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Palynostratigraphy of Late Cretaceous to Tertiary Basins in the Alice Springs District, Northern Territory

by

M. K. Macphail

Record 1997/31

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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Australian Geological Survey Organisation

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ABSTRACT

A palynological consultancy for AGSO has confirmed the palynostratigraphic framework for several Cenozoic basins in the southern part of the Northern Territory. These basins are significant sources of groundwater, and the stratigraphic framework is needed for groundwater exploration and assessment. Two small basins on the periphery of the Arunta Block preserve Late Cretaceous (Maastrichtian) organic sediments below the Cenozoic infill - the Ayers Rock Basin on the northeast margin of the Amadeus Basin, and the Bundey Basin on the southwest margin of the Georgina Basin. The accumulation of organic-rich sediments in these basins, and others in the region, has been quasi-continuous throughout Tertiary time. However, preservation of these organic facies has been haphazard within individual basins. Organic facies of Paleocene age have not been identified and may not have been preserved. Conditions were most conducive to preservation during the Early Eocene and Middle-Late Eocene, but less so during the Oligo-Miocene. A significant finding is the occurrence of probable Oligo-Miocene spore-pollen in a waterbore sited in a palaeodrainage system near Kintore on the NT/WA border. The youngest carbonaceous unit recorded to date is Late? Pliocene. The duration of the individual episodes of organic accumulation is unknown. The data confirm that lithology needs to be constrained by palynology in order to make inter-basin correlations, although organic facies of the same palynostratigraphic age provide the most useful datum for correlating widely spaced boreholes.

INTRODUCTION

The following report provides a palynostratigraphic reference framework for hydrogeological investigations in the Western Water Study. This Study (*Wiluraratja Kapi*) is a project directed towards a decision-support system for groundwater resources on Aboriginal lands in the Northern Territory. AGSO is collaborating with the NT Department of Lands, Planning and Environment and the Central Land Council in a two-year groundwater study in the Yuendumu-Papunya-Kintore region in the southwest part of the Northern Territory. The region is believed to have unexplored groundwater resources in Cenozoic basins and one of the objectives of the Western Water Study is the delineation of these basins. A stratigraphic reference framework is required for this delineation.

This is the second of two AGSO Records on the palynology of the small Cenozoic basins in central Australia. The first Record (Macphail, 1996) presented age determinations for organic sediments intersected in boreholes drilled by the Northern Territory Geological Survey (NTGS) in the Burt Plain, Hale, Ngalia, Santa Teresa, Ti-tree and Waite Basins (see Wyche, 1983). Three phases of organic deposition were identified: (1) during the Oligo-Miocene, (2) during the Middle to Late Eocene, and (3) during the Early Eocene. These episodes of unknown duration fall with the periods of geological time encompassed by the *Proteacidites tuberculatus-Canthiumidites bellus* Zone, the Lower to Middle *Nothofagidites asperus* Zone and *Malvacipollis diversus* Zone respectively in the Gippsland Basin, eastern Bass Strait (see Stover & Partridge, 1972, 1982).

With the exception of the Santa Teresa Basin, which occurs on the northeast margin of the Amadeus Basin, the basins sampled initially were elongate depressions (intermontane basins) located within the Arunta Block, uplands of Precambrian rock that separate the Neoproterozoic to Palaeozoic, Amadeus and Georgina Basins.

This report presents additional palynological data for the intermontane basins as well as for Cenozoic basins overlying the margins of the Amadeus Basin (southwest) and Georgina Basin (northeast). The former includes the Ayers Rock Basin whose main depocentre is located to the northwest of Uluru; the latter includes the Bundey Basin which was intersected by Corehole NTGS HUC 11 located on the Huckitta 1: 250 000 Sheet (Fig. 1).

None of the stratigraphic boreholes occur within the Western Waters Study area *sensu stricto* and the Cenozoic palynostratigraphic data base has also been extended to include samples from palaeodrainage channels lines the Yuendumu-Papunya-Kintore region - boreholes RN 16852 and RN 16860 incised into the Arunta Block, borehole RN 16861 incised into the Ngalia Basin and borehole RN 16858 incised into the Amadeus Basin. The new samples analysed in this study come from palaeodrainage channels within the Western Water Study area: boreholes RN 16852 and RN 16860 from a palaeodrainage system incised into the Arunta Block; and boreholes RN 16861 and RN 16858, from palaeodrainage systems incised into the Ngalia and Amadeus Basins respectively.

OBJECTIVES

- To determine the age of probable Cenozoic sediments within the Western Water Study area (Mt. Doreen and Mt. Liebig 1: 250 000 Geological map Sheets).
- To establish a primary palynostratigraphic framework for dating and correlating geological horizons and events that may be of regional significance in the future development of groundwater resources in the Alice Springs region.
- To extend the provisional palynostratigraphic framework developed for the intermontane basins to include Cenozoic basins on the adjoining margins of the Amadeus and Georgina Basins.
- To revise age determinations for the Santa Teresa and Ti-tree Basins.

DATA BASE

A total of 35 conventional core and cuttings samples were analysed for fossil spores, pollen and algal cysts. The samples represent the most organic-rich facies in a series of 13 holes drilled to investigate lignite and other resources in areas covered by the Ayers Rock, Finke, Henbury, Huckitta, Mt. Doreen, Mt. Liebig, Napperby and Rodinga 1: 250 000 Geological Map Sheets (Fig. 1). Lithostratigraphic logs were provided for all NTGS core holes. The stratigraphy and geological history of the basins are summarised in Senior *et al.* (1994a,b).

In addition, seven samples representing the most organic-rich facies in water bore cuttings from the Western Water Study region were processed and analysed for fossil algal cysts, pollen and spores.

Limitations of the database are that: (a) deep weathering has resulted in the oxidative destruction of fossil spores and pollen in sediments to depths of up to 50 m below present ground surface; (b) relatively few facies are suitable for palynological analysis and some of those that are suitable incorporate palynomorphs reworked from older sediments; (c) many of the facies are pervious, resulting in mud contamination of samples; (d) many cuttings samples have been contaminated by caved spore-pollen; and (e) the times of First and Last appearance of species in Central Australia may differ significantly from time ranges in the reference basins along the southern and northern margins of the Australian continent (see Macphail *et al.*, 1994).

PALYNOSTRATIGRAPHY

Age determinations are based on criteria developed to date, and correlate with Late Cretaceous-Tertiary sediments in the Gippsland Basin (Stover & Partridge, 1973, 1982; A.D. Partridge & M.K. Macphail, unpubl. results) and Murray Basin (Macphail & Truswell, 1989, 1993) in southeast Australia (Fig. 2), complemented by independently-dated palynosequences from the Bonaparte, Browse and Carnarvon Basins in northwest Australia (M.K. Macphail, unpubl. results).

Palynofloras have been referred to equivalent zones in the Gippsland Basin. With few exceptions, index species used to define palynological zones in the Gippsland and Murray Basins have not been recorded in Central Australia. Correlatives of these zones are recognised using less reliable criteria, e.g. relative abundance data and/or accessory species such as *Proteacidites reticulatus* and *Tricolpites thomasii* for the Middle *Nothofagidites asperus* Zone Equivalent and *Quadraplanus* sp. cf *Q. brossus* for the *Forcipites* (*al. Tricolpites*) *longus* Zone Equivalent.

A significant proportion of each palynoflora consists of long-ranging species and species whose time distribution is unknown or poorly constrained due to extreme rarity elsewhere. Many assemblages include unrecorded tricolpate, tricolporate types and triporate pollen types, and unusual variants of described species found in other basins. A selection of these and age-diagnostic taxa are illustrated in Figures 3-45.

ASSUMPTIONS

Assumptions underlying the use of fossil pollen and spores for correlation purposes in the Alice Springs region include:

At any point in time, climates (and dryland vegetation) were relatively uniform across the Alice Springs region. This allows the relative pollen abundance to be used for *local* correlation purposes (see Macphail *et al.* 1994).

Times of First and Last appearance are likely to be earlier in Central Australian than in coastal basins (see Macphail *et al.* 1994). For this reason the Middle *Nothofagidites asperus* Zone Equivalent in Central Australia is suggested to represent Middle as well as Late Eocene time, i.e. a period incorporating all or part of the Lower *N. asperus* Zone in the Gippsland Basin.

No attempt has been made to subdivide Early Eocene, *Malvacipollis diversus* Zone time. Late Maastrichtian palynofloras are referred to the informal Upper zonule of the *Forcipites* (*al. Tricolpites*) *longus* Zone of Macphail (1984) (see Helby *et al.*, 1987).

