also prevents future identification problems once and for all. So, the specimen here illustrated in Pl. 3, fig. 1 is designated as the lectotype of *S. tertiaria* Tate. All other specimens mentioned above from Schnapper Point and Muddy Creek, except the one illustrated in Pl. 2, fig. 7, are paralectotypes.

The measurements of the lectotype are: height 0.65 mm, width 1.08 mm, number of whorls 2 3/4.

The type locality is Muddy Creek near Hamilton, Otway Basin, Tyrendarra Embayment, Victoria, Australia. According to Ludbrook (1973, p. 252) Tate's indication 'lower beds, Muddy Creek' refers to what is now called the Muddy Creek Formation, which is of Balcombian to Bairnsdalian age, so almost on the boundary between Early and Middle Miocene.

Material studied — Muddy Creek, Hamilton, Australia (Miocene, Balcombian to Bairnsdalian): lectotype (Pl. 3, fig. 1), 6 paralectotypes (Pl. 3, figs. 2-7), SAM T 239, SAM P29782-29783; 1 specimen, SAM P29784; 54 specimens, NMV P116255; 55 specimens, RGM 229 472; 5 specimens, RGM 229 482; 9 specimens, ?2 juvenile specimens, BM(NH) G. 9308 (three of which were mentioned in Harris, 1897, p. 19); 28 specimens, 1 specimen (Pl. 4, fig. 6), from interior of *Harpa pulligera* Tate, RGM 229 486-487; 36 specimens, 22 juvenile specimens, 3 specimens (Pl. 3, fig. 8; Pl. 4, fig. 1; Pl. 11, fig. 1), 1 juvenile specimen (Pl. 11, fig. 2) from the interior of *Ancillaria pseudaustralis* Tate, RGM 229 497-499, 229 738-739.

Do., without any indication of the level: 1 specimen (Pl. 3, fig. 9), leg. Bailey, AMS C143.929.

Batesford, Australia (Miocene, Batesfordian to Bairnsdalian): 47 specimens, RGM 229 443.

Red Bluff, Shelford, Australia (Miocene, Balcombian): 4 specimens, NMV P116254; 5 specimens, RGM 229 465.

Schnapper Point, Mornington, Australia (Miocene, Balcombian or Bairnsdalian): 1 paralectotype, 4 paralectotypes (Pl. 4, figs. 2-5), SAM P29785- 6.

Balcombe Bay, Mornington, Australia (Miocene, Balcombian): 36 specimens, RGM 229 451.

Fossil Beach, Mornington, Australia (Miocene, Balcombian): 16 specimens, NMV P116253; 1 defective specimen, RGM 229 457; 1 specimen (from sediment contents of *Eutrephoceras* sp.), RGM 229 461.

Discussion — It is quite curious that Tate, with so many full-grown shells available, selected a juvenile specimen for illustration in which the very typical characteristics of the aperture are not yet developed. A possible explanation might be that he isolated a shell from the main sample, before careful study of the material had taken place, and that afterwards the description was based on the drawing rather than on the specimens themselves. This is not as unlikely as it sounds, because very similar indications were found in the cases of *Styliola rangiana* Tate and *S. bicarinata* Tate, as discussed below.

Tate (1887) placed his species *S. tertiaria* in the never formally introduced genus *Spiralis*, which Harris (1897, p. 19) presumed to be a spelling-error for *Spirialis* Eydoux & Souleyet, 1840. Earlier the same error also occurred to Adams & Adams (1853, p. 60) and Knocker (1868, p. 617 and 619), but also later authors became prey to the same printer's imp (Locard, 1897, p. 29; Wenz, 1921, p. 113; Zinndorf, 1928, p. 13, 15 and 53; Warén, 1980, p. 11). The type species of *Spirialis* is the Recent *Atlanta trochiformis* d'Orbigny, 1836 (subsequent designation Herrmannsen, 1847- 1849, p. 489), which is a spired limacinid without apertural reinforcements. The reader is referred to Janssen (in prep.) for a further discussion on the systematics of the genus *Limacina*.

As discussed above the specimen illustrated by Tate (1887, pl. 20, fig. 12) is a juvenile shell of *L. inflata* (d'Orbigny). The lectotype designation in this paper restricts the name *L. tertiaria* to the form with an apertural margin reinforced by a somewhat flexuous ridge followed by a widening. Harris (1897, p. 19), in his catalogue of Australa

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Plate 4

Figs. 1-6. *Limacina tertiaria* (Tate, 1887)

1a-d: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation, from interior of *Ancillaria pseudaustralis* Tate. Adult specimen with completely preserved apertural margin, RGM 229 497, × 25.

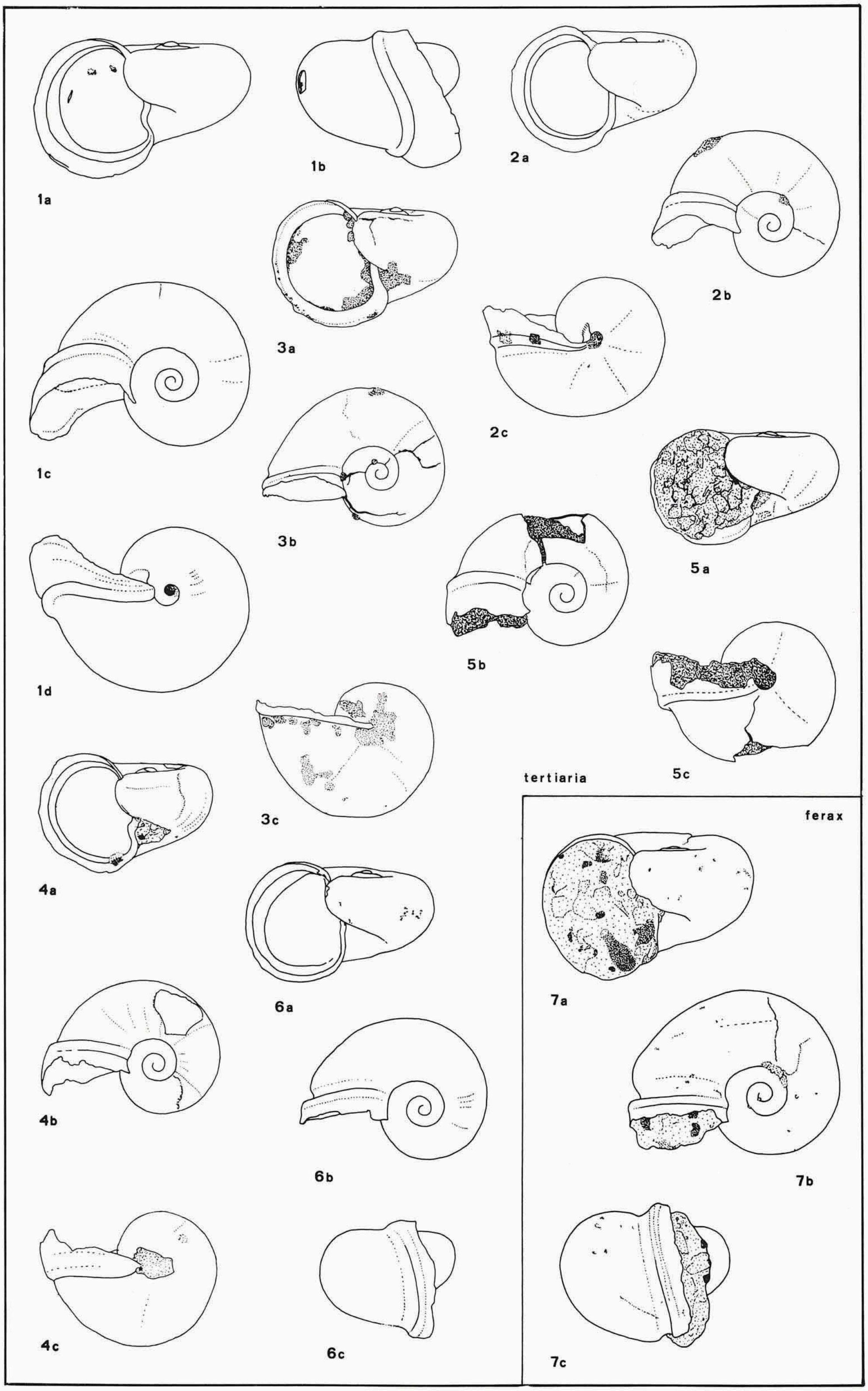
2-5: Schnapper Point near Mornington; Miocene, Balcombian ('blue clays'). Paralectotypes, SAM T 239, × 25.

6a-c: Locality data as for fig. 1, but from interior of *Harpa pulligera*. Adult specimen with comparatively deep furrow preceding the apertural margin and therefore resembling *Limacina ferax* (especially well visible in fig. 6b), RGM 229 486, × 25.

Fig. 7. *Limacina ferax* (Laws, 1944)

Pakaurangi Point, Kaipara Harbour (New Zealand); Miocene, Altonian, '*Vaginella*' Bed? Paratype, RGM 229 510, × 25.

Plate 4


1a
1b
2a
2b
3a
1c
2c
3b
5a
1d
5b
3c
tertiaria
5c
ferax
4a
6a
7a
4b
6b
7b
4c
6c
7c

sian fossils in the collection of the British Museum, merely repeated Tate's description, just using a slightly different wording. He also failed to mention the apertural features so typical for this species. His material, the G. 9308 sample, is still present in the BM(NH)-collection, where I studied it in 1986. It contains eleven shells, nine of which are adults, so even if indeed (as Harris stated) the sample comprised only three specimens in 1897, at least one of these was adult. When I studied the sample I was not yet prepared for the presence of two very similar species, so the two juveniles might include *L. inflata*. Tate (1899) accepted Harris's transfer of the species to the genus *Limacina*, but gave no additional information. Curry (1965) apparently was the first author who mentioned the apertural reinforcements ('what appear to be strengthening or supporting devices at the adult stage').

A very similar species was described from the Early Miocene of New Zealand by Laws (1944, p. 312) as *Spiratella ferax* Laws. Its age was indicated as Altonian, but Dr P.A. Maxwell (in litt., 1.8.1988) provided additional information (see quotation in the paragraph 'stratum typicum' in the description of *Limacina atypica* above). From these data it may be concluded that *L. ferax* occurs in strata that are older than the Batesfordian to Bairnsdalian occurrences of *L. tertiaria* in Australia.

Ten paratypes of *L. ferax* were donated by Mr D. Curry, enabling the execution of a direct comparison. One of the better *L. ferax* specimens is illustrated here in Pl.4,

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Plate 5

Figs. 1-4. *Creseis* cf. *chierchiae* (Boas, 1886)
1-2: Batesford, new quarry; Miocene, Batesfordian to Bairnsdalian, Fyansford Formation, grey clays.
1a-b: Adult specimen without protoconch, RGM 229 444, × 12.5.
2a-b: Fragment, RHGM 229 445, × 12.5.
3-4: Balcombe Bay, Mornington; Miocene, Balcombian, Fyansford Formation, beds h-k.
3a-c: Subadult specimen with protoconch, RGM 229 452, a-b: × 12.5, c: × 25.
4a-c: Juvenile specimen with protoconch, RGM 229 453, a-b: × 12.5, c: × 25.

Fig. 5. *Creseis chierchiae* (Boas, 1886)
Off SW Salayer, Indonesia, 6° 22' S, 120° 26' E, sea-depth 233-274 m; 28.09.1984, van Veen grab; Recent; leg. Snellius II expedition, sta. 4.155. Subadult specimen, tip of protoconch damaged, RGM 229 517, a-b: × 12.5, c: × 25.

Fig. 6. *Creseis chierchiae* (Boas, 1886) f. *constricta* Chen & Bé, 1964
Locality data as for fig. 5. Subadult specimen with protoconch, RGM 229 519, a-b: × 12.5, c: × 25.

Figs. 7-12. *Praehyalocylis annulata* (Tate, 1887)
7-9: Adelaide Bore (= Kent Town Bore), NE Parklands; Eocene, Aldingan, 'Glauconitic Clayey Sands' (= units 10 and 11, Blanche Point Banded Marls and equivalents of the Blanche Point Transitional Marls and Tortachilla Limestone).
7: Lectotype, SAM T 214, × 6.
8-9: Paralectotypes, strongly distorted, SAM T 214, × 6.
10-12: Aldinga Bay, Willunga Embayment, St Vincent Basin; Eocene, Aldingan, Blanche Point Formation, Gull Rock Member, Clay with '*Turritella*' *aldingae*.
10: Fragment, slightly distorted, RGM 229 410, × 6.
11-12: Paralectotypes, more or less strongly distorted; SAM T 214, × 6.

Figs. 13-19. *Styliola subula* (Quoy & Gaimard, 1827)
13-17: Muddy Creek, Hamilton; ?Miocene (no level indicated).
13: Lectotype of *Styliola rangiana* Tate, 1887, SAM T 238, × 12.5.
14-16: Paralectotypes of *Styliola rangiana* Tate, 1887, SAM T 238, × 12.5.
17: Paralectotype of *Styliola rangiana* Tate, 1887, found together with holotype of '*Styliola*' *bicarinata*, SAM, × 12.5.
18-19: Schnapper Point near Mornington; Miocene (level not indicated). Paralectotypes of *Styliola rangiana* Tate, SAM T 238, 18: × 5, 19: × 12.5.

Plate 5

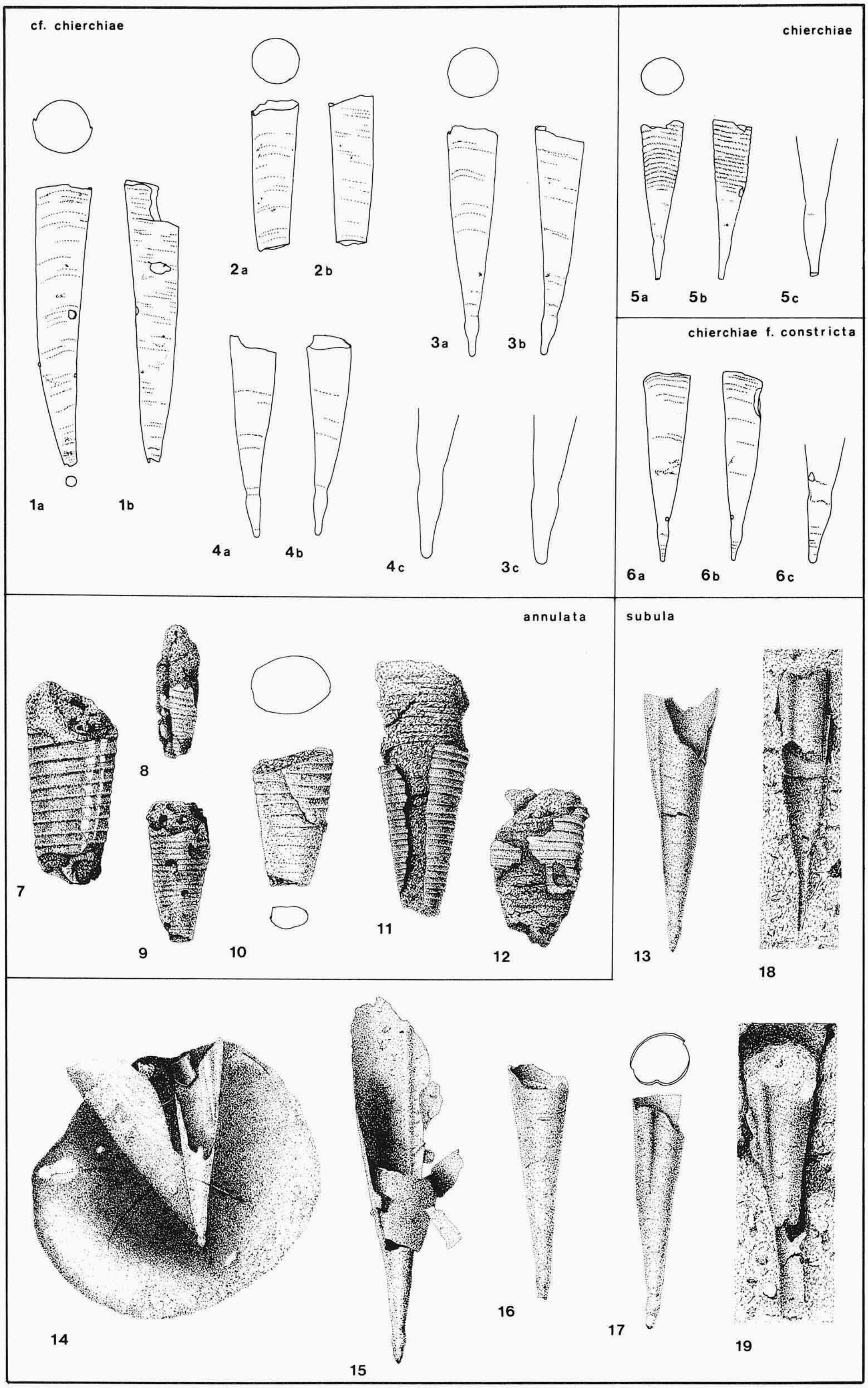

cf. chierchiae
chierchiae
chierchiae f. constricta
annulata
subula
1a 1b 2a 2b 3a 3b 3c 4a 4b 4c 5a 5b 5c 6a 6b 6c
7 8 9 10 11 12 13 14 15 16 17 18 19

fig. 7. Laws compared his species with the Muddy Creek *L. tertiaria* and considered it different, because 'It has the whorl more narrowly rounded and the channel near aperture not so strongly defined'. Indeed the shell of *L. ferax* is relatively higher and the pre- apertural constriction is hardly or not indicated in most Australian specimens. Sometimes, however, a distinct 'channel' is present (Pl. 4, fig. 6b). Also the New Zealand species is slightly larger (diameter to c. 1.3 mm). Considering these characteristics together with the differences in age it may be concluded that *L. tertiaria* and *L. ferax* are very closely related and probably represent subsequent stages of one and the same evolutionary lineage.

Familia CAVOLINIIDAE
Subfamilia CRESEINAE
Genus *Creseis* Rang, 1828

Creseis cf. *chierchiae* (Boas, 1886)
Pl. 5, figs. 1-4; Pl. 12, fig. 1.

References of Recent and Quaternary *C. chierchiae* occurrences:
* 1886a *Cleodora Chierchiae* n.sp., Boas, p. 62, 202, pl. 3, fig. 39ter, pl. 4, figs. 43bis-ter.
. 1886b *Cleodora (Creseïs) chierchiae* - Boas, p. 330.
1905 *Creseis Chierchiae* Boas - Meisenheimer, p. 17.
. 1913 *Creseis chierchiae* (Boas) - Tesch, p. 25, fig. 19A-C.
1934 *Creseis (Boasia) chierchia* (sic!) Boas 1886 - Johnson, p. 151.
1946 *Creseis chierchiae* Boas - Tesch, p. 21.
1948 *Creseis chierchiae* Boas - Tesch, p. 41.
. 1951 *Creseis chierchiae* (Boas) - Tokioka, p. 184, fig. 10.
. 1964 *Creseis virgula constricta* n. subsp., Chen & Bé, p. 194, figs. 3d, 4d, 9, 10, 12.
. 1965 *Creseis virgula constricta* Chen et Bé - Frontier, p. 12-14.
. 1965 *Creseis chierchiae* (Boas) - Frontier, p. 12-14, pl. 1, fig. 3; pl. 4, figs. 9-11.
1967 *Creseis virgula* (Rang, 1828) forma *virgula* (Rang, 1828) - van der Spoel, p. 61 (partim).
. 1967 '*Creseis chierchiae* (Boas, 1886)' - van der Spoel, p. 62.
. 1967 *Hyalocylis striata* - van der Spoel, fig. 42 (partim, only the apical part, the apertural part is indeed *Hyalocylis striata*).
. 1971 *Creseis virgula constricta* - Herman & Rosenberger, pl. 1, fig. 6.
. 1973 *Creseis chierchiae* - Richter, p. 269, fig. 3.
? 1973 *Creseis virgula constricta* Chen and Bé - Jung, p. 753ff, pl. 2, fig. 10.
. 1974 *Creseis bulgia* n. sp., Sakthivel, p. 619, figs. 1-2.
. 1975 *Creseis chierchiae* (Boas, 1886) - Rampal, p. 12ff, fig. 2-16.
1975 *Creseis virgula constricta* (Chen & B 1964) -Rampal, p. 253ff.
1975 *Creseis virgula constricta* - Wells,p. 509.
1976 *Creseis chierchiae* Boas - Richter, p. 145-148, figs.1-3, 5.
. 1976 *Creseis virgula constricta* Chen & Bé - Richter, p. 145, 146.
. 1976b *Hyalocylis striata* (Rang, 1828) - van der Spoel, p. 111 (partim).
. 1977 *Creseis virgula* (Rang, 1828) *constricta* (Chen and Bé, 1964) (sic!) - Bé & Gilmer, p. 748ff, pl. 5, fig. 12a-b (authors' names should not be between brackets).
1978 *Creseis chierchiae* - Rottman, p. 65.
1978 *Creseis bulgia* - Rottman, p. 65.
. 1979 *Creseis chierchiae* (Boas 1886) - Richter, p. 15, pl. 1, figs. 8, 11.
1980 *Creseis virgula constricta* - Buccheri et al., p. 100.
1980 *Creseis virgula constricta* - Rottman, p. 73.
. 1980 *Creseis bulgia* - Rottman, p. 73ff, fig. 4A, C.
. 1980 *Creseis chierchiae* - Rottman, p. 73ff, fig. 4B, D.
1983 *Creseis chierchiae* (Boas, 1886) - Shibata & Ujihara, p. 160, pl. 44, fig. 3.
? 1983 *Creseis virgula constricta* Chen and Be, 1964 - Shibata & Ujihara, p. 160, pl. 44, fig. 2a-b.

Description — Shell elongately conical, frequently with a slight curvature, especially in its apical part. The diameter of the shell increases rather quickly just after the embryonic shell, more slowly towards the aperture, which results in a somewhat caliciform outline. The transverse section is circular all over the length of the shell.

The embryonic shell has a rounded tip and an almost cylindrical initial part, followed by a distinct swelling, which is more abruptly separated on its apertural side. This results in a rather distinctly separated protoconch with an elongated triangular form, with slightly concave sidelines.

The growth-lines are rather distinct and somewhat irregular. They make a small angle with the shell's axis, lying higher at the concave side, which is interpreted as the dorsal side. There is no further surface sculpture.

