A U S T R A L I A N

PHANEROZOIC TIMESCALES 10

AUSTRALIAN PHANEROZOIC TIMESCALES: CAINOZOIC

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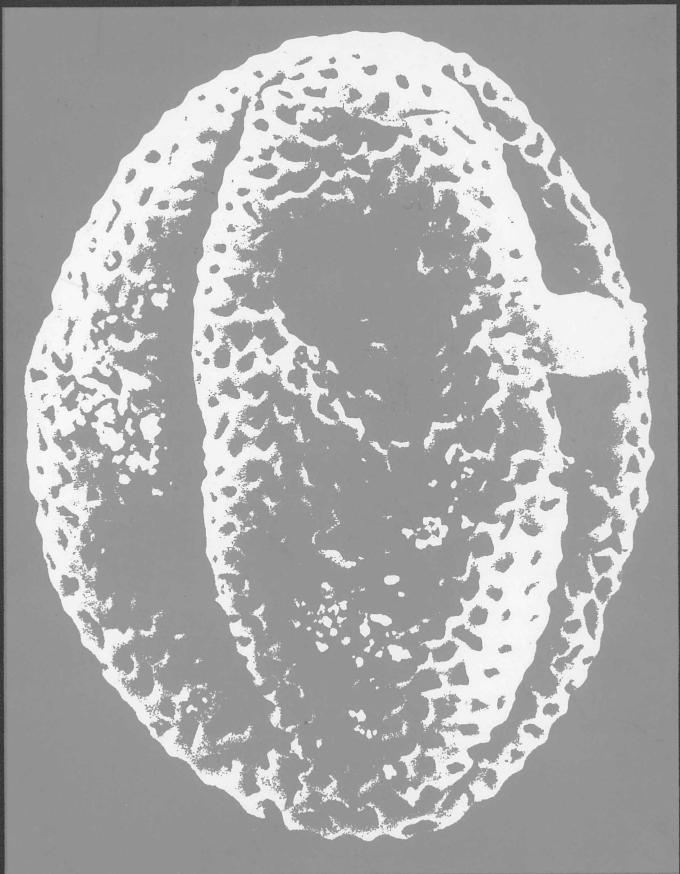

BUREAU OF MINERAL RESOURCES
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AUSTRALIAN PHANEROZOIC TIMESCALES

10. CAINOZOIC

BIOSTRATIGRAPHIC CHART AND EXPLANATORY NOTES

compiled by

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COVER ILLUSTRATION: Tricolpate angiosperm pollen grain from Eocene sediments, Bungonia, New South Wales.

FOREWORD

A time framework is essential to an understanding of all historical aspects of the geosphere. It is a prerequisite to interpreting the development and structure of the sedimentary basins which host our major petroleum, coal, and sedimentary mineral deposits, and is important when seeking patterns in the distribution of these resources through time. It is also critical to our understanding of the interactive factors which have shaped the modern Australian environment, and in determining the patterns of global change.

For the Phanerozoic (the last 570 million years, the period of 'visible life'), the most efficient way of establishing such a time framework is by the study of fossils (**palaeontology**), and their stratigraphic distribution (**biostratigraphy**).

Early palaeontological investigations of Australian sedimentary basins were used during the nineteenth century to establish the age of major suites of sedimentary rocks. This provided a framework for the application of more detailed biostratigraphic research, an early example being the use of graptolites to subdivide Ordovician strata in the Victorian goldfields at the beginning of this century. The Victorian sequence of graptolite zones is the current standard used throughout Australasia, and is one of the most finely subdivided in the world.

The development of Australian biostratigraphy over the last 50 years has provided many biostratigraphic schemes using the fossil remains of a wide range of organisms - from the microscopic (such as pollen grains and spores of land plants), to the macro- and megascopic (such as larger invertebrates, fish, mammals, even human artifacts). Recent years have also seen a rapid growth in other methods of measuring geological time, using radioactive decay of mineral elements, or reversals in the Earth's magnetic field. These provide a means of calibrating biostratigraphic schemes with a numerical time scale.

