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RESULTS OF A PRELIMINARY PALYNOLOGICAL EXAMINATION OF MESOZOIC GRAB SAMPLES FROM THE NORTH WEST SHELF

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INTRODUCTION

Dredge samples were collected by BMR Rig Seismic during Surveys nos 95 and 96, conducted on the North West Shelf in 1990. A series of 34 samples has been forwarded to the author for palynological age determination and environmental analysis. This report discusses the preliminary examination of those samples.

Twenty-one samples from the offshore Canning Basin were dated Late Triassic to Middle Jurassic; they represent paludal to open marine environments. Nine samples from the Carnarvon Terrace were dated (Late) Jurassic to Early Cretaceous, and represent open marine environments. Two nonmarine/paludal samples from the Scott and Exmouth Plateaus were tentatively dated Early Jurassic.

Locations of samples are plotted in Figure 1, and latitude and longitude of each sample are given in the text.

FIRST PART: CRUISE 95

Samples were dredged from the Exmouth Plateau and offshore Canning Basin (Exon & Ramsay 1990), and N.F. Exon selected 11 samples from the offshore Canning Basin for palynology. Most samples yielded rich and well-preserved fossil assemblages. The palynomorph data suggest that the sampled sediments range in age from Late Triassic to Middle Jurassic, and were deposited in brackish to near-coast saline environments (Table 1).

EXAMINATION OF SAMPLES

Sample 95/DR05/5A (15°23'south, 118°58'east)
Assemblage MFP-9236

Composition

Spores and pollen are more common than microplankton. The spore fraction includes common *Gleicheniidites*, *Cyathidites*, *Staplinisporites*, and relatively less common *Lycopodiumsporites*, *Matonisporites*, and *Klukisporites*. Several monolete species are present. The pollen fraction is smaller and includes relatively common *Araucariacites*, rare *Callialasporites*, Circumpolles, and *Inaperturopollenites*, and sporadic bisaccate and trisaccate types. No monosulcate forms are found.

The microplankton population contains very few dinoflagellates (*Batiacasphaera* sp). The acritarch group is relatively diverse, including common *Lecaniella*, *Leiosphaeridia*, rare *Schizocystia*, *Tasmanites*, *Schizosporis*, and several as yet undetermined types.

Zonal affinities

The spore-pollen assemblage can be placed with confidence within existing biostratigraphic schemes for the Jurassic (Fig. 2). In eastern Australia the first appearance of *Contignisporites* (specifically *C. burgeri*) falls within Filatoff & Price's (1988) Unit PJ4, which is approximately equivalent to Filatoff's (1975) *Contignisporites cooksoniae* Zone. The absence of *Murospora florida* and other species characteristic of younger zonal intervals indicates that the assemblage is older than Filatoff's *Murospora florida* Microflora and Filatoff & Price's Unit PJ5, and must be placed within basal Unit J5-6 of Evans (1966).

The scarce dinoflagellates do not allow biostratigraphic assignment of the phytoplankton assemblage.

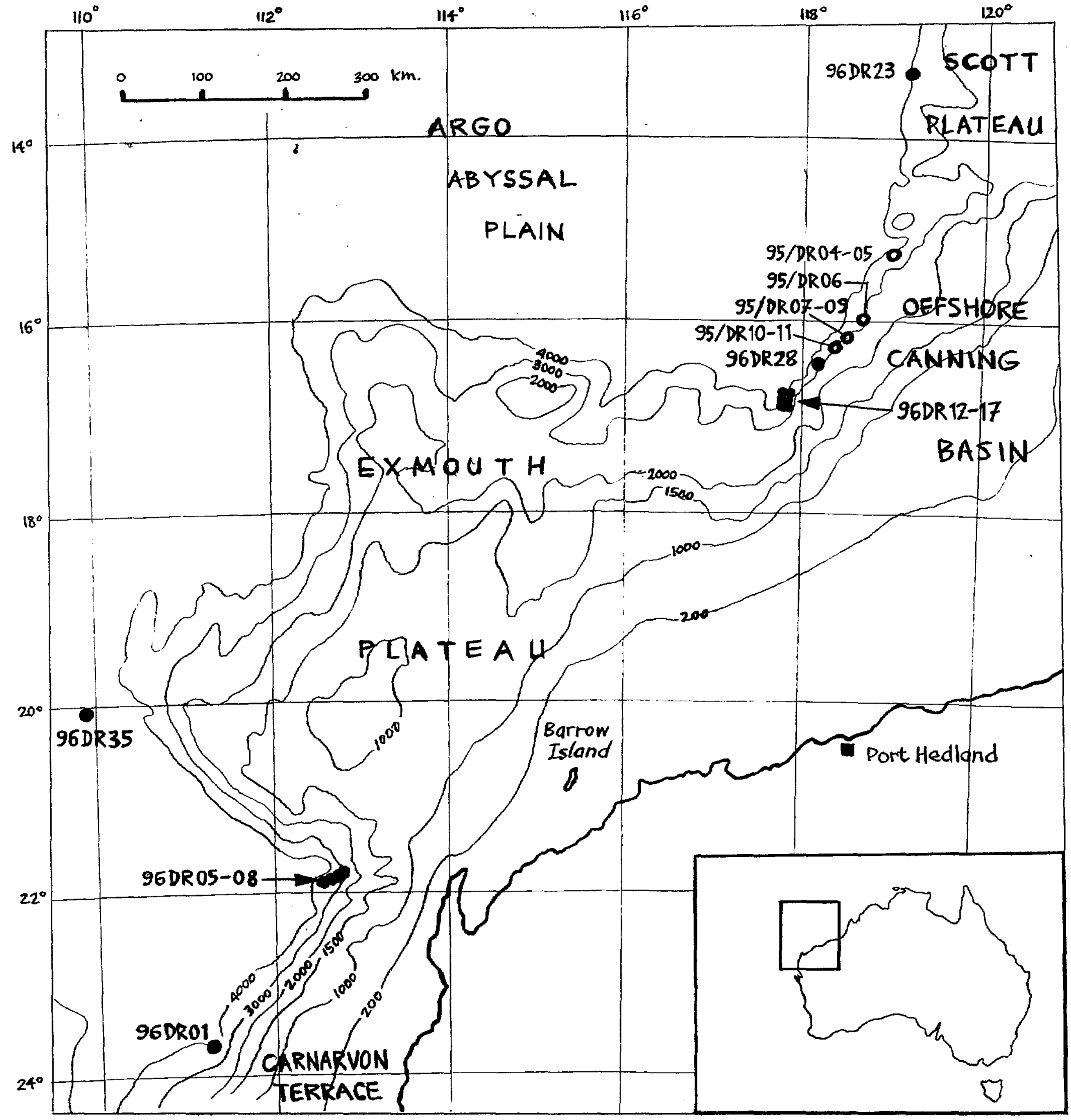


FIGURE 1. Locations of dredge samples from Cruises 95 and 96

Geological age

Filatoff (1975) dated the *Contignisporites cooksoniae* Zone Callovian to Oxfordian, and Helby *et al.* (1987) regarded the zone to be Bathonian to Callovian. In the Perth Basin the zone falls within the Yarragadee Formation, which cannot be accurately dated, but the underlying Cadda Formation is most likely not younger than early Bajocian, and provides a maximum age for the zone. Data from eastern Australia suggest that both age estimates for the zone may be too young. On indirect evidence McKellar (1974) regarded the sequence preceding the first appearance of *Contignisporites* (i.e. Unit J4 of Burger 1976a) as not younger than basal Bajocian. Filatoff & Price (1988) dated their Unit PJ4 late Bajocian to early Callovian. Burger (1990b) argued on indirect dinoflagellate evidence that Evans' (1966) Unit J5-6 might commence in the Bajocian, and that the first apparance of *Murospora florida* might be dated Bathonian.

All age estimates agree that Sample 95/DR05/5A is of Middle Jurassic age, and on the indirect evidence from eastern Australia is here suggested to be late Bajocian to early Bathonian.

Field number 95/DR	Palyn. number (MFP)	associations to palynological zones		envir. of depos.
		spores and pollen	dinoflagellates	
05/5A	9236	*Contignispor*. *cooksoniae*	?	1
05/9A	9237	*Contignispor*. *cooksoniae*	*W*.*indotata*-*digitata*	3
11/7A	9245	u.*C*.*turbatus*-l.*D*.*complex*	?	2
04/16A	9235	u.*C*.*turbatus*-l.*D*.*complex*	?	1
11/3A	9244	u.*C*.*turbatus*-l.*D*.*complex*	?	2
06/1A	9238	upper *Corollina* *torosa*	upper *D*. *priscum*?	1
07/14A	9241	upper *Corollina* *torosa*	upper *D*. *priscum*?	1
09/2C	9242	upper *Corollina* *torosa*	?	1
07/11A	9240	(*M*.*crenulatus*)-*A*.*reducta*	lower *D*. *priscum*	2
10/4A	9243	u.*S*.*specios*.-*M*.*crenulat*.	*Rhaetogon*. *rhaetica*	2
07/4A	9239	(*M*.*crenulat*)-l?*A*.*reducta*	upper *Heib*. *balmei*?	2

environments of deposition: 1 - paludal
2 - coastal marine
3 - shallow marine

TABLE 1. Cruise 95 samples: geological age and palaeoenvironments

Sample 95/DR05/9A (15°23'south, 118°58'east)
Assemblage MFP-9237

Composition

In this assemblage the spores and pollen are somewhat less abundant than the microplankton. The spore fraction is reasonably diverse; the trilete genus *Cyathidites* dominates, *Matonisporites*, *Gleicheniidites*, *Lycopodiumsporites*, *Contignisporites*, and *Klukisporites* are rare, and *Staplinisporites* very scarce. Few monolete spores were found. The pollen fraction is more common and is dominated by *Araucariacites* and mono- and bisaccate types (*Callialasporites*, *Alisporites*); the Circumpolles group is rare.

The microplankton assemblage contains a diverse dinoflagellate component dominated by *Batiacasphaera* spp., *Sentusidinium* spp., and rare *Leberidocysta* sp., *Pareodinia* spp., *Ellipsodictyum* sp., and ?*Leiosphaeridia perthensis*. The acritarch fraction is very small.

Zonal affinities

The spore-pollen assemblage includes *Contignisporites* and lacks *Murospora florida* and can be assigned to Filatoff's (1975) *Contignisporites cooksoniae* Zone. The dinoflagellate assemblage includes *Wanaea indotata*, which Helby *et al.* (1987) reported from their *Wanaea indotata-digitata* zonal interval.

