Department of Natural Resources and Mines
**Geological Survey of Queensland**

# Cenozoic oil-shale deposits in southeastern-central Queensland: palynostratigraphic age determinations and correlations for the Biloela Formation (Biloela Basin) in GSQ Monto 5

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Great state. Great opportunity.
**And a plan for the future.**
Queensland Government

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Cover photographs: Top, dissected sediments of the Biloela Formation forming benched flat-topped hills; Paleogene–Neogene basalt caps the hills in the distance. Looking north from the Burnett Highway near Lawgi Hall at the southern end of the Biloela Basin. Photograph courtesy Ian Withnall; figured in Withnall *et al.* (2009, figure 78c).
Bottom, Paleogene–Neogene columnar basalt, Mount Scoria, *ca.* 18 km southeast of Biloela. The basalt likely represents a plug; it is a small circular body, and the columnar jointing in its lower part is shallow to flat, suggesting steep contacts (Ian Withnall, personal communication, August 2014). Photograph courtesy of Owen Dixon, GSQ.

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# Contents

# SUMMARY

Fossil pollen and spores recovered from core chips of the Biloela Formation between 41.5 and 219.0 m in GSQ Monto 5:

- Confirm that freshwater, lacustrine sediments infilling the inland Biloela Basin *c*. 110 km southwest of Gladstone are a correlative of the oil-shale-rich Rundle Formation in the Narrows Graben near Gladstone on the central Queensland coast.
- Provide, within the resolution achieved by using palynostratigraphic-dating criteria, the first known evidence that the upper part of the Biloela Formation is Late Eocene–Early Oligocene. At present, the strongest evidence that the section is Late Eocene is the close similarity of the microflora to Late Eocene assemblages in the offshore Gippsland Basin in southeastern Australia.
- An Early (earliest?) Oligocene age is equally probable if age-range data from the Murray Basin, southeastern Australia, are used.

Differences in the age range of fossil species shared with southeastern Australia emphasise caution is needed when using zonation schemata developed for the continental margin Gippsland Basin and/or epicontinental Murray Basin to date Cenozoic deposits in central Queensland.


# INTRODUCTION

Sedimentary basins, which include thick oil-shale deposits of marine (tasmanite) to freshwater lacustrine (lamosite, torbanite) algal origin and range in age from Cambrian to Cenozoic, occur throughout eastern Australia, from northern Tasmania to northwestern Queensland (Geoscience Australia & ABARE, 2010; Pope, 2013).

A number of these deposits have been exploited since the mid-nineteenth Century and up to *c*. 1947 provided about 3% of Australia's petroleum consumption. Since reserves are estimated to be >13 billion barrels (Pope, 2013), the deposits remain an important resource of potentially recoverable unconventional hydrocarbons, as-and-when more environmentally acceptable ways of exploitation are developed. For example, between 1999 and 2004, 1.54 million barrels of oil were extracted from the Cenozoic Stuart oil-shale deposit in the Narrows Graben, near Gladstone on the central coast of Queensland (Figure 1).

Other Cenozoic basins whose infills accommodate oil shale and other organic-rich facies include:

- the Lowmead Graben 70 km to the south, Yaamba Basin 35 km to the northwest, Herbert Creek Basin 80 km to the north-northwest, and the Duaringa Basin 110 km to the west of Rockhampton respectively

- the Hillsborough Basin 100 km to the northwest of Mackay
- the Nagoorin Graben 70 km to the southeast, and the Redbank and Biloela Basins 100 km to the southwest of Gladstone (Figure 1).

Lacustrine depositional environments, which allowed the generation of hydrocarbons in the Narrows Graben and other Cenozoic basins in central Queensland, also promoted the sporadic preservation of microfloras that provide (as in this study) the basis for dating Cenozoic sequences in Queensland where other forms of age control are unavailable.

## BILOELA BASIN

This report presents and discusses fossil pollen and spores (miospores) preserved in lignitic facies intersected in **GSQ Monto 5**, a stratigraphic bore hole [24° 02' S, 150° 17' E; total depth 389.8 m] drilled by the Geological Survey of Queensland (GSQ) in the central part of the *c*. 120 km long/30 km wide Biloela Basin, *c*. 20 km north-northwest of the Jambin township (Noon, 1982). Adjacent basins include the Redbank Basin to the west, the Yaamba Basin to the north, and the Narrows Graben to the east (Figure 1).

## AIMS

The primary aim of the study was to date the Biloela Formation, a presumed correlative of the Rundle Formation in the Narrows Graben, for which Foster (1979) and Dettmann & Clifford (2000) have inferred a palynostratigraphic Late Eocene to Early Oligocene age for the lower part of the formation.

A subsidiary aim was to investigate foliar (leaf and cuticle) remains preserved in the Biloela Formation.

## GSQ MONTO 5

GSQ Monto 5 intersected 27.2 m of presumed Quaternary muds, sand and gravels, which are underlain by the Biloela Formation, embracing 335 m of freshwater mudstones, siltstones and sandstones, laminated to thinly-bedded oil shales and lignitic units, and minor limestone; at the base of the formation, brown oil shale and dark grey to black lignite, from 374 m to 369 m, is overlain by an 11.7 m sill of basalt at 357.3 m (Noon, 1982; Figures 1–2). The putative Paleogene lacustrine to fluvial section overlies 15.8 m of green olivine basalt, which may be intrusive (*i.e.*, it is younger than the Biloela Formation) or, alternatively, a possible correlative of an independently dated (48 Ma) dolerite to the south of the basin (see Cohen *et al*., 2013). It is thus unknown if any older 'Paleogene' sediments underlie the basalt at the base of GSQ Monto 5 (Withnall *et al*., 2009). Basement to the Biloela Basin comprises Late Devonian – Permian Yarrol Province elements, Permian rocks of the Gogango Thrust Zone, and Late Triassic sediments of the Callide Basin (Jell & McKellar, 2013).


Figure 1: Location of GSQ Monto 5, Biloela Basin, and other Cenozoic basins and lithostratigraphic units in Queensland (onshore only), including those hosting oil-shale deposits (modified from Cook & Jell, 2013, figure 8.2). Note: oil-shale-bearing basins/units are shown in red font, with the major oil-shale deposits comprising Stuart, Rundle and McFarlane (the latter, 18 km south-southeast of Proserpine, previously being known as *Condor* and presently representing the largest known oil-shale deposit in Australia).

