THE MEGAFOSSIL AND MICROFOSSIL FLORAS OF THE CURLEW FORMATION, QUEENSLAND.

by

Andrew Ian Rowett, B.Sc. (Hons)

Department of Botany,

University of Adelaide.

Thesis submitted for the Degree of Doctor of Philosophy

at the University of Adelaide,

October, 1986.

Awarded: February 17, 1988.

CONTENTS

ABSTRACT

The dispersed cuticle and pollen floras of the Curlew Formation were investigated with the intention of reconstructing the past environment and climate. The Middle to Late Eocene age of the deposit has been confirmed by the palynological examination of the Curlew sediments.

The Curlew cuticular flora has been divided into an autochthonous and allochthonous element. The autochthonous element is represented in the lignitic sediments by monocotyledon cuticle types whereas the allochthonous element is associated with the lighter coloured shales, clays and coals and represented by dicotyledon and gymnosperm cuticle types. The sequence has been divided into forty-one discrete depositional events (in the reference core ERD 118).

From the five drillhole cores, i.e. ERD 118, ERD 117, ERD 112, ERD 111 and ERD 110, 52 cuticle parataxa have been identified of which 22 have been assigned to 8 (possibly 9) dicot families and 10 genera, i.e. Casuarinaceae (Gymnostoma), possibly Cunoniaceae, Cyperaceae, Ebenaceae (Austrodiospyros), Lauraceae (Cryptocarya, Endiandra and Litsea), Podocarpaceae (Decussocarpus), Proteaceae (Cardwellia, Darlingia and Synaphea) and Zamiacaea (Bowenia). Five other parataxa have simply been assigned to the Monocotyledonae. The water fern Azolla capricornica (Salviniaceae) was also identified from megaspores, massulae and microspores.

A single correlation module has been recognised in the Formation. It consists of three distinct floristic bands, two dicot/gymnosperm bands which differ slightly in the cuticle types they contain and a central monocot band.

Comparison of the Curlew palynoflora with those of the southern Eocene deposits, e.g. Anglesea, Victoria, has indicated that a more tropical vegetation was present in Queensland during this period of the Tertiary. Cool floristic elements like the podocarps and Nothofagus are poorly represented in the Curlew palynoflora.

The Curlew fossil flora was deposited in a low energy, freshwater swamp, in generally reducing conditions. The local vegetation was probably represented by a marginal tropical-subtropical closed forest (megatherm-mesotherm vegetation, Nix, 1982) whose mixed canopy layer consisted of eucalypts as well as tropical (e.g. Olacaceae) and subtropical (e.g. Cupanieae) trees. The understorey contained some sclerophyllous elements but ferns and liliaceous plants probably dominated. Along the swamp margin reed-like plants were probably common under Gymnostoma. The allochthonous vegetation, probably introduced into the basin from wetter highlands to the west of the deposit, was marginal tropical closed forest with a mixed canopy of laurels and Proteaceae as well as some tropical and subtropical taxa with cycads and proteaceous shrubs scattered throughout the understorey.

DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University. To the best of my knowledge and belief this thesis contains no material previously published or written by another person except where due reference is made in the text.

Andrew Ian Rowett.

ACKNOWLEDGEMENTS

I wish to thank Dr. D.C. Christophel, for his supervision and assistance throughout this project. I am most grateful to Esso Australia Ltd. for their financial assistance during the first two years of this project and Mr. L. Coshell for access to core material and geological data of the Curlew Formation.

I would also like to thank Messrs. C. Foster and W. Harris of Western Mining Corporation Ltd. for their assistance with palynological analyses, Mr. L. Jessop of the Queensland Herbarium for providing information on modern Queensland vegetation, David Greenwood and fellow students and staff of the Botany Department for helpful discussion on all aspects of the project and Miss C. Marcelline for assistance with typing.

Finally, I wish to thank my wife Debra for her continued support and encouragement throughout this study.

CHAPTER 1

INTRODUCTION

1.1 History of Tertiary Fossil Floras of Queensland Oilshale Deposits.

Queensland has a large number of oilshale deposits which range in age from Cambrian to Tertiary (Figure 1). Tertiary oilshales are the most common. They occur in eight basins in eastern Queensland and, with the exception of some beds at the Narrows and Strathpine, contain mainly low grade shales (Swarbrick, 1974).

The presence of oilshale in the Narrows area was suspected as early as 1911, but was not confirmed until 1914, when the then Assistant Government Geologist, Mr. L.C. Ball, discovered high grade oilshale in the vicinity of Munduran Creek. In describing the geology of the area he noted that siliceous beds in the south contained abundant indistinct impressions of plant remains, as did the more earthy shale bands to the north. Because of the reported poor state of preservation of these fossils no further interest was shown. However, the faunal remains mentioned by Ball received a considerable amount of attention, particularly the ostracods, which were seen as possible biostratigraphic indicators. Beasley (1945) identified a number of species of fossil ostracods from this and other Queensland deposits enabling him to construct a zonation and approximate correlation of the strata. It was suggested here that both the Narrows Tertiaries and the Petrie Series (Jones, 1927), 7kms. north of Brisbane, were probably of Miocene age, but more recent palynological investigations in the Narrows region have found this date to be incorrect.

In the early 1970's OPEC (the Organisation of Petroleum Exporting Countries) imposed worldwide increases in oil prices, causing a renewed interest in oilshale as a possible substitute energy source. Stimulated by this situation, oilshale exploration in Queensland was expanded and known deposits reassessed. The increased availabilty of core material resulting from new drilling operations saw more palynological studies undertaken. Although the palynological resurgence was slow, megafossil floras were now finally being investigated.

Paten (1967) carried out a palynological analysis on Narrows material and dated the deposit as Eocene - Oligocene. This was the first floral examination of Narrows sediments since Ball (1914) recognised plant remains at two localities, some 50 years after the deposit was first discovered. Later, Hekel (1972) produced a palynological correlation for all known Tertiary deposits, in which the Narrows region was considered to be Palaeocene - Middle Oligocene in age.

Extensive investigations carried out in the Narrows region between 1974 and 1980 by Southern Pacific Petroleum N.L. and Central Pacific Minerals N.L. outlined two separate, but similar, oilshale deposits, i.e. Rundle and Stuart. During this period of exploration Foster (1979) analysed sediments from the Rundle deposit, noting that the uppermost oilshale unit (the Wattle Creek Seam - later referred to as the Curlew Formation) yielded a palynoflora of Late Eocene - Late Oligocene age, while the remaining sediments (within the Rundle Formation) contained very few pollen grains or spores. Mention was also made of undifferentiated masses of fossil plant material. In early 1980 the two companies entered into a joint venture with Esso Exploration and

Production Australia Inc. for the exploitation of the Rundle oilshale deposit (Henstridge and Missen, 1981). With the increased interest shown in the Rundle Project by these three companies, opportunities existed for the fossil flora to be extensively studied from core samples, in particular those of the Curlew and Rundle Formations.

Although macroscopic plant remains had continued to be recognised from the Narrows sediments (Lindner and Dixon, 1976) none had been identified until the description of the extinct water fern Azolla capricornica (Foster and Harris, 1981). Opportunity thus existed for the first extensive investigation of Tertiary oilshale (and related sediments) in Queensland, with both macro- and micro-fossils being considered , and led to this Ph.D. study being undertaken.

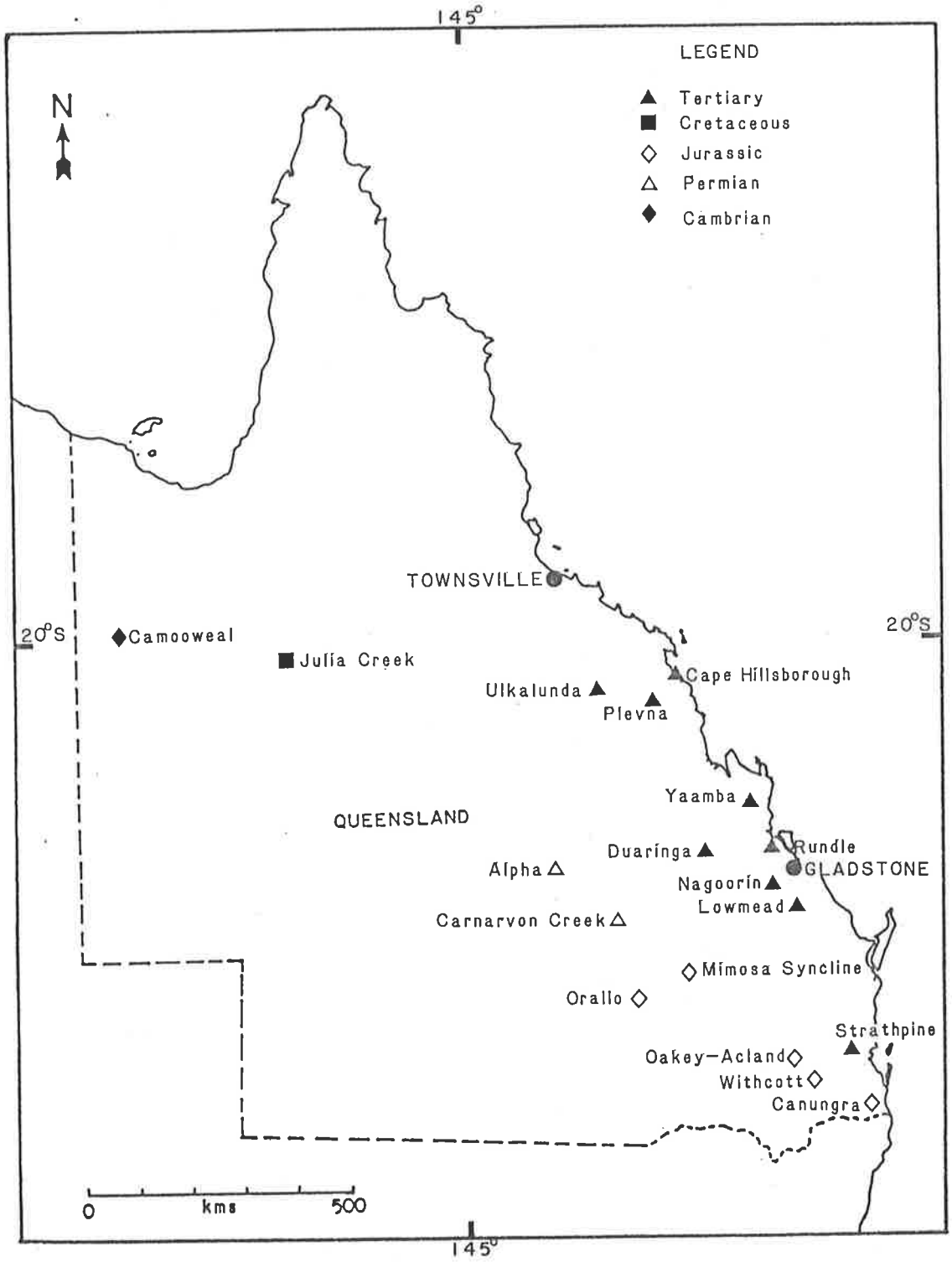


Figure 1: Map showing the Age and locality of Oilshale deposits in Queensland (after Swarbrick, 1974).

1.2 Location and Geology of the Curlew Formation

The Curlew Formation, as part of the Rundle Deposit is situated in the Narrows Graben which lies approximately 25kms northwest of Gladstone, Queensland, latitude 23° 40'S, longitude 151° 10'E (Figure 1). The Gladstone and Narrows areas of central Queensland are underlain by the Carboniferous Curtis Island Group (Kirkegaard et al., 1970; Fleming et al., 1974). The group consists of deep water sediments which were uplifted and folded during the Late Permian with synchronous granite emplacements. During the Upper Cretaceous, trachyte and rhyolite plugs (Mt. Larcom, White Rock) intruded the Curtis Island Group (Henstridge and Missen, 1981).

A lacustrine system developed in the Early Tertiary and sedimentary rocks accumulated within a narrow, north-northwest trenching graben in the Narrows area. These Early Tertiary sedimentary rocks were initially called the Casuarina-Narrows Series (Dunstan, 1913) but the name was amended to The Narrows Beds (Kirkegaard et al., 1970) to conform with the present stratigraphic code. Subsidence and deposition produced a sedimentary pile more than 1,000 metres thick that was later intruded by olivine dolerite. Quaternary alluvium now almost completely conceals the Tertiary sequence.

The extensive cover of alluvium which unconformably overlies the Tertiary sequence (i.e. immediately above the Curlew Formation) consists of gravel, sand and clay. Sand and gravel are more extensive in the south, and range up to 25 metres thick (Henstridge and Missen, 1981). A further unconformity exists between the Narrows Beds and the underlying Curtis Island Group.

Outcrops of the Tertiary sediments are uncommon, the main exposures being restricted to creek beds and coastal inlets of the Narrows Channel (Ball, 1914; Kirkegaard et al., 1970; Lindner and Dixon, 1976; Henstridge and Missen, 1981). They are deeply weathered and consist of kaolinised shale and claystone which is commonly off-white with patchy dark red-brown oxidation colours. Most of the outcrops are of the Brick Kiln and Kerosene Creek Seams, within the older Rundle Formation. There is no exposure of the Curlew Formation sediments.

The strata are considered to be horizontal to shallow westerly dipping (Henstridge and Missen, 1981) but dips of up to 45° have been recorded and are thought to be associated with localised faulting (Figure 2). The western limit of the graben is marked by near vertical dips close to the western faultline. In some creek outcrops small scale faulting is apparent.

The use of drill cores has been the sole source for providing stratigraphic information about the Tertiary sediments. The Narrows Beds consist of oilshale which is rich in organic matter - mainly kerogen, siliceous and argillaceous claystones, mudstones*, shales and minor impure carbonates, clayey sandstones, siltstones and lignites. Oilshales and shales predominate (Kirkegaard et al., 1970). Bedding is commonly massive and poorly expressed with sharply defined bedding and different colour contacts rare. It is characteristic of the sequence that bedding is less distinct in the sediments with low

* the term Mudstone is one of convenience, used by Lindner and Dixon (1976) to refer to fine grained barren or very low grade rocks containing a mixture of clay and silt sized particles.

organic content (Lindner and Dixon, 1976).

When fresh, the oilshale is typically brown to greyish-brown to olive-grey with a dull greasy lustre and brown streak and the shale is dark greenish-grey to greyish-blue-green. In outcrop the sediments are pale buff (due to the high shale content), blocky, jointed, indurate and less commonly fissile and papery. Primarily, the oilshales are laminate, sectile and fissile. The more laminate and fissile layers usually, but not always, represent the higher yielding oilshales. Some massive beds also have a high organic content.

Sedimentary structures noted by researchers (Lindner and Dixon, 1976; Henstridge and Missen, 1981) include sedimentary breccias, intraformational breccias, nodules, limestone, red beds and compaction features, ranging from wavy to non-parallel bedding to sedimentary dykes. Bioturbations, features produced by burrowing organisms, are also present. Megafossils of both plant and animal remains have been recognised in the sedimentary rocks of the sequence. These fossils are commonly fragmented and include vertebrate bones, fish remains, turtle carapaces, crocodilian teeth, scutes, seeds, fruiting bodies, leaves and twigs.

Gastropods and ostracods are common throughout, the latter to the extent of forming recognisable white bands, sometimes known as 'Ostracodite'. Fungal spores, pollen and Azolla capricornica (Foster and Harris, 1981) megaspores and microspores are also common in these sediments.

The sequence has been divided into three conformable formations: Worthington, the oldest, Rundle, the most extensive and Curlew, the youngest. The organic content has proved an important factor in determining these formations and their subsequent units (seams) i.e.,

Curlew Formation

Rundle Formation

- Kerosene Creek Seam
- Telegraph Creek Unit
- Munduran Creek Seam
- Humpy Creek Seam
- Brick Kiln Seam
- Upper Ramsey Crossing Seam
- Lower Ramsey Crossing Seam
- Upper Teningie Creek Seam
- Lower Teningie Creek Seam

Worthington Formation

The Worthington and Rundle Formations have been discussed in detail by Henstridge and Missen (1981) which will not be repeated here. The type section for the sequence is a composite section based on two drill holes: GSQ2 and Rundle diamond drill hole number 66 (RDD 66) (Henstridge and Missen, 1981). The latest drilling program undertaken by ESSO Australia Ltd. has provided further information on the stratigraphy of the sequence enabling the production of a more accurate stratigraphic column (Figure 3). ERD 118 provided the most complete Curlew sequence and has therefore been used as the reference core in this study.

1.2.1 The Worthington and Rundle Formations

The Worthington Formation includes the oldest sedimentary rocks of the Narrows Graben which consists mainly of conglomerate, sandstone, sandy and silty clays to claystone. The Rundle Formation is the most extensive stratigraphic unit with an approximate thickness of 500 metres. This kerogen rich sequence has been subdivided into seven units; the six kerogen units, known as seams are distinguished by the organic content of the oilshale, and a predominantly claystone unit containing very little oilshale.

1.2.2 The Curlew Formation

Stratigraphically, the Curlew Formation is the youngest section of the Narrows Beds sequence. Only in the north of the graben does the Formation exist, overlying the larger Rundle Formation. It is not known if this is the full extent of the Formation but comments made by some workers (Lindner and Dixon, 1976; Henstridge and Missen, 1981) about the deeply weathered and eroded sediments tend to suggest that the Formation may have extended further south in the past.

The section consists mainly of green claystone with interbedded carbonaceous shale, brown claystone and lignite. Minor calcareous sandstone and limestone beds also occur. Coal bands are common within the shales. A well defined base consisting of interbedded carbonaceous shale and green-grey claystone, which grades into carbonaceous oilshale, is evident for approximately 5 metres above the contact with Kerosene Creek oilshales (see Figure 4). Due most probably to erosion and weathering the upper limit of the Formation is undefined and

overlain unconformably by fluvial sands and gravels (Lindner and Dixon, 1976). Ostracods are common.

Plant remains in these sediments are particularly abundant, more so than in any other strata of the Rundle deposit. Azolla capricornica described by (Foster and Harris, 1981), is possibly one of the most common plant fossils in the Formation, having occurred in most core samples examined. There are two life cycle stages of the water fern represented — the large conical-shaped megaspores (Figure 154) and microspore massulae with their characteristically barbed glochidia (Figures 146, 153). Azolla microspores, both isolated and clusters, and isolated (detached) glochidia have been recognised during palynological examinations of Curlew samples. Intact megafossils are extremely rare but small leaf fragments, twig remnants and seeds are common in the carbonaceous clay, shale and coal horizons. The leaf fragments are particularly abundant. Pollen has also been recovered from these lithotypes. Chitinous fragments and small capsular structures are also present in small quantities throughout the section.

The megafossil flora was initially divided into two very broad botanical groupings, i.e. Monocotyledons and "Other Seed Plants" (Dicotyledons and Gymnosperms), whose cuticular differences were easily recognised. Generally, the cuticle of monocotyledons is characterised by rectangular epidermal cells arranged in longitudinal rows parallel to the long axis of the leaf, with sinuous anticlinal walls and a tetracytic stomatal arrangement. Gymnosperm cuticles are similar in gross morphology to those of the monocots but lack the same degree of cellular organization. The cuticle of the dicotyledons by contrast is far less organised; cell shape, stomatal arrangement and nature of the

cell walls all vary to some extent. Therefore at the cuticular level these two groups are easily distinguished.

The two groups have been noted as generally lithotype specific. The monocots are associated with the lignites and the dicot/gymnosperm group is associated with the shale/coal bands. The claystone contains parataxa of both plant groups but the dicots generally dominate.

Through the recognition of cuticle types and associated plant assemblages it is conceived that the cores analysed i.e. ERD 110, 111, 112, 117 and 118, may be biostratigraphically correlated. These cores are all located in the North-western end of the Narrows Graben (Figure 2) because this is the only region where the Formation remains. Therefore by defining correlatable zones between these cores a cross correlation of this part of the basin, ie. the Curlew Formation, is also achieved. The oilshale seams throughout the Rundle deposit have been found to be persistent and correlatable, using a combination of lithological sections and assay histograms (assay values recording the % of kerogen contained in each two metre interval of drill core) (Henstridge and Missen, 1981). Based on this information and the fact that all three formations are considered conformable it is expected that the minor lithotype bands of the Curlew Formation will be correlatable across the basin.

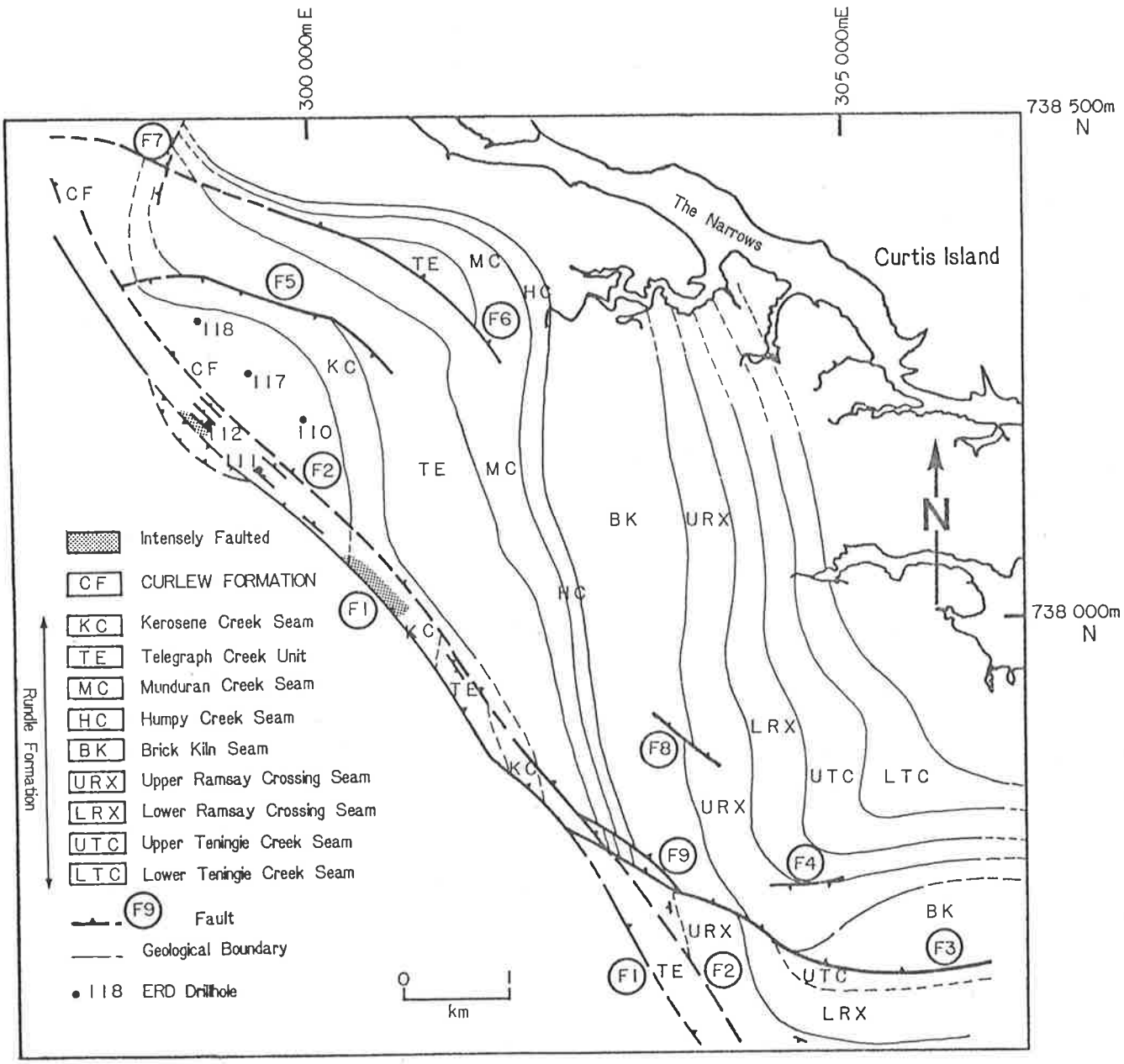
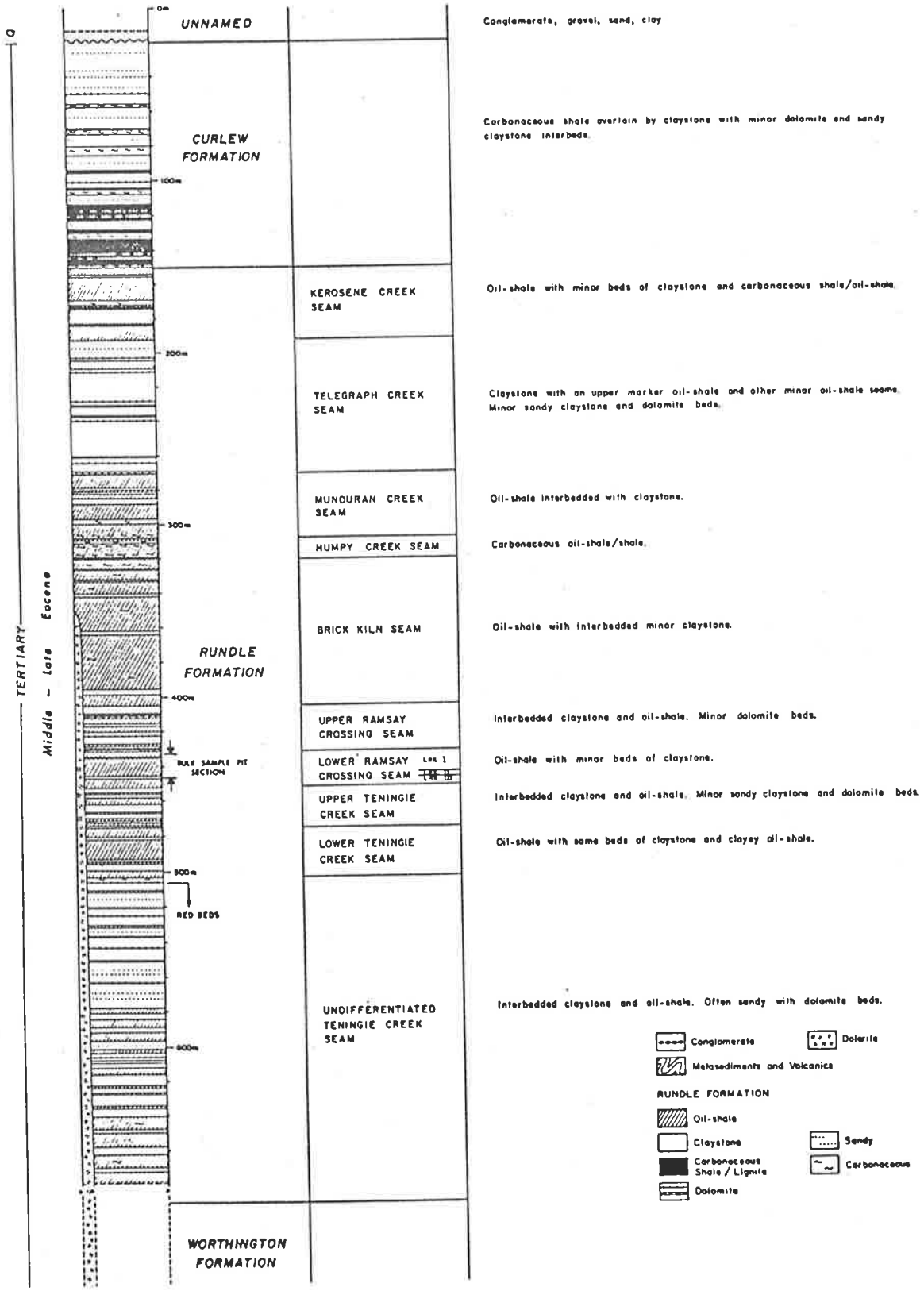


Figure 2: Map showing Drillhole Localities and Fault Systems associated with the Curlew Formation (reproduced courtesy of Esso Aust. Ltd. from Rundle Project Report, 1982).

Figure 3: Stratigraphy of the Rundle Deposit (after L.Coshell (Esso Aust. Ltd.) pers. comm., 1982).


Q
TERTIARY
Middle – Late Eocene
0m
UNNAMED
Conglomerate, gravel, sand, clay
CURLEW FORMATION
Carbonaceous shale overlain by claystone with minor dolomite and sandy claystone interbeds.
100m
KEROSENE CREEK SEAM
Oil-shale with minor beds of claystone and carbonaceous shale/oil-shale.
200m
TELEGRAPH CREEK SEAM
Claystone with an upper marker oil-shale and other minor oil-shale seams. Minor sandy claystone and dolomite beds.
MUNDURAN CREEK SEAM
Oil-shale interbedded with claystone.
300m
HUMPY CREEK SEAM
Carbonaceous oil-shale/shale.
BRICK KILN SEAM
Oil-shale with interbedded minor claystone.
RUNDLE FORMATION
400m
UPPER RAMSAY CROSSING SEAM
Interbedded claystone and oil-shale. Minor dolomite beds.
BULK SAMPLE PIT SECTION
LOWER RAMSAY CROSSING SEAM
Log 1
Oil-shale with minor beds of claystone.
UPPER TENINGIE CREEK SEAM
Interbedded claystone and oil-shale. Minor sandy claystone and dolomite beds.
LOWER TENINGIE CREEK SEAM
Oil-shale with some beds of claystone and clayey oil-shale.
500m
RED BEDS
UNDIFFERENTIATED TENINGIE CREEK SEAM
Interbedded claystone and oil-shale. Often sandy with dolomite beds.
600m
WORTHINGTON FORMATION
Conglomerate
Dolerite
Metasediments and Volcanics
RUNDLE FORMATION
Oil-shale
Claystone
Carbonaceous Shale / Lignite
Dolomite
Sandy
Carbonaceous

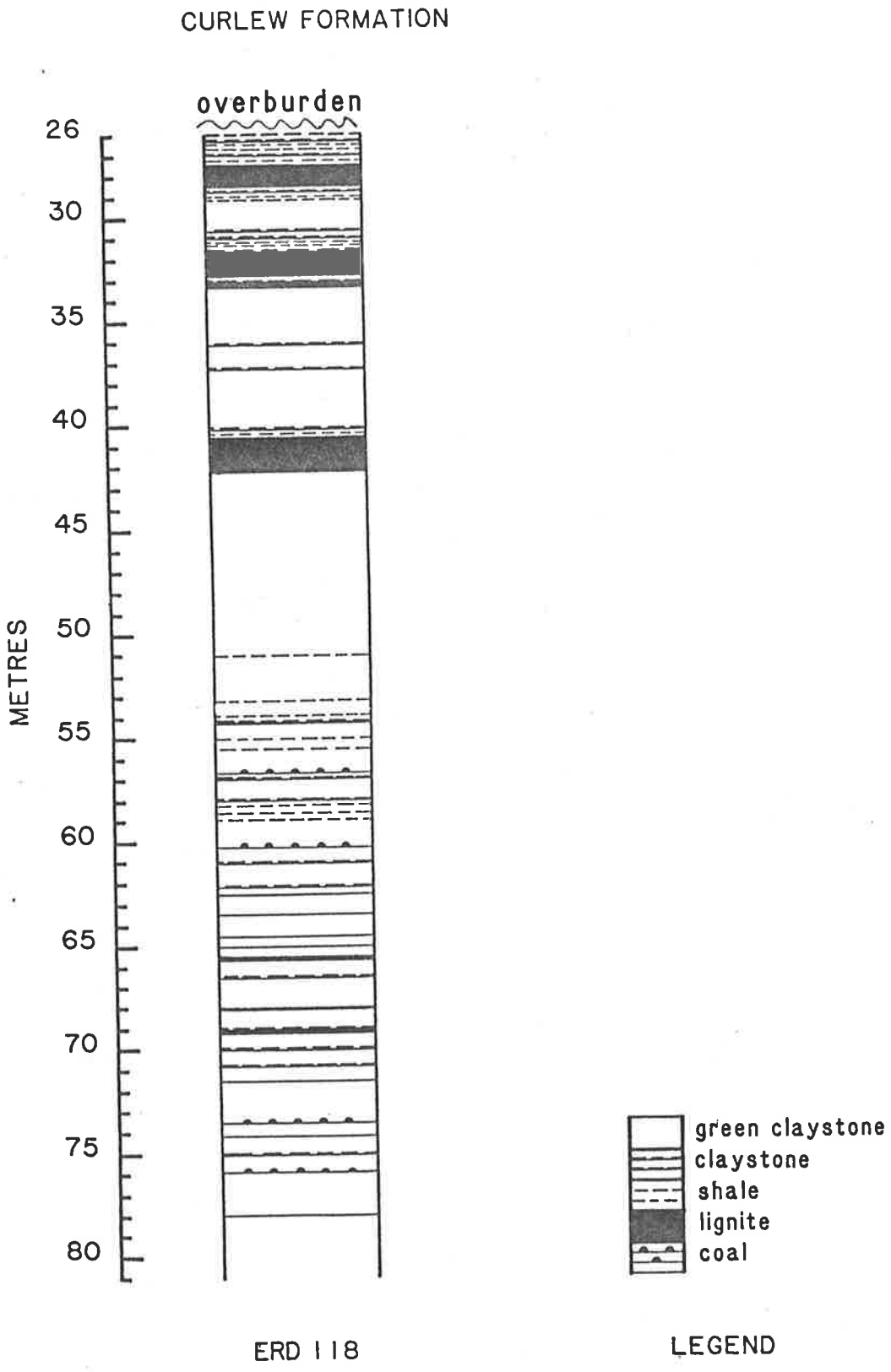


Figure 4: Revised Stratigraphic Column of the Curlew Formation, from the examination of sediments in the reference core ERD 118.

1.3 Age Determination

Initial investigations carried out by Beasley (1945) on Tertiary ostracods of Queensland recorded an age for the Narrows area as Miocene or Neogene. During the last decade however, as work in the area has become more intensive and specific to the Rundle deposit the age span has been progressively reduced. The palynoflora of the Narrows area was briefly investigated by Paten (1967) and Hekel (1972), both examined fossils extracted from isolated core samples collected throughout the region. Hekel (1972), in particular concentrated on obtaining a broad overview of the palynology as he was primarily concerned with producing a generalized biostratigraphic correlation for the Queensland Tertiary. He considered the age of Narrows sediments to be in the vicinity of Palaeocene to Middle Oligocene, this date being based on the occurence of a number of typical Lower Tertiary palynomorphs, that is, Cupanieidites orthoteichus, Malvacipollis diversus, Myrtaceidites eugeniioides, Nothofagidites mataurensis and Triorites orbiculatus.

In 1979, Foster examined specifically Rundle core material and noted that only the upper sediments (the Wattle Creek Seam i.e. the Curlew Formation) had a well represented palynoflora. The same distribution is also evident for the plant megafossils in the deposit. On the basis of the absence of Malvacearumpollis estelae and the presence of Anacolosidites sectus, which Stover and Partridge (1973) noted was confined to Late Eocene assemblages in southeastern Australia, he considered the deposit to be Late Eocene to Late Oligocene in age. The most recent age determination (Foster and Harris, 1981) based on a comparative study of time ranges of southeastern

Australian species and the age of Azolla capricornica Foster and Harris, is Middle to Late Eocene.

Using the ranges of spores and pollen, Stover and Partridge (1973) recognised ten biostratigraphic zones in the Gippsland Basin, Victoria, which range from the Late Cretaceous through to the Miocene. Four zones span the Eocene, i.e. The Malvacipollis diversus Zone (Early Eocene), Proteacidites asperopolus Zone (Early Eocene), Lower Nothofagidites asperus Zone (Middle to Late Eocene) and Upper Nothofagidites asperus Zone (Late Eocene to Early Oligocene) (see Figure 5).

The Lower Nothofagidites asperus Zone is defined by the appearance of 15 species (see Table 1), of which seven are restricted to this zone. Two of these species, Tricolpites simatus and T. thomasii, are present in the Curlew Formation. An additional 13 species are listed as first appearing within this zone (i.e. column A, Table 1) of which 2 species occur in the Curlew Formation, i.e. Tricolporites sphaerica and Anacolosidites sectus. A further 13 species terminate within this zone (i.e. column B, Table 1) and 4 of these are found in the Curlew sediments, i.e. Liliacidites bainii, Proteacidites kopiensis, P. pachypolus and P. tenuiexinus.

Foster (1982), in dating the Yaamba Basin deposit as Middle to Late Eocene, considered another six species as important indicators of this period. Three of these species also occur in the Curlew Formation: Banksieaeidites arcuatus, Helciporites astrus and Santalumidites cainozoicus. Therefore, based on the comparative ranges of pollen and spores from southern Australian deposits, the Yaamba Basin deposit and the identification of Azolla capricornica, the age of the Curlew

Formation could be considered Middle to Late Eocene.

The present study represents the only other major palaeobotanical work on the Curlew Formation.

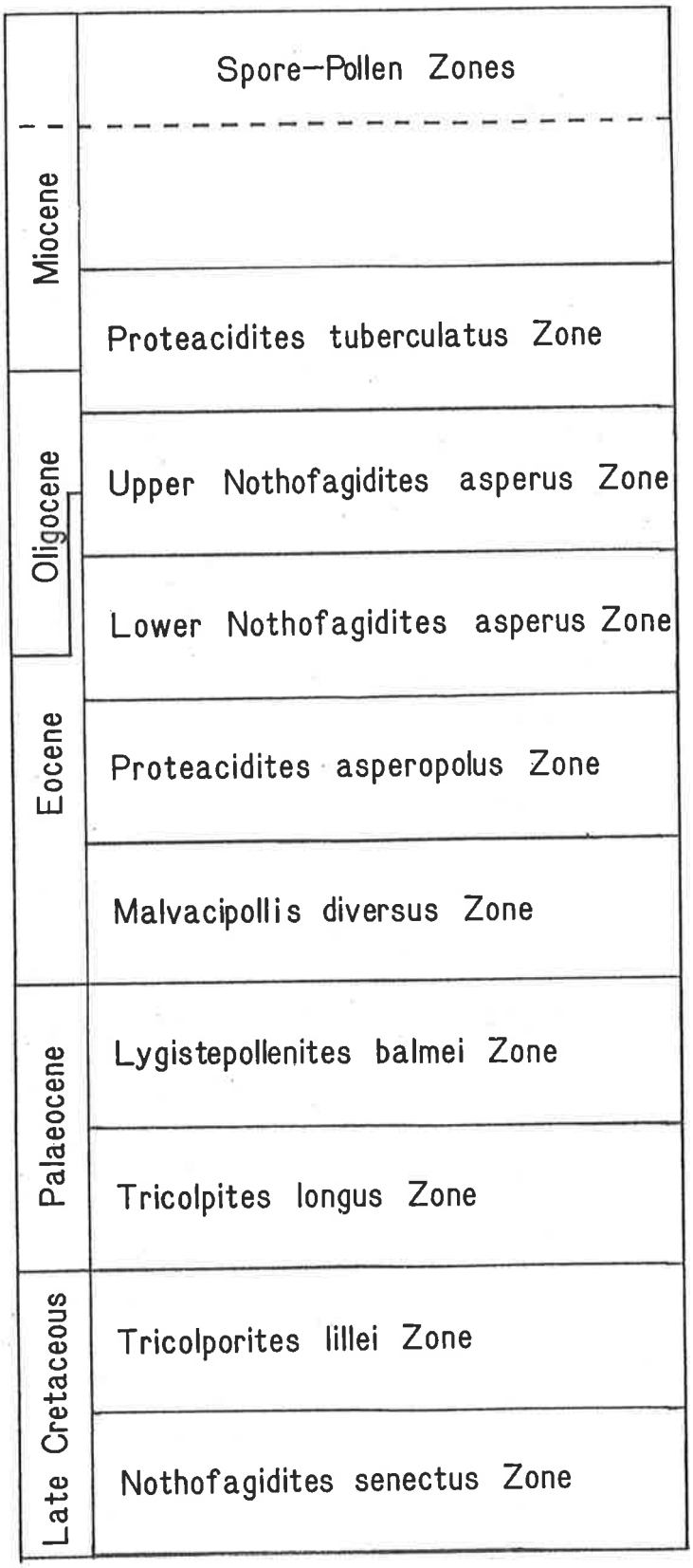


Figure 5: Stover and Partridge's (1973) spore-pollen zones of the Gippsland Basin, Victoria.

Table 1: Shows the pollen types associated with the Lower *Nothofagidites asperus* Zone (Stover and Partridge, 1973). The first column contains those species which define the base of the zone, those marked with an asterisk (*) are diagnostic of the zone. Column A contains those species that appear within the zone. Column B contains those which terminate within the zone.

POLLEN TYPES ASSOCIATED WITH THE LOWER NOTHOFAGIDITES ASPERUS ZONE

of SOUTHERN AUSTRALIA	CURLEW FORMATION	YAAMBA BASIN
✶ *Anisotricolporites triplaxis*		
Foveotriletes balteus		
✶ *Gemmatricolporites gestus*		
Gothanipollis bassensis		
Nothofagidites asperus		
Nothofagidites falcatus		
Nothofagidites vansteenisii		
Periporopollenites vesicus		
✶ *Proteacidites recavus*		
✶ *Proteacidites reflexus*		
Rugulatisporites trophus		
✶ *Tricolpites simatus*	▲	▲
✶ *Tricolpites thomasii*	▲	▲
✶ *Tricolporites angurium*		
Tricolporites leuros		
COLUMN A		
Aglaoreidia qualumis		
Anacolosidites sectus	▲	▲
Cephyrapollenites calathus		
Paripollis ochesis		
Polycolpites reticulatus		
Proteacidites stipplatus		
Tricolporites sphaerica	▲	▲
Triorites magnificus		
Foveotriletes palaequetrus		
Proteacidites rectomarginis		
Tricolporites retequetrus		
Triporopollenites chnosus		
Verrucosisporites cristatus		
COLUMN B		
Anacolosidites acutullus		
Anacolosidites luteoides		
Dryptopollenites semilunatus		
Liliacidites bainii	▲	
Proteacidites alveolatus		
Proteacidites asperopolus		
Proteacidites incurvatus		
Proteacidites kopiensis	▲	▲
Proteacidites pachypolus	▲	▲
Proteacidites tenuiexinus	▲	
Schizocolpus marlinensis		
Spinizonocolpites prominatus		
Tricolpites incisus		

Diagnostic species ✶

CHAPTER 2

AIMS AND TECHNIQUES USED

2.1 Aims of the study

Initial drilling and core sampling at Rundle has shown the presence of over 500 meters of continuous sediments. Many of these are carbonaceous (including lignites, carbonaceous claystones and shales) and preliminary sub-sampling of Esso cores indicated that they are rich in plant macrofossils. The stratagem initially proposed was to document and analyse these plant fossils, but this was later amended to include an investigation of the microfossils as well.

The major aims of the study (incorporating palynological studies) are as follows:

1) Biostratigraphy - Work with carbonaceous sediments in the Latrobe Valley, Victoria has shown strong correlation between lithotypes and plant assemblages contained within them (Luly et al., 1980). It is therefore planned to catalogue the plant assemblages of carbonaceous sediments from drill sites at Rundle and to establish a biostratigraphic correlation for this locality. If successful this could be used in correlations throughout the Narrows Graben, with possible extensions in the areas of exploration of other basins and possible dating of these sediments.

2) Palaeoenvironmental Studies - Analysis of the fossil assemblages contained within a specific stratigraphic unit, with emphasis on foliar physiognomy and gross commmunity structure will assist in the development of a picture of the environment. When

extended through the sedimentary column this will allow inferences to be made as to the nature of the vegetation and the depositional environment both at the time of oilshale deposition and in episodes between. A similar assessment of the associated palynology of the unit allows these inferences about the vegetation and environment to be expanded.

3) Fossil Identification - Specific identification of the mega- and microfossils and/or comparison with their most similar counterparts can provide a picture of the actual communities at Rundle during the Tertiary.

The major lignitic sequence found within the Curlew Formation became the starting point for the study (See Figure 4). This was primarily because both HQ (7.5cm) and 15cm core samples of these sediments were available for examination and as they occurred near the top of the Rundle sedimentary column, they would ultimately be the first exposed for mass sampling when open cut mining began. However, this open cut mining did not eventuate, as by the end of 1981 the Rundle project had almost ceased completely. This did not halt the study as sufficient core material of the Curlew formation had already been collected and was adequate for the task in hand.

2.2 Collections

A single trip to the Rundle site in February/March 1981 enabled collection of sufficient material for the complete analysis of the megafossil and microfossil flora of the Curlew Formation. Core material, both 7.5cm (3") and 15cm (6"), from the majority of drillholes was made accessible by ESSO Australia Ltd.. Seven of these, (i.e. ERD 110, 111, 112, 116, 117, 118, 139), containing a high proportion of carbonaceous sediments within the Curlew Formation, were selected for examination. A quarter core sample was collected from the cores listed above. Entire 15cm core samples were available. In late March 1983, additional quarter core material, required for the examination of a well defined lignitic band in the Humpy Creek Seam (Rundle Formation) was collected by Mr.L. Coshell (Esso geologist) from three additional drill holes ERD 159, 180, 297. A comparative investigation of the fossil flora of a similar lithotype, which appears to have been formed under identical circumstances but in a different formation, was envisaged.

During the collection of Curlew samples megafossil leaf remains were continually observed. These were highly carbonized in the coaly lithotypes and more fragmentary, though better preserved in the carbonaceous claystones.

2.3 Fossil Preservation

The carbonaceous lithotypes were sampled at 0.1 metre intervals, where possible, resulting in some 230 samples being collected. The samples were labelled according to the core number and depth at which they were recovered (e.g. ERD 118, 26.0m). Future reference to core samples in this study is by the recorded depth, i.e. sample 26.0m. Each sample was placed in a heavy duty resealable plastic bag, labelled and then placed into boxes for transport to Adelaide. Packaging of material greatly reduced dessication and contamination during transit from the mining site to storage in the laboratory. On arrival, each sample was described, lithology and fossil content in particular being noted.

Preservation of fossil material varied considerably, the majority of megafossils being highly carbonized, fragmentary leaf remains. No intact fossils other than the occasional seed or fruiting structure were recovered. The 15cm cores which were expected to reveal intact fossils (if available) were, however, more often than not barren. Therefore most research was carried out on 7.5cm material which by its size virtually assured only fragmentary megafossils.

Lithotype formation as well as plant type also influenced the degree of fossil preservation. The fine grained, though irregularly bedded claystones and mudstones generally presented good sized (> 0.5cm^2) compressions. Fragments were easily recognised and recovered from the maceration of these sediments and tended to be of sclerophyllous angiosperms. Lignites on the other hand contained monocotyledonous plant remains, very small in size, poorly preserved and highly carbonised. On maceration the material became very fragile

and hard to handle. These very thin cuticles are characteristic of hydrophytes and other aquatic monocots. The coaly lithotypes contained particularly brittle material which after maceration yielded only very small fragments. On occasion even the fruit-like bodies which were obvious as compressions were not recovered after maceration.

The most impressive megafossil found to date is a catkin-like structure recovered from the oilshales of the Kerosene Creek Seam in the Rundle Formation.

2.4 Extraction and Preparation of Fossils

In the laboratory, samples from ERD 118 were divided equally into two fractions for separate mega-and microfossil analysis. All other samples collected from cores ERD 110, 111, 112 and 117 were prepared solely for megafossil analysis. For the extraction of megafossils the sample was first split (if possible) and the state of preservation determined. If the fossils were found to be excessively fragmented, making it impossible to distinguish macroscopic leaf features, the sample was crushed into 0.5cm^3 pieces. This proved to be the case in nearly all instances. The crushed material was then macerated in approximately 200mls. of a dilute hydrogen peroxide solution with a small quantity of the dispersant, tetrasodium pyrophosphate added. The solution contained 100mls of industrial grade 50% w/w hydrogen peroxide (aqueous) and 100mls of distilled water, plus the dispersant.

The maceration solution, in a 500ml pyrex glass beaker, was heated on a hot plate at 100°C and maintained at that temperature until foaming began. Reaction rate increased rapidly as the reaction became more exothermic causing foaming to likewise increase rapidly. It is the vigorous effervescence that breaks down the matrix, releases the cuticles and carries them, in the foam, to the surface. At this point the beaker was removed from the heat and allowed to cool slowly in a waterbath. Once foaming had ceased, the foam was collected, washed and passed through a series of 300μ and 125μ sieves. This procedure was repeated until all the remaining matrix was completely broken down and the resultant foam passed through the sieves. This separation into coarse and fine sievings allowed the examination of the material which

would normally be obscured or lost if only a single sieving occurred.

This technique of examination was employed for a considerable period initially until it became apparent that many samples did not contain a large amount of fossiliferous material and that the collection could be made from a single 125µ sieving. Both coarse and fine material were easily distinguished, therefore dispelling earlier fears of losing information by having too much material available at any one instance.

The sieving (a combination of both coarse and fine material) was then transferred to a plastic petri dish (9cm diameter) and examined under a Leitz stereomicroscope. Cuticular fragments were selected from all over the dish. A representative sample was in this way collected, generally amounting to over 200 individual fragments per sample. The cuticles were then transferred to glass slides, stained with crystal violet teased apart to reveal both cuticular surfaces when necessary and mounted in phenol glycerine jelly. Nail polish was used to seal all slides. Each slide was then viewed under a Zeiss Triocular microscope which was fitted with an Olympus C-35A, PM-10A automatic camera system. Each new cuticle type was photographed.

The remainder of each ERD 118 core sample was prepared for microfossil extraction. The techniques used to extract palynomorphs from the matrix depended on the nature of the lithotype. Those with a high oilshale content were particularly difficult to breakdown. The sample was initially dehydrated with glacial acetic acid for 12 hours before being subjected to acetolysis for twenty minutes.

This particular procedure for acetolysis devised by Foster (1979), differs from the standard Erdtman's (1960) technique in that only a 8:1 ratio of acetic anhydride : conc. sulphuric acid was used. Washing in 5% potassium hydroxide solution was then followed by repeated washing in distilled water. If further oxidation was required the macerate was treated with warm concentrated nitric acid followed by washing in a 1-2% potassium hydroxide solution. Schulze solution was used in the extraction of pollen from the carbonaceous sediments and proved most satisfactory. The solution contains equal parts of concentrated nitric acid and hydrochloric acid and a small amount of potassium chlorate ($K Cl O_3$). Excessive potassium chlorate, i.e. greater than a rice grain, produces a highly explosive reaction.

The crushed sample was placed in a clean 400ml beaker which had been rinsed thoroughly with distilled water prior to the addition of the sample and schulze solution. The beaker was immediately covered with a petri-dish to prevent the introduction of airborne contaminants. The maceral was left for 12 hours, allowing for complete oxidation of the matrix. Washing with distilled water and centrifuging followed. This procedure was repeated several times until all the oxidizing solution had been removed from the matrix. After further rinsing, the sample was covered with a 2% solution of potassium hydroxide and centrifuged for no more than 5 minutes. Any longer severely damages the pollen exines. The solution was decanted off and the residue again washed.

To separate the organics from the inorganics in the residue a commercially produced zinc bromide with a specific gravity of 2.1 was used. The liquid was added to the particulate, the tube shaken to

disperse the sample and allow homogeneous mixing to occur. The lighter organic material forms a band on the top of the liquid after centrifuging and it is in this layer that the pollen is accumulated. The layer was removed and transferred to a clean tube where it was treated with 10% hydrochloric acid to remove all zinc salts and rinsed several times with distlled water. The transferals were carried out using sterile disposable pipettes.

With the removal of all extraneous material and organics the remainder of the sample appears clear or golden in colour. A drop of this material is then placed on a previously cleaned slide and fixed with glycerine jelly. A clean cover slip was then placed over the jelly, before airborne contaminants could settle, and allowed to harden. This usually took between 5 and 10 minutes. The slide was then made permanent by ringing the coverslip with nailpolish. A Reichert Univar Research microscope with interference contrast optics and automatic 35mm camera system was used to examine slides and photograph palynomorphs (see Figure 6).

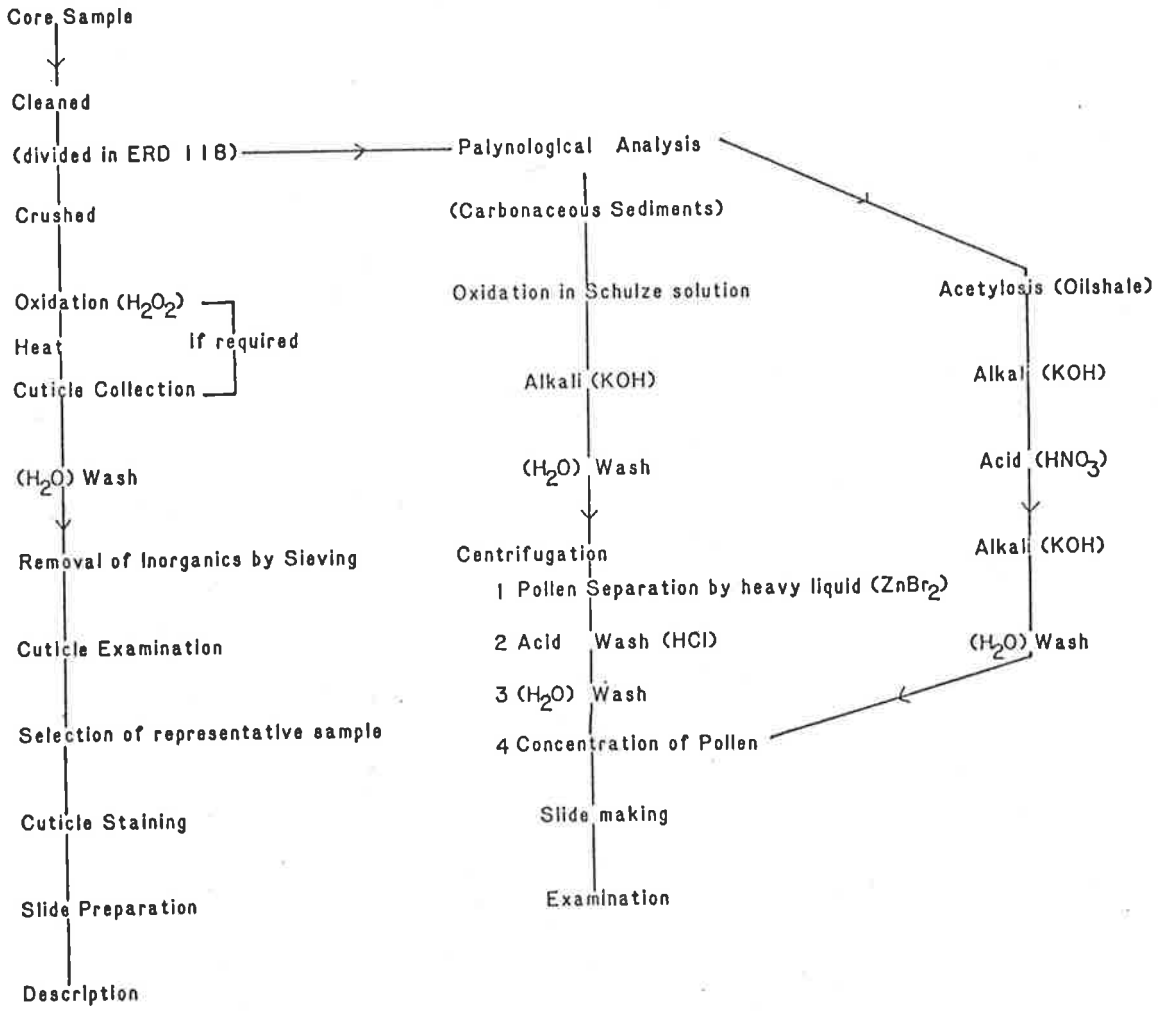


Figure 6:Flow diagram showing techniques used in the Extraction and Preparation of Megafossils and Microfossils from the Curlew Formation core material.

2.5 Photography

Macroscopic structures were photographed using a Wild dryplate camera system loaded with Ilford FP4 film. Cuticle fragments and smaller capsular structures were photographed initially using a Zeiss triocular microscope with an automatic Olympus C-35A, PM-10A 35mm camera system and for final plates a Reichert Univar Research microscope with an automatic 35mm camera system, both systems using Ilford FP-4 film. Palynomorphs were photographed using the latter system but with high contrast Ilford Pan F film.

CHAPTER 3

PALYNOLOGICAL EXAMINATIONS

3.1 Introduction

3.1.1 Yields

Palynomorphs do not occur continuously throughout the Rundle stratigraphic column (as stated previously, the standard column is in fact a composite from cores RDD 66 and GSQ 2, see Figure 3). They are confined to the carbonaceous strata of the Curlew Formation. However, a narrow carbonaceous band, the Humpy Creek seam, in the Rundle Formation contains a small assemblage which is very similar in composition to that of the Curlew Formation. This assemblage contains a large angiosperm component which is well represented in all core samples and an equally ubiquitous fern component. Fungal spores are present throughout the sequence but rarely do they occur in significant proportions. Monocotyledons and conifers are rarely represented.

Oilshale dominates the entire Rundle lithology (Figure 3). The lithotype persists through all units, either as very thick continuous strata or small interspersed discontinuous bands. Only in the latter sequences where oilshales are in a minority do other fossil bearing sediments occur. The Curlew Formation surprisingly contains only a small proportion of oilshale, the bulk of the sediments are carbonaceous claystones, mudstones and shales which all contain at least some foliar fragments and microfloral remains.

The maceration techniques used for these sediments varied considerably (see Section 2.4). The carbonaceous lithotypes were easliy broken down to release pollen but the oilshales proved more difficult. The few pollen grains recovered from the oilshales were so poorly preserved that identifications were not possible.

Well preserved palynomorphs are more likely to be found in sediments deposited under conditions of low pH and negative Eh, i.e. in a reducing acidic environment (Tschudy and Scott, 1969). Such conditions are commonly developed in bogs, bottoms of lakes and the depths of closed basins. It is generally accepted (Beasley, 1945; Swarbrick, 1973; Lindner and Dixon, 1976; Foster and Harris, 1981; Henstridge and Missen, 1981) that deposition of sediments in the Narrows Graben was in a lacustrine environment. This would tend to suggest the existence of a large, well preserved palynoflora at Rundle. Hence, the scarcity of pollen in the oilshales (Foster, 1979) is perplexing. Possible explanations for this scarcity are:

1) The presence of Ostracods; Ostracods are generalized bottom dwelling detrital feeders (Beasley, 1945) so the accumulation of pollen in the bottom sediments of the lake would be a potential food source. Freshwater copepods (i.e. Heterocope saliens), a group of animals related, but living solely in the water column, have been known to eat pollen and algae when zooplankton was not available (Monakov, 1968 ; cited in LeCren and Lowe-McConnell p.248, 1980). The high algal content of the lake would have been able to maintain a large ostracod population in the absence of zooplankton.

2) An unfavourable environment; The organic matter of the oilshale of the Rundle Deposit is chiefly composed of alginite B (lamellar alginite) with minor Botryoccocus sourced alginite A and particulate corpohuminite (Hutton et al., 1980). The parent algae (Cyanophyceae or Chlorophyceae) responsible for alginite B were probably mat forming, benthonic forms that bloomed in relatively shallow warm lakes. The accumulation of these microorganisms produced

incoherent organic oozes that were deposited under anaerobic conditions (Hutton et al., 1980). Suitable conditions were therefore available for the preservation of higher plant remains. The low concentration of organic matter derived from higher plants (Cutinite and Corpohuminite) in the Rundle oilshales (Hutton et al., 1980) would tend to indicate higher plants, and hence pollen, were scarce in the area where these lithotypes were formed. Therefore the scarcity of pollen from the oilshales is probably the result of few source plants, not an unfavourable depositional environment.

3.1.2 Palynological Categorisation

The palynomorphs have been placed into eight categories. These categories represent the major families and plant groups commonly occurring throughout the Australian Tertiary.

They are: (1) Myrtaceae
(2) Proteaceae
(3) Fagaceae
(4) Casuarinaceae
(5) Angiospermae (excluding Categories 1-4)
(6) Gymnospermae
(7) Pteridophyta
(8) Monocotyledonae

It should be noted that this categorisation is quite different to a classical palynological classification scheme in that it has been developed to examine the overall floristic trends within the Curlew Formation, i.e. the Angiospermae, Gymnospermae, Pteridophyta and Monocotyledonae categories, with particular interest to those families which have contributed to the evolution of the modern, characteristically Australian flora, i.e. Myrtaceae, Proteaceae, Fagaceae and Casuarinaceae. Identification of pollen and spores to species level is of lesser importance in this study but where modern affinities are suggested comments may be made concerning the past environment associated with the Curlew Formation. All identified palynomorphs (See Appendix 1) are figured (Plates 1 - 6), and where possible modern affinities are also listed (Table 3). Pollen and spore frequencies (200 grains counted) for ERD 118 are listed in Table 2 and represented in a pollen diagram in Figure 8.

3.2 The Myrtaceae Component

Cookson and Pike (1954) recognised the difficulty in assigning fossil pollen grains to either the family Myrtaceae or to the individual genera and so constructed a form genus Myrtaceidites for Australian Cainozoic types with strong myrtaceous affinities. Martin (1981), likewise maintained that the morphological homogeneity of myrtaceous pollen is such that fossil pollen resembling Eucalyptus may also be assignable to other genera, for example, Angophora, Syncarpia and possibly Metrosideros. The grains are recognised as small to medium, triangular to subtriangular in polar view with straight to slightly concave, or slightly convex sides; angulaperturate; tricolporate; oblate to subspheroidal; arci distinct, enclosing or not enclosing polar islands. The exine is smooth, granular or finely and distinctly patterned, but never clearly reticulate (Cookson and Pike, 1954).

These workers were able to distinguish myrtaceous fossil pollen that displayed features characteristic of extant Eucalyptus pollen and therefore proposed the species Myrtaceidites eucalyptoides for these palynomorphs. Other species are not as well defined and may have numerous modern affinities, for example, Myrtaceidites parvus and M.mesonesus. Grains of the former species have been compared to Metrosideros while the latter species contains specimens which display similarity to certain eucalypts, for example, Eucalyptus tessellaris (Cookson and Pike, 1954) as well as those that are like Metrosideros.

Myrtaceidites mesonesus (Plate 5, Figures 40,41), first reported in the Curlew Formation by Foster (1979) was particularly common

throughout the sequence and represented the principle pollen type of the Myrtaceae component, M.parvus was also common. Clumps of M.mesonesus were observed, which would tend to suggest either a local deposition of the anthers or anther transportation over small distances. Clumping of pollen was not recorded for the other pollen types. However, Luly et al. (1980) showed that myrtaceous trees tended to have extra-local or regional pollen dispersal which suggests these plants were either canopy or understorey taxa growing within the swamp basin some distance away from the sample site or top layer canopy taxa growing on dry land well away from the sample site. It would appear that the source trees responsible for the production of M. mesonesus probably grew nearer to the depositional site than other related species.

The absence of Eocene myrtaceous megafossil remains, not only in the Curlew Formation but generally throughout Australia (Anglesea, Victoria being an exception, Christophel and Lys, , 1986), tends to imply a regional pollen dispersal, but a limited foliar dispersal capability could explain the scarcity of these fossils. Hill and Gibson (pers. comm., 1985) consider a limited dispersal capability to be the situation at Lady Lake, Tasmania, where the dominant canopy species Eucalyptus coccifera is under-represented in the lake litter. They suggested this under-representation is due to myrtaceous leaves having a very poor ability to float. In view of this information and the palynological evidence, extra-local/local dispersal appears more appropriate. The other myrtaceous pollen types were more likely to have come from source plants located outside the depositional basin.

The Myrtaceae component comprises an additional eight species (Plate 5, Figures 35-48). These include Myrtaceidites parvus (Cookson and Pike, 1954), a broadly defined species for grains which are syncolpate and lack a polar island; Myrtaceidites verrucosus (Stover and Partridge, 1973), which differs from the other species of Myrtaceidites by having a distinctively sculptured exine; Myrtaceidites sp. cf. M. eucalyptoides; Myrtaceidites sp. cf. M. eugeniioides; Myrtaceidites sp. cf. M. rhamnoides, and three unknown types.

Myrtaceidites pollen is found in 84% of core samples analysed, and is therefore an important component of the palynoflora of the Curlew Formation. Pollen frequency varies considerably down through the sequence, from 26.0m to 78.0m (Table 2 and Figure 8). The vertical distribution of myrtaceous pollen shows a concentration in the upper sediments where the component generally represents more than 20% of the palynoflora of each sample. Two distinct 'peaks' were observed in this section of the Formation; the first, within a metre of the top of the Formation at a depth of 26.7m and the other, slightly deeper, at 31.0m. The frequencies recorded at these 'peaks' were 60.0% and 72.0% (i.e. of palynoflora for each sample) respectively.

A reduction in the abundance of Myrtaceidites was recorded from 32.0m to 42.0m. During this interval the pteridophyte component dominated, with the exception of a few samples which contained no pollen or spores. Minor occurences of myrtaceous pollen were recorded. Following this pteridophyte zone was an extensive band (11 metres) of barren sediment, mainly green claystone. A re-appearance of myrtaceous pollen at 53.3m indicated the end of the barren lithotypes but the percentages were not as high as those recorded in the upper part of the

Formation. Two lesser 'peaks' were recorded at 53.3m and 58.0m with frequencies of 37% and 45% respectively. From 61.0m to the base of the Formation the Myrtaceae component of each sample was generally found to be < 10% . A final myrtaceous rich sample (44.5%) was recorded at 69.8m (Figure 11). The Myrtaceae component represents 15.3% of the total Curlew Formation microfloral assemblage (palynoflora).

3.3 The Proteaceae Component

Most Proteaceae form genera are distinctive, and their extant affinities recognisable, with the possible exception being the form-genus Proteacidites. This genus was defined by Cookson (1950) and later validated by Couper (1953) who saw Proteacidites as a "catchall for pollen of proteaceous affinities which cannot be more accurately placed". In a reappraisal of Proteacidites and Beaupreaidites, Martin, A. (1973) discussed the propriety of accepting the occurrence of Proteacidites and other proteaceous palynomorph genera as evidence of the family Proteaceae and concluded that identity with the family could not be taken for granted. In a later publication, Martin and Harris (1974) subdivided Proteacidites on the basis of apertural morphology, proposing two genera Propylipollis and Cranwellipollis, as well as redefining Proteacidites. They also noted that although many of the described palynomorphs included in the three genera are definitely proteaceous, the natural affinity of many other dispersed pollen of this type still remains in doubt.

Banksieaeidites Cookson ex. Couper (1953) is easily distinguished from other proteaceous genera by having subpolar, bilateral, biaperturate pollen grains with an sexine thickened around the pores (Cookson, 1950). Extant relatives are found in the Banksieae, which includes the genera Banksia and Dryandra of the subtribe Banksiinae (both have morphologically identical pollen. Cookson, 1950; Martin, H. 1973) and Austromuellera and Musgravea of the subtribe Musgraveinae. Banksieaeidites arcuatus Stover (Stover and Partridge,1973) has been shown to display a number of features identical to those of

Austromuellera trinerva and Musgravea stenostachya (Memon, 1976). The finding of Banksieaeidites arcuatus (Plate 5, Figure 52) in the fossil flower Musgraveinanthus alcoensis (Christophel, 1984) is further supporting evidence for the affinity between the fossil pollen and the Musgraveinae.

The reappraisal of Beaupreaidites Cookson ex. Couper (1953) by Martin, A. (1973) resulted in the removal of a number of incorrectly identified palynomorphs, but more importantly, confirmed the affinity of Beaupreaidites elegansiformis (Plate 5, Figure 51) to the extant genus Beauprea. Beaupeaidites is characterised by straight sides, colpoid apertures, tapering exine and finely reticulate sexine (Cookson, 1950).

The re-examination of previously defined Proteacidites species (Cookson, 1950; Couper, 1960; Harris, 1965, 1972; Stover and Partridge, 1973) carried out by Martin and Harris (1974) was responsible for the establishing of Propylipollis and Cranwellipollis has already been mentioned, but definite affinities between the fossil genera and extant taxa has not been discussed in any detail. Propylipollis consists of some 15 previously recognised Proteacidites species, a number of which are considered to have affinities to the tribes Macadamieae, Embothrieae, Grevilleeae and Oriteeae. However a small group of palynomorphs tentatively assigned to the genus have features more characteristic of genera of the Icacinaceae and Sapindaceae (Martin and Harris, 1974).

Proteacidites Cookson ex. Couper (1953) emend. Martin and Harris (1974) has been greatly reduced from its previous size through the

recent work of these researchers. Some of these pollen types compare favourably with taxa of the Proteaceae, especially the tribes Proteeae and Persoonieae of the subfamily Proteoideae but it remains doubtful that all species are in fact true Proteaceae (Martin and Harris, 1974).

Northern Hemisphere forms of Beaupreaidites and Proteacidites have been reported from sediments of Senonian and Maestrichian age (Samoilovich, 1967; Srivastava, 1969), some have been transferred to two new genera Montanapollis and Siberiapollis (Tschudy, 1971) but are considered to be non-proteaceous (Memon,1976).

The bulk of fossil pollen (14 taxa) recovered from the Curlew sediments have simply been assigned to Proteacidites, (Plate 6, Figures 1-4,8,9,12-19) but two specific identifications have been made, i.e. Proteacidites kopiensis (Plate 6, Figures 5,6) and P. pachypolus (Plate 6, Figure 7). The only other proteaceous species positively identified are Banksieaeidites arcuatus, Beaupreaidites elegantiformis and Propylipollis latrobensis (Plate 6, Figures 10,11). The majority of palynomorphs have been compared to recognised fossil species (See Appendix 1) following a review of numerous comparative studies of extant and fossil pollen types which included Cookson (1950), Cookson and Pike (1954), Martin,A. (1973+81), Martin,H. (1973), Martin and Harris (1974), Memon (1976) and Syber (1983).