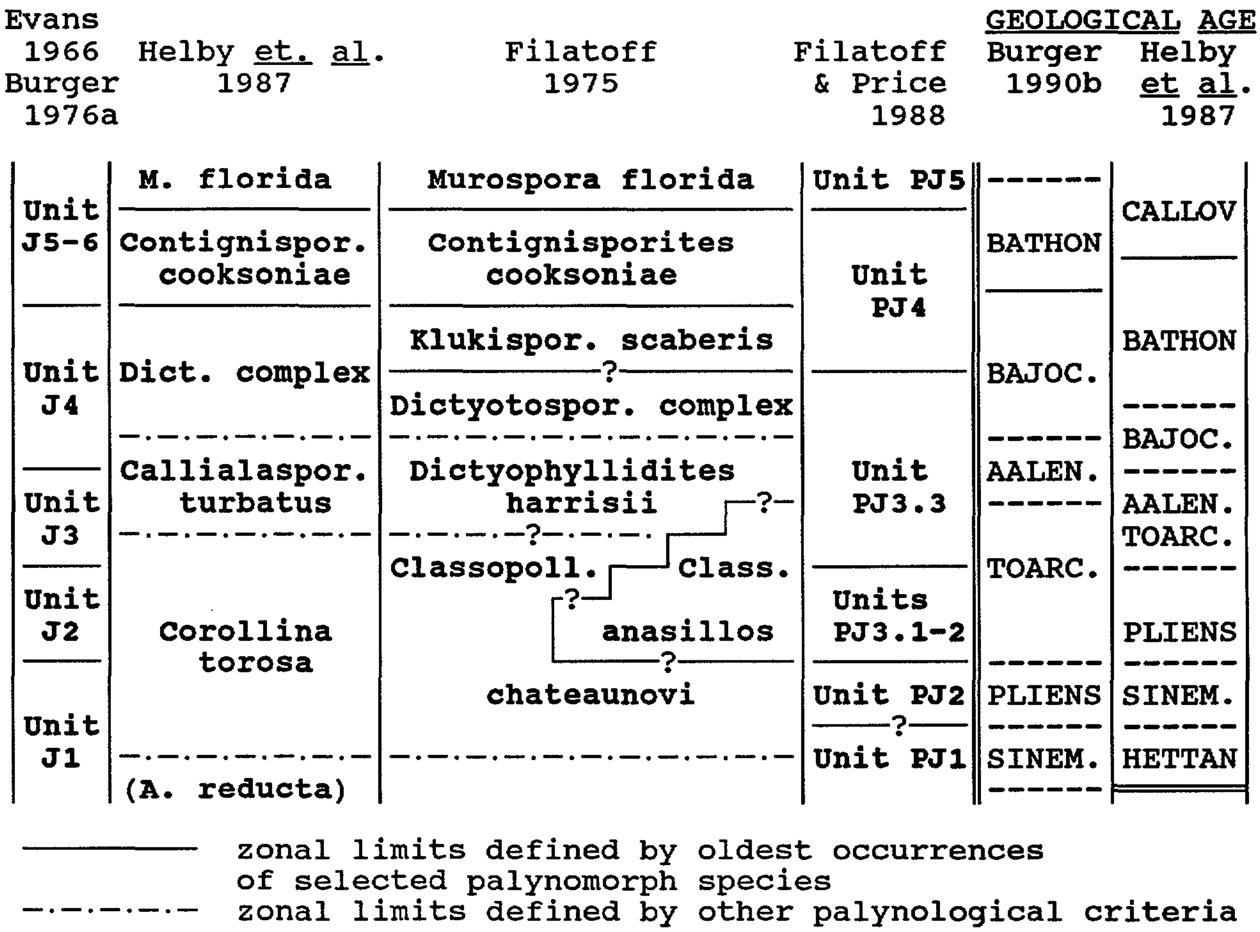


FIGURE 2. Australian Early and Middle Jurassic spore-pollen zones

Geological age

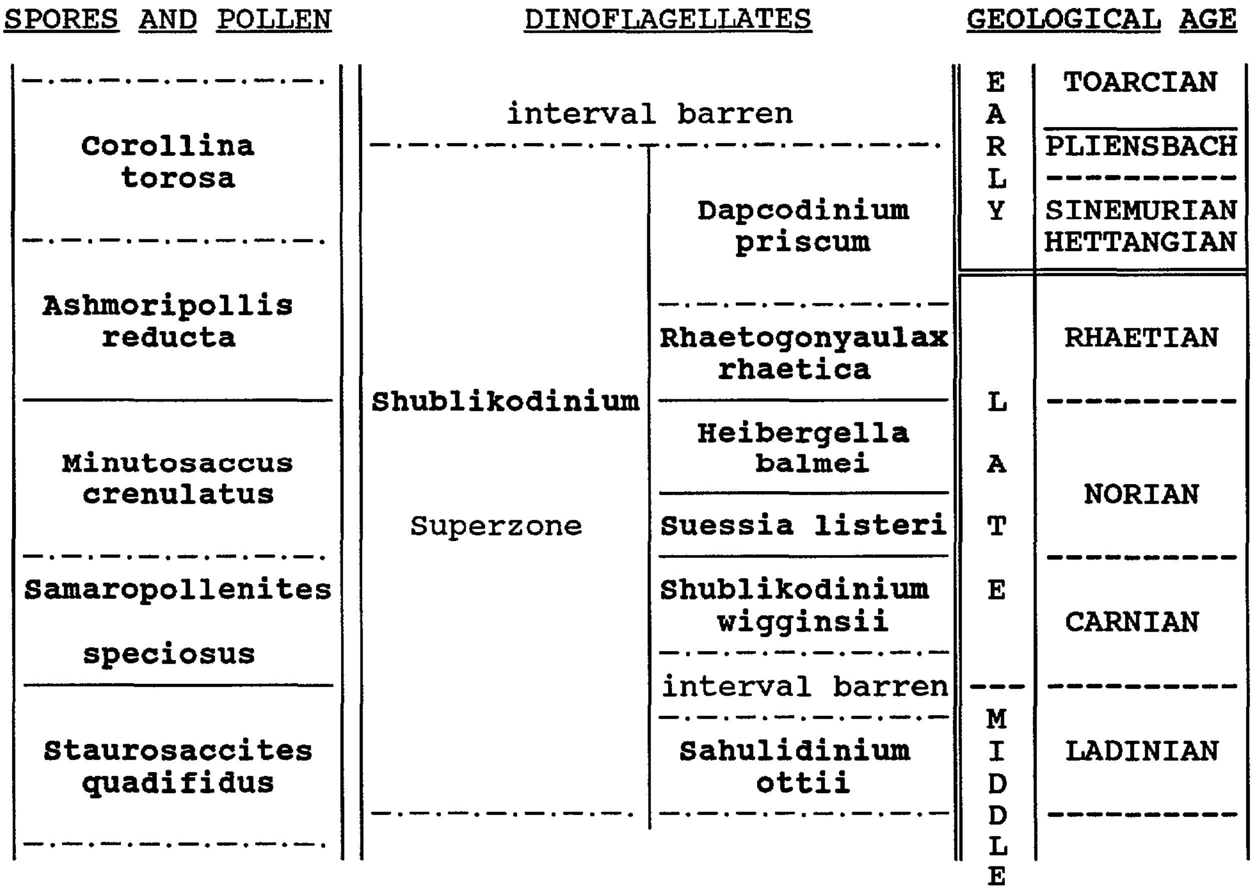
Like the previous sample, Sample 95/DR05/9A may be dated late Bajocian-early Bathonian, but its dissimilar microfloral contents indicates a different lithostratigraphic horizon.

Sample 95/DR11/7A (16°26'south, 118°11'east)
Assemblage MFP-9245

Composition

This assemblage is dominated by the spore-pollen fraction. The trilete group is common and includes chiefly *Cyathidites*, *Matonisporites*, and *Staplinisporites*, while *Lycopodiumsporites*, *Gleicheniidites*, *Striatella*, and *Klukisporites* are rare, and monolete forms were not found. The much larger pollen group is dominated by *Callialasporites* and *Araucariacites*, and also includes bisaccate types (*Alisporites*) and a few specimens of the Circumpolles group (including *Classopollis anasillos*).

The microplankton fraction is smaller and is dominated by very poorly preserved dinoflagellates (*Batiacasphaera*, *L*? *perthensis*, ?*Dissiliodinium*). Acritarchs are uncommon and include mainly *Fromea* and *Micrhystridium*.



———— zonal limits defined by oldest occurrences of selected palynomorph species
–·–·–·– zonal limits defined by other palynological criteria

FIGURE 3. Australian Middle and Late Triassic palynological zones (taken from Helby et al. 1987)

Zonal affinities

The spore-pollen assemblage includes the essential zonal index species *Callialasporites dampieri* and *Antulsporites saevus*, and apparently lacks *Camarozonosporites clivosus*, *Dictyotosporites complex*, *Klukisporites scaberis*, and *Contignisporites* spp. It can thus be assigned to the upper *Callialasporites turbatus* to basal *Dictyotosporites complex* zonal interval of Helby *et al.* (1987), or Units J3-4 of Burger (1976a). According to Filatoff (1975) *Pilasporites marcidus* appears later than *A. saevus* in the Perth Basin, and its presence might indicate that the assemblage is not older than the upper part of Unit J3 (see also the discussion for assemblage MFP-9235).

The dinoflagellate assemblage is not sufficiently diverse to be assigned to a specific zonal interval.

Geological age

The spore-pollen evidence suggests that Sample 95/DR11/7A is not older than Aalenian and not younger than early Bajocian.

Sample 95/DR04/16A (15°22'south, 118°58'east)
Assemblage MFP-9235

Composition

The spores and pollen constitute the largest part of the assemblage. The spore fraction is dominated by psilatrilete forms (*Cyathidites*, *Matonisporites*, *Dictyophyllidites*). *Gleicheniidites* is uncommon. Several species of *Ischyosporites*, *Klukisporites*, *Lycopodiumsporites*, and *Staplinisporites* are present. The pollen fraction is prominent and includes mainly *Callialasporites* and *Araucariacites*; the Circumpolles group and bisaccate types are uncommon, and monosulcate forms were not found.

The phytoplankton assemblage includes few extremely poorly preserved dinoflagellates (?*Batiacasphaera*, ?*Dichadogonyaulax*, ?*Pentafidia*) and rare acritarchs (*Tasmanites*, *Micrhystridium*, *Schizocystia*, *Lecaniella*).

Zonal affinities

There are still some uncertainties in Australian spore-pollen biostratigraphy in this part of the Jurassic sequence (Fig. 2). The assemblage includes *Klukisporites scaberis* and lacks *Lycopodiacidites asperatus* and *Camarozonosporites clivosus*, and therefore would equate with Filatoff's (1975) *Klukisporites scaberis* Zone. This fits with the low numbers of cheirolepidean pollen in the assemblage, and the absence of *Cadargasporites*, *Foraminisporis*, *Nevesisporites*, *Exesipollenites*, and other forms, all of which have been reported only from older zonal intervals.

Helby *et al.* (1987) could not recognise the *Klukisporites scaberis* Zone as such, and in their pan-Australian spore-pollen scheme incorporated it in their *Dictyotosporites complex* Zone, which encompasses both the *Dictyotosporites complex* and *Klukisporites scaberis* Zones of Filatoff (1975). The lower limit of this new zone is not sharply delineated, being defined by a fractional decrease of *Callialasporites turbatus* and an increase of *C. dampieri*. However, the authors reported that *D. complex* first appears at about that level, and they subdivided the zone on the first appearance of *Lycopodiumsporites circolumenus*.

