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Lower Balonne Airborne Geophysical Project

PALYNOSTRATIGRAPHIC ANALYSIS OF CORE AND CUTTINGS SAMPLES FROM THE LOWER BALONNE AREA, SOUTHERN QUEENSLAND, AUSTRALIA

M. K. Macphail

CRC LEME OPEN FILE REPORT 167

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1. INTRODUCTION

This report discusses plant microfossils recovered from stratigraphic holes drilled in the Lower Balonne area, near St George (Figure 1) as part of a program undertaken by the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) to understand the regolith geology of southern Queensland. Conventional cores were taken in Drillholes LB01-LB10. Cuttings samples are available from the other holes.

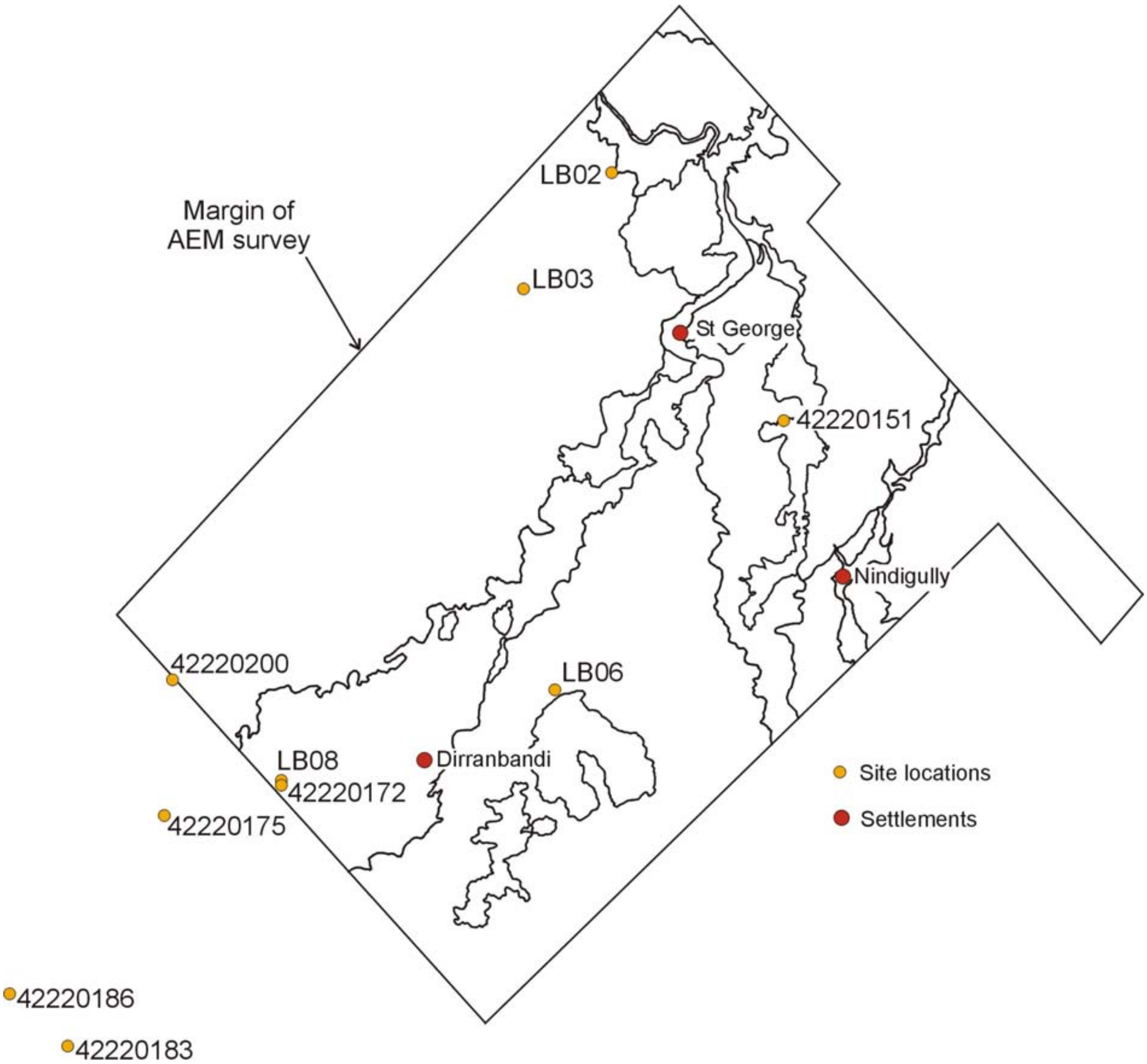

Figure 1. Location of holes from which samples were obtained.

Aims are to:

- Determine the age(s) of the Cenozoic regolith and environment(s) in which these sediments accumulated.
- Estimate the age(s) of the unconformity surface(s) separating the Cenozoic units from the underlying 'basement' rocks of the Surat Basin.
- Understand why relatively few samples yielded workable fossil pollen and spore assemblages, by providing data on the concentration and degree of humification of organic matter in the samples.

Seventy six core chip and cuttings samples from two series of drillholes were submitted by David Gibson, Ken Lawrie and Ben Maly, CRC LEME/Geoscience Australia. The overwhelming majority of these yielded residual quartz and/or strongly humified, often finely dispersed plant debris.

Six samples yielded sufficient numbers of fossil spores and pollen to establish a Late Cenozoic age for the sampled intervals. Another twelve samples yielded very sparse to diverse Early Cretaceous to Jurassic microfloras, indicating that some drillholes had intersected paralic sediments deposited in the Surat Basin or clasts reworked from Mesozoic rocks outcropping around the basin margins. Reworked? Middle Eocene to Middle Miocene pollen occur in three samples.

Age determinations and depositional environments are summarized in Table 1. Lithology and gamma log data were provided for Drillhole 42220175 by Jim Kellett (Bureau of Resource Sciences), who also provided 'log pick' depths for the base of the Cenozoic regolith in this hole and Drillholes 42220183 and 42220186.

Table 1: Inferred ages and depositional environments

Drillhole	Depth	Age	Zone	Environment
LB02	56.1 m	Late? Pliocene	*Tubulifloridites pleistocenicus* Equiv.?	fluvio-lacustrine
LB03	58.55 m	Pliocene	*Monotocidites galeatus* Equivalent?	fluvial?
LB03	58.65 m	Early? Pliocene	*Monotocidites galeatus* Equivalent?	fluvio-lacustrine
LB03	59.50 m	Early? Pliocene	*Monotocidites galeatus* Equivalent?	fluvio-lacustrine
LB06	58.6 m	Late Aptian-Early Albian	*Crybelosporites striatus*	restricted marine
LB08	62.3 m	Plio-Pliocene	*Tubulifloridites pleistocenicus* Equiv.?	fluvio-lacustrine
42220151	126-128 m	Early-early Late Albian	*Coptospora paradoxa*	fluvio-deltaic
42220172	111-113 m	Plio-Pliocene	*Tubulifloridites pleistocenicus* Equiv.?	backswamp
42220172	116-118 m	Late Aptian-Early Albian	*Crybelosporites striatus*	fluvio-deltaic
42220175	150-152 m	Eocene-Middle Miocene?	(reworked *Dictyotosporites complex*)	fluvial
42220175	172-174 m	Eocene-Middle Miocene?	(reworked *Callialasporites dampieri*)	fluvial
42220175	183-184 m	Eocene-Middle Miocene?	(reworked Jurassic)	fluvial
42220183	72-73 m	indeterminate	(reworked early Cretaceous?)	fluvial
42220183	151-153 m	Early-early Late Albian	*Coptospora paradoxa*	fluvio-deltaic
42220186	67-69 m	indeterminate	(reworked *Coptospora paradoxa*)	fluvio-deltaic?
42220186	115-117 m	indeterminate	(reworked *Ruffordiaspora australiensis*)	fluvial
42220200	140-143 m	Early-early Late Albian	*Coptospora paradoxa*	fluvio-deltaic
42220200	146-148 m	Early-early Late Albian	*Coptospora paradoxa*	fluvio-deltaic

2. GEOLOGICAL COMMENTS

As elsewhere in inland Australia, deep weathering has either wholly destroyed the organic content or reduced it to indeterminate fines down to depths of 50 m below ground surface in the Lower Balonne area. The lithologies most likely to preserve plant microfossils at shallower depths are lignites, massive medium to dark grey clays, and alginite horizons where the high organic content or oil released from the decaying algal cysts have rendered the host sediments impervious to penetration by oxygenated groundwater.

Drillholes LB06, 42220151, 42220172, 42220183and 42220200 penetrated through the unconformity surface separating the Cenozoic regolith and Early Cretaceous sediments of the Surat Basin.

Despite the low recovery, most of the sampled intervals which preserve fossil pollen, spores or dinocysts can be correlated with formations that have been formally described elsewhere in eastern Australia:

Cenozoic facies intersected in Drillholes LB02 (56.1 m), LB03 (58.55-59.5 m) , LB08 (63.2 m), and? 42220172 (111-113 m) are correlatives of the Loxton-Parilla Sands in the Murray Basin, and Lachlan Formation in the Lachlan Valley in southwestern NSW.

Low to trace numbers of fossil *Nothofagus* pollen (*Nothofagidites emarcidus-heterus*, *N. falcatus*) occur at 150-152 m, 172-174 m and 183-184 m in Drillhole 42220175. Alternative explanations are:

- The interval between 150-184 m is a correlative of the Middle Eocene to Middle Miocene Olney Formation in the Murray Basin;
- A correlative of this formation occurs upsection in this drillhole;
- Since Jurassic palynomorphs in the same intervals are definitely recycled (see below), the *Nothofagus* pollen has been reworked from Middle to Late Tertiary sediments upstream in the Lower Balonne area.

Early Cretaceous (*Coptospora paradoxa* Zone) freshwater facies intersected in Drillholes 42220151 (126-128 m), 42220183 (151-153 m) and 42220200 (140-148 m) are Griman Creek Formation.

Early Cretaceous (*Crybelosporites striatus* Zone) freshwater facies intersected in Drillhole 42220172 (116-118 m) probably are Griman Creek Formation.

Early Cretaceous (*Crybelosporites striatus* Zone) restricted marine facies intersected in Drillhole LB06 (58.6 m) are Wallumbilla Formation (Coreena Member?).

Only in Drillhole 42220172 are productive samples sufficiently closely spaced to use palynology to infer the location of the unconformity surface separating the Cenozoic facies from the Early Cretaceous facies of the Surat Basin (between 113-116 m depth).

Lithology and gamma log data indicate that Early Cretaceous microfloras at 67-69 m and 115-117 m in Drillhole 42220186 are reworked. The same is true of Jurassic microfloras at 150-174 m in Drillhole 42220175. The latter are likely to come from lignites transported by water from Jurassic sequences which outcrop around the northern and/or eastern margins of the basin.

3. PALYNOLOGY

3.1 Processing

All samples were processed using standard physical and oxidative chemical techniques designed to eliminate clays (Hydrofluoric Acid) and the more labile organic compounds (Schultze Solution), followed by filtration through millipore sieve-cloth to eliminate 5 μm or smaller particles (fines).

The last step concentrates pollen, spores and other relatively large (10-120μm) plant tissues.

Sub-samples of the acid-insoluble extracts were mounted on microscope slides (strew mounts) and scanned at low magnification (palynofacies analysis) or counted at high magnification (age determinations) using a *Zeiss* Photomicroscope II fitted with top-of-the-range (10-100 x) *Planapo* objectives.

3.2 Palynofacies analysis

Palynofacies comprise all organic remains preserved in a rock or sediment sample.

The relative abundance of the various types of organic matter in *unoxidized* (kerogen) extracts is widely used in the petroleum industry to predict the potential of the rock or sediment to generate liquid or gaseous hydrocarbons. This information is of limited use in regolith studies since most kerogen extracts are wholly dominated by indeterminate fines, which can be inorganic or organic.

Accordingly, the analyses are based on the acid-insoluble plant debris remaining after the samples have been processed using standard palynological techniques (see Section 3.1). These data provide proxy evidence of the extent of 'deep weathering'. The degree to which both organic and inorganic particles have been rounded (sphericity) provides some indication of transport distances. It is anticipated that the combined information may help reduce the high percentages of palynologically barren samples submitted for palynostratigraphic analysis in future drilling programs.

