BIOSTRATIGRAPHY

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Chapter 6

EARLY CRETACEOUS

Palynology

Plant microfossils are abundant and diverse in the claystone and coal of the Casterton Formation, Crayfish Group and Eumeralla Formation, and only absent from sandstone. Terrestrial spores and pollen dominate the assemblages with high diversity in the Aptian-Albian, but reduced diversity in the Neocomian-?Tithonian. Dispersed cuticle is also well represented throughout this interval and is part of a current MESA biostratigraphic study of the Crayfish Group (Rowett, 1994b).

Non-marine algae can be frequent, but only *Microfasta evansii* appears to have time significance. Spiny acritarchs and dinoflagellates are very rare, indicating some brackish intervals. A paralic dinoflagellate assemblage, probably of *Diconodinium davidii* Zone age, occurs in a few wells, possibly reflecting a marine maximum. Marine influence is concentrated in the western part of the basin, and may be more widespread in deeper rifted blocks as an extension of the more persistent marine influence seen in the Duntroon Basin. Such marine horizons have high correlative value as they probably reflect isochronous maximum flooding surfaces, but they may be thin. Drill cuttings may be the best means of detecting marine fossil indicators. Other fossil groups do not yet have proven potential for correlation.

Problems in dating

The widely used spore-pollen zonation of Helby *et al.* (1987) is essentially that of Dettmann (1963), based on Otway and Eromanga Basin data (Fig. 6.1). Subsequent Otway Basin studies have produced the refinements of Evans (1966) and Dettmann (1986). Problems applying the zonation are due to three factors, all of which complicate the correlation of the Neocomian-Aptian *Cyclosporites hughesii* Zone. These factors are (1) differences in ranges of taxa between basins, (2) extreme scarcity of some index taxa, and (3) different ranges being used by different authors in the Otway Basin.

Differing inter-basin species ranges

Dettmann and Playford (1969) and Helby *et al.* (1987) have attempted to produce zonations valid for all of eastern Australia (including the Otway and Eromanga Basins) despite some key species having different ranges between basins. Although generally successful, correlation of the base of the *C. hughesii* Zone of Helby *et al*. (1987) or its equivalent subzone of Dettmann and Playford (1969) is a problem, since the ranges of several important species are different, e.g. Dettmann (1986). As a result, the base of the *C. hughesii* Zone has a been correlated differently by different authors. In particular, the oldest occurrences of *Pilosisporites notensis* and *Foraminisporis asymmetricus* are nearly always coincident in the Eromanga Basin, but consistently different in the Otway Basin. Morgan (1980), working in the Eromanga Basin, used oldest *P. notensis* to correlate the two. As a result, the *C. hughesii* Zone (*sensu* Dettmann and Playford, 1969) may extend to slightly older horizons than *C. hughesii* Zone (*sensu* Helby *et al.* 1987, fig. 10) This different usage has been most confusing and the simplest solution is to introduce a new zonal name (*P. notensis* Zone) for the Helby *et al*. (1987) concept (Appendix 6.1).

Scarcity of key species

The above difficulties were largely caused by the extreme scarcity of some zonal fossils. Specifically, the base of the *C. hughesii* Zone was defined on the basis of the occurrence of youngest *Crybelosporites stylosus*, a species found to be too scarce to be reliable. Attempts to redefine this boundary on other criteria resulted in inconsistent usage as detailed above. Several other 'zone markers' of Dettmann and Douglas (1976) have been found by the current authors to be too scarce to be reliable, and other taxa with similar but more consistent ranges have been substituted. Specifically, youngest *Cooksonites variabilis* has been substituted for oldest *F. asymmetricus*, oldest *P. notensis* has been substituted for youngest *Murospora florida*, and oldest *Dictyotosporites speciosus* has been substituted for youngest *C. stylosus*. These substitutions have varied the respective boundaries only slightly up, not at all, and down, as shown on Figure 6.1.