The current *Phanerozoic Timescales Series* makes available for immediate use a preliminary set of charts based both on recent palaeontological data from the specialist scientific literature, and unpublished information from ongoing biostratigraphic research. The charts integrate, for each geological period, zonal schemes using different groups of fossils with isotopic and other data (magnetic reversal, eustasy curves), and show the relationship of the Australian zones to standard international timescales and their numerical calibration, where this information is available. Inevitably the detail of treatment and reliability varies for different parts of the column, and for different groups of fossils, and much work still needs to be done to develop a fully integrated chronological scale comparable to those available in the Northern Hemisphere. The current series is made available to provide a set of up-to-date calibrated biostratigraphic charts specifically for use in the Australasian region.

Biostratigraphic charts were initially prepared for the AMIRA (Australian Mineral Industries Research Association) sponsored *Palaeogeographic Atlas of Australia* project. The current charts and explanatory text have been revised and updated as part of the second phase of that project, the *Phanerozoic History of Australia*, which is funded in part by APIRA (Australian Petroleum Industry Research Association). The charts have been compiled by palaeontologists in BMR, but incorporate contributions by other specialists working in State Geological Surveys, universities and the exploration industry, without which such a comprehensive compilation would not have been possible.

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INTRODUCTION

The chart is designed to show the interrelationships between zonations based on marine microfossils (foraminiferids, calcareous nannofossils and organic-walled dinoflagellates), macrofossils represented by molluscs, terrestrial faunas represented by fossil mammals, and zones based on pollen and spores reflecting changes in terrestrial vegetation. These zonal schemes are calibrated, as far as possible, against the timescales for the Palaeogene and Neogene presented in a recent series of compilations by Berggren et al. (1985a, b).

The compilations of Berggren et al. (1985a-c, as well as other authors) incorporate correlations of foraminiferal and calcareous nannofossil zones with chronostratigraphic and magnetostratigraphic scales. We have reproduced here the foraminiferal and nannofossil zones shown in that compilation. The zones, which incorporate those of Blow (1969, 1979), Bolli (1957a, b, 1966), Berggren (1969), Berggren & van Couvering (1974), Bolli & Premoli Silva (1973), Hardenbol & Berggren (1978), Stainforth et al. (1975), Bukry (1973, 1975), and Martini (1971), represent a standard zonation for tropical oceanic plankton. We have included a correlation with the East Indian Letter Classification, based on 'larger' tropical foraminiferids, following Jenkins et al. (1985) for the Palaeogene and Adams (1984) for the Neogene. Adams (1970, 1984) reviewed the history of development of the letter classification, and provided a correlation of the lettered zones with the P and N foraminiferal zones. Some of the correlation details shown on the chart, viz. the lowering of the upper Te/f boundary from the base of Zone N9 to within Zone N6, rest on information provided from northwestern Australia by Chaproniere (1981, 1984a,b). McGowran (1979, 1986) has noted the possibility that changes in biostratigraphic boundaries of provinces based on larger foraminiferids are related to shifts in watermass; southern Australian correlations with the standard stages are viewed as extratropical excursions controlled by climate (McGowran 1986, Fig.4).

The magnetic reversal stratigraphy shown on the chart is reproduced from Berggren et al.(1985a-c). It should be noted that no direct correlations between the Australian biostratigraphic units shown on the chart and this 'global' magneto-stratigraphic standard have yet been directly established, although some work is in train to this end.

Shown also on the chart are the local stages recognized in Cainozoic sequences in southeastern Australia. The continuing usefulness of these stages is subject to debate; although suggestions have been made that their use be discontinued (e.g. Singleton, 1967), other authors (e.g. McGowran et al. 1971) have indicated that such a move would be premature, and should only be contemplated when correlations with global stratotypes were firm enough to make local stages redundant. Although considerable progress in making such correlations has been made since 1971, it is unlikely that the local stages have yet outlived their usefulness, and direct reference to the stages is still made by workers in molluscs and mammal faunas. New stages continue to be formalized for local stratigraphic purposes (e.g. Lindsay, 1985).