Organic debris is classified using the state of preservation of cellular tissues to assess the degree to which organic matter has been altered by natural oxidation processes. In this schema, plant tissues in which the cell walls are preserved are classified as s*tructured terrestrial*. Fossil pollen and spores fall into this class but are always assessed separately. Organic remains in which the cell wall structure has been destroyed but remain translucent at least around the margins are termed *semi-opaques*. Organic matter which as been oxidized to mineral carbon (vitrinite) or which lack translucent margins for other reasons are termed *opaques*.

Colour varies from light 'straw' to dark brown or black depending on geological age and depth of burial (maturity).

Many of the Lower Balonne samples included a black mineral characterized by reflective faces which intersect at highly oblique angles. Because these float in heavy liquid (SG 1.65) they are assumed to be organic in origin, i.e. vitrinite particles derived from coals which have not been broken down by chemical oxidation. The alternative identification of these minerals, as zircons, is considered less likely because of the processing techniques used in this study.

3.3 Palynostratigraphic analysis

Palynological subdivision of Mesozoic-Cenozoic time in Australia time is based on the First (FO) and Last (LO) Occurrence of typically uncommon but widely distributed spores produced by algal cysts (dinoflagellates), ferns, fern allies and liverworts (cryptogams), and pollen produced by gymnosperms and (Late Cretaceous-Tertiary) angiosperms.

Caveats

Whilst FOs provide a reliable <u>maximum</u> age for most samples, the actual geological age is less easily inferred for three reasons:

- Many gymnosperms, ferns and fern allies that first appear in the Jurassic and Early Cretaceous survived into early Late Cretaceous time in eastern Australia. Consequently zonal (and minimum) age determinations tend to be based on negative evidence, viz. the absence of species which first appear in the overlying palynological zone.

- The lack of palynostratigraphic data for the Late Cenozoic period in southern Queensland means that the LO of many species is imprecisely known. For example, no Neogene or Early Pleistocene microfloras have been found in southeast Queensland and, at present, the nearest independently-dated, quasi-continuous palynostratigraphic records of this period are preserved at high elevations in volcanic craters on the Atherton Tableland inland of Townsville (Kershaw, 1985, 1993), or in marine sediments accumulating on the continental shelf ~80 km offshore from Cairns (ODP Sites 815, 820 and 823: see Kershaw *et al*. 1993, Martin & McMinn 1993).

- Several of the key rainforest plants represented by fossil pollen and spores in the Lower Balonne samples are now extinct in Australia but survived into the Quaternary in northeast Queensland. Gymnosperms include two fossil species belonging to the family Podocarpaceae: *Dacrycarpites australiensis* (living equivalent *Dacrycarpus*) and *Lygistepollenites florinii* (living equivalent *Dacrydium*) which survived in wet sheltered habitats in northeast Queensland as recently as the Early (~900 kyr BP) and Late (~26 kyr BP) Pleistocene respectively (Kershaw 1985, Kershaw *et al*. 1993). Pollen of a third podocarp *Microalatidites palaeogenicus* whose living equivalent (*Phyllocladus*) in Australia is endemic to Tasmania, occur in trace numbers up to about 78,000 years ago in the same region. Angiosperms in the same (extinct) category include *Nothofagus* (*Brassospora*) spp. whose fossil equivalents (*Nothofagidites emarcidus-heterus*, *N. falcatus*) are now confined to montane rainforest in New Caledonia and Papua New Guinea.

Whether, and for how long, these podocarps and *Nothofagus* (*Brassospora*) spp. survived into Pleistocene time in wet sheltered habitats on the Great Dividing Range 350 km to the east of the Lower Balonne area is unknown, but all species became extinct in mainland southeastern Australia and Tasmania during the Pliocene or (*Dacrydium*) during the earliest Pleistocene (see Macphail 1997).

The other major family of gymnosperms represented by fossil pollen (Araucariaceae) presents a different problem in that the nearest living equivalent (*Araucaria*) of the fossil species *Araucariacites australis* still survives as emergent trees in tropical rainforest and may dominate stands of dry rainforest on the coast and adjacent ranges in southeast Queensland. Relict stands of the Bunya Pine (*Araucaria bidwillii*) occur up to 160 km inland, e.g. on Bunya Mt. northeast of Dalby, due to year-round high humidity (900-2000 mm pa) and frequent mists (Boland *et al*. 1994 pp. 40-45).

Modern climatic and distribution data show that it is improbable that *Araucaria* or other rainforest gymnosperms will have extended westward into the Lower Balonne area during the ?Middle or Late Pleistocene. However it is noted that Araucariaceae, Podocarpaceae and *Nothofagus* populations show a transient expansion during the mid Pliocene ‘warm period’ in southern Australia (see Macphail 1997), and (2) lake levels, and therefore effective mean annual precipitation within southwest Queensland, were higher than at present as recently as the middle Holocene (see Fig. 6 in Harrison 1993). Whether conditions in inland southeast Queensland were also wetter at this time is uncertain, but fossil pollen confirms that a deepwater lake on Fraser Island was surrounded by rainforest with *Araucaria*, then *Podocarpus*, between ~600-350 kyr BP (Longmore 1997).

Yields and preservation

Six core chips and 12 cuttings from the LB and 42220 drillholes yielded sufficient spore and pollen to infer the age of the sampled interval (Table 1).

Preservation of fossil pollen and spores was good to near perfect. The one exception is the sample at 150-152 m in Drillhole 42220175 where the microflora was degraded (‘blurred’) by the prolonged oxidation required to release the palynomorphs (chiefly gymnosperm pollen) from the lignitic matrix.

Contamination

Many of the fossil pollen taxa recovered from the Cenozoic units have close relatives in the present-day flora of the Lower Balonne area. Examples are (fossil species in parentheses) *Acacia* (*Acaciapollenites myriosporites*), *Allocasuarina*/*Casuarina* (*Haloragacidites harrisii*) and *Selenothamnus* (*Malvacipollis spinyspora*). For this reason, trace occurrences of these pollen types are assumed to be modern or sub-fossil contaminants, introduced into the sediment during drilling or when the cores or cuttings were collected.

Samples yielding significant numbers of these pollen types are unlikely to be contaminated since the lithology logs indicate much of the overlying Cenozoic regolith is deeply weathered (J. Kellett pers. comm.). Most of the samples also also preserved pollen and spores of plants which are not present in the modern flora of the Lower Balonne area, e.g. *Cyathea* (*Cyathidites paleospora*), *Araucaria*, *Dacrycarpus*, *Dacrydium* and *Podocarpus*.

Trace occurrences of pollen produced by the exotic pine genus *Pinus* are due to contamination of the samples during processing.

Reworking

Five samples yielding Mesozoic microfloras come from intervals that are unconsolidated Cenozoic sediments (J. Kellett pers. comm.). These are (age in parentheses): 150-184 m in Drillhole 42220175 (Middle Jurassic), 72-73 m in Drillhole 42220183 (Early Cretaceous?) and 67-69 m in Drillhole 42220186 (Albian). The Jurassic microfloras are mixed with low numbers of Tertiary *Nothofagus* pollen that may or may not be *in situ*.

4. PALYNOFACIES

Qualitative estimates of the dispersed organic remains, mineral carbon (vitrinite?) and residual quartz present in the acid-insoluble extracts (Table 2) were made by scanning the acid-insoluble extracts under low (x125) magnification.

The results show:

- The amount of microquartz crystals, other minerals and acid-insoluble organic detritus (*palynofacies*) remaining after chemical oxidation varies markedly from sample to sample within, and between drillholes.
- Although many of the sampled interval yielded significant amounts of organic matter, what is preserved has been strongly humified (reduced to semi-opaques or fines).
- Exceptions were samples from (1) drillholes which intersected the remains of tree roots and (2) some horizons within the Griman Creek Formation (see Section 5).
- Many samples included trace to high amounts of opaques. If the identification of these as vitrinite is correct, then coaly material derived from Mesozoic or ?Palaeozoic rocks is widely dispersed within the Cenozoic alluvium. Whether coals (sic) are useful as sediment tracers in the Lower Balonne area is unknown.
- The residual inorganic fraction mostly consists of angular to subangular micro-quartz (including phytoliths). The low sphericity is strongly against the particles having been transported long distances by wind or water to the core sites.
- Deep weathering during the Late Cenozoic has destroyed most or all of the fossil pollen and spores in alluvial sediments to depths of about 50 m below the present-day ground surface.

TABLE 2 Palynofacies data (acid insoluble extracts)

Drillhole	Depth (m)	MFP No.	INORGANIC		ORGANIC							
			microquartz		Structured terrestrial		semi-opaques			opaques (vitrinite?)		spore-pollen
			yield	angularity	yield	colour	yield	angularity	colour	yield	angularity	
LB01	3.45	20943	trace	angular	medium	yellow	high	angular	mid brown	trace	subangular	(fungal spores)
LB01	58.6	21470	trace	angular	low	orange	high	subangular	dark brown	-	-	high
LB02	22.5	20944	low	subangular	-	-	low	subround	mid brown	medium	angular	-
LB02	29.85	20945	low	angular	trace	orange	trace	angular	orange	medium	subangular	-
LB02	56.1	20946	-	-	low	orange	high	subangular	dark brown	trace	angular	high
LB03	38.2	21480	low	subangular	-	-	-	-	-	trace	subround	-
LB03	58.55	21479	trace	subangular	trace	mid brown	medium	subround	dark brown	-	-	trace
LB03	58.65	21478	trace	angular	trace	mid brown	high	subround	dark brown	-	-	medium
LB03	59.5	21477	trace	angular	high	orange	high	subangular	dark brown	-	-	high
LB04	43.3	20947	trace	trace	-	-	trace	subangular	mid brown	high	subround	(contaminants)
LB05	19.8-20.3	21476	high	angular	trace	light yellow	trace	subround	yellow brown	low	subround	-
LB05	15.5	21475	medium	subangular	-	-	trace	subround	mid brown	low	subround	-
LB05	19.6	20948	trace	angular	-	-	trace	subangular	mid brown	low	subround	(contaminants)
LB05	47.75	21474	trace	angular	-	-	-	-	-	trace	angular	-
LB06	4.7	21473	high	angular	(root tissue)	orange	low	subangular	dark brown	trace	subangular	-
LB06	7.8	20949	low	angular	-	-	low	(fines only)	dark drown	trace	angular	-
LB06	17.9	21472	medium	angular	-	-	medium	subround	mid brown	trace	subangular	-
LB06	35.0	21471	-	-	trace	orange	trace	subround	mid brown	trace	subangular	-
LB07	20.75	21481	medium	angular	-	-	low	subround	mid brown	trace	subangular	-
LB07	21.45	20950	-	-	-	-	low	subangular	dark brown	medium	angular	(contaminants)
LB08	62.3	20951	phytoliths?	Angular	trace	light brown	high	angular	dark brown	medium	angular	high
LB09	6.9	20952	low	angular	(root tissues)	yellow	medium	subangular	dark brown	high	angular	(fungal spores)
LB09	20.2	20953	low	angular	(root tissues)	yellow	medium	subangular	orange	high	angular	-
LB09	30.8	21483	high	angular	-	-	low	subround	mid brown	low	subround	-
LB09	48.0	21482	low	subround	-	-	trace	subround	light brown	trace	subangular	-

TABLE 2 (cont.)

Drillhole	Depth (m)	MFP No.	INORGANIC microquartz		ORGANIC structured terrestrial		semi-opaques			opaques (vitrinite?)		spore-pollen
			yield	angularity	yield	colour	yield	angularity	colour	yield	angularity	
42220151	17-19	21697	trace	angular	-	-	high	(fines)	dark brown	low	angular	trace
42220151	36-38	21698	-	-	-	-	low	(fines)	dark brown	low	angular	-
42220151	40-42	21699	-	-	trace	mid brown	low	(fines)	dark brown	medium	angularb	-
42220151	67-69	21700	high	angular	trace	mid brown	trace	angular	dark brown	low	subangular	trace
42220172	61-63	21688	-	-	low	dark brown	high	(fines)	dark brown	low	angular	-
42220172	67-69	21689	-	-	trace	yellow	-	-	-	high	subround	-
42220172	72-74	21690	-	-	(root)	yellow	-	-	-	medium	subround	-
42220172	104-106	21691	-	-	low	mid round	low	(fines)	mid brown	high	angular	trace
42220172	111-113	21692	-	-	high	mid brown	high	angular	mid brown	-	-	trace
42220172	116-118	21693	low	angular	low	mid brown	high	angular	mid brown	-	-	medium
42220175	62-65	21702	-	-	-	-	trace	angular	mid-brown	medium	subround	-
42220175	70-72	21703	trace	angular	low	orange	trace	angular	mid brown	medium	subround	trace
42220175	79-81	21704	low	angular	-	-	high	(fines)	mid brown	-	-	-
42220175	104-106	21705	low	angular	trace	orange	low	(fies)	mid brown	low	angular	-
42220175	144-146	21760	low	(colloidal)	-	-	low	(fines)	mid brown	low	angular	-
42220175	150-152	21707	-	-	low	orange	high	angular	orange	-	-	high
42220175	172-174	21708	trace	angular	high	orange	high	angular	orange	-	-	trace

TABLE 2 (cont.)