Unless there is compelling evidence to the contrary, accessory zone index species are presumed to be *in situ*.

CENOZOIC BASINS OVERLYING THE AMADEUS BASIN

Ayers Rock Basin

Several boreholes drilled through the Cenozoic succession underlying the desert plain surrounding Uluru (Ayers Rock) have intersected thin carbonaceous units close to the unconformity with the folded Precambrian and Cambrian basement rocks. Provisional Palaeocene dates for these organic facies (Twidale & Harris, 1977) were revised as Late Cretaceous by Twidale & Harris (1991).

Samples analysed in this study come from two boreholes drilled by the NT Power and Water Authority:- Ayers Rock RN 10598 which intersected a single stratum of lignitic siltstones between 78-87 m and Ayers Rock RN 11577 which intersected two strata of lignitic sands, at 66-72 m and 84-90 m.

(a) *Ayers Rock RN 10598*

Organic facies consist of a 9 m thick interval of lignitic siltstones at the base of a 78 thick sequence of fine to coarse quartzose sands (0-78 m). The siltstone grades into weathered dolomite below 87 m. Age determinations are based on cuttings samples.

Upper *Forcipites longus* Zone Equivalent 78-84 m Late Maastrichtian

Cuttings samples at 78-81 m and 81-84 m yielded essentially the same diverse *Proteacidites*-dominated palynofloras. The age determination is based on (a) multiple specimens of *Quadraplanus* sp. cf *Q. brossus*, *Tricolporites lilliei*, *Liliacidites* sp. aff *Retimonocolpites pereticulatus* and echinate tricolporate species closely related to *T. lilliei* at 78-81 m, and (b) *Ornamentifera sentosa* at 81-84 m.

The age determination is supported by a range of species which first appear in the Campanian or Maastrichtian, e.g. *Beaupreaidites verrucosus*, *Proteacidites amolosexinus*, *P. confragosus*, and *Tetracolporites verrucosus*. Isolated specimens of species which first appear in the Paleocene, *Haloragacidites harrisii* and *Nothofagidites emarcidus*, are presumed to be caved. *Anacolosidites acutullus* and *Gambierina rudata*, recorded by Twidale & Harris (1977), are absent.

Cuttings at 84-87 m yielded trace amounts of several species not recorded at 78-81 m or 81-84 m. These include *Australopollis obscurus*, *Nothofagidites emarcidus-heterus* and *Proteacidites annularis*

Comment:

Without independent age control such as K/Ar-dated basalts, it is impossible to be certain that species which become extinct at the K/T boundary in the marginal basins also became extinct at the same time in Central Australia. For example, N. Alley (MESA, pers. comm.) has recovered the Late Cretaceous index species *Grapnelispora evansii* in Cenozoic sediments in South Australia and the same species occurs in sediments infilling the Paleocene? Goats Paddock Meteor Crater in northwest Western Australia (E.M. Truswell, pers. comm.).

Nevertheless the close match between palynofloras recorded at 78-84 m in Ayers Rock RN 10598 and Maastrichtian palynofloras elsewhere in Australia makes a Late Cretaceous age highly probable. The presence of *Proteacidites annularis* at 84-87 m is more difficult to explain since this species first appears in the Late Paleocene and remains a rare but widespread element in Eocene to Miocene palynofloras. It is uncertain whether the species and *Nothofagidites emarcidus-heterus* have been caved from Cenozoic sediments higher within the section or remoblished downwards in groundwater.

Australopollis obscurus (84-87 m) first appears in the Turonian and could have been derived from the underlying Late Cretaceous interval (see Twidale & Harris, 1977). *Anacolosidites acutullus*, recorded by Twidale & Harris (1977), is frequent in Early Eocene sediments in the study area (see Macphail, 1995) and may represent the reworked remnants of an Early Eocene unit in the basin. *Anacolosidites* first appears in independently dated Early Maastrichtian palynofloras in the (offshore) Bonaparte, Browse, and Carnarvon Basin in northwest Australia (M.K. Macphail unpubl. results).

(b) *Ayers Rock RN 11577*

Lignitic sands which are separated by about 12 m of coarse, moderately well-sorted quartzose sands, occur at 66-72 m and 84-90 m. The overlying coverbeds are sands and weakly indurated sandstones similar to the succession in RN 10598. The lower lignitic sand is underlain by about 15 m of weathered siltstone and (below 114 m) dolomite. Age determinations, based on cuttings samples, indicate that the two organic strata are of markedly different ages.

Upper *Forcipites longus* Zone Equivalent 84-87 m Late Maastrichtian

Cuttings samples at 84-87 m yielded essentially the same diverse *Proteacidites*-dominated palynoflora as found at 78-84 m in Ayers Rock Borehole RN 10589. The Upper *Forcipites longus* Zone Equivalent date is based on *Stereisporites* (*Tripunctisporis*) sp., *Ornamentifera sentosa* and frequent *Tetracolporites verrucosus* and *Tricolpites waiparensis*.

Rare species include *Amolosexinus cruciformis*, *Australopollis obscurus*, *Beaupreaidites verrucosus*, *Cyathidites splendens*, *Dicotetradites meridinanus*, *Lygistepollenites balmei*, *Phyllocladidites mawsonii* and a range of undescribed *Proteacidites* spp. Single grains of *Haloragacidites harrisii* and *Nothofagidites emarcidus-heterus* are presumed to be caved. *Anacolosidites acutullus* and *Gambierina rudata* were not recorded.

Middle *Nothofagidites asperus* Zone Equivalent 66-72 m Middle-Late Eocene

Cutting samples at 66-69 m and 69-72 m yielded moderate to abundant spore-pollen, dominated by *Nothofagidites emarcidus-heterus* and *Haloragacidites harrisii*. Both palynofloras include low to frequent numbers of *Malvacipollis* and *Proteacidites* spp.

The date is based on *Proteacidites reticulatus*, an undescribed *Verrucatosporites sp.* which also occurs in Middle *N. asperus* Zone palynofloras in the Gippsland Basin, and frequent *Dicotetradites meridianus* and *Proteadites pachypolus*. The maximum age is Middle Eocene Lower *Nothofagidites asperus* Zone Equivalent based on *Nothofagidites falcatus*.

Rare taxa include *Liliacidites lanceolatus*, *Malvacipollis spinyspora*, *Nothofagidites* sp. cf *N. goniatus*, *Proteacidites nasus*, *Sapotaceoidaepollenites latizonatus* and *Tricolpites patulus*. The last species first appears in the latest Early-Middle Eocene in southeast Australia.

Comment:

The data confirm suspicions (Twidale & Harris, 1977) that at least two phases of organic deposition are preserved in the Ayers Basin - the first in the Maastrichtian and the second some 17-25 million years later during the Middle-Late Eocene. The latter may be a correlative of the Ulgnamba Lignite Member of the Hale Formation, Hale Basin (see Senior *et al.*, 1995; Macphail, 1996).

It is possible that Early Eocene sediments are (or had been) preserved elsewhere in the basin.

Finke

(a) *Finke DDH Finke 1*

Core samples at 109.80-109.82 m and 112.40-112.50 m yielded essentially identical, sparse palynofloras that are wholly dominated by Palaeozoic monosaccate gymnosperm pollen.

Pseudoreticulatispora (*Granulatisporites*) *confluens* Zone Equivalent 109.80-112.50 m
Early Permian (Stage 2)

The age determinations are based on rare occurrences of *Microbaculispora tentula*, and the absence of *Didecitriletes* and *Dulhuntyispora* spp., in palynofloras dominated by *Plicatipollenites* spp.

Other, less common, gymnosperm genera include *Potonieisporites balmei*, *P. novicus*, *Protohaploxypinus* and *Striatopodocarpidites*. Spores were relatively uncommon but included *Horriditriletes curvibacula, H. ramosus* and *Maculatisporites* sp. cf *M. minimus*. Additional material is being studied by Associate Professor C. Foster, Australian Geological Survey Organisation.

Comment:

Permian sediments outcrop on the eastern and western extremities of the Amadeus Basin (Wells *et al.*, 1970) and in one borehole near Haasts Bluff (Truswell, 1985).

It is unknown whether Early Permian sediments have been recorded elsewhere within the Finke Sheet area, but on present indications, the interval between 109.80-112.50 m in Finke DDH 1 is a correlative of the Crown Point Formation.

Henbury

One core hole is located on the Henbury 1: 250 000 Sheet: Tempe Downs T1A.

