

Early Tertiary pollen from Napperby, central Australia

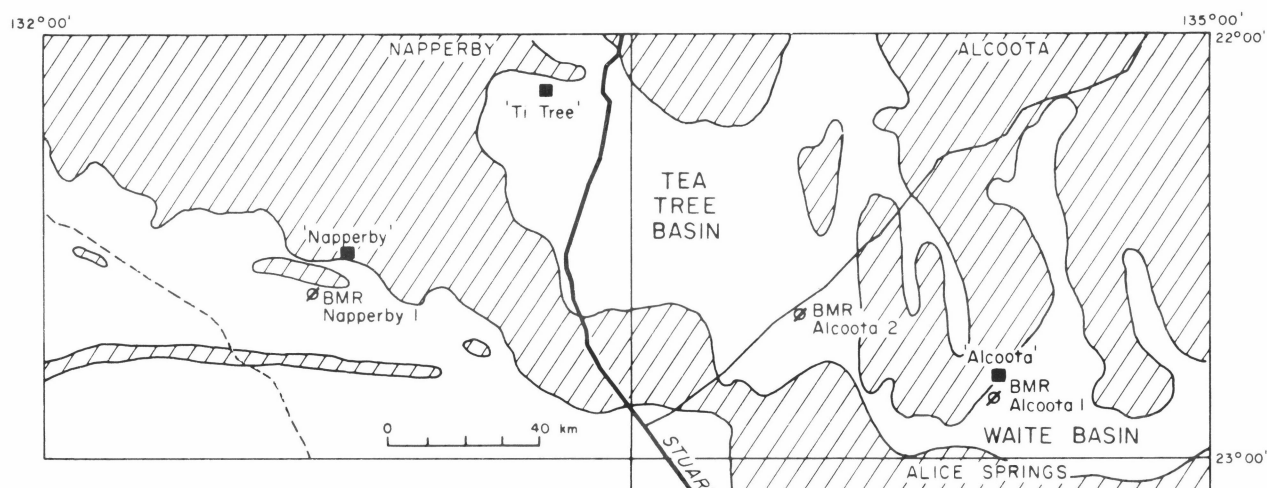
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Carbonaceous clays in a stratigraphic borehole near Napperby homestead, in the southern part of the Northern Territory, have yielded a microfloral assemblage comprising over thirty form-species of pollen. The assemblage can be referred to the middle Eocene *Proteacidites confragosus* Zonule on the basis of the presence of the nominate species, and is the most inland of any Australian Tertiary flora described. The Napperby sediments may be correlated, on a palynological basis, with the upper part of the Eyre Formation of northeastern South Australia; they are older than the vertebrate-bearing Waite Formation of the adjoining Alcoota Sheet area. A high frequency of pollen from aquatic and marsh-loving angiosperms and the presence of dinoflagellate cysts indicates deposition under lacustrine conditions. The presence of *Nothofagus* and podocarpaceous pollen types in significant amounts suggests that a humid climate prevailed, although seasonal aridity cannot be ruled out.

Tertiary sediments in the Napperby 1:250 000 Sheet area in the Northern Territory overlie folded Adelaidean and Palaeozoic sedimentary rocks (Evans, 1972). The sediments occupy depressions in the pre-Tertiary land surface and locally reach thicknesses of around 250 m (Evans & Glikson, 1967). Shallow stratigraphic drilling in the area has shown the Tertiary sequences to consist for the most part of reddish-brown, yellow and white sands and sandy clays (Evans & Nicholas, 1970). Silcrete and ferricrete beds occur in several of the drilled sections, and as cappings on exposures of older rocks; the relationship between these

beds in outcrop and in the subsurface is presently unknown. Subdivision and formal naming of the units present have yet to be attempted.