Drillhole	Depth (m)	MFP No.	INORGANIC microquartz		ORGANIC structured terrestrial		semi-opaques			opaques (vitrinite?)		spore-pollen
			yield	angularity	yield	colour	yield	angularity	colour	yield	angularity	
42220183	68-69	21672	trace	subround	trace	orange	low	(fines)	dark brown	low	angular	trace
42220183	72-73	21673	trace	subangular	trace	orange	high	(fines)	mid brown	trace	angular	trace
42220183	127-141	21674	-	-	trace	orange	high	angular	mid brown	-	-	-
42220183	144-146	21675	high	(colloidal)	-	-	low	subangular	mid brown	low	angular	-
42220183	151-153	21676	-	-	low	mid brown	medium	angular	dark brown	-	-	high
42220186	67-69	21677	low	angular	-	-	high	subangular	dark brown	-	-	low
42220186	74-76	21678	-	-	-	-	high	(fines)	mid brown	trace	angular	-
42220186	90-92	21679	-	-	trace	orange	trace	subangular	orange	high	subangular	-
42220186	115-117	21680	-	-	medium	orange	trace	subangular	orange	high	subangular	trace
42220186	124-126	21681	high	(colloidal)	low	orange	high	(fines)	dark brown	trace	subangular	-
42220186	131-133	21682	-	-	(root)	orange	low	subangular	dark brown	high	angular	trace
42220192	66-68	21694	trace	angular	trace	mid brown	high	(fines)	mid brown	-	-	-
42220192	74-76	21695	trace	angular	low	orange	trace	(fines)	orange	low	subangular	-
42220192	85-86	21696	-	-	trace	mid brown	trace	angular	orange	medium	subangular	-
42220194	4-6	21710	high	subangular	-	-	-	-	-	medium	subangular	-
42220200	13-15	21711	-	-	-	-	high	(fines)	dark brown	low	subangular	-
42220200	83-86	21683	low	subangular	-	-	high	(fines)	mid brown	-	-	-
42220200	140-143	21684	low	subangular	trace	orange	high	angular	dark brown	-	-	medium
42220201	146-148	21685	high	subangular	low	orange	high	angular	dark brown	-	-	high
42220203	86-88	21686	-	-	low	orange	trace	angular	orange	high	angular	trace
42220203	100-101	21687	-	-	-	-	trace	angular	orange	high	angular	-

5. PALYNOSTRATIGRAPHY

Quantitative estimates of the relative abundance of pollen, spores and algal cysts were made by scanning the acid-insoluble extracts under medium to high (x500-800) magnification until a minimum of 250 identifiable taxa had been counted or, in the case of low-yielding samples the whole extract was counted. The remainder of this and additional strew mounts were then scanned for rare species.

The relative abundance of all identifiable plant microfossils in samples yielding statistically significant numbers of pollen and spores is given in Tables 3 and 4. Values are expressed as a percentage of a pollen sum comprising the total pollen and spore count excluding fungal spores, algal cysts, reworked taxa and modern-subfossil contaminants. Values less than 1% are shown as '+': species recorded after the pollen count was completed as shown as '•'. Age diagnostic species and a selection of other distinctive microfossils are illustrated in Appendix 1.

5.1 Early Cretaceous samples

Early Cretaceous age and zonal determinations are based on criteria developed by Helby *et al*. (1987) which incorporate the results of an earlier, highly detailed palynostratigraphic analysis of Early Cretaceous microfloras preserved in the Surat Basin (Burger 1980). Estimates of the relative abundance of all identifiable fossil pollen, spores and algal cysts are given in Table 3. The data allow the sampled intervals to be assigned to formally described formations in the Surat Basin with moderate to good confidence.

LB DRILLHOLE SAMPLES

Drillhole LB06	*58.6 m depth*
Environment:	Restricted marine.
Preferred Age:	Early Albian (*Crybelosporites striatus* Zone) based on multiple specimens of *Clavatipollenites hughesii* and *Crybelosporites striatus* in an assemblage lacking *Coptospora paradoxa* and *Clavifera triplex*.
Minimum Age:	Early-Late Albian (*Coptospora paradoxa* Zone) based on multiple specimens of *Pilosisporites notensis* and *Pseudoceratium turneri*.
Maximum Age:	Latest Aptian (*Crybelosporites striatus* Zone) based *on Clavatopollenites hughesii* and *Crybelosporites striatus*.
Comment:	1. The sample yielded a diverse assemblage of well-preserved but mostly long-ranging Early Cretaceous spores, pollen and dinocysts. Zone index dinoflagellates such as *Diconodinium davidii* (Late Aptian) and *Muderongia tetracantha*, *Pseudoceratium ludbroookiae* and *Xenascus asperatus* (Albian) were not recorded although this might be due to dilution of the marine component by the very high spore-pollen influx. 2. On present indications the age of the sample is more likely to be Early Albian than latest Aptian and, based on the diversity of marine dinocysts, was deposited in a restricted marine rather than in a paralic environment. If correct, then the sample comes from Coreena Member of the Wallumbilla Formation rather than the overlying Griman Creek and Surat Siltstone Formations or, less certain, the underlying Doncaster Member of the Wallumbilla Formation (see Appendix A in Burger 1980). 3. The microflora includes a single corroded specimen of *Lygistepollenites florinii* (FO Campanian). Because the Early Cretaceous component includes numerous relatively fragile dinocysts, it is unlikely that the sampled interval is

reworked and the preferred explanation is that the record of *L. florinii* is due to bioturbation or down-hole contamination from overlying Plio-Pleistocene units.

42220 DRILLHOLE SAMPLES

Drillhole 42220151 126-128 m depth

Environment: Fluvio-deltaic (freshwater) based on the diverse fern flora and occurrence of fossil members of the water-fern family Marsileaceae (*Balmeisporites holodictyus*, *Crybelosporites striatus*).

Preferred Age: Early to early Late Albian *Coptospora paradoxa* Zone based on *Coptospora paradoxa* in a diverse microflora dominated by long-ranging Early Cretaceous gymnosperm and fern species.

Minimum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa* in an assemblage which lacks indicator species of the overlying Late Albian *Phimopollenites pannosus* Zone.

Maximum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa*.

Comment: The inferred age, supported by the absence of marine dinocysts, indicates that the sample represents Griman Creek Formation or possibly a non-marine facies of the underlying Surat Siltstone (see Table 2 in Burger 1980). The high relative abundance of fern spores data indicates the sampled sediment is likely to have been deposited close to the palaeoshoreline (cf Burger 1980: 40).

Drillhole 42220172 116-118 m depth

Environment: Fluvio-deltaic (freshwater lake?) based on the diverse fern flora and occurrence of fossil members of the water-fern family Marsileaceae (*Balmeisporites tridictyus*, *Crybelosporites striatus*).

Preferred Age: Early Albian (*Crybelosporites striatus* Zone) based on *Crybelosporites striatus* and *Clavatipollenites hughesii* in a diverse microflora dominated by long-ranging Early Cretaceous gymnosperm and fern species.

Minimum Age: Early Albian (*Crybelosporites striatus* Zone) based on *Crybelosporites striatus* and *Clavatipollenites hughesi* in an assemblage that lacks *Coptospora paradoxa* and other indicator species of the *C. paradoxa* Zone.

Maximum Age: Late Aptian (*Crybelosporites striatus* Zone) based on *Crybelosporites striatus* and *Clavatipollenites hughesii*.

Comment: The inferred age and absence of marine dinocysts indicates that the sample represents Griman Creek Formation or possibly a non-marine facies of the underlying Surat Siltstone (see Table 2 in Burger 1980). On present indications, *Coptospora paradoxa* Zone facies have been eroded from the top of the Surat Basin at this drill site.

The source vegetation included gymnosperm (*Podosporites*) and fern heath or swamp. The high relative abundance of *Cyathidites* (*Cyathea*) and *Araucariacites* (Araucariaceae) indicate the sample accumulated at some distance from the shoreline of the lake (cf Burger 1980: 40).

Drillhole 42220183 151-153 m depth

Environment: Fluvio-deltaic (freshwater lake?) based on the diverse fern flora and occurrence of fossil members of the water-fern family Marsileaceae (*Balmeisporites holodictyus*, *Crybelosporites striatus*).

Preferred Age: Early to early Late Albian *Coptospora paradoxa* Zone based on *Coptospora paradoxa* in a diverse microflora dominated by long-ranging Early Cretaceous gymnosperm and fern species.

Minimum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa* and *Clavatipollenites hughesii* in an assemblage which lacks indicator species of the overlying Late Albian *Phimopollenites pannosus* Zone.

Maximum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa*.

Comment: The age and absence of marine dinocysts indicates that the sample represents Griman Creek Formation. The high relative abundance of gymnosperms indicates the sample is likely to have accumulated at some distance from the shoreline of the lake (cf Burger 1980).

Drillhole 42220200 140-143 m depth

Environment: Fluvio-deltaic (freshwater lake?) based on the diverse fern flora and occurrence of fossil members of the water-fern family Marsileaceae (*Balmeisporites holodictyus*, *B. tridictyus*, *Crybelosporites striatus*).

Preferred Age: Early to early Late Albian *Coptospora paradoxa* Zone based on *Coptospora paradoxa* in a diverse microflora dominated by long-ranging Early Cretaceous gymnosperm and fern species.

Minimum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa* and *Clavatipollenites hughesii* in an assemblage which lacks indicator species of the overlying Late Albian *Phimopollenites pannosus* Zone.

Maximum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa*.

Comment: The age and absence of marine dinocysts indicates that the sample represents Griman Creek Formation. The high relative abundance of *Cyathidites* indicates the sample is likely to have accumulated at some distance from the shoreline of the lake (cf Burger 1980).

Drillhole 42220200 146-148 m depth

Environment: Fluvio-deltaic (freshwater lake?) based on the diverse fern flora and occurrence of fossil members of the water-fern family Marsileaceae (*Balmeisporites holodictyus*, *B. tridictyus*, *Crybelosporites striatus*).

Preferred Age: Early to early Late Albian *Coptospora paradoxa* Zone based on *Coptospora paradoxa* in a diverse microflora dominated by long-ranging Early Cretaceous gymnosperm and fern species.

Minimum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa* an assemblage which lacks indicator species of the overlying Late Albian *Phimopollenites pannosus* Zone.

Maximum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa*.

Comment: The age and absence of marine dinocysts indicates that the sample represents Griman Creek Formation. The high relative abundance of *Crybelosporites striatus* and *Gleicheniidites* indicates the sample is likely to have accumulated in a pond or swamp close to the palaeoshoreline (cf Burger 1980).

5.2 Samples yielding reworked Mesozoic microfloras

Jurassic age and zonal determinations are based on criteria developed by Helby *et al.* (1987). Estimates of the relative abundance of all identifiable fossil pollen, spores and algal cysts are given in Table 3.

42220175 150-152 m depth

Environment: Fluvial.

Age: Cenozoic based on stratigraphic position (Middle Eocene to Middle Miocene if trace numbers of *Nothofagidites emarcidus-heterus* are *in situ*).

Minimum Age: Late Miocene-Early Pliocene based on the extinction of *Nothofagus* (*Brassospora*) spp. across inland eastern Australia by this time.

Maximum Age: Middle Jurassic *Dictyotosporites complex* Zone, based on *Contignisporites* cf *fornicatus* and the high relative abundance of *Callaliasporites dampieri* and *Retitriletes* spp. in a microflora that lacks *Corollinia* spp.

Comment: The gymnosperm component is poorly preserved ('blurred') and includes numerous pollen clumps that are difficult to distinguish from other plant detritus. The assemblage is likely to come from a block of lignite preserved in Cenozoic alluvium.