Type material — This species was based on a large number of specimens from Panama and a single shell from the Mindoro Sea (Philippines, 120° E, 10° N). Syntypes are presumably kept in the Zoological Museum, University of Copenhagen, Denmark.

Material studied — Batesford, Australia (Miocene, Batesfordian to Bairnsdalian): 1 defective specimen, 2 defective specimens (Pl. 5, figs. 1-2), RGM 229 444-446.

Balcombe Bay, Mornington, Australia (Miocene, Balcombian): 2 juvenile specimens (Pl. 5, figs. 3-4), 1 juvenile specimens, 3 fragments, RGM 229 452-454.

Fossil Beach, Mornington, Australia (Miocene, Balcombian): 2 juvenile specimens, RGM 229 458; 12 juvenile specimens, 1 juvenile specimen (Pl. 12, fig. 1) from interior of *Eutrephoceras* sp., RGM 229 462, 229 741.

Discussion — Among the abundant and predominantly juvenile material of *Styliola subula* (Quoy & Gaimard, 1827) from the Miocene of the Mornington area quite surprisingly a small number of specimens was isolated that closely resemble *Creseis chierchiae* (Boas, 1886), a form exclusively known from the latest Quaternary and Recent faunas. In the typical form of this species the shell (Pl. 5, fig. 5) is conical, straight or slightly bent, and provided with a characteristic transverse sculpture on the postembryonic shell parts. The protoconch resembles somewhat that of *C. virgula* (Rang, 1828), but differs from that species by its more abrupt transition into the post-embryonic shell, which gives the protoconch a peculiar elongate-triangular appearance.

Ever since its introduction *C. chierchiae* was considered an enigmatic species, which was predominantly caused by the fact that it was only very rarely encountered. Johnson (1934) even created a separate subgenus, *Boasia*, for this form, which was, however, not accepted among the 'pteropodologists'. Van der Spoel (1967, p. 62, fig. 42; repeated in van der Spoel, 1976a, p. 111) considered *C. chierchiae* to be the larval shell of *Hyalocylis striata* (Rang, 1828), an equally Recent species with transverse ribbing of the shell, the protoconch of which was unknown. He demonstrated this by giving a composite drawing of *C. chierchiae* and *H. striata*, 'both drawn to the same scale (16 x)'. This reconstruction, however, is erroneous: the *C. chierchiae* part is magnified x 10 and the *H. striata* part x 16.

Frontier (1965), a paper apparently still unknown to van der Spoel in 1967, studied an abundant material of *C. chierchiae*. In his opinion typical *C. chierchiae* is connected by numerous intermediates to a form without the obvious transverse ribbing, but with identical protoconch and shell outline. This latter form (Pl. 5, fig. 6) was described by Chen & Bé (1964) as *Creseis virgula constricta* (syn.: *C. bulgia* Sakthivel, 1974), which van der Spoel (1967, p. 61) considered to be a synonym of *C. virgula* s.str., although he admitted the differences of the embryonic shell. This point of view is maintained in van der Spoel (1976a, p. 16). In this latter paper, in which Frontier's (1965) paper is mentioned in the list of references, van der Spoel did not express his opinion concerning *C. chierchiae.*

Frontier's views were confirmed by Richter (1976, 145-148; 1979, p. 15) on the basis of abundant material caught in plankton hauls from the Gulf of Aden area. I myself could study this problem on material from a bottom sample collected during the Snellius II expedition (sta 4.155, 6°22' S, 120°26' E, depth 233-274 m, 28.9.1984) from the Flores Sea, off SW Salayer, Indonesia. This sample yielded numerous *C. constricta* and just one typical *C. chierchiae*. Considering this sample and the data supplied by Frontier and Richter it seems inevitable to interpret *C. chierchiae* as an independent *Creseis* species and *C. constricta* as a forma. González & Princz (1979, p. 104) published the unjustifiable opinion that *C. chierchiae* is a synonym of *Creseis acicula* (Rang, 1828).

The Miocene material from Australia yielded exclusively smooth forms. They differ from the Recent Indonesian material by the somewhat larger adult shell and by the dimensions of the protoconch. A comparison of protoconch measurements (10 specimens measured for both samples) yielded the following results (Table 2):

Table 2. Measurements (in mm) of protoconchs of *Creseis chierchiae* (Boas, 1886) f. constricta Chen & Bé, 1964 (Recent, Flores Sea, off Salayer) and *Creseis* cf. *chierchiae* (Boas, 1886) (Miocene, Balcombe Bay, Australia).

	diameter of protoconch tip	length of inflated part	length of protoconch
Recent, off Salayer	0.06	0.14-0.15	0.40-0.46
mean value	0.06	0.144	0.428
Miocene, Balcombe Bay	0.08-0.09	0.16-0.18	0.48-0.54
mean value	0.083	0.168	0.516

From these measurements it is obvious that the Miocene specimens have a distinctly larger protoconch than the Recent ones, even without any overlap. In the absence of any further information on the variability of Recent populations, however, this may not yet be considered a specific criterion and therefore the Miocene form is indicated as *Creseis* cf. *chierchiae* for the time being.

It is the first time that forms related to *C. chierchiae* are recognized from the Cainozoic fossil record, but it is not exceptional that Recent euthecosomatous species are found to be very long-ranging and to occur already during the Miocene. In this paper similar observations are made with respect to the species *Limacina inflata* and *Styliola subula*.

Further related forms are known, e.g. from Miocene deposits of Poland [*Creseis spina* (Reuss, 1867), see Janssen, 1984a, p. 66, pl. 1, figs. 1-2; Vienna collection], from the Late Oligocene and Miocene of SW France and the Early Pliocene of SE France (RGM coll.), and MacNeil & Dockery (1984) illustrated similar material from the Early Oligocene of Mississippi, United States. A thorough inspection of this material, in which certainly various (mainly undescribed!) species are represented, might also influence the taxonomy of the Miocene Australian material. It might even be concluded that a subdivision of the genus *Creseis* into two subgenera (*Creseis* s.str. and *Boasia*) will prove to be useful.

Genus *Praehyalocylis* Korobkov, in Korobkov & Makarova, 1962

Praehyalocylis annulata (Tate, 1887)
Pl. 5, figs. 7-12.

v* 1887 *Styliola annulata*, spec. nov., Tate, p. 195, pl. 20, fig. 1.
1903 *Styliola annulata* Tate - Dennant & Kitson, p. 94.
1921 *Clio (Styliola) rangiana* (Tate) - Suter, p. 71 (non Tate) (Dr P.A. Maxwell, pers. comm., 1.8.1988).
1924 *Clio rangiana* (Tate) - Marwick, p. 317, 323 (partim).
1924 *Clio* n. sp. - Marwick, p. 330.
1924 ?*Clio* sp. - Marwick, pl. 6, fig. 3.
1924 *Clio annulata* Tate (*Styliola*) - Finlay, p. 336.
1934 *Styliola annulata* Tate - Collins, p. 211 (sub *Hyalocylix haitensis*).
1962 *Praehyalocylis chivensis* Korobkov et Makarova, sp. nov., Korobkov & Makarova, p. 84, 85, pl. 3, figs. 1-8.
1966 *Praehyalocylis chivensis* - Korobkov, p. 71.
1970 *Clio annulata* - Darragh, p. 111.
1982 *Hyalocylis annulata* - Beu & Maxwell, p. 44 (tab. 11, no. 595).
1982 *Praehyalocylis annulata* (Tate) - Bernasconi & Robba, p. 213.
1985 *Clio annulata* - Darragh, p. 111.
1989 *Praehyalocylis cretacea* (Blanckenhorn, 1889) - Squires, p. 444, figs. 2.1-2.5 (partim, ? only the Late Eocene occurrences).
non: 1853 *Creseis annulata*. Rang, Deshayes, pl. 103, figs. 11, 12 [= *Hyalocylis striata* (Rang, 1828)]

Description — Shell medium-sized, built as a straight, conical tube with an apical angle of c. 10°. The transverse section seems to be perfectly circular. Apical parts not preserved. The very thin shell-wall bears a distinct sculpture of threadlike annulations, which are also visible internally. In the youngest available shell parts the intervals between these annulations are about three times as wide as the riblets themselves. Towards the apex the annulations are somewhat weaker and more crowded. In none of the available specimens the aperture is preserved.

Further information on this species is supplied in the thesis of Dr M.F. Buonaiuto [1979] (see chapter 'Pteropods described by Buonaiuto' below), who had more material at his disposal. In his description it is stated that the shell of *P. annulata* is slightly curved dorsally towards the apex. The protoconch is illustrated in his figs. 495 and 496. It has a slightly elliptical form, elongated in axial direction, with a rounded tip. In the illustrated specimen the protoconch demonstrates a sharp boundary with the younger shell parts, but this may rather be a crack in the shell material.

Syntypes — Tate had specimens at his disposal from two localities: 'Glauconitic clayey sands, Adelaide bore' and 'Turritella clays, Blanche Point, Aldinga Bay'. The syntype material, lent to me from the South Australian Museum in Adelaide, was stored in a cylindrical glass-cover cardboard box, which is glued on a wooden tablet, bearing a label, stating:

> Form.: Eocene T.214
> Loc.: Aldinga
> Sp.: Creseis
> annulata Tate

The words 'annulata Tate' were subsequently added (different ink, different hand-writing). On the outer side of the cylindrical container another small label states: 'Creseis - Aldinga'.

Inside the container lies a dark blue, circular cardboard with two defective specimens of *S. annulata* (Pl. 5, figs. 11-12). On the back of this cardboard is written in pencil 'Cleodora. Aldinga, L. marl'. Closer inspection of this real 'box of Pandora' revealed that the dark blue cardboard was resting on a fluff of cotton wool, hiding a second circular cardboard, this time white in colour, on which a small piece of clay is glued with some shell remnants and bearing three further glue scars, from which specimens apparently had broken off. Below this white cardboard, finally, I found three damaged shells of *P. annulata* (Pl. 5, figs. 7-9), filled with clayey sediment, together with some very small shell and clay crumbles. On the back of the white cardboard is written 'Adelaide'. Obviously the isolated specimens once were glued on the white cardboard. Some glue is still sticking to the larger specimen, whereas both smaller ones show damaged places that could very well match the glue scars on the white cardboard. So, all in all, we may decide that two syntypes are available from Aldinga and four (of which one is not worth talking about) from the Adelaide borehole. This well is also named Kent Town Bore (Ludbrook, 1973, p. 244, 247).

Lectotype designation — None of the available syntypes corresponds with Tate's illustration, which according to the explanation of plate 20, originated from Aldinga. The drawing might be a reconstruction, but it is also possible that the figured shell (may be the one illustrated here in Pl. 5, fig. 11) was damaged afterwards. At any rate, among the small fragments found at the bottom of the cylindrical container certainly no embryonic shell part was present. It must be feared that its representation in the drawing published by Tate is merely artistic licence.

The larger specimen from Adelaide is the only undistorted one, fairly well demonstrating the sculptural features and the fact that this species has a true circular transverse section. The morphology of both apical and apertural shell parts is not preserved in any of the syntypes and therefore the better Adelaide specimen (Pl. 5, fig. 7) is herewith chosen as the lectotype. All other specimens are paralectotypes. Like all available specimens the lectotype is preserved with an internal clay mould. In this clay two further mollusc shells are present, viz. an elongated cerithiacean or epitoniacean shell, which can be observed at the place where the pteropod is damaged by the glue scar, and a small naticoid shell, lying at the apical side and partly visible in my drawing.

Dimensions — The following measurements (between brackets if incorrect by distortion or damaging) were taken from the syntype series (Table 3).

Table 3. Measurements (in mm) of the syntype series of *Praehyalocylis annulata* (Tate).

Locality	L	Dap	Dar	AA	NA	Plate 5
Adelaide	3.40	1.74	2.32	10°	10	fig. 7 (lectotype)
	1.91	(0.66)	(1.08)	(10°)	14	fig. 8
	2.82	(1.00)	(1.58)	(16°30')	21-22	fig. 9
Aldinga	4.22	(1.00)	(2.24)	(18°)	23	fig. 11
	2.49	(2.32)	-	-	10	fig. 12

L = length of shell, Dap = apical diameter, Dar = apertural diameter, AA = apical angle, NA = number of annulations.

The lectotype designation restricts the type locality to: Adelaide borehole = Kent Town bore, northeast Parklands, city of Adelaide (Ludbrook, 1973, pp. 244, 247). Depth not indicated, but according to Ludbrook (p. 247) Tate's material came from depths between 45 and 66.4 m. Stratum typicum are the 'Glauconitic clayey sands' (Tate, 1887). According to Lindsay (1969, appendix 2, p. 59, bore no. 70) the interval mentioned by Ludbrook (see above) comprises the units 10 (basal part) and 11, which are respectively the Blanche Point Banded Marls and equivalents of the Blanche Point Transitional Marls and Tortachilla Limestone (Late Eocene, Aldingan).

Two paralectotypes originate from Blanche Point, Aldinga, between Maslin Bay and Aldinga Bay, Willunga Embayment, St Vincent Basin, South Australia, from the '*Turritella* clays'. This deposit belongs to the Late Eocene (Aldingan) Gull Rock Member of the Blanche Point Formation (frequently also called 'Blanche Point Marls', in the literature). Extensive information, including nice, coloured illustrations of the Blanche Point locality and of the clay with '*Turritella*' *aldingae* Tate is to be found in Cooper (1979, pp. 18-19, pls 8-9).

Material studied – Lectotype (SAM P29778) and paralectotypes (SAM T 214, P29779-29780) from Adelaide and Aldinga (Pl. 5, figs. 7-9, 11-12), as discussed above.
Aldinga Bay, Australia (Late Eocene, Aldingan): 1 defective specimen (Pl. 5, fig. 10), RGM 229 410.

Discussion – A very similar form, *Praehyalocylis chivensis* Korobkov & Makarova, 1962, was described from Late Eocene deposits (Zone with *Variamussium fallax*) at Khiva, Uzbekistan, U.S.S.R. (south of Lake Aral). This species, judging from the illustration given by its authors, matches *S. annulata* closely. Tate's taxon was obviously unknown to the Russian authors, they only compared their *P. chivensis* extensively with the European Oligocene species '*Tentaculites*' *maximus* Ludwig, 1864. In my opinion there is no evidence to be found in the available information to consider *P. annulata* and *P. chivensis* as separate species. There are differences in the density of the annulations, but this characteristic is quite variable in *P. chivensis*. Furthermore both taxa are approximately of the same age and it may safely be assumed that both occurrences formed part of one and the same species, with a wide distribution pattern.

From the North Sea Basin a still insufficiently known species, *P. cincta* (von Koenen, 1892), is known from Latdorfian sediments in Germany and Belgium. These deposits belong to nannoplankton zone NP 21 (Martini & Ritzkowski, 1969; Locker, 1988; Verbeek et al., 1988), which nowadays is regarded as Late Eocene by many workers. Information on the nannoplankton flora of the Aldinga units would be necessary to decide whether or not *P. annulata* and *P. cincta* are contemporaneous. It might even be that *P. cincta* does not differ specificly from *P. annulata*, but I have insufficient material available of the North Sea Basin form for an objective conclusion in this matter. Evidently *P. cincta* is the ancestral species of the Rupelian *P. maximus* complex.

Doubtful *Praehyalocylis* occurrences in the Tethys area, geographically intermediate between the Uzbekistan and Atlantic localities are '*Tentaculites*' *cretaceus* Blanckenhorn, 1889 and *Hyalocylis euphratensis* Avnimelech, 1945. Both were described from one and the same locality in southern Turkey ('West of Nizip', see map in Avnimelech, 1945, p. 637). The age of the sediment, in which these species were found, was originally considered to be Late Cretaceous (probably Senonian; Blanckenhorn, 1889). Avnimelech (1936) suggested that the age probably was Eocene, but later the same author (1945, p. 637) stated that a Miocene age seems to be the most probable. Bernasconi & Robba (1982, p. 213), however, apparently had reason still to consider these forms as Eocene. I have no direct evidence, but the fact that the same locality yielded also the pteropod *Clio multicostata* (Bellardi, 1873) contradicts the Eocene, and makes a Miocene age much more likely. Also I think it very acceptable, judging from the literature, that *H. euphratensis* indeed is the apical part of '*Tentaculites*' *cretaceus*. This was also Blanckenhorn's opinion, but it was denied by Avnimelech, who gave no other basis for his view than 'there are several reasons against this opinion' (Avnimelech, 1945, p. 643). Finally, the Turkish species fits much better in the genus *Hyalocylis*, because of its curved shell. *H. cretacea* seems to be closely related to, if not identical with, *Hyalocylis haitensis* (Collins, 1934), described from the Miocene of the Caribbean, which because of its curved and dorso-ventrally compressed shell is a typical representative of the genus *Hyalocylis*.

Further genuine *Praehyalocylis* occurrences are known from the European Oligocene: *P. maximus* (Ludwig, 1864) and related taxa, known from the Paratethys (Czechoslovakia; Oppenheim, 1922, p. 82) and from the Atlantic region: Mainz, North Sea and Paris basins (up to now partly unpublished). Some members of the *P. maximus*-complex resemble *P. annulata* closely and it will be very difficult to find discriminating characteristics, other than the difference in age! This will mainly depend on the availability of well-preserved material.

In a very recent paper, received just in time to be discussed here, Squires (1989, p. 444) described equally Late Eocene specimens from the Keasey Formation in NW Oregon, and the Quimper Sandstone, NW Washington, U.S.A. He identified this material as *Praehyalocylis cretacea* (Blanckenhorn, 1889) and included in this taxon Early Oligocene to Early Miocene specimens from the U.S.A. (Blakeley and Pysht Formations, NW Washington; Astoria Formation, SW Washington). In his figs. 1-5 Squires illustrated only specimens from the Keasey Formation. These resemble closely the Australian material of *P. annulata*, but have a very slender basal shell part. As this part of the shell is still unknown in *P. annulata* this can be no reason to consider the new worl specimens to differ specificly. The younger specimens mentioned by Squires cannot be interpreted without seeing the actual material. As discussed above, the name *Tentaculites cretaceus* Blanckenhorn, 1889 cannot be applied for this material.

It is interesting to see that the oldest *Praehyalocylis* occurrences are widely distributed in the Pacific area. Bernasconi & Robba, 1982, p. 213, text-fig. 2) suggested that *Praehyalocylis* originated in the Tethys area. The now known Late Eocene distribution: South Australia, New Zealand, NE Pacific and southern U.S.S.R., completed by an only very slightly younger representative in the North Sea Basin, rather suggest an origin somewhere in the Pacific and subsequent migration through the Tethys.

Styliola annulata Tate, 1887 is not preoccupied by *Creseis annulata* Rang in Deshayes, 1853, which is a junior synonym of *Hyalocylis striata* (Rang, 1828) (see van der Spoel, 1967, p. 65).

Genus *Styliola* Gray, 1850
Type species — *Styliola recta* Lesueur ms [= *S. subula* (Quoy & Gaimard, 1827)].

Styliola subula (Quoy & Gaimard, 1827)
Pl. 5, figs. 13-19; Pl. 6, figs. 1-9.

*	1827	*Cleodora subula*, Quoy & Gaimard, p. 233, pl. 8, figs. D1-D3.
.	1828	*Creseis spinifera* N., Rang, p. 313, pl. 17, fig. 1.
.	1873a	*Styliola sulcifera*. Gabb, n.s., Gabb, p. 200.
	1875	*Clio subulata* Quoy et Gaimard - Seguenza, p. 148.
	1876	*Cleodora subulata*, Quoy e Gaym. - Seguenza, p. 41.
	1878	*Creseis subulata (Cleodora)*, Quoy et Gaimard - Tiberi, p. 74.
	1880	*Creseis subulata (Cleodora)*, Quoy et Gaimard - Tiberi, p. 36.
	1880	*Creseis subulata* Quoy et Gaim. - Seguenza, p. 276.
	1881	*Styliola sulcifera* - Gabb, p. 337.
	1882	*Styliola sulcifera* - Guppy, p. 175.
v.	1887	*Styliola Rangiana*, spec. nov., Tate, p. 194, pl. 20, fig. 2.
	1893	*Styliola sulcifera* Gabb - Dall, p. 430.
v.	1897	*Clio (Styliola) rangiana*, Tate (sp.) - Harris, p. 20, pl. 1, fig. 6a-b.
.	1903	*Styliola rangiana*, Tate - Dennant & Kitson, p. 94.
	1905	*Styliola subulata*, Quoy et Gaimard sp. (*Cleodora*) - Bellini, p. 44.
.	1912	*Clio (Styliola) subula* (Quoy et Gaimard) - Yamakawa & Ishikawa, p. 4, pl. 1, fig. 4a-b.
.	1921	*Clio (Styliola) Lamberti* Checchia-Rispoli, Checchia- Rispoli, p. 10, figs. 3, 3a.