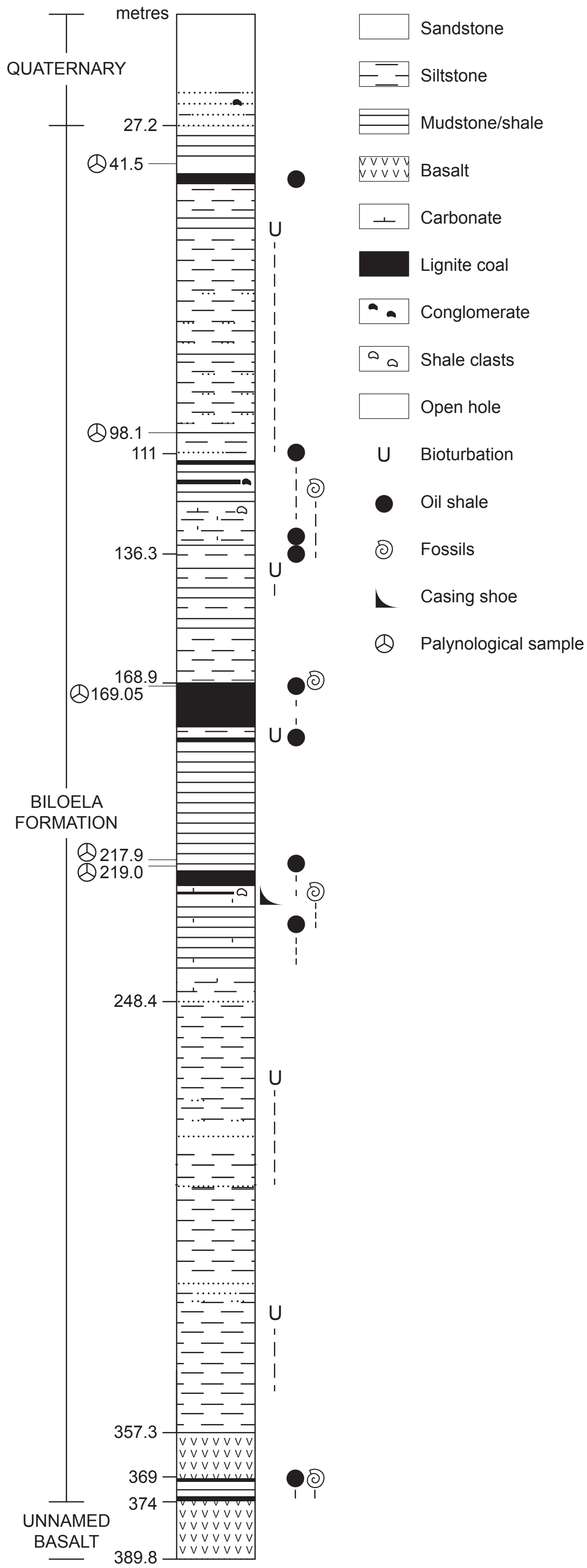



Figure 2: Lithostratigraphy of GSQ Monto 5 (after: Noon, 1982, figure 2; Cook & Jell, 2013, figure 8.8). For detailed descriptions of the rock types between the marked depth intervals, see Noon (1982).

## PREVIOUS STUDIES

Most of the *en echelon* graben and half-graben structures in central Queensland are believed to have developed in response to an extensional tectonic regime initiated during opening of the Coral Sea in the Early Cretaceous and which continued into the Late Paleogene (see references in Cook & Jell, 2013). For the same reason, estimates of the geological age of the lacustrine infills vary from Middle – Late Eocene in the Lowmead and the Yaamba Basins (Foster, 1982; Dudgeon, 1982, 1983; Wood, 1986) to Middle Eocene to Oligocene in the Hillsborough Basin (Hekel, 1972; Foster, 1982), Middle – Late Eocene and Oligo–Miocene for the lower and upper parts respectively of the succession in the Duaringa Basin (Foster, 1980), and Late Eocene to Early Oligocene for the Narrows Graben and lower part of the sequence in the Casuarina Basin (Foster, 1980; Noon, 1980; Dettmann & Clifford, 2000).

In most instances, the palynostratigraphic age determinations are based on, or have been constrained by, 1970's vintage, age-range data from the Gippsland Basin, southeastern Victoria (*cf.* Hekel, 1972; Stover & Partridge, 1973; Foster, 1979).

The lacustrine sequence in the Biloela Basin (Biloela Formation) is deeply weathered and laterised, and the oxidation of organic matter has been cited as a reason for the 'lack of recoveries of palynofloras' (Cook & Jell, 2013, page 591). As far as we are aware, the results presented in this report are the first microfossil evidence that tests the assumed Eocene age for the Biloela Formation (*cf.* Grimes, 1980; Noon & Grimes, 1982).

# PALYNOSTRATIGRAPHY

Five core chips of lignitic and other organic-rich strata in the Biloela Formation were collected (RJC) from GSQ's Exploration Data Centre at Zillmere, Brisbane. Three of these samples, from depths of 41.5 m, 169.05 m and 219.0 m, yielded workable numbers of miospores in organic extracts dominated by plant detritus (palynodebris) in which the cellular structure was mostly well-preserved (structured terrestrial kerogen). Preservation was adequate to good, but many palynomorphs were crumpled and/or partially obscured by palynodebris. The remaining two samples, from 98.1 m and 217.9 m, yielded little more than silt and very fine sand (micro-quartz).

All samples were processed for plant microfossils by *Core Laboratories (Australia) Pty Ltd*, using a combination of standard chemical and microfiltration techniques (see Traverse, 1988). Estimates (MM) of the relative abundance of miospores able to be identified to a fossil genus (morphogenus) or species (morphospecies) are given as a percentage of the total spore and pollen count in Appendix 1. Morphotaxa with relative abundances of less than 1%, or recorded outside the total count, are denoted by '+' and 'x' respectively. The miospore recovery from the 169.05 m sample was below the minimum required for statistically robust estimates, and data for this sample are given as raw counts (in parentheses). Nearest living relatives (NLRs) of the fossil taxa are given in parentheses in the text and in Appendix 1.