Lithology and gamma log data confirm that the sample comes from an unconsolidated (mostly sandy) unit overlying the Mesozoic 'basement'. These data provide compelling evidence that the lignite has been reworked, presumably from Jurassic rocks outcropping around the northern and eastern margins of the Surat Basin (see Fig. 1 in Burger 1980). Whether the *Nothofagidites* component is *in situ*, caved or reworked from Tertiary deposits upstream of the drill site cannot be determined (see below).

Drillhole 42220175 172-174 m depth

Environment: Fluvial.

Age: Cenozoic based on stratigraphic position [Middle Eocene to Middle Miocene if significant numbers of *Nothofagidites emarcidus-heterus* (15 specimens) and *N. falcatus* (2 specimens) are *in situ*].

Minimum Age: Late Miocene-Early Pliocene based on the extinction of *Nothofagus* (*Brassospora*) spp. across inland eastern Australia by this time.

Maximum Age: Middle Jurassic *Dictyotosporites complex* Zone, based on the significant presence of *Callaliasporites dampieri* (10 specimens) and *Retitriletes* spp. (15 specimens) in a microflora dominated by bisaccate gymnosperm pollen.

Comment: The lithology log shows a “brown coal” occurs at this depth in Drillhole 42220175. The palynostratigraphic data indicate that the ‘coal’ is likely to comprise one or more blocks of lignite rather than e.g. a stratified lignitic clay.

As for the sample at 150-152m, the material almost certainly has been transported by water from Jurassic rocks outcropping around the northern and eastern margins of the Surat Basin.

The presence of *Nothofagidites falcatus* indicates that interval could be a correlative of the Middle Eocene to Middle Miocene Olney Formation in the Murray Basin. Alternatively, deposits of this age occurs upsection in the drillhole or upstream in the palaeovalley (see Macphail *et al*. 1994, Macphail 1999). J. Kellett (pers. comm.) notes that the fossil *Nothofagus* pollen cannot have travelled more than ~100 km based on palaeotopographic constraints.

Drillhole 42220175 183-184 m depth

Environment: Fluvial.

Age: Late? Cenozoic based on stratigraphic position (Middle Eocene to Middle Miocene if low to trace numbers of *Podocarpidites*, *Nothofagidites emarcidus-heterus* and *Milfordia* are *in situ*).

Minimum Age: Late Miocene-Early Pliocene based on the extinction of *Nothofagus* (*Brassospora*) spp. across inland eastern Australia by this time.

Maximum Age: Middle Jurassic *Dictyotosporites complex* Zone, based on the similarity of the microflora to those recorded at 150-152 m and 172-174 m depth.

Comment: As for samples at 150-152 m and 172-174 m.

Drillhole 42220183 72-73 m depth

Environment: Fluvial.

Preferred Age: Cenozoic based on stratigraphic position.

Minimum Age: indeterminate.

Maximum Age: Late Jurassic based on trace numbers of *Podosporites* spp.

Comment: Lithology and gamma log data indicate that the top of the Mesozoic 'basement' rocks occur at ~140 m (J. Kellett pers. comm.). The very sparse microflora includes sub-fossil or modern *Pinus* pollen.

Drillhole 42220186 67-69 m depth

Environment: Fluvial.

Preferred Age: Late Cenozoic based on stratigraphic position.

Minimum Age: Indeterminate.

Maximum Age: *Coptospora paradoxa* Zone based on *Coptospora paradoxa* in an assemblage which is dominated by long-ranging Early Cretaceous gymnosperm and fern species and lacks indicator species of the overlying Late Albian *Phimopollenites pannosus* Zone.

Comment: Lithology and gamma log data (J. Kellett pers. comm.) indicate the base of the Cenozoic alluvium occurs at ~125 m. The inferred age and absence of marine dinocysts indicates that the sample iincorporates a rip up clast of Griman Creek Formation.

Drillhole 42220186 115-117 m depth

Environment:	Fluvial? based on rare cysts of an unidentified freshwater alga.
Preferred Age:	Indeterminate (no older than *Ruffordiaspora australiensis* Zone).
Minimum Age:	Cenozoic based on stratigraphic position.
Maximum Age:	*Ruffordiaspora australiensis* Zone based on *Ruffordiaspora australiensis*.
Comment:	Lithology and gamma log data indicate the unconformity surface separating the Cenozoic regolith and Early Cretaceous sediments of the Surat Basin is at about 125 m (J. Kellett pers. comm.).

Table 3: Relative abundance of all identifiable taxa (Mesozoic) ('+' equals less than 1%, • indicates rare taxa recorded outside pollen count)

FOSSIL TAXON	DRILLHOLE											
	LB06	**42220151**	**42220172**	**42220175**			**42220183**		**42220186**		**42220200**	
	58.6 m	126-128 m	116-118 m	150-152 m	172-174 m	183-184 m	72-73 m	151-153 m	67-69 m	115-117 m	140-143 m	146-148 m
MARINE DINOCYSTS												
Adnatosphaeridium cf *filosum*	•											
Canningia spp.	+											
Circulodinium colliveri	•											
cf *Coronifera oceanica*	•											
Cribroperidium edwardsii	•											
Odontochitina operculata	•											
Oligosphaeridium pulcerrimum	+											
Pseudoceratodinium turneri	•											
Spinidinium spp.	•											
Spiniferites spp.	•											
Tanyosphaeridium isocalamus	•											
Unidentified dinocysts	3%											
TOTAL MARINE DINOCYSTS	4%	-	-	-	-	-	-	-	-	-	-	-
FRESHWATER ALGAE												
Botryococcus		+									+	
Unidentified freshwater algae		1%				(2)		•		(1)	+	
TOTAL FRESHWATER ALGAE	-					(2)		•		(1)	+	
FUNGI												
spores & hyphae	2%	5%	1%		2%	(6)		+	1%	(3)	+	+
TOTAL FUNGI	2%	5%	1%		2%	(6)		+	1%	(3)	+	+

Table 3 (cont.):

FOSSIL TAXON	DRILLHOLE											
	LB06	**42220151**	**42220172**	**42220175**			**42220183**		**42220186**		**42220200**	
	58.6 m	126-128 m	116-118 m	150-152 m	172-174 m	183-184 m	72-73 m	151-153 m	67-69 m	115-117 m	140-143 m	146-148 m
MOSSES, LIVERWORTS, FERN ALLIES AND FERNS												
Aequitriradites spinulosus	●	●	●					●				
Aequitriradites spp.	●	●						+	+		2%	+
Baculatisporites spp.	5%	7%	4%	10%	3%			5%	5%		5%	5%
Balmeisporites holodictyus		●						●	●		●	●
Balmeisporites tridictyus			●								3%	1%
Biretisporites spp.		+	●					●	●		4%	+
Ceratosporites equalis	+	●	+					1%				1%
Cingutriletes clavatus	●	●						●	●		●	●
Concavissimisp. penolaensis	●	●						●	●		●	
Contignisporites cf *glebulentus*				●							●	
Contignisporites spp.								●				●
Coptospora paradoxa		+						●	●		●	●
Coronatispora perforata	●											
Crybelosporites striatus	●	●	●					●	●		●	●
Cyathidites australis/minor	12%	15%	14%	9%	7%	(1)		13%	14%	(7)	21%	15%
Densoisporites velatus	●		●									
Dictyophyllid. pectinaeformis								●			●	
Dictyotosporites complex			●									
Dictyotosporites speciosus			●									
Foraminisporis asymmetricus	●	●	●					2%	●			●
Foraminisporis dailyii	●	●	●					●	●			●
Foraminisporis wonthaggiensis			●									
Total *Foraminisporis*	+	●	●					2%	+			+
Gleicheniidites	10%	5%	2%					3%	7%		5%	125
Ischyosporites punctatus			●		+			●	+			1%
Laevigatosporites spp.	+	1%	+		2%			●			2%	2%
Leptolepidites verrucatus	●											
Lycopodiacidites asperatus	●		●	●					●			●
Matonisporites cooksoniae								●	+			
Neoraistrickia spp.	●		1%	4%	3%						●	+

Table 3 (cont.):

FOSSIL TAXON	DRILLHOLE											
	LB06	**42220151**	**42220172**	**42220175**			**42220183**		**42220186**		**42220200**	
	58.6 m	126-128 m	116-118 m	150-152 m	172-174 m	183-184 m	72-73 m	151-153 m	67-69 m	115-117 m	140-143 m	146-148 m
Osmundacites		●		+					●		+	
Pilosisporites notensis	●	●	●					●				●
Retitriletes australoclavatidites				●				●	●	(1)	●	●
Retitriletes eminulus			●					●				
Retitriletes nodosus			●					●				
TOTAL *Retitriletes*	2%	+	3%	8%	15%			+	1%		1%	1%
Ruffordiaspora australiensis	2%	5%	2%					3%	1%		4%	5%
Stereisporites antiquisporites	●	●						●	●	(1)		●
Stereisporites pocockii	●		●					●				●
Stereisporites cf *regium*		●										
Total *Stereisporites*	3%	3%	4%		+			3%	6%	(1)	4%	2%
Trilobosporoites tribotrys	●	●	●					●			●	●
Trilobosporites trioreticulatus		●	●					●	●		●	●
TOTAL *Trilobosporites*		+						+	+		2%	1%
Triporoletes radiatus			●					●				●
Triporoletes reticulatus		●	●					●	●			
TOTAL *Triporoletes*		2%	+					+			1%	
Velosporites triquetrus	●	●										
Unidentified monolete spores		2%	+						1%		3%	+
Unidentified trilete spores	10%	21%	18%	9%	3%	(4)		11%	22%	(1)	23%	24%
TOTAL CRYPTOGAMS	**47%**	**60%**	**50%**	**40%**	**39%**	**(5)**		**43%**	**60%**	**(12)**	**76%**	**74%**

Table 3 (cont.):

FOSSIL TAXON	DRILLHOLE											
	LB06	**42220151**	**42220172**	**42220175**			**42220183**		**42220186**		**42220200**	
	58.6 m	126-128 m	116-118 m	150-152 m	172-174 m	183-184 m	72-73 m	151-153 m	67-69 m	115-117 m	140-143 m	146-148 m
GYMNOSPERMS												
Alisporites grandis	●	●						●				
Alisporites simplis			●	●								
Araucariacites australis	15%	4%	8%	3%	5%			9%	5%		2%	1%
Callaliasporites dampieri				3%	10%						+	
Corollinia spp.			●		+			+				+
Cupressacites			+					+	+			
Cyacadopites		●						●				
Ephedripites notensis											+	
Microcachrydites antarcticus	1%	1%	2%					2%	3%		2%	2%
Podocarpidites/*Falcisporites* spp.	19%	30%	33%	54%	40%	(6)		42%	30%	(1)	18%	21%
Trichotomosulcites/*Podosporites*	13%	3%	5%				(1)	3%		(1)		1%
Trisaccites	+	+	+						1%		+	+
Viretisporites pallidus			●		●							
Unassigned gymnosperms			+		+						+	+
TOTAL GYMNOSPERMS	**45%**	**39%**	**49%**	**60%**	**55%**	**(6)**	**(1)**	**57%**	**40%**	**(2)**	**25%**	**26%**
ANGIOSPERMS												
cf *Asteropollis asteroides*	●											
Clavatipollenites hughesii	●		+					+	+		+	
Retitrescolpites		+										
Unassigned tricolporates	+											
TOTAL ANGIOSPERMS	+	+	+					+	+		+	
PERMO-TRIASSIC		+	●	●	+							+
CENOZOIC CONTAMINANTS	+			●	24%	(7)	(2)					+
POLLEN SUM *	**252**	**296**	**341**	**270**	**96**	**n/a**	**n/a**	**303**	**290**	**n/a**	**337**	**332**

Values in parentheses are total (raw) counts.

5.3 Late Cenozoic samples

Age and zonal determinations are based on presence/absence criteria and ecostratigraphic considerations.

The former have been developed by Stover & Partridge (1973, 1982) and Macphail (1999) for dating and correlating Cenozoic sediments in southeastern Australia; the latter are based on the ecological preferences of the nearest living relatives (NLRs) of commonly occurring taxa *versus* known or extrapolated patterns of environmental change during the Late Cenozoic (cf Kershaw *et al*. 1994, Hope 1994, Macphail 1997, 2000).