(a) *Tempe Downs T1A*

This hole intersected lignitic clays and sands, including plant remains between ca. 37-72 m. With one exception (36.8-38.20 m), core samples from this interval yielded very low to negligible amounts of spore-pollen, including *Nothofagidites* spp. and reworked Palaeozoic gymnosperms (*Alisporites*, *Plicatipollenites*). If *in situ*, the former (*Nothofagidites*) provides a minimum age of Middle-Late Eocene for the interval 43.8-52.63 m.

Tubulifloridites pleistocenicus Zone Equivalent 36.8-38.20 m Late? Pliocene

A core sample taken from within a highly (80%) carbonaceous clay interval between 37-39 m yielded abundant fossil pollen. The dominant species is *Haloragaciidtes harrisii*, with frequent *Lygistepollenites florinii*, *Nuxpollenites* sp. (*Dodonaea triquetra*-type) and *Podocarpidites* spp. Cysts of the brackish water alga *Botryococcus* are present in low numbers.

The Late? Pliocene age is based on (a) the presence of gymnosperms (*L`ygistepollenites*, *Podocarpidites*) and angiosperms (*Milfordia homeopunctatus*) which appear to have become extinct in Central Australia by terminal Pliocene time and (b) the absence of *Nothofagidites* spp. which became extinct in Central Australia during the Miocene or (less likely) Early Pliocene.

Proteacidites tuberculatus-Canthiumidites bellus Zone Equivalent 43.8-52.63 m
Oligo-Miocene

Three core samples from weakly carbonaceous fine sands and silts between ca. 39-59 m yielded very sparse palynofloras 'dominated' by modern pollen types. The Oligo-Miocene date is provisional, based on multiple specimens of *Nothofagidites emarcidus-heterus* and absence of pollen species indicative of older zones. Zone indicator species are absent.

Comment:

It is highly unlikely that *Nothofagidites* was derived from the overlying black clays at 36.8-38.20 m, although it is possible that the taxon has been reworked from sediments elsewhere in the catchment. If the pollen type is *in situ*, then the interval is older than Pliocene and probably younger than Middle-Late Eocene. Reworked species of *Plicatipollenites* demonstrate the presence of Permian sediments within the pollen source area.

Santa Teresa Basin

(a) *Santa Teresa 81 ST4*

Macphail (1996) noted that palynofloras recovered from lignitic intervals in the Santa Teresa Basin differed from those recorded in the Middle-Late Eocene Hale Formation in the Hale Basin in that *Nothofagidites* spp. were rare and the assemblages included a species (*Intratriporopollenites notabilis*) which first appears in the Early Eocene, as well as fossil genera such as *Malvacipollis* which first become abundant in the same period.

The palynofloras also included a larger number of species which first appear in the Late Cretaceous, but range no higher than the Early Eocene, e.g. *Tricolpites waiparensis*. These were associated with several distinctive pollen types but undescribed species of *Anacolosidites* (Fig. 39), Triprojectacites sp. cf *Integricorpus* (Figs. 8-10), *Longapertites* (Figs. 4-5) and *Tricolpites* (Figs. 11-13), all of which occur in Late Cretaceous-Early Eocene sediments in the Bonaparte Basin.

For this reason, Macphail (1995) proposed that organic facies in the Santa Teresa Basin represented an earlier (*Malvacipollis diversus* Zone Equivalent) phase of organic accumulation in Central Australia. To attempt to define more narrowly the time of deposition within the Early Eocene, two additional samples were analysed from a 1.7 m thick unit of dark grey clays in Core hole 81 ST4 .

Early Eocene *Malvacipollis diversus* Zone Equivalent 65.1-65.62 m Early Eocene

A core sample at 65.1-65.13 m yielded a rich palynoflora dominated by *Gleichniidites* with frequent occurrences of *Cyathidites splendens*, *Proteacidites* spp. (including *P. annularis*, *P. grandis*, *P. leightonii*, *P. nasus*, *P. obscurus*, *P. recavus*) and *Malvacipollis* spp. The core sample at 65.61-65.62 m yielded a depauperate version of the same palynoflora.

The Early Eocene date is based on frequent *Malvacipollis diversus* and *M. subtilis* with *Proteacidites leightonii*, *P. recavus* and *Tricolpites patulus*. Supporting the age determination are multiple specimens of an undescribed *Striatocolporites* sp. related to *S. cephalus* (Figs. 3, 7) found in Early Eocene sediments but not Late Cretaceous palynofloras in the Bonaparte Basin. The minimum age is late Early Eocene based on *Anacolosidites* sp. cf *A. acutullus*, *Australopollis obscurus*,. Triprojectacites sp. cf *Integricorpus*, *Longapertites* sp. nov. and *Tricolpites waiparensis.*

Comment:

The high relative abundance of *Malvacipollis* spp. make it highly unlikely that the interval is older than latest Paleocene. However, the palynoflora lacks the index species used to subdivide the *Malvacipollis diversus* Zone into Lower, Middle and Upper zonules in the Gippsland Basin. The presence of *Proteacidites leightonii* and *Tricolpites patulus* are more consistent with a later than earlier date within the Zone. The virtual absence of *Nothofagidites* spp. is strongly against the interval being younger than Middle Eocene.

Contaminant species such as *Nothofagidites falcatus* and *Tricolpites thomasii* in Core hole 81 ST1 (Macphail, 1996) strongly indicate that (Middle-Late *N. asperus* Zone Equivalent) correlatives of the Hale Formation occur elsewhere in the Santa Teresa Basin.

3.11 Bore hole RN 16858 (Tarrawarra)

The borehole intersected about 30 m of sand with calcrete horizons, up to 3m thick, overlying sandy clays (30-57 m) and interbedded calcareous, non-calcareous and gypsiferous clays with minor sand units (57-162 m). No lignitic units were observed in the cuttings.

Three cuttings samples representing the intervals 120-123 m, 135-138 m and 162m were examined.

135-138 m. Indeterminate

The lower two cuttings samples yielded modern pollen contaminants only, e.g. *Acacia,* Asteraceae, Chenopodiaceae-Amaranthaceae, *Eucalyptus, Gonocarpus*, Poaceae and (162 m) the introduced agricultural weed *Echium* (Paterson's Curse).

? *Proteacidites tuberculatus-Canthiumidites bellus* Zone Equivalent 120-123 m
Oligo-Miocene

The highest cuttings sample (120-123 m) yielded very low numbers of two *Nothofagidites* species (*N. emarcidus-heterus, N. falcatus*) which became extinct during the Late Neogene in Central Australia.

It is uncertain whether these fossil pollen are *in situ* or reworked. If the former then the sample is unlikely to be younger than Oligo-Miocene.

CENOZOIC BASINS OVERLYING THE GEORGINA BASIN

Bundey Basin

The NTGS HUC11 core hole occurs on the southwest margin of the Georgina Basin. The basement rocks were not reached. The samples analysed in this report, and those studied by Truswell (1987), come from lignitic, black claystones between 95.3-108.1 m. The unit is overlain by mudrocks, siltstones and (43.7-49.9 m) marls capped by silicified limestones. As with the Ayers Rock boreholes, minor but significant differences exist between palynofloras recovered in previous studies and samples analysed in this report.

(a) *NTGS HUC11*

Upper *Forcipites longus* Zone Equivalent 99.17-107.89 m Late Maastrichtian

Four core samples from this interval yielded essentially the same *Stereisporites antiquisporites/Cingutriletes clavus-Proteacidites* dominated palynoflora. The saline-water dinoflagellate *Deflandrea obliquipes* and an unidentified algal cyst (*Tetracysta* sp.?) occurs in three of these, at 99.17-99.21 m, 105.55-105.58 m and 107.83-107.89 m (Macphail, 1997). The brackish-water alga *Botryococcus* is common in the fourth sample, at 102.45-102.54 m.

The Upper *Forcipites longus* Zone Equivalent date is based on *Quadraplanus* sp. cf *Q. brossus* at 99.17-99.21 m, *Stereisporites* (*Tripunctisporis*) sp. at 102.45-102.54 m, and *Proteacidites amolosexinus* at 105.55-105.58 m and 107.83-107.89 m. The last palynoflora includes an undescribed species of *Jaxtacolpus* that appears to be restricted to the Late Cretaceous in northern Australia. Multiple specimens of the *Tricolporites lilliei* and related species, and *Liliacidites* sp. aff *Retimonocolpites pereticulatus*, occur throughout the interval.

The age determination is supported by a range of species which first appear in the Campanian-Maastrichtian, e.g. *Beaupreaidites elegansiformis*, *Dicotetradites meridianus*, *Proteacidites angulatus*, and *P. confragosus*.. A significant number of other species are unlikely to range higher than the Paleocene, e.g. *Amosopollis cruciformis*, *Camarozonosporites bullatus* complex, *Lygistepollenites balmei* and *Proteacidites angulatus*. Rare species include *Bysmapollis emaciatus* and *Phyllocladidites mawsonii*.