Another key taxon which is very rare near its oldest occurrence is *Cicatricosisporites australiensis* (or other species of the genus), the species used to define the base of the Australian Cretaceous. This species is very consistent to frequent in the *Phimopollenites pannosus* to basal *P. notensis* Zones, rare but consistent in the upper *Foraminisporis wonthaggiensis* Zone, and extremely rare beneath. The defining criterion for the base of the *C. australiensis* Zone is thus useless in the Otway Basin, and the lower *C. australiensis* Zone cannot be distinguished from the *Retitriletes watherooensis* Zone. They are therefore lumped as a 'lower *C. australiensis* to *R. watherooensis'* interval, which may therefore be entirely Cretaceous in age, but which might be partly Late Jurassic (Fig. 6.1). The presence of a Jurassic section in the Otway Basin is therefore unproven; this interval is usually recorded from the Casterton Formation.

F. wonthaggiensis is also consistent in the *P. pannosus* to upper *F. wonthaggiensis* Zones, very scarce or absent in the lower *F. wonthaggiensis* Zone (as defined by oldest *D. speciosus* discussed above) and absent beneath. Correlation using oldest *F. wonthaggiensis* can thus be risky.

Differing species range concepts

Another significant problem is different ranges reported by different authors for the same species. In particular, Dettmann (1986) reported the following oldest occurrences in descending order: *F. asymmetricus, Triporoletes reticulatus*, coincident *P. notensis/F. wonthaggiensis*, then *D. speciosus*. The current authors see them in a different order, namely *F. asymmetricus*, *P. notensis* coincident *T. reticulatus/*consistent *F. wonthaggiensis*, then absolute *F. wonthaggiensis* then *D. speciosus.* Clearly the two ranges for *P. notensis* cannot be easily reconciled but may be caused by diachronism within the basin, or by sample mix-up or contamination. The senior author believes that oldest *P. notensis* is synchronous in the Otway and Eromanga Basins at base Aptian, for some of the geological reasons outlined below.

Current status

Because of these complicating factors, the best approach is to erect a zonation which works in the Otway Basin (while changing the existing framework as little as possible) and makes sense against the geological and seismic constraints. The sequence of events shown on Figure 6.1 can be constructed and general agreement reached amongst palynologists active in the basin with the possible exception of Dettmann regarding oldest *P. notensis.* These zones can be named as on Figure 6.1 and applied easily in the South Australian Otway Basin at least. Close liaison with industry geologists and geophysicists indicates that the *P. notensis/F. wonthaggiensis* Zone boundary occurs consistently at the angular unconformity at the base of the Eumeralla Formation, and can usually be located within metres using oldest *P. notensis* above the unconformity, and youngest occurrences of the alga *M. evansii* below. These palynological criteria are vital in the identification of Katnook Sandstone. Significant blooms of *M. evansii* can occur in the upper *F. wonthaggiensis* Zone in the Laira Formation and can be correlated locally (Morgan 1993) and probably represent maximum lake development. Much or all of the underlying section can also be truncated at the unconformity.

Current research using quantitative dispersed cuticle and spore-pollen data has improved resolution of the Crayfish Group. A joint MESA-GSV-petroleum company sponsored study of 14 wells focusing on floristic trends and associations of common, well-represented taxa has successfully subdivided the *F. wonthaggiensis* Zone of Helby *et al.* (1987) into six palynological and three dispersed cuticle zones (Rowett, 1994b). Results of the study are confidential to project sponsors, and will not be made available to others until mid-1995. Research is continuing with several other wells being added, and the study has been expanded to establish dispersed cuticle and palynological biozonations for the *C. australiensis* Zone of Helby *et al.* (1987).

No dinoflagellate zonation can yet be applied as marine influence is too minor and ephemeral. The late Aptian marine horizon noted above is a useful datum and more close-spaced sampling of cuttings, especially in deep palaeogeographic settings, may prove a more extensive marine section.