Four key assumptions (and related *caveats*) are:

1. *Nothofagus* (*Brassospora*) spp. became extinct in southeast Queensland during the Middle or ?Late Miocene. *Nothofagus* (*Brassospora*) spp. are abundant in the probable Early to Middle Miocene Suttor Formation in central Queensland (Beeston 1994) but occur only in low to trace numbers in the few independently dated Late Miocene-Early Pliocene (*Monotocidites galeatus* Zone) assemblages in southern Australia. A reasonable conclusion is that during the Middle to Late Miocene, *Nothofagus* populations were reduced to isolated/relict stands except where cool uniformly humid conditions persisted at high latitudes or elevations, e.g. in western Tasmania (Macphail *et al*. 1995) or on the Atherton Tableland in northeast Queensland (Kershaw & Sluiter 1982). Younger (Plio-Pleistocene) records in Queensland are considered to be reworked from older Tertiary sediments (cf Kershaw 1985).

2. *Dacrycarpus*, *Dacrydium* and ?*Podocarpus* became extinct in gallery rainforest stands bordering <u>inland</u> rivers in southeast Queensland during the Late Pliocene to Early Pleistocene. Fossil pollen evidence confirms that *Dacrycarpus*, *Dacrydium* and *Podocarpus* were widely distributed across Australia during the Late Miocene to Early Pliocene. As with *Nothofagus* (*Brassospora*) spp., *Dacrycarpus* and *Dacrydium* became confined to high elevations in northeast Queensland during the Late Pliocene or Early Pleistocene. On present indications, *Dacrycarpus* became extinct during the Early Pleistocene whilst relict stands of *Dacrydium* survived on the Atherton Tableland up to about 26,000 years ago (see Kershaw *et al*. 1993).

3. Drier rainforest types dominated by *Araucaria* and/or *Podocarpus* became extinct along rivers draining inland riverine plains in southern Queensland during the Late Pliocene or Early Pleistocene although both genera still occur on (freely draining) sands and river alluvium close to the coast in regions receiving in excess of 1000-1500 mm annual rainfall. On present indications, environments west of the Eastern Highlands in southern Queensland would have been sub-humid to semi-arid throughout most of the Quaternary (see Hope 1994) but may have been sufficiently warm and wet to support gallery rainforest during the mid Pliocene ‘warm period’ about 2.5-3 million years ago (see Macphail 1997). High lakes levels during the Middle-Late Pleistocene may not be relevant in this context since these occur during periods of relatively low (cool-cold) temperatures.

4. High relative abundances of *Acaciapollenites myriosporites* and *Haloragacidites harrisii* represent drought-tolerant (dry climate) species of *Acacia* and *Allocasuarina*/*Casuarina* respectively. This assumption is difficult to test unless macrofossils are preserved. Although *Haloragacidites harrisii* (representing the rainforest margin genus *Gymnostoma*) is common in Tertiary sediments, *Acaciapollenites myriosporites* does not become consistently recorded until the Late Neogene and then only in trace numbers (see Macphail & Hill 2001). *Tubulifloridites pleistocenicus* Zone microfloras recovered from the Cowra Formation in the Lachlan Valley (Martin 1973) and probable correlatives in the Mooki and Namoi Valleys on the northwest slopes of NSW (Martin 1979, 1980) indicate Asteraceae (daisy-bush family), Chenopodiaceae (salt-bush family) and Poaceae (grass family) first become common to abundant during the Late Pliocene or Pleistocene depending on locality.

LB DRILLHOLE SAMPLES

Drillhole LB02 56.1 m depth

Environment:	Fluvio-lacustrine based on *Botryococcus* (2%), indeterminate freshwater algal cysts (6%) and trace numbers of the freshwater dinocyst *Saeptodinium* and pollen of the obligate aquatic herbs *Myriophyllum* (*Haloragacidites myriophylloides*)
Preferred Age:	Late? Pliocene based on (a) *Dacrycarpites australiensis* (3%), and *Podocarpidites* (21%) and *Thymelaepollis* sp. and (b) the absence of *Nothofagidites*.
Minimum Age:	Early Pleistocene, based on *Dacrycarpites australiensis*.
Maximum Age:	Late Miocene, based on *Glencopollis ornatus* and *Graminidites* (4%). *Thymelaepollis* sp. (NLR *Pimelea*) first occurs in Late Pliocene or Early Pleistocene sequences in southeastern Australia.
Comment:	The *Podocarpus*-Casuarinaceae dominated microflora includes a relatively diverse fern component as well as pollen types not found in other samples, e.g. *Perfotricolpites digitatus* (NLR *Merremia*) and *Thymelaepollis* sp.

Drillhole LB03 59.5 m depth

Environment:	Fluvio-lacustrine based on *Pediastrum* (2%), indeterminate freshwater algal cysts (3%) and semi-aquatic herbs such as *Striasyncolpites laxus* (modern equivalent *Villarsia*) and *Tricolporites pelargonioides* (modern equivalent *Pelargonium*).
Preferred Age:	Early? Pliocene based on (a) *Dacrycarpites australiensis* (2%), and frequent *Acaciapollenites myriosporites* (7%) in an microflora dominated by *Araucaria* (26%) and Casuarinaceae (31%) and which lacks *Nothofagus*.
Minimum Age:	Early Pleistocene based on *Dacrycarpites australiensis*.
Maximum Age:	Late Miocene, based on *Acaciapollenites weissii*, *Glencopollis ornatus*, *Graminidites* (5%), *Monotocidites galeatus*, *Nothofagidites emarcidus* and *Tubulifloridites* (2%)
Comment:	1. Although *Araucaria bidwillii* (Bunya Pine) occurs in the Bunya Mountains northeast of Dalby, I am unaware that this species, or the other araucarian found in subtropical dry rainforest in Australia (*A. cunninghamii*), or *Podocarpus*, extend further westward into the relatively dry Lower Balonne area. As such, *Acacia* and Casuarinaceae in the microflora are likely to represent xerophytic species and therefore an early stage in the development of Brigalow (*Acacia harpophylla-Casuarina cristata* open forests, woodlands and shrubland), now found over a wide (>60, 000 km^2) region in central and southern Queensland. If correct, then mean annual rainfall is likely to have been between 900-750 mm pa. Low to frequent occurrences of saltbush (*Chenopodipollis*), grass (*Graminidites*) and daisy (*Tubulifloridites*) pollen point to low, open vegetation types occupying very dry/saline habitats within the source area although the area covered by these taxa does not seem to have been extensive. 2. The microflora included low numbers of reworked long-ranging spores and bisaccate gymnosperm pollen derived from Early Cretaceous sediments in the Surat Basin, e.g. *Corollinia* spp.

Drillhole LB03 58.65 m depth

Environment: Fluvio-lacustrine based on *Pediastrum* (1%) and indeterminate freshwater algal cysts (6%)

Preferred Age: Early? Pliocene based on *Dacrycarpites australiensis* (2%), and *Acaciapollenites myriosporites* (2%) in a microflora dominated by *Araucaria* (17%) and Casuarinaceae (46%) and which lacks *Nothofagus*.

Minimum Age: Early Pleistocene based on *Dacrycarpites australiensis*.

Maximum Age: Late Miocene-Early Pliocene, based on *Rhoipites ampereaformis*, *Graminidites* (3%) and *Haloragacidites haloragoides* (4%)

Comment: The microflora closely resembles that found at 59.50 m depth in Drillhole LB03 except that sclerophyll woody taxa including Casuarinaceae and *Eucalyptus* are more common (46%, 4% *vs* 26%, 1%) and ferns and other cryptogams are less common (7% *vs* 12%).

The high relative abundance of charcoal particles indicate wildfires were common within the catchment at the time of the sediment accumulated.

Drillhole LB03 58.55 m depth

Environment: Fluvial?

Preferred Age: Pliocene based on *Dacrycarpites australiensis* (~8%), *Araucariacites australis* (~8%) and *Acaciapollenites myriosporites* (~2%) in a microflora dominated by Casuarinaceae (~45%) which lacks *Nothofagus*.

Minimum Age: Early Pleistocene based on *Dacrycarpites australiensis*.

Maximum Age: Early Miocene based on *Acaciapollenites myriosporites*.

Comment: The microflora is a depauperate version (total spore-pollen yield <65 grains) of those recorded at 56.1 m depth in Drillhole LB02, and 59.5 m and 58.65 m depth in Drillhole LB03. *Araucariacites* and *Podocarpidites* are relatively common. The microflora is presumed to be of the same general geological age as those recovered from the latter samples.

Drillhole LB08 62.3 m depth

Environment: Fluvio-lacustrine based on *Botryococcus* (1%), indeterminate freshwater algal cysts (1%), Azolla, and trace numbers of pollen of the semi-aquatic herb *Ranunculus* [*Tricolpites* (*Ranunculus*) sp.].

Preferred Age: Late? Pliocene based on (a) *Dacrycarpites australiensis* (3%), and *Podocarpidites* (28%) and (b) the absence of *Nothofagidites*.

Minimum Age: Early Pleistocene based on *Dacrycarpites australiensis*.

Maximum Age: Late Miocene, based on *Glencopollis ornatus* and *Graminidites* (1%).

Comment: The *Podocarpus*-Casuarinaceae dominated assemblage is a depauperate version of the microflora recorded at 56.1 m depth in Drillhole LB02.

42220 DRILLHOLE SAMPLES

Drillhole 42220172 111-113 m depth

Environment: Backswamp based on *Azolla* and rare freshwater algal cysts.

Preferred Age: Pliocene based on *Dacrycarpites australiensis*, *Lygistepollenites florinii* and *Podocarpidites* spp. in a sparse assemblage which lacks *Nothofagidites*.

Minimum Age: Early Pleistocene based on *Dacrycarpites australiensis*.

Maximum Age: Late Miocene based on *Hypolepis spinyspora* and absence of *Nothofagidites emarcidus-heterus*.

Comment: The age determination assumes that *Dacrycarpites australiensis, Lygistepollenites florinii* and *Podocarpidites* are *in situ*. If correct, then the unconformity separating the Cenozoic cover beds and Griman Formation or? Surat Siltstone occurs between 113-116 m depth in Drillhole 42220172.

The only spores present in this microflora are derived from rainforest and rainforest margin species which no longer occur this far inland in southeast Queensland, e.g. *Cyathea* (*Cyathidites paleospora*) and *Pteris* (*Polypodiaceoisporites retirugatus*). Modern and sub-fossil contaminants include *Eucalyptus* and *Selenothamnus* (Malvaceae).

Table 4: Relative abundance of all identifiable taxa (Cenozoic) ('+' equals less than 1%, • indicates rare taxa recorded outside pollen count)

FOSSIL PLANTS REPRESENTED BY POLLEN, SPORES OR (ALGAE) BY CYSTS		DRILLHOLE					
		LB02	LB03			LB08	42220172
FOSSIL TAXON	**NEAREST LIVING RELATIVE (NLR)**	**56.1 m**	**59.5 m**	**56.65 m**	**58.55 m**	**62.3 m**	**111-113 m**
ALGAE & FUNGI							
Botryococcus	*Botryococcus*	2%				1%	
Pediastrum	*Pediastrum*		2%	1%			
freshwater algae incl. *Cribroperidium*	Chlorophyta incl. Dinophyaceae	6%	3%	6%	+	6%	•
fungal spores & hyphae	Fungi			10%	(11%)		•
MOSSES, LIVERWORTS, FERNS ALLIES & FERNS (CRYPTOGAMS)							
Azolla	*Azolla* (Azollaceae)						•
Baculatisporites spp.	Hymenophyllaceae	+	1%	+		+	
Cingulatisporites spp.	Anthocerotae		1%	+			
Cyathidites spp.	includes *Cyathea* (Cyatheaceae)	3%	2%	2%	(3%)	+	•
Dictyophyllidites arcuatus	*Dicranopteris* (Gleicheniaceae)	+		+		+	
Gleicheniidites spp.	*Gleichenia, Sticherus* (Gleicheniaceae)	+	2%	+		+	
Herkosporites elliotii	*Lycopodium deuterodensum* (Lycopodiaceae)			+			
Hypolepis spinyspora	*Hypolepis* (Dennstaedtiaceae)						•
Ischyosporites spp.	extinct Dicksoniaceae?			+	+	+	
Laevigatosporites/Peromonolites	includes Blechnaceae	+	+	+			
Latrobosporites marginis	*Lycopodium laterale*-type (Lycopodiaceae)	+					
Leptolepidites verrucatus (Cz var.)	extinct? Pteridophyta	+		+			
Matonisporites ornamentalis	*Dicksonia antarctica*-type (Dicksoniaceae)	+					
Polypodiaceoidaesporites retirugatus	*Pteris* (Pteridaceae)	+				+	•
Polypoliaceoisporites sp. nov.	*Pteris* sp.	+				+	
Polypodiisporites spp.	includes Polypodiaceae, Davalliaceae	+	+		(5%)		
Retitriletes spp.	Lycopodiaceae		1%	1%			
Riccaesporites	Riccicaceae?	+				+	
Rudolphisporis rudolphi	Riccaceae (liverwort)	+	1%	+	+		
Rugulatisporites cowrensis	*Calochlaena* (Thyrsopteridaceae)		+	+			
unassigned trilete spores	Numerous families	4%	2%	2%	(3%)	+	
TOTAL CRYPTOGAMS		**6%**	**12%**	**9%**	**(12%)**	**5%**	

<u>TABLE 4</u> (cont.)

