EOCENE BIVALVES AND GASTROPODS FROM THE PALLINUP SILTSTONE, WESTERN AUSTRALIA, WITH NEW RECORDS FROM THE EOCENE AND OLIGOCENE OF SOUTHEASTERN AUSTRALIA

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New species and new records of bivalves and gastropods (Patellogastropoda, Vetigastropoda) from the Middle Eocene to Early Oligocene of southern Australia are presented. The study material is mostly from the Pallinup Siltstone (Late Eocene) with supplementary contributions from the Werillup Formation, Blanche Point Formation, Browns Creek Formation, Glen Aire Clay and Jan Jue Formation. Extensions of stratigraphic range and/or first Eocene records for Australia are recorded for 15 genera, including a first possible fossil record for the Thysanodontinae. A post-Eocene age for the Quagering Beds is indicated from fossil evidence. A neotype is selected for *Liotia lamellosa* Tenison Woods, 1877 and *L. roblini* Johnson, 1880. Newly described and named taxa from the Pallinup Siltstone are *Plicatula (P.) emaciata*, *Homalopoma (H.) limnaios*, *Tricolia psilia*, *Danilia vialis*, *Micrelenchus (Plumbelenchus) armulatus*, *Calliostoma (Fautor) annapum*, *Trochachlis stillata*, *Leucorhynchia rotulina* and *L. ventricosa*. *Pseudoniuella? squarrosa*, *Collonia variabilis* (Browns Creek Formation), *Danilia euglypta* (Jan Jue Formation) and *Micrelenchus (Plumbelenchus) lirulatus* (Glen Aire Clay) are described from the Otway Basin, Victoria.

Key words: Mollusca, Late Eocene, southern Australia, taxonomy, new taxa.

EOCENE MOLLUSCA are common in the Plantagenet Group of the Bremer Basin, southwestern Western Australia. This paper presents new records and descriptions of new species of bivalve and gastropod (Patellogastropoda, Vetigastropoda) molluscs, principally from the Pallinup Siltstone of that group, together with supplementary contributions from other regions of southern Australia. It enlarges upon an earlier study (Darragh & Kendrick 1980), which was confined to bivalves from the Pallinup Siltstone of North Walpole, Western Australia. That locality has provided most of the new material described below. Remaining gastropod groups (Mesogastropoda, Neogastropoda, etc.) will be the subject of a further paper.

Our previous contribution (1980) recorded 23 bivalve species from the North Walpole deposit. Further collecting has produced an additional seven species from that locality, making a new total of 30 bivalve species. We also report 21 vetigastropod and one species of caenogastropod from North Walpole (including one species described by Beu & Ponder 1979: 20–21), giving a progressive total of 51 species of Mollusca from that source. Of these, one bivalve and eight gastropod species from North Walpole are described and named below. Four other gastropod species, all congeneric with particular North Walpole taxa, are also formally described. These are from the Browns Creek Formation, Glen Aire Formation (both Otway Basin) and Jan Jue Formation (Port Phillip Basin) in Victoria.

The study material has been drawn from seven localities in the Plantagenet Group (one reworked), Bremer Basin and others from the Otway, Port Phillip and Bass basins. Distributional data for each species is summarised in Table 1. All specimens cited herein are registered in the collections of the Western Australian Museum (WAM) and Museum of Victoria (NMV).

PRESERVATION

North Walpole fossil molluscs are mostly preserved as siliceous replacements, with or without distortion, of the original carbonate structures, as has been described in detail by Darragh & Kendrick (1980). Some specimens are not well preserved, so that fine details such as protoconch sculpture are missing. New material from the Lueky Bay deposit, east of Esperance, Western Australia, is

	A		B			C	D					E		F
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
BIVALVES														
1. *Nucula tatei* Finlay		x			x		x	x						
2. *Nuculana (Saccella) chapmani* Finlay		x			x		x	x						
3. *Sarepta planiuscula* (Tate)		x			x				x					
4. *Arca pseudonavicularis* Tate		x			x			x						
5. *Barbatia (B.) limatella* Tate	x	x			x			x						
6. *Barbatia (Acar) gunsoni* Darragh & Kendrick	?	x			x									
7. *Notogrammatodon cainazoicus* (Tate)	x	x			x	x	x	x	x	x	x			x
8. *Arcopsis dissimilis* (Tate)		x			x		x							
9. *Limopsis (L.) chapmani* Singleton	x	x			x		x	x	x					
10. *Limopsis (L.) multiradiata* Tate		x			x		x	x						
11. *Tucetona lenticularis* (Tate)	x	x	x		x		x	x	x					
12. *Limarca angustifrons* Tate		x			x				x					
13. *Septifer (S.) subfenestratus* Basedow		x			x									
14. *Vulsella laevigata* Tate		x		x										
15. *Plicatula (P.) emaciata* sp. nov.		x												
16. *Anomia (A.) cymbula* Tate		ef			x									
17. *Spondylus gaderopoides* MeCoy		ef		x				x				x		
18. *Dimya sigillata* Tate		x			x			x	x					
19. *Limea (Genellima?)* sp.		x												
20. Limid, genus and species undetermined		x												
21. *Epicodakia* sp.		x												
22. *Venericardia (Rotundicardia) latissima* (Tate)		x			x		x	x						
23. *Cyclocardia (Vimentum?)* sp.		x												
24. *Salaputium communis* (Tate)		x			x		x	x	x					
25. *Vepricardium (Hedecardium) monilefectum* (Tate)		?			x									
26. *Glossus (Miocardiopsis)* sp.		x												
27. *Dosinia multilamellata* (Tate)		x			x			x				x		x
28. *Corbula (Caryocorbula) pixidata* Tate		x			x		x	x	x					
29. *Verticordia* sp. A		x												
30. *Verticordia* sp. B		x												
GASTROPODS														
31. *Nacella (?) jutsoni* (Chapman & Crespin)		x												
32. *Emarginula* (?) sp.		x												
33. *Liotina lamellosa* (Tenison Woods)	x	x					x		x		x	x		x
34. *Pseudoninella? squarrosa* sp. nov.								x						
35. *Pseudoninella?* sp.	x	x												
36. *Collonia variabilis* sp. nov.								x						
37. *Homalopoma (H.) limnaios* sp. nov.		x												
38. *Eutinochilus otwayensis* (Pritchard)	x	x			x			x	x					
39. *Turbo (Euninella)* sp. cf. *T. (E.) hamiltonensis* Harris		x												
40. *Bolma (B.) flindersi darraghi* Beu & Ponder		x					x							
41. *Astralium?* sp.		x												
42. *Tricolia psilia* sp. nov.		x												
43. *Danilia vialis* sp. nov.		x												
44. *Danilia euglypta* sp. nov.												x		
45. *Agathodonta* (?) sp.		x												
46. *Micrelenchus (Plumbelenchus) armulatus* sp. nov.		x			x									
47. *Micreleuchus (P.) lirulatus* sp. nov.									x					
48. *Clanculus* (s.l.) sp.		x												
49. *Calliostoma (Fautor) numapum* sp. nov.		x												

Table 1 continued next page

	A		B			C	D					E		F
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
GASTROPODS (*continued*)														
50. *Calliostoma* (s.l.) sp.		x												
51. *Carinastele* (?) sp.		x												
52. Trochid, genus undetermined Species A		x												
53. Trochid, genus undetermined Species B		x												
54. *Trochaclis (?) stillata* sp. nov.		x												
55. *Leucorhynchia rotulina* sp. nov.	x	x												
56. *Leucorhynchia ventricosa* sp. nov.		x												
57. *Circulus* sp.		x												
Totals	8	53	1	2	22	1	12	17	11	1	2	4	1	2

Table 1. Stratigraphic ranges (Middle Eocene to Middle Miocene) of selected bivalves and gastropods from southern Australia. Sources: Ludbrook (1961, 1965); Darragh & Kendrick (1980); Darragh (1985, this paper); WAM collections. A, Bremer Basin; B, St Vincent Basin; C, Murray Basin; D, Otway Basin; E, Port Phillip Basin; F, Bass Basin. 1, Werillup Formation; 2, Pallinup Siltstone; 3, South Maslin Sand; 4, Tortachilla Limestone; 5, Blanche Point Formation; 6, Morgan Limestone (Cadell Marl Member); 7, lower Browns Creek Formation; 8, upper Browns Creek Formation; 9, lower Glen Aire Formation; 10, Gellibrand Formation; 11, Muddy Creek Formation; 12, Jan Juc Formation; 13, Fyansford Formation; 14, Freestone Cove Sandstone.

similarly preserved, likewise a small collection of specimens from a locality east of Northcliffe, Western Australia. All of this siliceous material is assigned to the Pallinup Siltstone.

Specimens from two other Pallinup localities, Green Range and Lort River, are moulds, which is the more usual form of preservation of mollusean fossils at these localities. Latex casts have provided the figures in these examples.

Specimens from the Oeumup No. 1 deep well, located near Bremer Bay, are assigned to the Werillup Formation and occur as undeformed carbonate shells, in which the original aragonite seems essentially unmodified.

All other material described from sources in southeastern Australia occur as unmodified aragonitic shells.

PALAEOECOLOGY, PALAEOGEOGRAPHY, CORRELATION

Relevant comments on palaeoecology, palaeogeography and correlation have been noted in the discussion of individual species below and we defer a comprehensive account of these questions until taxonomic evaluation of the remaining gastropods is completed. By way of some preliminary observations, it is noted (see Table 1) that of the 30 bivalve species now recorded by us from the Plantagenet Group, about 20 (67%) also occur in the Blanche Point Formation of the St Vincent Basin: about 14 (47%) are known from the upper Browns Creek Formation, 10 (33%) from the lower Browns Creek Formation and 8 (27%) from the lower Glen Aire Formation, all Otway Basin. Eight of the bivalve species (27%) are as yet known only from the Pallinup Siltstone.

Distributional patterns of the gastropods reported here differ somewhat from those of the bivalves. Of the 23 species recorded below from the Plantagenet Group, no less that 19 (83%) are as yet unknown elsewhere, suggesting a much higher degree of endemism when compared with the bivalves (Table 1). However, this may reflect collection and other bias, in view of the small to minute size of some of the Vetigastropoda and the difficulties in establishing identifications for many of them.

Extensions of stratigraphic range and/or first Eocene records for Australia are presented for 17 genera or subgenera. These are: *Nacella*, *Vinentnia*, *Emarginula*, *Angaria*, *Eminella*, *Astralium*, *Tricolia*, *Homalopoma*, *Danilia*, *Agathodonta*(?), *Micrelenchus (Plmabelenchus)*, *Clanculus*, *Calliostoma (Fautor)*, *Carinastele*? (first 'fossil record for the Trochidae : Thysanodontinae), *Trochaclis*(?) and *Leucorhynchia*.

Definitive correlations of the Middle and Late Eocene of the Bremer Basin, based on local and standard planktonic foraminiferal biostratigraphy, are yet to be established and this is particularly true for the Pallinup Siltstone (McGowran 1989). However, the Nanarup Limestone Member of the Werillup Formation is associated by McGowran (1989: 50–52, figs 2, 8) with the Tortachilla Transgression of the Middle to Late Eocene, straddling the Johannian–Aldingan Stages boundary.

Foraminifera in the coarse residues from Ocumup No. 1 include *Lenticulina* and *Operculina* as the most common forms. Less common are *Pseudopolymorphina carteri* Quilty and *Linderina glaessneri* Quilty. The assemblage characterises the Tortachilla transgression (McGowran 1989) of late Middle Eocene age, cycle TA4.1, ~39 Ma. (B. McGowran, pers. comm., 21 January 1997).

We report for the first time fossil material from the Quagering Beds of Finkl & Fairbridge (1979), which occur typically as sheet deposits of quartz gravels in a coarse sandy matrix, located widely across the Ravensthorpe Ramp (Cope 1975) of southern Western Australia, often in proximity to occurrences of the Plantagenet Group.

Fossils collected from the Quagering Beds near Northeliffe comprise a sponge and silicified gastropods of Eocene character, including the sponge-associated *Tenagodus* sp. and *Nacella jutsoni* (Chapman & Crespin), the latter examined below. These have been reworked into the Quagering Beds presumably from an adjacent Pallinup Siltstone source, yet to be located. The reduced level of this locality lies within the range of 120–140 m above sea level. A post-Eocene age for these quartz gravels is therefore indicated, apparently subsequent to the silicification of the Pallinup, which may have occurred in the Oligocene. At that time, the Darling Plateau experienced epeirogenic uplift of *c.* 50 m (Cope 1975) with consequent erosion and stream incision.

Spondylus gaderopoides, additional to the above, is recorded from the Wilson Bluff Limestone, Abrakurrie Limestone and Colville Sandstone, all of the Eucla Basin (Lowry 1970; Darragh & Kendrick 1980). *Venericardia (Rotundicardia) latissima* is cited in Darragh & Kendrick (1980) as *Glans (Fasciculicardia) latissima* and in Darragh (1985) as *Glans latissima*.

LOCALITIES

(see Fig. 1)

(a) Western Australian Museum

Bremer Basin

1. North Walpole. For a detailed locality description see Darragh & Kendrick (1980: 7). Located in a poorly drained sandy depression 26 km north along Thompson Highway from Walpole townsite. Map reference: Deep River (1 : 100 000 series) 743486. Reduced level 124 m above AHD. Collected V. A. Ryland, T. A. Darragh and G. W. Kendrick, 14–16 October 1981. Pallinup Siltstone, Late Eocene.

2. Lucky Bay via Esperance. Track surface (ripped prior to revegetation) 4.3 km SE from Frenchman Peak and 0.1 km downslope (NW) from road to Lucky Bay, Cape Le Grand National Park. Map reference: Merivale (1 : 100 000 series) 264386. Collected V. A. Ryland, A. F. Longbottom and G. W. Kendrick, 7 October 1980; A. F. Longbottom, 11 July 1983 and 29 January 1984. Pallinup Siltstone, Late Eocene.

3. Green Range. Plantagenet Location 6475 on Litho 350/80. Collected P. G. Quinn, 1975. Pallinup Siltstone, Late Eocene.

4. Lort River. Near farm dam *c.* 0.5 km E of River and 0.1 km S of Albany–Esperance Highway. Map reference: Stokes Inlet (1 : 100 000 series) 388648. Collected J. Pas, June 1986. Pallinup Siltstone, Late Eocene.

5. Northcliffe. Nine miles (14.5 km) E of Northcliffe townsite on W side of Eggling Road, Nelson Location 10366. W side Canterbury River; quartzose gravel in shallow excavation and adjacent creek bed. Collected G. Gardner, 1967; G. Gardner and A. Jackson, June 1968 and 1 March 1970; G. Gardner, T. A. Darragh and G. W. Kendrick, 15 March 1969. Gravel contains reworked silicified fossil material (sponges, molluses) apparently derived from unknown Eocene source, presumably Pallinup Siltstone. Gravels represent Quagering Beds of Finkl & Fairbridge (1979). An attempt to relocate this locality in 1995 was unsuccessful, due to extensive road construction and track realignments; area is mostly heavily forested.

6. Ocumup No. 1 deep well. Exploratory well (tenement E-68), drilled June 1976 by SILFAR, located at 34°23′45″S,119°12′53″E. Map reference: Bremer (1 : 100 000 series) QG 036918. Log details copied from the Index Sheet are:

depth (m)	lithology	stratigraphy
0–12	sand, clay	Quaternary
12–34	spongolite	Pallinup Siltstone
34–73	siltstone, calcarenite, sand, lignite	Werillup Formation
73–81	sandstone	basal sandstone
81	granite, gneiss	Precambrian

Twenty-seven samples from this bore are held at the Western Australian Museum, of which eight are assigned to the Pallinup Siltstone and 17 to the Werillup Formation.

7. Nanarup Lime Quarry, near head of Taylor Inlet, beside road to Nanarup, east of Albany. Map reference: Manypeaks (1 : 100 000 series) 967285. Werillup Formation, Nanarup Limestone Member, Middle (?) Eocene.

(b) Museum of Victoria

Otway Basin

8. PL 3011 BCI, 9.6 m dark clay with *Turritella* below greensand in Washout 1, nearest mouth of Browns Creek, Johanna, Victoria. Map reference: Glen Aire (1 : 25 000 series) 079058. Browns Creek Formation, Late Eocene (Aldingan).

9. PL 3013 BCIII, dark gritty clay 16 m above greensand in Washout 1 nearest mouth of Browns Creek, Johanna, Victoria. Map reference: Glen Aire (1 : 25 000 series) 079058. Browns Creek Formation, Late Eocene (Aldingan).

10. PL 3014 BCIII, dark gritty clay in Washout 2, forked gully nearest mouth of Johanna River, Johanna, Victoria. Map reference: Glen Aire (1 : 25 000 series) 079059. Browns Creek Formation, Late Eocene (Aldingan).

11. PL 3019 G.S.V. loc. Awl, slips immediately north of Point Flinders, near Cape Otway, Victoria. Map reference: Glen Aire (1 : 25 000 series) 162983. Glen Aire Clay, Early Oligocene.

12. PL 3024. Cliff section opposite Bird Rock, below Bird Rock cap, Torquay, Victoria. Map reference: Torquay (1 : 25 000 series) 642518. Jan Juc Formation, Late Oligocene (Janjukian).

St Vincent Basin

13. Silicified specimens from cherty band about 2.5 m above base of formation at Uncle Toms Cabin, Maslin Bay, South Australia. Map reference: Noarlunga (1 : 50 000 series) 696970. Blanche Point Formation, Late Eocene (Aldingan).

SYSTEMATIC PALAEONTOLOGY

Class Bivalvia Linnaeus, 1758

Subelass Palaeotaxodonta Korobkov, 1954

Order Nuculoida Dall, 1889

Superfamily Nuculanoidea H. & A. Adams, 1858

Family Sareptidae A. Adams, 1860

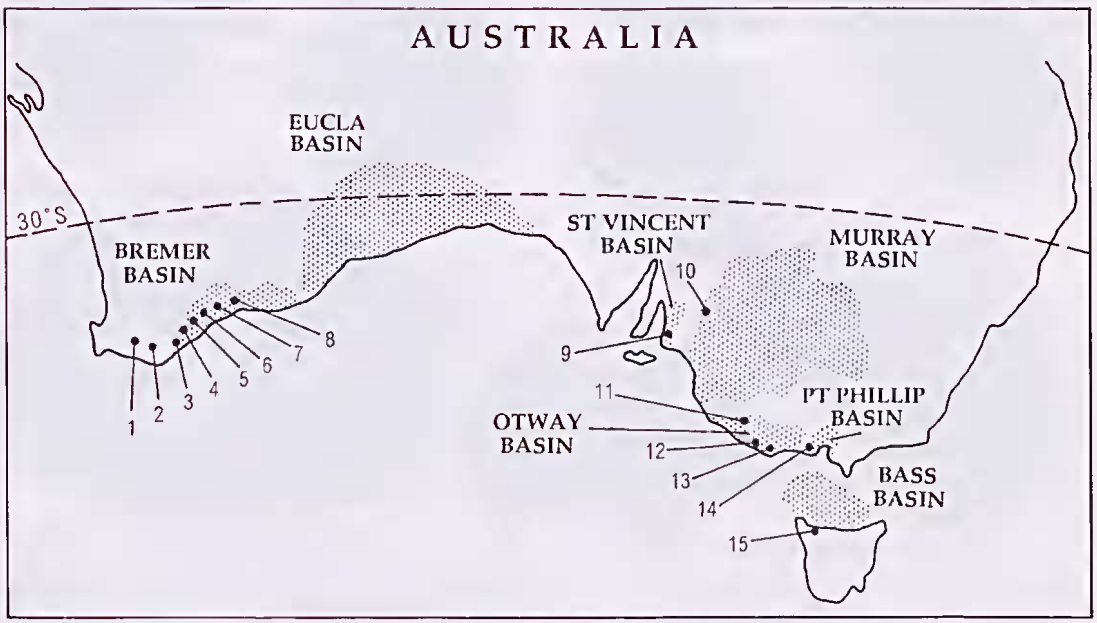


Fig. 1. Onshore sedimentary basins of southern Australia. Localities: 1, Northcliffe; 2, North Walpole; 3, Albany; 4, Nanarup; 5, Green Range; 6, Ocumup; 7, Lort River; 8, Lucky Bay; 9, Blanche Point–Maslin–Aldinga; 10, Morgan; 11, Hamilton; 12, Browns Creek–Johanna River; 13, Pt Flinders; 14, Torquay; 15, Table Cape.