. 1924 *Clio rangiana* Tate (*Styliola*) - Finlay, p. 336.
. 1924 *Clio rangiana* (Tate) - Marwick, p. 323, pl. 6, fig. 4 (copy of Tate's 1887 figure).
. 1934 *Styliola sulcifera* Gabb - Collins, p. 202, pl. 9, figs. 9-12.
? 1945 *Styliola* aff. *S. subula* (Quoy and Gaimard) - Avnimelech, p. 640, fig. 2.
. 1959 *Styliola subula* (Quoy & Gaimard) - Zilch, p. 50, fig. 166.
. 1968 *Styliola lamberti* Checchia-Rispoli - Sirna, p. 420, fig. 6.
. 1971 *Styliola sulcifera* Gabb - Jung, p. 216, pl. 19, figs. 14, 15.
. 1971 *Styliola subula* (Quoy and Gaimard) - Jung, p. 217 (sub *S. sulcifera*).
1974 *Styliola* cfr. *subula* Q. e G. - di Geronimo, p. 183.
1977 *Styliola* cf. *subula* (Quoy & Gaimard, 1827) - Robba, p. 587.
. 1978 *Styliola* cf. *subula* (Quoy & Gaimard, 1827) - Robba & Spano, p. 762, pl. 76, figs. 2, 3.
. 1979 *Styliola subula* (Quoy and Gaimard) - Shibata, p. 111 ff., pl. 20, figs. 31-40.
. 1979 *Styliola lamberti* Checchia Rispoli, 1921 - d'Alessandro et al., p. 84, pl. 16, figs. 43-45.
1979a *Styliola lamberti* - Krach, p. 659, 660.
1979b *Styliola lamberti* Chec.-Rispoli - Krach, p. 1391.
1979c *Styliola lamberti* (Chec.-Rispoli) - Krach, p. 1392.
1980 *Styliola subula* (Quoy & Gaimard) - Shibata, p. 62.
. 1980 *Styliola subula lamberti* (Checchia Rispoli, 1921) - d'Alessandro & Robba, p. 617, pl. 61, figs. 1-5.
1981 *Styliola subula* (Quoy and Gaimard) - Shibata & Ishigaki, p. 57ff.
. 1981 *Styliola lamberti* Checchia-Rispoli, 1921 - Krach, p. 122, pl. 1, fig. 10.
. 1982 *Styliola sulcifera* Gabb - Bernasconi & Robba, p. 214.
. 1982 *Styliola rangiana* Tate - Bernasconi & Robba, p. 215.
. 1982 *Styliola subula* (Quoy & Gaimard) - Bernasconi & Robba, p. 216.
. 1982 *Styliola subula lamberti* (Checcia Rispoli) - Bernasconi & Robba, p. 217.
. 1982 *Styliola subula sulcifera* Gabb - Bernasconi & Robba, p. 217, 218.
1982 *Styliola* aff. *subula* (Quoy & Gaimard) - Bernasconi & Robba, p. 217-219.
. 1982 *Styliola subula* (Quoy & Gaimard, 1827) - Grecchi, p. 719, pl. 52, fig. 3.
Non: 1921 *Clio (Styliola) rangiana* (Tate) - Suter, p. 71 (= *Praehyalocylis annulata*) (Dr P.A. Maxwell, pers. comm.).

(For further references, mainly concerning Quaternary and Recent occurrences, the reader is referred to the relevant literature.)

Description — Shell small, elongated conical, straight, slightly curved or somewhat irregular. The protoconch is pointed. At a short distance from the apex a distinct swelling of the larval shell is present, not abruptly separated from the postembryonic shell parts. The posterior and anterior transitions of the swollen part are about equally gradual. At a shell diameter of c. 0.5 mm a longitudinal groove develops, running obliquely (from posterior left to anterior right) towards the aperture. Posteriorly of this groove the shell transverse section is circular, more anteriorly the presence of the groove makes it more or less cordiform to distinctly elliptical. The aperture is broken in all available specimens, but from the growth-lines it can be decided that the shell-wall is produced at the place where the groove reaches the apertural margin. The shell-wall is very thin, making the groove internally just as apparent as externally.

Type material — The syntypes were not found in the collection of the malacological department, Musée national d'Histoire naturelle, in Paris (van der Spoel, 1976a, p. 189). Their present whereabouts is unknown. The type locality is 'Côte de Ténériffe' (Quoy & Gaimard, 1827, p. 233) (Recent).

Material studied (exclusively Australian Cainozoic samples are mentioned here) — Muddy Creek, Hamilton, Australia (Miocene, Balcombian to Bairnsdalian): 12 more or less defective specimens (5 measured), NMV P116250; 19 specimens (3 measured), RGM 229 473; 1 specimen (Pl. 6, fig. 7), 6 specimens (6 measured), from interior of *Harpa pulligera* Tate, RGM 229 488-489; 2 specimens, from interior of *Ancillaria pseudaustralis* Tate, RGM 229 500; 2 specimens (Pl. 6, figs. 5-6), BM(NH) G. 9306 (one of these figured in Harris, 1897. According to this author the sample originally comprised 3 specimens) .

Do., without any indication of the level: 4 specimens (lectotype and paralectotypes of *S. rangiana* Tate; Pl. 5, figs. 13-17), SAMBBM T 238/1-4; 1 specimen (paralectotype of *S. rangiana* Tate, found together with holotype of *'Styliola' bicarinata* Tate), SAM P29781; 2 specimens (Pl. 6, figs. 8-9), leg. Bailey, AMS C143.929.

Do., (locality specified as Muddy Creek, SW below Clifton Homestead, in MacDonald's Bank) (Pliocene, Kalimnan, Grange Burn 'Coquina', but probably reworked from the underlying Muddy Creek Formation): 1 specimen, leg. W.F. Ponder and E.K. Yoo, 4.3.1977, AMS C149.280.

Batesford, Australia (Miocene, Batesfordian to Bairnsdalian): 1 specimen (Pl. 6, fig. 4), 52 specimens, RGM 229 447-448.

Red Bluff, Shelford, Australia (Miocene, Balcombian): 4 specimens, RGM 229 466.

Altona Bay, Australia (Miocene, ?Balcombian): 8 juvenile specimens, RGM 229 438.

Schnapper Point, Mornington, Australia (level not indicated): 2 specimens (paralectotypes of *S. rangiana* Tate; Pl. 5, figs. 18-19), SAM T 238/5- 6.

Balcombe Bay, Mornington, Australia (Miocene, Balcombian): 115 specimens, RGM 229 455; 1 specimen (Pl. 6, fig. 3), 3 specimens, BM(NH) G. 74.541.

Fossil Beach, Mornington, Australia (Miocene, Balcombian): 151 more or less defective specimens, NMV P116252 (in the same sample there are also a turritellid gastropod and two scaphopods); 1 specimen (Pl. 6, fig. 1), 101 more or less defective specimens, RGM 229 459-460; 1 defective specimen (with additional locality data), AMS C149.276; 438 predominantly juvenile specimens, from interior of *Eutrephoceras* sp., RGM 229 463; (sample indicated Mornington, Port Phillip Bay) 8 more or less defective specimens, AMS C149.277; (sample indicated 'Mornington') 1 specimen (Pl. 6, fig. 2), BM(NH) coll., not registered.

Discussion — The species *Styliola rangiana* Tate, 1887 was based on specimens from 'Muddy Creek and Schnapper Point, Victoria'. Remnants of seven specimens are still available in the Tate collection. Six of these are glued on a tablet of dark blue cardboard, stored in a glass-cover container. This container again is glued on a wooden console, carrying a label. This label states:

Name: Styliola Rangiana Tate pl. XX fig. 2 Hab.: Eocene. Muddy Creek. 1: Schnapper Pt. T.238

Above the label a figure '1.' is written in ink, referring to the rightmost specimen in the container, which is a piece of brownish-grey clay, in which two very defective specimens are visible. The larger one of these (L 7.9 mm) is hardly more than a fragmentary external mould in the clay, in which only the apertural part of the internal mould is present, visible from its dorsal side (see Pl. 5, fig. 18). Between the internal and external moulds some shell material is still present. The second specimen in the same piece of sediment is somewhat hidden and only visible in a left lateral view (Pl. 5, fig. 19). It also is a damaged external mould (L 3.7 mm), in which the greater part of the internal mould is preserved (apical and apertural parts missing). This specimen too shows its dorsal side. The state of preservation and the figure '1' on the label indicate that these two specimens represent the syntypes from Schnapper Point.

The four remaining specimens in the container are divided into a middle group of three specimens and a single shell on the left side of the cardboard, glued separately on a circular piece of board in the same dark blue colour. Above the label this latter shell is indicated (in ink) as 'type'. Later the prefix 'Holo' was added in pencil. This shell (L 2.6 mm), probably what is left of the illustrated specimen, is badly crushed and almost entirely covered with a drop of joiner's glue (compare Pl. 5, fig. 14). Only the apical part (c. 1.2 mm) is undamaged. Among the middle three specimens (Pl. 5, figs. 13, 15-16) one is crushed (L c. 4.6 mm) and two have their apertural parts damaged (L of the remaining parts resp. 3.0 and 3.3 mm). The apical parts of these three shells are preserved. These four specimens are syntypes from Muddy Creek. It is not possible to remove the shells from the cardboard, without complete destruction of the specimens. A further specimen (Pl. 5, fig. 17) of this species was encountered in the glass vial containing the only specimen of *Styliola bicarinata* Tate, 1887 (also originating from Muddy Creek and in a similar state of preservation). This specimen, probably mislaid, is also considered to be a syntype of *S. rangiana*.

In his paper Tate didn't designate a holotype and the indication '(Holo) type' on the label is not a valid type-designation (ICZN art. 73-a- iii). Therefore the rightmost specimen from Muddy Creek on the cardboard is designated here as the lectotype (see Pl. 5, fig. 13). The other four specimens from Muddy Creek and two specimens from Schnapper Point are paralectotypes.

The measurements of the type series of *Styliola rangiana* are given in Table 4.

Table 4. Measurements (in mm) of the *Styliola rangiana* syntype series.

Locality	L	W	AA	AD	Plate 5
Muddy Creek	3.32	0.99	15°	11°	fig. 13 (lectotype)
	2.57	0.66	13°	-	fig. 14
	4.57	1.0+?	16°	-	fig. 15
	2.98	0.75	14°	-	fig. 16
	2.92	0.68	13°	12°	fig. 17
Schnapper Point	7.88	1.41	-	11°	fig. 18
	3.74	0.99	17°	10°	fig. 19
mean value			14.7°	11°	

L = length, W = width, AA = apical angle, AD = angle of deviation of longitudinal sulcus.

Tate distinguished his *Styliola rangiana* from the Recent '*Cleodora subulata*, Quoy and Gaimard' [= *Styliola subula* (Quoy & Gaimard, 1827)] by its elliptical aperture, the proportionally greater width and the abruptly tapering apex. These characteristics again seem to be taken from his illustration rather than from the actual specimens. The drawing, however, is incorrect in several respects. First of all the apical part of the shell is represented as much too broadly conical; in the specimens this shell-part is distinctly more elongate and slender. The double constriction of the protoconch is not indicated in the drawing. Furthermore the position of the longitudinal sulcus is entirely erroneous: it should run from lower left to upper right, instead of the other way around. It is possible, however, that the furrow indicated in the drawing, does not at all represent the longitudinal sulcus. The transverse section of the shell, as given in Tate's fig. 2, suggests the presence of a furrow on either side of the shell. This does not agree with the specimens, and one of these furrows probably represents a crack in the shell-material, indicating that the illustrated specimen was crushed. This indeed also accounts for the high value of the width/length-ratio of the drawing, as well as for the 'elliptical aperture'. A final error in the illustration is the indicated curvature of the shell, which is not supported by the existing syntype material.

From these observations it is obvious that neither the apical shell-part nor the transverse section demonstrate significant differences from Recent *Styliola subula.* Still, the measurements given above show that the apical angle of the *S. rangiana* specimens ranges from 13 to 17°, with a mean value of 14.7°. If these figures are compared with data supplied by d'Alessandro & Robba (1980, p. 620, fig. 6) for Recent Mediterranean specimens it seems that the Australian form is considerably less slender. Possibilities for discrimination might also be found in the angle of deviation of the longitudinal sulcus, as defined by d'Alessandro & Robba (loc. cit.). I studied these possibilities for the following *Styliola* populations (Fig. 2):

1.*Styliola subula* (Quoy & Gaimard, 1827). Recent, off Salayer, Flores Sea, Indonesia (Snellius II expedition, sta. 4.155, 6° 22' S, 120° 26' E, depth 233-274 m, bottom sample, 28.9.1984, coll. RGM) (n = 30).
2. *Styliola subula* (Quoy & Gaimard, 1827). Recent, Mediterranean (data from d'Alessandro & Robba, 1980) (n = 21).
3.*Styliola subula* (Quoy & Gaimard, 1827). Recent, Nicholas Channel, off N. Cuba, Caribbean [Atlantis expedition, sta. 2.987, 23° 22' N, 79° 53' W, depth 280-300 fathoms, bottom sample, 13.3.1938 (compare Chase, 1940), coll. RGM] (n = 25).
4.*Styliola sulcifera* Gabb, 1873. Late Pliocene, Bowden Beds, Bowden, Jamaica (coll. RGM, leg. Dr J.P. Krijnen) (n = 19). Note: The age of the Bowden Beds is usually given as Miocene (viz. 'Middle Miocene': Collins, 1934; 'Upper Miocene': Bernasconi & Robba, 1982), but inspection of a sediment sample from the RGM collections for its nannoplankton contents by Dr E. Martini (Frankfurt am Main, F.R.G.) demonstrated a Late Pliocene age (pers. comm., 1988, Dr R. Janssen, Senckenberg Museum, Frankfurt am Main, F.R.G.).
5.*Styliola lamberti* (Checchia-Rispoli, 1921). Miocene, Gargano Peninsula, Italy (data from d'Alessandro & Robba, 1980) (n = 23).
6.*Styliola rangiana* Tate, 1887. Miocene, Muddy Creek, Victoria, Australia (syntype series) and 14 topotypes from other Muddy Creek samples (n = 20 for AA and 18 for AD).

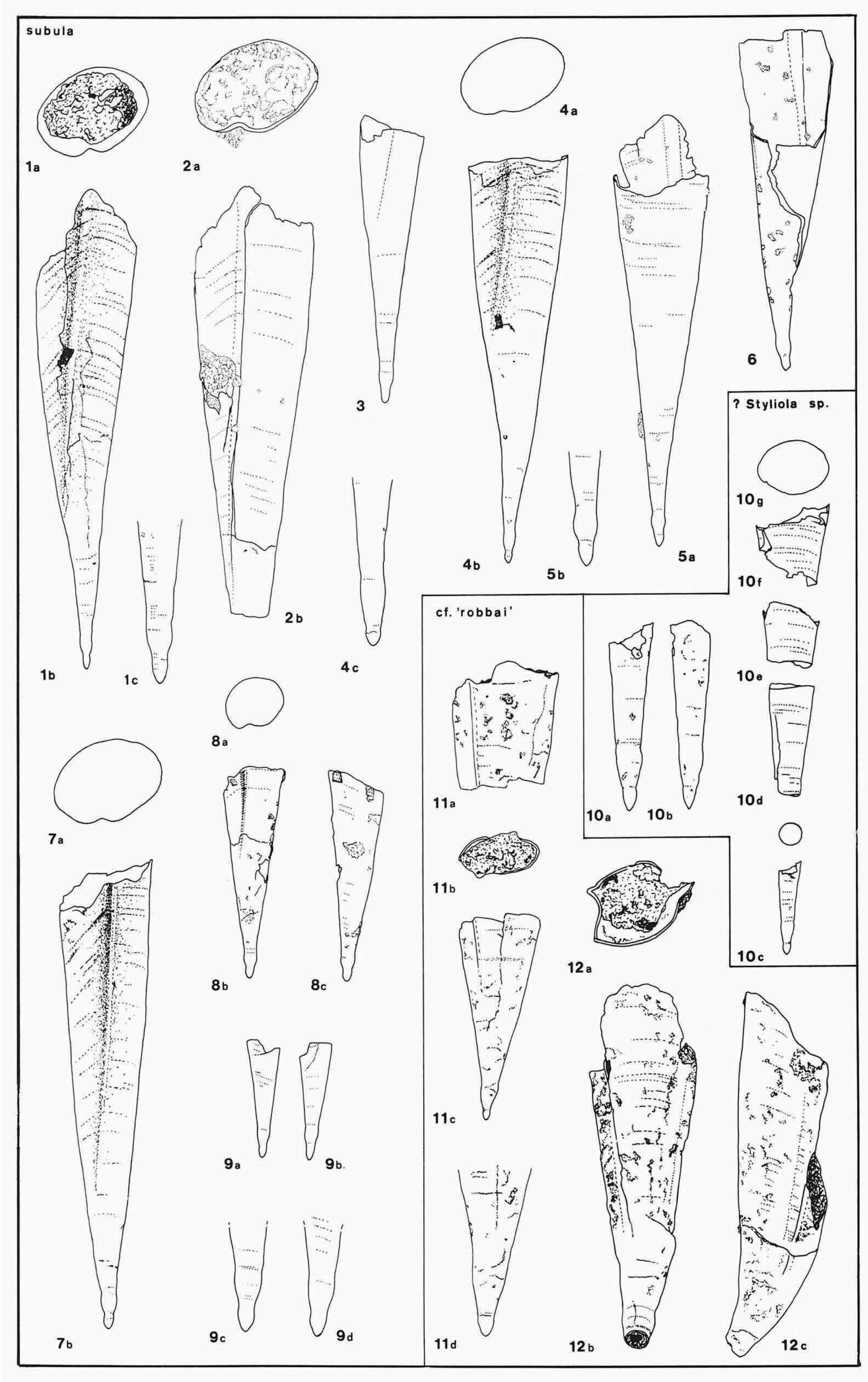
Plate 6

Figs. 1-9. *Styliola subula* (Quoy & Gaimard, 1827)
1a-c: Fossil Beach, Mornington, Balcombe Bay; Miocene, Balcombian, Fyansford Formation. Adult specimen with only slightly damaged aperture, RGM 229 459, a-b: × 12.5, c: × 24.
2a-b: Mornington, Port Phillip Bay; Miocene, Balcombian. Adult defective specimen, BM(NH), not registered, × 12.5.
3: Balcombe Bay; Miocene, Balcombian, Fyansford Formation. Juvenile specimen, BM(NH) G 74541, × 12.5.
4a-c: Batesford, new quarry; Miocene, Batesfordian to Bairnsdalian, Fyansford Formation, grey clays. Adult specimen, aperture damaged, RGM 229 447, a-b: x 12.5, c: × 24.
5-7: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation. More or less defective specimens, BM(NH) G 9306, 5a, 6: × 12.5, 5b: × 22; 7a-b: adult specimen with damaged aperture, from interior of *Harpa pulligera* Tate, RGM 229 488, × 12.5.
8-9: Locality data as for figs. 5-7, but level not indicated (?Miocene). Juvenile specimens, AMS C143.929, 8a-c, 9a-b: × 12.5, 9c-d: × 25.

Fig. 10. ?*Styliola* sp.
Spring Creek near Torquay; ?Late Oligocene to Early Miocene, Janjukian-Longfordian, Jan Juc Formation or overlying Puebla Formation. One specimen in four fragments, RGM 229 417, a-b: × 25, c-g: × 12.5.

Figs. 11-12. ?*Clio* sp.
Aldinga Bay, Willunga Embayment, St Vincent Basin; Late Eocene, Aldingan, Blanche Point Formation, Gull Rock Member, Clay with '*Turritella*' *aldingae* Tate.
11a-d: Distorted specimen in two fragments, RGM 229 412, a-c: × 12.5, d: × 25.
12a-c: Distorted specimen, RGM 229 411, × 12.5.

Plate 6


subula
1a
2a
4a
1b
1c
2b
3
4b
4c
5a
5b
6
? Styliola sp.
10g
10f
10e
10d
10c
cf. 'robbai'
11a
10a
10b
11b
12a
7a
7b
8a
8b
8c
9a
9b
9c
9d
11c
11d
12b
12c

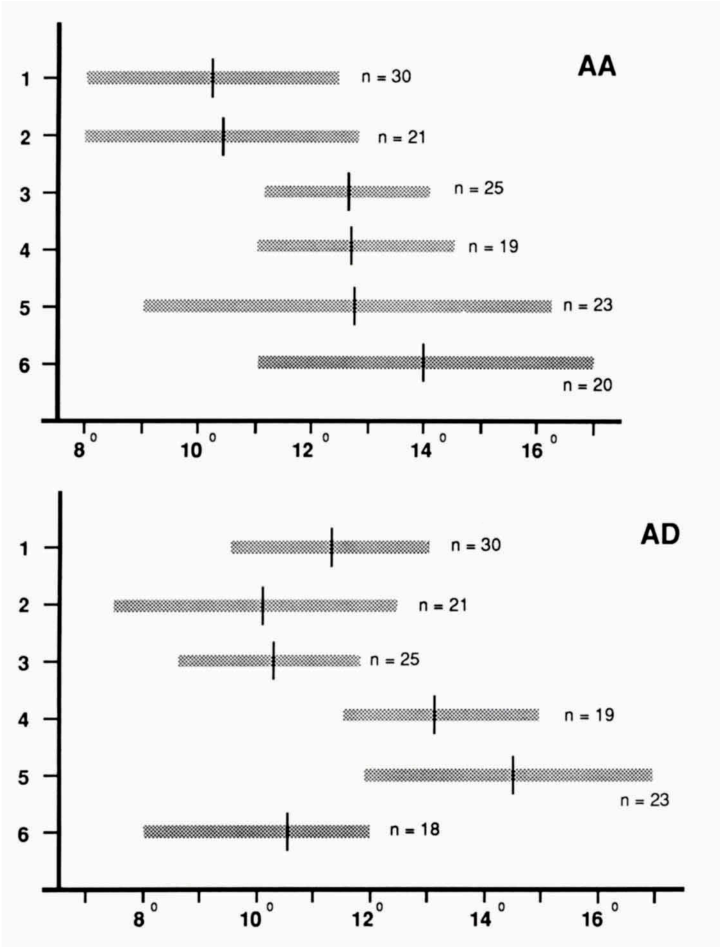


Fig. 2. Measurements of *Styliola*-populations.
1. *Styliola subula* (Quoy & Gaimard, 1827), Recent, Flores Sea, Indonesia.
2. *Styliola subula* (Quoy & Gaimard, 1827), Recent, Mediterranean (data from d'Alessandro & Robba, 1980).
3. *Styliola subula* (Quoy & Gaimard, 1827), Recent, off N. Cuba, Caribbean.
4. *Styliola sulcifera* (Gabb, 1873), Late Pliocene, Bowden, Jamaica.
5. *Styliola lamberti* (Checchia-Rispoli, 1921), Miocene, Gargano Peninsula, Italy (data from d'Alessandro & Robba, 1980).
6. *Styliola rangiana* Tate, 1887, Miocene, Muddy Creek, Victoria, Australia (including the syntype series).
AA = apical angle, AD = angle of deviation of longitudinal sulcus.

During the measuring procedure it was painfully noticed that the values obtained are strongly influenced by the orientation of the shell, especially if a specimen is not regularly conical or has a more or less elliptical transverse section. A slight rotation of the specimen frequently changes the measured angles with more than one to several degrees. Thus, it seems hardly useful to give these values in minutes and seconds, as has been done by d'Alessandro & Robba (1980, p. 618). To make my results comparable as much as possible the shells were measured in such a position that in a straight vertical view through the binoculars the initial point of the longitudinal groove just touches the left side line of the specimen.