Hekel, in 1972, remarked that "Proteacidites seems to be quantitatively much less important in the Queensland Tertiary than at the same time in southern Australia". Throughout the Curlew Formation the quantity of proteaceous pollen is low. Proteacidites, which is the most common genus, does not even represent 1.0% of the total

palynoflora (Table 2, Figure 8). Banksieaeidites and Beaupreaidites palynomorphs are even more uncommon. Similarly, in the Yaamba Basin (Foster, 1982), which is of the same age as this deposit, the proteaceous component represents only 2.4% of the total palynoflora. These values are substantially less than that recorded for the south eastern Anglesea deposit (Syber, 1983)* which had a Proteacidites frequency of 11%.

The Middle to Late Eocene has been identified by Martin (1982) as a period of decline for the Proteaceae with many taxa becoming extinct. This trend does not appear to be as obvious in Queensland where, as Hekel (1972) noted, taxa were typically scarce during the entire Tertiary . The southern Australian deposits which range from Early Middle Eocene (Kingston, south-eastern South Australia (Wood, 1981) and Nerriga, southern New South Wales (Owen, 1975)) to Late Middle Eocene (Anglesea, Victoria (Syber, 1983)) all have a greater number of proteaceous species and represent a greater percentage of the total palynoflora. A decrease in diversity has been reported by Syber (1983) for the proteaceous component of Anglesea but without a decrease in quantity.

A Tertiary climatic gradient (Hekel, 1972; Martin, 1982) parallel to that which exists today in eastern Australia may explain this variation between the northern (Queensland) and southern (Victoria) Tertiary deposits. From a value of <1% for the total palynoflora of the Curlew Formation, the proteaceous component increases to 7% for the Hay deposit (Murray Basin) in central New South Wales (Martin, 1982) and reaches 11% at Anglesea (Syber, 1983), 23% at Nerriga (Owen, 1975) and 25% at Kingston (Wood, 1981). The particularly high proteaceous percentage in the

* NOTE: This unpublished work is now in press and should in future be referred to under - Christophel, D.C., W.K. Harris and A.K. Syber (1987). The Eocene flora of the Anglesea locality, Victoria. Alcheringa (10).

Nerriga deposit, which is located in south-eastern New South Wales, would suggest that local climatic influences probably disrupted the overall climatic gradient. Martin, H. (1982) has implied the existence of an east-west gradient of rainforest in the Mid-Tertiary which, if it had existed earlier may also account for this difference.

The major concentration of proteaceous pollen occurs in the youngest Curlew sediments, from the top of the Formation (i.e. 26.0m) to a depth of 26.7m. On one occasion during this short interval a frequency of 9.5% (ie, % of the palynoflora for that specific sample: Table 2) was recorded.

Luly et al. (1980) considered pollen production of the Proteaceae to be either under or equally represented, which implies that the parent plants occur in the vicinity of the sample site. They also considered that a local or extra-local dispersal behaviour characterises the family and indicates the parent plants are either prostrate scramblers growing very close to the ground and dropping their pollen or having it dispersed by animals; or they are animal/wind pollinated canopy or understorey taxa.

Based on these considerations the plants responsible for the Curlew proteaceous component were probably scarce, located in the vicinity of the Narrows Graben with a tall canopy tree habit. As tall canopy trees the pollen production when compared to that of a sclerophyllous shrub layer would be expected to be much greater (Birks and Birks, 1980). However, some Proteaceae trees are found in Queensland rainforests today that produce only small quantities of pollen (Kershaw, 1970b), therefore it is possible that some source taxa may have been common in the canopy layer.

3.4 The Fagaceae Component

Nothofagidites Potonie (1960), which is referable to the extant genus Nothofagus Blume (1851), is the single representative of this component. All fossil palynomorphs of this type are assignable to this genus. Three distinct morphological pollen groups are recognised amongst living species of Nothofagus, i.e. fusca, brassii and menziesii.

The brassii type (Cookson, 1952; Erdtman, 1954) is small to medium in size, usually having an angular amb and firm exine of uniform thickness. The menziesii type (Cranwell, 1939; Cookson, 1946; Couper, 1953; Cookson and Pike, 1955; Cookson, 1959) is characterised by its large size (equatorial diameter 40-60um, Cookson and Pike, 1955), extremely thin exine, and inconspicuous pores or fissure points around the equator which, when the grains are ruptured, appear as large unrimmed furrows of varying lengths. The fusca type (Cranwell, 1939; Cookson, 1947; Couper, 1953; Cookson and Pike, 1955; Cookson, 1959) is characterised by medium size, convex polar surfaces, i.e. biconvexity (Cookson, 1959) and firm exine which is distinctly thickened around the pores. The apertures, although ± colpoid, are referred to as pores because of their rounded ends (Faegri and Iverson, 1950).

All three types occurred in the Australian Tertiary, with the brassii type the most common. Eocene deposits of south-eastern Australia have a greater abundance of Nothofagidites pollen than those of Queensland. The Fagaceae component (as a percentage of the pollen flora of each sample) for the south-eastern deposits, range from <1% to 46% (see Appendix 3), whereas the Queensland deposits, including Yaamba (Foster, 1982) and Rundle (Curlew Formation) have percentages ranging

from <1% to 6%. Curlew percentages occur at the lower end of the range, i.e. <1% to 4%, indicating that in this sequence Nothofagidites palynomorphs are particularly scarce. Although the abundance varied considerably between the two regions, the overall compositional trends were identical, with the brassii type also dominating the northern deposits.

Nothofagidites is evenly distributed down through the Curlew Formation, but populations are usually very small, in some samples the component is represented by a single palynomorph (Table 2, Figure 8). A slight increase is recorded in the older sediments from 63m to 65m and again from 68m to the base of the Formation. In this lower section values of 3% (per sample) are not uncommon. The maximum value obtained for the Fagaceae component in any one sample was 5% which occurred at a depth of 71.4m. This component is considered to be of minor importance in the Curlew Formation as it represents only 1% of the total palynoflora.

Seven species of Nothofagidites were identified in the Curlew Formation (Plate 5, Figures 2-5,8-10). As stated above, the brassii type is the most common and includes the species, Nothofagidites heterus, N. emarcidus, N. incrassatus and Nothofagidites sp. A and sp. B. The fusca type is represented by a single species, N. brachyspinulosus, while the menziesii type is represented by a single palynomorph of N. asperus. The most common brassii type was N. heterus which occurred in almost every Nothofagidites population throughout the sequence. This pollen species is so similar morphologically to N. emarcidus that species are difficult to distinguish and both may have been recorded under N. heterus. It is possible that both species are

members of a larger complex, i.e. the N. heterus/N. emarcidus complex (Hill and MacPhail, 1983; Foster, pers.comm., 1984).

In the Yaamba Basin both species were recorded, but N. emarcidus was the most abundant (Foster, 1982). N. mataurensis (= N. emarcidus), another brassii type, was noted as the most common species occurring throughout the Queensland Tertiary by Hekel (1972). The age of the sediments from which these samples were taken ranges from the Lower Tertiary (Palaeocene) to Miocene. These samples and core localities are listed by Hekel (1972).

The fusca and menziesii pollen types are low in numbers in the southern Eocene deposits, e.g. Anglesea (Syber, 1983), and again this trend is repeated in Queensland deposits.

As stated previously, there is a distinct difference in the abundance of Nothofagidites pollen in Queensland and southeastern Eocene microfloras. For example, approximately 50% of the total assemblage of the Hay microflora (Martin, 1982) is represented by Nothofagidites spp. whereas in the Curlew microflora these pollen represent less than 1%. This difference was originally discussed by Harris (1965) who considered the minor occurrence of Nothofagidites in the Lower Tertiary of Queensland may be explained either by 1) the phytogeographical environment being restricted in the Lower Tertiary for the migration of the genus, possibly due to volcanic activity, or 2)(the more probable explanation being) a widespread lag in the migration of Nothofagus from southern to northern Australia, due to the existence of a south-north climatic gradient. This is discussed in more detail in Section 6.2.1

Only during the Miocene did Nothofagidites pollen types appear in any significant quantities, and only for a short period. Hekel (1972) considered this a unique event which may be associated with a climatic change and suggested that the North was not as suitable for Nothofagus as in the South-east. Martin (1982) suggested that there may have been a north-south temperature gradient during the Tertiary judging from the greater abundance of Nothofagus in south-eastern Australia when compared to Queensland.

The complete absence of megafossils assignable to the brassii type of the extant genus Nothofagus (i.e. subsection bipartitae) is not unique to the Queensland Tertiary but a common absence throughout Australia (Christophel and Blackburn, 1978; Christophel, 1981; Hill, 1982,1983a; Hill and Macphail, 1983). The absence of megafossil remains is perplexing but it is possible that megafossils may have been overlooked in some of these studies due to an inability to correctly identify material (Hill and Macphail, 1983). Reasons for the great abundance of Nothofagus brassii type pollen is discussed in detail by Hill and Macphail (1983). They considered Nothofagus species to be abundant pollen producers but not all have effective wind dispersal of pollen. This feature (viz. lack of effective dispersal and high pollen production) of the genus is generally considered the principle factor for the common occurence of the pollen type throughout the Australian Tertiary. They maintained that the pollen is an allochthonous element in these deposits but suggest, based on information concerning Nothofagus menziesii (New Zealand) and N. gunni (Tasmania) pollen, that water transport is involved in dispersal.

A review of previous studies of pollen dispersal and deposition in the areas where Nothofagus forms the regional forest vegetation (e.g. Heusser, 1974; Hope, 1976; Macphail, 1975, 1979; Pocknall, 1980) led Hill and Macphail to conclude that wind dispersed pollen rain, which represents the regional vegetation, is abundantly recorded only when the site of deposition is very open or when pollen production by local vegetation is very low. Considering these proposals it is possible that the Nothofagidites pollen types of the Curlew Formation were transported into the Narrows Graben by eastern trending streams which originated in the western highlands (Figure 7). However, if Nothofagus is an abundant pollen producer and pollen is dispersed by water, then a greater percentage of pollen could be expected to be deposited in a basin the size of the Narrows Graben, if only because of the number of streams that feed the basin. The forests of the high eastern facing gullies of the Mt. Larcom Range, and nearby ranges (e.g. Calliope Range) appear the most probable source areas for Nothofagus. These highlands are some distance (at least 6km) away from the Narrows Graben so that any pollen transported via streams and creeks would be subject to a considerable amount of abrasion and damage before final deposition.

Hill and Macphail (1983) suggest that in highland regions, the present habitat of Nothofagus, an upslope movement of wind dispersed pollen would be favoured. If this was the case in the Mt. Larcom and Calliope Ranges pollen would be carried westward away from the Narrows region in the east. This movement would be assisted by the general direction of the prevailing winds. Therefore only when the wind direction was reversed, which would be very occasionally, would pollen

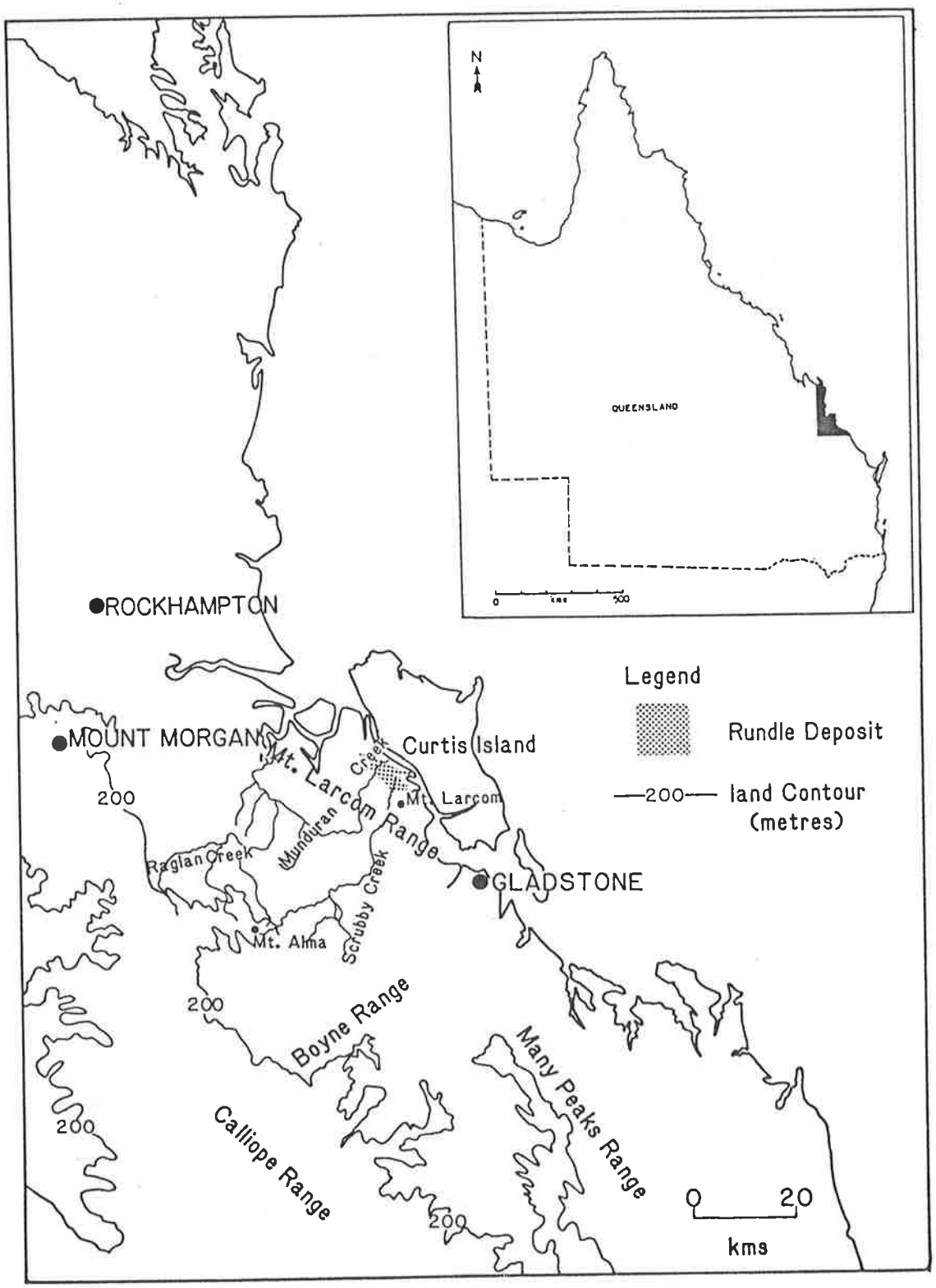
be expected to be deposited in the Narrows Graben. This argument could be used in relation to the entire east coast of Australia where the eastern highlands, the most likely source of Nothofagus, are under the influence of the prevailing onshore winds (Southeast Trades) therefore carrying pollen away from coastal areas. If Nothofagus did not occur in the upland regions near the Narrows Graben the likelihood of pollen being deposited appears even more remote considering these wind conditions.

Luly et al. (1980) listed Nothofagus brassii type pollen as either extra-local or regionally dispersed in which case the source plants were probably a considerable distance from the sample site and the pollen wind dispersed. They also considered the genus was over-represented in deposition. The low frequencies of Nothofagidites spp. would suggest they are not over-represented in the Curlew Formation and imply the dispersal mechanism responsible for depositing pollen in the graben was either not highly effective or employed irregularly. One would expect water to be a particularly efficient and regularly occurring method of transporting pollen from the upland sites to the basin. A further concentration of pollen could be expected with the union of streams as they moved down slope. It seems most unlikely that Nothofagidites spp. were deposited in the Narrows graben by water, even if the source population was very small because the grains recovered from the sediments were intact. The method appears more feasible for the southern localities where Nothofagidites frequencies are much larger.

From the low frequencies of Nothofagidites pollen in the Curlew sediments it would appear that wind was the most likely method of

dispersal and that deposition only occurred when there was an interruption to the general upslope movement of pollen, i.e. a temporary change in the prevailing wind direction.

Figure 7: Map showing Mountain Ranges and eastern trending watercourses within close proximity of the Rundle Deposit. The ancestral vegetation of these areas was possibly the source of the fossil plant material present in the Curlew sediments. A similar stream pattern would have had to exist during the deposition of these sediments for the accumulation of vegetation within the Narrows Graben.


N
QUEENSLAND
0
kms
500
ROCKHAMPTON
MOUNT MORGAN
Mt. Larcom Range
Curtis Island
Creek
Mt. Larcom
200
Mundoran
Raglan Creek
GLADSTONE
Scrubby Creek
Mt. Alma
200
Boyne Range
Many Peaks Range
200
Calliope Range
200
Legend
Rundle Deposit
—200— land Contour (metres)
0
20
kms

3.5 The Casuarinaceae Component

The family Casuarinaceae is an important element in the modern Australian vegetation and has been so in the past (Kershaw, 1970a). Haloragacidites Couper (1953) is the presently used fossil genus attributed to this family, although a number of generic synonyms exist, e.g. Triorites Cookson ex Couper (1953) and Casuarinidites Cookson and Pike (1954). Haloragacidites harrisii (Plate 5, Figure 49), which is the most abundant species in the Australian Tertiary is still referred to by the name Triorites harrisii (Couper, 1953) and likewise H. trioratus, another common species, by Casuarinidites cainozoicus (Cookson and Pike, 1954). A synonymy was presented by Mildenhall and Harris (1971) with further additions made by Stover and Partridge (1973).

Kershaw (1970a) showed that the modern species of the Casuarinaceae exhibited a range of continuous morphological variation in which no one species exhibited more than a part of the range and as Tertiary fossils fall within this range (Martin, 1978), intra-generic identifications may be possible. All species have the same basic morphology. An abbreviated version of Kershaw's description follows;

"Pollen grains are medium sized (17-41.8μm), oblate to apiculate in lateral view, rounded to semiangular in polar view and normally triporate, although pore number varies from 2 to 6. Apertures are small, 1-3μm in diameter, rather angular, and show no preferred alignment with any grain axis. Each is raised on a protrusion which has a roughly circular base and flattened top folding inward slightly

around the rim. The exine 1.5-4µm thick, is two layered with a thicker ektexine, showing traces of columellae and thinner, lighter coloured, homogenous endexine of constant thickness".

The characters that show variation are equatorial diameter, pore height, pore width, index polaris, area of pore/area of body, costae distinctiveness, crevassing and pore number (Kershaw, 1970a).

From a comparative analysis of 34 species using the characters listed above, Kershaw was able to distinguish the genus Gymnostoma from Casuarina and Allocasuarina. The revised taxonomy of the Casuarinaceae by Johnson (1982) resulted in Kershaw's original Casuarina groups containing species of both the genera, Casuarina and Allocasuarina. His groupings were Gymnostoma, Casuarina Group A , Casuarina Group B and Casuarina distyla. Gymnostoma grains displayed less variation. They are small, generally more triangular than circular in polar view, with a consistent number of pores, which lack costal rings and obvious crevassing (Kershaw, 1970a).

Pollen grains attributed to Haloragacidites harrisii have been described as free, isopolar, triradially symmetric, triatriate, triorate, subtriangular with convex sides, angulaperturate, amb interrupted by slightly bulging pore rim, pores equatorial. Pores circular 2.5 - 3µm; exine 1.0 - 1.5µm thick in interradial region, thickening around aperture to 2.0 - 2.5µm, pore canal 2.5µm exine tectate, sexine about as thick as nexine, faintly scabrate in holotype, psilate. Equatorial diameter range 29 (34) 48µm (Mildenhall and Harris, 1971).

Haloragacidites harrisii has generally been recognised as having a strong affinity to the Casuarinaceae, however Loganiaceae (Geniostoma) (Mildenhall and Harris, 1971) and Myricaceae (Canamyrica) (Cookson and Pike, 1954) have also been considered as possible relatives. Prior to Johnson's (1980, 1982) revision of the the family, which is discussed in detail in section 4.2.4, all fossil palynomorphs have simply been attributed to Casuarina, no divisional affinities being attempted.

Recently, Haloragacidites harrisii pollen grains from Anglesea (Victoria) have been positively identified as those of Gymnostoma by Syber (1983). The pollen was extracted from fossil material of a male Gymnostoma inflorescence (Christophel, 1980) and found to be indistinguishable from that of the extant Gymnostoma. These grains exhibited an absence of pore protrusion which is characteristic of the pollen type described by Kershaw (1970a). Equatorial diameter measurements also fell within the recognised generic range (Syber, 1983). A comparison between Haloragacidites harrisii from the Curlew Formation and those Anglesea grains extracted from a Gymnostoma inflorescence may be identical. Therefore the Casuarinaceae component of the Curlew Formation contains pollen that may be assignable to Gymnostoma.

Haloragacidites harrisii is one of the most commonly occurring angiosperm types in the Formation. Rarely is it absent in the palynoflora of any sample. The pollen is more abundant in the older sediments (Table 2, Figure 8), from a depth of 53.3m to the base of the sequence, where frequencies in excess of 50% and as high as 71% are recorded. The Casuarinaceae component represents 10% of the total palynoflora.

Extant Casuarinaceae species are anemophilous and prolific pollen producers (Kershaw, 1970a). Based on these characteristics they are considered to be major contributors to the regional pollen rain and over-represented in Modern and Late Quaternary sedimentary deposits (Luly et al., 1980). This suggests the plants were located some distance away from the sample site and that they represented a part of the top canopy layer. Extra-local pollen dispersal, although not a common characteristic of the family, is a recognised possibility (Walker and Flenley, 1979). Plants contributing to this type of pollen dispersal would have been growing closer to the depositional site, possibly within the same basin, as part of the canopy or understorey layers.

The frequencies recorded for Haloragacidites harrisii in the Curlew Formation would suggest over-representation and a regional distribution of source plants. Clumps of grains found in samples taken from the other cores could indicate a more extra-local distribution however. Casuarinaceae is an important dry land vegetation component growing in lower, drier parts of the catchment, or as secondary plants associated with closed forest (Luly et al., 1980). Gymnostoma is found in marginal closed forest communities of North East Queensland (Christophel, pers.comm.), not necessarily the drier areas of the catchment or infertile regions as would be expected for the more characteristically sclerophyllous genera Casuarina and Allocasuarina.

Little consideration has been given to the possibility of Gymnostoma pollen being the major contributor to the Casuarinaceae component of Tertiary pollen assemblages. All speculations regarding reconstruction of past vegetations refer to Casuarina (Martin, 1978,

1980; Luly et al., 1980), and deduce that the pollen producing plants were either located on infertile sediments within the depositional basin or in disturbed areas of closed forests. The identification of Gymnostoma pollen from Anglesea by Syber (1983) and a favourable comparison to the Curlew palynomorphs presents strong evidence that this genus was an important taxon of the Australian Eocene.

Haloragacidites trioratus (Plate 5, Figure 50) is poorly represented in the Curlew sediments, appearing in low numbers and only in a few samples of ERD 118. Frequencies recorded ranged from 0.5% to 3%. These grains could have come from plants that occupied either the infertile or drier areas within the catchment area. It is also possible that these plants grew in small areas of disturbance within the closed forest.

Water transport is again considered (Martin, 1980) as a possible explanation for over representation of Haloragacidites pollen in the Curlew sediments, whereby, the plants grew in or along the margins of swamps or lakes. Although this method of transportation does increase pollen concentrations, damage must be incurred over long distances, i.e. regionally located source plants, resulting in poorly preserved material being deposited. The palynomorphs recovered from the Curlew Formation were particularly well preserved, and occasionally clumped together, which would tend to indicate that source plants grew in the vicinity of the basin. An extra-local pollen dispersal is therefore a possibility, one which was considered by Walker and Flenley (1979).

3.6 The Angiospermae Component*

The Angiospermae component is the principle pollen group of the Curlew Formation (See Appendix 1), containing pollen types with affinities to a number of floristically diverse modern taxa and representing 30.8% of the total palynoflora.

These palynomorphs are evenly distributed, vertically throughout the Formation. In almost all samples where pollen was recorded the miscellaneous angiosperm component represented a significant percentage of the pollen flora, which ranges from 9% to 81% (Table 2, Figure 8). No definite distributional trends were recognised for individual pollen types.

The pollen types assignable to modern families and genera are few compared to the large number of unidentifiable palynomorphs. A large percentage of these unknown fossil angiosperms are of forms (i.e. tricolpate and tricolporate) very similar to many modern taxa, making it particularly difficult to determine their modern affinities. Tricolporate pollen is found within numerous families including the Anacardiaceae, Araliaceae, Cunoniaceae, Eleocarpaceae, Lauraceae, Rutaceae, Sapindaceae, Sapotaceae and Umbelliferae. Tricolpate pollen is found within several families including the Loranthaceae, Oleaceae and Nyctaginaceae (Markgraf and D'Antoni, 1978; Martin, 1978; Heusser, 1971).

Of the 58 fossil pollen types recognised only 18 have been assigned to modern families (Table 3). Although the number is small,

*excluding pollen of Categories 1-4.

vegetation reconstructions are still possible. The families to which these pollen types are attributable represent both closed forest and sclerophyll woodland (forest) elements. Families present with highest modern diversity in the Australian tropics are more numerous and include Olacaceae, Sapindaceae, Santalaceae, Ebenaceae, Rhamnaceae, Malvaceae, Euphorbiaceae, Loranthaceae, Rhizophoraceae, Oleaceae and possibly Saxifragaceae and Anacardiaceae.

The presence of the fossil genus Anacolosidites is generally considered indicative of a tropical element and is assigned to Anacolosa of the Olacaceae (McIntyre, 1968; Martin, 1978). Anacolosidites pollen is described as "isopolar, medium to small, triangular to round, triangular in polar view, 6-porate, 3 pores towards the angles of each face. Sculpture indistinct to prominent" (Cookson and Pike, 1954). Anacolosidites sectus Partridge (in Stover and Partridge, 1973) was recovered in small quantities from a number of samples (Plate 5, Figures 15,32). The modern genus Anacolosa is represented in the Australian flora by a single species, i.e. Anacolosa sp., from the Chester River, Cape York Peninsula, Queensland. This species had previously been recorded as A. papuana by B. Hyland (George, 1984). The genus is primarily distributed through the tropical zone of the western Pacific region and southern India (Cookson and Pike, 1954).

The Sapindaceae, in particular the tribe Cupanieae, has pollen which closely resembles that of the fossil genus Cupanieidites. Pollen of this genus was described by Cookson and Pike (1954) as "medium-sized, tricolporate; amb triangular to almost circular, angulaperturate; arci present, either uniting to form more or less

distinct polar islands or not reaching the poles. Sexine as thick as nexine, distinctly to faintly reticulate". Four distinct fossil types were identified, Cupanieidites sp. cf. C. orthoteichus (Plate 4, Figures 5,14,37) was the most common, occurring in most samples while, the other pollen types comparable to C. major (Plate 5, Figure 31), C. reticularis (Plate 5, Figure 27) and Cupanieidites sp.B (Foster, 1982) (Plate 4, Figure 25) were randomly distributed in low numbers throughout the Formation. Cupanieidites orthoteichus, because of the size variation of the sexine reticulum mesh is probably related to more than one modern species.

Cookson and Pike (1954), considered the Queensland rainforest tree species Mischocarpus pyriformis (F.Muell.) Radlk. the closest relative, while Cupaniopsis curvidens Radlk., Jagera pseudorhus (A. Rich.) Radlk., Rhysotoechia bifoliolata (F.Muell.) Radlk. and Toechima tenax (Benth.) Radlk. bear some similarity. Cupanieidites major more closely resembles pollen of Cupaniopsis wadsworthii (F.Muell.) Radlk., another rainforest tree species which is found in Queensland and New South Wales. Lepiderema punctulata (F. Muell.) Radlk. and Sarcopteryx stipitata (F. Muell.) Radlk. have a similar shape and type of sexinous reticulum to Cupanieidites reticularis (Cookson and Pike, 1954). Species of the Cupanieae are primarily found in the closed forest (rainforest) communities extending from Sydney (New South Wales) north through Queensland.

Santalumidites cainozoicus (Plate 4, Figure 15) is assignable to the family Santalaceae. The fossil pollen, though slightly larger in size, compares favourably with that of Santalum. The grains were described by Cookson and Pike (1954) as "triporate, prolate, with a

broad oroid zone in which the exine is more coarsely sculptured and thicker than at the poles, the maximum thickness being around the pores". Santalum has a very broad environmental range from open sclerophyll woodland to warm temperate closed forest.

Christophel and Basinger (1982) recovered tricolporate pollen from fossil flowers assignable to Diospyros (Ebenaceae), i.e.Tricolporites cf. Diospyros. A formal description of this pollen type has recently been produced by the authors (Basinger and Christophel, 1985). Tricolporate pollen of similar morphology is numerous in the Curlew Formation and some grains (Tricolporites sp.B cf. Diospyros?, Plate 4, Figure 13) do appear similar to the grain figured by Christophel and Basinger. The Ebenaceae are pantropical, occurring in tropical to temperate closed forests. The pollen type tentatively assigned to this family occurs in low frequencies and irregularly throughout the Curlew sediments. It is not a major contributor to the total palynoflora of the Curlew Formation.

Tricolporites sphaerica Cookson (1947) is considered to be similar to those pollen types characteristic of the modern Oleaceae. T. sphaerica is not easily distinguished from most other tricolporate palynomorphs, particularly T. microreticularis Harris (1965). Stover and Partridge (1973) suggest T. microreticularis may be conspecific with T. sphaerica. Grains similar to these species, i.e. Tricolporites sp. cf. T. sphaerica (Plate 4, Figure 11; Plate 5 Figures 22,28) and Tricolporites sp. cf. T. microreticularis (Plate 5, Figure 15), occurred throughout the Curlew Formation. The Oleaceae has a cosmopolitan distribution which includes a number of tropical taxa. In Australia the family is well represented in the moist subtropical

closed forests of Queensland by Notelaea, Mayepea and the anemophilous, canopy tree species Olea paniculata (Kershaw, 1976). Pollen assignable to Olea was common in the pollen rain of Lynch's Crater, Atherton Tablelands, which lies within this vegetation type, during the Quaternary. At Lynch's Crater it has been suggested that the source plants were located several kilometres away from the deposition site (Kershaw, 1976).

The fossil pollen genus Malvacipollis Harris (1965) possesses morphological features which are characteristic of the modern families Malvaceae and Euphorbiaceae. Two species of Malvacipollis were identified in the Curlew sediments, i.e. Malvacipollis sp. [which is equivalent to Malvacipollis sp. C (Foster, 1982) and Malvacearumpollis estelae (Hekel, 1972)] and Malvacipollis sp. cf. M. subtilis. Pollen of this genus is described as stephanoaperturate, oblate to subspherical, with a circular amb. The exine is distinctly stratified, columellae are singular, uniformly distributed and dense.

The major differences between the two species is that Malvacipollis sp. cf. M. subtilis (Plate 4, Figure 21) has spines whereas Malvacipollis sp. (Plate 4, Figure 1) has large conical projections and is generally much larger. Malvacipollis subtilis and most specimens of M. diversus are considered to belong to the Euphorbiaceae. However, a few specimens of M. diversus are considered assignable to the Malvaceae (Martin, 1978). This suggests M. diversus is not a good taxonomic unit and that revision is required. Within the Euphorbiaceae the Malvacipollis species more closely resemble the pollen of Austrobuxus swainii, Dissiliaria baloghioides and Petalostigma (Martin, 1974,1978). Both Austrobuxus swainii and Dissiliaria baloghioides are timber producing

trees of the wetter subtropical to warm temperate closed forests of north-eastern New South Wales and south-eastern Queensland. It is most probable that Malvacipollis sp. also belongs to the Euphorbiaceae.

The Malvaceae, a tropical family, is considered to be a warm indicator by Kemp (1978). Some Malvacipollis grains bear a similarity to those of Plagianthus and Hoheria (Martin, 1977).

A very distinctive palynomorph that occurred in generally low frequencies in the Curlew palynoflora was Corsinipollenites oculus noctis (Thiergart) Nakoman 1965. The species was first reported in the Queensland Tertiary as Oligocene (Hekel, 1972), apparently because of the general similarity of C. oculus noctis to Jussiaea champlainensis (Traverse, 1955) from the Oligocene of Vermont, U.S.A. (Daghlian et al., 1984). Specimens of C. oculus noctis were subsequently found in the Yaamba Basin by Foster (1982) confirming the Eocene age of the species.

The modern affinities of the species are quite clear. The very distinctive wall structure, i.e. "paracrystalline" ektexine (Daghlian et al., 1984), is a diagnostic feature of pollen of the Onagraceae. Within this family Muller (1981) recognised two types of fossil pollen, i.e. the Epilobium and Fuchsia types. The former is characterised by three prominent, protruding collared pores while the latter has only two apertures (Daghlian et al., 1984). Therefore the generic affinity of C. oculus noctis is clearly with Epilobium.

Epilobium is one of five genera that occur in Australia* (Fuchsia, Oenothera, Gaura and Ludwigia are the others). It is the largest genus being represented by fifteen species which are found in temperate open

* A single species of Boisduvalia (ie. B. tasmanica) is also present.

habitats. The plants are usually soft annual herbs which would suggest pollen dispersal is very localized and source plants grow near to the site of deposition.

The monosulcate pollen grains of Clavatipollenites hughesii (Couper) (Plate 2, Figure 10) occurred irregularly throughout the Formation. This species is morphologically very similar to pollen found in the Chloranthaceae (e.g. Ascarina lucida, Couper, 1958) which is a small family of herbs, shrubs and trees of the tropics and southern temperate regions. The family does not occur in Australia but some species of Ascarina are found in New Zealand.

Tricolporites sp. cf. T. adelaidensis (Harris) (Plate 4, Figure 4) is similar to the pollen of the extant genus Polyosma, of the family Saxifragaceae. This family has in the past been divided into a number of smaller families, e.g. Baueraceae, Escalloniaceae and Hydrangeaceae. Polyosma was included in the Escalloniaceae (Francis, 1981). In Australia the Saxifragaceae is distributed mainly along the east coast, particularly in New South Wales and Queensland. Polyosma, like Argophyllum and Quintinia, in the same family, is mainly a secondary canopy tree of the wetter parts of the warm temperate closed forests of north-eastern New South Wales and south-eastern Queensland. The genus also occurs in South East Asia.

Pollen assignable to Tricolpites simatus Partridge (in Stover and Partridge, 1973) and T. thomasii Cookson and Pike (1954) occurred throughout the Formation but only in small quantities. These species, particularly T. simatus (Plate 5, Figure 30), resembles the pollen types of the modern family Loranthaceae (Martin, 1978; Cookson and

Pike, 1954). T. simatus is described as isopolar, having a triangular amb with straight to concave sides and truncated or broadly rounded apices. The colpi commonly have faint arcus-like poleward extensions. A vaguely to moderately well differentiated exine with undiscernable columellae is exhibited. The triangular to subcircular polar thickenings are diagnostic of the species which differs from Tricolpites thomasii (Plate 4, Figures 3,34) by lacking inter-radial reticulation (Stover and Partridge, 1973). The Loranthaceae is a family of parasitic shrubs that are widely distributed in the tropics and southern temperate regions, but most species are tropical. These plants have an Australia-wide distribution.

The pollen type Zonocostites ramonae Germeraad, Hopping and Muller (1968) was first reported from the Rundle Deposit (i.e. Narrows sediments) by Hekel (1972). This is the first report of the species from the Curlew Formation (Plate 4, Figure 35). The species resembles the pollen of the modern tropical family Rhizophoraceae (Muller, 1964; Martin, 1982). Zonocostites ramonae is described by Germeraad et al. (1968) as "radially symmetrical, isopolar, spherical. Tricolporate, colpi ectexinous, medium long, straight with pointed ends, slightly costate, endexinous apertures equatorially elongated to almost fused, distinctly costate, in polar view slightly vestibulate. Endexine <0.5µm thick; columellae <0.5µm thick and high; tectum, 0.5µm thick, densly perforate, coarser on poles and finer to almost psilate on equatorial belt, perforations <0.5µm wide".

Rhizophoraceae is frequently found in mangrove conditions or as fringing forest trees close to creeks (McAlister in Morley and Toelken, 1983). In Australia the family is concentrated in northern

regions but does extend southward along the eastern coast to a latitude of 27° S, and in doing so, is present on the coastal mudflats near the Rundle Deposit. This distribution and the presence of Zonocostites ramonae suggests that a similar coastal community may have existed during the deposition of the Curlew sediments. Plants producing Zonocostites ramonae pollen cannot be considered as representatives of a closed forest community. They are more likely to occur in either marginal, fringing forests close to a watercourse or in coastal mangrove communities.

A striate patterning of the sexine distinguishes the tricolporate pollen type Simpsonipollis (Srivastava, 1975) sp.A from those of the genus Tricolporites. A few specimens of Simsonipollis sp.A were recognised in the Curlew sediments (Plate 5, Figure 20). Muller (1968), commented on the difficulty of recognising the affinity of tricolporate palynomorphs with a striate exine pattern, as such ornamentation is found in several modern families including Leguminosae, Anacardiaceae, Sapindaceae, Cucurbitaceae and Nolanaceae (cf. Nolana) (Kemp, in Kemp and Harris, 1977). All families have a predominantly tropical - subtropical distribution.

The sclerophyllous element is represented by fossil pollen types whose modern affinities are associated with the less favourable climatic and edaphic areas within the closed forest community, e.g. areas with low rainfall, low nutrient soils and steep terrain. The presence of such areas throughout the subtropical and tropical regions of Queensland has produced a mosaic of closed forest and sclerophyllous vegetation types.

Fossil pollen assigned to Amaranthaceae, Chenopodiaceae, Polygalaceae and Proteaceae may have modern relatives that are associated with sclerophyll vegetation. Polyporina chenopodiaceoides Martin (1973), is a polyporate species with an affinity to either the Chenopodiaceae or Amaranthaceae (Plate 5, Figure 21). Pollen of the Chenopodiaceae and some of the Amaranthaceae is practically indistinguishable. These two families are best known from arid regions and as halophytes, but some species are pioneers in higher rainfall areas (Martin, 1978). They are also represented in coastal salt marsh communities. The distinctive stephanocolpate pollen of Polycolporites esobalteus McIntyre (1968) is attributed to the family Polygalaceae. A number of grains comparable to this species were recovered from Curlew sediments (Plate 4, Figure 38).

The Proteaceae component, which has been discussed previously, contains a couple of pollen types that may be associated with taxa of sclerophyllous communities. The modern relative of Beaupreaidites, Beauprea, is part of the heath-like 'Maquis' community of New Caledonia (Christophel, pers. comm.). It has also been described by Martin (1982) as a tropical sclerophyllous shrub which would suggest this plant is associated with disturbed or infertile sites within closed forest communities. The morphologically similar pollen of modern genera within the Banksieae has made assigning a modern relative to Banksieaeidites a difficult task. The fossil pollen type has been attributed to the closed forest Musgraveinae on the basis of Banksieaeidites pollen being recovered from a fossil anther assigned to that sub-tribe (Christophel, 1984). It has also been suggested that Banksieaeidites may be related to Banksia and Dryandra (Luly et al., 1980; Martin, 1978)

which are characteristic of tall open forest, sclerophyllous woodland and shrubland.

3.7 The Gymnospermae Component

This component contains predominantly coniferous fossil species, i.e. Lygistepollenites florinii, Microcachryidites antarcticus, Phyllocladidites mawsonii, Dilwynites granulatus, Dacrycarpites sp. cf. D. australiensis, Araucariacites sp., Podocarpidites spp., Dacrycarpites sp. and Phyllocladidites sp. (Plate 3). The only other pollen types included in the component are Ephedra notensis (Plate 3, Figures 11,15) and a single cycad pollen grain (i.e. Cycad sp. Plate 3, Figure 16). These palynomorphs appear irregularly throughout the formation and usually in very low frequencies. Approximately a third of all samples examined did not contain any gymnosperm pollen. In the remaining samples rarely did the component represent more than 1% and never more than 4% of a sample flora. The gymnosperm component represents only 0.94% of the total palynoflora of the Curlew Formation and is therefore considered to be of minor importance (Table 2, Figure 8). Distribution throughout the Formation is random, no definite trends are obvious.

The Podocarpidites species (Plate 3, Figures 1,7,12,17), Lygistepollenites florinii (Plate 3, Figures 8,9) and Ephedra notensis are the most commmon gymnosperm pollen types in the Formation. These species are found to resemble pollen of the modern genera, Podocarpus, Dacrydium and Ephedra respectively. Of the remaining species, Microcachryidites antarcticus (Plate 3, Figure 13) is attributable to the modern genus Microcachrys, Dacrycarpites to Dacrycarpus, Araucariacites to Araucaria or Agathis and Dilwynites to Araucaria.

By considering the pollen production and dispersal characteristics of these modern genera a reconstruction of the Curlew gymnosperm vegetation is possible. An interesting feature noted by Luly et al. (1980) is that gymnosperm pollen, apart from Podocarpus and Dacrydium in Australia, to some extent, have restricted pollen production and dispersal, despite the fact that fertilization is dependant on wind dispersal. This may account for the very low frequencies recorded for Microcachryidites, Phyllocladidites and Dacrycarpites in the Curlew sediments.

Podocarpus and Dacrydium are both considered to be good pollen producers and dispersers. Podocarpus is particularly effective, and is recognised as having high pollen production and dispersal (Luly et al., 1980). Plants possessing these features are considered to be part of the top canopy layer of the vegetation, where they are sufficiently exposed to enable their pollen to be wind dispersed and well away from the depositional site. Dacrydium likewise has an extra-local or regional dispersal, and therefore has a similar ecological and regional position, but its pollen production is relatively lower. The fossil relatives of these two genera, i.e. the producers of Podocarpidites and Lygistepollenites, probably occurred in the canopy layer of a forest located well away from the depositional site, too far even for the podocarpaceous pollen to be carried regularly. This would account for the low number of individuals recorded. If the trees grew locally they must have been scarce to contribute this small amount of pollen.

It would appear, in view of results obtained from other deposits, for example, Anglesea (Syber, 1983), the Gippsland Basin (Stover and Partridge, 1973), Murray Basin (Martin, 1978) and Albany (Hos, 1975)

that the gymnosperm vegetation was more abundant in southern Australia during the Middle to Late Eocene. Hekel (1972), reported Podocarpidites as common in some samples and present throughout all age units but Dacrydium rare. Throughout the Queensland Eocene, gymnosperm pollen types are generally not common and remain so until the Miocene.

Fossil Araucariaceae pollen types i.e., Araucariacites sp. (Plate 3, Figure 6) and Dilwynites granulatus (Plate 3, Figure 10), are particularly rare in the Curlew Formation. The modern Araucariaceae is represented by two genera, Araucaria and Agathis, both of which occur in Australia but whose distribution is restricted to the closed forest communities of north-eastern New South Wales through to North East Queensland. According to Owen (1975) araucarian species are commonly located on the steeper slopes within these communities, where good drainage is ensured. As emergents of the closed forest canopy layer pollen could be expected to be wind dispersed, however, Kershaw (1976) has noted that both genera have a poor dispersal capacity. When widely distributed throughout an area their pollen is absent from sites where the trees do not grow nearby. Therefore the occurence of Araucariacites and Dilwynites pollen types in the Curlew sediments would tend to indicate the source plants grew no more than a short distance from the depositional site.

The pollen of Araucaria and Agathis are very similar morphologically, making it almost impossible to determine the modern generic affinities of the fossil pollen types.

The dispersal characteristics of Ephedra are most unusual. Normally wind dispersed pollen is transported over a distance between

50 and 100km per day, but in this genus distances of 3000km per day have been recorded (Faegri and Iversen, 1964). Such possible long distance dispersal suggests that the source plants may be located well away from the depositional site, possibly in a completely different vegetation type and environment.

As noted previously, cycad pollen is particularly rare in the Curlew Formation and only one tentative identification has been made, i.e. Cycad sp. (Plate 3, Figure 16).

Most of the Gymnospermae component, i.e. the conifers, are characteristic of tropical-warm temperate to cool temperate closed forest. Occasionally they are associated with Nothofagus, particularly species of Podocarpus, Phyllocladus and Dacrycarpus in New Guinea and only the former two genera in south-eastern Australia (Luly et al., 1980). Podocarpus with Podocarpidites ellipticus-type pollen is presently found in north-eastern Queensland (Owen, 1975). Dacrydium and Microcachrys are not presently found on the Australian mainland. Both occur in Tasmania, where Microcachrys is endemic. Podocarpus is present throughout the closed forests of Australia in a wide range of habitats. Dacrydium franklinii whose pollen is comparable to that of Phyllocladidites mawsonii (Martin, 1982), which was particularly abundant in south-eastern Australia during the Late Eocene, is restricted to temperate closed forests.

The association between Nothofagus and gymnosperms may be indicative of "mixed" forests, particularly on sub-optimal or highly disturbed sites (Luly et al, 1980). This would suggest such habitats existed during the Tertiary. In the palynoflora of the Murray Basin

(Martin, 1982) Nothofagidites species and Phyllocladidites mawsonii exhibited similar patterns of decline from the Late Eocene to the Early Miocene which may signify the decline of extensive marginal mixed forests throughout eastern Australia.

In the Yaamba Basin gymnosperm palynomorphs are common, representing 18.5% of the palynoflora. This would tend to indicate no such decline. However, a large percentage of the pollen is either Araucariacites australis, Dilwynites granulatus or Dilwynites sp.C and all are related to Araucaria, a noted poor pollen disperser (Kershaw, 1976). This could have resulted in them being over-represented in the palynoflora. The presence of only a few plants could be responsible for this high quantity and gymnosperms may not have been as common in the Yaamba flora as the pollen data suggests.

3.8 The Pteridophyta Component

The pteridophyte component is particularly large, representing 31.8% of the total palynoflora of the Curlew Formation (Table 2). It is comprised almost entirely of pteridophyte (fern) spore types but a small quantity of bryophyte (mosses) spore types have been included. The plants that contributed spores to the pollen rain were probably small low ferns, erect ferns, tree ferns, epiphytic ferns and club mosses. The diversity of spore types reflects the diversity in habit with in excess of 40 spore types recognised.

The spores of both plant groups are particularly abundant in the youngest and oldest sediments, where percentages are rarely >10% (i.e. of the pollen flora per sample) but they do occur randomly throughout the sequence. Rarely does a single spore type dominate the component in consecutive samples. Percentages as high as 81.5% were recorded in the younger sediments and 58.0% in the older sediments. For a short interval, immediately after the green claystone band, between 53.3m and 58.4m, percentages are generally low. This interval coincides with increases in the Myrtaceae component (Table 2, Figure 8). Possibly this was a drier period in which fewer ferns existed.

Identification of these spore types and their subsequent associating with extant relatives enables some comments being made about the past understorey layer. Affinities have been made to the following families; Gleicheniaceae (*Gleicheniidites*), Osmundaceae (*Todisporites*, *Osmundacidites* and *Baculatisporites*), Cyatheaceae (*Cyathidites*, *Kuylisporites*), Schizaeaceae (*Cyathidites*), Matoniaceae (*Dictyophyllidites*), ?Lycopodiaceae (*Camarozonosporites*), Polypodiaceae

(Laevigatosporites), Salviniaceae (Azolla), RICCIACEAE (Rousesporites), SELAGINELLACEAE (Ceratosporites) and SPHAGNALES (Stereisporites).

Spores of Gleicheniidites Ross ex Delcourt and Sprumont emend (1955), are described as trilete microspores, with a triangular amb. The exine is smooth or almost smooth, and has exinal thickenings (crassitudes) in each equatorial, interradial region (Dettmann, 1963). The spores of the modern Gleichenia circinata and G. laevissima are comparable to Gleicheniidites (Dettmann, 1963). These extant species are characteristically scrambling plants which grow in wet bogs and swamps and have limited aerial spore dispersal capacity. The spores of these plants are considered by Luly et al. (1980) over-represented, dispersed locally and to be dispersed and concentrated principally by water transport. Fern sp.Z cf. Gleicheniidites (Plate 2, Figure 24) spores occur irregularly throughout the Formation.

Todisporites Couper (1958) was established for the reception of fossil spores of the type met within Todites williamsonii and T. princeps. Spore are described by Couper (1958) as "trilete, more or less spherical with comparatively long laesurae and a thin, unsculptured to finely scabrate exine". Large, spherical spores with long laesurae are characteristic of the family Osmundaceae, but smooth or finely patterned spores are not found in any of the extant species (Martin, 1973). The habit of the source plants remains unknown. A number of Todisporites spp. (Plate 1, Figures 8,12,13) occur throughout the Curlew sequence and represent the major percentage of the pteridophyte component. The characteristic simple structure of these palynomorphs makes specific identifications very difficult. Generally, these type of spores are simply assigned to the form genus.

One Osmundacidites species, i.e. Osmundacidites sp.A and Fern sp.L cf. O. wellmanii (Plate 2, Figure 17), and one Baculatisporites species, i.e. Fern sp.A cf. Baculatisporites comaumensis (Plate 1, Figure 1), are represented in the sediments of the Curlew Formation. The former species is most common. Osmundacidites Couper (1953) and Baculatisporites Thomson and Pflug (1953) are very similar morphologically except in sculpture. Osmundacidites possesses a predominantly granulate exine and is distinct from Baculatisporites which has baculate sculpture (Dettmann, 1963). Osmundacidites is characterised by spherical spores, often distorted with arcuate folds and with a circular amb in undistorted specimens. The exine is thin displaying granulate grana with irregular, sometimes confluent bases. The laesurae are straight, their length is greater than 3/4 the spore radius and they have granulate margins. Several other fossil representatives of the Osmundaceae compare favourably with these spores (Couper, 1953, 1958, 1960) as does the living species Osmunda japonicum (Dettmann, 1963). Modern representative of the family are terrestrial or subaquatic (Lawrence, 1968) with a short erect or, occasionally, creeping habit (Smith, 1938). The family is cosmopolitan.

Cyathidites Couper (1953) contains a number of species which are considered to be assignable to a number of different families, i.e. Cyatheaceae, Dicksoniaceae and Schizaeaceae. Palynomorphs are smooth or faintly patterned, trilete, with a concavely triangular amb (Dettmann, 1963). Cyathidites minor (Plate 2, Figures 3,4), which is smooth walled and lacking any form of patterning, occurs regularly throughout the entire Formation. Couper (1953, 1958) has discussed the possible affinity of C. minor to the Cyatheaceae and Dicksoniaceae ferns, in

particular, the fossil Coniopteris hymenophylloides. Of the spores of recent New Zealand species it is similar to those of Cyathea smithii, C. colensoi and C. novae-zealandiae.

Cyathidites minor occurs throughout the Australian fossil record from the Jurassic to the Tertiary period. Extant Cyatheaceae and Dicksoniaceae are tree fern taxa that may reach heights of 5 metres. The Cyatheaceae is restricted in distribution to tropical mountain forests from Mexico to Chile, Malaysia to Australasia and New Zealand, and Africa (Lawrence, 1968). A fern similar to Cyathea producing Cyathidites spores, occupied the riparian niche in the closed temperate rainforests at Pioneer, in Tasmania during the Oligocene. The same vegetation exists today but the floristic components have changed. Dicksonia antarctica has replaced the Cyathea-like fern (Hill and MacPhail, 1983). Besides Tasmania, the Dicksoniaceae is represented in eastern Asia, Malaysia, Hawaii, Central America and the Juan Fernandez Islands producing a disjunct tropical distribution.

Cyathidites is not well represented in the deposit. Only a few C. australis (Plate 1,Figure 16) spores were recovered from the Curlew Formation.

The tree fern Cyathea is noted as a copious spore producer with limited dispersal by wind. This generally indicates the close proximity of the parent plants to the sample site. Water transport is considered responsible for high fern concentrations (Luly et al., 1980). Recent studies by Ladd (1978) and Head (1979) of the pollen component of estuarine sediments fed by large rivers in south-eastern Australia have found that fern spores derived from river-edge communities tend to

overshadow pollen derived from higher plants. This over representation could be further emphasized in the Curlew Formation because the complex vine forests of North East Queensland are so floristically diverse and lacking in anemophilous species that even the presence of any pollen-spore taxon could automatically indicate over representation (Kershaw, 1973).

Several Russian authors (e.g. Bolkhovitina, 1961) have shown that other species now included within Cyathidites i.e. C. punctatus, C. asper and C. concavus are comparable to some of the spores found in Lygodium Swartz, and these authors attribute the fossil dispersed spores to this modern genus (Dettmann, 1963). Spores similar to, if not identical, to C. punctatus have been attributed to Lygodium punctatituberculatum, L. fumatum, L. scrobiculatum, L. concors and L. granulatum. Cyathidites asper spores differ from those of C. punctatus in having a thicker exine, longer lasurae and more acutely rounded amb-angles and more closely resembles spores of Lygodium japonicum, L. flexuosum and L. cubense (Dettmann, 1963).

The family Schizaeaceae, to which Lygodium belongs, is represented by terrestrial ferns of very diverse habit, some extremely small and grass-like, others climbing by leaves of indeterminate growth. The family is mostly tropical, only occasionally found in temperate regions (Lawrence, 1968). In Australia Lygodium, is referred to as the 'Climbing Maidenhair', and found to inhabit regrowth areas of tropical closed forest margins and sometimes swamps. The genus is considered distinct from the other members of Schizaeaceae (Clifford and Constantine, 1980) and has therefore been placed in the Lygodiaceae.

Megafossil remains of Lygodium have been recovered from south-eastern Australia, i.e. Anglesea. Epiphytic fern spores are considered to range from equal to over represented and have local to extra-local dispersal (Luly et al., 1980). This again implies that parent plants are located near the sample site and that water transport is responsible for the dispersal of spores.

Megaspores and massulae of the water fern Azolla capricornica (Salviniaceae) are common throughout the Curlew sediments. These structures were recovered from the megafossil macerations. The micro spores (up to 12) contained within the massulae are described by Foster and Harris (1981) as "spherical, trilete; laesurae simple or with narrow, low labra, almost reaching the equator; exine 1.5 to 2.0µm thick, laevigate to finely granulate". Modern Azolla is mostly found in warm temperate to tropical, relatively still freshwater lakes in Australia.

Dictophyllidites Couper emend. Dettmann (1963) spores are compared to those of Matonia species. The microspores are trilete, with a triangular amb. The exine is smooth to faintly patterned and thickened about the laesurate margins. Laesurae are enclosed within membraneous, elevated lips. The resemblance of D. pectinataeformis to the spores of the living Matonia pectinata has been noted by Bolkhovitina (1953) (see Dettmann, 1963). Matoniaceae is a family that is restricted to the tropical floras of Indonesia, Borneo and New Guinea (Foster and Gifford, 1974). As it grows, a prostrate rhizome gives rise to short erect fronds.

Dictyophyllidites spores are not common in the Curlew sediments although a number of different types appear to be present. There are

only two types that can be assigned to the genus with any certainty, i.e. Dictyophyllidites sp.A (Plate 1, Figure 7) and Dictyophyllidites sp. cf. D. concavus (Plate 2, Figure 29). The four others that may have a possible affinity are Fern spp. B,C,D and J (Plate 1, Figures 2,3,4,14 respectively).

Two species of Laevigatosporites Ibrahim (1933), L. major (Plate 2, Figure 5) and L. ovatus (Plate 2, Figure 8) are common spore types in the Curlew Formation. Spores characteristic of this genus are described as being concavo-convex, monolete, with smooth, firm walls (Cookson, 1947). L. ovatus Wilson and Webster (1946), is attributable to similar smooth-walled monolete spores of a number of modern genera, e.g. Asplenium, Blechnum, Dryopteris (Kemp and Harris, 1977), Dicranopteris, Vittaria and Cystopteris. L. major (Cookson) Krutzch (1959) is considerably larger than L. ovatus but of the same general morphology. The species is considered to have affinities with the Polypodiaceae. However, the family is generally considered by pteridologists not to be a phylogenetically natural grouping making the assigning of Laevigatosporites major to it rather ambiguous. Spores of L.ovatus have been compared to those of a number of genera, which, using Clifford and Constantine's classification, occur in different families.

Blechnum belongs to the Blechnaceae, a family of terrestrial ferns whose habitats range from very dry open eucalypt forest to damp rainforest and freshwater swamps. Blechnum specifically occupies habitats in alpine meadows, heathlands, rainforests and eucalypt forests throughout Australia. Asplenium (Aspleniaceae) represents terrestrial and epiphytic ferns. Terrestrial or rarely epiphytic ferns

of temperate or tropical rainforests or wet sclerophyll forests characterise the family Aspidiaceae, to which Dryopteris belongs. A single species is known from high mountains in North East Queensland (Clifford and Constantine, 1980). Vittaria (Vittariaceae) represents epiphytic ferns of tropical and subtropical rainforest, that may also grow on rocks. There is only one Australian species, V. elongata, which grows from Cape York to northern New South Wales. Dicranopteris (Gleicheniaceae) represents terrestrial ferns found growing on road cuttings, cliffs, margins of rainforests and wet sclerophyll forest. Plants are often straggling and forming dense thickets (Clifford and Constantine, 1980). Cystopteris is quite distinct from the other fern genera mentioned in that it is represented by small terrestrial ferns confined to alpine regions.

For the fern families already discussed, over representation is characteristic of both terrestrial and epiphytic forms and water transport is the most likely method of dispersal.

Another type of spore, i.e. Lycopod sp.A (Plate 1, Figure 5), of minor importance in the Curlew Formation is that which is comparable to Camarozonosporites Pant ex. Potonie (1956) emend. Klaus (1960). Spores of this genus are trilete, zonate, with a circular amb. They are assignable to the family Lycopodiaceae, in particular the extant genus Lycopodium. The family is represented by low terrestrial of epiphytic lycopods which are abundant in subtropical and tropical rainforests. Tropical species of Lycopodium are predominantly epiphytes (Lawrence, 1968). Clifford and Constantine (1980) considered Lycopodium to be an unnatural assemblage.

The fossil bryophyte spore genus, Rouseisporites Pocock (1962) is morphologically comparable to some of the spores found in the Ricciaceae and Clevaceae. In particular the type species Rouseisporites reticulatus closely resembles the spores of the living Riccia beyrichiana and R. canaliculata (Dettmann, 1963). The spores are inaperturate proximally, with an amb that is convexly triangular to circular. The sclerine is two layered, the outer layer is membraneous and sometimes loosely enveloping, zonate. The zona has a flask-shaped to conical invagination in each radial region. The distal surface has muroid ridges which may anastomose to form a reticulum while the proximal surface is smooth to reticulate (Dettmann, 1963). These spores were common throughout the Curlew sequence (Plate 2, Figure 1).

It is evident from the comparisons of fossil spore types to extant families that terrestrial and epiphytic ferns dominated the understorey of the vegetation that surrounded the Narrows Graben. It was most probably a marginal tropical-subtropical closed forest.

3.9 The Monocotyledonae Component

The monocot pollen types occur regularly throughout the Curlew Formation and represent 6.9% (Table 2, Figure 8) of the palynoflora of the Formation. This percentage is much larger than that recorded for the more distinctive Proteaceae, Nothofagaceae and Gymnospermae components. It is apparent that monocots formed an important part of the Curlew flora.

Liliaceae pollen types dominate the component (Plate 2, Figures 26-28,30-32,34,35), with the Palmae related pollen type, Arecipites (Plate 2, Figure 39) and a pollen type simply referred to as Genus A sp. (Plate 2, Figure 37) also common. Of the remaining pollen types, all of which occur in low frequencies, one has been tentatively assigned to the Restionaceae and two others to the Graminae.

Distinguishing between the genera Liliacidites Couper (1953) and Arecipites Wodehouse (1933) emend. Anderson (1960) is difficult. Kemp and Harris (1977) made the following comments on these two genera, " Distinction between Arecipites and Liliacidites remains unclear; Nicols et al. (1973) reserved Arecipites for species with a tectate exine, and assigned grains with a reticulate exine structure to Liliacidites. These two structural conditions are in fact gradational, as fusion of columellate heads may occur to any degree. It is interesting to note in this context that forms compared by Dettmann (1963) to L. kaitangataensis Couper (1953), the type species of Liliacidites, shows an exine surface pattern which is clearly tectate-perforate!".

There are several pollen types assigned to Liliacidites, which have an affinity to the modern family Liliaceae. The family has a world-wide distribution with major centres of diversity in the temperate regions. Plants are mainly tufted perennial herbs. Liliacidites pollen is described by Couper (1953) as "anisopolar, bilateral, monosulcate, occasionally trichotomosulcate, sulcus long and broad. Grain usually long. Exine clearly reticulate, lumen of reticulum variable in size, clavate, baculate in optical section". The majority of pollen types have been assigned to this genus but one monosulcate palynomorph, of reasonable abundance, has a definite affinity to Arecipites.

Arecipites is the preferred genus over the more broadly circumscribed Monosulcites Cookson ex Couper (Kemp and Harris, 1977) for Tertiary pollen of palm-like form, with a stratified exine. Pollen attributed to Arecipites is considered having an affinity to the Palmae (= Arecaceae) which is a large family occurring throughout tropical and warm temperate regions of the world. The main centres of diversity are the Malay Archipelago and New Guinea. Palms are tree-like, shrubby, or climbing monocots characteristic of swamps or other areas of poor water drainage; in drier climates they are often restricted to areas of permanent water, e.g. river channels (Rodd in Morley and Toelken, 1983).

Genus A sp. is comparable to the genus Sparganiaceaepollenites Thiegart ex. Potonie (1960). It is a small grain, more or less spherical but is often folded. The single pore is not easily seen due to this folding and reticulation of the exine is variable. This species compares favourably with others of the Sparganiaceaepollenites, and as

the generic name implies, has an affinity to extant Sparganiaceae. This family is mainly found in the Northern Hemisphere but extends in a discontinuous distributional band through South East Asia into Australia. (Morley, in Morley and Toelken, 1983). These reed-like plants are a distinctive part of marginal vegetation of sluggish freshwater habitats. Sparganium, a known inhabitant of this environment, has been favourably compared to the fossil species, Sparganiaceaepollenites irregularis, by Kemp and Harris (1977). However, Machin (1971) indicated that it was difficult to differentiate between Typhaceae and Sparganiaceae based on pollen.

Milfordia sp. cf. M. punctatus (McIntyre) Partridge (in Stover and Partridge, 1973) and Rectosulcites sp. cf. R. microreticularis Harris (1965) both occur in low numbers in Curlew sediments (Plate 2, Figure 4). The latter species has no known modern relative but the former species, which is comparable to Milfordia homeopunctata is considered similar to the pollen types of the Restionales. Pollen of certain species of Restio show a pronounced similarity to M. homeopunctata (Kemp and Harris, 1977). This species under the synonym Restioniidites homeopunctatus (Plate 2, Figure 40) was previously reported in the Queensland Tertiary by Hekel (1972).

Daghlian (1981), noted that it is difficult to differentiate between pollen of the Restionales (i.e. Restionaceae, Centrolepidaceae and Flagellariaceae; Cronquist, 1981) and pollen of grasses, although Hochuli (1979) indicated that the scorbiculate exine sculpture distinguishes Restionaceae. Two basic aperture types are recognised in restionalean pollen, centrolepidoid and graminoid, but distinguishing them does not make familial identifications any easier. Centrolepidoid

apertures are large (7.0µm to 8.0µm in diameter), irregular in outline and often with rough edges, while graminoid apertures are small, circular in outline and may have an annulus or operculum. Centrolepidoid apertures occur in the Restionaceae and Centrolepidaceae, graminoid in the Restionaceae and several segregates from this family (Ladd, 1977). Luly et al. (1980) assigned pollen of this type to the taxon Restionaceae/Centrolepidaceae which implies no distinction has been made between the pollen types of both families to date.

The Restionaceae is a Southern Hemisphere family of sedge-like plants whose great diversity and largest aggregation of genera is in south-western Australia. There is also a considerable representation in eastern Australia. The family is characteristically found on infertile soils but many species occur in areas subject to intermittent waterlogging, e.g. swamps (Johnson and Briggs, in Morley and Toelken, 1983).

The Centrolepidaceae is a small Australian family represented by small, sedge-like annuals and perennials that grow in all major terrestrial habitats except dense forest and more arid regions (Cooke, in Morley and Toelken, 1983). As already stated, the family is very closely related to the Restionaceae.

Another family of the Restionales whose pollen is possibly more difficult to distinguish from that of the Graminae is Flagellariaceae. This is a small Australian family represented by a single native species Flagellaria indica, which is a climber that occurs in rainforest and monsoon forest from the north of Western Australia to

eastern Queensland and eastern New South Wales (Briggs and Johnson, in Morley and Toelken, 1983).

Graminidites species (Plate 2, Figures 33,36) are rare in Curlew sediments. This is common for Tertiary deposits and it is not until the Miocene that percentages show significant increases (Daghlian, 1981). The pollen types may have an affinity to the modern grasses, although graminoid pollen was not restricted to the Gramineae during the Eocene, as discussed above.

Monocotyledons, with the exception of the Palmae and some of the liliaceous forms, are most likely to disperse pollen locally. This occurs in the Restionaceae, which has been recognised by Luly et al. (1980), through their Restionaceae/Centrolepidaceae taxon, as having a limited aerial pollen dispersal capacity and achieving high pollen representation in depositional samples. They concluded that these plants grew within the swamp basin, as part of the autochthonous element of the vegetation. The Sparganiaceae, a similar plant group to the Restionaceae, is a possible major representative of the Curlew Formation flora through the resemblance of Genus A sp. to Sparganiaceaepollenites. Plants of this family, or the closely related Typhaceae, grew within the depositional basin and in doing so, also contributed to the autochthonous element.

Figure 8: Pollen Diagram of the Curlew Formation in ERD 118, showing the frequencies of the 8 palynomorph categories recognised for all sample intervals.

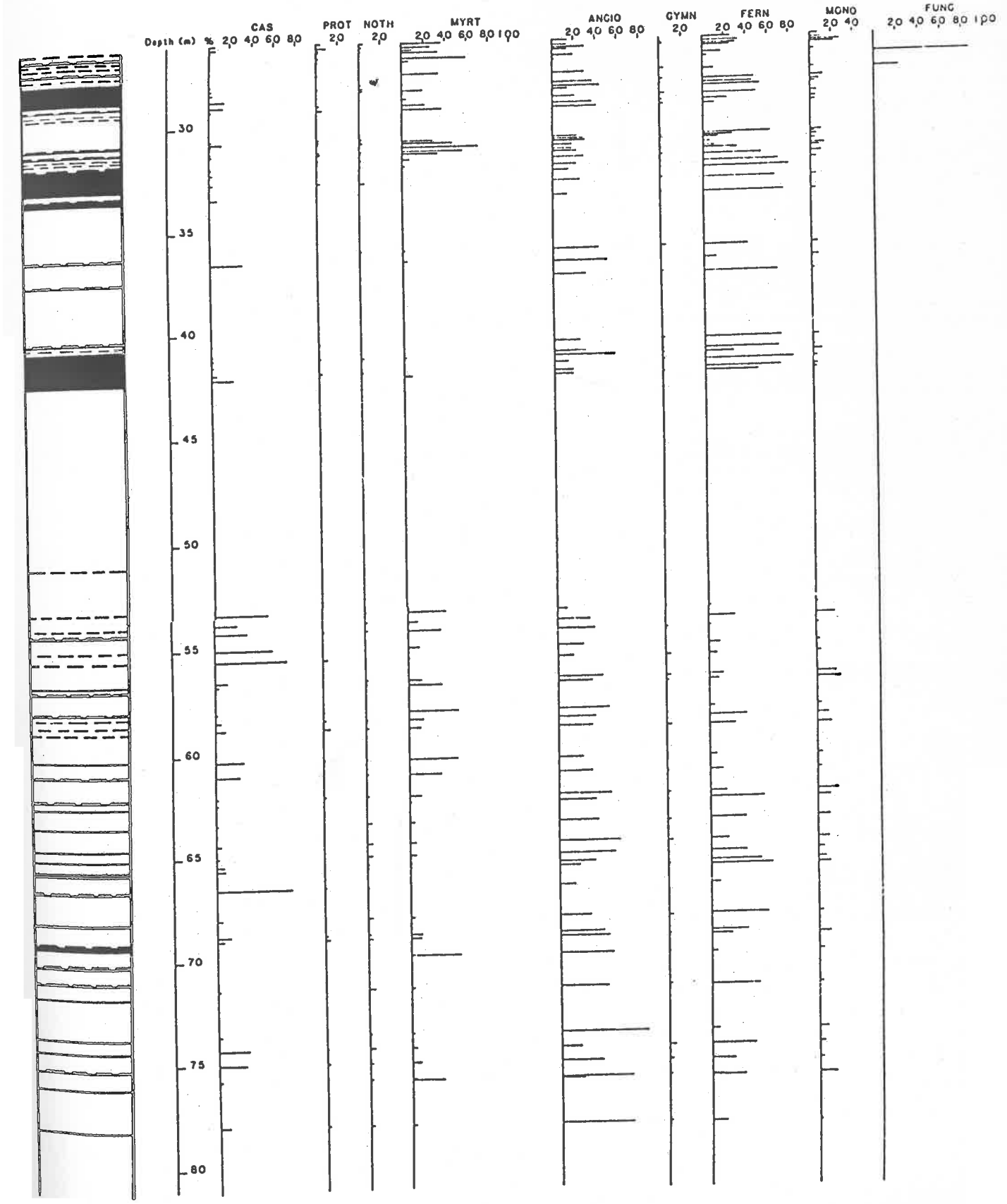

Depth (m)
%
CAS
2.0 4.0 6.0 8.0
PROT
2.0
NOTH
2.0
MYRT
2.0 4.0 6.0 8.0 10.0
ANCIO
2.0 4.0 6.0 8.0
GYMN
2.0
FERN
2.0 4.0 6.0 8.0
MONO
2.0 4.0
FUNG
2.0 4.0 6.0 8.0 10.0
30
35
40
45
50
55
60
65
70
75
80

Table 2: Pollen Frequencies of the Major Components of the Curlew Formation Palynoflora of ERD 118.