Subfamily Sareptinae A. Adams, 1860

Genus **Sarepta** A. Adams, 1860

Type species. Sarepta speciosa A. Adams, 1860. By monotypy. Recent, Korea Strait.

Sarepta planiuscula (Tate, 1886)

Fig. 2I

Leda planiuscula Tate, 1886: 130, pl. 5, fig. 2.
Sarepta planiuscula—Chapman & Singleton, 1927: 116, pl. 10, figs 8–12; Darragh, 1985: 111, table 1.
Ovaleda planiuscula—Ludbrook, 1961: 61, pl. 3, figs 3, 4.

Material. WAM 83.2606. Two conjoined pairs.

Description. The species agree in external characters with the revised description of the species in Ludbrook (1961). Internal characters not seen.

Dimensions

	Length	Height	Inflation
WAM 83.2606, pair	4.91	3.69 (est.)	1.75

Discussion. This rare species, widely distributed across southern Australian waters during the Late Eocene–Early Oligocene, is as yet unknown from the Browns Creek Formation. In New Zealand, the genus is recorded from Middle to Late Eocene and Early Miocene (Beu & Maxwell 1990: 393). It is included in the Tethyan–Indo Pacific element by Darragh (1985: 90–91, 111, table 1).

Occurrence. Otway Basin: lower Glen Aire Clay, Early Oligocene. St Vincent Basin: 'Adelaide Bore' (= Kent Town Bore), Kent Town (type), Blanche Point Formation, Late Eocene. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Subclass Pteriomorpha Buerlen, 1944

Order Arcoida Stoliczka, 1871

Superfamily Arcoidea Lamarck, 1809

Family Arcidae Lamarck, 1809

Genus **Area** Linnaeus, 1758

Type species. Arca noae Linnaeus, 1758. By subsequent designation of Schmidt, 1818 (I.C.Z.N. Opinion 189).

Area pseudonavicularis Tate, 1886

Fig. 2A–B

Arca pseudonavicularis Tate, 1886: 139, pl. 11, fig. 8; Ludbrook, 1965: 94, pl. 3, figs 30, 31; Darragh & Kendrick, 1980: 9, fig. 2G; Darragh, 1985: 101, 111, table 1.

Material. WAM 83.2577, 2 LVs, 1 deformed pair, 3 fragments. Six specimens all from North Walpole.

Description. Walpole specimens agree closely with the revised description of the species by Ludbrook (1965).

Dimensions

	Total length	Length hinge margin	Height	Inflation
WAM 83.2577a, LV	13.52	9.82	5.35	3.18

One fragment in the study material would have an estimated original length in excess of 30 mm and probably larger than that of the holotype.

Discussion. The new material from North Walpole allows a better illustration of the species than was previously possible (Darragh & Kendrick 1980). The genus, which persisted until the Pliocene in southern Australian waters (Ludbrook 1954) and in New Zealand up to the Castlecliffian (Beu & Maxwell 1990), has been regarded as a tropical element by Ludbrook (1954) and by Beu & Maxwell (1990); however Darragh (1985) groups it with cosmopolitans.

Occurrence. Otway Basin: upper Browns Creek Formation, Late Eocene. St Vincent Basin: Blanche Point Formation (type), Late Eocene. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Genus **Notogrammatodon** Maxwell, 1966

Type species. Pseudogrammatodon (Notogrammatodon) inexpectatus Maxwell, 1966. By original designation. Late Eocene, New Zealand.

Notogrammatodon cainozoicus (Tate, 1886)

Fig. 2C

Macrodon cainozoicus Tate, 1886: 143, pl. 10, fig. 4.
Arca (Plagiarca) cainozoica—Harris, 1897: 335.
Barbatia (Plagiarca) cainozoica—Ludbrook, 1965: 101, pl. 5, figs 1–9.
Notogrammatodon cainozoica—Darragh, 1985: 100, 111, table 1.

Material. WAM 83.2580, one juvenile LV, one medium-sized LV (lacking antero-ventral area) and one fragment (LV). Three specimens.

Description. The material agrees with the revised description of the species in Ludbrook (1965). The posterior teeth are horizontal, anterior convergent on a point well below the beak and median area edentulous. The distinctive external sculpture of predominant transverse ribs and finer, discontinuous radials is well preserved.

Dimensions	Length of shell	Length hinge margin	Height	Inflation
WAM 83.2580a	17.33	13.50	8.42	2.92

Discussion. Rare at North Walpole, the speeies is here recorded from the Bremer Basin for the first time. The two smaller speeimens have dissimilar gastropod boreholes, one bevelled—natieiform, the other of cylindrieal form.

N. cainozoicus is elosely related to the only known eongener, *N. inexpectatus* Maxwell, 'differing in being less oblique, in having the anterior end sloping baekwards sharply and in details of dentition' (Maxwell 1966: 440). The genus is ineluded in Darragh's Australian–New Zealand element (Darragh 1985: 88–90, fig. 6).

Occurrence. Port Phillip Basin: Fyansford Formation, Baleombian. Otway Basin: lower and upper Browns Creek Formation, Late Eoeene; lower Glen Aire Clay, Early Oligoeene; Gellibrand Formation, Bairnsdalian; Muddy Creek Formation (type), Baleombian. Murray Basin: Morgan Limestone (Cadell Marl Member), Balcombian. St Vineent Basin: Blanehe Point Formation, Late Eocene. Bremer Basin: Ocumup No. 1 deep well, 71.7 m. Werillup Formation, Middle Eoeene; North Walpole, Pallinup Siltstone, Late Eocene.

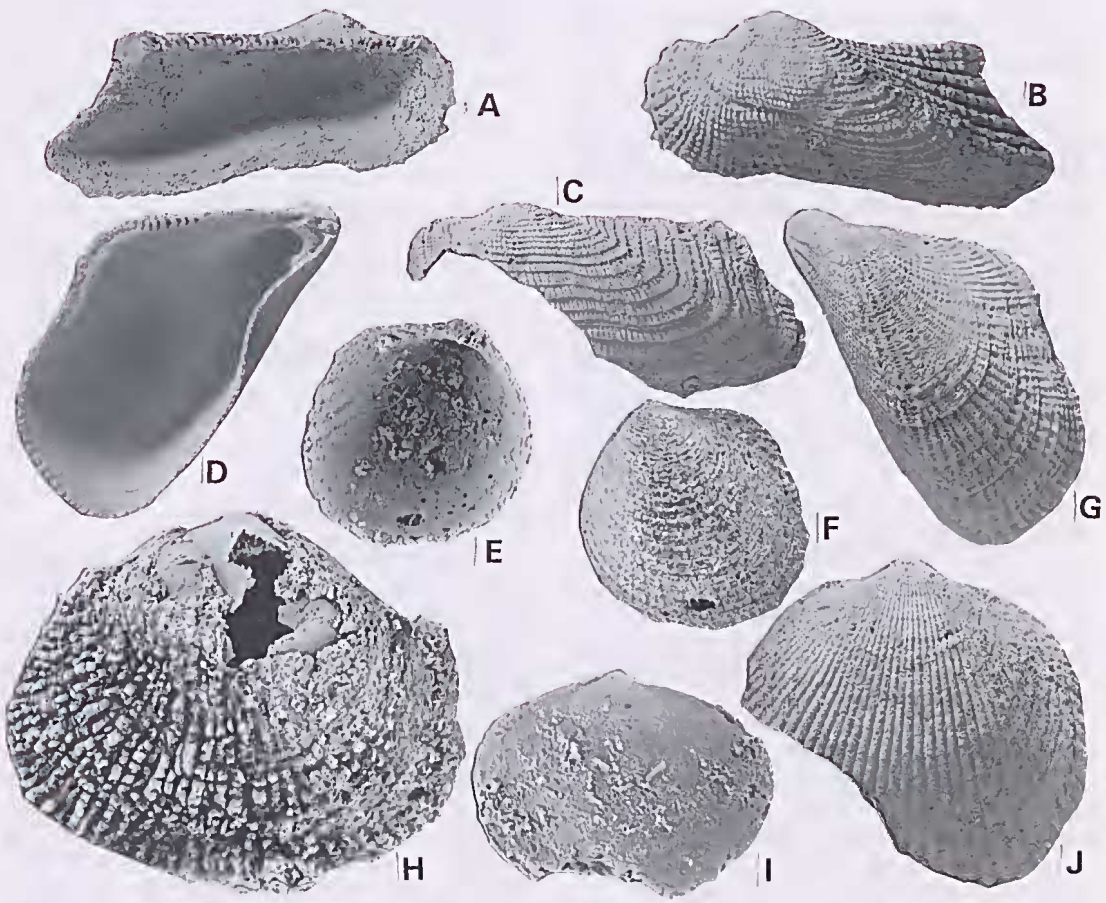


Fig. 2. A–B, *Arca psendonavicularis* Tate. WAM 83.2577a, LV interior, exterior, × 4. C, *Notogrammatodon cainozoicus* (Tate). WAM 83.2580a, LV exterior, × 3. D, G, *Septifer (Septifer) subfenestratus* Basedow. WAM 83.2586a, LV interior, exterior, × 3. E–F, *Limarca angustifrons* Tate. WAM 83.2600, LV interior, exterior, × 8.2. H, *Anomia (Anomia)* sp. cf. *A. (A.) cymbula* Tate. WAM 83.2592, LV exterior, × 6.4. I, *Sarepta planiuscula* (Tate). WAM 83.2606a, LV, exterior, × 8. J, *Tucetona lenticularis* (Tate). WAM 86.1632, LV exterior (latex peel), × 2.1.

Superfamily Limopsoidea Dall, 1895

Family Limopsidae Dall, 1895

Genus **Limopsis** Sassi, 1827

Type species. *Arca aurita* Brocchi, 1814. By original designation. Pliocene–Recent, N. Atlantic–Mediterranean.

Subgenus **Limopsis**

Limopsis (Limopsis) chapmani Singleton, 1932

Limopsis chapmani Singleton, 1932: 296–299, pl. 24, figs 12–14, pl. 25, fig. 16; Ludbrook, 1965: 83–84, pl. 1, figs 1–9. Synonymy; Darragh, 1985: 111, table 1.
Limopsis (Limopsis) chapmani—Darragh & Kendrick, 1980: 13, fig. 2O–R.

Material. WAM 95.391, 95.403, 95.429. Four juvenile valves.

Discussion. Specimens from the Plantagenet Group are invariably smaller and thinner than those from other regions. The species, which is the most common bivalve at North Walpole, is here recorded for the first time from the Werillup Formation.

Occurrence. Port Phillip Basin: Jan Jue Formation (type), Late Oligocene–Early Miocene. Otway Basin: lower and upper Browns Creek Formation, Late Eocene; lower Glen Aire Clay, Early Oligocene. St Vincent Basin: Blanche Point Formation, Late Eocene. Bremer Basin: Ocumup No. 1 deep well, 53.4–68.6 m, Werillup Formation, Middle Eocene; North Walpole, Pallinup Siltstone, Late Eocene.

Family Glycymerididae Newton, 1922

Genus **Tucetona** Iredale, 1931

Type species. *Pectunculus flabellatus* Tenison Woods, 1878. By original designation. Recent, southeast Australia.

Tucetona lenticularis (Tate, 1886)

Fig. 2J

Pectunculus lenticularis Tate, 1886:138, pl. 11, fig. 1.
Glycymeris lenticularis—Chapman & Singleton, 1925: 31, pl. 1, fig. 8a–b, pl. 4, fig. 6; Darragh, 1985: 111, table 1.
Glycymeris (Tucetona) lenticularis—Ludbrook, 1965: 93, pl. 3, figs 11–13.

Material (Bremer Basin). WAM 83.2583, 86.1632, 95.417, 95.425. One external mould, one incomplete juvenile valve and 12 fragments.

Discussion. The type material from the Blanche Point Formation has been redescribed and figured by Ludbrook (1965). Specimens identified with this species from the Plantagenet Group are here recorded for the first time; there it appears to be uncommon and poorly preserved. Rib counts are 36 and 44 (Pallinup Siltstone) and 33 and 35 (Werrilup Formation), within the range of variation ('usually from 30 to 50') reported by Ludbrook (1965).

Occurrence. Otway Basin: lower and upper Browns Creek Formation, Late Eocene; lower Glen Aire Clay, Early Oligocene. St Vincent Basin: South Maslin Sand, Middle Eocene; Blanche Point Formation (type), Late Eocene. Bremer Basin: Ocumup No. 1 deep well, 71.7–73.2 m, Werillup Formation, Middle Eocene. North Walpole and Lort River district, Pallinup Siltstone, Late Eocene.

Family Philobryidae Bernard, 1897

Genus **Limarca** Tate, 1886

Type species. *Limarca angustifrons* Tate, 1886. By monotypy. Late Eocene, Adelaide district, South Australia.

Limarca angustifrons Tate, 1886

Fig. 2E–F

Limarca angustifrons Tate, 1886: 135, pl. 8, fig. 5a–b; Darragh, 1985: 111, table 1.

Materials. WAM 83.2600, one LV.

Description. Shell small, roundly sub-rhomboidal, slightly higher than long, extended and slightly alate posteriorly; umbone moderately inflated, slightly prosogyrate, projecting above dorsal margin; beak incurved, prosogyrate, close to anterior end of straight dorsal margin; prodissoconch small; anterior and ventral margins evenly rounded; posterior margin obliquely and roundly subtruncate, meeting dorsal margin at obtuse angle; sculpture of low, flattened, transverse costellae and incised, linear interspaces, numbering *c.* 20 in height of 3.9 mm; radial sculpture obscure, poorly preserved, confined to ventral area; hinge comprises three raised, slightly oblique, parallel teeth below beak and about three short, sub-horizontal, posterior teeth, well spaced from anterior series and set on a narrow hinge plate; posterior and postero-ventral margin internally crenulate, elsewhere poorly preserved; adductor scars not seen.

Dimensions	Length	Height	Inflation
WAM 83.2600, LV	3.78	3.90	1.08

Discussion. The single specimen to hand from North Walpole of this rare species compares satisfactorily with Tate's description and figures, despite imperfect preservation in some parts. The genus, apparently monotypic, belongs with Darragh's (1985: 92) Southern Australian Endemic Element. It is unknown after the Early Oligocene. The genus *Limarca* differs from the speciose *Philobrya* Carpenter in features of the hinge, shape and sculpture. In the latter genus, the anterior and posterior series of teeth are more or less proximate on a wide hinge plate; the shell is sub-mytiliform and carries spaced radial sculpture across the disc; the prodissoconch is also larger.

Occurrence. Otway Basin: lower Glen Aire Clay, Early Oligocene. St Vincent Basin: Blanche Point Formation (type), Late Eocene. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Order Mytiloida Férussac, 1822

Superfamily Mytilodea Rafinesque, 1815

Family Mytilidae Rafinesque, 1815

Subfamily Mytilinae Rafinesque, 1815

Genus **Septifer** Réeulz, 1848

Type species. Mytilus bilocularis Linnaeus, 1758. By subsequent designation of Stoliczka, 1871. Recent, Indo-SW Pacific.

Subgenus **Septifer** s. str.

Septifer (Septifer) subfenestratus
Basedow, 1904

Fig. 2D, G

Septifer subfenestratus Basedow, 1904: 251–252, text fig.
Septifer (Septifer) sp. cf. *S. (S.) fenestratus* Tate. Darragh & Kendrick, 1980: 13, fig. 3A–C.

Material. WAM 67.84, 69.109, 69.110, 74.551, 76.1, 83.2586. Total of three RVs, one LV, one conjoined pair (deformed), associated internal and external moulds and 21 fragments. NMV P40639, P40655.

Description. Small for genus, thin, triangularly mytiliform, compressed and sub-acute anteriorly, expanded dorso-posteriorly; umbone compressed, high, rostrate, with slight spiral twist; beaks terminal; postero-dorsal area alate; ventral area short, almost normal to commissural plane and bordered by angulate shoulder; dorsal margin straight, meeting slightly concave postero-dorsal margin at 125–145°; posterior margin roundly sub-truncate; ventral margin sinuate with prominent byssal sinus at anterior fourth; sculpture of fine, close, divaricate, bifurcating radial costellae, strongest and about as wide as interspaces on median area, elsewhere finer and narrower than interspaces; on unworn specimens, fine transverse growth striae crowd intercostal spaces, usually much reduced on worn specimens; juvenile shell up to 7 mm long, fenestrate with fine, crowded, radial and transverse costellae, persisting in adult on ventral area; elliptical area around byssal gape with reduced sculpture, mainly transverse, or smooth; resilifer a shallow sub-marginal groove below anterior half of dorsal margin; anterior extremity with strong internal septum bearing two low dysodont teeth; amphidetic teeth present behind ligament, grading into very fine internal crenulation around posterior and ventral margins, much reduced ventrally especially around byssal gape; anterior adductor scar weakly defined, beneath septum on dorsal side; posterior adductor scar obscure; pallial line thin, entire, close to margin,; margin everted posteriorly; interior faintly nacreous.

Dimensions	Length beak–posterior	Length dorsal margin	Height	Inflation
WAM 83.2586a, LV	17.12	9.50	8.83	4.91
WAM 83.2586b, RV	12.44	7.48	7.50	3.33

Discussion. In a previous study (Darragh & Kendrick 1980), based on inferior material, we were unable to establish a positive determination for the Walpole Septifer. Specimen WAM 69.109, figured by us (1980: fig. 3A–C) is now seen to be deformed by dorso-ventral compaction and is not a good representation of the species. Subsequent collecting has produced well preserved material, which permits a revised description and determination. Our material agrees reasonably well with the description and figure of *Septifer subfenestratus* Basedow, erected on a 'pseudomorphous cast in glauconite', a possible equivalent of the Blanche Point Formation of the Adelaide District (Basedow 1904: 251–252, text fig.). Walpole specimens differ from the Balcombian *S. fenestratus* Tate in having a broader umbone, greater postero-dorsal flair, fewer stronger ribs on the median area and a more angulate shoulder bordering the ventral area.

Septifer subfenestratus and *S. fenestratus* appear to represent an endemic southern Australian lineage of this essentially tropical to subtropical genus, which lineage is not known to have survived beyond the Middle Miocene. In New Zealand, the genus has a recorded range of from Early Eocene to Middle Miocene (Beu & Maxwell 1990: 33).

Occurrence. St Vincent Basin: Royal Vale Vineyards, Happy Valley, glauconitic sandstone (type), probably Blanche Point Formation, Late Eocene. Bremer Basin: North Walpole; Green Range, Plantagenet Location 6475; Pallinup Siltstone, Late Eocene.

Superfamily Plicatuloidea Watson, 1930

Family Plicatulidae Watson, 1930

We follow Waller (1978) in according superfamilial status to the Plicatuloidea, equal to and separate from the Dimyoidea.

Genus **Plicatula** Lamarck, 1801

Type species. Spondylus plicatus Linnaeus, 1758. By subsequent designation of Schmidt, 1818. Recent, Indo-SW Pacific.

Subgenus **Plicatula** s. str.

Plicatula (Plicatula) emaciata sp. nov.

Fig. 3A, C, E, G–J

Plicatula (Plicatula) sp. Darragh & Kendrick, 1980: 15, fig. 3I–L.

Material. Holotype WAM 67.79, separate paired valves, from 26 km along Thompson Highway north from Walpole, Western Australia. Paratypes WAM 69.112a, 69.113, 72.267a–b, 74.552a–b, 78.4092a, 83.2589a–h. Total of five LVs two pairs. NMV P302328 (left valve), P302329 (pair).