In summary, the correlative framework is fair to good. Too few core and sidewall samples have been studied from the bland assemblages of the Casterton Formation to consider them well controlled, and they could be all Cretaceous or partly Jurassic. Further work to be undertaken on the Crayfish Group is expected to provide an answer. Within the Neocomian, all zonal boundaries are based on oldest occurrences of fairly rare species and so boundaries may appear to be diachronous due to scarcity of marker species. Experience has shown that if these are absent from three or more consecutive samples then the absence is real. In the Laira Formation, local high resolution can be achieved using algal acmes. The top Crayfish Group unconformity can usually be located fairly precisely at the base of the *P. notensis* Zone as frequent excellent markers are available. Zones in the Eumeralla Formation interval can be confidently identified with the possible exception of the upper/lower *P. notensis* Zone boundary which is of lower confidence, being based on the youngest occurrence of the rare species *C. variabilis.*

Age control in the section is poor in the Neocomian as these continental palynofloras lack associated marine fossil control. The Aptian-Albian is well calibrated due to the marine megafauna associated with these zones in the Eromanga Basin to the north.

LATE CRETACEOUS

Palynology

Plant microfossils are abundant and diverse in claystone of the Late Cretaceous Sherbrook Group and only absent from sandstone lithologies. Terrestrial spores and pollen dominate, but are of more limited diversity in the Santonian to Cenomanian, reducing resolution. Dinoflagellates are much less frequent throughout, but are common and distinctive at certain horizons, providing useful correlations. Again, resolution is less in the early Santonian to Cenomanian. Other fossil groups are not very useful, although foraminifera have some application in the marine horizons.

Pollen and spores

The spore-pollen zonation evolved in two halves. The older half (*Tricolporites apoxyexinus* to *Appendicisporites distocarinatus* Zones) was developed in the Otway Basin in response to oil company exploration (Dettmann and Playford, 1969). Palynofloras above this point were loosely grouped into a '*Nothofagidites* Microflora'. The younger half of the palynological succession (*Nothofagidites senectus* to *Tricolpites (Forcipites) longus* Zones) was developed in the Gippsland Basin by Esso, and was published by Stover and Evans (1973), Stover and Partridge (1973) and Partridge (1976). These two halves were brought together by Helby *et al.* (1987), and provide the current framework (Fig. 6.1). The bases of the zones are mostly defined on oldest occurrences of key marker species, several of which are quite rare, near to the base of their range. They may therefore appear diachronous at times, especially in cuttings where specimens may be caved. The base of the *T. apoxyexinus* Zone is