The Australian biostratigraphic schemes shown on the chart represent a mixture of zonal concepts. Some of the earlier foraminiferal zones (e.g. Taylor, 1966; Carter, 1958a,b, 1964) are assemblage zones, as are the palynological zones (Harris, 1971, 1985; Stover & Partridge, 1973; Stover & Evans, 1973). The mammal and molluscan assemblages are closely tied to localities, in many cases with little understanding of the total ranges in time of the taxa involved. Parts of the foraminiferal stratigraphies are based on evolving lineages (for example, the lineage beginning with the first appearance of *Globigerinoides sicanus*, and leading to *Orbulina universa*). The foraminiferal column of McGowran, and the nannofossil column of Shafik, in contrast, are constructed from first and last appearance datums. The advantage of such a presentation of biostratigraphic data, as noted by McGowran (1986) and Shafik (1990a), is that it permits ease of correction when fresh advances in knowledge are made; new data can be incorporated within the biostratigraphic system without the formal redefinition of zones and subzones.

The chart represents the most comprehensive attempt yet to relate biostratigraphic schemes based on diverse groups of fossils in the Australian Cainozoic. It owes much, however, to previous regional compilations such as those of McGowran et al. (1971), Quilty (1972), Abele (1976), and Mallett (1977). The last-named correlation chart remains unpublished.

THE CRETACEOUS - TERTIARY BOUNDARY

The Cretaceous - Tertiary boundary is here placed at 66.4Ma following Berggren et al. (1985a). The placement of the boundary within the reversed polarity interval between anomalies 29 and 30 (magnetochron C29R) is based on planktic microfaunal events in a number of deep sea sections, and is supported by some floral studies.

Radiometric dating of bentonites which lie near or just above the boundary defined by the disappearance of dinosaurs together with floral changes in North America, give a less precise age of about 65Ma, and this figure has been adapted by Burger (this series) for the top of the Cretaceous (Burger, 1990).

NOTES ON THE COLUMNS

The following notes provide a brief history of the usage of stage and biozone terminology. They are primarily designed, however, to provide a source of reference to the biostratigraphy.

1. Southeastern Australian local stages

A terminology based on local stratotypes in southeastern Australia was first introduced by Hall & Pritchard (1902) in order to reduce confusion caused by attempts to use European terminology. The stages shown in the column are those in current use in Victoria (Abele, 1976) and South Australia (Ludbrook, 1973), with the addition of the Willungan Stage as defined by Lindsay (1985). For a history of stage usage reference should be made to Carter (1964, especially to fig. 18 on p.47) and to Abele (1976).

The Janjukian, Balcombian, Kalimnan and Werrikooian were first defined by Hall & Pritchard (1902); Batesfordian was added by Chapman & Singleton (1923); Singleton (1941) added Cheltenhamian and other stages now fallen into disuse, and redefined some of the earlier stages.

Crespin (1943) introduced Mitchellian, and also Longfordian and Bairnsdalian; these last two she considered as substages of the Balcombian. O.P. Singleton (1954) considered Cheltenhamian and Mitchellian to be time equivalent, a postulate which was supported by Mallett (1977). The relationship of these stages, together with the Kalimnan, was meanwhile further discussed by Wilkins (1963). The term 'Aldingan', introduced by Hall & Pritchard (1902), was revived by Carter (1964) and redefined by Ludbrook & Lindsay (1966) to restrict it to the Late Eocene sequence typified in the eastern St. Vincent Basin. The name 'Johannian' lacks formal definition, but is used for strata which contain Eocene faunas older than Aldingan (Ludbrook & Lindsay, 1966; Ludbrook, 1971). 'Wangerripian', a term informally proposed by O.P. Singleton (see Abele, 1976) is used for the Middle Paleocene to Early Eocene intervals, typified by the Wangerrip Group in the Otway Basin. Ludbrook (1963, 1973) introduced 'Yatalan', first as a term to describe faunas, later as a stage name to include Pliocene strata between the Kalimnan and Werrikooian in South Australia, replacing the older term 'Adelaidean', and thus avoiding confusion with Precambrian terminology. The relationship between the Werrikooian stratotype and the Pliocene-Pleistocene boundary was reassessed by Singleton et al. (1976).