Other material. WAM 67.93, 69.108, 69.117, 72.268, 74.537, 74.539, 88.153, 83.2589. Total of 56 valves. NMV P52337 (8 valves), P40638 (11 valves), P301957 (30 valves). Total 49 specimens.

Description. Small, thin-shelled, compressed, inequivalve, extended posteriorly, irregularly folded, ostreiform, without marginal gape, higher than long; RV the more convex with large attachment area; LV more or less flat in juvenile, becoming slightly concave or convex with growth; LV margin slightly everted to fit RV margin; auricles absent; sculpture more or less similar on each valve, transversely lamellose with hollow, raised, incurved scales and from 15–20 irregular, often bifurcate, radial costae of variable width, weakly to moderately developed; costae absent from attachment area (RV) and corresponding part of LV; adductor scars of both valves oval, centred in postero-dorsal quadrant; crura thick, erect, with points directed out as in *Spondylus*; weakly serrated; crura of RV close to resilium pit, those of LV more spaced; cardinal area present on RV, absent on LV.

Dimensions

	Length	Height	Inflation
WAM 67.79a holotype, RV	11.90	13.65	4.45
WAM 67.79b holotype, LV	11.35	12.48	2.70
WAM 72.267 paratype, LV	13.30	18.13	3.94
WAM 74.552a paratype, pair	17.34	18.78	7.80
WAM 78.4092 paratype, LV	13.90	15.47	3.12

The largest specimen to hand, paratype WAM 69.112a, is broken but the estimated height *c.* 20 mm.

Discussion. Previously described species of *Plicatula* from the Australian Tertiary (Early and Middle Miocene) all differ from the present in their relatively thicker shells and fewer, more spaced, wider radials (Tate 1898; Chapman 1922). This is the first Australian Eocene record for the genus, which has a long record in Australia, an undescribed species being present in the Bajocian Newmarracarra Limestone of the northern Perth Basin (Playford 1959; WAM, unpub. records). Cretaceous records of *Plicatula* from Western Australia (Feldtmann 1963) are considered to belong with the genus *Atreta* Étallon (Darragh & Kendrick 1991), a genus subsequently relocated in the Dimyidae (Hodges 1991). As noted previously (Darragh & Kendrick 1980), single LVs (64 valves) greatly outnumber single RVs (nine valves) in the study material, indicating differential post-mortem transportation.

Gastropod boreholes are present on 22 valves, a predation rate of 35%. Twenty of these are on the LV, all but one of the non-bevelled 'muriciform' type. Both RVs have been bored well clear of the attachment area.

The specific name is derived from the Latin *emacio*—to waste away, in view of the notably small thin shell of this species.

The genus, in modern seas restricted to tropical and subtropical waters, is recorded from the Early Eocene of New Zealand (Beu & Maxwell 1990: 90, pl. 3d, g). It is included in Darragh's (1985) cosmopolitan element.

Occurrence. Bremer Basin: North Walpole (type), Pallinup Siltstone, Late Eocene.

Superfamily Anomioidea Rafinesque, 1815

Family Anomiidae Rafinesque, 1815

Genus **Anomia** Linnaeus, 1758

Type species. Anomia ephippium Linnaeus, 1758. By subsequent designation of Schmidt (1818). Recent, Atlantic–Mediterranean.

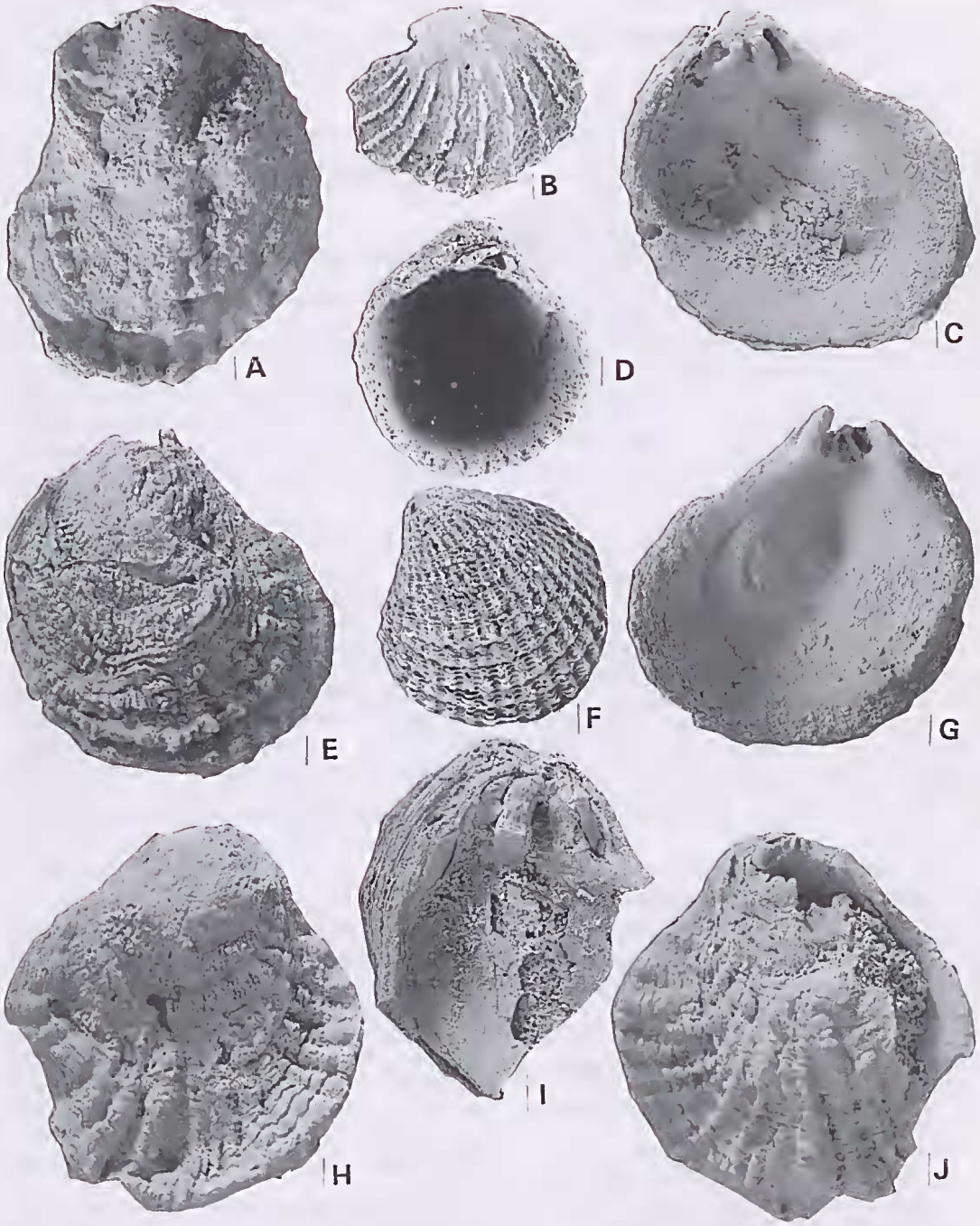


Fig. 3. A, C, E, G–J, *Plicatula (Plicatula) emaciata* sp. nov. A, C, E, G, WAM 67.79, holotype: A, RV exterior; C, interior; E, LV exterior; G, LV interior; all ×4. H, J, WAM 74.552a, paratype, conjoined pair: H, RV exterior; J, LV exterior; both ×3. I, WAM 69.117, RV interior, fragment attached to a sponge, ×4. B, *Verticordia (Verticordia)* sp. WAM 83.2610, LV exterior, ×8.4. D, F, *Cyclocardia (Vimentum?)* sp. WAM 83.2599, LV interior, exterior, ×6.

Subgenus **Anomia** s. str.

Anomia (Anomia) sp. cf. A. (A.) cymbula Tate, 1886

Fig. 2H

cf. *Anomia cymbula* Tate, 1886: 101, pl. 11, fig. 5.

Material. WAM 83.2592. One LV.

Description. Small for genus, thin, of irregular outline and profile, possibly deformed a little by compaction; longer than high; umbone broad, more or less orthocline, inflated, broken in median area; without foramen; anterior and posterior slopes oblique, former being slightly convex on margin, latter slightly concave on margin; ventral margin broadly rounded; axis of greatest length located in ventral half; sculpture of numerous, fine, crowded radial costellae, bearing packed, irregular, erect scales, variously aligned; margin somewhat abraded; body cavity with large dorsal callosity; muscle scars not preserved.

Dimensions

	Length	Height	Inflation
WAM 83.2592, LV	9.26	7.89	2.66

Discussion. In proportions, the sole specimen to hand (from North Walpole) appears to be unlike Tate's figure of *Anomia cymbula* (Tate 1886: 101, pl. 11, fig. 5) from '*Turritella*-clays at Blanche Point, Aldinga Bay'. In neither specimen (apparently both LVs) are the muscle scars known; however the finely scaled radial costellae of our specimen are anomiid in character and suggest at least an affinity between the Blanche Point and North Walpole specimens.

Collection of more material from both sources may confirm the generic determination and indicate the range of variation in each. The present species is rare at North Walpole.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Subclass Heterodonta Neumayer, 1884

Order Veneroida H. & A. Adams, 1856

Superfamily Carditoidea Fleming, 1820

Family Carditidae Fleming, 1828

Subfamily Carditamerinae Chavan, 1969

Genus **Cyclocardia** Conrad, 1867

Type species. Cardita borealis Conrad, 1831. By subsequent designation of Stoliczka, 1871. Recent, North Atlantic.

Subgenus **Vimentum** Iredale, 1925

Type species. Cardita dilecta E. A. Smith, 1885. By original designation. Recent, southern Australia.

Cyclocardia (Vimentum?) sp.

Fig. 3D, F

Material. WAM 83.2599. One LV.

Description. Small, robust, ovate-subtrigonal, inflated, higher than long, subequilateral, very slightly extended anteriorly; posterior area weakly defined; umbone broad, elevated, slightly prosogyrate; beak slightly posterior of centre; lunule shallow, weakly defined, elliptical; antero-dorsal margin concave; anterior and ventral margins evenly curved in outline; posterior margin slightly truncate; postero-dorsal margin slightly convex; hinge plate broad, tooth 2 short, erect; tooth 4 long, massive; cardinals subtend 90° angle below beak; posterior lateral PII weak, poorly indicated; ligamental attachment groove submarginal, shallow; sculpture of 24 radial costellae, about as wide as interspaces except for six narrower radials on posterior area; radials and interspaces overlain by numerous fine, transverse threads, combining to form weak plicae on crests of costellae; internal margin strongly crenulate corresponding to external radials; anterior adductor scar large, close to anterior extremity; posterior adductor scar larger and close to posterior extremity; pallial line entire, distanced from margin.

Dimensions

	Length	Height	Inflation
WAM 83.2599, LV	5.32	5.79	2.32

Discussion. This rare and evidently undescribed species is assigned provisionally to the subgenus *Vimentum* from a broad similarity in sculpture and hinge structure to the type species *Cardita dilecta* E. A. Smith and other related species, such as *V. excelsior* (Verco), from the Recent of southern Australia. It differs from these in the apparent presence of a weak posterior lateral tooth (PII), in the spacing and number of ribs, the transverse microsculpture, height exceeding length and greater inflation.

Further determination of this species must await the collection of a RV. The subgenus is hitherto not recorded from the Eocene according to Chavan (in Moore 1969: N551, fig. E49, 7).

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Superfamily Crassatelloidea Férussac, 1822

Family Crassatellidae Férussac, 1822

Subfamily Crassatellinae Férussac, 1822

Genus **Salaputium** Iredale, 1924

Type species. Crassatella fulvida Angas, 1871. By original designation. Recent, Australia.

Salaputium communis (Tate, 1896)

Crassatella astartiformis Tate, 1886: 147, pl. 11, figs 12, 15 *non* Nyst, 1847.
Crassatella corrugata Tate, 1886: 147, pl. 2, fig. 14 *non* Adams & Reeve, 1850.
Crassatella communis Tate in Tate & Dennant, 1896: 129 *nom. nov.* for *Crassatella astartiformis* Tate, 1886 (*non* Nyst, 1847).
Salaputium aldingensis Finlay, 1930: 38, *nom. nov.* for *Crassatella corrugata* Tate, 1886 (*non* Adams & Reeve, 1850).
Salaputium communis—Darragh & Kendrick, 1980: 18, fig. 5A–C; Darragh, 1985: 100, 111, table 1.

Material. WAM 88.155, an external mould (RV) in bryozoal calcarenite; 95.419, an incomplete LV. Two specimens.

Discussion. The synonymy above follows Darragh & Kendrick (1980: 18) in recording the species from the Pallinup Siltstone at North Walpole. The additional material reported here is from the Werrilup Formation and resembles the fine, closely ribbed form of shell characteristic of Walpole specimens. The genus in New Zealand is recorded from the Late Oligocene to Early Miocene (Beu & Maxwell 1990: 398).

Occurrence. Otway Basin: lower and upper Browns Creek Formation, Late Eocene; lower Glen Aire Clay, Early Oligocene. St Vincent Basin: Blanche Point Formation (type), Late Eocene. Bremer Basin: Ocumup No. 1 deep well, 71.7 m, Werillup Formation, Middle Eocene. North Walpole, Pallinup Siltstone, Late Eocene.

Subclass Anomalodesmata Dall, 1889

Order Pholadomyoida Newell, 1965

Superfamily Poromyoidea Dall, 1886

Family Verticordiidae Stoliczka, 1871

Genus **Verticordia** Sowerby, 1844

Type species. Hippagus? cardiiformis Sowerby, 1844. By monotypy. Pliocene, England.

Subgenus **Verticordia** s. str.

Verticordia (Verticordia) sp. B

Fig. 3B

Material. WAM 83.2610. One LV. P301941. Pair, crushed and poorly preserved.

Description. Shell minute, thin, fragile, transversely ovate, longer than high, moderately inflated; umbone broad; beak strongly prosogyrate above recessed lunule; margin mostly poorly preserved, ventral margin missing; cardinal area thickened along margin behind beak; apical area more or less smooth, developing sculpture of 11 thin, spaced radial costellae, weakly spinose on crests; intercostal spaces broad, smooth; internal layer faintly nacreous; interior filled with spicular silica.

Dimensions	Length	Height	Inflation
WAM 83.2610, LV	4.02	3.27*	1.35

*ventral margin is lost and original height was probably closer to length.

Discussion. The present species differs markedly from *Verticordia (Verticordia)* sp., also from North Walpole, recorded by Darragh & Kendrick (1980: 19), in its fewer (11 against 16) and more widely spaced radials.

Seulptural features likewise distinguish the Walpole species from those from the Miocene of Morgan, Hamilton and Balcombe Bay described by Tate (1887: 149–150, pl. 14, figs 4, 13) and by Pritchard (1901: 30).

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Class Gastropoda Cuvier, 1797

Order Patellogastropoda Lindberg. 1986

In limpet systematics, we follow the classification of Lindberg (1986, 1988), in which the name Patellogastropoda replaces Docoglossa Troschel, 1866 and incorporates the families Patellidae, Nacellidae, Lepetidae, Aemaeidae and Lottiidae. By long custom regarded as 'Archaeogastropoda', the patellogastropods are now ranked as a distinct order of the Prosobranchia.

Suborder Nacellina Lindberg, 1988

Superfamily Nacelloidea Thiele, 1891

Family Nacellidae Thiele, 1891

Genus **Nacella** Schumacher, 1817

Type species. Nacella mytiloides Schumacher, 1817 (= *Patella mytilina* Helbling, 1779). Recent, southern Chile.

Nacella (?) jutsoni (Chapman & Crespin, 1934)

Fig. 4L, N

Cellana jutsoni Chapman & Crespin, 1934: 122, 126, pl. 11, fig. 28; Darragh, 1985: 110, table 1.

Material. Holotype NMV P14634 (internal mould) and P14635 (external mould). WAM 67.733. One specimen.

Description. Holotype comprises internal and external moulds in brown siltstone representing small limpet of oval outline, longer than wide; apex low, at anterior fourth, tip small, well defined, directed anteriorly; apical angle (left–right cross-section) *c.* 115°; midline profile gently convex posteriorly, slightly concave anteriorly; apical area smooth; sculpture confined to periphery, of *c.* 48 radial costellae of variable strength and spacing but generally narrower than interspaces; very fine transverse growth striae cross interspaces; margin internally crenulate; muscle scar not apparent.

WAM 67.733 from the Northcliffe district is a small conical-patelliform shell, outline oval, apex at about anterior third, not deflected; apical angles—left–right cross-section *c.* 90°, antero-postero cross-section *c.* 120°; apex to anterior and posterior profiles both very slightly convex; sculpture of up to 40 fine, spaced, radial costellae of variable strength and spacing; apical area without radial sculpture, possibly abraded; no discernible transverse sculpture or siphonal noteh; margin probably finely crenulated; internal characters unknown.

Dimensions	Length	Max. width	Height
NMV P14635 holotype, ext. mould	19	13.5	2.5 (est.)
WAM 67.733	13 (est.)	10 (est.)	3.8

Discussion. The holotype and hitherto only known specimen of *'Cellana' jutsoni* Chapman & Crespin is a pair of moulds in brown siltstone from the Albany district. A second specimen, WAM 67.733, from the Northcliffe area is a silica replacement of a small limpet with a probably abraded apex, broken anteriorly and along much of the left margin; interior solidly infilled. Despite some differences in relative heights, apical angles and rib totals, we consider them to be probably conspecific, subject to confirmation from further material.

In both specimens, radial ribbing is confined to the periphery, the rest of the exterior being essentially smooth; apex on both specimens is located well anteriorly. These characters are consistent with the Southern Hemisphere offshore genus *Nacella*, to which the species is provisionally referred. The range of variation within *Nacella jutsoni* cannot be established adequately until further material becomes available.

Occurrence. Bremer Basin: Albany, W.A., 'in fine spicular ooze' (type), ie., Pallinup Siltstone, Late Eocene. Northcliffe district, W.A. (see Localities). Quartz gravel (Quagering Beds) containing sparse fossils, presumably reworked from unknown outcrop of Pallinup Siltstone. Late Eocene.

Order Vetigastropoda Salvini-Plawen, 1980

Superfamily Fissurelloidea Fleming, 1822

Family Fissurellidae Fleming, 1822

Subfamily Emarginulinae Gray, 1834

Genus **Emarginula** Lamarck, 1810

Type species. Emarginula conica Lamarck, 1810. Recent, North Atlantic.