FOSSIL PLANTS REPRESENTED BY POLLEN, SPORES OR (ALGAE) BY CYSTS		DRILLHOLE					
		LB02	LB03			LB08	42220172
FOSSIL TAXON	**NEAREST LIVING RELATIVE (NLR)**	**56.1 m**	**59.5 m**	**56.65 m**	**58.55 m**	**62.3 m**	**111-113 m**
Araucariacites australis	*Araucaria* (Araucariaceae)	+	26%	17%	(8%)	3%	•
Cupressacites	Cupressaceae-Taxodiaceae					+	
Dacrycarpites australiensis	*Dacrycarpus* (Podocarpaceae)	3%	3%	2%	(8%)	3%	•
Lygistepollenites florinii	*Dacrydium* (Podocarpaceae)	+				+	•
Microalatidites cf *palaeogenicus*	*Phyllocladus*			+			
Podocarpidites spp.	*Podocarpus-Prumnopitys* (Podocarpaceae)	21%	6%	7%	(11%)	28%	•
TOTAL GYMNOSPERMS		**26%**	**36%**	**26%**	**(27%)**	**34%**	
Acaciapollenites myriosporites	*Acacia*	+	7%	2%	(2%)	+	
Chenopodipollis chenopodiaceoides	Chenopodiaceae-Amarathaceae	+	+	+			
Crotonipollis sp.	*Croton* (Euphorbiaceae)		+				
Cyperaceaepollis spp.	Cyperaceae	+	1%	2%			•
Dodonaea spherica	*Dodonaea ericifolia*-type (Sapindaceae)			+			
Ericipites spp.	Epacridaceae, Ericaceae	+					
Glencopollis ornatus	*Polygonum* (Polygonaceae)	+				+	
Graminidites spp.	Poaceae (Gramineae)	4%	5%	3%	(5%)	1%	
Gyropollis psilatus	Gyrostemonaceae			+			
Hakeidites sp.	*Grevillea*-type (Proteaceae)	+		+			
Haloragacidites haloragoides	*Haloragis-Gonocarpus* (Haloragaceae)	+	+	4%			
Haloragacidites harrisii	Casuarinaceae	62%	31%	46%	(45%)	57%	
Haloragacidites myriophylloides	*Myriophyllum* (Haloragaceae)	+					
Liliacidites spp.	Liliaceae			+	+		
Malvacipollis spinyspora	*Micrantheum* (Euphorbiaceae), *Selenothamnus* (Malvaceae)	+				+	•
Malvacipollis subtilis	*Austrobuxus* (Euphorbiaceae),	+	+				•
Milfordia hypolaenoides	Restionaceae (non-graminoid genera)		+	+		+	
Monotocidites galeatus	*Monotoca* (Euphorbiaceae)	+	+				
Myrtaceidites eucalyptoides	*Eucalyptus* (Myrtaceae)		+	4%	(3%)		•
Myrtaceidites spp.	Non-eucalyptoid Myrtaceae		+				
Nothofagidites emarcidus	*Nothofagus* (*Brassospora*) spp. (Nothofagaceae)		+				

TABLE 4 (cont.)

FOSSIL PLANTS REPRESENTED BY POLLEN, SPORES OR (ALGAE) BY CYSTS		DRILLHOLE					
		LB02	**LB03**			**LB08**	**42220172**
FOSSIL TAXON	**NEAREST LIVING RELATIVE (NLR)**	**56.1 m**	**59.5 m**	**56.65 m**	**58.55 m**	**62.3 m**	**111-113 m**
ANGIOSPERMS (cont.)							
Perfotricolpites digitatus	*Merremia*-type (Convolvulaceae)	+					
Proteacidites spp.	unidentified Proteaceae	+		+	(3%)		
Proteacidites punctiporus	*Stirlingia* (Proteaceae)	+		+			
Pseudowinterapollis cranwellae	Winteraceae			+			
Rhoipites ampereaformis	*Amperea* (Euphorbiaceae)			+	+		
Rhoipites/*Tricolporites* spp.	numerous families		1%	+	(2%)		•
Striasyncolpites laxus	*Vilarsia* (Menanthaceae)		+				
Themelaepollis sp.	*Pimelea* (Thymeleaceae)	+					
Tricolpites (*Ranunculus*) sp.	*Ranunculus*					+	
Tricolpites ***spp.***	numerous families			+			
Tricolporites pelargonioides	*Pelargonium*-type		+				
Tubulifloridites spp.	Asteraceae (Tubuliflorae)	+	2%	+			
TOTAL ANGIOSPERMS		**69%**	**52%**	**65%**	**(61%)**	**60%**	
REWORKED MESOZOIC SPP.		+	2%	4%	+	+	•
POLLEN SUM		**351**	**316**	**293**	**(64)**	**349**	**(14)**

Note: Values in parenthses are statistically unreliable.

6. DISCUSSION

6.1 Cenozoic

Tertiary climates in Australia reflect global and regional tectonic and eustatic events superimposed on strengthening equator to pole temperature gradients and decreasing atmospheric carbon dioxide concentrations (see Frakes 1999).

Of particular importance have been (1) development of deep marine circulation between Australia and Antarctica at about the Eocene-Oligocene boundary and (2) Australia's subsequent rapid drift into middle-low latitudes. This provided background warming and (Paleocene-Eocene) increased humidity over a period when the earth as a whole underwent progressive warming, then cooling/drying episodes. Since the Eocene, increasingly seasonal climates have resulted in the fragmentation of active river systems in inland Australia, first into chains of brackish to freshwater lakes connected by seasonally inactive channels, then into hydrologically closed saline basins during the Late Neogene (see Clarke 1994, Macphail *et al*. 1994, Alley *et al*. 2000, Hou *et al*. 2003).

Over the same period, predominantly mesic biomes such as rainforest were replaced by more xeric/open biomes such as sclerophyll forests, woodlands and savanna (see Macphail *et al*. 1994, Kershaw *et al* 1994, Macphail 1997). Nevertheless relict populations of some rainforest elements, including *Araucaria*, *Dacrycarpus*, *Dacrydium*, *Podocarpus* and *Nothofagus* (*Brassospora*) spp. survived in favourable niches such as spring-fed channels within sub-humid to semi-arid environments along the south-west and western margins as recently as the mid Pliocene (Macphail 1994, Macphail 1996, Dodson & Macphail 2004). Alternatively, Late Cenozoic populations of these genera included (now extinct) ecotypes that were more tolerant of water-stress than their NLRs in Australia or (*Dacrycarpus*, *Dacrydium*) islands in the South-West Pacific.

Wetter conditions allowed forest-sized stands of *Nothofagus* (*Brassospora*) spp. to survive in western Tasmania (Macphail *et al*. 1995) and the Atherton Tableland in northeast Queensland (Kershaw & Sluiter 1982) into Late Pliocene time. Whether the same was true for other areas of the Eastern Highlands is unknown, but a species (*Nothofagus moorei*) belonging to the typically cool-cold temperate subgenus *Lophozonia* is found as far north as the Macpherson Ranges on the Queensland-NSW border at present. A complicating factor is that easterly winds or rivers might have transported pollen and spores from relict *Nothofagus* rainforest on the Eastern Highlands as far west as the Lower Balonne area long after the genus became extinct on the much drier inland plains.

Assuming that the age determinations are broadly correct, the Lower Balonne data imply that dominant vegetation types in the modern vegetation, e.g. Brigalow (*Acacia harpophylla-Casuarina cristata* open forests, woodlands and shrubland) began forming across interfluve areas during the Early Pliocene. *Nothofagus* was extinct in the region by Late Miocene-Early Pliocene time whilst relatively drought-tolerant rainforest gymnosperms, including araucarians and podocarps, survived along river channels into the Late Pliocene and Early Pleistocene. Corollaries are:

1. Continuous flow along channels draining the Lower Balonne area ceased sometime before or during the Late Miocene-Early Pliocene.

2. Fluvio-lacustrine deposits infilling shallow valleys in the Lower Balonne area are correlatives of the Loxton-Parilla Formation in the Murray Basin (see Brown & Stephenson 1991) and the Lachlan Formation infilling the Lachlan Valley on the central west slopes of NSW (see Martin 1973, 1987).

Fossil pollen data (Table 5) from infilled palaeochannels on the western slopes of the Eastern Highlands in northern NSW provide moderately strong support for these hypotheses. The closest sites are the Gwydir Valley near Moree about 200 km to the southeast (Martin 1980), the lower Namoi Valley to the west of Narrabri about 270 km to the south (Martin 1980, 1994), and the Mooki (~upper Namoi) Valley south of Gunnedah on the western escarpment of the Great Dividing Range about 370 km to the southeast of the drillhole area (Martin 1979)

As with the Lower Balonne microfloras, independent age control is lacking and therefore the inferred chronology involves a measure of circular reasoning because the same fossil microfossil evidence is used to infer the age of the deposits and reconstruct the past vegetation and environments. All three valleys are relatively close the Highlands and therefore the fossil microfloras are likely to include a significant percentage of fossil pollen and spores derived from wet-forest communities occupying the upper slopes and highly dissected summit plateau. For example the spores of tree ferns such as *Cyathea* which are transported by water over long distances, are particularly common in the Mooki assemblages prior to the Middle?-Late Pleistocene.

Nonetheless, the combined data clearly record the replacement of *Nothofagus*-Myrtaceae dominated rainforest (Miocene) by Asteraceae-Chenopodiaceae shrublands (Middle?-Late Pleistocene) via transitional (mixed) communities in which gymnosperms and Casuarinaceae were prominent (Pliocene-Early Pleistocene). Assuming that similar shifts in dominance at about the same time in vegetation growing on the plains west of the Highlands in southeast Queensland then:

1. The virtual absence of fossil *Nothofagus*, Asteraceae and Chenopodiaceae pollen in assemblages makes it highly probable that the maximum and minimum age limits for the sampled intervals in Drillholes LB02, LB03 and LB08 are Early Pliocene and Early Pleistocene respectively.

2. Although these microfloras are provisionally assigned a Pliocene age based on the high relative abundance of *Podocarpus* (LB02, LB08) and *Araucaria* (LB03) an Early Pleistocene age cannot be ruled out on the limited palynostratigraphic data available.

3. The former (LB02, LB08) samples are likely to be younger than the LB03 samples, based on the empirical observation that species of *Podocarpus* sensu lato are more tolerant of climatic extremes than *Araucaria*. A not unreasonable prediction is that the sampled intervals will prove to be Late and Early-Middle Pliocene respectively, based on analogous trends in the Lachlan Valley (see Martin 1987, 1994).

If correct then precursors of the important Brigalow communities have been present in inland southeast Queensland during and since the Late Neogene. The virtual absence of Myrtaceae other than eucalypts is best explained by edaphic factors as well as drying climates (see Johnson & Burrows 1984).

6.2 Early Cretaceous

Early Cretaceous microfloras recovered in LB06 and the 42220 drillholes are variants of those described by Burger (1980). This allows the sampled intervals to be dated with good confidence using criteria proposed by Helby *et al*. (1987). Two distinct depositional environments are represented:

1. Early to early Late Albian (*Crybelosporites striatus* to *Coptospora paradoxa* Zone) sediments were deposited in freshwater deltaic (lake?) environments after regression of the sea from the southeastern margin the basin during the Late Aptian (see Stuckmeyer & Totterdell 1990).

   Active streams appear to have been lined by ferns, in particular Hymenophyllaceae (*Baculatisporites*) and Cyatheaceae (*Cyathidites*). Several usually rare cryptogams occur in significant numbers in some samples, e.g. *Balmeisporites tridictyus* (Marsileaceae) and *Trilobosporites tribotrys* (Dicksoniaceae?). Other wetland communities included Gleicheniaceae fernland and *Sphagnum* bogs. The dryland vegetation was podocarp-dominated form of Austral Conifer Woodland, analogous to the boreal conifer forests that cover high latitude landmasses in the Northern Hemisphere today (see Macphail 2000).