As noted above, there is still some question surrounding the continued use of these stages. Uncertainties remain concerning their correlation with standard European series and stages. Usage of the stages by different authors has been variable and in many cases has been extended to cover broader intervals of time than that represented by the stratotype. Problems of relating stage stratotypes to standard ages are highlighted by Mallett's (1977) unpublished analysis of foraminiferal faunas, which asserts that the stratotypes of Bairnsdalian, Cheltenhamian and Mitchellian overlap, and that all fall within the *Globorotalia conomiozea* Zone (Late Miocene).

2. Foraminiferal Zonal Schemes

The zonal schemes illustrated in this section are arranged broadly in historical order, following their development or application in Australia.

a) Carter Faunal Units and Zones

Carter (1958a,b; 1964) established a sequence of faunal units which were based on distinctive associations or assemblages of foraminiferids, including both benthic and planktic forms. The sequence was compiled from outcrop sections in the Longford, Bairnsdale, Lakes Entrance, Aire and Torquay districts of Victoria. The associations first recognised were designated Faunal Units 1-11; these were expressed also as a set of ten named zones. Subsequently, 13 events based on planktic foraminiferids were isolated and used as the basis for intercontinental correlation. The relationship of the faunal units and zones to the P and N zones of Blow (1969) is as indicated by McGowran et al. (1971).

b) Taylor Zonules

Taylor (1966) established what he referred to as a 'down-sequence' scheme for the Late Eocene to Late Miocene of the offshore Gippsland Basin. The scheme was based on the down-hole appearance of selected taxa, but was tested against fragmentation and bifurcations in evolving lineages. The system of zonules established by Taylor was elaborated in McGowran et al. (1971) and correlated therein with the P and N zones.

c) Ludbrook and Lindsay Zonation
These authors (Lindsay, 1967, 1969; Ludbrook & Lindsay, 1969; Ludbrook, 1971), following the work of Jenkins (1966, 1967) in New Zealand, proposed a zonation based solely on planktic foraminiferids, with some modifications to suit less open marine conditions. The zonal scheme was used to indicate possible correlations with sequences in New Zealand, east Africa and Trinidad.

These zones are based mainly on first and last appearance datums. In the Middle Miocene the sequence used is essentially that of the evolving series leading from *Globigerinoides triloba* s.s. to *Orbulina universa*, first observed by Blow (1956) in Venezuela, and applied to the Australian Miocene by Jenkins (1958, 1960). Modifications to the scheme were expressed by McGowran et al. (1971), who also provided a correlation of the zones with those of Taylor (1966), Wade (1964) and Carter (1958, 1964).

d) McGowran - foraminiferal events
Shown in this column is a succession of 'local' or Australian biostratigraphic events; this is a composite column constructed from discontinuous sequences at localities from the Naturaliste Plateau to southwest Victoria. The basis for the Palaeogene sequence is drawn from McGowran (1978) and re-expressed in McGowran & Beecroft (1985). The full sequence is drawn from McGowran (1986). In this compilation, McGowran (1986, p.250) advocated the use of datums - horizons defined by first and last appearance events - as a means of classifying 'the clutter of local zones', although noting that such local zones remain a necessity because biological assemblages are geographically determined. The advantage of presenting information on the biological evolution of assemblages as datums is that of flexibility; there is no longer the need to redescribe and formally redefine zones each time there is an advance in understanding. The basis of the correlation of these events with the P and N Zones was emphasized by McGowran (1986, p.250) thus, 'There is no implication whatsoever...that the P Zones are actually being recognized in southern Australia or New Zealand. Instead, the local biostratigraphic succession is calibrated against the radiometrically calibrated P-Zones as a best present estimate'. The indirect nature of correlation with the P and N zones was also stressed by Lindsay (1985), who noted that zonal index species may not necessarily be present in Australian sections.

Hollow symbols in the column mark short-lived events in disjunct distributions. It is notable that the biostratigraphic record, particularly in the later part of the Eocene, provides a clear reflection of transgressive events. In this interval four trangressions are identifiable. McGowran (1986, fig.7) refers to these as the Wilson Bluff (p.12), Tortachilla (base p.15), Tuketja (late p.15) and Aldinga (p.17) transgressions; these find a biological expression in ingressions of *Hantkenina* species, and of acmes in *Globorotralia increbescens*. The relationship of the dinoflagellate zones recognized by Harris (1985) to these transgressions is noted below.