For the above populations the ranges and mean values of AA (apical angle) and AD (angle of deviation of longitudinal sulcus) are given in Fig. 2. From this diagram it is obvious that the Muddy Creek material, including the *S. rangiana* syntypes, has the highest mean value for the apical angle of all populations measured. The range of this sample, however, almost completely falls within the range of the Italian *S. 'lamberti'* and the mean value of *S. 'lamberti'* coincides with Recent Caribbean *S. subula* and Pliocene *S. 'sulcifera'*. So it is impossible to apply the apical angle for a subdivision of *Styliola*. Still, the diagram could indicate a general decrease of the AA parameter in the course of time. However, the value for sample 3, compared with those of samples 1 and 2, indicates that the degree of variability among the various Recent populations is quite high and therefore I reject the introduction of species or subspecies based on the characteristic of a certain value for AA without a further biometric investigation of an abundant material.

The AD diagram demonstrates a similar pattern of values decreasing in the course of time, with the exception of the admittedly rather few *S. 'rangiana'* specimens, showing values resembling those of the Recent populations. The *S. 'sulcifera'* and *S. 'lamberti'* values are distinctly higher. So, apparently this value too does not change according to a time-dependant evolutionary mechanism, but possibly as a result of environmental circumstances. These observations lead to the conclusion that the various names have, at best, value for the denomination of formae, not for taxa of the species-group. All populations belong to one and the same species, which should be named *Styliola subula* (Quoy & Gaimard, 1827).

The name *S. subula* is applied here to this species following the current use in zoological literature, in recognition, however, of the fact that an interpretation of the original description and illustration of this taxon is extremely hazardous and confusing (see also Vayssière, 1915, p. 94). This is already demonstrated by the paper of Rang (1828), just one year later than Quoy and Gaimard's paper, in which the new taxon *Creseis spinifera* is treated separately from *C. subula*, the former being easily recognizable as what nowadays is considered to be 'typical' *S. subula*! In the apparent absence of *Cleodora subula* syntypes it is strongly advised to exclude further confusion and to stabilize nomenclature in this case by the designation of a neotype.

?*Styliola* sp.
Pl. 6, fig. 10.

Description — Four fragments are available, that may have belonged to one and the same specimen. The shell is apparently almost straight, slender conical, with an apical angle of c. 11°. In the apical fragment the larval shell is completely preserved. It has a double constriction, just as in *S. subula*, also without a sharp boundary to the postembryonic shell. The apex of the protoconch is pointed. The transverse section of the shell is circular near to the apical part, but slightly compressed dorso-ventrally towards the aperture. The growth-lines are rather indistinct and show locally some curvature in apertural direction. This is only visible in the two fragments with the largest diameter and may indicate the dorsal side of the shell. There is no further surface sculpture.

Material studied — Spring Creek, Torquay, Australia (?Oligocene, ?Janjukian): 4 fragments, probably belonging to one and the same specimen (Pl. 6, fig. 10), RGM 229 417.

Discussion — The present material, of course, is insufficient to allow a sound identification. The embryonic shell resembles the Miocene specimens of *Styliola subula* (Quoy

& Gaimard, 1827) closely, but an oblique longitudinal groove, as present in *Styliola*, is not found in the specimen from Spring Creek, although the largest fragment has a diameter of c. 1 mm, where such a groove should already have been developed. Still, the growth- lines show a similar curvature in apertural direction, indicating that we might be dealing here with a species ancestral to *S. subula*, in which a longitudinal groove is absent or only developed beyond a shell diameter of 1 mm. In the absence of more and better preserved specimens little else can be done than referring to this specimen in open nomenclature.

Subfamilia CLIOINAE
Genus *Clio* Linné, 1767

?*Clio* sp.
Pl. 6, figs. 11-12.

? 1982 *Bovicornu robbai* Buanoiuto – Bernasconi & Robba, p. 213 (nomen nudum).

Description – Only two distorted specimens are available, one of which is broken in two fragments. The shell is conical. The larger specimen has a distinct curvature in its apical part. Analogous to the Recent species *Clio polita* (Pelseneer, 1888) (see van der Spoel, 1967, p. 75, fig. 68a-b) this is supposed to be a dorsal curvature. The other specimen, however, is straight. Initially the transverse section of the shell is circular, but later, at a diameter of some 0.75 mm, two sharp lateral carinae develop. Both shells are obliquely compressed, but in adapical views it can be seen that the carinae are not situated at mid-shell, but that they are somewhat shifted to one side (i.e. the dorsal side in the curved specimen). The ratio between the dorso-ventral and the transverse diameters is difficult to estimate because of the distortion, but it seems to be close to 1.

The protoconch is preserved in the smaller specimen only. It is ovoid and has apparently a rounded tip. There is a vague boundary between this initial part and the younger shell parts, followed by a slight and gradual further swelling of the oldest part of the teleoconch.

The growth-lines are virtually invisible because of the worn condition of both shells, but on the dorsal side they seem to curve slightly in apertural direction.

Material studied – Aldinga Bay, Willunga Embayment, St. Vincent Basin, South Australia [Late Eocene, Aldingan, Gull Rock Member of the Blanche Point Formation (frequently also called 'Blanche Point Marls', in the literature), clay with *'Turritella' aldingae*]: 1 specimen and 1 defective specimen (Pl. 6, figs. 11-12), RGM 229 411-412.

Discussion – Buonaiuto [1979] described his *Bovicornu robbai* from the Late Eocene Blanche Point Formation of the Adelaide (= Kent Town) borehole. The only specimen available to him was preserved in the sediment content of a *Sinum (Ectosinum)* sp. It belongs to the collection of the South Australian Museum at Adelaide, but the specimen seems to be missing (see also the chapter 'Pteropods described by Buonaiuto' below). The name *Bovicornu robbai*, however, is just a manuscript name. It would have been easy to validate this name in the present paper by including Buonaiuto's description, in which case he would have been the author of the taxon. In the absence, however, of the specimen and with the uncertainty concerning the identity of my material I prefer to leave the situation as it is. Should the Adelaide specimen turn up, then the taxon has to be validated as yet.

Especially from new illustrations of *Bovicornu*, given by MacNeil & Dockery

(1984) it is obvious that the present material cannot be assigned to this genus. The structure of the '*robbai*' protoconch and the shape of the shell with the lateral carinae suggest strongly a close affinity to *Clio*, of which it would be the oldest known representative.

Subfamilia CUVIERININAE

Spoelia gen. nov.

Diagnosis – Shell uncoiled, bilaterally symmetrical, elongately triangular with a slight dorso-ventral flattening. The larval shell is creseiform. The adult shell is characterized by the presence of two lateral carinae with a squarish transverse section, that disappear just before the aperture. Shell surface with a very fine radial sculpture. Incremental lines straight to very slightly bent in apertural direction on one side of the shell (interpreted as the ventral side) and more strongly curved in the same direction on the other, presumably dorsal side. Aperture of completely adult specimens regularly elliptical in adapical view.

Type species – *Spoelia torquayensis* sp. nov.

Distribution – The type and only known species *S. torquayensis* is known from the Late Oligocene of southern Australia and the Aquitaine Basin in southwestern France.

Derivatio nominis – This genus is named in honour of the Dutch zoologist Professor Siebrecht van der Spoel (Instituut voor Taxonomische Zoölogie, Amsterdam University), whose long list of publications testifies to his substantial contribution to the knowledge of mainly Recent planktonic gastropods. He has always been prepared to discuss fossil pteropod taxonomics with me, for which I am really grateful. The name *Spoelia* should be pronounced ['Spuli:a], according to the Dutch pronunciation of the name 'van der Spoel'.

Discussion – The new genus is provisionally classified in the Cuvierininae. Admittedly, the form of the larval shell agrees roughly with several Creseinae (especially *Styliola*), but a radial sculpture, a distinct dorso-ventral flattening and lateral carinae are not known from representatives of that subfamily.

The general appearance of *Spoelia* resembles the genus *Clio* closely, but in this group the globular larval shell is distinctly separated from the post-larval shell by just one constriction and a sharp boundary; a radial micro-sculpture is unknown in this group.

The *Spoelia* protoconch demonstrates a remarkable resemblance to that of *Cuvierina*, as could be established by a study of juvenile *Cuvierina* specimens from the Early Pliocene of SE France (locality Le Puget-sur- Argens, H.-J. von Hacht leg., RGM collection). In the Cuvierininae furthermore a very similar radial sculpture is found, for example in the Recent species *C. columnella* (Rang, 1827). Representatives of the Cuvierininae are characterised, however, by a circular transverse section without carinae, and furthermore by the fact that the species shed their larval shell and close the opening with a septum, characteristics that do not occur in *Spoelia*.

Also to be classified in the Cuvierininae are a number of species, to which e.g. belong '*Vaginella*' *tenuistriata* Semper, 1861 (Late Oligocene of NW Europe) and '*Vaginella*' *torpedo* Marshall, 1918 (Miocene of New Zealand) and other, yet undescribed species from the Eocene of Patagonia [British Museum (Natural History) no. G.

12030] and the Miocene of the Aquitaine Basin in SW France (RGM). In this group the various species also do not shed their larval shells, but the general appearance, inclusive of the radial sculpture and the construction of the aperture distinctly resembles *Cuvierina*, thus forming a bridge to the new genus *Spoelia*.

Spoelia torquayensis sp. nov.
Pl. 7, figs. 1-5.

Holotype — Pl. 7, fig. 1, leg./don. D. Curry, NMV P123408.
Type locality — Torquay, Bird Rock, Otway Basin, Victoria, Australia.
Stratum typicum — The type sample was collected from the so-called '*Glycymeris* Beds', as described in Singleton (1941, p. 39), belonging to the Torquay Group, Jan Juc Formation (Oligocene, Janjukian; see Ludbrook, 1967, p. 14; 1973, p. 248).
Derivatio nominis — This species is named after its type locality.

Description — Not one complete adult specimen is available, so this is a composite description, based on several specimens.

Shell small, uncoiled, bilaterally symmetrical, elongately triangular, with a dorso-ventral flattening in apertural direction. The larval shell has a rounded apex. There are two slight constrictions, one at a diameter of c. 0.08 mm and one at c. 0.15 mm. There is no sharp boundary between the larval and post larval shells. The transverse section of the shell is circular in the apical shell part, but towards the aperture the dorso-ventral diameter is only c. three fourth of the transverse one.

At a shell diameter (ventral view) of c. half a mm two distinct lateral carinae develop. They have a squarish section, so each carina has two rather sharp edges. These carinae disappear rather abruptly just before the aperture (visible in one specimen only), at a shell diameter of c. 1.2 mm. From here on, the transverse section

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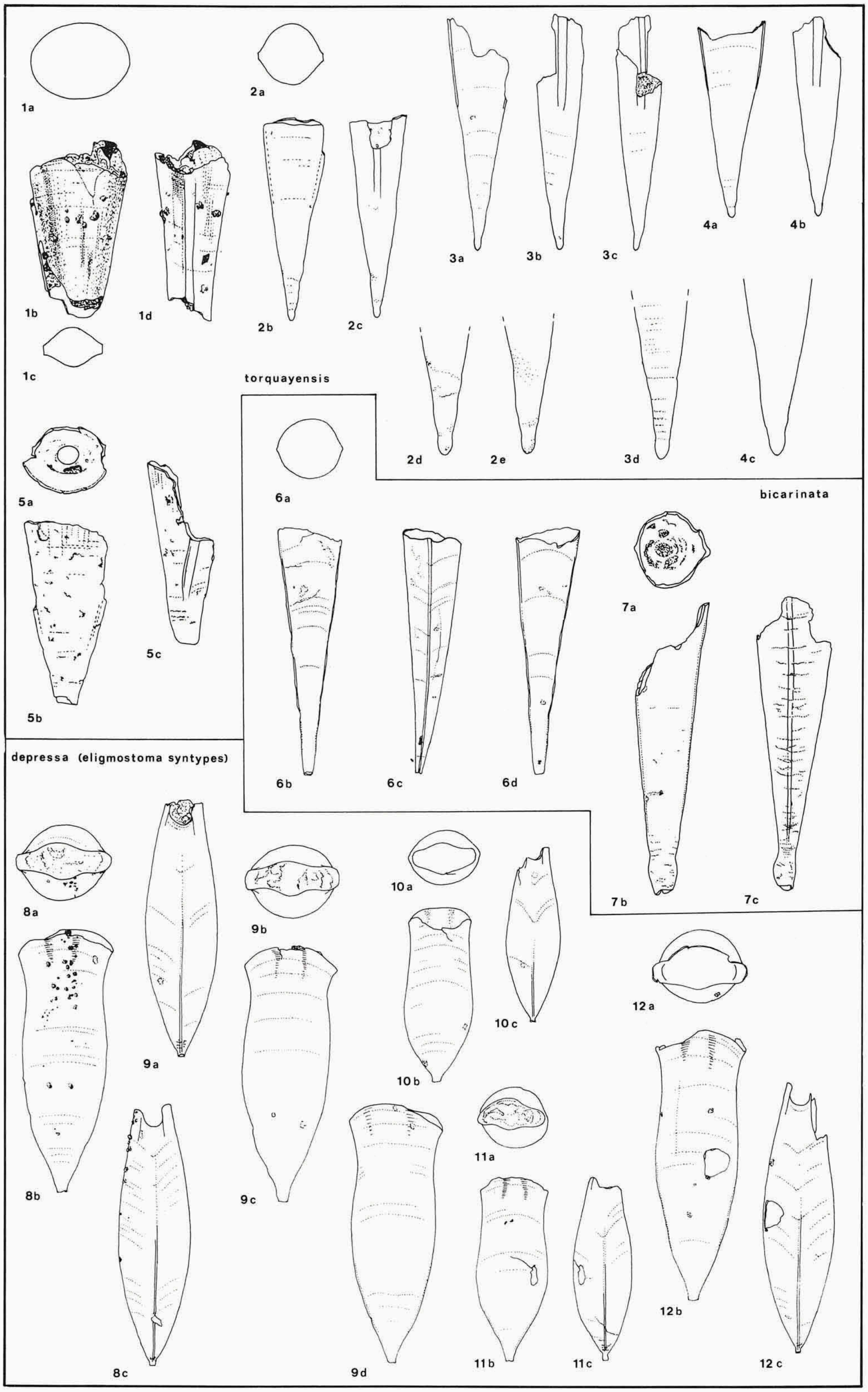
Plate 7

Figs. 1-5. *Spoelia torquayensis* sp. nov.
1-2: Torquay, Bird Rock, Otway Basin; Oligocene, Janjukian, Torquay Group, Jan Juc Formation, *Glycymeris* Beds.
1a-d: Adult specimen, apical part broken, holotype, NMV P123408, × 12.5.
2a-e: Juvenile specimen, paratype, RGM 229 428, a-c: × 12.5, d-e: × 25.
3-4: Peyrehorade, abandoned clay-pit near Peyrère (France, Landes department); Oligocene, Chattian, Marnes de St. Etienne-d'Orthe. Juvenile specimens, apertures damaged, resp. RGM 229 505-506, 3a-c, 4a-b: × 12.5, 3d, 4c: × 25.
5a-c: St. Paul-les-Dax, outcrop Estoti (France, Landes department); Oligocene, Chattian, Falun de St. Paul-les-Dax. Defective specimen, paratype, RGM 229 508, × 12.5.

Figs. 6-7. *Vaginella bicarinata* (Tate, 1887)
6a-d: Muddy Creek, Hamilton; ?Miocene (no level indicated). Juvenile specimen without protoconch, holotype, SAM T 237, × 6.
7a-c: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation. Very juvenile specimen, protoconch damaged, RGM 229 474, × 25.

Figs. 8-12. *Vaginella depressa* Daudin, 1800
Muddy Creek, Hamilton; Miocene Balcombian to Bairnsdalian, 'lower beds' (= Muddy Creek Formation).
8a-c: Adult specimen without protoconch, lectotype, SAM T 236, × 6.
9-12: Adult, more or less damaged specimens, paralectotypes, SAM T 236, × 6.

Plate 7


1a
1b
1c
1d
2a
2b
2c
2d
2e
3a
3b
3c
3d
4a
4b
4c
torquayensis
5a
5b
5c
6a
6b
6c
6d
bicarinata
7a
7b
7c
depressa (eligmostoma syntypes)
8a
8b
8c
9a
9b
9c
9d
10a
10b
10c
11a
11b
11c
12a
12b
12c

of the shell is regularly elliptical. The carinae are accentuated by the presence of a slightly concave part of the shell wall on either side.

An extremely fine but unmistakable radial sculpture is present from a shell diameter of c. 0.7 mm towards the aperture. The growth-lines are almost horizontal to very slightly bent in apertural direction on one side of the shell (interpreted as the ventral side), whereas they are curved somewhat stronger in the same direction on the other, presumably dorsal side.

Material studied – Holotype, NMV P123408, and 2 paratypes (one illustrated in Pl. 7, fig. 2), RGM 229 428-9, from the type locality.

Spring Creek, Torquay, Australia (?Oligocene, ?Janjukian): 1 juvenile specimen, RGM 229 418.

St. Etienne-d'Orthe (France, Landes department), outcrop in Ruisseau de l'Eglise, at coordinates x = 316.400 and y = 148.800 (map-sheet XIII-43, St. Vincent-de-Tyrosse; locality described in Janssen, 1985b, p. 120) (Oligocene, Chattian, 'Marnes de St. Etienne-d'Orthe'), 2 juvenile specimens, 1 defective adult specimen, leg. A.W. Janssen, RGM 229 503; 8 juvenile specimens, leg./don. P. Lozouet, RGM 229 504.

Peyrehorade (France, Landes department), abandoned marl-pit near Peyrère, from sediment wasted during former excavation activities (Oligocene, Chattian, 'Marnes de St. Etienne-d'Orthe'), 2 juvenile specimens (Pl. 7, figs. 3-4), 11 juvenile specimens, leg. A.W. Janssen, 1981, RGM 229 505- 507.

St. Paul-les-Dax (France, Landes department), outcrop near Estoti (Oligocene, Chattian, Falun de St. Paul-les-Dax): 1 juvenile specimen (Pl. 7, fig. 5), 13 juvenile specimens, leg./don. P. Lozouet, RGM 229 508-509.

Discussion – The squarish lateral carinae make this species resemble the Recent *Clio convexa* (Boas, 1886), which has, however, an entirely different shell-form and protoconch (compare Boas, 1886a, p. 73, 203, figs. 97a-d; van der Spoel, 1967, p. 70, figs. 55, 59). *C. convexa* has generally been considered a form of the well-known species *C. pyramidata* Linné, 1767, but I agree with Bé & Gilmer (1977, p. 773) that the differences in both larval shell and lateral carinae justify its separation as an independent taxon.

The Recent *Clio orthotheca* (Tesch, 1948) resembles the present species at first glance, but it has a more compressed shell with somewhat flexuous side edges, which are sharp, not squarish in transverse section, and there is no radial sculpture on the shell's surface. Finally *C. orthotheca* has an entirely different embryonic shell (Tesch, 1948, p. 21, pl. 2, fig. 4).

In the French material one defective specimen from St. Etienne-d'Orthe reaches almost the same state of maturity as the holotype and demonstrates very convincingly the radial sculpture. The larval shells and the carinae are completely identical with the Australian specimens, so there is no doubt whatsoever on their specific identity.

The French 'Marne de St. Etienne d'Orthe' is considered to be latest Chattian in age (Steurbaut, 1984), which agrees comfortably with the present-day age interpretation of the Jan Juc Formation (Abele, in Douglas & Ferguson, 1988, p. 307, fig. 8.13). Thus, *Spoelia torquayensis* represents a magnificent tool for correlation between Australia and Europe.

Subfamilia CAVOLINIINAE

Genus *Vaginella* Daudin, 1800

Type species – Vaginella depressa Daudin, 1800 (monotypy).

Discussion – A classification of the genus *Vaginella* within the subfamily Clioinae, a point of view maintained by several authors, is rather unsatisfactory. The shell characteristics of this group demonstrate many differences with the Clioinae, as for example the construction of the embryonic shell, which is not spherical and indistinctly separated from the post-embryonic shell, resembling more closely that of Creseinae and/or Cuvierininae. In the vaginellids the aperture is frequently narrowed and provided with a more or less distinct lip, which are unknown features in the Clioinae s.str., pointing towards a relationship with the Cavoliniinae. The same relation is strongly suggested by the fact that *Vaginella* individuals undergo a shell metamorphosis during the early ontogenetic stage (Janssen, 1985a), as is also the case, in a very similar fashion, in *Cavolinia* and in *Diacria*.

The genus *Vaginella* has frequently been interpreted too broadly. This name should be restricted to species possessing a straight, elongately triangular shell, with a more or less accentuated pre-apertural constriction. The embryonic shell has an inflated part, separated from the younger shell parts by a distinct constriction, but without a sharp boundary; its axis may or may not be deviating from the adult shell axis. Rarely (*Vaginella chipolana* Dall, 1893) the embryonic shell part is shed and the opening closed subsequently by a septum. The full-grown shell has a circular or broadly elliptical transverse section in its apical part and a dorso-ventral flattening towards the aperture, which therefore has an elliptical form, frequently influenced by the presence of vertically running apertural folds or an apertural lip. The apertural folds may be either present or absent, depending on the species. Quite typical for this genus is the presence of weak lateral carinae in the posterior half or one third of the shell. Fine radial sculpture or a coarse transverse undulation of the shell surface is rarely found. Up to now typical *Vaginella* species were exclusively known from Oligocene and Miocene deposits.

Such a restricted diagnosis would mean that species like *Vaginella torpedo* Marshall, 1918 (Miocene, New Zealand) and *V. tenuistriata* Semper, 1861 (Late Oligocene, NW Europe), which lack the lateral carinae and have a more or less triangular aperture (not unlike the *Cuvierina* species), do not belong in *Vaginella*. A new genus for these two taxa (and several others, see above in the remarks on the genus *Spoelia*), also differing in the characteristics of their embryonal shells, and to be classified in the subfamily Cuvierininae, will be introduced in the near future. Furthermore, '*Vaginella*' *varanica* Sirna, 1968 (Miocene, southern Italy) seems to differ at the generic level, as it has lateral sulci, instead of carinae.

The systematics of Australian vaginellids could not be unravelled in a satisfactory way. Material is mainly available from just one locality (Muddy Creek, Hamilton) and most samples lack sufficient data on the stratigraphical level. The few syntypes of *V. eligmostoma* Tate, described from Muddy Creek, cannot be distinguished from certain representatives of the European *Vaginella depressa*, which itself as yet is an insufficiently defined taxon.