This scheme is difficult to relate to that developed for eastern Australia. For the Great Artesian Basin, Filatoff & Price (1988) selected the first appearances of *Klukisporites lacunus* and *L. circolumenus* to define the lower and upper limits of their Unit PJ3.3. They correlated this unit with the upper part of Helby *et al.*'s (1987) *Callialasporites turbatus* Zone and, as argued below, this agrees with Filatoff (1975). Burger (1976a) developed a zonal scheme including Palynological Units J2, J3, J4, and J5, on the first appearances of

Callialasporites dampieri, *Antulsporites saevus*, *Camarozonosporites clivosus*, and *Contignisporites cooksoniae* respectively. Those units can be identified in several eastern Australian basins (McKellar, 1974; Burger, in press). It is not yet known exactly where in this scheme *Dictyotosporites complex* first appears, but it is almost certainly at a higher level than Unit J3.

Stratigraphic ranges of species given by Filatoff (1975, text-fig. 5) indicate that Units J2 and J3-4 can be identified also in the Perth Basin; Unit J4 is not outlined as such, as *C. clivosus* appears simultaneously with *C. cooksoniae*. Unit PJ3.3 can also be identified, and regionally equates with the lower part of Units J3-4. The presence of *C. dampieri*, *A. saevus*, *Staplinisporites mathurii*, and *Klukisporites lacunus*, and the apparent absence of *L. circolumenus*, *D. complex*, and *C. clivosus* suggest that assemblage MFP-9235 falls within that same interval, which in the scheme of Helby *et al.* (1987) coincides with the upper *Callialasporites turbatus* to basal *Dictyotosporites complex* Zone.

The scarce dinoflagellates present cannot be pinpointed within Helby *et al.*'s (1987) dinoflagellate zonal scheme.

Geological age

The above zonal assignments allow Sample 95/DR04/16A to be dated with reasonable confidence. In the Perth Basin the lower *Dictyotosporites complex* Zone is associated with the Cadda Formation. This formation is correlated with the Champion Bay Group, whose upper part - the Newmarracarra Limestone - is dated early Bajocian on ammonites (Hall, 1989). Helby *et al.* (1987) dated their *Callialasporites turbatus* Zone Toarcian to early Bajocian, partly on foraminiferal evidence from the North West Shelf, and party on dinoflagellate evidence. On indirect evidence Filatoff & Price (1988) dated Unit PJ3.3 Aalenian-Bajocian, and Burger (1990b) placed Unit J3 at the Toarcian-Aalenian boundary. The age of the sample may therefore be estimated as late Toarcian to early Bajocian. A sample from the same dredge line (DR04/7) yielded a nannofossil species whose stratigraphic range spans the Bajocian to the Barremian (Exon & Ramsay 1990).

Sample 95/DR11/3A (16°26'south, 118°11'east)
Assemblage MFP-9244

Composition

The assemblage is dominated by the spore-pollen group. There are relatively few trilete spores (*Cyathidites*, *Gleicheniidites*, *Matonisporites*, very rare *Lycopodiumsporites*, *Staplinisporites*, *Antulsporites*, *Stereisporites*) and sporadic monolete grains. The much larger pollen fraction is dominated by *Callialasporites*, *Araucariacites*, *Classopollis* (including *C. anasillos*), and some bisaccate types (*Pinuspollenites*, *Alisporites*). Trisaccate and monosulcate specimens are very rare.

The microplankton fraction is relatively common. It includes several poorly preserved dinoflagellates (mainly *Batiacasphaera* and *Dissiliodinium*) and several acritarch genera (*Leiosphaeridia*, *Sigmopollis*, *Micrhystridium*, *Schizosporis*, *Veryhachium*).

Zonal affinities

The presence of *Callialasporites dampieri*, *Antulsporites saevus*, *Staplinisporites mathurii*, and *Klukisporites lacunus*, and the absence of *Camarozonosporites clivosus*, *Dictyotosporites complex*, and *Contignisporites* spp. restricts the spore-pollen assemblage to Units J3-4 of Burger (1976a). Filatoff (1975) described *Classopollis anasillos* from the Perth Basin as occurring only below the first appearance of *A. saevus*. This report suggests that in the North West Shelf region *C. anasillos* extends into Unit J3. *Classopollis* appreciably decreases in fractional abundance up-sequence, and this decrease has been observed within Unit J3, the lower *Callialasporites turbatus* Zone of Helby *et al.* (1987), and their equivalent intervals in eastern and Western Australia (Reiser & Williams 1969;

McKellar 1974; Filatoff 1975; Helby *et al.* 1987). It is suggested, therefore, that the assemblage is not younger than Unit J3 (see also discussion for assemblage MFP-9235).

The microplankton assemblage lacks distinct zone-indicative species and cannot be assigned to a specific zonal interval.

Geological age

Helby *et al.* (1987) dated the base of their *Callialasporites turbatus* Zone Toarcian on dinoflagellate evidence from the North West Shelf. On indirect evidence Burger (1990b) dated Unit J3 late Toarcian to early Aalenian, and Filatoff & Price (1988) dated Unit PJ3.3 Toarcian to Bajocian. These estimates suggest a late Toarcian to early Aalenian age for Sample 95/DR11/3A.

Sample 95/DR06/1A (16°01'south, 118°46'east)
Assemblage MFP-9238

Composition

The fossils in this assemblage are very poorly preserved. The spore-pollen assemblage lacks nearly every trilete species found in the samples mentioned above, and includes no monolete spores. It is dominated by only a few gymnosperm types (*Callialasporites*, *Araucariacites*), and bisaccate forms (*Alisporites*) are very rare. The taxodiacean species *Exesipollenites tumulus* and the group of Circumpolles (including *Classopollis anasillos*) are relatively common.

The microplankton assemblage is fractionally somewhat smaller, and includes *?Batiacasphaera* and the peculiar genus *Susadinium*. The acritarch group is more abundant, with common *Micrhystridium* and sporadic *Fromea*, *Veryhachium*, and *Leiosphaeridia*.

Zonal affinities

The spore-pollen assemblage includes *Callialasporites dampieri* and common *Classopollis anasillos* and *Exesipollenites tumulus*. This, and the conspicuous absence of many trilete species (including *Antulsporites saevus*) are features characteristic of Filatoff's (1975) *Classopollis anasillos* Zone in the Perth Basin. Assemblage MFP-9238 may therefore be placed in Unit J2 of Burger (1976a), or Helby *et al.*'s (1987) upper *Corollina torosa* Zone.

The restricted dinoflagellate assemblage includes no zonal marker species. However, Helby *et al.* (1987) reported the brief appearance of *Susadinium* sp. A near the upper limit of their *Dapcodinium priscum* Zone in Western Australia.

Geological age

Evidence for the age of assemblage MFP-9238 is circumstantial but reasonably consistent. Filatoff (1975) suggested an early Toarcian age for his *Classopollis anasillos* Zone. McKellar (1974) referred to overseas records stating a late Toarcian first appearance of *C. dampieri*. Filatoff & Price (1988) placed the equivalent lower limit of their Unit PJ3 at the base of the Toarcian. Helby *et al.* (1987) placed the (vaguely defined) upper limit of their *Corollina torosa* Zone on indirect evidence from associated dinoflagellates also within the Toarcian.

The presence of *Susadinium* sp. suggests that the marine assemblage might fall near the upper limit of the *Dapcodinium priscum* Zone, for which Helby *et al.* (1987) suggested a mid-Rhaetian to Pliensbachian age (Fig. 3).

All estimates point to a Toarcian age for Sample 95/DR06/1A. Burger (1990b) suggested his Unit J3 to straddle the Toarcian-Aalenian boundary, and that age is consistent with the dinoflagellate data for a possible early Toarcian age of this sample. Foraminifera recovered from the same dredge line (sample DR06/3) are dated late Toarcian (Lynch, in Exon & Ramsay 1990).

Sample 95/DR07/14A (16°18'south, 118°23'east)
Assemblage MFP-9241

Composition

The spore-pollen assemblage contains only a small spore fraction, including *Cyathidites*, *Matonisporites*, *Gleicheniidites*, *Dictyophyllidites*, and very rare *Staplinisporites*, *Striatella*, and *Lycopodiumsporites*. No monolete spores were found. The much larger pollen fraction is dominated by the Circumpolles group (over 70%, including *Gliscopollis* and *Classopollis anasillos*). Additional minor elements are *Araucariacites*, *Callialasporites*, bisaccate forms, and *Exesipollenites*.

The microplankton assemblage is smaller. Dinoflagellates are very poorly preserved and include *Batiacasphaera*, *Susadinium*, *Pareodinia*, and ?*Dissiliodinium* and ?*Phallocysta* (only single specimens). Acritarchs are much more common, in particular *Micrhystridium*; *Leiosphaeridia*, *Pterospermopsis*, *Veryhachium*, and *Schizosporis* are very rare.

Zonal affinities

The presence of *Callialasporites dampieri*, the abundance of Circumpolles, and the apparent absence of *Antulsporites saevus* indicate that the spore-pollen assemblage represents Unit J2 of Burger (1976a), or the upper *Corollina torosa* Zone of Helby *et al.* (1987).

The dinoflagellate assemblage is too meagre to be confidently assigned to a specific zonal interval. The presence of *Susadinium* might indicate that the assemblage falls within the upper *Dapcodinium priscum* Zone of Helby *et al.* (1987).

Geological age

In a biostratigraphic sense Sample 95/DR07/14A is closely comparable to the previous sample, and is therefore suggested to be also of (early) Toarcian age. Foraminifera recovered from the same dredge line (DR07/8) have been dated Bajocian to Callovian (Lynch, in Exon & Ramsay 1990). Calcareous nannofossils recovered from that same sample are dated Middle Jurassic, possibly Late Bathonian to early Callovian, and include some reworking from Lower Jurassic sources (Exon & Ramsay 1990). No comparable reworking is apparent from assemblage MFP-9241.

Sample 95/DR09/2C (16°19'south, 118°25'east)
Assemblage MFP-9242

Composition

The microfossils are poorly preserved and the assemblage is dominated by pollen grains and spores. The spore fraction is small and includes only a few trilete species (*Cyathidites*, *Dictyophyllidites*, rare *Matonisporites*); no monolete forms were found. The pollen fraction is much larger; the Circumpolles group (including *Classopollis anasillos* and *Gliscopollis*) constitutes well over 50% of the assemblage, and *Callialasporites* and *Araucariacites* are also common. Bisaccate forms (*Alisporites*, *Vitreisporites*, rare *Falcisporites*) are not uncommon but often fragmented. *Exesipollenites* and very few monosulcate grains (*Cycadopites*) are present as well.

The microplankton group includes few dinoflagellates, which are poorly preserved and difficult to identify (*Dichadogonyaulax*, aff. *Batiacasphaera*), and a much larger acritarch population, including common *Micrhystridium* and infrequent *Leiosphaeridia* and *Fromea*.

Zonal affinities

The spore-pollen assemblage is closely comparable to that of assemblage MFP-9238. The presence of *Callialasporites dampieri* and common *Classopollis anasillos* and *Exesipollenites tumulus*, and the absence of many trilete species reported from the Early Jurassic of Western Australia (including *Antulsporites saevus*) indicates the fossils to represent Filatoff's (1975) *Classopollis anasillos* Range-Zone, or Unit J2 of Burger (1976a).