POLLEN FREQUENCIES OF MAJOR COMPONENTS

DEPTH UNIT	SAMPLE	CAS	PROT	NOTH	MYRT	ANGIO	GYMN	FERN	MONO	FUNG/ALG
	26.0	5.5	4.0	3.0	37.0	16.5	–	27.0	7.0	–
	26.2	6.0	9.5	1.5	26.5	15.0	0.5	31.0	10.0	–
1	26.3	1.0	1.5	–	10.0	30.5	1.0	28.5	27.5	–
	26.4	–	1.0	0.5	35.0	16.0	–	26.5	21.0	–
	26.7	–	1.0	–	60.0	20.0	–	16.0	3.0	–
	26.9	–	0.5	–	7.5	1.5	–	3.5	–	87.0
	27.5	–	0.5	–	34.5	29.5	2.0	8.0	3.5	22.0
	28.0	1.5	–	0.5	0.5	37.0	1.5	46.5	12.5	–
2	28.2	2.0	0.5	1.0	–	43.5	0.5	45.5	7.0	–
	28.3	3.5	–	1.0	18.0	16.0	–	57.5	4.0	–
	28.7	15.0	–	–	3.5	21.5	2.5	52.0	5.5	–
3	29.0	12.0	2.5	–	21.0	37.5	1.0	22.0	4.0	–
	29.2	2.0	4.0	–	38.0	40.5	1.5	10.5	3.5	–
	30.6	3.0	1.0	1.0	–	23.5	–	62.0	9.5	–
4	30.7	12.0	1.0	0.5	29.0	28.5	0.5	26.0	2.5	–
	30.8	1.0	0.5	1.5	46.0	31.5	0.5	13.0	6.0	–
	31.0	–	–	–	72.0	19.0	–	6.5	2.5	–
5	31.2	1.0	1.0	1.0	57.5	19.0	–	9.0	11.5	–
	31.3	1.5	2.0	0.5	33.0	23.0	0.5	32.5	7.0	–
	31.6	–	0.5	0.5	7.0	29.0	1.0	54.0	8.0	–
	31.9	2.0	–	0.5	2.0	21.5	0.5	68.0	5.0	Saept.
6	32.2	4.0	0.5	–	–	15.5	0.5	79.5	–	–
	32.7	4.0	2.0	2.5	–	25.5	1.0	62.5	2.5	–
	33.4	7.0	–	–	–	14.00	0.5	75.5	3.0	–
7	36.0	7.5	–	1.0	1.0	42.5	3.5	40.5	4.0	–
	36.5	30.0	–	–	2.5	49.5	–	12.0	6.0	–
8	37.3	–	–	0.5	–	28.5	1.5	67.5	1.5	Saept. N.P.*
9,10	40.5	0.5	0.5	–	–	23.5	1.0	71.0	3.5	–
	41.0	1.0	–	–	–	29.5	0.5	67.5	1.0	–
11	41.2	1.5	1.0	1.5	1.0	58.0	1.0	27.5	8.5	–
	41.5	1.5	–	–	–	14.0	1.0	81.5	2.0	–
	41.9	4.0	1.5	1.0	–	18.0	–	71.5	4.0	–
12	42.1	21.0	–	–	7.0	19.5	1.0	49.5	2.0	– N.P.*
13	53.3	52.0	–	0.5	37.0	9.0	–	1.0	0.5	–
14	53.8	20.5	–	1.5	10.0	28.0	–	23.0	17.0	–
15	54.2	30.0	0.5	1.5	31.0	33.5	1.0	1.0	1.0	Saept.
16	55.0	54.5	–	–	11.0	23.5	–	9.5	1.5	–
17	55.5	64.5	2.5	0.5	0.5	15.0	3.0	7.5	2.0	–
18	56.5	11.0	–	1.0	13.5	40.5	2.5	13.5	18.0	–
19	56.7	4.0	0.5	0.5	32.0	31.5	1.5	9.0	21.0	–
20	58.0	2.0	0.5	–	45.5	46.5	–	2.5	3.0	–
21	58.4	5.0	1.0	0.5	14.0	34.0	–	35.5	10.0	–
	58.8	8.0	3.5	1.0	11.0	31.5	4.0	23.5	13.5	–

N.P.* = No Pollen/Spores

22	60.3	23.5	0.5	0.5	45.0	22.5	–	3.0	5.0	–	
23	61.0	21.5	–	1.0	30.5	32.5	1.0	11.5	2.0	–	
24	62.1	1.5	1.5	1.0	11.0	48.5	2.0	15.5	19.5	–	
25	62.4	1.5	–	–	1.0	35.0	0.5	50.0	12.0	–	
26	63.4	1.0	–	3.5	3.5	37.5	2.0	33.0	12.5	–	
27	64.4	3.5	–	4.5	1.5	58.5	3.0	17.0	11.0	–	
28	65.0	2.5	–	3.0	2.5	52.0	0.5	34.5	4.5	–	
29	65.4	7.0	–	0.5	6.5	32.0	–	47.0	6.0	–	
	65.6	8.0	–	0.5	2.5	19.0	1.0	58.0	11.0	–	
30	66.5	71.0	1.0	0.5	3.0	16.0	–	8.5	–	–	
31	68.0	4.5	–	3.5	2.0	29.0	3.0	54.5	3.5	–	
32	68.8	13.0	1.0	1.5	11.5	41.0	–	31.5	0.5	–	
33	69.0	7.0	2.0	3.0	9.0	46.5	1.0	20.5	11.0	–	
34	69.8	–	–	–	44.5	48.0	0.5	2.5	4.5	–	
35											N.P.*
36	71.4	1.5	–	5.0	2.0	43.0	2.0	42.5	4.0	–	
37	73.6	2.0	–	1.0	1.0	81.0	–	6.5	8.5	–	
38	74.3	27.0	0.5	4.0	3.0	18.0	2.5	40.5	4.5	–	
39	75.0	24.5	1.0	1.5	6.5	39.5	2.0	21.5	3.5	–	
40	75.8	2.0	0.5	1.5	2.5	65.5	1.0	11.0	16.0	–	
	75.8	0.5	–	0.5	30.5	21.0	–	30.5	17.0	–	
41	78.0	9.0	1.5	2.0	2.5	66.5	1.5	16.0	1.0	–	
		10.0	0.9	1.0	15.3	30.8	0.94	31.8	6.9	1.7	

Table 3: Modern Affinities of Fossil Spores and Pollen recovered from the Curlew Formation of ERD 118.

NOTE: Pollen Plates are presented at end of this Chapter immediately after Table 3

MODERN AFFINITIES OF FOSSIL SPORES AND POLLEN OF THE CURLEW FORMATION

	AFFINITY		AUTHORITY
Myrtaceae			
Myrtaceidites eucalyptoides	MYRTACEAE	Eucalyptus	Cookson & Pike 1954
M. mesonesus	"	E.tessellaris, Metrosideros	"
M. parvus	"	Metrosideros	Hill & MacPhail 1983
M. verrucosus	"		
Myrtaceidites sp. A			
Myrtaceidites sp. B			
Myrtaceidites sp. C			
Myrtaceidites sp. D cf. M. eugeniioides	"	EUGENIINAE (Cleistocalyx, Eugenia	Cookson & Pike 1954
Myrtaceidites sp. E cf. M. rhamnoides	"	Austromyrtus	Martin 1973
Myrtaceidites sp. F cf. M. eucalyptoides		Rhodamnia, R.argentea	Martin 1973
Casuarinaceae			
Haloragacidites trioratus			
Haloragacidites harrisii	CASUARINACEAE	Gymnostoma	Hill & MacPhail 1983; Syber 1983
Proteaceae			
Banksieaeidites arcuatus	PROTEACEAE	Banksia, Dryandra; Austromuellera; Musgravea	Martin 1973,78
Beaupreaidites elegansiformis			
Propylipollis sp.			
Proteacidites kopiensis			
Proteacidites pachypolus			
Proteacidites sp. cf. P. tenuiexinus			
Proteacidites sp. cf. P. granulatus			
Proteacidites sp. cf. P. angulatus			
Proteacidites sp. cf. P. lepidus			
Proteacidites sp. cf. P. grandis			
Proteacidites sp. cf. Proteacidites sp. H			
Proteacidites sp. A			
Proteacidites sp. B			
Proteacidites sp. C			
Proteacidites sp. D			
Proteacidites sp. E			
Proteacidites sp. F			

Fagaceae			
Nothofagidites heterus/emarcidus	FAGACEAE	Nothofagus grandis	Martin 1978
Nothofagidites brachyspinulosa	"	N.gunnii	Martin 1978, Hill&Macphail 1983
Nothofagidites incrassata	"		
Nothofagidites asperus	"	N.cunninghamii N.menziesii	Hill & MacPhail 1983
Nothofagidites sp. A			
Nothofagidites sp. B			
Pteridophyta			
Azolla sp.	SALVINIACEAE	Azolla	Foster & Harris 1981
Fern sp. A. cf. Baculatisporites comaumensis	OSMUNDACEAE	Todea Osmunda	Dettmann 1963
Fern sp. B. cf. Dictyophyllidites	MATONIACEAE		
Fern sp. C. cf. Dictyophyllidites	MATONIACEAE	Matonia, M.pectinata	Campbell 1905
Fern sp. D. cf. Dictyophyllidites	"		Dettmann 1963
Lycopod sp.A cf. Camarozonosporites	LYCOPODIACEAE	Lycopodium	Harris 1965
Fern sp. H. cf. Stereisporites	SPHAGNALES	Sphagnum	Wilson & Webster 1946
Crassoretitriletes van raadshooveni			
Cyathidites splendens			
Cyathidites minor	CYATHEACEAE	Cyathea	Hill & MacPhail 1983
Fern sp. I cf. Cyatheacidites			
Dictyophyllidites sp. cf. D. concavus	MATONIACEAE		Dettmann 1963
Fern sp. J. cf. Dictyophyllidites	MATONIACEAE		Dettmann 1963
Fern sp. K. cf. Gleicheniidites circinidites	GLEICHENIACEAE	Gleichenia circinata	Dettmann 1963
Hamulatisporis sp.			
Kuylisporites waterbolkii			
Laevigatosporites major	POLYPODIACEAE		Kemp & Harris 1977
Laevigatosporites ovatus	BLECHNACEAE	Blechnum	Kemp & Harris 1977
Fern sp. L. cf. Osmundacidites wellmanii	OSMUNDACEAE		Couper 1958
Dictyophyllidites sp. A	MATONIACEAE		Dettmann 1965
Polypodiaccoisporites retirugatus			
Rugulatisporites sp.			
Punctatisporites spp.			
Rouseisporites reticulatus	RICCIACEAE	Riccia behyrichiana, R.canaliculata	Dettmann 1965
Fern sp. M. cf. Todisporites	CLEVACEAE OSMUNDACEAE		Martin 1978

Stereisporites sp.	SPHAGNALES	Sphagnum	Wilson & Webster 1946
Stereisporites sp. cf. S. antiquasporites	"		"
Todisporites spp.	MATONIACEAE		Dettmann 1965
Verrucatosporites sp.			
Fern sp. N.			
Fern sp. O.			
Fern sp. P.			
Fern sp. Q.			
Fern sp. R.			
Fern sp. S.			
Fern sp. T.			
Fern sp. U.			
Fern sp. V.			
Fern sp. W. cf. Ceratosporites	SELAGINELLACEAE	Selaginella	Cookson & Dettmann 1958
Fern sp. X. cf. Gleicheniidites	GLEICHENIACEAE	Gleichenia	Martin 1978
Fern sp. Y.			
Osmundacidites sp. A.			
Fern sp. Z. cf. Gleicheniidites			

Gymnospermae			
Phyllocladidites mawsonii	PODOCARPACEAE	Microcachrys tetragona	Martin 1978 Hill & MacPhail 1983
Ephedra notensis	EPHEDRACEAE		Martin 1978
Podocarpidites sp. A.	PODOCARPACEAE	Podocarpus	Harris 1965, Martin 1978 Luly et al 1980
Lygistepollenites florinii	"	Dacrydium, Podcarpus	Cookson 1956 Hill & Macphail 1983
Podocarpidites sp. cf. P. magnificus	PODOCARPACEAE		Harris 1970
Podocarpidites sp. B.	PODOCARPACEAE		Luly et al 1980
Dacrycarpidites australiensis			
Microcachryidites antarcticus	PODOCARPACEAE	Microcachrys tetragona	Luly et al 1980
Dilwynites granulatus	ARAUCARIACEAE		Hill & MacPhail 1983; Martin 1978
Cycad sp.	CYCADALES		
Phyllocladiditesssp.	PODOCARPACEAE		Harris 1965, Martin 1978, Luly et al 1980
Araucariacites sp.	ARAUCARIACEAE		Kershaw 1976
Ephedra sp.			
Monocotyledonae			
Liliacidites sp. A.	Liliaceae		Dettmann 1965, Kershaw 1970b Kemp & Harris 1977
Liliacidites sp. B.	"		"
Liliacidites sp. C.	"		"
Liliacidites sp. D.	"		"
Liliacidites sp. cf. L. aviemorensis	LILIACEAE		

Liliacidites sp. E.	LILIACEAE		Dettmann 1965, Kershaw 1970b; Kemp & Harris 1977
Liliacidites sp. cf. L. bainii	"		
?Graminidites sp. A.			
?Graminidites sp. B.			
Unknown A. cf. Sparganiaceaeipollenites	SPARGANIACEAE TYPHACEAE	Sparganium	Martin 1978 Kemp & Harris 1977
Unknown B.			
Rectosulcites sp. cf. R. microreticulatus			
Restioniidites sp. cf. R. homeopunctatus	RESTIONACEAE	Restio	Kemp & Harris 1977
Arecipites sp. A.	ARECACEAE (PALMAE)		Kemp & Harris 1977, Muller 1982
Angiospermae			
Tricolporites sp. A.			
Tricolporites sp. B. cf. Diospyros?	EBENACEAE	Diospyros	Christophel & Basinger 1982
Tricolporites sp. C.			
Tricolporites sp. cf. T. delicatus			
Tricolpites sp. cf T. alveolatus			
Tricolporites sp. cf. T. sphaerica	OLEACEAE		Cookson 1947
Tricolporites sp. N			
Tricolpites sp. cf. T. coprosmoides			
Tricolporites sp. cf. T. concinnus			
Tricolporites sp. D.			
Tricolporites sp. cf. T. valvatus			
Tricolporites sp. cf. T. microreticulatus			
Tricolporites sp. cf. T. prolata			
Tricolporites sp. E.			
Tricolporites sp. F.			
Tricolporites sp. cf. T. adelaidensis	SAXIFRAGACEAE	Polysoma	Harris 1970
Triorites orbiculatus			
Tricolpites sp. cf. T. voraginosus			
Simpsonipollis sp. A.	LEGUMINOSAE, ANACARDIACEAE, SAPINDACEAE, NOLANACEAE, CUCURBITACEAE		Kemp & Harris 1977
Tricolpites sp. B.			
Tricolporites sp. G.			
Tricolpites simatus	LORANTHACEAE		Cookson & Pike 1954, Martin 1978
Tricolpites thomasii	"		
Tricolpites sp. C.			
Tricolpites sp. cf. T. minutus			

Tricolpites sp. D.

Tricolpites sp. E.

Tricolpites sp. F.

Tricolpites sp. G.

Dilwynites sp. A.

Santalumidites cainozoicus SANTALACEAE Santalum Cookson & Pike 1954

Corsinipollenites oclus noctis ONAGRACEAE Epilobium Daghlian et al 1984

Anacolosidites sectus OLACACEAE Anocolosa Cookson & Pike 1954

Concolpites sp. cf. C. leptus

Polycolporites sp. cf. P.esobalteus POLYGALACEAE McIntyre 1968

Tetracolpites sp. A.

Cupanieidites sp. cf. C. major SAPINDACEAE (CUPANIEAE) Cupaniopsis wadsworthii Cookson & Pike 1954

Cupanieidites sp. cf. C. orthoteichus " — Mischocarpus pyriformis, Cupaniopsis curvidens, Jagera pseudorhus, Rhysotoechia bifoliolata, Toechima tenax — Cookson & Pike 1954

Cupanieidites sp. cf. C. reticularis " — Lepiderema punctulata, Sarcopteryx stipitata — Cookson & Pike 1954

Cupanieidites sp. cf. C. sp. B "

Tricolpites sp. H.

Tricolporites sp. H.

Malvacipollis sp. cf. M. sp. C

Malvacipollis sp. cf. M. subtilis EUPHORBIACEAE — Petalostigma Martin 1978,82; Dissilaria baloghioides "; Austrobuxus swainii "

Zonocostites ramonae RHIZOPHORACEAE Muller 1964, Martin 1978

Clavatipollenites hughesii CHLORANTHACEAE Couper 1958

Tiliaepollenites sp. cf. T. notabilis

Polyporina chenopodiaceoides CHENOPODIACEAE, AMARANTHACEAE Martin 1978

Margocolporites sp. A.

Polycolporites sp. A.

Tricolpites sp. I.

Tricolporites sp. I.

Tricolpites sp. J.

Tricolporites sp. J.

Tricolporites sp. K.

Tricolporites sp. L.

Helciporites sp. cf. H. astrus

EXPLANATION OF POLLEN PLATES (1-6).

Unless otherwise stated, all figures are at a magnification of 630X. Coordinates for specimens are from either a Zeiss (Z) standard research microscope (BOT. RES. No. 10) or a Reichart Univar research microscope (R) they are given immediately after the slide number. The first part of this number represents the sample interval and unless otherwise stated, these are from ERD 118. The slides are held in the Palaeobotany Laboratory, Botany Department, University of Adelaide.

PLATE 1

Figure 1. Fern sp.A cf. Baculatisporites comaumensis (Cookson) Potonie, 28.3/3 87.0, 28.0 (Z).

Figure 2. Fern sp.B cf. Dictyophyllidites, 29.0/1 134.7, 39.6 (R).

Figure 3. Fern sp.C cf. Dictyophyllidites, 65.6/1 128.8, 50.2 (R).

Figure 4. Fern sp.D cf. Dictyophyllidites, 27.7/3 130.0, 44.1 (R).

Figure 5. Lycopod sp.A cf.Camarozonosporites, 41.5/1 130.4, 52.8 (R)

Figure 6. Fern sp.I cf. Cyatheacidites, 400X, 41.5/1 135.0, 51.1 (R).

Figure 7. Dictyophyllidites sp.A., 28.0/1 128.7, 37.7 (R).

Figure 8. Todisporites sp.A, 28.0/1 128.9, 42.5 (R).

Figure 9. Crassoretitriletes van raadshooveni Germeraad, Hopping and Muller. 58.8/1 120.6, 56.8 (R).

Figure 10. Rugulatisporites sp., 400X, 61.0/1 131.0, 56.0 (R).

Figure 11. Punctatisporites sp., 28.0/1 128.9, 42.3 (R).

Figure 12. Todisporites sp.B, 30.7/1 129.3, 33.2 (R).

Figure 13. Fern sp.M cf. Todisporites, 32.7/1 128.9, 37.9 (R).

Figure 14. Fern sp.J cf. Dictyophyllidites, 30.6/1 141.6, 19.2 (R).

Figure 15. Fern sp.Y, 31.2/1 123.1, 43.0 (R).

Figure 16. Cyathidites australis Harris, 71.4/1 120.1, 52.4 (R).

Figure 17. Fern sp.U, 68.0/1 135.3, 42.1 (R).

Figure 18. Azolla capricornica Foster and Harris, microspore massulae 65.6/1 91.2, 26.8 (R).

Figure 19. Fern sp.S, 41.0/4 131.3, 35.8 (R).

Figure 20. Fern sp.R, 40.3/2 125.3, 24.5 (R).

PLATE 1

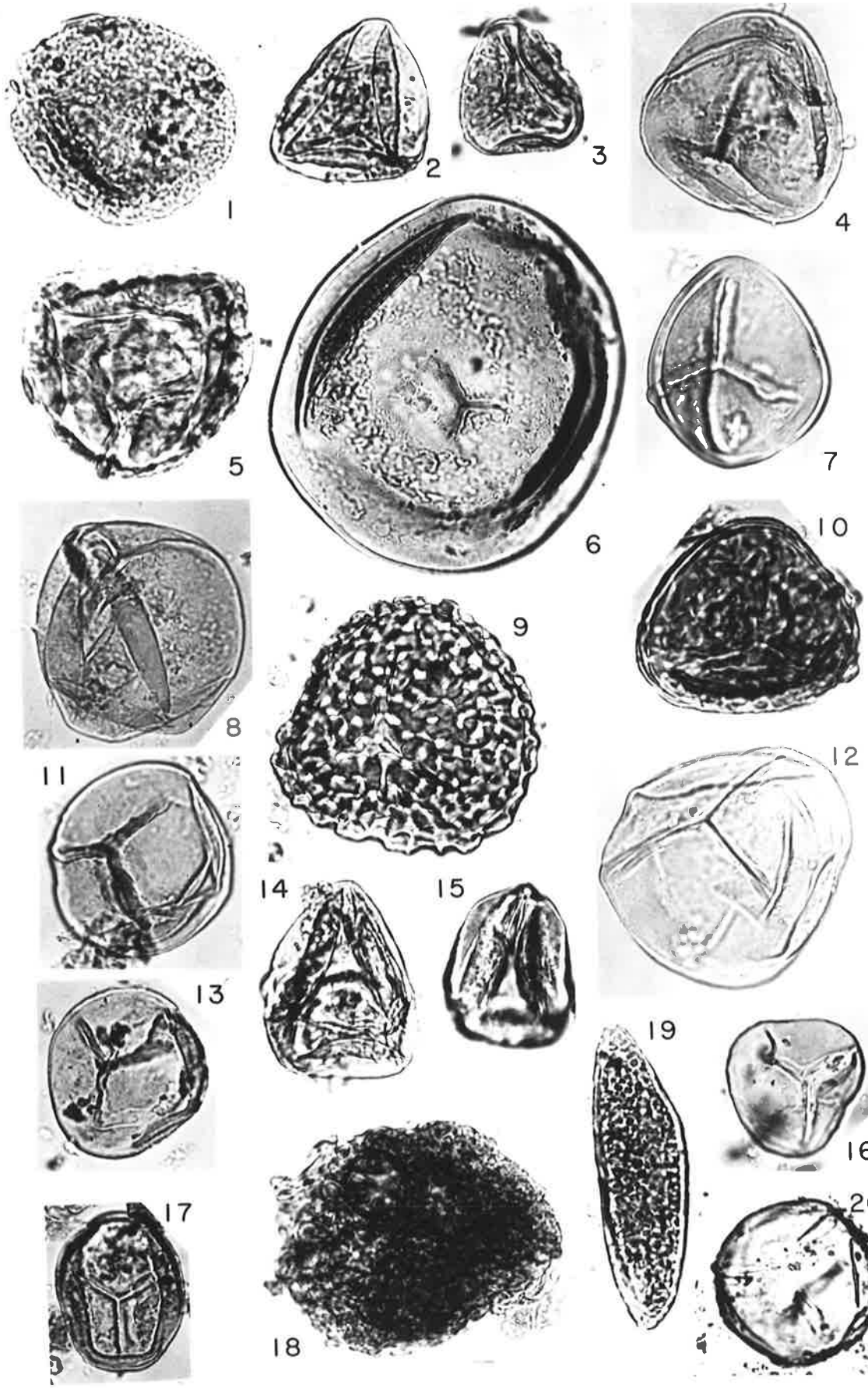


Figure 39. Arecipites sp.A, 1000X, ERD 110, 37.3/1 92.1, 32.9 (Z).

Figure 40. Restioniidites sp. cf. R. homeopunctatus (McIntyre) Partridge, 65.6/1 128.9, 50.0 (R).

Figure 41. Rectosulcites sp. cf. R. microreticulatus Harris, 30.6/1 135.7, 32.8 (R).

Figure 18. Hamulatisporis sp., 41.2/2 126.2, 62.2 (R).

Figure 19. Ephedra sp. 26.3/2 127.3, 30.5 (R).

Figure 20. Same as Figure 19.

Figure 21. Verrucatosporites sp., 31.2/1 129.5, 46.3 (R).

Figure 22. Fern sp.P, 1000X, 41.9/2 124.9,48.2 (R).

Figure 23. Fern sp.W cf. Ceratosporites, 1000X, 61.0/2 108.2, 26.4 (Z).

Figure 24. Fern sp.Z cf. Gleicheniidites, 40.3/2 91.2, 26.8 (Z).

Figure 25. Fern sp.X cf. Gleicheniidites, 1000X, 30.6/1 109.9, 32.4 (Z).

Figure 26. Liliacidites sp.A, 28.3/3 123.8, 32.1 (R).

Figure 27. Liliacidites sp.B, 56.7/1 133.8, 40.3 (R).

Figure 28. Liliacidites sp.C, 1000X, ERD 117, 46.1/1 98.1, 36.0 (Z).

Figure 29 Dictyophyllidites sp. cf. D. concavus Harris, 31.2/1 136.5, 55.0 (R).

Figure 30. Liliacidites sp.D, 1000X, ERD 112, 106.5/1 108.3, 22.2 (Z)

Figure 31. Liliacidites sp. cf. L. aveimorensis McIntyre, 30.8/1 129.7, 30.9 (R).

Figure 32. Liliacidites sp.E, 1000X, ERD112, 106.5/1 96.2, 28.2 (Z).

Figure 33.?Graminidites sp.A, 30.6/1 129.4, 30.1 (R).

Figure 34. Liliacidites sp.F, 1000X, ERD 110, 37.3/1 93.0, 33.4 (Z).

Figure 35. Liliacidites sp. cf. L. bainii Stover, 1000X, ERD 117, 46.1/1 96.4, 34.8 (Z).

Figure 36.?Graminites sp.B, 1000X, 26.3/1 113.6, 27.2 (R).

Figure 37. Genus A sp. cf. Sparganiaceaepollenites, 1000X, 68.0/1 135.8, 37.1 (R).

Figure 38. Genus B sp., 69.0/1 133.5, 37.9 (R).

PLATE 2

Figure 1. Rouseisporites sp., 30.6/1 136.0, 15.5 (R).

Figure 2. Polypodiaceoisporites retirugatus Muller, 30.8/1 133.2, 37.1 (R).

Figure 3. Cyathidites minor Couper, 1000X, 29.0/1 129.4, 48.8 (R).

Figure 4. Cyathidites minor Couper, 78.0/1 131.7, 18.0 (R).

Figure 5. Laevigatosporites major (Cookson) Krutzch, 1000X, ERD 110 37.3/1 101.0, 38.3 (R).

Figure 6. Fern sp.V, 68.8/1 134.0, 28.4 (R).

Figure 7. Fern sp.O, 31.3/1 130.0, 40.6 (R).

Figure 8. Laevigatosporites ovatus Wilson and Webster, 28.3/2 134.5, 45.2 (R).

Figure 9. Stereisporites sp. cf. S.antiquasporites Wilson and Webster, 28.3/2 134.5, 45.2 (R).

Figure 10. Clavatipollenites hughesii Couper, 41.2/1 132.3, 19.7 (R).

Figure 11. Kuylisporites waterbolkii Potonie, 58.0/1 127.0, 20.5 (R).

Figure 12. Fern sp.Q, 40.3/2 125.3,24.5 (R).

Figure 13. Fern sp.H cf. Stereisporites 33.4/2 130.9, 41.1 (R).

Figure 14. Fern sp.T, 30.6/1 129.7, 30.2 (R).

Figure 15. Fern sp.N, 1000X, 28.0/1 128.3, 50.5 (R).

Figure 16. Stereisporites sp., 75.0/1 124.9, 17.7 (R).

Figure 17. Fern sp.L cf. Osmundacidites wellmanii Couper, 41.2/2 126.2, 62.0 (R).

PLATE 2

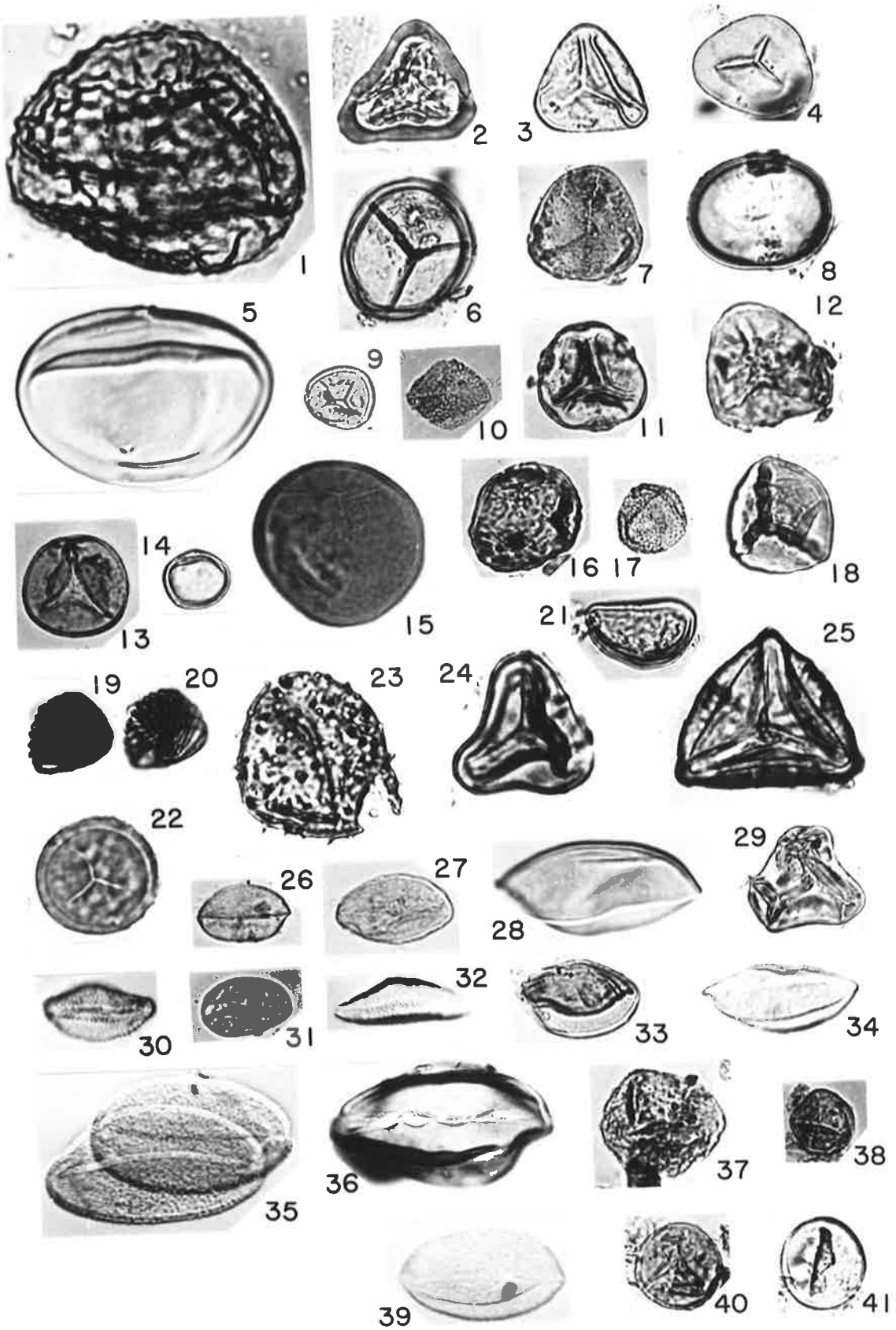

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41

PLATE 3

Figure 1. Podocarpidites sp. cf. P. magnificus Harris, 28.2/1 137.9, 64.2 (R).

Figure 2. Phyllocladidites mawsonii (Cookson) Couper, 37.3/1 136.8, 23.7 (R).

Figure 3. Phyllocladidites mawsonii (Cookson) Couper, 29.0/1 130.8, 46.2 (R).

Figure 4. Phyllocladidites sp., 78.0/1 129.6, 24.0 (R).

Figure 5. Phyllocladidites sp., 31.3/1 130.1, 40.6 (R).

Figure 6. Araucariacites sp., 75.0/1 125.1, 18.6 (R).

Figure 7. Podocarpidites sp. cf. P. magnificus Harris, 74.3/1 128.3, 31.2 (R).

Figure 8. Lygistepollenites florinii (Cookson and Pike) Stover and Evans, 41.2/2 126.2, 62.2 (R).

Figure 9. Lygistepollenites florinii (Cookson and Pike) Stover and Evans, 36.0/1 130.0, 52.4 (R).

Figure 10. Dilwynites granulatus Cookson, 30.8/1 127.9, 40.0 (R).

Figure 11. Ephedra notensis Cookson, 29.0/1 130.8, 46.2 (R).

Figure 12. Podocarpidites sp.A, 71.5/1 132.0, 30.5 (R).

Figure 13. Microcachryidites antarcticus Cookson, 71.4/1 130.8, 46.0 (R).

Figure 14. Dacrycarpidites australiensis Cookson and Pike, 26.4/1 127.3, 47.8 (R).

Figure 15. Ephedra notensis Cookson, 1000X, ERD 117, 46.1/1 93.0, 26.7 (Z).

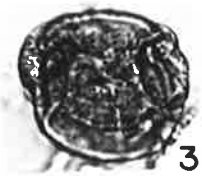
Figure 16. Cycad sp. 1000X, 60.3/1 119.2, 46.7 (Z).

Figure 17. Podocarpidites sp.B, 500X, 26.3/2 99.6, 30.8 (Z).

PLATE 3


1


2

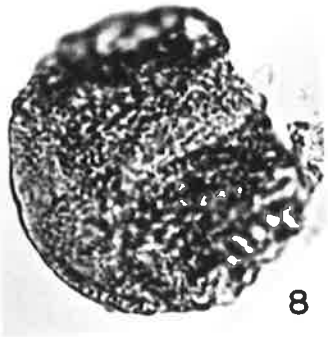

3


4


5


6

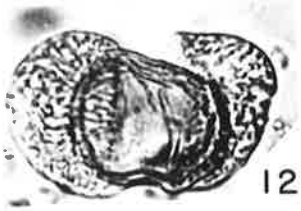

7

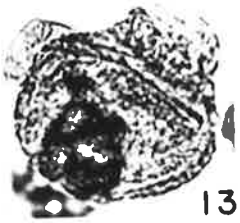

8

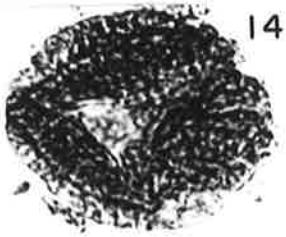

9

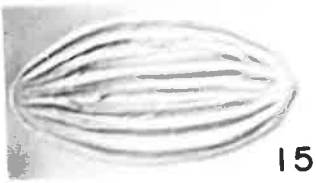

10


11


12


13


14


15


16


17

Figure 34. Tricolpites thomasii Cookson and Pike, 31.0/1 121.6, 56.7 (R).

Figure 35. Zonocostites ramonae Germeraad, Hopping and Muller, 56.7/1 127.1, 61.7 (R).

Figure 36. Tricolporites sp.J, 28.0/1 130.3, 26.3 (R).

Figure 37. Cupanieidites sp. cf. C. orthoteichus Cookson and Pike, 58.0/1 132.9, 25.7 (R).

Figure 38. Polycolporites sp. cf. P. esobalteus McIntyre, 37.3/1 131.9, 25.3 (R).

Figure 15. Santalumidites cainozoicus Cookson and Pike, 29.0/1 132.1, 54.0 (R).

Figure 16. Dilwynites sp.A, 30.8/1 129.7, 42.3 (R).

Figure 17. Tricolpites sp. cf. T. coprosmoides Couper, 26.3/1 138.4, 24.9 (R).

Figure 18. Tricolporites sp.E, 29.2/1 130.4, 33.8 (R).

Figure 19. Tricolporites sp.D, 75.0/1 137.3, 16.8 (R).

Figure 20. Tricolporites sp.N, 41.2/1 137.2, 22.0 (R).

Figure 21. Malvacipollis sp. cf. M. subtilis Stover, ERD 117, 1000X, 46.1/1 92.5, 22.1 (Z).

Figure 22. Tricolpites sp.F, 30.8/1 125.9, 45.1 (R).

Figure 23. Tricolporites sp.F, 29.0/1 132.1, 54.0 (R).

Figure 24. Tricolporites sp.I, 41.5/1 139.8, 45.0 (R).

Figure 25. Cupanieidites sp. cf. Cupanieidites sp.B Foster, 30.7/1 134.5, 46.6 (R).

Figure 26. Corsinipollenites oclus noctis (Thiergart) Nakoman, 36.0/1 135.2, 30.3 (R).

Figure 27. Tricolpites sp.E, 58.8/1 141.2, 53.8 (R).

Figure 28. Tricolporites sp. cf. T. concinnus Harris, 28.3/1 128.3, 32.1 (R).

Figure 29. Tricolporites sp.C, 31.0/1 140.0, 61.9 (R).

Figure 30. Tricolpites sp.I, 68.8/1 132.8, 44.6 (R).

Figure 31. Tricolporites sp. cf. T. voraginosus Harris, 30.7/1 133.3, 36.8 (R).

Figure 32. Tricolpites sp.B, 31.0/1 124.9, 63.1 (R).

Figure 33. Tricolpites sp.E, 58.8/1 141.2, 53.8 (R).

PLATE 4

Figure 1. Malvacipollis sp. cf. Malvacipollis sp.C Foster, 28.0/1 134.5, 46.0 (R).

Figure 2. Tricolporites sp. cf. T. valvatus Harris, 42.1/1 120.3, 46.8 (R).

Figure 3. Tricolpites thomasii Cookson and Pike, 1000X, 31.2/1 136.1, 57.1 (R).

Figure 4. Tricolporites sp. cf. T. adelaidensis Harris, 55.5/1 134.0, 51.0 (R).

Figure 5. Cupanieidites sp. cf. C. orthoteichus Cookson and Pike, 30.8/1 137.0, 32.8 (R).

Figure 6. Tricolporites sp.M, 1000X, 41.0/1 139.5, 43.0 (R).

Figure 7. Triorites orbiculatus McIntyre, ERD 117, 1000X, 46.1/1 94.4, 30.5 (Z).

Figure 8. Corsinipollenites oclus noctis (Thiergart) Nakoman, 32.2/1 124.6, 48.5 (R).

Figure 9. Tricolporites sp.A, 29.2/1 123.9, 21.9 (R).

Figure 10. Tiliaepollenites sp. cf. T. notabilis Harris, 1000X, 26.3/ 86.4, 40.3 (Z).

Figure 11. Tricolporites sp. cf. T. sphaerica Cookson, 62.4/1 137.3, 33.5 (R).

Figure 12. Margocolporites sp.A, 30.8/1 134.9, 36.5 (R).

Figure 13. Tricolporites sp.B cf. Diospyros? Christophel and Basinger 31.2/1 135.2, 52.9 (R).

Figure 14. Cupanieidites sp. cf. C. orthoteichus Cookson and Pike, 30.8/1 131.1, 42.6 (R).

PLATE 4

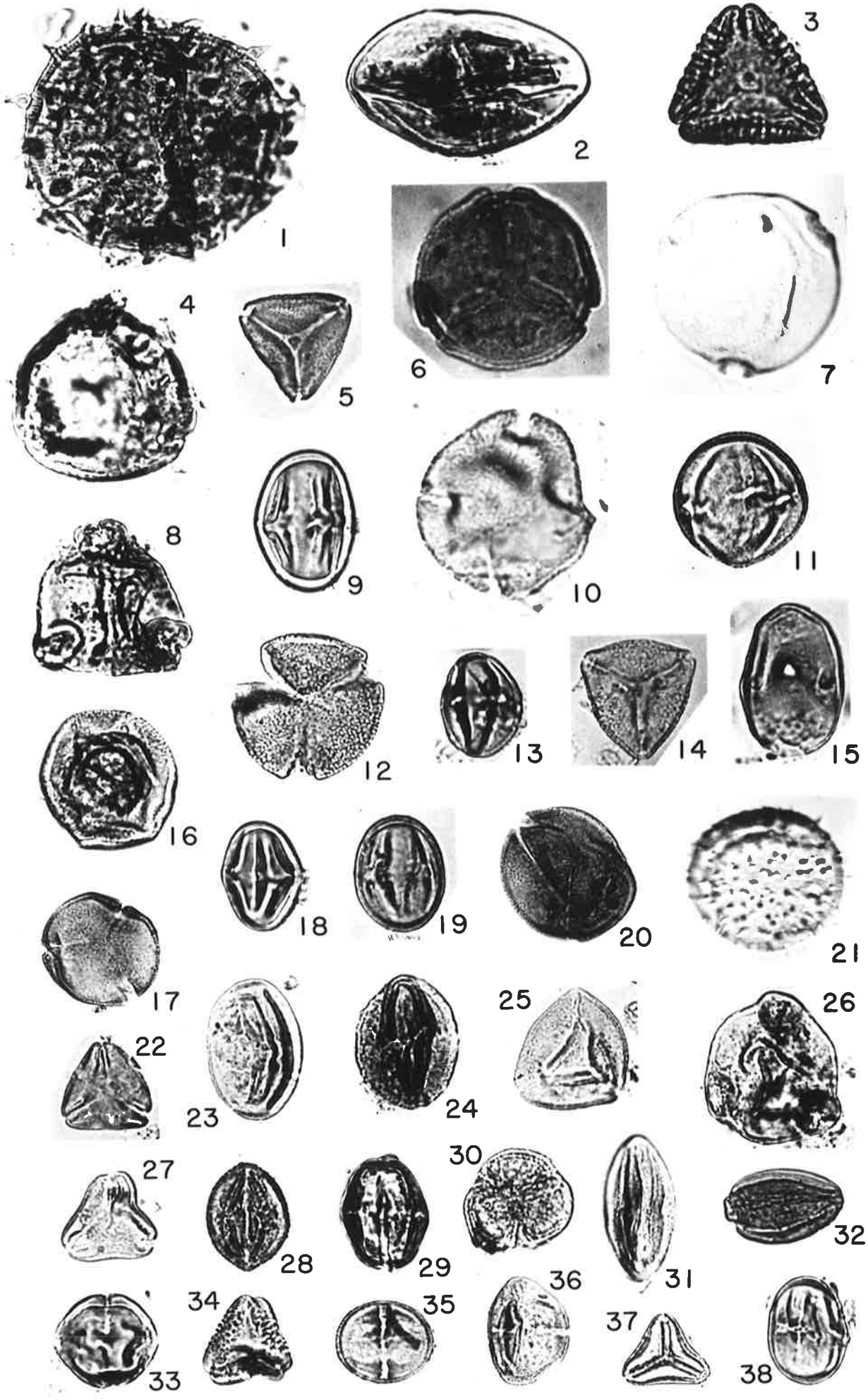

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38

Figure 52. Banksieaeidites arcuatus Stover, 32.2/3 134.0, 42.8 (R).

Figure 36. Myrtaceidites parvus Cookson and Pike, 30.8/1 126.9, 37.9 (R).

Figure 37. Myrtaceidites verrucosus Partridge, 78.0/1 128.5, 39.0 (R)

Figure 38. Tricolporites sp.K, 68.8/1 127.5, 40.4 (R).

Figure 39. Myrtaceidites eucalyptoides Cookson and Pike, 31.0/1 128.5 63.1 (R).

Figure 40. Myrtaceidites mesonesus Cookson and Pike, 30.8/1 128.0, 54.5 (R).

Figure 41. Myrtaceidites mesonesus Cookson and Pike, 26.9/4 131.5, 21.2 (R).

Figure 42. Myrtaceidites sp.B, 31.0/1 130.4, 55.8 (R).

Figure 43. Myrtaceidites sp.D cf. M. eugeniioides Cookson and Pike, 30.7/1 131.3, 43.9 (R).

Figure 44. Myrtaceidites sp.E cf. M. rhamnoides Martin, 308./1 127.9 35.0 (R).

Figure 45. Myrtaceidites sp.A, 58.0/1 127.0, 20.5 (R).

Figure 46. Myrtaceidites sp.C, 29.0/1 126.4, 40.2 (R).

Figure 47. Myrtaceidites sp.F cf. M. eucalyptoides Cookson and Pike, 31.0/1 129.2, 58.7 (R).

Figure 48. Myrtaceidites sp.F cf. M. eucalyptoides cluster, 31.0/1 130.5, 62.9 (R).

Figure 49. Haloragacidites harrisii Mildenhall and Harris, 1000X, 58.8/1 134.7, 61.1 (R).

Figure 50. Haloragacidites trioratus Couper, 1000X, 27.5/1 119.0, 38. (R).

Figure 51. Beaupreaidites eleganiformis Stover, 26.7/2 134.0, 42.8 (R).

Figure 18. Concolpites sp. cf. C. leptus Partridge, 1000X, 41.9/2 138.3, 42.5 (R).

Figure 19. Helciporites sp. cf. H. astrus Partridge, 41.9/1 139.9, 35.7 (R).

Figure 20. Simpsonipollis sp.A, 62.1/1 125.0, 60.0 (R).

Figure 21. Polyporina chenopodiaceoides Martin, 31.1/1 139.2, 15.6 (R).

Figure 22. Tricolporites sp. cf. T. sphaerica Cookson, 29.2/1 133.0, 29.2 (R).

Figure 23. Tricolpites sp.H, 54.2/1 131.3, 32.2 (R).

Figure 24. Polycolporites sp.A, 78.0/1 132.2, 36.2 (R).

Figure 25. Tricolporites sp. cf. T. delicatus 61.0/1 128.2, 56.0 (R).

Figure 26. Tricolpites sp.C, 31.0/1 123.6, 61.8 (R).

Figure 27. Cupanieidites sp. cf. C. reticulatus Cookson and Pike, 40.3/2 129.7, 28.9 (R).

Figure 28. Tricolporites sp. cf. T. sphaerica Cookson, 30.6/1 123.9, 30.0 (R).

Figure 29. Tricolporites sp.L, 30.7/1 128.0, 35.9 (R).

Figure 30. Tricolpites simatus Partridge, 31.0/1 123.2, 61.9 (R).

Figure 31. Cupanieidites sp. cf. C. major Cookson and Pike, 30.8/1 137.0, 30.5 (R).

Figure 32. Anacolosidites sectus Partridge, 58.0/1 123.8, 22.8 (R).

Figure 33. Tricolpites simatus Partridge, 31.0/1 135.0, 61.0 (R).

Figure 34. Tetracolpites sp.A, 56.7/1 133.0, 61.8 (R).

Figure 35. Cluster of Myrtaceidites mesonesus grains, 31.1/1 138.0, 62.9 (R).

PLATE 5

Figure 1. Saeptodinium sp. cf. S. gravattensis Harris, ERD 117, 1000X, 46.1/1 93.3, 29.2 (Z).

Figure 2. Nothofagidites heterus Cookson, 62.1/1 125.8, 58.9 (R).

Figure 3. Nothofagidites asperus Cookson, 28.0/1 133.5, 30.2 (R).

Figure 4. Nothofagidites brachyspinulosa Cookson, 1000X, 65.0/3 124.0, 17.1 (R).

Figure 5. Nothofagidites incrassata Cookson, 58.8/1 120.0, 58.1 (R).

Figure 6. Tricolporites sp.G, 78.0/1 123.3, 36.7 (R).

Figure 7. Tricolporites sp.J, 58.0/1 128.7, 27.8 (R).

Figure 8. Nothofagidites incrassata Cookson, ERD 117, 1000X, 46.1/1 96.0, 35.6 (Z).

Figure 9. Nothofagidites sp.A, 68.0/1 13.9, 44.0 (R).

Figure 10. Nothofagidites sp.B, 78.0/1 129.0, 36.6. (R).

Figure 11. Tricolpites sp.G, 30.8/1 134.3, 33.3 (R).

Figure 12. Tricolpites sp. cf. T. alveolatus Couper, 30.8/1 131.0, 46.2 (R).

Figure 13. Tricolpites sp. cf. T. minutus (Brenner) Dettmann, 37.3/1 129.4, 37.2 (R).

Figure 14. Tricolporites sp. cf. T. microreticulatus Harris, 56.5/1 122.3, 46.9 (R).

Figure 15. Anacolosidites sectus Partridge, 58.0/1 132.8, 24.8 (R).

Figure 16. Tricolporites sp. cf. T. prolata Cookson, 29.2/1 123.9, 20.9 (R).

Figure 17. Tricolpites sp.G, 41.2/1 137.2, 22.0 (R).

PLATE 5

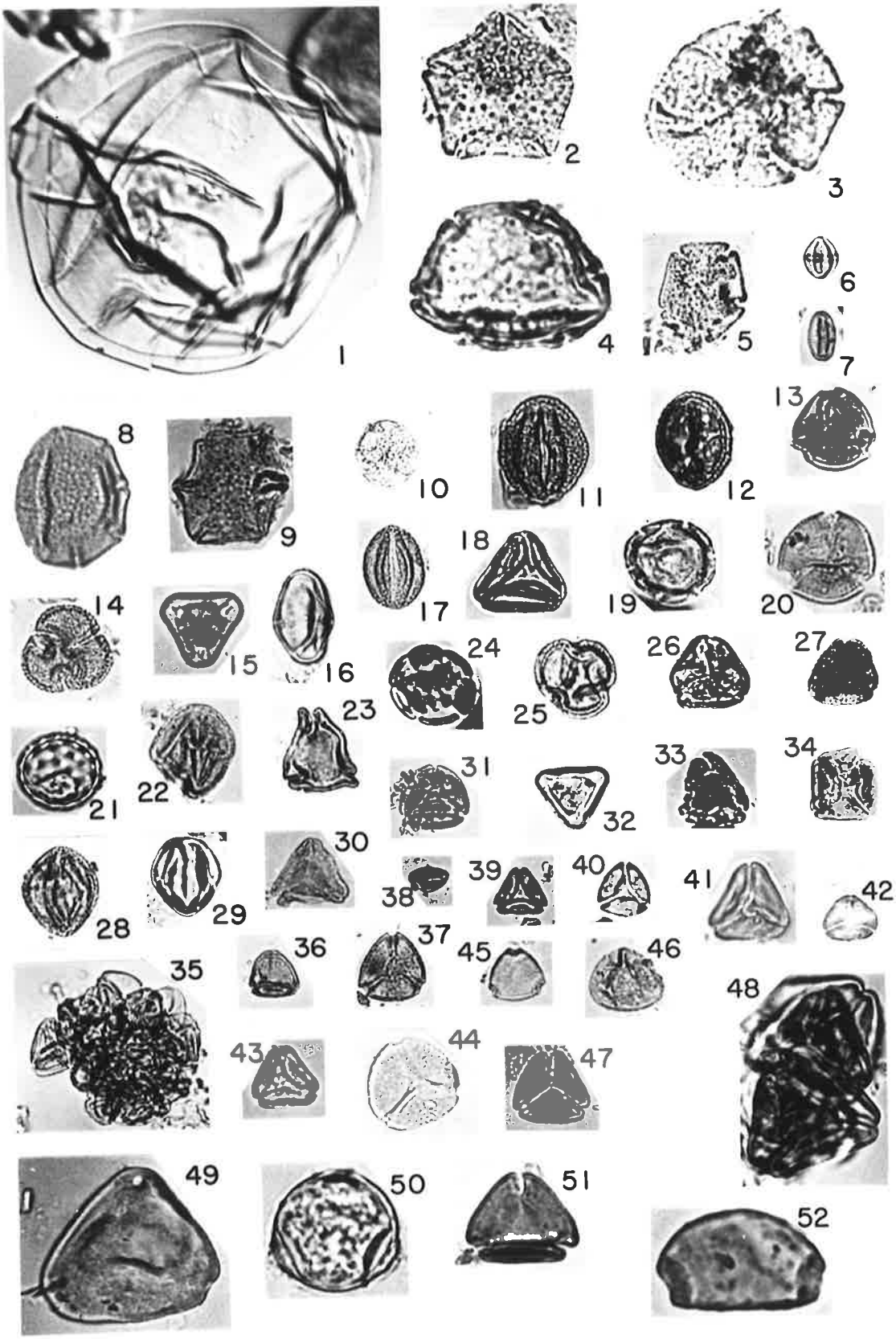

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52

Figure 18. Proteacidites sp.D, 62.1/1 123.0, 60.3 (R).

Figure 19. Proteacidites sp.A, 58.0/1 124.6, 33.7 (R).

PLATE 6

Figure 1. Proteacidites sp.D, 62.1/1 126.9, 61.1 (R).

Figure 2. Proteacidites sp. cf. P. granulatus Cookson, 28.3/2 123.1, 40.5 (R).

Figure 3. Proteacidites sp. cf. P. grandis Cookson, 40.3/1 132.1, 39.6 (R).

Figure 4. Proteacidites sp. cf. Proteacidites sp.H Foster, 29.2/1 129.2, 32.2 (R).

Figure 5. Proteacidites kopiensis Harris, 58.0/1 125.1, 35.0 (R).

Figure 6. Same as Figure 5.

Figure 7. Proteacidites pachypolus Cookson and Pike, 41.9/1 136.4, 58.0 (R).

Figure 8. Proteacidites sp. cf. P. tenuiexinus Stover, 55.5/1 135.5, 27.5 (R).

Figure 9. Proteacidites sp.C, 56.7/1 126.0, 34.0 (R).

Figure 10. Propylipollis latrobensis (Harris) Martin and Harris, 30.7/1 127.9, 33.3 (R).

Figure 11. Same as Figure 10.

Figure 12. Proteacidites sp. cf. Proteacidites sp.H Foster, 29.0/1 131.4, 57.5 (R).

Figure 13. Proteacidites sp.E, 58.8/1 135.4, 62.3 (R).

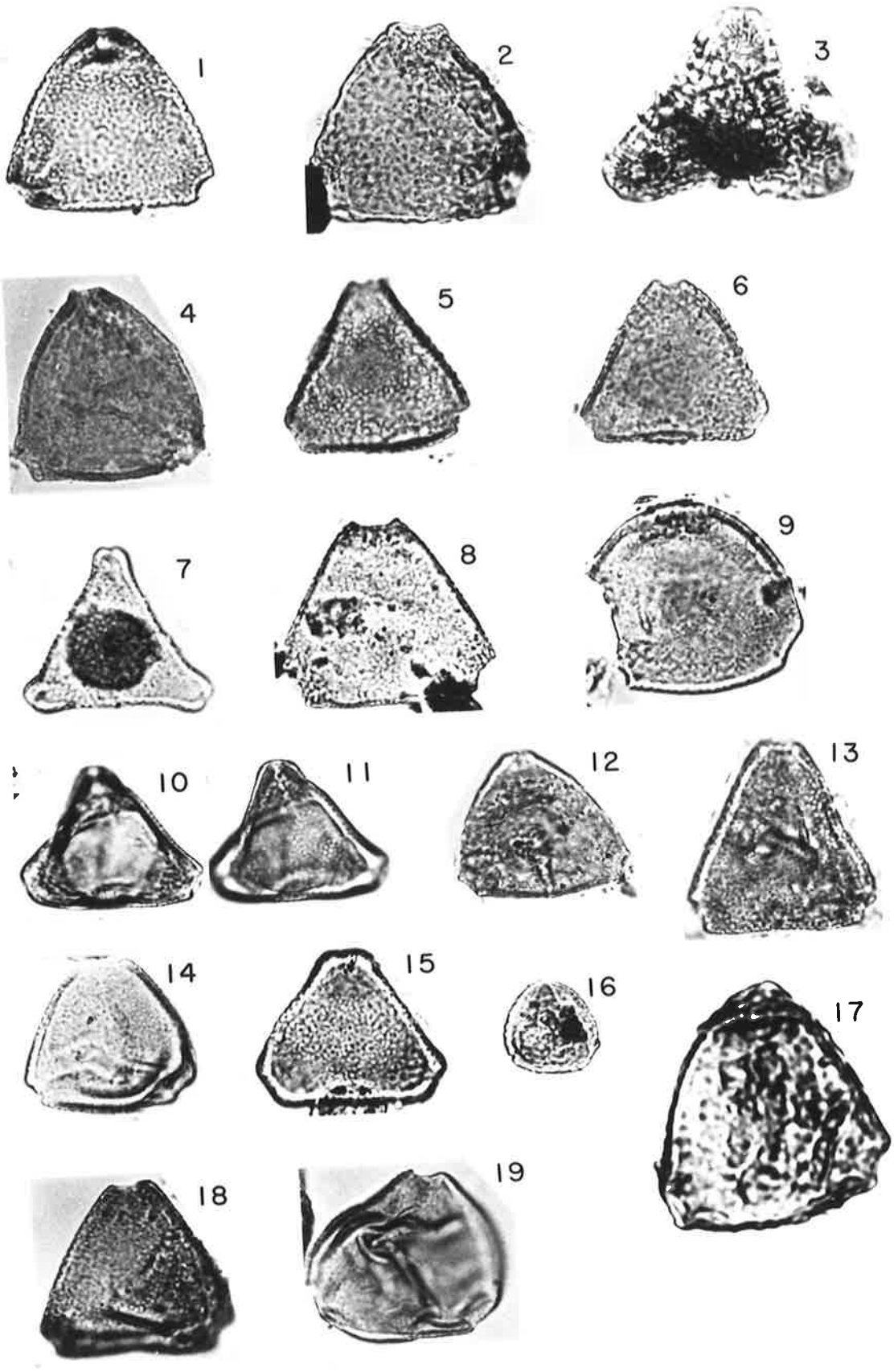
Figure 14. Proteacidites sp.B, 58.0/1 125.1, 35.2 (R).

Figure 15. Proteacidites sp. cf. P. angulatus Stover, 55.5/1 139.7, 19.9 (R).

Figure 16. Proteacidites sp. cf. P. lepidus Harris, 62.1/1 77.5, 28.6 (Z).

Figure 17. Proteacidites sp.F, 66.5/1 130.0, 19.7 (R).

PLATE 6



CHAPTER 4

MEGAFOSSIL DESCRIPTIONS

4.1 Cuticular Analysis

After initial examinations of the material, the 15cm core samples were no longer considered suitable as they came from very few holes, contained very little in the way of plant fossils and the majority of holes sampled were outside the scope of this study (i.e.,not in the Curlew Formation). Extensive 7.5cm core drilling over the entire deposit provided a plentiful supply of Curlew sediments which importantly contained plant remains. The fact that these 7.5cm cores provided the fossil material meant that intact/entire plant remains were highly unlikely and as a result of this a study of leaf architecture, using a character set similar to Hickey's (1973) was not possible. The material recovered, as expected, was very fragmentary but well preserved in most instances. It consists of variable sized leaf fragments. A cuticular investigation was therefore undertaken.

The cuticle (cuticular membrane: Roelofsen, 1952, 1959) has long been used by palaeobotanists in classification as it represents an imprint of the underlying epidermal features which provide consistently definable characters (Stace, 1965). It consists of a two layered sheet of non-cellular material covering all mature parts of the plant, with the possible exception being the root. The inner layer, known as the cuticular layer, is composed of cellulose and cutin. The thinner outer layer, known as the cuticle proper, is almost entirely composed of cutin. Cutin consists of a number of highly polymerized long-chain hydroxy-fatty acids which on exposure to air harden to a vanish-like cover (Stace, 1965). It is this property which make the cuticle highly

resistant to the effects of age, micro-organisms and chemicals and is therefore most suitable for palaeobotanical studies.

Cuticular analysis of fossil leaves has been in use since the start of the twentieth century when a large number of works, from short notes to large volumes, began to appear on the subject of fossil cuticles. A number of important works produced during this early stage include, Solereder (1908), Narthorst (1907-12) and Florin (1920). Bandulska (1923-31) was the first to describe fossil and extant dicotyledonous cuticles. She studied the cuticular anatomy of coniferous and angiospermous leaves from the Eocene flora of Bournemouth, England and placed species in the families Lauraceae, Fagaceae and Myrtaceae. In 1932 Odell attempted to prove that epidermal and cuticular features of angiosperms had no taxonomic value. There were, however, two major points she failed to recognise, firstly that the identification of species could not be achieved using a single character and that a degree of variation in form is often more important taxonomically than is a conservative feature.

Other more recent but equally important contributions to the study of cuticular anatomy have been made by Stace (1965), Dilcher (1974), Metcalfe and Chalk (1950) and Wilkinson in Metcalfe and Chalk (1979).

4.1.1 Description of Cuticle Parataxa

The main aim of a description is to aid in subsequent recognition of the taxon involved (Mayr, 1969). To achieve such an aim when describing plant fossils which are fragmentary, e.g. dispersed

cuticles, it is important to use as many features as possible. Good descriptive terminology is therefore very important. The character set adopted and terminology used in this study have been derived from the authors listed in the previous section.

Hill (1980) in discussing Mayr's (1969) recommendations on the preparation of descriptions considered the following to be important in the preparation of parataxonomic descriptions: 1) The taxonomic characters should be treated in a standardized sequence. 2) The most easily visible characters should be featured. 3) The description should provide quantitative data. These recommendations have been considered in preparing the following dispersed cuticle parataxa.

4.1.2 Definition of Terms

A) The Upper and Lower Epidermises: The cuticle as defined earlier is a two layered sheet comprising the outer 'cuticular layer' and the inner 'cuticle proper'. The cuticles of these surfaces are generally distinct. The lower cuticle is thinner and has a smaller cell size and higher stomatal frequency, to name a few of the more distinctive features. The upper cuticle is thicker, has larger cells and has a smaller stomatal frequency. Further differences are discussed by Stace (1965).

B) Subsidiary Cells: Van Cotthem (1970) described these cells as epidermal cells that surround the stoma where they differ in shape and size from the other epidermal cells. Differences in cuticle thickness and nature of cell content may also distinguish these cells from the

surrounding epidermal cells (Wilkinson, in Metcalfe and Chalk, 1979). An ontogenetic classification also exists for the stomatal complex which is related to the subsidiary cells. Those cells which arise from the same mother cell as the guard cells are termed syndetochielic and those which arise from a separate mother cell are termed haplochielic. However, this terminology has not been applied here, the fragmentary nature of the cuticles preventing the ontogenetic development of the cells being observed.

C) Additional Stomatal Terminology: The terminology used in defining these features and the subsequent parataxa is diagrammatically represented in Figure 9.

4.1.3 Character set

The character set used in the identification of the cuticle types (parataxa) of the Curlew Formation contains 39 distinct characters which are represented by single, two or multi states. The states of each character are defined below.

1) Presence of Stomata (on one or both epidermal surfaces)

Whether the stomata occur only on the lower surface or on both the upper and lower surfaces, in which case the parataxon is defined as either hypostomatic or amphistomatic, respectively. This character has only been employed when both cuticular surfaces have been available for examination.

2) Upper Epidermal Cell Shape

The general outline, in surface view, of an upper epidermal cell. The anticlinal walls are usually straight but the number of walls is

variable. Cell shape is defined by the number of anticlinal walls recognised. A three-sided cell is termed triangular, a four-sided cell - tetragonal, 5 - pentagonal, 6 - hexagonal, 7, 8, 9.... - polygonal. Cells are elongate over veins.

3) Upper Epidermal Cell Length

The longest axis for the cell. An average measurement of 50 cells, selected from a high power field (500X), is given. This number is dependant on cuticle size and state of preservation.

4) Upper Epidermal Cell Width

The greatest perpendicular distance to the Upper Epidermal Cell Length. An average measurement for 50 cells from a high power field (500X), is given. This number is dependant on cuticle size and state of preservation.

5) Nature of Anticlinal Wall of Upper Epidermal Cell

A character class which incorporates two characters. A) The outline of the anticlinal wall which ranges from straight, to curved to undulate. The degree of undulation of the wall is defined by the number of waves present per cell wall length. Wilkinson (see Fig.10.14., page 153, 1979) has defined eight categories for undulation. B) The degree of cuticular thickening ranges from thin (< 2µm), to irregularly thickened to thick (> 2µm). The types of irregular thickening are classified as beaded, ridged (see p.89 Dilcher, 1974) and buttress. Buttress thickening (Figure 106) may be defined as a compacted form of ridged thickening in which the periclinal wall is also affected.

6) Nature of Periclinal Wall of Upper Epidermal Cell

The nature of the cuticular thickening of the periclinal wall of a

typical cell which ranges from smooth (i.e. no obvious thickening) to irregularly thickened. The types of irregular thickening are defined as granulate, striate, reticulate and papillate (Figures 128, 131, 134 and 111 respectively).

7) Stomatal Distribution on Upper Epidermis

The presence of stomata on the upper epidermis and whether they are arranged in rows, restricted to well defined areolae or evenly distributed over the leaf surface.

8) Stomatal Frequency (Stomatal Index) on Upper Epidermis

Stomatal frequency is known to vary considerable during the development of a leaf. It also varies considerably on different parts of the leaf, and on different leaves on the same plant. Environmental factors also influence stomatal frequency, therefore an expression of the number of stomata per unit area is an unacceptable estimate of frequency. The best available method, Salisbury's (1927) Stomatal Index, almost entirely cancels out this variation by recording stomatal frequency in terms of a proportion of stomata to epidermal cells. This expression has been used in this study to define stomatal frequency.

$$\text{STOMATAL INDEX} = \frac{\text{No. of Stomata}}{\text{No. of stomata} + \text{No. of epidermal cells}} \times 100$$

This is calculated for a High Power field (500x magnification) using a Zeiss Triocular research microscope. Number of counts varied considerable due primarily to the state of the cuticle. The presence of stomata on either the upper or lower epidermis or both and whether they are arranged in rows, restricted to well defined areolae or evenly distributed over the leaf surface has also been recorded.

9) Stomatal Orientation on Upper Epidermis

The overall orientation (of the long axis) of the stomata on the upper surface.

10) Stomatal Arrangement on Upper Epidermis

The stomatal arrangement is defined as that arrangement of cells incorporated in the stomatal complex, i.e. guard and subsidiary cells. Arrangements are based on those of Van Cotthem (1970) (Figure 10).

11) Shape of Stomatal Aperture on Upper Epidermis

The shape of the stomatal aperture is that shape defined by the outline of the inner poral walls of the guard cells. This ranges from ovoid to elliptic to closed.

12) Position of Guard Cells on Upper Epidermis

The level at which the guard cells are positioned in the stomatal cavity. They may be sunken , near to the sub-stomatal cavity, slightly sunken or not sunken, in which case the cells are flush with the epidermal layer (Figure 9b).

13) Degree of Cutinization of Guard Cells on Upper Epidermis

The degree to which the epidermal wall of the cells are cutinised, i.e. thin (< 2µm), irregularly thickened to thick (> 2µm), and whether an outer stomatal ledge is present.

14) Number of Subsidiary Cells

This is the number of cells that surround and make contact with the guard cells. This number is given as a range from 50 counts when possible.

15) Nature of Anticlinal Wall of Subsidiary Cell on Upper Epidermis

Same as No.5

16) Nature of Periclinal Wall of Subsidiary Cell on Upper Epidermis

Same as No.6

Trichome Taxonomy

The use of trichome anatomy in providing taxonomic characters depends on the extent to which the trichomes are cuticularised. Of the three main types, i.e. multiseriate, pauciseriate and uniseriate, the former is more heavily cuticularized and is less likely to be removed during cuticle preparation. The latter two are generally represented by trichome bases only. Likewise, the fossilization process tends to leave cuticles devoid of their emergences, even the robust multiseriate trichomes are rarely intact. Therefore, the trichome base is invariably the only remaining part of the trichome avaliable for taxonomic use. Trichome bases are common on Curlew Formation cuticles. The characters listed below are titled "Trichome Base" and terms used in defining these characters are presented in Figure 11.

17) Trichome/Trichome Base Distribution on Upper Epidermis

The distribution of trichome bases over the upper epidermis, i.e. whether they are restricted to areolae, found only over veins or evenly (uniformly) distributed over the entire leaf surface.

18) Trichome/Trichome Base Frequency on Upper Epidermis

This is a particularly difficult character to define. The same principles which applied to stomatal frequency should apply here if the character is to be truly diagnostic but the fragmentary nature of the material makes this particularly difficult. Of all cuticles bearing trichome bases not all fragments are sufficiently large enough to enable a realistic number of counts being made. This has therefore necessitated the use of a more subjective method, i.e. bases/unit area. Trichome base have been counted per high power field (500x) of a Zeiss triocular research microscope and three frequency levels arbitarily assigned.

Level 1) Rare: < 5 Trichome Bases/field

Level 2) Common: > 5 and <15 Trichome Bases/field

Level 3) Very Common: >15 Trichome Bases/field

19) Trichome/Trichome Base Arrangement on Upper Epidermis

The appearance of the foot cell and the arrangement of cells directly in contact with this cell. Stace (1965) recognised four main types of bases. These arrangements will be referred to in this study as; Scarcely modified, Poral,and complex/multicellular (Figure 11).

20) Presence of Glandular Bodies on Upper Epidermis

Whether glandular bodies are present on the upper epidermis or not.