   The Albian age and absence of marine dinoflagellates allows the sampled intervals to be identified as Early to Middle Albian Griman Creek Formation with a high degree of confidence (see Table 2 in Burger 1980).

2. Late Aptian to? Early Albian (*Crybelosporites striatus* Zone) sediments were deposited in a restricted marine environment (Drillhole LB06 58.6 m).

The abundance of Aracuariaceae pollen in this sample relative to the *Coptospora paradoxa* Zone samples (15% vs 1-9%) indicate that Drillhole LB06 was located in a shallow? seaway away from the palaeoshoreline (weak Neves Effect).

The marine flora indicates the sampled interval is Late Aptian Wallumbilla Formation or (considered less likely because of the high dinocyst diversity) Early Albian Surat Siltstone (see Table 2 in Burger 1980).

6.3 Jurassic

Middle Jurassic lignites reworked into Cenozoic sands in Drillhole 42220175 provide a 'snap shot' of the composition of plant communities when the Balonne area and southeast Queensland in general was located at high palaeolatitudes (~ 70 ^{0}S: see Veevers *et al*. 1991). Dominant woody taxa included representatives of the Araucariaceae (*Araucariacites*, *Callialasporites*), Podocarpaceae (*Podocarpidites*), and an extinct group (Pteridospermophyta) 'intermediate' between the ferns and cycads (*Falcisporites*).

It is unknown whether these plants co-existed in communities similar to Cretaceous Austral Conifer Woodland or formed a fern heath with Lycopodiaceae (*Retitriletes*) and other presumed ground ferns is unknown. However, since similar microfloras are preserved in correlative sediments in the Bremer Basin, in southwest Western Australia (M.K. Macphail unpubl. data), it is probable that pteridosperm-conifer-fern associations extended across much of southern Australia during the Middle Jurassic.

Table 5: Comparison of Late Neogene-Early Pleistocene microfloras in northern NSW and southeast Queensland

	NORTHERN NSW'							LOWER BALONNE	
AGE LIMITS (from Martin)	**Miocene**	**Pliocene**	**Pliocene**	**Plio-Pleistocene**		**Pleistocene**		**-**	
AGE LIMITS (this study)	**Early -Middle? Miocene**		**Early? Pliocene**	**Late? Pliocene--Early Pleistocene**		**Middle?-Late Pleistocene**		**Late Pliocene-Early Pleistocene**	
LOCALITY	**Gwydir**	**Mooki**	**Mooki**	**Namoi**	**Mooki**	**Gwydir**	**Mooki**	**LB02, LB08**	**LB03**
REFERENCE	**Martin 1980**	**Martin 1979**	**Martin 1979**	**Martin 1980**	**Martin 1979**	**Martin 1980**	**Martin 1979**	**this study**	
DOMINANT TAXA	Myrtaceae	Myrtaceae	Cyatheaceae	Araucariaceae	Casuarinaceae	Asteraceae	Asteraceae	Casuarinaceae	Casuarinaceae
	Nothofagus	Nothofagus	Araucariaceae	Casuarinaceae	Myrtaceae	Myrtaceae	Myrtaceae	Podocarpaceae	Araucariaceae
	Casuarinaceae	Casuarinaceae	Casuarinaceae	Myrtaceae	Cyatheaceae				Podocarpaceae
LIVERWORTS, FERNS & FERN ALLIES									
Cingulatisporites bifurcatus	+		3%	+		2%	+	+	
Cyathidites paleospora	2-4%	7%	19%	3%	8%			+ to 3%	2%
Cyathidites subtilis	2-4%	1%							
Gleicheniidites/Dictyophyllidites	0-2%	2%			1%			+	0-2%
Hypolepis spinyspora									
Ischyosporites cf *lachlanensis*	+							+	1%
Matonisporites ornamentalis	+	7%			2%	1%		+	
Polypodiaceoisporites retirugatus		2%	2%						
Rugulatisporites cf *cowrensis*		1%				+	1%		+
Rugulatisporites mallatus	+								
Verrucosisporites kopukuensis	+								
GYMNOSPERMS									
Araucariacites australis	1-2%	1%	17%	22%	3%	4%	3%	+ to 3%	8-26%
Cupressacites				3%	4%	1%	+	+	
Dacrycarpites australiensis	0-2%		1%		1%			3%	2-8%
Lygistepollenites florinii	1-4%	1%							
Microalatidites palaeogenicus	1-2%		1%		2%				+
Podocarpidites spp.	2-4%	1%	5%	3%	4%	1%		21-28%	6-11%
ANGIOSPERMS									
Acaciapollenites myriosporites				3%	+			+	2-7%
Canthiumidites bellus	+			+					
Chenopodipollis chenopodiaceoides			+			4%	13%	+	+
Cupanieidites orthoteichus	+	1%		+					

TABLE 5 (cont.)

	NORTHERN NSW'							**LOWER BALONNE**	
AGE LIMITS (from Martin)	**Miocene**	**Pliocene**	**Pliocene**	**Plio-Pleistocene**		**Pleistocene**		**-**	
AGE LIMITS (this study)	**Early -Middle? Miocene**		**Early? Pliocene**	**Late? Pliocene--Early Pleistocene**		**Middle?-Late Pleistocene**		**Late Pliocene-Early Pleistocene**	
LOCALITY	**Gwydir**	**Mooki**	**Mooki**	**Namoi**	**Mooki**	**Gwydir**	**Mooki**	**LB02. LB08**	**LB03**
REFERENCE	**Martin 1980**	**Martin 1979**	**Martin 1979**	**Martin 1980**	**Martin 1979**	**Martin 1980**	**Martin 1979**	**this study**	
ANGIOSPERMS (cont.)									
Glencopollis ornatus		1%					+	+	
Graminidites spp.	0-1%	2%	+	7%	2%	3%	14%	1-4%	3-5%
Haloragacidites haloragoides			4%		+	4%	2%	+	0-4%
Haloragacidites harrisii	2-10%	10%	16%	16%	30%	8%	2%	57-62%	31-44%
Haloragacidites myriophylloides	+								
Malvacipollis spinyspora								+	
Malvacipollis subtilis	0-3%						+	+	+
Milfordia hypolaenoides	0-1%				+			+	+
Monotocidites galeatus								+	+
Myrtaceidites eucalyptoides	2-7%	1%		3%	13%	8%	11%	+	
other *Myrtaceidites*	10-16%	9%	9%	8%	16%	6%	+	+	+ to 4%
Nothofagidites asperus	4-8%	6%						+	
Nothofagidites brachyspinulosus	+	1%							
Nothofagidites emarcidus-heterus	7-17%	14%							reworked?
Nothofagidites falcatus	0-2%								
Polyporina granulata			3%	2%			2%		
Proteacidites spp.	2-6%	2%			1%		1%	+	+ to 3%
Pseudowinterapollis cranwellae	0-1%		1%		1%	1%			+
Quintiniapollis	0-1%	1%	+						
Rhoipites ampereaformis									+
Stephanocolpites oblatus			+		+				
Striasyncolpites laxus									+
Tricolporites leuros	+								
Tricolporites pelargonioides			+	+					+
Triporopollenites endobalteus	4-11%								
Tubulifloridites pleistocenicus							1%		
Tubulifloridites spp.			3%	7%	1%	44%	20%		
unassigned angiosperms	19-38%	7%	5%	13%	4%	6%	5%	+	0-2%

7. ACKNOWLEDGEMENTS

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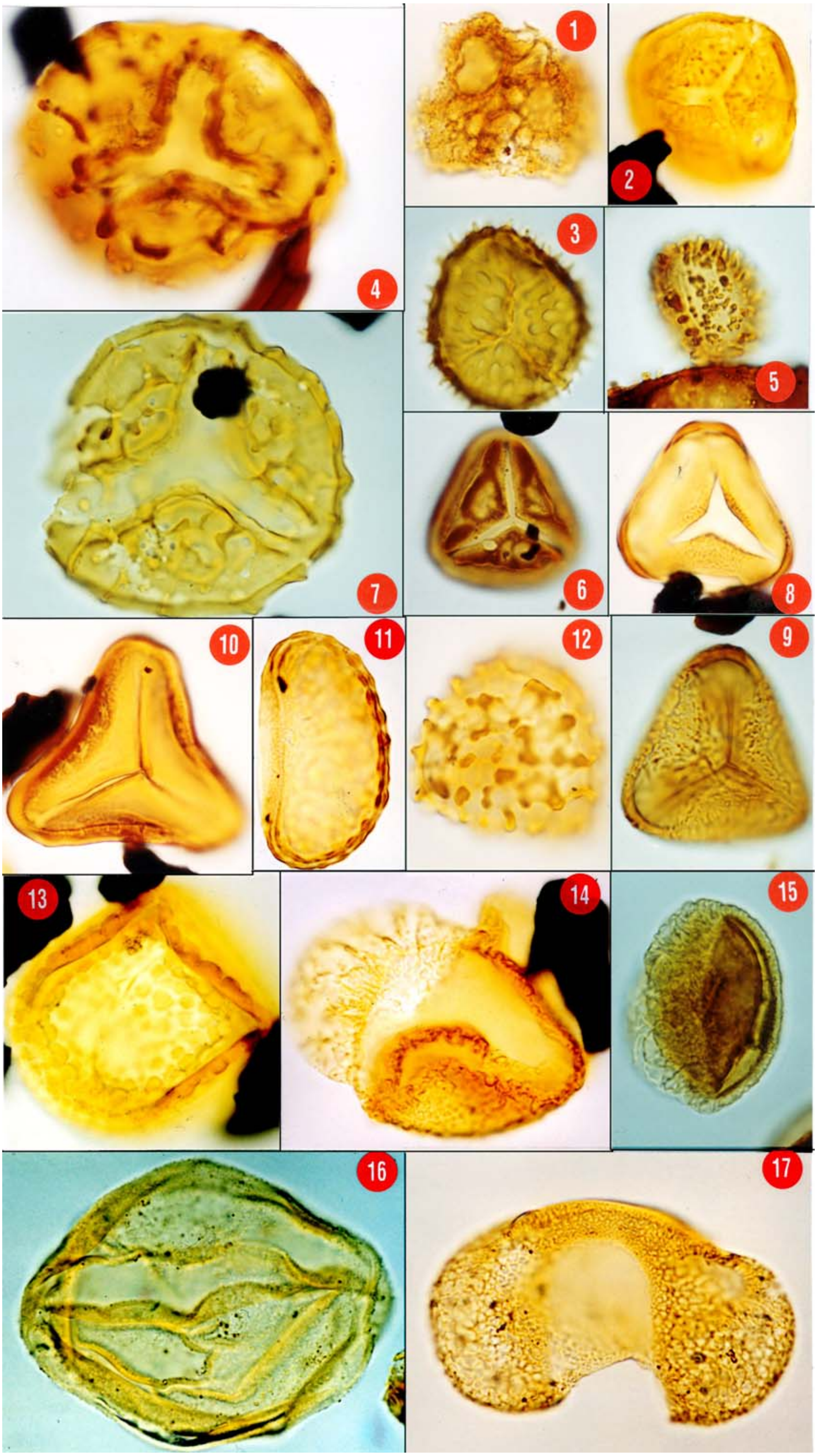
APPENDIX 1. **Photomicrographs of age-diagnostic and other distinctive plant microfossils**

All photomicrographs taken at x 788 magnification (larger 50 μm scale bar) except for Figs. 42-44 which were taken at x 600 magnification (smaller 50 μm scale bar)

Nearest living equivalents (if known) of the fossil taxa are given in parentheses.