The marine fossils are too sparse and poorly preserved to be associated with a specific zonal interval.

Geological age

The spore-pollen assemblage suggests Sample 95/DR09/2C to be (early) Toarcian (see also discussion for assemblage MFP-9238).

Sample 95/DR07/11A (16°18'south, 118°23'east)
Assemblage MFP-9240

Composition

This sample yielded much coarse cuticular and cellular plant detritus and only few poorly preserved palynomorphs. The spore assemblage includes trilete types (*Gleicheniidites*, *Cyathidites*, *Neoraistrickia*), and the pollen assemblage chiefly bisaccate (*Alisporites*, *Vitreisporites*, ?*Falcisporites*) and few monosulcate (*Cycadopites*) types. Single specimens of ?*Exesipollenites* and ?*Gliscopollis* were also found.

The assemblage is dominated by dinoflagellates. The most common form is ?*Geiselodinium*, with very sparse ?*Batiacasphaera*, *Suessia*, and *Phallocysta* as additional elements. The acritarch assemblage is small and contains chiefly *Micrhystridium* and ?*Lecaniella*.

Zonal affinities

According to Helby *et al* (1987) the presence of *Cycadopites stonei* and *Enzonalasporites vigens* restricts the spore-pollen assemblage to the *Minutosaccus crenulatus*/*Ashmoripollis reducta* zonal interval in their upper *Falcisporites* Superzone (Fig. 3). The presence of *Gleicheniidites*, ?*Araucariacites fissus*, and cf. *Callialasporites turbatus* (all very rare) suggests that the assemblage may be transitional between the *Ashmoripollis reducta* and *Corollina torosa* Zones.

The presence of *Suessia listeri* restricts the dinoflagellate assemblage to Helby *et al.*'s (1987) *Shublikodinium* Superzone. The additional presence of *Dapcodinium priscum* indicates that it falls within the upper part of that superzone, and more specifically the basal part of the *Dapcodinium priscum* Zone. This zonal assignment is suggested also by the absence of the nominate species of the preceding *Rhaetogonyaulax rhaetica* Zone.

Geological age

On the combined spore, pollen, and dinoflagellate evidence Sample 95/DR07/11A is dated latest Triassic to basal Jurassic, and more specifically late Rhaetian to Hettangian.

Sample 95/DR10/4A (16°24'south, 118°10'east)
Assemblage MFP-9243

Composition

The assemblage is low in number of species and the fossils are poorly preserved. The small spore-pollen fraction is dominated by bisaccate forms (*Falcisporites*, *Minutosaccites*) and a ?mono-aperturate form (*Enzonalasporites*). Specimens of the Circumpolles group were not found, and only very few trilete spores are present (*Cyathidites*, ?*Baculatisporites*, *Gleicheniidites*).

The much larger microplankton fraction consists chiefly of the dinoflagellate species *Rhaetogonyaulax rhaetica* and the acritarch *Bartenia communis*. A few specimens of *Shublikodinium wigginsii* were found, and scarce *Micrhystridium* and *Leiosphaeridia* are also present.

Zonal affinities

The presence of *Minutosaccus crenulatus*, *Samaropollenites speciosus* (1 specimen), and *Enzonalasporites vigens* restricts the spore-pollen assemblage to the upper *Falcisporites* Superzone of Helby *et al.* (1987), specifically to the upper *Samaropollenites speciosus/Minutosaccus crenulatus* zonal interval. This assignment is also suggested by the common presence of the acritarch species*Bartenia communis*. The apparent absence of Circumpolles elements,which in Western Australia are common to abundant in assemblages from the upper *Minutopollenites crenulatus* Zone upwards, may be significant.

The abundant presence of *Rhaetogonyaulx rhaetica* restricts the marine assemblage to the zone of the same name in Helby *et al.*'s (1987) upper *Shublikodinium* Superzone.

Geological age

On the zonal intercorrelations given by Helby *et al.* (1987) and shown in Figure 3 the spore-pollen and dinoflagellate zonal assignments do not coincide or even overlap in time. It is clear that range limits of some of the index species given by those authors need to be revised. Given the generally well-documented first appearance of *R. rhaetica* it seems reasonable to put prior weight to the marine evidence, which dates Sample 95/DR10/4A as latest Triassic (Rhaetian). The less precise spore-pollen data suggest a pre-Rhaetian age for the sample.

Sample 95/DR07/4A (16°18'south, 118°23'east)
Assemblage MFP-9239

Composition

This assemblage is dominated by spores and pollen grains. Relatively few spores are present, and in the group of trilete spores *Dictyophyllidites* dominates, with very rare *Calamospora*, *Neoraistrickia*, *Baculatisporites*, and *Cyathidites*. Several monolete types are present. The much larger fraction of pollen grains includes mostly bisaccate (*Alisporites*, *Falcisporites*) and several monosulcate types, and very rare *Callialasporites*, *Ephedripites*, *Enzonalasporites*, and *Gliscopollis*.

The microplankton assemblage is relatively large but not very diverse. The dinoflagellate population is dominated by *Suessia* spp., and includes also *Shublikodinium*, ?*Dissiliodinium*, and ?*Dapcodinium*. The large acritarch population is dominated by *Micrhystridium*; several *Veryhachium* types and *Bartenia* are present, and *Tasmanites*, *Lecaniella*, and *Leiosphaeridia* have also been found.

Zonal affinities

The spore-pollen assemblage is characteristic of the upper *Falcisporites* Superzone of Helby *et al.* (1987). The presence of *Cycadopites stonei*, *Ephedripites macistratus*, and single specimens of *Ashmoripollis reducta* and *Gliscopollis meyeriana* restricts the assemblage to their *Minutosaccus crenulatus/ Ashmoripollis reducta* zonal interval (Fig. 3). The presence of ?*Zebrasporites* sp. A (only a single specimen) suggests that the assemblage may be placed in the lower *Ashmoripollis reducta* Zone.

The presence of the microplankton species *Suessia swabiana*, *S. listeri*, *Shublikodinium wigginsii*, and *Bartenia communis* places the marine assemblage in the *Sublikodinium* Superzone, within the *Suessia listeri/Rhaetogonyaulax rhaetica* zonal interval of Helby *et al.* (1987). The presence of *Dapcodinium priscum* (identified by only 2 specimens) and the apparent absence of *Rhaetogonyaulax rhaetica* suggests that the assemblage should be placed slightly below the *Rhaetogonyaulax rhaetica* Zone.

Geological age

The spore-pollen evidence indicates a Late Triassic (Norian) to lowermost Jurassic age for Sample 95/DR07/4A. The almost total absence of the Circumpolles group suggests that the fossils are older than Jurassic, and this is supported by a Late Triassic (Norian) age suggested by the microplankton. On the species distribution ranges given by Helby *et al.* (1987) the sample is dated Late Triassic, and probably late Norian to early Rhaetian.

SECOND PART: CRUISE 96

Samples were dredged from the Carnarvon Basin and Terrace, southwest Exmouth Plateau margin, Rowley Terrace, and Scott and Wallaby Plateaus (Colwell, Graham, *et al.* 1990). J.B. Colwell selected a series of 23 samples for palynology, and like those from Cruise 95 most samples yielded abundant fossil assemblages. The evidence from the palynomorphs is summarised in Table 2.

The samples from Carnarvon Terrace, except 96DR06/2 whose age is uncertain, range from Late Jurassic (Oxfordian?) to Middle Cretaceous (Aptian) in age. They yielded moderately to well-preserved fossil assemblages which have in common small to moderate spore-pollen fractions, large and species-diverse marine dinoflagellate fractions, and few acritarchs. With the exception of that from 96DR06/2 the assemblages indicate open (probably shallow) marine depositional environments for the sampled strata.

The samples from the offshore Canning Basin are dated latest Triassic and Jurassic and - with exception of 96DR28/11B - yielded rich and moderately to well-preserved fossil assemblages. The Bajocian and older samples represent coastal environments, and those of Bathonian and younger age open to restricted marine environments.

Two of the three samples from the Scott and Exmouth Plateaus yielded poorly preserved assemblages, which may be of Jurassic age and probably represent coastal to nonmarine environments.

EXAMINATION OF SAMPLES

CARNARVON TERRACE

Sample 96DR01/3A (23°42'14"south, 111°16'30"east)
Assemblage MFP-9246

Composition

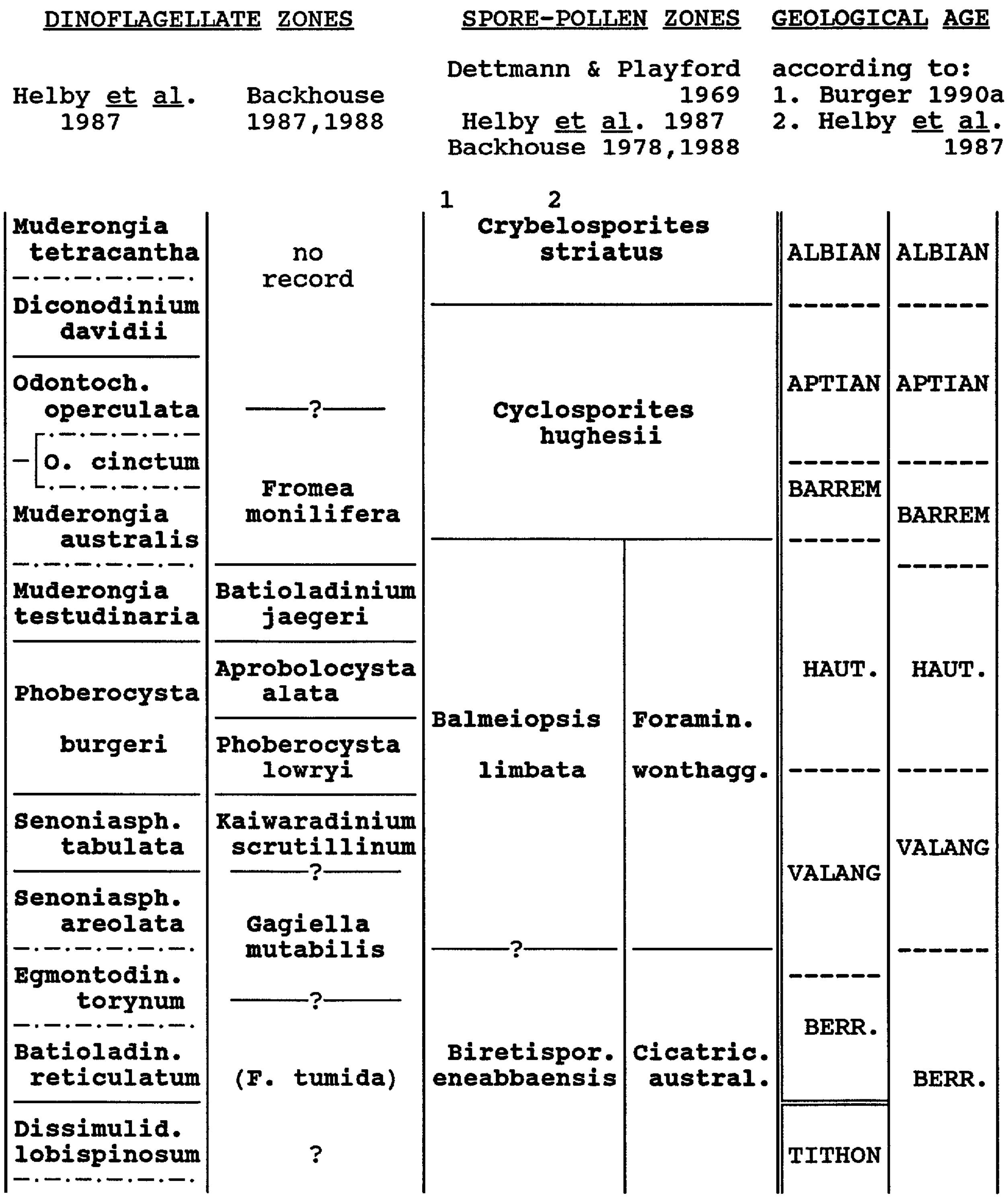
The assemblage includes a spore-pollen fraction with only few spores (mainly *Gleicheniidites*) and relatively common pollen, almost exclusively bisaccate (*Podocarpidites* and *Alisporites*, rare *Rugubivesiculites*) and trisaccate forms (*Microcachryidites*, *Podosporites*).