21) Lower Epidermal Cell Shape

As for No.2

22) Lower Epidermal Cell Length

As for No.3

23) Lower Epidermal Cell Width

As for No.4

24) Nature of Anticlinal Wall of Lower Epidermal Cell

As for No.5

25) Nature of Periclinal Wall of Lower Epidermal Cell

As for No.6

26) Stomatal Distribution on Lower Epidermis

As for No.7

27) Stomatal Frequency (Stomatal Index) on Lower Epidermis

As for No.8

28) Stomatal Orientation on Lower Epidermis

As for No.9

29) Stomatal Arrangement on Lower Epidermis

As for No.10

30) Shape of Stomatal Aperture on Lower Epidermis

As for No.11

31) Position of Guard Cells on Lower Epidermis

As for No.12

32) Degree of Cutinization of Guard Cells on Lower Epidermis

As for No.13

33) Number of Subsidiary Cells on Lower Epidermis

As for No.14

34) Nature of Anticlinal Wall of Subsidiary Cell on Lower Epidermis

As for No.5

35) Nature of Periclinal Wall of Subsidiary Cell on Lower Epidermis

As for No.6

36) Trichome/Trichome Base Distribution on Lower Epidermis

As for No.17

37) Trichome/Trichome Base Frequency on Lower Epidermis

As for No.18

38) Trichome/Trichome Base Arrangement on Lower Epidermis

As for No.19

39) Presence of Glandular Bodies on Lower Epidermis

As for No.20

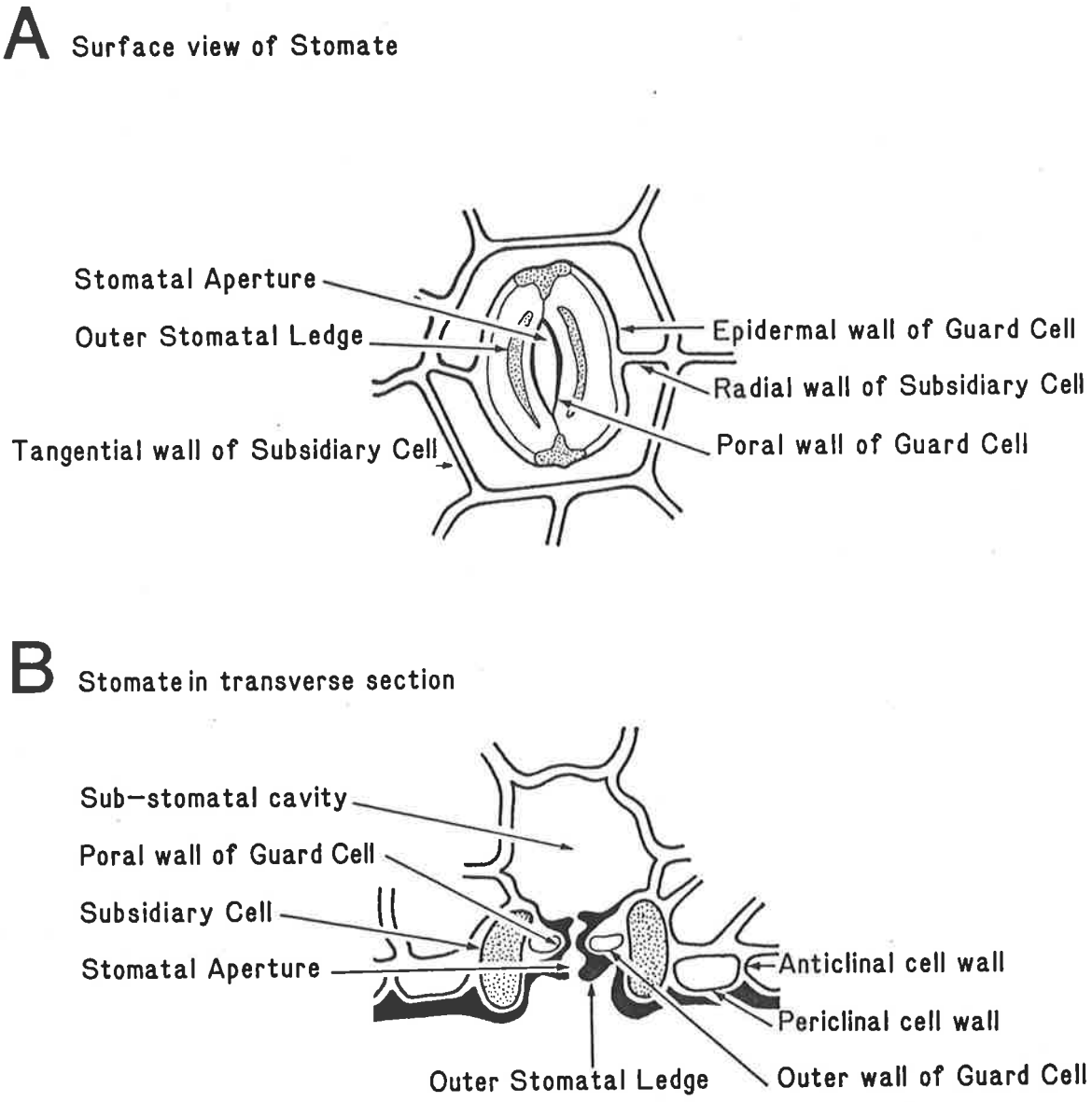
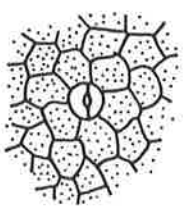


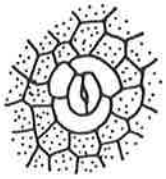
Figure 9: Diagrammatic explanation of Stomatal Terminology Used in Cuticular Descriptions (after Stace, 1965).

Stomatal Types

(after Van Cotthem, 1970)

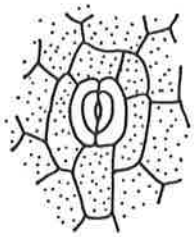


A Anomocytic

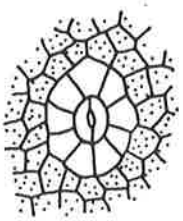


B Anisocytic

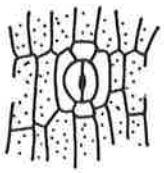
C Diacytic



D Paracytic



E Actinocytic



F Tetracytic

G Cyclocytic

Note: stoma and subsidiary cells not shaded

Figure 10: Van Cotthem's (1970) seven Main Stomatal Types used in defining Stomatal arrangement.

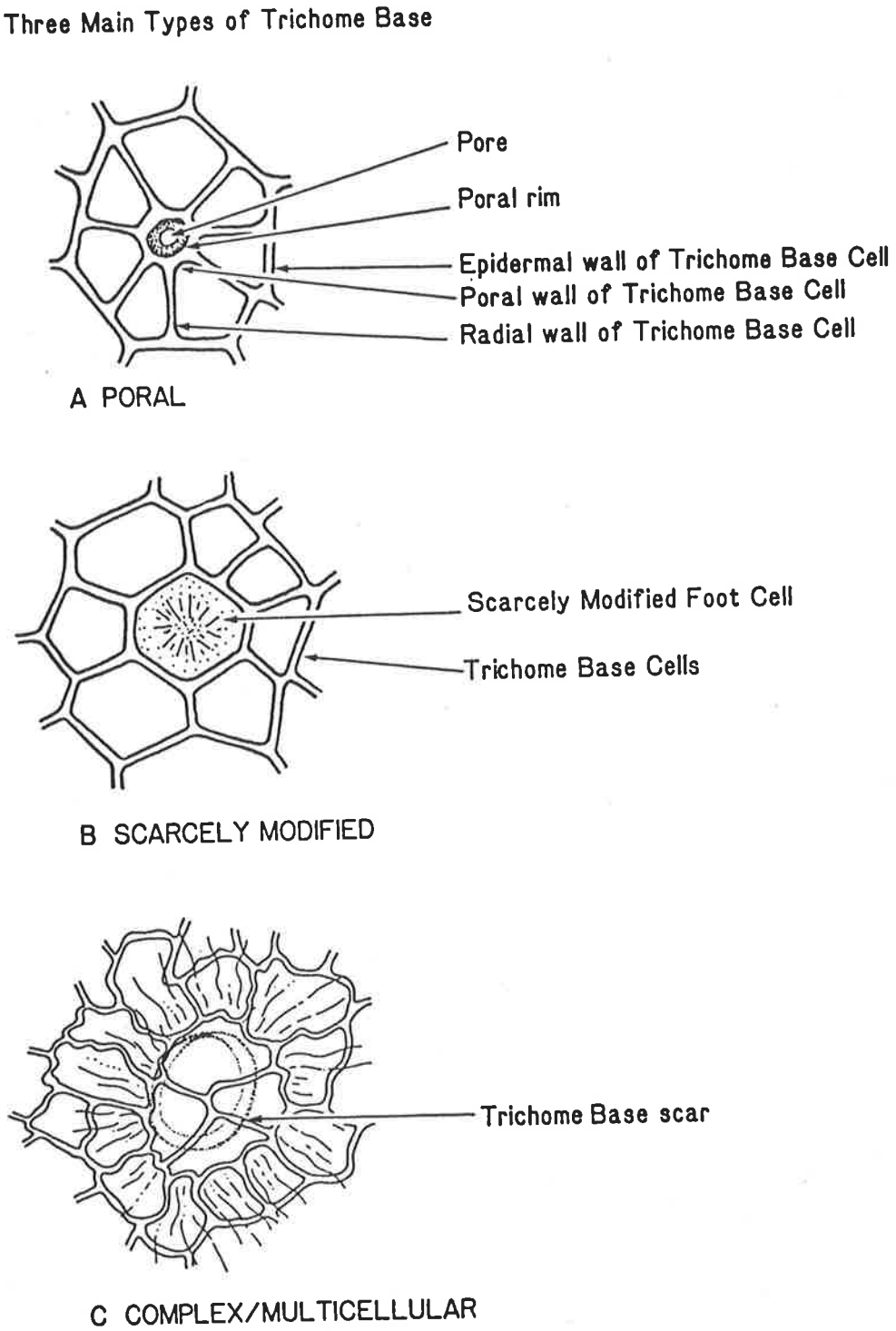


Figure 11: A diagrammatic representation of the three Trichome base Types (after Stace, 1965) used in defining Trichome base arrangement.

4.1.4 Cuticle Parataxa.

In the following descriptions of cuticle parataxa possible affinities to modern plant groups are also mentioned. The majority of parataxa are labelled "Affinity Unknown" but a number are listed as having associations at the Class (e.g. Liliopsida, i.e. Monocotyledonae), Family (e.g. Lauraceae) and in some instances the genus (e.g. Cryptocarya) and species (e.g. Litsea leefeana) level. Where a generic affinity is suggested comments have been made regarding the Australian distribution of the genus and its vegetation type. Specific listings indicate that species which bears closest similarity (of any extant member of the genus) to the fossil parataxon. Both generic and specific affinities are discussed in more detail in section 4.2.

The number in brackets at the end of the description indicates the number of specimens used in defining the parataxon.

Parataxon 1 Slide No. 118-327

Hypostomatic: Upper epidermis cells tetragonal to hexagonal, becoming elongate over veins. Cells 23.75 - 35µm in length, 15 - 21.2µm in width. Anticlinal wall thin, straight, smooth. Periclinal wall irregularly thickened, granulate to striate to reticulate. Trichome bases poral, rare, restricted to areas over veins. Anticlinal wall thin, smooth, thickening towards poral wall. Periclinal wall irregularly thickened, striate.

Lower epidermis cells tetragonal to polygonal (7) becoming elongate over veins. Cells 20 - 32.5µm in length, 12.5 - 17.5µm in width. Anticlinal wall thin, straight, smooth. Periclinal wall irregularly thickened, smooth to granulate. Stomata randomly oriented, uniform distribution. Stomatal aperture elliptical. Stomatal arrangement actinocytic. Guard cells not sunken. Stomatal index (S.I.) 6.4. Subsidiary cells 5 - 7. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, granulate to broadly striate. Trichome bases poral, common, random distribution. Basal cells 5 - 8. Anticlinal wall thin, smooth, thickening towards poral wall. Periclinal wall irregularly thickened, striate. (>200)

Affinity Unknown Figures 28, 29, 99.

Parataxon 2 Slide No. 118-349A

Hypostomatic: Upper epidermis cells undulate becoming elongate over veins. Cells 12.5 - 20µm in length, 7.5 - 15µm in width. Anticlinal wall smooth, some irregular thickening. Periclinal wall thin, smooth.

Lower epidermis cells undulate, becoming elongate over veins. Cells 10 - 20.5µm in length, 7.5 - 15µm in width. Anticlinal wall straight to undulate, thin, smooth. Periclinal wall irregularly thickened, thin to granulate. Stomata randomly oriented, uniform distribution (not as common over veins). Heavily cutinized raised stomatal collar, a most distinctive feature. Stomatal aperture elliptical to ovoid. Stomatal arrangement anomocytic. Guard cells not sunken. S.I= 14.5. Subsidiary

cells indistinguishable from surrounding cells. (>200)

Affinity Unknown Figures 30, 31, 100.

Parataxon 3 Slide No.118-367

Amphistomatic: Entire Margin: Upper epidermis cells tetragonal to polygonal, becoming elongate over veins. Cells 43 - 70µm in length, 30 - 50µm in width. Anticlinal wall straight, 2.5µm thick, smooth. Periclinal wall similar thickness, smooth. Glandular bodies present. Stomata randomly oriented, uniform distribution. Stomatal aperture elliptical. Stomatal arrangement paracytic. Guard cells not sunken. S.I. = 5.4. Subsidiary cells 2. Anticlinal wall smooth, straight, similar thickness to surrounding epidermal cells. Poral wall of guard cells heavily cutinised.

Lower epidermis cells tetragonal to polygonal, becoming elongate over veins. Cells 22 - 50µm in length, 19 - 30µm in width. Glandular bodies common. S.I.= 8.3. All other features identical to those of upper surface. (>200)

Affinity Unknown Figure 32, 101.

Parataxon 4 Slide No. 118-307

Stomatiferous surface only. Cells triangular to pentagonal, some curved. Cells 30 - 110µm in length, 16 - 40µm in width. Anticlinal wall variable, generally straight, thickening occurs in such a fashion as to produce distinct cell groupings delimited by thickened outer walls of

peripheral cells. Periclinal wall irregularly thickened, smooth to finely striate. Stomata randomly oriented, uniform distribution. Stomatal aperture narrowly elliptical. Stomatal arrangement paracytic. Guard cells not sunken. S.I.= 6.4. Subsidiary cells 2. Anticlinal wall curved, variable thickness, tangential wall generally thicker than wall in contact with guard cell epidermal wall. Periclinal wall irregularly thickened, granulate. Guard cell poral wall slightly cutinised. Outer stomatal ledge evident. (20)

Affinity Unknown Figure 33, 102.

Parataxon 5 Slide No. 118-408

Stomatiferous surface only. Cells triangular to pentagonal, some rounded, 27 - 43µm in length, 10 - 30µm in width. Anticlinal wall generally straight, smooth, thin. Periclinal wall thin, smooth. Stomata randomly oriented, uniform distribution. Stomatal aperture very narrowly elliptical. Stomatal arrangement paracytic (occasionally anisocytic). Guard cells slightly sunken. S.I.= 4.7. Subsidiary cells 2 (occasionally 3). Anticlinal wall straight, thicker than surrounding epidermal cells, particularly on inner tangential wall. Periclinal wall irregullarly thickened, striate. Poral wall of guard cell cutinised. Hydathodes present. Immature stomata are common. (32)

Affinity Unknown Figure 34, 103.

Parataxon 6 Slide No. 118-291,338

Hypostomatic: Upper epidermis cells triangular to pentagonal (generally rectangular), becoming elongate over veins. Cells 25 - 35µm in length, 15 - 25µm in width. Anticlinal wall straight, smooth, thin. Periclinal wall irregularly thickened, smooth to granulate.
Lower epidermis cells triangular to pentagonal (generally rectangular), some rounded, becoming elongate over veins. Cells 25 - 60µm in length, 20 - 27.5µm in width. Anticlinal wall straight, smooth, thin. Periclinal wall irregularly thickened, granulate to striate. Stomata randomly oriented, uniform distribution. Stomatal aperture narrowly elliptical to elliptical. Stomatal arrangement paracytic to actinocytic. Guard cells not sunken. S.I= 8.3. Subsidiary cells 2 - 5. Anticlinal wall straight, smooth, thin. Periclinal wall irregularly thickened, granulate to striate. Outer stomatal ledge evident on some stomata. Poral wall of guard cell cutinised. (35)

Affinity Unknown Figures 35, 36, 104.

Parataxon 7 Slide No. 118-401

Amphistomatic: Upper epidermis cells tetragonal to hexagonal, becoming elongate over veins. Cells 40 - 67µm in length, 19 - 23µm in width. Anticlinal wall straight, smooth, thin. Periclinal wall thin, smooth. Stomata rare, rudimentary, oriented parallel to vein direction. Lower epidermis cells tetragonal to hexagonal, becoming elongate over veins. Cells 23 - 50µm in length, 13 - 21µm in width. Anticlinal wall thin, smooth, slightly undulate. Periclinal wall irregularly thickened,

granulate to papilliate. Stomata oriented parallel to vein direction, confined to longitudinal bands (up to 160µm wide). Stomatal asperture narrowly elliptical. Stomatal arrangement paracytic. Guard cells sunken. S.I.= 21.8. Subsidiary cells 2. Anticlinal wall straight, irregularly thickened, heavily cutinised along the epidermal wall of guard cells forming a distinct collar around the stomate. Periclinal wall irregularly thickened, small to large granulations, papilliate. Guard cells heavily cutinised. (5)

Affinity Cyperaceae Figures 37, 38, 105.

A cosmopolitan family, well represented in the Australian flora, particularly in wetter habitats and areas of permanent water.

Parataxon 8 Slide No. 246-036

Stomatiferous surface only. Cells rectangular, arranged in longitudinal rows, 18 - 50µm in length, 14 - 25µm in width. Anticlinal wall irregular buttress thickening. Periclinal wall slightly undulate, irregularly thickened,granulate to finely striate. Stomata oriented parallel to vein direction, confined to longitudinal uniseriate rows. Stomatal aperture broadly elliptical. Stomatal arrangement tetracytic. Guard cells not sunken. S.I.= 7.09*. Subsidiary cells 4, lateral cells curved, polar cells triangular. Anticlinal wall irregular buttress thickening. Thickening on epidermal wall of guard cells responsible for stomatal collar. Periclinal wall irregularly thickened, broad concentrically arranged striations about the aperture. Guard cells little cutinisation. (3)

Affinity Podocarpaceae Figure 39, 106.

Decussocarpus, section Dammaroides: Trees of this genus are confined to lowland closed forest and swamp forests of New Caledonia and New Guinea. The genus is not present in the modern Australian Flora.

* based on an incomplete field count.

Parataxon 9 Slide No. 118-406

Hypostomatic: Upper epidermis cells tetragonal to polygonal tending to undulate, becoming elongate over veins. Cells 19.3 - 40µm in length, 15 - 22.5µm in width. Anticlinal wall rounded, smooth to sligthly beaded thickening. Periclinal wall irregularly thickened, granulate. Trichome bases poral, common, located over veins. Basal cells 4 - 7, radially arranged. Anticlinal wall smooth to slightly beaded, radially thickened. Periclinal wall irregularly thickened, granulate.

Lower epidermis cells tetragonal to polygonal tending to undulate, becoming elongate over veins. Cells 15 - 25µm in length, 7.5 - 17.5µm in width. Anticlinal wall straight to rounded, beaded thickening. Periclinal wall irregularly thickened, granulate to striate. Stomata randomly oriented, restricted to areoles (between veins). Stomatal aperture narrowly elongate. Stomatal arrangement paracytic, occasionally anomocytic. Guard cells slightly sunken. S.I.= 19.9. Outer stomatal ledge conspicuous, covers slightly cutinised guard cells. Subsidiary cells (0-)2. Anticlinal wall thin, smooth. Periclinal wall thin, smooth. Trichome bases poral, abundant, uniform distribution. Anticlinal wall thin, smooth. Periclinal wall thin to irregularly thickened, granulate to striate. Basal cells 4 to 7 radially arranged. (>200)

Affinity Lauraceae Figures 40, 41, 107.

Endiandra: Trees of subtropical scrubs and tropical closed forests that extend along the eastern coast of Australia.

Parataxon 10 Slide No. 118-352

Hypostomatic: Upper epidermis cells tetragonal to polygonal, becoming elongate over veins. Cells 20 - 27.5µm in length, 15 - 22.5µm in width. Anticlinal wall 2.5µm thick, smooth. Periclinal wall irreglarly thickened, granulate.

Lower epidermis cells triangular to polygonal, becoming elongate over veins. Cells 15 - 28µm in length, 7.5 - 14µm in width. Anticlinal wall straight ,thin, smooth. Periclinal wall irregularly thickened, granulate to striate. Stomata randomly oriented, restricted to areoles. Stomatal aperture narrowly elliptical. Stomatal arrangement mainly paracytic, occasionally tetracytic and anomocytic. Guard cells slightly sunken. S.I.= 15.5. Subsidiary cells (0-)2-4. Anticlinal wall thin, smooth to slightly undulate. Periclinal wall irregularly thickened, granulate to striate. Outer stomatal ledge conspicuous. (>200)

Affinity Lauraceae Figures 42, 43, 108.

Endiandra: Trees of subtropical scrubs and tropical closed forests that extend along the eastern coast of Australia.

Parataxon 11 Slide No. 118-390

Architectural features; leaf margin slightly serrate.

Amphistomatic: Upper epidermis cells undulate, up to 3.5 waves/ wall length, amplitude rarely exceeds wavelength, becoming elongate over veins. Cells 31.7 - 47.5µm in length, 13.7 - 27.5µm in width. Anticlinal wall undulate, irregularly thickened, ridged . Periclinal wall thin to irregularly thickened, smooth to finely striate. Stomata rare, occur over larger veins. Stomatal arrangement paracytic. Trichome bases complex, rare, uniform distribution. Basal cells 2 - 6, surrounded by radially arranged modified epidermal cells with radiating striations. Anticlinal wall undulate, irregularly thickened, ridged. Periclinal wall thin, irregularly thickened, slightly granlulate to finely striate. Scar appears as two concentric circles.

Lower epidermis cells undulate, up to 5 waves/wall length, amplitude rarely exceeds wavelength. Cells 25 - 35µm to in length, 12.5 - 20µm in width. Anticlinal wall undulate, irregularly thickened, ridged. Periclinal wall thin irregularly thickened, sligthly granulate. Stomata randomly oriented, restricted to areoles. Stomatal aperture ovoid. Stomatal arrangement paracytic. Guard cells sunken. S.I.= 18.8. Subsidiary cells 2, overlap guard cells. Anticlinal wall rounded, thin, smooth. Periclinal wall thin, irregularly thickened, smooth to granulate. Guard cells heavily cutinised, T-shaped thickening prominent at poles.

Trichome bases complex, rare, uniform distribution. Basal cells 2 - 4, surrounded by radially arranged modified epidermal cells. Anti-clinal wall thicker (3µm) than that of epidermal cells, ridged. Periclinal wall thin, irregularly thickened, slightly granulate. Scar appears as

two concentric circles. (>200)

Affinity Proteaceae Figures 44, 45, 109, 110.

Darlingia: Endemic trees of the tropical closed forests of northern Queensland.

Parataxon 12 Slide No. 118-368A,B

Hypostomatic: Upper epidermis cells triangular to pentagonal, to undulate, up to 1.5 waves/wall length, amplitude rarely exceeds wavelength, becoming angular over veins. Cells 32.5 - 45µm in length, 20 - 30µm in width. Anticlinal wall straight to undulate, irregularly thickened, thin to ridged. Periclinal wall marginal thickening extends into cell lumen and down anticlinal wall, striate to reticulate. Trichome bases rare, complex, uniform distribution. Basal cells 4 - 7. Anticlinal wall straight, irregularly thickened, thin to ridged. Periclinal wall as for epidermal cells. Bases larger over veins.
Lower epidermis cells undulate, up to 2 waves/wall length, amplitude rarely exceeds wavelength, angular over veins. Cells 15 - 27.5µm in length, 8.5 - 17.5µm in width. Anticlinal wall straight to undulate, thin, smooth. Periclinal wall irregularly thickened, marginal thickening common to vein cells; areolar cells, granulate to papilliate. Stomata randomly oriented, restricted to areoles. Stomatal aperture ovoid. Stomatal arrangement paracytic. Guard cells not sunken. S.I.= 11.7. Subsidiary cells 2. Anticlinal wall rounded to undulate, thin, smooth. Periclinal wall thin, smooth. Guard cell poral wall cutinised. Trichome bases scarcely modified, common. Basal cells central cell surrounded by up to 12 radially arranged modified

epidermal cells. Anticlinal wall smooth, irregularly thickened, thin to marginal thickening over veins. Periclinal wall irregularly thickened, papilliate to striate over veins. (>200)

Affinity Proteaceae Figures 46, 47, 111, 112.

Synaphea shows strong affinity to Lange's (1978b) Lake Lefroy proteaceous cuticle. The genus is represents by sclerophyllous shrubs restricted to south west, Western Australia.

Parataxon 13 Slide No. 246-006

Upper and lower epidermis indistinguishable. Non-stomatiferous surface. Cells rectangular, 19 - 33µm in length, 4 - 6.5µm in width. Anticlinal wall straight,thin, smooth. Periclinal wall thin, smooth, darker staining cuticular band passes longitudinally down the cell. Cells interlocked in a brick-like arrangement. (>200)

Affinity Monocotyledonae Figure 48.

Parataxon 14 Slide No. 118-379

Hypostomatic: Upper epidermis cells tetragonal to hexagonal to rectangular over veins. Cells 15 - 25µm in length, 10 - 18.5µm in width. Anticlinal wall straight, irregularly thickened, ridged? Periclinal wall irregularly thickened, granulate.
Lower epidermis cells undulate, up to 2 waves/ wall length, amplitude rarely exceeds wavelength, becoming rectangular over veins. Cells 18.2

- 35µm in length, 15 - 25µm in width. Anticlinal wall undulate, irregular beaded thickening. Periclinal wall irregularly thickened, granulate. Stomata randomly oriented, restricted to areoles. Stomatal aperture narrowly elliptical. Stomatal arrangement paracytic. Guard cells not sunken. S.I.= 11.4. Subsidiary cells 2. Anticlinal wall rounded, slight beaded thickening. Periclinal wall irregularly thickened, granulate. Guard cell poral wall cutinised. Outer stomatal ledge evident. (>200)

Affinity Lauraceae Figures 49, 50, 113.

Cryptocarya: Trees of the subtropical and tropical closed forests that extend along the eastern coast of Australia.

Endiandra: Trees of the subtropical scrubs and tropical closed forests thet extend alon the eastern coast of Australia.

Parataxon 15 Slide No. 118-407

Hypostomatic: Upper epidermis cells triangular to hexagonal becoming elongate over veins. Cells 16.5 - 25µm in length, 9.7 - 17.5µm in width. Anticlinal wall thin, smooth, straight to slightly undulate. Periclinal wall irregularly thickened, granulate to tuberculate. Trichome bases poral, rare, mainly over veins. Basal cells 4 - 6, radially arranged. Anticlinal wall straight, thickened epidermal wall. Periclinal wall smooth, irregularly thickened,granulate to tuberculate. Lower epidermis cells triangular to hexagonal becoming elongate over veins. Cells 10 - 15µm in length, 6.7 - 12.5µm in width. Anticlinal wall straight, irregularly thickened, ridged to T-shape. Periclinal wall irregularly thickened, tuberculate to reticulate. Stomata randomly

oriented, restricted to areoles. Stomatal aperture elliptical. Stomatal arrangement paracytic. Guard cells sunken. S.I.= 18.4. Subsidiary cells 2. Anticlinal wall rounded, thin, smooth. Periclinal wall thin, smooth. Guard cell polar wall cutinised. Outer stomatal ledge variable thickness, common. Trichome bases poral, common, mainly over veins. Basal cells 5 - 8, radially arranged. Anticlinal wall straight, epidermal wall thickened. Periclinal wall irregularly thickened, tuberculate to reticulate. (>200)

Affinity Lauraceae Figures 51, 52, 114.

Litsea leefeana: A tree that occurs in subtropical to tropical closed forests extending from Belling^er River, New South Wales to Endeavour River, North Queensland.

Parataxon 16 Slide No. 118-369

Hypostomatic: Upper epidermis cells tetragonal to hexagonal becoming elongate over veins. Cells 20 - 27.5µm in length, 12.5 - 20µm in width. Anticlinal wall straight, thin, smooth. Periclinal wall irregularly thickened, granulate. Trichome bases poral, common, uniform distribution. Basal cells 5 - 8, radially arranged. Anticlinal wall straight, thickened, epidermal wall. Periclinal wall irregularly thickened, granulate. Glandular bodies evident.

Lower epidermis cells tetragonal to hexagonal becoming elongateover veins. Cells 17.5 - 25.5µm in length, 10 - 17.5µm in width. Anticlinal wall straight to slightly rounded, smooth, irregularly thickened, thin to finely beaded. Periclinal wall irregularly thickened, granulate. Stomata randomly oriented, restricted to areoles. Stomatal aperture

narrowly elliptical. Stomatal arrangement paracytic. Guard cells not sunken. S.I.= 13.1. Subsidiary cells 2. Anticlinal wall rounded, thin, smooth. Periclinal wall irregularly thickened, granulate. Guard cells cutinised. Outer stomatal ledge prominent. Trichome bases poral, abundant, uniform distribution. Basal cells 5 - 10, radially arranged. Anticlinal wall straight, thickened epidermal wall. Periclinal wall thin, smooth. Glandular bodies evident. (>200)

Affinity Lauraceae Figures 53, 54, 115.

Endiandra introrsa: A tree of the subtropical humid evergreen closed forests of the Dorrigo Plateau, northern New South Wales and southern Queensland.

Parataxon 17 Slide No. 118-270

Upper and lower epidermis indistinguishable. Stomatiferous surface. Cells tetragonal to hexagonal, strongly angular, 12.5 - 27.5µm in length, 12.5 - 20µm in width. Anticlinal wall straight, irregular marginal thickening extends onto periclinal wall (up to 5µm thick). Periclinal wall irregularly thickened, granulate to reticulate. Stomata rare. Stomatal aperture narrowly elliptical. Stomatal arrangement paracytic. Guard cells not sunken. S.I.= 0.06. Subsidiary cells 2. Anticlinal wall straight, smooth to irregularly thickened (up to 3µm thick). Periclinal wall thin, smooth. (10)

Affinity Unknown Figure 55,63,124.

Parataxon 18 Slide No. 118-214

Stomatiferous surface only. Cells triangular to hexagonal becoming elongate over veins. Cells 15 - 27.5µm in length, 10 - 17.5µm in width. Anticlinal wall straight, thin, smooth. Periclinal wall thin, smooth. Stomata randomly oriented, restricted to areoles. Stomatal aperture elliptical. Stomatal arrangement tetracytic to actinocytic. Guard cells slightly sunken. S.I.= 6.75. Subsidiary cells 4 - 5. Anticlinal wall rounded, thin, smooth. Periclinal wall thin, smooth. Trichomes abundant, uniform distribution, single celled, acute apex, up to 100um in length. Trichome bases poral. Basal cells 5 - 8, radially arranged. Anticlinal wall straight, thin, smooth. Periclinal wall thin, smooth. Hydathodes present. (90)

Affinity Lauraceae? Figure 56, 116.

Endiandra?: Trees of the subtropical and tropical closed forests that extend along the eastern coast of Australia.

Parataxon 19 Slide No. 118-273

Upper and lower epidermis indistinguishable. Stomatiferous surface. Cells rectangular to hexagonal, arranged in longitudinal rows, 35 - 50µm in length, 20 - 42.5µm in width. Anticlinal wall straight, irregularly thickened, smooth to beaded. Periclinal wall thin with large cuticular folds. Stomata oriented parallel to vein direction, confined to longitudinal uniseriate rows. Stomatal aperture broadly elliptical. Stomatal arrangement paracytic. Guard cells not sunken. S.I.= 6.45. Subsidiary cells 2. Anticlinal wall straight, irregularly

thickened, smooth to beaded. Periclinal wall thin, folds present in lateral cells. Guard cell poral wall cutinised. Thin outer stomatal ledge evident. (>200)

Affinity Monocotyledonae Figure 57, 117.

Parataxon 20 Slide No. 118-272

Upper and lower epidermis indistinguishable. Stomatiferous surface. Cells hexagonal, arranged in longitudinal rows, 32.5 - 60µm in length, 17.5µm - 27.5µm in width. Anticlinal wall straight, irregularly thickened, beaded, up to 3µm thick. Periclinal wall irregularly thickened, two large crescent-shaped papillae located centrally. Stomata oriented parallel to vein direction, confined to longitudinal uniseriate rows. Stomatal aperture broadly elliptical to ovoid. Stomatal arrangement paracytic (occasionally tetracytic). Guard cells slightly sunken. S.I.= 5.3. Subsidiary cells 2 - 4. Anticlinal wall straight, thin, smooth. Periclinal wall thin, smooth. Papillae on epidermal cells often overlay subsidiary cells. Guard cell poral wall cutinised. (12)

Affinity Monocotyledonae Figure 58.

Parataxon 21 Slide No. 118-280

Upper and lower epidermis indistinguishable. Stomatiferous surface. Cells hexagonal, 15 - 27.5µm in length, 12.5 - 20µm in width.

Anticlinal wall straight, irregularly thickened, finely beaded. Periclinal wall irregularly thickened, papilliate. Each papilla centrally located, varies from circular to crescent-shaped. Stomata randomly oriented, uniform distribution. Stomatal aperture elliptical. Stomatal arrangement paracytic. Guard cells slightly sunken. S.I.= 5.45. Subsidiary cells 2. Anticlinal wall rounded, irregularly thickened, slightly beaded. Periclinal wall irregularly thickened, granulate to striate. Guard cell poral wall cutinised. Thin outer stomatal ledge evident. (>200)

Affinity Monocotyledonae? Figure 59, 118.

Parataxon 22 Slide No. 118-400

Upper and lower epidermis indistinguishable. Non-stomatiferous surface. Cell outline absent, surface shows irregular cuticular thickening, smooth to striate. Stomata absent. Trichome bases absent. Very indistinct cuticle.

Affinity Unknown Figure 60.

Parataxon 23 Slide No. 118-414,415

Architectural Features; Leaf margin serrate, veins terminate in serrations, parallel venation

Amphistomatic: Upper epidermis cells elongate, 90 - 257µm in length, 7.5 - 27.5µm in width. Cells long axes mainly oriented parallel to vein

direction, occasionally this orientation is oblique. Anticlinal wall straight, thin, smooth. Periclinal wall thin, pitted. Stomata rare, long axes parallel to vein direction. Stomatal aperture narrowly elliptical. Stomatal arrangement actinocytic (haplocheilic, Greguss, 1968). Guard cells slightly sunken. Subsidiary cells 3 - 5. Anticlinal wall straight, thin, smooth. Periclinal wall irregularly thickened, strongly pitted.

Trichome bases rare, poral, roughly circular. Basal cells 3 - 5. Anticlinal wall straight, thickened epidermal wall. Periclinal wall thick, smooth.

Lower epidermis cells elongate, long axes oriented parallel to vein direction, 60 - 282µm in length, 25 - 35µm in width. Anticlinal wall straight, thin, smooth. Periclinal wall thin, smooth. Stomata oriented parallel to vein direction, restricted to bands (110µm wide) between veins. Guard cells not sunken. Stomatal aperture narrowly elliptical. Stomatal arrangement actinocytic (haplocheilic, Greguss 1968). S.I = 7.6. Subsidiary cells 3 - 7. Anticlinal wall straight, thin, smooth. Periclinal wall irregularly thickened, strongly pitted. Guard cells slightly cutinised. Fine outer stomatal ledge evident. (95)

Affinity Zamiaceae Figures 61,62,119,120,121,122,123.

Bowenia papillosa: An extinct understorey species, first identified from the Eocene megafossil flora of Nerriga, New South Wales (Hill, 1978).

Parataxon 24 Slide No. 118-370

Upper and Lower epidermis indistinguishable. Cuticle thick. Non-stomatiferous surface only. Cells tetragonal to pentagonal, mainly rectangular, some rounded, 20 - 50µm in length, 12.5 - 25µm in width. Anticlinal wall straight, thin , irregularly thickened, fine beaded thickening. Periclinal wall irregular thickening, smooth to slightly granulate. (50)

Affinity Unknown Figure 64.

Parataxon 25 Slide No. 118-310

Stomatiferous surface only. Cells tetragonal to hexagonal, some rounded becoming elongate over veins. Cells 22.5 - 35µm in length, 15 - 22.5µm in width. Anticlinal wall straight, variable thickness, up to 2µm . Periclinal wall irregularly thickened, intricate web-like striations. Stomata randomly oriented, uniform distribution. Stomatal aperture not seen. Guard cells not seen. Stomatal arrangement actinocytic. S.I.= 9.05. Subsidiary cells 4 - 8. Anticlinal wall straight to rounded, epidermal wall heavily cutinised. Thickening extends over stomatal aperture. Periclinal wall irregularly thickened, granulate to intricate web-like striations. (44)

Affinity Ebenaceae Figure 65, 125.

Austrodiospyros: Trees of the modern relative Diospyros occur in the tropical closed forests of northern Australia and extend down the east coast to the southern limit of the subtropical closed forest

in New South Wales.

Parataxon 26 Slide No. 118-375

Non-stomatiferous cuticle. Cells undulate, up to 1.5 waves/wall length, amplitude rarely exceeds wavelength, becoming elongate over veins. Cells 20 - 35µm in length, 12.5 - 25µm in width. Anticlinal wall undulate, thin, smooth. Periclinal wall irregularly thickened, smooth to finely granulate. Glandular bodies present, dark staining, lie over veins, numerous modified epidermal cells surround lumen. Germlings of grades 1 to 2 (Lange, 1976) present. Possibly mesophyll. (15)

Affinity Unknown Figure 66.

Parataxon 27 Slide No. 118-248

Stomatiferous surface only. Cells tetragonal to hexagonal, some rounded, 17.5 - 60µm in length, 17.5 - 42.5µm in width. Anticlinal wall straight, smooth, irregularly thickened (up to 2µm). Periclinal wall irregularly thickened, pitted, granulate, fine network of striations, becoming quite pronounced, leading to complete division of cells. Stomata randomly oriented, uniform distribution. Stomatal aperture elliptical. Guard cells not sunken. Stomatal arrangement paracytic. S.I.= 3.9. Guard cells poral wall strongly cutinised. Outer stomatal ledge evident. Subsidiary cells 2. Anticlinal wall rounded, smooth, irregularly thickened. Periclinal wall irregularly thickened, granulate

to slightly striate. (5)

Affinity Unknown Figure 67, 126.

Parataxon 28 Slide No. 118-332

Hypostomatic: Upper epidermis cells tetragonal to hexagonal tending to slightly undulate becoming elongate over veins. Cells 20 - 35µm in length, 11.3 - 17.5µm in width. Anticlinal wall straight to undulate, irregularly thickened, smooth to slightly beaded thickening. Periclinal wall irregularly thickened, smooth to granulate. Trichome bases rare, poral, uniform distribution. Basal cells 5 - 8, radially arranged. Anticlinal wall thin, smooth. Periclinal wall smooth to slightly granulate.

Lower epidermis cuticle thin. Cells tetragonal to hexagonal, some undulate, becoming elongate over veins. Cells 17.5 - 22.5µm in length, 5 - 15µm in width. Anticlinal wall straight to undulate, thin, smooth. Periclinal wall thin, smooth. Stomata randomly oriented, restricted to areoles. Stomatal aperture elliptical. S.I.= 13.04. Guard cells not sunken. Stomatal arrangement not seen, possibly actinocytic. Subsidiary cells not seen. Guard cell poral wall cutinised, darker staining. Hydathodes present. Trichome bases abundant, poral, uniform distribution. Basal cells 5 - 8, radially arranged. Anticlinal wall straight, thin, smooth. Periclinal wall irregularly thickened, smooth to slightly striate. (>200)

Affinity Unknown Figures 68, 69, 127.

Parataxon 29 Slide No. 118-294

Stomatiferous surface only. Cells triangular to pentagonal becoming rectangular over veins. Cells 12.5 - 22.5µm in length, 6.3 - 17.5µm in width. Anticlinal wall straight, irregularly thickened, beaded thickening. Periclinal wall irregularly thickened, smooth to granulate. Stomata randomly oriented, restricted to areoles. Stomatal aperture narrowly elliptical. Guard cells not sunken. Stomatal arrangement paracytic tending actinocytic. S.I.= 13.2. Subsidiary cells 2 - 6. Anticlinal wall rounded, thin, smooth. Periclinal wall irregularly thickened, smooth to granulate. Guard cells cutinised. Outer stomatal ledge evident. Trichome bases rare, poral, uniform distribution. Basal cells 8 - 10, radially arranged. Anticlinal wall straight, irregularly thickened, epidermal wall thickened towards pore. Periclinal wall thin, smooth.

Affinity Lauraceae Figure 70, 128.

Endiandra: Trees of subtropical scrubs through to tropical closed forests along the east coast of Australia.

Parataxon 30 Slide No. 118-324

Upper and Lower epidermis indistinguishable. Cuticle thin. Non-stomatiferous surface only. Epidermal cells undulate, 30 - 67.5µm in length, 12.5 - 37.5µm in width. Anticlinal wall undulate,

irregularly thickened, ridged. Periclinal wall thin, smooth. Possibly mesophyllous tissue. (30)

Affinity Unknown Figure 71.

Parataxon 31 Slide No. 117-027

. Stomatiferous surface only. Cells rectangular to hexagonal, 17.5 - 37.5µm in length, 4 - 12.5µm in width. Anticlinal wall straight, irregularly thickened, smooth. Periclinal wall irregularly thickened, granulate to striate. Stomata long axes perpendicular to vein direction, occur in rows near leaf margins. Rows 4 cells apart, occasionally anastomosing. Stomatal aperture elliptical. Guard cells not sunken. Stomatal arrangement anomocytic. Subsidiary cells 0 - 1. Anticlinal wall straight, slightly thinner than surrounding cells, smooth. Periclinal wall irregularly thickened, granulate. Guard cells cutinised, poral wall thickened. All specimens measured had > 65% hexagonal shaped cells. (180)

Affinity Casuarinaceae Figure 72, 129.

Gymnostoma: A single species occurs in marginal tropical closed forest in North Queensland and is closely associated with streams and swamps.

Parataxon 32 Slide No. 118-401

Upper and Lower epidermis indistinguishable. Non-stomatiferous possibly petiole or vein cuticle. Cells tetragonal to hexagonal, becoming rectangular over veins. Cells 15 to 32.5µm in length, 12.5 - 22.5µm in width. Polygonal cells occur in small patches between the much broader bands of rectangular cells, which are longitudinally arranged. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, smooth to granulate. (100)

Affinity Unknown Figure 73.

Parataxon 33 Slide No. 118-235

Upper and Lower epidermis indistinguishable. Stomatiferous surface only. Cells tetragonal to pentagonal, rectangular cells most common. The linearly arranged rectangular cells 7.5 - 17.5µm in length, 5 - 12.5µm in width. Irregularly arranged cells, 10 - 20µm in length, 7.5 - 17.5µm in width, occur in areas between the broad bands of rectangular cells. Anticlinal wall straight to rounded, irregularly thickened, up to 2.5µm thick, smooth. Periclinal wall thin, smooth. Stomata randomly oriented, restricted to areas of irregularly arranged cells. Stomatal aperture elliptical. Guard cells sunken. Stomatal arrangement actinocytic. S.I.= 0.5. Subsidiary cells 3 - 6. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, granulate. Guard cell poral wall heavily cutinised. Possibly petiole fragment. (>200)

Affinity Unknown Figure 74, 130.

Parataxon 34 Slide No. 118-245

Upper and Lower epidermis indistinguishable. Non-stomatiferous surface only. Cells tetragonal to hexagonal, becoming rectangular over veins. Cells 15 - 22.5µm in length, 8.8 - 15µm in width. Anticlinal wall straight, thin, smooth. Periclinal wall irregularly thickened, granulate. Trichome bases poral, abundant, uniform distribution. Basal cells 6 - 9, radially arranged. Anticlinal wall straight, smooth, poral wall thickened. Periclinal wall irregularly thickened, granulate to striate. (8)

Affinity Unknown Figure 75.

Parataxon 35 Slide No. 111-010

Upper and Lower epidermis indistinguishable. Stomatiferous surface only. Cells tetragonal to pentagonal, becoming elongate over veins. Cells 17.5 - 27µm in length, 10 - 17.5µm in width. Anticlinal wall straight to slightly undulate, thin, smooth. Periclinal wall irregularly thickened, striate to reticulate giving anticlinal wall a sinuous appearance in some cells. Stomata randomly oriented, uniform distribution. Stomatal aperture elliptical. Stomatal arrangement not obvious. Guard cells slightly sunken. Subsidiary cells not obvious. This is due to the particularly heavy striation around the thin cuticular membrane of the stomata. Guard cells well cutinised. Outer stomatal ledge evident. (16)

Affinity Unknown Figure 76, 131.

Parataxon 36 Slide No. 118-363

Hypostomatic: Upper epidermis cells undulate up to 3 waves/wall length, amplitude rarely exceeds wavelength, to elongate over veins. Cells 25 - 45µm in length, 15 - 27.5µm in width. Anticlinal wall undulate, thin, smooth. Periclinal wall irregularly thickened, striate. Trichome bases complex, rare, uniform distribution. Basal cells 2 - 10, surrounded by a number of radially arranged epidermal cells. Anticlinal wall rounded to undulate, smooth, thicker than epidermal cells, up to 3um, some T-shape thickening. Periclinal wall irregularly thickened, smooth to striate, striations radiate outwards into surrounding cells. Trichome base scar is evident in all bases. Glandular bodies numerous. Lower epidermis cells undulate up to 4 waves/wall length, amplitude rarely exceeds wavelength, elongate over veins. Cells 27.5 - 55µm in length, 20 - 30µm in width. Anticlinal wall irregularly thickened, smooth to ridged. Periclinal wall irregularly thickened, smooth to slightly granulate, folding occurs near margin due to undulations. Stomata randomly oriented, uniform distribution. Stomatal aperture elliptical. Stomatal arrangement paracytic. Guard cells sunken. S.I.= 15.1. Subsidiary cells 2. Anticlinal wall rounded, irregularly thickened, smooth to fine beaded thickening. Periclinal wall irregularly thickened, granulate. Guard cells strongly cutinised. Trichome bases rare, complex, uniform distribution. Basal cells 1 - 4, surrounded by numerous radially arranged epidermal cells. Anticlinal wall undulate, smooth, thicker than surrounding cells. Periclinal wall

irregularly thickened, smooth to striate, striations radiate outwards into surrounding cells. Hair base scars prominent. Glandular bodies numerous. (>200)

Affinity Proteaceae Figures 77, 78, 132, 133.

Darlingia: endemic trees of tropical closed forest in North Queensland.

Parataxon 37 Slide No. 117-037

Stomatiferous surface only. Cells pentagonal to hexagonal, 15 - 25µm in length, 7.5 - 15µm in width. Anticlinal wall smooth, thick up to 3µm. Periclinal wall irregularly thickened, granulate. Stomata randomly oriented, uniform distribution. Stomatal aperture narrowly elliptical. Stomatal arrangement possibly paracytic, cuticle particularly thin around stomata. S.I. insufficient material. Guard cells slightly sunken. Subsidiary cells possibly 2. Anticlinal wall rounded, irregularly thickened, smooth to fine buttress thickening. Periclinal wall irregularly thickened, granulate to striate. Guard cell poral wall cutinised. Outer stomatal ledge evident. (10)

Affinity Unknown Figure 79.

Parataxon 38 Slide No. 110-010

Hypostomatic: Upper epidermis cells tetragonal to pentagonal, becoming elongate over veins. Cells 15 - 35µm in length, 10 - 15µm in width. Anticlinal wall straight, thin, smooth. Periclinal wall

irregularly thickened, strongly granulate to reticulate. Trichome bases poral, common, uniform distribution. Basal cells 5 to 7, radially arranged. Anticlinal wall straight, poral wall thickened. Periclinal wall irregularly thickened, granulate to reticulate.

Lower epidermis cells tetragonal to hexagonal, becoming elongate over veins. Cells 17.5 - 25µm in length, 7.5 - 17.5µm in width. Anticlinal wall straight, irregularly thickened, smooth to fine buttress thickening. Periclinal wall irregularly thickened, strongly granulate to reticulate. Stomata randomly oriented, restricted to areoles. Stomatal aperture narrowly elliptical. Stomatal arrangement anomocytic, occasionally paracytic. S.I.= 11.3. Guard cells not sunken. Subsidiary cells 2. Anticlinal wall rounded, thin, smooth. Periclinal wall thin, smooth. Guard cell: poral wall cutinised. Outer stomatal ledge prominent.

Trichome bases poral, common, uniform distribution. Basal cells 5 - 8, radially arranged. Anticlinal wall straight, epidermal and poral walls cutinised. Periclinal wall irregularly thickened, granulate to reticulate. (16)

Affinity Lauraceae Figures 80, 81, 134.

Cryptocarya?: Trees of subtropical to tropical closed forests that extend along the eastern coast of Australia.

Parataxon 39 Slide No. 112-020

Stomatiferous surface only. Cells undulate, up to 4 waves/wall length, amplitude rarely exceeds wavelength, elongate over veins. Cells 15 - 30µm in length, 8.8 - 17.5µm in width. Anticlinal wall undulate,

irregular thickening, smooth to ridged. Periclinal wall irregularly thickened, smooth, granulate to striate. Stomata randomly oriented, uniform distribution. Stomatal aperture narrowly elliptical to ovoid. Stomatal arrangement anisocytic. S.I.= 15.1. Guard cells not sunken. Subsidiary cells 3 - 6. Anticlinal wall rounded to undulate, irregularly thickened, ridged. Periclinal wall irregularly thickened, striate. Striations in a concentric arrangement around guard cells. Outer stomatal ledge thick, prominent, encircles stoma. Guard cell cutinised. Hydathodes present. Glandular bodies present. (20)

Affinity Unknown Figure 82, 135.

Parataxon 40 Slide No. 118-283

Hypostomatic: Upper epidermis cells undulate, up to 5 waves/wall length, amplitude rarely exceeds wavelength, elongate over veins. Cells 25 - 37.5µm in length, 15 - 27.5µm in width. Anticlinal wall undulate, irregularly thickened, ridged. Periclinal wall irregularly thickened, granulate. Trichome bases rare, complex, uniform distribution. Basal cells 2 - 4, surrounded by radially arranged epidermal cells. Anticlinal wall undulate, thin, smooth. Periclinal wall irregularly thickened, thick, granulate to striate, thicker than surrounding cells, darker staining. Striations radiate out into surrounding cells. Hair scar prominent. Glandular bodies present.

Lower epidermis extremely thin, making features difficult to interpret. Cells triangular to polygonal becoming undulate, up to 6 waves/wall length, amplitude rarely exceeds wavelength, undulations extremely small, elongate over veins. Cells 22.5 - 35µm in length, 15 - 20µm in

width. Anticlinal wall straight to undulate, irregularly thickened, finely beaded. Periclinal wall irregularly thickened, granulate. Stomata randomly oriented, uniform distribution. Stomatal aperture elliptical. Stomatal arrangement paracytic. S.I.= 17.0. Guard cells not sunken. Subsidiary cells 2. Anticlinal wall rounded, thin, smooth. Periclinal wall irregularly thickened, finely striate. Outer stomatal ledge evident. Guard cell polar wall cutinised.

Trichome bases abundant, scarcely modified, uniform distribution. Basal cells 6 - 10, radially arranged around central cell. Anticlinal wall straight, irregularly thickened, finely beaded. Periclinal wall irregularly thickened, granulate to striate. Striations radiate outwards. Trichomes short, terete, truncate apex. (88)

Affinity Proteaceae Figures 83, 84, 136.

Cardwellia: Endemic trees of tropical closed forest in North Queensland.

Parataxon 41 Slide No. 118-318

Amphistomatic: Upper and Lower epidermis indistinguishable. Stomatiferous surface. Cells tetragonal to hexagonal, 12.5 - 32.5µm in length, 8.8 - 15µm in width. Cells arranged in roughly linear pattern. Anticlinal wall straight, irregularly thickened, smooth. Periclinal wall thin, smooth. Stomata long axes oriented perpendicular to cell rows, restricted to areas of hexagonal cells. Stomatal aperture elliptical. Guard cells sunken. Stomatal arrangement paracytic. S.I.= 0.5. Subsidiary cells 2. Anticlinal wall rounded, thin, smooth. Periclinal wall irregularly thickened, granulate. Guard cells heavily

cutinised. Fragment possibly lauraceous petiole. (>200)

Affinity Lauraceae Figure 85.

Parataxon 42 Slide No. 117-001

Non-stomatiferous surface only. Cells undulate, up to 2 waves/wall length, amplitude rarely exceeds wavelength. Cells 15 - 32.5µm in length, 12.5 - 25µm in width. Anticlinal wall undulate, thin, smooth. Periclinal wall irregularly thickened, granulate. Germlings grades 1 to 3 (Lange, 1976) present. Similar to Parataxon 2. (3)

Affinity Unknown Figure 86.

Parataxon 43 Slide No. 117-003

Upper epidermis cells elongate, long axes usually oriented parallel to vein direction. Cells 60 - 118µm in length, 12.5 - 19µm in width. Anticlinal wall straight, thin, smooth. Some cells have thicker, darker staining wall. Periclinal wall thin, some slight pitting.
Lower epidermis cells elongate, long axes oriented parallel to vein direction. Cells 83 - 133µm in length, 15 - 23µm in width. Anticlinal wall straight, thin, smooth. Periclinal wall thin, smooth. Stomata oriented parallel to vein direction, occur in bands between veins. Stomatal aperture elliptical to ovoid. Stomatal arrangement actinocytic (haplocheilic, Greguss 1968), darker staining than surrounding cells. S.I.= 6.4. Guard cells not sunken. Subsidiary cells 2 - 6. Anticlinal wall rounded, thicker than that of surrounding cells. Periclinal wall

irregularly thickened, strongly granulate. Epidermal cells in contact with polar subsidiary cells perpendicular to vein direction. Guard cells poral wall cutinised. Fine outer stomatal ledge evident. (115)

Affinity Zamiaceae Figure 87, 88, 137.

Bowenia eocenica: Extinct understorey species that was first identified from the Eocene megafossil flora of Anglesea, Victoria.

Parataxon 44 Slide No. 117-004

Stomatiferous surface only. Cells triangular to pentagonal, mainly rectangular, 17.5 - 42.5µm in length, 12.5 - 30µm in width. Cells arranged in longitudinal rows. Anticlinal wall straight, irregularly thickened, up to 5um thick, smooth. Periclinal wall irregularly thickened, granulate to striate to reticulate. Stomata long axes oriented parallel to cell rows, uniform distribution. Stomatal aperture elliptical. Stomatal arrangement tetracytic. Guard cells sunken. S.I.= 2.0. Subsidiary cells 4. Anticlinal wall rounded, irregularly thickened, finely beaded. Periclinal wall irregularly thickened, granulate. Guard cells poral wall cutinised. Outer stomatal ledge evident. Trichome bases common, scarcely modified, uniform distribution. Basal cells 1. Anticlinal wall straight, irregularly thickened, up to 7µm thick, smooth. Periclinal wall irregularly thickened, granulate, darker staining than surrounding cells. Trichomes short, rounded apex. (22)

Affinity Unknown Figure 89, 138.

Parataxon 45 Slide No. 117-005

Stomatiferous surface only. Cells curved, tetragonal to pentagonal, curved to undulate, becoming elongate over veins. Cells 20 - 37.5µm in length, 12.5 - 20µm in width. Anticlinal wall straight to undulate, thin, smooth. Periclinal wall irregularly thickened, granulate, striate. Stomata randomly oriented, restricted to areoles. Stomatal aperture narrowly elliptical. Stomatal arrangement actinocytic. S.I. insufficient material. Guard cells not sunken. Subsidiary cells 3 - 5. Anticlinal wall rounded to undulate, thin, smooth. Periclinal wall irregularly thickened, thicker than surrounding cells, darker staining, granulate, reticulate. Guard cell poral wall cutinised. (16)

Affinity Unknown Figure 90, 139.

Parataxon 46 Slide No. 117-006

Stomatiferous surface only. Cells hexagonal, 20 - 30µm in length, 10 - 22.5µm in width. Anticlinal wall straight, irregularly thickened, finely beaded. Periclinal wall irregularly thickened, granulate to papilliate. Stomata randomly oriented, uniform distribution. Stomatal aperture narrowly elliptical. Stomatal arrangement not obvious. Guard cells slightly sunken. S.I. insufficient material. Subsidiary cells not obvious. Guard cells cutinised. Outer stomatal ledge prominent. Similar to Parataxon 21. (10)

Affinity Unknown Figure 91.

Parataxon 47 Slide No. 139-002

Stomatiferous surface only. Cells triangular to hexagonal, becoming elongate over veins.Cells 12.5 - 27.5µm in length, 12.5 - 15µm in width. Anticlinal wall straight, thin, smooth. Periclinal wall irregularly thickened, smooth to granulate. Stomata randomly oriented, uniform distribution. Stomatal aperture ovoid. Stomatal arrangement mainly paracytic, anisocytic. Guard cells not sunken. S.I.= 15.5. Subsidiary cells 2(- 3). Anticlinal wall straight, thin, smooth. Periclinal wall irregularly thickened, granulate to striate. Guard cell poral wall strongly cutinised. Outer stomatal ledge evident. Trichome bases poral, uniform distribution, abundant. Basal cells 4 - 8, radially arranged. Anticlinal wall straight, poral wall thickened, occasionally epidermal wall. Periclinal wall irregularly thickened, granulate to striate. Striations radiate outwards from pore. (12)

Affinity Unknown Figure 92, 140.

Parataxon 48 Slide No. 139-003

Stomatiferous surface only. Cells tetragonal to hexagonal, becoming elongate over veins. Cells 15 - 22.5µm in length, 7.5 - 12.5µm in width. Anticlinal wall straight, irregularly thickened, strongly beaded. Periclinal wall irregularly thickened, reticulate. Stomata randomly oriented, restricted to areoles. Stomatal aperture elliptical. Stomatal arrangement anomocytic. Guard cells not sunken. S.I.

insufficient material. Subsidiary cells 2. Anticlinal wall rounded, thinner than surrounding cells, smooth. Periclinal wall thin, smooth. Guard cell poral wall cutinised. Outer stomatal ledge evident. Hydathodes present. Trichome bases common, poral, uniform distribution. Basal cells 4 - 9, radially arranged. Anticlinal wall poral wall thickened. Periclinal wall identical to that of surrounding cells. (10)

Affinity Lauraceae Figure 93, 141.

Cryptocarya: Trees of subtropical to tropical closed forests that extend along the eastern coast of Australia.

Parataxon 49 Slide No. 111-002

Upper and lower epidermis indistinguishable. Stomatiferous surface . Cells elongate, generally rectangular, 57.5 - 222.5µm in length, 7.5 - 25µm in width. Anticlinal wall straight to curved. Periclinal wall irregularly thickened. (3)

Affinity Monocotyledonae Figure 94.

Parataxon 50 Slide No. 111-001

Stomatiferous surface only. Cells tetragonal to hexagonal, becoming elongate over veins. Cells 15 - 32.5µm in length, 12.5 - 17.5µm in width. Anticlinal wall straight, thin, smooth. Periclinal wall thin, smooth. Stomata randomly oriented, restricted to areoles. Stomatal aperture closed. Stomatal arrangement anisocytic. Guard cells sunken. S.I.= 16.6. Subsidiary cells 3 - 6. Anticlinal wall straight,

thin, smooth. Periclinal wall irregularly thickened, smooth to finely granulate. Guard cells cutinised. (5)

Affinity Cunoniaceae? Figure 95, 142.

The family consists mainly as trees that occur in subtropical to tropical closed forests of eastern Australia, but regional endemics are found in South West, Western Australia and Tasmania.

Parataxon 51 Slide No. 117-016

Upper and lower epidermis indistinguishable. Non-stomatiferous surface. Cells rectangular, some triangular to tetragonal, 15 - 30µm in length, 7.5 - 15µm in width. Anticlinal wall straight, irregularly thickened, smooth to beaded. Periclinal wall irregularly thickened, granulate. Rectangular cells predominate, arranged in distinct rows. Other cells, located along the margins of fragment. Trichome bases restricted to area of polygonal cells, abundant, poral. Basal cells 6 - 12, radially arranged. Anticlinal wall straight, thin, smooth, some poral wall thickening. Periclinal wall irregularly thickened, granulate. (5)

Affinity Unknown Figure 96.

Parataxon 52 Slide No. 118-28

Hypostomatic: Upper epidermis cells tetragonal to hexagonal becoming undulate, elongate over veins. Cells 20 - 37.5µm in length, 10 - 22.5µm in width. Anticlinal wall undulate, irregularly thickened,

smooth to finely ridged. Periclinal wall irregularly thickened, smooth to granulate. Trichome bases complex, rare, uniform distribution. Basal cells 1 - 2, surrounded by 10 - 12 radially arranged cells. Anticlinal wall straight to undulate, irregularly thickened, smooth to finely ridged. Periclinal wall irregularly thickened, granulate to striate. Striations radiate outwards into surrounding cells. Hair scar appears as two concentric circles over basal cells. Glandular bodies present. Lower epidermis cells tetragonal to hexagonal becoming undulate, up to 3 waves/wall length, amplitude rarely exceeds wavelength, elongate over veins. Cells 12.5 - 37.5µm in length, 10 - 22.5µm in width. Anticlinal wall undulate, irregularly thickened, ridged. Periclinal wall irregularly thickened, smooth to granulate to striate. Stomata randomly oriented, restricted to areoles. Stomatal aperture narrowly elliptical. Stomatal arrangement paracytic. Guard cells not sunken. S.I.= 14.0. Subsidiary cells 2. Anticlinal wall rounded, irregularly thickened, smooth to finely ridged. Periclinal wall irregularly thickened, smooth to granulate. Guard cell poral wall cutinised. Outer stomatal ledge evident.

Trichome bases abundant, uniform distribution. Two types present, i.e. scarcely modified and complex. Scarcely modified; Basal cells 6 - 12 radially arranged cells surround a central cell. Anticlinal wall straight to undulate, irregularly thickened, smooth to finely ridged. Periclinal wall irregularly thickened, granulate to striate. Striations radiate outwards into surrounding cells. Trichomes short, terete with truncated apex. Complex bases; same as those on upper surface. (125)

Affinity Proteaceae Figures 97, 98.

Cardwellia: Endemic trees of tropical closed forests in North

Queensland.

4.2 Identification of Megafossil Parataxa (i.e. Cuticle types)

Initially it was estimated that the Curlew Formation contained 85 cuticle types but re-examination showed that only 52 distinctly different parataxa existed. These parataxa have been described above and their possible affinities to extant families also listed. The families represented in the flora are the Casuarinaceae (1 parataxon), possibly Cunoniaceae (1), Cyperaceae (1), Ebenaceae (1), Lauraceae (10), Podocarpaceae (1), Proteaceae (5) and Zamiaceae (2). Of this group only two families occur regularly throughout the Formation, i.e. the Lauraceae and Proteaceae. The Lauraceae, because of its larger representation and higher frequency of distribution, is the primary floristic component.

The remaining families are rarely found in more than one sample and usually in very low numbers, with the only exception being the Zamiaceae which has been recorded in five samples, being the dominant taxa in one of these, and the Cyperaceae which was found in three samples in very low frequencies.

4.2.1 LAURACEAE

Identification of lauraceous fossils has typically been carried out using classical taxonomic features like floral, leaf architectural, and occasionally leaf anatomical features, although they possess a very distinctive cuticular morphology. This led to the situation whereby only fossil floras consisting of complete, intact, well preserved specimens were examined and described. Reference to cuticular features was generally neglected.

Bandulska (1927), in her examination of the Middle Eocene flora of Bournemouth, United Kingdom, provided the first, and until recently (e.g. Dilcher, 1963; Sturm, 1973) the most comprehensive, investigation of fossil lauraceous cuticles. Kovach and Dilcher (1984) described seven fossil cuticles from the Middle Eocene Claiborne Formation of Tennessee (North America) as having possible Lauraceae affinities but assigned them to form genera of the morphologic classification system adopted by Roselt and Schneider (1969). Solereder (1908) considered cuticular features and their diagnostic importance in classification in his lengthy work on the anatomy of dicotyledons but the information provided on the Lauraceae was limited and at times incorrect.

The most clearly diagnostic features of these cuticles are those associated with the stomatal arrangement. Solereder's (1908) statement that the Lauraceae are accompanied by subsidiary cells on either side and parallel to the pore has since been confirmed by Bandulska (1927). She also showed that this paracytic arrangement was characteristic of fossil forms. The presence of depressed guard cells and an outer stomatal ledge (Stace, 1965), referred to as cuticular scales by Bandulska (1927), in association with this predominantly paracytic arrangement distinguishes both extant and fossil representatives of this family. Both of these features, i.e. morphology of guard cells and their associated cuticular ledge, were emphasised as diagnostically important by Solereder (1908). Other important features noted by Hutchinson (1964) were a uniform indumentum (when present), simple, unicellular hairs and an absence of glandular hairs.

Solereder (1908) had previously noted that these projections were confined to the abaxial surface of lauraceous leaves but this is not

the case. Trichomes are found on both the adaxial and abaxial leaf surfaces. A well defined areolation (see Hickey in Metcalfe and Chalk (eds.), 1979) could also be considered a diagnostic feature of the Lauraceae.

The taxonomic importance of cuticular features at the generic and specific levels varies considerably between families. This variation has been discussed in some detail by Wilkinson (in Metcalfe and Chalk (eds.), 1979) through the use of numerous examples, some of which are: stomatal size, stomatal arrangement and the shape of hydathodes.

In the Australian Lauraceae the identification of the genera is based primarily on epidermal cell characters while those associated with the stomatal apparatus tend to be more diagnostic at the specific level. These will be discussed in more detail in the relevant sections below.

Of the approximate 47 extant genera of Lauraceae (Hutchinson, 1964), it is possible to assume that the fossils are most likely to have as affinity to those genera present in the modern Australian flora. Only seven genera occur naturally on the Australian mainland*: Beilschmiedia and Endiandra of the tribe Apollonieae, Cryptocarya of the Cryptocaryeae, Cinnamomum of the Cinnamomeae, Litsea and Neolitsea of the Litseae and Cassytha of the Cassytheae. As Cassytha includes only leafless climbers, this genus may be excluded from these

* This is based on the existing taxonomy of the Australian Lauraceae which is at present being revised by B. Hyland.

comparative investigations. This leaves 6 genera with a total number of species in excess of 60 (Hutchinson, 1964) and up to 90 (Hyland, 1983) available for examination. It is obvious from this wide range in species number that the family is not particularly well known in Australia. The taxonomic uncertainty of the family is further emphasised by Hyland's proposal to erect more genera. In view of this present situation in the Australian Lauraceae the number of possible species available for examination could not be determined with any certainty. Therefore the following generic determinations are based on species present in leaf and cuticle collections of, and those recently made available to, the Palaeobotanical Laboratory, Botany Department, University of Adelaide.

For Beilschmiedia all 4 of the 4 known species were examined.

Endiandra 10 of 18

Cryptocarya 15 of 29

Cinnamomum 2 of 5

Litsea 5 of 7

Neolitsea 1 of 2

In addition a further 17 non-Australian species were examined, i.e. Beilschmiedia 2, Endiandra 4, Cryptocarya 5, Cinnamomum 3, Litsea 1, Neolitsea 1, and Dehaasia 1, which is also a representative of the tribe Apollonieae (See, Table 4).

4.2.1.1 Cuticular Characteristics of Modern Australian Genera

Summary of Genera

The sinuous nature of the anticlinal wall of the upper epidermal cells is a feature displayed in all genera except Endiandra. and all but one species of Beilschmiedia (i.e. B. obtusifolia). These two genera also possess other similar features which include irregular thickening of both the anticlinal and periclinal walls of all epidermal cells, a generally poorly defined guard cell - subsidiary cell wall, unequal sized subsidiary cells and a prominent outer stomatal ledge. This close morphological similarity could be expected as both are of the tribe Apollonieae.

Despite this similarity the genera may be separated by the type and degree of thickening of the anticlinal wall of the upper epidermal cells. In Endiandra the anticlinal wall is thin, i.e. < 2.5µm in width, and finely beaded, but the beading is not continuous around the entire cell. Beilschmiedia, on the other hand, has an upper epidermal anticlinal wall that is much thicker, i.e. > 2.5µm in width, and continuous, very pronounced beaded thickening which in some species has become strongly buttressed.

Cinnamomum is a small Australian genus that is easily distinguished from the other lauraceous genera by the high degree of sinuosity of the epidermal cells (type 8*), extremely dense granular thickening on the periclinal wall of all epidermal cells, a prominent butterfly shaped outer stomatal ledge and lobed guard cell - subsidiary cell wall.

Cryptocarya is the largest genus of the Australian Lauraceae and by far the most diverse. However, a number of diagnostic cuticular features do exist. All species have either rounded or progressively more sinuous shaped upper epidermal cells with a thin, i.e. < 2.5µm in width, regularly thickened (straight) anticlinal wall. The lower epidermal cells all tend to be undulate (type 3* upwards, see page 153; Wilkinson, 1979) with a narrow, regularly thickened anticlinal wall. A well defined, regularly thickened guard cell - subsidiary cell wall is also diagnostic. Another feature commonly asociated with the genus is the presence of triangular subsidiary cells.

Litsea and Neolitsea are both of the tribe Litseae and show a considerable amount of cuticular similarity. The only possible distinction between the two is an increased upper epidermal sinuosity in Neolitsea from type 3 to type 5, otherwise the genera are characterised by a thin lower cuticle, sunken guard cells, poorly defined (if not absent) guard cell - subsidiary cell wall, a narrow outer stomatal ledge that lies near to the stomatal pore and unequal subsidiary cells of which one is generally triangular in shape.

* The "types" used to describe the degree of sinuosity of the epidermal cells have been taken from Wilkinson's (1979) Figure 10.14. titled "Basic patterns of anticlinal walls (flanges) as seen in surface view", page 153.

Cuticular Key to Australian Genera

1a) Upper epidermal cells are straight walled, angular in appearance (type 1).....2.

1b) Upper epidermal cells are not straight walled, rounded to sinuous in appearance (types 2 to 8).....3.