The age of the Tertiary sequence in the region is difficult to determine as it generally lacks fossils. Palynology appears to offer the best scope for setting up a chronology because of the probable continental origin of the sediment, but even this tool is hampered by deep weathering and by the sandy nature of many sediments. Attempts were made in this investigation to recover pollens from core samples from nine shallow stratigraphic holes on Napperby and the



adjoining Mount Doreen and Alcoota Sheet areas, but only one locality, BMR Napperby 1 borehole, was productive. Lignitic clays at the base of the drilled sequence at this site were examined in a preliminary way by D. Burger, who suggested a 'post-Eocene—pre-Pliocene' age for them (quoted in Evans, 1972). In the present study this material has been re-processed and re-examined, and the age revised in the light of refinements which have been made in Australian Tertiary stratigraphic palynology during the last five years. The revised, more precise dating permits interpretation, although still in broad terms, of the relationship of this part of the Napperby sequence to Tertiary sequences in northeastern South Australia, which have recently been dated by palynological means (Wopfner *et al.*, 1974), and to sequences on the Alcoota Sheet which are dated by vertebrate fossils (Woodburne, 1967). Additionally, the Napperby microflora, which is the most inland of any Australian Tertiary pollen assemblage described, permits some broad inferences to be made regarding Early Tertiary climates in the region, and throws new light on the past distribution of some plant taxa.

Sample details

The BMR Napperby 1 borehole is situated some 13.5 km southwest of Napperby Homestead (Grid reference 587.5, 179.8 and Figure 1), at latitude 22°36'4"S and longitude 132°40'1"E. The sequence penetrated at the site is illustrated in Figure 2. Only Core 2, cut in the interval 135.94–138.99 m was suitable for the recovery of palynomorphs. Four samples from within this interval were macerated, from depths of 138.07 m, 138.25 m, 138.68 m and 138.83 m. The upper three samples, designated by the BMR palynological collection numbers MFP 4964, 6621 and 6622, were taken from a brownish-grey puggy clay; the fourth, MFP 6623, was cut in grey clay containing an abundance of black lignitic material.

Composition of the microflora

Plant microfossils were recovered from all four samples of core 2. They are excellently preserved, and over 30 form-species of pollen and spores were identified. These are listed in Table 1, and forms of particular stratigraphic or ecological interest are illustrated in Figure 4. Additionally, some five species of dinoflagellate cysts and acritarchs were isolated; these are grouped together in Table 1. It seems probable that these are fresh water types as they occur in sediments of lignitic character, but their identification could only be made to broad categories. The four closely spaced samples examined in this study differ from each other in the proportions of the major palynomorphs in each, probably as a result of rapid, minor fluctuations in local depositional environments.

In their general aspect, the microfloral assemblages have much in common with Palaeogene microfloras known from southern Australia. Pollen of *Nothofagus* Bl. (as *Nothofagidites* spp.) is present in proportions ranging from 5 to 50 percent; only grains of the *brassi* species group were observed. Casuarinaceae is well represented, as the form-species *Haloragacidites harrisii* (Couper) Harris, which occurs in relative frequencies of from 6 to 48 percent. Proteaceous pollen occurs in some diversity, with at least nine form-species recognizable. Pollen of Myrtaceae, which is usually common in southern Australian assemblages, is, however, rare, reaching maxima of less than one percent in two samples. Fern spores are another rare element.