McGowran (1989) considered the synchroneity of these transgressions. While there is evidence for mild diachronism in (for example) the Tortachilla Trangression, in general he considered the successive transgressions to be isochronous to within hundreds of thousands of years.

e) Mallett's Victorian zonation

This zonation (Mallett, 1977, 1978) is based on Early Miocene to Pleistocene faunas from the Otway and Gippsland Basins and the Port Phillip Embayment. The zonation is based on the evolutionary appearance of planktic species and incorporates a number of internationally recognized datum planes, allowing correlation with Blow's (1969) zones. The numbered 'V' zones on the right of the column were introduced by Mallett in his unpublished thesis, for ease of reference; they are included here as they have been referred to in some published papers (e.g. Darragh, 1985). In the chart these zones have been related to the datum planes of McGowran, and their placement has been adjusted to fit the Berggren et al. (1985b) timescale.

f) Northwest Shelf Zonation

A series of zones for the Paleocene and Eocene of the Northwest Shelf was established by Wright (1973) using planktic foraminiferal species. The Zones T1 to T9, shown on the present chart, were established because of the difficulty in defining the international P Zones from the Northwest Shelf faunas. In his published account, however, and largely to preserve confidentiality, Wright (1977) broadly referred faunas from Scott Reef No. 1 well to the planktic zones of Blow (1969). Zones T10 to T20 are based on more recent work by M. Apthorpe and R. Heath. Recognition of Zones N8 to N23 of Blow is as demonstrated by Heath & Apthorpe (1984) and by Heath (1979).

The relationship of the Northwest Shelf zonation to the 'standard' tropical zonation was further elaborated by Heath & McGowran (1984) and Heath & Apthorpe (1984). There is a problem in that a few of the P zonal indices appear to have different ranges in the Indian Ocean from the Atlantic and Pacific.

As shown on the chart, the scheme is principally a 'down-hole' one to permit dating during the drilling of a well, and hence relies heavily on species tops or extinctions. However, some of the zones could not be defined on last appearances and have had to be delineated on first appearances, so require good sidewall control. Such zones include T3, the top of T10, T11a and T16.

g) Foraminiferal events after Chaproniere

This list of foraminiferal events considered important in the Australian and New Zealand region was published by Chaproniere (1984a, fig. 7, p.13). The positioning of some events is based on data from northwestern Australia; included too are some events that were either not included by McGowran (1986), or which differ in their placement. Included also was the 'larger' foraminiferal extinction datum of *Lepidocyclina (Eulepidina) badjirraensis.*

h) Other foraminiferal zonations

Zonations not included on the chart are those of Jenkins (1958, 1960), who identified a sequence of Miocene zones in the Lakes Entrance Shaft, East Gippsland, basing his zonation on members of the the *G. trilobus* - *Orbulina* lineage and other criteria. Mallett (1977) pointed out the unsuitability of this sequence as a reference section, noting the condensed nature of the Middle to Late Miocene section there. Wade (1964), using sequences in the Port Campbell Embayment and the St. Vincent and Murray Basins, developed a zonation based on evolving lineages within *Globigerina*, *Globigerinoides* and *Globorotalia*. Wade's zones, spanning the Late Eocene to Middle Miocene, were related to other Australian biostratigraphic units by McGowran et al. (1971).

In Victoria, data from an unpublished scheme of Nicholls (1968) dealing with faunas above the level of *Orbulina universa* (Middle Miocene) was incorporated by Abele (1976) into a numbered scheme which extended the faunal units of Carter (1958a,b) into younger sequences. According to Mallett (1977), this amalgamation involved some redefinition of the Carter units.