Additional vaginellid material from Muddy Creek demonstrates significant differences from this *V. eligmostoma/depressa*-type, leading to the presumption that four different *Vaginella* species are represented at Muddy Creek. Two of these seem to be connected by a full range of transitional forms. They are treated together below sub nomine *V. depressa*. The third species deviates so strongly from the other two by its extreme elongate form and strongly developed apertural folds that it is introduced here as a new taxon, *Vaginella victoriae*. The fourth species is *V. bicarinata*, which in several respects differs distinctly from the other vaginellids.

A really satisfactory naming of the Muddy Creek *Vaginella depressa* complex will only be possible if a rich material, carefully collected at short intervals, will be available. Probably a redefinition of these taxa will need a biometrical analysis, which makes high demands upon the quality of the samples and their labelling.

Vaginella bicarinata Tate, 1887
Pl. 7, figs. 6-7.

* 1887 *Styliola bicarinata*, spec. nov., Tate, p. 195, pl. 20, fig. 9.
1903 *Styliola bicarinata*, Tate - Dennant & Kitson, p. 94.
1982 *Vaginella bicarinata* Tate - Bernasconi & Robba, p. 215, 216.

Description — Shell rather small, elongately conical with a very slight dorso-ventral curvature, uncoiled, bilaterally symmetrical. Larval shell only partly available in one specimen. Its extreme point is missing, but what remains forms a distinct swelling of the shell, separated from the younger shell parts by a constriction, but without a sharp boundary. In a lateral view the ventral side of the swollen larval shell is somewhat more convex than the dorsal side.

The post-larval shell has an apical angle of c. 11-13° (ventral view), with straight to very slightly concave sidelines. The apertural part of the shell is damaged in the two available specimens and therefore it is not known whether or not the adult shell has a dorso-ventral flattening in apertural direction, as present in many other *Vaginella* species. There is no indication of such a flattening in the largest specimen, in which the transverse dimension is still about nine-tenth of the dorso-ventral one.

Two distinct but not very accentuated carinae are present, one on either side of the shell. They start a short distance above the constriction separating the larval shell and continue towards the damaged aperture, also in the largest shell (the holotype), without any weakening in apertural direction. In the smaller shell distinct wrinkles are present over the whole length of the two lateral carinae, indicating that this specimen had already passed the shell metamorphosis and reached the adult stage.

Plate 8

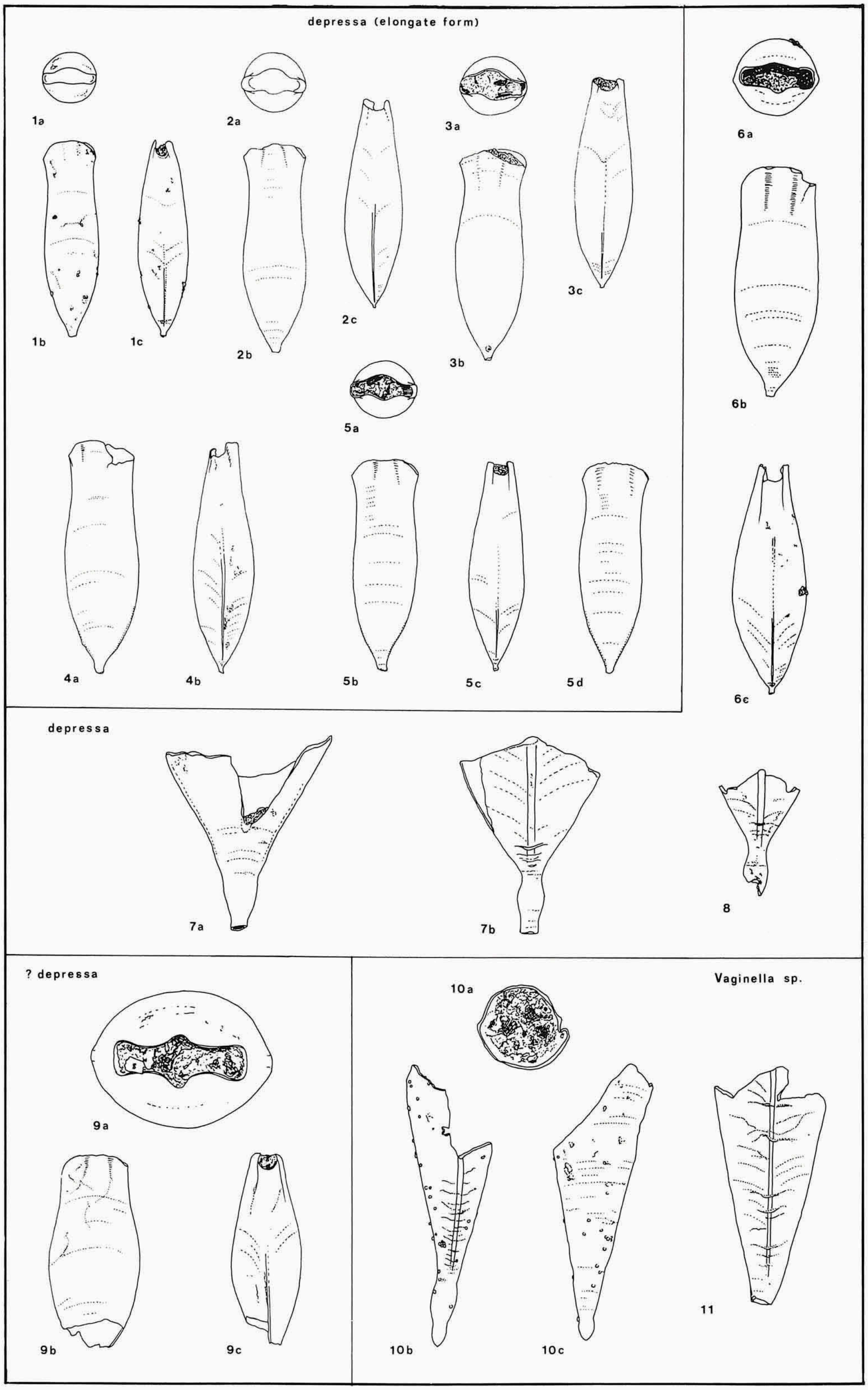
Figs. 1-5. *Vaginella depressa* Daudin, 1800 (elongate form)
Muddy Creek, Hamilton; ?Miocene (no level indicated).
1a-c: Adult specimen, protoconch broken, SAM T 235, × 6.
2-5: Adult specimens, protoconchs broken, leg. Mr Bailey, AMS C143.929, × 6.

Figs. 6-8. *Vaginella depressa* Daudin, 1800
6a-c: Balcombe Bay, Mornington; Miocene, Balcombian, Fyansford Formation, beds h-k. Adult specimen, protoconch broken, RGM 229 456, × 6.
7a-b: Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation. Apical fragment of adult specimen, protoconch partly preserved, RGM 229 475, × 25.
8: Altona Bay, SW of Newport, near Melbourne on Port Phillip Bay; Miocene, ?Balcombian, Fyansford Formation. Apical fragment of adult specimen, protoconch partly preserved, RGM 229 439, × 25.

Fig. 9. *Vaginella ? depressa* Daudin, 1800
Fossil Beach, Mornington, Balcombe Bay; Miocene, Balcombian, Fyansford Formation. Adult specimen, apical part broken, NMV P116251, a: × 12.5, b- c: × 6.

Figs. 10-11. *Vaginella* sp.
10: Locality data as for fig. 8. Apical fragment of adult specimen, protoconch preserved, RGM 229 440, × 25.
11: Batesford, new quarry; Miocene, Batesfordian to Bairnsdalian, Fyansford Formation, grey clays. Apical fragment of adult specimen, protoconch broken, RGM 229 449, × 25.

Plate 8


depressa (elongate form)
1a
2a
3a
6a
1b
1c
2b
2c
3b
3c
6b
5a
4a
4b
5b
5c
5d
6c
depressa
7a
7b
8
? depressa
9a
9b
9c
Vaginella sp.
10a
10b
10c
11

Growth-lines are only visible in the holotype. They are weakly curved in abapical direction and meet at an obtuse angle on the lateral carinae. The curvature of the growth-lines is about equally strong on the ventral and on the dorsal side.

Holotype — Tate's illustrated specimen, apparently the only one available to him and therefore the holotype, is still present in the collections of the South Australian Museum at Adelaide, registration number T 237. The shell was glued on a small piece of blue cardboard and kept in a glass vial. This vial is glued on a wooden console, carrying a label stating:

> Name: Styliola bicarinata Tate Pl. XX fig. 9
> Hab.: Eocene. Muddy
> Creek T 237

Later the indication 'holotype' was written in pencil above the label.

As the shell could not very well be studied it was removed from the blue cardboard by means of immersion in a bit of water, which dissolved the glue rapidly without damaging the shell. The specimen is represented here in Pl. 7, fig. 6.

Several differences are found with Tate's description and illustration. Though the shell is described as 'straight' the drawing suggests an obvious curvature. In reality the shell is slightly curved indeed, but much less so than indicated in Tate's drawing. In the transverse section accompanying Tate's fig. 9 the lateral carinae are exaggerated, also the description says the lateral margins to be 'strongly keeled'. So again we find indications that Tate's descriptions are based on the drawings rather than on his material! From the new drawings given here it is clear that the carinae are rather weak, although they continue from base to aperture on both sides of the shell. In the original illustration the carinae seem to be situated in the ventral half of the shell, which is contradicted by the accompanying transverse section. This latter section agrees with the holotype with respect to the position of the carinae.

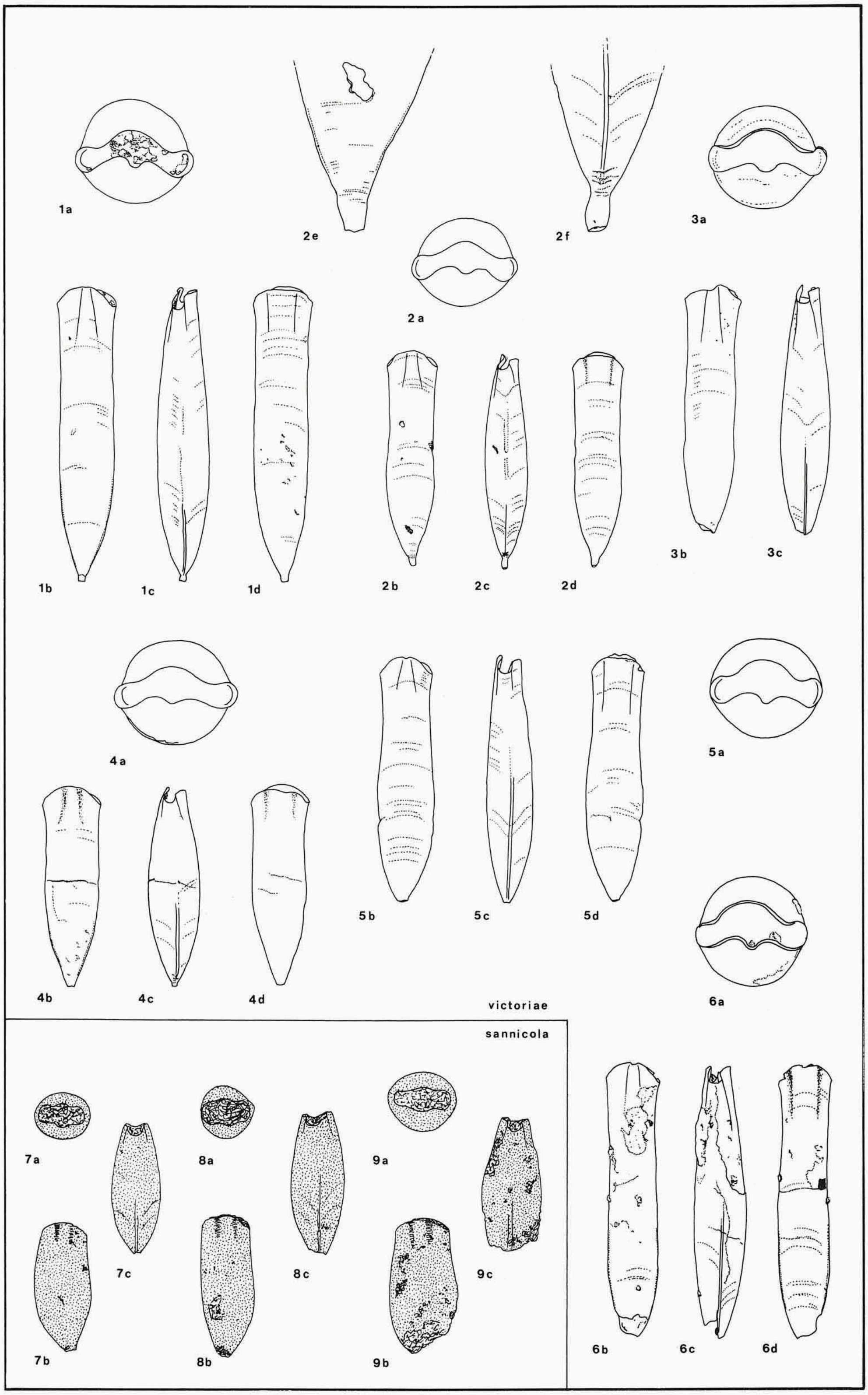
The growth-lines are neither described in the original description, nor indicated in the illustration of this species. They are only difficultly visible in low-angle light. Both on the ventral and the dorsal side they describe abapical curves, meeting each

Plate 9

Figs. 1-6. *Vaginella victoriae* sp. nov.
Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation.
Fig. 1a-d: adult specimen, protoconch broken, holotype, NMV P123409, a: × 11, b-d: × 5.5.
Fig. 2a-f: adult specimen, protoconch partly preserved, paratype, RGM 229 478, a: × 11, b-d: × 5.5, e-f: × 22.
Figs. 3a-c, 4a-d: adult specimens, protoconchs broken, paratypes, resp. RGM 229 479-480, 3a, 4a: × 11, 3b-c, 4b-d: × 5.5.
5-6: Locality data as above, but level not indicated (?Miocene). Adult specimens, protoconchs broken, paratypes, SAM T 235, 5a, 6a: × 11, 5b-d, 6b-d: × 5.5).

Figs. 7-9. *Vaginella sannicola* sp. nov.
San Nicola Varano (Italy, Puglia, Gargano), abandoned limestone quarry; Miocene, Late Serravallian to Late Tortonian, Lago di Varano Formation (?reworked from Late Langhian to Early Serravallian sediments); phosphatic internal moulds, apical and apertural parts more or less damaged.
7a-c: Holotype, RGM 229 540, × 6.
8-9: Paratypes, resp. RGM 229 541-542, × 6.

Plate 9


1a
2e
2f
3a
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1b
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1d
2b
2c
2d
3b
3c
4a
5a
5b
5c
5d
4b
4c
4d
6a
victoriae
sannicola
7a
8a
9a
7c
8c
9c
7b
8b
9b
6b
6c
6d

other at obtuse angles on the lateral carinae, exactly the same as in *Vaginella*. There is no trace of any other surface sculpture.

Length of holotype 6.17 mm, width at aperture 1.67 mm, apical angle 13°. The aperture is almost circular (apertural view), the dorso-ventral diameter is c. 9/10 of the width. Type-locality is Muddy Creek near Hamilton, Otway Basin, Tyrendarra Embayment, Victoria, Australia. 'Upper bed' or 'lower bed' was not indicated by Tate (1887), but it is highly unlikely that such a delicate shell could have been found in the 'upper beds' (= Grange Burn Formation). The only known additional specimen, also from the type locality, is indicated as 'Balcombian' and may therefore equally be supposed to originate from the lower bed, the Muddy Creek Formation.

Material studied — Torquay, Fishermans Steps, Australia (?Oligocene, ?Janjukian): ?1 defective, juvenile specimen, RGM 229 431.

Muddy Creek, Hamilton, Australia (level unknown): 1 defective specimen (holotype, Pl. 7, fig. 6), SAM T 237.

Do., (Miocene, Balcombian to Bairnsdalian): 1 defective specimen (Pl. 7, fig. 7), RGM 229 474.

Discussion — It is clear that this shell does not match the present-day concept of the genus *Styliola*. I agree with Bernasconi & Robba (1982, p. 215) that the closest affinities exist with the genus *Vaginella* (form of larval shell, transverse section, presence of lateral carinae, etc.), as demonstrated by the holotype and the only additional specimen available.

The available material of this species is too insufficient to obtain a fair impression: the apertural shell parts are missing, so the shell may or may not be compressed dorso-ventrally and a pre-apertural constriction may be present or absent in the full-grown shell. Also the shape of the complete larval shell is not yet known.

The poor specimen from Torquay is included in this species with some doubt. It resembles closely the smaller specimen from Muddy Creek, but its larval shell is missing. Still, its general shell form, the apical angle and the presence of distinct wrinkles on the lateral carinae make it resemble *V. bicarinata* closely. Irrespective of the considerable difference in age I would not have hesitated to consider the specimen conspecific with *V. bicarinata*.

Vaginella bicarinata (Tate, 1887) may be compared with other slender *Vaginella* species, as for example *V. lapugyensis* Kittl, 1886 (compare Janssen, 1984b, p. 76, pl. 3, figs. 6-10). In this species, however, the shell is entirely straight and the lateral carinae disappear towards the aperture. *V. lapugyensis* is known from Early and Middle Miocene deposits in the Paratethys, the Mediterranean and the North Sea Basin. More or less doubtful occurrences of this species are known from the Late Oligocene (Italy, Bernasconi & Robba, 1982) and the Early Miocene of the Caribbean (Carriacou, Jung, 1971; Trinidad, Rutsch, 1934). The species *V. bicostata* (Gabb) (compare Collins, 1934, pl. 13, figs. 26-27) resembles *V. bicarinata* closely, but its apical angle is slightly wider and the shell shows no trace of a curvature. Also the shell of *V. bicostata* seems to be slightly more compressed dorso-ventrally.

The provisional conclusion should be, that *V. bicarinata* (Tate, 1887) seems to be a valid, independent taxon, related to *V. lapugyensis*, but a final evaluation will only be possible when more and better preserved material is available. The name *V. bicarinata* at least should be maintained to prevent premature conclusions in the field of palaeozoogeography.

Vaginella depressa Daudin, 1800
Pl. 7, figs. 8-12; Pl. 8, figs. 1-8.

For general references and European occurrences the reader is referred to Janssen (in prep.).

*	1800	*Vaginella depressa* Daudin, p. 145, pl. 11, fig. 1.
v.	1887	*Vaginella eligmostoma*, spec. nov., Tate, p. 195, pl. 20, fig. 7.
.	1903	*Vaginella eligmostoma*, Tate - Dennant & Kitson, p. 94, 137.
.	1905	*Vaginella eligmostoma* - Clarke, p. 419.
.	1914	*Vaginella eligmostoma*, Tate - Chapman, p. 199, fig. 102E.
.	1962	*Vaginella eligmostoma* Tate, 1887 - Glibert, p. 62.
?	1971	*Vaginella* cf. *depressa* Daudin, 1800 - Jung, p. 214, pl. 19, figs. 5-7.
	1977	*Vaginella depressa* - Shibata, in: Ikebe, p. 152.
.	1978	*Vaginella depressa* Daudin - Itoigawa, pl. 3, fig. 9.
.	1980	*Vaginella eligmostoma* Tate, 1887 - d'Alessandro & Robba, p. 623, pl. 64, figs. 6a-d, 7a-d (partim, non pl. 63, figs. 4-7, pl. 64, figs. 1-5 and pl. 65, figs. 1-3 = *Vaginella sannicola* sp. nov., described in the present paper).
?	1980	*Vaginella depressa* Daudin - Shibata, p. 64, 66, pl. 3, figs. 13-17.
.	1981	*Vaginella depressa* Daudin - Itoigawa et al., p. 8, 48, 49, pl. 47, figs. 6a-b, 7a-b.
.	1981	*Vaginella depressa* Daudin - Shibata & Ishigaki, p. 57, fig. 5
.	1981	*Vaginella inflata* n. sp., Hayward, p. 199, figs. 15-17.
	1982	*Vaginella depressa* Daudin - Itoigawa et al., p. 295.
.	1982	*Vaginella eligmostoma* Tate - Bernasconi & Robba, p. 215 (non p. 217 = *Vaginella sannicola* sp. nov.).
.	1983	*Vaginella depressa* Daudin - Shibata, p. 66, 77, pl. 2, figs. 7a-b, 8a-b (spelling error on p. 66: *deressa*).
.	1983	*Vaginella inflata* Hayward - Shibata, p. 79.
	1985	*Vaginella depressa* Daudin - Nakagawa & Takeyama, p. 34.

Description — Shell medium-sized, elongated triangular, uncoiled and bilaterally symmetrical. Apex pointed, broken in all available nearly complete specimens. Transverse section in the apical shell part elliptical, with the dorso-ventral diameter slightly smaller than the shell-width. The largest diameter of the pre-apertural shell lies at about half to two thirds of the shell height. A more or less accentuated constriction is always present between the most inflated shell part and the aperture. In this part of the shell a dorso-ventral flattening is present, which continues towards the aperture.

The embryonal shell is partly preserved in two apical shell fragments (Pl. 8, figs. 7-8)). It is separated from the younger shell parts by a rather obvious constriction. Its axis does not deviate from that of the post-larval shell.

Just above the embryonal shell two weak carinae develop, one on either side of the shell. These carinae disappear gradually at about half the shell height. In the basal part of the post-embryonal shell weak irregular wrinkles are present on these carinae.

The aperture occupies the entire anterior part of the shell and is slightly curved in a straight frontal view. The size of the aperture may slightly exceed the width of the pre-apertural shell or remain somewhat narrower. The dorsal labium is somewhat higher than the ventral one. Both labiae bear two weak vertical folds, which lie closer on the ventral side of the shell. They reach in apical direction for a short distance only.

The growth-lines are usually well-marked. On both sides of the shell they describe a curve in apertural direction, somewhat stronger on the dorsal side than on the ventral one. They meet on the lateral carinae in a v-shape.

Type material — The whereabouts of Daudin's material is unknown to me. Type locality is 'environs de Bordeaux' (France, dept. Gironde). The stratigraphical origin is not indicated in Daudin's paper, which only states that the specimens were collected from the interior of several fossil shells. Beyond any doubt the material originated from sediments of Early Miocene (Aquitanian or Burdigalian) age.