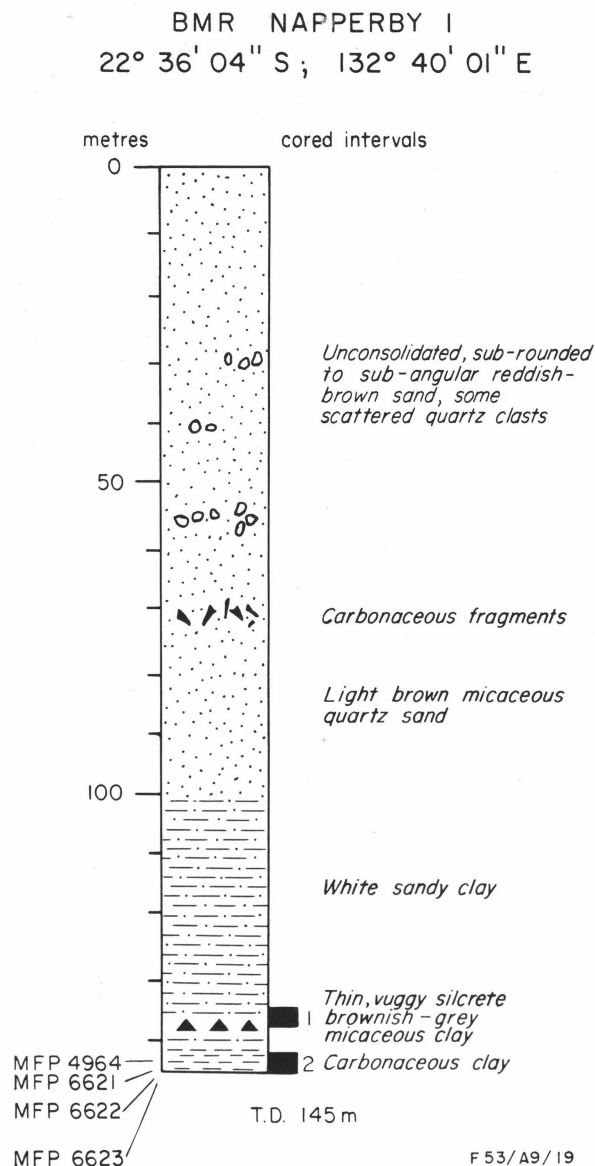


Figure 2. Lithological sequence in BMR Napperby 1 borehole. Palynological sample horizons are indicated by, MFP numbers on left of column.

Conifer pollens are dominated by those of podocarpaceous parentage: included here are representatives of the form-genera *Microcachrydites* Cookson, *Podocarpidites* Cookson, *Lygistipollenites* Stover & Evans, and a form herein informally referred to as '*Phyllocladus*' (Figure 4, f-h), which displays the small sacs characteristic of the extant genus, but for which there is presently no appropriate form-genus. The somewhat nondescript pollen of the Cupressaceae (Figure 4, d) is locally abundant.

Pollen of aquatic and marsh-loving angiosperms is represented in highest numbers in the deepest, lignitic core sample. In this interval the form-species *Aglaoreidia qualumus* Partridge (Figure 4, i, j), which probably derives from the burr reed family Sparganiaceae, occurs with a frequency of 17 percent. Pollen of Restionaceae, or bog rushes, as *Milfordia* cf. *M. hypolaenoides* Erdtman (Figure 4, k-m), and of sedges (Cyperaceae; Figure 4, a, b) also reach their highest frequencies in this sample; pollen of the latter family has hitherto only been described from Plio-Pleistocene deposits in Australia (Martin, 1973a). The Liliaceae is represented by *Liliacidites bainii* Stover (Figure 4, q, r) and

by an undescribed form-species. *Helcioporites astrus* Partridge (Figure 4, e), an angiosperm pollen of unknown affinity but some stratigraphic utility, occurs rarely in one of the higher clay samples.

Of particular botanical interest is the presence in two samples of tricolporate pollens (Figure 4, u-w) comparable to those produced by members of the extant genus *Diplopeltis* Endl. (Sapindaceae), which has not previously been identified in fossil form. The dispersed forms in the Napperby samples are morphologically closest to the pollen of the extant *D. heugelii* Endl.; presently, the genus is represented in the area by *D. stuartii* F. Muell (see distribution maps in George & Erdtman, 1969).

Dinoflagellates and acritarchs make up approximately 40 percent of the total palynomorph suite in Sample MFP 6623. Most are thin-walled and fragmented. The most common dinoflagellate is referable to the genus *Saepodinium* Harris, and is probably a new species. The acritarchs include smooth-walled *Leiosphaeridia* and spinose forms tentatively referred to *Baltisphaeridium* Eisenack emend. Downie & Sarjeant.