2a) Anticlinal wall of upper epidermal cells < 2.5µm in width, shows irregular beaded thickening... .....*Endiandra*.

2b) Anticlinal wall of upper epidermal cells > 2.5µm in width, shows continuous, regular beaded thickening tending to buttressing.....*Beilschmiedia*.

3a) High degree of sinuosity (type 8) for epidermal cells of both surfaces, periclinal wall of epidermal cells highly granular in appearance.....*Cinnamomum*.

3b) Degree of sinuosity of epidermal cells less pronounced (< type 8), periclinal wall of epidermal cells not highly granular in appearance.....4.

4a) A well defined guard cell/subsidiary cell wall in stomatal apparatus, difference in sinuous nature of epidermal cells of both surfaces common, outer stomatal ledge of variable shape.....*Cryptocarya*.

4b) A poorly defined guard cell/subsidiary cell wall in stomatal apparatus, difference in sinuous nature of epidermal cells of both surfaces uncommon, outer stomatal ledge narrow confined to poral region.....5.

5a) Degree of sinuosity of upper epidermal cells generally < type 4.....*Litsea*.

5b) Degree of sinuosity of upper epidermal cells generally > type 4.....*Neolitsea*.

Beilschmiedia

Both cuticular surfaces are robust (Figures 160, 161, 163, 164). Pronounced buttress thickening of the anticlinal wall of the epidermal cells (Figure 165) and the rarity of trichome bases (poral type) on the upper surface are features common to all species including the non -Australian species B. grandiosa. The trichome bases are characterised by a rosette arrangement of modified, triangular epidermal cells which have thickened radial anticlinal walls. The pore is also thickened. Stomata are abundant, randomly oriented and uniformly distributed within well defined areoles over the lower surface. A prominent outer stomatal ledge of variable thickness overlies slightly sunken guard cells, except in the non Australian species B. tawa (Figures 166, 167). The guard cell - subsidiary cell wall is not well preserved in most species. The stomatal arrangement is paracytic with the subsidiary cells showing some variation between species.

In B. elliptica (Figure 162) and Beilschmiedia sp. No.1 the subsidiary cells are of equal size (i.e. length to width) and uniform in shape giving both cells a similar appearance. The guard cell - subsidiary cell wall is obscured by a prominent outer stomatal ledge in both species but in Beilschmiedia sp. No.1 the ledge is doubled (see Wilkinson, 1979; fig.10.4 (i)). This easily distinguishes the species. An interesting and specifically important feature of B. elliptica (Figure 161) is the presence of darker staining encircling cells (3-5) around the stomate. The two other Australian species B. obtusifolia (Figure 165) and B. oligandra have unequal sized subsidiary cells with at least one of them being triangular in shape, i.e. the greatest width

is perpendicular to the stomatal pore and at the cell's mid-point. The outer stomatal ledge is prominent though very thin in both species and restricted to the poral region. The absence of a guard cell - subsidiary cell wall in B. obtusifolia (Figure 165) distinguishes the two species.

Endiandra

The lower cuticular surface is more delicate than the upper. Areolation is very distinctive on both surfaces. Epidermal cells of both surfaces are angular with straight anticlinal walls which are generally thin, showing beaded thickening. This is a feature of all Australian species, except E. pubens (Figures 175, 176) which has sinuous lower epidermal cells. The non-Australian species examined display both anticlinal wall characters, e.g. in E. polyneura (Figures 171, 172) and E. coreacea they are undulate while in E. eleocarpa and E. aneityensis (Figures 173, 174) they are straight. Poral trichome bases are a feature of all species. However, frequency and degree of cuticular thickening varies considerably. For example, the lower surface trichomes of E. hayesi (Figure 182) have a large pore surrounded by a number of modified epidermal cells in a radial arrangement, whereas the same surface of E. pubens has trichome bases which are thickened around the pore and along a section of the radial wall of the surrounding cells, giving a star-shaped pattern (Figures 176, 177).

The stomatal arrangement is paracytic with the guard cells slightly sunken and one particularly obvious subsidiary cell. This

generally results in unequal sized subsidiary cells. Triangular cells are only found in E. crassiflora (Figure 180) and E. muelleri (Figure 189), and the non-Australian species E. aneityensis and E. polyneura. The guard cell - subsidiary cell wall is evident in all species except E. crassiflora and E. discolor (Figure 170) where the extensively thickened outer stomatal ledge obscures it. In these species the ledge is very distinctive with an arrow-shaped section occurring in the polar area of the guard cells. The shape of the outer stomatal ledge varies in the other species. In E. hayesi (Figures 182, 183), E. muelleri and E. sankeyana the ledge is most prominent around the stomatal pore (see fig. 10.4 (b); Wilkinson, 1979), whereas in the other species the ledge is butterfly-shaped, with no thickening occurring around the poles of guard cells, e.g. E. introrsa (Figure 186). A unique feature of E. crassiflora is the presence of darker-staining encircling cells, (Figure 179) whose number varies from 4 to 8, around the stomatal apparatus.

Cinnamomum

The cuticles of all species of Cinnamomum examined, including non-Australian species, were distinctly different from those of the fossil lauraceous parataxa. The most distinctive feature of this genus is the sinuous nature of the epidermal cells of both epidermal surfaces (Figures 192, 193). In all species examined the degree of sinuosity is such that the (anticlinal) walls are deeply convoluted, i.e. "Omega" shape (see page 153; Wilkinson, 1979). Other features which characterize the genus are a paracytic stomatal arrangement in which

guard cells are sunken, unequal sized subsidiary cells, a prominent butterfly—shaped outer stomatal ledge, dense granulation of the periclinal wall of all epidermal cells of both surfaces and the lobed appearance of the guard cell - subsidiary cell wall.

Cryptocarya

The lower epidermis is more delicate than that seen in most other genera, except Litsea and Neolitsea. In most Australian species examined the angular nature of the epidermal cells, characteristic of Endiandra, is less conspicuous. The epidermal cells of the upper surface are rounded or undulate with undulation becoming more pronounced in the lower epidermal cells. The only possible exceptions are C. glabella and C. glaucescens (Figure 196) which have straight , angular upper epidermal cells. At the other extreme, sinuous upper epidermal cells are characteristic of C. erythroxylon (Figure 199), C. oblata (Figure 206) and Cryptocarya sp. No.3. Therefore the shape of the upper epidermal cells of Cryptocarya are generally in the range, using Stace's classification for patterns of anticlinal walls (see page 153,fig.10.14; Wilkinson, 1979), type 2 to type 6.

The stomatal arrangement is paracytic with the guard cells positioned below the subsidiary cells. The size and shape of the subsidiary cells varies considerably throughout the genus, but in all species both cells are unequal in size. Triangular subsidiary cells occur in a number of species, e.g. C. ilocana, C. oblata (Figures 207, 208), C. murrayi, C. triplinervis and Cryptocarya spp. Nos.1 and 3. An outer stomatal ledge is well-defined in all species but shows some variation in form. For the majority of species a butterfly-shaped ledge

completely covers the guard cell - subsidiary cell wall but this wall can still be seen, which suggests it is well cutinized.

Only in C. cinnamomifolia (Figure 205) and Cryptocarya sp. No.2 where heavily cutinized subsidiary cells completely overly the guard cells is the outer stomatal ledge absent. However, some poral thickening of the guard cell is still evident. A thin, though recognisable, outer stomatal ledge is found in C. oblata (Figures 207, 208) and Cryptocarya sp. No.3. The guard cell - subsidiary cell wall is well-defined in all species. Lobing of this wall is a feature of three species, the Australian species C. glaucescens (Figure 198) and C. triplinervis and the non-Australian species C. woodii. The only species which do not display any thickening of the guard/subsidiary cell wall are C. glabella and the non-Australian species, C. turrilliana and C. brachybotrya.

Trichomes are common throughout the genus. However, frequency and distribution differ significantly between species. All trichome bases are poral with up to 10 modified epidermal cells radially arranged around the pore. Thickening is generally restricted to the area around the pore, but in C. triplinervis (Figure 210) and C. rigida the thickening appears star-shaped with a small portion of the radial walls of the surrounding cells thickened. Only C. glaucescens is devoid of trichomes.

The cuticular characteristics of Litsea and Neolitsea have been described by Bandulska (1927) using extant European and tropical species. No Australian material was examined by Bandulska. The following generic descriptions are based on Australian species but

other species including those investigated by Bandulska (1927), are also considered.

Litsea

The cuticle of the lower surface is delicate. The shape and structure of the epidermal cells of both surfaces is variable, a feature already noted by Bandulska (1927). The only species where straight anticlinal walls are characteristic of the epidermal cells of both surfaces are Litsea leefeana (Figures 212, 213) and the non Australian L. montana. Litsea ferruginea (Figures 215, 216) and L. glutinosa (Figures 223, 224) have sinuous epidermal cells on both surfaces, while L. reticulata (Figures 218, 219) exhibits sinuosity only on the lower surface. The stomata are randomly oriented and distributed evenly over the surface, except in L. leefeana, L. japonica and L. glutinosa where numerous areoles cause the stomata to be clustered. In L. japonica the areolation is so pronounced that the area between these thick veins tends to be sunken. Bandulska (1927) noted that there were no distinct grouping of the stomata, which would suggest the Australian species mentioned above are exceptional. The stomatal arrangement is paracytic. In those species where subsidiary cells are easily recognised, they are generally of equal dimensions and range from elongate (L. reticulata), i.e. the longest dimension is parallel to the guard cell wall, to triangular (L. glutinosa). The guard cell - subsidiary cell wall is generally evident, only in L. glutinosa (Figure 225) is the wall not obvious.

The outer stomatal ledge is also thin, with most cutinization being around the pore. Striations in the vicinity of the pore are also

a common feature, for example in L. ferruginea (Figure 217). Trichomes are absent from both surfaces of L. reticulata, rare on L. leefeana and common on L. ferruginea, L. glutinosa and L. montana. The single-celled trichomes are particularly long (up to 1mm in length) on L. glutinosa and L. ferruginea. The majority of these trichomes occur over veins. The density of trichomes in L. japonica (Figure 222) is such that all other features of the lower surface are completely obscured.

Neolitsea

Although no fossil parataxon was shown to be related to Neolitsea it should be noted that the cuticle of the genus is very similar to that of Litsea. The only difference observed between the two genera is an increase in cell sinuosity in Neolitsea (Figures 226, 227). This was also observed by Bandulska (1927).

4.2.1.2 Comparisons with fossil Lauraceae

From the examination of the extant Australian species of Beilschmiedia it is evident that there is considerable variation between these species and the fossil cuticle types. Of all the fossil parataxa only one, No.29 (Figures 70, 128), with a tendency towards beaded thickening of the anticlinal wall of lower epidermal cells and the occasional triangular shaped subsidiary cells, could be considered possibly related to the genus. However, this parataxon along with the majority of others are more similar to Endiandra which with Beilschmiedia comprise the Apollonieae in Australia.

Of the six fossil parataxa, i.e. Nos.9, 10, 14, 16, 18 and 29, which appear to be related to Endiandra only No.16 (Figures 53, 54, 115) and No.14 have particularly close affinities to any of the examined extant Australian species (E. introrsa and E. pubens respectively). The similarities between E. introrsa (Figures 184, 185, 186) and No.16 include the arrangement, shape and structure of the epidermal cells of both surfaces, a stomatal arrangement that is usually paracytic (this shows some variation), a define outer stomatal ledge and variation in size and shape of the subsidiary cells. Despite the sinuous nature of epidermal cells in parataxon No.14 most other features suggest an affinity to Endiandra. E. pubens (Figures 175, 176), the only species examined that exhibited cell sinuousity does compare favourably with the fossil. Both have irregular, beaded thickening of the anticlinal and periclinal walls of the lower epidermal cells, a poorly defined guard cell - subsidiary cell wall, prominent, though thin outer stomatal ledge and slightly sunken guard cells.

Parataxon No.29, which has a slightly more undulate cell shape and irregularly thickened anticlinal wall, but still maintains the same overall appearance of the epidermal cells, bears some resemblance to E. muelleri (Figures 187, 188, 189). Both have similar guard cell, subsidiary cell and outer stomatal ledge shape. The straight walled epidermal cells of parataxon No.9 (Figures 40, 41, 107) suggest a possible association to either E. discolor or E. crassiflora but no one species displays a sufficient degree of similarity to permit a more positive association.

The similarity of Nos.10 and 19 to Endiandra is less obvious. Parataxon No.10 (Figures 42, 43, 108) could be related to E. introrsa and E. muelleri, but the fossil also bears some resemblance to the non Australian species Dehaasia incrassata (Figures 190, 191) which belongs to the same tribe as Endiandra, the Apollonieae. An abundance of hairs covers the lower surface of parataxon No.18 (Figures 56, 116) obscuring most cuticular features and making a positive identification impossible. None of the modern Australian species examined have as high a trichome frequency as the fossil.

The undulate nature of the lower epidermal cells and the presence of triangular subsidiary cells suggests a possible affinity between this genus and parataxon No.14. Sinuosity of epidermal cells is indeed a diagnostic feature of the genus and some species, e.g. C. ilocana and C. murrayi (Figures 202, 195 respectively), do have such a subsidiary cell shape but the many different features exhibited by the fossil cuticle suggests the relationship is very tenuous or distant. Similarly, parataxa Nos. 38 (Figures 81, 134) and 48 (Figures 93, 141), which both exhibit granulate cuticular thickening on the periclinal wall of the lower epidermal cells (at least) and darker staining encircling cells around the stomata, do not compare favourably to any species. Only one Australian species displays any kind of thickening of the periclinal wall of the epidermal cells and possesses what could be considered encircling cells, and that is C. erythroxylon.

Parataxon No.15 (Figures 51, 52, 114) appears to be related to Litsea leefeana (Figures 212, 213, 214) because several features are common to both species. These include straight to slightly undulate epidermal cells of the upper surface; straight, thin walled epidermal

cells of the lower surface; paracytic stomatal arrangement; an overall scarcity of trichomes and little guard cell cutinization. None of the other species examined display this same degree of similarity.

Table 4: Modern Species of Lauraceae used in the Identification of the lauraceous cuticles of the Curlew Formation.

SPECIES OF LAURACEAE USED IN DETERMINING THE AFFINITY OF FOSSIL PARATAXA

GENUS	AUSTRALIAN	NON-AUSTRALIAN
Beilschmiedia	B. elliptica B. obtusifolia B. oligandra B. sp. No. 1.	B. grandiosa B. tawa
Cinnamomum	C. laubatii C. oliveri	C. culitlawau C. pedatinerinnum C. verum
Cryptocarya	C. angulata C. cinnamomifolia C. erythroxylon C. glabella C. glaucescens C. ilocana C. mackinoniana C. meisnerana C. micronеura C. murrayi C. oblata C. rigida C. triplinervis C. sp. No. 1 (Dome Mt., N.S.W.) C. sp. No. 2 (New England, N.S.W.) C. sp. No. 3 (Qld)	C. brachybotrya C. turrilliana C. umborata C. woodii
Dehaasia		D. incrassata
Endiandra	E. cowleyana E. crassiflora E. discolor E. hayesi E. hypotephra E. introrsa E. muelleri E. pubens E. sankeyana E. sieberi	E. anietyensis E. coreacea E. eleocarpa E. polyneura
Litsea	L. ferruginea L. glutinosa L. japonica L. leefeana L. reticulata	L. montana
Neolitsea	N. dealbata	N. megacarpa

4.2.2 PROTEACEAE

The Proteaceae with five parataxa is the only other family that occurs consistently and in relative abundance throughout the Curlew Formation. The family is large, being represented by 14 tribes, 75 genera and 1,500 species and having a primarily Southern Hemisphere distribution. However, a few genera do extend into China and southern India (Johnson and Briggs, 1983). Diversity in Australia is high (45 genera, 900 species) with the majority of species occurring in either south-western or eastern Australia. Only one tribe and two subtribes are absent (Johnson and Briggs, 1983).

Unlike the Lauraceae, a good fossil record exists for the Proteaceae in the Southern Hemisphere. Early contributors included Cookson and Duigan (1950) and Patton (1957) and those responsible for the recent expansion of the proteaceous megafossil record include Christophel (1984), McNamara and Scott (1983), Blackburn (1981), Christophel and Blackburn (1978) and Lange (1978b). Cuticular characters were used exclusively by Lange (1978b) in the identification of the megafossils from Eocene localities in South and Western Australia. Blackburn (1981), also considered cuticular features in his investigation of megafossils from the same South Australian deposit investigated by Lange, i.e. Maslin Bay.

The bulk of proteaceous fossils have been recovered form south-eastern Australia, in a region which extends from Maslin Bay, South Australia (35° 13',S; 138° 28',E) in the west to Nerriga, New South Wales (35° 05',S; 150° 05',E) in the east and as far south as Anglesea, Victoria (38° 25',S; 144° 11',E). Sites within this

region include the Yallourn Coalfields (Cookson and Duigan, 1950) and Dean's Marsh, both of which occur in Victoria. Other smaller localities which have reported proteaceous megafossils are scattered over the continent and include Lake Lefroy, Western Australia (31° 20',S; 121° 40', E) (Lange,1978b), Kennedy Range, Western Australia (24° 25',S; 115° 05',E) (McNamara and Scott, 1983) and the site of this study, Rundle, Queensland.

The family is an ancient and isolated one (Johnson and Briggs, 1983) and for these reasons has maintained a distinctive homogeneity which is reflected in the morphology of all representatives. Therefore features of the floral, foliar and wood anatomy may be used to distinguish Proteaceae fossil material. The cuticular characters which best identify the family are brachyparacytic stomates and those of the trichome bases. There are two principle types: (A) the scarcely modified trichome base (Figure 11B), (B) the very distinctive multicellular trichome base (Figure 11C). The Araliaceae have a similar multicellular trichome base structure (Lange, 1978b) but exhibit other cuticular features more diagnostic of the family, e.g. biseriate hairs and a beaded stomatal ledge. The trichome bases appear on both cuticular surfaces but are more conspicuous on the non-stomatiferous (adaxial) surface. The multicellular trichome base is seen as a cluster of modified epidermal cells, ranging in number from 2 - 16, arranged in such a fashion as to distinguish the base from the surrounding epidermal cells. The most obvious feature is that the cell junctions are angular and cell walls thicker. For example, in those bases where four cells are incorporated, a cruciate pattern is common. The overall shape of the base is variable, ranging from circular to modified ovoid.

A deciduous trichome scar, which is closely associated with the base, overlies the structure and appears as two concentric circles (Figure 11C). The circular outline may vary depending on the actual shape of the trichome base. Cuticular striations which radiate outwards from the trichome base are another feature commonly associated with this structure. The trichome scars on the stomatiferous (abaxial) surface are identical in appearance to those of the upper surface. The trichomes themselves are generally of the scarcely modified type and less robust.

Scarcely modified trichome bases (Stace, 1965) consist of a central, scarcely modified foot cell, surrounded by numerous epidermal cells. These cells maybe radially arranged around the foot cell giving the base a rosette-like appearance; however, occasionally these cells are not distinct and the base appears as a single cell. The foot cell differs from the other hair base cells by displaying slightly more cutinization along the anticlinal wall. Small striations are not uncommon also. The trichome scar only overlies the central foot cell.

In determining the affinities of the Lauraceae, species of all eight genera were examined, but using such a procedure for investigating the Proteaceae of Australia is not practical. A more appropriate method of investigating this family is to initially consult the Australian Eocene fossil record and determine the relationship between the Curlew fossils and those of other localities (e.g. Maslin Bay). If similarities are observed then extant relatives may be examined. In this way only the most likely extant genera with possible affinities are considered.

While a good fossil record for the Australian Proteaceae exists it is based primarily on palynological reports (e.g. Martin, A. and Harris, 1974). However, the megafossils that have been recovered are generally well documented, with cuticular descriptions included making this section of the fossil record particularly useful in the identification of the Curlew proteaceous parataxa. Of all the Eocene deposits with a recorded proteaceous element, Maslin Bay and Anglesea are probably the most diverse. The Anglesea flora has yet to be properly documented but research to date, carried out by the Palaeobotany Laboratory at the University of Adelaide, reveals the family was well represented during the Eocene.

The older deposit, Maslin Bay is better known and five proteaceous taxa have been identified. The family was first recognised by Harvey (1974) from dispersed cuticle fragments. In 1978, Lange formally described three proteaceous cuticle types and made comments on the fossils possible modern affinities. He concluded that Maslin Bay cf. Proteaceae III was most similar to Darlingia, Maslin Bay cf. Proteaceae II showed some resemblance to Darlingia also while Maslin Bay cf. Proteaceae IV displayed features indicative of a number of modern genera but lacking a sustantial combination of characters to favourably compare any one genus. Banksieaephyllum incisum and Maslinia grevilleoides two more proteaceous fossils were described from leaf compressions and cuticles by Blackburn (1981). Architectural and epidermal features show that B. incisum has a range of characters possessed by the modern genera Banksia and Dryandra. Maslinia grevilleoides is architecturally most similar to the species Grevillea hilliana and therefore of the tribe Grevilleae (Blackburn, 1981).

The other proteaceous fossil described by Lange (1978b) was from Lake Lefroy, Western Australia, which he related to the extant genus Synaphea on the basis of trichome base and papillae morphology. The trichome base features a central, scarcely modified foot cell surrounded by numerous (up to 12) radially arranged epidermal cells. It is also important to note that the trichome scar always overlies the foot cell. Papillae, unlike the trichomes, are confined to the lower surface and associated with the epidermal cells only. They are short, cylindrical prot-uberances with truncate apices.

Of the five proteaceous cuticle types recovered from the Curlew Formation only one parataxon, No.12 (Figures 46, 47, 111, 112), has a vestiture which would suggest an affinity to Synaphea. An examination of cuticles from seven extant species, i.e. S. acutiloba, S. decorticans, S. favosa, S. petiolaris, S. pinnata, S. polymorpha and S. preissii (some of these cuticle specimens were those originally examined by Lange (1978b) and Lange's Lake Lefroy fossil shows that parataxon No.12 is more closely related to the Western Australian fossil than any of the extant species.

The other parataxa, i.e. Nos.11, 36, 40 and 52, represent two distinctly different types. Parataxa Nos.11 (Figures 44, 45, 109, 110) and 36 (Figures 77, 78, 132, 133) both have very similar cuticles but display subtle differences in the degree of sinuosity of epidermal cells, cell size and stomatal frequency. An examination of cuticles representing the 42 proteaceous genera suggests the two fossil cuticles are most similar to Darlingia. Of the extant species considered (D. ferruginea Figures 228, 229, 230, D. spectatissima, D. darlingiana and Darlingia sp. (after Lange, 1978b)) D. spectatissima appears to have

the greatest similarity. The sinuous nature of the anticlinal wall of the epidermal cells of both surfaces, paracytic stomatal arrangement, uniform stomatal distribution on the lower surface, multicellular trichome bases on the upper surface and cuticular thickening of the guard cells and stomatal pore are features which compare favourably with those of the fossil types. It would appear the two fossils are more closely related than previously proposed and have a strong affinity to the extant species Darlingia spectatissima.

Parataxa Nos.40 (Figures 83, 84, 136) and 52 (Figures 97, 98) also appear similar, both possess scarcely modified trichome bases on the lower surface, multicellular trichome bases on the upper surface, uniform distribution of stomata on the lower surface, paracytic stomatal arrangement and high trichome frequency on the lower surface. Of all the extant species examined, only the cuticle of Cardwellia sublimis (Figures 231, 232, 233) bears any similarity. The upper surface with angular epidermal cells is very different in appearance to that of the fossils even though multicellular trichome bases are present. It is on the lower surface of C. sublimis that the major cuticular similarities occur. The scarcely modified trichome bases, with the central foot cell covered by an obvious circular hair scar, are a common feature of this surface. Two lightly staining subsidiary cells are associated with the stomata which are abundant and evenly distributed over the surface. The epidermal cells are generally angular in shape but undulate cells are occasionally observed. All these features would tend to support the proposal that these two fossil cuticle have a closer affinity to Cardwellia, at least, than any other extant genera of the Knightieae, i.e. Darlingia, Eucarpha and Knightia.

4.2.3 ZAMIACEAE

The Zamiaceae is the only other family to be represented by more than one parataxon, that is, Nos.23 and 43. Parataxon No.23 (Figures 61, 62, 119 to 123) is both more common and abundant than parataxon No.43 (Figures 87, 88, 137) having been recorded three times in the younger sediments of the Formation and on two of these occasions the parataxon was the dominant cuticle type. No.43, on the other hand, is based on a single cuticle fragment and has been recorded only once (See Appendix 2, Parataxa distribution in ERD 118).

The family comprises eight genera which are arranged in three tribes (Johnson, 1959). Three genera, Bowenia, Lepidozamia and Macrozamia, are endemic to Australia. Distribution is restricted to small disjunct areas within the tropical and warm temperate regions of Africa, Australia and North and South America (Hill, 1980). Hill (1978, 1980) has shown that the distribution of the Zamiaceae in Australia, now relict, was once far more extensive. The cuticular morphology of fossil and extant taxa of the Zamiaceae is well documented (Cookson, 1953; Pant and Nautiyal, 1963; Harris,1964; Greguss, 1968; Hill, 1978, 1980). Hill's recent papers dealt with the identification and evolution of Australian Tertiary cycads and have been particularly useful in assigning the specific affinities of both fossil cuticle types.

A number of specimens of parataxon No.23 were examined and in some instances stomata were observed on both upper and lower surfaces. The

stomata were scattered over the upper surface and grouped into broad longitudinal bands on the lower surface. Greguss (1968) found such an arrangement to be unique to Bowenia. Other features of the fossil which Greguss also considered characteristic of the genus are the much lower stomatal frequency on the upper surface and thin walled epidermal cells. A serrate margin was observed on two leaf fragments, intact teeth had acute apices and on clearing a vein was seen to terminate in each tooth. This feature is characteristic of three of the four species of Bowenia, The extant B. serrulata and the fossil species B. papillosa Hill (Nerriga) and B. eocenica Hill (Anglesea). The fossil species described and identified by Hill (1978) are separable on cuticular features. The most distinguishing feature is the presence of papillae or papillae bases on the upper and lower surfaces of B. papillosa. These papillae are considered distinct (Hill, 1978) from the deciduous hairs described by Johnson (1959).

Trichomes and trichome bases were not observed on any of the fossil fragments; however, papillae bases very similar in appearance to those found on B. papillosa were observed on the upper surface of most fragments. Papillae/papillae bases occurred over the upper surface of most fragments. They were identical in structure to those of B. papillosa, i.e. unicellular, more or less circular and having a thickened wall. Other similar epidermal features include epidermal cell shape (narrowly elongate) and subsidiary cell number (3-(5)-7). The high degree of similarity between the two fossil cycads leaves little doubt that they are identical. Therefore, parataxon No.23 is a new record for B. papillosa.

The lack of cuticle fragments made the generic identification of parataxon No.43 difficult. An examination of species from the three Australian genera included, Lepidozamia hopei, L. peroffskyana, Macrozamia macdonnelli, and the fossil species Lepidozamia foveolata, L. hopeites (Cookson) Johnson, Bowenia eocenica, B. papillosa, Pterostoma anastomosans and P. zamioides. All fossil species, with the exception of Lepidozamia hopeites, were described and identified by Hill (1978, 1980).

The orientation of the long axes of the epidermal cells parallel to the long axes of the pinna is a feature of the fossil and also characteristic of the Bowenia and Macrozamia. In Lepidozamia, however, the long axes of the epidermal cells are obliquely oriented and Pterostoma with sinuous epidermal cell walls is distinctly different.

The similarities between Bowenia and Macrozamia are numerous and include, the arrangement of the stomata of the lower surface into longitudinal bands, the number of subsidiary cells (although variable in Macrozamia, a number of species have the same number characteristic of Bowenia) and amphistomatism. This makes their separation difficult, however, subtle differences are evident and based on these the two may be distinguished. The most distinguishing feature is the position of the guard cells, i.e. in Macrozamia the guard cells are positioned at the base of a stomatal pit. Greguss (1968) points out that the depth of the stomatal pit varies, but in all instances the pit is present. In Bowenia the guard cells are not sunken. As the fossil does not possess sunken stomata it is assignable to Bowenia.

Of the four Bowenia species examined (B. spectabilis, B. serrulata, B. papillosa and B. eocenica) only one B. eocenica compares favourably with the fossil. The shape, size and arrangement of the epidermal cells and stomatal size and shape all closely resemble those of parataxon No.43.

4.2.4 CASUARINACEAE

The single parataxon No.31 has been assigned to the Casuarinaceae. The cuticle type is restricted in its distribution in the sequence, being concentrated in core ERD 117 where it occurs at irregular intervals but generally as a high percentage of the respective cuticular flora.

The family Casuarinaceae has a centre of diversity in Australia which extends into the islands of the Pacific and North and South-East Asia (Johnson and Wilson, 1983). The recent taxonomic revision of the family by Johnson (1980, 1982) saw the creation of three new genera, i.e. Allocasuarina, Gymnostoma and an as yet unnamed genus referred to as Genus nov. A by Johnson and Wilson (1983). Allocasuarina was established for a number of species formerly assigned to Casuarina. Gymnostomae was elevated to the generic level (i.e. Gymnostoma) by Johnson after it was originally created (but with no true taxonomic significance) as a division of the genus Casuarina by Poisson (1871). The undescribed Genus nov. A (also referred by Johnson (1982) as "Genus C") is confined to Malesia.

Australian Tertiary megafossils attributable to the Casuarinaceae have been reported by Paterson (1935), Patton (1936), Pike (1953), Lange (1970) and Christophel (1980, 1981) from south-eastern Australian deposits. In almost all of these reports subgeneric affinities received little consideration and the fossils were discussed in comparison to Casuarina, an important exception was the recent study by Christophel (1980) on the occurence of Casuarina megafossils in the Tertiary of

south-eastern Australia. He reported that all Eocene megafossils were shown to have clear affinities to the extant generic division Gymnostomae (note: this was prior to Johnson's 1980 nomenclatural changes) and the Miocene fossils a similarity to Cryptostomae. Cuticular descriptions of these fossils permitted a comparison being made with the Curlew parataxon No.31.

Of the cuticles described by Christophel those which are most closely related to the extant genus Gymnostoma compare very favourably with parataxon No.31. Features which strongly support an affinity to the modern genus are the high percentage of hexagonally-shaped epidermal cells (>65%) and the subsidiary cell number which ranges between 0 and 1 (Figures 72, 129). These diagnostic features are discussed in detail by Christophel (1980).

4.2.5 PODOCARPACEAE

A single cuticle fragment represents parataxon No.8 and has been assigned to the Podocarpaceae. As in the Zamiaceae, the use of cuticular morphology in the identification of living and fossil podocarps is also well documented (Florin, 1931 and 1940; Cookson and Pike, 1953a and 1953b; Townrow, 1965; Dilcher, 1969; Blackburn, 1981). This greatly assisted the generic identification of parataxon No.8. The fossils' most distinctive characteristics include rows of longitudinally oriented stomata, a feature diagnostic of the family (Dilcher, 1969; Blackburn, 1981), buttress thickening of the anticlinal wall of the epidermal cells and broadly rectangular shaped epidermal cells which are both distinctive at the generic level (Figures 39, 106).

A similar degree of buttress thickening of the anticlinal wall of the epidermal cells is common in both Podocarpus s.s., Decussocarpus and some species of Prumnopitys. The broadly rectangular epidermal cells with straight anticlinal walls and square ends is characteristic of Decussocarpus, compared with narrowly rectangular cells and irregular ends in Podocarpus s.s and Prumnopitys which has irregular anticlinal walls (D.Greenwood pers. comm., 1984). One other feature of the fossil is the ring effect of the subsidiary cells which is characteristic of (though not unique to) Decussocarpus (Florin, 1931). This is in comparison to the lateral subsidiary cells of Podocarpus s.s which are greatly enlarged in relation to the polar cells. Prumnopitys is similar to Podocarpus.

It would appear the fossil has a strong affinity to Decussocarpus. This is supported by closely resembling D. wallichianus and D. nagi (P. blumei and P. nagi respectively; Florin, 1931). Both species occur in Section Dammaroides of Decussocarpus (sensu, de Laubenfel, 1969).

4.2.6 EBENACEAE

Parataxon No.29 is attributable to the Ebenaceae, a pantropical and subtropical family whose greatest diversity is found in the Indo-Malaysian region. As many as nine genera were previously recognised, but a more recent revision has included all but one of these genera, Euclea Murr., in Diospyros L., the currently valid type genus (Christophel and Basinger, 1982). Of the two genera, Diospyros sensu lato is the larger, containing in excess of 400 species (only 14 are attributable to Euclea). The family is represented in Australia by 15 species of Diospyros s.l.(Bailey, 1900; Beadle et al, 1963).

The Australian Tertiary fossil record for the Ebenaceae is poor. In most instances the leaf and floral remains assigned to the family are poorly preserved making positive identifications impossible. The recent reports of ebenaceous leaf and floral remains from the Late Eocene of Anglesea by Christophel and Basinger (1982) and Basinger and Christophel (1985) are exceptions. Identification of both the leaves and flowers as Austrodiospyros cryptostoma Basinger and Christophel (1985), and their association with each other, has been based primarily on cuticular analyses.

Although parataxon No.25 was a small group, represented by only a few specimens, the recognition of distinctive cuticular features made an identification possible (Figures 65, 125). These included extensive thickening of subsidiary cells which extended over the stomata, an actinocytic stomatal arrangement and the degree of ornamentation of the periclinal wall of the epidermal cells. An examination of recognised taxa from other Australian Tertiary deposits (eg, Anglesea, Maslin Bay,

Nerriga and Yallourn) resulted in only Austrodiospyros from Anglesea displaying any similarity to the fossil. The similarity was, however, strong with both fossil types exhibiting extensive thickening of subsidiary cells which extended over the stomatal pore, an actinocytic stomatal arrangement and prominent ornamentation of the periclinal wall of the epidermal cells. Therefore parataxon No.25 is assigned to Austrodiospyros. These features, discussed above, were identified by Christophel and Basinger (1982) in many of the extant species of Diospyros.

4.2.7 CUNONIACEAE

The placing of parataxon No.50 in the Cunoniaceae is very tentative. The similarity between this cuticle and a number of species representing different families, e.g. Lauraceae, suggests other possible affinities. The small size of the fragments prevents a comprehensive cuticular examination being undertaken to accurately determine a positive family affinity. The recovery of more material is necessary before identification is possible.

4.2.8 MONOCOTYLEDONAE

Monocotyledons are well represented in the cuticular flora of the Curlew Formation, dominating the floras of the lignitic bands. This abundance is unusual as in most past and modern individual floras the monocotyledons are generally not as common as the dicotyledons. There are approximately six times as many dicotyledon as monocotyledon genera recognised in the total angiosperm flora and this is also reflected in their fossil records (Daghlian, 1981). The earliest record of a supposed monocot plant (i.e. Sanmiquelia; Brown, 1956) is dated Late Triassic but both the age and affinity of the fossil to the Monocotyledonae are disputed by palaeobotanists. Pollen and leaves from the Middle Cretaceous are considered the oldest fossils with monocotyledonous affinities (Daghlian, 1981). Many of the Tertiary fossils, which include fruits, pollen and seeds, have been assigned to modern families. Vegetative remains, primarily, leaf (including cuticle), rhizome and stem fragments, are also common in Tertiary deposits but family affinities are generally difficult to determine using these fossils. This has been made evident in the examination of the Curlew monocot cuticles.

Parataxon No.7 (Figures 37, 38, 105) is the only cuticle to be assigned to a modern family, ie. Cyperaceae, but this has been done with some reservation. The Cyperaceae belongs to the Cyperales, one of several orders of the Commelinidae which Daghlian (1981) could not easily differentiate on the basis of vegetative fragments. There is, however, a combination of features which suggest a possible cyperaceous affinity, i.e. the paracytic stomatal arrangement, thin walled,

reniform guard cells, a generally uniform epidermal cell length and orientation of stomata parallel to the long axis of the leaf/stem.

One feature which would positively identify the fossil as Cyperaceae, but could not be distinguished on parataxon No.7, is the presence of silica-bodies, more specifically conical shaped silica-bodies, in the anticlinal wall of the epidermal cells. As pointed out by Daghlian it is possible that the silica-bodies, if present, were removed through the action of percolating ground water. The high frequency of papillae on the periclinal wall of the epidermal cells made it difficult to determine if the cavities, which would have contained the silica-bodies, were present in the anticlinal walls of the epidermal cells.

The Cyperaceae has a reliable fossil record based mainly on fruit and pollen. Had these fossils been positively identified in the Curlew sediments, the proposed affinity of parataxon No.7 would be more feasible. It should be noted that cyperaceous pollen has been reported from other Australian Eocene deposits in Central Australia (Kemp, 1976) and the St. Vincent Basin, South Australia (Harris pers. comm. in Martin, 1978).

The remaining parataxa (Nos.13, 19 and 20) cannot be closely related to any of the modern monocotyledon families. No.13 is represented by small strip-like cuticular fragments that are devoid of stomatal apparatus and have rectangular epidermal cells arranged in an interlocking brick work pattern (Figure 48). Each cell has a darker staining stripe passing longitudinally down the centre of the cell. Cell size varies to some degree which may suggest an affinity to the

Gramineae. The family is characterised by having an arrangement of short and long cells (Metcalfe, 1960).

Parataxa Nos.19 and 20 are similar in general morphology but features are better defined in the latter parataxon due to the thicker anticlinal wall of the epidermal cells. Both have epidermal cells arranged in longitudinal rows with stomata oriented parallel to the long axis of these cells (the assumed long axis of the leaf/stem) and a paracytic stomatal arrangement. A difference in epidermal cell shape exists between the two cuticle types. In parataxon No.20 (Figure 58) the cells are predominantly hexagonal whereas in No.19 they are rectangular. Another distinguishing feature is the nature of cuticular thickening on the periclinal wall of the epidermal cells. Irregular cuticular folds are common on all cells, including subsidiary cells, of parataxon No.19 (Figures 57, 117). Two crescent-shaped papilla /folds are centrally located in all epidermal cells of No. 20 and occasionally overlie the subsidiary cells.

Possible affinities for both parataxa include the Juncaceae and the Cyperaceae. Parataxon No.19, the most common cuticle type associated with the lignites, is also a possible relative of the Alismataceae, but the family possesses few vegetative fea-tures which allow accurate identification (Stant, 1964, 1967; Ancibor, 1979). Like the other major monocot families (e.g. Cyperaceae and Juncaceae) the Alismataceae is best identified from fruits, seeds and pollen. Reinforcing what has been stated earlier, all familial affinities of the monocotyledons are only tentative.

4.3 Description of Other Structures and Seeds

CF1 ERD 118 33.4m

Ovoid fruit-like structure 1.4mm in length, 1.3mm in width. Surface features, numerous angular pits concentrically arranged. These structures not particularly common, only found at this depth (Figure 148).

Capsule-like structures occur throughout the Curlew sediments. Their variety of form suggests they could represent a number of diverse, very distinct plant groups. Some may be associated with the Bryophytes, possibly as moss capsules, others appear as anther heads, therefore having angiosperm affinities while others resemble the seed coat of a rush-like plant similar to that of the Typhaceae.

CF2 ERD 112 127.2m

Ovoid in shape, 890µm in length, 470µm in width. Cellular detail poorly preserved. Cells at the polar regions dark staining, polygonal, radially arranged around small apical pore. Numerous longitudinal creases run the entire length of the structure (Figure 149).

Slide No.112-026 (Coordinates 90.5, 26.1)

CF3 ERD 112 108.3m

Roughly ovoid in shape, 380µm in length, 290µm in width. Cells polygonal. Anticlinal wall variable thickness. Periclinal wall granular thickening. Sizes vary. Dark staining narrow band of tissue runs down the length of the structure. 4 tricolpate pollen grains (cf. Haloragacidites harrisii) lie within the structure in close proximity to this band (Figure 155).

Slide No.112-021 (Coordinates 95.1, 31.2)

CF4 ERD 117 49.0m

Obovate in shape, 1.1mm in length, 0.7mm in width, attached to delicate stem 0.2mm in length,0.3mm in width. No cellular detail, proximal aperture evident. Inner seed-like structure, ovoid, with a small apical verruca. Basal thickening also evident, 0.9mm in length, 0.5mm in width (Figure 150).

Slide No.117-015 (Coordinates 122.8, 32.9)

CF5 ERD 118 28.2m

Capsule-like structure, ovate. Cells polygonal, randomly arranged, uniform size, darker staining basal region where remnants of stalk evident. Apical region, darker staining. Dimensions, 1.9mm in length, 1.1mm in width (Figure 152).

Slide No.118-276 (Coordinates 97.8, 30.4)

CF6 ERD 118 58.0m

Rootlet, 2.8mm in length, central axis 0.5mm in width. Central axis comprises rectangular longitudinally oriented cells with thickened longitudinal anticlinal walls. Numerous, multicellular uniseriate filaments, apices are rounded and length varies. Filaments arise from the central axis at random (Figure 157).

Slide No.118-383 (Coordinates 95.1, 28.0)

CF7 ERD 139 110.0m

Scale-like structure, roughly triangular in shape. 1.2mm in length, 0.9mm in width. Cells hexagonal, arranged in rows which run parallel to curved edge. Cell wall thickening extensive, lumen represented as a very narrow aperture (Figure 151).

Slide No.139-001 (Coordinates 97.5, 27.2)

CF8 ERD 118 33.4m

Rhizome (af. Cyperaceae or Juncaceae). 1.8mm in length, 1.2mm in width. Nobby in appearance. Cells triangular to polygonal, in groups of 2 - 4, arranged roughly longitudinally, range from 50 to 80µm in length, 35 to 50µm in width. Seven swollen nodule-like processes

randomly occur over the cylindrical fragment, responsible for knobby appearance (Figure 156).

Slide No.118-420 (Coordinates 93.4, 27.4)

CHAPTER 5

BIOSTRATIGRAPHY AND CORRELATIONS

5.1 Relationships Between Lithology and Megafossils

Identification of all fossil-bearing sediments (and their associated floras) of the entire sequence was considered a necessary prerequisite to biostratigraphic correlations. ERD 118, being the only drillcore with a complete Curlew section, was selected as the starting point for these investigations. Once the core had been logged, i.e. lithology and dispersed cuticular flora recorded, other drillcores were similarly examined.

The plant assemblages of the 41 lithotypes identified in ERD 118 are described separately as they represent the major successional intervals of fossil deposition. Each lithotype is considered to be a discrete stratigraphic unit but a number of possible biostratigraphically useful zones have been recognised in the Formation. These zones will be discussed in section 5.2. In the upper section of the Formation the stratigraphic units are generally thick and separated by distinct intervals where fossil accumulation did not occur. These intervals are marked by the presence of the barren green claystones. However, in the lower part of the Formation (below 53.0m) units are much narrower and closer grouped. In this part of the Formation the barren sediments are mainly oilshales.

Forty-one units were recognised (Figure 12) and their respective plant assemblages are described below. These have been summarised in Table 5. The lithological changes that occur between these units also reflect a number of floristic changes. It is evident from Figure 3 that the sequence is not exposed but overlain by a considerable amount of weathered and reworked fluvial material and that an unconformity exists

between the overburden and tha Curlew Formation. The units are discussed in order of descent down through the sequence.

UNIT 1 (26.0m - 27.6m)

A shale with two minor carbonaceous bands. Dicotyledonous and gymnospermous cuticles dominate the plant assemblage. The most common parataxa are Nos. 10 (aff. Lauraceae), 14 (aff. Lauraceae), 16 (aff. Lauraceae), 17 (aff. Lauraceae), 18 (aff. Lauraceae), 40 (aff. Proteaceae) and the cycad No. 23 (aff. Zamiaceae). Monocotyledon cuticles were recorded in low frequencies in the claystones. Some Azolla capricornica megaspores were present in the claystones.

UNIT 2 (27.6m - 28.8m)

Lignite. Monocot cuticles dominate the plant assemblage. The most common parataxa are Nos. 13 (reedy unknown) and 19.

UNIT 3 (28.9m - 29.3m)

Shale. Dicot cuticles dominate the plant assemblage. The most common parataxa are Nos. 40 (aff. Proteaceae) and 52 (aff. Proteaceae).

UNIT 4 (30.6m - 30.9m)

Claystone. A single monocot parataxon (i.e. No. 19) dominates the plant assemblage but the dicot parataxon No. 10 (aff. Lauraceae) is also common.

UNIT 5 (31.0m - 31.4m)

Shale. Dicot and gymnosperm cuticles dominate the plant assemblage. The most common parataxa are Nos. 4 and 28. Ostracod remains are common.

UNIT 6 (31.6m - 33.5m)

Lignite. Monocot cuticles dominate the plant assemblage. The most common parataxa are Nos. 13 (reedy unknown) and 19. Ostracod remains and Azolla capricornica megaspores are also present.

UNIT 7 (36.0m - 36.6m)

Claystone. Monocot cuticles dominate the plant assemblage. The most common parataxa are Nos. 13 (reedy unknown) and 19. Another monocot parataxon present is No. 7 which is assignable to the Cyperaceae. Azolla capricornica megaspores are particularly common. Ostracod remains are also present.

UNIT 8 (37.0m - 37.4m)

Claystone. Monocot cuticles dominate the plant assemblage. The most common parataxa are Nos. 13 (reedy unknown) and 19. Azolla capricornica megaspores are common. Ostracod remains are present.

UNIT 9 (40.0m - 40.2m)

Claystone. Monocot cuticles dominate the plant assemblage. The most common parataxa are Nos. 13 (reedy unknown), 19 and 21. Azolla

capricornica megaspores are present.

UNIT 10 (40.3m -40.4m)

Shale. Dicot cuticles completely dominate the plant assemblage. The most common parataxa are Nos. 10 (aff. Lauraceae) and 16 (aff. Lauraceae). Some Azolla capricornica megaspores are present.

UNIT 11 (40.5m - 42.2m)

Lignite. Monocot cuticles completely dominate the plant assemblage. The most common parataxon is No. 13 (reedy unknown). A few Azolla capricornica megaspores are present.

UNIT 12 (50.9m - 51.0m)

Shale. Dicot cuticles completely dominate the conservative plant assemblage. Of the four parataxa, No. 12 (aff. Proteaceae) is the most common.

UNIT 13 (53.3m - 53.4m)

Shale. Dicot cuticles completely dominate the plant assemblage. The most common parataxa are Nos. 2 and 10 (aff. Lauraceae).

UNIT 14 (53.8m - 53.9m)

Shale. Dicot cuticles completely dominate the plant assemblage. The most common parataxon is No. 10 (aff. Lauraceae).

UNIT 15 (54.2m - 54.3m)

Claystone. Dicot cuticles completely dominate the plant assemblage. The most common parataxa are Nos. 12 (aff. Proteaceae), 14 (aff. Lauraceae) and 16 (aff. Lauraceae).

UNIT 16 (55.0m - 55.1m)

Shale. Dicot cuticles completely dominate the plant assemblage. The most common parataxa are Nos. 16 (aff. Lauraceae) and 33.

UNIT 17 (55.5m - 55.6m)

Shale. Dicot cuticles completely dominate the plant assemblage. Three lauraceous parataxa are equally common, i.e. Nos. 10, 15 and 16.

UNIT 18 (56.5m - 56.6m)

Coal. Dicot cuticles completely dominate the plant assemblage. The most common parataxon is No.11 (aff. Proteaceae).

UNIT 19 (56.7m - 56.8m)

Claystone. Dicot cuticles completely dominate the plant assemblage. The most common parataxon is No. 12 (aff. Proteaceae) but the lauraceous parataxon No. 16 is also well represented.

UNIT 20 (58.0m - 58.1m)

Claystone. Dicot cuticles completely dominate the plant assemblage. The most common parataxon is No. 16 (aff. Lauraceae) but

the unknown parataxon No. 2 is also well represented.

UNIT 21 (58.4m - 58.9m)

Shale. Dicot cuticles completely dominate the plant assemblage. The most common parataxa are Nos. 3 and 15 (aff. Lauraceae). The proteaceous parataxon No. 11 is also abundant. Ostracod remains are also present.

UNIT 22 (60.3m - 60.4m)

Coal. Dicot cuticles completely dominate the plant assemblage. The most common parataxa are Nos. 9 (aff. Lauraceae) and 16 (aff. Lauraceae) but parataxon No 12 (aff. Proteaceae) is also abundant.

UNIT 23 (61.0m - 61.1m)

Claystone. Dicot cuticles completely dominate the plant assemblage. The most common parataxon is No. 16 (aff. Lauraceae).

UNIT 24 (62.1m - 62.2m)

Claystone. Dicot cuticles dominate the plant assemblage. The most common parataxon is No. 16 (aff. Lauraceae). A small monocot element is represented by parataxon No. 13 (reedy unknown).

UNIT 25 (62.4m - 62.5m)

Lignite. Monocot cuticles dominate the plant assemblage. The most common parataxon is No. 13 (reedy unknown). Parataxon No. 16 (aff.

Lauraceae) has a minor occurrence.

UNIT 26 (63.4m -63.5m)

Lignite. Monocot cuticles completely dominate the plant assemblage. The most common parataxon is No. 13. Some Azolla capricornica megaspores are present.

UNIT 27 (64.4m - 64.5m)

Lignite. Monocot cuticles completely dominate the plant assemblage. The most common parataxon is No. 13 (reedy unknown).

UNIT 28 (65.0m - 65.1m)

Lignite. Monocot cuticles dominate the plant assemblage. The most common parataxa are Nos. 13 (reedy unknown) and 19. A small dicot component is represented by the unknown parataxon No. 2.

UNIT 29 (65.4m - 65.7m)

Lignite. Monocot cuticles dominate the plant assemblage. The most common parataxon is No. 19. Parataxon No. 13 is absent. A small dicot component is represented by parataxon No. 16 (aff. Lauraceae).

UNIT 30 (66.5m - 66.6m)

Claystone. A conservative dicot assemblage is dominated by the lauraceous parataxon No. 16. Parataxon No. 12 is also common.

UNIT 31 (68.0m - 68.1m)

Lignite. Monocot cuticles completely dominate the plant assemblage. The most common parataxon is No. 19 but No. 13 is also well represented.

UNIT 32 (68.8m - 68.9m)

Claystone. Dicot cuticles dominate the plant assemblage. The most common parataxon is No. 16 (aff. Lauraceae).

UNIT 33 (69.0m - 69.1m)

Lignite. Monocot cuticles dominate the plant assemblage. The most common parataxa are Nos. 13 (reedy unknown) and 19. Parataxon No. 11 (aff. Proteaceae) is the only dicot present.

UNIT 34 (69.8m - 69.9m)

Claystone. Dicot cuticles completely dominate the plant assemblage. The most common parataxon is No. 9 (aff. Lauraceae) but parataxa Nos. 12 (aff. Proteaceae) and 16 (aff. Lauraceae) are also well represented.

UNIT 35 (70.7m - 70.8m)

Claystone. Dicot cuticles dominate the plant assemblage. The most common parataxon is No. 18 but the monocot parataxon No. 19 is also well represented.

UNIT 36 (71.4m - 71.5m)

Lignite. Monocot cuticles completely dominate the plant assemblage. The most common parataxon is No. 13 (reedy unknown).

UNIT 37 (73.6m - 73.7m)

Coal. The conservative plant assemblage is dominated by the unknown parataxon No. 5, but the lauraceous No. 16 is also common.

UNIT 38 (74.3m - 74.4m)

Lignite. Monocot cuticles completely dominate the plant assemblage. The most common parataxon is No. 13 (reedy unknown). Some ostracod remains are present.

UNIT 39 (75.m - 75.1m)

Claystone. Dicot cuticles dominate the plant assemblage. The most common parataxon is No. 16 (aff. Lauraceae). A small monocot component is represented by parataxon No. 21. Some ostracod remains are present.

UNIT 40 (75.8m - 76.0m)

Coal. Dicot and gymnosperm cuticles completely dominate the plant assemblage. The most common parataxa are Nos. 9 (aff. Lauraceae) and 23 (aff. Zamiaceae).

UNIT 41 (78.0m - 78.1m)

Lignite. Monocot cuticles completely dominate the plant assemblage. The most common parataxon is No. 13 (reedy unknown). Some ostracod remains are present.

Summary

It is evident from the analysis of ERD 118 that the cuticle/lithotype relationships mentioned in Chapter 1 do in fact exist. In the lignites the plant assemblage is always dominated by monocot cuticles. The most abundant and common monocot parataxa are Nos. 13 and 19. Dicot cuticles, if present, only occur in very low frequencies. The reverse association is a feature of the shales, i.e. dicot cuticles dominate the plant assemblage, and in many of the strata (e.g. UNIT 21) the dominance is complete. Gymnosperm cuticles are also present in a number of the shale bands (e.g. UNIT 1). The dicot/gymnosperm cuticle flora is more diverse than the monocot flora, but still only a few parataxa occur regularly and in considerable abundance, i.e. Nos. 9, 10 and 16, all of which have an affinity to the Lauraceae. Other parataxa which occur occasionally include Nos. 11 and 12, both with an affinity to the Proteaceae, and No. 23 which has an affinity to the Zamiaceae and is the most commonly occurring gymnosperm cuticle type.

Dicot cuticles also dominate the plant assemblages of the coal bands. The coal is very friable and contains sizeable cuticle fragments ($0.5cm^2$) interspersed between thin, irregularly bedded charcoal

lenses making it quite distinct from the lignite, both lithologically and botanically. The most abundant cuticle types are again the lauraceous parataxa Nos. 9 and 16 and the proteaceous No. 11. Gymnosperm cuticle types are also found in the coal.

The claystone has an unusual relationship with the two cuticle groups, i.e. dicot/gymnosperm and monocot. It could be considered an intermediate between the shale and lignite because it shows strong relationships with both cuticle groups. It is interesting to note that these relationships occur at different levels in the sequence. From the top of the Formation to the base of Unit 11 (42.2m), prior to the large barren green claystone interval, these sediments are dominated by monocot cuticles. Following this barren interval to the base of the Formation the association is reversed, i.e. the dicot/gymnosperm cuticle types now dominate the claystone.

Azolla capricornica is found to be associated with the monocot floras of the lignites and the claystones above the depth of 42.2m. Ostracod remains, probably carapace fragments, are mainly associated with the shales.

These lithotype/cuticle relationships (between monocot cuticles and lignites and dicot/gymnosperm cuticles and shale and coal) can also be identified in other Curlew Formation cores which suggests that the depositional events responsible for the relationships were widespread, occurring throughout the graben. The overall similarity of the floristic composition of the cuticle groups in all cores implies that deposition of sediments occurred concurrently and in similar environments. Hence it may be possible to biostratigraphically relate

all of the Curlew cores, i.e. ERD 118, 117, 112, 111 and 110.

An oscillating lacustrine/paludal system appears to have existed throughout the deposition of Curlew sediments and these environmental changes produced a number of distinct associations between the flora and sediments which have already been discussed. It is generally accepted that lignites are produced from the accumulation of plant material in a swamp environment and therefore the swamp is responsible for the production of the Curlew lignites which were dominated by a monocot flora. Inundation of the swamp, e.g. by flooding, saw the deposition of sediments and plant remains from outside the basin which produced the dicot/gymnosperm dominated shales. The presence of dicot and gymnosperm fragments in the coals is possibly the result of a localised accumulation of this material in a small channel along the floor of the lake. Therefore the Curlew vegetation comprises an autochthonous (monocot) and allochthonous (dicot/gymnosperm) element. A more detailed explanation of these interpretations are presented in section 5.2.1.

Table 5: The Lithological Units recognised in the Curlew Formation of ERD 118 and the associated plant assemblages, showing dominant parataxa and their modern affinities.

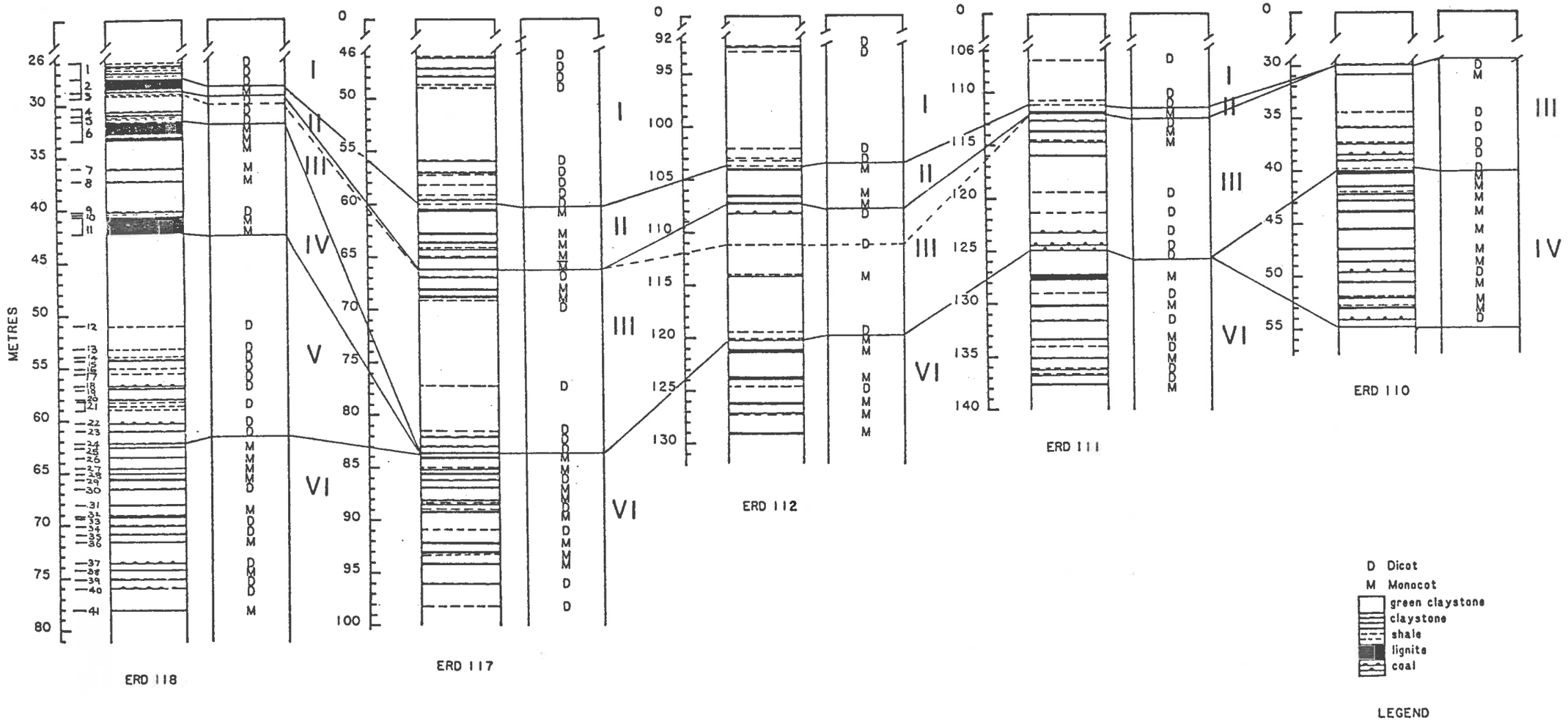
UNIT	LITHOTYPE	DOMINANT FLORA	DOMINANT PARATAXA	MODERN AFFINITY
1	Shale	Dicot/Gymnosperm	1	Unknown
			10,14,16,17,18	Lauraceae
			28	Zamiaceae
			40	Proteaceae
			Azolla	
2	Lignite	Monocot	13	Reedy Unknown
			19	Unknown
3	Shale	Dicot	40,52	Proteaceae
4	Claystone	Monocot	13	Reedy Unknown
			19	Unknown
			Azolla	
5	Shale	Dicot/Gymnosperm	4,28	Unknown
6	Lignite	Monocot	13	Reedy Unknown
			19	Unknown
			Azolla	
7	Claystone	Monocot	7,19	Unknown
			13	Reedy Unknown
			Azolla	
8	Claystone	Monocot	13	Reedy Unknown
			19	Unknown
			Azolla	
9	Claystone	Monocot	13	Reedy Unknown
			19,21	Unknown
			Azolla	
10	Shale	Dicot	10,16	Lauraceae
			Azolla	
11	Lignite	Monocot	13	Reedy Unknown
			Azolla	
12	Shale	Dicot	12	Proteaceae
13	Shale	Dicot	2	Unknown
			10	Lauraceae
14	Shale	Dicot	10	Lauraceae
15	Claystone	Dicot	12	Proteaceae
			14,16	Lauraceae
16	Shale	Dicot	16	Lauraceae
			33	Unknown
17	Shale	Dicot	10,15,16	Lauraceae
18	Coal	Dicot	11	Proteaceae
19	Claystone	Dicot	12	Proteaceae
			16	Lauraceae
20	Claystone	Dicot	2	Unknown
			16	Lauraceae

21	Shale	Dicot	3 11 15	Unknown Proteaceae Lauraceae
22	Coal	Dicot	12 9,16	Proteaceae Lauraceae
23	Claystone	Dicot	16	Lauraceae
24	Claystone	Dicot	16	Lauraceae
25	Lignite	Monocot	13	Reedy Unknown
26	Lignite	Monocot	13 Azolla	Reedy Unknown
27	Lignite	Monocot	13	Reedy Unknown
28	Lignite	Monocot	13 19	Reedy Unknown Unknown
29	Lignite	Monocot	19	Unknown
30	Claystone	Dicot	12 15,16	Proteaceae Lauraceae
31	Lignite	Monocot	13 19	Reedy Unknown Unknown
32	Claystone	Dicot	16	Lauraceae
33	Lignite	Monocot	13 19	Reedy Unknown Unknown
34	Claystone	Dicot	9,16 12	Lauraceae Proteaceae
35	Claystone	Dicot	18	Lauraceae
36	Lignite	Monocot	13	Reedy Unknown
37	Coal	Dicot	5,16	Lauraceae
38	Lignite	Monocot	13	Reedy Unknown
39	Claystone	Dicot	16	Lauraceae
40	Coal	Dicot/Gymnosperm	9 23	Lauraceae Zamiaceae
41	Lignite	Monocot	13	Reedy Unknown

Figure 12: Summarises the relationship between the lithotypes and associated floras in all cores and shows the correlations between these cores. The correlations have been determined from the distributional stages identified in ERD 118. It is evident that Stages 1, 2, 3 and 6 feature in all cores except ERD 110 which exhibits distributions comparable to Stages 3 and 4. The single module that correlates all cores has the upper limit marked as a broken line (- - -) and the lower limit as the base of Stage 3 (a solid line). Note: the lithological units identified and described in ERD 118 are marked on the left of that stratigraphic column.

D = Dicot/gymnosperm dominated lithotype.

M = Monocot dominated lithotype.


METRES
ERD 118
ERD 117
ERD 112
ERD 111
ERD 110
D Dicot
M Monocot
green claystone
claystone
shale
lignite
coal
LEGEND

5.2 Biostratigraphic Interpretations within the Curlew Formation

5.2.1 Introduction

Having established forty-one discrete fossil-bearing units in the reference core it is perceived that these will prove useful in determining stratigraphic correlations within the Curlew Formation. Although the Curlew sequence was found to be incomplete in the other cores (ERD 117, 112, 111 and 110) correlations could still be made if index fossils (more specifically distributional trends in cuticle types) could be identified and used to relate strata of the five cores.

Recently, plant megafossils from some geological periods have been useful in biozonation when used in the formulation of assemblage zones (Taylor, 1981). However, using cuticles in this capacity is unique to this study. The cuticles must still comply with the criteria for index fossils if they are to be suitable biostratigraphic indicators. The necessary criteria are: an index fossil should,

1) be distinguishable from other fossils and easily identified.

2) have existed during a relatively short period of geological time.

3) be abundant.

4) be widely distributed geographically.

5) have lived in different sedimentary environments so that it

may be preserved in differing sedimentary rocks (Taylor, 1981).

Because the area under investigation only encompasses the Narrows Graben, the criteria may be adjusted to compensate for the level at which the correlations are to be made. By doing this there appear to be many cuticle types that satisfy most of the necessary criteria, but as these cuticle types are lithotype specific all criteria are not satisfied. Therefore a combination of dicot/gymnosperm and monocot cuticle types must be selected if the Curlew sediments of all cores are to be considered in these correlations.

Two monocot parataxa, Nos.13 and 19, have been selected for correlating the lignitic sediments of the Curlew Formation. No.13 is particularly abundant in ERD 118 and 117 whereas No.19 dominates the monocot floras of ERD 110, 111 and 112. The dicot/gymnosperm cuticular flora is large, containing in excess of 40 different types but none of them, even though a number of very distinct types exist, are suitable as individual biostratigraphic indicators. This is because many occur irregularly throughout the depositional sequence and others are restricted to one or two of the cores. However, a combination of the distributions of all dicot/gymnosperm cuticle types from that assemblage does provide a suitable indicator, i.e. the distribution of the total dicot/gymnosperm assemblage. Therefore, the relationship between the shales of the cores can be determined.

5.2.2 Distribution Comparisons between Cores

5.2.2.1 Distribution Trends in ERD 118

An examination of the distributional trends of the total dicot/gymnosperm assemblage and monocots No.13 and 19 reveals a definite distributional sequence in ERD 118. This sequence can be divided into a number of distinct stages (see Figure 13). Beginning at the top of the Formation;

Stage 1) Confined to the uppermost shale lens (i.e. Unit 1, 26.0m - 27.6m). The stage is characterised by an almost complete dominance of the plant assemblage by dicot/gymnosperm cuticle types. There are two minor intervals near the top (26.2m) and bottom (27.3m) where frequencies are slightly reduced.

Stage 2) Confined to the uppermost lignite lens (i.e. Unit 2, 27.6m - 28.8m). This stage is characterised by the dominance of the monocot parataxa. Parataxon No. 13 is represented as a broad single peak while No. 19 occurs as a number of acute peaks which gradually increase in frequency.

Stage 3) This stage is comprised of two shale and a single central claystone band (i.e. Units 3, 4 and 5, 28.8m - 31.4m). The floral distribution is characterised by two dicot/gymnosperm peaks (at 100%), the second being slightly broader (Unit 5, 31.0m - 31.4m), separated by an interval of monocot dominance. Although both monocot parataxa are present, No. 19 is most abundant.

Stage 4) Another composite stage spanning a considerable interval in the Formation is represented by two broad lignite bands separated by

a number of small claystone lenses (Units 6 - 11, 31.6m - 42.2m). The distribution of the cuticle groups is distinctive with two broad monocot intervals separated by a single dicot/gymnosperm peak (100% , from 40.3m - 40.4m). Two interesting distributional trends are evident within the monocot assemblage; from the top of Stage 4, parataxon No. 13 shows a general increase in abundance and this continues even after the dicot/gymnosperm peak. The reverse trend is seen for No. 19

Stage 5) This stage incorporates a number of narrow shale, coal and claystone lenses (Units 12 - 25, 50.9m - 62.5m). The floral distribution is characterised by a very broad peak where dicot/gymnosperm parataxa completely dominate.

Stage 6) This stage is represented by a number of small lignite, claystone and coal lenses (Units 26 - 41, 63.4m - 78.1m). A number of narrow alternating dicot/gymnosperm and monocot peaks distinguish this stage. Dominance oscillates between both cuticle groups.

The identification of these six distributional stages in ERD 118 assists in interpreting the sequence of major environmental changes associated with the deposition of the Curlew sediments. Stage 6 represents the base of the Formation and the first major period of deposition. The alternation between shale/coal/claystone and lignite and their respective floras suggests a rather shallow basin persisted in which the accumulation of swamp vegetation (monocots) was regularly inundated producing an open water system into which allochthonous plant remains (dicot and gymnosperm) were deposited. Subsequent draining or drying of the lake led to the formation of a swamp, thus repeating the cycle.

The regular alternation between these two systems (i.e. lacustrine and paludal) suggests the basin was tectonically stable and the regular flooding and drying of the basin led to the development of a succession of lignite and shale/coal/claystone strata.

Stage 5 corresponds to an open lake system in which there were regular inflows of leaf material from outside the basin, i.e. dicot and gymnosperm cuticles. Stage 4 is associated with the desication of the lake and the formation of a swamp. Climatic changes, e.g. increased temperatures and decreased precipitation, are probably responsible for this change in environment. Tectonic activity cannot be discounted as a possible explanation for the environmental change as intensive faulting is associated with the region (see Figure 2).

Further environmental changes, probably bought about by a reversal in the climatic strategy (discussed in reference to Stage 4) and subsidence, resulted in the swamp reverting to an open lake in Stage 3. Towards the end of this stage continued environmental fluctuations result in a period of minor swamp development followed by flooding of the basin again and the lake reforming.

Stage 2 corresponds to a reasonably stable environmental period in which the lake has dried and a swamp produced and maintained in the basin. One final inundation of the swamp again sees a lake formed (Stage 1) and this is maintained to the top of the Formation.

5.2.2.2 Distribution comparisons between Cores

An examination of the total dicot/gymnosperm and monocot Nos. 13 and 19 distributions for each core reveals a number of definite similarities which may be correlated. These similarities are discussed below in terms of the distributional stages identified in the reference core ERD 118.

The comparison between ERD 118 and ERD 117.

The floral distributions of both cores are very similar, particularly in the upper part of the sequence (see Figure 14). Stages 1,2, 3 and 6 can all be identified in ERD 117. Stage 1 correlates with the shale and claystone bands at the very top of the Formation (i.e. between 46.1m - 60.1m). The dicot/gymnosperm distributional trend is almost identical showing a complete dominance of the floral assemblage, with two similarly positioned intervals, one near the top of the stage (i.e. 47.9m) and the other near the base (59.2m), where the dominance is reduced to less than or equal to 90%. The monocot trend over the interval 62.8m - 66.2m compares well with that of Stage 2. The only major difference between the two cores is that in ERD 118 parataxon No. 13 is the most common whereas in ERD 117 it is parataxon No. 19.