Figs. 1-13, 21	**Cryptogams**
Fig. 1	*Azolla* (*Azolla*). LB02 56.1 m depth.
Fig. 2	*Cingulatisporites bifurcatus* (Anthocerotae). LB03 58.65 m depth
Fig. 3	*Rudolphisporis rudolphi* (Riccaceae). LB03 58.55 m depth.
Fig. 4	*Baculatisporites* cf *scabridus* (Hepaticae?). LB03 58.65 m depth
Fig. 5.	*Polypodiaceoisporites retirugatus* (*Pteris*). LB02 56.1 m depth
Fig. 6	*Polypodiaceoisporites* sp. nov. (*Pteris*). LB02 56.1 m depth
Fig. 7	*Ischosporites* cf *lachlanensis*. (Dicksoniaceae). LB03 58.65 m depth
Fig. 8	*Matonisporites* cf *ornamentalis* (*Dicksonia*). LB02 56.1 m depth
Fig. 9	*Cyathidites paleospora* (*Cyathea*). 42220171 172-174 m depth
Fig. 10	*Dictyophyllidites arcuatus* (*Dicranopteris*). LB02 56.1 m depth
Fig. 11	*Polypodiisporites* sp. (Davalliaceae/Polypodiaceae). LB02 56.1 m depth
Fig. 12	*Rugulatisporites* cf *cowrensis* (*Culcita*). LB03 59.5 m depth
Fig. 13	*Verrucosisporites* sp. LB03 58.65 m depth.
Figs. 14-17	**Gymnosperms**
Fig. 14	*Dacrycarpites australiensis* (*Dacrycarpus*). LB02 56.1 m depth
Fig. 15	*Lygistepollenites florinii* (*Dacrydium*). 42220172 111-113 m depth
Fig. 16	*Araucariacites australis* (*Araucaria*). LB03 59.5 m depth
Fig. 17	*Podocarpidites* sp. A (*Podocarpus-Prumnopitys*). LB02 56.1 m depth
Figs 18-19	**Gymnosperms (cont.)**
Fig. 18	*Podocarpidites* sp. B (*Podocarpus-Prumnopitys*). LB03 58.65 m depth
Fig. 19	*Microalatidites palaeogenicus* (*Phyllocladus*). LB03 58.65 m depth
Figs. 20, 22-41	**Angiosperms**
Fig. 20	*Acaciapollenites myriosporites* (*Acacia*). LB03 58.65 m depth
Fig. 21	*Leptolepidites verrucatus* (Cenozoic var.). LB03 58.65 m depth
Fig. 22	*Acaciapollenites weissii* (*Acacia*). LB03 59.5 m depth
Fig. 23	*Proteacidites punctiporus* (*Stirlingia*). LB03 58.65 m depth
Fig. 24	*Haloragacidites harrisii* (Casuarinaceae). LB02 56.1 m depth
Fig. 25	*Nothofagidites emarcidus* [*Nothofagus* (*Brassospora*) sp.]. LB03 59.5 m depth
Fig. 26	*Nothofagidites falcatus* [*Nothofagidites* (*Brassospora*) sp.]. 42220175 172-174 m depth
Fig. 27	*Hakeidites* sp. (*Grevillea*). LB02 56.1 m depth
Fig. 28	*Monotocidites galeatus* (*Monotoca*). LB02 56.1 m depth
Fig. 29	*Rhoipites ampereaformis* (*Amperea*). LB03 58.65 m depth
Fig. 30	*Malvacipollis spinyspora* var. (*Selenothamnus*). LB02 56.1 m depth
Fig. 31	*Striasyncolpites laxus* (*Villarsia*). LB03 59.5 m depth
Fig. 32	*Tricolporites* sp. (Apiaceae?). LB03 58.65 m depth
Fig. 33	*Liliacidites* sp. (Amaryllidiaceae/Liliaceae). LB03 58.65 m depth
Fig. 34	*Tricolpites* sp. (Scrophulariaceae?). LB02 56.1 m depth
Fig. 35	*Perfotricolpites digitatus* (*Merremia*-type). LB02 56.1 m depth
Fig. 36	*Glencopollis ornatus* (*Polygonum*). LB03 59.5 m depth
Fig. 37	*Haloragacidites haloragoides (Gonocarpus*). LB03 59.5 m depth
Fig. 38	micro-variant of *Haloragacidites haloragoides*. LB02 56.1 m depth
Fig. 39	*Tubulifloridites simplis* (Asteraceae: Tubuliflorae). LB03 59.5 m depth
Fig. 40	*Schizocolpus* sp. LB02 56.1 m depth
Fig. 41	*Rhoipites* sp. (Brassicaceae?). LB02 56.1 m depth

Figs. 42-43	**Early Cretaceous dinoflagellates**
Fig. 42	*Pseudoceratium turneri* (Dinophyaceae). LB06 58.6 m depth
Fig. 43	cf *Coronifera oceanica* (Dinophyaceae). LB06 58.6 m depth
Figs. 44-47	**Early Cretaceous cryptogams**
Fig. 44	*Balmeisporites tridictyus* (Marsileaceae). 42220200 140-143 m depth
Fig. 45	*Coptospora paradoxa* (Hepaticae?). 42220151 126-128 m depth.
Fig. 46	*Crybelosporites striatus* (Marsileaceae). 42220200 146-148 m depth
Fig. 46	**Jurassic cryptogams**
Fig. 47	*Contignisporites* cf *glebulentus* (Schizeaceae?). 42220175 150-152 m depth
Fig. 48	**Jurassic gymnosperms**
Fig. 48	*Callaliasporites dampieri* (Araucariaceae). 42220175 150-152 m depth
Fig. 49	**Early Cretaceous angiosperms**
Fig. 49	*Clavatipollenites hughesii* (cf *Ascarina*). 42220172 116-118 m depth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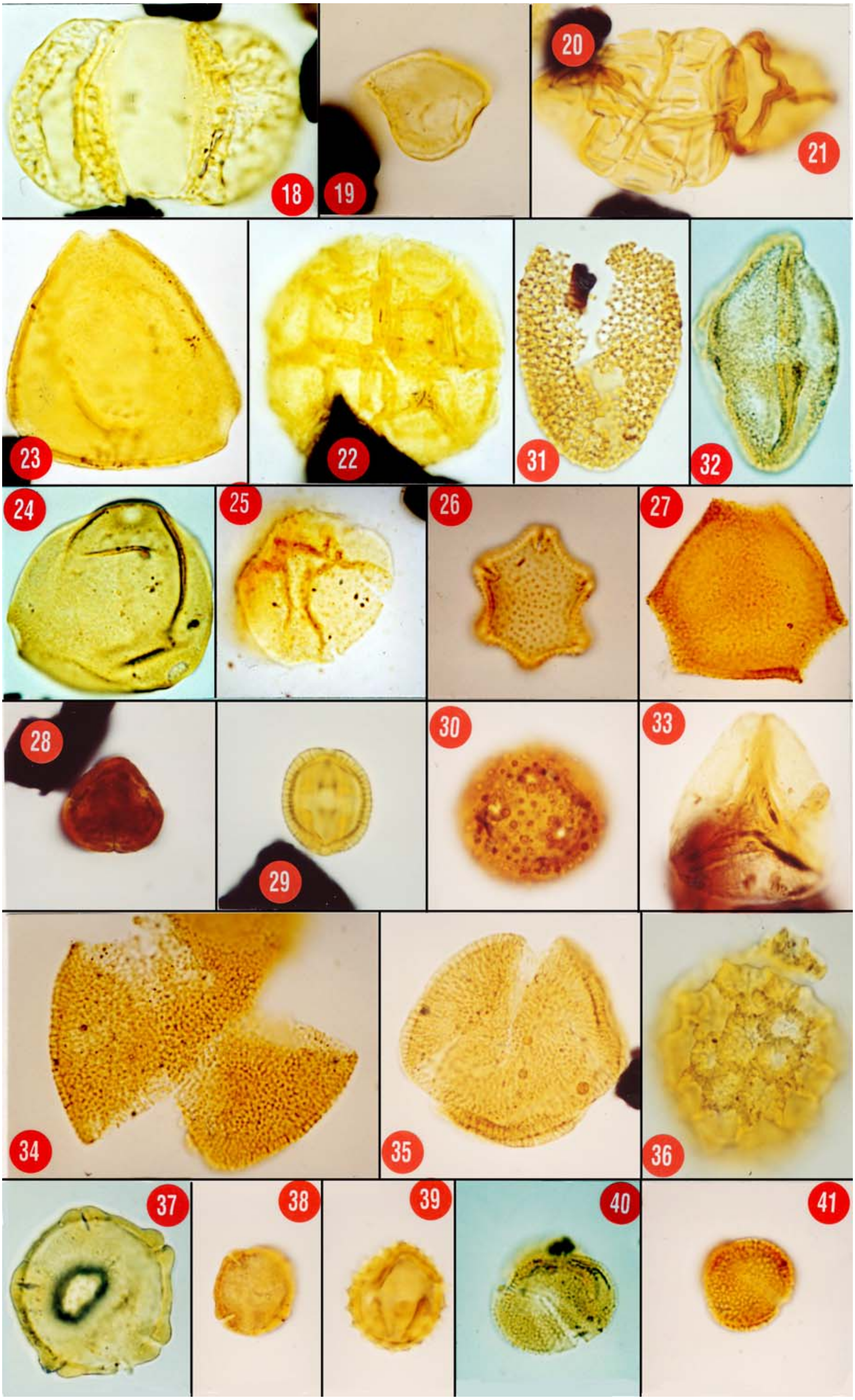
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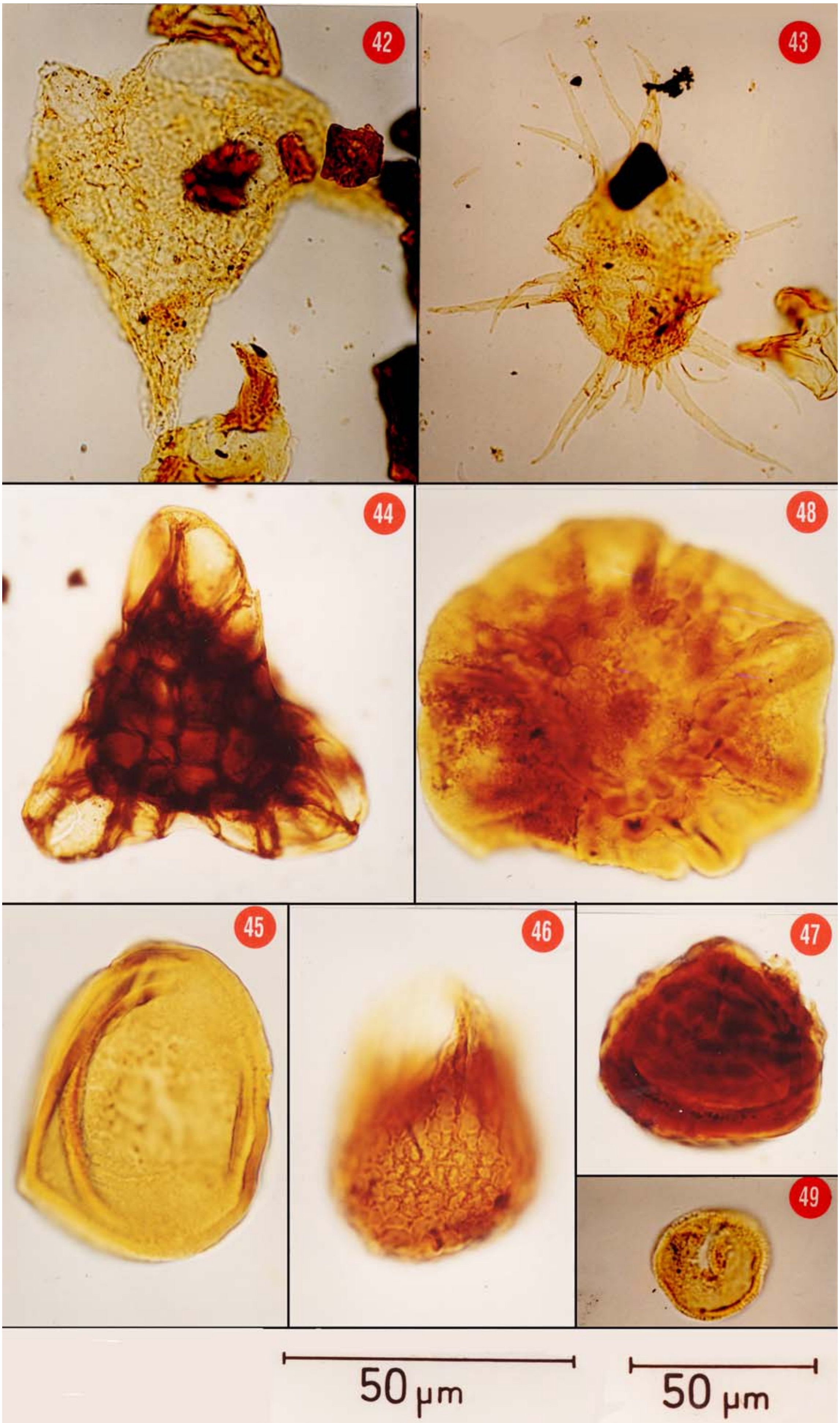
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