TABLE 1. DISTRIBUTION OF POLLEN AND SPORE FORM-SPECIES IN BMR NAPPERBY 1 SAMPLES. Sample positions are indicated in Figure 2.

	MFP 4964	6621	6622	6623
Angiosperms				
<i>Aglaoreidia qualumus</i> Partridge				0
<i>Banksiaeidites elongatus</i> Cookson	0			
Cyperaceae pollen	0	0		0
<i>Erecipites scabratus</i> Harris		0	0	0
<i>Haloragacidites harrisii</i> (Couper) Harris	0	0	0	0
<i>Helcioporites astrus</i> Partridge		0		
<i>Liliacidites bainii</i> Stover				0
<i>Liliacidites</i> sp.				0
' <i>Micrantheum</i> ' cf. <i>spinyispora</i> Martin	0	0		
<i>Milfordia</i> cf. <i>hypolaenoides</i> Erdtman		0	0	0
<i>Myrtacidites</i> sp.	0	0		
<i>Nothofagidites emarcida</i> Cookson	0	0	0	0
<i>N. falcata</i> Cookson			0	0
<i>Polycolpites</i> sp.		0		
<i>Proteacidites annularis</i> Cookson	0	0	0	0
<i>P. confragosus</i> Harris	0	0		0
<i>P. crassus</i> Cookson	0	0		0
<i>P. cf. parvus</i> Cookson	0	0	0	0
<i>P. cf. truncatus</i> Cookson	0	0		
<i>P. spp.</i> indet.	0	0		0
<i>Sapotaceapollenites rotundus</i> Harris		0		
<i>Tetracolporites</i> sp.	0			
<i>Tricolpites</i> spp.	0	0		0
<i>Tricolporites</i> sp. (aff. <i>Diplopeltis</i>)		0		0
Conifers				
<i>Araucariacites australis</i> Cookson	0	0		
<i>Lygistepollenites florinii</i> (Cookson & Pike)	0	0	0	0
<i>Microcachrydites antarcticus</i> Cookson	0	0		0
' <i>Phyllocladites</i> ' sp.	0	0		
<i>Podocarpidites ellipticus</i> Cookson	0	0		0
Cupressaceae pollen	0	0	0	
Fern spores				
<i>Cyathidites minor</i> Cookson	0	0		
<i>Gleicheniidites</i> sp.	0	0		
Dinoflagellates and acritarchs				0
<i>Botryococcus</i> sp.				0

Age of the assemblage

Biostratigraphic schemes based on spore and pollen distribution in the Australian Tertiary have been erected by