Stage 3 can be correlated in ERD 117 with the distribution of both cuticle groups over the interval 66.2m - 83.1m. The same ERD 118 trends are recognised, a narrow initial dicot/gymnosperm peak (66.9m) is followed by a monocot peak (68.0m - 68.8m) with another broader dicot/gymnosperm peak signifying the end of the stage.

Stages 4 and 5, which represent the middle section of the floral distribution curve in ERD 118, are not recognised in ERD 117.

From a depth of 83.5m to the base of the Formation the floral distribution in ERD 117 oscillates between dicot/gymnosperm and monocot dominance. This trend is also displayed in the basal sediments of ERD 118 where it is recognised as Stage 6.

Comparison between ERD 118 and ERD 112.

The floral distribution of ERD 112 (see Figure 15) has a number of obvious similarities to that of ERD 118, i.e. Stages 1,2 and 3. Stage 1 can be identified at the top of the Formation, between 92.5m and 104.0m, where the dicot/gymnosperm cuticles completely dominate. Although minor monocot occurrences are characteristic of Stage 1 in ERD 118 the overall distributional trends are identical.

The monocot flora that dominates the interval 104.1m - 107.4m compares favourably with Stage 2 in ERD 118. The only significant difference in ERD 112 is that both parataxa Nos. 13 and 19 are codominants whereas in ERD 118 No. 13 is by far the most abundant cuticle type.

Two dicot/gymnosperm peaks, separated by an interval of monocot abundance, are evident in ERD 112 between 108.3m and 119.5m. This trend is characteristic of Stage 3 in ERD 118 although the monocot peak in ERD 112 is less prominent and parataxon No. 13 is not a major contributor. From a depth of 120.3m to the base of the Formation cuticle dominance oscillates between the two cuticle groups. This trend

compares well with Stage 6 in ERD 118.

Comparison between ERD 118 and ERD 111.

The floral distribution of ERD 111 (see Figure 16) is not as closely related to ERD 118 as the previous two cores. The broad dicot/gymnosperm peak characteristic of Stage 1 in ERD 118 is not present, there is instead a narrow dicot/gymnosperm peak (106.8m - 111.2m) which could be considered the latter part of Stage 1. The following monocot distribution over the interval 111.7m - 111.8m does appear to correlate with Stage 2 but the abundance is not as great as found in ERD 118. As shown in ERD 117 and 112, parataxon No. 13 is not particularly common.

Stage 3 is probably the most well defined in ERD 111, occurring over the interval 112.5m - 124.8m. The proportions of the dicot/gymnosperm peaks in ERD 111 are very similar to the respective paeks in ERD 118 and monocot parataxon No. 19 also dominates the central monocot peak. As in the other cores, a number of oscillations occur towards the base (127.1m - 137.6m) which may be compared to Stage 6 in ERD 118.

Comparison between ERD 118 and ERD 110.

The floral distribution of ERD 110 (see Figure 17) appears to compare most favourably with that of the middle section of ERD 118, i.e. Stage 3 and 4. A slightly incomplete Stage 3 distribution (the

initial increase in dicot/gymnosperm abundance of the first peak in ERD 118 is absent) can be identified at the top of the core between 30.1m and 39.3m. A central monocot peak (30.8m), completely dominated by parataxon No.19, is followed by the characteristically broader dicot/gymnosperm peak. Over the interval 40.3m - 54.1m the floral distribution is very similar to the upper section of Stage 4 in ERD 118 which is characterised by a broad monocot peak followed by a narrow central dicot/gymnosperm peak (see Figure 13). This dicot/gymnosperm peak occurs at the very base of ERD 110 (54.0m - 54.1m).

DISTRIBUTION CURVES

The following distrbution curves, Figures 13, 14, 15, 16 and 17, are sequential representations of the frequencies of the three selected biostratigraphic indicators, i.e. Total Dicot/gymnosperm, Monocot parataxon No. 13 and Monocot parataxon No. 19, which occur in the sample intervals within the carbonaceous lithotypes of the five cores, i.e. ERD 110, 111, 112, 117 and 118. Because barren intermediate lithotypes (green claystones and oilshales) have not been considered these curves are not truly chronological. The floristic stages identified for each core are represented as a broken line across the three distribution curves for each core and labelled on the right side of each figure (Additional comparisons may be seen in Appendix 4).

Figure 13: The Distribution Curve of ERD 118 showing the Stages identified.

Distribution Curves of ERD 118 showing the six distributional stages identified

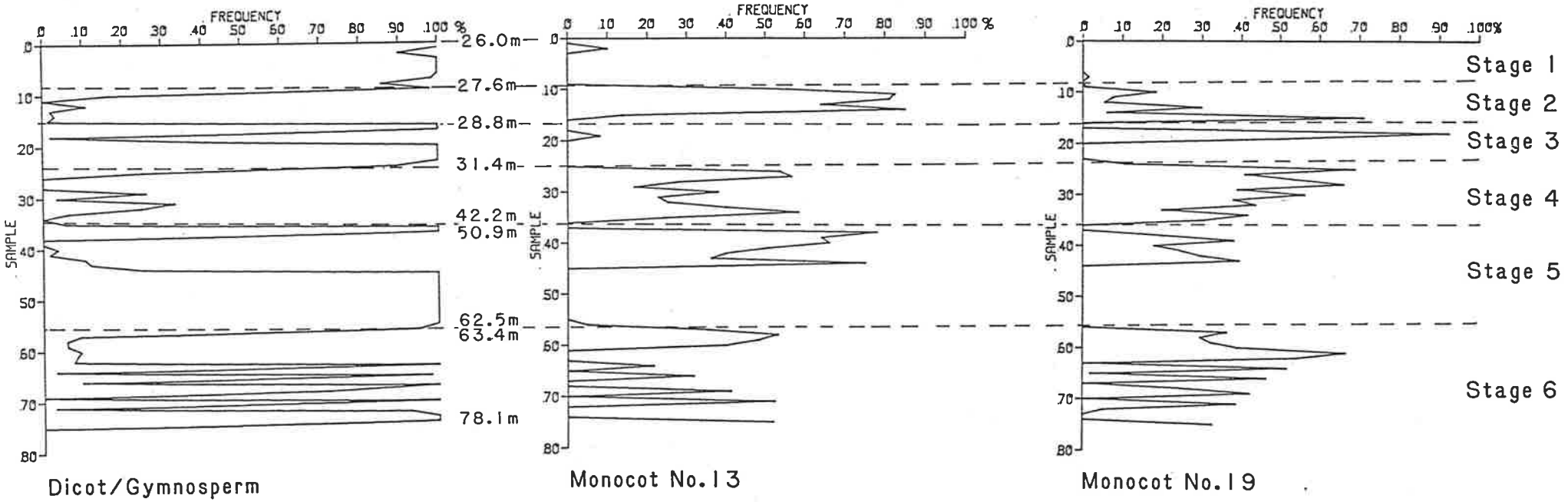


Figure 14: The Distribution Curve of ERD 117 showing correlations with ERD 118.

Distribution Curves of ERD 117 showing correlations with ERD 118 (Stages 1,2,3,6)

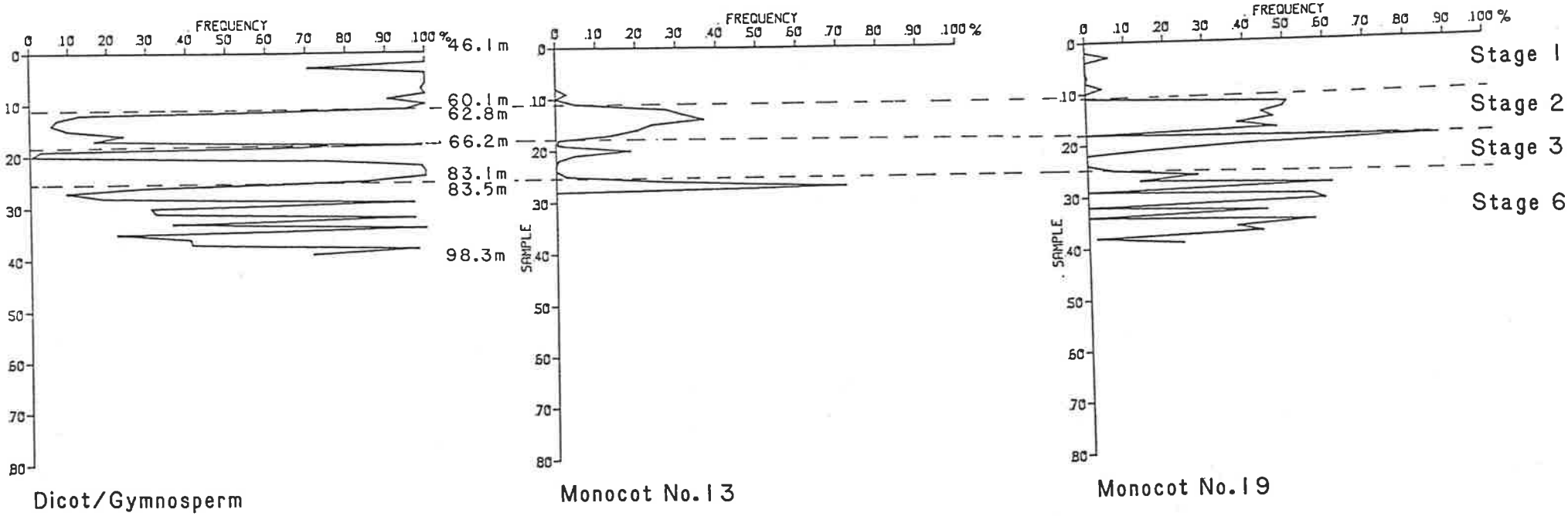
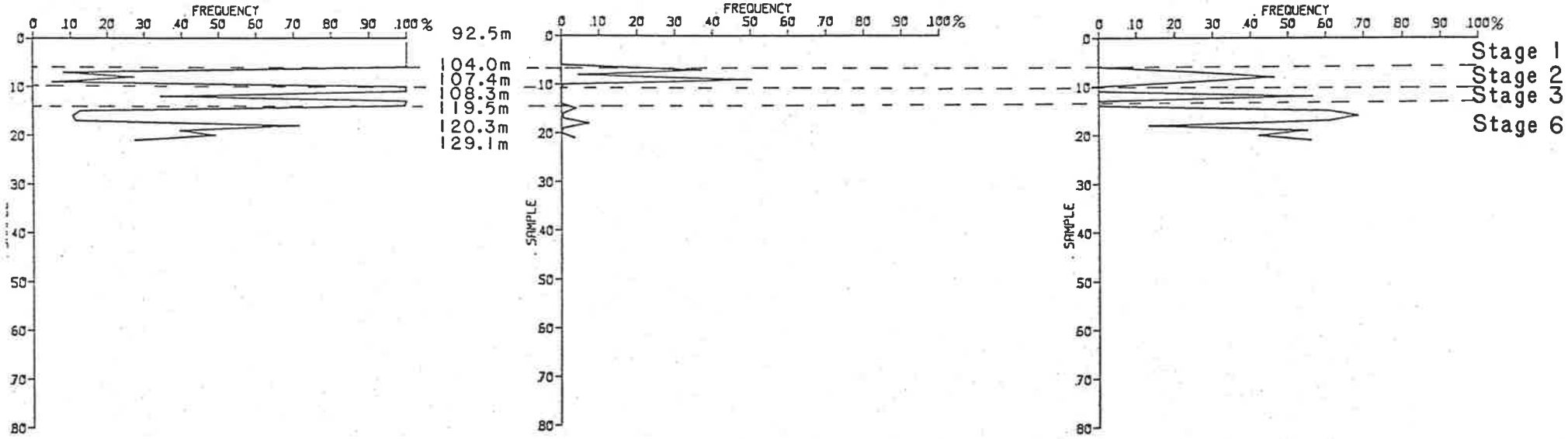


Figure 15: The Distribution Curve of ERD 112 showing correlations with ERD 118.

Distribution Curves of ERD 112 showing correlations with ERD 118 (Stages 1,2,3,6)



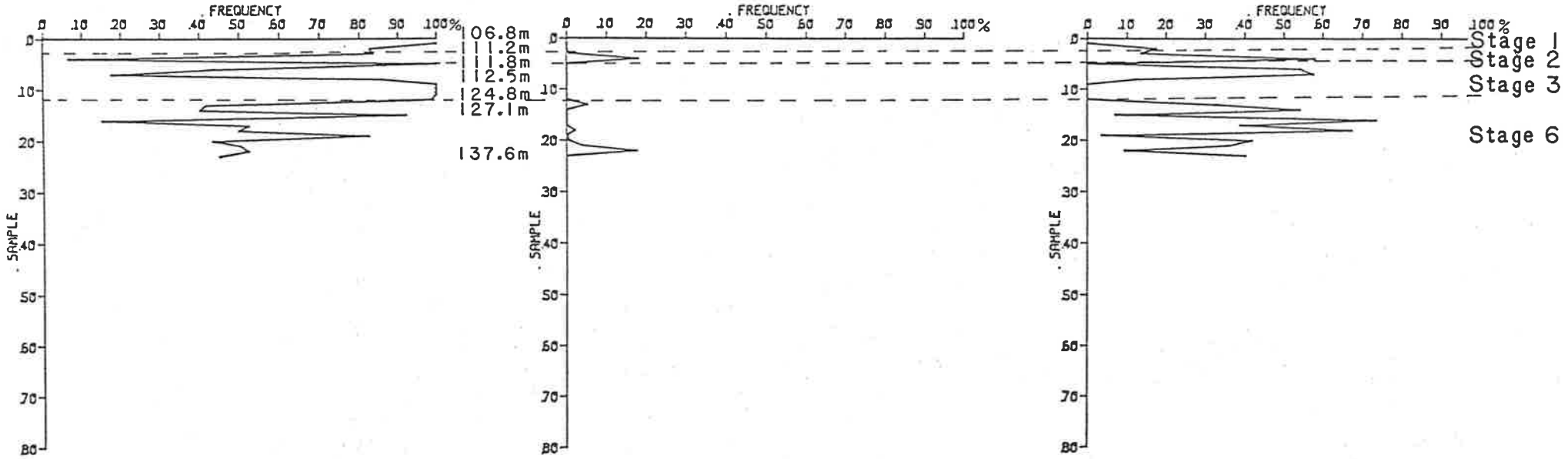
Dicot/Gymnosperm

Monocot No.13

Monocot No.19

Figure 16: The Distribution Curve of ERD 111 showing correlations with ERD 118.

Distribution Curves of ERD 111 showing correlations with ERD 118 (Stages 1,2,3,6)



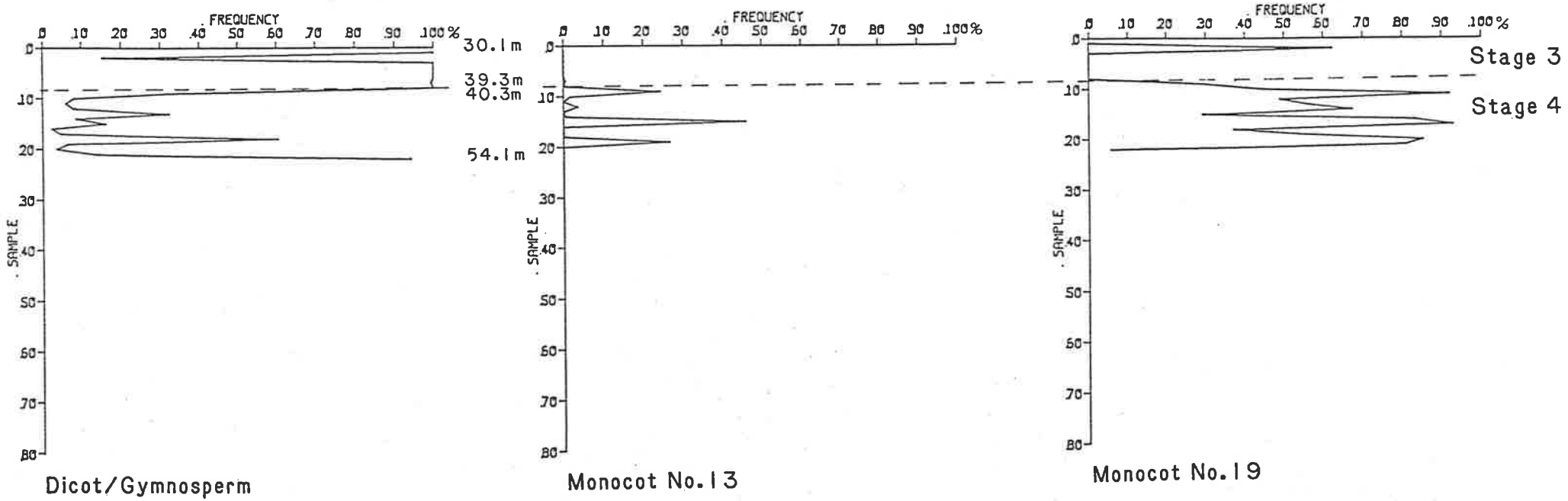
Dicot/Gymnosperm

Monocot No.13

Monocot No.19

Figure 17: The Distribution Curve of ERD 110 showing correlations with ERD 118.

Distribution Curves of ERD 110 showing correlations with ERD 118 (Stages 3,4)



5.2.3 Cross Basin Correlations

A comparison of the four Curlew cores with the reference core has shown a number of correlatable stratigraphic zones exist. These zones can be identified by the floral distribution stages, i.e. Stages 1 - 6. The most distinctive zone comprises Stages 1, 2 and 3 and is recognised in cores ERD 118, 117, 112 and 111. The thickness and depth at which the zone is located varies between these cores. In ERD 118 Stages 1 - 3 extend from 26.0m - 31.4m, in ERD 117 from 46.1m - 83.1m, in ERD 112 from 92.5m - 119.5m and in ERD 111 from 106.8m - 124.8m (see Figure 12). The overall floristic sequence of the zone is a dicot/gymnosperm dominated flora (Stage 1) followed by a monocot dominated flora (Stage 2), followed by a period of alternation between the two floras before the final more prolonged interval of a dicot/gymnosperm dominated flora (Stage 3). These floristic changes are associated with the following respective lithological changes; shale/claystone, lignite, shale/claystone, lignite, shale/claystone.

Another correlation zone in the cores is represented by Stage 6. The zone is characterised by an extended period of oscillation between dicot/gymnosperm and monocot dominated floras and occurs towards the base of the Curlew Formation in all cores, i.e. from 63.4m - 78.1m in ERD 118, 83.5m - 98.1m in ERD 117, 120.3m - 129.2m in ERD 112 and 127.1m - 137.6m in ERD 111.

The only other correlation zone identified is between ERD 118 and ERD 110. It comprises the latter part of Stage 3 and the first part of Stage 4. The zone represents the entire floristic distribution pattern of ERD 110, i.e.its entire Curlew sequence from 30.1m - 50.7m (Figure

17). The floristic sequence of the zone commences with a dicot/gymnosperm dominated flora which is immediately replaced by a monocot dominated flora which in turn is replaced by a more stable period of dicot/gymnosperm dominance (this part of the sequence represents the latter part of Stage 3). A monocot dominated flora follows and is maintained for an extended period before finally being replaced by a dicot/gymnosperm dominated flora (this part of the sequence represents the first part of Stage 4).

It is evident from these correlations that ERD 118, 117, 112 and 111 all show a similar stratigraphic sequence. This relationship is strongest at the beginning (i.e. Stage 6) and towards the end (i.e. Stage 1,2 and 3) of the Curlew Formation. The floral distribution of both the Total dicot/gymnosperm assemblage and the two monocot parataxa are most similar over these depositional intervals. ERD 110 can also be correlated to ERD 118 but the strength of this association is less than that between the reference core and the other four cores noted above. The entire stratigraphic sequence of ERD 110 has a floral distribution that compares to the middle section of ERD 118, i.e. the latter part of Stage 3 and the initial part of Stage 4.

The identification of part of Stage 3 in ERD 110 indicates there is a relationship between this and the other cores. Only the floristic distribution of this interval biostratigraphically links the five cores of the Curlew Formation. The series of floristic events that define this interval are; the upper limit (the youngest shale/claystone sediments) is represented by a cuticle assemblage completely dominated by dicot/gymnosperm parataxa. This dominance is only for a short period before the monocot parataxa become dominant. The reappearance of a

dicot/gymnosperm dominated flora that persists for a considerably longer period than on the first occasion indicates the end of the interval.

This interval or module shows a considerable variation in thickness across the basin, ranging from 2.2 metres (29.2m - 31.4m) in ERD 118 to 16 metres (66.9m - 83.0m) in ERD 117. The depth at which it occurs also varies (see Figure 12), in cores ERD 111 and ERD 112 the module is found at much greater depths which is probably because the drillholes are located within the highly faulted region near the western boundary of the graben, where subsidence was most likely.

There are three distinct floristic bands of the module; two dicot/gymnosperm bands that define the upper and lower limits and a central monocot band. The thickness of these bands varies from core to core due to the presence of intermediate barren sediments. The floristic composition of the dicot/gymnosperm bands is similar within the module as well as between cores. Some differences do occur and these are mainly confined to ERD 118 and ERD 117. In the former core the upper dicot/gymnosperm band consists mainly of the proteaceous cuticle of parataxon No. 52 whereas the lower band is dominated by the unidentified parataxon No. 4. The cuticles of parataxon No.52 have been compared favourably to those of the extant rainforest genus Cardwellia. Another unknkown cuticle type (No. 2) occurs in great abundance in the top band of ERD 117 while the Lauraceae parataxon No. 16, which has been assigned to Endiandra, is very common in the lower band.

The dicot/gymnosperm bands of the other three cores all contain a significant quantity of parataxon No. 16 cuticles. Cores ERD 111 and

112 are very similar with Lauraceae cuticles dominating the flora of both bands. In ERD 112 the Proteaceae parataxon No. 11 (aff. Darlingia) is also common. Proteaceae cuticle is even more abundant in ERD 110 where the upper band is dominated by parataxon No. 12 (aff. Synaphea) and the lower by No. 11. Parataxon No. 16 is still common in both bands (see Table 6).

The monocot flora of the central band of all cores is dominated by either of the two principle cuticle types, i.e. No. 13 or 19. The latter parataxon is most abundant, occurring in all cores in significantly large quantities. The reed-like cuticle of No. 13 only dominates the monocot assemblages of ERD 118 but is common in both ERD 117 and 112. It is completely absent from the monocot band in ERD 110.

5.2.4 Discussion.

An examination of the topography of the basin in which the Curlew Formation is located, and the position of the cores within the Formation may assist in interpreting these correlations. The drillhole localities from which the cores have been recovered are arranged in two parallel rows which run in a Northwest - Southeast direction through the Formation. ERD 117 is situated almost in the middle of the Formation with ERD 118 above and to the northwestern end and ERD 110, along the same transect, below and to the southeastern end. Drillholes ERD 112 and 111 lie to the west of the other three on a parallel transect, close to the Western Fault which marks the edge of the Narrows Graben (see Figure 2). Between the two transects is another extensive fault system which runs parallel to the Western Fault for almost the entire length of the graben. Minor faulting occurs around ERD 111, the southern most drillhole, while ERD 112 is in an area of considerably more extensive faulting. The tectonic activity experienced in this area has probably influenced the relationship between the western drill sites and those in the more stable central region of the basin.

The depth at which the Curlew Formation occurs in the cores varies considerably. This would tend to suggest an irregular basal relief which would subsequently bring about variations in deposition rate over the basin. In turn this would affect the accumulation of sediments and plant remains. From Figure 18 it is evident that the base of the Formation at the site of drillhole ERD 110 is well above that level in the other drillholes. Therefore deposition of the sediments would occur

at a greater rate in deeper, more gently sloping areas of the basin, leaving the ERD 110 core with a shallower sequence. In this instance the top and basal Curlew sediments present in the other cores are absent in ERD 110.

Drillholes ERD 118 and 117 are situated next to one another on the same transect in an area where the gradient at the base of the Curlew Formation is relatively shallow. This physical closeness is reflected in their biostratigraphy. In both cores the vertical thickness of the Formation is approximately the same and carbonaceous lithotypes more common than in any other cores. Their floral assemblages and vertical distributions are also similar.

The two other drillhole sites are located within the highly faulted area along the western edge of the Narrows Graben and both are associated with small fault systems (see Figure 2). In the vicinity of ERD 112 this is very intensive. The major tectonic activity (Western Fault) was responsible for the formation of the graben and therefore had little influence on the subsequent depositions within. Small faults however appear to have occurred more recently and in doing so have probably disrupted the structure of the basin and deposition of Curlew sediments even further. Faults occurring to the west of each drill site immediately prior to deposition would cause downward displacement of those blocks in which the holes are located, resulting in a lowering of the basin and an increase in depth at which the Curlew sediments are found. It is in the lower parts of the sequence that these cores are correlated to sediments in ERD 118.

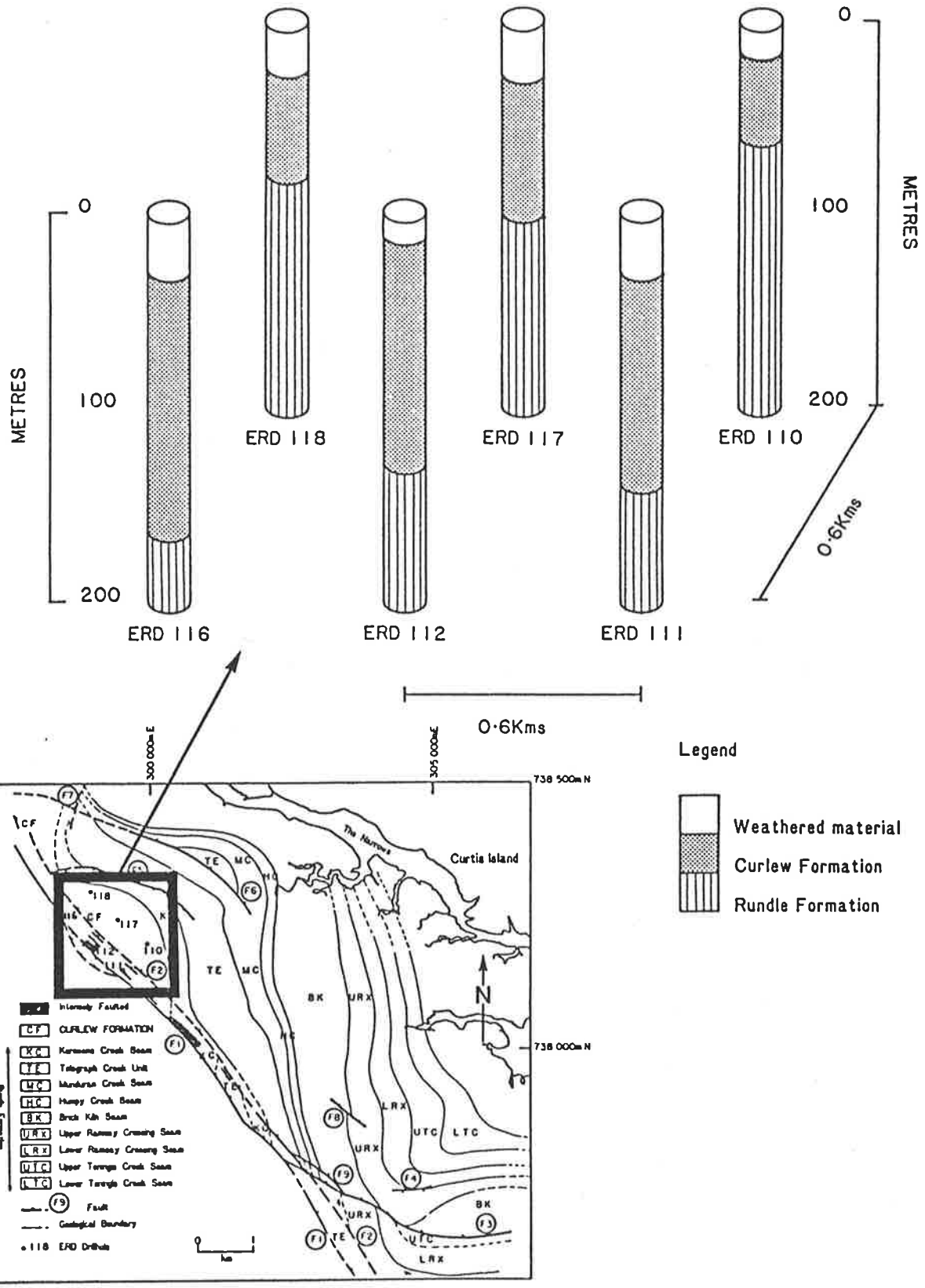
By comparing the floral distribution trends of all cores palaeoenvironmental interpretations concerning the whole basin (during the deposition of Curlew sediments) are possible. It is evident from the discussion of environmental changes associated with ERD 118 that similar changes, i.e. from swamp to lake and vice versa, were widespread throughout the basin. The synchrony of the sedimentology as a result of these changes appears to have been disrupted by tectonic activity, which has already been mentioned in section 5.2.2.1. These disruptions have probably led to the increased number of fossil bearing strata in ERD 118, particularly in the middle of the sequence (Stages 4 and 5). The absence of these strata in the other cores, except in ERD 110 where part of Stage 4 is evident, may be the result of subsidence.

The base of each core (except ERD 110) shows an alternation between lignite and shale/claystone/coal bands which could be interpreted as a period of tectonic stability whereby the shallow basin has been subject to repeated flooding and desication. Following the period in which additional fossil bearing sediments in ERD 118 were deposited there appears to have been increased temporal and regional tectonic stability in the basin with environmental changes having had a widespread influence throughout the basin.

ERD 110 is somewhat unique in that it only compares well (biostratigraphically) with ERD 118 and only through the middle of the Formation. It could be suggested that the geographic relief in the vicinity of ERD 110 was different, possibly elevated, so that the deposition of fossil bearing sediments did not occur until much later in respect to the other cores.

Identification of correlatable sedimentary zones in cores of the Curlew Formation highlights the usefulness of cuticular analysis in biostratigraphy, and the recognition of a single floristically similar sedimentary module that persists across the basin confirms it. They are considered similar in the sense that the floral distributional sequence is the same, although the cuticle assemblages associated with the three floristic bands of the module show some differences (see Table 6).

Figure 18: It is evident from the six cores in the upper half of this figure that the thickness of the Curlew Formation varies considerably across the basin in which it occurs (see inset). The faults associated with this part of the Rundle Deposit probably influenced the cross-sectional thickness of the Curlew Formation.


METRES
0
100
200
ERD 116
ERD 118
ERD 112
ERD 117
ERD 111
ERD 110
0·6Kms
0·6Kms
Legend
Weathered material
Curlew Formation
Rundle Formation
300 000mE
305 000mE
738 500mN
738 000mN
Curtis Island
The Narrows
CF
TE
MC
HC
BK
URX
LRX
UTC
LTC
N
Intensely Faulted
CURLEW FORMATION
Karoonda Creek Seam
Telegraph Creek Unit
Mundurus Creek Seam
Hungy Creek Seam
Brick Kiln Seam
Upper Ramsay Crossing Seam
Lower Ramsay Crossing Seam
Upper Terenga Creek Seam
Lower Terenga Creek Seam
Fault
Geological Boundary
ERD Drillhole
Rundle Formation

ERD	118	117	112	111	110
UNIT	Dominant Parataxa				
1st Dicot Band	52	2	12 16	16	16
Monocot Band	13	19 13	19	19	13 19
2nd Dicot Band	4	16	11 16	16	11 16

Table 6: The Cuticular composition of the Correlation Module in the five Curlew Cores. The module is represented as three distinct floristic bands.

CHAPTER 6

COMPARISON WITH OTHER AUSTRALIAN TERTIARY DEPOSITS

6.1 Comparison with Eocene Megafossil Deposits

The Curlew Formation, as a part of the Rundle Deposit is unique in that it is the only Eocene (or any other Tertiary) sequence in Queensland whose megafossil flora has been extensively studied. Isolated records of plant remains have been reported from the Red Bank Plains Formation (Hill, Playford and Woods, 1970; Churchill, 1969) of Queensland. However, it is considered to be Palaeocene (Harris, pers comm. 1985).

The fragmentary nature of the plant remains recovered from the Curlew sediments resulted in all identification being based on cuticular features. Comparative cuticular studies have been made with the south-eastern Australian Eocene floras of Anglesea, Victoria; Maslin Bay, South Australia and Nerriga, New South Wales. All three floras have taxa comparable with elements in the Curlew flora.

The Anglesea Flora, has been studied for the past 7 years by David Christophel, of the University of Adelaide, and is the only one presently under continuous investigation. Twelve taxa have been assigned to 6 extant families which are Gymnostoma, Casuarinaceae (Christophel, 1980); Austrodiospyros, Ebenaceae (Basinger and Christophel, 1985); Bowenia eocenia (Hill, 1978) and Pterostoma zamioides, Zamiaceae (Hill, 1980); Musgraveinanthus (Christophel, 1984), Orites (Christophel pers. comm., 1985) and Banksieaephyllum (Christophel, 1981), Proteaceae; Myrtaciphyllum, Myrtaceae (Christophel and Lys, 1986) and Dacrycarpus (1 sp), Decussocarpus (1 sp), Falcatifolium (1 sp), Podocarpus (1 sp) and Prumnopitys (2 sp) Podocarpaceae (Greenwood pers. comm., 1985). The Lauraceae is also well

represented but as yet no taxa have been formally described.

Four of these families are represented by the same genera in the Curlew Flora, i.e. Casuarinaceae (Gymnostoma), Ebenaceae (Austrodiospyros), Zamiaceae (Bowenia eocenica) and Podocarpaceae (Decussocarpus). The Proteaceae is also represented but by different genera, i.e. Synaphea, Darlingia and Cardwellia. A similarly large Lauraceae component is present in the Queensland deposit.

The Maslin Bay Flora is largely undescribed, but a number of studies have been undertaken by Lange (1970, 1978b), Blackburn (1978), Harvey (1974), Christophel and Blackburn (1978), Blackburn (1981) and Christophel (1981). The number of recognised taxa is less than that for Anglesea, only 5 fossil taxa assignable to 3 modern families have been identified, they are Banskieaphyllum incisum, Maslinia grevilleoides, Proteaceae (Blackburn, 1981), Gymnostoma, Casuarinaceae (Christophel, 1980) and Decussocarpus, Podocarpaceae (Blackburn, 1981). Lange (1978b) suggested a dispersed proteaceous cuticle type (i.e. Proteaceae III) was similar to that of the genus Darlingia and this is considered a most likely affinity. All of these families are represented in the Curlew flora, the Casuarinaceae and Podocarpaceae by the same genera. Of the Proteaceae component only the Darlingia-related cuticle type occurs in the Queensland deposit, i.e. parataxon No.11 (parataxon No.36 has also been assigned to Darlingia).

Another proteaceous cuticle type recovered from core material from Lake Lefroy, Western Australia (Lange, 1978b), has a strong affinity to the extant genus Synaphea which is also present in the Curlew flora.

The majority of taxa identified from the Nerriga flora are cycads of the Zamiaceae, i.e. Bowenia papillosa (Hill, 1978), Pterostoma anastomosans and Lepidozamia foveolata (Hill, 1980). The only exception is Gymnostoma of the Casuarinaceae (Christophel, 1980). Another taxon, possibly of the fern family Gleicheniaceae, has tentatively been compared to Sticherus flabellatus (Hill, 1982). Only two of those taxa appear in the Curlew Flora - Bowenia papillosa and Gymnostoma. An examination of photographic plates in Hill's Ph.D thesis suggests that two other families are represented in the assemblage, i.e. Proteaceae and Lauraceae. Hill's (1980) parataxon NER/025 has cuticle very similar to the Curlew parataxon No.12 which is assigned to Synaphea.

6.1.1 Conclusion

1) Only Gymnostoma occurs in all four floral assemblages which indicates the genus was more widely distributed during the Eocene, occurring down much of the east coast of Australia..

2) The Proteaceae is represented in all of the floras but the composition of this component differs in each. It can be concluded that although the distribution of the family throughout eastern Australia has continued, changes in habitat have resulted in compositional changes. For example, the sclerophyllous Synaphea is today confined to southwestern Western Australia. This genus evidently had a much wider distribution during the Eocene.

3) The Lauraceae occurs in the three eastern deposits and has undergone minor distributional, as well as compositional changes since the Eocene. The most significant alteration has been the slight

northward movement of the southern limit to around the Victoria/New South Wales border which has led to the exclusion of the family from the modern Victorian vegetation. The absence of Endiandra (see Table 7) from rainforests in the vicinity of the Rundle Deposit is one floristic difference that may be associated with a change in habitat.

4) The Podocarpaceae is only absent from the Nerriga flora but it is interesting to note that some of the genera present during the Eocene (i.e. Decussocarpus and Falcatifolium) have been replaced in the modern Australian flora by other podocarps. The family's distribution has otherwise remained the same.

5) The Anglesea Flora is similar to that of the Curlew Formation having an identical (family) composition although slight differences occur in the diversity of families represented, e.g. the Proteaceae and Zamiaceae. The three proteaceous genera of the Curlew flora are not found at Anglesea and similarly the Anglesea genera, i.e. Orites, Banksieaephyllum and Musgraveinanthus do not occur in the Curlew flora. Two cycad types, from Bowenia are present in the Curlew flora but only one of these (B. eocenica) is represented at Anglesea. Similarly, the cycad component of Anglesea consists of two species but from different genera, i.e. Bowenia and Pterostoma.
Both floras have a large, diverse Lauraceae component and an Ebenaceae component consisting of one genus (Austrodiospyros) (see Table 7).

6) Although the Curlew Formation and Anglesea deposit have similar floristic elements, their sources are different. At Anglesea the fossil flora was actually derived from the vegetation situated within the depositional basin. The preservation of material, i.e. intact leaf

material, confirms this and therefore it is autochthonous. On the other hand, in the Curlew Formation the same floristic elements are not of local origin. They have been transported into the basin from a flora or floras that existed outside the area of deposition and therefore considered allochthonous. Streams probably transported the material from the highland regions to the west of the Narrows Graben where closed forests existed.

Table 7: A comparison of the major Australian Eocene Megafossil Floras.

A COMPARISON OF MAJOR AUSTRALIAN EOCENE MEGAFOSSIL FLORAS

TAXON	CURLEW	ANGLESEA	MASLIN BAY	NERRIGA
CASUARINACEAE				
Gymnostoma	▲	▲	▲	▲
PROTEACEAE		▲	▲	▲
Synaphea	▲			
Darlingia	▲		△	
Cardwellia	▲			
EBENACEAE				
Austrodiospyros	▲	▲		
LAURACEAE	▲	▲		▲
PODOCARPACEAE				
Decussocarpus	▲	▲	▲	
ZAMIACEAE				
Bowenia				
B.papillosa	▲			▲
B.eocenica	▲	▲		

▲ positive identification

△ probable identification

6.2 Comparisons with Eocene Palynofloras.

Palynological research is the major source of information regarding Australian Tertiary floras. Microfossil deposits are located throughout the continent. Many have made valuable contributions to our understanding of these floras, but possibly none more than those of southern Australia, particularly in the Gippsland Basin, Victoria. Stover and Partridge (1973) used the palynological data collected in this region over a considerable period by numerous workers including Cookson (1946), Cookson and Pike (1954), Harris (1965) and Stover and Evans (1973) to produce ten biostratigraphic spore-pollen zones which spanned the Late Cretaceous to Miocene. This spore pollen zonation has proven invaluable in the correlation and dating of Australian Tertiary deposits. These zones have already been discussed in Chapter 1.

In this study the Curlew palynoflora has been compared to seven other Eocene palynofloras from Anglesea, Victoria (Syber, 1983); Nerriga, New South Wales (Owen, 1975); Yaamba, Queensland (Foster, 1982) and four originally discussed by Martin (1982, see Figures 9 and 10). These were from Hay, New South Wales (Martin, 1977); Officer Basin, Central South Australia (Hos, 1978); St. Vincent Basin, southern South Australia (Hos, 1977) and the Murray Basin, western New South Wales (Martin, 1978).

The Curlew assemblage is very diverse comprising 163 spore-pollen types of which 106 are of angiosperm origin, 45 fern, 12 gymnosperm and 1 probable bryophyte. Less than a third of the species have been recognised. The large angiosperm component contains several recognised pollen taxa of the Myrtaceae, Proteaceae, Casuarinaceae, Fagaceae and

Liliaceae along with numerous unidentified tricolpate and tricolporate grains. Palynomorphs of the Myrtaceae are the most abundant representing 15% of the total assemblage, while those of the Casuarinaceae (10%) and Liliaceae (6.9%) are also common. Proteaceae and Nothofagidites pollen types are very poorly represented, i.e. 0.9% and 1% respectively. The rather diverse gymnosperm component is of minor importance in the overall composition of the assemblage representing 0.9% (Table 2).

The Yaamba Basin, which is located near to the Rundle deposit (see Figure 1) has a similar floral composition but of markedly different proportions. There are 92 spore-pollen species of which 70 are of angiosperm origin, 13 fern, 5 gymnosperm, 3 algal and one of probable byrophyte origin (Foster, 1982). The most significant difference is the strong showing of the gymnosperms which represent 19.0% of the total microfossil assemblage, in which Araucariacites australis and the related pollen types Dilwynites granulatus and Dilwynites sp. C are the major contributors. These pollen species occur very infrequently in the Curlew microflora. Similarly, large quantities of the algal species Saeptodinium gravattensis are present at Yaamba, in one particular sample (CPY 21:6520*) recording a frequency of 93.5%, but only a few specimens have been recorded in the Curlew Formation. Another significant difference is the absence of Haloragacidites harrisii (Casuarinaceae), which dominates that component in the Curlew Formation.

Comparing the Curlew microflora to that of the southern deposits, differences are recognised in almost every component. The Anglesea microflora consists of 178 spore-pollen species. Of these, 131 are of

angiosperm origin, 22 gymnosperm and 25 fern. The angiosperm Nothofagidites spp. represent 20% of the total palynoflora. This is a significant increase compared to that of the Curlew but is in accordance with the trend discussed by Martin (1982) and mentioned previously in Chapter 3. A similar trend is shown in the Proteaceae and Gymnospermae components, but not to the same degree. Casuarinaceae pollen occurs in approximately the same frequencies in both floras but the Curlew microflora has a greater abundance of Myrtaceae and fern palynomorphs.

The Nerriga deposit also has a diverse microflora but there is an overall increase in abundance of angiosperm pollen when compared to that of the Curlew Formation. The microflora comprises 112 (Owen 1975) spore-pollen species of which 72 are of angiosperm origin, 12 gymnosperm, 25 fern and 3 unknown.

Within the angiosperm component (72.83%), proteaceous palynomorphs account for 20% of the assemblage which is a significant increase compared to their representation in the Curlew microflora (i.e. < 1%). Gymnosperm palynomorphs are more common in the Nerriga deposit than in the Curlew sediments but not by a large quantity (i.e. 3.5 %). In contrast, however, the Myrtaceae, Casuarinaceae and fern components are all of minor significance. These differences are possibly due to differences in altitude.

The following comparisons are made with those Eocene microfloras that were originally compared by Martin (1982).

The Hay microflora has a typically large angiosperm component, but a number of compositional differences are evident. The most obvious,

are the very high frequencies of Nothofagus-related pollen which represent approximately 50% of the microflora. Such an abundance is unmatched by any of the microfloras discussed to date. By comparison, the Curlew Nothofagidites component is insignificant. The differences between the Casuarinaceae and Gymnospermae components are less pronounced. An approximate 5% and 10% respective increase is recorded in these components of the Hay microflora. Only fern spores (50%) and Myrtaceae grains (< 10%) are not as common as in the Curlew microflora.

The Officer Basin microflora is substantially different to that of the Curlew Formation. An exceptionally large Casuarinacae component is the most distinghishing feature. It represents approximately 37% of the assemblage which is at least a three-fold increase on the Curlew component. Nothofagidites species are also abundant, but occur at lower frequencies than recorded in the Hay microflora (i.e. 25%). A gymnosperm frequency of 17% is much greater than that recorded in the Curlew microfloral (> 1%). Higher frequencies of Myrtaceae pollen and fern spores are again recorded for the Curlew microflora.

The St. Vincent Basin microflora is dominated by palynomorphs of the Casuarinaceae (40% of the total palynoflora) but Proteaceae pollen is also common (20%). In the Curlew palynoflora, these groups do not achieve the same level of significance (i.e. Proteaceae > 1% and Casuarinaceae 10%). The Myrtaceae component is possibly more common in southern South Australia than in the eastern deposits but it is still less than that recorded for the Curlew. Fern spores are more abundant in the Curlew deposit.

The Murray Basin microflora is very similar in composition to that of the Hay deposit which is located in the same geological region and therefore the major difference between this microflora and that of the Curlew are almost identical to those discussed in reference to the Hay microflora.

6.2.1 Conclusions

The Yaamba palynoflora was similar in composition to that of the Curlew Formation, with the exception of the gymnosperm component which was larger. This suggests that the pollen rain responsible for both palynofloras came from the same source vegetation. The high Araucariaceae frequency recorded in the Yaamba deposit is most likely a local event, as these trees are known to have poor pollen dispersal capabilities (Luly et al., 1980).

It is evident from the comparisons that all deposits located outside Queensland had microfloras with higher proportions of Nothofagidites, Proteaceae, Casuarinaceae and Gymnospermae pollen types. However, the Myrtaceae and Pteridophyte components were generally smaller than those of the Curlew microflora (with the St Vincent Basin being the possible exception in regards to Myrteaceae pollen).

The variations between the southern and western Eocene microfloras have already been discussed by Martin (1982) and the inclusion of the

Queensland microfloras provides further evidence for the floristic trends she and Hekel (1972) recognised. The most important difference between northern, i.e. Queensland, and southern Eocene deposits is the proportion of Nothofagidites pollen (of the brassii type) recorded. This low frequency appears to have persisted throughout the Queensland Tertiary up until the Miocene, where Nothofagidites was abundant for a short interval. Hekel (1972) assumed this peak to be associated with a climatic change, as a result of the elevation of highlands in the region, and suggested that the North was not as suitable for Nothofagus as in the South. Martin (1978) reaffirmed this view by suggesting that there may have been a North-South temperature gradient during the Tertiary judging from the greater abundance of Nothofagus in south-eastern Australia when compared to Queensland. An inability to migrate quickly may have contributed to the absence of these plants in Queensland but more importantly climatic factors were probably responsible for confining Nothofagus to southern Australia.

The existence of a climatic gradient across the Australian continent (from equator to pole) during the Eocene is now generally accepted. Based on the available palaeogeographical, palaeoclimatic and palaeobotanical (mainly palynological) evidence Kemp (1978) considered this gradient to be low with Australia surrounded by warm oceans and situated within a zone (60°S - 80°S) of sluggish and variable atmospheric circulation. It was this system that produced the warm, wet climate over the continent at this time. The palynological evidence which comes mainly from southern and central Australian localitied suggests rainforest extended across Australia from the east to the south-west, and locally, inland central Australia (Kemp, 1978).

The northward movement of Australia away from Antarctica had produced a large southern gulf which was fed by the warm Indian Ocean greatly influenced the composition of rainforests across southern Australia. The warm, wet conditions extended inland, possibly as a result of intense summer storms (Kemp, 1978) to produce the local pockets of rainforest in central Australia. All of these forests contained a strong temperate element, i.e. Nothofagus (of the brassii type) trees and podocarps, and a diverse tropical element represented by relatives of the Cupanieae, Myrtaceae, Santalaceae, Anacolosa and Beauprea. The westerly wind system prevailing in Antarctica and moving north during the winter is considered responsible for the increased rainfall in south-eastern Australia (Kemp, 1978) and the resultant high proportion of temperate rainforest taxa, i.e. Nothofagus.

Nix (1982) also pointed out that as the Tertiary progressed or-ographic influence became more important in extending the range of southern temperate vegetation. He suggests the development of the eastern highlands of Australia provided the avenues for mesotherm (e.g. closed canopy Eucalypt spp., Araucaria, Nothofagus spp. brassii type) and microtherm (e.g. Nothofagus spp., Phyllocladus, Dacrydium and Podocarpus) taxa to move northward into lower latitudes. It would appear mountain development climaxed in Queensland during the Miocene when Nothofagus was abundant (Hekel, 1972) for a short period.

The Queensland Eocene vegetation is poorly known but of the available information it is evident that compositional differences exist. The high proportion of Myrtaceae, the presence of other tropical indicators, i.e. Cupanieae and Anacolosa (and mesotherm Nix, 1982), and the very low quantities of Nothofagidites pollen types indicate a

warmer climate existed in northern Australia during the Eocene. The climatic gradient was probably slightly steeper than that considered by Kemp (1978). The climatic influences associated with the large southern gulf and the Antarctic wind systems appear to have had little affect in Queensland which suggests or-ographic influences were probably responsible for maintaining the small temperate element in the vegetation. The presence of both tropical and temperate taxa in the Curlew flora implies a marginal tropical/subtropical vegetation persisted in the region during the Eocene. Based on Nix's classification (1982, see Figure 9) the vegetation would be described as an overlap between mesotherm and megatherm environments.

6.3 Comparison of the Curlew Formation Megafossil and Microfossil Floras.

The Megafossil and Microfossil floras of the Curlew Formation are quite distinct. They exhibit some compositional similarities but the importance of the components vary considerably. The Proteaceae, Casuarinaceae and Podocarpaceae are present in both floras. In the microflora, Casuarinaceae pollen is reasonably abundant throughout the sequence, recording frequencies as high as 70% at specific intervals, and representing 10% of the total floral assemblage, whereas megafossils (cuticle fragments) were scattered throughout the sequence in very small quantities. They were mainly concentrated in the sediments of core ERD 117. A reverse situation existed for the Proteaceae components where cuticles were common in all cores and pollen scarce, representing less than 1% of the total palynoflora. Within the megafossil gymnosperm component podocarps are exceedingly rare only two fragments have been recovered. Similarly, pollen assignable to the family recorded a frequency that was a fraction of the total percentage recorded for the entire Gymnospermae which was only 0.9%.

The Myrtaceae and Lauraceae were particularly abundant in the microfossil and megafossil floras respectively. Myrtaceae pollen was common throughout the sequence and represented 23% of the total palynoflora. Only the combined angiosperm component was more common. No Myrtaceae megafossils were found in any of the Curlew sediments. The Lauraceae component was a major contributor to the megafossil flora but no palynomorphs with an affinity to the Lauraceae were identified.

In 1980, Hill commented on the fact that the Nerriga microfossil and megafossil floras could not be satisfactorily compared due to the "paucity of taxonomic determinations of megafossils". It is evident in this study that this situation unfortunately still exists in 1986 and will continue until more workers become involved in Tertiary, megafossil research.

CHAPTER 7

PALAEOENVIRONMENTAL INTERPRETATIONS

7.1 Introduction

One of the aims of this study was to propose a number of hypotheses concerning the palaeoenvironment in which the Curlew megaflora was deposited. Initially it was envisaged that the main analysis would involve foliar physiognomy and taxonomic studies of the gross community structure. These approaches have been summarised by Dilcher (1973) and their usefulness in determining the palaeoclimate of Australian Tertiary megaflora is to be discussed here. Hill (1980) in a similar investigation noted that taxonomic approaches outlined by Dilcher must be treated with caution because Australian Tertiary plant fossils are taxonomically very poorly known thereby limiting the opportunity of finding modern equivalents on which the palaeoclimatic estimations are based. He suggested these approaches when used in conjunction with others may enable more accurate comparisons being made.

Works presently being undertaken by a number of palaeobotanists have continued to broaden our knowledge of the composition of Australian Tertiary megafloras thereby improving the accuracy of palaeoenvironmental reconstruction. Some of the more important contributions have been made by Blackburn (1981), Christophel (1980,1981,1984) Christophel and Basinger (1982), Hill (1983a, b) and Hill and MacPhail (1983). Despite this additional information, these approaches must continue to be used in conjunction with others to make comparisons more accurate. The four additional approaches considered in this study are epiphyllous fungi, palynology, geology (including both physical and chemical factors) and biology (i.e. faunal).

7.2 Interpretative Approaches Available

7.2.1 Foliar Physiognomy

Modern foliar physiognomy is based on the research of Bailey and Sinnot (1916) who concluded that "there is a very clearly marked correlation between leaf margin and environment in the distribution of Dicotyledons in the various regions of the earth". As an approach independent of taxonomy it has been favoured by many workers, particularly those investigating Tertiary climates (e.g. Wolfe, 1971, 1978; Dilcher, 1973; Blackburn and Christophel, 1978). The increased application of foliar physiognomy led to the introduction of new foliar features that could also be correlated to climate, e.g. leaf size (Dilcher, 1973; Wolfe, 1978) and the presence or absence of drip tips (Wolfe, 1978) but at the same time the whole philosophy of the approach was receiving increasing criticism.

It became apparent that an inaccurate interpretation of fossil floras would be developed unless the features (e.g. differential preservation) that exist within living floras are fully understood. From the combined research of the following workers - Spicer, 1975; MacGinitie, 1953; Dolph, 1974, 1975, 1976, 1978b and 1979; Dolph and Dilcher, 1979a and b; Roth and Dilcher, 1978; Chaney, 1924 and Ferguson, 1971 - it was concluded that the foliar physiognomy of fossil deposits cannot be compared directly to the foliar physiognomy of living plant communities until the relationship between living plant communities and the leaf deposits derived from them are better understood.

This has led to numerous studies being carried out on potential megafossil environments, i.e. lakes and other closed water systems which have an influx of floristic elements. These studies include those of the Northern Hemisphere, i.e. Birks and Birks (1980) and MacGinitie (1969) and a large number from Australia and New Zealand, i.e. McQueen (1969), Burrows (1980), Drake and Burrows (1980), Hill (1981) and Hill and Gibson (pers. comm., 1985). As a result of these investigations long distance dispersal was highlighted as a potentially important feature that would probably affect any foliar physiognomic analysis if it caused species from more than one vegetation type to be present in an assemblage, (e.g. Hill, 1980).

Long distance dispersal is one of the simplest methods by which plants from a number of habitats may enter a depositional site but the input of megafossils by this process is considered minor by Hill (1980). This is definitely the case if only intact foliar megafossils are considered but a wealth of dispersed cuticle floras exist (see Kovach and Dilcher, 1984), which would surely indicate the impact this mechanism has had in forming fossil deposits.

Although applicable to the majority of known Australian Eocene fossil floras, foliar physiognomy is of little benefit in trying to interpret vegetation types represented in the Curlew Flora because it consists entirely of leaf fragments. No intact fossils have been recovered. A better understanding of long distance dispersal is required if these floras, which have the potential to be very numerous throughout the Australian Eocene, are to be accurately interpreted.

The fact that foliar physiognomy could not be employed in this study is in itself a particularly useful piece of information. Foliar physiognomy can only be used in the examination of intact leaves which has been interpreted by workers as leaves that have been deposited by source plants growing within the depositional area. Christophel and Blackburn (1978), noted that "because of their delicate nature leaves, flowers and fruits can be transported only limited distances before decay, mechanical disruption and hydrodynamic sorting have effects". They suggested a dispersal distance of a few kilometres is possible before leaves and flowers begin to breakdown. The fragmentary nature of the Curlew foliar remains therefore implies these fossils were transported long distances from their source area outside the depositional basin.

The geography of the Narrows region would suggest that the source area of the Curlew foliar fossils was in the highlands to the west of the Narrows Graben in the northern Calliope Ranges and around Mt. Larcom. The streams which originate on the eastern fringe of the ranges, near Mt. Alma, (e.g. Raglan and Munduran Creeks) flow generally east, through the Mt. Larcom Range, into the Narrow Graben (Figure 10). A similar river system may have existed during the Eocene.

Considering the other approaches in reference to the long distance dispersal of Curlew foliar fragments a rather confused picture arises.

During the analysis of the palynoflora of the Curlew Formation a number of pollen types, mainly angiosperm, have been noted to occur in clusters or clumps. This has been a particularly common feature of Myrtaceae and Casuarinaceae palynomorphs. The presence of these clumps,

which would easily be destroyed if transported over long distances, suggests the source plants must have grown near to the deposition site. However, Casuarinaceae, (despite normally having very small leaves) is also represented in the megafossil flora by tiny foliar fragments (approx. .5mm²) which would, to the contrary, suggest source plants were located some distance from the depositional site.

An examination of the lithology of the Curlew Formation adds more complications. It has already been suggested (section 5.1) that both an autochthonous and allochthonous element exists in the flora. The monocots are considered the autochthonous element even though the plant remains are fragmentary. Their delicate nature suggests a local deposition; the lignites being the result of 'in situ' deposition of vegetable matter. The absence of stomata on the recovered material could imply either root periderm or non-aerial epidermal material which would most probably be accummulated at the immediate site.

Considering the more robust nature of the dicotyledon and gymnosperm cuticles, the degree of fragmentation must have resulted from long distance transport. Therefore these cuticle types are the allochthonous element of the Curlew Flora. Periodic flooding of the 'monocot' swamp was responsible for the deposition of these fragments. The light coloured clays and shales in which the cuticle remains were deposited are fine-grained indicating a low energy system was maintained even during flooding. The flooding was probably not a catastrophic event because there has been little disruption to the sedimentation process, no erosion of beds or introduction of coarse grained material.

Therefore it can be concluded that the allochthonous element of the Curlew flora is represented by the dicotyledon and gymnosperm remains that were introduced into the basin during low level flooding. The plants responsible for these cuticle fragments were probably located in tropical/subtropical closed forest communities some distance from the site of deposition. The Mt. Larcom Range (Figure 10) which encloses the south-western end of the graben is approximately ten kilometres away and appears the most likely source region. The autochthonous element is represented by the monocot cuticles that were deposited 'in situ', within the limnic swamp.

7.2.2 Comparative Taxonomic Identifications

Of the 27 parataxa identified in the Curlew megafossil flora, 17 have determined affinities to 7 modern families and 9 genera (plus 1 extinct genus), i.e. Casuarinaceae (Gymnostoma), Cyperaceae, Ebenaceae (Austrodiospyros), Lauraceae (Cryptocarya, Endiandra and Litsea) Podocarpaceae (Decussocarpus), Proteaceae (Cardwellia, Darlingia and Synaphea) and Zamiaceae (Bowenia, 2 spp. B. eocenica and B. papillosa). The family Salviniaceae is represented in the megafossil flora by megaspores of Azolla capricornica.

Gymnostoma is at present confined to a single locality in Australia, in tropical northern Queensland (L.A.S. Johnson pers comm.). In P.N.G. and New Caledonia it is a true rainforest plant often associated with swampy conditions (Christophel, pers. comm.). Cuticular remains were recovered from all but one drillhole locality (i.e. ERD 118) which suggests plants existed in substantial numbers throughout the area. The fact that these fossils are so morphologically similar to modern Gymnostoma infers this genus has undergone very little evolutionary change since the Eocene. Therefore it could be interpreted that the Curlew plants were located within the Narrows Graben or near to a swamp, probably situated along a river or stream, within a tropical rainforest community that flowed into the Narrows Graben.

The Cyperaceae is a cosmopolitan family and well represented in the Australian flora, particularly in wetter habitats, or where permanent water exists. Cyperaceous remains were recovered from the lignitic sediments dominated by a number of other unidentified monocotyledons (i.e. parataxa No. 13 and 19). It could be concluded

that plants related to this family in association with other sedge/reed-like plants occupied the lakeside, river-bank and swamp habitats within the depositional basin.

The Ebenaceae is pantropical and subtropical in distribution with minor occurrences in temperate regions. Diospyros is the only genus represented in Australia, where it extends across the top of the continent down the east coast to the southern limit of the subtropical zone.

Fossil flower and leaf remains from Anglesea provide evidence that both floral and foliar features typical of many Ebenaceae were well established by Eocene times (Christophel and Basinger, 1982). The Curlew fossils are rare, having occurred sporadically through the sequence of drillhole ERD 118, which suggests very few plants would have been located within, or near, the depositional basin. Again these plants were probably associated with a subtropical/tropical rainforest community.

The Lauraceae has a worldwide distribution concentrated around the tropics and subtropics with major centres of distribution in the South-East Asian, South and Central American rainforests (Hyland 1983). In Australia, the family has a coastal distribution which extends from tropical north-eastern Western Australia through the Northern Terrority and Queensland down the east coast to the subtropical limit in the vicinity of the New South Wales/Victoria border (Figure 19 B). Cryptocarya, Endiandra and Litsea are three of the six naturally occurring genera in Australia.

Species of these genera occur in the three 'ecofloristic' regions described by Webb et al (1984) as; A) Temperate and subtropical humid evergreen rainforests. B) Tropical humid evergreen grading into highly seasonal raingreen forests and C) Subtropical moderately seasonal humid/subhumid raingreen forests. Endiandra introrsa, which has a close affinity to parataxon No. 16, is a component of subtropical humid evergreen rainforests. This rainforest type (A_2) is centred in subtropical coastal southern Queensland and northern New South Wales. There are outliers, one to the north is located on patches of basaltic red earths on wet uplands (600-900 m) to the west of Gladstone (Webb et al. 1984, see figure 2(b)), not far from the Narrows Graben, to the east.

Parataxon No. 15 has an affinity to Litsea leefeana. This extant species is not as restricted in its distribution as E. introrsa and is known to extend from subtropical northern New South Wales to tropical northern Queensland. Therefore L. leefeana probably occurs in all three of the ecofloristic regions of Webb et al. (1984).

None of the Australian Cryptocarya species compared favourably enough with parataxon No. 14 to make a positive association. The two most similar species were C. murrayi and a Fijian species C. turriliana. The latter appears to be most closely related to the fossil. Without any strong affinity being evident between the fossil and a particular modern species only a generic association was possible. Cryptocarya is represented in all three ecofloristic regions and therefore has a distribution similar to that of Litsea leefeana.

The Lauraceae dominate the Curlew cuticular flora. Parataxon No. 16 is the most abundant and all other types, (many of which are unidentified) are very common also. Therefore it is suggested that all of these plant types existed in reasonably high frequencies in probable subtropical closed forests some distance away from the Narrows Graben, possibly in the vicinity of Mt. Larcom. Parataxon No. 16, with its proposed similarity to E. introrsa was probably associated with a subtropical humid evergreen rainforest. The presence of L. leefeana and Cryptocarya species in this vegetation type also suggests the other identified lauraceous parataxa may well have occurred in the same plant community or a very similar one, i.e. subtropical humid evergreen rainforest.

The overall distribution of the Proteaceae may be considered Gondwanic with the three "super regions" (Johnson and Briggs, 1975) centred on Australia, South Africa and South America. In Australia, the family is spread over the entire continent with the greatest diversity occurring in south-west, Western Australia and down the east coast from Cape York, in North East Queensland to Tasmania and around into South Australia (Figure 19 A). Cardwellia, Darlingia and Synaphea are located in two completely different vegetation types. Synaphea is at present restricted to the sclerophyll forests of south-west, Western Australia. Darlingia and Cardwellia are present in the tropical rainforest of north-east Queensland, the former is an endemic to this region. Both genera are considered relicts that possess numerous primitive features (e.g. peduncle, pluriovulate condition and rainforest habit) but were probably more widespread in the past (Johnson and Briggs, 1975). It could therefore be suggested that these Curlew plants were probably

numerous in a tropical rainforest community some distance from the deposit, e.g. the Mt. Larcom Range.

Sclerophyllous vegetation in Australia is by no means confined to areas of Mediterranean climate but it is very largely restricted to infertile soils. Floristically rich sclerophyllous communities are found in eastern Australia, under actual tropical conditions of monsoon climate. With a virtually rainless 'winter', heaths and scrubs may occur on highly deficient soils (Johnson and Briggs, 1975). It is therefore possible that the sclerophyllous Synaphea, today restricted to south-west, Western Australia, was more widely distributed throughout the continent during the Tertiary prior to the major marine incursions of the Eocene (Churchill, 1973) and that plants related to Synaphea were common on infertile soils in the vicinity of the deposit. Such a comparison is not unique for some southeastern Tertiary fossils of the Banksiinae, i.e. Banksieaephyllum pinnatum (Cookson and Duigan, 1950) from Victoria and B. incisum from South Australia, exhibit types of leaf division now confined to certain Western Australian species of both Banksia and Dryandra. This possibly suggests a former extension to the east by such forms.

Decussocarpus has a predominantly tropical Gondwanic distribution. However, the section Dammaroides, to which the Curlew fossil (parataxon No.8) is attributed is distinctly Indo-Malaysian in its distribution. The section Decussocarpus is found in montane rainforests whereas the section Dammaroides is confined to lowland rainforest and swamp forests (de Laubenfels, 1969). The nearest modern relative to the fossil is found in the rainforests of New Guinea. The fossil was extremely rare in the Curlew sediments which suggests its deposition was an isolated

event and that the source plant was located a considerable distance from the basin.

Bowenia is a distinctive, though small (2 extant species and 2 extinct) genus and like the other cycad genera is evolutionary conservative, making it a particularly useful palaeoclimatic indicator. The two parataxa (Nos. 23 and 43) have a very strong affinity to the two extinct species B. papillosa (No. 23), which was recovered from Eocene sediments of Nerriga, and B. eocenica (No. 43) from Eocene sediments of Anglesea.

The two extant species of Bowenia are restricted to North East Queensland (Johnson, 1959). Bowenia serrulata generally forms a dense understorey in eucalypt (dry sclerophyll) forests, while B. spectabilis is found in and around rainforest (Johnson, 1959). B. eocenica and B. papillosa are distinct from both extant species (Hill, 1978). Modern Bowenia is a shrublike plant, with no above ground trunk and extremely leathery and persistent leaves. Therefore it can be concluded that potential fossil material would have to grow near to the depositional basin. Assuming then that B. eocenica and B. papillosa had similar habits to the modern Bowenia species, they probably grew along a river or lake shore near dry sclerophyll vegetation or on the margin of a rainforest (Hill, 1980).

An abundance of megaspores and massulae of Azolla capricornica Foster and Harris (1981) have been recovered from the Curlew and other sediments of the Rundle deposit. These fossils are assumed to have the same ecological requirements as extant Azolla, which Foster and Harris (1981) consider to be a valuable environmental indicator in present day

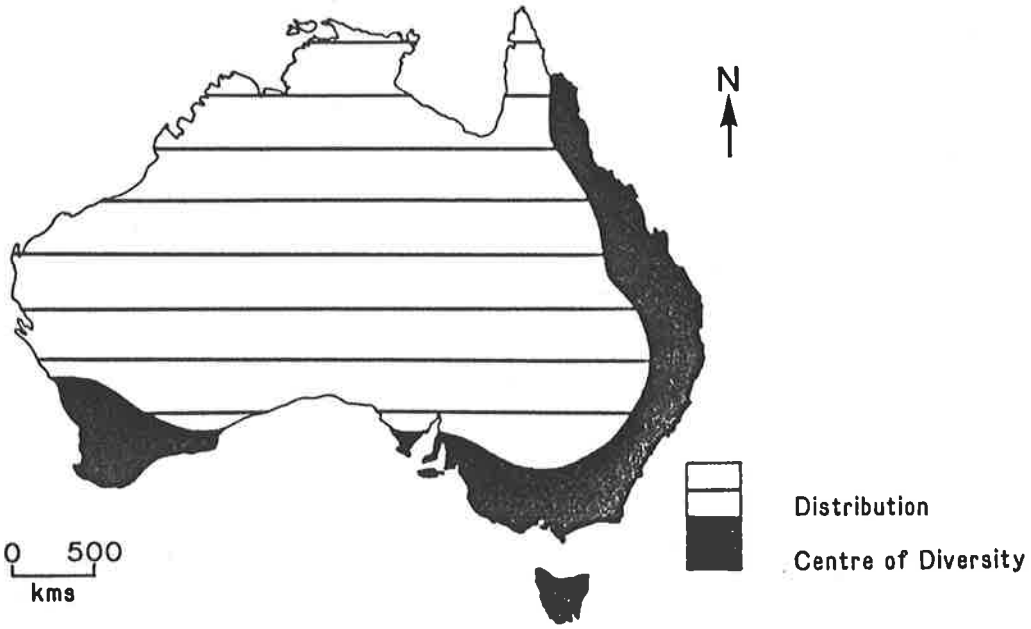
environments. Azolla is mostly a warm temperate to tropical genus, inhabiting freshwater. A. filiculoides is common in Australia today. Ideal growing conditions for Azolla are still water where the effects of turbulence and periodic flooding will not fragment the colonies. Should intermittent turbulence occur, the fern has the ability to regenerate rapidly once favourable conditions are restored (Foster and Harris 1981). They conclude that the abundance of Azolla fossils indicates that sedimentation occurred in a freshwater environment with little turbulence and low detrital sedimentary influx.

The recovery of Azolla capricornica remains from the lignites and upper claystones would tend to suggest such an environment existed in the Curlew Formation prior to flooding and the deposition of the light coloured sediments.

Based on these comparisons it is suggested that the Curlew allochthonous taxa occurred in a marginal tropical/subtropical closed forest where lauraceous taxa dominated the canopy layer which included some proteaceous trees and the understorey contained cycads and proteaceous shrubs. The source plants probably occurred in the south-western highlands of the Mt. Larcom Range. Locally, Gymnostoma, sedges and reedy plants were probably restricted to the wetter swampy areas in the basin and Azolla capricornica floated on the swamp waters.

Figure 19: A) Present Distribution of the Proteaceae and its Centres of Diversity in Australia.

B) Present Distribution of the Lauraceae in Australia.



A Australian Distribution of the Proteaceae
(after Johnson and Briggs, 1975)

B Australian Distribution of the Lauraceae
(after Morley and Toelken, 1983)

7.2.3 Geological Approaches

The geological reports about the Narrows sediments concentrate on the more financially important Rundle Formation and only a limited amount of geological data is available on the Curlew sediments.