The palynoflora, at 107.83-107.89 m, also includes a number of long-ranging spores that are typically found in Early Cretaceous sediments, e.g. *Ceratosporites equalis*, *Contignisporites* spp. and *Densoisporites velatus*. *Anacolosidites acutullus* and *Gambierina rudata* were recorded by Truswell (1987) but were not found in the present study.

Comment:

As for the Ayers Rock boreholes, there is no compelling evidence that the palynofloras are as young as Paleocene. *Anacolosidites* spp. may indicate that the mudrock and siltstones above 95.3 m include an Early Eocene interval. Addditional samples have been requested to test this possibility. The HUC11 Core hole is likely to be a key stratigraphic drill hole for the Alice Springs region.

INTERMONTANE CENOZOIC BASINS

Sediments analysed from this sector comprise: (a) core material which provides a test of provisional age determinations for the Ti-tree Basin (Macphail, 1996); and (b) core and cuttings samples from drill holes in the Finke, Henbury, Mt. Doreeen and Mt. Liebig 1: 250 000 Sheets.

Ti-tree Basin

(a) *Ti-tree 78 TTW2*

Samples of black carbonaceous clays between 107.2-132.39 m in Core hole 78 TTW2 yielded mixed age (Middle-Late Eocene and Early Eocene) palynofloras.

Macphail (1996) provisionally dated the interval 119.05-119.10 m in 78 TTW2 as *Malvacipollis diversus* Zone Equivalent based on rare specimens of the Early Eocene indicators *Anacolosidites* sp. cf *A. acutullus*, Triprojectacites sp. cf *Integricorpus* sp. and *Longapertites* sp. nov. in an assemblage that included abundant *Nothofagidites* spp.

Additional samples from the same interval of black carbonaceous clays (118.00-118.05m, 122.05-122.09 m, 122.44-122.50 m) were analysed to test this age-dermination.

Malvacipollis diversus Zone Equivalent 118.00-118.05 m Early Eocene

The sample at 118.00-118.05 m yielded very low numbers of fossil spores and pollen in a matrix of strongly biodegraded organic material. Although contaminated by modern pollen, the presence of *Anacolosidites* sp. cf *A. acutullus* and the absence of *Nothofagidites,* strongly support an Early Eocene minimum age. The sample yielded abundant cysts of an unidentified freshwater alga.

The sample at 122.05-122.09m yielded single specimens of *Malvacipollis* and *Nothofagidites* sp. cf *N. flemingii* in an Asteraceae-dominated assemblage, and cannot be dated with any degree of confidence.

Unzoned Givetian-Frasnian 122.44-122.50 m Middle-Late Devonian

The core sample at 122.44-122.50 m, from unit listed (lithological log 10/1978) as "almost sub-lignitic" yielded moderate numbers of Palaeozoic spores mixed with very low numbers of modern pollen contaminants.

The sample is dated as Givetian-Frasnian based on *Ancyrospora langii, A.* sp cf *A. longispinosa* and *Rhabdosporites* sp. cf *R. langii.*

Comment:

The data strengthen the probability that the organic clay unit at 116.5-119.10 m is Early Eocene. While it is possible that the Palaeozoic spores at 122.44-122.50 m have been reworked into a younger (Early Eocene) sediment, it is more probable that the horizon is dolomite that has decomposed to a black clay 'pug'. If this is correct, then the interval at and below 122.44 m is a correlative of the Mt. Eclipse Sandstone. Intervals between 119.10-122.44 in the same carbonaceous unit may or may not be of Devonian age.

(b) *Ti-tree 81 TT1*

Carbonacous claystones at 196.3-198.7 m preserve *Nothofagidites*-dominated palynofloras which closely resemble those preserved in the Middle-Late Eocene Ulgnamba Lignite Member in the Hale Basin except for rare occurrences of 'Early Eocene' species such as Triprojectacites sp. cf *Integricorpus*.

These data are inadequate to determine whether the Early Eocene species are *in situ* or have been reworked from sediments elsewhere in the basin. Two core samples, from slightly carbonaceous sands (190-193 m) and claystones (193-196 m) overlying the black carbonaceous claystone were analysed to help resolve the age uncertainty.

Proteacidites tuberculatus Canthiumidites bellus Zone Equivalent 190-196 m
Oligo-Miocene

Both samples yielded moderate numbers of fossil pollen and spores, including obviously caved modern pollen types such as *Acacia*, Asteraceae and Poaceae. The dominant *in situ* genera are *Gleicheniidites* with frequent to abundant *Nothofagidites* and *Podocarpidites* spp. The palynoflora is provisionally dated as *Proteacidites tuberculatus-Canthiumidites bellus* Zone Equivalent based on the absence of indicator species of both Middle-Late and Early Eocene age.

Comment:

Oligo-Miocene sediments overlying the black clays in 78 TTW2 cannot have been the source of the Late Cretaceous-Early Eocene indicator pollen. This strengthens the case for dating the black carbonaceous clay unit between 195.8-199.0 m as Middle *Nothofagidites asperus* Zone Equivalent rather than Early Eocene *Malvacipollis diversus* Zone Equivalent as proposed by Macphail (1996).

If this is correct, then the unit is a correlative of the Middle-Late Eocene Ulgnamba Lignite in the Hale Basin. The corollary is that the Ti-tree Basin preserves organic facies deposited during all three of the phases identified by Macphail (1996).

Mt. Doreen

Hand-picked cuttings samples were analysed for three boreholes in the Mt. Doreen 1: 250 000 Sheet area: Mt. Doreen RN 15470 (81-84 m), Papunya RN 16694 (147-150 m, 177-180 m) and a hole drilled by the Bureau of Mineral Resources (now Australian Geological Survey) BMR Mt. Doreen MD11 (415-420 ft., 483 ft. 3 1/2 in.-483 ft.)

With one exception (see below) the only palynomorphs recovered were modern pollen types derived from dominants shrubs and herbs in the local vegetation (*Allocasuarina*, Asteraceae, Chenopodiaceae-Amaranthaceae, Gyrostemonaceae, Myrtaceae, Poaceae) or from water imported to make up drilling mud (*Ranunculus*). Several assembalges included pollen of exotic (northern hemisphere) pines (*Pinus*) and agricultural weeds (*Stellaria*). The samples cannot be dated on the evidence available.

(a) *BMR Mt. Doreen MD11*

Unzoned Givetian-Frasnian 415-420 ft. Middle-Late Devonian

Cuttings at 415-420 ft. yielded the Givetian-Frasnian spore *Geminospora lemurata* and two other probable Palaeozoic spores in a very sparse palynospora 'dominated' by modern pollen.

Comment:

If *in situ*, then *G. lemurata* indicates that the corehole bottomed in Mt. Eclipse sandstone or a correlative formation.

Mt. Liebig

Cuttings samples were analysed for two boreholes in the Mt. Liebig 1: 250 000 Sheet area: Mt. Liebig RN 11394 (72-75 m, 96-99 m) and Papunya RN 16695 (132-135 m, 135-138 m, 138-141 m, 147-150 m, 159-162 m)

As for the Mt. Doreen Sheet samples, the only palynomorphs recovered were modern pollen types derived from dominants shrubs and herbs in the local vegetation (*Allocasuarina*, Asteraceae, Chenopodiaceae-Amaranthaceae, Gyrostemonaceae, Myrtaceae, Poaceae) or from water imported to make up drilling mud (*Ranunculus*).

Comment:

The samples cannot be dated on the evidence available. The prevalence of amorphous and strongly biogegraded organic debris suggests that the sediments are intrinsically barren or have been strongly weathered due to groundwater movements.

Arunta Block

Two boreholes were sampled: borehole RN 16852 drilled 12 km west of Kintore (88 m), and borehole RN 16860, drilled south of Mt. Wedge (24-27 m).

(a) Borehole RN 16852

The bore hole intersected ca. 30 m of sands and sandstone with interbedded calcrete horizons overlying interbedded sandstones and claystones. Carbonaceous stringers occur at 78-81 m and a thicker/laminated lignite at 81-84 m. The organic fraction sampled in cuttings at 88 m is presumed to come from the latter interval.