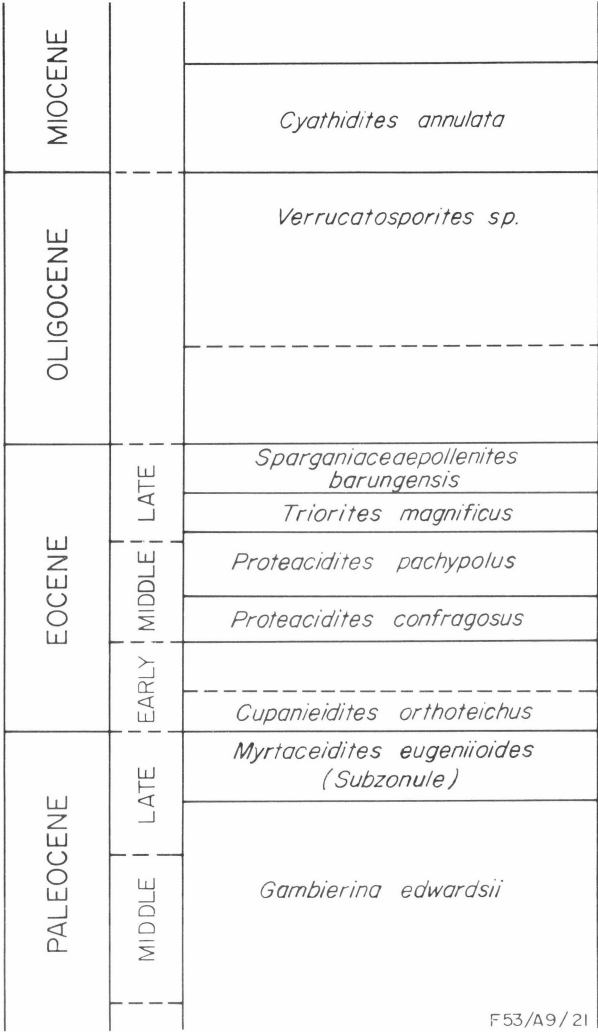


Figure 3. Palynological zonation in Tertiary sequences of the Otway Basin (after Harris, 1971).

Harris (1971), Stover & Evans (1973), Stover and Partridge (1973) and Hekel (1972). All of these schemes, with the exception of the relatively broad one of Hekel, have been derived from studies of coastal basins in the southeast, where the age of the zonal units has been provisionally established through their relationship with planktonic foraminiferal zones, although debate about the precise correlation of zonal boundaries continues. Recognition of the same palynological assemblage zones in more northerly, inland sediments involves the assumption that regional differences in the Tertiary vegetation were not pronounced, and that migration of species from one area to another did not involve geologically significant intervals of time. That these palynological assemblage zones can be recognized away from the coast has recently been demonstrated by Harris (in Wopfner et al., 1974) who identified, in north-eastern South Australia, Palaeogene zonules which were originally set up in coastal sequences of the Otway Basin. For the present, it is assumed that the zonal units are not time transgressive; in the absence of independent age control on the inland sediments this is impossible to ascertain. If the coastal and inland pollen assemblages are indeed contemporaneous, this suggests that the geographic zonation of the Australian vegetation was much less pronounced than it is today, which probably reflects a less rigorous delineation of climatic belts.

Eleven units ('Zonules') were erected by Harris (1971) in Palaeocene to Pliocene sediments of the Otway Basin of

southeastern South Australia and western Victoria (see Fig. 3); ten units have been isolated in the Late Cretaceous to Miocene sequences in the Gippsland Basin of coastal eastern Victoria (Stover & Evans, 1973; Stover & Partridge, 1973). These are based primarily on the restricted ranges of selected form-species, and are reinforced by variations in the relative abundances of long-ranging taxa. Those which have been identified inland, in the Eyre Formation of northeastern South Australia, are the *Gambierina edwardsi* Zonule, of late Palaeocene age, the *Proteacidites confragosus* Zonule, of probable middle Eocene age, and the *P. pachypolus* Zonule, which ranges from late middle to perhaps late Eocene.

The palyniferous sediments in Napperby 1 are considered to belong to Harris' *Proteacidites confragosus* Zonule, and hence to be approximately middle Eocene in age. The main justification for such an assignment rests on the presence of the nominate species in all samples. Other species which accord with the Eocene age attribution include *Helciaporites astrus*, which is described as ranging from early to late Eocene in the Gippsland Basin (Stover & Partridge, 1973), and which has also been reported from the Eyre Formation, and *Liliacidites bainii*, which has a similar known range. Additionally, a high content of Casuarinaceae pollen is typical of sediments of this zone in northern South Australia, and this feature is shared by the Napperby sediments. The species *Aglaoreidia qualumus* is another species common at Napperby with a published restricted range, given as late Eocene to early Oligocene (Stover & Partridge, loc. cit.), but which Partridge (1975, pers. comm.) now regards as extending through a longer time interval.