3. Nannofossil biostratigraphy

The low-latitude nannofossil zones of Bukry (1973, 1975) and the 'standard' zones of Martini (1971) are shown on the left of this group of columns, together with two columns depicting events recognized in the published literature on Australian nannofossil sequences. Shafik (1973) presented, in summary form, a nannofossil zonation for the Early Eocene to mid Oligocene, based on sections in the southern and western margins. In his study of the Capricorn Basin, offshore Queensland, Hekel (1973) referred some eighteen zones and zonal intervals to a slightly modified version of Bukry's (1973) zonal scheme.

The Australian sequence of nannofossil biostratigraphic events assembled here is from discontinuous sections on the Australian southern, western and northern margins. West Australian Paleocene and Eocene events are based on material from Rottnest Island (Shafik, 1978), Perth Canyon (Shafik, 1991) and Challenger No. 1 well in the Perth Basin (Shafik, in press); many of these events are identifiable in the offshore of both the Carnarvon and Canning Basins (Shafik, 1990c,d). Events in the West Australian Late Oligocene to Early Miocene are based on the sequence in Ashmore Reef No. 1 well in the Bonaparte Gulf Basin (Shafik, in Shafik & Chaproniere, 1978). Some of these events have been identified in the recently-discovered Oligocene in the Perth Basin (Shafik, 1991; in press). The interval with the key species *Sphenolithus heteromorphus* has been identified from areas as widely spaced as the offshore Otway and Canning Basins (Shafik, 1987; Shafik, 1990e).

In the southern Australian Palaeogene, Shafik (1983) used one section at Browns Creek in the eastern part of the Otway Basin, and three in the Gambier Embayment to the west, to identify a sequence of biostratigraphic events spanning the interval from the first appearance of *Cyclicargolithus reticulatus* in the Middle Eocene, to the last appearance of *Discoaster saipanensis* in the latest Eocene. These nannofossil events were compared to foraminiferal events identified by McGowran (1973, 1978). Southern Australian Palaeogene events older than the first appearance of *Cyclicargolithus reticulatus* are based on material from the Great Australian Bight and the Naturaliste Plateau to the southwest of Australia (Shafik, 1985; 1990b); the base of the open-marine calcareous planktic section is diachronous along the southern margin, being younger in an easterly direction (Shafik, 1973). Shafik (1990b) identified open-marine Middle Eocene in the Great Australian Bight, older than that in the Otway Basin, and two Early Eocene assemblages indicating successive appearances of the index species *Discoaster lodoensis* and *D. sublodoensis*. Further identification of events in the Early to Middle Eocene was made previously by Shafik (1985) in the sequence on the Naturaliste Plateau; these events fill a substantial gap in the Palaeogene nannofossil biostratigraphic record of the Australian southern margin, between the first appearances of *D. sublodoensis* and *Cyclicargolithus reticulatus*. Among the Oligocene events identifed by Shafik (1987; 1990b), two appearance events, indicated by excursions of the low-latitude *Sphenolithus distentus* and *S. ciperoensis* into southern Australia, are particularly important for correlation with low-latitude zonations; the younger event (the appearance of *S. ciperoensis*) is more widely recognisable, having been identified from the Great Australian Bight, west Tasmania and the Otway Basin. Other nannofossil data have also been used to suggest correlation of local foraminiferal events with P zones. For example, Shafik (1981) suggested that the *Hantkenina* interval should be placed high in foraminiferal Zone P16, rather than high in Zone P15 as shown here.

4. Palynostratigraphy

a) Spore and pollen assemblage zones

The units of Stover & Evans (1973) and Stover & Partridge (1973) were originally defined in the Gippsland Basin, and were correlated with Taylor's (1966) system of zonules. Partridge (1976) related the Gippsland Basin palynological zones to the 'standard' foraminiferal zones of Blow (1969), Berggren (1969) and Stainforth et al. (1975). Isotopic dating, particularly of basalts overlying, or interbedded with, palyniferous sediments in highland sequences, has provided an independent age control on Gippsland Basin zone equivalents recognised there (Owen, 1975). Radiometrically dated Paleocene (Taylor et al. 1990), Eocene (Truswell & Owen, 1988) and Early Miocene (Dudgeon, 1982, Owen, 1988) sequences have been determined.

