Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Special Volume, no. 6 (Hatai Memorial Volume), p. 241-261, 1 fig., 1 table, pls. 24-28, February 25, 1973

Distribution and Stratigraphic Utility of Cenozoic Molluscan Faunas in Southern Australia

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Abstract

In sedimentary basins marginal to the present coastline of southern Australia mollucan faunas of Paleocene to Pleistocene age are preserved, although the full sequence is not present in any single basin. The stratigraphic position of the formations carrying the richest and most fully described faunas is shown on a correlation chart based on a succession of planktonic foraminiferal zones.

Some of the problems associated with correlation by means of molluscs are discussed. Species which are diagnostic or in need of clarification by illustration are figured.

INTRODUCTION

Most Australian Tertiary molluscs were described between 1865 and 1899 by McCoy, Tenison Woods, and Tate. Correlation of Tertiary rocks of South Australia, Victoria, and Tasmania by means of the molluscs they contained began with McCoy in 1861, but was largely achieved by Tate and Dennant in the period 1893–1896 and by Hall and Pritchard in 1895 to 1902; the results of their correlations were published in the "Catalogue of the Described Species of Fossils................in the Cainozoic Fauna of Victoria, South Australia and Tasmania" (Dennant & Kitson, 1903). Although there has been considerable nomenclatural refinement at both the generic and specific level since 1903, this still remains a useful reference list, provided that the stratigraphic levels attributed to the recorded localities are revised along the following general lines:

1. "Eocene to Oligocene" localities.
   "Group A" are Eocene (Aldingan), "Group B" are mostly Miocene (Batesfordian to Bairnsdalian), but some are Oligocene (Janjukian), "Group C" are Late Oligocene to Early Miocene (Janjukian to Longfordian), "Group D" are Miocene and Late Miocene to Early Pliocene.
2. "Miocene" localities.
   Most of these are of Pliocene age (Kalimnan), but some are younger.
3. "Pliocene and Pleistocene".
   These are Upper Pliocene (Yatalan), Pleistocene (Werrikooian) and younger.

The "kaleidoscopic changes" which prevailed in Australian Tertiany geology for 80 years were well summarized by Singleton (1941).

It was not until the early 1950's when studies of planktonic foraminifera were commenced at the University of Adelaide, and in the Geological Surveys of South Australia and Victoria, that a reliable basis for biostratigraphic correlation was established whereby Tertiary marine deposits of southern Australia could be more confidently placed in relation to the standard stratigraphic scale. A chart showing the correlation of Tertiary rock units in Australia and New Zealand was prepared by the writer with the collaboration of N. de B. Hornibrook in New Zealand and D.J. Taylor, W.K. Harris and J.M. Lindsay in Australia (Ludbrook, 1967a). Part of this chart is now presented in Table 1 to show the

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stratigraphic position of rock units from which molluscan faunas have been described. It has been modified in accordance with more recent work on planktonic biostratigraphy (Blow, 1969; Ludbrook and Lindsay, 1969), Tertiary boundaries and correlation, and radiometric data (Berggren, 1969, 1971).

Classical localities from which Tate and other workers described molluscan faunas are shown by numbers on the locality map (Fig. 1) and in bold type with corresponding numbers on the chart (Table 1).

In the lists, the generic nomenclature is often tentative, following Darragh's (1970) catalogue with the same caution as that expressed by Darragh in making the allocations. As a high proportion of the species were described by Tate, the authors' names have been omitted from the lists; they can be obtained from Darragh's catalogue and recent papers. Although they are an important element in Australian Tertiary faunas, most of the turritellids have been omitted, since a recent nomenclatural revision by Garrard (1972) refers to type localities only and gives no information on the stratigraphic range of the species.

The species figured on the five plates are either diagnostic or in need of illustration. The Tate type collection, formerly in the Adelaide University Geology Department, is now in the South Australian Museum. Other specimens used are in the collections of the Geological Surveys of South Australia (GSSA) and Western Australia (GSWA).

ACKNOWLEDGMENTS

The assistance of Mr. J.M. Lindsay and Mr. W.K. Harris of the Geological Survey in providing material and critical comments and of Mr. Colin Smith of the Drafting Branch of the South Australian Department of Mines in preparing the map and table is gratefully acknowledged. The paper is published with the approval of the Acting Director of Mines.

STRATIGRAPHIC AND GEOGRAPHIC SETTING: THE CENOZOIC SEDIMENTARY BASINS

The sedimentary basins in which rich molluscan faunas occur are large marginal embayments in the present coastline from the Eucla Basin in the west to the Gippsland Basin in the east. Molluscs in the two westerly basins, Eucla and St. Vincent, show distinct provincial differences from those of the eastern basins, particularly in their Miocene molluscs.

EUCLA BASIN

The surface geology, physiographic features and sedimentary succession of the Eucla Basin are most recently described by Lowry (1970). This basin, astride the Western Australian/South Australian border, extends inland from the Great Australian Bight and seaward to the edge of the continental shelf. It is chiefly notable for its main physiographic unit – the Bunda Plateau — one of the world's most extensive featureless areas, a large part of which consists of the Nullarbor ("no tree") Plain. The topography of this extremely flat plain is controlled by the Miocene Nullarbor Limestone the eroded surface of which is an emerged sea floor; except for slight tilting and uniform erosion the Nullarbor Limestone has been undisturbed since it was deposited and elevated.

The Basin formed during the Cretaceous and filled with a discontinuous succession of Cretaceous and Tertiary rocks. From the point of view of their molluscan faunas the Eocene Wilson Bluff Limestone and the Lower to Middle Miocene Abrakurrie and Nullarbor Limestones have received most attention as material from these units at Wilson Bluff was reported by Tate in 1879.

On the Western Australian side of the border the precipitous cliffs of the Great

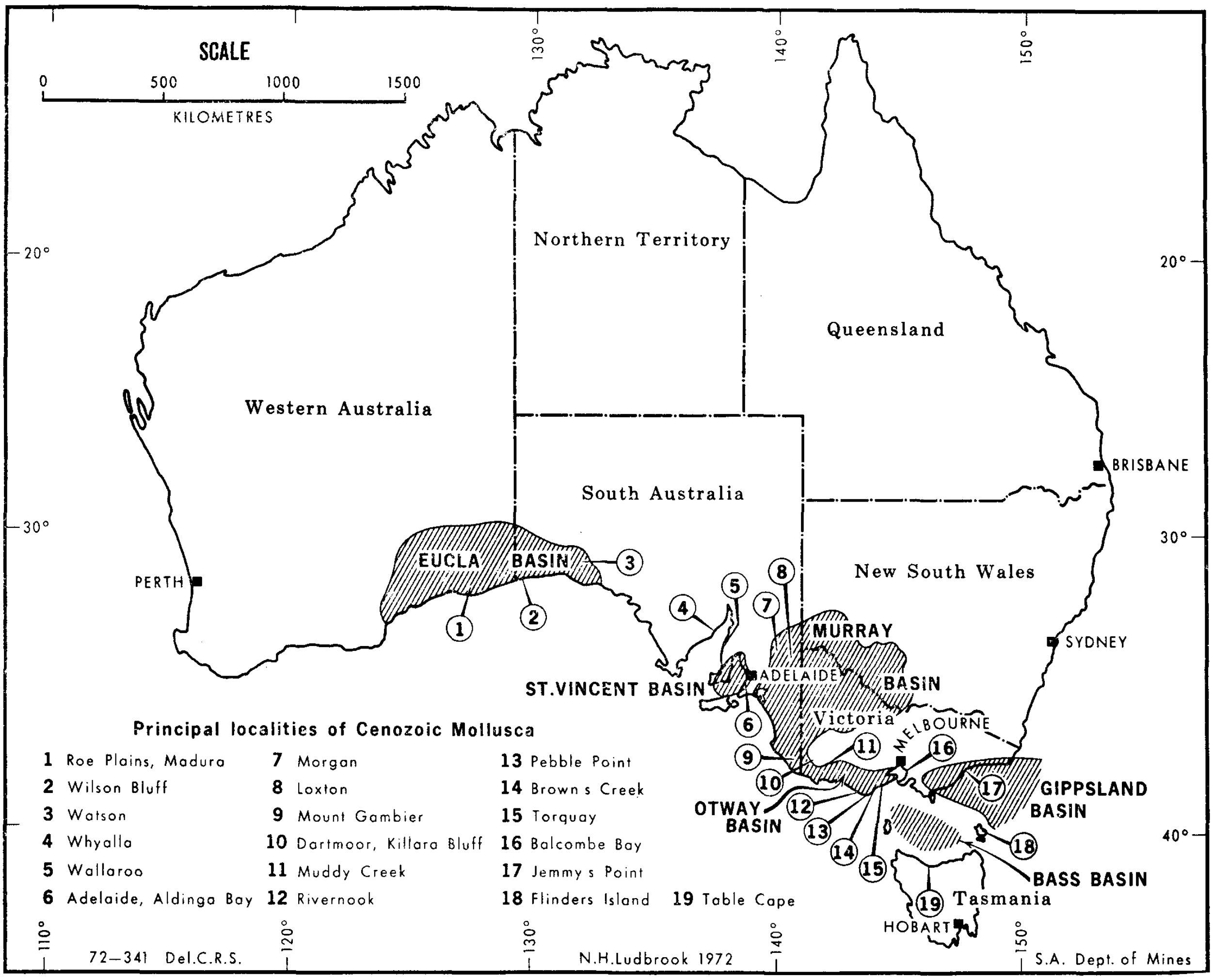


Fig. 1. Principal localities of Cenozoic Mollusca within Australia.

Australian Bight turn inland to form the Hampton Range, south of which are the Roe Plains on which the Nullarbor Limestone has been eroded and the Pleistocene Roe Calcarenite deposited. The Roe Calcarenite carries a very rich and well-preserved molluscan fauna, large collections of which have been made from roadside quarries for road metal and from the spoil of foundation holes sunk for the Hampton Microwave Repeater Tower near Madura (1). Description of the fauna is nearing completion. (Ludbrook, in preparation). Owing to the precipitous nature of the cliffs of the Great Australian Bight, collections of Tertiary molluscs were limited to Wilson Bluff (2), but now they are made mainly from caves and sinkholes and from the quarry at Watson (3).

ST. VINCENT BASIN

This is a small and rather shallow basin in a graben produced by block faulting on lines of weakness on the western side of the Mount Lofty Ranges. Adelaide is situated on the eastern side of Gulf St. Vincent, the present remnant of the former Cenozoic basin. A succession of Middle Eocene to Middle Miocene sediments includes the Blanche Point Marls and the Upper Eocene to Miocene Port Willunga Beds overlain with slight angular unconformity by the Pliocene Hallett Cove Sandstone and Dry Creek Sands, all with rich molluscan faunas. Most of the sequence is exposed in Maslin and Aldinga Bays (Reynolds, 1953), the richest faunas being in the Blanche Point Marls at Blanche Point between the two bays and in the Port Willunga Beds and Hallett Cove Sandstone in Aldinga Bay. Otherwise, molluscs are known from numerous boreholes drilled on the Adelaide Plains for underground water. Most of the molluscs come from the Dry Creek Sands, but those from the old Kent Town (or Adelaide) Bore situated on the upthrow side of one of the steep faults are from Upper Eocene equivalents of the Blanche Point Marls.

The youngest rocks underlying those of Cenozoic age are Permian glacigenes and clastics. No Cretaceous sediments are known to occur in the St. Vincent region.

MURRAY BASIN

The Murray Basin is essentially a Cenozoic basin, although Cretaceous and Permian strata occur below an almost complete Tertiary succession described by Ludbrook (1961a). Except where they are exposed in the cliffs of the River Murray the sediments and faunas of the Basin are known from bores sunk for underground water supplies and during oil exploration programmes.

The most completely described collections of molluscs (Tate, 1886–1893) came from the Cadell Marl Lens (Tate's "Gastropod Bed") in the Morgan Limestone (7), and from two water bores the locations of which, "Tareena" and "Mindarie", have always been in some doubt (Tate, 1899) although from the matrix it is fairly clear that the material came from the Bookpurnong Beds, the type locality of which is near Loxton (8).

OTWAY BASIN

The Otway Basin is an extensive east-west trough the north western limit of which crosses the coast about 10 km south of Cape Jaffa in South Australia and the south eastern margin of which is delineated by the King Island–Mornington Peninsula Basement Ridge.

Results of studies of surface mapping, subsurface data, biostratigraphic data and electric logging by the Geological Surveys of South Australia and Victoria have recently been published in a Special Bulletin of the two Surveys (Wopfner & Douglas, Eds. 1971).

In the trough thick deposits of Lower Cretaceous Otway Group were laid down, after which the trough became a marginal basin with five embayments separated by ridges of Otway Group sediments (Wopfner & Douglas, 1971, Fig. 1.1).

The most westerly, *Gambier Embayment,* was formerly included in the Murray Basin; structurally it belongs to the Otway Basin although during part of the mid-Tertiary sedimentation was continuous from the *Gambier Embayment* into the Murray Basin (Ludbrook, 1969a, p. 178). The Embayment contains a sequence of Paleocene to Pleistocene sediments of which the Late Miocene and Pliocene are missing, partly as a result of erosion during the Pleistocene.

The principal recorded molluscan faunas are those of the Paleocene Bahgallah Formation (Kenley, 1971) and Eocene to Miocene Gambier Limestone (Tenison Woods, 1867) and the Werrikooian (Pleistocene) fauna of the Whalers Bluff Formation at Caldwells Cliff (Singleton, 1941b). Others have been listed but not yet described (Kenley, 1971).

In the *Tyrendarra Embayment* over 4,000 metres of Mesozoic and Cenozoic sediments are mostly covered by extensive basalt flows of Late Pliocene to Recent age. However, at the margin a thin succession of (?) Oligocene to Pliocene sediments is exposed in the valleys of Grange Burn and Wannon River west of Hamilton (Spencer-Jones, 1971). These include the richly fossiliferous Miocene Muddy Creek Marl and Pliocene Grange Burn "Coquina" (11) from which most of the molluscs described by Tenison Woods (1880) and by Tate (1878–1893) were collected.

The *Port Campbell Embayment,* located to the north and west of the Otway Ranges High, contains a thickness of 3,000 metres of Upper Cretaceous and Tertiary sediments exposed in only partly accessible precipitous seacliff sections and road cuttings and intersected in borings. The initial Tertiary marine transgression on to the Otway Group north west of Moonlight Head (13) is represented by the Pebble Point Formation of the Wangerrip Group from which Paleocene faunas have been described (Baker, 1943–1953; Singleton, 1943; Teichert, 1943; McGowran, 1965). An important locality for mid-Tertiary molluscs (Tate's "Gellibrand River" or "Gellibrand beds") is accessible in the seacliffs 2.4 km west northwest of Princetown (12).

Included in the *Port Campbell Embayment* for the purposes of this paper are two small structural basins on the southwest of the Otway Ranges High between Cape Otway and Johanna River (14). These contain the Early Tertiary sediments of the Aire District and Browns Creek described by Carter (1958). The Browns Creek Clays, which carry important Late Eocene microfaunas, crop out in coastal sections between Browns Creek and Johanna River.

East of the Otway Ranges the *Torquay Embayment* and *Port Phillip Embayment* are still under study by the Geological Survey of Victoria. The city of Melbourne is situated on Port Phillip Bay. The stratigraphy between Torquay and Eastern View was described by Raggatt and Crespin (1955), who defined the rock units, in particular the Torquay Group comprising the Jan Juc Formation (stratotype of the Janjukian Stage) and Puebla Formation, previously included in the Janjukian (15). But the biostratigraphy and correlations of these authors has been largely superseded, particularly since the foraminiferal assemblage they attributed to the Jan Juc Formation is a mixture of two mutually exclusive assemblages, one of which is not indigenous to the Jan Juc Formation but occurs in the Browns Creek Clays (Carter, 1958). The top of the Jan Juc Formation or Janjukian Stage is at present interpreted as being of Early Miocene age (Zone N4), and the base at Bells Headland appears to lie in the Late Oligocene within Zone N2=P21 of Blow (1969) (McGowran *et al.*, 1971).

The Tertiary stratigraphy and sedimentation of the western side of the *Port Phillip Embayment* has been described by Bowler (1963) and of the Mornington District on the eastern side by Gostin (1966) whose correlation chart (p. 509) compares the sedimentary sequences on either side of Port Phillip Bay. The Balcombe Clay has an abundant molluscan fauna mainly from Fossil Beach (16), 3.7 km south of Mornington, the type section for the Balcombian Stage, which has not been shown to go higher than the *Praeorbulina glomerosa curva* Zone at Fossil Beach. But the Balcombe Clay extends into the *O. universa* Zone (Bairnsdalian) at Grices Creek.