The dinoflagellate population includes common *Muderongia* and ?*Batiacasphaera*. The acritarch assemblage is very restricted and includes *Micrhystridium* and sporadic *Leiosphaeridia*.

Field number 96DR	Palyn. number (MFP)	associations to palynological zones		envir. of depos.
		spores and pollen	dinoflagellates	
		Carnarvon Terrace		
01/3A	9246	?	Odont. operculata	4
08/4	9253	Balmeiopsis limbata?	Muderong. testudinaria	4
08/3	9252	Cic. australiensis?	P.burgeri-M.testudin.	4
07/12	9251	Balmeiopsis limbata?	P.burgeri-M.testudin.	4
08/5	9254	Balmeiopsis limbata?	upper? S. tabulata	4
07/7	9250	u.Biret. eneabbaens.?	Senoniasph. tabulata	4
05/5	9247	?	upper? B. reticulatum	4
05/6	9248	?	O.montgom.-D.jurassic.	4
06/2	9249	?	?	3-4?
		Offshore Canning Basin		
15/2	9259	---	Dingodin. jurassicum?	3
12/1	9255	Contign. cooksoniae?	O.montgom.-l.D.jurass.	4
13/4	9256	lower C. cooksoniae?	O.montgom.-D.jurass.?	4
14/5	9257	Contign. cooksoniae	?	3
14/10	9258	Dictyotospor. complex	Caddasphaera halosa?	2
16/2	9260	Dictyotospor. complex	?	2
28/15	9265	lower Dict. complex	?	2
17/5	9261	lower? Dict. complex	?	2
17/9	9262	lower Dict. complex	---	2
28/11B	9263	?	?	3-4?
28/14	9264	M.crenul.-l.C.torosa	---	2
		Scott & Exmouth Plateaus		
35/2	9267	upper Call.turbatus +	?	3?
23/2	9266	upper Coroll.torosa +	---	1
35/3	9356	---	---	--

environments of deposition: 1 - nonmarine 3 - restricted marine
2 - paludal 4 - open marine

TABLE 2. Cruise 96 samples: geological age and palaeoenvironments



———— zonal limits defined by oldest occurrence of selected palynomorph species

—·—·—·—·— zonal limits defined by other palynological criteria

FIGURE 4. Australian Early Cretaceous palynological zones

Zonal affinities

Biostratigraphic conclusions can be drawn only from the marine fossils (Fig. 4). The presence of *Muderongia* and *Odontochitina* places the assemblage within the upper *Muderongia* Superzone of Helby *et al.* (1987). The presence of *Muderongia australis*, *Ascodinium cinctum*, and *Diconodinium boydii*, and the absence of *Diconodinium davidii* and *Pseudoceratium turneri* suggests that the assemblage falls within the *Odontochitina operculata* Zone of Morgan (1977, modified by Helby *et al.* 1987).

Geological age

In the Great Artesian Basin the equivalent interval of the *Odontochitina operculata* Zone is associated with Aptian ammonites (Morgan 1980; Burger 1980), and Sample 96DR01/3A is here dated Aptian. Nannofossils from the same dredge line (DR01/5) have been dated early Albian (Shafik, *in* Colwell, Graham, *et al.* 1990).

Sample 96DR08/4 (21°50'56"south, 112°45'41"east)
Assemblage MFP-9253

Composition

The spore-pollen fraction is reasonably species-diverse, with relatively few trilete and monolete spores (*Cyathidites*, *Contignisporites*, *Laevigatosporites*, *Cicatricosisporites*) and common pollen grains, mainly *Alisporites*, *Microcachryidites*, and *Podocarpidites*, and scarce *Classopollis* and *Callialasporites*.

The dinoflagellate fraction includes common *Sentusidinium*, *Cleistosphaeridium*, *Mendicodinium*, and infrequent *Phoberocysta*, *Gonyaulacysta*/*Cribroperidinium*, *Circulodinium*, *Muderongia*, and *Dingodinium*. A tiny acritarch fraction includes *Leiosphaeridia*, *Micrhystridium*, and *Veryhachium*.

Zonal affinities

In a biostratigraphic sense the spore-pollen assemblage is not very clear-cut (Fig. 4). The presence of *Cicatricosisporites* spp, *Laevigatosporites belfordii*, and *Retitriletes watherooensis* places it in the middle *Microchachryidites* Superzone of Helby *et al.* (1987). Based on the youngest known occurrence of *L. belfordii* in eastern Australia (see Burger 1976b, 1988) the assemblage may be not younger than the lower *Cyclosporites hughesii* Zone. Several other species characteristic of that interval, such as *Biretisporites eneabbaensis*, *Foraminisporis*, and *Pilosisporites*, were not found, but the presence of *Concavissimisporites crassatus* (a single specimen only) suggests that the assemblage may be not older than Backhouse's (1988) *Balmeiopsis limbata* Zone.

The dinoflagellate assemblage includes *Muderongia tetracantha* and *Phoberocysta burgeri*, and therefore is not older than the *Phoberocysta burgeri* Zone of Helby *et al.* (1987). The additional presence of *Dingodinium cerviculum*, *Senoniasphaera tabulata*, and cf. *Circulodinium attadalicum* (a single specimen only) suggests that the assemblage may be restricted to the *Muderongia testudinaria* Zone.

Geological age

The spore-pollen assemblage suggests a latest Jurassic to Aptian, and perhaps Late Neocomian-early Aptian age for Sample 96DR08/4. The more specific dinoflagellate evidence dates the sample Hauterivian, and possibly late Hauterivian.

DINOFLAGELLATE ZONES Helby et al. 1987	SPORE-POLLEN ZONES Backhouse 1978,1988 Burger 1990b Filatoff & Price 1988		GEOLOGICAL AGE according to: 1. Burger 1990 2. Helby et al. 1987	
			1	2
Dissimulidin. lobispinosum	Biretispor. eneabbaensis	Cicatric. austral.	TITHON	BERR.
Cassiculosph. delicata				
Kalyptea wisemaniae			-?--?-	
Pseudoceratium iehiense			KIMM.	
Dingodinium jurassicum	Retitriletes watherooens.	Unit PJ6	------	TITHON
Omatia montgomeryi			OXFORD	
Cribroperidinium perforans				
Dingodinium swanense	Murospora florida	Unit PJ5	CALLOV	KIMM.
Wanaea clathrata				------
Wanaea spectabilis				OXFORD
Rigaudella aemula				------
Wanaea digitata			------ BATHON	CALLOV
Wanaea indotata	Contignispor cooksoniae	Unit PJ4		------
Caddasphaera halosa	Dictyotospor complex		------	BATHON
(interval not zoned)			BAJOC.	
Dissiliodinium caddaense	—·—·—·—·—	Unit PJ3		BAJOC.

——— zonal limits defined by oldest occurrences of selected palynomorph species

—·—·—·— zonal limits defined by other palynological critaria

FIGURE 5. Australian Middle and Late Jurassic palynological zones

Sample 96DR08/3 (21°50'56"south, 112°45'41"east)
Assemblage MFP-9252

Composition

The spore-pollen fraction is large and includes trilete spores (psilatrilete forms, *Baculatisporites*, and *Cicatricosisporites* as most common elements) and many gymnosperm pollen (*Alisporites*, *Vitreisporites*, *Podocarpidites*, *Microcachryidites*, *Classopollis*). Very few monolete and inaperturate forms are found.

The dinoflagellate fraction is equally large. *Mendicodinium*, *Batiacasphaera*, and *Leberidocysta* are the most common genera, and are accompanied by *Muderongia*, *Circulodinium*, *Sentusidinium*, *Kaiwaradinium*, and the group of *Gonyaulacysta-Cribroperidinium*. The small acritarch fraction includes *Leiosphaeridia* and *Veryhachium*.

Zonal affinities

The presence of *Cicatricosisporites*, *Antulsporites saevus*, and *Concavissimisporites concavus* suggests that the spore-pollen assemblage is not younger than the lower *Biretisporites eneabbaensis* Zone or the *Cicatricosisporites australiensis* Zone (Helby *et al.* 1987; Backhouse 1988).

The presence of the dinoflagellate species *Muderongia testudinaria*, *M. australis*, *Senoniasphaera tabulata*, *Phoberocysta burgeri*, and *Kaiwaradinium scrutillinum* restricts the marine assemblage to the interval of the *Phoberocysta burgeri* and *Muderongia testudinaria* Zones.

Geological age

The spore-pollen evidence suggests that Sample 96DR08/3 may not be younger than basal Valanginian, but the dinoflagellate evidence, which in this instance is more reliable, places the sample in the Hauterivian.

Sample 96DR07/12 (21°52'40"south, 112°43'07"east)
Assemblage MFP-9251

Composition

The assemblage includes a spore-pollen fraction with few trilete spores (*Gleicheniidites*, *Cyathidites*, *Baculatisporites*) and a much larger saccate pollen element (*Podocarpidites*, *Alisporites*, *Microcachryidites*), as well as *Classopollis*.

The marine dinoflagellate fraction is very rich in species (see below), and the small acritarch population includes common *Leiosphaeridia* and aff. *Fromea*.

Zonal affinities

Although the spore-pollen assemblage includes mostly long-ranging species the association of *Cicatricosisporites* spp., *Biretisporites eneabbaensis*, *Reticuloidosporites arcus*, and *Balmeiopsis robusta* (all very rare) indicates that it is not older than the *Balmeiopsis limbata* Zone of Backhouse (1978).

The rich dinoflagellate assemblage includes common *Muderongia testudinaria*, *Senoniasphaera tabulata*, *Canningia reticulata*, moderate *Muderongia tetracantha*, *Chlamydophorella nyei*, and rare *Cassiculosphaeridia magna*, *Gardodinium attenuatum*, *Muderongia mcwhaei*, *Sentusidinium aptiense*, *Occisucysta tenuiceras*, and *Fibradinium variculum*. The apparent absence of *Odontochitina operculata* restricts the assemblage to the lower *Muderongia* Superzone of Helby *et al.* (1987), and the co-presence of *M. tetracantha* and *M. testudinaria* indicates the assemblage to fall within their *Phoberocysta burgeri* to *Muderongia testudinaria* zonal interval, and zone DK3 of Burger (1982).