Prior to using geological features in environmental reconstructions it must be established that the features observed are those that were produced at the time of deposition and not the result of processes of compaction, diagenesis and metamorphism. Therefore only primary features can be used in the reconstruction of the depositional environment for a particular rock (Reineck and Singh, 1980).

The minerological and chemical composition of a sediment can be altered by diagenesis and caution must be taken in their application. Faunal and Physical features, although susceptable to diagenesis, are much more reliable than the other features (Reineck and Singh, 1980).

7.2.3.1 Faunal Approach

The faunal features of a sediment are those which have been left behind by animals generally in the form of fossils. These may include 1) hard skeletal and biogenic parts e.g. shells, teeth. 2) sedimentary bioturbate structures. 3) excretory matter. 4) organic matter. Of all the animal communities, benthic communities are the most important in characterising a given environment because they are preserved within the sediment therefore giving excellent information about the depositional environment (Reineck and Singh, 1980).

In the sediments of the Narrows Graben fossil ostracod carapaces are common. Beasley (1945) believed these fossils could have no other origin than burial 'in situ'. He also observed that ostracods were generally more abundant in the oilshales, common in some of the non-bituminous shales, but rare and completely absent from some of the bituminous as well as the non bituminous shales. Based on this distribution Beasley concluded that the ostracods themselves had not played the principal role in the formation of the oilshales. Species of the freshwater genera, Zonocypris, Cypris, Candona, Eucandona and Cyprinotus have been identified (Lindner and Dixon, 1976). Freshwater ostracods are known to favour a still shallow water environment containing sufficient organic material for them to pursue their scavenging habits and in such an environment they may be found in vast swarms swimming near the surface, or creeping among the plants and in the mud of the lake floor (Beasley, 1945).

Ostracod remains were only common in the grey shales of the Curlew Formation. As this sequence contains the greatest quantity of carbonaceous material this overall scarcity of ostracods is not unexpected. Beasley (1945), noted ostracods were absent from the higher bituminous shales and suggested a change in environment which resulted in a large increase in vegetable matter in the water body. Henstridge and Missen (1981) proposed an environment change from a lagoon/mud flat in the Rundle Formation to a limnic swamp in the Curlew Formation. (Such a change would most probably be acccompanied by an increase in vegetable matter.)

Bioturbation structures are produced by the activity of living animals within the sediments or on the sediment surface. These

structures are noted in the Narrows sediments by Henstridge and Missen (1981). Although the products of these animals activities were not observed in the Curlew Formation, jaw fragments of a polychaete worm have been recovered from a sample in ERD 110. The overall lack of animal remains in the Curlew Formation confirms a change in environment. As density of animal population and bioturbation depends mainly on the oxygen content of water (Reineck and Singh, 1980) it is likely the environment became more anaerobic, possibly the result of a much increased vegetative content. Rapid deposition and rapid erosion also affects the density of bioturbation but there is no evidence to suggest these factors were responsible for the absence of animals in the Curlew Formation.

An absence of recognisable excretory matter in the Curlew sediments reaffirms the proposal that the environmental change was not favourable to the benthic and pelagic faunal communities that had existed previously.

A difference in the type of organic matter of the older Rundle Formation and the Curlew Formation again reflects environmental changes. The Rundle Formation, which is the most extensive, consists almost entirely of oilshales. The organic content of these sediments is mainly kerogen. Hutton et al. (1980) determined that kerogen is composed of numerous thin laminae of organic matter, i.e. Alginite B (a product of plankton algae), cryptically interbedded with mineral matter.

Kerogenous sediments are not a significant feature of the Curlew Formation. Only at the base of the sequence are very low grade oilshales present. The bulk of the sediments are carbonaceous,

resulting from the accumulation of vegetable matter. Barrier green claystones are also present in the sequence. Henstridge and Missen (1981) considered the carbonaceous sediments were deposited in freshwater swamps in a reducing environment and that regressive phases (perhaps climatic or tectonic changes) led to alterations in the swampy conditions (removal of organic matter), resulting in the deposition of the green claystones. Hutton (1978) suggested, based on petrological evidence, that with the change in environment there was also a change in provenance (source).

7.2.3.2 Physical Features

There are numerous physical features that may be considered in determining post depositional environments. These can be divided into two major groups: primary sedimentary structures and sedimentary textures. These provide information about the mode and medium of transport and energy conditions at the time of deposition. Some examples of energy conditions are; depth of water, velocity of flow, turbulence, wind velocity (Reineck and Singh, 1980).

A) Primary Sedimentary Structures.

Primary sedimentary structures are defined as those formed at the time of deposition or shortly thereafter and before consolidation of the sediments in which they are found (Pettijohn and Potter, 1964). They include various kinds of surface marking and spiral bedding. Surface markings are all those observed on the sediment surface or a bedding plane surface. Bedding features include all the forms observed in a section cut normal to the sediment surface.

Investigations of the Curlew Formation have been carried out solely on core material thereby restricting the information on primary sedimentary structure to that concerned with bedding.

i) Bedding:

The Curlew sediments are recognised as having massive bedding. This type of bedding is used to describe more or less homogeneous looking sediments (Reineck and Singh, 1980). The feature may be the result of:

1) Strong bioturbation activity

2) The draining of water out of sediments during compaction

3) The upward movement of gases through the sediments

4) Very rapid sedimentation

5) Sediments deposited by grain flow.

Any one of these processes could have produced the massive bedding in the Curlew Formation except bioturbation because of the scarcity of benthic animals in the sequence. Unfortunately none of the remaining processes provide any useful information regarding past depositional environments therefore making it impossible to interpret the Curlew environment from the type of bedding represented.

ii) Sedimentary Textures:

Important features of sedimentary textures are grain size, grain size parameters, shape and roundness, surface texture and primary fabric. These are controlled mainly by the medium and mode of

transport, and to a lesser degree by the depositing medium. They provide more accurate information about the transport medium and only limited information about depositional conditions. Therefore they are not important in the reconstruction of ancient physical environments.

Grain size does provide some information about the energy of the depositing medium and the energy of the basin of deposition (Reineck and Singh 1980) and therefore the energy status of the environment. It is generally accepted that coarser sediments are found in high energy environments and finer sediments in low energy environments. The Curlew sediments are predominantly fine grained indicating a low energy environment existed during their deposition. For a short interval, during which coarser sandy claystones were deposited, a slightly higher energy environment must have existed.

7.2.3.3 Chemical and Mineralogical Factors

Chemical factors existing in an environment are important in defining a given environment. Salinity and temperature are possibly the most important because they control the distribution of fauna and with that the biogenic sedimentary structures. Reconstructing the chemical environment is based mainly on the minerals which have been precipitated at the time of deposition. It should be noted, however, that chemical attributes sensitive to the environment are also susceptible to diagenetic changes.

Important chemical factors are Eh (oxidation-reduction potential), pH (acidity-alkalinity), salinity and temperature (Pettijohn, 1957).

Iron minerals are commonly associated with oxidizing and reducing environments. Haematite indicates a fully aerated or oxidizing environment while pyrite indicates an oxygen deficient or reducing environment.

Pyrite is common in the Curlew Formation, particularly in the green claystone which lies between the major carbonaceous sections. The green claystone forms a distinctive band (10 m thick in ERD II8) in the middle of the sequence. Reineck and Singh (1980) highlighted the association between pyrite and the absence of benthonic fauna and traces of benthonic activity, referring to it as positive evidence of anaerobic conditions of deposition. They also noted that a high content of preserved organic matter is also good evidence of anaerobic conditions.

In the north-west of the graben towards the limits of the Formation, reddish-brown (haematitic) sediments have been recorded by Henstridge and Missen (1981).

It is evident by the amount of pyrite present (and preserved organic matter) that deposition occurred primarily under anaerobic conditions, with the occasional short aerobic period. The absence of minerals like gypsum, anhydrite, halite and potassium salts indicates the low salinity of the Curlew environment. The presence of minor calcareous sandstone and limestone beds (Henstridge and Missen, 1981; Lindner and Dixon, 1976) suggests short periods where an alkaline medium existed in a rather warm environment.

Based on the geological features discussed above the Curlew sediments were deposited under warm, quiet, predominantly reducing

conditions in a fresh water swamp. The swamp contained a high content of vegetable matter and possibly few fauna. However, it should be noted that even though animals appear to be absent they may be present as they are often not incorporated into plant bearing sediments.

7.2.4 Palynological Approach

Palynology has provided the most recent and thorough analysis of Australian Tertiary floras (Christophel and Blackburn, 1978) but its usefulness in palaeoenvironmental interpretation is limited. This is primarily due to the difficulty in judging the geographical relationships between depositional site and the source of the pollen flora (Potter, 1976). Despite this difficulty, palynological data are still very useful in biostratigraphy (Hill, 1980). Variability in dispersal ability of pollen types results in a pollen flora that may represent several vegetation types, not all located within the area of deposition. Nothofagus, for example, produces large amounts of pollen which may travel over very long distances (in excess of 700 km; Dodson, 1976) thereby being deposited in areas well outside its vegetative range. Therefore caution must be taken when interpreting pollen floras. Luly et al. (1980) have taken this factor into consideration in defining the representative value of pollen types in a deposit and this has greatly improved the usefulness of palynology in palaeoenvironmental interpretation.

In addition to this problem, Christophel and Blackburn (1978) noted others, i.e. : 1) the difficulty in determining exact taxonomic affinities of palynomorphs, particularly at the generic and specific level, due to their relatively simple structure; 2) An approach independent of taxonomy cannot be carried out on palynological data (c.f. foliar physiognomy). These additional problems are not necessarily inhibitory. There is a wealth of identified Tertiary palynomorphs. Many have no known modern affinities while others have

more than one (even at the family level), but there is a group of very distinctive grains whose generic affinities are known and accepted. These grains are easily recognised and particularly useful climatic indicators. A taxonomically independent approach to palaeoenvironmental interpretation is particularly useful but none of those presently in use are without faults. Foliar physiognomy deals with many unknown foliar parameters and its application is only acceptable when used in conjunction with the taxonomic approaches.

In Chapter 3 the elements of the Curlew Formation palynoflora have already been discussed in detail. A summary of the modern affinities of several pollen types and their environmental implications will be considered in this section.

The Myrtaceae component comprised a number of pollen types, none of which have easily recognised modern relatives. The genera Angophora, Eucalyptus, Metrosideros and Syncarpia have all been mentioned as a possible relatives of the Myrtacidites species. The Myrtaceae is considered an Australasian element with its centre of diversity in Australia. Genera are represented in almost all vegetation types ranging from dry open scrub, through heathlands, to tropical closed forest. Although an ecologically diverse family that produces characteristic, though morphologically, very similar pollen it is a recognised indicator of a warm climate (Kemp, 1978). Based on the dispersal capacities of modern eucalypts it would appear the source plants that contributed to this pollen component were trees of the canopy or understorey layers which grew around the site of deposition. The source plants of Myrtaceidites mesonesus probably grew closer to the site of deposition than those of other species because its greater

abundance and clumping of grains.

The Proteaceae component, though a minor element in the Curlew pollen flora, contains a few palynomorphs that can be assigned to modern taxa with some degree of confidence. Banksieaeidites arcuatus is easily distinguished from other proteaceous fossil pollen type by its bilateral, biaperturate pollen. The recent discovery of Banksieaeidites arcuatus in an anther of the fossil Musgravea-related flower, Musgraveinanthus alcoensis (Christophel, 1984) suggests a strong affinity to Musgravea. This genus is represented by tall canopy trees that are restricted to the tropical closed forests of North East Queensland.

Beaupreaidites elegani̊formis is another distinctive species whose affinities are with the extant genus Beauprea. This genus is no longer present in the Australian flora and is only found as an endemic in the tropical to warm temperate closed forests of New Caledonia (Luly et al, 1980).

Luly et al. (1980) considered all proteaceous taxa to have a limited aerial dispersal ability, resulting in either local or extra-local pollen dispersal. Therefore the source plants, as either understorey or canopy taxa or scramblers, grow in the vicinity of, or at the site of, deposition. It has also been suggested by Johnson and Briggs (1975) that based on morphological analysis and biogeographical evidence, the Proteaceae were (at the time of their early diversification into subfamilies, tribes and most of the subtribes, and their spread amongst the southern landmasses), trees growing in closed forests. It is therefore probable that the sclerophyllous shrubs

present in the modern Australian flora were originally derived from closed forest trees. Eucalyptus has probably a similar phylogenetic development to the Proteaceae. The groups retaining most primitive characters tend to be associated with tropical conditions whilst those groups more closely associated with the highly sclerophyllous communities of southern Australia are more advanced (Johnson and Briggs, 1975).

It can therefore be concluded that the Proteaceae component was probably produced by a small number of canopy and/or understorey plants from subtropical/tropical closed forest located within the depositional basin near to the sample site.

The Casuarinaceae component is another important contributor to the overall palynflora of the sequence (see section 3.5). It is dominated by Haloragicidites harrisii which is attributed to the modern genus Gymnostoma. Haloragacidites trioratus, the only other fossil pollen type recovered, occurred in very low frequencies.

All previous palaeoenvironmental reconstructions have been based on features characteristic of Casuarina (e.g. Luly et al., 1980) with little discussion of Gymnostoma (see section 3.5). The recovery of clumps of H. harrisii pollen and intact anthers from both Curlew and Anglesea sediments (Syber, 1983) suggests the source plants grew at the margin of a tropical closed forest community very close to the site of deposition. These plants were probably common in the forest community.

There were very few Nothofagidites pollen grains in the Curlew sediments. Even though the quantity of pollen was small, all three living groups of Nothofagus were present, Nothofagidites emarcidus

(brassii type) has been assigned to Nothofagus grandis (Martin, 1978). This modern tree species is only found in the tropical and temperate montane closed forests of New Caledonia and New Guinea. Nothofagidites brachyspinulosa (fusca type), in the past has been attributed to Nothofagus gunnii (Martin, 1978; Hill and Macphail, 1983) which is a small deciduous tree endemic to the subalpine and cool temperate closed forests of Tasmania. Similarly, Nothofagidites asperus (menziesii type) has been assigned to Nothofagus cunninghamii (Hill and Macphail, 1983) a dominant canopy species of cool temperate (mossy) closed forests of Tasmania and Victoria. Although it is unlikely that climatic conditions required for N.gunnii and N. cunninghamii existed in the vicinity of the Curlew deposit during the Eocene it is possible that at a considerable distance from the locality (Up to 700km) a suitable upland microthermal flora existed.

The scarcity of Nothofagidites suggests that the source plants were rare or located far away from the depositional site in vegetation types which ranged from subalpine to tropical closed forest. These source plants would have been located in restricted upland areas that were subject to high precipitation or humidity. Nothofagus is considered to be part of the Antarctic element in the Australian flora. As stated previously, it is evident that this element was not common in Queensland during the Middle to Late Eocene.

The majority of the Angiospermae component is represented by tricolpate and tricolporate palynomorphs. These types of grains are produced by many different modern plant taxa making it very difficult to identify the modern relatives of these fossil pollen types. There are however a few distinctive palynomorphs that can be related to modern taxa. Five species with strong affinities to modern taxa are

Anacolosidites sectus, Cupanieidites orthoteichus, C. major, C. reticularis and Santalumidites cainozoicus and all are considered indicators of tropical, albeit high altitude, conditions (Kemp, 1978; Truswell and Harris, 1982). The Cupanieidites species resemble pollen of a number of species in the tribe Cupanieae (Sapindaceae) which is considered by Luly et al. (1980) to have extra-local pollen dispersal characteristics suggesting the source plants were associated with a closed forest canopy or understorey layer. The proposed modern relatives of Cupanieidites pollen types (see Chapter 3) are all rainforest trees of the canopy layer.

The two species of Malvacipollis, i.e. M. subtilis and Malvacipollis sp., present in the Curlew Formation are considered to possess morphological features of both Malvaceae and Euphorbiaceae (Martin, 1974). The affinities within these families (see Chapter 3) are associated with either subtropical or tropical rainforests.

There is a small percentage of the tricolpate and tricolporate grains that have however been either identified or tentatively assigned to fossil species. Some of these species are recognised as having modern affinities and these have already been discussed in Chapter Three. Of the tricolpate palynomorphs Tricolpites simatus and T. thomasii are both considered affiliates of the predominantly tropical family Loranthaceae (Martin, 1978; Cookson and Pike, 1954). Similarly the tricolporate palynomorphs, i.e. Zonocostites ramonae, Tricolporites sphaerica, Tricolporites sp. af. Diospyros, Tricolporites sp. af. T.adelaidensis and Simpsonipollis sp.A, all have modern relatives that occur in either subtropical or tropical rainforests, with the exception of Zonocostites ramonae which has an affinity to the Rhizophoraceae, a

family predominantly associated with mangrove habitats. This affinity suggests a small part of the vegetation, i.e. to the east of the graben, may have been under a maritime influence. The rarity of these grains suggests there was minimal easterly movement (of pollen) from the coastal areas.

The small sclerophyllous element represented in the Curlew Formation tends to indicate that less favourable climatic and edaphic areas persisted near the site of deposition. The sclerophyllous Proteaceae have already been mentioned and this only leaves two other pollen species to be discussed, i.e. Polyporina chenopodiaceoides (Chenopodiaceae/Amaranthaceae) and Polycolporites esobalteus (Polygalaceae). The modern relatives of these species are shrubs or ground covers that are not regarded as true rainforest taxa. Based on the habit of these plants local pollen dispersal would be expected, which would suggest the source plants grew near to, or within, the depositional basin. However, these pollen types are not common in the Curlew Formation in which case the source plants were rare or through some isolated event a few grains were carried into the Narrows Graben from some distance away. The affiliates of Polyporina chenopodiaceoides both have representatives in the tidal salt marsh community which is part of the succession that begins with the coastal mangrove community and progresses inland through less saline marsh communities. The presence of this pollen species in association with Zonocostites ramonae implies such a succession may have existed east of the Curlew Formation along the coast but the species was only a minor contributor to the Curlew palynoflora.

Corsinipollenites oculus noctis is clearly related to Epilobium (Onograceae) whose modern species are low annual herbs which occur in more open, possibly sclerophyllous, habitats. A limited pollen dispersal capacity is expected for these plants which would suggest that source plants were located wihin the depositional basin.

It would appear from this analysis that a significant number of different tropical and subtropical canopy taxa, were located, within the depositional basin, in the vicinity of the sample site. Canopy trees of the Cupanieae and Myrtaceae were probably the most common. A few plants of tropical closed forest margin taxa (e.g. Gymnostoma) probably occurred along stream, river banks and lake/swamp sides while a few sclerophyllous shrubs were found in less favourable areas of the understorey and possibly away to the east in a salt marsh/coastal environment.

An important feature of the Australian gymnosperms noted by Luly et al. (1980) was that all, except Podocarpus and Dacrydium to some extent, have restricted production and dispersal which would suggest that only those plants growing in the vicinity of the deposition site will be represented in that palynoflora. Therefore it could be concluded that the scarcity of gymnosperm pollen in the Curlew palynoflora is most likely due to few source plants being located in the vicinity of the deposition site. It is also possible that no suitable habitat existed in the area as the gymnosperms listed above (section 3.7) tend to be associated with moist cool temperate closed forests or subalpine communities. Araucaria is an exception, being a common emergent of drier vine forests (Kershaw, 1976).

Ephedra, a sclerophyllous shrub, probably occurred in less fertile areas well away from the basin, because the genus is a recognised long distant pollen disperser (Faegri and Iversen, 1964). The low frequencies recorded could also indicate that few plants existed in the area around the depositional site.

The pteridophyte component is one of the major contributors to the Curlew palynoflora. It is comprised almost entirely of fern spores but small bryophyte and lycopod elements are also present. The modern families to which these spores have affinities include Cyatheaceae (tree ferns) Schizaeaceae (Epiphytic ferns) Osmundaceae (Terrestrial and subaquatic ferns) and Gleicheniaceae (scrambling fern). For most of the modern fern taxa (including epiphytic taxa) over-representation of spores is typical which suggests that plants generally grow near to the site of deposition.

It is evident from the comparisons in Chapter 3 that the terrestrial and epiphytic ferns probably dominated the understorey of a tropical to warm temperate closed forest located near to the Curlew depositional site.

The Monocotyledonae component is well represented in the palynoflora. It is dominated by pollen types of the Liliacidites with the morphologically similar Arecipites and an unidentified palynomorph (Genus A sp.) also common. The modern relatives of the fossil types are either herbs or grasses and most likely disperse pollen locally. Arecipites, the palm-related taxon, is a possible exception. Distribution of these plants ranges from open grasslands through to tropical closed forest. Sedges and palms are usually associated with

swamp or poorly drained areas, in drier areas they are often restricted to permanent water. Therefore it could be concluded that source plants were located near to the site of deposition and occupied both drier and swampy areas in the understorey. Liliaceous plants were probably the most common with a few scattered sedges and palms.

The palynological data suggests a marginal tropical/subtropical closed forest community was located in the vicinity of the Narrows Graben. The forest probably had a mixed canopy layer containing eucalypts as well as tropical and subtropical taxa of the Sapindaceae, Euphorbiaceae, an understorey dominated by ferns with liliaceous taxa also common. In the less fertile areas of the forest sclerophyllous trees and shrubs (e.g. Santalum and Beauprea) occurred in association with other liliaceous plants, annual herbs and grasses. Along the lake/swamp margin and river banks a few palms and reeds were scattered under Gymnostoma. In the lake/swamp Azolla capricornica flourished. In the eastern coastal region a mangrove and tidal salt marsh successional vegetation persisted.

Based on this data it could be proposed that the source plants responsible for the Curlew fossil floras were not located as far from the graben as previously suggested. It would appear that the rainforest communities, which are generally restricted to highland regions today in Queensland, were more widely spread during the Eocene. The discovery of Gymnostoma and Bowenia in the Curlew Formation would tend to support this proposal. The valleys and gorges in which many rainforest refugia now exist (see, Webb and Tracey, 1981) were probably the corridors down which the migration onto the coastal plains occurred.

7.2.5 Epiphyllous Fungi

The use of fossil epiphyllous fungi as a method of estimating palaeohabitat was first attempted by Lange (1976). Using the presence and absence of different "grades" of germlings (Dilcher, 1965) showed that some direct indicator value for the Australasian area could be demonstrated on the basis of precipitation and vegetation type. An important feature of this approach was that it was independent of taxonomy.

In a later study (1978a) Lange added several other easily identified epiphyllous fungi to the original scheme. Lange's conclusions were based on the acceptance of the assumption that the fossils occupied the same habitat as their living equivalents and that for the Australasian region "as sampling of a Tertiary flora discloses cumulatively (a) grade 5 "germlings", (b) form 1 manginuloid hyphae, (c) rangiferoid setae (d) the combination of germinated melioloid spores (e) callimothalloid shields and (f) cribritoid shields then the inferred palaeohabitat is progressively restricted towards conditions of present day wet tropical vegetations".

The main advantages of the approach are (1) its simplicity, the forms used by Lange are easily identified and quickly assessed (Hill, 1980). (2) It can be applied to a wide range of deposits because it only requires dispersed cuticle fragments.

Epiphyllous fungi are not particularly common in the Curlew Formation. The highest grade of germling recovered was 5. Fragments of Callimothallus shields were present in one sample (ERD 110, 37.3 M). A

single cuticle fragment (see Figure 158) exhibited markings which could be interpreted as Manginuloid hyphae but they show little similarity to the forms recognised by Lange (1978a).

7.3 Conclusions

The Curlew Flora consists of two distinct elements; an autochthonous element which was contained within the Narrows Graben and included vegetation of the swamp margin and marginal tropical/subtropical closed forest; and an allochthonous element represented by closed forest ranging from subtropical to tropical and located well away from the depositional basin, probably in the eastern highlands. The floristic composition of these elements will by discussed in more detail in the following chapter, section 8.4.

The deposition of all organic material occurred in a low energy, anaerobic environment under a warm, moist climate.

An improved knowledge of the Australian Tertiary flora, through the work of a tireless few, has enabled taxonomic comparisons with modern equivalents being made with greater accuracy and subsequently this approach has become a most useful method for estimating palaeoenvironments. The reconstruction of these vegetation types is based mainly on such comparisons. Palynological studies, although dismissed outright by Hill (1980) as unreliable, do provide information concerning past environments which can be used if the limitations of the approach are fully understood. Epiphyllous fungi are potentially useful in interpreting palaeoenvironment, but Lange's (1976, 1978a) classification needs refining and this can only be achieved with further research.

From the examination of the approaches used in estimating palaeoenvironments it became apparent that foliar physiognomy is not as simple as first believed. Most studies to date have been based on either canopy (Webb,1959+67) or herbarium (Roth and Dilcher, 1978) data and are not representative of the physiognomy of the whole community and in such a situation the foliar features, i.e. leaf size and margin type, used to determine types of fossil floras are greatly influenced by a wide range of factors. These include climatic factors, e.g. precipitation and temperature; physical factors, e.g. position of tree (Hill, 1980) and deposition factors, e.g. leaf floating ability and more than one vegetation type being represented in the deposit. A fossil deposit is a subset of a whole community or communities therefore it is concluded, based on canopy and herbarium data, that foliar physiognomy cannot be successfully employed for estimating palaeoenvironments unless these factors are taken into consideration. This method of analysis is presently being tested on leaf litter of known types of tropical rainforest with promising results (Christophel and Greenwood, pers.comm.,1986).

Palynology has become a very useful approach for estimating palaeoenvironments through the recent increase in information regarding pollen production and dispersal characteristics of modern plant types, particularly in the Australian region (e.g. Luly et al., 1980). This has enabled the source area for pollen rain being more accurately defined through the identification of local, extra-local and regional components. This provides a much firmer basis for Tertiary vegetation reconstructions if account is also taken of possible evolutionary changes in the ecology of component taxa and their community

relationships (Luly et al., 1980).

The most reliable geological features for use in reconstructing past environments are primary ones, i.e. those features not altered by compaction, diagenesis or metamorphism. Faunal features, on which the study of palaeontology is based, provide a wealth of valuable information on past environments. The most important physical features are those involved with sedimentation, e.g. bedding and sedimentary texture. Chemical and mineralogical features are subject to alteration by diagenesis but with caution some of these, such as Eh, pH and salinity, can be used.

CHAPTER 8

DISCUSSION AND CONCLUSIONS

8.1 Discussion

Dispersed cuticular analysis has long been a neglected field of palaeobotany. This is unfortunate because it is potentially one of the most significant approaches available for use in palaeobotanical research, particularly in the areas of palaeoecology, biostratigraphy and systematics. Its advantages over whole leaf megafossil studies have been noted by Kovach and Dilcher (1984). They write "Many kinds of sediments contain abundant cuticular fragments that can be freed by bulk maceration. This procedure yields remains of a large number of individual plants, giving a large statistically reliable sample size, much larger than is practical with megafossils. Also, since sediments containing leaf fragments are generally more common than those with whole leaves, more individual localities can be sampled".

In Australia, very few dispersed cuticle studies have been made. Harvey (1978) investigated the diversity of a number of cuticular features of dispersed cuticle fragments from Maslin Bay, South Australia, but never actually described any of the different cuticle forms. Lange (1978b) also looked at dispersal cuticles from the same locality but was primarily concerned with the proteaceous cuticles and their fossil and modern affinities. Therefore this study is the first to use the dispersed cuticle approach to determine palaeoenvironments, carryout biostratigraphic correlations and identify plant fossils.

As the first Australian study to use this approach only a limited amount of cuticular information is available and if the aims of the project are to be achieved additional information must be obtained from other sources. Of those selected and discussed in a previous chapter,

palynology has proved the most useful.

Australian Tertiary palynological data is extensive and a vast number of palynomorphs have been identified. For some, their name implies their proposed generic affinity whereas others are named in accordance to Potonie's systematics (1956, 1958). In the early days of Australian palynology, pollen named in the former fashion was used with little reservation in making bold conclusions about palaeoclimate and vegetation type, on the basis of the distribution of their modern relatives. With the development of palynology it was realised that many of these early statements of affinity were incorrect and this left numerous pollen types with names that suggested incorrect modern relatives, e.g. Haloragacidites harrisii is known to be related to the genus Gymnostoma in the Casuarinaceae.

Fortunately, the number of workers in the field is quite large so progress has been rapid over such a short period enabling many of the incorrect affinities of the past to be corrected. Today palynological data is a valuable tool for estimating palaeoclimate and vegetation type but, because some confusion regarding Tertiary pollen and spore taxomony persists, caution is always necessary. When combined with megafossil palaeobotany and taxonomic studies, estimations of palaeoclimate and vegetation types are more conclusive.

Megafossil palaeobotany has also been a useful aid in the taxonomy of pollen and spores. For example, Christophel (1980, 1984) has reported pollen grains in the anthers of male inflorescences of fossil Gymnostoma (1980) from Anglesea and in the fossil inflorescence Musgraveinanthus alcoensis (1984); and Basinger and Christophel (1985)

the identification of tricolporate grains in association with Austrodiospyros (Ebenaceae). Similarly, pollen grains comparable to those of Gymnostoma have been found within an anther in the Curlew sediments. Blackburn (pers comm.) has also discovered a complete anther containing pollen from the Yallourn coal depths.

8.2 Megafossil Taxonomic Conclusions

The identification of the Curlew cuticles has had some success. Of the 52 parataxa comprising the flora, 27 have been identified as having affinities to either other known fossils or modern plant groups. This has only been possible through the increased use of cuticular analysis in the analysis of angiosperm leaf remains. The very recent increase in cuticular information in Australia is primarily the result of more research being done on Tertiary megafossil floras (e.g. Blackburn, 1981;Christophel, 1980, 1981; Hill, 1978). Only one other fossil taxon has been identified, i.e. Azolla capricornica.

Of those assigned to extant families the only tentative identification has been made with the Cyperaceae, which has a very poor megafossil record. All the other identifications are supported by good cuticular evidence, i.e. favourable comparisons with both modern and known fossil relatives. Within the Australian section of the Lauraceae it has been possible to distinguish the six naturally occurring genera on their cuticular features, particularly those related to the structure and form of the anticlinal wall of the epidermal cells. This distinction has enabled the fossil lauraceous parataxa being assigned to a number of modern genera. The specific affinities suggested here are only tentative because the taxonomy of the Australian Lauraceae is at present undergoing a complete revision. The outcome and extent of this revision is unknown but it is possible a number of new species will be included. Two fossil cycad species have been identified, i.e. Bowenia eocenica and B. papillosa. These are the only specific identifications (i.e. based on cuticle analysis) made in the Curlew

megafossil flora. Both species are extinct and morphologically quite distinct from their modern relatives B. eocenica was first recovered from the Anglesea deposit while B. papillosa was found at Nerriga.

All of the identifications are the "first" records of these families in the Queensland Tertiary megafossil flora, with the exception of the water fern Azolla capricornica. They also represent new geographical distributions for the families, genera and species. The presence of both Bowenia species in the one deposit has not occurred before.

8.3 Microfossil Taxonomic Conclusions

The microfloral assemblage of the Curlew Formation comprises 165 different pollen-spore types of which approximately 50% have been either identified or tentatively assigned to species. A fresh water dinoflagellate Saeptodinium sp. cf. S. gravattensis (Harris, 1973; Plate 5, Figure 1) and shield fragments of the epiphyllous fungus Callimothallus (Lange, 1978a; Figure 159) were also present, as well as, numerous unidentified fungal spores and hyphae. The pollen and spores have been placed in eight groups, representing the major floristic components of the Australian Tertiary palynoflora. The eight components are the Angiospermae, Casuarinaceae, Gymnospermae, Myrtaceae, Monocotyledonae, Fagaceae, Proteaceae, Pteridophyta.

The Casuarinaceae, Myrtaceae and Proteaceae components are considered the Australian element (Owen, 1975). Australia is the centre of diversity for all three families. Proteaceae and Myrtaceae are thought to have originated in the rainforest environments of eastern Australia and the south-western Pacific region (Owen, 1975; Johnson and Briggs, 1975) during the late Cretaceous before diverging into a wider range of habitats at a later time. The Casuarinaceae and Myrtaceae components are both major contributors to the Curlew palynoflora through Haloragacidites harrisii and Myrtaceidites spp. respectively.

The Antarctic element is represented by the Nothofagus and Gymnospermae components. The latter contains mainly pollen of the families Podocarpaceae and Araucariaceae (Owen, 1975) but is of minor importance in the Curlew palynoflora.

The Angiospermae component, which is particularly large, contains a definite tropical element that is represented by palynomorphs of the family Sapindaceae (e.g. Cupanieidites orthoteichus) and Olacaceae (e.g. Anacolosidites sectus). The Santalaceae is often included as part of this element even though it has a wider ecological range. This is another well-represented element in the Curlew palynoflora.

8.4 Palaeoenvironmental Interpretations

On the basis of the approaches employed, the following conclusions were reached;

1) The Curlew Flora consists of an autochthonous and allochthonous element. The autochthonous element has been defined as a predominantly monocot lined (probably reed-like plants) swamp bordered by marginal tropical/substropical closed forest with a mixed canopy layer of eucalypts, tropical and subtropical taxa and having an understorey of abundant ferns and liliaceous plants. Gymnostoma is also common in the tree layer of this habitat, particularly along the swamp margin.

A much broader classification is given to the vegetation of the allochthonous element. The vegetation type ranges from tropical to subtropical closed forest. The canopy layer contains mainly tropical closed forest taxa, i.e. laurels, and Proteaceae tree species, such as Darlingia. Cycads and some sclerophyllous proteaceous shrubs are present in the understorey. The presence of Gymnostoma implies the vegetation was near to a river or stream, probably restricted to a river valley. The eastern-facing valleys of the highlands to the west of the Narrows Graben are far enough away and serviced by small east flowing streams to be considered the source area for this kind of vegetation.

2) The deposition of all organic matter was in a low energy, freshwater paludal system.

3) The deposition of all inorganic and organic matter occurred in an anaerobic environment.

4) A warm moist clim-ate persisted throughout the Narrows regions.

8.5 Biostratigraphic Interpretations

The biostratigraphic correlations undertaken in this study were based on the distribution of 3 cuticle groups that occurred regularly throughout the Curlew Formation. Both groups were lithotype specific with the monocot parataxa dominating the lignitic bands and the dicot parataxa dominating the lighter coloured clays, coals and shales. Gymnosperms were only found in these latter sediments.

Comparing the distribution of the chosen stratigraphic indicators in all cores, i.e. ERD 118, 117, 112, 111, 110 has enabled a number of correlations to be made. All cores have been compared to the reference core, ERD 118. The strongest correlations are with cores ERD 117, 112 and 111 which exhibit similar distribution patterns to ERD 118 at the commencement (Stage 6) and near the end of the Curlew Formation (Stages 1, 2 and 3). A rather unique correlation exists between ERD 118 and 110. The entire distribution of the indicators in ERD 110 is evident in the middle section of ERD 118, i.e. the latter part of Stage 3 and the beginning of Stage 4. A comparison of all cores does reveal a single interval where similar distribution patterns can be recognised. This interval or module is represented by the latter part of Stage 3 whose upper limit is defined by that dicot/gymnosperm distribution at the top of the Formation in ERD 110.

The module is not extensive but varies in thickness between cores. Floristically it may be divided into three distinct zones; An upper dicot/gymnosperm zone that is dominated by either Proteaceae parataxa (e.g. No.52 aff. Cardwellia) or Lauraceae parataxa (e.g. No.16 aff. Endiandra). A central monocot zone in which both cuticle types are

common. Parataxon No.13 appears to be more scarce in the southern cores;A lower dicot/gymnosperm zone which is generally dominated by the lauraceous parataxon No.16. The absence of very distinctive cuticle types within the zones of the module would probably limit its biostratigraphic usefulness to within the Narrows Graben. An examination of the Stuart deposit, to the north of Rundle, would therefore prove to be a most useful exercise in the near future.

The stratigraphy of the Formation would suggest the basin increased in depth towards the western barrier of the graben (i.e. the F1 fault, see Figure 1). The sedimentary events characterised in ERD 118 were of a greater thickness and occurred deeper in the column in the cores ERD 111 and ERD 112. Extensive minor faulting along the western barrier during the deposition of these sediments resulted in further subsidence and cause of thicker sedimentary layers being produced. Continued subsidence after the deposition of the Curlew Formation increased the depth at which the sequence could be identified.

8.6 Future Studies

The single most important problem facing Australian Tertiary palaeobotany is the need for increased research. In recent years, the few workers in the field have taken on this task with vigor and made some major discoveries. For example the identification of Nothofagus leaves in Tertiary deposits of both mainland Australia, i.e. Bacchus Marsh (Christophel, 1985) and Tasmania (Hill, 1983 a & b). Although the use of cuticular analysis has expanded as a result of these recent studies, dispersed cuticle analysis has been neglected. An expansion of the study of intact fossil leaves, which most Australian Tertiary deposits contain, to include more cuticular research would greatly benefit palaeobotany, particularly in the area of biostratigraphy. The creation of a large reference collection of Australian Tertiary cuticle types would make it possible to formulate a Tertiary biozonation for the entire continent. Therefore initial emphasis is on the production of such a collection that would require the assistance of all workers.

Deposits containing well preserved foliar remains are limited whereas dispersed cuticle source materials (i.e. drillcores) are not. The variety of sediments that contain dispersed cuticles is enormous (Kovach and Dilcher, 1984) making the analysis of these fossils an integral part of any proposed biostratigraphic studies of the Australian Tertiary megaflora.

The preparation of an extant leaf cuticle collection is also needed. This task is at present being incorporated in Dr. David Christophel's (University of Adelaide, South Australia) extant leaf collection which is based on modern rainforest species of the Gondwana

continents. These plants are the probable descendants of the past representatives of the Australian Tertiary flora. This will assist greatly in estimations of palaeoenvironments based solely on cuticles.

Further research into the production of a well defined character set for use in dispersed cuticle analysis is required. The character set used in this study was based on those proposed by Stace (1965) and Dilcher (1974) but some of the characters selected in this instance proved to be of little discriminatory value, e.g. Shape of stomatal aperture. For comparisons to be made with ease and precision, a more refined character set could be designed.

Recent studies of foliar physiognomy have highlighted the complexity of fossil deposition, i.e. many factors influence the representation of leaves in a fossil deposit. Long distance dispersal is one of these factors but proving that it has occurred in a fossil assemblage is difficult (Hill, 1981). Research into the effects of mechanical disruption and hydrodynamic sorting have on the cuticular features (e.g. trichomes and epiphyllous fungi) of transported leaves may provide some information regarding the occurrence of long distance dispersal.

Dispersed cuticle appears to be the ultimate product of long distance dispersal. Christophel and Blackburn (1978) stated that, because of the delicate nature of leaves only limited distances ("up to a few kilometres") could be travelled before decay. Therefore using leaves of modern taxa known to be represented in the fossil record of the Australian Tertiary it could be possible to determine rates of decay (over distance). Superficial cuticular features could also be

used in determining distances travelled.

The work of Kershaw (e.g. 1970b, 1976) and Luly et al. (1980) highlighted the need for more research into the pollen production and dispersal ability of modern plants which has proved an invaluable tool in interpreting plant community relationships and distributions of fossil palynofloras.

In conclusion, there should be greater emphasis on dispersed cuticle analyses in future palaeobotanical research. In biostratigraphic investigations these fossils are potentially very useful, not only within a single depositional basin as shown in this study but on a much larger scale. Similarly, in reconstructing past environments, dispersed cuticles provide valuable information about the regional vegetation that contributed to the floral assemblage of a deposit and when used in conjunction with megafossil information a more detailed picture of the past environment is possible. Therefore megafossil studies must be continued but expanded to include dispersed cuticle investigations along with all related modern projects. Unfortunately, in Australia there are very few Tertiary palaeobotanists, making it difficult if not impossible for all the necessary research to be undertaken. This is the major problem facing Australian Tertiary megafossil research.

Tertiary palynology, on the other hand, is in a very healthy state with a large number of researchers. The main problem here is that very little research beside taxonomy, and palaeoenvironmental determination based on the taxonomy is undertaken. An increased accuracy for palynological interpretations of past environments could

be achieved if more taxonomic revisions and new interpretative approaches (e.g. pollen production and dispersal ability of modern taxa) were undertaken.

BIBLIOGRAPHY

Ancibor, E. (1979). Systematic anatomy of vegetative organs of the Hydrocharitaceae. J. Linn. Soc. Bot. 78: 237-266.

Anderson, R.Y. (1960). Cretaceous - Tertiary palynology, eastern side of the San Juan Basin, New Mexico. Bureau Min. Resour. New Mexico, Mem. 6: 1-59.

Bailey, F.M. (1900). The Queensland Flora. Part 3. 739-1030. Diddams, Brisbane.

Bailey, I.W. and E.W. Sinnot (1916). The climatic distribution of certain types of angiosperm leaves. Amer. J. Bot. 3(1): 24-39.

Ball, L.C. (1914). Tertiary oilshales of the Narrows, Port Curtis District. Qld. Govt. Min. J. 15: 73-76.

Bandulska, H. (1923). A preliminary paper on the cuticular structure of certain dicotyledonous and coniferous leaves from the middle Eocene flora of Bournemouth. J. Linn. Soc. Bot. 46: 241-269.

---------- (1924). On the cuticles of some recent and fossil Fagaceae. J. Linn. Soc. Bot. 46: 427-441.

---------- (1926). On the cuticles of some fossil and recent Lauraceae. J. Linn. Soc. Bot. 47: 383-425.

---------- (1928). A Cinnamon from the Bournemouth Eocene. J. Linn. Soc. Bot. 48: 139-147.

---------- (1931). On the cuticles of some recent and fossil Myrtaceae. J. Linn. Soc. Bot. 48: 657-671.

Basinger, J.F. and D.C. Christophel. (1985). Fossil Flowers and Leaves of the Ebenaceae from the Eocene of Southern Australia. Can. J. Bot. 43 (10): 1825 - 1843.

Beadle, N.C.W., Evans, O.D. and Carolin, R.C. (1963). Flora of the Sydney Region. 724 pp. Reed, Sydney, 1963.

Beasley, A.W. (1944). Notes on the Petrie Series, South-East Queensland. Pro. R. Soc. Qld. 55(7): 87-101.

---------- (1945). Ostracods from some Queensland Tertiary basins and their bearing on the correlation of strata. Proc. Roy. Soc. Qld. 56: 95-124.

Birks, H.J.B. and Birks, H.H. (1980). Quaternary Palaeoecology. Edward Arnold. London.

Blackburn, D.T. (1973). The macromorphological leaf spectrum of a lower Middle Eocene carbonaceous clay lens at Maslin Bay, South Australia. BSc. Hons. Thesis, University of Adelaide (unpubl.).

---------- (1981). Tertiary megafossil flora of Maslin Bay, South Australia: numerical taxonomic study of selected leaves. Alcheringa 5: 9-28.

Bolkhovitina, N.A. (1953). Spores and Pollen characteristic of Cretaceous deposits of central regions of U.S.S.R. Tr. Inst. Geol., Akad. Nauk S.S.S.R. 145 (Geol. Ser. 61) 184 pp. (In Russian).

---------- (1961). Fossil and Recent spores in the Schizaeaceae. Tr. Inst. Geol., Akad. Nauk S.S.S.R. 40: 176 pp. (In Russian).

Briggs, B.G. and L.A.S. Johnson (1983). The Flagellariaceae. In: Morley, B.D. and J.R. Toelken (eds), Flowering Plants in Australia. 375 - 376. Rigby Publishers, Adelaide.

Burrows, C.J. (1980). Long-distance dispersal of plant macrofossils. N.Z. J. Bot. 18: 321-322.

Chaney, R.W. (1924). Quantitative studies of the Bridge Creek Flora. Amer. J. Sci. 8: 127-144.

Christophel, D.C. (1980). Occurrence of Casuarina megafossils in the Tertiary of south-eastern Australia. Aust. J. Bot. 28: 249-259.

---------- (1981). Tertiary megafossil floras of Australia as indicators of floristic associations and palaeoclimate. In: A. Keast (ed.), Ecological Biogeography of Australia, 377-390. Dr.W. Junk, The Hague.

---------- (1984). Early Tertiary Proteaceae: The first floral evidence for the Musgraveinae. Aust. J. Bot. 32: 177-186.

---------- (1985). First record of well preserved megafossils of Nothofagus from mainland Australia. Proc. R. Soc. Vict. 97 (4): 175 - 178.

Christophel, D.C. and J.F. Basinger. (1982). Earliest floral evidence for the Ebenaceae in Australia. Nature, (London) 296: 439-441.

Christophel, D.C. and D.T. Blackburn. (1978). The Tertiary megafossil flora of Maslin Bay, South Australia - a preliminary report. Alcheringa 2: 311-319.

Christophel, D.C. and S.D. Lys (1986). Two new species of mummified Myrtaceae leaves from the Eocene of Victoria. In press.

Churchill, D.M. (1969). The Fossil occurrence of Lygodium in Australia. N.Jb. Geol. Palaont. Mh. Jg. 1969 H5, 257-265.

Churchill, D.M. (1973). The ecological significance of tropical mangroves in the Early Tertiary floras of southern Australia. Spec. Publs. Geol. Soc. Aust. 4: 79-86.

Clifford, H.T. and J. Constantine (1980). Ferns, Fern allies and conifers of Australia. 150 pp. University of Qld. Press, St Lucia.

Cooke, D.A. (1983). The Centrolepidaceae. In: Morley, B.D. and J.R. Toelken (eds.) Flowering Plants in Australia. Rigby Publishers, Adelaide. 373 - 374.

Cookson, I.C. (1946). Pollens of Nothofagus Blume from Tertiary deposits in Australia. Proc. Linn. Soc. N.S.W. 71: 49-63.

---------- (1947). On fossil leaves (Oleaceae) and a new type of fossil pollen grain from Australian brown coal deposits. Proc. Linn. Soc. N.S.W. 72: 207-214.

---------- (1950). Fossil pollen grains of proteaceous types from Tertiary deposits in Australia. Aust. J. Sci. Res., Ser. B 3: 166-177.

---------- (1952). Identification of Tertiary pollen grains with those of New Guinea and New Caledonian beeches. Nature (London) 170: 127.

---------- (1953). The identification of the sporomorph Phyllocladidites with Dacrydium and its distribution in southern Tertiary deposits. Aust. J. Bot. 1: 64-70.

---------- (1956). Pollen grains of the Ephedra type in Australian Tertiary deposits. Nature (London) 177: 47-48.

Cookson, I.C. (1959). Fossil pollen grains of Nothofagus from Australia. Proc. R. Soc. Vict. 71: 25-30.

Cookson, I.C. and S.L. Duigan (1950). Fossil Banksieae from Yallourn, Victoria, with notes on the morphology and anatomy of living species. Aust. J. Sci. Res., Ser. B 3: 133-165.

Cookson, I.C. and K.M. Pike (1953a). A contribution to the Tertiary occurrence of the genus Dacrydium in the Australian region. Aust. J. Bot. 1: 474-484.

---------- (1953b). The Tertiary occurrence and distribution of Podocarpus (section Dacrycarpus) in Australia and Tasmania. Aust. J. Bot. 1: 71-82.

---------- (1954). Some dicotyledonous pollen types from Cainozoic deposits in the Australian Regions. Aust. J. Bot. 2: 197-219.

---------- (1955). The pollen morphology of Nothofagus BI sub-section Bipartitae Steen. Aust. J. Bot. 3: 197-206.

Couper, R.A. (1953). Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. N.Z. Geol. Surv. Pal. Bull. 22: 77 pp.

---------- (1958). British Mesozoic microspores and pollen grains, a systematic and stratigraphic study. Palaeontographica, Abt. B 103: 75-179.

---------- (1960). New Zealand Mesozoic and Cainozoic plant microfossils. N.Z. Geol. Surv. Pal. Bull. 32: 88 pp.

Cranwell, L.M. (1939). Southern-Beech Pollens. Rec. Auckland (N.Z.) Inst. 2: 175-197.

Cronquist, A. (1981). An integrated system of classification of Flowering Plants. Columbia University Press. New York. 1262 pp.

Daghlian, C.P. (1981). A review of the fossil record of monocotyledons. Bot. Rev. 47(4): 517-555.

Daghlian, C.P., J.J. Skvarla, D.T. Pocknall and P.H. Raven. (1984). Epilobium pollen from Oligocene sediments in New Zealand. N.Z. J. Bot. 22: 285-294.

De Laubenfels, D.J. (1969). A revision of the Malesian and Pacific rainforest conifers 1. Podocarpaceae in part. J. Arn. Arboretum, 50: 275-369.

Delcourt, A. and G. Sprumont (1955). Les spores et grains de pollen du Wealdien du Hainaut. Mem. Soc. Belg. Geol. 4: 73 pp.

Dettmann, M. (1963). Upper Mesozoic microfloras from south-eastern Australia. Proc. R. Soc. Vict. 77:1-148.

Dilcher, D.L. (1963). Cuticular analysis of Eocene leaves of Ocotea obtusifolia. Amer. J. Bot. 50 (1): 1 - 8.

---------- (1965). Epiphyllous fungi from Eocene deposits in the western Tennessee, U.S.A. Palaeontographica, Abt. B 116: 1-54.

---------- (1969). Podocarpus from the Eocene of North America. Science 164: 299-301.

Dilcher, D.L. (1973). A palaeoclimatic interpretation of the Eocene floras of south-eastern North America. In: A. Graham (ed.), Vegetation and Vegetational History of Northern Latin America. Elsevier Scient. Pub. Co., Amsterdam.

---------- (1974). Approaches to the identification of angiosperm leaf remains. Bot. Rev. 40(1): 1-157.

Dodson, J.R. (1976). Pollen spectra from Catham Island, New Zealand. N.Z. J. Bot. 14: 341-347.

Dolph, G.E. (1972). A comparison of local and regional leaf characteristics in Indiana. Proc. Ind. Acad. Sci. 8: 99 - 103.

---------- (1974). A statistical analysis of Apocynophyllum mississippiensis. Palaeontographica Abt. B. 151: 1 - 51.

---------- (1975). Character correlations in Angiosperm leaves. Amer. J. Bot. 62 (suppl): 20 (abs).

---------- (1976). Taxometric partitioning of leaf collections. Palaeontographica Abt. B. 156: 65 - 86.

---------- (1978). Variations in leaf size and margin type with respect to climate. Cour. Forsch - Inst. Senckenberg. 30: 153-158.

---------- (1979). Variation in leaf margin with respect to climate in Costa Rica. Bull. Tor. Bot. Club. 106: 104-109.

Drake, H. and C.J. Burrows (1980). The influx of potential macrofossils into Lady Lake, North Westland, New Zealand. N.Z. J. Bot. 18: 257-274.

Dudgeon, M.J. (1983). Eocene pollen of probable proteaceous affinity from the Yaamba Basin, Central Queensland. Mem. Ass. Australas. Palaeontols. 1: 339-362.

Dunstan, B. (1913). Queensland Mineral Index. Publ. Geol. Surv. Qld. 241: 1-1014.

Erdtman, G. (1960). The acetolysis method, a revised description. Svenskbot. Tidskr. 54: 561-564.

Faegri, K. and J. Iversen (1950). Textbook of Modern Pollen Analysis. Munksgaard, Copenhagen.

---------- (1964). Textbook of Pollen Analysis. Blackwell, London.

Ferguson, D.K. (1971). Miocene flora of Kreuzau, West Germany. I. The leaf remains. Verh. Koning. Ned. Akad. Veteschap., Afd. Naturk. 60: 1-297.

Fleming, P.J.G., C.G. Murray and W.G. Whitaker (1974). Later Palaeozoic Invertebrate Fossils in the Wandilla Formation, and the deposition of the Curtis Island Group. Qld. Govt. Min. J.

Florin, R. (1920). Uber Cutikularstrukturen der Blatter bei einigen rezenten und fossilen Coniferen. Ark. Bot. 16(6): 1-32.

--------- (1931). Untersuchungen zur stammesgeschichte der Coniferales under Cordaitales Erste Teil. K. svensk. Vet. - Akad. Handl. (3) 10(1): 1-588.

Florin, R. (1940). The Tertiary conifers of southern Chile and their phyto-geographical significance. K. svensk. Vet. - Akad. Handl. (3) 19(2): 1-107.

Foster, A.S. and E.M. Gifford (1974). Comparative Morphology of Vascular plants. 2nd ed. W.H. Freeman and Co. San Francisco.

Foster, C.B. (1979). Report on Tertiary miospores from the Rundle Oil shale deposit. Qld. Govt. Min. J. 80: 442-443.

---------- (1982). Illustrations of Early Tertiary (Eocene), Plant microfossils from the Yaamba Basin, Queensland. Geol. Surv. Qld. Pub. 381 pp.

Foster, C.B. and W.K. Harris (1981). Azolla capricornica sp. nov. First Tertiary record of Azolla Lamarck (Salviniaceae) in Australia. Trans. Roy. Soc. S.A. 105(3 & 4): 195-204.

Francis, W.D. (1981). Australian Rainforest Trees. 4th ed. Aust. Govt. Publ. Service, Canberra. 468 pp.

George, A.S. (1984). The Olacaceae. In: The Flora of Australia, Vol. 22, Rhizophorales to Celastrales. Aust. Govt. Printer, Canberra. 239 pp.

Germeraad, J.H., C.A. Hopping and J. Muller (1968). Palynology of Tertiary sediments from tropical areas. Rev. Palaeobot. Palyn. 6: 189-348.

Greguss, P. (1968). Xylotomy of the living cycads: with a description of their leaves and epidermis. Akademiai. Kiado, Budapest.

Harris, T.M. (1964). The Yorkshire Jurassic Flora II. Caytoniales, Cycadales and Pteridosperms. Br. Mus. Nat. Hist. London.

Harris, W.K. (1965). Tertiary Microflora from Brisbane. Qld Geol. Surv. Qld. Report No. 10.

Harris, W.K. (1972). New Form species of pollen from South Australian Early Tertiary sediments. Trans. R. Soc. S. Aust. 96: 53-65.

---------- (1973). Tertiary non-marine Dinoflagellate cysts assemblages fromm Australia. Spec. Publ. Geol. Socc. Aust. 4: 159-166.

Harvey, W.J. (1974). The Maslin Bay Flora: an analysis of cuticular features. M.Sc. Thesis, University of Adelaide, (unpubl.).

---------- (1978). The Maslin Bay Flora: South Australia IV. A Cuticular survey of angiosperm leaves. N. Jb. Geol. Palant. Abh., 155: 360-373.

Head, L.M. (1979). A palaeoecological study in the Otway region of south-western Victoria. Hons. Thesis, Monash University, Victoria (unpubl.).

Hekel, H. (1972). Pollen and spore assemblage from Queensland Tertiary sediments. Geol. Surv. Qld. Publ. 35 pp.

Henstridge, D.A. and D.D. Missen (1981). The Geology of the Narrows Graben near Gladstone, Queensland, Aust. Report to 51st ANZAAS Congress Brisbane, Australia, May, 1981.

Heusser, C.J. (1971). Pollen and Spores of Chile. Tucson, University of Arizona Press. 95 pp.

---------- (1974). Vegetation and climates of the southern Chilean Lake District during and since the last interglaciation. Quaternary Res. 4: 290-315.

Hickey, L.J. (1973). Classification of the architecture of dicotyledonous leaves. Am. J. Bot. 60: 17-33.

Hill, D., G. Playford and J.T. Woods (1970). Cainozoic Fossils of Queensland. Queensland Palaeontographical Society. Brisbane. 36 pp.

Hill, R.S. (1978). Two new species of Bowenia Hook. ex Hook.f. from the Eocene of eastern Australia. Aust. J. Bot. 26: 837-846.

--------- (1980). Three new Eocene Cycads from eastern Australia. Aust. J. Bot. 28: 105-122.

--------- (1982). The Eocene megafossil flora of Nerriga, New South Wales, Australia. Palaeontographica, Abt. B 181: 44-77.

--------- (1983a). Nothofagus macrofossils from the Tertiary of Tasmania. Alcheringa 7: 169-183.

--------- (1983b). Evolution of Nothofagus cunninghamii and its relationship to N. moorei as inferred from Tasmanian macrofossils. Aust. J. Bot. 31: 453-465.

Hill, R.S. and N. Gibson (1985). Distribution of potential macrofossils in Lake Dobson, south central Tasmania, Australia. Unpubl. manuscript.

Hill, R.S. and M.K. Macphail (1983). Reconstruction of the Oligocene vegetation at Pioneer, north-east Tasmania. Alcheringa 7: 281-299.

Hochuli, P.A. (1979). Ursprung und Verbreitung der Restionaceen. Vierteljahrsschr. naturf. Ges Zurich 124: 109-131.

Hope, G.S. (1976). The vegetation history of Mt Wilhelm, Papua New Guinea. J. Ecol. 64: 627-661.

Hos, D. (1975). Preliminary investigation of the palynology of the Upper Eocene Werillup Formation, Western Australia. J. Proc. Roy. Soc. W. Aust. 58: 1-14.

------ (1977). Eocene palynology of a sample from Golden Grove, South Australia. Dept. Mines and Energy, South Aust. Rept. Bk. No. 77/88.

------ (1978). Eocene palynology of Sadme Wilkinson No. 1, Eastern Officer Basin. Dept. Mines and Energy, South Aust. Rept. Bk. No. 78/149.

Hutchinson, J. (1964). The Genera of Flowering Plants. Dicotyledonae Vol. I. Clarendon Press, London.

Hutton, A.C. (1978). Aspects of the petrology of the Rundle oilshale, The Narrows, Queensland. B.Sc. Hons. Thesis. University of Wollongong (unpubl.).

Hutton, A.C., A.J. Hantsler, A.C. Cook and D.M. McKirdy. (1980). Organic Matter in Oilshales. A.P.E.A. Journ. 20: 44-67.

Hyland, B.P.M. (1983). The Lauraceae. In: Morley, B.D. and J.R. Toelken (eds.), Flowering Plants in Australia. 42-44. Rigby Publishers, Adelaide.

Johnson, L.A.S. (1959). The families of cycads and the Zamiaceae of Australia. Proc. Linn. Soc. N.S.W. 84: 64-117.

---------- (1980). Notes on Casuarinaceae. Telopea 2(1): 83-84.

---------- (1982). Notes on Casuarinaceae II. J. Adel. Bot. Gard. 6(1): 73-87.

Johnson, L.A.S. and B.G. Briggs (1975). On the Proteaceae - the evolution and classification of a southern family. Bot. J. Linn. Soc. 83-182.

Johnson, L.A.S. and B.G. Briggs (1983). The Proteaceae. In: Morley, B.D. and H.R. Toelken (eds.), Flowering Plants in Australia. 238-244. Rigby Publishers, Adelaide.

Johnson, L.A.S. and K.L. Wilson (1983). The Casuarinaceae. In: Morley, B.D. and H.R. Toelken (eds.), Flowering Plants in Australia. 66-67. Rigby Publishers, Adelaide.

Jones, O.A. (1927). The Tertiary Deposits of the Moreton District, South-East Queensland. Proc. Roy. Soc. Qld. 38: 23-46.

Kemp, E.M. (1976). Early Tertiary pollen from Napperby, Central Australia. B.M.R. J. Austral. Geol. Geophys. 1: 109-114.

--------- (1978). Tertiary climatic evolution and vegetation history in the southeast Indian Ocean Region. Palaeogeogr., Palaeoclim., Palaeoecol. 24: 169-208.

Kemp, E.M. and W.K. Harris (1977). The palynology of Early Tertiary sediments of Ninety East Ridge, Indian Ocean. Spec. Pap. Palaeont. 19: 70 pp.

Kershaw, A.P. (1970a). Pollen morphological variation within the Casuarinaceae. Pollen et Spores 7: 145-161.

Kershaw, A.P. (1970b). A pollen diagram from Lake Euramoo, North East Queensland, Australia. New Phytol. 69: 785-805.

---------- (1973). Late Quaternary vegetation of the Atherton Tableland, north-east Queensland, Australia. Ph.D. Thesis. Australian National University (unpubl.).

---------- (1976). A late Pleistocene and Holocene pollen diagram from Lynch's Crater north-eastern Queensland, Australia. New Phytol. 77: 469-498.

Kirkegaard, A.G., R.D. Shaw and C.G. Murray (1970). Geology of the Rockhampton and Port Clinton 1:250,000 Sheet Areas. Geol. Surv. Qld. Rept. No. 38. 155 pp.

Klaus, W. (1960). Sporen der karnis chen stufe der ostalpinen Trias. Jb. geol. Reich sanst. 5: 1007-184.

Kovach, W.L. and D.L. Dilcher (1984). Dispersed cuticles from the Eocene of North America. Bot. J. Linn. Soc. 88: 63-104.

Krutzch, W. (1959). Mikropalaontologische (sporenpalaontologische) Untersuchungen in der Braunkohle des Geisettales. Geologie 8 (Beih. 21/22). 425 pp.

Ladd, P.G. (1977). Pollen morphology of some members of the Restionaceae and related families, with notes on the fossil record. Grana 16: 1-14.

--------- (1978). Vegetation history of Lake Curlip in lowland eastern Victoria, from 5,000 B.P. to present. Aust. J. Bot. 26: 393-414.

Lange, R.T. (1970). The Maslin Bay flora, South Australia. 2. The assemblage of fossils. N. Jb. Geol. Palaont. Mh. 8: 486-490.

---------- (1976). Fossil Epiphyllous "Germlings", their living equivalents and their palaeohabitat indicator value. N. Jb. Geol. Palaont. Abh. 151: 142-165.

---------- (1978a). Carpological evidence for fossil Eucalyptus and other Leptospermae (subfamily Leptospermoideae of Myrtaceae) from a Tertiary Deposit in the South Australian Arid Zone. Aust. J. Bot. 26: 221-233.

---------- (1978b). Some Eocene leaf fragments comparable to Proteaceae. J. Roy. Soc. Western Aust. 60: 107-114.

Lawrence, G.H.M. (1968). Taxonomy of Vascular Plants, 12th ed. MacMillan & Co., New York.

Le Cren, E.D. and R.H. Lowe-McConnell (eds.)(1980). The functioning of freshwater ecosystems. International Biological Programme, 22. Cambridge University Press.

Lindner, A.W. and D.A. Dixon (1976). Some aspects of the Geology of the Rundle oil shale deposit, Queensland. A.P.E.A. Journal, 165-172.

Luly, J., I.R. Sluiter and A.P. Kershaw (1980). Pollen studies of Tertiary brown coals: Preliminary analysis of lithotypes within the Latrobe Valley, Victoria. Monash Publ. in Geography, No. 23. 77 pp. Monash University, Melbourne, Victoria.

Machin, J. (1971). Plant microfossils from Tertiary deposits of the Isle of Wright. New Phytol. 70: 851-872.

MacGinitie, H.D. (1953). Fossil plants of the Florissant Beds, Colorado. Carnegie Inst., Washington Publ. 599 pp.

---------- (1969). The Eocene Green River flora of north-western Colorado and north-eastern Utah. University of California publs. Sci. 83: 1-140.

Macphail, M.K. (1975). Late Pleistocene environments in Tasmania. Search. 6: 295-300.

Macphail, M.K. (1979). Vegetation and climates in southern Tasmania since the last glaciation. Quaternary Res. 11: 306-341.

Markgraf, V. and H.L. D'Antoni (1978). Pollen Flora of Argentina: Modern Spore and Pollen types of Pteridophyta, Gymnosermae and Angiospermae. University of Arizona Press. Tucson, Arizona. 208 pp.

Martin, A.R.H. (1973). Reappraisal of some palynomorphs of supposed proteaceous affinity. I The genus Beaupreaidites Cookson ex. Couper and the species Proteacidites hakeoides Couper. Spec. Publs. Geol. Soc. Aust. 4: 73-78.

Martin, A.R.H. and W.K. Harris (1974). Reappraisal of some palynomorphs of supposed proteaceous affinity. Grana 14: 108-113.

Martin, H.A. (1973). The palynology of some Tertiary Pleistocene deposits, Lachlan River Valley, New South Wales. Aust. J. Bot. Suppl. 6: 1-57.

---------- (1974). The identification of some Tertiary pollen belonging to the family Euphorbiaceae. Aust. J. Bot. 22: 271-291.

---------- (1977). The Tertiary stratigraphic palynology of the Murray Basin in New South Wales. I The Hay, Balranald-Wakool Districts. J. & Proc. Roy. Soc. N.S.W. 110: 41-47.

---------- (1978). Evolution of the Australian flora and vegetation through the Tertiary: evidence from Pollen. Alcheringa 2: 181-202.

Martin, H.A. (1980). Stratigraphic palynology from shallow bores in the Namoi River and Gwydir Rivers, north central New South Wales. J. & Proc. Roy. Soc. N.S.W. 113: 81-87.

---------- (1981). The Tertiary Flora. In: A. Keast (ed.), Ecological Biogeography of Australia. 393-406. Dr. W. Junk, Publishers, The Hague.

---------- (1982). Changing Cenozoic barriers and the Australian palaeobotanical record. Ann. Miss. Bot. Gard. 69: 625-667.

Mayr, E. (1969). Principles of Systematic Zoology. 2nd ed. McGraw Hill, New York.

McAlister, E.J. (1983). The Rhizophoraceae. In; Morley, B.D. and J.R. Toelken (eds.), Flowering Plants in Australia. 171-172. Rigby Publishers, Adelaide.

McIntyre, D.J. (1968). Further new pollen species from New Zealand Tertiary and uppermost Cretaceous deposits. N.Z. J. Bot. 6: 177-204.

McNamara, K.J. and J.K. Scott (1983). A new species of Banksia (Proteaceae) from the Eocene Merlinleigh Sandstone of the Kennedy Range, Western Australia. Alcheringa 7: 185-193.

McQueen, D.R. (1969). Macroscopic plant remains in recent lake sediments. Tuatara 17: 13-9.

Memon, H.R. (1976). A comparative Scanning Electron Microscope study of pollen of modern Proteaceae and fossil forms from Australia and the Northern Hemisphere attributable to the family. Ph.D. Thesis, University of Sydney, Australia (unpubl.).

Metcalfe, C.F. (1960). Anatomy of the Monocotyledons. Vol. I, Graminae. Oxford Univ. Press, London.

Mildenhall, D.C. and W.F. Harris (1971). Status of Haloragacidites (al. Triorites) harrisii (Couper) Harris comb. nov. and Haloragacidites trioratus Couper, 1953. N.Z. J. Bot. 9: 297-306.

Monakov, A. V. (1968). Some data on the feeding of Heterocope saliens Lill. (Copepoda, Caleinoida). Trudy Instituta Biologii Untremnikh Vod. 17 (20): 27-32. (In Russian)

Morley, B.D. (1983). The Sparganiaceae. In: Morley, B.D. and J.R. Toelken (eds.) Flowering Plants in Australia. 401-402. Rigby Publishers, Adelaide.

Muller, J. (1964). A palynological contribution to the history of mangrave vegetation in Borneo. In: Cranwell, L.M. (ed.) Ancient Pacific Floras. 33-42. University of Hawaii Press.

Muller, J (1968). Palynology of the Pedawan and Plateau Sandstone Formation (Cretaceous-Eocene) in Sarawak, Malaysia. Micropalaeontology 14: 1-37.

--------- (1981). Fossil pollen record of extant angiosperms. Bot. Rev. 47: 1-142.

Narthorst, A.G. (1907-12). Palaeobotanische Mitteilungen, 1-11. K. Svensk. Vetenskapsakad. Handl. Ny Fioligd.

Nichol s, D.J., H.T. Ames, and A. Traverse (1973). On Arecipites Wodehouse, Monocolpopollenites Thompson & Pflug and the species Monocolpopollenites tranquillus. Taxon 22: 241-256.

Nix, H. (1982). Environmental determinants of biogeography and evolution in Terra Australis. In: Burke, W.R. and P.J.M. Greenslade (eds.), Evolution of the Flora and Fauna of Arid Australia. 47-66. Peacock Publications, South Australia.

Odell, M.E. (1932). The determination of fossil angiosperms by the characteristics of their vegetative organs. Ann. of Bot. 46: 941-963.

Owen, J.A. (1975). Palynology of some Tertiary deposits from New South Wales. Ph.D. Thesis, Australian National University (unpubl.).

Pant, D.D. and D.D. Nautiyal (1963). Cuticle and epidermis of recent Cycadales. Leaves, sporangia and seeds. Senckenbergiana Biol. 44: 257-347.

Paten, R.J. (1967). Memorandum to Carpentaria Exploration Manager on the Age of the Oilshale at the Narrows (unpubl.).

Patton, R.T. (1936). A fossil Casuarina. Proc. Roy. Soc. Vict. 49 (N.S.): 36-39.

---------- (1957). Fossil wood from Victorian Brown Coal. Pro. Roy. Soc. Vict. 70(2): 129-143.

Pettijohn, F.J. (1957). Sedimentary Rocks. 718 pp. New York, Harper & Row.

Pettijohn, F.J. and P.E. Potter (1964). Atlas and glossary of primary sedimentary structures, 370 pp. Berlin Gottingen, Heildelberg, New York, Springer.

Petzold, V. (1907). Systematisch - anatomisch Untersuchungen uber die Laublatter der amerikanischen Lauraceen. Bot. Jahrb. 98: 445 pp.

Pike, K.M. (1953). Fossil fruiting cones of Casuarina and Banksia from Tertiary deposits in Victoria. Proc. R. Soc. Vict. 48 (N.S.): 67-75.

Pocknall, D.T. (1980). Modern pollen rain and Aranuian vegetation from Lady Lake, North Westland, New Zealand. N.Z. J. Bot. 18: 275-284.

Pocock, S.J. (1962). Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the Western Canada Plains. Palaeontographica, Abt. BIII: 1-95.