On the western side of Port Phillip Bay the Fyansford Clay and upper part of the Batesford Limestone are equivalent to the Balcombe Clay

GIPPSLAND BASIN

Present interest in the Gippsland Basin is focussed on the important economic fact that the central deep of the basin is occupied by the Gippsland Shelf petroleum province which provides a major part of Australia's oil and gas production (Hocking, 1972). It is a Cretaceous-Cenozoic basin one-fifth of which is onshore, the remainder extending on to the continental shelf. The onshore biostratigraphy was described by Crespin (1943), revised by Carter (1964) and somewhat modified by later authors (James & Evans, 1971; Hocking, 1972) in dealing with the major units of the offshore basin.

Although Crespin gave very comprehensive faunal lists for all her stratigraphic units, which cover practically the whole of Tertiary time and not only the Middle Miocene to Lower Pliocene, the only molluscan fauna which has been described in any detail is that of the Jemmys Point Formation, the stratotype Kalimnan Stage (17).

Thin Tertiary sediments occur on islands in Bass Strait and in the northwest of Tasmania. The best known of these are the Table Cape Group, precise correlation of which has presented problems, which are discussed below, and the Late Cenozoic marls and other sediments on Flinders Island (Sutherland & Kershaw, 1971).

MOLLUSCAN FAUNAS

PALEOCENE (WANGERRIPIAN)

The oldest Australian Tertiary marine molluscs are those of the transgressive Paleocene Pebble Point Formation, the lower unit of the Wangerrip Group described by Baker (1943, 1944, 1950, 1953), outcropping 5.2 km southeast of Princetown (13) in the *Port Campbell Embayment*, and the Bahgallah Formation at Killara Bluff (10) 11 km south of Casterton in the *Gambier Embayment*, described by Kenley (1951, 1954, 1971).

The Pebble Point molluscs occur in ferruginous grits transgressive on Otway Group. They include a species of *Lahillia* and one of *Cucullaea* for the New Zealand "Wangaloan" relative of which the subgenus *Cucullona* was created by Finlay & Marwick (1937). The subgenus is now regarded as a synonym of *Cucullaea*, but this does not invalidate the affinity of the Australian and New Zealand species, which was immediately recognized by Singleton (1943), who described the fauna and determined its age as Eocene or possibly Paleocene from its affinities with the Wangaloan. Finlay & Marwick (1937) correlated the Wangaloan with the Danian, but it is now omitted from the New Zealand stages and regarded as of uncertain position within the Danian-Lower Eocene sequence (Hornibrook & Harrington, 1957). However, its affinities with the Pebble Point Formation, which is well dated from its microfauna, are worthy of consideration.

Teichert (1943) described the two nautiloids, *Aturoidea distans* and *Eutrephoceras victorianum* as of Eocene age.

McGowran's (1965) study of the foraminifera has established that the fauna of the Pebble Point Formation can be correlated with the Middle Paleocene *Globorotalia pusilla pusilla–G. angulata* Zone of the Tethyan region (Zone P3, Berggren, 1971b), and the Rivernook Member of the overlying Dilwyn Formation with the *G. pseudomenardii* Zone (P4).

The fauna from the Bahgallah Formation at Killara Bluff (10), almost identical with that from Pebble Point, is poorly preserved in deeply weathered ferruginous sands and clays (Kenley, 1951, 1954, 1971).

The known Paleocene molluscs from these two localities are: *Nuculana paucigradata* Singleton, *Cucullaea psephea* Singleton, *Limopsis* sp. nov., *Lahillia australica* Singleton, *Eotrigonia* sp. nov., *Dentalium* (*Fissidentalium*) *gracilicostatum* Singleton, *Athleta* (*Athleta*) *wangerrip* Darragh, which has recently been described by Darragh (1971) from the Dilwyn Formation, *Aturoidea distans* Teichert, and *Eutrephoceras victorianum* (Teichert). The two species which resemble those of the New Zealand Wangaloa fauna are figured on Plate 24: *Lahillia australica* (Figs. 4, 5), related to *Lahillia neozelanica* Finlay & Marwick, and *Cucullaea psephea* (Figs. 1, 3) related to *C. inarata* Finlay & Marwick. Hinges of *C. psephea* and the long ranging *C. corioensis* are illustrated in support of Newell's (1969) placing of *Cucullona* in synonymy with *Cucullaea* (Figs. 1, 2).

EOCENE (ALDINGAN)

The Upper Eocene carries a rich fauna of small molluscs dominated by Muricidae and Fasciolariidae, and most have been described by Tate (1878–1892) from two principal localities: Blanche Point, Aldinga Bay, and "Adelaide" (Kent Town) Bore, both near Adelaide in the St. Vincent Basin (6), and also from Browns Creek and Hamilton Creek in the Otway Basin (14) and the Wilson Bluff Limestone in the Eucla Basin.

Table 1. Generalized correlation chart for the Cenozoic of Southern Australia.

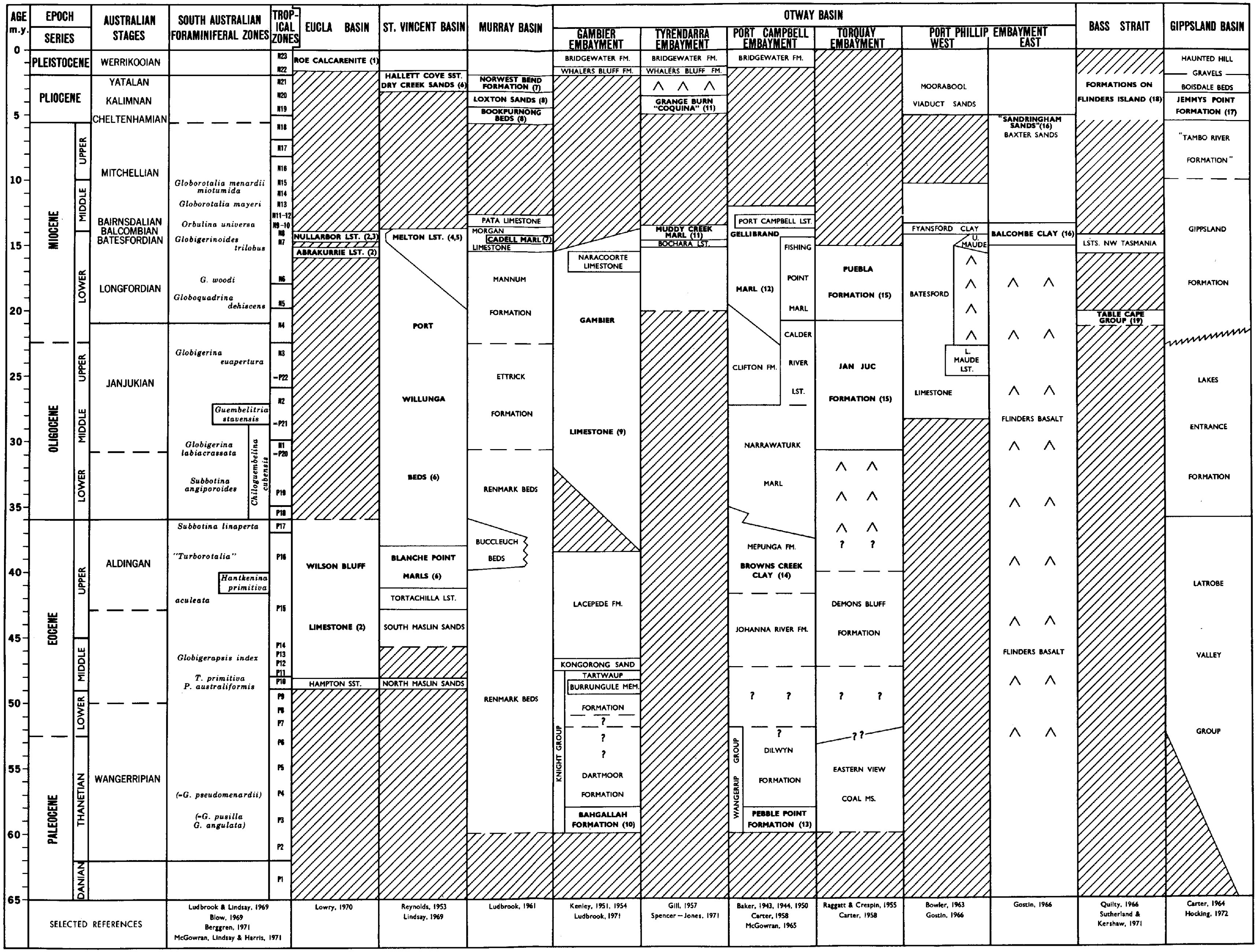
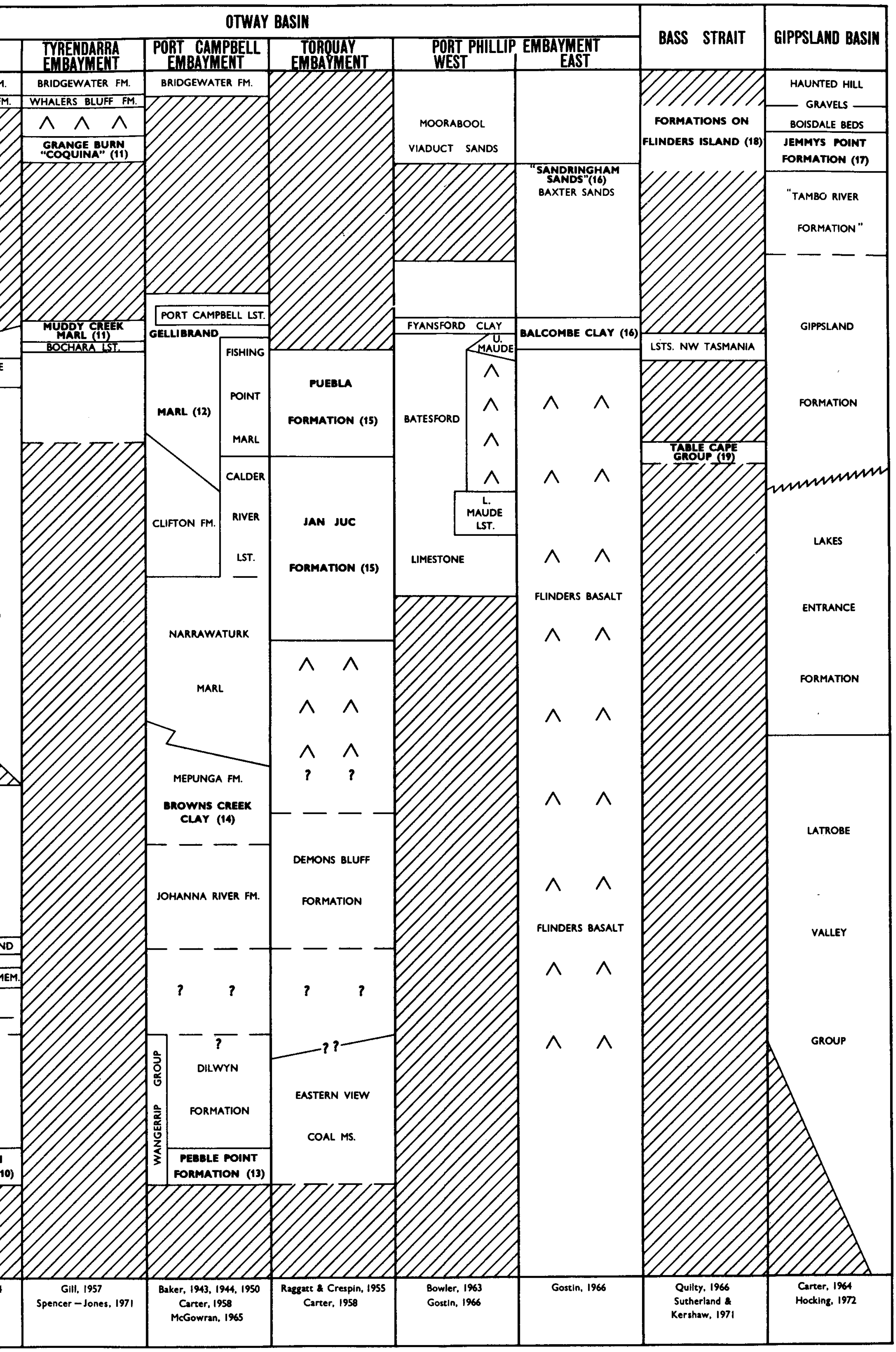


Table 1. Generalized correlation chart

AGE m.y.	EPOCH / SERIES		AUSTRALIAN STAGES	SOUTH AUSTRALIAN FORAMINIFERAL ZONES	TROPICAL ZONES	EUCLA BASIN	ST. VINCENT BASIN	MURRAY BASIN	GAMBIER EMBAYMENT
0	PLEISTOCENE		WERRIKOOIAN		N23, N22	ROE CALCARENITE (1)			BRIDGEWATER FI
	PLIOCENE		YATALAN		N21		HALLETT COVE SST. DRY CREEK SANDS (6)	NORWEST BEND FORMATION (7)	WHALERS BLUFF F
	PLIOCENE		KALIMNAN		N20			LOXTON SANDS (8)	
5	PLIOCENE		CHELTENHAMIAN		N19			BOOKPURNONG BEDS (8)	
	MIOCENE	UPPER	MITCHELLIAN		N18, N17, N16				
10	MIOCENE	MIDDLE		*Globorotalia menardii miotumida*	N15, N14				
	MIOCENE	MIDDLE		*Globorotalia mayeri*	N13				
	MIOCENE	MIDDLE	BAIRNSDALIAN	*Orbulina universa*	N11-12			PATA LIMESTONE	
	MIOCENE	MIDDLE	BALCOMBIAN		N9-10, N8	NULLARBOR LST. (2,3)	MELTON LST. (4,5)	MORGAN LIMESTONE; CADELL MARL (7)	
15	MIOCENE	LOWER	BATESFORDIAN	*Globigerinoides trilobus*	N7	ABRAKURRIE LST. (2)			NARACOORTI LIMESTONE
	MIOCENE	LOWER	LONGFORDIAN	*G. woodi*	N6			MANNUM	
20	MIOCENE	LOWER		*Globoquadrina dehiscens*	N5, N4		PORT	FORMATION	GAMBIER
25	OLIGOCENE	UPPER	JANJUKIAN	*Globigerina euapertura*	N3, =P22			ETTRICK	
	OLIGOCENE	MIDDLE		*Guembelitria stavensis*	N2, =P21		WILLUNGA	FORMATION	LIMESTONE (9)
30	OLIGOCENE	LOWER		*Globigerina labiacrassata*; *Chiloguembelina cubensis*	N1, =P20				
35	OLIGOCENE	LOWER		*Subbotina angiporoides*	P19, P18		BEDS (6)	RENMARK BEDS	
	EOCENE	UPPER	ALDINGAN	*Subbotina linaperta*	P17			BUCCLEUCH BEDS	
40	EOCENE	UPPER		"*Turborotalia*"	P16	WILSON BLUFF	BLANCHE POINT MARLS (6)		
	EOCENE	UPPER		*Hantkenina primitiva*; *aculeata*	P15		TORTACHILLA LST.		LACEPEDE FM.
45	EOCENE	MIDDLE		*Globigerapsis index*	P14, P13, P12, P11	LIMESTONE (2)	SOUTH MASLIN SANDS		KONGORONG SA
	EOCENE	MIDDLE		*T. primitiva*; *P. australiformis*	P10	HAMPTON SST.	NORTH MASLIN SANDS	RENMARK BEDS	TARTWAUP; BURRUNGULE N
50	EOCENE	LOWER			P9, P8, P7				KNIGHT GROUP: FORMATION ? ? ?
55	PALEOCENE	THANETIAN	WANGERRIPIAN		P6, P5				DARTMOOR FORMATION
	PALEOCENE	THANETIAN		(=*G. pseudomenardii*)	P4				
60	PALEOCENE	THANETIAN		(=*G. pusilla G. angulata*)	P3, P2				BAHGALLAH FORMATION (
65	PALEOCENE	DANIAN			P1				
	SELECTED REFERENCES			Ludbrook & Lindsay, 1969; Blow, 1969; Berggren, 1971; McGowran, Lindsay & Harris, 1971		Lowry, 1970	Reynolds, 1953; Lindsay, 1969	Ludbrook, 1961	Kenley, 1951, 1954; Ludbrook, 1971

for the Cenozoic of Southern Australia.