Proteacidites tuberculatus-Canthiumidites bellus Zone Equivalent 88m Oligo-Miocene

Cuttings at 88m yielded moderate numbers of well-preserved spore-pollen in a matrix of dispersed/water-winnowed plant tissues and (very rare) *Botryococcus*. The palynoflora is dominated by *Nothofagidites emarcidus-heterus* (54%) with lower numbers of *Haloragacidites harrisii* (27%), *Podocarpidites* (7%), *Lygistepollenites florinii* (4%), and *Nothofagidites falcatus* (4%).

The sample is provisionally dated as *P. tuberculatus-C. bellus* Zone Equivalent based on the high relative abundance of *Nothofagidites* spp. and the absence of index species of younger (Late Miocene-Pliocene) and older (Eocene) zones. One species, *Hakeidites (Grevillea)* sp., is more typical of Late Miocene or younger palynofloras and may have been caved.

(b) Borehole RN16860

24-27 m. Indeterminate

The borehole intersected interbedded gravels, sands and clays down to ca. 45 m. Calcrete is present between 6-12 m: lacustrine? shells occur at 27-30 m. A cuttings sample from the overlying sandy clays (24-27 m) yielded very low numbers of modern pollen only, e.g. *Allocasuarina*.

Ngalia Basin

Borehole RN 16861

Borehole RN 16861 was drilled for the Western Water Study, 2.4 km north of Mt. Wedge, and intersected gravels, sands and clays down to 36 m. The sandy clays between

12-35 m included freshwater (ostracod?) shells up to 1 mm diameter. No lignitic units were observed. Two cuttings samples were analysed, at 24-27 m and 30-33 m.

24-33 m Indeterminate

The cuttings samples yielded very low numbers of modern pollen, e.g. Brassicaceae.

CONCLUSIONS

LITHOSTRATIGRAPHY

1. Lithology is a relatively poor basis for inter-basin correlation without some form of independent age control. Fossil spores and pollen are arguably the most cost-effective form of age control in non-marine basins such as those in Central Australia in that they also provide evidence for the nature of depositional environments in which Cenozoic aquitard and aquifer facies accumulated. This has predictive value regarding facies architecture and water quality. In addition, the dated horizons provide a chronostratigraphic framework within which the evolution and depositional histories of the individual basins can be compared.

DEPOSITIONAL ENVIRONMENTS

1. The majority of organic facies almost certainly accumulated under low energy fluvio-lacustrine conditions. However the texture/degree of sorting of other coarse clastic units suggest that (short-term?) higher energy fluvial regimes have been a feature of the environment in the Alice Springs region throughout during the Cenozoic, resulting in erosion or non-deposition over considerable intervals of geologic time.

2. The majority of the samples analysed in this report yielded low to abundant numbers of algal cysts and are presumed to have accumulated in fresh to brackish water. The major exception are organic facies at 99.17-107.89 m in HUC11 which accumulated in a saline pond or lake capable of supporting the otherwise typically marine dinoflagellates *Deflandrea obliquipes* and *D. pachyceros*. Dominance of the palynofloras by *Stereisporites* spp implies that the site was surrounded by a *Sphagnum* bog. Since *Sphagnum* is a moss now found in middle-high latitude (cool-cold), permanently wet mires, it is improbable that dry climates were responsible for raised salinity levels. Accordingly the HUC11 drill site is suggested to have been a salt-water discharge zone during the Late Maastrichtian.

3. Abundant *Botryococcus* cysts in one sample imply that salinity levels were variable. Terrestrial environments appear to have been cool and wet, consistent with the middle latitude position of central Australia during the Late Cretaceous and a probable reduced photoperiod during winter months.

AGE DISTRIBUTION OF ORGANIC SEDIMENTS

1. The palynological data confirm earlier suggestions (Truswell, 1987, Twidale & Harris, 1991) that the Ayers Rock and Bundey Basins preserve Late Cretacous organic deposits overlying the Proterozoic-Cambrian basement rocks.

2. The same data confirm that organic sediments of Early Eocene, Middle-Late Eocene and Oligo-Miocene age are moderately widespread within the Cenozoic basins but, to date, there is no compelling evidence for organic deposits of Paleocene age in the Alice Springs region.

3. The youngest organic facies recorded to date in the region are Late? Pliocene lignitic clays at 36.8-38.2 m in Tempe Downs T1A (Henbury Sheet). The age, depth and good preservation are surprising given the depth and strong degree of weathering in Central Australia.

BASIN HISTORIES

1. The combined data (Macphail 1996, this report) demonstrate that the accumulation of organic sediments within the region as a whole has been qusi-continuous throughout the Maastrichtian and Tertiary.

2. Within any one basin, preservation of organic sediments has been more haphazard. For example a possible correlative of the Middle-Late Eocene Ulgnamba Lignite Member (Hale Formation, Hale Basin) overlies Late Maaastrichtian lignitic sands in the Ayers Rock Basin. The intervening 9 m thick unit of fluvial sand may have been deposited at any time during the Paleocene and Early Eocene. In contrast, in the Santa Teresa Basin to the east, the earliest preserved organic deposits are Early Eocene.

3. Five major periods of organic accumulation can be identified within the Alice Springs region: (1) during the Late Maastrichtian; (2) during the Early Eocene, (3) during the Middle and/or Late Eocene; (4) during the Oligo-Miocene and (5) during the Late? Pliocene. The duration of the individual episodes is unknown.

4. In spite of the relatively coarse resolution, it does appear possible to use organic strata of the same palynological age as a *datum* for correlating non carbonaceous clastic units in widely spaced boreholes.

5. On present indications, the tectonic structuring leading to the development of basins within the Arunta Block occurred during the Paleocene or earliest Eocene. This is based on the apparent restriction of Late Cretaceous sediments to basins on the margins of the Arunta Block and the absence of correlatives in the intermontane Cenozoic basins. For example, in Ti-tree Basin Corehole 78 TTW2, Early Eocene organic clays overlie weathered Middle-Late Devonian dolomites.

6. For organic matter to accumulate, rates of influx must exeed rates of decay or erosion. Both are functions of climate and, based on relative prevalence, conditions were most favourable for the preservation of organic matter during the Early Eocene and Middle-Late Eocene.

7. Although possibly warm and wet (non-seasonal megatherm-mesotherm) by present-day standards, the period was one of gradual global cooling away from values reached during the latest Paleocene (Cenozoic thermal maximum). It is tempting to link the episodes of organic deposition, and migration of *Nothofagus* into Central Australia in the Middle Eocene, with the onset of seasonally cool, continental conditions (see Truswell & Marchant, 1986).

8. The relative paucity of Oligo-Miocene organic deposits is attributed to fragmentation of river systems into isolated chains of ephemeral? lakes. The presence of Late? Pliocene organic facies at ca. 38 m depth in Tempe Downs T1A supports Late Neogene structuring in the Alice Springs region (see Senior *et al.*, (1995).

SAMPLES FROM THE WESTERN WATER STUDY AREA

1. The samples confirm previous observations that only rarely do sediments in this sector of the Alice Springs district preserve fossil spores and pollen.

2. The one confirmed exception are lignites preserved between 78-84 m in Borehole RN 16852, drilled 12 km west of the Kintore turnoff on the Kintore-Kiwikurra Road. These are provisionally dated as Oligo-Miocene and are unlikely to be younger than Middle Miocene.

3. It is unclear from the lithological log whether potential aquifer facies higher within the section are similar or substantially younger in age. The depositional environment is suggested to have been a cut-off channel or point bar.

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FIGURE CAPTIONS

Fig. 1	Location of boreholes in the small, predominantly Cenozoic basins within, and adjacent to, the Arunta Block (after SENIOR ET AL. 1995).
Fig. 2	Correlation of Gippsland and Murray Basin palynostratigraphic zones with the international geological time scale (A.D. Partridge & M.K. Macphail unpubl.)
Figs. 3-45:	Photomicrographs of fossil spores and pollen (scale bar = 10 micrometres)
Figs. 3,7	*Striacolporites* sp. cf *S. cephalus* SAH & KAR 1970. Fig. 3 - Corehole 81ST4 64.90-64.93 m; Fig. 7 - Corehole 81ST3 76.70-76.72; (Early Eocene).
Figs. 4-5	*Longapertites* sp. nov. Fig. 4 - Corehole 81ST4 64.90-64.93 m; Fig. 5 - Corehole 81ST3 76.70-76.72 m; (Early Eocene).
Fig. 6	*Intratriporopollenites notabilis* (HARRIS) STOVER & PARTRIDGE 1973. Corehole 81ST3 76.70-76.72 (Early Eocene).
Figs. 9-10	Triprojectacites sp. cf *Integricorpus*. Corehole 81ST4 64.90-64.93 m (Early Eocene).
Figs. 11-13	*Tricolporites* sp. nov. Corehole Fig. 11-12 - 81ST4 64.90-64.93 m; Fig. 13 - Corehole 81ST3 76.70-76.72 m (Early Eocene).