Age-diagnostic miospores are illustrated in Plate 1. A selection of unidentified morphotypes, including several that are not known to have been recorded previously, is illustrated in Plate 2.

## AGE CONTROL

Estimates of the maximum and minimum age of the productive samples from GSQ Monto 5 are based primarily on the first occurrence (First Appearance Datum: FAD) and last occurrence (Last Appearance Datum: LAD) of palynostratigraphically useful morphospecies in the two sedimentary basins in Australia where deposition is known to have been quasi-continuous during the Eocene to Miocene, namely the offshore Gippsland Basin and epicontinental Murray Basin (Macphail, 1999; Partridge, 1999, 2006) in southeastern Australia.

Where possible, the zonation criteria used to subdivide Late Paleogene – Early Neogene time in southeastern Australia have been constrained by: (a) age-range data from the Capricorn Basin, off the central coast of Queensland (*cf.* Hekel, 1972; Foster, 1982); and (b) presence/absence data from central Queensland (*cf.* Foster, 1980, 1982; Wood, 1986; Beeston, 1994; Dettmann & Clifford, 2000, 2003; Macphail & Gibson, 2014).

We recognize that this approach necessarily assumes that the evolution and/or migration of plant taxa and their subsequent extinction were broadly ‘synchronous’ along the eastern margin of Australia—an assumption that is improbable for geographic, as well as ecological reasons (Macphail, 2007).

Several Cenozoic oil-shale deposits include volcanic interbeds, but, so far, the only known test of the reliability of the Gippsland and Murray Basin zonations in Queensland is a self-funded (MM) palynostratigraphic analysis of a claystone between two lavas dated by $^{40}Ar/^{39}Ar$ to 23 Ma (Oligocene–Miocene boundary) at Toowoomba at 649 m elevation on the eastern highlands in southeastern Queensland (Macphail & Gibson, 2014). How relevant the Toowoomba data are to the coastal-lowland sequences of the cited basins is unclear.

## INFERRED AGE OF THE BILOELA FORMATION

Inferred ages for the three productive samples from the Biloela Formation (with NLRs in parentheses) are:

### 41.5 m

***Maximum age***: The maximum age limit for the sample at 41.5 m is inferred to be Late Eocene, based on FAD data for *Polypodiaceoisporites retirugatus* (*Pteris*), *Anacolosidites sectus* (*Anacolosa*), *Perfotricolpites digitatus* (Convolvulaceae), *Reevesiapollis reticulatus* (*Ungeria*) and *Tricolpites thomasii* (Loranthaceae).
The same maximum age is supported by: (a) occurrences of *Malvacearumpollis mannanensis* (Malvaceae) and *Corsinipollis* cf. *epilobioides* (Onagraceae), assuming

the FADs inferred by Foster (1980) and Wood (1986) are correct; and (b) the absence of species whose LADs occur in the Middle Eocene, Lower *Nothofagidites asperus* Zone/ Zone Equivalent in the Gippsland and Murray Basins, namely *Proteacidites asperopolus* and other distinctive extinct Proteaceae species, such as *Proteacidites grandis* and *P. tuberculiflormis* (criteria that assume the parent plants ranged northwards into Queensland).

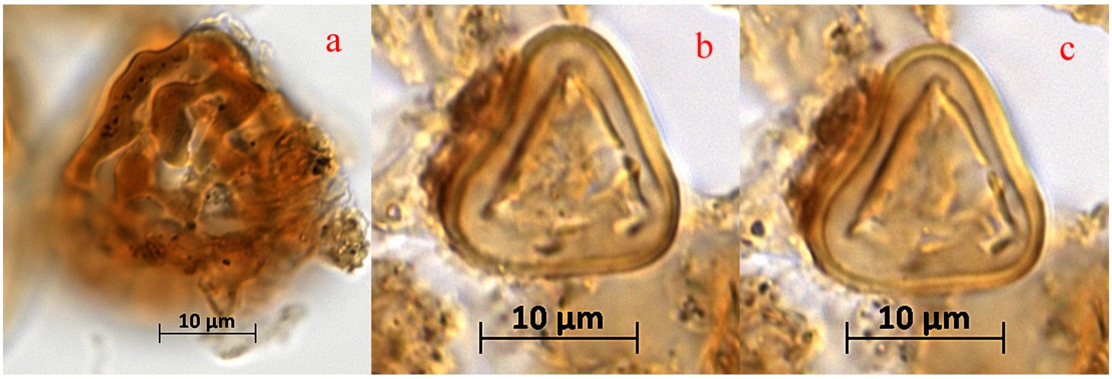
***Preferred age***: The preferred age (low confidence) is Late Eocene, based on the similarity of the microflora at 41.5 m to Middle *Nothofagidites asperus* Zone/Zone Equivalent microfloras in the Gippsland and Murray Basins. However, it is recognized that this age is based on the assumptions that (a) *Corsinipollis* cf. *epilobioides* and *Polyorificites oblatus* first appeared earlier in central Queensland than in southeastern Australia; and (b) morphospecies such as *Malvacipollis diversus* (this study) and *Propylipollis biporus* (Yaamba Basin), which last occured in the Middle Eocene, Lower *Nothofagidites asperus* Zone in the Gippsland Basin, also have extended ranges in central Queensland. An Early Oligocene age is equally probable *if* age-range data from the Murray Basin are used as the primary criteria for the age determination (see below).

***Minimum age***: The minimum age limit is more difficult to infer since times of species extinctions are known to be diachronous between, and occasionally within, the larger sedimentary basins (see Macphail, 2007). On present indications, the sample at 41.5 m is unlikely to be younger than Early (earliest?) Oligocene, based on the occurrence of *Anacolosidites sectus*, *Santalumidites cainozoicus* (Santalaceae), *Tricolpites thomasii* and (considering Murray Basin data) *Corsinipollis* cf. *epilobioides* and *Malvacearumpollis mannanensis*. The sample is highly unlikely to be younger than Late Oligocene to late Early Miocene, based on the absence of *Dryadopollis retequetrus*, *Triporopollenites* cf. *bellus* and *T. bellus*, all of which occur in Miocene deposits in southeastern-central Queensland.