The sequence in Maslin Bay on the north side of Blanche Point is of Middle Eocene North Maslin Sands overlain by the South Maslin Sands which carry a sparse and poorly preserved molluscan fauna and which are in turn overlain by a normal marine sequence with the Tortachilla Limestones at the base followed by the richly fossiliferous Blanche Point Marls of which the lower part of Blanche Point is composed. These are of Upper Eocene age, "*Turborotalia*" *aculeata* Zone, with *Hantkenina primitiva* near the base of the marls. On the south side of Blanche Point in Aldinga Bay the Blanche Point Marls are overlain by the Chinaman's Gully Beds and the Port Willunga Beds. The Aldingan Stage as redefined (Ludbrook & Lindsay, 1966) is the time interval required for the deposition of the Tortachilla Limestones, the Blanche Point Marls, the Chinaman's Gully Beds and the lower part of the Port Willunga Beds of the *Subbotina linaperta* Zone.

There has been some misunderstanding of the locality and stratigraphic position of the material from Kent Town Bore, the section of which Tate described in 1882 (a). It was located in the northeast Parklands of the City of Adelaide on the eastern upthrow side of the Para Fault. Tate's stratigraphic interpretation has been modified by Lindsay (1969) as:

0– 21 m	Quaternary sediments
21–24.3 m	Port Willunga Beds
24.3–59.4 m	Blanche Point Marls
59.4–66.4 m	undifferentiated Blanche Point Marls and Tortachilla Limestone equivalents
66.4–93 m	equivalents of South Maslin Sands, Muloowurtie Clays and North Maslin Sands
93–125.3 m	bedrock

Tate's types came from depths between 45 and 66.4 m, stratigraphically low in the Aldingan. Tate (1882a) stated these beds to be of Miocene age, but in subsequent papers (Tate, 1890; Tate & Dennant, 1896) correctly placed them in the Eocene.

Misunderstanding of the stratigraphic position of the Adelaide Bore molluscs doubtless influenced Cernohorsky's (1970) placing of Tate's *Mitra complanata* and *M. crenularis* in the Pliocene–Recent genus *Microvoluta* instead of in *Waimatea* (Middle Eocene-Recent) where they would appear to belong, and where Darragh had tentatively placed *M. crenularis*.

Molluscs are rare in the Wilson Bluff Limestone: *Notostrea lubra* Finlay (Pl. 24, figs. 6–9), *Dimya sigillata* Tate (Pl. 24, figs. 14, 15), and *Chlamys eyrei* (Tate) occur with brachiopods and echinoids in chalky bryozoal limestone.

The following species have been recorded only from Eocene localities, those marked with * have been recorded from one locality only.

Bivalvia:

Ledella leptorhyncha, Ovaleda planiuscula, Arca pseudonavicularis, Barbatia limatella*, B. (Cucullaearca) equidens, Cucullaea adelaidensis, Arcopsis dissimilis, Limopsis multiradiata, Glycymeris (Tucetona) lenticularis, Limarca angustifrons, Cosa praenuntia*, Musculus (Ryenella) arcacea, Modiolus adelaidensis*, Trichomusculus semigranosa*, Pteria nasuta*, Vulsella laevigata*, Chlamys aldingensis, C. flindersi, Dimya sigillata, Placunanomia (Monia) cymbula*, Divarilima polyactina,* Limatulella polynema*, Limea (Isolimea) alticostata*, L. (I.) multiradiata*, Notostrea lubra, Eotrigonia* sp. nov., *Glans latissima, Cardita (Jesonia) alata, Cuna rugosa, Salaputium communis, S. lamellata, S. aldingensis*, Veprecardium (Hedecardium) moniletectum, Tellina (Semelangulus) porrecta*, Dosina (Dosina) multitaeniata, D. (D.) imparistriata, Notocallista (Fossacallista) tenuis, Corbula (Caryocorbula) pixidata, Jouannetia cuneata*, Myadora lamellata, Cuspidaria adelaidensis*, C. latesulcata*.*

Gastropoda:

Basilissa cossmanni, Pareora stylacris, Spirocolpus aldingae, Lilax actinotus*, Anguillospira* *adelaidensis, Jetwoodsia nullarborica, Cirsotrema mariae, Punctiscala loxopleura, Cerithioderma angulifera, Sirius tabulatus, S. triplicatus, S. interlineatus, S. costatus, S. fenestratus, Zegalerus placuna, Calyptropsis arachnoideus, Atlanta fossilis*, Friginatica aldingensis, Ampullina effusa, Archierato pyrulata, Willungia ovulatella, Trivia pompholugata*, Cypraedia clathrata*, Austrosassia cribrosa, Cymatiella oligostira, Semitriton dennanti*, Cantharus varicosus*, Siratus tenuicornis*, S. tridentatus*, Enatimene monotropis*, Gemixystus icosiphyllus*, Zeatrophon hypsellus, Z. torquatus, Hexaplex (Murexsul) sublaevis, Pterynotus (Pterochelus) adelaidensis, P. (P.) manubriatus, P. (P.) otwayensis, Pterynotus (Pterynotus) bifrons, P. (P.) calvus, Laevityphis (L.) ludbrookae, Cominella pertusa*, C. pumila*, Ratifusus nodulata*, Peristernia pumilus*, Tectifusus aldingensis*, T. tholoides*, Columbarium cochleatum*, Microcolus apiciliratus, Brocchitas aldingensis, Austrolithes incompositum, Fusinus sculptilis, Waimatea complanata*, W. subcrenularis, Austromitra citharelloides, Mitraria varicosa*, Notovoluta pagodoides, N. cribrosa, Notopeplum protorhysa*, Athleta (Ternivoluta) curvicostata*, Inglisella turriculata, Anapepta micra*, Oamaruia ptychotropis*, Borsonia otwayensis, B. polycesta, B. protensa, Conorbis attractoides, Actaeon evanescens, A. olivellaeformis.*

OLIGOCENE (PARTLY JANJUKIAN)

The time interval represented in the Oliogcene Epoch, its boundaries and faunas have been well discussed by Berggren (1971).

In southern Australia the Janjukian stage is wholly or mostly of Oligocene age, the top of the stratotype Jan Juc Formation being at Bird Rock, Torquay, and the base at Bell's Headland (Raggatt & Crespin, 1943). Until a description of the microfaunal sequence within the Jan Juc Formation is published it cannot be said unequivocally that the uppermost Janjukian is Oligocene. From the evidence discussed by McGowran *et al.* (1971, p. 279), the late Janjukian as represented in the Clifton Formation (not shown on Table 1) in the *Port Campbell Embayment* belongs to the *Globigerina euapertura* Zone, the boundary of which with the *Globoquadrina dehiscens* Zone is placed high in Zone N 4, and the Janjukian-Longfordian boundary drawn in the Lower Miocene (McGowran *et al.*, 1971, Enclosure 14.1).

As Berggren has pointed out, Oligocene faunas are strongly related to those of the Late Eocene, and this is so with the Australian Oligocene foraminiferal zones *Subbotina angiporoides*, *Chiloguembelina cubensis*, and *Guembilitria stavensis*. As the Janjukian is at present defined its lowermost part at Bell's Headland belongs to the upper part of the *Chiloguembelina cubensis* Zone and the *Guembelitria stavensis* Zone, i.e. Zone N 2 (=P 21) (McGowran *et al., loc. cit.*). The interval between the top of the Aldingan and base of the Janjukian is represented in the "siliceous unit" of the Port Willunga Beds (Lindsay, 1967, 1969) and the siliceous sponge spicule member of the Gambier Limestone (Ludbrook, 1971b), corresponding to the *G. labiacrassata–S. angiporoides* Zones (Ludbrook and Lindsay, 1969).

The molluscan faunas from this and the Janjukian part of the sequence have not been differentiated from those of the Eocene at Aldinga Bay, partly because the Port Willunga Beds carry a poor molluscan fauna as compared with that of the Blanche Point Marls. Resolution of the problem of Oligocene faunas can begin only by study of the faunas of the post-Eocene Port Willunga Beds at Aldinga Bay and Port Noarlunga and their equivalents at the appropriate levels in the St. Vincent Basin; the Jan Juc Formation throughout its sequence from Bell's Headland to Bird Rock, which includes the Point Addis Limestone Member, the Ettrick Formation, the *G. angiporoides*, *G. labiacrassata* and *G. euapertura* Zones of the Gambier Limestone and the Glen Aulin Clay Member (Kenley, 1971), the Glen Aire Clays and the Calder River Limestone, and the Lakes Entrance Formation.

If the top of the Janjukian at Bird Rock is older than Zone N 4 then the species *Anadara interclathrata*, *Modiola pueblensis*, *Spissatella maudensis*, *Proxichione etheridgei* and *Columbarium uniliratum* could be restricted to the Oligocene.

UPPER OLIGOCENE OR LOWER MIOCENE FAUNAS OF THE JANJUKIAN-LONGFORDIAN BOUNDARY

These are the faunas of the Jan Juc Formation at Bird Rock. Torquay, and the Freestone Cove Sandstone, the lower formation of the Table Cape Group at Table Cape. Faunas of the Puebla Formation overlying the Jan Juc Formation and of the Fossil Bluff Sandstone, if not of all the Table Cape Group, are of Longfordian (Lower Miocene) age.

The position of the top of the Jan Juc Formation has been discussed in the previous section; whether any part of the Table Cape Group is Janjukian has not yet been proven, although in a recent paper Darragh (1971, p. 174) placed both the Freestone Cove Sandstone and the Fossil Bluff Sandstone in the Janjukian presumabably because the Janjukian subspecies *Athleta* (*Ternivoluta*) *anticingulata anticingulata* occurs also in the Table Cape Group. Darragh (1965) gave the age of the Freestone Cove Sandstone as "Longfordian (pers. comm. D.J. Taylor, 1964)". Evidence for the Longfordian age of the Table Cape Group was presented by Quilty (1966) and Ludbrook (1967). The foraminiferal fauna of the Freestone Cove Sandstone, the "*Crassatella* Bed" 1.3 m thick at the base of the Group includes *Sherbornina atkinsoni*, *Sphaerogypsina globula*, *Astrononion centroplax* and abundant *Crespinella* sp. nov. a species common in though not restricted to the Mannum Formation. The absence of typical Janjukian benthonic species such as *Victoriella conoidea* and *Massilina torquayensis* precludes any unqualified correlation of even the basal part of the Table Cape Group with the Janjukian, and a stratigraphic level just below that of the lower bryozoal member of the Melton Limestone as shown by Lindsay (1970) is likely.

In the light of more recent work on planktonic foraminifera, Mr. Lindsay has very kindly examined the foraminiferal content of three samples from the Table Cape Group, two from the Fossil Bluff Sandstone supplied to Mr. W.K. Harris by Mr. M.R. Banks of the University of Tasmania, and one collected by the writer as matrix on molluscs from the Freestone Cove Sandstone. Mr. Lindsay comments as follows:

"Sample F 121/72 is from 71–74 feet (21.6–22.6 m) above the base of the Fossil Bluff Sandstone, near the top of the formation. Planktonic foraminifera include: *Globigerina woodi woodi* Jenkins (common), *Globigerina woodi connecta* Jenkins (common), *Globigerina bradyi* Wiesner, *Globigerina brazieri* Jenkins, *Globigerina ciperoensis* "forma typica" Bolli, *Globigerina* sp. aff. *G. euapertura* Jenkins (rare), *Globoquadrina dehiscens dehiscens* (Chapman, Parr, & Collins), *Globigerinoides* sp. aff. *G. primordius* Blow & Banner, *Globigerinoides* spp. indet. (two forms), *Globorotalia* (*Turborotalia*) *pseudokugleri* Blow (common but small specimens with six chambers in the final whorl, and tendency to the coarsely-pitted test of the *kugleri* group).

According to Blow (1969) *Globorotalia* (*T.*) *pseudokugleri* and *Globigerina ciperoensis* "forma typica" became extinct in mid-Zone N 4, *Globoquadrina dehiscens dehiscens* commenced "in the latest part of Zone N 4", *Globigerina bradyi* ranged up from basal zone N 4, *Globigerinoides primordius* through N 4 to early N 5, and *Globigerinoides* diversified from mid-N 4 onwards. The age of sample F 121/72 on these criteria would be middle to late Zone N 4, Early Miocene.

In terms of the sequence in New Zealand (Jenkins, 1971) *G. woodi woodi* commenced in mid-Waitakian Stage, *G. woodi connecta* in the upper Waitakian, *G. dehiscens dehiscens* at the base of the Waitakian, and *G. brazieri* is known only from the Waitakian. *G. euapertura* ranges up to the Waitakian, but the *G.* (*T.*) *kugleri* group is known only from the succeeding Otaian Stage. A compromise level near the Waitakian-Otaian boundary within the *Globigerina woodi connecta* Zone seems to be indicated. According to Jenkins (1971) this is Aquitanian, Lower Miocene, and Neogene, but it is at or just above the Oligocene-Miocene, Paleogene-Neogene, boundary according to Hornibrook and Edwards (1971) and

Berggren (1971, Table 52–40) who put the Waitakian in the Upper Oligocene.

The presence of occasional small *Operculina victoriensis* Chapman & Parr, and well-developed *Triloculina collinsi* Carter and the absence of any restricted Janjukian benthonic species *e.g. Massilina torquayensis* (Chapman) or *Victoriella conoidea* (Rutten) would support a Neogene age. According to Carter (1958, 1964) *Operculina victoriensis* commenced its range within his Faunal Unit 6, post-Janjukian Stage.

Sample F 120/72 from 27–32 feet (8.2–9.8 m) above the base of the Fossil Bluff Sandstone yielded similar planktonic forms, except for *G. dehiscens dehiscens*, *G. primordius* and *G.* (*T.*) *pseudokugleri*; and only one specimen of *Globigerinoides* sp. indet. Benthonic forms include *Lamarckina glencoensis* Chapman & Crespin which ranges as high as F.U. 6 according to Carter (1958, 1964). The microfauna supports a similar zonation to F 121/74, namely N 4; but in New Zealand terms could be Upper Waitakian.

Sample F 129/72 is from the Freestone Cove Sandstone, underlying the Fossil Bluff Sandstone. Planktonic forms include *G. woodi woodi*, *G. woodi connecta*, *G. brazieri* and *G.* aff. *euapertura*, which suggest a date similar to F 120/72. Of the benthonic forms present, *Sherbornina atkinsoni* ranges only into the lower part of F.U. 6 according to Carter (1958, 1964).

These conclusions accord with those of Quilty (1966) who assessed the lower 8 feet (2.4 m) of the Fossil Bluff Sandstone as Carter's Faunal Unit 6, lower Longfordian, Aquitanian, Lower Miocene."

The faunas of the Janjukian at Bird Rock and the Longfordian at Table Cape belong to the difficult transitional period between the Paleogene and Neogene, and that at Table Cape presents the usual problem of the fauna of a transgressive unit as well as having a large trochid fauna not recorded elsewhere. It is also notable for its considerable volute population, the holotypes of which still housed in the Tasmanian Museum, Hobart, were figured by Ludbrook (1967b).

Although the exercise has doubtful merits because the faunas need redescribing, and, in the case of those recorded from "Spring Creek", distinguishing between those from the Jan Juc Formation and those from the overlying Puebla Formation of the Torquay Group, it may be noted that of some 250 species of molluscs recorded from Table Cape only three, including *Limopsis chapmani*, are Eocene species, only 16 are recorded also from the Torquay Group, 48, including *Proxichione hormophora*, occur also in the Torquay Group and at Miocene localities; 48 occur at Table Cape and in the Miocene, 54 are not yet recorded from other localities, and the remainder are long ranging or of doubtful range.

The molluscan fauna at Table Cape from this evidence would appear to be almost entirely Neogene.

Glycymeris (*Grandaxinea*) *ornithopetra* Chapman & Singleton, *Spissatella maudensis* (Pritchard), *Athleta* (*Ternivoluta*) *anticingulata anticingulata* (McCoy) are known as occurring only in the Jan Juc Formation and Table Cape Group or at comparable stratigraphic levels in the late Janjukian or early Longfordian.

The following species are possibly, but not confirmed as occurring in the Torquay and Table Cape Groups, those marked * are recorded only from the Puebla (without distinction between Janjukian and Longfordian), and those marked # only from Table Cape.