Fig. 14 *Triporopollenites* sp. cf *Gemmapollis raglanensis* POCKNALL 1981. Corehole 81ST4 64.90-64.93 m (Early Eocene).

Fig. 15 *Malvacipollis subtilis* STOVER & PARTRIDGE 1973. Corehole 81 ST4 64.9-64.93 m (Early Eocene).

Fig. 16 *Malvacipollis diversus* (HARRIS) STOVER & PARTRIDGE 1973. Corehole 81 ST4 64.9-64.93 m (Early Eocene).

Fig. 17 *Cyathidites splendens* HARRIS 1965. Corehole 81ST3 76.70-76.72 m (Early Eocene).

Fig. 18-19 *Tricolporites lilliei* (COUPER) STOVER & PARTRIDGE 1973. Corehole HUC11 96.0-96.03 m (Maastrichtian).

Fig. 20 *Ornamentifera sentosa* DETTMANN & PLAYFORD 1968. Corehole HUC11 99.17-99.21 m (Maastrichtian).

Fig. 21 *Stereisporites* (*Tripunctiporus*) sp. of HELBY, MORGAN & PARTRIDGE 1987. Corehole HUC11 96.0-96.03 m (Maastrichtian).

Fig. 22 *Grapnelispora evansii* STOVER & PARTRIDGE 1982. Corehole HUC11 97.00-97.04 m (Maastrichtian).

Figs. 23-28 *Quadraplanus* sp. cf *Q. brossus* STOVER & PARTRIDGE 1973. Corehole HUC11 96.00-96.03 m (Maastrichtian).

Fig. 29 ?*Beaupreaidites* sp. cf *Beaupreaidites verrucosus* COOKSON 1950. Corehole HUC11 97.00-97.04 m (Maastrichtian).

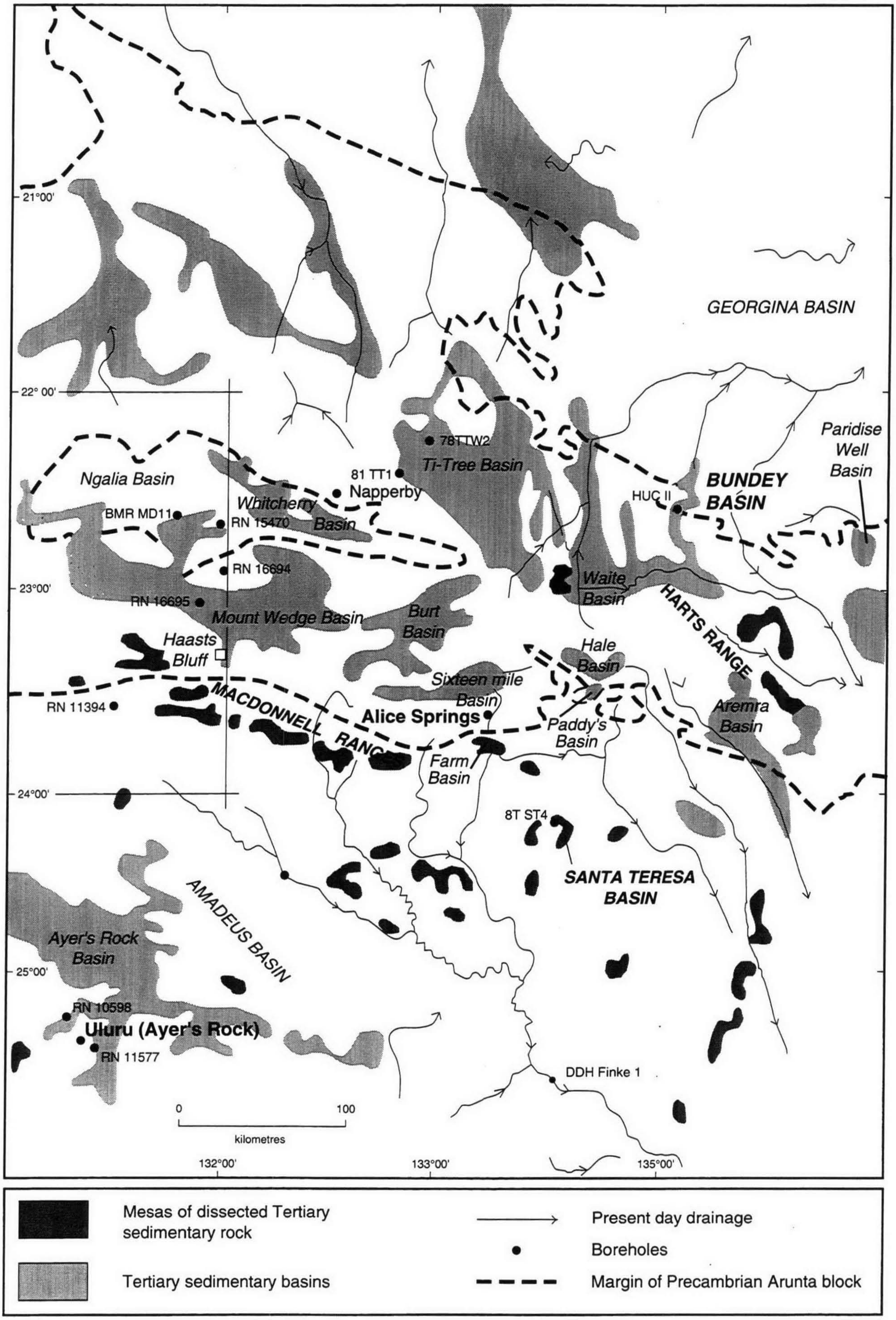
Fig. 30	*Proteacidites amolosexinus* DETTMANN & PLAYFORD 1968. Corehole HUC11 99.17-99.21 m (Maastrichtian).
Fig. 31	*Triporopollenites* sp. cf *P. amolosexinus* DETTMANN & PLAYFORD 1968. Corehole HUC11 97.00-97.04 m (Maastrichtian).
Fig. 32	*Dicotetradites meridianus* (STOVER & PARTRIDGE) MILDENHALL & CROSBY 1979. Corehole HUC11 97.00-97.04 m (Maastrichtian).
Fig. 33	*Tricolpites reticulatus* (COOKSON) DETTMANN & JARZEN 1989. Corehole 81ST4 64.9-64.93 m (Early Eocene).
Fig. 34-35	*Liliacidites* sp. aff *Retimonocolpites pereticulatus* (BRENNER) DOYLE, van CAMPO & LUGARDON 1975. Corehole HUC11 99.17-99.21 m (Maastrichtian).
Fig. 36	*Anacolosidites acutullus* COOKSON & PIKE 1954. Corehole 81ST4 64.90-64.93 m (Early Eocene).
Figs. 37-38	*Anacolosidites* sp. cf *A. acutullus* COOKSON & PIKE 1954. Corehole 81ST3 76.70-76.72 m (Early Eocene).
Fig. 39	*Anacolosidites acutullus* COOKSON & PIKE 1954. Corehole 81ST4 64.90-64.93 m (Early Eocene).
Fig. 40	*Proteacidites confragosus* HARRIS 1972. Corehole HUC11 96.00-96.03 m (Maastrichtian).

Fig. 41-42 *Triporopollenites* sp. aff *Proteacidites incurvatus* STOVER & PARTRIDGE 1973. Corehole HUC11 96.00-96.03 m (Maastrichtian).

Fig. 43 *Triangulorites* sp cf *T. (Triorites) bellus* (SAH & KAR) KAR 1985. Corehole HUC11 96.00-96.03 m (Maastrichtian).

Fig. 44 *Lygistepollenites balmei* STOVER & EVANS 1973. Corehole HUC11 99.82-99.86 m (Maastrichtian).