**169.05–219.0 m**

Microfloras recovered from the samples at 169.05 m and 219.0 m lack age-diagnostic taxa, but otherwise resemble those recorded at 41.5 m in terms of palynological dominance by *Haloragacidites harrisii* (Casuarinaceae) and the presence of uncommon to very rare, described and undescribed morphospecies (Appendix 1). Examples include the diverse striate-pseudostriate morphotypes variously referred to *Ailanthipites*, *Simpsonipollis* or *Striatricolporites*, *Proteacidites vargexinus* and quadra- and triporate specimens of a pollen type referred to *Triorites orbiculatus* by Foster (1982). For this reason, the interval between 169.05 m and 219.0 m also is suggested to be Late Eocene (very low confidence). The absolute maximum age of the interval is Middle Eocene, based on *Nothofagidites falcatus* [*Nothofagus* (*Brassospora*) sp.].

## Plate 1: Age-diagnostic morphospecies



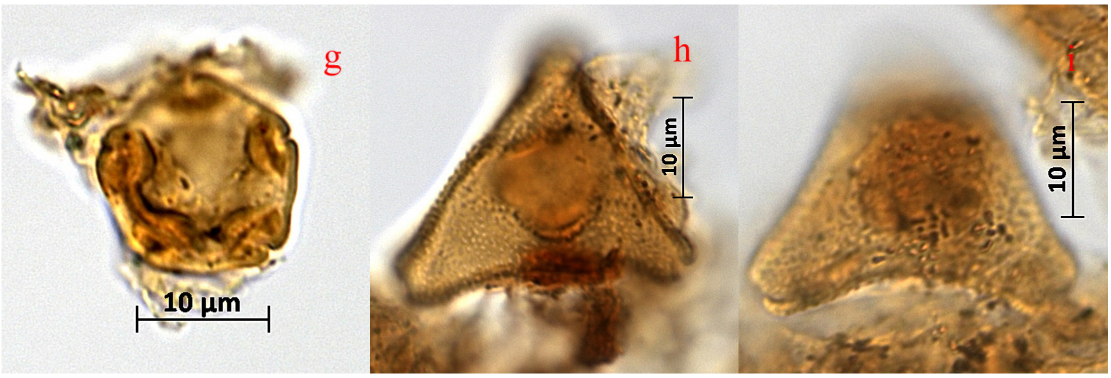

*Polypodiaceoisporites retirugatus* (41.5 m)

*Anacolosidites sectus* (41.5 m)


*Corsinipollis* cf. *epilobioides* (41.5 m)

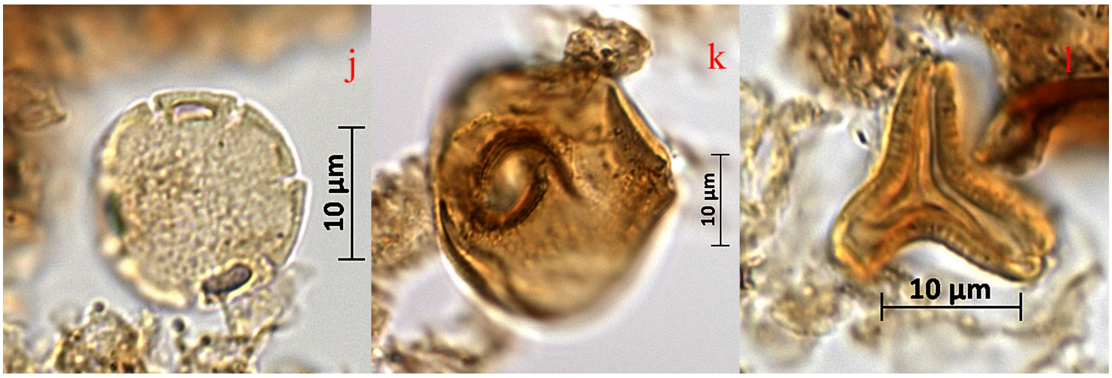
*Malvacearumpollis mannanensis* (41.5 m)

*Perfotricolpites digitatus* (41.5 m)




*Polyorificites oblatus* (41.5 m)

*Proteacidites pachypolus* (41.5 m)

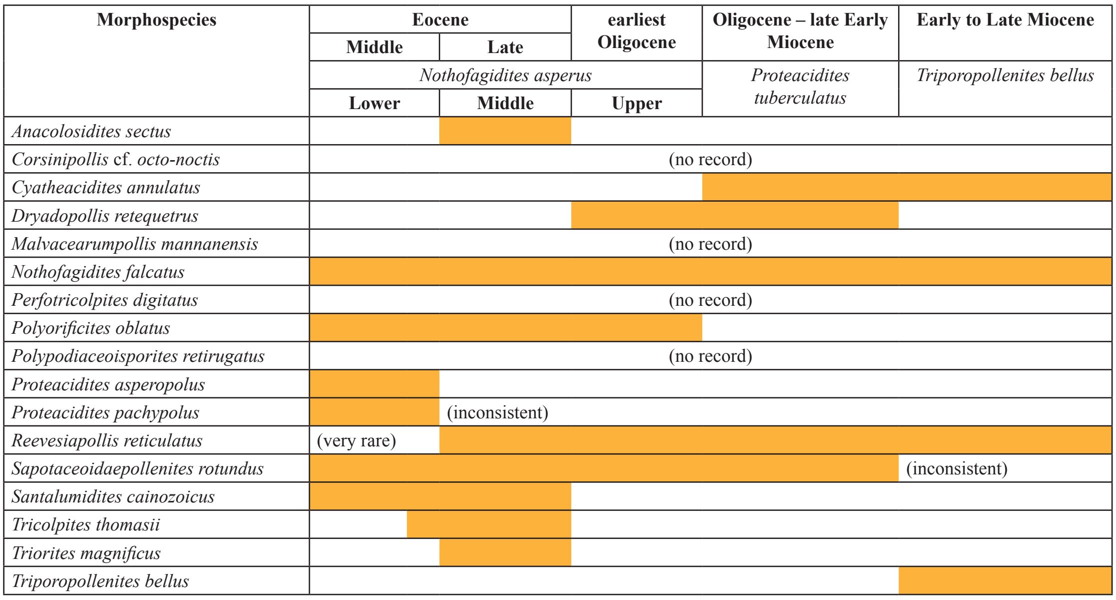



*Reevesiapollis reticulatus* (41.5 m)