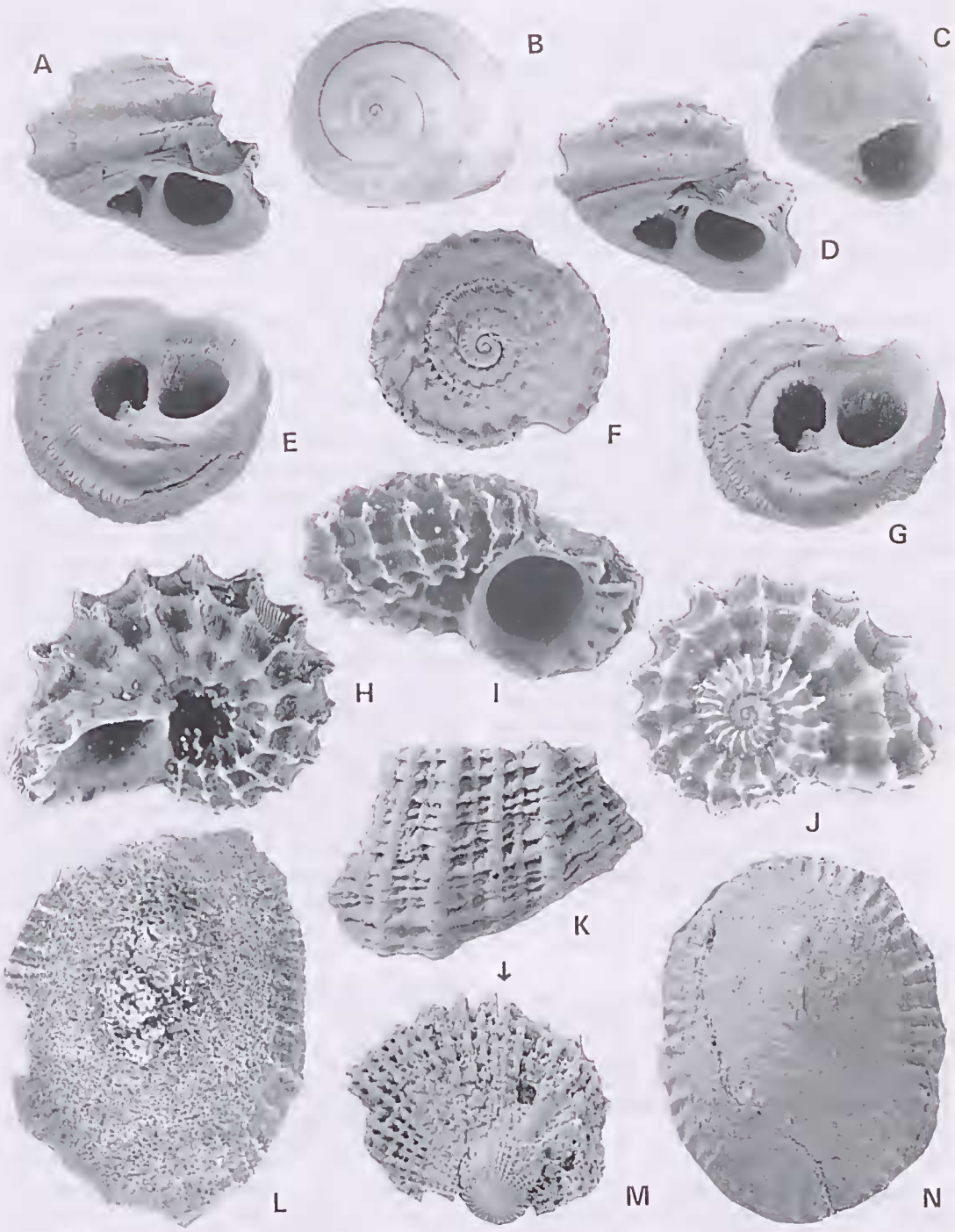
Emarginula (?) sp.

Fig. 4K, M

Material. WAM 83.2628, 83.2644. Eleven fragments, two with parts of the selenizone. NMV P302011, P302012 nine very incomplete fragments.

Description. Fragments of a robust emarginuline shell with strong sub-cancellate sculpture; apex imperforate, low, blunt, gently inclined posteriorly; selenizone narrow, not elevated, between two narrow ribs, terminating at slit; sculpture of numerous straight, raised, radial costellae, generally alternately stronger and finer, with stronger costae weakly subspinose adapically; transverse sculpture lamellose, adapically only present between costae, toward margin passing across costae to form low scales on their crests; margin unevenly crenulated within, corresponding to radial sculpture; other internal characters unknown.

Fig. 4. A, D–G, *Pseudoniuella? squarrosa* sp. nov. A, E–F, NMV P302268, holotype, × 4. D, G, NMV P302269, paratype, × 4. B–C, *Eutinochilus otwayensis* (Pritchard). NMV P134100, lectotype: B, × 9; C, × 7.5. H–J, *Liotina lamellosa* (Tenison Woods). NMV P302173, neotype, × 7.5. K, M, *Emarginula* (?) sp. K, WAM 83.2628a, fragment with marginal sculpture, × 3. M, WAM 83.2644a, anterior fragment with apical part of selenizone (arrow). L, N, *Nacella (?) jutsoni* (Chapman & Crespin). L, WAM 67.733, exterior, × 4.9. N, NMV P14635, holotype, external mould (latex peel), × 3.


A
B
C
D
E
F
G
H
I
J
K
L
M
N

Dimensions. Unobtainable from the fragmentary condition of the material but comparable in size with *Emarginula wannonensis* Harris (1897), ie., up to 20 mm in length.

Discussion. The species is referred with reservations to *Emarginula* from the presence on two fragments (WAM 83.2644) of a clear selenizone, bordered by two narrow ribs. The selinizone on one fragment terminates at a slit. The apical characters are atypical of *Emarginula*, rather more resembling those of the genus *Tugali* Gray, as does the sealed transverse sculpture of the more mature shell. So far as can be seen, the specimen does not closely resemble any known emarginuline from the Australian Tertiary.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Other records of Emarginulinae. Two samples (WAM 83.2645, 83.2646) from North Walpole comprise small, poorly preserved and fragmentary specimens consistent with one or two species of *Emarginula*, additional to the above. The shells are finely sculptured with an incurved, low and posteriorly overhanging apex; dimensions of an internal mould (83.2645) are L 6.5, W 2.6, H 2.3, indicating a shell with a length about twice the width and three times the height. In shape and fineness of sculpture, this material recalls *E. clypeata* Lamarck from the Paris Basin Eocene. A further fragmentary specimen (WAM 95.382) from the Werillup Formation in the Ocumup No. 1 deep well, 53.4 m, may represent a third species of *Emarginula* from the Plantagent Group.

Superfamily Trochoidea Rafinesque, 1815

Family Turbinidae Rafinesque, 1815

Subfamily Liotiinae H. & A. Adams, 1854

Genus **Liotina** Fischer, 1885

Globarena Iredale, 1929.

Type species. Delphinula gervillei Defrance, 1818 by subsequent designation of Cossmann (1888). Lutetian, France.

In according full generic rank to *Liotina* and in the above synonymy, we follow Hickman & McLean (1990: 37).

Liotina lamellosa (Tenison Woods, 1877)

Fig. 4H–J

Liotia lamellosa Tenison Woods, 1877: 96. Table Cape.
Liotia roblini Johnston, 1880: 39. Table Cape; Tate, 1885: 211; Harris, 1897: 284, pl. 8, fig. 4a–c.
Munditia lamellosa—Darragh, 1985: 100, table 1.

Material. WAM 67.105, 69.129, 72.279, 83.2629, 83.2648, 85.633, 95.405, 95.436. Total 118 specimens. NMV P301962, P301963, P301983, P301984, P302173 (neotype). Total 99 specimens.

Description. Shell small, robust, diameter exceeding height; juveniles almost planispiral, adults subdiscoidal; spire low, whorls about four; protoconch of 0.7–1.0 smooth whorls, concordant with shell axis and terminating at onset of very fine axial threads; apical 2.5 whorls depressed, subsequently descending; whorls strongly convex, with subsutural, channelled shelf and impressed suture; peripheral edge of penultimate whorl almost vertical (slightly overhung); periphery of last whorl convexly rounded between projecting axial plicae; base excavate, umbilicus open, broad, deep, on some specimens narrower in adult; aperture circular, peristome continuous, attached to parietal surface; outer and basal lips thickened to form prominent varix; columellar margin free, projecting, evenly rounded; teleoconch sculpture predominantly axial, of three orders; first 0.7 whorls with *c.* 14 simple, close, axial costellae, thereafter becoming stronger, more spaced and plicate at intersections with spirals; on last whorl, primary axials (including apertural varix) number 12–16, on penultimate whorl 16–17; axials continuous onto base, entering umbilicus; spiral sculpture subordinate, beginning as raised points on post-brephic axials, subsequently forming continuous lirae between and across axials; spirals number three or four on penultimate whorl (three on topotypes) and five on last whorl (six on topotypes); another circumumbilical spiral on base and smaller one within umbilicus; tertiary microsculpture of very fine, crowded, axial striae on entire teleoconch, entering umbilicus. Operculum poorly preserved, circular, with concentric growth lines; nucleus not preserved.

Dimensions	Height	Max. diameter	No. whorls
NMV P302173, neotype	4.13	6.69	4.2
WAM 95.436a	5.73	6.96	4.2
WAM 95.436b	3.85	5.26	4.3
WAM 95.436c	4.31	4.84	3.9

Discussion. Johnston (1880: 39) acknowledged the 'marked resemblance' of his species *Liotia roblini* to *L. lamellosa* Tenison Woods and the two were considered to be conspecific by May (1919: 71). May also noted that the type of *L. roblini* was missing from the collection of the Tasmanian Museum but made no mention of the type of

L. lamellosa. Ludbrook (1967) included neither of the above in an inventory of Tertiary molluscan primary types from the same repository, remarking (1967: 65) 'Although the collection represents only a small percentage of the material described by Tenison Woods and Johnston, it appears to be all that remains in Hobart'. Mr Noel Kemp, Tasmanian Museum, advises that neither specimen has been found since Ludbrook's paper was published. We presume therefore that the type material of both *Liotia lamellosa* Tenison Woods and *Liotia roblini* Johnston are now irretrievably lost.

Comparing the descriptions of the above species of Tenison Woods and Johnston (there were no figures), we concur with May's (1919) opinion that they relate to the same species. The former's specimen apparently was a juvenile, about half the size of Johnston's. However to stabilise the names, we propose to designate as neotype, jointly for both *Liotia lamellosa* Tenison Woods and *Liotia roblini* Johnston, NMV specimen P302173 (Fig. 4) from the common type locality of both species, the Longfordian Freestone Cove Sandstone (= *Crassatella* bed of Johnston, 1877: 84), lower bed, Table Cape, north of Wynyard, Tasmania; specimen ex. F. A. Cudmore Collection, 'lower bed, Table Cape'.

Topotypes of *L. lamellosa* from the Freestone Cove Sandstone of Table Cape (NMV collection) are rather thick, heavy shells, some relatively wider and lower in the spire compared with specimens from the Late Eocene of the Bremer Basin but are otherwise very similar and, in our view, conspecific. Small, immature specimens (NMV P302175) from the Browns Creek Formation (lower shell bed), Otway Basin, are identical with those from the Bremer Basin. Other records of the species from Museum Victoria collections are from the lower Glen Aire Clay (Early Oligocene; rare), Jan Juc Formation (Janjukian; rare) and Muddy Creek Formation (Balcombian; common). These records suggest that *L. lamellosa* was more common in relatively shallow waters; however it is common at North Walpole, where water depths are estimated at about 160 m.

L. lamellosa is related, probably ancestrally, to *Liotina tasmanica* (Tenison Woods), which ranges from Kalimnam to Recent according to Ludbrook (1956: 22, pl. 2, fig. 6). The modern specimen from Tasmania attributed to *L. lamellosa* by Tenison Woods (1877: 97) is probably the extant *L. tasmanica*, which differs from *L. lamellosa* in its bicarinate periphery, weaker radials and wider umbilicus (Wilson 1993: 100).

The present species is related to the New Zealand Early Eocene (Mangaorapan?) *Liotina turna* Maxwell, 1978, Kauru Formation, New Zealand (South Island) (Beu & Maxwell 1990: 94–96, pl. 4, figs l–m). On *L. lamellosa*, the axial costae are more numerous and closer together and the whorl profile is less angulate, compared with Maxwell's species. The prominences at the intersection of the radials and spirals are lower in *L. lamellosa*.

The present species and its congener *L. tasmanica* (Tenison Woods) appear to be a lot closer in shell characters to *Delphinula gervillei* Defrance, the type species of *Liotina* Fischer, 1885 than to *Liotina tryphenensis* Powell, the type species of Munditia Finlay, 1927, Recent, New Zealand.

The genus *Liotina* ranges from Eocene to Recent and is recorded from Europe, North and East Africa, Pakistan, Indo-SW Pacific, Japan, South America and Australasia, according to Keen (in Moore 1960: 1267), Morley Davies (1971: 297) and Wenz (1938: 338, fig. 787). It is included among Darragh's (1985: 91) Tethyan Indo-Pacific element.

In the material from Walpole, eight specimens out of 212 (3.8%) have gastropod boreholes, mostly on the spire whorls. Many of the Walpole specimens have been deformed by sediment compaction.

Occurrence. Bass Basin: Freestone Cove Sandstone (type), Early Miocene. Port Phillip Basin: Jan Juc Formation, Early Oligocene. Otway Basin: lower Browns Creek Formation, Late Eocene; lower Glen Aire Clay, Early Oligocene; Muddy Creek Formation, Middle Miocene. Bremer Basin: Ocumup No. 1 deep well, 68.6 m, Werillup Formation, Middle Eocene; North Walpole and Lucky Bay, Pallinup Siltstone, Late Eocene.

Subfamily Angariinae Thiele, 1921

Genus **Pseudoninella** Sacco, 1896

Type species. *Delphinula miosolarioides* Sacco, 1896.

Pseudoninella? squarrosa sp. nov.

Fig. 4A, D–G

Material. Holotype NMV P302268 from uppermost bed, washout nearest Browns Creek, Johanna, Victoria. Locality PL 3013. Paratype NMV P302269 from uppermost bed, washout nearest Johanna River, Johanna, Victoria. Locality PL 3014. NMV P31006–7. Total 2 specimens.

Description. Shell small, robust, turbinate, diameter exceeding height with about four gradate whorls; apex depressed; suture adpressed, attached immediately anterior to lesser of two prominent

peripheral cords; protoconch of one smooth whorl, concordant with shell axis, terminating at onset of fine radial lamellae, which persist over entire teleoconch (including umbilicus) as prosocline microsculpture; first teleoconch whorl depressed, subsequent whorls strongly gradate with broad concave shelf; last whorl strongly biangulate about periphery, adapical cord stronger; base convex; whorl profile concave between cords; aperture circular, tangential, peristome continuous, extended across parietal area; inner lip recessed; outer lip prosocline, internally smooth and bevelled; umbilicus deep, of moderate width, partly constricted by thickened, crenulate circumumbilical rim. Spiral sculpture initiated on second teleoconch whorl as double row of nodules, which become raised cords bearing scales and tubercles on crest formed by grouping of axial microsculpture; first subsutural cord fine, initially with spaced nodules on crest, changing to elevated scales; second cord strongest, bearing erect scales; third cord peripheral and scaled like second but slightly weaker; fourth cord on base, like third but finer; fifth cord on base, nodose, finer than fourth; one spiral with raised scales within umbilicus; inner layer of shell nacreous.

Dimensions	Height	Max. diameter	No. whorls
NMV P302268, holotype	8.93	10.20	4.5
NMV P302269, paratype	8.56	10.18	4.3

Discussion. Species of *Pseudoniuella* occur widely in the European Tertiary from Paleocene to Miocene but have not been recorded hitherto from Australia. The present species resembles *Pseudoninella rauliui* Cossmann & Peyrot, Miocene, France (Cossmann & Peyrot 1917: 75, pl. 3, figs 21–24); *P. depressa* Ravn, Danian, Denmark (Ravn 1933: 29, pl. 2, fig. 3a–c); and *P. brouni* (Philippi), Early Oligocene, Germany (Koenen 1892: 871, pl. 56, fig. 1a–c), but seems to be more depressed apically than any of these.

The syntype of *Delphinula miosolarioides* Sacco (Middle Miocene, Italy) is a poorly preserved specimen, of which the original figure conveys little. This specimen, refigured by Ferrero Mortara et al. (1984: 274, pl. 50, fig. 2), appears to be an internal mould retaining remnants of shell, which leaves some uncertainty as to the essential diagnostic characters of *Pseudoniuella*. However, there seems little doubt that the present species, together with that which follows, are closely related to the species cited above.

Small turbiniform opercula of circular to subcircular outline occur in the upper levels of the Browns Creek Formation. Most of these are probably referrable to *Bolma*, which is common there, but some may be derived from the present species. This can only be settled by the collection of an associated shell and operculum.

A second species of *Pseudoniuella* is reported below from the Plantagenet Group of the Bremer Basin. It differs from the present species in being wider relative to height and in having a more depressed spire and more numerous spiral cords (nine).

The specific name is derived from the Latin *squarrosa* (feminine), rough, with scales or processes, etc.

Occurrence. Otway Basin: upper Browns Creek Formation, Late Eocene.

Pseudoninella? sp.

Fig. 8C–E

Material. WAM 69.131, 72.237, 83.2651, 95.366, 96.249. Five juvenile specimens.

Description. Shell minute, subdiscoidal, diameter exceeding height, spire low, apex depressed for initial 2.5 whorls; suture initially incised, becoming canaliculate on last whorl, attached just below bicarinate periphery; base convex with deep, moderately wide umbilicus; protoconch of one smooth whorl, terminating at a weak varix and succeeded by very fine, crowded axial threads, persisting over entire teleoconch (including umbilicus) as orthocline microsculpture; from *c.* 1.7 whorls, initially two, then four spiral cords develop, which are, at first, nodulose, becoming finely scalar by penultimate whorl; new cords arise by intercalation; last whorl with four scaled cords above periphery, two stronger scaled cords form bicarinate periphery with five scaled cords on base, of which fifth (circumumbilical) is strongest; within umbilicus are two additional fine cords with recurved scales; aperture broken, internally smooth, circular; peristome probably continuous; columella smooth, everted at apertural margin; innermost shell layer nacreous.

Dimensions	Height	Max. diameter	No. whorls
WAM 72.237	1.81	3.62	3.5+

Discussion. All specimens to hand are minute and none has an intact aperture. We consider them to be juveniles of a species distinct from but closely related to *Pseudoninella? squarrosa* sp. nov., described above.

The principal differences with the foregoing are, most obviously, the greater number of spiral cords (nine against five) on the last whorl and the presence of two cords within the umbilicus. The circumumbilical cord is distinct and well developed in the present species but reduced to a thickened, crenulate rim in the other. The apex is more depressed, the umbilicus narrower and less constricted and the periphery less bicarinate in the present species. Otherwise, particularly in the nature of the axial microsculpture and its elaboration on the crests of the spiral cords, the two species are rather similar and, in our view, congeneric.

Further determination of this species depends on the collection of mature specimens.

Occurrence. Bremer Basin: Oeunup No. 1 deep well, 56.4 m, Werillup Formation, Middle Eocene; North Walpole, Pallinup Siltstone, Late Eocene.

Subfamily Colloniinae Cossmann, 1916

Genus **Collonia** Gray, 1850

Type species. Delphinula marginata Lamarck, 1804. By subsequent designation of Cossmann (1888). Lutetian, France.

We utilise the genus in the broader sense adopted by Hickman & McLean (1990).

Collonia variabilis sp. nov.

Fig. 8A–B, G

Material. Holotype NMV P302634, from PL3014, uppermost shell bed, washout nearest Johanna River, Johanna, Victoria. Paratypes NMV P302263; WAM 94.664a–e. Total of 11 specimens, all from type locality.

Other material. NMV P302256, P302257, P302259, P302261. Total of 40 specimens.

Description. Small for genus, depressed–turbinate, wider than high; spire usually low, occasionally slightly elevated; whorls to 3.5, convexly rounded; last whorl evenly rounded or faintly subangulate above periphery; suture lightly impressed, becoming adpressed and terminally descending in maturity; protoconch of one smooth whorl, not set off from teleoconch; aperture (mature) circular, peristome continuous with narrow adaxial internal thickening; adapical margin near-tangential to previous whorl; columella concave, thickened at parietal attachment and anteriorly by low umbilical keel; umbilicus wide to narrow (immature), becoming entirely sealed (mature) by expansion of umbilical keel; spire sculpture with or without short prosocline axial folds, strong to faint or absent and confined to subsutural shelf; fine spiral thread borders suture; spire otherwise smooth, polished; base with weak spiral striae and on some specimens, weak short axial folds radiating from umbilicus (if open); circumumbilical keel weak, weakly nodulose; internally strongly nacreous.

Dimensions	Height	Max. diameter	No. whorls
NMV P302634, holotype	1.7	2.2	3.3
WAM 94.664a, paratype	1.59	2.62	4.3

Discussion. With its rather variable umbilical features and sculpture, the present species does not agree readily with any of the subgenera of *Collonia* in either Cossmann (1918: 53–63) or Keen in Moore (1960: 1269–1270) and we defer subgeneric assignment.