*Modiolus pueblensis**, *Limatula crebresquamata*, *Cardita platycostata*#, *Glans tasmanica*#, *Eucrassatella oblonga*, *Veprecardium* (*Hedecardium*) *septuagenarium*#, *Solecurtus legrandi*#, *Phragmorisma anatinaeformis*, *Vacerrena hemipsila*#, *Tugali crassireticulata*#, *Infundibulum latesulcatum*#, *Herpetopoma woodsi*#, *Calliostoma latecarina*#, *C. blaxlandi*#, *C. tasmanica*#, *C. atoma*#, *Notogibbula aequisulcata*#, "*Gibbula*" *clarkei*#, *Ethminolia crassigranosa*#, *Trochus josephi*#, *Bellastraea ornatissimum*#, *Euninella atkinsoni*#, *Turbo tenisoni*#, *Crosseola semiornata*#, *Cirsonella laevis**, *Munditia lamellosa*#, *Delphinula imparigranosa*#, *Antisolarium gibbuloides*#, *Spectamen kekwicki*#, *Colpospira*

(*Platycolpus*) *warburtoni**, *Crossea tetragonostoma**, *Morchiella johnstoni**, "*Potamides wynyardense*"*, *Cerithioderma quinquelirata**, *Ectosinum microstira**, *Archierato duplicata**, *Umbilia platyrhyncha*, *Austrosassia crassicostata**, *A. abbotti**, *Columbarium acanthostephes echinatum**, *Zeapollia purpuroides*, *Paziella legrandi**, "*Murex*" *minutus**, *Retizafra gracilirata*, *Eburnopsis tessellatus**, *Phos lyraecostatus**, "*Atkinsonella fragilis*", *Austrosipho roblini**, *Hispidofusus semiundulatus*, *Latirus tatei**, *Microcolus transennus**, *M. affinis**, *Brocchitas johnstoni**, *Austrolithes tateanus**, *Fusinus meredithae**, *Austroharpa pachycheila*, *Lyria semiacuticostata*, *Notovoluta pueblensis*, *Pterospira macroptera**, *P. atkinsoni**, *P. stephensi**, *Topaginella octoplicata*, *Comitas crenularoides*.

LOWER MIOCENE (LONGFORDIAN)

Because they are often rather poorly preserved as compared with those found in shell beds and in the marly facies of the Batesfordian, Balcombian, and Bairnsdalian, Lower Miocene molluscs of the Longfordian apart from those at Table Cape and Torquay have been neglected. Faunas representing this interval of time from the *G. dehiscens dehiscens* Zone to the *G. trilobus trilobus* Zone of Ludbrook & Lindsay (1969), corresponding to Zones N4–N7 of Blow (1969) occur in the Abrakurrie Limestone (Lowry, 1970), the Mannum Formation, Naracoorte Limestone (Ludbrook, 1961) and the appropriate intervals of the Gambier Limestone (Ludbrook, 1961, 1971; Kenley, 1971) and the Gippsland Limestone (Carter, 1964).

LOWER MIOCENE (BATESFORDIAN)

In geochronological terms the time interval represented by the Batesfordian and Balcombian (Zones N8–N9) as compared with other Australian stages with the possible exception of the Mitchellian and Cheltenhamian is very short (McGowran *et al.*, 1971, Enclosure 14.1), although within the interval the important lineage from *Globigerinoides sicanus*=*G. bisphericus* to *Orbulina suturalis* is represented. At this time palaeotemperatures based on species of *Ostrea* and *Chlamys* reached their maximum (Dorman, 1966). Apart from facies considerations, and on the whole the Batesfordian is represented by bryozoal limestones with *Lepidocyclina* which has been assumed to occur always at the same level and the Balcombian by marls and clays, it is improbable that very marked differences between Batesfordian and Balcombian molluscan faunas are to be expected.

In the Cadell Marl Lens of the Morgan Limestone 5.8 km south of Morgan (Tate's "Gastropod Bed, River Murray") (7) exposed in the cliffs on the east side of the River Murray, a rich molluscan fauna occurs in carbonate sediments, the age of which has been determined as Batesfordian (Ludbrook, 1961). The lens occurs above the level of *Lepidocyclina* in the Morgan Limestone and *Globigerinoides transitorius* was noted in the upper member of the Morgan Limestone immediately above the lens, but the type section is not rich in diagnostic planktonic foraminifera and needs re-examination parallel with a redefinition of the Balcombian stage as suggested by Gostin (1966, p. 496).

In the present paper the Batesfordian is regarded as synonymous with the *G. sicanus*=*G. bisphericus* Zone (N8) and the Balcombian regarded broadly as containing in its lower part *G. transitorius* and *Praeorbulina glomerosa curva*, and in its upper part *G. transitorius*, *P. glomerosa* and *Orbulina suturalis*, Carter's Faunal Unit 10 synonymous with the Balcombian (Carter, 1969, Table 2), Zone N9 of Blow. This covers a period aproximating to the New Zealand Clifdenian and Early Lillburnian (Hornibrook & Edwards, 1971). The Cadell Marl Lens may prove to be Early Balcombian (=Clifdenian) rather than Batesfordian (=uppermost Altonian), but in either case its molluscan fauna is a little older than that of the Muddy Creek Marl, the Gellibrand Clay 2.4 km west northwest of Princetown, and the Balcombe Clay at Grice's Creek and Manyung Rocks.

From Batesfordian localities in the Fishing Point Marl (Fischer's Point), Curlewis Formation (Curlewis, Belmont, and Amphitheatre, Leigh River), Gellibrand Clay (Kennedy's Creek and south of Melrose Road), Myaring Beds (=part of Gambier Limestone sequence) (Glenelg River) Darragh (1969) described a number of columbariids.

Species characteristic of this stage are

Glycymeris (*Tucetona*) *subtrigonalis*, *Litigiella crassa*, *Glans murrayana*, *Solecurtus murrayvianus*, *Proxichione dimorphophylla*, *Austrotriton radialis*, *Chicoreus basicinctus*, *Serratifusus bovarius*, *S.* (?) *youngi*, *Peristernia altifrons*, *P. morundiana*, *Hispidofusus piscatorius*, *Austroharpa clathrata*, *Notovoluta lintea*, *Conus murrayvianus*.

However, Batesfordian to Early Balcombian assemblages in the Eucla and St. Vincent Basins preserved in algal and shelf limestones differ from those of the Murray and more easterly basins. Lindsay (1970) showed that limestones on either side of Spencer Gulf near Whyalla (4) and Wallaroo (5) which had been determined by several authors as of Pliocene age contained *Austrotrillina howchini* and *Flosculinella bontangensis* and were in fact the youngest member of the Miocene Melton Limestone of Early Balcombian age.

The Eucla and St. Vincent Basins fall within the Tertiary equivalent of the present day Flindersian Province (Ludbrook, 1971), but only from the western side of Yorke Peninsula do large molluscs such as *Anodontia*, *Miltha*, and *Diastoma* dominate the Miocene faunas. The fauna is illustrated on Plate 26; it also contains *Pseudarcopagia planatella*, described from Table Cape, and *Proxichione dimorphophylla*, otherwise restricted to the Cadell Marl.

MIDDLE MIOCENE (BALCOMBIAN-BAIRNSDALIAN)

The calcareous clayey silts deposited in the Otway Basin have provided the most abundant and best preserved Tertiary molluscan assemblages in southern Australia. These have come for the most part from the Balcombian to Early Bairnsdalian sections of the Muddy Creek Marl (11), the Gellibrand Clay (12) and the Balcombe Clay (16). This part of the sequence is moreover of considerable correlative value in that the evolutionary bioseries from *Globigerinoides transitorius* to *Orbulina universa* is represented within the Balcombian and Early Bairnsdalian. Most of the clayey formations in which Middle Miocene molluscs are abundant extend over a greater time interval and for purposes of correlation by molluscs it is essential, as Darragh has demonstrated in recent papers, that the levels from which species have been collected are known precisely. The Muddy Creek Marl ("lower beds, Muddy Creek") is Balcombian (*Orbulina suturalis* Zone) at Clifton Bank, but Bairnsdalian (*O. universa* Zone) at Grange Burn (Wade, 1964, p. 281). Although the Gellibrand Marl is of Longfordian to Bairnsdalian age, the cliff exposure 2.4 km westnorthwest of Princetown is Bairnsdalian; the Balcombe Clay is Balcombian at the type section, Fossil Beach 2.4 km south of Mornington, but Bairnsdalian in the downstream section at Grices Creek and Manyung Rocks (Gostin, 1966). A very useful guide to Victorian Tertiary localities is given by Darragh (1969, p. 66).

Balcombian-Bairnsdalian silts and clays are rich in Volutidae, Cypraeidae, Muricidae and Turridae, as well as carrying most of the Australian fossil Harpidae.

In the list below no distinction is attempted between Balcombian and Early Bairnsdalian species of the *Orbulina suturalis* and *O. universa* Zones, but from Darragh's (1969) study of the Columbariidae *Columbarium acanthostephes* and *Serratifusus foliaceus* occur only in the Balcombian and *S. clydoniatus*, *S. archimedes* and *S. squamulatus* in the Bairnsdalian, and from Beu (1970) *Concholepas antiquatus* is restricted to the Balcombian.

Poroleda tatei, *Arca capulopsis*, *Papyridea* (?) *cuculloides*, *Semele krauseana*, *Proxichione subtilicostata*, *Cuspidaria subrostrata*, *Emarginula wannonensis*, *Colina apicilirata*, *Thericium* (*Chavaniceri-

thium) flemingtonense, Jetwoodsia apheles, Striatiscala interstriata, Hirtoscala basinodosa, H. prionota, H. hamiltonensis, H. eritima, Circuloscala foliosa, Cirsotrema orycta, C. transenna, Mammiscala ralphi, M. escharoides, M. glyphospira, M. mutica, M. cylindracea, M. gonioides, Acrilla crebrelamellata, Sigaretotrema subinfundibulum, Globosinum perspectiva, Palaeocypraea gastroplax, Notoluponia subpyrulata, Austrocypraea ampullacea, A. scalena, Obex turritus, O. texturatus, Ratifusus leptoskeles, R. citharella, Austrotriton protensa, Ranella intercostalis, Concholepas antiquatus, Trophon (Litozamia) brevicaudatus, Murex wallacei, Chicoreus amblyceras, Pterynotus (P.) didymus, P. (P.) rhysus, Hispidofusus senticosus, Columbarium vulsum, C. acanthostephes, Serratifusus foliaceus, S. archimedes, S. squamulatus, Fax cominelloides, Austrosipho lamellifera, Varicosipho labrosus, Latirolagena tumida, L. staminea, L. micronema, Fasciolaria fusilla, Pleia concinna, P. tenisoni, Fusinus henicus, Ancillista subampliata, Baryspira lanceolata, Mitra (Eumitra) multisulcata, M. (Dibaphimitra) dennanti, Diplomitra uniplicata, Austroharpa pulligera, A. tenuis, A. abbreviata, A. sulcosa, Eocithara lamellifera, Pterospira gatliffi, Ericusa hamiltonensis, Leptoscapha crassilabrum, Volutoconus limbatus, Ericusa ellipsoidea, Athleta (Ternivoluta) antiscalaris levior, Microginella septemplicata.

LATE MIOCENE FAUNAS AND THE MIOCENE-PLIOCENE BOUNDARY

Molluscan faunas from the Late Miocene correlating with the *Globorotalia mayeri* and *G. menardii miotumida* Zones or with Zones N11–N17 are virtually undescribed, and only in the Gippsland Basin is this part of the stratigraphic sequence apparently complete, in the upper part of the Bairnsdalian (Bairnsdale Limestone Member of the Gippsland Limestone) and the Mitchellian (Tambo River Formation). The age of the Cheltenhamian at Beaumaris is not yet satisfactorily resolved. As noted by Stirton *et al.* (1968) there is a considerable hiatus between the Mitchellian and Cheltenhamian molluscs listed by Wilkins (1963), but, as Wilkins found, most species can be recorded only by affinity. From Rose Hill Farm, Mitchell River, *Tylospira clathrata* and *Eucrassatella rosicollina* have been recorded as restricted to the Mitchellian, while *Proxichione moondarae* has a limited range from Bairnsdalian to Cheltenhamian in Victoria. Apart from unrestricted forms, the species recorded by Wilkins as occurring without doubt in the stratotype Cheltenhamian at Beaumaris include 21 Pliocene and 7 Miocene species. Correlation of the Cheltenhamian presents boundary problems similar to those of the Oligocene-Miocene boundary. Its position in the Upper Miocene has been determined from the presence in the type section of *Aturia australis*, since *Aturia* is not recorded as surviving the Miocene, but in a letter to the writer dated 2 July, 1969, Dr. A.G. Beu of the Geological Survey of New Zealand wrote: "I have recently discovered two small specimens of *Aturia* in the Waipipian (Middle Pliocene) rocks of North Canterbury". This important discovery makes the evidence for assigning the Cheltenhamian to the Upper Miocene tenuous. The discovery was known to Simpson (1970) who quoted a letter from T.A. Darragh also of 2 July, 1969, as follows: "New evidence recently to hand from New Zealand suggests that perhaps we should not place too much emphasis on the presence of *Aturia*. The forams at Beaumaris tend to give a latest Miocene age but could be earliest Pliocene". No data on correlation of the type Cheltenhamian by means of foraminifera have been published.

Because she considered that the Cheltenhamian bore a close relationship to the Kalimnan, Crespin (1943, p. 5, 25), instituted the Mitchellian Stage to include the beds between the Balcombian (i.e. the Bairnsdalian) and the Kalimnan, which is accepted as of Lower Pliocene age.

The stratotype Kalimnan section is contained within the Jemmys Point Formation above sea level at Jemmys Point and 40 m east of Kalimna Jetty, Lakes Entrance, as redescribed by Wilkins (1963). The Kalimnan Stage is interpreted by Carter (1964, p. 45) as synonymous with the Jemmys Point Formation.

The type section includes two units, a lower 4 m with the lower shell bed (c) of

Singleton (1941) and Wilkins (1963) with *Eucrassatella kingicoloides, Phos gregsoni* and *Singletonaria lirata,* and an upper with the upper shell bed (h) of Singleton (1941) and Wilkins (1963) with *Bankivia howitti* and *Mactra axiniformis.* Similar beds continue below sea level and in deeper parts of the Gippsland Basin the Jemmys Point Formation becomes continuous with the Mitchellian Tambo River Formation (Carter, 1964).

In describing *Athleta* (*Ternivoluta*) *bungae* Darragh (1971, p. 182) has unequivocally placed the Jemmys Point Formation in the "Cheltenhamian, Upper Miocene" and at the same time (p. 183) excluded the Pliocene from the Tertiary of southern Australia. Two localities from which the species was collected correspond to the lower unit of the Jemmys Point Formation as described by Wilkins.

In thus equating the lower part of the Kalimnan with the Cheltenhamian Darragh would appear to have given support to Crespin's interpretation and to her later (1950) exclusion of the Cheltenhamian as a stage. The alternatives of either allowing the Cheltenhamian to lapse into synonymy or preferably, of using it for that part of the Gippsland Basin sequence between the top of the shell bed at Rosehill (*i.e.* the top of the Mitchellian) and the top of the lower shell bed (b) in the Bunga Creek road cutting (north side), *i.e.* the lower part of the Kalimnan, was proposed by Wilkins (*l.c.* p. 53, 55), and presumably so used by Darragh. His usage, however, necessitates a formal redefinition of the base of the Kalimnan Stage within the Jemmys Point Formation, and a clearer understanding of the age of the Cheltenhamian.

Darragh's Upper Miocene age for any part of the Jemmys Point Formation is at variance with the Pliocene age determined by Carter (1964) and the statement by Taylor (1971, p. 238) that "the Lower Pliocene age of the Jemmys Point Formation was confirmed by D. Nicholls (formerly University of Melbourne) who studied the planktonic foraminifera".

It is obvious that these conflicting views need reconciliation.

Unfortunately an opportunity of establishing a continuous foraminiferal or molluscan sequence in the Late Miocene and Early Pliocene was lost in 1941–1945 when the Lakes Entrance Oil Shaft was sunk 1.6 km northeast of Lakes Entrance and only two samples were taken between the surface and 61 m (200 feet). In the shaft the upper part of the stratigraphic sequence determined by Crespin was: Recent to Pleistocene (Post Kalimnan) 0–10 feet, Lower Pliocene (Kalimnan) 10–150 feet, Upper Miocene (Mitchellian Stage) 150–208 fet, and Middle Miocene (Bairnsdale Substage) 208–524 feet (Crespin, 1947, unpublished report Bureau of Mineral Resources 1947/69). Working on planktonic foraminifera from samples collected between 64 m (212 feet) and 367 m (1204 feet), Jenkins (1960) proposed a zonal sequence which he correlated with planktonic foraminiferal zones of Trinidad and Venezuela. By this means the Bairnsdale Substage as determined by Crespin includes the *Orbulina universa, Globorotalia mayeri* and *G. miotumida* Zones, shown by Jenkins (1967) to occur from the Upper Lillburnian to Tongaporutuan in New Zealand, or Zones N11–N18. The Kapitean *G. miozea sphericomiozea* Zone of Jenkins (1967) has not so far been recorded in southern Australia between the *G. miotumida* and *G. inflata* Zones, the base of *G. inflata* Zone being placed within N18; Jenkins draws it at the base of the Pliocene or the New Zealand Opoitian. If the upper limit of the Bairnsdalian has been correctly deduced, the Mitchellian should come between the uppermost part of the *G. miotumida* Zone and the lowermost part of the *G. inflata* Zone.