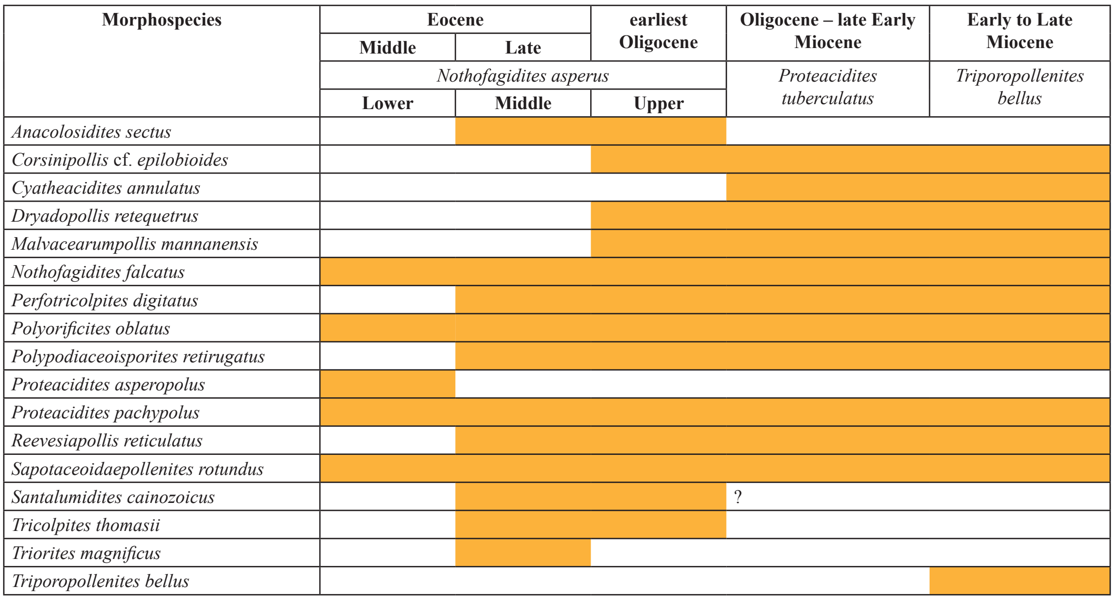
*Santalumidites cainozoicus* (41.5 m)

*Tricolpites thomasii* (41.5 m)

***Gippsland Basin*** (after Stover & Partridge, 1973; Partridge, 1999; A.D. Partridge & M.K. Macphail, unpublished records).




***Murray Basin*** (after Macphail, 1999).




***Southeast Queensland*** (Foster, 1980; Wood, 1986; Beeston, 1994; Dettmann & Clifford, 2000, 2003; Macphail & Gibson, 2014).

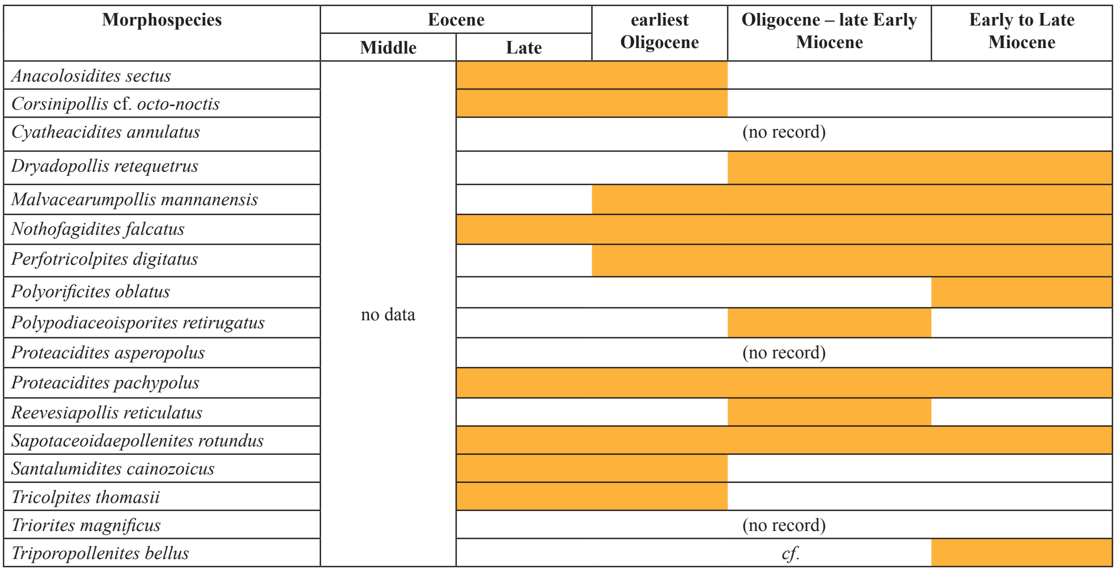



Figure 3: Comparison of range data for eastern Australia.

## FOSSIL FOLIAR REMAINS

Samples from 169.05 m and 219.0 m yielded more than 10 cuticle taxa. These included the cycad *Bowenia*, an unidentified conifer (Podocarpaceae?), one Proteaceae, and at least three morphospecies of Lauraceae. *Bowenia* is currently restricted to northeastern Queensland (Hill, 1978, 1998), and this observation, in addition to the presence of diverse Lauraceae, is considered to be evidence of a warm and wet past climate in the region.

## DISCUSSION AND CONCLUSIONS

A comparison of age-range data from the two major sedimentary basins in southeastern Australia and correlative sequences in southeastern-central Queensland (Figure 3) confirms that:

- A number of important zone index morphospecies used to subdivide Eocene and Oligocene time in the Gippsland and Murray Basins are unlikely to have ranged as far north as Queensland, *e.g.*, *Triorites magnificus* and *Cyatheacidites annulatus*. *Triporopollenites bellus* is a known exception.
- A number of the morphospecies found in the Biloela Basin and, for example, the Narrows Graben have relatively short time distributions in the Gippsland Basin compared to the Murray Basin, *e.g.*, *Proteacidites pachypolus*. One variant of this morphospecies, found at 41.5 m in GSQ Monto 5, has a coarse reticulate ornamentation that is intermediate between *Proteacidites pachypolus* and *P. nasus*, a related morphospecies that ranges no higher than the Late Eocene in the Gippsland Basin (Middle *Nothofagidites asperus* Zone) and Murray Basin (Middle *Nothofagidites asperus* Zone Equivalent).
- Several long-ranging morphospecies in central Queensland have not been recorded in the Gippsland Basin, *e.g.*, *Corsinipollis* cf. *epilobioides* and *Malvacearumpollis mannanensis*. Foster (1982) has inferred these morphospecies first appeared in southeastern-central Queensland in the Late Eocene, *i.e.*, earlier than in the Murray Basin.