The species superficially recalls *Crossea parvula* Tenison Woods from the Early to Middle Miocene of Victoria (Tenison Woods 1880: 4, pl. 1, fig. 7); however that species is widely umbilicated and is not internally nacreous. The present species lacks the strong granose circumumbilical spiral of *C. marginata* (Lamarck). It is more rounded in whorl profile than *C. canalifera* (Lamarck) from the French Middle Eocene and lacks the thickened, slightly reflexed outer lip of that species.

Of the 51 specimens to hand, 4 (8%) bear naticiform boreholes, three on the base, one on the spire.

Occurrence. Otway Basin: upper Browns Creek Formation, Late Eocene.

Genus **Homalopoma** Carpenter, 1864

Type species. Turbo sanguineus Linnaeus, 1758. Recent, Mediterranean.

Our location of *Homalopoma* within the subfamily Colloniinae follows Hickman & McLean (1990).

Subgenus **Homalopoma** s. str.

Homalopoma (Homalopoma) limnaios sp. nov.

Fig. 5G–H, K, N

Material. Holotype WAM 83.2620a, from 26 km along Thompson Highway north from Walpole, Western Australia. Paratypes WAM 83.2620b–d, 83.2632a–e, 95.562. NMV P302031. Total of 8 specimens, all from the type locality.

Other material. WAM 67.101, 69.119, 72.238, 72.275, 80.1329, 82.1481, 83.2620, 83.2624, 83.2625, 83.2631, 83.2632, 85.629, 85.1458, 95.547, 95.548. Total of 118 specimens. NMV P302013, P302014, P302015, P302016, P302028, P302039, P302030. Total of 95 specimens.

Description. Shell small for genus, of about five whorls in a height of 6 mm, thick, robust, roundly trochiform, squat, height slightly exceeding diameter; spire short, truncated, apical area, comprising first 2.5 whorls, slightly sunken; last and penultimate whorls swollen, the former contracted towards aperture. Protoconch paucispiral, depressed, initially smooth for about 1.3 whorls, then gradually developing very fine, close axial threads; at 1.7 whorls, weak nodules appear, to form three primary, nodose, spiral lirae (2.0 whorls); at about 2.5 turns, whorl begins to descend, acquiring by intercalation two more nodose spirals; lirae total five above periphery on penultimate whorl and two below, latter lirae scaled, not nodose; last whorl with 11–14 spirals from suture to base, all finely nodose to scabrous and becoming obsolete abapically; lirae about as wide as interspaces except on base where they are narrower; lirae and interspaces crossed by very fine, close, prosocline growth striae; suture canaliculate, descending at aperture; aperture continuous, circular and with thick, internally bevelled, recessed rim, presumably to receive operculum; outer lip prosocline with narrow marginal rim; columella smooth, evenly rounded; narrow callus extending continuously over parietal area to columellar area; umbilicus open and spirally striate in juvenile, becoming sealed in adult; umbilical area bordered by slightly more prominent nodose spiral. Inner shell layer weakly naercous. Operculum not seen.

Dimensions	Height	Max. height	No. whorls
WAM 83.2620a, holotype	5.9	5.2	5.0
WAM 83.2620b, paratype	5.9	5.2	5.0
WAM 83.2620c, paratype	5.7	5.1	4.9
WAM 83.2620d, paratype	6.1	4.9	4.7
WAM 83.2632a, paratype	6.0	5.3	4.8
WAM 83.2632b, paratype	5.2	4.7	4.7
WAM 83.2632c, paratype	5.4	5.0	4.5
WAM P302021, paratype	5.4	4.8	4.5

Discussion. The present species differs from all congeners known to us, eg., *H. sanguineum* (Linnaeus), *H. obtusalis* (Baudon), *H. inermis* (Deshayes) (the two latter from the Lutetian of the Paris Basin), in its abbreviated spire, depressed apex, narrower whorls relative to height and deeply canaliculate suture. The Walpole species is similar in size and shape to *H. eugenii* (Deshayes), also from the Paris Basin Lutetian but differs in having scabrous rather than smooth lirae.

This is the first record from the Australian Tertiary of this wide-ranging Cenozoic genus *sensu stricto*, which, according to Hickman (1974) was 'well defined ... in shallow waters throughout the Eocene'. The ex-Australian stratigraphic range of the genus s. str. is Paleocene–Recent in Europe and Eocene–Recent in the Americas (Keen, in Moore 1960: 1270). Modern records are from warm temperate to tropical seas, excluding southern Australia.

Of the 222 specimens available for examination, 38 had one gastropod borehole and three each had two boreholes, in all cases on the base and usually close to the umbilical area; predation rate is 18%.

The specific name is from the Greek *limnaios*, of a marsh, descriptive of the type locality.

Occurrence. Bremer Basin: North Walpole (type) and Lucky Bay, Pallinup Siltstone, Late Eocene.

Genus **Eutinochilus** Cossmann, 1918

pro *Houalochilus* Cossmann, 1892 *non* Fischer, 1856.

Type species. Collonia miliaris Cossmann, 1892. Lutetian, Franee.

Eutinochilus otwayensis (Pritchard, 1904)

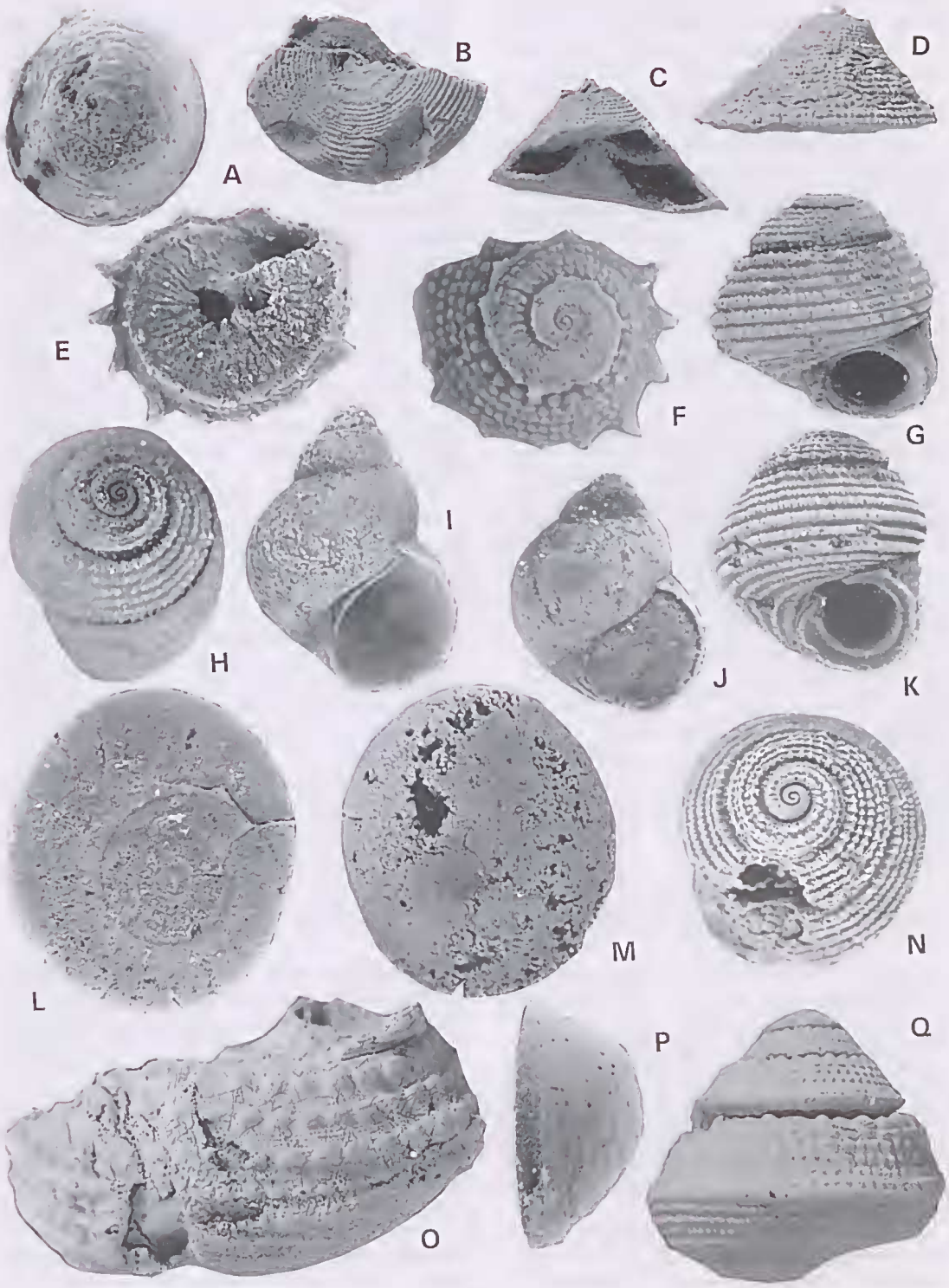
Fig. 4B–C

Collonia otwayensis Pritchard, 1904: 331, pl. 18, figs 6, 7.

Collonista otwayensis—Darragh, 1985: 101, table 2: 113.

Material. NMV P134100 lectotype, P301985, P301986, P302176, P302177, P302178, P302179, P302180. Total 147 specimens. WAM 67.102, 69.125, 72.281, 95.387, 95.598. Total 124 specimens.

Fig. 5. A, E–F, P–Q, *Bolma (Bolma) flindersi darraghi* Beu & Ponder. A, P, operculum WAM 95.611a, exterior: A, × 8.7; P, × 9.3. E–F, WAM 78.922d, juvenile, × 8.6. Q, WAM 83.2623a, showing unworn sculpture, × 4. B–D, *Astralium?* sp., WAM 85.1446, juvenile, × 4. G–H, K, N, *Houalopoma (Houalopoma) limnaios* sp. nov. G–H, WAM 83.2620a, holotype, × 6.2. K, N, 83.2632a, paratype, × 6.5. I–J, *Tricolia (Tricolia) psilia* sp. nov. I, WAM 67.107a, holotype, × 6.3. J, WAM 83.2619a, paratype showing operculum *in situ*, × 6.5. L–M, O, *Turbo (Euninella)* sp. cf. *T. (E.) hauiltonensis* Harris. L–M, WAM 85.631a, operculum, internal, external, × 6.8. O, WAM 83.2639, fragment opposite aperture showing seulpture, × 4.


A
B
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Description. Shell small to minute, robust, subglobose–turbiniform, diameter usually exceeding height when immature, tending to reverse when fully grown; apex bluntly rounded: protoconch usually somewhat flattened, of 1.0–1.5 whorls, on well-preserved specimens seen to be separated from teleoconch by very fine axial thread; spire low to moderately elevated; whorl profile slightly to moderately convex according to position of sutural plane relative to periphery; whorls very slightly depressed below (anterior to) suture; suture incised, weakly offset below by a spiral thread, more apparent near aperture; teleoconch sculpture variable, either with light to very faint spiral striae or smooth; apical whorls on some specimens (NMV P302179) weakly to moderately axially ridged; base a little flattened and bordered by weak angulation in immature specimens, more convexly rounded in adult, with or without faint spiral striae; with or without small, shallow, umbilical recess; aperture ovate, higher than wide, slightly oblique, peristome discontinuous, adapically descending and projecting; outer lip prosocline and internally bevelled, forming (adult) sharp edge; columellar lip thickened and with callus extending onto base, occasionally with weak tubercle (mature shells) and joining with basal rim of aperture; small parietal glaze extends to columellar area; interior not nacreous; operculum unknown.

Dimensions	Height	Max. diameter	No. whorls
NMV P134100, lectotype	4.00	3.90	5.0
NMV P302176, topotype	4.06	3.13	5.0
NMV P302177	3.59	2.92	4.8
NMV P302178	3.04	2.44	4.5
NMV P302179	2.39	3.07	4.2
NMV P302180	2.44	2.88	4.0
WAM 67.102	2.66	2.72	4.3
WAM 69.125	2.45	2.69	4.2
WAM 72.281	2.78	3.01	4.2
WAM 95.387	2.51	2.61	4.12

Discussion. Pritchard's type material appears to have comprised three specimens (Pritchard 1904), only one of which (his figured specimen) has been located in this study. Because Pritchard did not choose a holotype and to ensure that the species name continues to be used as before, we now designate his extant specimen, NMV P134100 (MUGD 1818), as lectotype of *Collonia otwayensis* Pritchard. The type locality is 'Point Flinders' (PL 3019), near Cape Otway, Victoria, from the lower Glen Aire Clay.

The materials to hand, drawn from the Browns Creek Formation, Glen Aire Clay, Blanche Point Formation, Pallinup Siltstone and Werillup Formation, vary somewhat, both within and between samples but we view this as intraspecific variation, reflecting perhaps environmental, predation and clinal factors, singly or in combination and we see no justification for the taxonomic separation of any of these.

The largest specimens in our material (H >4 mm, W *c.* 5) are from the Glen Aire Clay and present a more exert spire than those from elsewhere. This arises from the tendency of the plane of sutural attachment to change direction with growth so that the suture shifts from being at or slightly above the periphery to slightly below, thus generating a more convex whorl profile, a more elevated spire and rounded base. Specimens with a height of up to 3 mm and less than 4.5 whorls tend to have a gently convex whorl profile, low spire, slightly flattened base and a maximum diameter greater than the height. This latter is the more common form of shell in our material overall, particularly (though not exclusively) that from the Bremer Basin.

Fine, close, spiral sculpture on spire and/or base varies in strength and persistence in all of the samples to hand and may be absent altogether. Specimens from the Browns Creek Formation and Pallinup Siltstone tend to be lightly sculptured or smooth, though poor replication may have diminished this character to a degree among the latter. A single shell (WAM 95.398) from the Werillup Formation entirely lacks spirals. Low axial ridges are present on the spire whorls of some Browns Creek specimens, becoming obsolete on the last whorl.

Most specimens from the Glen Aire Clay have a sealed umbilicus (some retaining, nevertheless, a distinct umbilical depression), one has an open immature umbilicus. Shells from Browns Creek Formation, Blanche Point Formation and Pallinup Siltstone have closed or narrowly open umbilici, depending on individual variable growth parameters.

Specimens somewhat similar to the present occur in the Fishing Point Marl (Early Miocene) and Muddy Creek Formation (Middle Miocene). The latter resemble in shape specimens from the Glen Aire Clay but are even larger. Taxonomic consideration of these is deferred.

A high predation rate seems to have been a factor influencing shell size and hence proportion. The largest single source of specimens, North Walpole (Pallinup Siltstone), contributed 75% of the study material and of these 44 shells or 22% showed gastropod boreholes, almost all of bevelled–naticiform type, the shell base being the preferred site of attack. The overall predation rate

is 22%. The likely principal predator is the small naticid *Friginatica aldingensis* (Tate), which is not uncommon at North Walpole and elsewhere.

The present species compares well with the description and figures of *Collonia miliaris* Cossmann 1892 from the Lutetian of Parnes, Paris Basin, which is type species of *Eutinochilus* Cossmann (Cossmann 1918: 129–130, pl. iv, figs 13–14). The genus *Argalista* Iredale, 1915 has been utilised in Australia and New Zealand for species resembling the present but its type species is dissimilar, being more umbilicate and having a lower spire. Umbilical size, however, varies somewhat among other species assigned to that genus, eg., *Argalista kaiparensis* Finlay, Early Miocene, New Zealand (Beu & Maxwell 1990: pl. 53f, i). The type species of *Collonista* Iredale, 1918, *Collonia picta* Pease, 1868 (Recent) has a turbiniform shell with very strong spiral lirae, again quite unlike our study material.

From topotypic material kindly lent to us by the New Zealand Institute of Geological & Nuclear Sciences, we consider the present type species to be very close indeed to *'Argalista' proimpervia* Laws, 1935 from the Kaiatan–Whaingaroan (Late Eocene–Oligocene) of New Zealand (Beu & Maxwell 1990: 113, 404). This seems to be a little larger than the Australian specimens and more consistently marked with fine spirals; the two species are unquestionably congeneric.

The genus (as *Collonista*) is included among Darragh's (1985: 91) Tethyan Indo-Pacific element.

Occurrence. Otway Basin: upper Browns Creek Formation, Late Eocene; lower Glen Aire Clay (type), Early Oligocene. St Vincent Basin: Blanche Point Formation, Late Eocene. Bremer Basin: Ocumup No. 1 deep well, 54.8 m, Werillup Formation, Middle Eocene. North Walpole, Pallinup Siltstone, Late Eocene.

Subfamily Turbininae Rafinesque, 1815

Genus **Turbo** Linnaeus, 1758

Type species. *Turbo petholatus* Linnaeus, 1758. By subsequent designation of Montfort (1810). Recent, Indo-SW Pacific.

Subgenus **Euninella** Cotton, 1939

Type species. *Turbo gruneri* Philippi, 1846. By original designation. Recent, southern Australia.

Turbo (Euninella) sp. cf. **T. (E.) hamiltonensis** Harris, 1897

Fig. 5L–M, O

cf. *Turbo hamiltonensis* Harris, 1897: 274, pl. 8, fig. 3a–c.

Material. WAM 83.2639, 85.631. One incomplete shell and two opercula.

Description. The shell comprises part of the last whorl and columella, possibly a little deformed by compaction. Small for genus and subgenus, whorl profile convexly rounded, with weak peripheral carina; sculpture (suture to base) of 14 spiral ribs of diverse strengths; three subsutural ribs are prominently beaded, fourth narrower and more lightly beaded; these four ribs are well spaced,

Formation	Catalogue Nos	No. of specimens	No. bored	% bored
Glen Aire Clay	NMV P302176	12	4	33
Glen Aire Clay	NMV P302177	9	3	33
Browns Creek Formation	NMV P302179	4	1	25
Browns Creek Formation	NMV P302180	5	4	80
Blanche Point Formation	NMV P302178	17	3	18
Pallinup Siltstone	NMV P301985	1	1	100
Pallinup Siltstone	NMV P301986	98	20	20
Pallinup Siltstone	WAM 67.102	16	4	25
Pallinup Siltstone	WAM 69.125	10	4	40
Pallinup Siltstone	WAM 72.281	1	—	—
Pallinup Siltstone	WAM 95.598	96	15	16
Werillup Formation	WAM 95.387	1	—	—
	Totals	270	59	22

Table 2. Gastropod predation in *Eutinochilus otwayensis*.

occupying adapical shoulder of whorl between suture and periphery; latter bears a strong, continuous, slightly irregular spiral rib; below periphery are ten spirals, some beaded and becoming obsolete toward umbilical area; intercostal spaces bear very fine spiral striae (1–3) and weak, spaced, transverse, slightly prosocline growth ridges; columella evenly rounded, thick and callused over umbilical area; apertural profile a little wider than high, probably due to deformation; internal shell in places faintly nacreous. Operculum small, oval, higher than wide, exterior finely pustulose, asymmetrically convex with shallow eccentric depression, bordered by low spiral rib and narrow peripheral flange; interior flat, spiralled, nucleus eccentric.

Dimensions. Standard dimensions are unobtainable from this incomplete specimen; the aperture from columella to outerlip measures 8 mm, vertically about the same. Estimated original height 25 mm. The larger operculum measures 7.24 × 6.29 (diameters) and 1.76 max. thickness.

Discussion. As far as can be observed from the available characters, the present species appears to be related closely to the Balcombian *T. (E.) hamiltonensis* Harris. It differs in that the whorl profile is more rounded with reduced angulation. The beaded spirals between suture and periphery are similar but a little stronger on the Walpole shell, recalling this aspect of *T. (E.) tenisoni* Finlay. The basal sculpture is closer to that of *T. hamiltonensis* than of *T. tenisoni*. Both species are figured by Harris (1897: 273–274, pl. viii, figs 2–3), the latter as *T. etheridgei* Tenison Woods, 1877 [*non* Lycett, 1857].

Our association of the shell from North Walpole with opercula from Lucky Bay is circumstantial and subject to confirmation from the collection of further material.

The subgenus is included among Darragh's (1985) Southern Australian Endemic element. This record extends the first appearance of *Eminella* back from the Late Oligocene to the Late Eocene.