The only fossil form which appears to be at odds with an Eocene age determination is that referred to *Proteacidites* cf. *P. truncatus* Cookson (Figure 4, y). The species *P. truncatus* was originally described from the Yallourn Open Cut (Cookson, 1950), and is unknown in southeastern Australia before the Miocene. The central Australian form is not, however, strictly conspecific with *P. truncatus*, differing from it in the structure of the exine adjacent to the pores.

Suggested regional correlation

The narrow sampling interval in BMR Napperby 1 means that it is not possible to determine just how much of the penetrated section is of Eocene age. The reference of the palyniferous sediments to the *P. confragosus* Zonule establishes the correlation of these with the younger parts of the Eyre Formation, which is widespread in northeastern South Australia. Much of this formation is Palaeocene, but a later depositional phase, commencing in the middle Eocene and extending perhaps into the late Eocene, has been identified in the southern part of its depositional area (Wopfner *et al.*, 1974). Silcretes occur in the upper parts of the Eyre Formation, and are believed to have formed in the

late Eocene and Oligocene, a time interval which is bracketed by the presence of overlying fossiliferous Miocene beds. It is tempting to equate these silcretes with those that occur immediately above the carbonaceous clays in Napperby 1, and to suggest a parallel depositional history for that area, with silcrete formation following an early depositional phase that extended into the middle Eocene. However, the silcrete in Napperby 1 is thin and discontinuous, and in the absence of evidence concerning the time of its formation such a correlation is purely speculative.

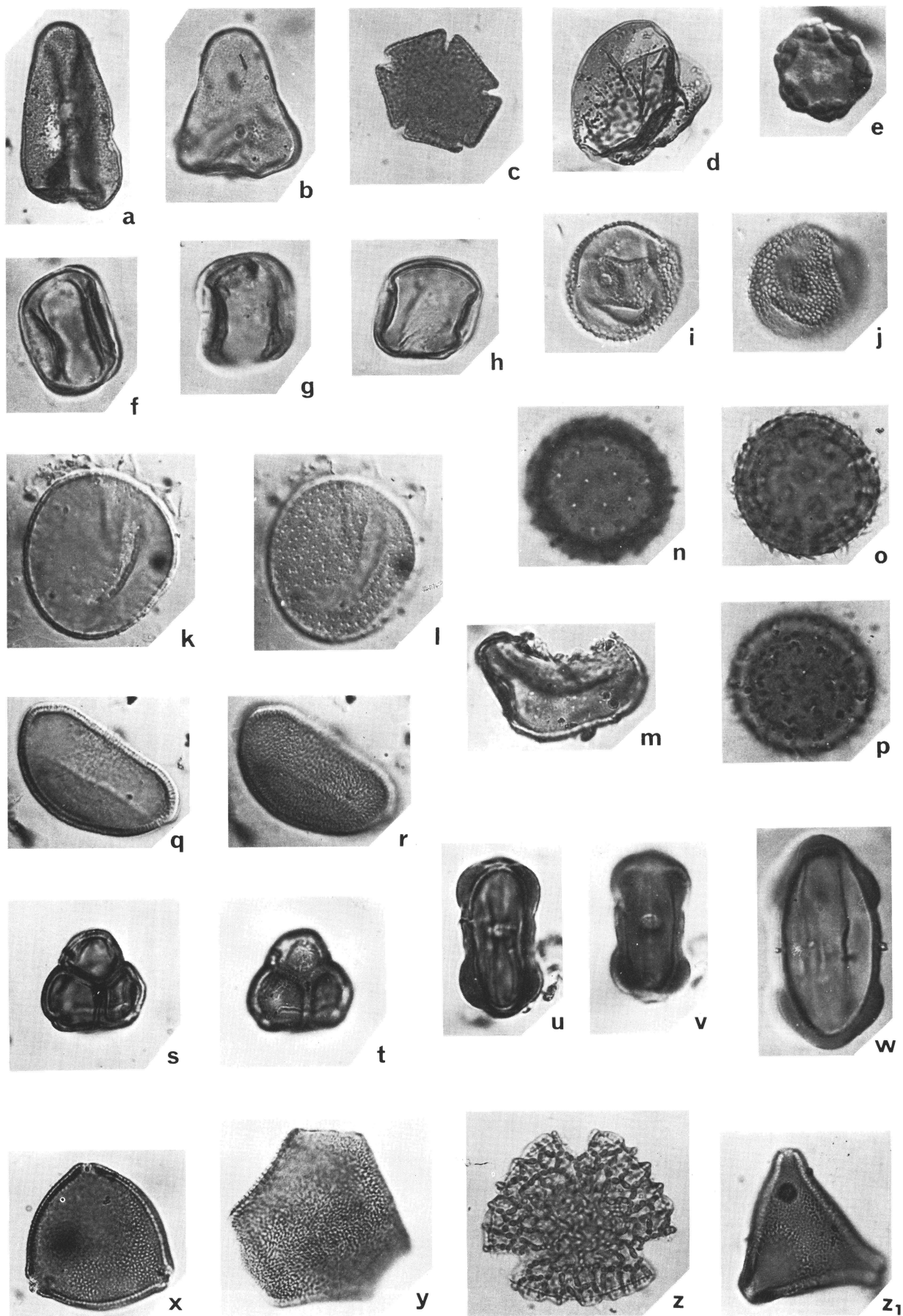
Correlation with Tertiary sequences in the adjacent Alcoota Sheet area is difficult because of the scarcity of fossils in that sequence. The Cainozoic sequence on Alcoota has been subdivided into a number of mostly unnamed depositional and weathering units (Senior, 1972; Shaw & Warren, 1975), but includes the Waite Formation of Woodburne (1967), which is tentatively dated as late Miocene-Pliocene on the vertebrate fossils. The Waite Formation in outcrop rests on lateritized Precambrian metamorphics; in BMR drillholes (Senior, 1972), it overlies a lacustrine mudstone and siltstone sequence of unknown age. Whether or not this latter sequence (designated Unit Ta by Senior) is as old as the Napperby sediments is presently unknown; attempts made in the course of this study to recover palynomorphs from greenish-grey mudstones cored in BMR Alcoota bores 1 and 2 proved unsuccessful.