The assemblage zones of Harris (1971) were defined in the Otway Basin, and correlated with Australian and intercontinental zones (McGowran et al. 1971). Recently, Harris (1985) related the Eocene units, that is, the *Cupanieidites orthoteichus* through to the *Sparganiaceaepollenites barungensis* Assemblage Zones, to the P zones, following McGowran (1978), and thence effected a correlation with the Palaeogene timescale of Berggren et al. (1985a). The Late Oligocene record of first *Acacia* pollen is from foraminiferally-dated sequences in the western Murray Basin (Lindsay, 1983) examined by Truswell et al. (1985). The palynological 'phases' of Martin (1973) are based on relative abundances of taxa in the Lachlan Formation, eastern Murray Basin; time constraints on the units are poor. Martin (1973, 1984) also used ratios of selected pollen species as a chronological tool within the Murray Basin. The value of these methods, and of the more traditional zonal methodologies in providing a chronological framework within the Murray Basin, was evaluated by Macphail & Truswell (1989).

The zonal scheme of Hekel (1972), based on sequences in Queensland coastal and offshore areas, has not been included on the chart because of difficulties in relating its units to the timescale. Of the five units delineated by Hekel, the basal Unit I could be dated only as possible Paleocene to Middle Oligocene; time control on younger units was considered to be firmer, being established by relationships with foraminiferids and nannoplankton. On this basis Hekel suggested that Unit II may be Late Oligocene, Unit III Early Miocene, Unit IV Middle to Late Miocene, and Unit V, Pliocene. Foster (1983) reviewed the criteria for the recognition of Hekel's units II and III, and indicated that, on the basis of the ranges of key palynomorphs, as now understood, these units can no longer be used for chronologic or biostratigraphic studies.

b) Dinoflagellate zones

The Gippsland Basin units were referred to as Assemblage Zones by Partridge (1976) but have been published in name only, and currently lack definition in terms of the ranges of their constituent species. Taxonomic assignment of the nominate taxa and age limits of the zones were revised by Partridge (written communication, 1985). The Eocene dinocyst zones of Harris (1985), described as Assemblage or perhaps Oppel Zones, were defined in the Otway and St. Vincent Basins, and were related to McGowran's (1978) foraminiferal correlations, and thence to the Berggren et al. (1985a, b) timescale. The relationship of the patterns of eustatic change in the early Tertiary of Australia's southern margin was outlined by Harris (1985), and expressed by McGowran (1986) in terms of the four trangressions named by that author. Thus, the lower boundaries of the *Achilleodinium biformoides* zone, and the *Corudinium incompositum* Zone correspond with the Wilsons Bluff and the Tortachilla Transgressions respectively; the base of the *Spiniferites ramosus* Zone is just below the Aldinga, at the level of a sharp regression.

Dinoflagellates from the younger part of the Tertiary are poorly known, but Martin (1991) has begun to fill this gap by describing assemblages from the western Murray Basin. The oldest part of the succession in the SADME MC63 bore there is identified with the *Spiniferites ramosus* Zone; above that, Early to Middle Miocene sequences lack any formal zonal nomenclature.

5. Land mammal faunal assemblages

The two columns shown represent a condensation of the eleven columns depicted by Woodburne et al. (1985) as representing Australian land mammal fossil localities. Much of the chronological ordering of the faunas has been based on the stage of evolution of selected taxa; in some cases it rests on stratigraphic superposition; less commonly, age control is derived by relationship of the vertebrate-bearing strata to marine sequences or to dated volcanic rocks. Faunas which can be related to marine rocks include the Wynyard, Beaumaris, Forsyths Bank, Lake Tyers and Hamilton local faunas. Faunas with age constraints established by relationship to dated volcanics include those at Hamilton, Geilston Bay and Bluff Downs.

6. Molluscan Assemblage Zones, southeastern Australia

The units shown are those of Darragh (1985). They are based on assemblages from geographic localities considered to typify the biostratigraphic unit; localities are from the Murray, Otway, Bass and Gippsland Basins. The assemblages were related to standard Tertiary timescales by means of the foraminiferal zonations of Taylor (1966), Carter (1964), and Mallett (1977).

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CAINOZOIC BIOSTRATIGRAPHIC CHART

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