Reasons why the age ranges (time distributions) of morphospecies vary along the eastern margin of the continent are likely to include:

1. ***Latitude***: There is *c*. 17° difference in latitude between Gippsland Basin (*c*. 38°S) and Cenozoic basins in central Queensland (*c*. 21°S).

   Latitudinal thermal gradients during the Late Eocene, when the two regions were at paleolatitudes of respectively 60°S and 45°S, were relatively low compared to the present (Figure 4). Against this, the Gippsland Basin would have been more exposed than the central Queensland basins to the cooling events in the proto-Southern Ocean, following rifting between Antarctica and Australia during the Middle to Late Eocene and the submergence of the South Tasman Rise to abyssal depths during the Eocene–Oligocene transition. This transitional interval coincides with the initial development of the Circum-Antarctic Current and onset of major glaciation in Antarctica (Exon *et al*., 2004, figure 4).

2. ***Catchment size***: The relatively high diversity of Late Paleogene microfloras in the Murray Basin compared to those in the Gippsland Basin and central Queensland basins almost certainly reflects the very large size of this basin (300,000 $km^2$) and the diversity of marginal-marine, coastal-plain, fluvio-lacustrine, fluvial and upland habitats within the catchment.

   Catchment size almost certainly is mirrored by the extended time distribution of morphospecies shared with the Gippsland Basin and, on the more limited data available, southeastern and central Queensland (Figure 4).

3. ***Depositional environment***: As for all ancient swamp (coal, lignite) successions, microfloras recovered from the oil-shale deposits are dominated by miospores of the relatively few plants that are tolerant of seasonally-to-perennially-high water-table levels. Examples in this study include ferns, a member of the lily family (*Liliacidites bainii*) and the unknown plants producing *Proteacidites vargexinus* and *Rhoipites alveolatus*. Shifts in palynological dominance, *e.g*., in *Nothofagus* (*Brassospora*) spp. and Casuarinaceae (*Gymnostoma*?), between 219.0 m and 41.5 m depth in GSQ Monto 5 are likely to reflect long-term trends in water-table level.

   For the same reason, age-diagnostic-pollen taxa produced by dryland plants would be expected to be much less common in lacustrine deposits, and their sporadic occurrence is likely to reflect rare, fortuitous depositional events. Examples in the central Queensland basins, based on their present-day ecology, include three of the age-diagnostic morphospecies utilised in this study, specifically *Anacolosidites sectus* (whose NLR is the rainforest genus *Anacolosa*, now restricted to the Old World Tropics), *Tricolpites thomasii* (an extinct member of the mistletoe family Loranthaceae), and *Reevesiapollis reticulatus* [whose NLR (*Ungeria*) is endemic to Norfolk Island].

4. ***Undetected reworking/caving***: A recent review of the Pliocene Calivil Formation in the Murray Basin (Macphail, 2013) revealed reworking of older microfloras into younger sediments, although this was difficult to verify in many boreholes where detailed bore-log evidence is lacking.

   Since the bulk of the samples on which the Murray Basin zonation (Macphail, 1999) was based were cuttings (which are equally subject to downhole caving of younger miospores), it is possible that the chronologic range of some rare but distinctive morphospecies is more restricted than implied by their stratigraphic distribution in this basin. Possible examples include *Anacolosidites sectus* and *Tricolpites thomasii*, occasional specimens of which are found in earliest Oligocene (Upper *Nothofagidites asperus* Zone Equivalent) sediments in the basin.

Despite the chronostratigraphic uncertainties, the age determination for the sample at 41.5 m in GSQ Monto 5 provides compelling evidence that the Biloela Formation is a correlative of the Wattle Creek seam of the Rundle Formation in the Narrows Graben (*cf.* Foster, 1979) and that the accumulation of lacustrine sediments in the Biloela Basin and Narrows Graben (and adjacent tectonic structures) occurred under similar climatic conditions (Figure 4) and possibly the same tectono-sedimentary regime. Further evidence that sediments in the two formations are the same age is that the *Bowenia* and Proteaceae cuticles recorded here from the Biloela Formation appear to be identical to taxa reported from the Rundle Formation (Rowett, 1986).