Fig. 45 *Amosopollis cruciformis* COOKSON & BALME 1962. Corehole HUC11 99.82-99.86 m (Maastrichtian).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RN 16695
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Burt Basin
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HUC II
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Waite Basin
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Hale Basin
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MACDONNELL RANGES
RN 11394
Alice Springs
Paddy's Basin
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SANTA TERESA BASIN
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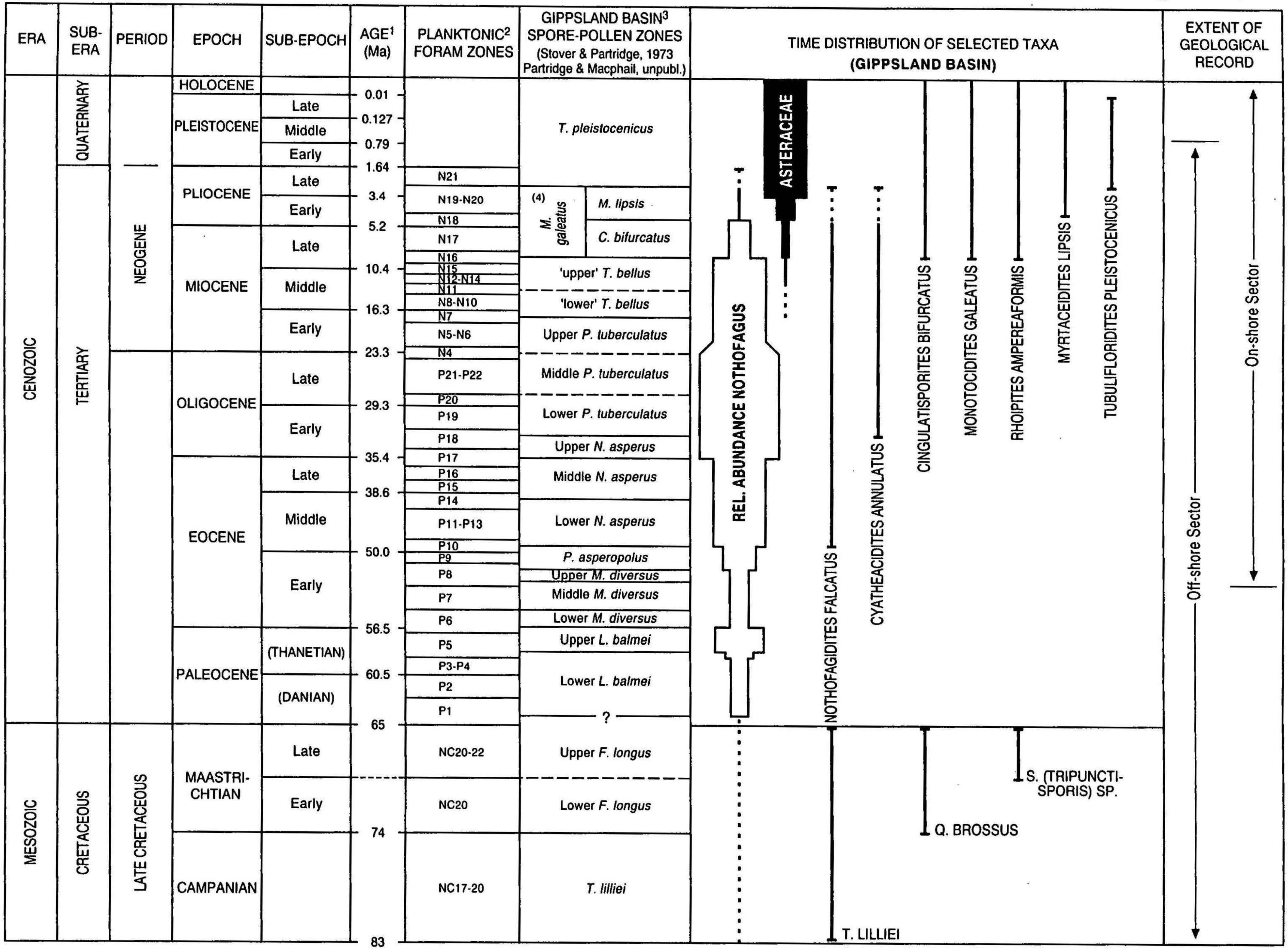
Mesas of dissected Tertiary sedimentary rock
Tertiary sedimentary basins
Present day drainage
Boreholes
Margin of Precambrian Arunta block

Fig. 1



ERA
SUB-ERA
PERIOD
EPOCH
SUB-EPOCH
AGE[1] (Ma)
PLANKTONIC[2] FORAM ZONES
GIPPSLAND BASIN[3] SPORE-POLLEN ZONES (Stover & Partridge, 1973 Partridge & Macphail, unpubl.)
TIME DISTRIBUTION OF SELECTED TAXA (GIPPSLAND BASIN)
EXTENT OF GEOLOGICAL RECORD
CENOZOIC
MESOZOIC
QUATERNARY
TERTIARY
CRETACEOUS
NEOGENE
LATE CRETACEOUS
HOLOCENE
PLEISTOCENE
PLIOCENE
MIOCENE
OLIGOCENE
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MAASTRI-CHTIAN
CAMPANIAN
Late
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16.3
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56.5
60.5
65
74
83
N21
N19-N20
N18
N17
N16
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N12-N14
N11
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N7
N5-N6
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P21-P22
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P18
P17
P16
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P3-P4
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M. galeatus
M. lipsis
C. bifurcatus
'upper' T. bellus
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Lower P. tuberculatus
Upper N. asperus
Middle N. asperus
Lower N. asperus
P. asperopolus
Upper M. diversus
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Upper L. balmei
Lower L. balmei
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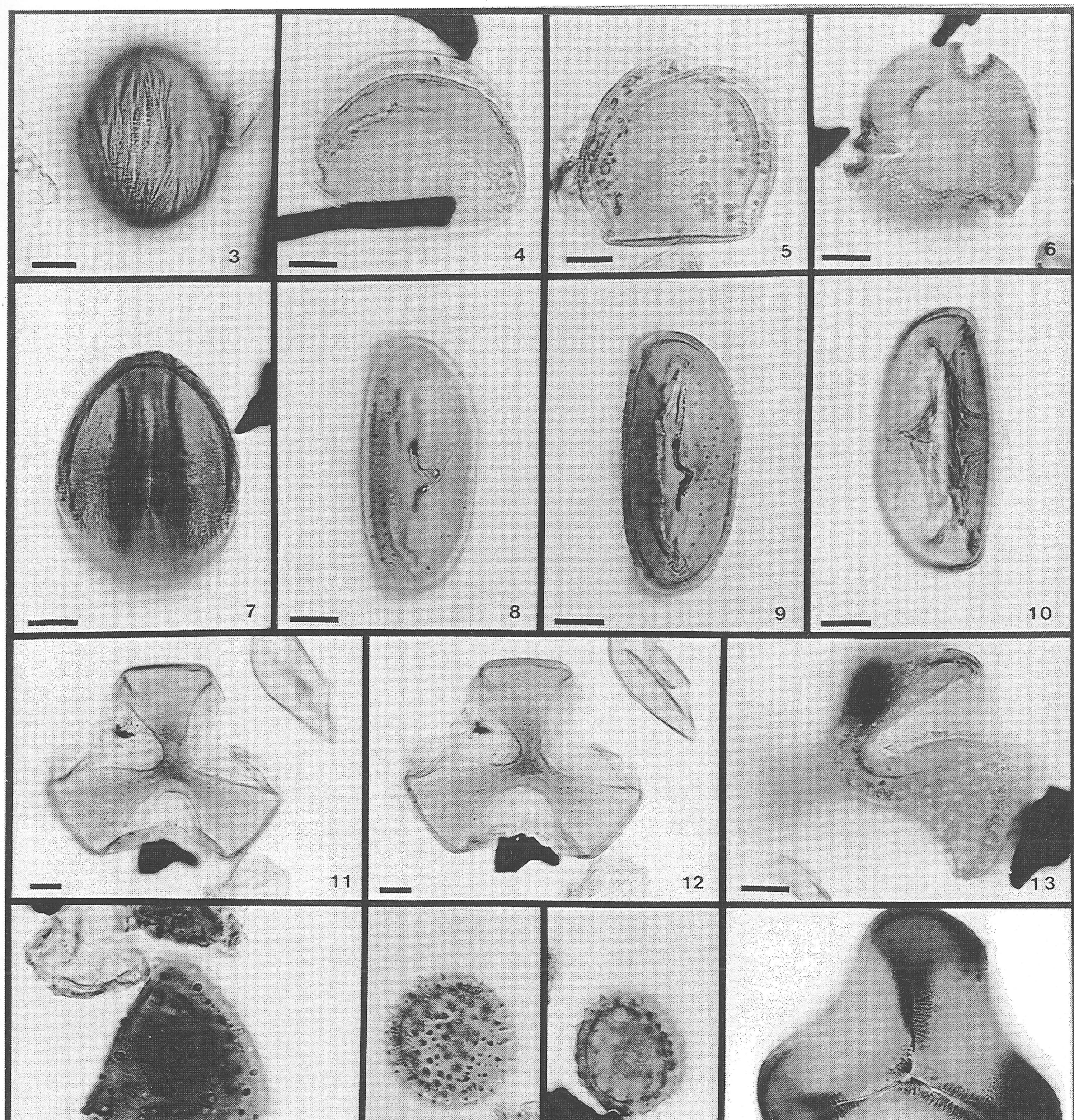
Upper F. longus
Lower F. longus
T. lilliei
REL. ABUNDANCE NOTHOFAGUS
ASTERACEAE
NOTHOFAGIDITES FALCATUS
CYATHEACIDITES ANNULATUS
CINGULATISPORITES BIFURCATUS
MONOTOCIDITES GALEATUS
RHOIPITES AMPEREAFORMIS
MYRTACEIDITES LIPSIS
TUBULIFLORIDITES PLEISTOCENICUS
S. (TRIPUNCTI-SPORIS) SP.
Q. BROSSUS
T. LILLIEI
On-shore Sector
Off-shore Sector