Pollen-bearing sediments of Tertiary age are also known from near Alice Springs (P. R. Evans, quoted in Lloyd, 1968). Residues from cuttings from Alice Springs Farm Bore WRB/2G were re-examined in this investigation, but although they contain abundant pollen, the flora lacks diversity, consisting mainly of Casuarinaceae and Podocarpaceae types which are long-ranging, and indicate nothing more precise than a Palaeocene to perhaps Pliocene age.

Palaeoecological and palaeoclimatic considerations

The presence of abundant freshwater dinoflagellates indicates a lacustrine depositional environment for the Napperby microfloras; the high relative frequencies of pollen of aquatic and marsh-loving taxa accords with this. Variation in the pollen spectrum between samples of differing lithology probably reflects variations in the location of the depositional site with respect to the pollen source. The highly carbonaceous sediments at the base of the core, with their high count of aquatics and their dinoflagellate suite, probably represent a flora of extremely local origin, deriving from the lake waters themselves and from the immediate lake margin vegetation. Clays higher in the core have a higher content of tree pollen, notably of Casuarinaceae and Cupressaceae, and may represent inwash from a wider area of the surrounding drainage basin.

Figure 4. Selected form-species of pollen from BMR Napperby 1. All magnifications X 750. CPC numbers are those of the Commonwealth Palaeontological Collection in the BMR, where all figured specimens are housed. a, b, Cyperaceae gen. and sp. indet. Basal and lateral apertures are clearly visible in a. Sample MFP4964, CPC16501, CPC16502. c, *Nothofagidites emarcida* Cookson, MFP4964, CPC16503. d, Cupressaceae gen. and sp. indet., MFP4964, CPC16504. e, *Helciaporites astrus* Partridge, MFP6621, CPC16505, f-h, '*Phyllocladus*' sp., MFP4964, CPC16506, CPC16507, CPC16508, i, j, *Aglaoreidia qualumus* Partridge, i, focus on pore, j, deep focus on sexine reticulum. MFP6621, CPC16509. k-m, *Milfordia* cf. *M. hypolaenoides* Erdtman. k, sectional focus on wall, l, focus on sexine surface, MFP6623, CPC16510. m, laterally compressed grain showing sulcoid aperture, MFP6623, CPC16511. n-p, '*Micrantheum*' *spinyspora* Martin, n, high focus showing clusters of spines about pores. o, p, median and deep foci. MFP6621, CPC16512. q, r, *Liliacidites bainii* Stover, q, sectional focus on wall, r, deep focus on sexine surface. MFP6623, CPC16513. s, t, *Erecipites scabratus* Harris, sectional and surface foci, MFP6621, CPC16514. u-w, *Tricolporites* sp. aff. *Diplopeltis*. u, v, sectional and surface foci, MFP6621, CPC16515. w, sectional focus, corroded grain, MFP6623, CPC16516. x, *Proteacidites* sp. indet. MFP6621, CPC16517. y, *Proteacidites* cf. *P. truncatus* Cookson, MFP6621, CPC16518. z, *Proteacidites confragosus* Harris, MFP6621, CPC16519. zl, *Proteacidites* sp. indet., MFP6621, CPC16520.



The spore and pollen data bearing on the Eocene climate of this part of central Australia are ambiguous. The genus *Nothofagus* is represented only by pollen of the *brassi* species group, which is presently confined to New Guinea and New Caledonia and flourishes under precipitation regimes of 150-180 cm per year (Martin, 1973b). Additionally, the podocarpaceous genera, which occur in the pollen spectrum in frequencies up to 10 percent, are also presently members of rain-forest communities. The existence of climatic conditions necessary to support such rain-forests at the continental centre is difficult to visualize, especially in the Eocene when a significantly narrower Southern Ocean would have made effective continentality greater. This continental configuration may, however, have drawn moisture-bearing winds of monsoonal character inland from warm northern seas.

The question also arises as to whether the *Nothofagus* pollen in the sediments was derived from forests which grew in the immediate area, or whether it was transported to the depositional site from forests growing in wetter regions to the east and south. Dominance of *Nothofagidites* pollen in the Eyre Formation has been accepted as evidence of wet conditions in inland South Australia in the Eocene (Wopfner *et al.*, 1974). In only one of the Napperby samples, however, was *Nothofagidites* dominant; in the others it occurred in abundances ranging from 5 to 10 percent; these figures are perhaps low enough for a long-distance origin to be a possibility in an abundant pollen producer, especially if pollen sources were closer to the continental centre than they are now.

Other aspects of the Napperby microflora contrast with known coastal assemblages of the same age, and may reflect conditions of relative aridity. The first of these is the near-absence of a fern component — fern spores occur in frequencies of less than 1 percent — a scarcity which does not seem in accord with a high rainfall regime. The second is the abundance of Cupressaceae pollen in some samples; similar pollen is produced in Australia today by species of *Callitris*, which occur most commonly in dry sclerophyll forest associations. In sample MFP4964 this pollen type exceeds 70 percent, an abundance greatly in excess of that recorded previously in Tertiary microfloras from western New South Wales (Martin, 1973b), and which may indicate a climate with at least seasonal aridity.

Summarizing the climatic data, there are elements of the microflora which suggest the proximity of rain-forests, viz., the presence of *Nothofagus* type pollen, and of some podocarpaceous conifers; percentages of these are, however, generally low in relation to contemporary coastal microfloras. Other aspects, notably the scarcity of ferns and the abundance of Cupressaceae, can possibly be equated with a degree of dryness greater than that suggested by east and south coastal assemblages — seasonal aridity might perhaps be represented.

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