In the Murray Basin the problem of the Miocene-Pliocene boundary is presented by the Bookpurnong Beds (8). Good molluscan and foraminiferal faunas have been collected from the top of the formation at the type section 4 km downstream from Loxton and also from bore cuttings. The original material described by Tate (1893, 1899) came from two bores, one at "Tareena", a homestead in the southwest corner of New South

Walse 73 km northeast of Loxton, 141°3′ E, 33°58′S, Anabranch Sheet S1SI 54–7 Series R502, coordinates 405803, the other from Mindarie, a township 42 km southwest of Loxton, the formation being identifiable from matrix of some of Tate's types. The formation was described by Ludbrook (1961) and molluscs and foraminifera from the type section and subsurface section listed. From the time they were first described, Tate (1899) recognized the occurrence together of what he called "Eocene" (*i.e.* Miocene) and "Miocene" (*i.e.* Pliocene) species.

The fauna has been dated as Cheltenhamian (Ludbrook, 1961) largely because like the type Cheltenhamian it contains Miocene and Pliocene elements, but whether this correlation should be sustained awaits description of the faunas from both type localities. If it is supported, the Bookpurnong Beds could provide a key to the age of the Cheltenhamian. On the whole, the molluscs and foraminifera of the Bookpurnong Beds are Pliocene, some species, as Tate observed, being otherwise restricted to the Upper Pliocene (Yatalan) Dry Creek Sands. It is noteworthy that *Eotrigonia* and *Neotrigonia* occur together and that the Miocene species *Serripecten yahliensis* and *Pododesmus sella* are common. The larger molluscs listed below, most of which are illustrated of Plate 27, are Kalimnan species with the exception of those whose ranges are stated. The small species await closer study.

Glycymeris (*Glycymeris*) *halli*, *G.* (*Tucetona*) *convexa*, *Mytilus linguatulus*, *Hinnites tatei* (? = *H. corioensis*), *Serripecten yahliensis* (Longfordian-Mitchellian), *Pododesmus sella* (?Batesfordian-Cheltenhamiae), *Pinctada crassicardia*, *Eotrigonia lutosa* (Balcombian), *Neotrigonia trua* (Yatalan), *Eucrassatella deltoides* (Middle to Upper Pliocene of Flinders Island), *E. kingicoloides* (Kalimnan-Yatalan), *Miltha dennanti* (Mitchellian-Cheltenhamian), *Proxichione moondarae* (?Bairnsdalian-Cheltenhamian or Lower Kalimnan), *Placamen subroborata*, *Tylospira coronata* (Cheltenhamian-Kalimnan), *Polinices subjugum* (Yatalan), *Pterospira heptagonalis* (?Miocene), *Thericium* (*Chavanicerithium*) *torri* and *Umbilia tatei* are restricted to the formation.

The foraminifera include *Flintina intermedia*, "the most characteristic species of the Kalimnan in Victoria" (Parr, 1939) and *Elphidium pseudonodosum*, both of which are shown by Carter (1959) as possibly diagnostic of the Kalimnan and (1964) as restricted to the outcropping Jemmys Point Formation. Whether the first of these two species can be relied upon is a little doubtful (Ludbrook, 1961, p. 68). Moreover, the presence of *Operculina victoriensis* both in the type section and immediately above the Pata Limestone in the described subsurface section is inconsistent with a Pliocene age, unless *O. victoriensis* is derived from underlying limestones or the waters in which the Bookpurnong Beds were deposited and in which *Pinctada crassicardia* lived were warm enough for *O. victoriensis* to survive.

As the Bookpurnong Beds are highly glauconitic particularly just below river level at Loxton, it is hoped that radiometric dating may prove useful in solving the Miocene-Pliocene boundary problem at least in the Murrary Basin.

LOWER PLIOCENE (KALIMNAN)

Rich molluscan faunas occur in marls and sandy marls in the Grange Burn "Coquina" (11) (Tate's "upper beds, Muddy Creek") cropping out on Grange Burn and at Macdonald's Bank on Muddy Creek (Parr, 1939; Gill, 1957; Spencer-Jones, 1971) west of Hamilton in the Tyrendarra Embayment of the Otway Basin and in the Kalimnan Jemmys Point Formation (17) described in the previous section.

Typical Kalimnan molluscs, of which those marked "C" occur also in the Cheltenhamian at Beaumaris above the nodule bed (Wilkins, 1963) and "B" in the Bookpurnong Beds, marked * in the Grange Burn Coquina and # in the Jemmys Point Formation only are:

Nucula kalimnae, Scaeoleda acinaciformis*[C], *Mytilus deperditus**, *M. linguatulus**[B], *Trichomya hamiltonensis, Isognomon percrassa, Chlamys subconvexa, Limatula subnodulosa, Ostrea manubriata, Vimentum calva*[CB], *Arcturellina solida*[C], *Cardita kalimnae**, *Mactra axiniformis, M. hamiltonensis*[C], *Sunetta* (*Sunameroe*) *gibberula* (very common in the Grange Burn Coquina, but also occurring in the Pleistocene Roe Calcarenite), *Myochama plana, Myadora praelonga, Leiopyrga quadricingulata, Dolicrossea lauta**, *Amaea triplicata, Hartungia dennanti, Tylospira coronata*[CB], *Singletonaria lirata, Sulcerato illota**, *Vernotriton ovoida**, *Dermomurex crassiliratus**, *Pterynotus* (*P.*) *trinodosus**, *Lepsiella subreticulata**, *Dicathais abjecta**, *Buccinulum semicostatum**, *Cominella crassina, Tavaniotha crassigranosa, Phos gregsoni**, *P. tuberculatus**, *Zeapollia obliquicostata**, *Maculotriton rostratus**, *Austrosipho spatiosa, Propefusus dumetosus**, *Mitra* (*Strigatella*?) *atypha**, *Harpella gemmata**, *Cymbiola tabulata**, *Ericusa fulgetroides**, *Amoria* (*Amorena*) *masoni**, *Alocospira papillata**, *Sydaphera modestina**, *S. wannonensis, Eucithara glabra, Spineoterebra convexiuscula**, *Pervicacia subspectabilis**, *Noditerebra geniculata, Gemmaterebra subcatenifera**.

In the absence of planktonic foraminifera, the pelagic janthinid mollusc *Hartungia* Bronn (=*Heligmope,* Tate) has been shown to have potential in interregional correlation (Chavan, 1951; Fleming, 1953). The Kalimnan species *Hartungia dennanti* (Tate), closely related to *Hartungia typica* Bronn and to *H. chouberti* (Chavan) is figured on Plate 28, figs. 93, 94.

(?) MIDDLE TO UPPER PLIOCENE OF FLINDERS ISLAND

On Flinders Island in Bass Strait (18), marine sediments of the Cameron Inlet Formation, with a varying lithology of sandy gravel, coquina, to marl, carry numerous thick-shelled molluscs (Sutherland and Kershaw, 1971). The fauna indicates a post-Kalimnan age. It contains a number of Kalimnan species, including *Glycymeris* (*G.*) *halli, G.* (*Tucetona*) *convexa, Cucullaea praelonga, Tylospira coronata, Leiopyrga quadricingulata,* and *Cupidoliva nymphalis,* as well as *Eucrassatella deltoides,* which occurs also in the Bookpurnong Beds, *Proxichione moondarae* (Bairnsdalian–Cheltenhamian), *Miltha flindersiana,* common also in the Dry Creek Sands, and a high percentage of living species. A Middle to Upper Pliocene age is determined by Darragh and Kendrick (1971) and Sutherland and Kershaw (1971).

UPPER PLIOCENE (YATALAN)

Fossiliferous limestones of Upper Pliocene age underlie the City of Adelaide (6) and were formerly exposed at Government House and the University of Adelaide. These are the equivalents of Tate's "oyster banks" at Aldinga Bay, the type section of which is a small outcrop named and designated the Hallett Cove Sandstone by Crespin (1954) at Hallett Cove. Large molluscs, mainly

Chlamys antiaustralis, C. (*Equichlamys*) *consobrina, C.* (*E.*) *palmipes, C.* (*E.*) *subbifrons, Spondylus spondyloides, Ostrea arenicola, Anodontia sphericula, Miltha flindersiana, Tellinella aldingae, Pseudarcopagia basedowi, Anapella variabilis, Diastoma provisi,* and *Campanile triseriale*

are common as moulds in the limestone (Ludbrook, 1959).

On the western (downthrow) side of the Para Fault fossiliferous calcareous sands, the Dry Creek Sands, with rich shell beds, are partially equivalent to the Hallett Cove Sandstone with which they are interbedded in the upper part of the formation. The stage name "Adelaidean" was once used for the interval represented by the Dry Creek Sands, but as this name is preoccupied for the Precambrian Adelaide System, the name Yatalan was proposed (Ludbrook, 1963) to replace it.

Despite the richness of the molluscan fauna, material is limited by the fact that it has to be obtained by boring. The assemblage was described by Ludbrook (1954–1958), but has since been considerably increased and is in need of additions and revisions.

It is now generally accepted that the fauna is of Upper Pliocene age. It is characterized by a considerable warm water element (Ludbrook, 1954). Some species of which such as *Cymbiola* (*Aulicina*) *irvinae* (Pl. 28, fig. 107) being represented now in Western Australia from Cape Naturaliste to Geraldton, *Amoria grayi* from Geographe Bay to the North Kimberley (Wilson & Gillett, 1971) and others being congeneric with Western Australian species of *Timoclea* (*Veremolpa*) and *Diastoma*. Over 57 per cent of the species were regarded as indigenous (Ludbrook, 1954) but this figure will be reduced when the number of those also occurring in the Pleistocene Roe Calcarenite is known.

Oyster beds, limestones and calcareous sandstones of the same age occur in the Norwest Bend Formation at the top of the marine sequence in the cliffs of the Murray River (Tate, 1885; Ludbrook, 1959, 1961).

PLEISTOCENE

The biostratigraphic sequence in the Pleistocene awaits detailed study. It includes in the Otway Basin the deposits of the "Pleistocene" delta of the Glenelg River, of which the Werrikoo Member of the Whalers Bluff Formation at Caldwells Cliff is the type section for the Werrikooian stage (Singleton, 1941a; Kenley, 1971), and the calcarenite relics of former dunes and associated beach deposits which comprise the Bridgewater Formation considered by Kenley (1971) to span almost the whole of Quaternary time.

Lists of fossils from the Pleistocene (or Upper Pliocene) of Glenelg River have been given by Dennant (1887, 1890), Dennant & Kitson (1903), Singleton (1941a) and Kenley (1971), all in need of revision, but description of faunas has been sporadic. Singleton (1941b) described *Nuculana* (*Scaeoleda*) *killara*, *Glycymeris* (*Veletuceta*) *pseudaustralis*, *Ostrea sinuata glenelgensis* and *Aulacomya suberosa* from the Werrikooian. The faunal sequence in South Australia remains undescribed.

Taxonomic description of the rich fauna of the Roe Calcarenite (Lowry, 1970) on the Roe Plains in the western Eucla Basin (1) is nearing finality (Ludbrook, in preparation). The molluscs are of particular interest in that they include, among Recent and indigenous species, taxa otherwise restricted to the Hallett Cove Sandstone or Dry Creek Sands or those apparently beginning in the Dry Creek Sands and migrating westwards. These include

Chlamys (*Equichlamys*) *subbifrons*, *Spondylus spondyloides*, *Pseudarcopagia basedowi*, *Myrtea fabuloides*, *Eomiltha salebrosa*, *Anapella variabilis*, *Timoclea* (*Veremolpa*) sp., *Notocallista* (*Striacallista*) *pestis*, *Anodontia sphericula* (beginning in the Miocene), *Tellinella aldingae*, *Cocculinella salisburyensis*, *Cantharidus* (*Phasianotrochus*) *subsimplex*, *Turritella* (*Gazameda*) *adelaidensis*, *T.* (*G.*) *iredalei*, *Semivertagus subcalvatus*, *Batillaria* (*Zeacumantus*) *multilirata*, *Manulona arrugosa*, *Diala* (*Mereldia*) *incommoda*, *Turbonilla* (*Chemnitzia*) *mappingae*, *Hinia* (*Reticunassa*) *subcopiosa*, *Cymatiella sexcostata*, *Mitrella* (*Ademitrella*) *insolentior*, *Cymbiola* (*Aulicina*) *irvinae*, *Amoria grayi*, *Liratomina adelaidensis*, *Tomopleura ludbrookae*, *Syntomodrillia decemcostata*.

The fauna seems to be of Early Pleistocene age. It contains also many excellent examples of *Hartungia* which are at present being studied by Dr. A.G. Beu of the Geological Survey of New Zealand.

REFERENCES

Baker, G., 1943, Eocene deposits south-east of Princetown, Victoria. *Roy. Soc. Vict., Proc.*, v. 55 (n.s.), pt. 2, p. 237–255.

———, 1944, The geology of the Port Campbell District. *Ibid.*, v. 56 (n.s.), pt. 1, p. 77–111.

———, 1950, Geology and physiography of the Moonlight Head District, Victoria. *Ibid.*, v. 60 (n.s.), p. 17–43.

———, 1953, The relationship of *Cyclammina*-bearing sediments to the older Tertiary deposits south-east of Princetown, Victoria. *Nat. Mus. Vict., Mem.*, 18, p. 125–134.

Berggren, W.A., 1969, Cenozoic chronostratigraphy, planktonic foraminiferal zonation and the radiometric time scale. *Nature*, v. 224, Dec. 13, p. 1072–1075.

————, 1971a, Tertiary boundaries and correlations. *In* Funnell, B.M., and Riedel, W.R., Micropaleontology of the oceans. p. 693–809, *Camb. Univ. Press*, Cambridge.

————, 1971b, Multiple phylogenetic zonations of the Cenozoic based on planktonic Foraminifera. *Proc. II Planktonic Conference, Roma*, 1970, p. 41–56.

Beu, A.G., 1967, Notes on Australasian Anomiidae (Mollusca, Bivalvia). *Roy. Soc. N.Z., Trans., Zool.*, v. 9, pt. 18, p. 225–243.

————, 1970, Taxonomic position of *Lippistes pehuensis* Marwick, with a review of the species of *Concholepas* (Gastropoda: Muricidae). *Malac. Soc. Aust., Jour.*, v. 2, pt. 1, p. 39–46.

Blow, W.H., 1969, Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. *1st. Internat. Conf. Planktonic Microfossils, Geneva, 1967, Proc.*, v. 1, p. 199–422, *E.J. Brill*, Leiden.

Bowler, J.M., 1963, Tertiary stratigraphy and sedimentation in the Geelong-Maude area, Victoria. *Roy. Soc. Vict., Proc.*, v. 76, pt. 1, p. 69–137.

Carter, A.N., 1958, Tertiary Foraminifera from the Aire District, Victoria. *Geol. Surv. Vict., Bull.*, 55, p. 1–76.

————, 1959, Guide Foraminifera of the Tertiary stages in Victoria. *Vict. Min. Geol., Jour.*, v. 6, no. 3, p. 2–7.

————, 1964, Tertiary Foraminifera from Gippsland, Victoria, and their stratigraphical significance. *Geol. Surv. Vict., Mem.*, 23, p. 1–154.

Cernohorsky, W.O., 1970, Systematics of the families Mitridae and Volutomitridae (Mollusca: Gastropoda). *Auck. Inst. Mus., Bull.*, 8, p. 1–190.

Chavan, A., 1951, Deux interessants gastropodes du Pliocene marocain. *Serv. Geol. Maroc., Notes et Mem.*, 83, p. 135–139.

Crespin, I., 1943, The stratigraphy of the Tertiary marine rocks in Gippsland, Victoria. *Dept. Supply & Shipping, Min. Res. Surv., Bull.*, 9, p. 1–101 (mimeographed).

————, 1947, A summary of the stratigraphy and palaeontology of the Lakes Entrance Oil Shaft, Gippsland, Victoria. *Bur. Min. Res. Geol. Geophys., Rep.*, no. 1947/69 (mimeographed).

————, 1950, Australian Tertiary microfaunas and their relationships to assemblages elsewhere in the Pacific Region. *Jour. Paleont.*, v. 24, pt. 4, p. 421–429.