Fig. 2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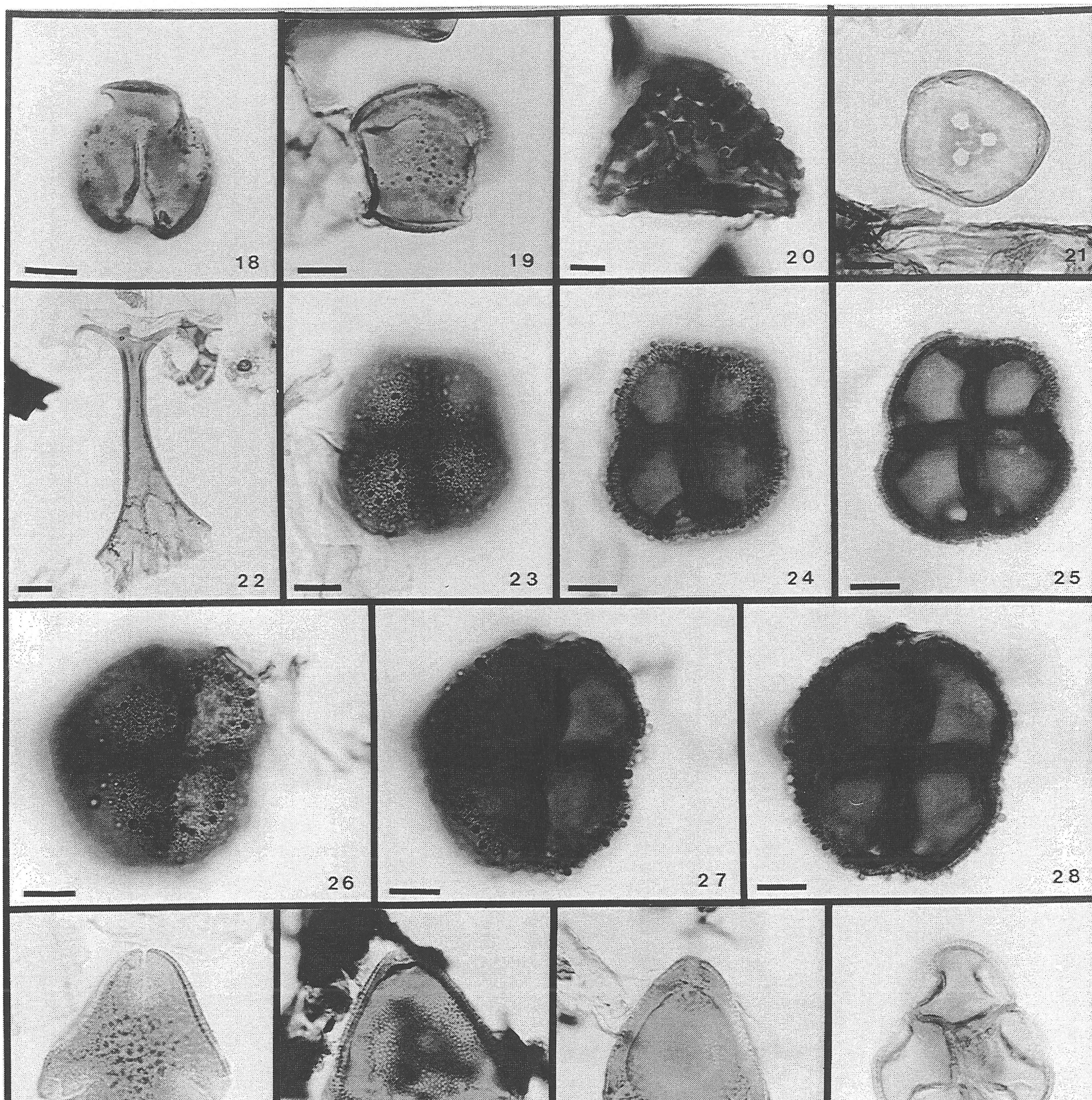
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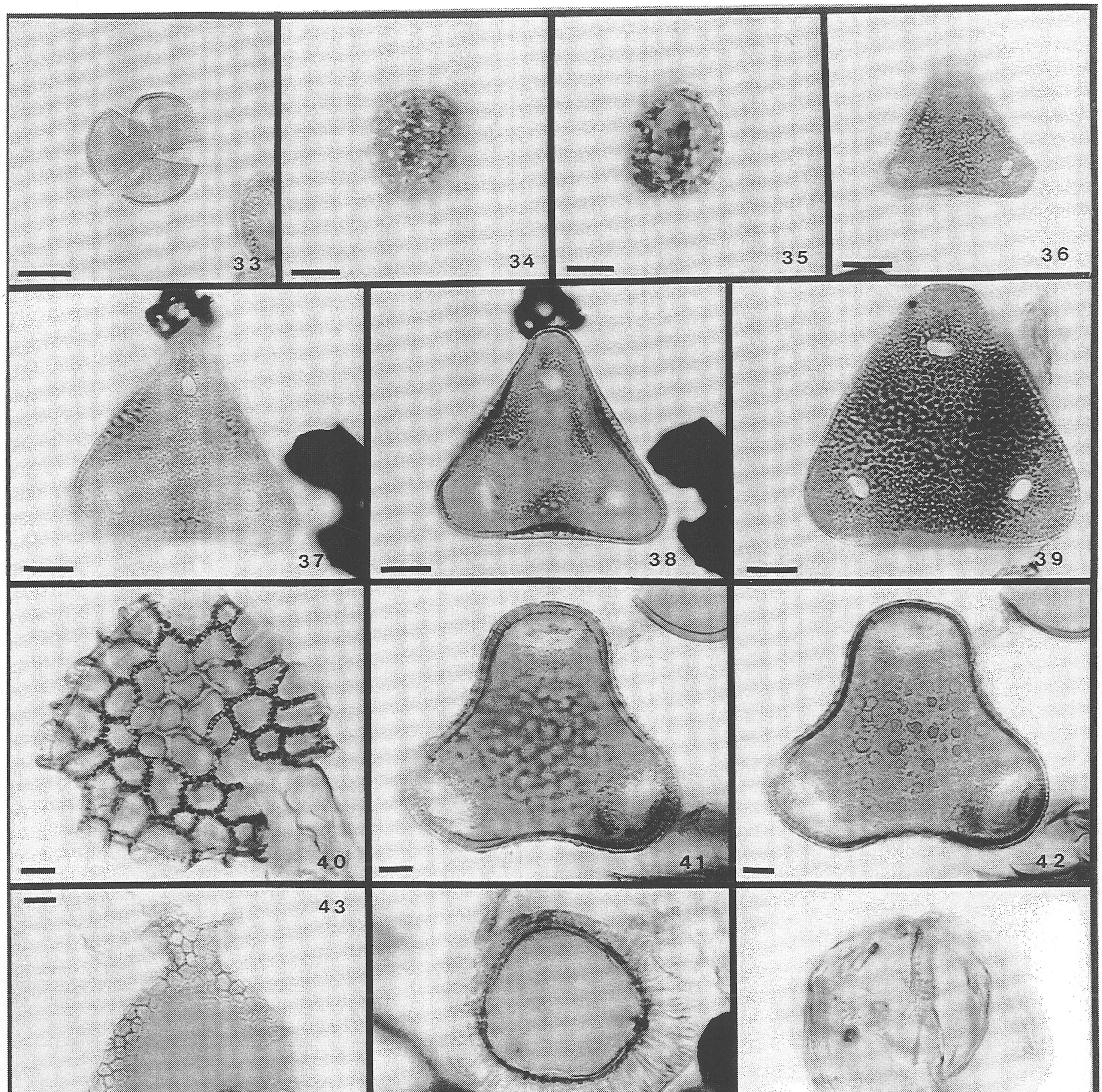
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