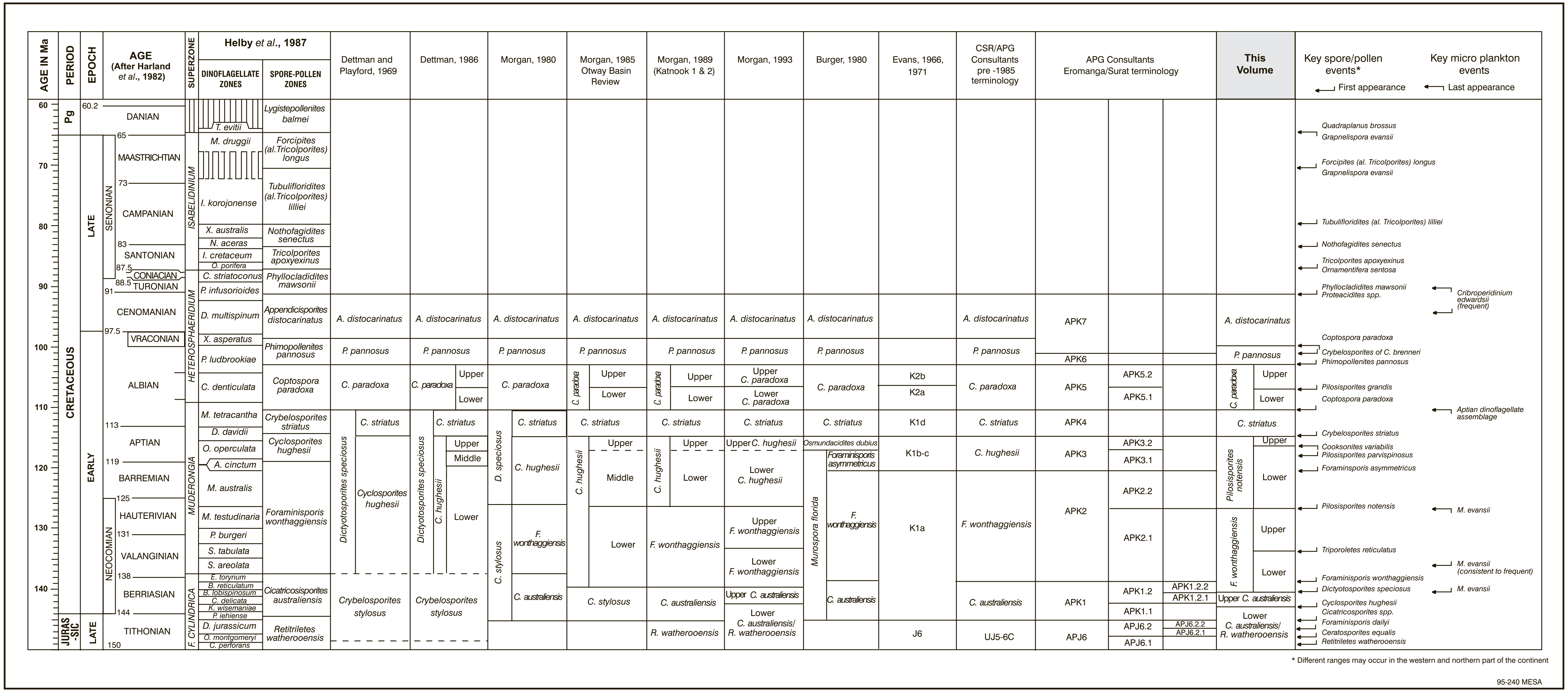

Fig. 6.1 *Late Jurassic - Late Cretaceous palynological zonal nomenclature*

especially difficult, as the nominate species is always extremely rare. However, the base of a large increase in *Amosopollis cruciformis* is nearly coincident and may be more regionally valid. Other criteria are currently being tested.

Dinoflagellates

The dinoflagellate zonation also evolved in a piecemeal fashion. The Campanian to Santonian *Xenikoon australis* to *Isabelidinium cretaceum* and Cenomanian *Ascodinium parvum* Zones were developed by Evans (1966) in the Otway Basin. The youngest zones are certainly the most distinctive and are easily recognised. The late Maastrichtian *Mannumiella druggii* Zone was developed in the Gippsland Basin and published by Partridge (1976) without definition. It is easily identified in the Otway Basin although often only as a brief interval. The *Conosphaeridium striatoconus* and *Odontochitina porifera* Zones were described from New Zealand by Wilson (1984), but the oldest occurrences of the nominate species can be very rare. All these were compiled, and the last three zones added, by Helby *et al.* (1987, fig. 2).

Several aspects of this framework require comment. Resolution is certainly best in the *X. australis* to *I. cretaceum* interval and new subzones are being tested. Below this, the *O. porifera* and *C. striatoconus* Zones frequently appear diachronous due to extreme scarcity to absence of zonal fossils. New zonal definitions in this interval are being tested, although the published definitions can be applied in more open marine sections in the Carnarvon and Perth Basins. The *Palaeohystricophora infusorioides*, *Isabelidinium korojonense* and *M. druggii* Zones can be reliably identified in favourable facies, but marginally marine to non-marine facies sometimes make interpretation difficult. The Cenomanian *Diconodinium multispinum* Zone has not yet been identified in the Otway Basin although it occurs in the Duntroon Basin to the west. This may be due to restricted marine facies and the absence of key fossils in the basin, or may be caused by a regional mid-Cretaceous hiatus.

Age control for the Late Cretaceous is good, being based on planktonic foraminifera and nannofossils associated with the dinoflagellate zones in offshore Western Australia, and the Bight and Duntroon Basins.