————, 1954, Stratigraphy and micropalaeontology of the marine Tertiary rocks between Adelaide and Aldinga, South Australia. *Bur. Min. Res. Geol. Geophys., Rep.*, no. 12.

Darragh, T.A., 1965, Revision of *Eucrassatella* and *Spissatella* in the Tertiary of Victoria and Tasmania. *Roy. Soc. Vict., Proc.*, v. 78, pt. 1, p. 95–114.

————, 1969, A revision of the family Columbariidae (Mollusca: Gastropoda). *Ibid.*, v. 83, pt. 1, p. 63–119.

————, 1970, Catalogue of Australian Tertiary Mollusca (except Chitons). *Nat. Mus. Vict., Mem.*, 31, p. 125–212.

————, 1971, Revision of the Australian Tertiary Volutidae (Mollusca: Gastropoda). 1. The subfamily Athletinae. *Malac. Soc. Aust., Jour.*, v. 2, pt. 2, p. 163–185.

————, and Kendrick, G.W., 1971, *Zenatiopsis ultima* sp. nov., terminal species of the *Zenatiopsis* lineage (Bivalvia: Mactridae). *Roy. Soc. Vict., Proc.*, v. 84, pt. 1, p. 87–92.

Dennant, J., & Kitson, A.E., 1903, Catalogue of the described species of fossils (except Bryozoa and Foraminifera) in the Cainozoic fauna of Victoria, South Australia and Tasmania. *Geol. Surv. Vict., Rec.*, v. 1, pt. 2, p. 89–147.

Dorman, F.H., 1966, Australian Tertiary paleotemperatures. *Jour. Geol.*, v. 74, pt. 1, p. 49–61.

Finlay, H.J., and Marwick, J., 1937, The Wangaloan and associated molluscan faunas of Kaitangata-Green Island Subdivision. *N.Z. Geol. Surv., Paleont. Bull.*, no. 15, p. 1–140.

Garrard, T.A., 1972, A revision of Australian Recent and Tertiary Turritellidae (Gastropoda: Mollusca). *Malac. Soc. Aust., Jour.*, v. 2, pt. 3, p. 267–338.

Gill, E.D., 1957, The stratigraphical occurrence and palaeoecology of some Australian Tertiary marsupials. *Nat. Mus. Vict., Mem.*, no. 21, p. 135–203.

Gostin, V.A., 1966, Tertiary stratigraphy of the Mornington District, Victoria. *Roy. Soc. Vict., Proc.*, v. 79, pt. 2, p. 459–512.

Hall, T.S., and Pritchard, G.B., 1895, The older Tertiaries of Maude, with an indication of the sequence of the Eocene rocks of Victoria. *Roy. Soc. Vict., Proc., n.s.*, v. 7, p. 180–196.

————, 1897, A contribution to our knowledge of the Tertiaries in the neighbourhood of Melbourne. *Ibid.*, v. 9, p. 187–229.

————, 1902, A suggested nomenclature for the marine Tertiary deposits of southern Australia. *Ibid.*, v. 14, pt. 2, p. 75–81.

Hocking, J.B., 1972, Geologic evolution and hydrocarbon habitat, Gippsland Basin. *Aust. Petrol. Explor. "Assoc". (APEA), Jour.*, v. 12, pt. 1, p. 132–137.

Hornibrook, N. de B., and Edwards, A.R., 1971, Integrated planktonic foraminiferal and calcareous nannoplankton datum levels in the New Zealand Cenozoic. *Proc. II Planktonic Conf. Roma 1970*, v. 1, p. 649–657.

————, and Harrington, H.J., 1957, The status of the Wangaloan stage. *N.Z. Jour. Sci. Technol., sec. B.*, v. 38, pt. 6, p. 655–670.

James, E.A., and Evans, P.R., 1971, The stratigraphy of the offshore Gippsland basin. *Aust. Petrol. Explor. Assoc. (APEA), Jour.*, v. 11, no. 1, p. 71–74.

Jenkins, D.G., 1960, Planktonic Foraminifera from the Lakes Entrance oil shaft, Victoria, Australia. *Micropaleontology*, v. 6, no. 4, p. 345–371.

————, 1971, New Zealand Cenozoic planktonic Foraminifera. *N.Z. Geol. Surv., Paleont. Bull.*, no. 42, p. 1–278.

Kenley, P.R., 1951, Marine Eocene sediments near Casterton, Victoria. *Aust. Jour. Sci.*, v. 14, p. 91–92.

————, 1954, The occurrence of Cretaceous sediments in south-western Victoria. *Roy. Soc. Vict., Proc.*, v. 66, p. 1–16.

————, 1971, Cainozoic geology of the eastern part of the Gambier Embayment. *In* H. Wopfner and J.G. Douglas (Ed.), The Otway Basin of Southeastern Australia. *Geol. Survs. S. Aust. and Vict., Spec. Bull.*, p. 89–153, Enclosures.

Lindsay, J.M., 1967, Foraminifera and stratigraphy of the type section of the Port Willunga beds, Aldinga Bay, South Australia. *Roy. Soc. S. Aust., Trans.*, v. 91, p. 93–109.

————, 1969, Cainozoic Foraminifera and stratigraphy of the Adelaide Plains Sub-Basin, South Australia. *Geol. Surv. S. Aust., Bull.*, no. 42, p. 1–60.

————, 1970, Melton Limestone: multiple mid-Tertiary transgressions, South-eastern Gawler Platform. *Geol. Surv. S. Aust., Quart. Geol., Notes*, no. 33, p. 2–10.

Lowry, D.C., 1970, Geology of the Western Australian part of the Eucla Basin. *Geol. Surv. W. Aust., Bull.*, no. 122, p. 1–201.

Ludbrook, N.H., 1954–1958, The molluscan fauna of the Pliocene strata underlying the Adelaide Plains. *Roy. Soc. S. Aust., Trans.*, Part 1, 1954, v. 77, p. 42–64; Part 2, Pelecypoda, 1955, v. 78, p. 18–87; Part 3, Scaphopoda, Polyplacophora, Gastropoda (Haliotidae to Tornidae), 1956, v. 79, p. 1–36; Part 4, Gastropoda (Turritellidae to Struthiolariidae), 1957, v. 80, p. 17–58; Part 5, Gastropoda (Eratoidae to Scaphandridae), 1958, v. 81, p. 43–111.

————, 1959, A widespread Pliocene molluscan fauna with *Anodontia* in South Australia. *Ibid.*, v. 82, p. 219–233.

————, 1961a, Stratigraphy of the Murray Basin in South Australia. *Geol. Surv. S. Aust., Bull.*, no. 36, p. 1–96.

————, 1961b, Revision of the Tate molluscan types: Pelecypoda-Nuculidae and Nuculanidae. *Roy. Soc. S. Aust., Trans.*, v. 85, p. 55–65.

————, 1967a, Correlation of Tertiary rocks of the Australasian Region. *In* Tertiary correlations and climatic changes in the Pacific. Symposium No. 25. The Eleventh Pacific Science Congress, Tokyo, 1966. *Sasaki Printing and Publishing Co. Ltd.*, Sendai, Japan.

————, 1967b, Tertiary molluscan types from Table Cape in the Tasmanian Museum, Hobart. *Roy. Soc. Tas., Pap. Proc.*, v. 101, p. 65–69.

————, 1969a, Tertiary Period. *In* L.W. Parkin (Ed.), Handbook of South Australian Geology, *Geol. Surv. S. Aust.*, p. 172–203.

————, 1969b, The genus *Miltha* (Mollusca: Bivalvia) in the Australian Cainozoic. *Roy. Soc. S. Aust., Trans.*, v. 93, p. 55–63.

————, 1971a, Large gastropods of the families Diastomatidae and Cerithiidae (Mollusca: Gastropoda) in southern Australia. *Ibid.*, v. 95, pt. 1, p. 31–42.

————, 1971b, Stratigraphy and correlation of marine sediments in the western part of the Gambier Embayment. *In* H. Wopfner and J.G. Douglas (Ed.). The Otway Basin of southeastern Australia, *Geol. Surv. S. Aust.* and *Vict., Spec. Bull.*, p. 47–66.

———, and Lindsay, J.M., 1966, The Aldingan Stage. *Geol. Surv. S. Aust., Quart. Geol. Notes*, no. 19, p. 1–2.

———, and ———, 1969, Tertiary foraminiferal zones in South Australia. *Proc. 1st Internat. Conf. Planktonic Microfossils, Geneva*, 1967, p. 366–375, *E.J. Brill*, Leiden.

McCoy, F., 1861, On the ancient and recent natural history of Victoria. Intercolonial Exhibition Essays, 1861, p. 167–170, reprinted *Ann. Mag. Nat. Hist., ser. 3*, v. 9, no. 50, p. 137–150, 162.

———, 1865, On the occurrence of *Limopsis belcheri, Corbula sulcata,* and some other recent shells in the fossil state in Miocene Tertiary beds near Melbourne. *Ibid., ser. 3*, v. 16, p. 113–114.

———, 1866, On the Australian Tertiary species of *Trigonia*. *Geol. Mag.*, v. 3, no. 29, p. 481–482.

———, 1866, On some new species of fossil volutes from the Tertiary beds near Melbourne. *Ann. Mag. Nat. Hist., ser. 8*, v. 18, no. 107, p. 375–381.

———, 1867, Descriptions of two new fossil cowries, characteristic of Tertiary beds near Melbourne. *Ibid., ser. 3*, v. 20, no. 120, p. 436–438.

———, 1869, On a new volute. *Ibid., ser. 4*, v. 4, no. 3, p. 34.

———, 1875a, On a third new Tertiary species of *Trigonia*. *Ibid., ser. 4*, v. 15, no. 89, p. 316–317.

———, 1875b, On a Tertiary *Pleurotomaria*. *Ibid., ser. 4*, v. 16, no. 92, p. 101, 102.

———, 1874–1879, Prodromus of the Palaeontology of Victoria. Decades 1–6. *Geol. Surv. Vict.*

McGowran, B., 1965, Two Paleocene foraminiferal faunas from the Wangerrip Group, Pebble Point coastal section, western Victoria. *Roy. Soc. Vict., Proc.*, v. 79, pt. 1, p. 9–74.

———, Lindsay, J.M., and Harris, W.K., 1971, Attempted reconciliation of Tertiary biostratigraphic systems. *In* H. Wopfner and J.G. Douglas (Ed.). The Otway Basin of southeastern Australia. *Geol. Survs. S. Aust. and Vict., Spec. Bull.*, p. 273–281.

Newell, N.D., 1969, Arcoidea. *In* R.C. Moore (Ed.), Treatise on Invertebrate Paleontology, Part N, v. 1, Mollusca 6, Bivalvia, p. N248–N270, *Kansas Univ. Press and Geol. Soc. America.*

Parr, W.J., 1939, Foraminifera of the Pliocene of southeastern Australia. *Vict., Min. and Geol. Jour.*, v. 1, no. 4, p. 65–71.

Quilty, P.J., 1966, The age of Tasmanian marine Tertiary rocks. *Aust. Jour. Sci.*, v. 29, no. 5, p. 143–144.

Raggatt, H.G., and Crespin, I., 1955, Stratigraphy of Tertiary rocks between Torquay and Eastern View, Victoria. *Roy Soc. Vict., Proc.*, v. 67, pt. 1, p. 75–142.

Reynolds, M.A., 1953, The Cainozoic succession of Maslin and Aldinga Bays, South Australia. *Roy. Soc. S. Aust., Trans.*, v. 76, p. 114–146.

Simpson, G.G., 1970, Miocene penguins from Victoria, Australia, and Chubut, Argentina. *Nat. Mus. Vict., Mem.*, no. 31, p. 17–23.

Singleton, F.A., 1941a, The Tertiary geology of Australia. *Roy. Soc. Vict., Proc.*, v. 53, pt. 1, p. 1–125.

———, 1941b, Studies in Australian Tertiary Mollusca, Part II. *Ibid.*, v. 53, pt. 2, p. 423–428.

———, 1943, An Eocene molluscan fauna from Victoria. *Ibid.*, v. 55, pt. 2, p. 267–278.

Spencer-Jones, D., 1971, Marginal Tertiary deposits of the Tyrendarra Embayment-Grassdale and Hamilton district. *In* H. Wopfner and J.G. Douglas (Ed.). The Otway Basin of southeastern Australia, *Geol. Survs. S. Aust. and Vict., Spec. Bull.*, p. 241–249.

Stirton, R.A., Tedford, R.H., and Woodburne, M.O., 1968, Australian Tertiary deposits containing terrestrial mammals. *Univ. Calif. Publ. Geol. Sci.*, v. 77, p. 1–30.

Sutherland, F.L., and Kershaw, R.C., 1971, The Cainozoic geology of Flinders Islands. *Roy. Soc. Tas., Pap. Proc.*, v. 105, p. 151–175.

Tate, R., 1878, The fossil Marginellidae of Australasia. *Philos. Soc. Adel., Trans.*, for 1877–1878 (*Roy. Soc. S. Aust., Trans.*, v. 1), p. 90–98.

———, 1879, The natural history of the country around the Head of the Great Australian Bight. *Roy. Soc. S. Aust., Trans.*, v. 2, p. 94–128.

———, 1882a, Notes on the Tertiary strata beneath Adelaide. *Ibid.*, v. 5, p. 40–43.

———, 1882b, Diagnoses of new species of Miocene fossils from South Australia. *Ibid.*, 5, p. 44–46.

———, 1885, Notes on the physical and geological features of the basin of the lower Murray River.

Ibid., 7, p. 24–46.
———, 1886a, The fossil Terebridae of Australia. *Southern Sci. Rec.*, *n.s.*, v. 2, pt. 1, p. 4–8.
———, 1886b, The lamellibranchs of the older Tertiary of Australia. (Part 1.) *Roy. Soc. S. Aust., Trans.*, v. 8, p. 96–158.
———, 1887, *Ibid.*, (Part 2.) *Ibid.*, v. 9, p. 142–200.
———, 1888, The gastropods of the older Tertiary of Australia. (Part 1.) *Ibid.*, v. 10, p. 91–176.
———, 1889, *Ibid.*, (Part 2.) *Ibid.*, v. 11, p. 116–174.
———, 1890, *Ibid.*, (Part 3.) *Ibid.*, v. 13, pt. 2, p. 185–235.
———, 1892, Plates 5–13. *Ibid.*, v. 15.
———, 1893, *Ibid.*, (Part 4.) *Ibid.*, v. 17, p. 316–345.
———, 1899, On some older Tertiary fossils of uncertain age from the Murray Desert. *Ibid.*, v. 23, pt. 1, p. 102–111.
———, and Dennant, J., 1893, Correlation of the marine Tertiaries of Australia, Part 1, Victoria. *Ibid.*, v. 17, pt. 1, p. 203–226.
———, and ———, 1895, *Ibid.*, Part 2, Victoria. *Ibid.*, v. 19, pt. 1, p. 108–121.
———, and ———, 1896, *Ibid.*, Part 3, South Australia and Tasmania. *Ibid.*, v. 20, pt. 1, p. 118–148.
Taylor, D.J., 1971, Foraminiferal biostratigraphy of a marginal area of the Otway Basin. *In* H. Wopfner and J.G. Douglas (Ed.), The Otway Basin of southeastern Australia, *Geol. Survs. S. Aust. and Vict., Spec. Bull.*, p. 235–239.
Teichert, C., 1943, Eocene nautiloids from Victoria. *Roy. Soc. Vict., Proc.*, v. 55, pt. 2, p. 257–265.
Wade, M., 1964, Application of the lineage concept to biostratigraphic zoning based on planktonic Foraminifera. *Micropaleontology*, v. 10, pt. 3, p. 273–290.
Wilkins, R.W.T., 1963, Relationships between the Mitchellian, Cheltenhamian and Kalimnan Stages in the Australian Tertiary. *Roy. Soc. Vict., Proc.*, v. 76, pt. 1, p. 39–59.
Wilson, B.R., and Gillett, K., 1971, Australian shells. *A.H. and A.W. Reed*, Sydney.
Woods, J.E. Tenison, 1867, The Tertiary rocks of Australia, Part 2. The Mount Gambier Fossils. *Pap. Adel. Philos. Soc.* for 1864/5.
———, 1880, On some Tertiary fossils. *Linn. Soc. New South Wales, Proc.*, v. 4, p. 1–20.
Wopfner, H., and Douglas, J.G., (Ed.), 1971, The Otway basin of southeastern Australia. *Geol. Survs. S. Aust. and Vict., Spec. Bull.*

Plate 24

Paleocene and Eocene bivalves

(All figures natural size, unless otherwise stated)

Figs. 1, 3. *Cucullaea psephea* Singleton. 1. GSSA M3259, hinge, Pebble Point Formation, Pebble Point, Paleocene; 3. GSSA M3260, Bahgallah Formation, Killara Bluff, Paleocene.