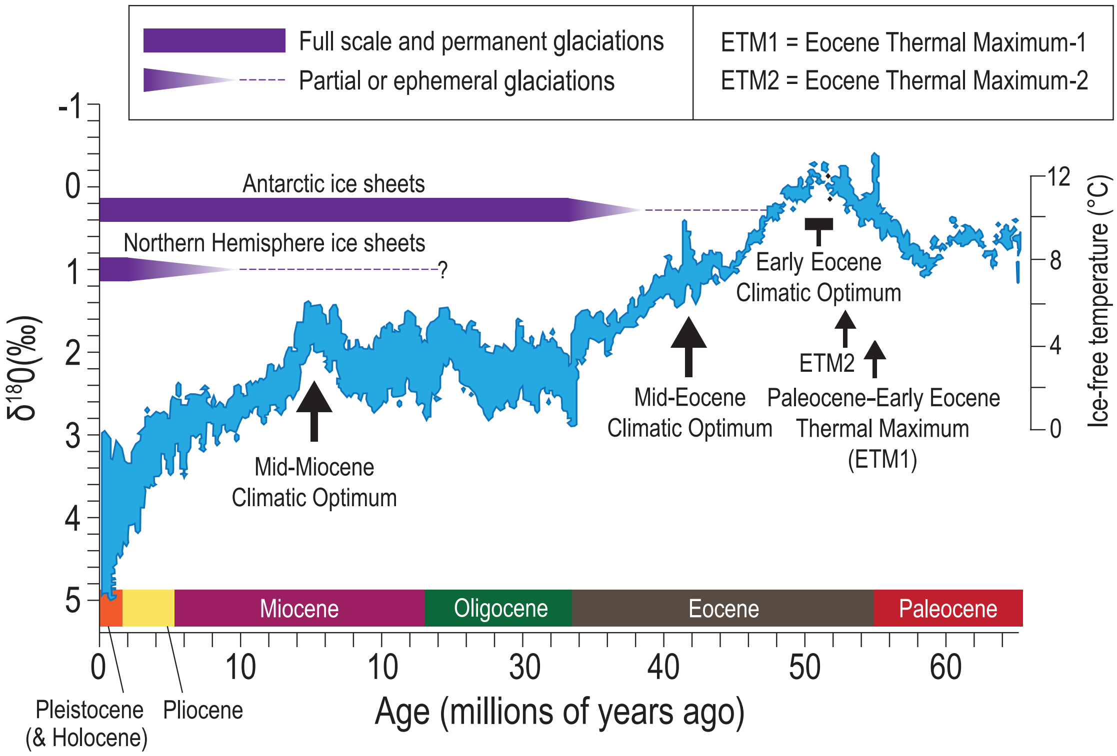
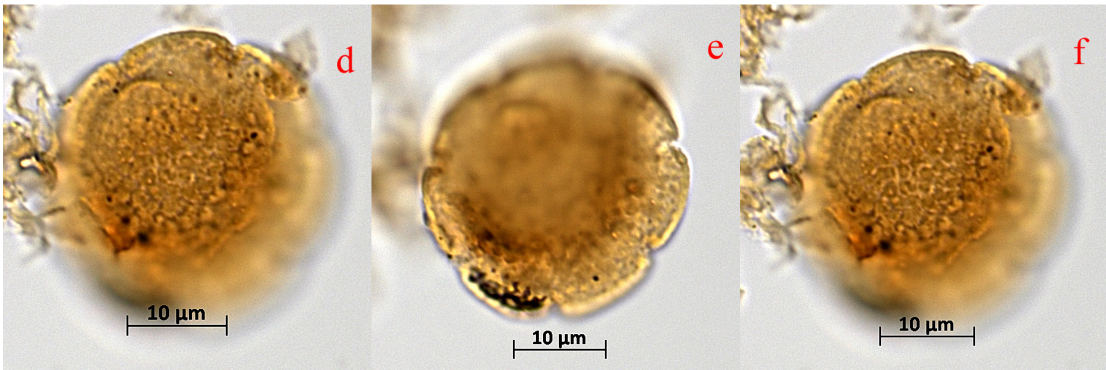



Figure 4: Trends in Paleogene–Neogene paleotemperature (modified from Zachos *et al.*, 2008, figure 2; with permission from Macmillan Publishers Ltd., copyright 2008).

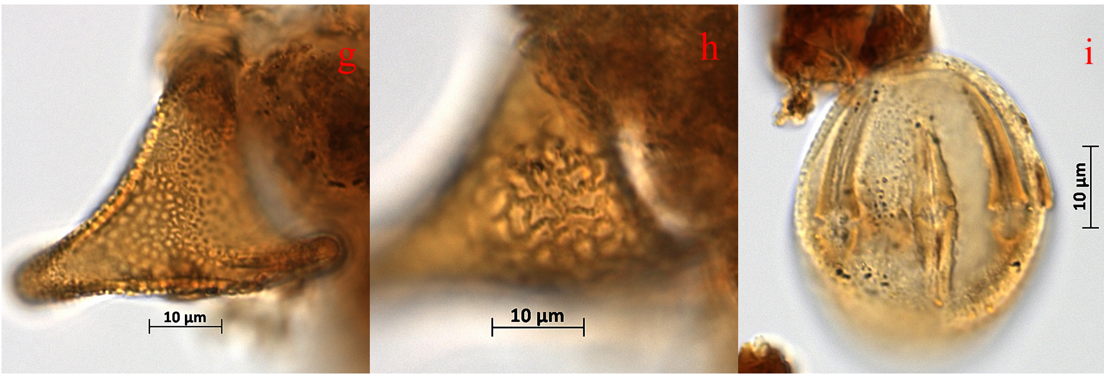
## Plate 2: Unidentified and/or undescribed morphotypes


trilete spore cf. *Baculatisporites scabridus* (219.0 m)

hilate trilete spore cf. *Crassiretitriletes vanraadshoovenii* (219.0 m)

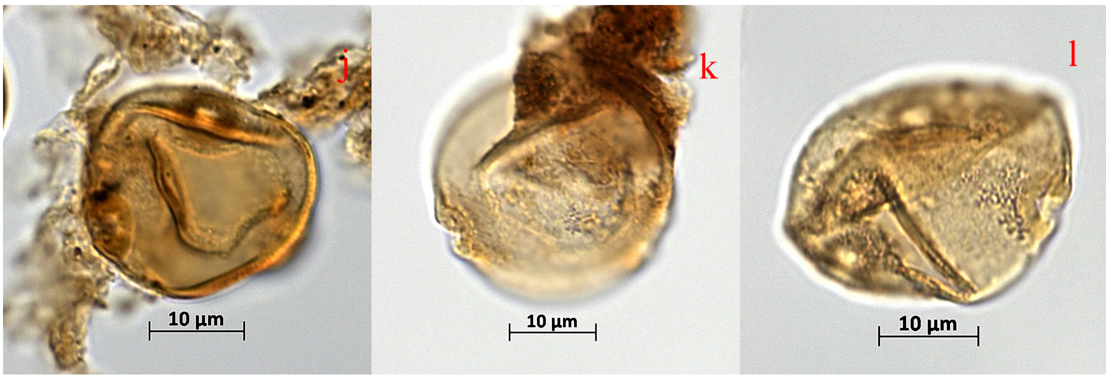



*Polycolpites* sp. aff. *Psilastephanocolpites micus* (41.5 m)




*Proteacidites* cf. *crassus* (41.5 m)

*Rhoipites* sp. B




*Triorites* cf. *orbiculatus* (41.5 m)

*Triorites* cf. *orbiculatus* (217.9 m)

*Triorites* cf. *orbiculatus* (219.0 m)