TERTIARY

Plant microfossils are abundant and diverse in claystone of the Pebble Point-Dilwyn succession (Paleocene to Middle Eocene). Terrestrial spores and pollen are dominant and diverse, but marine dinoflagellates usually minor. Above the Dilwyn Formation, plant microfossils become less frequent and sporadic in occurrence because of the establishment of marine conditions represented by carbonates. However, palynology is still quite useful up to the Early Miocene, at least in Victoria. In contrast, foraminifera (particularly planktonic foraminifera) are not abundant in the Paleocene to Middle Eocene part of the succession but are often abundant in the younger strata.

Pollen and spores

Two main spore-pollen-based zonations exist for the Tertiary of southeastern Australia. Harris (1965, 1971) developed a zonation based mostly on the onshore Otway Basin, but condensed and incomplete sections make resolution difficult. The scheme of Stover and Evans (1973), refined by Stover and Partridge (1973), was developed largely from extensive offshore oil drilling in thick and complete sections in the Gippsland and Bass Basins by Esso. Subsequent refinement is unpublished, but the zonal framework was published by Partridge (1976) without explanation. The two schemes are largely compatible due to relative uniformity in the southeastern part of Australia (Fig. 6.2). The latter scheme has become more widely used due to its greater resolution.

However, the application of the scheme developed in southeastern Australia is not without problems in more westerly and northerly basins. This is mainly a reflection of the different ranges of key pollen and spores elsewhere, the use of the assemblage concept to define some zones and first appearances for others, and the lack of evolutionary points in the Oligocene-Early Miocene interval (*Proteacidites tuberculatus* Zone). Attempts at subdividing the latter interval (Martin, 1984; Macphail and Truswell, 1989) in the adjacent Murray Basin have met with only partial success or may have only local application.

Recent work in the Murray, Otway and other South Australian basins shows significant differences in species ranges and in ratios between dominant taxa used to recognise some zones in the Gippsland area. Notwithstanding these weaknesses, most zonal boundaries are still valid, although some may be recognised on other evidence.

Since the youngest Late Cretaceous *T. longus* Zone encompasses the early Paleocene (Helby *et al*., 1987), the Cretaceous-Tertiary boundary is not recognisable on palynological evidence in Australia. The transition into *Lygistepollenites balmei* palynofloras may also be blurred by the recycling of older taxa into younger strata. Moreover, species thought to be tightly constrained chronologically, such as *Grapnelispora evansii* in the latest Maastrichtian, are found to range up into the Late Paleocene-Early Eocene in South Australia. Probably the most reliable events for defining the upper boundary of the *L. balmei* Zone are the last appearances of *Gambierina rudata* and *Lygistepollenites ellipticus* (although very rare outside of southeastern Australia) and a decline in the overall frequency of *Australopollis obscurus*, *Intratriporopollenites notabilis*, *Dryptopollenites semilunatus* and *Cyathidites splendens*. Otherwise, Early Eocene *Malvacipollis diversus* palynofloras are similar to those of the Late Paleocene.

The most widely recognised change appears at the Early-Middle Eocene boundary, or base *Nothofagidites asperus* Zone. Here there is a large increase in the frequency of *Nothofagidites* spp. pollen, especially in the *brassii* group. Although the first appearance of *N. asperus* is a good indicator of the base of the zone, it is generally rare outside the Gippsland Basin, and the first appearance (concurrent with the nominate species) of the more common species *N. falcatus* is more reliable. The oldest and most consistent occurrence of *Triorites magnificus* is still useful in defining the