Fig. 2. *Cucullaea corioensis* McCoy, GSSA, M35, Dry Creek Sands, Bore sec. 4251, hd. Munno Para, 72.5–78 m, Upper Pliocene (for comparison of hinge with M 3259, which belongs to *Cucullona*= *Cucullaea*).

Figs. 4, 5. *Lahillia australica* Singleton. 4. GSSA M3261, hinge of right valve, Pebble Point Formation, Pebble Point, Paleocene; 5. GSSA M3262, right valve exterior, same locality.

Figs. 6–9. *Notostrea lubra* Finlay. 6. Tate Coll. T916A, left valve; 7. T916E, right valve, "Bunda Cliffs", *i.e.* Wilson Bluff Limestone, Wilson Bluff, Upper Eocene; 8. GSSA M3196, left valve interior; 9. GSSA M3196, right valve interior, Browns Creek Clay, Browns Creek, Upper Eocene.

Fig. 10. *Cardita* (*Jasonia*) *alata* (Tate). Holotype, Tate Coll. T1126, right valve, Adelaide (Kent Town) Bore, Tortachilla Limestone-Blanche Point Marls equivalents, Upper Eocene.

Figs. 11, 12. *Glans latissima* (Tate). 11. Holotype, Tate Coll. T1130A, right valve; 12. Paratype, T1130B, left valve, Adelaide (Kent Town) Bore as above.

Fig. 13. *Notocallista* (*Fossacallista*) *tatei* (Cossmann). Holotype, Tate Coll. T1167A, Adelaide (Kent Town) Bore as above.

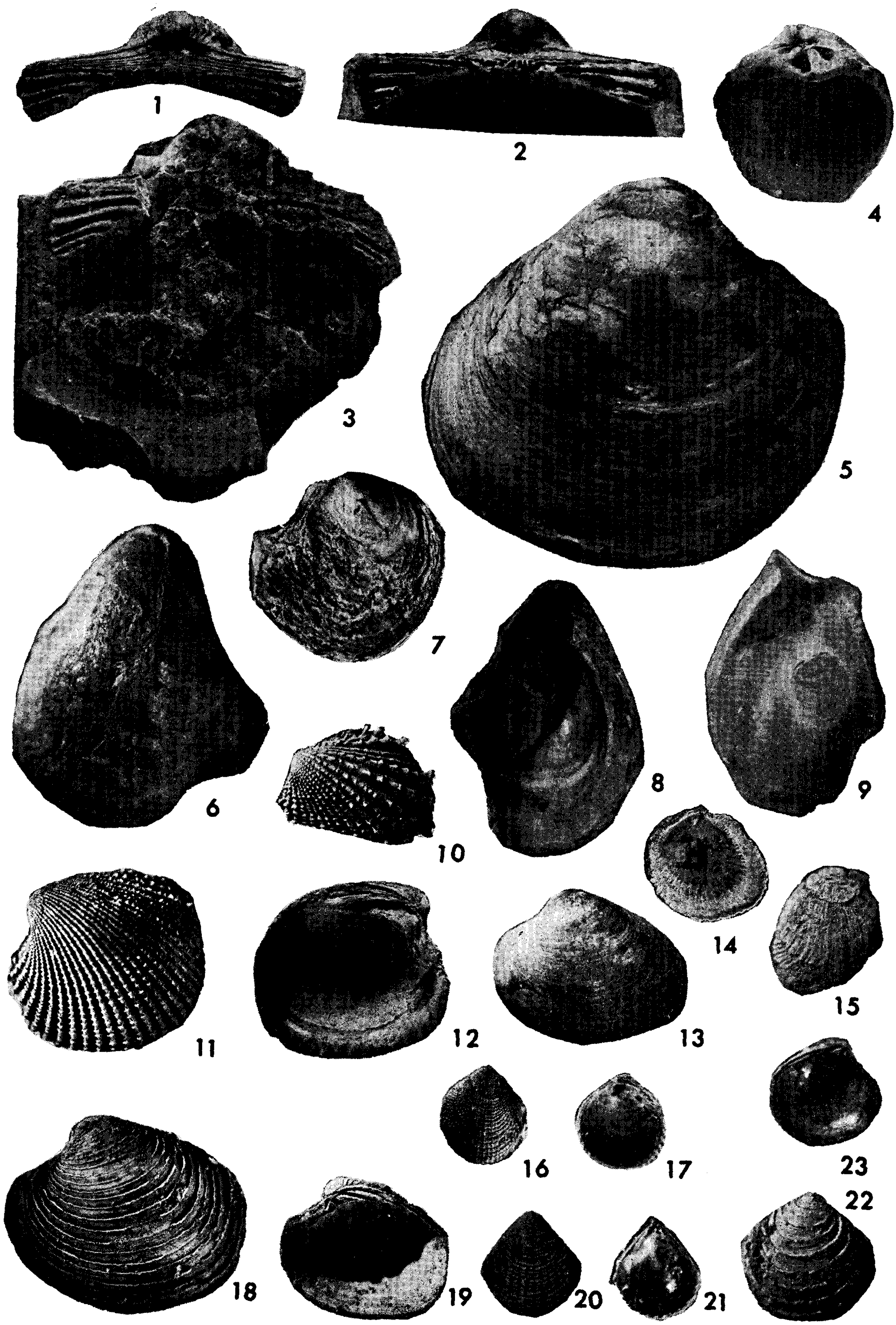
Figs. 14, 15. *Dimya sigillata* Tate. Syntypes, Tate Coll., 14. T913B, left valve, interior, Blanche Point Marls, Aldinga Bay; 15. T913E, right valve exterior, ? Adelaide (Kent Town) Bore; Upper Eocene.

Figs. 16, 17. *Limarca angustifrons* Tate. 16. Holotype, T1002A, left valve, exterior, ×3; 17. Paratype, T1002B, right valve interior ×3, Adelaide (Kent Town) Bore as above.

Figs. 18, 19. *Dosina* (*Dosina*) *multitaeniata* (Tate). 18. Holotype, Tate Coll. T1175A, Adelaide (Kent Town) Bore as above.

Figs. 20, 21. *Cuna rugosa* (Tate). 20. Holotype, Tate Coll. T1085A; 21. T1085 ×5, Adelaide (Kent Town) Bore as above.

Figs. 22, 23. *Salaputium lamellata* (Tate). 22. Holotype, Tate Coll. T1084 ×5; 23. Paratype, T1084 ×5, Blanche Point Marls, Aldinga Bay, Upper Eocene.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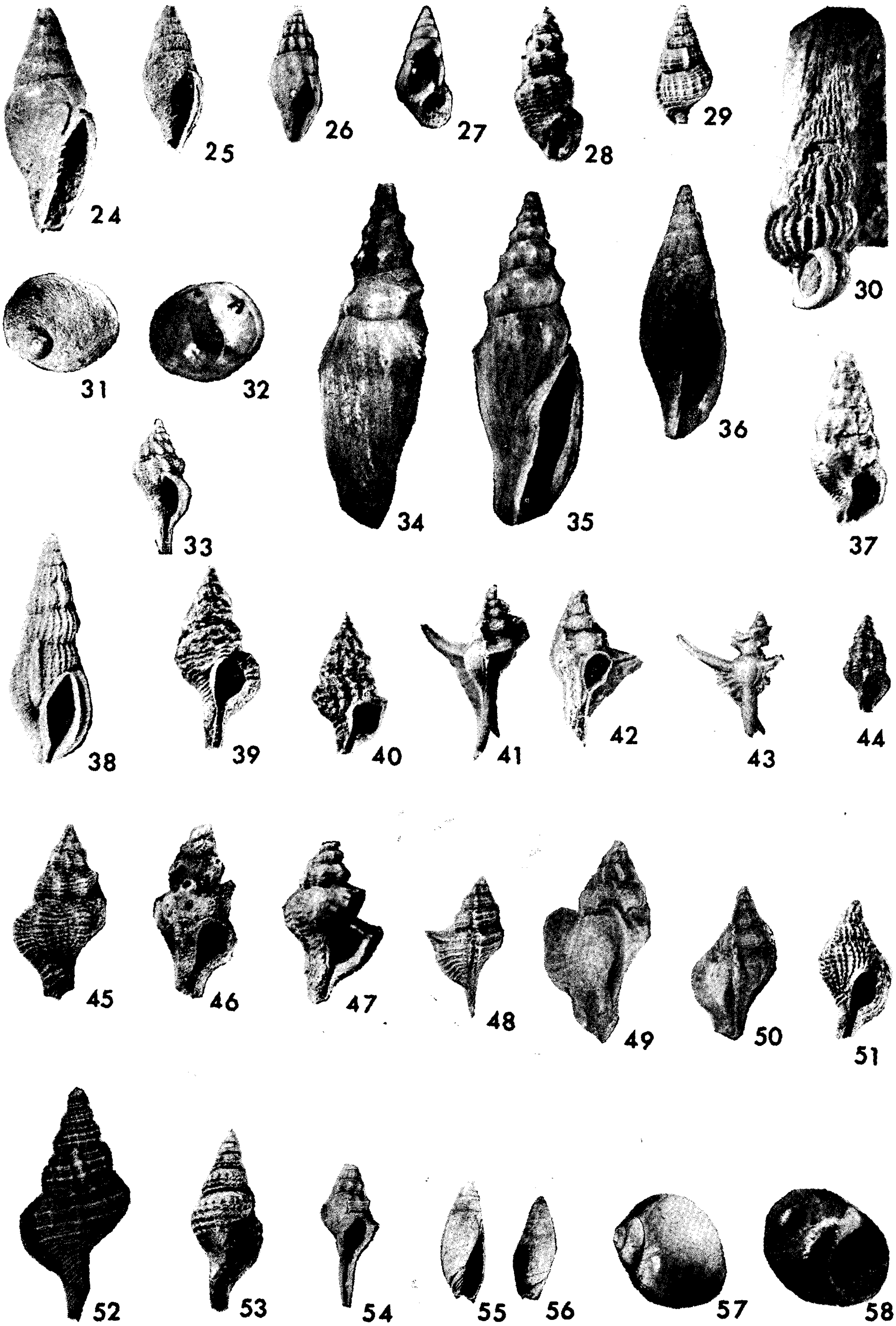
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Plate 25

Eocene gastropods, all from Adelaide (Kent Town) Bore, Tortachilla Limestone-Blanche Point Marls equivalents unless otherwise stated

Fig. 24. *Waimatea complanata* (Tate). Holotype, Tate Coll. T643 ×4.
Fig. 25. *Waimatea subcrenularis* (Tate). Holotype Tate Coll. T647 ×2.
Fig. 26. *Austromitra citharelloides* (Tate). Holotype, Tate Coll. T631 ×2, Blanche Point Marls, Aldinga Bay, Upper Eocene.
Fig. 27. *Pareora stylacris* (Tate). Holotype, Tate Coll. T1442A ×5, Blanche Point Marls, Aldinga Bay, Upper Eocene.
Fig. 28. *Inglisella turriculata* (Tate). Holotype, Tate Coll. T724B ×4, Aldinga Bay as above.
Fig. 29. *Cymatiella oligostira* (Tate). Holotype, Tate Coll. T495C ×1.
Fig. 30. *Cirsotrema mariae* (Tate). Type species of *Caloscala* Tate. Holotype, Tate Coll. T778A, ×1, Aldinga Bay as above.
Figs. 31, 32. *Calyptropsis arachnoideus* Tate. Holotype, Tate Coll. T1438A ×1.5.
Fig. 33. *Brocchitas aldingensis* (Tate). Holotype, Tate Coll. T570B ×1, Aldinga Bay as above.
Figs. 34, 35. *Notovoluta pagodoides* (Tate). 34. Holotype, Tate Coll. T610B ×1; Paratype, T610A ×1, Aldinga Bay as above.
Fig. 36. *Notopeplum protorhysa* (Tate). Holotype, Tate Coll. T589A ×1.
Fig. 37. *Fusinus* (*Microcolus*) *actinostephes* (Tate). Holotype, T589C ×4.
Fig. 38. *Ratifusus nodulatus* (Tate). Holotype, Tate Coll. T497 ×2.
Fig. 39. *Trophon* (*Enatimene*) *monotropis* Tate. Holotype, Tate Coll. T441 ×3.
Fig. 40. *Trophon* (*Zeatrophon*) *hypsellus* Tate. Holotype, Tate Coll. T448A ×4.
Figs. 41, 42. *Pterynotus* (*Pterochelus*) *manubriatus* (Tate). 41. Holotype, Tate Coll. T435B ×1; 42. Paratype, T435C ×1.
Fig. 43. *Pterynotus* (*Pterochelus*) *tenuicornis* (Tate). Holotype, Tate Coll. T431 ×1.
Fig. 44. *Fusinus* (*Microcolus*) *apiciliratus* (Tate). Holotype, Tate Coll. T568C ×3.
Fig. 45. *Murexsul prionotus* (Tate), Holotype, Tate Coll. T411B ×1.5.
Fig. 46. *Laevityphis* (*Laevityphis*) *ludbrookae* Keen and Campbell. Holotype, Tate Coll. T453 ×3.
Fig. 47. *Poiriera sublaevis* (Tate). Holotype, Tate T423C ×1, Blanche Point Marls, Aldinga Bay, Upper Eocene.
Fig. 48. *Pterynotus* (*Pterochelus*) *adelaidensis* (Tate). Holotype, Tate Coll. T418B ×1.
Fig. 49. *Pterynotus* (*P.*) *bifrons* (Tate). Holotype, Tate Coll. T439 ×2.
Fig. 50. *Pterynotus* (*P.*) *calvus* (Tate). Holotype, Tate Coll. T427B ×1.
Fig. 51. *Trophon* (*Gemixystus*) *icosiphyllus* Tate. Holotype, Tate Coll. T442B ×3.
Fig. 52. *Austrosassia cribrosa* (Tate). Holotype, Tate Coll. T503B ×1.
Fig. 53. *Trophon* (*Zeatrophon*) *torquatus* Tate. Holotype, Tate Coll. T451A ×3, Blanche Point Marls, Aldinga Bay, Upper Eocene.
Fig. 54. *Tectifusus tholoides* (Tate). Holotype, Tate Coll. T493A ×1.
Figs. 55, 56. *Baryspira* (*Gracilispira*) *ligata* (Tate). 55. Holotype, Tate Coll. T700C ×1; 56. Paratype T700H ×1.
Figs. 57, 58. *Friginatica aldingensis* (Tate). 57. Holotype, Tate Coll. 1505B ×1; 58. Paratype T1505A ×1.

Plate 26

Miocene molluscs, all from Melton Limestone, Late Batesfordian to Balcombian, Lower to Middle Miocene unless otherwise stated. All natural size.

Figs. 59, 60. "*Potamides wynyardensis*"=*P. pyramidale* Tate. Syntypes Tate Coll. T828. Table Cape Group, Table Cape, Longfordian, Lower Miocene. The syntypes were not previously located (Ludbrook, 1971a, p. 38).

Fig. 61. *Miltha nullarborensis* Ludbrook. GSSA M3262, Wallaroo.

Fig. 62. ?*Myochama* sp., Latex cast, GSSA M3264, Wallaroo.

Fig. 63. *Pseudarcopagia planatella* (Tate). Latex cast, GSSA M3265, Wallaroo.

Fig. 64. *Proxichione dimorphophylla* (Tate). Latex cast, GSSA M3266, Wallaroo.

Fig. 65. *Anodontia sphericula* (Basedow). Latex cast, GSSA M3267, Wallaroo.

Fig. 66. *Chama lamellifera* (Tenison Woods). GSSA F80/68, Deep Creek, hd. Poynton.

Fig. 67. *Columbarium spinulatum* Cossmann. GSSA M3130, Cadell Marl, type section, 5.8 km south of Morgan; Longfordian Table Cape Group — Batesfordian Cadell Marl.

Fig. 68. *Peristernia morundiana* Tate. GSSA F81/68, Deep Creek, hd. Ponyton; also Cadell Marl; Batesfordian — Lower Balcombian.

Fig. 69. *Gyrineum* (*Biplex*) *maccoyi* (Pritchard). GSSA M3136, Cadell Marl, as above; Batesfordian-Bairnsdalian.