Lectotype designation of Vaginella eligmostoma Tate, 1887 — The only *Vaginella* species described from the Australian continent is *V. eligmostoma* Tate. Its type-locality is Muddy Creek near Hamilton, Otway Basin, Tyrendarra Embayment, Victoria, Australia. The stratum typicum is 'lower beds, Muddy Creek'. According to Ludbrook (1973, p. 252) this indication refers to what is now called the Muddy Creek Formation, which is of Balcombian to Bairnsdalian age, so almost on the boundary between Early and Middle Miocene.

Although stated to be 'very abundant in the lower beds at Muddy Creek' (Tate, 1887, p. 195) only five specimens are present in the Tate collection. This sample has the following label:

Name: Vaginella eligmostoma Tate Pl. XX fig. 7 Hab.: Eocene, Muddy Creek T 236

None of the syntypes is entirely complete, in all specimens the embryonic shell-part is missing and the apertural labiae are more or less damaged in all syntypes. These specimens are illustrated here (Pl. 7, figs. 8-12). Tate's drawing is a fair representation of this species, except for the fact that the apertural folds seem much too long, occupying about half the shell length, which is incorrect. Also the constriction of the shell just below the aperture is too strong. The outline of the aperture, given at the left side of the main drawing, illustrates very well that on the dorsal side the apertural folds lie closer together than on the ventral side.

An additional observation is the occurrence of weak wrinkles at both sides of the basal post-embryonal shell, exactly the same as described for *Vaginella austriaca* and *V. depressa* by Janssen (1985a).

The syntypes of *V. eligmostoma* agree fairly well with the original description and measurements. The specimen most closely approaching the dimensions given by Tate is chosen here as the lectotype (Pl. 7, fig. 8), the four other specimens are paralectotypes. Measurements of the syntype series yielded the following data:

Table 5. Measurements (in mm) of the *Vaginella eligmostoma* Tate syntype series.

Locality	H	Wmi	Wap	T	Plate 7
Muddy Creek	6.97	2.24	2.49	1.91	fig. 8 (lectotype)
	6.71	2.32	2.49	1.91	fig. 9
	4.65	1.83	1.66	1.41	fig. 10
	4.90	1.91	1.83	1.66	fig. 11
	7.22	2.16	2.41	1.91	fig. 12

H = height, Wmi = width at mid-shell, Wap = width at aperture, T = thickness (dorso-ventral diameter).

Material studied — Muddy Creek, Hamilton, Australia (Miocene, Balcombian to Bairnsdalian) (in some of these samples the locality is indicated as 'Clifton Bank on Muddy Creek'; the age indication frequently is 'Eocene', in one case 'Oligocene, Balcombian'): 5 specimens (lectotype and 4 paralectotypes of *V. eligmostoma* Tate; Pl. 7, figs. 8-12), SAM T 236, SAM P29789; 26 specimens (measured), 44 defective specimens, WAM 79.742: 3 defective specimens, RGM 229 484; 1 apical fragment (Pl. 8, fig. 7), 5 specimens (measured), 9 more or less defective specimens, RGM 229 475-476; 7 specimens (measured), 13 defective specimens, several fragments, from interior of *Harpa pulligera* Tate, RGM 229 490; 1 fragment, from interior of *Ancillaria pseudaus-*

tralis Tate, RGM 229 501; 4 defective specimens (incorrectly labelled 'Muddy Creek, Altona'), AMS C149.278; 9 specimens (measured), 7 defective specimens, RGM 229 483; 37 specimens (measured), 8 defective specimens, BM(NH) G. 60835-41.

Do., without any indication of the level: 1 specimen (Pl. 8, fig. 1) (found together with *Vaginella victoriae*), SAM P 29790; 4 specimens (Pl. 8, figs. 2-5), 5 specimens, AMS C143.929; 29 more or less defective specimens, AMS C143.929 (this sample also contains 1/2 specimen of *Limopsis* sp.); 3 specimens (measured), 2 defective specimens, RGM 229 468; 5 specimens (measured), 3 defective specimens, BM(NH) G. 9310.

Do., (Pliocene, Kalimnan, probably reworked): 3 specimens (measured), 2 defective specimens, RGM 229 502.

Do., (locality specified as Muddy Creek, Hamilton, SW below Clifton Homestead, in MacDonald's Bank): 5 defective specimens, several fragments, AMS C143.928; 17 specimens (measured), 54 defective specimens, several fragments, AMS C149.281.

Red Bluff, Shelford, Australia (Miocene, Balcombian): ? 1 defective specimen, RGM 229 467.

Altona Bay, Australia (Miocene, ?Balcombian): 1 apical fragment (Pl. 8, fig. 8), RGM 229 439.

Balcombe Bay, Mornington, Australia (Miocene, Balcombian): 1 specimen (Pl. 8, fig. 6), 1 defective specimen, RGM 229 456.

Fossil Beach, Mornington, Australia (Miocene, Balcombian): ? 4 more or less defective specimens (one of these figured Pl. 8, fig. 9), NMV P116251; 1 fragment, from interior of *Eutrephoceras* sp., RGM 229 464.

Discussion – Tate (1887) compared his *V. eligmostoma* with the European Early Miocene species *V. depressa* 'Basterot'. Apparently he had no material for comparison available and based his knowledge of the European species on literature sources (Rang & Souleyet, 1852, p. 54, pl. 6, fig. 8). In this paper unfortunately *Vaginella depressa* was incorrectly illustrated (sub nomine *Cleodora vaginella*). Thus, Tate stated the main difference between *V. eligmostoma* and *V. depressa* to be the absence of a 'sinuated aperture' in the latter species. This, however, is incorrect. Such apertural folds are certainly present in the French species (compare Janssen, 1985a, figs. 13a-b). In fact, the syntypes of *V. eligmostoma* in all aspects, also in the ratios of the measurements, fall within the wide range of variability of *V. depressa* in its present concept. It is concluded that for the time being the name *V. eligmostoma* Tate, 1887 has to be considered a junior synonym of *V. depressa* Daudin, 1800.

The wide variability of the Australian material, as already expressed (vide supra) in the syntype sample of *V. eligmostoma* becomes very obvious when studying more material. Several samples were available to me from the type locality Muddy Creek and looking through this material gives the strong impression that a long and slender species might be distinguished from a more thick-set type.

A more objective approach was pursued by measuring height and width of all nearly complete specimens. As stated in the description not a single complete specimen has its embryonic shell completely preserved and in most specimens the apertural labiae are more or less damaged. In measurements of height and width these features only influence the shell height, which obviously always had a higher value in the undamaged shell. Of course the damage is not identical in all specimens, so in some shells the deviation from the correct dimensions will be higher than in others. Still the present material is all we have!

A severe disadvantage is that most samples from Muddy Creek have no indication of the level from which the material was collected. Some samples are stated to originate from the 'lower beds' or the 'Muddy Creek Marl'. These are considered to be of Miocene age (Balcombian to Bairnsdalian, although one sample is stated to be Batesfordian in age!).

Three samples have been collected from the overlying Pliocene (Kalimnan) deposits, the so-called 'Grange Burn Coquina'. This, of course, would be extremely interesting, as Pliocene *Vaginella* species are unknown up to now. The samples, however, demonstrate only minor differences from the other *V. 'eligmostoma'* material, whereas a number of further *Vaginella* specimens (three samples, one of these labelled as having been collected 'just below base of upper bed') is distinctly different from the *'eligmostoma'* type (see *Vaginella victoriae*, below). Without having collected at Muddy Creek personally and lacking sufficient knowledge of the local circumstances I am inclined to suppose that the samples from the upper beds are either incorrectly labelled or reworked, in the latter case probably inside larger gastropod shells. Dr T. Darragh acknowledged that there is indeed a fair degree of reworking. For the time being this unsatisfactory situation remains unsolved.

The measurements of the Muddy Creek *Vaginella depressa* samples are summarized in tables 6 and 7.

A closer look at these results reveals that the five specimens in the lectotype series of *V. eligmostoma*, together with five further shells in the BM(NH) collection, represent a relatively slender form. The greater part of the samples, however, has a higher mean value for the W/H-ratio, but there are considerable overlaps in the ranges. A further sample from Muddy Creek (AMS C143.929, level unknown; not measured, but four specimens from this lot are illustrated om Pl. 8, figs. 2-5) contains even more elongate specimens. The measured 'Pliocene' sample of 17 specimens is on the average as elongate as the AMS sample.

As the available material apparently originates from different levels we may be dealing with a more or less strongly mixed population. Thus it might be possible that we are in fact dealing with two taxa, mainly differing in the W/H-ratio and presumably with unidentical vertical distributions. This can only be verified on samples with full stratigraphical information.

Among the samples from other Australian localities the four specimens from Fossil Beach, Mornington ('Balcombian') and the unfortunately strongly damaged specimen from Shelford have strikingly narrow apertures (much narrower than the inflated shell part below the aperture) and the apertural folds on the dorsal side lie almost as close as the ones on the ventral side (Pl. 8, fig. 9). It cannot be excluded that this sample represents another taxon and therefore it has been mentioned in the list of studied material above with a question mark. These specimens offer a certain resemblance in general shell form with the Late Oligocene European species *Vaginella*

Plate 10

Figs. 1, 3. *Limacina atypica* (Laws, 1944)
1a-b: Pakaurangi Point, Kaipara Harbour (New Zealand); Miocene, Altonian, *'Vaginella'* Bed? Paratype, juvenile, RGM 229 735, × 50.
3a-b: Spring Creek near Torquay; ?Late Oligocene to Early Miocene, Janjukian-Longfordian. Juvenile specimen, RGM 229 736, × 50.

Fig. 2. *Limacina inflata* (d'Orbigny, 1836)
Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation. Near-adult specimen with well-developed 'rostrum', fragile shell-wall broken above and below rostrum, RGM 229 737, a: × 50; b: × 100.

Plate 10

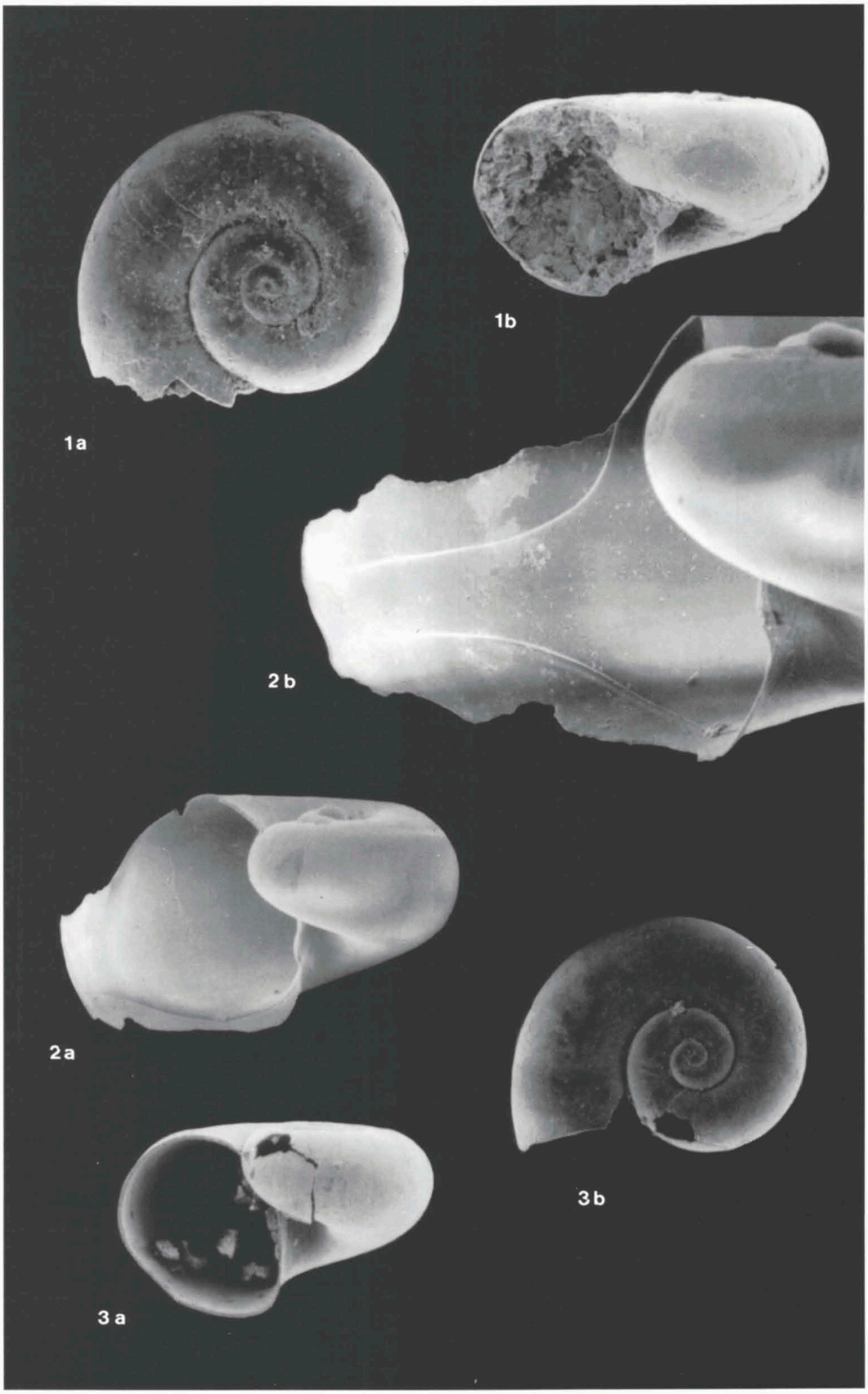

Table 6. Width/height measurements (in 0.1 mm) and W/H-ratios of *Vaginella depressa* samples from Muddy Creek, Hamilton. Miocene samples and samples without level indication.

number of specimens	range of heights	range of widths	width/height ×100-range	mean ratio	coll.
37	44 - 59	18 - 24	32.48-46.67	39.3446	BM(NH)
3	49½- 60	19 - 20½	34.17-40.40	37.5233	RGM
5	47 - 51½	16 - 20½	32.00-43.62	37.4820	RGM
7	44 - 58	17 - 20½	29.31-41.84	37.4786	RGM
26	45 - 66	17 - 24	28.57-43.14	36.0973	WAM
9	47 - 58	18 - 20½	31.58-41.18	35.6600	RGM
5	46½- 72	18½- 23	29.86-39.78	34.9780	SAM*)
5	53 - 67	16½- 21	31.13-37.04	34.6440	BM(NH)
97	44 - 72	16 - 23	28.57-46.67	37.3779	

Standard deviation of W/H-ratio = 4.56.

*) Lectotype series of *V. eligmostoma* Tate.

Table 7. Width/height measurements (in 0.1 mm) and W/H-ratios of *Vaginella depressa* samples from Muddy Creek, Hamilton. 'Pliocene' samples.

number of specimens	range of heights	range of widths	width/height ×100-range	mean ratio	coll.
3	47½- 57	19 - 19½	33.33-40.00	36.7067	RGM
17	44 - 62½	16 - 19½	29.60-37.25	33.8282	AMS
20	44 - 62½	16 - 19½	29.60-40.00	34.2600	

Standard deviation of W/H-ratio = 2.48.

chattica R. Janssen, 1979, in which, however, the dorsal folds are separated much more than the ventral ones.

Populations from the Miocene of the Bordeaux area in southern France (type area of *V. depressa*) equally demonstrate a considerable variability. Material from the famous, but nowadays inaccessible locality Léognan is relatively thick-set, but has a more conical base than the Muddy Creek specimens. At Léognan the apertural folds of *V. depressa* are hardly visible, sometimes even virtually absent, and the pre-apertural constriction is less marked, with the aperture consistently wider than the inflated shell part. These forms differ markedly from the Australian type.

At yet another French Burdigalian locality more to the south in the Aquitaine Basin, viz. Moulin-de-Cabanes at St. Paul-les-Dax (Landes department) the similarity of the *Vaginella*'s to the Muddy Creek material is much better, and for instance the type series of *V. eligmostoma* can certainly not be distinguished from this material at specific level. Up to now no author has separated the Moulin-de-Cabanes material from *V. depressa*.

It follows that also within the material from the *Vaginella depressa* type area more than one taxon may be present, but all this material has up to now been referred to as *V. depressa*. To settle this matter in a satisfactory way it will be necessary to designate a neotype (assuming that the original types are lost, which is not necessarily so) and to study carefully a large number of samples from the Aquitaine Basin. This might result in a subdivision of Miocene *Vaginella*'s, both in France and in Australia! But again, to realize such an ambitious project well-documented samples will be indispensable.

Several authors, viz. Checchia-Rispoli (1921, p. 15), Sirna (1968, p. 424) and d'Alessandro et al. (1979, p. 86) identified a Miocene southern Italian *Vaginella* species from the Gargano Peninsula as *V. depressa*. D'Alessandro & Robba (1980, p. 623) disputed this identification of the Gargano species. They summarize the differences between these two species as follows:

'Tuttavia questo taxon (= *V. depressa*) ha forma generale più slanciata, con massima ampiezza della sezione a metà della teleoconcha e non spostata adapicalmente come nel materiale esaminato; lo spessore e l'indice di rigonfiamento sono minori. Inoltre l'aperture è lenticolare biconvessa e le labbra non sono sinuose'.

So, here again *V. depressa* is erroneously considered to lack apertural folds. Yet I agree with d'Alessandro & Robba that the Gargano species is different from *V. depressa*. This is not only indicated by the differences mentioned by these authors, but especially also by the fact that the Italian species always has the aperture considerably less wide than the maximal width of the shell. This difference was not mentioned by d'Alessandro & Robba, but it is very obvious from their illustrations and from the biometric data given in their table on p. 625. The RGM collection contains a fine sample of this Gargano species, collected by colleague M. van den Bosch in 1970, at the same locality San Nicola Varano from which the Italian authors described (parts of) their material.

Having rejected the identity of the Italian *Vaginella* species with *V. depressa*, d'Alessandro & Robba continue:

'Secondo noi si ha invece una buona corrispondenza con tutti i caratteri di *Vaginella eligmostoma* Tate di cui figuriamo, per confronto, due topotipi; ...'.

The two illustrated topotypes do not entirely agree with the syntypes, especially the shell figured on pl. 64, figs. 6a-c, which is considerably wider than the syntype series. Both topotypes incidently have their aperture slightly narrower than the shell width, but this is also the case in two of the five syntypes. With only such a restricted material at hand it is, of course, not at all surprising to find specimens outranging the variability of the type series.

From the above discussion it is clear that the name *V. eligmostoma* cannot be applied to the Italian material, as it is considered to be a junior synonym of *V. depressa*. There are several differences between *Vaginella depressa* and the species from the South-Italian Miocene, for which therefore the name *Vaginella sannicola* sp. nov. is introduced in this paper (see annex).

It is quite certain that the various *Vaginella* populations from Japan and New Zealand (*V. inflata*), mentioned in the list of synonyms all belong to the same species or group of species as the Muddy Creek material. A further subdivision of this latter material (excluding *Vaginella victoriae* sp. nov. and *V. bicarinata* Tate, which are clearly distinguishable from the *V. depressa* group) will also necessitate a revision of the other populations.

Vaginella victoriae sp. nov.
Pl. 9, figs. 1-6.

Holotype — Pl. 9, fig. 1; don. D. Curry, NMV P123409.
Type locality — Muddy Creek, Hamilton, Otway Basin, Tyrendarra Embayment, Victoria, Australia.
Stratum typicum — Muddy Creek Formation (Miocene, Balcombian to Bairnsdalian), see Ludbrook (1973, p. 252).
Derivatio nominis — This new species is named after the state of Victoria, Australia, where the type locality is situated.

Description — Shell medium-sized, elongated, almost cylindrical, uncoiled and bilaterally symmetrical. The H/W-ratio is quite variable. Apex pointed, broken in all available specimens. Transverse section in the apical shell part broadly elliptical to almost circular, with the dorso-ventral diameter only very slightly smaller than the shell width. The largest diameter of the pre-apertural shell lies at one-third to one-fourth of the shell height. A very gradual constriction is always present between the most inflated shell part and the aperture. In this part of the shell a dorso-ventral flattening is present, which continues towards the aperture.

The embryonal shell is separated from the younger shell parts by an obvious constriction. In just one specimen the larval shell is preserved for the greater part, although the extreme apical part is missing. In this specimen the axis of the embryonal shell deviates slightly from the axis of the adult shell, in such a way, that it seems slightly tilted in ventral direction (Pl. 9, fig. 2f). Just above the embryonal shell two weak carinae develop, one on either side of the shell. These carinae disappear gradually at about half the shell height. In the basal part of the post-embryonal shell weak irregular wrinkles are present on these carinae.

The aperture occupies the entire anterior part of the shell and is slightly curved in a straight frontal view. The width of the aperture equals more or less the width of the inflated pre-apertural shell part. Contrary to most other *Vaginella* species the dorsal labium is somewhat less high than the ventral one. Both labiae bear two strong vertical folds. Especially on the ventral side of the shell these folds are well-marked and lie close together. In apical direction these folds demonstrate a clear divergence. On the dorsal side the folds are somewhat less strong and they are more apart. The presence of these folds results in a peculiar shape of the aperture in a straight anterior view.

The growth-lines are usually well-marked. On both sides of the shell they describe a curve in apertural direction. They meet on the lateral carinae in a v-shape.

Material studied (all samples from the type locality) — Holotype, NMV P123409, 3 paratypes Pl. 9, figs. 2-4, 4 paratypes, RGM 229 478-481; 2 paratypes (Pl. 9, figs. 5-6), 2 defective paratypes, SAM T 235 (no level indicated for this sample); 16 defective paratypes and several fragments, AMS C124.717. The locality of this latter sample is indicated as: Muddy Creek, N. behind Yulecart Hall, in Muddy Creek Marl (Lower Beds, just below base of Upper Beds, Lower Miocene, Batesfordian).