Occurrence. Bremer Basin: North Walpole and Lucky Bay, Pallinup Siltstone, Late Eocene. The type locality of *T. (E.) hamiltonensis* is Muddy Creek, Victoria (= Muddy Creek Formation, Middle Miocene, Balcombian).

Genus **Bolma** Risso, 1826

Type species. Turbo rugosus Linnaeus, 1767. Pliocene–Recent, Mediterranean.

Subgenus **Bolma** sensu stricto

Bolma (Bolma) flindersi darraghi Beu & Ponder, 1979

Fig. 5A, E–F, P–Q

Bolma flindersi darraghi Beu & Ponder, 1979: 20–21, fig. 5a–h.

Material. WAM 67.108, 69.127, 78.922, 80.1332, 83.2623, 83.2640 (opercula), 83.2641, 85.630, 85.1448, 88.157, 95.611 (opercula). Total 20 shells, four opercula. NMV P47775, P47776, P47777, P301961, P302000 (operculum). Total eight shells, one operculum.

Description (Walpole material). Shell small, robust, trochiform, a little wider than high, 6.2 whorls in a height of 10.7 mm; spire whorls flattened in profile, subtending an angle of about 70°; last whorl with rounded but distinct peripheral keel and lesser basal carination, profile between these slightly concave; plane of attachment a little below periphery, to form canaliculate suture; base slightly convex; aperture subcircular, slightly wider than high, discontinuous with small parietal callus; columella thick, rounded, smooth and somewhat varicose at base; outer lip rounded, prosocline; umbilicus perforate and bounded by a gemmate cord in juvenile specimens, closed in adults; protoconch smooth, lobate, initial 1.5–2.0 whorls sunken, thereafter becoming emergent, astraeiform and spinose at raised periphery; at third whorl, fine radial costellae and more distinct peripheral spinosity appear as whorl begins to descend; at 3.5 whorls, a strong subsutural gemmate spiral appears, followed by others of variable prominence (up to eight including peripheral carina) on subsequent whorls; spinosity variable, usually present on early whorls and may persist weakly or be absent from mature whorls; between peripheral and basal carinae, two or three beaded spirals occur; base smooth in juveniles (up to five whorls), acquiring up to seven weak, beaded spirals on adult shells (6.2 whorls); operculum subcircular, nucleus slightly eccentric, sunken, internal surface slightly concave, external strongly convex, slightly pustulose centrally, elsewhere transversely wrinkled and with distinct marginal rim.

Dimensions	Height	Max. diameter	No. whorls
WAM 83.2623a	10.7	11.2	6.4
WAM 83.2641b	7.1	8.3	5.4

Remarks. The Western Australian specimens of *B. (B.) flindersi darraghi* from Walpole differ consistently from those from the type area (Browns

Creek Formation, Johanna River district, Otway Basin) in their more depressed apex, greater spire angle, reduced spinosity on the adult whorls and more numerous, gemmate (non-scalar) spirals. The reduced spinosity appears, from several well-preserved examples (eg., WAM 83.2623a, 83.2641c), to represent an authentic morphological variant and not a consequence of abrasion. Three incomplete specimens from near Lucky Bay, east of Esperance (WAM 80.1332, 85.630, 85.1448) are closer, both geographically and morphologically, to Victorian material in their more elevated, pagodiform spire, lesser apical angle and greater spinosity (extending to the periphery of the last whorl). These differences between the Walpole–Lucky Bay and Victorian material we regard as intraspecific, possibly clinal.

The present subspecies appears to be ancestral to *B. (B.) flindersi flindersi* (Tenison Woods), described from the Early Miocene (Longfordian Stage) of Table Cape, Tasmania (Beu & Ponder 1979). The genus is included in Darragh's (1985: 91) Tethyan Indo-Pacific element.

Occurrence. Otway Basin: lower Browns Creek Formation (type), Late Eocene. Bremer Basin: North Walpole and Lucky Bay, Pallinup Siltstone, Late Eocene.

Genus **Astralium** Link, 1807

Type species. Turbo calcar Linnaeus, 1758. By subsequent designation of Fischer, 1873. Recent, Indo-SW Pacific.

Bellastraea Iredale, 1924.

Astralium? sp.

Fig. 5B–D

Material. WAM 85.1446. One juvenile shell.

Description. Shell small, immature, lacking apex and part of last whorl; robust; broadly conical, wider than high; spire profile slightly coeloconoid; spire angle almost 90°; sutures adpressed, attached at periphery which is projecting, carinate, not spinose; peripheral angle 55°; base flat with open, shallow umbilical depression; aperture poorly preserved, wider than high; columella short, oblique; sculpture of fine, close, gemmate, spiral lirae, seven per whorl, that below suture with more prominent beading; a few very fine intercalary spirals present; base with 14 fine, non-gemmate spirals, about equal in width to interspaces; umbilical depression bordered by a thicker spiral and with a finer one within.

Dimensions	Height	Max. diameter	No. whorls
WAM 85.1446	6 (est.)	8.8	3+

Discussion. Previous records of *Astralium* from the Australian Tertiary are from the Longfordian Freestone Cove Sandstone, Balcombian Muddy Creek Formation and Pliocene Dry Creek Sands and Roe Calcarenite (Ludbrook 1967; Tenison Woods 1879; Ludbrook 1941, 1956, 1978). The present species, as far as can be seen from the limited material, differs from all of these in its finely gemmate spiral sculpture (spire), near-flat spire profile and absence of spinosity, the latter notwithstanding its juvenile state. This appears to be a true character, not a consequence of abrasion, to which the shell has certainly been subjected.

The sculpture of the shell is not unlike that of *Trochus virgatus* Gmelin, type species of the subgenus *Tectus (Cardinalia)* Gray, 1847 and of other trochid species. However, the keeled periphery and umbilical configuration are very much like those of *Astralium*.

Occurrence. Bremer Basin: Lucky Bay, Pallinup Siltstone, Late Eocene.

Subfamily Tricoliinae Woodring, 1928

Assignment of the Tricoliinae to subfamilial rank within the Turbinidae follows Hickman & McLean (1990).

Genus **Trieolia** Risso, 1826

Type species. Turbo pullus Linnaeus, 1758. Recent, North Atlantic.

A synonymy of the genus was given by Robertson (1985).

Trieolia psilia sp. nov.

Fig. 5I–J

Material. Holotype WAM 67.107a, from 26 km along Thompson Highway north from Walpole townsite, W.A. Paratypes WAM 67.107b, 83.2619, 83.2630a, 83.2650a–f. Total of 12 specimens. NMV P302253. One specimen. All specimens from type locality.

Other material. WAM 67.107, 69.128, 72.280, 83.2619, 83.2630, 83.2650. Total of 153 specimens. NMV P301989–92. 119 specimens.

Description. Shell small, robust, higher than wide, subglobose, naticoid (juvenile) to bulimoid (maturity); height relative to width increasing with

growth; spire equal to about half total height; spire angle 55°; whorls evenly rounded; suture impressed, attached below periphery; protoconch smooth, merging imperceptibly with teleoconch; aperture ovate, higher than wide, angulate above; peristome discontinuous, joined (maturity) by parietal callus; outer lip thin, prosocline, not expanded; columella narrow, raised, evenly curved and extending across but not sealing narrow umbilical fissure (maturity); surface smooth; colour pattern not retained; operculum subpyriform, externally concave, angulate above, rounded below, thickened along adaxial margin; abaxial margin narrowly ridged (paratype WAM 83.2619a).

Dimensions	Height	Max. diameter	No. whorls
WAM 67.107a, holotype	6.97	4.68	5.6
WAM 67.107b, paratype	4.91	3.68	4.9
WAM 83.2630, paratype	5.95	4.26	5.3
NMV P302253, paratype	6.1	4.3	5.3

The height : maximum diameter ratios of the above are 1.48, 1.33, 1.39 and 1.42 respectively, demonstrating the change of shape with growth.

Discussion. The genus *Tricolia* is well represented (as '*Phasianella*') in the Eocene of the Paris Basin (Cossmann & Pissarro 1910: pl. 5, figs 35-1–12) and the Walpole species is broadly comparable with several of these, eg., *T. parisiensis* (d'Orbigny). We have compared our material with specimens (WAM 80.1444, 82.1378) of (Lamarck), type species of the subgenus *Phasianochilus* Cossmann, 1918, noting that both species share a moderately elevated spire with well-impressed sutures. Both have a minute but distinct umbilical fissure but in the Walpole species this develops only in mature specimens and is absent in juveniles. Our largest specimen, the holotype, is much smaller than shells of Lamarck's species.

Robertson (1985) has revised the Indo-West Pacific species of *Tricolia*, all extant; the oldest record of these, *T. variabilis* (Pease), is from the Early Miocene of Bikini Atoll (Ladd 1966). Specimens of *T. variabilis* are deeply grooved beside the columella and do not greatly resemble the Walpole species. According to Robertson (1985), sexual dimorphism occurs in the shells of some species of *Tricolia*, including *T. variabilis*, in which the males are smaller than females and have a flared outer lip. We have been unable to recognise this in the present species.

There are no previous records of *Tricolia* from the Tertiary of either Australia or New Zealand (Beu & Maxwell 1990), though the genus is represented in WAM collections from the Roe Calcarenite of the Eucla Basin. The genus *Pellax* Finlay, 1926 (type species *Phasianella huttoni* Pilsbry) has sometimes been associated with *Tricolia* (eg., Ludbrook 1956: 25) but has been shown by Ponder (1965) to be a mesogastropod and a synonym of *Eatoniella* Dall, 1876 of the Eatoniellidae. *Pellax jejuna* Ludbrook from the Dry Creek Sands of the St Vincent Basin is not a phasianelline, according to Robertson (1985: 23, fig. 15).

The specific name is from the Greek *psilos*, bare, smooth.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Family Trochidae Rafinesque, 1815

Subfamily Eucyclinae Koken, 1897

Genus **Danilia** Brusina, 1865

Olivia Cantraine, 1835 *non* Bertholoni, 1810.
Craspedotus Phillippi, 1847 *non* Schoenherr, 1844.

Type species. Monodonta tinei Calcara, 1835, Recent, Mediterranean.

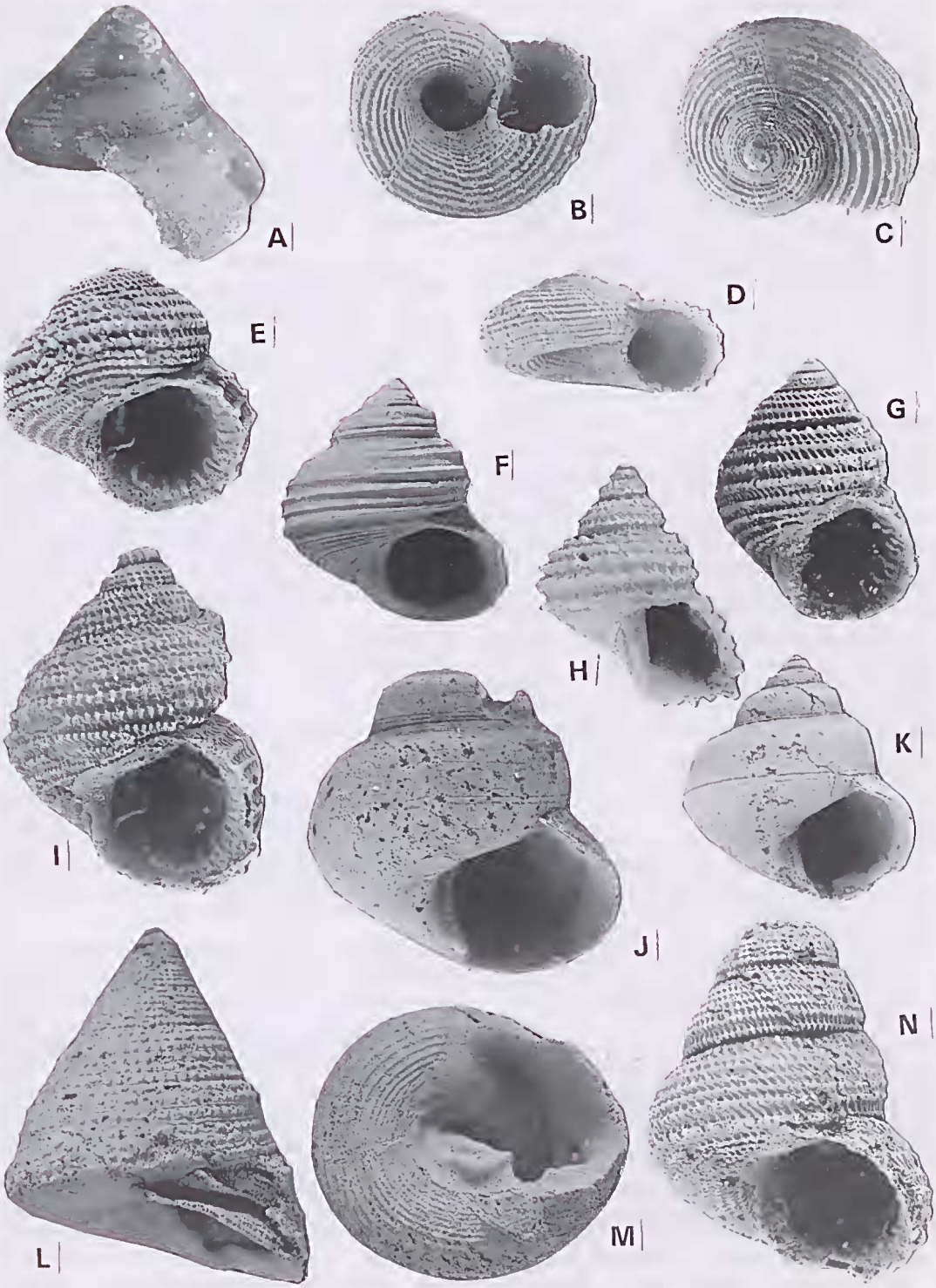
In the above taxonomic arrangement, we follow Wenz (1938) and Hickman & McLean (1990).

Danilia vialis sp. nov.

Fig. 6E–I

Material. Holotype WAM 67.103, from 26 km along Thompson Highway north of Walpole townsite, W.A. Paratypes WAM 72.276, 83.2635, 85.1447, 95.612. Total of nine specimens. Paratype NMV P302183. One specimen.

Fig. 6. A, *Calliostoma* (s.l.) sp. WAM 95.613a, ×6.5. B–D, *Circulus* sp. WAM 67.104, ×8.2. E, I, *Danilia vialis* sp. nov. E, WAM 67.103, holotype, ×5.6. I, WAM 83.2635a, paratype, ×6.5. F, *Micreleuclus (Plumbeleuclus) lirulatus* sp. nov. NMV P302185, holotype, ×4. G, *Danilia euglypta* sp. nov. NMV P302208, holotype, ×6.7. H, *Carinastele* (?) sp. WAM 80.1330, ×6.6. J–K, *Micreleuclus (Plumbeleuclus) armulatus* sp. nov. J, WAM 83.2622e, paratype, ×6.7. K, WAM 83.2622a, holotype, ×6. L–M, *Clanculus* (s.l.) sp. WAM 95.573a, ×4. N, *Agathodonta* (?) sp. WAM 67.99, ×5.7.


A
B
C
D
E
F
G
H
I
J
K
L
M
N

Other material. NMV P301997, P301998, P301999. Total of five specimens.

Description. Shell small, robust, turbiniform, higher than wide, of about 4.5 tumid whorls; spire equal to about half total height; apex subacuminate, subtending with spire angle of about 75°; whorls convexly rounded; suture impressed, narrowly canaliculate and attached below periphery, particularly on apical whorls; protoconch of about 1.5–2.0 smooth, elevated, convex whorls, tip slightly sunken, coiled in axis of shell; aperture moderately large, subcircular, about as wide as high; peristome discontinuous; on mature shell, thin callus extends across parietal area; outer lip strongly prosocline with strong external varix (slightly behind apertural lip) and weaker internal thickening, latter finely crenulate; columella concave, merging evenly with basal margin of aperture and buttressed with strong plate bearing one prominent tooth and notch; false umbilicus a prominent vertical groove on plate; imperforate; sculpture of first teleoconch whorl of very fine close axial costellae, extending over and beyond periphery as short spines; three or four very fine spiral lirae appear at about 1.5–2.0 whorls, increasing to five or six on second whorl and six to eight on penultimate whorl, all finely nodulose (almost scabrous) at intersections with axials, latter strongly prosocline and finer than spirals; on last whorl, spirals number 12–15 from suture to umbilical area, of which fourth is strongest and peripheral, sixth and seventh form doublet and eighth to fifteenth are on base; axial sculpture intensifies on apertural varix and also on base with reduced nodulation on spirals; innermost shell layers weakly nacreous.

Dimensions	Height	Max. diameter	No. whorls
WAM 67.103, holotype	7.5*	6.7	3.0+
WAM 72.276, paratype	8.0*	6.8	3.2+
WAM 83.2635a, paratype	8.4*	5.7	4.6
NMV P302183, paratype	7.8*	6.0	3.0+

* denotes estimated heights; holotype and NMV P302183 lack two apical whorls; others deformed.

Discussion. One deformed and incomplete specimen (85.1447) from Lucky Bay has 15 spirals on the last whorl (suture to umbilical area), of which the seventh is peripheral and strongest. Further material may widen the range of variation in sculpture from that given above.

The Walpole material compares well with a specimen of *Danilia tinei* (Calcara) from Piacenza (WAM 82.1473) and there is no doubt as to their congeneric status. Spiral sculpture on our species is finer and more numerous and it seems to be a little wider relative to height, albeit mostly deformed. From the extant southern Australian *D. telebatha* Hedley, the present species differs in its much stronger columellar plate and tooth.

Danilia vialis is readily distinguished from the Janjukian *D. euglypta* sp. nov. (see below) by its more numerous spirals, stronger apertural varix and by the deep groove on the ventral surface of the columellar plate, a character absent from the latter species. *Danilia neozelanica* Laws from the Runangan (Late Eocene) of New Zealand (Laws 1935: 30, fig. 2) is of comparable age with *D. vialis* but differs in its substantially fewer spiral lirae. The Walpole species has some resemblance to *Danilia perelegans* (Deshayes) from the French Lutetian (figured in Cossmann & Pissaro 1910: pl. 3, fig. 22-2), differing in its finer and more numerous spiral lirae.

Ryckholt (1862) listed 38 nominal, mostly fossil, species of *Craspedotus* (=*Danilia*), most of which were assigned to stages of the Late Cretaceous. The status of these nomina are for the most part subject to confirmation but it is unlikely that any is directly relevant to the present species.

The specific name is from the Latin *vialis*, of roads, in view of the close proximity of the type locality to a public highway.

Occurrence. Bremer Basin: North Walpole (type) and Lucky Bay, Pallinup Siltstone, Late Eocene.

Danilia euglypta sp. nov.

Fig. 6G

Material. Holotype NMV P302208 from Spring Creek, near Torquay, Victoria; ledge and above ledge, Bird Rock Cliffs, J. Dennant Coll. Paratypes NMV P302204, P302205. Two specimens. Other material P302206, P302207*, P302209*, P302210*, P302211*. Five specimens. * denotes specimen from type locality.

Description. Shell small for genus, robust, ovate-turbiniform, higher than wide; spire slightly exceeds half total height; apex subacuminate; spire angle 60°; whorls tumid; sutures impressed, canaliculate, attached below periphery, descending slightly at aperture; base rounded, anomphalous; aperture moderately large, subcircular; peristome discontinuous, weakly angulate above and joined by a thin parietal glaze; other lip prosocline, thin, bevelled and denticulate within and with weak external varix behind; peristome slightly effuse, more so on basal and columellar margins where reflected over umbilical area; columella thick with strong vertical plate with basal tooth and notch anterior to it; protoconch smooth, of about

1.5 whorls, coiled in axis of shell; subsequent 1.3 whorls bear fine, close, prosocline axial threads; three fine spiral cords appear at *c.* 2.0 whorls, becoming four on third whorl; spirals stronger and more spaced than axials; points of intersection nodose, more strongly on spiral below suture which is gemmate; four or five spirals on penultimate whorl, 11–12 on last whorl of which fifth (from suture) is strongest; spirals narrower than interspaces; intercalary spirals occasionally present; axials almost lamellate on last whorl.