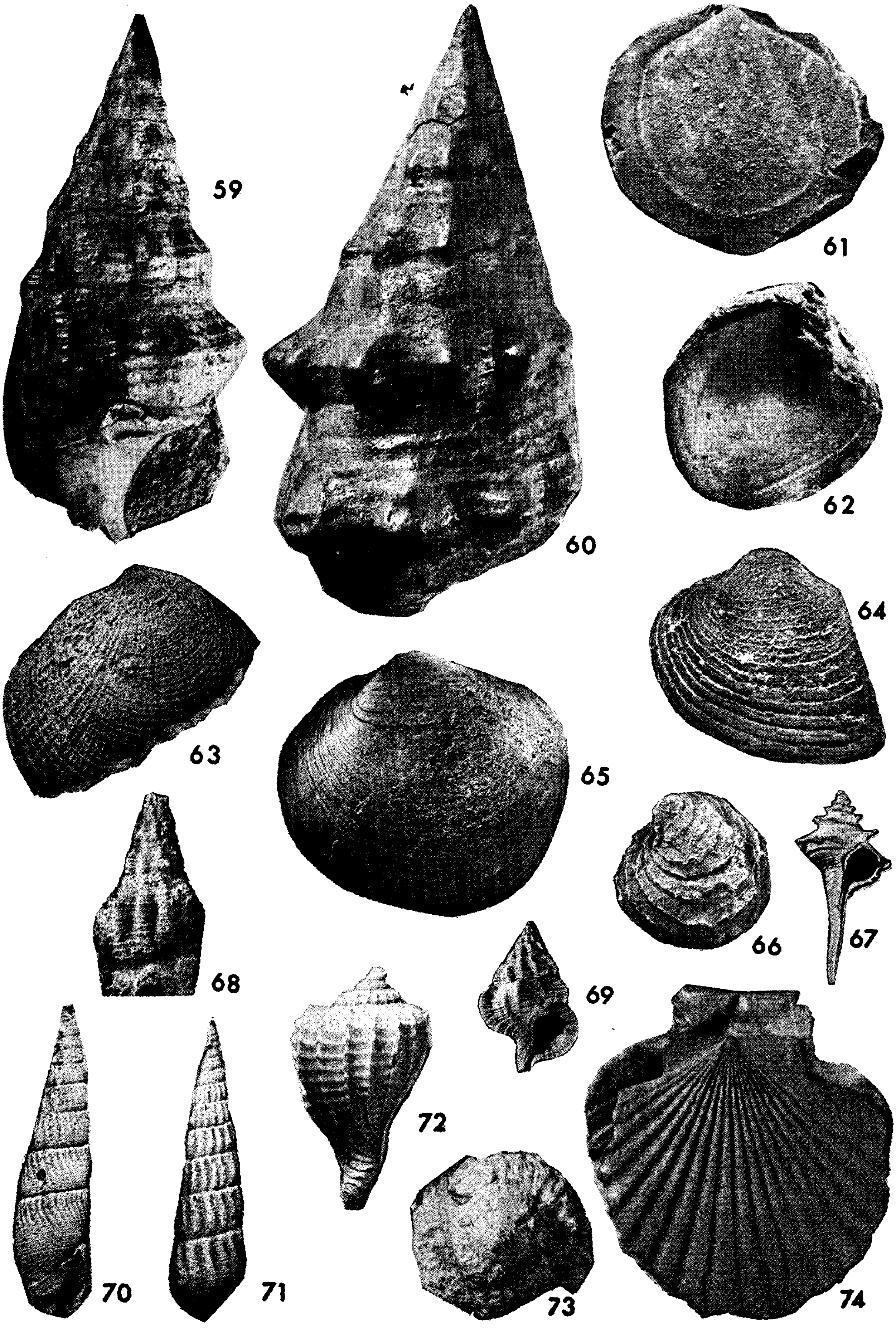
Fig. 70. *Diastoma* sp. Latex cast, GSSA F29/68, 1.6 km northeast of Myponie Point.

Fig. 71. *Diastoma adelaidense* Ludbrook, Latex cast, GSSA F80/68, Deep Creek, hd. Poynton.

Fig. 72. *Austroharpa clathrata* (Tate). Holotype, Tate Coll. T699A, Cadell Marl, as above; Batesfordian, Lower Miocene.

Fig. 73. *Xenophora tatei* Harris. Tate Collection unnumbered, Cadell Marl. Type locality Muddy Creek Marl, Muddy Creek, Balcombian. Batesfordian–Balcombian.

Fig. 74. *Pecten murrayanus* Tate. Holotype, Tate Coll. T955A, Blanchetown, South Australia, Morgan Limestone, ? Batesfordian.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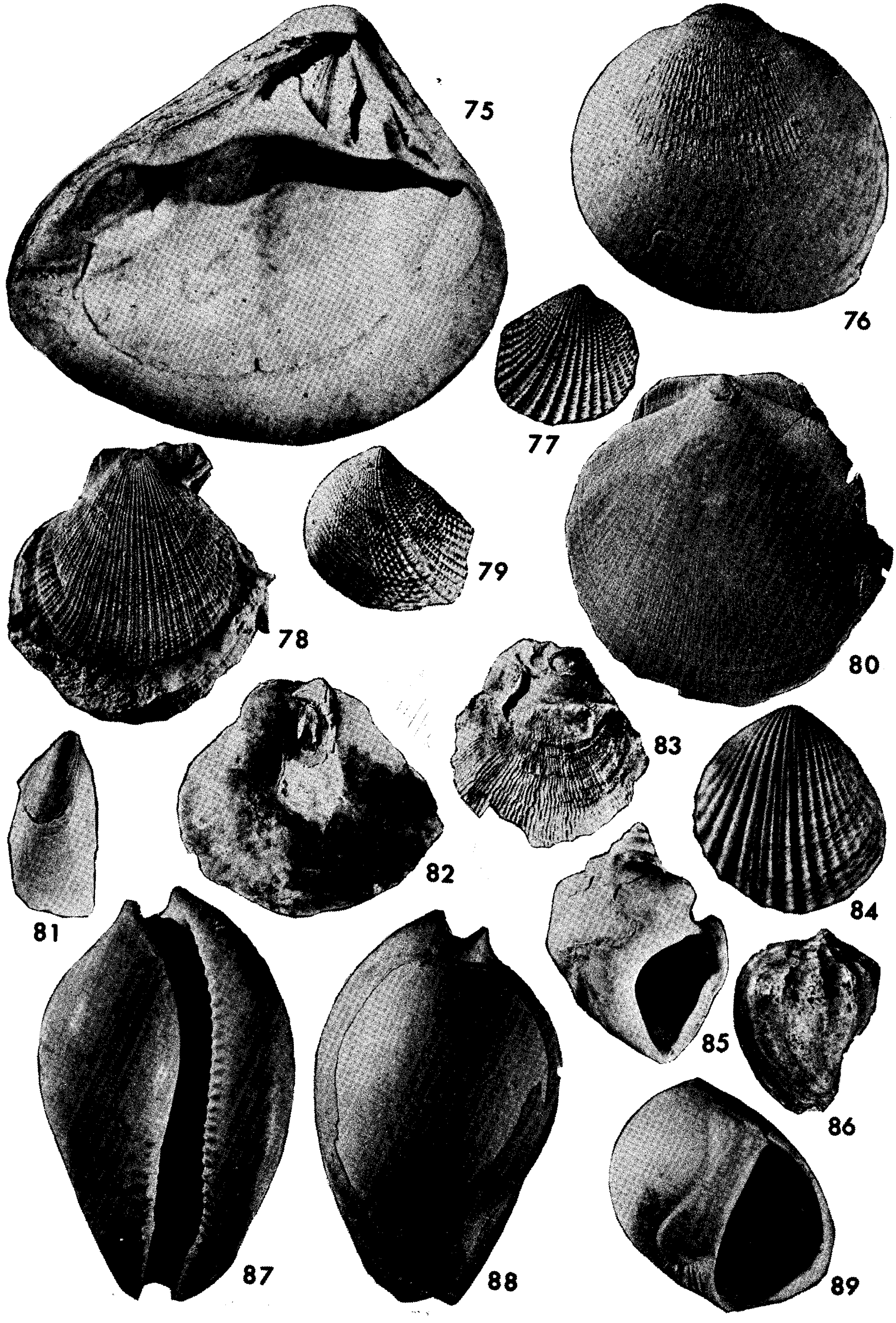
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Plate 27

All from Bookpurnong Beds, Lower Pliocene (? Upper Miocene). All natural size.

Fig. 75. *Eucrassatella deltoides* Darragh. GSSA M2788, Type section, hd. Pyap, sec. 11.
Fig. 76. *Glycymeris* (*G.*) *halli* Pritchard. GSSA M1336, 1.5–3.0 m below river level, Loxton.
Fig. 77. *Neotrigonia trua* Cotton. GSSA M1348, 1.5–3.0 m below river level, Loxton.
Fig. 78. *Hinnites tatei* Cossmann (?=*H. corioensis* McCoy). GSSA M1342, top of Bookpurnong Beds, hd. Pyap, sec. 142.
Fig. 79. *Eotrigonia lutosa* Pritchard. GSSA M2772, 0–3 m above river level, hd. Pyap, sec. 11.
Fig. 80. *Serripecten yahliensis* (Tenison Woods). GSSA M1324, top of Bookpurnong Beds, hd. Pyap, sec. 142.
Fig. 81. *Mytilus linguatulus* Tate. GSSA M1325. 1.5–3 m below river level, Loxton.
Figs. 82, 83. *Pododesmus sella* (Tate). 83. GSSA M2767; 84. GSSA M2765, hd. Pyap, sec. 11.
Fig. 84. *Glycymeris* (*Tucetona*) *convexa* (Tate). GSSA M1345, 1.5–3 m below river level, Loxton.
Fig. 85. *Tylospira coronata* (Tate). GSSA 1341, 1.5–3 m below river level, Loxton.
Fig. 86. *Austroharpa cassinoides* (Tate). Holotype, Tate Coll. T692. "Tareena", New South Wales.
Figs. 87, 88. *Cypraea tatei* Cossmann. GSSA M1335, 1.5–3 m below river level, Loxton.
Fig. 89. *Polinices subjugum* Cotton. GSSA M1346, 1.5–3 m below river level, Loxton.

Plate 28

Pliocene-Pleistocene species, from Dry Creek Sands, Yatalan, Upper Pliocene, unless otherwise stated. All natural size, unless otherwise stated.

Fig. 90. *Spondylus spondyloides* (Tate). GSSA M156, Cowandilla Bore, hd. Adelaide, sec. 92, 147.8–154.5 m.

Figs. 91, 92. *Timoclea* (*Veremolpa*) *protomarica* (Cotton). GSSA M2680, Government Bore No. 20, Woodville South, hd. Yatala, sec. 526, 110–115 m.

Figs. 93, 94. *Hartungia dennanti* (Tate). Syntypes, Tate Coll. T1494B, A. Grange Burn Coquina, Muddy Creek, Kalimnan.

Figs. 95, 96. *Austroharpa cassinoides* (Tate). GSSA M918. hd. Munno Para, sec. 4256, 72.5–78 m.

Fig. 97. *Phos gregsoni* Tate. GSSA M2617. Tennants Bore, hd. Port Adelaide, sec. 5024, 88.7–102.1 m.

Fig. 98. *Cancellaphera confirmans* Ludbrook. GSSA M2328 $\times 3$, hd. Port Adelaide sec. 5031, 91 m.

Fig. 99. *Phalium* (*Semicassis*) *subgranosum* (Tate). Holotype, Tate Coll. T757, Edithburg, Hallett Cove Sandstone, Upper Pliocene.

Fig. 100. *Liratomina adelaidensis* Powell. GSSA M2376, Observation Bore A, Virginia, hd. Munno Para, sec. 3036, 63.7–66 m.

Fig. 101. *Murexiella* (*Subterynotus*) *antecedens* (Ludbrook). GSSA M847. Bore 20, Woodville South, hd. Yatala, sec. 526, 110–115 m.

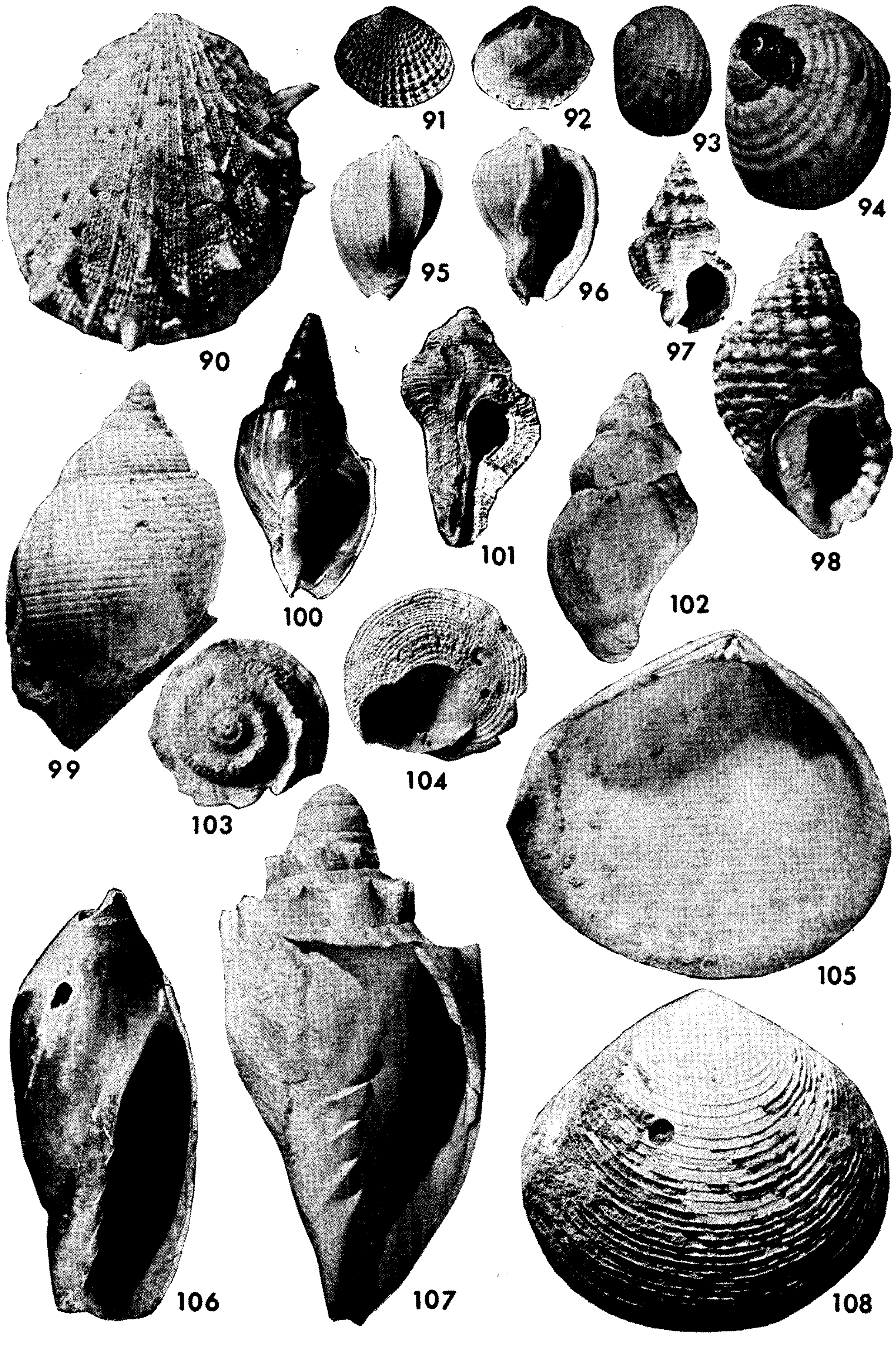
Fig. 102. *Bedeva crassiplicata* (Ludbrook). GSSA M759. Bore 20, Woodville South, hd. Yatala, sec. 526, 110–115 m.

Figs. 103, 104. *Astraea* (*Bellastraea*) *hesperus* Ludbrook. Western Australian Museum 69.477, Hampton Microwave Repeater Tower, Roe Calcarenite, Lower Pleistocene.

Figs. 105, 108. *Pseudarcopagia basedowi* (Tate). GSWA F7095 (1), 106, left valve interior, 109, right valve exterior, Eyre Highway, 61 km east of Madura, Roe Calcarenite, Lower Pleistocene.

Fig. 106. *Amoria grayi* Ludbrook. GSSA M2663, Islington Workshops Bore (1914), hd. Yatala, sec. 380, 115–134 m.

Fig. 107. *Cymbiola* (*Aulicina*) *irvinae* (Smith). GSSA M2373. Observation Bore A, Virginia, hd. Munno Para, sec. 3036, 63.7–66 m.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