Geological age

The spore-pollen evidence indicates an Early Cretaceous, maximum Valanginian age for Sample 96DR07/12 (see Backhouse 1988), and the dinoflagellate assemblage places the sample more specifically within the Hauterivian.

Sample DR08/5 (21°50'56"south, 112°45'41"east)
Assemblage MFP-9254

Composition

The spore-pollen fraction includes few trilete spores, such as *Cyathidites*, *Lycopodiumsporites*, and *Cicatricosisporites*, and the relative large group of gymnosperms includes *Microcachryidites*, *Podocarpidites*, *Alisporites*, *Callialasporites*, *Classopollis*, and scarce *Inaperturopollenites*). The most common elements in the dinoflagellate fraction are *Sentusidinium*, ?*Batiacasphaera* spp., *Mendicodinium*, *Gonyaulacysta*/*Cribroperidinium*, *Senoniasphaera*. Very few acritarchs were found (*Leiosphaeridia*, *Micrhystridium*).

Zonal affinities

The spores and pollen can be dated as not older than the *Cicatricosisporites australiensis* Zone. The possible presence of *Balmeiopsis robusta* suggests the assemblage to be not older than the *Balmeiopsis limbata* Zone of Backhouse (1988). The age of the dinoflagellate assemblage can be pinpointed more accurately. The presence of *Gardodinium attenuatum*, *Phoberocysta neocomica*, and common *Senoniasphaera tabulata*, and the absence of *Phoberocysta burgeri* and known *Muderongia* species (only a single specimen of a probably new species was found) places the assemblage within the (upper) *Senoniasphaera tabulata* Zone of Helby *et al.* (1987).

Geological age

On the evidence of the dinoflagellates Sample 96DR08/5 may be dated (late) Valanginian (Helby *et al.* 1987; Burger 1990a).

Sample 96DR07/7 (21°52'40"south, 112°43'07"east)
Assemblage MFP-9250

Composition

The assemblage includes a spore-pollen fraction including several trilete types (*Lycopodiumsporites*, *Cyathidites*, *Cicatricosisporites*, *Baculatisporites*) and a relatively large bisaccate conifer component (*Podocarpidites*, *Callialasporites*, *Microcachryidites*) and several other gymnosperms (*Alisporites*, *Vitreisporites*, *Araucariacites*).

Among the most common elements in the dinoflagellate fraction are *Cleistosphaeridium*, *Oligosphaeridium*, aff. *Batiacasphaera*, *Sentusidinium*, *Senoniasphaera*, and (mostly fragmented) elements of the *Gonyaulacysta*/*Cribroperidinium* group. The minute acritarch fraction includes *Leiosphaeridia* and *Veryhachium*.

Zonal affinities

The presence of *Cicatricosisporites* spp., especially *Cic. hughesii*, and *Crybelosporites stylosus* suggests that the spore-pollen assemblage is not older than the upper *Biretisporites eneabbaensis* Zone of Backhouse (1987). The absence of several other Early Cretaceous zonal indicators, such as *Biretisporites*, *Pilosisporites*, and *Foraminisporis* may not be significant in view of the low yield of fossils.

The dinoflagellate assemblage includes *Phoberocysta neocomica* and *Cassiculosphaeridia magna*, and lacks convincing *Muderongia*, and for that reason is placed within the *Senoniasphaera tabulata* Zone of Helby *et al.* (1987).

Geological age

The dinoflagellate evidence establishes Sample 96DR07/7 as (late?) Valanginian, and the spore-pollen evidence indicates a similar maximum age for the sample.

Sample 96DR05/5 (21°52'07"south, 112°43'45"east)
Assemblage MFP-9247

Composition

The spore-pollen fraction includes some spore species and a complement of bisaccate pollen (*Alisporites*) and other gymnosperm elements (*Callialasporites*, *Araucariacites*, *Classopollis*).

The dinoflagellate assemblage includes *Cassiculosphaeridia*, *Egmontodinium*, *Sentusidinium*, *Avellodinium*, and *Batiacasphaera* as the dominating to common forms. The acritarch fraction includes *Micrhystridium* and *Sigmopollis*.

Zonal affinities

The spore-pollen flora cannot be given a firm biostratigraphic assignment. The dinoflagellate assemblage includes common *Tubotuberella vlamingii*, which according to Backhouse (1988) does not occur above his *Kaiwaradinium scrutinillum* Zone (Fig. 4). *Muderongia* spp. were not found, and the presence of *Dingodinium jurassicum*, *Hystrichogonyaulax serrata*, and common *Egmontodinium torynum* suggests that the assemblage is not younger than the *Dingodinium jurassicum* Zone of Helby *et al.* (1987). The presence of *Cassiculosphaeridia delicata* and *C. magna* suggests that the fossils represent the (upper) *Batioladinium reticulatum* Zone of Helby *et al.* (1987).

Geological age

The spores and pollen do not allow an age determination for Sample 96DR05/5 except that the presence of *Cicatricosisporites* and *Crybelosporites stylosus* restricts the sample to the latest Jurassic to Early Cretaceous (Aptian). Burger (1990a) argued that the *Batioladinium reticulatum* Dinoflagellate Zone is probably of basal Cretaceous (Berriasian) age, and that age is suggested for this sample.

Sample 96DR05/6 (21°52'07"south, 112°43'45"east)
Assemblage MFP-9248

Composition

The assemblage includes a spore-pollen component with several trilete spore species, and it is dominated by saccate pollen (*Alisporites*, *Podocarpidites*, and *Microcachryidites*) and other gymnosperm elements (*Araucariacites*, *Classopollis*).

The dinoflagellate component is much more diverse in species. *Mendicodinium* is most common, and *Batiacasphaera*, *Egmontodinium*, *Hystrichodinium*, and *Circulodinium* are among the significant secondary elements. The acritarch fraction includes chiefly *Leiosphaeridia*, *Micrhystridium*, and *Veryhachium*.

Zonal affinities

The spore-pollen assemblage is too poor for a biostratigraphic determination. On the presence of *Biretisporites eneabbaensis* and *Cicatricosisporites* spp. the assemblage is taken as not older as the *Biretisporites eneabbaensis* Zone of Backhouse (1978), or the *Cicatricosisporites australiensis* Zone of Helby *et al.* (1987) and Burger (1989).

The dinoflagellate assemblage includes *Omatia montgomeryi*, *Cyclonephelium densebarbatum*, *Egmontodinium torynum*, and *Dingodinium jurassicum*, and lacks *Cassiculosphaeridia delicata* and *Pseudoceratium iehiense*. This species association restricts the assemblage to the interval of the *Omatia montgomeryi* and *Dingodinium jurassicum* Zones (Fig. 5).

The species association found in this assemblage raises questions with regard to individual species range limits given by Helby *et al.* (1987) for this part of the sequence. The presence of the spore genus *Cicatricosisporites*, which according to those authors does not appear prior to their *Pseudoceratium iehiense* Zone, means that either the range of that genus must be extended further downwards (a view held by this author), or that the dinoflagellate assemblage represents the *Pseudoceratium iehiense* Zone, in spite of the fact that a) the guide species *P. iehiense* was not found, and b) according to Helby *et al.* the species *Omatia montgomeryi* does not range upwards into that zone.

Geological age

On the assumption that the marine fossils represent the *Omatia montgomeryi-Dingodinium jurassicum* zonal interval Sample 96DR05/6 is dated Late Jurassic, either Tithonian or (late) Oxfordian.

Sample 96DR06/2 (21°52'06"south, 112°43'05"east)
Assemblage MFP-9249

Composition

A large amount of coalified plant matter and very few poorly preserved plant microfossils were recovered from this sample. The assemblage includes long-ranging Jurassic-Early Cretaceous pollen and dinoflagellate species, as well as several Late Cretaceous or Tertiary pollen grains.

Geological age

Keeping in mind the age span represented by the other samples investigated from the Carnarvon Terrace it seems reasonable to accept a middle Mesozoic age also for Sample 96DR06/2, but the fossil evidence does not allow its age to be narrowed down further than late Early Jurassic to Neocomian.

OFFSHORE CANNING BASIN

Sample 96DR15/2 (16°50'06"south, 117°37'59"east)
Assemblage MFP-9259

Composition

The assemblage is virtually bereft of spores and pollen grains; only a few unidentified (very probably recycled) trilete forms, single specimen of *Callialasporites dampieri* and *Classopollis*, and remnants of a bisaccate pollen grain were found. The dinoflagellate fraction consists largely of *Rigaudella* spp., which forms tangled clusters in the preparation. Other common types are *Gonyaulacysta*/*Cribroperidinium*, *Egmontodinium*, ?*Escharisphaeridium*, *Ellipsoidictyum*, and *Hystrichogonyaulax*. The tiny acritarch group includes *Leiosphaeridia* and *Schizocystia.*

Zonal affinities

The dinoflagellate assemblage is rather restricted, but the presence of *Hystrichogonyaulax serrata* and *Systematophora areolata* suggests that it is not older than the middle *Fromea cylindrica* Superzone of Helby *et al.* (1987). The assemblage's upper zonal limit is difficult to estimate, since the absence of forms typical of the upper part of the superzone may not be of much significance. Davey (1987) reported *Nannoceratopsis pellucida* not above his *Nummus similis* Zone in Papua New Guinea, which includes «relatively abundant» *Rigaudella*. This zone falls within the *Dingodinium jurassicum* Zone of Helby *et al.* (1987) in Australia, and based on species range limits the assemblage is placed provisionally in the *Dingodinium jurassicum* Zone, although the nominate species was not found (Fig. 5).

Geological age

The dinoflagellate evidence suggests that Sample 96DR15/2 is late Oxfordian-early Kimmeridgian in age. Much younger (Ryazanian to Hauterivian) calcareous nannofossils were recovered from other samples (15/01, 15/05) in this dredge line (Shafik, *in* Colwell, Graham, *et al.* 1990).

Sample 96DR12/1 (16°54'30"south, 117°36'05"east)
Assemblage MFP-9255

Composition

The spore-pollen and dinoflagellate assemblages are moderately poor in number of species. The first is dominated by the gymnosperm elements *Callialasporites* (common), *Classopollis* (moderate), and *Araucariacites* (infrequent). There are only few trilete forms (common *Gleicheniidites*, rare *Cyathidites*, *Dictyophyllidites*, *Matonisporites*, *Baculatisporites*). The marine assemblage is fractionally more abundant, and is dominated by *Batiacasphaera*, *Mendicodinium*, *Komewuia*, and *?Leiosphaeridia perthensis*. A very small acritarch component consisting of *Leiosphaeridia*, *Micrhystridium*, and *Veryhachium* is also present.