Discussion — The present material deviates so strongly from the *Vaginella depressa*-group material from the same locality, that it is inevitable to consider it a separate taxon. Only three samples are available. One of these gives some additional information on the stratigraphic level. Apparently it was collected from the uppermost part of the Miocene beds, just below the boundary with the overlying Kalimnan 'Grange Burne Coquina'. As a form of *Vaginella*, belonging to the *V. depressa*-complex, is also

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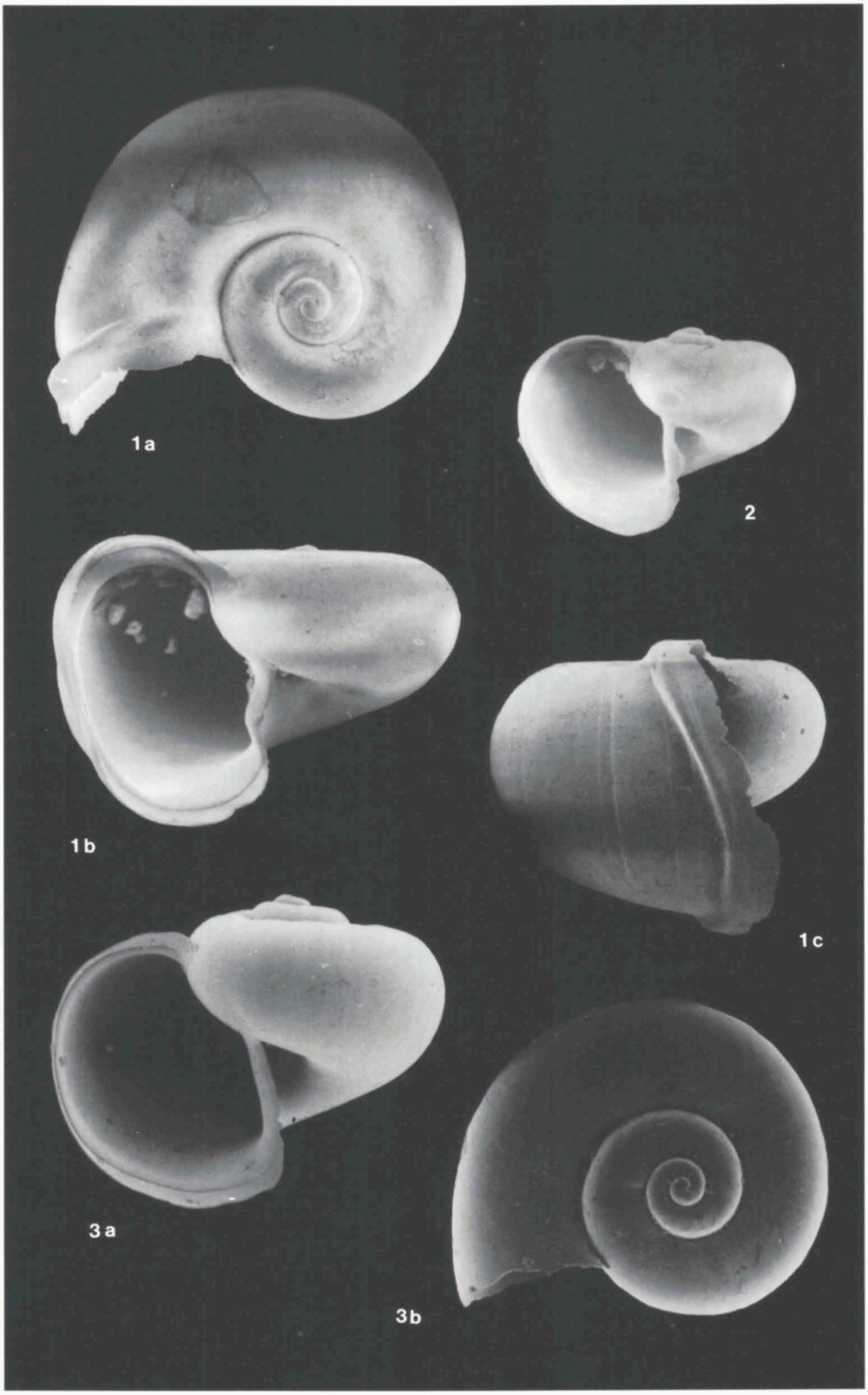
Plate 11

Figs. 1-2. *Limacina tertiaria* (Tate, 1887)
Muddy Creek, Hamilton; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation, from interior of *Ancillaria pseudaustralis* Tate.
1a-c: Adult specimen, RGM 229 738, × 50.
2: Juvenile specimen, RGM 229 739, × 50.

Fig. 3. *Limacina curryi* sp. nov.
Torquay, Bird Rock, Otway Basin; Oligocene, Janjukian, Torquay Group, Jan Juc Formation, *Glycymeris* Beds. Paratype, RGM 229 740, × 50.

Plate 11



present above this boundary, it is not possible to consider *V. victoriae* a younger evolutionary development of this complex. Should later be established that the Kalimnan occurrences of *Vaginella depressa* s.lat. are reworked (as suggested above) than this concept may have to be reconsidered. Again it is obvious that the information on the Muddy Creek sequence and its planktonic mollusc fauna is painfully insufficient.

There is a considerable variability in the width/height ratios in this species, but the least slender specimens can be distinguished from the most elongate representative of the *V. depressa* group, although they approach each other closely in the width/height ratio, by the strongly developed apertural folds (especially obvious in an apertural view), which show a distinct downward divergence, and by the fact that the dorsal labrum remains slightly lower than the ventral one.

Several slender *Vaginella* species are known that should be compared with the new Australian species. The species *V. lapugyensis* Kittl, 1886 (Miocene of western Europe and of the Paratethys) has a regularly conical shell form, without an inflated pre-apertural shell part and with a much more acuminate apical part and completely differing apertural characteristics.

Vaginella rotundata Blanckenhorn, 1889 (described from the 'Upper Cretaceous' of northern Syria, but now considered to be Miocene) is based on insufficient material. It was redescribed by Avnimelech (1945), who considered *V. acutissima* Audenino, 1897 a junior synonym. This species is related to *V. lapugyensis*, but differs by a somewhat more inflated pre-apertural shell. From *V. victoriae* it differs by its conical base and by the absence of labial folds.

Vaginella calandrellii Michelotti, 1847 (Mediterranean Miocene) has a conical apical part and its sides become almost parallel in the younger shell parts. It has no pre-apertural inflation and there are no folds at the apertural labiae.

Vaginella sp.
Pl. 8, figs. 10-11.

Description — From two localities fragmentary *Vaginella* specimens are available that cannot be considered to belong to one of the afore mentioned species.

At Altona Bay an apical shell part was found, still possessing its complete larval shell (Pl. 8, fig. 10). The fragment belonged to a specimen that already had passed shell metamorphosis, as is distinctly indicated by the presence of wrinkles on the lateral carinae. The apical angle of the post larval shell (measured in ventral view) is c. 25°, so much less wide than in *V. depressa* or *V. victoriae*, and much wider than in *V. bicarinata*. Furthermore the larval shell demonstrates a slight but distinct ventral inclination with

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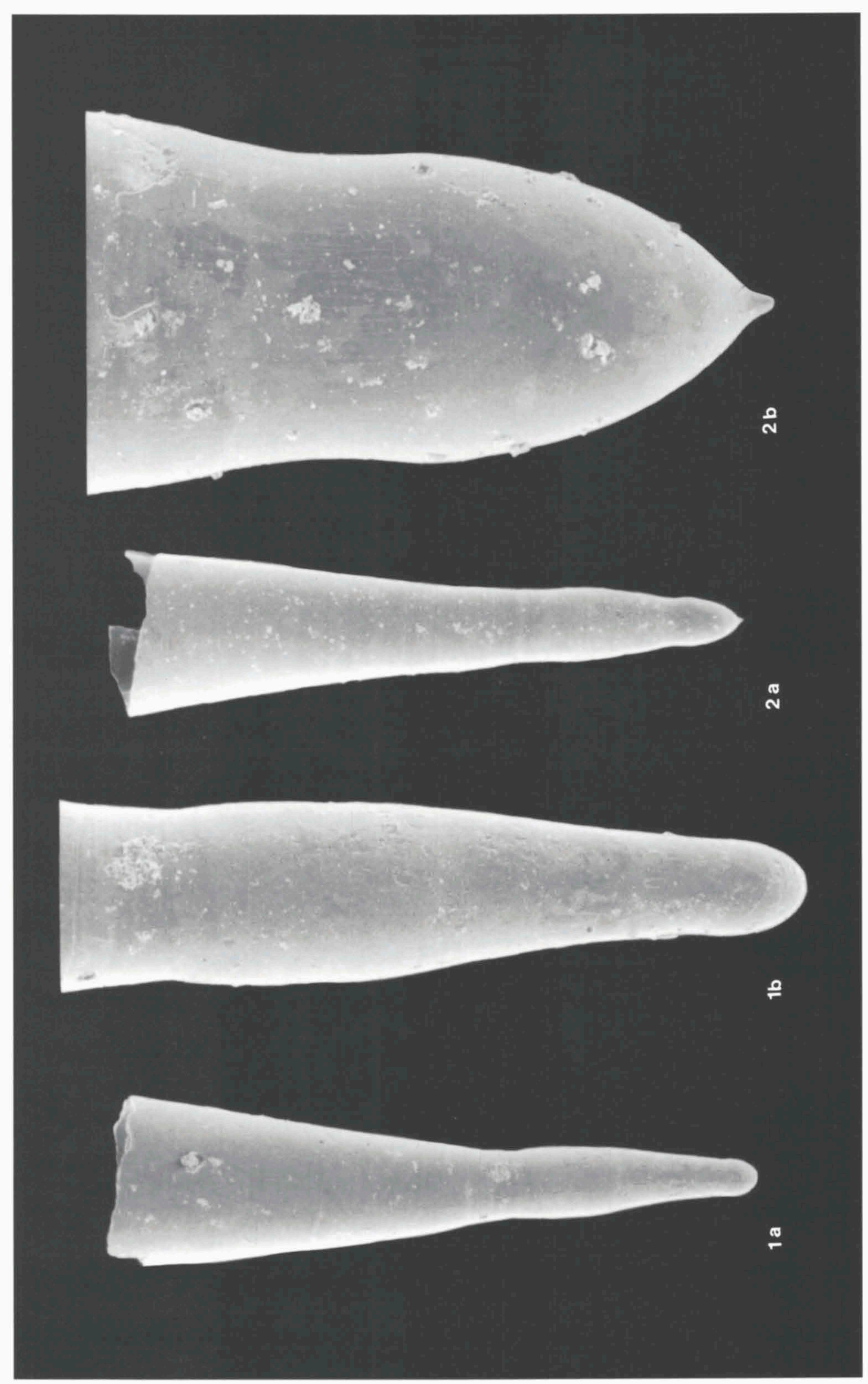
Plate 12

Fig. 1. *Creseis* cf. *chierchiae* (Boas, 1886)
Fossil Beach, Mornington, Balcombe Bay; Miocene, Balcombian, Fyansford Formation. Juvenile specimen, RGM 229 741, a: × 70, b: × 180.

Fig. 2. *Styliola subula* (Quoy & Gaimard, 1828)
Balcombe Bay, Mornington; Miocene, Balcombian, Fyansford Formation, beds h- k. Juvenile specimen, RGM 229 742, a: × 70, b: × 450.

Plate 12



respect to the axis of the post-larval shell, which is only present in *V. victoriae*, but absent in both *V. depressa* and *V. bicarinata.*

In the same sample from Altona Bay a further *Vaginella* fragment was present (Pl. 8, fig. 8), which equally has its larval shell (partly) preserved. It has a wider apical angle of the post-larval shell and the larval and post-larval shell parts are in line. This second specimen is therefore considered to belong to the *V. depressa*-complex.

From Batesford a further apical shell fragment is available, in which however the larval shell is missing (Pl. 8, fig. 11). Its characteristics match the first-mentioned Altona Bay shell perfectly and the two specimens are certainly conspecific.

Material studied — Altona Bay, Australia (Miocene, ?Balcombian): 1 fragment (Pl. 8, fig. 10), RGM 229 440.

Batesford, Australia (Miocene, Batesfordian to Bairnsdalian): 1 defective specimen (Pl. 8, fig. 11), RGM 229 449.

Pteropods described by M.F. Buonaiuto

Dr Massimo F. Buonaiuto, a geologist from Italian origin, graduated for his Ph. D. in June, 1979, on a thesis called: Late Eocene Mollusca and related composite species from southern Australia (Buonaiuto [1979]). Only four copies of this paper exist, two of which are in the library of the University of South Australia, Adelaide. One of these, with registration number 09PH.B943.SR, was traced there on my request by Dr W. Backhuys, who found it to be a typescript with photographical prints for the plates. He was not allowed to xerox parts of the paper unless possessing a written permission of the author. A further copy is in the library of the Istituto di Geologia e Paleontologia in Milano, Italy. Here too an authorization of the author is necessary for consultation. Finally one copy, of course, is present in Dr Buonaiuto's private library, currently at Coolbinia, W.A. Dr Buonaiuto kindly supplied me with copies of the relevant pages.

In this thesis two pteropod species were discussed, viz. *Praehyalocylis annulata* (Tate, 1887) and, introduced as a new species, *Bovicornu robbai.*

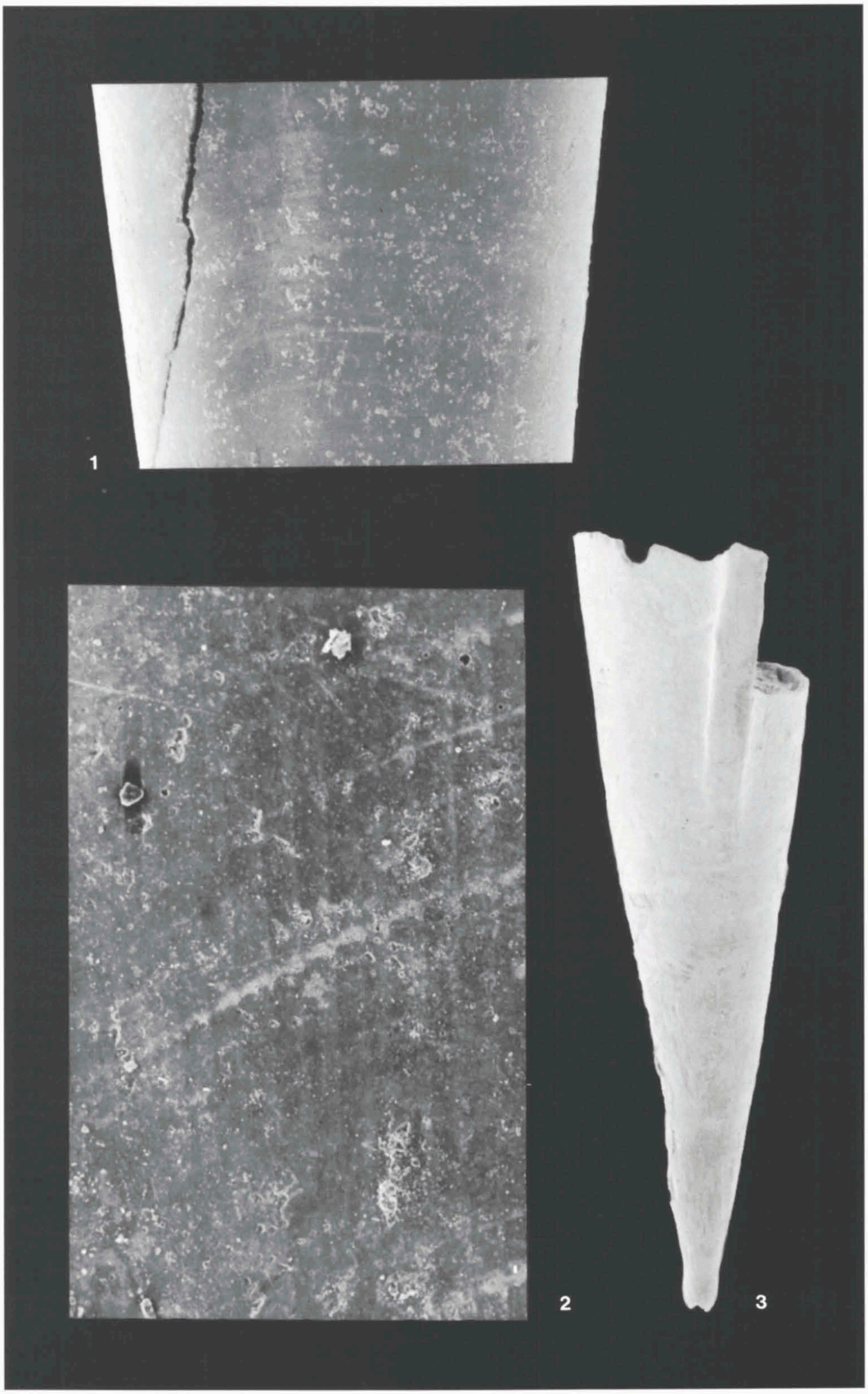
Of the former species not less than 23 specimens were available, from the localities 'St. Vincent Basin, Adelaide Plains SubBasin, Adelaide (Kent Town) Bore; Willunga SubBasin, Aldinga and Maslin Bays.'. The Adelaide (Kent Town) Bore specimens no doubt are Tate's syntypes, also studied in the present paper, in which a specimen from the Aldinga locality is also mentioned. The Maslin Bay locality, however, is new.

Plate 13

Fig. 1. *Styliola subula* (Quoy & Gaimard, 1828)
Balcombe Bay, Mornington; Miocene, Balcombian, Fyansford Formation, beds h-k. Detail of adult specimen, showing dorsal furrow and growth-lines, RGM 229 743, × 100.

Figs. 2-3. *Spoelia torquayensis* sp. nov., paratypes.
St. Etienne d'Orthe (France, Landes department), outcrop in Ruisseau de l'Eglise; Oligocene, Chattian, Marnes de St. Etienne-d'Orthe.
2: Fragment of adult shell, showing growth-lines and radial microsculpture, RGM 229 744, × 200.
3: Juvenile specimen, apex and aperture damaged (lateral view), RGM 229 745, × 60.

Plate 13



'Bovicornu robbai' is discussed in the systematic part above, sub nomine ?*Clio* sp. The type specimen, unfortunately, seems to be missing. The protoconch, illustrated in Buonaiuto's fig. 486, seems to be equal-sized and very similar in shape as the one described above, but in Buonaiuto's specimen the apex is pointed and there seems to be a more distinct boundary between the protoconch and the teleoconch. These differences, on the other hand, could very well be the result of the unfavourable preservation of the Aldinga specimens. As both occur in the same deposits, at both known localities associated with the pteropod *Praehyalocylis annulata* (Tate) the probability is very large that the two samples represent the same species indeed.

In an earlier, equally unpublished report (Buonaiuto [1978]) some further pteropod species are mentioned, without descriptions or illustrations. In this report Buonaiuto discussed molluscan assemblages from the Late Eocene of the Padthaway Ridge in the Murray Basin. *Limacina* sp. nov. B is mentioned from the so-called II *Spirocolpus* Horizon. From the Lower Port Willunga Formation the same species and *'Praehylocylis'* sp. nov. were recorded, and supposed to be 'closely related, yet different at species level' from *Limacina* sp. nov. A and *Praehyalocylis 'annulta'* (Tate), known from the Blanche Point Formation 'under the Adelaide city' and in the Willinga Subbasin. Two *Limacina* acmes are mentioned for the Buccleuch Beds 'A'.

From these data it is obvious that the SW Australian Eocene deposits contain more pteropod species, no material of which has been available to me for the present paper. Unfortunately, the specimens seem to be missing, just like the ones mentioned in Buonaiuto's thesis. It would be highly intriguing to study this additional material as soon as it will be available again!

Biostratigraphy of Australian pteropods and potential tools for long distance correlations

In the present paper the occurrence of 18 pteropod species could be established in the Australian Cainozoic. Five of them are new to science, several others could only provisionally be identified. If we compare these numbers for instance with the pteropod record of the North Sea Basin (more than 60 species known from the same time interval) it may be concluded that the pteropod fossil record of southern Australia is still (very?) incompletely known. It may be expected that further research will reveal several more pteropod species.

The 18 species recognised in this paper originate from six different stratigraphic levels (see Fig. 3). On the basis of benthic molluscs Darragh (1985) subdivided the Cainozoic deposits in a number of assemblages. The pteropod distributions, as far as they can be reconstructed from the frequently insufficient stratigraphic information accompanying the samples, can be compared with Darragh's zonation, but they do not offer possibilities for a refinement.

From Darragh's Assemblage IV, of Aldingan age, two pteropod species are known, viz. *Praehyalocylis annulata* and ?*Clio* sp. The former is also known from New Zealand, the NE Pacific (Oregon and Washington, U.S.A., identified as *P. cretacea*) and, as *P. chivensis* Korobkov & Makarova, from Uzbekistan, U.S.S.R., in the Paratethys area. Occurrences of the same or closely related species in the North Sea Basin need further research. This distribution pattern obviously offers useful possibilities for long distance correlation.

Only one species, *Limacina ? dilatata*, is known from the younger Aldingan Assemblage V. What seems to be the same species is also known from New Zealand. In

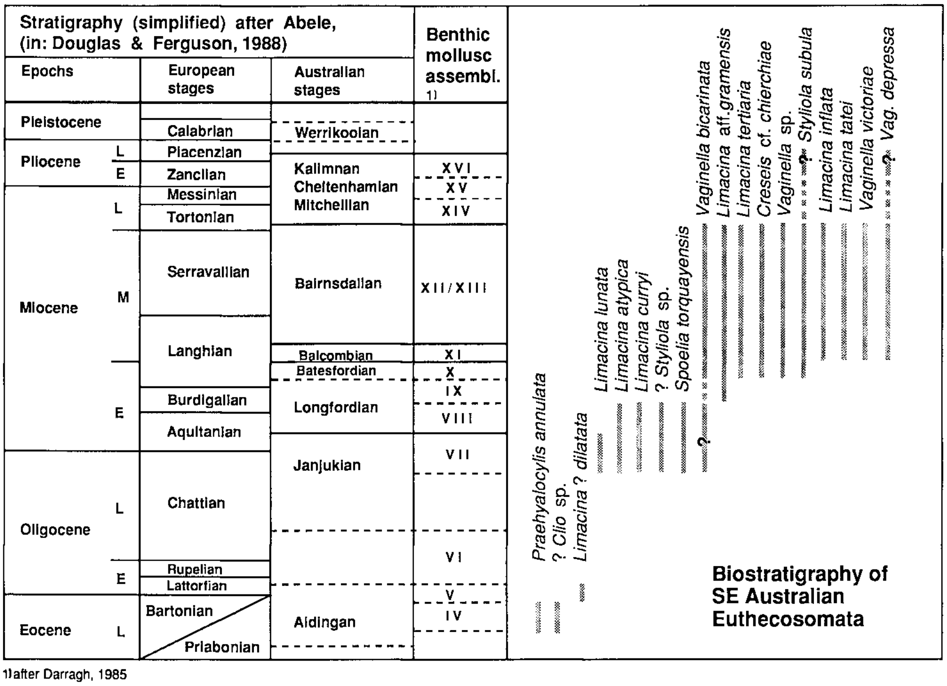


Fig. 3. Biostratigraphy of SE Australian Euthecosomata. Absolute ages and chronostratigraphical subdivision based on Abele (1988); they deviate at several places from the most recent data, as given by Cowie & Bassett (1989). Darragh's (1985) subdivision in benthic mollusc assemblages had to be modified slightly because of the newer chronostratigraphy.

the North Sea Basin *L. dilatata* is known from deposits of a similar age (Latdorfian, see Janssen, 1989, p. 95).