Dimensions	Height	Max. diameter	No. whorls
NMV P302208, holotype	6.03	4.14	5.2
NMV P302204, paratype	5.43	3.90	5.0
NMV P302205, paratype	5.48*	4.15	3.7+

* denotes apex slightly truncated.

Discussion. The present species differs from both *Danilia tinei* (Calcara) and the Late Eocene *D. vialis* (see above) in its less gradate spire, its reduced post-apertural varix, the absence of a deep groove on the columellar plate and a tendency to finer sculpture. It differs from the extant *D. telebatha* Hedley in its less gradate spire and stronger columellar plate: it appears to be smaller than all of the above three species.

No post-Janjukian fossil records of *Danilia* are as yet known from Australia; the genus is not recorded as a fossil from New Zealand after the Runangan (Late Eocene) (Beu & Maxwell 1990: 403), but is represented in the modern fauna by *D. insperata* Beu & Climo, 1974.

The specific name is from the Greek *eu*, good, well, true, etc., and *glyptos*, carved, engraved, etc., from the elaborate sculpture of the shell.

Occurrence. Port Phillip Basin: Jan Juc Formation, Late Oligocene–Early Miocene (Janjukian Stage).

Genus **Agathodonta** Cossmann, 1918

Agnathodonta—Wenz, 1938: 298, fig. 653 (obj.).

Type species. Trochus deutigerus d'Orbigny, 1843. By original designation, Neocomian, France.

Agathodonta (?) sp.

Fig. 6N

Material. WAM 67.99. One specimen.

Description. Shell small, robust, elevated-turbiniform, spire acute, estimated at about two-thirds total height; spire angle *c.* 45°; whorls gently convex; suture impressed, attached below periphery; aperture roundly subquadrate, slightly higher than wide; peristome discontinuous; outer lip strongly prosocline, slightly thickened but without a varix; internally bevelled and weakly crenulate; columella thick, vertical, with single small, projecting median-low tooth and wide basal notch; columella merges into slightly effuse basal margin; base rounded, imperforate. Sculpture of fine, spiral lirae, about equal to interspaces, numbering seven on penultimate whorl and 14 on last whorl (seven each on shoulder and base), of which seventh from suture is strongest; subordinate sculpture of very fine, axial/prosocline threads forming very fine, close nodulations at intersections with spirals; axials intensify on abapical side of suture, around aperture and on base.

Dimensions	Height	Max. diameter	No. whorls
WAM 67.99	11.5 (est.)*	7.51	3.8+

*Several apical whorls have been lost by breakage.

Discussion. In the general form of the shell and its sculpture, the specimen resembles both *Agathodonta deutigera* (d'Orbigny), type species of the genus and also *A. nortoni* McLean, Recent, Philippines (Cossmann 1918: 193, 200, 201; Cox, in Moore 1960: 1249, fig. 160,2; McLean 1984: 121–123; Hickman & McLean, 1990: 78, fig. 40E) and is referred provisionally to that genus. It differs from both of the above mentioned species in having only a single columellar tooth, in contrast to the prominent double teeth of the others.

Further taxonomic evaluation of the present species is deferred until more specimens are to hand.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Subfamily Trochinae Rafinesque, 1815

Genus **Micrelenchus** Finlay, 1926

Type species (monotypy). *Trochus sanguineus* Gray, 1843. Recent, New Zealand.

In according full generic status within the Trochinae to *Micrelenchus*, we follow Hickman & McLean (1990) and Marshall (1998b).

Subgenus **Plumbelenchus** Finlay, 1926

Type species. Trochus capillaceus Philippi, 1848, Recent, New Zealand.

Micrelenchus (Plumbelenchus) armulatus sp. nov.

Fig. 6J–K

Material. Holotype WAM 83.2622a from 26 km along Thompson Highway north from Walpole townsite, W.A. Paratypes WAM 67.100, 67.106, 83.2622b–c, 83.2636a–c. Total of ten specimens. NMV P301184. One specimen.

Other material. WAM 69.124, 72.277, 83.2622d–f, 83.2627, 83.2636d–r, 85.632. Total of 30 specimens. NMV P301993, P301994, P301995, P301996. Total of 28 specimens.

Description. Shell small, robust, turbiniform, higher than wide, spire equal to about half total height; whorls usually stepped with distinct subsutural shelf and roundly subangulate shoulder; second shoulder corresponds with plane of sutural attachment; last whorl contracted basaly, usually subangulate to (less often) rounded in profile; apical angle 60°; aperture subquadrate to subcircular, peristome discontinuous, outer lip strongly prosocline, on some specimens contracted at suture, bevelled within, lacking varix and internal crenulation; columella short, obliquely concave, expanded and thickened toward base, merging evenly with basal margin of aperture, lacking tooth; base rounded, anomphalous; protoconch smooth, of one whorl, slightly deviated from axis of shell, tip sunken; succeeded by convex, shouldered whorl with three spiral lirae, of which adapical forms angulate edge of subsutural shelf; sculpture, where present, entirely spiral, of very fine striae, intensified on shelf, mostly faint to obscure elsewhere; spirals occasionally stronger and extending over most or all of shell, including base. Traces of remnant nacre sometimes present within aperture and on exposed inner shell layer.

Dimensions	Height	Max. diameter	No. whorls
WAM 83.2622a, holotype	5.90	5.76	5.4
WAM 83.2622b, paratype	5.80	5.18	5.2
WAM 67.100a, paratype	6.41	5.96	5.3
WAM 83.2636a, paratype	6.51	5.90	5.3
NMV P302184, paratype	5.8	5.0	5.0

One poorly preserved, slightly deformed specimen (83.2636, part) has a height of 7.68 mm, MD 7.47 mm.

Discussion. Variation in the present species is to be noted both in the whorl profile and in the strength and persistence of the sculpture, the latter noted above. The holotype and most other specimens have a distinct subsutural shelf and a roundly biangulate profile to the last whorl. Paratype WAM 83.2622b has a less well defined shelf and more rounded whorl profile and is relatively a little higher in the spire. All other characters are shared and we regard these differences, including sculptural, as intraspecific.

Shell characters of *Micrelenchus* Finlay and *Plumbelenchus* Finlay are weakly differentiated according to Marshall (1998b), who evaluated the latter as a subgenus of the former, followed herein. Compared with the figures of the type species of each taxon (Marshall 1998b: figs 17–19, 34–39), the present species more closely resembles *M. (P.) capillaceus* (Philippi) in sculpture and whorl/apertural profiles.

As presently understood, the genus is centred on New Zealand with a stratigraphic range of Duntroonian to Recent (Beu & Maxwell 1990: 31, 36, 138, 403–404). The Australian stratigraphic range—Late Eocene to Early Oligocene—thus predates its trans-Tasman counterpart. The specific name is from the Latin *armus*, a shoulder, a salient character of the whorl profile.

Occurrence. Bremer Basin: North Walpole (type) and Lucky Bay, Pallinup Siltstone, Late Eocene. St Vincent Basin: Uncle Tom's Cabin, Maslin Bay, South Australia, Blanche Point Formation, Late Eocene.

Micrelenchus (Plumbelenchus) lirulatus sp. nov.

Fig. 6F

Material. Holotype NMV P302185, from slips at Station Beach, north of Point Flinders near Cape Otway, Victoria (locality PI 3019). Paratypes NMV P302186, P302187, from type locality. Total of three specimens.

Other material. NMV P133326, P133338, P302286. 20 specimens.

Description. Small, robust, turbiniform, slightly higher than wide; spire about equal to half total height; whorls regularly convex with narrow subsutural shelf, on some specimens shouldered; spire of variable height, angle 60–80°; suture impressed, inserted below periphery; aperture subcircular, peristome discontinuous, outer lip prosocline; columella regularly concave, bounded by narrow parallel groove, merging into basal margin of aperture; protoconch smooth, of about one whorl, tip depressed, slightly deviated and weakly offset from teleoconch; sculpture of prominent spiral lirae of variable strength and spacing, five or six on penultimate whorl, 14–20 on last whorl; lirae more or less spaced above periphery, stronger on

periphery and crowded on base; microsculpture of very fine, crowded spiral threads and prosogyrate axials on lirae and interspaces; interior nacreous.

Dimensions	Height	Max. diameter	No. whorls
NMV P302185, holotype	10.74	8.32	5.9
NMV P302186, paratype	11.27	8.33	6.9
NMV P302187, paratype	8.55	8.50	5.7

Discussion. The species varies somewhat in proportions of height (and also spire height) to diameter, in the spire angle, width of subsutural shelf and number and spacing of the primary spiral lirae. It is larger and much more strongly sculptured than the Late Eocene *M. (P.) armulatus* (see above) and the two are morphologically well differentiated. This species bears some resemblence to *M. (P.) mortenseni* (Odhner, 1924), Recent, New Zealand, but has fewer spiral lirae and the lirae are not nodulate as in *M. (P.) mortenseni*.

Occurrence. Otway Basin: lower Glen Aire Clay, Early Oligocene.

Genus **Clanculus** Montfort, 1810

Type species. Trochus pharaonius Linnaeus, 1758. By monotypy. Recent, Indo-West Pacific.

Subgenus **Paraclanculus** Finlay, 1926

Type species (monotypy). *Paraclanculus peccatus* Finlay, 1926, Recent, New Zealand.

Clanculus (Paraclanculus) sp.

Fig. 6L–M

Material. WAM 95.573. Two specimens. NMV P302001. Two specimens.

Description. Shell small, robust, trochiform, higher than wide; spire profile almost straight, very slightly attenuated apically; spire angle 60°; suture linear, lightly impressed, inserted at periphery; base almost flat; periphery roundly angulate; aperture wider than high, discontinuous, outer lip strongly prosocline, internally bevelled, smooth but neither crenulate, dentate nor costate within; parietal glaze thin; columella oblique, twisted, emerging from shallow false umbilicus; one very weak adapical tooth and strong, projecting, basal-terminal tooth and sinuate notch, the former being termination of strong, smooth spiral rib which emerges from false umbilicus; second, weaker, smooth spiral borders umbilical area, terminating at notch; basal margin thickened with small, recurved, internal shelf; sculpture of finely granose spiral cords, six on each whorl, those on apical four whorls weakly cancellate and showing radial alignment of granules; last and penultimate whorls with additional very fine intercalary spiral threads; base with eight fine, non-granulose, spiral threads; interior nacreous.

Dimensions	Height	Max. diameter	No. whorls
WAM 95.573a	13.60	11.65	7.2

Discussion. The species is at present known from only four specimens, two of which are poorly preserved; one only has an intact aperture. Of the available trochine genera, the species agrees generally with *Clanculus sensu lato* but does not match closely any of the known subgenera, including those of Iredale (1924) and Cotton & Godfrey (1934), based on southern Australian species. The nearest of these seems to be *Euclanculus* Cotton & Godfrey (type species *Clanculus leucomphalus* Verco, Recent, South Australia), which has a spiral 'funicle' emerging from the pseudumbilicus and terminating at the basal columellar tooth (Verco 1905: 168–169, pl. 31, figs 9–11). Differences on the present species from *C. leucomphalus* include the almost straight spire/whorl profile (recalling that of *Calliostoma*), the absence of any circumumbilical nodulation, the entirely smooth outer lip and interior and the much finer overall sculpture, particularly on the base.

In its spire profile, the present species resembles a number of extant Australian species of *Clanculus*, eg., *C. brunneus* A. Adams, *C. comarilis* Hedley, *C. margaritarius multipunctatus* Jansen and *C. septenarius* Melvill & Standen, differing from all of these in its simple apertural, umbilical and columellar features and fine sculpture (Jansen 1995). This species bears a close resemblence to *C. (Paraclanculus) peccatus* Finlay, 1926, Recent, New Zealand (Marshall 1998a: 100, figs 54–56).

The present species, which appears to be new, is the first record of the genus from the Eocene of Australia. Further determination is deferred until more material comes to hand.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Subfamily Calliostomatinae Thiele, 1924

Genus **Calliostoma** Swainson, 1840

Type species. Trochus conulus Linnaeus, 1758. By subsequent designation of Herrmannsen, 1846. Recent, western Europe.

Subgenus **Fautor** Iredale, 1924

Type species. Ziziphinus comptus A. Adams, 1855. Recent, Australia.

Calliostoma (Fautor) numapum sp. nov.

Fig. 7A

Material. Holotype WAM 83.2633a, from 26 km along Thompson Highway north from Walpole townsite, W.A. Paratypes WAM 67.95a–b, 67.96, 72.236, 83.2621a–b, 83.2626a, 83.2633b–c, 96.249. Total of eleven specimens. NMV P302254. One specimen.

Other material. WAM 67.95c–f, 67.182, 69.120, 69.122, 69.130, 72.278, 83.2621c–i, 83.2626b–g, 83.2633d–z. Total of 53 specimens. NMV P301958, P302002, P302003, P302004. Total of 38 specimens.

Description. Shell small, robust, trochiform-conical, higher than wide; spire moderately elevated, whorls up to seven, early whorls convexly rounded, by third whorl flat in profile; last whorl a little contracted; spire angle 51°; suture lightly impressed; periphery carinate in immature shell, roundly subcarinate in adult; base gently convex, without umbilicus; aperture roundly quadrangular, peristome discontinuous; outer lip strongly prosocline, attached slightly below periphery; basal lip

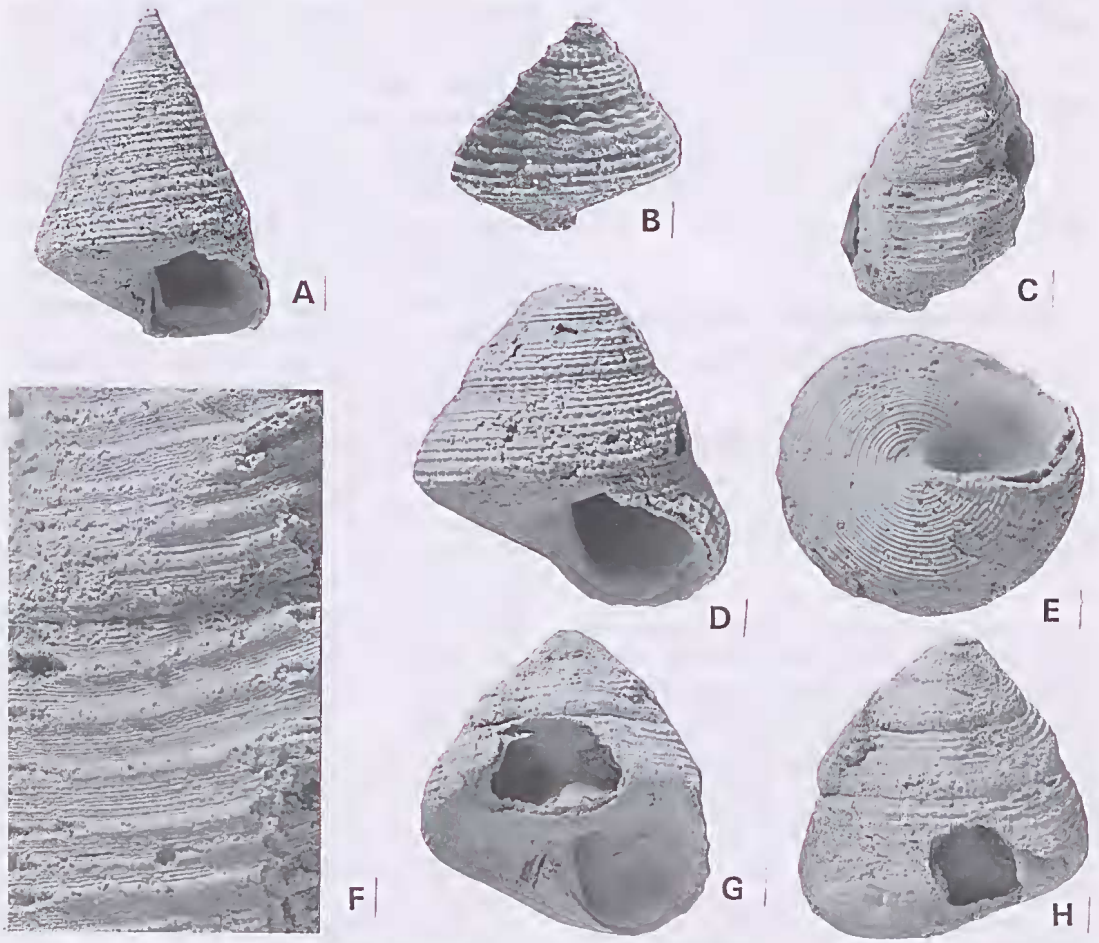


Fig. 7. A, *Calliostoma (Fautor) numapum* sp. nov. WAM 83.2633a, holotype, × 4. B, Trochid, genus undetermined, species B. WAM 67.98, × 6.8. C, F, G–H, *Calliostoma* (s.l.) sp. WAM 83.2634, deformed shell: C, G–H, × 1.3; F, × 6.5. D–E, Trochid, genus undetermined, species A. WAM 95.614, × 4.

thickened internally, slightly reflected; columella short, thick without tubercle, oblique, meeting base at angle of *c.* 100°; protoconch paucispiral, of one whorl, slightly oblique to shell axis; reticulate microsculpture occasionally preserved; teleoconch sculpture of fine, close, spiral lirae and subordinate, prosocline axials, all rather variable in number, spacing and persistence; first two whorls cancellate with two or three spiral lirae and finer, prosocline axial threads, weakly nodulose at the intersections; on subsequent whorls, spirals increase by intercalation up to six/nine, all finely nodulose, those about suture more prominent than others; axials tend to weaken after fourth whorl but may persist onto last whorl and base as axially aligned rows of nodules (eg., paratype WAM 83.2633b); last whorl with seven/nine spirals above periphery and 16/22 spirals on base, latter of variable strength, with or without nodules; inner layers nacreous (eg., WAM 69.130, paratype 83.2633b).

Dimensions	Height	Max. diameter	No. whorls
WAM 83.2633a, holotype	10.74	7.30	7.7
WAM 72.236, paratype	10.76	6.81	7+
WAM 83.2626a, paratype	8.35	6.27	7.1
WAM 83.2633b, paratype	9.93	6.38	7.2
NMV P302254, paratype	8.4	6.4	6+

Discussion. In size and proportions, the present species recalls *Calliostoma waiareka* (Laws) from the Kaiatan (Late Eocene) of New Zealand (Laws 1935: 32, fig. 5; Beu & Maxwell 1990: 116, pl. 7, fig. m). The Walpole species differs from that of Laws in sculptural details, particularly in its more numerous basal spirals, which may or may not bear fine nodules.

A somewhat similar species of *Calliostoma* occurs in the Glen Aire Clay, Otway Basin, having thin, widely spaced spiral lirae which are prominently gemmate at intersections with thin axial costellae. The shell is much wider relative to height than that from Walpole.

The specific name, from the Nyoongar (south-west Australian) Aboriginal *nu-map*, small, little, diminutive (Bindon & Chadwick 1992: 382), alludes to the small size of the species.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Calliostoma (s.l.) sp.

Figs 6A; 7C, F, G–H

Material. WAM 83.2634, 95.613. Three specimens.

Description. Shell of medium size for genus, robust, trochiform, height and width approximate; spire probably exceeding half height; spire probably coeloconoid; apex bluntly rounded; whorls exceeding five in height of about 30 mm; suture linear, lightly impressed, attached at or slightly below periphery; whorls almost flat in profile; periphery of last whorl roundly subangulate; aperture large, discontinuous, roundly quadrangular, outer lip prosocline and internally bevelled; columella oblique, concave, without tooth, bordered by a rim, which is continuous with margin of outer lip; base anomphalous, probably gently convex; protoconch apparently smooth, of *c.* 0.8 whorl, tip sunken; primary spiral thread appears on first teleoconch whorl, followed by other spirals on second and third whorls; no axial sculpture; on fourth and subsequent whorls, spirals become six or seven weakly nodulose, ridge-like cords with very fine, crowded, spiral threads in interspaces; eight spirals on base.