## ACKNOWLEDGEMENTS

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# APPENDIX 1

**Relative abundance and stratigraphic distribution of fossil miospores in GSQ Monto 5, 41.5 m–219.0 m**

| FOSSIL TAXON | NLR | 41.5 m | 169.05 m | 217.9 m | 219.0 m |
|---|---|---|---|---|---|
| CRYPTOGAMS | | | | | |
| *Baculatisporites disconformis* | Hymenophyllaceae | + | x | | x |
| *Ceratosporites equalis* | Lycopodiales | x | | | |
| *Crassiretitriletes vanraadshoovenii* | *Lygodium* | | | | x |
| *Cyathidites australis/minor* | includes *Cyathea* | + | x | | |
| *Cyathidites splendens* | *Acrostichum* | x | | | + |
| *Foveotriletes balteus* | Lycopodiaceae | x | | | |
| *Gleicheniidites* | Gleicheniaceae | + | | | |
| *Laevigatosporites major* | includes Blechnaceae | 20% | (2) | | 2% |
| *Latrobosporites* cf. *crassus* | Lycopodiales | + | | | |
| *Polypodiisporites* spp. | includes Polypodiaceae | + | x | | |
| cf. *Rouseisporites*? sp. of Foster, 1982 | Hepaticae | 2% | | | + |
| *Verrucosisporites kopukuensis* (monolete) | *Lygodium*? | + | | | |
| unidentified trilete spores | unknown | 1% | x | | 11% |
| GYMNOSPERMS | | | | | |
| *Araucariacites australis* | *Araucaria* | + | (1) | | |
| *Dacrycarpites australiensis* | *Dacrycarpus* | + | x | | |
| *Dacrydiumites florinii* | *Dacrydium* | + | (1) | | x |
| *Dilwynites granulatus* | *Agathis/Wollemia* | | | | |
| *Ephredripites notensis* | *Ephedra* | | x | | |
| *Microalatidites palaeogenicus* | *Phyllocladus* | + | | | |
| *Microcachryidites antarcticus* | *Microcachrys* | x | | | |
| *Phyllocladidites mawsonii* | *Lagarostrobos* | x | | | |
| *Phyllocladidites reticulosaccatus* | *Lagarostrobos* | | x | | |
| *Podosporites microsaccatus* complex | *Microcachrys*? | + | | | |
| *Podocarpidites* spp. | *Podocarpus/Prumnopitys* | 1% | (2) | | + |
| ANGIOSPERMS | | | | | |
| *Ailanthipites-Striatricolporites* spp. | Anacardiaceae | + | (1) | | + |
| *Anacolosidites sectus* | *Anacolosa* | x | | | |
| *Arecipites* | Arecaceae? | + | | | |
| *Banksieaeidites* cf. *arcuatus* | *Banksia* | + | | | |
| *Beaupreaidites elegansiformis* | *Beauprea* | | | | x |
| *Canthiumidites* sp. | *Randia*? | x | | | |
| *Compositoipollenites* sp. | Loranthaceae? | + | | | |
| *Corsinipollis* cf. *epilobioides* | Onagraceae | 2% | | | |
| *Cupanieidites orthoteichus* | Cupanieae | + | x | | + |
| *Cupanieidites* sp. A of Foster, 1982 | Cupanieae | x | (1) | | |
| *Cyperaceaepollis* spp. | Cyperaceae | 6% | | | |
| *Haloragacidites harrisii* | Casuarinaceae | 20% | (6) | | 58% |
| *Liliacidites bainii* complex | Liliaceae | 22% | x | | x |

| FOSSIL TAXON | NLR | 41.5 m | 169.05 m | 217.9 m | 219.0 m |
|---|---|---|---|---|---|
| *Malvacearumpollis mannanensis* | Malvaceae | x | | | |
| *Malvacipollis diversus* | *Austrobuxus* | x | | | x |
| *Malvacipollis subtilis* | Euphorbiaceae | 1% | x | | x |
| *Milfordia homeopunctata* | Anarthriaceae | + | | | + |
| *Myrtaceidites parvus-mesonesus* | Myrtaceae | + | (5) | | + |
| *Myrtaceidites verrucosus* f. *verrucosus* | Myrtaceae (Myrteae) | x | | | + |
| *Nothofagidites brachyspinulosus* | *Noth*. (*Fuscospora*) spp. | 1% | (4) | | + |
| *Nothofagidites emarcidus-heterus* complex | *Noth*. (Brassospora) spp. | 11% | x | | x |
| *Nothofagidites falcatus* | *Nothofagus* (*Brassospora*) sp. | 1% | | | x |
| *Nothofagidites vansteenisii* complex | Myrtaceae (Myrteae) | + | | | |
| *Perfotricolpites digitatus* | Convolvulaceae | x | | | |
| *Periporopollenites demarcatus* | Trimeniaceae? | x | | | |
| *Poluspissusites* sp. | Goodeniaceae? | x | x | | |
| *Polyorificites oblatus* | unknown | x | | | |
| *Polycolpites* sp. cf. *Psilastephanocol-porites micus* | unknown | | | | |
| *Propylipollis annularis* | *Xylomelum* | x | | | |
| *Proteacidites* cf. *adenanthoides* | extinct Proteaceae | x | | | |
| *Proteacidites differentipolis* | extinct Proteaceae | x | | | |
| *Proteacidites kopiensis* | extinct Proteaceae | x | | | |
| *Proteacidites pachypolus* fine reticulate var. | extinct Proteaceae | + | x | | x |
| *Proteacidites pachypolus* coarse reticulate var. | extinct Proteaceae | x | | | x |
| *Proteacidites vargexinus* | extinct Proteaceae | x | (20) | | 7% |
| *Proteacidites* spp. | Proteaceae | + | x | | 1% |
| *Reevesiapollis reticulatus* | *Ungeria* | x | | | |
| *Rhoipites alveolatus* | unknown | 4% | (21) | | 8% |
| *Santalumidites cainozoicus* | Santalaceae | x | | | |
| *Sapotaceoidaepollenites latizonatus* | Apocynaceae | | (5) | | |
| *Sapotaceoidaepollenites rotundus* | Apocynaceae | | (1) | | x |
| *Tricolpites thomasii* | Loranthaceae | x | | | |
| *Tricolporites adelaidensis* | unknown | + | | | |
| *Tricolporites valvatus* | unknown | x | x | | x |
| *Rhoipites/Tricolporites* spp. | unknown | x | (13) | | 7% |
| *Triorites* sp. cf. *T. orbiculatus* | unknown | x | (1) | (2) | x |
| **POLLEN SUM** | | **500** | **84** | **2** | **382** |