Assemblages VII and/or VIII are well-characterised by the occurrence of at least five, may be six species. Among them *Limacina atypica* offers possibilities for correlations with New Zealand deposits, whereas *Spoelia torquayensis* supplies a magnificent first order correlation with the southern Aquitaine Basin in France. *Vaginella* ? *bicarinata* seems to be identical with *V. bicarinata* in the Miocene Assemblages XI/XIII.

Just one species, *Limacina* aff. *gramensis*, was found in the Longfordian Assemblage IX. This taxon, also present in Assemblages XI/XIII, resembles closely a Late Miocene North Sea Basin species, where it is supposed to evolve from the Chattian to Middle Miocene *Limacina valvatina* (Reuss). As the vertical ranges of *L. gramensis* and *L.* aff. *gramensis* differ in Europe and Australia and as ancestral species resembling *L. valvatina* are as yet unknown from Australia it is unlikely that the material from both occurrences represents the same species. Further study and more material will be necessary to clarify the real identity of the Australian material.

In the Assemblages X or XI to XIII the richest pteropod association is found, comprising ten species. Among them two, may be three species, are also known from the Recent pteropod fauna, viz. *Limacina inflata*, *Creseis* cf. *chierchiae* and *Styliola subula*. The Australian material yielded the first certain Miocene occurrence of *L. inflata*, which elsewhere was only known with certainty from Pliocene and younger deposits. An ancestral species of the more common species *Limacina tertiaria* is known from New Zealand (*L. ferax*). The also very common taxon *Vaginella depressa* has a very wide distribution, including parts of the Indo-Pacific, the Caribbean and Europe. It may be, however, that in fact more than one species is assigned to this taxon, and therefore further study is indispensible before *V. depressa* can be applied successfully for the correlation of remote areas. There also is an age discrepancy between the European and Australian occurrences of *V. depressa*. In Europe the species is restricted to the Aquitanian and Burdigalian, the Australian populations are of Balcombian to Bairnsdalian age, which correlates with Late Burdigalian to Serravallian.

Two pteropod species were encountered in the Pliocene (Kalimnan) Assemblage XVI. One of these, *Vaginella depressa*, agrees completely with part of the material from Assemblages XI/XIII and is therefore believed to be reworked or mislabelled. The same might be true for the second species, *Styliola subula*, although its known vertical distribution (Middle Miocene to Recent) does not exclude its occurrence in the Pliocene.

Summarizing, it may be concluded that the Australian Cainozoic pteropod record, although apparently still incomplete, can succesfully be applied for the characterization and regional correlation of southern Australian Tertiary deposits. These possibilities can be strongly improved by collecting detailed information on the vertical distribution of the various taxa. Tools for interregional and long-distance correlation are present, but here too accurate conclusions are hampered by insufficient knowledge on the upper and lower boundaries of the vertical ranges of the Australian species.

In Table 8 all Australian pteropod material studied in this paper is specified per locality, giving full geographical and stratigraphical details, together with the number of specimens per sample and their registration numbers (if any).

Table 8. Specification of Australian pteropod species per locality.

Adelaide, South Australia; Adelaide borehole (= Kent Town bore), northeast Parklands, depth 45-66.4 m according to Ludbrook, 1973 (Late Eocene, Aldingan, 'glauconitic clayey sands' = Blanche Point Banded Marls and equivalents of the Blanche Point Transitional Marls and Tortachilla Limestone, see Lindsay, 1969). Sample collected by R. Tate, 1882.		
Praehyalocylis annulata	4 more or less defective specimens (lecto- and paralectotypes)	SAM T 214 and P29779-80
Aldinga Bay, Willunga Embayment, St. Vincent Basin, South Australia (Late Eocene, Aldingan, Blanche Point Formation, Gull Rock Member, clay with *'Turritella' aldingae* Tate, or 'lower marl'). Samples collected by R. Tate (coll. SAM) and D. Curry (donated to coll. RGM)		
Praehyalocylis annulata	2 def. specimens (paralectotypes)	SAM T 214
	1 def. specimen	RGM 229 410
?*Clio* sp.	2 def. specimens	RGM 229 411-412
NW of Cape Otway, N of Pt. Flinders, South Victoria, Australia, in slipping, low seacliff (Late Eocene or Early Oligocene, Glen Aire Clay Formation). Sample collected by W.F. Ponder, T.A. Darragh and E.K. Yoo, 10 March 1977.		
Limacina ? dilatata	1 defective specimen	AMS C149.279
Spring Creek near Torquay, Victoria, Australia (probably Late Oligocene to Early Miocene, Janjukian-Longfordian, Jan Juc Formation or overlying Puebla Formation). Sample donated by Mr D. Curry. Dr T.A. Darragh (in litt., 7.4.1989) noted that 'Spring Creek' is an old name for the Torquay District. It embraces all the 'modern' localities for the following formations: Point Addis Limestone, Jan Juc Formation, Puebla Formation, Zeally Limestone, ranging in age from Late Oligocene to Middle Miocene).		
Limacina atypica	39 specimens and some fragments	RGM 229 413-415
Limacina curryi	4 juvenile specimens (paratypes)	RGM 229 416
?*Styliola* sp.	4 fragments (= ?1 def. specimen)	RGM 229 417
Spoelia torquayensis	1 juv. specimen (paratype)	RGM 229 418
Torquay, Bird Rock, Otway Basin, Victoria, Australia (Oligocene, Janjukian, Torquay Group, Jan Juc Formation, *Glycymeris* Beds). Sample collected by D. Curry (donated to coll. RGM).		
Limacina curryi	1 specimen (holotype)	NMV P123405
	62 specimens (paratypes)	RGM 229 420-422

Limacina lunata	1 specimen (holotype)	NMV P123406
	7 juv. specimens (paratypes)	RGM 229 424-426
Spoelia torquayensis	1 specimen (holotype)	NMV P123408
	2 specimens (paratypes)	RGM 229 428-429

Torquay, Bird Rock, Otway Basin, Victoria, Australia (Oligocene, Janjukian, Torquay Group, Jan Juc Formation, *Ancilla* Clays). Sample collected by D. Curry (donated to coll. RGM).

Limacina curryi	2 specimens (paratypes)	RGM 229 430

Torquay, Fishermans Steps, Otway Basin, Victoria, Australia (?Oligocene, ?Janjukian, 'lowest beds'). Sample collected by D. Curry (donated to coll. RGM). [Mr Curry, who sampled this locality personally, indicated the level as 'lowest beds', referring to the local outcrop. According to Abele, in Douglas & Ferguson, 1988: 308) the lowermost beds at Fishermans Steps belong to the upper part of the Jac Juc Formation s.str. Dr T.A. Darragh, however, presumes that the shell might as well have been collected from the Puebla Formation. In this latter case the specimen would be of Early Miocene (Longfordian) age].

Vaginella bicarinata	?1 def. juv. specimen	RGM 229 431

South side of Lake Costin, landslip at grid reference 363163, Victoria, Australia (Miocene, ?Longfordian, Fishing Point Marl). Sample collected by D.C. Long, June 12, 1972 (donated in coll. RGM)

Limacina aff. *gramensis*	1 juvenile specimen	RGM 229 432

Altona Bay, SW of Newport near Melbourne on Port Phillip Bay, Victoria, Australia (Miocene, ?Balcombian, see Singleton, 1941, p. 16, map 2; Fyansford Formation). Sample donated by D. Curry. According to Dr T.A. Darragh this material was collected on the spoil heap of a shaft dug for coal. It is therefore possible that younger material is present.

Limacina aff. *gramensis*	4 juv. specimens	RGM 229 433-436
Limacina inflata	40 juv. specimens	RGM 229 437
Styliola subula	8 juv. specimens	RGM 229 438
Vaginella depressa	?1 fragment	RGM 229 439
Vaginella sp.	1 def. specimen	RGM 229 440

Batesford, new quarry, Victoria, Australia (Miocene, Batesfordian to Bairnsdalian, grey clays, see Singleton, 1941, p. 31, line 39; Fyansford Formation). Sample collected by D. Curry (donated to coll. RGM).

Limacina aff. *gramensis*	1 and 2 juv. specimens	RGM 229 441-442
Limacina tertiaria	47 specimens	RGM 229 443
Creseis cf. *chierchiae*	3 def. specimens	RGM 229 444-446
Styliola subula	53 specimens	RGM 229 447-448
Vaginella sp.	1 def. specimen	RGM 229 449

Schnapper Point, Balcombe Bay, Mornington, Victoria, Australia (Miocene, Balcombian to Bairnsdalian, 'blue clays'). Sample collected by R. Tate (?). According to Dr T.A. Darragh this material could also have been collected at localities North of Balcombe Bay.

Limacina tertiaria	4 and 1 juv. specimens (paralectotypes)	SAM T 238/5-6

Schnapper Point, Balcombe Bay, Mornington, Victoria, Australia (level not indicated, but presumably Miocene, Balcombian). Sample collected by R. Tate (?). According to Dr T.A. Darragh this material could also have been collected at localities North of Balcombe Bay.

Styliola subula	2 specimens (paralectotypes of *S. rangiana*)	SAM T 238/5-6

Balcombe Bay, Mornington, Victoria, Australia (Miocene, Balcombian, beds h-k, see Singleton, 1941, p. 27; Fyansford Formation) (stated by Mr D. Curry, in litt., 1988, to be the same locality as the next one). Sample collected by D. Curry (donated to coll. RGM).

Limacina aff. *gramensis*	1 juv. specimen	RGM 229 450
Limacina tertiaria	36 specimens	RGM 229 451
Creseis cf. *chierchiae*	3 specimens, 3 fragments	RGM 229 452-454
Styliola subula	4 specimens	BM(NH) G 74.541
	115 specimens	RGM 229 455
Vaginella depressa	1 and 1 def. specimens	RGM 229 456

Fossil Beach, Balcombe Bay, Mornington, Victoria, Australia (Miocene, Balcombian, Fyansford Formation). Sample collected by D.C. Long, 1970-1971 (donated to coll. NMV and RGM).

Limacina tertiaria	16 specimens	NMV P 116253
	1 def. specimen	RGM 229 457
Creseis cf. *chierchiae*	2 juv. specimens	RGM 229 458
Styliola subula	151 ± def. specimens	NMV P 116252
	102 ± def. specimens	RGM 229 459-460

Vaginella depressa	?4 ± def. specimens	NMV P 116251

Fossil Beach, Balcombe Bay, Mornington, Victoria, Australia (Miocene, Balcombian, Fyansford Formation). Sample collected by D.C. Long, 1970-1971, from interior of *Eutrephoceras* sp. (donated to coll. RGM).

Limacina tertiaria	1 specimen	RGM 229 461
Creseis cf. *chierchiae*	13 juvenile specimens	RGM 229 462
Styliola subula	438 specimens	RGM 229 463
Vaginella depressa	1 fragm.	RGM 229 464

Fossil Beach, Balcombe Bay, Mornington, Victoria, Australia, 38°15' S, 145°02' E, Cranbourne 072 845 (Miocene, Balcombian, Fyansford Formation). Sample collected by P. Rodda.

Styliola subula	1 ± def. specimen	AMS C149.276

Fossil Beach (?), Balcombe Bay, Mornington, Victoria, Australia (just indicated 'Mornington, Port Phillip Bay') (Miocene, Balcombian, Fyansford Formation). Sample collected by T.S. Hall, 1900.

Styliola subula	8 ± def. specimens	AMS C149.277
	1 specimen	BM(NH) not reg.

Red Bluff, Shelford, Shelford-Inverleigh road, grid reference Beeac 064066, FL 69, Victoria, Australia (Miocene, Balcombian, Fyansford Formation). Samples collected by D.C. Long, 23 January 1972 (coll. NMV) and 20 May 1972 (coll. RGM).

Limacina tertiaria	4 specimens	NMV P116254
	5 specimens	RGM 229 465
Styliola subula	4 specimens	RGM 229 466
Vaginella depressa	?1 def. specimen	RGM 229 467

Muddy Creek, Hamilton, Victoria, Australia (without indication of level). Samples collected by (?) R. Tate (coll. SAM), Mr Bailey (coll. AMS) and C.R. Laws (donated by D. Curry to coll. RGM) and unknown [BM(NH) G 9310].

Limacina tertiaria	1 specimen	AMS C143.929
Styliola subula	4 specimens (lecto- and paralectotypes of *S. rangiana* Tate)	SAM T 238/1-4
	1 specimen (paralectotype, found in vial of *V. bicarinata*)	SAM P29781
	2 specimens	AMS C143.929
Vaginella bicarinata	1 def. specimen (holotype)	SAM T 237
Vaginella depressa	1 specimen	SAM P29790
	9 + 29 ± def. specimens	AMS C143.929
	3 and 2 def. specimens	RGM 229 468
	5 and 3 def. specimens	BM(NH) G 9310
Vaginella victoriae	2 and 2 def. specimens (paratypes)	SAM T 235

Muddy Creek, Hamilton, Victoria, Australia (Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation; see Ludbrook, 1973, p. 252). Samples collected by (?) R. Tate.

Limacina inflata	1 juv. specimen (syntype of *L. tertiaria*)	SAM P29787
Limacina tertiaria	8 specimens (lecto- and paralectotypes)	SAM T 239 and P29782-4
Vaginella depressa	5 specimens (lectotype and paralectotypes of *V. eligmostoma*)	SAM T 236 and P29789

Muddy Creek, Hamilton, Victoria, Australia (Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation; see Ludbrook, 1973, p. 252). Samples collected by D.C. Long, 29 May 1971 (coll. NMV) and undated (RGM 229 483), G.W. Kendrick, 24 February 1978 (coll. WAM), Mrs L.C. Schekkerman (RGM 229 484), E.O. Teale [BM(NH) G 60835-41) and unknown [BM(NH) G 9306 and G 9308, and coll. AMS].

Limacina inflata	1 specimen	NMV P122061
Limacina tertiaria	54 specimens	NMV P116255
	9 and ?2 juv. specimens BM(NH) G 9308	
Styliola subula	2 specimens	BM(NH) G 9306
Vaginella depressa	26 and 44 def. specimens	WAM 79.742
	3 def. specimens	RGM 229.484
	4 def. specimens	AMS C149.278
	9 and 7 def. specimens	RGM 229.483
	37 and 8 def. specimens	BM(NH) G60835-41

Muddy Creek, Hamilton, Victoria, Australia (Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation; see Ludbrook, 1973, p. 252). Samples collected by C.R. Laws (donated by D. Curry, RGM

229 482), and donated by D. Curry (other samples in coll. RGM).

Limacina aff. *gramensis*	1 and 8 juv. specimens	RGM 229 469-470
Limacina inflata	44 specimens	RGM 229 471
Limacina tertiaria	55 specimens	RGM 229 472
	5 specimens	RGM 229 482
Styliola subula	19 specimens	RGM 229 473
Vaginella bicarinata	1 def. specimen	RGM 229 474
Vaginella depressa	5 and 10 def. specimens, 3 fragments	RGM 229 475-476
Vaginella victoriae	1 specimen (holotype)	NMV P123409
	7 specimens (paratypes)	RGM 229 478-481

Muddy Creek, Hamilton, Victoria, Australia (Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation; see Ludbrook, 1973, p. 252). Samples collected from interior of *Harpa pulligera* (donated by D. Curry to coll. RGM).

Limacina inflata	4 specimens	RGM 229 485
Limacina tertiaria	29 specimens	RGM 229 486-487
Styliola subula	7 specimens	RGM 229 488-489
Vaginella depressa	7 and 13 def. specimens, several fragments	RGM 229 490

Muddy Creek, Hamilton, Victoria, Australia (Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation; see Ludbrook, 1973, p. 252). Samples collected from interior of *Ancillaria pseudaustralis* (donated by D. Curry to coll. RGM).

Limacina inflata	19 specimens	RGM 229 491-494
Limacina tatei	1 specimen (holotype)	NMV P123407
	1 specimen (paratype)	RGM 229 496
Limacina tertiaria	39, 23 juv. specimens	RGM 229 497-499
Styliola subula	2 specimens	RGM 229 500
Vaginella depressa	1 fragment	RGM 229 501

Muddy Creek, Hamilton, Victoria, Australia (locality indicated as: Clifton Bank; Miocene, Balcombian to Bairnsdalian, Muddy Creek Formation; see Ludbrook, 1973, p. 252). Sample collected by D.C. Long, 29 May 1971.

Styliola subula	12 specimens	NMV P116250

Muddy Creek, Hamilton, Victoria, Australia (locality specified as Muddy Creek, North behind Yulecart Hall, Muddy Creek Formation, Lower Beds, just below base of Upper Beds, Lower Miocene, 'Batesfordian'). Sample collected by W.F. Ponder and E.K. Yoo, 3 March 1977.

Vaginella victoriae	16 def. specimens, several fragments (paratypes)	AMS C124.717

Muddy Creek, Hamilton, Victoria, Australia (Pliocene, Kalimnan, Grange Burn Coquina, but probably reworked from Muddy Creek Formation, or mislabelled). Sample collected by Mrs L.C. Schekkerman.

Vaginella depressa	3 specimens	RGM 229 502

Muddy Creek, Hamilton, Victoria, Australia (locality specified as Muddy Creek, Hamilton, Victoria, SW below Clifton Homestead, in MacDonald's Bank; Pliocene, Kalimnan, Grange Burn Coquina, but probably reworked from Muddy Creek Formation or mislabelled). Sample collected by W.F. Ponder and E.K. Yoo, 4 March 1977.

Styliola subula	1 specimen	AMS C149.280
Vaginella depressa	5 def. specimens, several fragments	AMS C143.928
	17 and 54 def. specimens	AMS C149.281

Annex: Description of *Vaginella sannicola* sp. nov. from the Miocene of Gargano, Italy

Vaginella sannicola sp. nov.
Pl. 9, figs. 7-9.

. 1921 *Vaginella depressa* Daudin - Checchia-Rispoli, p. 15, fig. 6 (non Daudin).
. 1968 *Vaginella depressa* Daudin, 1800 - Sirna, p. 424, fig. 12a-b (non Daudin; excl. syn.).
. 1979 *Vaginella* aff. *depressa* Daudin, 1800 - d'Alessandro et al., p. 86, figs. 23-24.
. 1980 *Vaginella eligmostoma* Tate - d'Alessandro & Robba, p. 623, pl. 63, figs. 4-5, pl. 64, figs. 1-5 (non figs. 6-7 = *V. depressa* Daudin), pl. 65, figs. 1-3 (non Tate).
. 1982 *Vaginella eligmostoma* Tate - Bernasconi & Robba, p. 217 (non p. 215 = *Vaginella depressa* Daudin) (non Tate).

Holotype — Plate 9, fig. 7, RGM 229 540.
Type locality — San Nicola Varano (Italy, Puglia, Gargano), abandoned limestone quarry.
Stratum typicum — Miocene, Late Serravallian to Late Tortonian, Lago di Varano Formation. D'Alessandro & Robba (1980) suppose on the basis of planktonic foraminifers that the pteropods from this locality are reworked from deposits of Late Langhian to Early Serravallian age.
Derivatio nominis — This new species is named after its type locality.

Description — For a general description the reader is referred to d'Alessandro & Robba (1980, p. 623). All available material is preserved in the form of phosphatic internal moulds on which the embryonal shell parts and the apertural margins are missing. *Vaginella sannicola* resembles *V. depressa* closely, inclusive of the wide variability in the H/W ratio (see measurements in d'Alessandro & Robba, 1980), but it is strikingly small (height 3-4 mm). A further important difference is the width of the aperture, which is consistantly smaller than the diameter of the inflated shell-part. The dorsal apertural folds are less widely separated than in *V. depressa.*

Material studied — San Nicola Varano (Italy, Puglia, Gargano), abandoned limestone quarry (Miocene, Late Serravallian to Late Tortonian, but possibly reworked from sediments of Late Langhian to Early Serravallian age): holotype and 2 paratypes (Pl. 9, figs. 7-9), 185 paratypes (all specimens preserved as phosphatic internal moulds), leg. M. van den Bosch, 1970, RGM 229 540-543.

Melpignano (Italy, Puglia) (Miocene, Late Serravallian, Calcareniti di Andrano 'Pietra Leccese', possibly reworked from Late Langhian to Early Serravallian sediments): 4 paratypes (phosphatic internal moulds), don. E. Robba, June 1984, RGM 229 545.

Malta (Miocene, undetermined horizon, possibly *Globigerina* limestone): 2 paratypes, don. E. Robba, June 1984, RGM 229 544.

Discussion — The present species was identified (see list of synonyms above) with Tate's Australian species *V. eligmostoma.* In the present paper it is concluded, that at least the type specimen of *V. eligmostoma* cannot be separated from *V. depressa.* As there are consistant differences between the Italian *Vaginella* and *V. depressa* it must be concluded that the former is a new species.

V. sannicola is found, in several Italian localities, in a quite rich association of pteropod species. The age indicated by this assemblage is not conform the age indicated by the planktonic Foraminifera (see details in d'Alessandro & Robba, 1980), and therefore the pteropods were supposed to be reworked after phosphatization. This conclusion, however, is not supported by the state of preservation of the material, which does not show any sign of transport. Furthermore the pteropod specimens were not collected in a basal conglomerate nor was there a sedimentary structure indicative of redeposition. I wonder if any other explanation of the supposed discrepancy in age might be possible. The very common occurrence of the species *Vaginella austriaca* in the Italian material strongly suggests an ultimate Burdigalian to Langhian age, which is supported by the presence of the benthic gastropod *Eudolium* sp. in the San Nicola Varano locality (RGM collection). It might be useful to make a new approach in this problem by consulting a further fossil group, as e.g. the nannoplankton of dinoflagellates.

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