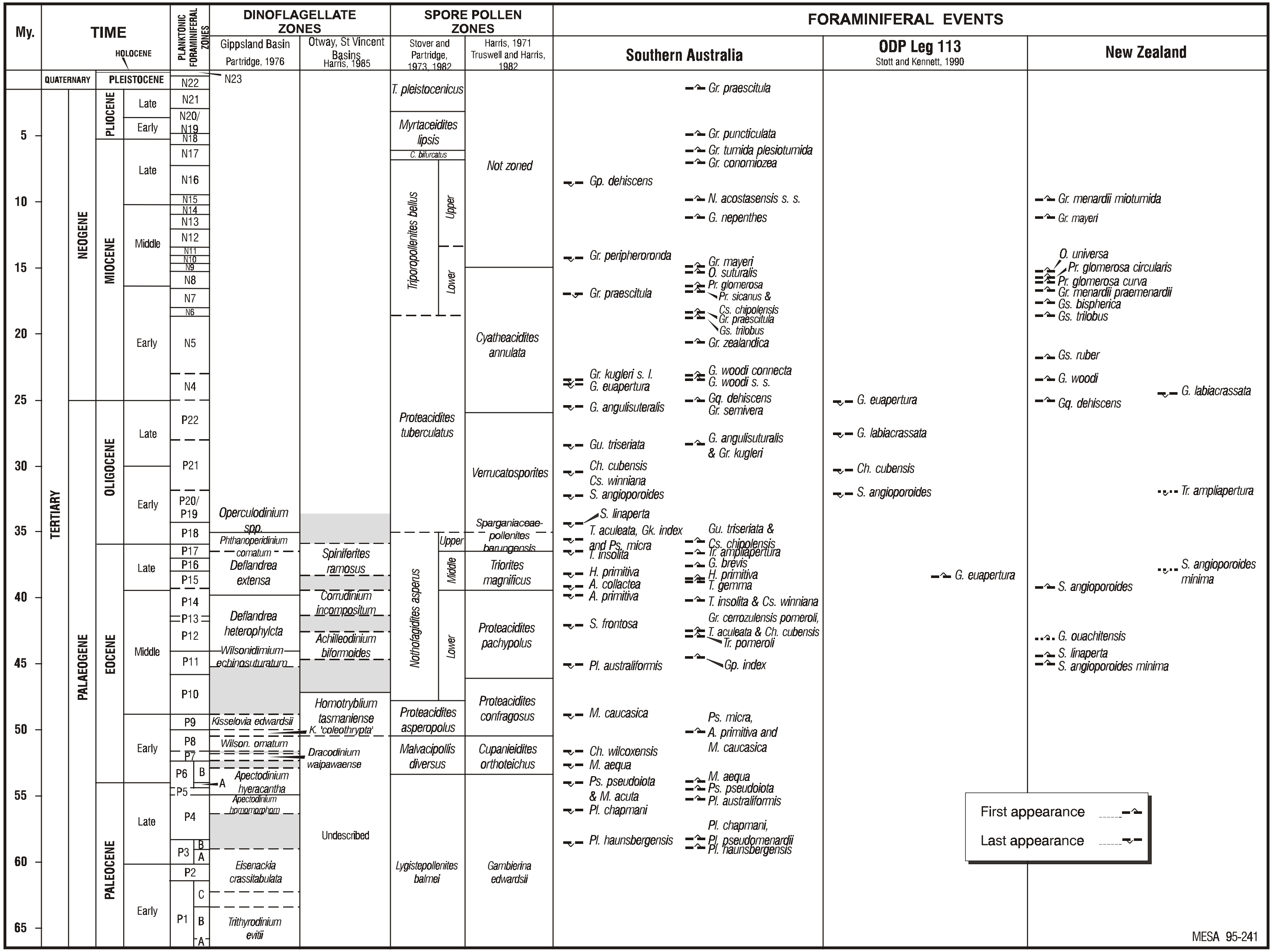

Fig. 6.2 *Foraminiferal events (first and last appearances) recognised in southern Australia, ODP leg 113, and New Zealand.*

base of the largely Late Eocene Middle *N. asperus* Zone, even though some workers find that it may appear sporadically in the Middle Eocene. Recognition of the Upper *N. asperus* Zone on the basis of key species is very problematic. Probably the great decrease in the diversity and frequency of *Proteacidites* spp. along with the preponderance of *Nothofagidites* spp. are the only clues to the transition into the subzone, but this fails to separate the palynofloras from the succeeding *P. tuberculatus* Zone.