Zonal affinities

The presence of *Contignisporites* spp. indicates that the spore-pollen assemblage is not older than the *Contignisporites cooksoniae* Zone (Fig. 5). According to Helby *et al.* (1987) the presence of *Microcachryidites antarcticus* indicates that the fossils are not older than the succeeding *Murospora florida* Zone, but *M. florida* was not found, and neither were several other species reported to appear first within that zone by Filatoff (1975), Helby *et al.* (1987), and Filatoff & Price (1988).

The dinoflagellate assemblage consists largely of as yet undescribed species, whose stratigraphic distribution is not known. Among several identified species *Komewuia glabra* is biostratigraphically the most significant one, as Helby *et al.* (1987) reported it only from their *Omatia montgomeryi* and lower *Dingodinium jurassicum* Zone.

Geological age

The dinoflagellates indicate a younger biostratigraphic age for assemblage MFP-9255 than the spores and pollen, and in view of their comparative diversity are here taken as more reliable biostratigraphic indicators. Helby *et al.* (1987) placed the *Omatia montgomeryi/Dingodinium jurassicum* zonal interval in the Tithonian. Burger (1990b) suggested a (late) Oxfordian to basal Kimmeridgian age for that interval, and on his arguments Sample 96DR12/1 is dated as (late) Oxfordian.

Sample 96DR13/4 (16°54'24"south, 117°38'27"east)
Assemblage MFP-9256

Composition

The spore-pollen assemblage is reasonably varied in species. The spore group includes mostly trilete forms, such as common *Gleicheniidites*, *Cyathidites*, and *Matonisporites*. The much larger pollen group includes mainly *Callialasporites* and several bisaccate types, and *Classopollis* is an infrequent component.

The dinoflagellate assemblage dominates fractionally, and includes *Prolixosphaeridium*, *Mendicodinium*, and *Gonyaulacysta* as the most abundant forms, with *Oligosphaeridium*, *Sentusidinium*, *Kallosphaeridium*, and *Dingodinium* as common secondary elements. A very small acritarch population was observed, which includes *Micrhystridium*, *Leiosphaeridia*, and *Veryhachium*.

Zonal affinities

The spore-pollen assemblage includes *Contignisporites burgeri* and is thus not older than Filatoff's (1975) *Contignisporites cooksoniae* Zone (Fig. 5). Elements typical of younger Jurassic zonal intervals, such as *Murospora florida*, *Microcachryidites antarcticus*, and *Retitriletes watherooensis* were not found. Filatoff & Price (1988) reported *Seebergella patenii* in the Great Artesian Basin as ranging up into their Unit PJ4.1, and this unit coincides approximately with the lower *Contignisporites cooksoniae* Zone. Other clear indications for an upper zonal limit for this assemblage are not present.

In a biostratigraphic sense the dinoflagellate assemblage carries contradictory elements. Apart from many still undescribed forms it includes several long-ranging Jurassic-basal Cretaceous species, and lacks typical mid-Neocomian and younger elements. *Wanaea indotata* (2 specimens), *Nannoceratopsis* sp. (1 specimen), and a form closely resembling *Dissiliodinium caddaense* (common), together represent an Early-Middle Jurassic element, but rather disjointed, since reported ranges for those species do not overlap. Those elements may therefore have been reworked.

A Middle-Late Jurassic element is present, with *Systematophora palmula* and *Cassiculosphaeridia delicata* (single specimens), which reportedly first appear in the *Dingodinium jurassicum* and *Cribroperidinium perforans* Zones (Helby *et al.* 1987). Cookson & Eisenack (1958) reported *Cannosphaeropsis filamentosa* from Middle and Upper Jurassic strata of Western Australia. *Oligosphaeridium complex* has to date not been reported from strata older than Late Jurassic (Sarjeant 1979; Burger 1982). Wiggins (1975) described *Pareodinia robusta* from the Late Jurassic of Canada.

As to a firm zonal assignment of the assemblage: the common presence of *Dingodinium jurassicum* is a suggestive clue, but except for *Cassiculosphaeridia delicata* none of the other species which Helby *et al.* (1987) indicated to appear first within the *Dingodinium jurassicum* Zone was found. Therefore the assemblage is placed tentatively within the *Omatia montgomeryi/Dingodinium jurassicum* zonal interval.

Geological age

Sample 96DR13/4 is regarded as of (late?) Oxfordian age (see dicussion for the previous sample). Shafik (*in* Colwell, Graham, *et al.* 1990) retrieved Early Cretaceous calcareous nannofossils from several samples (13/03, 13/05, 13/08) in the same dredge line.

Sample 96DR14/5 (16°50'01"south, 117°35'13"east)
Assemblage MFP-9257

Composition

The spore-pollen assemblage is reasonably small and includes a trilete component dominated by *Gleicheniidites*, *Cyathidites*, and *Matonisporites*, and a larger pollen component dominated by *Callialasporites* and *Araucariacites*, and in which *Classopollis* is a modest element.

The dinoflagellate assemblage is fractionally large but very restricted. The dominating forms are identified as *Batiacasphaera* and allied forms, and *Mendicodinium*, with *Komewuia ?glabra* and *Wanaea* sp. (granulate species, see Helby *et al.* 1987 Fig. 17B,C), as significant secondary elements. A small acritarch assemblage includes *Micrhystridium*, *Leiosphaeridia*, and extremely rare *Veryhachium* and *Lecaniella*.

Zonal affinities

The presence of *Contignisporites* and the absence of *Murospora florida* suggests that the spore-pollen assemblage falls within the *Contignisporites cooksoniae* Zone of Filatoff (1975). Zonal affinity of the dinoflagellate assemblage is uncertain because of the scarcity of truly marine forms. Helby *et al.* (1987) reported *Wanaea* (granulate sp.) only from their *Pareodinia ceratophora* Superzone, but the presence of *Komewuia*, as well as *Scriniodinium crystallinum* and *Cassiculosphaeridia delicata* (single specimens) suggests affinity to their lower *Fromea cylindrica* Superzone.

Geological age

The spore-pollen evidence dates Sample 96DR14/5 as late Bajocian to early Bathonian. The less specific dinoflagellate data suggest that the sample is Oxfordian-Kimmeridgian. This discrepancy may probably be attributed also to insufficient documentation of species ranges, and the spore-pollen age is here taken as more reliable.

Sample 96DR14/10 (16°50'01"south, 117°35'13"east)
Assemblage MFP-9258

Composition

The spore-pollen assemblage is reasonably large and contains a comparatively small spore fraction including chiefly psilatrilete forms (*Gleicheniidites*, *Matonisporites*, *Cyathidites*), and *Klukisporites*, *Lycopodiumsporites*, and *Baculatisporites* as secondary elements. The larger pollen fraction is dominated by *Callialasporites*, and includes *Araucariacites* and *Classopollis*.

The dinoflagellate assemblage is large but not species-diverse, with aff. *Batiacasphaera* and *Mendicodinium* as its main components, and scarce *Wanaea* (granulate sp.) and *Pareodinia*. The tiny acritarch assemblage includes *Leiosphaeridia*, *Schizocystia*, and *Micrhystridium*.

Zonal affinities

The spore assemblage includes ?*Camarozonosporites clivosus* (1 specimen) and *Antulsporiters saevus*, and lacks *Contignisporites*, and therefore seems to be part of Burger's (1976a) Unit J4 (Fig. 2). This zone is not recognised as such in the Western Australian Jurassic, but the presence of *Dictyotosporites complex* (very rare) and ?*Lycopodiumsporites circolumenus* (1 specimen) suggests that the assemblage falls within the *Dictyotosporites complex* Zone of Helby *et al.* (1987).

Except for *Wanaea* (granulate sp.), which is restricted to the *Caddasphaera halosa* Zone (Helby *et al.* 1987) the dinoflagellate assemblage includes no recognised zonal index species.

Geological age

The evidence from both spores-pollen and dinoflagellates dates Sample 96DR14/10 as Bajocian. Shafik (*in* Colwell, Graham, *et al.* 1990) dated calcareous nannofossils from sample 14/08 in this dredge line late Ryazanian to late Hauterivian.

Sample 96DR16/2 (16°44'05"south, 117°33'04"east)
Assemblage MFP-9260

Composition

The spore-pollen assemblage contains a small complement of trilete spores (*Cyathidites*, *Gleicheniidites*, *Lycopodiumsporites*, *Staplinisporites*) and a much larger pollen complement, in which *Callialasporites* and *Alisporites* dominate, and the Circumpolles fraction is small.

Dinoflagellates are common, the assemblage being dominated by ?*Batiacasphaera* and *Mendicodinium*. The tiny acritarch fraction includes *Schizocystia* and *Leiosphaeridia*.

Zonal affinities

This assemblage resembles very much that of MFP-9258, and the presence of *Lycopodiumsporites circolumenus*, *Camarozonosporites clivosus*, and *Dictyotosporites complex* (single specimens only) strongly suggests that the spores and pollen represent the *Dictyotosporites complex* Zone of Helby *et al.* (1987). The dinoflagellate assemblage contains no indicative species for a biostratigraphic determination.

Geological age

Like the previous sample, Sample 96DR16/2 is dated Bajocian on its contents of spores and pollen.

Sample 96DR28/15 (16°18'30"south, 118°23'25"east)
Assemblage MFP-9265

Composition

The assemblage is dominated by spores and pollen grains. A moderate trilete spore component is present including chiefly *Cyathidites*, *Osmundacidites-Baculatisporites*, *Lycopodiumsporites*, and *Gleicheniidites*. Very few monolete types are present. The equally large pollen component is dominated by *Callialasporites*, with *Vitreisporites* as a sizeable secondary component. Virtually no other bisaccate types are present, and the Circumpolles group is represented very moderately.

Very few dinoflagellate types were found (?*Batiacasphaera*), and the equally small acritarch assemblage includes chiefly *Micrhystridium*, *Leiosphaeridia*, and *Pterospermopsis*.

Zonal affinities

The presence of *Callialasporites dampieri*, *Antulsporites saevus*, *Dictyotosporites complex*, and the apparent absence of *Contignisporites* spp., *Lycopodiumsporites circolumenus*, and *Camarozonosporites clivosus* places the spore-pollen assemblage within Unit J3 of Burger (1976a), or the lower *Dictyotosporites complex* Zone of Helby *et al.* (1987). The marine assemblage is too meagre for a biostratigraphic determination (Fig. 2).

Geological age

The spore-pollen data point to a (late) Toarcian to (early) Aalenian age for Sample 96DR28/15. Calcareous nannofossils from sample 28/16 in the same dredge line are given a maximum Bajocian age (Shafik, *in* Colwell, Graham, *et al.* 1990).

Sample 96DR17/5 (16°44'53"south, 117°35'54"east)
Assemblage MFP-9261

Composition

The assemblage is dominated by the spore-pollen fraction, with common *Gleicheniidites*, *Cyathidites*, rare *Baculatisporites*, *Lycopodiumsporites*, *Staplinisporites*), and a large pollen element with *Callialasporites*, *Araucariacites*, and common *Classopollis*.

The dinoflagellate fraction consists largely of *Mendicodinium* and ?*Batiacasphaera*, and the small acritarch population includes chiefly *Leiosphaeridia* and *Micrhystridium*.