Dimensions	Height	Max. diameter	No. whorls
WAM 83.2634	32	30/15	5+
WAM 95.613a, juvenile	5.72	6.06	5.2

Of the two measured specimens, the larger is strongly deformed by compaction; the other is a juvenile.

Discussion. The material to hand permits only a limited description, establishing little more than the presence of another, rare and apparently unnamed species of *Calliostoma* at North Walpole. It is distinguished readily from the associated congeners by its greater size and somewhat atypical sculpture.

The combination of weakly nodulose spirals and interspaces crowded with very fine spiral threads is uncommon in *Calliostoma*. The subordinate sculpture (and also shell size and proportions) resemble those of *Calliostoma moniliferum* (Lamarck) from the Bartonian (Late Eocene) of France and England (eg., WAM 82.1204) but Lamarck's species (figured by Cossmann & Pissarro 1910: pl. 4, fig. 30-1) has fewer and more strongly nodulose spirals than the present species. Further determination of this species is subject to the collection of additional material.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Subfamily Thysanodontinae Marshall 1988

The subfamily was erected by Marshall (1988b) for three extant trochid genera, the species of which, all modern, are from New Zealand, New

Caledonia, southern Australia and South Africa. The shells are calliostomatine in form and share with that subfamily a protoeonch microsculpture described as 'a network of interconnected hexagons' (Marshall 1988: 215). The thysanodontines are characterised by a highly distinctive, specialised jaw and radular structure, interpreted as adaptions to a suctorial mode of feeding. A Mesozoic origin for the subfamily is postulated by Marshall (1998: 217).

Genus **Carinastele** Marshall, 1988

Type species. *Carinastele kristelleae* Marshall, 1988. By original designation. Recent, Cook Strait and Macquarie Ridge, New Zealand, 126–274 m, on coarse substrata.

Carinastele (?) sp.

Fig. 6H

Material. WAM 80.1330. One deformed specimen.

Description. Shell small, robust, trochiform, higher that wide; whorls convexly rounded, without median carination; spire slightly coeloconoid, spire angle *c.* 70°; suture impressed, canaliculate, attached below periphery; apex and protoconch abraded, protoconch of about 0.8 whorls, terminated by weak varix; base almost flat, anomphalous; aperture subrectangular (deformed); peristome discontinuous; outer lip slightly prosocline; columella extended, mostly straight but slightly twisted at base, meeting basal margin of aperture at *c.* 90° (deformed); basal margin effuse near columella; sculpture of first teleoconch whorl initially of faint axial threads crossing weak subsutural shoulder, latter becoming on second whorl primary spiral cord, to be joined by others; on third whorl three spirals are cancellated at intersections with finer axial threads; penultimate and last whorls strongly cancellate with five strong, raised spirals, narrower than interspaces and crossed by weaker axials, nodulose at intersections; no intercalary spirals present; base bordered by carinate angulation corresponding to plane of sutural attachment; basal sculpture finer than that of spire, comprising six narrow spiral cords with wide interspaces crossed by numerous fine axial threads, scabrous at intersections; internal nacreous lustre not observed.

Dimensions	Height	Max. diameter	No. whorls
WAM 80.1330	5.9	4.0	5.5

Discussion. Of the trochid subfamilies revised by Hickman & McLean (1990), the present species seems best located in the Thysanodontinae, a provisional assignment in view of the limited nature of the material to hand. The specimen shares a suite of characters with *Carinastele kristelleae* Marshall, the type species of *Carinastele*, eg., the whorl profile and general form, channelled suture, the cancellate sculpture (dissimilar on spire and base) and apertural shape. Differences include the much more nodulose spire sculpture with a stronger axial component, the absence of intercalary spirals and any carination on the early teleoconch; the basal twist of the columella is present but weaker than in *C. kristelleae* and its new Zealand congeners. The present species lacks the conspicuous nacreous lustre of other thysanodontines but this may be a consequence of the silica replacement process. SEM examination of this specimen shows that the protoconch and apical 2.5 whorls, site of several diagnostic thysanodontine characters, are much abraded. Consequently, the present identification, possibly the first fossil record for the subfamily, remains subject to confirmation.

Occurrence. Bremer Basin: Lucky Bay, Pallinup Siltstone, Late Eocene.

Trochid, genus undetermined

Species A

Fig. 7D–E

Material. WAM 95.614. One specimen.

Description. Shell small, robust, trochiform, higher than wide; spire angle 68°; whorls slightly convex, periphery subangulate, becoming rounded toward aperture; sutures lightly impressed, attached slightly below periphery; base rounded, anomphalous; aperture roundly subquadrate; peristome discontinuous; outer lip broken, probably strongly prosocline; no parietal glaze apparent; columella curved, without tooth; apex missing; sculpture of fine, close, gemmate spirals, increasing by intercalation, 11 on penultimate whorl and above periphery of last whorl; on base, 21 finer spirals, not gemmate; aperture and interior faintly nacreous.

Dimensions	Height	Max. diameter	No. whorls
WAM 95.614	12 (est.)	10.2	4+

Discussion. The specimen lacks the apex and appears to be an immature shell. Its proportions and sculpture set it apart from all other trochids

in the assemblage. Further determination of this rare species depends on collection of additional specimens.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Species B

Fig. 7B

Material. WAM 67.98. One shell.

Description. Shell very small, probably juvenile, trochiform with gradate spire and deeply impressed suture, attached at periphery; spire angle almost 90°; base gently convex with narrow umbilical fissure; aperture rectangular, peristome discontinuous, no parietal glaze; columella straight, a little effuse at base where meeting apertural margin; periphery roundly subangulate; sculpture of apical whorls poorly preserved; protoconch with tip depressed; by third whorl, sculpture of five, narrow, slightly undulating and weakly scalar spiral cords; on last whorl, these number seven, all wider than interspaces with scales expanding into low axial plicae; base sculptured with *c.* 13 regularly spread lirae, slightly narrower than interspaces.

Dimensions	Height	Max. diameter	No. whorls
WAM 67.98	4.32	4.50	4.6

Discussion. The identity of this rare species remains to be clarified from further, better preserved material. The distinctive sculptural combination (base and apex) resembles that of no other species in the study material.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Family Trochaclidídae Thiele, 1928

Genus **Trochaelis** Thiele, 1912

Type species. Trochaclis antarctica Thiele, 1912. By monotypy. Recent, Antarctica.

The systematics and taxonomy of the trochaclidid gastropods have been discussed recently by Hickman & McLean (1990) and by Marshall (1995). We follow the latter in according them full family status. Generic arrangement of the family relies primarily on anatomical, particularly radular, characters, not available with fossil material, so that determinations of the latter are, to some extent, subjective.

The shell characters of *Trochaclis* have been summarised by Marshall (1995: 93) thus: 'Shell turbiniform, up to about 2.00 mm wide, narrowly umbilicate or anomphalous, white. Interior surface set with scattered platelets, presumably aragonite, and representing vestigial nacreous layer. Protoconch of less than one whorl, sculptured with fine network of crisp threads that enclose irregularly polygonal spaces, tip of apical fold pinched. Teleoconch whorls convex, a rounded varix early on first whorl, with or without shoulder angulation on first one or two whorls or (one species) with shoulder and peripheral keel on all whorls, with or without a few basal spiral threads.' From the available characters, the species described below seems best located in this genus.

The distribution of the family (or subfamily of the Trochidae in the view of Hickman & McLean 1990) is Antarctica, NE Pacific, North Atlantic–Mediterranean, New Caledonia, New Zealand and southern Australia. Living animals have been found to be sponge-associated (Hickman & McLean 1990) and abundance of sponges throughout the Pallinup Siltstone, including the North Walpole site, suggests that this association has persisted at least since the Late Eocene.

Trochaelis (?) stillata sp. nov.

Fig. 8H, J

Material. Holotype WAM 83.2649a, from 26 km along Thompson Highway north from Walpole townsite, W.A. Paratypes WAM 67.188, 69.123, 83.2638, 83.2649b–d. Total of 15 specimens. NMV P302216. One specimen.

Other material. NMV P301959. Total 12 specimens.

Description. Shell minute, robust, turbiniform, slightly wider than high, of up to four smooth whorls with broad subsutural shelf, descending a little at maturity and strongly convex periphery; suture linear, impressed, attached below periphery; apex flattened; protoconch poorly preserved, apparently smooth, weakly distinguishable from teleoconch by obscure varix; tip slightly sunken; base roundly convex; umbilicus a narrow fissure; aperture subcircular, in maturity, peristome continuous across parietal area, discontinuous in immature shell; outer lip prosocline; columella short, vertical, slightly reflected across umbilical fissure and curving evenly into basal peristome; surface smooth, without visible sculpture.

Dimensions	Height	Max. diameter	No. whorls
WAM 83.2649a, holotype	2.04	2.40	4.0
NMV P302216, paratype	2.1	2.5	4 (est.)

Discussion. Marshall (1995) has recorded nine species of *Trochaclis* from the southwest Pacific region, five from the Recent of New Zealand, three from the Early Miocene (Otaian) of New Zealand and one from the Middle Miocene (Balcombian) of Victoria. The present species, possibly the first record of genus and family from the Eocene, differs from all of the foregoing in its combination of a notably wider than high shell, devoid of sculpture, with broad subsutural shelf and narrow umbilical fissure. From *Trochaclis antarctica* Thiele (figured by Dell 1990: 119, 120, fig. 201), it differs in its wider base and lower spire.

The present species differs from the trochaclidids *Acremodontina translucida* (May), Recent, southern Australia and from *A. balcombiana* Marshall, Middle Miocene, Victoria (Marshall 1995) in its greater width relative to height, broader subsutural shelf and absence of spiral sculpture.

The specific name is from the Latin *stillo*, a drop, alluding to the minute size of the shell.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Family Skeneidae Clark, 1851

Genus **Leucorhynchia** Crosse, 1867

Type species. Leucorhynchia caledonica Crosse, 1867. By monotypy. Recent, SW Pacific.

This genus is recorded from the Paleocene–Miocene of Europe, Eocene–Miocene of Australia. Modern records are from the SW Pacific.

Leucorhynchia rotulina sp. nov.

Fig. 8F, I, K–N, P-Q, T

Material. Holotype WAM 83.2642a, from 26 km along Thompson Highway north from Walpole townsite, W.A. Paratypes WAM 83.2642b–p. Total of 16 specimens. NMV P302255. One specimen.

Other material. WAM 67.178, 69.126, 83.2642, 95.371, 95.392, 95.426, 95.430. Total of 88 specimens. NMV P301960. Total of 64 specimens.

Description. Shell minute, robust, of few whorls, subdiscoidal–rotelliform, wider than high; spire very low, apex flattened; last whorl with broad subsutural shelf, on some specimens slightly sunken; periphery convexly rounded, smooth to subangulate according to sculpture; suture linear, impressed, attached above periphery but descending on last whorl; protoconch lobate, of about one smooth whorl, not readily distinguished from teleoconch (Walpole specimens); base gently convex; immature umbilicus open, reduced to fissure or almost closed in maturity; aperture circular, peristome continuous; outer lip slightly prosocline, thin; adapical lip projecting beyond abapical lip; columella short, concavely arched with parietal callus and stronger, expanded, basal callus extending over umbilical area; sculpture variable—from almost smooth with faint spiral threads, continuous or otherwise, on spire and/or last whorl—to fine, close, spiral cords of uneven strength and spacing over entire adapical surface; cord below suture on some specimens stronger than others and axially gemmate; base without spirals, most specimens show pinched, axial folds crowding umbilical area; operculum calcareous, circular, spiral, nucleus central. Nacreous lustre not observed.

Dimensions	Height	Max. diameter	No. whorls
WAM 83.2642a, holotype	1.60	2.48	3.2
WAM 95.430a	1.42	2.56	3.2
NMV P302255, paratype	1.9	2.5	3.3

Discussion. The above description is based on topotypic material, all siliceous replacements, from North Walpole. Six well preserved specimens (WAM 95.371, 95.392, 95.426, 95.430) from the Werillup Formation in the Ocumup No. 1 deep well (53.4–73.2 m), though quite similar, differ slightly in being more consistently spirally striate on spire and base, subsutural beading may extend to become weak axial plicae across the shelf and the umbilicus becomes sealed earlier in growth by extension of the basal apertural callus directly into the umbilicus; the protoconch is prominent, smooth, lobate, of 0.8 whorls, terminated by the abrupt onset of spiral teleoconch sculpture (two threads).

Fig. 8. A–B, G, *Collonia variabilis* sp. nov. NMV P302634, holotype, × 16. C–E, *Pseudoninella?* sp. WAM 95.366, × 7. F, I, K–N, P–Q, T, *Leucorhynchia rotulina* sp. nov. F, I, K, WAM 83.2642c, paratype. L–M, P, WAM 83.2642d, paratype. N, Q, T, WAM 83.2642a, holotype, × 15. H, J, *Trochaclis (?) stillata* sp. nov. H, WAM 83.2649a, holotype. J, WAM 67.188, paratype. × 15. O, R–S, *Leucorhynchia ventricosa* sp. nov. WAM 83.2643a, holotype, × 15.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Both Crosse (1867) and Cossmann (1918) refer to a nacreous interior for species of *Leucorhynchia*, including its type species *L. caledonica* Crosse, but this has not been observed on any of our material, whether siliceous replacements (Walpole) or carbonate shells (Ocumup No. 1 deep well). The latter we refer provisionally to the present species.

In general form, the present species resembles *L. callifera* (Deshayes) from the Lutetian of France and Hungary, figured by Cossmann & Pissaro (1910: pl. 4, fig. 33-8) and by Strausz (1966: 104, pl. 2, figs 7, 10, 11), differing in its smaller size, stronger circumumbilical folds and in the presence of well-defined spiral sculpture on many shells. From *L. nitida* Briart and Cornet, Caleaire de Mons (Montian, Belgium) the present species differs in its much stronger circumumbilical folds (Glibert 1973: 28, pl. 3, fig. 16).

L. caledonica Crosse has a circular, multispiral opercelum with a central nucleus. Two specimens of the present material (holotype and paratype WAM 83.2642b) retain opercula within the aperture. As far as can be seen, these show spiral rather than concentric growth.

Variation in the present species is observed in the strength, persistence and distribution of spiral sculpture and occasionally axial plications on the adapical surface, on the presence or absence of beading below the suture and on the degree of constriction or infilling of the umbilicus. The latter is open in the juvenile, closing with growth.

Of the 163 shells to hand, 31 (19%) show naticiform gastropod boreholes. No preferred borehole position has been observed.

The specific name is from the Latin *rota*, a wheel, referring to the shell profile.

Occurrence. Bremer Basin: Ocumup No. 1 deep well, 53.4–73.2 m, Werillup Formation, Middle Eocene; North Walpole, Pallinup Siltstone (type), Late Eocene.

Leucorhynchia ventricosa sp. nov.

Fig. 8O, R–S

Material. Holotype WAM 83.2643a from 26 km along Thompson Highway north from Walpole townsite, W.A. Paratypes WAM 67.177, 83.2643b–f. Total of eight specimens. NMV P302251. One specimen.

Other material. NMV P301960. Six specimens.

Description. Shell minute, robust, wider than high, subdiscoidal–lenticular; spire low, of few, rapidly enlarging whorls; spire profile smoothly and evenly rounded, apex flattened, not projecting; protoconch poorly preserved, lobate, apparently smooth; periphery subangulate; suture adpressed, attached well above periphery, descending at aperture (maturity); aperture subcircular, tangential to last whorl; peristome continuous, thickened at periphery and with strong parietal callus and short, thick columella, at base of which massive, bluntly rounded fold projects across (without sealing) umbilicus; umbilicus narrow, partly concealed, on some specimens with few weak circumumbilical wrinkles; base convex, ventricose; with sculpture (preservation permitting) of very fine, close, spiral striae on spire and base; operculum unknown. Nacreous lustre not observed.

Dimensions	Height	Max. diameter	No. whorls
WAM 83.2643a, holotype	1.62	3.09	3.0
WAM 83.2643b, paratype	1.72	2.92	3.5
NMV P302251, paratype	1.3	2.70	4.0

Discussion. This second species of *Leucorhynchia* in the Pallinup Siltstone at North Walpole is distinguished from the preceding and all other congeners known to us by its lower, more smoothly rounded spire, tangential aperture, subangulate periphery, reduced circumumbilical wrinkling and prominent trans-umbilical fold at the base of the columella. In shape, the species resembles *L. caledonica* (Crosse), differing in the very fine, close spiral striae, which are lacking in Crosse's species.

None of the specimens shows evidence of gastropod predation.

The specific name is from the Latin *ventricosa* (feminine), swollen, bulging, referring to the base.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

Superorder Caenogastropoda Cox, 1959

Superfamily Rissooidea Gray, 1847

Family Vitrinellidae Bush, 1897

Genus **Circulus** Jeffreys, 1865

Type species. Delphinula duminyi Requien, 1842 = *Solarium philippi* Contraine, 1842. By monotypy. Recent, Atlanti–Mediterranean.

Circulus sp.

Fig. 6B–D

Material. WAM 67.104, 95.599. Two shells. NMV P301988. One shell.

Description. Shell minute, sub-discoidal, of few convex whorls; spire very low with broad subsutural shelf and rounded periphery; suture incised, channelled, attached close to periphery, in maturity descending at aperture; protoconch poorly preserved, apparently smooth, lobate; aperture subcircular with continuous, thin peristome, attached by thin parietal callus; columella thin, not differentiated from margin of aperture; base concave, widely and deeply umbilicate exposing to apex adaxial surfaces of whorls; entire shell sculptured with very fine, raised, narrow, spiral lirae with smooth interspaces, six on penultimate whorl, last whorl with 12 spirals from suture to broader intercostal space just below periphery and a further 16 extending across base and deeply into umbilicus; sculpture of first teleoconch whorl poorly preserved but resembles that of later whorls; no axial sculpture evident.

Dimensions	Height	Max. diameter	No. whorls
WAM 67.104	1.93	4.58	3.5

Discussion. Early records for the genus are from the Thanetian Calcaire de Mons of Belgium (Glibert 1973: 29, pl. 4, fig. 2-4). By the Middle Eocene, it was dispersed widely throughout the Tethyan Realm to Australasia. Possible occurrences from the Paleocene to Recent of Western Europe, the Americas, North Africa and East Asia are listed in Cossmann as *Adeorbis* species (1918: 97–99). Miocene species from The Netherlands are described by Janssen (1984: 129–131, pl. 45).

The Walpole species resembles *'Adeorbis' intermedius* Deshayes from the Lutetian of the Paris Basin, as figured in Cossmann & Pissarro (1910: pl. 8, fig. 59-11) and is not unlike *Circulus mitorraphes* Gardner from the Miocene Alum Bluff Group of Florida (Gardner 1947: 599, pl. 61, figs 1, 2, 27). In its rounded whorl profile and multiple spiral lirae, the present species recalls *Partubiola varilirata* Ludbrook from the Dry Creek Sands of the St Vincent Basin (Ludbrook 1941: 87, pl. 4, fig. 17; 1956: 21), differing in its more numerous spirals on the last whorl and in the complete absence of axial microsculpture. A probable *Circulus* from the New Zealand Late Eocene (Kaiatan) in Maxwell (1992: 89, pl. 9, figs a–c, e) is similar to the Walpole species, differing in its peripheral keel and finer more numerous basal sculpture.

This species bears some resemblence to *Elachorbis subtatei* (Suter, 1907), Recent, New Zealand, so it may well be a cyclostrematid and not a vitrinellid.

This appears to be the first record of the genus from the Australian Eocene. We believe it to be new but defer full determination in view of the limited material to hand.

Occurrence. Bremer Basin: North Walpole, Pallinup Siltstone, Late Eocene.

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