Work in progress (Martin, Macphail and Truswell, and Alley) is attempting to subdivide the long *P. tuberculatus* Zone and calibrate these divisions against the marine record through associated foraminifera and microplankton. The upper boundary of the zone (i.e. base *Triporopollenites bellus* Zone) has been shifted downwards to the Early Miocene (Macphail *et al*., 1994) but is still recognised on the oldest appearance of the nominate species. Several other younger zones have been informally defined in the Gippsland area and the Murray-Darling Basin, and are in the process of being tested for potential application in the Otway and other basins.

Dinoflagellates

No comprehensive dinoflagellate zonal scheme is available for the Australian Tertiary. Partridge (1976) published a set of zonal names for the Paleocene to Early Oligocene of the Gippsland Basin, but the zones were not defined. Some of these were based on a dinoflagellate sequence described by Wilson (1967, but not defined as a formal zonation until 1984) from New Zealand and applicable in Australia. Subsequent refinement of these zones in Australia is unpublished. Harris (1985) published a set of four dinoflagellate zones for the Otway Basin (Early Eocene to Early Oligocene). Since dinoflagellates in the basin are often rare and nondescript, the zones are less precise than the spore-pollen data and thus have not been widely accepted. However, some samples in some sections can be assigned confidently to zones from either scheme.

Age control of these schemes is excellent in the Middle Eocene and younger deposits through associated planktonic foraminifera and nannofossils although the foraminiferal faunas are not well represented in the South Australian part of the basin. Age control beneath Middle Eocene strata is only good to fair, mostly relying on dinoflagellate correlation to New Zealand where more marine equivalents have excellent planktonic foraminiferal and nannofossil control.

Foraminiferal zonations

Several zonations based on foraminifera have been proposed for the Tertiary of southeastern Australia (e.g. Crespin, 1943; Carter, 1958, 1964; Wade, 1964; Taylor, 1966; Ludbrook and Lindsay, 1969) and various attempts have been made to correlate these with each other, similar schemes in New Zealand, and the standard planktonic zones of the low latitudes. The growing confusion resulting from the proliferation of foraminiferal zonations for the extratropical Austral region gradually led workers to abandon these schemes in favour of using foraminiferal events or datum levels (e.g. Hornibrook, 1967; Hornibrook and Edwards, 1971; McGowran, 1978; Lindsay, 1985). Datum recognition is now the generally accepted method of foraminiferal dating and correlation in southeastern Australia. The data are used to relate local successions to the standard P and N planktonic foraminiferal zones erected in the tropics.

While most of the zonal schemes previously used include datum levels (first and last appearances) in their zonal definitions, elimination of zonal names has served to clarify the similarities between successions. However, the problems of facies control on taxa and possible diachroneity encountered in recognising zones, also apply to datum recognition.

Sedimentation in the Murray and St Vincent Basins is more restricted than in the open marine Gambier Basin. The resulting lower abundance and diversity of planktonic foraminifera has meant that at least some of the age diagnostic taxa found in the Gambier Basin are rare or absent in the Murray and St Vincent basins. Similar facies problems are posed when attempting correlation with the low latitude zonal schemes. In this case the environmental factor is temperature. The tropical, warm-water faunas are considerably more diverse than their temperate, cool-water counterparts. Although some taxa are common to both regions, the large distance over which correlation is being attempted introduces the possibility of diachroneity. Nevertheless, correlation of local datum levels with the P and N zones has been possible and continues to be refined. A major contributing factor to this refinement has been the adoption of a sequence stratigraphic approach by McGowran and others (e.g. McGowran, 1991; McGowran *et al.*, 1992; McGowran and Li, 1993). The foraminiferal events recognised in southern Australia for which correlation with the P and N zones has been attempted are listed on Fig. 6.2 together with others recognised in the high latitudes.