Zonal affinities

The presence of *Callialasporites dampieri*, *Lycopodiumsporites circolumenus*, *Antulsporites saevus*, and ?*Dictyotosporites complex*, and the apparent absence of *Camarozonosporites* *clivosus* and *Contignisporites* spp. suggests that the spores and pollen represent Burger's (1976a) Unit J3. Helby *et al.* (1987) reported *L. circolumenus* to appear not before their upper *Dictytosporites complex* Zone (Unit J4 of Burger 1976a), which shows again that this part of the Jurassic palynorecord presents biostratigraphic problems, due to uncertainties in recorded first appearances of species (see Fig. 2, and the discussion for assemblage MFP-9235). Records from Western and eastern Australia associate a common presence of *Classopollis* with Unit J3 and not unit J4 (or their equivalent intervals, see Reiser & Williams 1969; McKellar 1974; Filatoff 1975), and for that reason assemblage MFP-9261 is placed tentatively within Unit J3.

Geological age

The spore-pollen evidence suggests Sample 96DR17/5 to be (late) Toarcian to (early) Aalenian in age. The poor marine evidence does not contribute towards dating the sample.

Sample 96DR17/9 (16°44'53"south, 117°35'54"east)
Assemblage MFP-9262

Composition

The assemblage is dominated by the spore-pollen fraction, which includes a relatively moderate spore component, chiefly with *Gleicheniidites*, *Cyathidites*, *Lycopodiumsporites*, and a much larger pollen component, with common *Araucariacites*, *Callialasporites*, *Alisporites*, *Vitreisporites*, and Circumpolles. The marine fossil fraction is very small and insignificant.

Zonal affinities

The presence of *Callialasporites dampieri*, *Antulsporites saevus*, *Lycopodiumsporites circolumenus*, and the apparent absence of *Camarozonosporites clivosus* and *Dictyotosporites complex* places the spore-pollen assemblage in Burger's (1976a) Unit J3 (Fig. 2).

Geological age

Like the previous sample, Sample 96DR17/9 can be dated (late) Toarcian to (early) Aalenian.

Sample 96DR28/11B (16°18'30"south;118°23'25"east)
Assemblage MFP-9263

Composition

This sample yielded abundant microscopic coaly detritus but virtually no fossils.

Geological age

The few single grains observed do not allow a confident age estimation, but the presence of the pollen *Callialasporites* and (fragments of) the dinoflagellate *Rigaudella* suggests that Sample 96DR28/11B is Jurassic, and not older than late Early Jurassic.

Sample 96DR28/14 (16°18'30"south, 118°23'25"east)
Assemblage MFP-9264

Composition

The spore-pollen assemblage is large but restricted, including few trilete spores and Circumpolles elements, and an abundant bisaccate component (*Alisporites*, *Falcisporites*). The combined dinoflagellate-acritarch assemblage is very small and includes several as yet unidentified types.

Zonal affinities

The presence of *Ephedripites macistratus*, *Cycadopites stonei*, and *Classopollis* indicates that the spore-pollen assemblage falls within the upper *Falcisporites* Superzone of Helby *et al.* (1987), and is not older than the *Minutosaccus crenulatus* Zone (Fig. 3). The presence of the acritarch *Bartonia communis* supports this assignment. Other zonal index species were not found, but by the scarce presence of *Classopollis* and the abundance of *Alisporites* and *Falcisporites* this assemblage resembles De Jersey's (1976) Assemblage B in eastern Australia, which is dated late Rhaetian to Early Jurassic (?Sinemurian).

Geological age

Sample 96DR28/14 can be dated Late Triassic (Norian, perhaps late Rhaetian?) to basal Early Jurassic (?Sinemurian).

SCOTT & EXMOUTH PLATEAUS

Sample 96DR35/2 (20°10'52"south, 109°54'51"east)
Assemblage MFP-9267

Composition

The assemblage includes very few spores and pollen grains, and *Callialasporites*, *Araucariacites*, and *Classopollis* are relatively the most common elements. Several fragments of possible marine palynomorphs were found, and some fragments are tentatively identified as *Rigaudella*.

Zonal affinities

The presence of *Callialasporites dampieri* and *Antulsporites saevus* establish the spores and pollen as not older than Unit J3 of Burger (1976a), or the uppermost *Callialasporites turbatus* Zone of Helby *et al.* (1987). The scarcity of fossils prevents an upper zonal limit to be suggested for the assemblage.

Geological age

Sample 96DR35/2 may be dated as not older than late Toarcian. An upper age limit cannot be estimated, but the relatively common presence of *Classopollis* is more common in Early Jurassic (Unit J3) than Middle Jurassic (Unit J4+) assemblages (Reiser & Williams 1969; McKellar 1974; Filatoff 1975).

Sample 96DR23/2 (13°26'10"south, 119°22'15"east)
Assemblage MFP-9266

Composition

The assemblage consists almost exclusively of bisaccate pollen grains (chiefly *Alisporites*), with a tiny component of trilete spores. No recognisable marine palynomorphs have been found.

Zonal affinities

The presence of *Callialasporites dampieri* and *Matonisporites crassiangulatus* indicates that the assemblage is not older than the upper *Classopollis chateaunovi* Assemblage Subzone of Filatoff (1975). The presence of *Lycopodiumsporites ?circolumenus* (a single specimen) suggests that the assemblage may be much younger (Fig. 2). Apart from *Alisporites similis* the bisaccate population includes *Falcisporites* spp. (infrequent), ?*Samaropollenites* (rare), and *Pinuspollenites globosaccus* (rare). A low number of trisaccate pollen is also present, including *Podosporites castellanosii*, which according to Filatoff (1975) first appears together with *P. globosaccus* at the top of his *Dictyotosporites harrisii* Assemblage Subzone in the Perth Basin (Fig. 2).

An upper biostratigraphic age limit cannot be estimated for this assemblage, as the dominance of one pollen type may swamp the presence of zonal indicator species, which frequently occur in low quantities in the preparations. It may be significant that abundant bisaccate fractions have also been retrieved from Samples 95DR07/4A and 96DR28/14, both of which fall within the upper *Falcisporites* Superzone of Helby *et al.* (1987).

Geological age

Sample 96DR28/15 can be dated as not older than Toarcian. An upper age limit cannot be given, but on indirect pollen evidence the sample may possibly be regarded as Early Jurassic rather than Middle Jurassic.

PALAEOENVIRONMENTS

Late Triassic

The Upper Triassic samples 95/DR07/4A, /11A, and /DR10/4A from the northern Exmouth Plateau (Table 1) were dredged from what Exon & Ramsay (1990) referred to as a sequence of shallow marine and deltaic detrital sediments of more than 1,000 m thick, which is overlain by trachytes and rhyolites. The microplankton assemblages recovered from those samples include marine elements but are poor in numbers of species, and this indicates restricted (intermittent) connections with open marine or continental shelf environments.

Upper Triassic sample 96DR28/14 from the offshore Canning Basin (Table 2) was dredged from a sequence of fluvio-deltaic sandstone, siltstone, and limestone unconformably overlain by Jurassic alluvial plain clastics (Stagg & Exon 1981). This sample yielded only few acritarchs and virtually no recognisable marine fossils; this is interpreted to indicate at most mildly brackish environments suggestive of a more inland (coastal) facies than indicated by the other three samples.

Early Jurassic

Samples 95/DR06/1A, /DR07/14A, /DR09/2C, /DR11/3A (Table 1), and 96DR17/5, /9, and 96DR28/15 (Table 2), all from the offshore Canning Basin, represent a sequence of alluvial plain sandstone, siltstone, mudstone, and red beds unconformably overlying sediments of Triassic age (Stagg & Exon 1981). They yielded very few and restricted microplankton assemblages in which the presumed brackish element prevailed, and so are interpreted as representing mildly brackish, coastal environments where connections with the open ocean were intermittent and brief. The only exception is Sample 95/DR11/3A, which contained a few marine species and is thought to represent a shallow marine incursion into the region.

Samples 96DR23/2 and 35/2 from the western Scott Plateau and southwestern Exmouth Plateau margins (Table 2) could not be dated accurately, but if the Early Jurassic age is correct they were dredged from alluvial plain and rifting paralic strata sequences respectively (Stagg & Exon 1981; Exon & Ramsay 1990). Sample 23/2 contained fragments of marine palynomorphs, which may indicate a shallow marine incursion onto the Plateau. Sample 35/2 yielded very few and poorly preserved unidentified microplankton types, and this poor yield is taken to indicate nonmarine (e.g. non-saline) environments.

Middle Jurassic

Samples 95/DR04/16A, /DR05/5A, /9A, /DR11/7A (Table 1), and 96DR14/5, /10, and 96DR16/2 (Table 2) all represent the same thick sedimentary sequence in the offshore Canning Basin from where the abovementioned Lower Jurassic samples were dredged. But there appears to be a gradual change towards more marginally marine conditions, with a brief return of paludal environments during the Bajocian. Those changes may reflect local conditions only. The scattered sampling prevents them from being linked with eustatic sea level movements, but they reflect a slowly rising sea level for that region during the Middle Jurassic, which broadly corresponds with the global sea level curve of Haq *et al.* (1987).

Late Jurassic

Samples 96DR12/1, 96DR13/4, 96DR12/1, and 96DR15/2 from the offshore Canning Basin (Table 2) were dredged from the east slope of Swan Canyon, where a sequence of Upper Jurassic to Lower Cretaceous shale, sandstone, and mudstone is exposed. This sequence rests unconformably on the abovementioned Jurassic sedimentary sequence and was deposited in paralic to restricted marine environments (Stagg & Exon 1981). Samples 12/1 and 13/4 represent levels of open marine environments, and due to its peculiar marine assemblage sample 15/2 might represent hyposaline (evaporative?) conditions.

An Upper Jurassic sample dredged further south (96DR05/6, Table 2) indicates open marine environments also for the northern Carnarvon Terrace (Dingo Claystone?, see Colwell, Graham *et al.* 1990, and Burger 1990b).

Early Cretaceous

Six Neocomian samples (96DR05/5, 96DR06/2, 96DR07/7,/12, 96DR08/3-5) and one Aptian sample (96DR01/3A) were dredged from the Carnarvon Terrace (Table 2). These samples represent the Barrow and lower Winning Groups or their western correlative intervals, and indicate open marine environments during the Neocomian and Aptian. Due to the scattering of the sample localities the author has not tried to recognise Neocomian sea level movements logged by Wiseman (1979) in the Neocomian of the Carnarvon Basin.

CONCLUSIONS

In most instances the biostratigraphic affinities of samples could be ascertained with reasonable confidence, even when interpreted on the basis of data from eastern Australia only. This exercise has confirmed that broad spore-pollen correlations between the Mesozoic of eastern and Western Australia are possible, and confirmed a few remaining problems still existing for the Early Jurassic outlined by Burger (1990b).

There still differences of opinion as to geological ages of various zonal intervals discussed, especially in the Middle and Late Jurassic. In some instances (dredge lines 95/DR04 and /06) palynological determinations agreed reasonably well with ages based on foraminiferal and nannofossil evidence. Unavoidably, stratigraphic relationships within series of samples collected from single dredge profiles are uncertain, and it is not possible to assess the considerable age discrepancies apparent from other localities (dredge lines 95/DR07, 96DR01, 14, 15, and 28).

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