Poisson, I. (1871). Recherches sur les Casuarina et en particulier sur ceux de la Nouvelle-Caledonie. Nouv. Archs Mus. Hist. Nat. Paris

Potonie, R. (1956). Synopsis der Gattungen der sporae dispersae. I. Teil: Sporites. Beih. Geol. Jahrb. 23: 103 pp.

---------- (1958). Synopsis der Gattungen der Sporae dispersae. II. Teil: Sporites (Nachtrage) Saccites, Aletes, Praecolpates, Polyplicates, Monocolpates. Beih. Geol. Jahrb. 31: 114 pp.

---------- (1960). Synopsis der Gattungen der Sporae dispersae III. Teil: Beih. geol. Jb. 39: 1-161.

Potonie, R. and J. Gelletich (1933). Uber Pteridophyten - Sporen einer eo zanen Braunkohle aus Dorog in Ungarn. S.B. Ges. naturf. Fr. Berl. 33: 517-526.

Potter, F.W. (1976). Investigations of angiosperms fromm the Eocene of south-eastern North America : Pollen assemblages from Miller Pit, Henry County, Tennessee. Palaeontographica, Abt. B. 157: 44-96.

Reineck, H.E. and I.B. Singh (1980). Depositional sedimentary Environments. 2nd ed. Springer-Verlag. Berlin.

Rodd, A.N. (1983). The Arecaceae (Palmae). In: Morley, B.D. & J.R. Toelken (eds.), Flowering Plants in Australia. 392-395. Rigby Publishers. Adelaide.

Roelofsen, P.A. (1952). On the submicroscopic structure of cuticular cell walls. Acta bot. neerl. 1: 99-114.

---------- (1959). The plant cell-wall. In: Handbuch Pflanzenanat, 111/4. Gebruder Borntraeger, Berlin.

Roselt, G. and W. Schneider (1969). Cuticulae dispersae, ihre Merkmale, Nomenklatur und Klassifikation. Palaobot. Abt. B. 3: 1-128.

Roth, J.L. and D.L. Dilcher (1978). Some considerations in leaf size and leaf margin analysis of fossil leaves. Cour. Forsch.-Inst. Senckenberg. 30: 165-171.

Salisbury, E.J. (1927). On the causes and ecological significance of stomatal frequency, with special reference to the woodland flora. Phil. Trans. R. Soc. Lond. Ser. B 216: 1-65.

Samoilovich, S.R. (1967). Tentative botanico-geographical subdivision of northern Asia in Late Cretaceous time. Rev. Palaeobotan. Palynol. 2: 127-139.

Smith, G.M. (1938). Cryptogamic Botany. Vol. II Bryophytes and Pteridophytes. McGraw-Hill. New York, London.

Solereder, H. (1908). Systematic anatomy of the Dicotyledons. (Trans. L.A. Boodle and F.E. Fritsch, revised by D.H. Scott.) 2 Vols. Clarendon Press, Oxford.

Specht, R.L. (1981). Major vegetation formations in Australia. In: A. Keast (ed.), Ecological Biogeography of Australia. 163-783. Dr.W. Junk, The Hague, Netherlands.

Spicer, R.A. (1975). The sorting of plant remains in a recent depositional environment. Ph.D. Thesis, London University.

Srivastava, S.K. (1969). Upper Cretaceous proteaceous pollen from the Edmonton Formation, Alberta (Canada) and their paleoecological significance. Can. J. Bot. 47: 1571-1578.

Srivastava, S.K. (1975). Maastrichtian microspore assemblages from the interbasaltic lignites of Mull, Scotland. Palaeontographica, Abt. B. 150: 125-156.

Stace, C.A. (1965). Cuticular studies as an aid to plant taxonomy. Bull. Br. Mus. (Nat.. Hist.) Bot. 4(1): 1-78.

Stant, M.Y. (1964). Anatomy of Alismataceae. J. Linn. Soc. Bot. 59: 1-42.

---------- (1967). Anatomy of Butomaceae. J. Linn. Soc. Bot. 60: 31-60.

Stover, L.E. and A.D. Partridge (1973). Tertiary and Late Cretaecous spores and pollen from the Gippsland Basin, south-eastern Australia. Proc. Roy. Soc. Vict. 85(2): 237-286.

Sturm, M. (1971). Die Eozane Flora von Messel bei Darmstadt. 1 Lauraceae. Palaeontographica, Abt. B. 134: 1 - 60.

Swarbrick, C.F.J. (1974). Oil shale resources in Queensland. Rep. Geol. Surv. Qld. 83: 55 pp.

Syber, A.K. (1983). Palynological analysis of the Eocene Anglesea fossil flora assemblage. B.Sc. Hons. Thesis, University of Adelaide (unpubl.)

Taylor, T.N. (1981). Paleobotany: An Introduction to Fossil Plant Biology. 589 pp. McGraw-Hill, New York.

Thompson, P.W. and H. Pflug (1953). Pollen und Sporen des Mitteleuropaischen Tertiars. Palaeontographica, Abt. B 94: 1-138.

Townrow, J.A. (1965). Notes on some Tasmanian 1. Some Lower Tertiary Podocarps. Pap. Proc. R. Soc. Tasm. 99: 87-107.

Traverse, A. (1955). Pollen analysis of the Brandon Lignite in Vermont. U.S Department of the Interior, Bureau of Mines, Report of Investigations. 5151.

Truswell, E.M. and W.K. Harris (1982). The Cainozoic palaeobotanical record in arid Australia: Fossil evidence for the origin of an arid adapted flora. In: Barker, W.R. and P.J.M. Greenslade (eds.), Evolution of Flora and Fauna in Arid Australia. 67 - 76. Peacock Publications, Adelaide. South Australia.

Tschudy, B.D. (1971). Two new fossil pollen genera from Upper Campanian (Cretaceous) rocks of Montana. U.S. Geol. Surv. Prof. Pap. 750 B: B53-B61.

Tschudy, R.H. and Scott, R.A. (1969). Aspects of Palynology. An Introduction of Plant Microfossils in Time. Wiley, Interscience.

Van Cotthem, W. (1970). A Classification of Stomatal Types. J. Linn. Soc. Bot. 63(3): 235-246.

Walker, D. and J.R. Flenley (1979). Late Quaternary vegetational history of the Enga Province of upland Papua and New Guinea. Philosophical Trans. Roy. Soc. London B 286: 265-344.

Webb, L.J. (1959). A physiognomic classification of Australian rainforests. J. Ecol. 47: 551-570.

--------- (1967). Environmental relationships of the structural types of Australian rainforest vegetation. Ecology 49: 296-311.

Webb, L.J. and J.G. Tracey (1981). Australian Rainforests: patterns and change. In: A. Keast (ed.) Ecological Biogeography of Australia. 607-691. Dr. W. Junk. Publ., The Hague.

Webb, L.J., J.G. Tracey and W.T. Williams. (1984). A floristic framework of Australian rainforests. Aust. J. Ecol. 9: 169-198.

Wilkinson, H.P. (1979). The Plant Surface (Mainly Leaf). In: Metcalfe, C.R. and L. Chalk (eds.) Anatomy of the Dicotyledons. Vol. I. 2nd ed. 97-165.

Wilson, L. R. and Webster, R.M. (1946). Plant microfossils from a Fort Union Coal of Montana. Amer. J. Bot. 33: 271-278.

Wodehouse, R.P. (1933). Tertiary Pollen II. Pollens of the Green River Oil Shales. Bull. Torr. Bot. Club, 60: 479-524.

Wolfe, J.A. (1971). Tertiary Climate fluctuations and methods analysis of Tertiary floras. Palaeogeog., Palaeoclimatol., Palaeoecol. 9: 27-57.

---------- (1978). A paleobotanial interpretation of Tertiary climates in the northern hemisphere. Amer. Scient. 66: 694-703.

Wood, G. (1981). Palynological Analysis of Eocene Coals in the Gambier Embayment near Kingston. B.Sc. Hons. Thesis, University of Adelaide (unpubl.).

ADDENDUM

Brown, R.W. (1956). Palm-like plants from the Dolores Formation (Triassic) in southwest Colorado. U.S. Geol. Surv. Prof. Paper, 274-H: 205-209.

Christophel, D.C., W.K. Harris and A.K. Syber (1987). The Eocene flora of the Anglesea locality, Victoria. Alcheringa (10): In press.

Dolph, G.E. and D.L. Dilcher (1979a). Variation in leaf size with respect to climate in Costa Rica. Biotropica, 12 (2): 91-99.

Dolph, G.E. and D.L. Dilcher (1979b). Foliar physiognomy as an aid in determining palaeoclimate . Palaeontographica Abt. B, 170: 151-172.

APPENDIX 1

Pollen Species list from ERD 118 of the Curlew Formation

The 162 different palynomorphs identified from the sediments of the Curlew Formation have been listed here under the same eight categories used in Chapter 3.

POLLEN SPECIES LIST OF THE CURLEW FORMATION

Myrtaceae		
Myrtaceidites eucalyptoides		Cookson & Pike 1954
M. mesonesus		Cookson & Pike 1954
M. parvus		Cookson & Pike 1954
M. verrucosus	Partridge in	Stover & Partridge 1973
Myrtaceidites sp. A		
Myrtaceidites sp. B		
Myrtaceidites sp. C		
Myrtaceidites sp. D cf. M. eugeniioides		Cookson & Pike 1954
Myrtaceidites sp. E cf. M. rhamnoides		Martin 1973
Myrtaceidites sp. F cf. M. eucalyptoides		Cookson & Pike 1954
Casuarinaceae		
Haloragacidites trioratus		Couper 1953
Haloragacidites harrisii		Mildenhall & Harris 1971
Proteaceae		
Banksieaeidites arcuatus	Stover in	Stover & Partridge 1971
Beaupreaidites elegansiformis		Cookson 1950
Propylipollis sp.		
Proteacidites kopiensis		Harris 1972
Proteacidites pachypolus		Cookson & Pike 1954
Proteacidites sp. cf. P. tenuiexinus	Stover in	Stover & Partridge 1973
Proteacidites sp. cf. P. granulatus		Cookson 1953
Proteacidites sp. cf. P. angulatus	Stover in	Stover & Partridge 1973
Proteacidites sp. cf. P. lepidus		Harris 1970
Proteacidites sp. cf. P. grandis		Cookson 1950
Proteacidites sp. cf. Proteacidites sp. H		Foster 1979
Proteacidites sp. A		
Proteacidites sp. B		
Proteacidites sp. C		
Proteacidites sp. D		
Proteacidites sp. E		
Proteacidites sp. F		

Fagaceae	
Nothofagidites heterus/emarcidus	Cookson 1959
Nothofagidites brachyspinulosa	Cookson 1959
Nothofagidites incrassata	Cookson 1959
Nothofagidites asperus	Cookson 1959
Nothofagidites sp. A	
Nothofagidites sp. B	
Pteridophyta	
Azolla sp.	
Fern sp. A. cf. Baculatisporites comaumensis	(Cookson) Potonié 1956
Fern sp. B. cf. Dictyophyllidites	
Fern sp. C. cf. Dictyophyllidites	
Fern sp. D. cf. Dictyophyllidites	
Lycopod sp.A cf. Camarozonosporites	
Fern sp. H. cf. Stereisporites	
Crassoretitriletes van raadshooveni	Germeraad, Hopping & Muller 1968
Cyathidites splendens	Harris 1965
Cyathidites minor	Couper 1953
Fern sp. I cf. Cyatheacidites	
Dictyophyllidites sp. cf. D. concavus	Harris 1970
Fern sp. J. cf. Dictyophyllidites	
Fern sp. K. cf. Gleicheniidites circinidites	(Cookson) Dettmann 1963
Hamulatisporis sp.	
Kuylisporites waterbolkii	Potonié 1956
Laevigatosporites major	(Cookson) Krutzsch 1959
Laevigatosporites ovatus	Wilson & Webster 1946
Fern sp. L. cf. Osmundacidites wellmanii	Couper 1953
Dictyophyllidites sp. A	
Polypodiaceoisporites retirugatus	Muller 1968
Rugulatisporites sp.	
Punctatisporites spp.	
Rouseisporites sp.	
Fern sp. M. cf. Todisporites	

Stereisporites sp.	
Stereisporites sp. cf. S. antiquasporites	Wilson & Webster 1946
Todisporites spp.	
Verrucatosporites sp.	
Fern sp. N.	
Fern sp. O.	
Fern sp. P.	
Fern sp. Q.	
Fern sp. R.	
Fern sp. S.	
Fern sp. T.	
Fern sp. U.	
Fern sp. V.	
Fern sp. W. cf. Ceratosporites	
Fern sp. X. cf. Gleicheniidites	
Fern sp. Y.	
Osmundacidites sp. A.	
Fern sp. Z. cf. Gliecheniidites	
Gymnospermae	
Phyllocladidites mawsonii	(Cookson) Couper 1953
Ephedra notensis	Cookson 1957
Podocarpidites sp. A.	
Lygistepollenites florinii	(Cookson & Pike) Stover & Evans 1974
Podocarpidites sp. cf. P. magnificus	Harris 1970
Podocarpidites sp. B.	
Dacrycarpidites australiensis	Cookson & Pike 1952
Microcachryidites antarcticus	Cookson 1947
Dilwynites granulatus	Harris 1970
Cycad sp.	
Phyllocladidites spp.	
Araucariacites sp.	
Ephedra sp.	
Monocotyledonae	
Liliacidites sp. A.	
Liliacidites sp. B.	
Liliacidites sp. C.	
Liliacidites sp. D.	
Liliacidites sp. cf. L. aviemorensis	McIntyre 1968

Liliacidites sp. E.		
Liliacidites sp. cf. L. bainii	Stover in	Stover & Partridge 1973
?*Graminidites sp. A.*		
?*Graminidites sp. B.*		
Unknown A. cf. Sparganiaceaeipollenites		
Unknown B.		
Rectosulcites sp. cf. R. microreticulatus		Harris 1970
Restioniidites sp. cf. R. homeopunctatus		(McIntyre) Partridge 1973
Arecipites sp. A.		
Angiospermae		
Tricolporites sp. A.		
Tricolporites sp. B. cf. Diospyros?		Christophel & Basinger 1982
Tricolporites sp. C.		
Tricolporites sp. cf. T. delicatus		Harris 1970
Tricolpites sp. cf T. alveolatus		Couper 1953
Tricolporites sp. cf. T. sphaerica		Cookson 1947
Tricolporites sp. N		
Tricolpites sp. cf. T. coprosmoides		Couper 1960
Tricolporites sp. cf. T. concinnus		Harris 1970
Tricolporites sp. D.		
Tricolporites sp. cf. T. valvatus		Harris 1970
Tricolporites sp. cf. T. microreticulatus		Harris 1970
Tricolporites sp. cf. T. prolata		Cookson 1947
Tricolporites sp. E.		
Tricolporites sp. F.		
Tricolporites sp. cf. T. adelaidensis		Harris 1970
Triorites orbiculatus		McIntyre 1965
Tricolpites sp. cf. T. voraginosus		Harris 1970
Simpsonipollis sp. A.		
Tricolpites sp. B.		
Tricolporites sp. G.		
Tricolpites simatus	Partridge in	Stover & Partridge 1973
Tricolpites thomasii		Cookson & Pike 1954
Tricolpites sp. C.		
Tricolpites sp. cf. T. minutus		(Brenner) Dettmann 1963

Tricolpites sp. D.		
Tricolpites sp. E.		
Tricolpites sp. F.		
Tricolpites sp. G.		
Dilwynites sp. A.		
Santalumidites cainozoicus		Cookson & Pike 1954
Corsinipollenites oclus noctis		(Thiergart) Nakoman 1965
Anacolosidites sectus	Partridge in	Stover & Partridge 1973
Concolpites sp. cf. C. leptus	Partridge in	Stover & Partridge 1973
Polycolporites sp. cf. P.esobalteus		McIntyre 1968
Tetracolpites sp. A.		
Cupanieidites sp. cf. C. major		Cookson & Pike 1954
Cupanieidites sp. cf. C. orthoteichus		Cookson & Pike 1954
Cupanieidites sp. cf. C. reticularis		Cookson & Pike 1954
Cupanieidites sp. cf. C. sp. B		Foster 1982
Tricolpites sp. H.		
Tricolporites sp. H.		
Malvacipollis sp. cf. M. sp. C		Foster 1982
Malvacipollis sp. cf. M. subtilis	Stover in	Stover & Partridge 1973
Zonocostites ramonae		Germeraad, Hopping & Muller 1968
Clavatipollenites hughesii		Couper 1958
Tiliaepollenites sp. cf. T. notabilis		Harris 1970
Polyporina chenopodiaceoides		Martin 1973
Margocolporites sp. A.		
Polycolporites sp. A.		
Tricolpites sp. I.		
Tricolporites sp. I.		
Tricolpites sp. J.		
Tricolporites sp. J.		
Tricolporites sp. K.		
Tricolporites sp. L.		
Helciporites sp. cf. H. astrus	Partridge in	Stover & Partridge 1973

APPENDIX 2

Distribution of Parataxa across the Curlew Formation.

Distribution of Parataxa in Core ERD 118 of Curlew Formation

DEPTH/SAMPLE	PARATAXA
26.0	1,15,16,33
26.2	2,13,16,23,26,35
26.3	10,12,16,24
26.4	2,10,14,15,40
26.7	2,10,16,28,33
26.9	2,9,10,11,16,23,24,17,33,40
27.0	1,10,12,16,17,19,26,33,40
27.3	3,19,23,34
27.5	1,10,11,16,17,19,20,23,27,33,40
27.6	6,12,13,19,21,40
27.7	13,19,
28.0	13,19,21
28.2	13,16,19,
28.3	13,16,19,20
28.7	13,19
29.0	6,10,11,12,14,16,28,33,40,52
29.2	2,9,14,16,33,40,41
30.6	14,19
30.7	2,3,10,11,13,14,17,19,28,29,33
30.8	2,9,10,16,17,24,29,33,38
31.0	2,3,4,9,10,16,23,25,28,39
31.2	9,13,28,
31.3	2,4,9,16,19,25,26,41,52
31.6	1,10,16,19,41
31.9	13,19
32.2	13,19
32.7	13,19
33.4	7,9,13,14,17,19,21,41,44
36.0	13,19,
36.5	13,19,30,41
37.0	2,7,13,19,21,26,41,46
37.3	8,12,13,14,19,21,22,30,35,38
39.0	13,19,21
40.0	1,2,11,13,19,21
40.3	1,3,9,10,14,28,35
40.5	13,19
41.0	13,19,21
41.2	6,13,16,19,21
41.5	13,16,19,21
41.9	13,16,19,21,41,46
42.1	13,16,19,33
43.4	----------
45.1	13
46.2	----------
49.0	----------
50.9	1,9,12,16
53.3	2,3,10,12,15,16
53.8	10,17
54.2	2,9,11,12,14,15,16
55.0	3,6,16,33
55.5	3,10,15,16

56.5	1,2,3,9,11,16
56.7	2,5,9,12,14,15,16,41
58.0	2,3,10,11,15,16,24,29,40
58.4	2,3,11,17
58.8	6,11,12,15,26,52
60.3	1,2,3,9,12,14,16
61.0	2,9,14,15,16,29,33
62.1	1,9,11,13,14,16,52
62.4	13,16,19,21,35
63.4	13,19,21,35
64.4	2,13,19,21
65.0	2,13,16,19,21
65.4	19,44
65.6	16,19
66.5	12,15,16
68.0	--------
68.8	16,19
69.0	11,13,19,21
69.8	2,5,9,12,16,22
70.7	9,11,12,14,15,18,19,21,41
71.4	13,19,21
73.6	5,15,16
74.3	7,13,19
75.0	2,5,7,16,19,21,35,41
75.8	2,9,11,14,16,23,33
75.8	1,10,14,16
78.0	13,19,21

Distribution of Parataxa in Core ERD 117
Curlew Formation

DEPTH/SAMPLE	PARATAXA
46.1	2,9,10,16,18,33,42
47.2	1,2,3,16,22,29,31,33,44
47.9	9,19,20,21,35,43
48.6	1,2,3,5,9,12,14,16,22,29,33,50
49.0	1,2,3,10,16,22
55.9	1,3,6,12,16,29,32,33
57.0	1,6,9,14,15,16,24,28,29,31,33,40
58.2	6,10,16,33,40,43
59.2	9,13,16,18,19,21,26,28,31,43,44
59.5	1,2,3,10,11,16,23,24,28,41
60.0	1,10,13,16,24,29,33,41,44
60.6	10,13,19,21,30
62.8	2,12,13,16,19,21,52
63.7	6,13,19,21
64.1	13,19,21,
65.0	7,13,16,19,20,21,46
66.1	1,2,13,16,19,21,24,30,33
66.9	2,3,9,14,16,19,24,28,29,32,33,40
68.0	2,13,19,21
68.7	13,19,21
69.2	3,12,13,16,18,19,32,33,40
77.3	1,2,3,10,12,13,16,45,46
81.5	1,3,9,11,12,14,16,17,24,28,30,33,40,41
82.0	2,3,6,14,16,28,33,41
83.0	2,3,11,13,14,16,19,21,22,28,33,41
83.5	1,3,6,13,16,19,20,21,22,29,33,41
84.0	2,13,19,20,21
85.6	1,11,12,16,19,21,22,43,44
86.2	1,11,22,24
86.9	16,19,22,24
88.3	1,19,21,22,28
88.8	1,3,11,16,22,28,41
89.0	3,19,21,22,24,28,31,43
90.7	2,3,9,11,12,14,16,17,22,33,41,43
92.1	2,16,19,21,22,43
93.2	13,16,19,21,22
94.1	2,3,16,19,21,28,29,33
95.3	--------
95.9	2,3,11,12,16,19
98.3	2,16,19,21,22
98.8	--------

Distribution of Parataxa in Core ERD 112
Curlew Formation

DEPTH/SAMPLE	PARATAXA
92.5	2,3,14,16,41
92.8	1,2,9,12,14,16,41
102.2	2,9,10,12,16,28,29,43
103.1	1,2,3,6,9,10,14,17,16,22,24,34,35,37, 41,43,45,47,49
103.5	1,2,6,9,14,16,33
103.9	1,2,10,12,14,16,28,33,41,43
104.1	13,19,21,22
106.5	13,15,16,19,21,22,39
107.3	13,16,19,21,22,
108.3	12,13,16,32,33,41
111.3	3,12,16,27,32,33,41
114.0	3,12,15,16,19,21,22,24,28,31
118.5	1,3,10,11,16,41,43,52
119.4	1,2,11,12,16,22,31,33,36,41
120.3	13,19,21,22,30,33
121.4	13,19,21,22,30
123.8	13,19,21,22
124.5	1,11,13,14,16,19,20,21,28,29,33,36,41
126.3	13,16,19,21
127.2	16,19,21,24,28
129.1	2,13,16,19,21

Distribution of Parataxa in Core ERD 111
Curlew Formation

DEPTH/SAMPLE	PARATAXA
106.8	1,2,3,6,9,11,12,14,15,16,28,29,41
110.8	11,14,15,16,17,19,28,33,36,41,43,44
111.1	5,11,13,16,19,21,33,41
111.7	13,16,19,21
112.5	15,16,24,32,33
113.5	15,16,19,21,22,28,33,41
114.5	2,16,19,21,24
115.9	--------
119.3	2,3,10,16,19,24,28,41
121.4	2,11,16,41
123.3	2,3,10,11,16,28,31,33,41
124.4	2,3,11,12,16,41
124.7	1,2,9,16,21,31
127.1	13,16,19,21
127.4	16,19,21
128.9	9,16,19,21,28,41
130.0	16,19,21
131.4	16,19,21,41
133.3	13,16,19,43
133.8	2,3,11,16,19,21,25,36,41,44
135.1	13,16,19
136.0	9,13,16,19,21,22,44
136.5	13,16,19,21,22
137.5	16,19,21,22

Distribution of Parataxa in Core ERD 110
Curlew Formation

DEPTH/SAMPLE	PARATAXA
30.1	3,12,16,17,28,33,41
30.8	19,21,22,24
34.4	3,12,14,16,22,33,41
35.9	1,2,3,9,10,11,12,14,16,28,33,41
37.3	11,31,36,37,39,41,52
38.4	1,11,16,36,41
39.2	1,2,3,6,9,11,12,14,15,16,31,41
39.9	1,11,13,16,28,31,33,38,41,47
40.3	2,13,16,19,21,22,33
41.4	13,19,20,21,22
42.9	13,19,21,22
43.9	11,19,31,44
45.6	3,13,19,21,22
46.3	13,16,19,21,28,33,36,41,45
47.5	19,22
48.6	19
49.6	3,9,12,16,19,22,28,33,41
50.6	3,11,13,19,21,41
51.9	19,22
52.9	19,22,31
54.0	9,16,19,28,30,31
54.8	-------

APPENDIX 3

Occurrences of Nothofagus in the Australian Eocene

Quantatitive Relationships of Eocene Nothofagus Occurences

Site	Age	Nothofagus %	Source
Otway Basin - Princetown	Mid - Late Palaeocene	4 - 6%	Harris, 1965
Kingston	Early - Mid Eocene	32 - 46%	Wood,1981
Nerriga	Early - Mid Eocene	2 - 10%	Owen, 1975
Anglesea	Mid - Late Eocene	11 -(19)- 29%	Syber, 1983
Murray Basin - Hay	Mid - Late Eocene	40 - 45%	Martin, 1977

APPENDIX 4

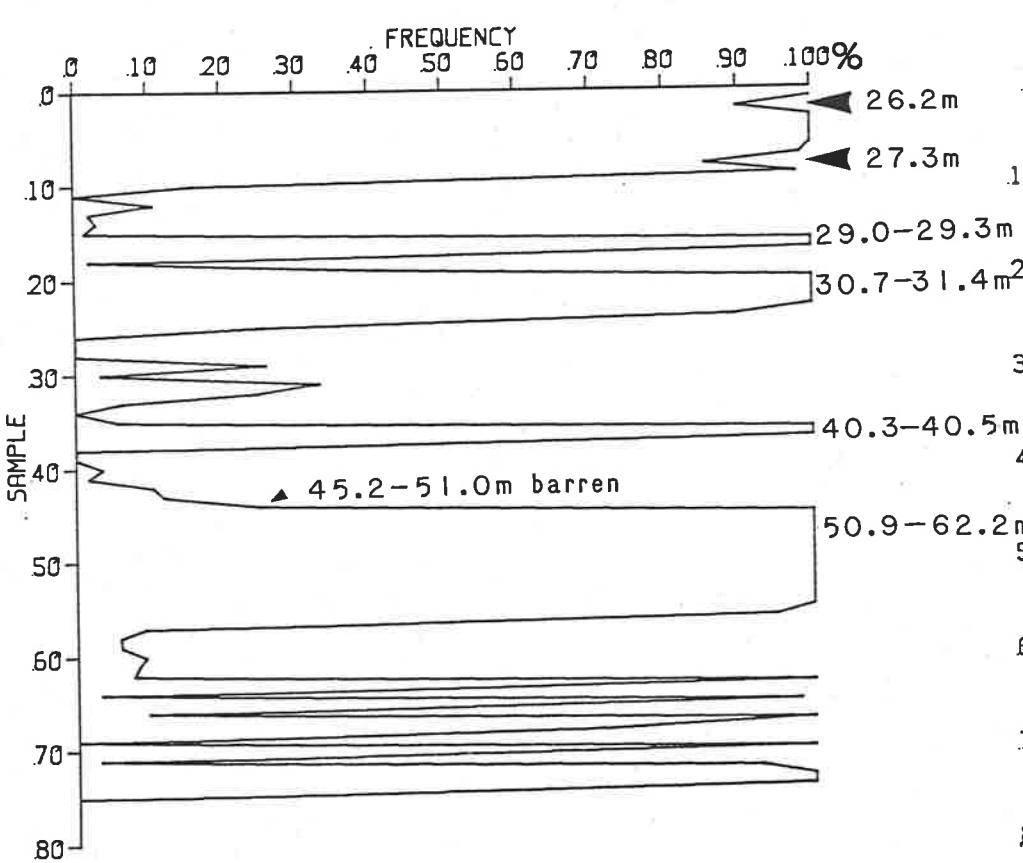
Comparison of the Three Floral Distribution Curves of ERD 118 with those of cores ERD 117, 112, 111 and 110

These curves, like those in Figures 13 - 17, are sequential representations of the frequencies of the three selected indicators, i.e. Total dicot/gymnosperm, Monocot No.13 and Monocot No.19. Each indicator curve (i.e. Total dicot/gymnosperm) of ERD 118 is compared separately with the respective curve in the other cores so that specific intervals (sample depths) may be highlighted. important intervals are indicated on the respective curves by an arrow and the depth recorded.

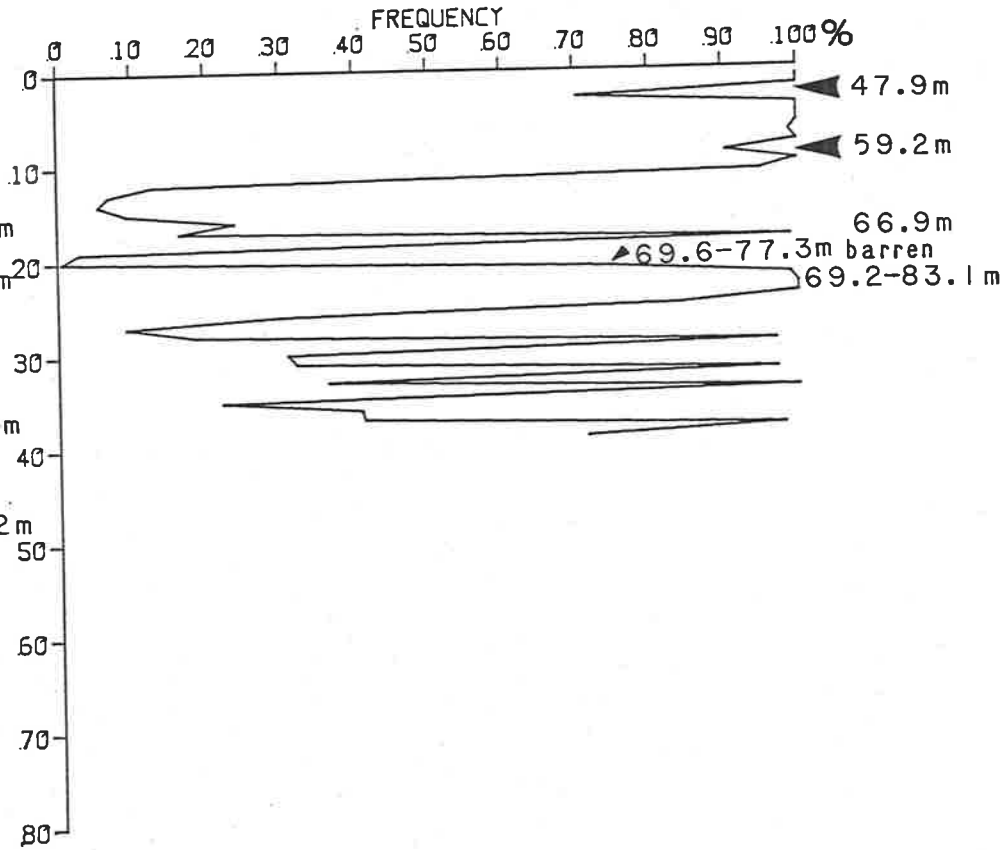
Figures 20: Comparison of the Dicot/gymnosperm Distribution Curves of ERD 118 and ERD 117.

Figure 21: Comparison of the Monocot No.13 Distribution Curves of ERD 118 and ERD 117.

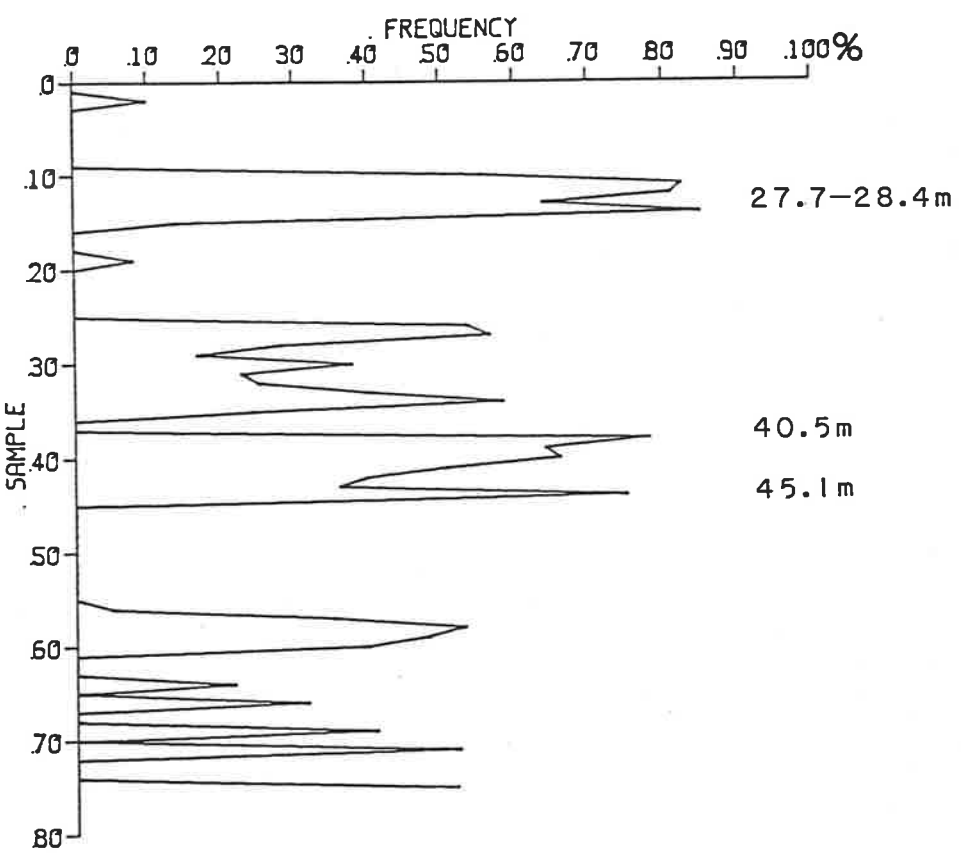
Figure 22: Comparison of the Monocot No.19 Distribution Curves of ERD 118 and ERD 117.



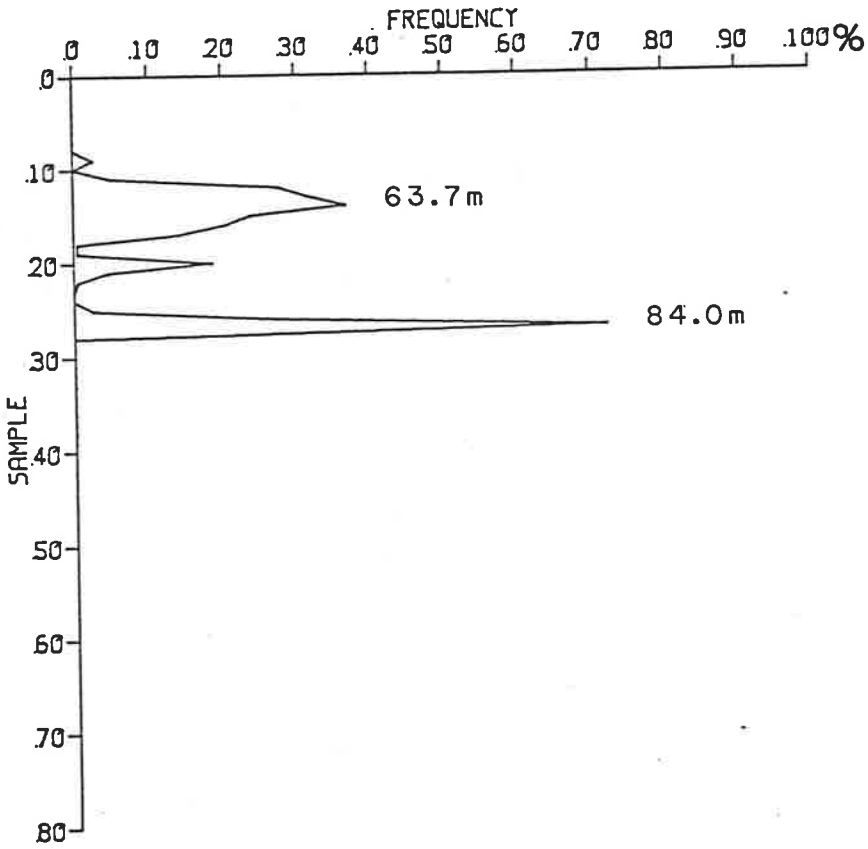
ERD 118 Dicot/Gymnosperm



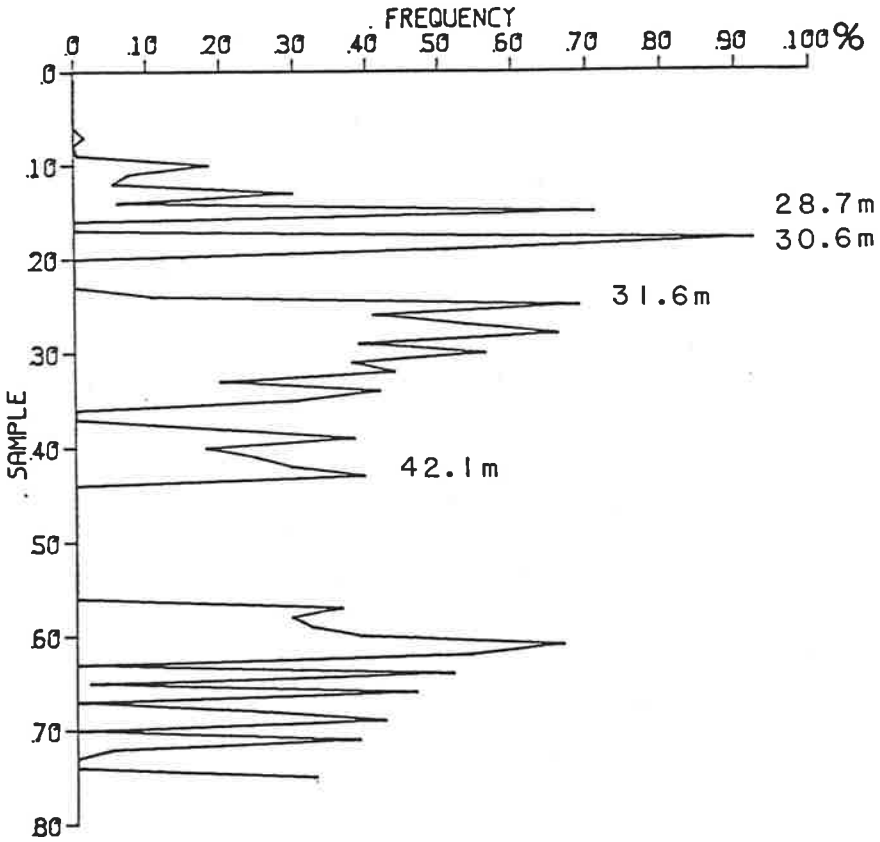
ERD 117 Dicot/Gymnosperm



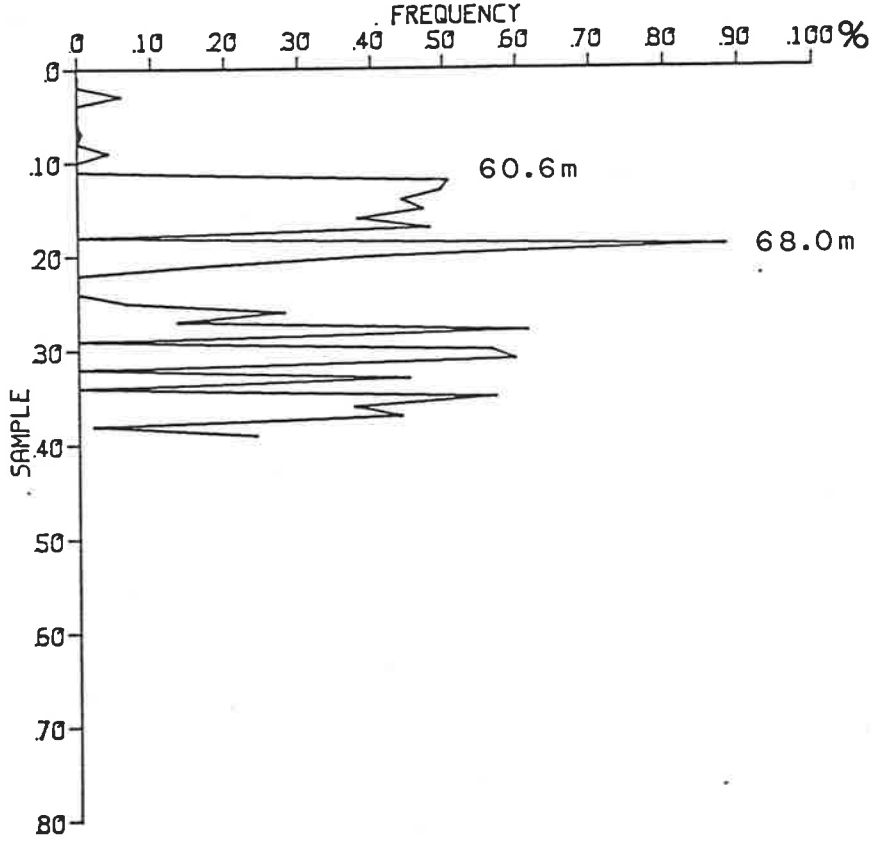
ERD 118 Monocot No.13



ERD 117 Monocot No.13



ERD 118 Monocot No.19

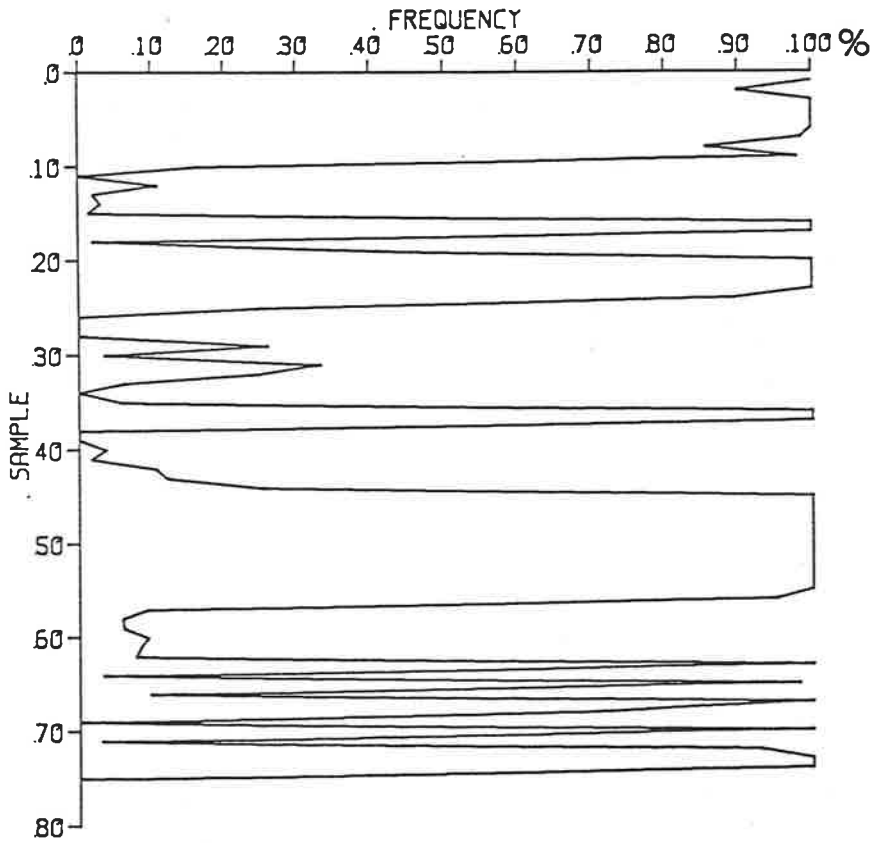


ERD 117 Monocot No.19

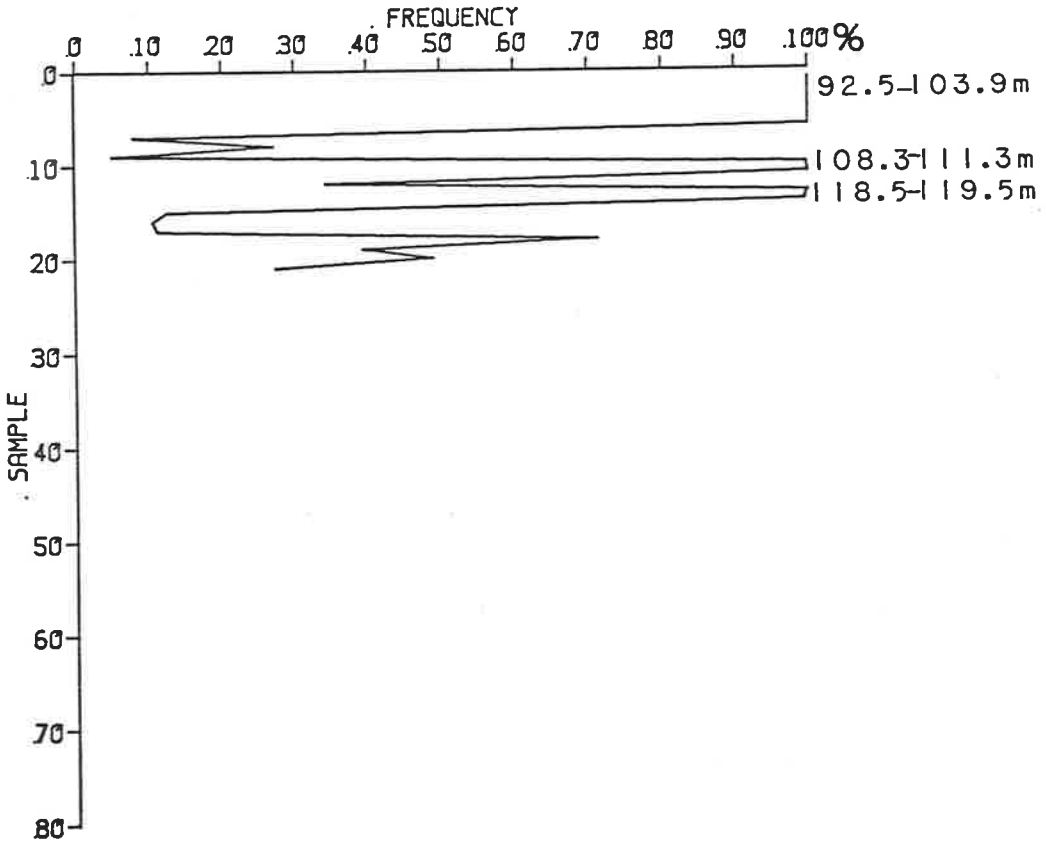
Figure 23: Comparison of the Dicot/gymnosperm Distribution Curves of ERD 118 and ERD 112.

Figure 24: Comparison of the Monocot No.13 Distribution Curves of ERD 118 and ERD 112.

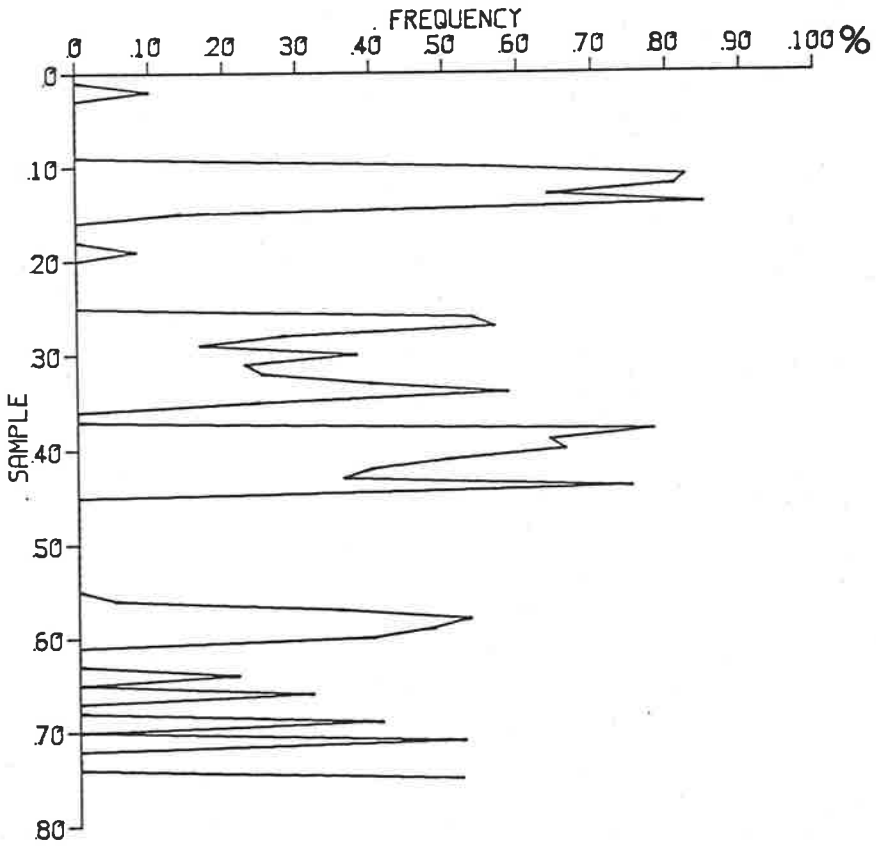
Figure 25: Comparison of the Monocot No.19 Distribution Curves of ERD 118 and ERD 112.



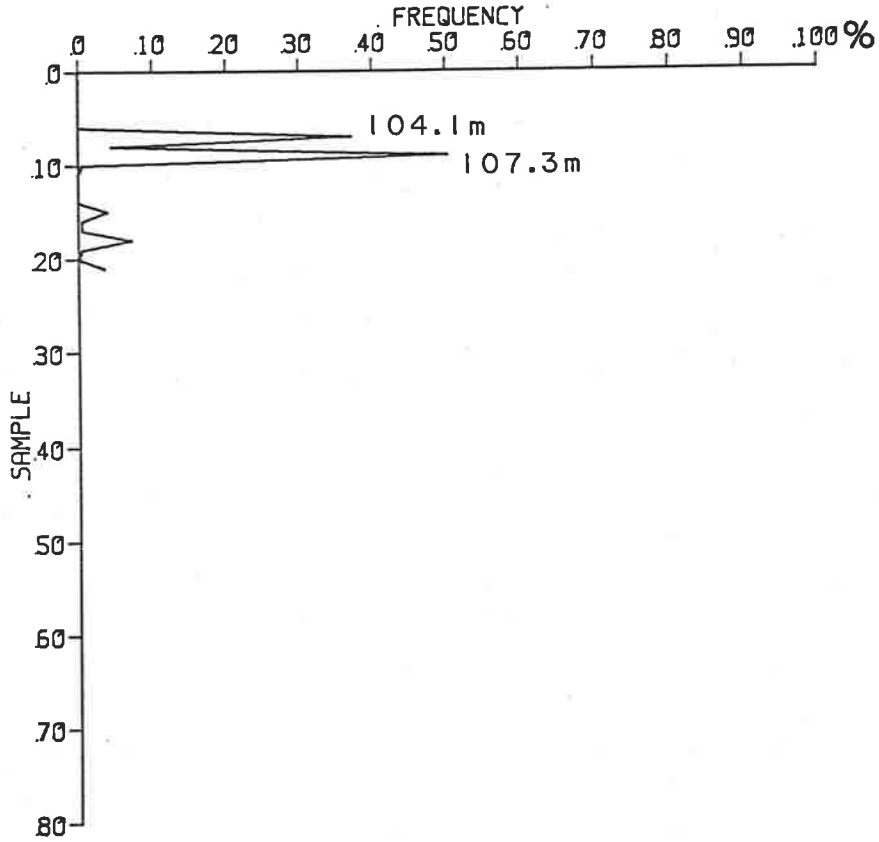
ERD 118 Dicot/Gymnosperm



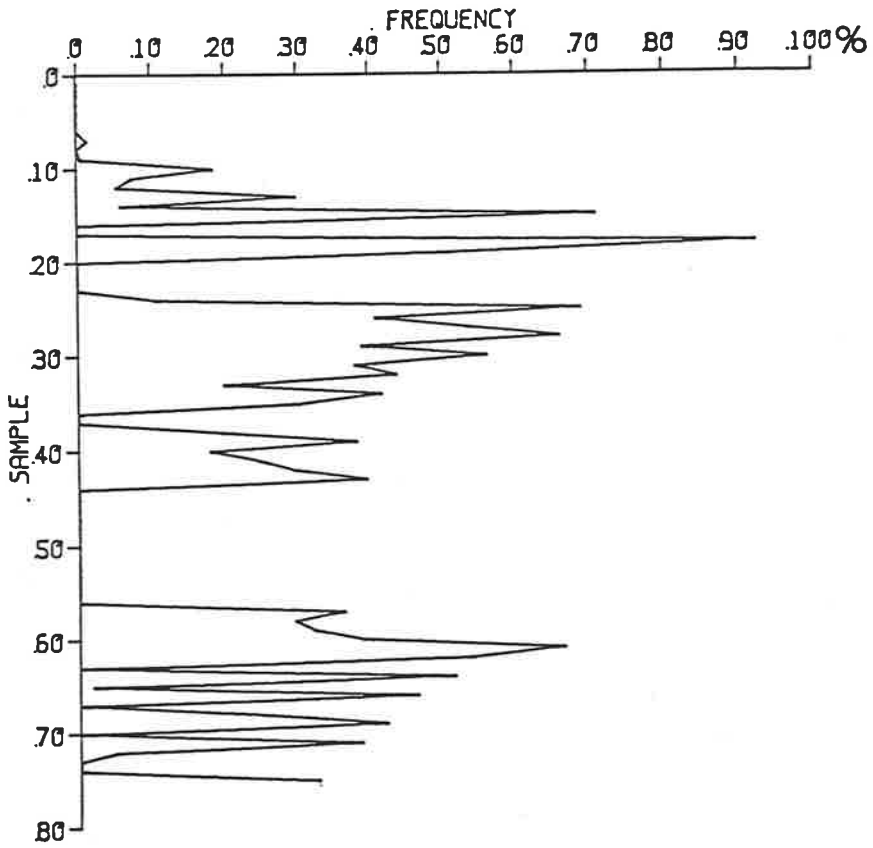
ERD 112 Dicot/Gymnosperm



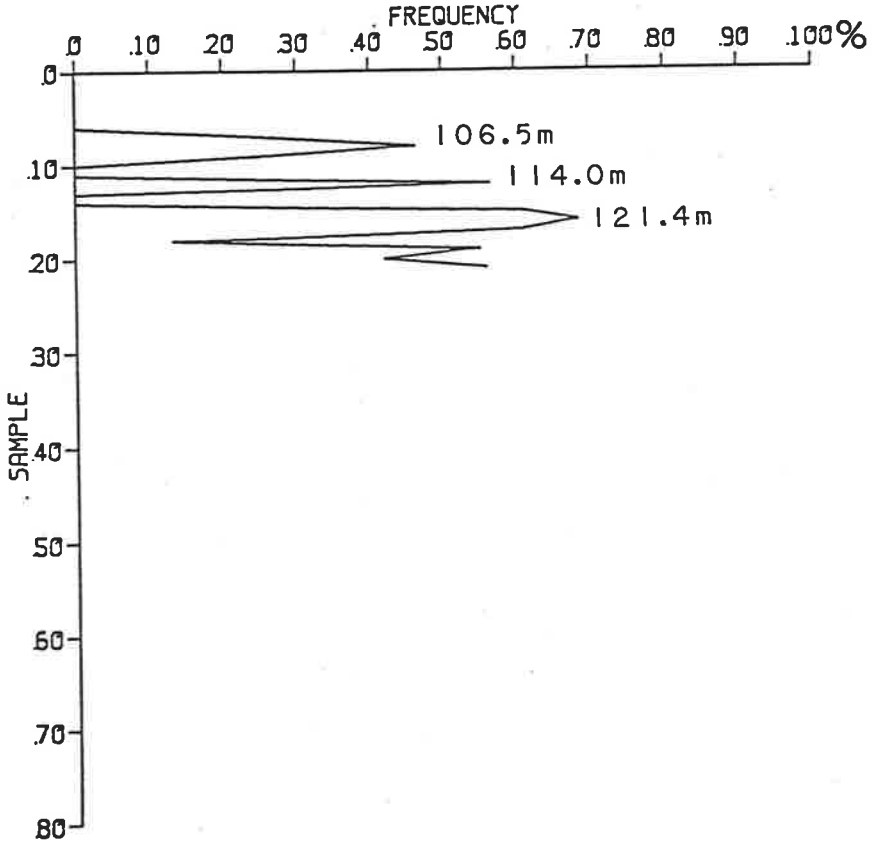
ERD 118 Monocot No.13



ERD 112 Monocot No.13



ERD 118 Monocot No.19



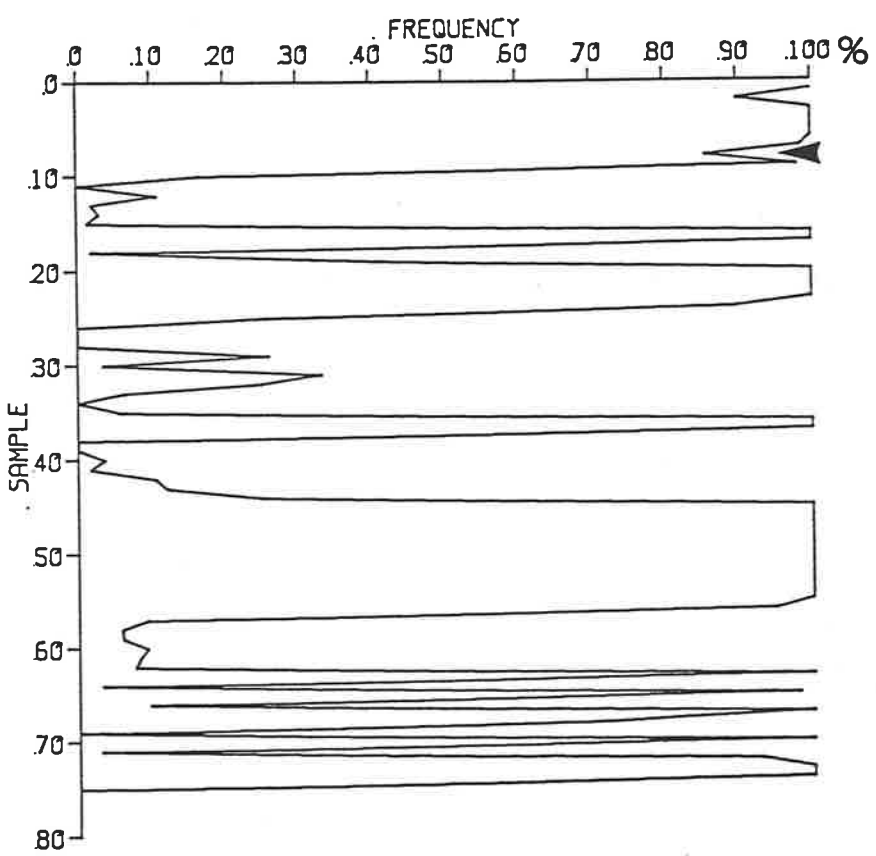
ERD 112 Monocot No.19

Figure 26: Comparison of the Dicot/gymnosperm Distribution Curves of ERD 118 and ERD 111.

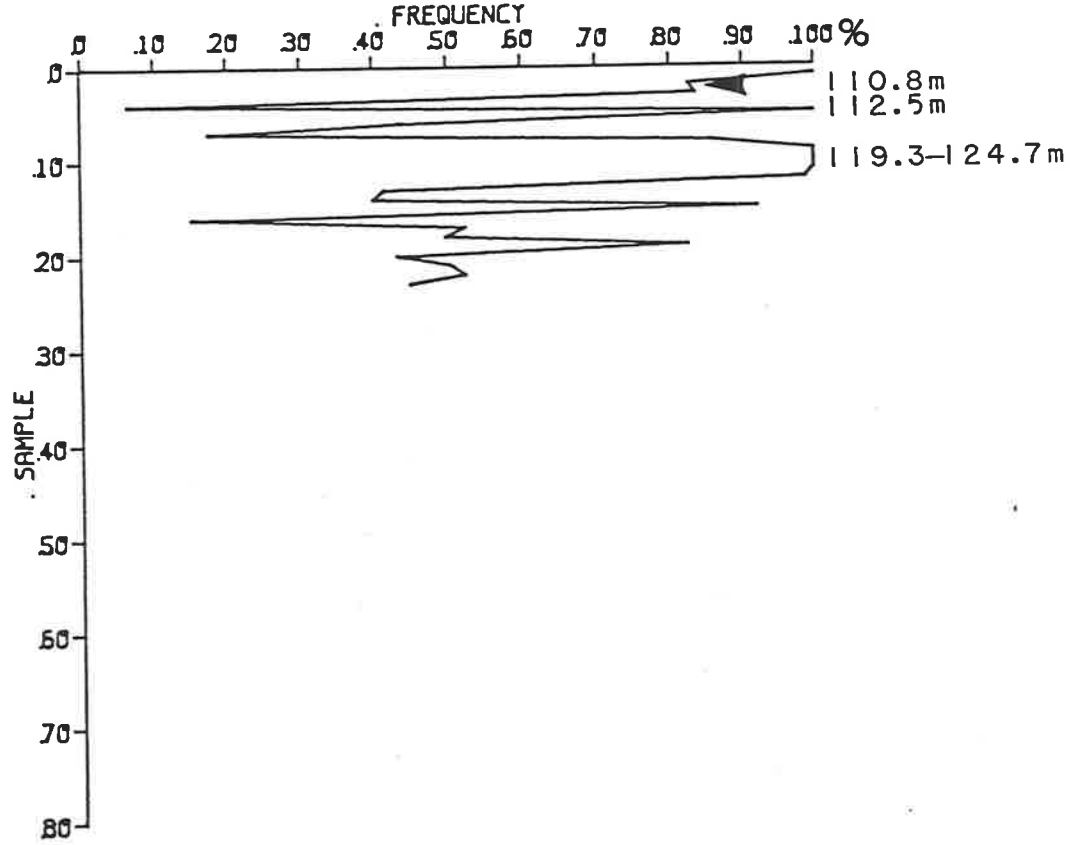
Figure 27: Comparison of the Monocot No.13 Distribution Curves of ERD 118 and ERD 111.

Figure 234: Comparison of the Monocot No.19 Distribution Curves of ERD 118 and ERD 111.

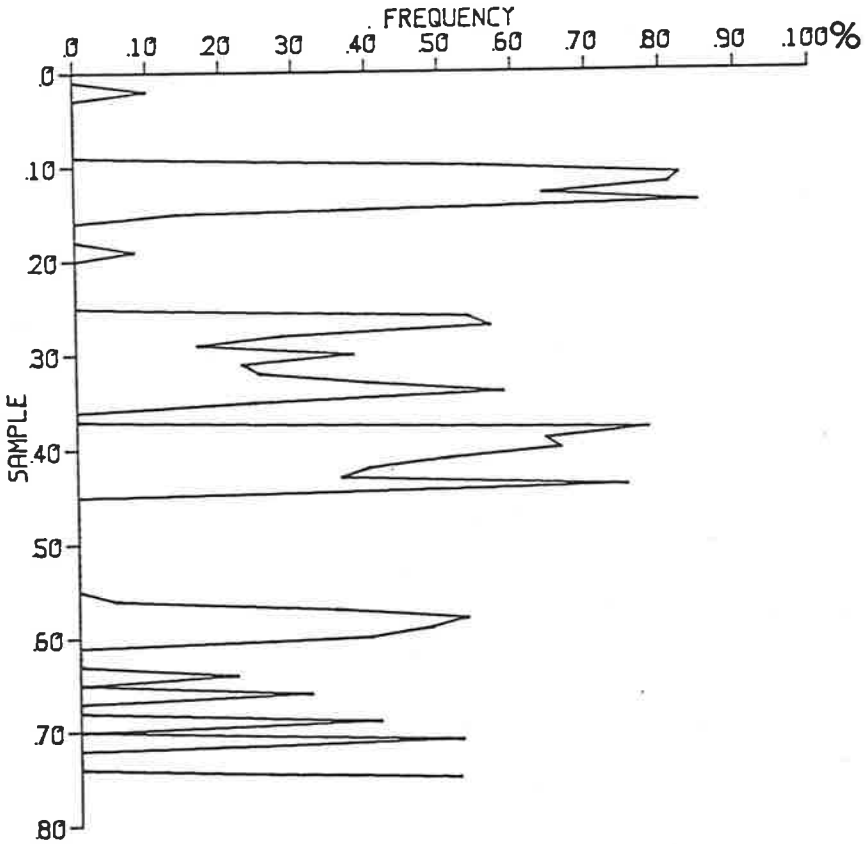
Note: Figures 28 - 233 refer to the Megafossil cuticle figures which occur immediately after these appendices.



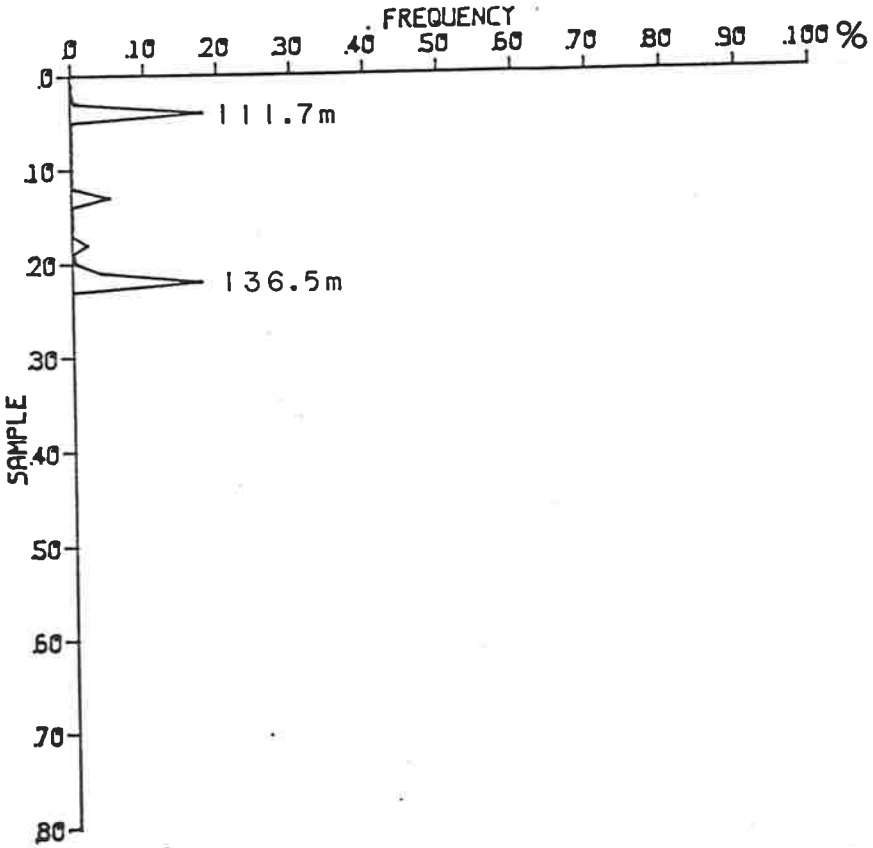
ERD 118 Dicot/Gymnosperm



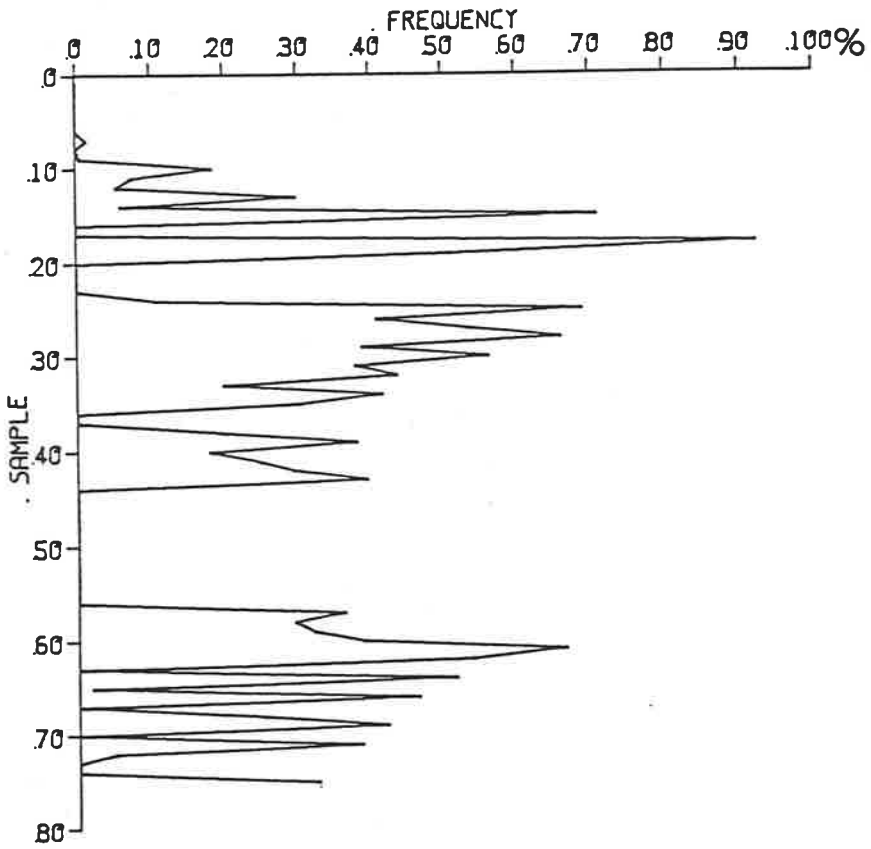
ERD 111 Dicot/Gymnosperm



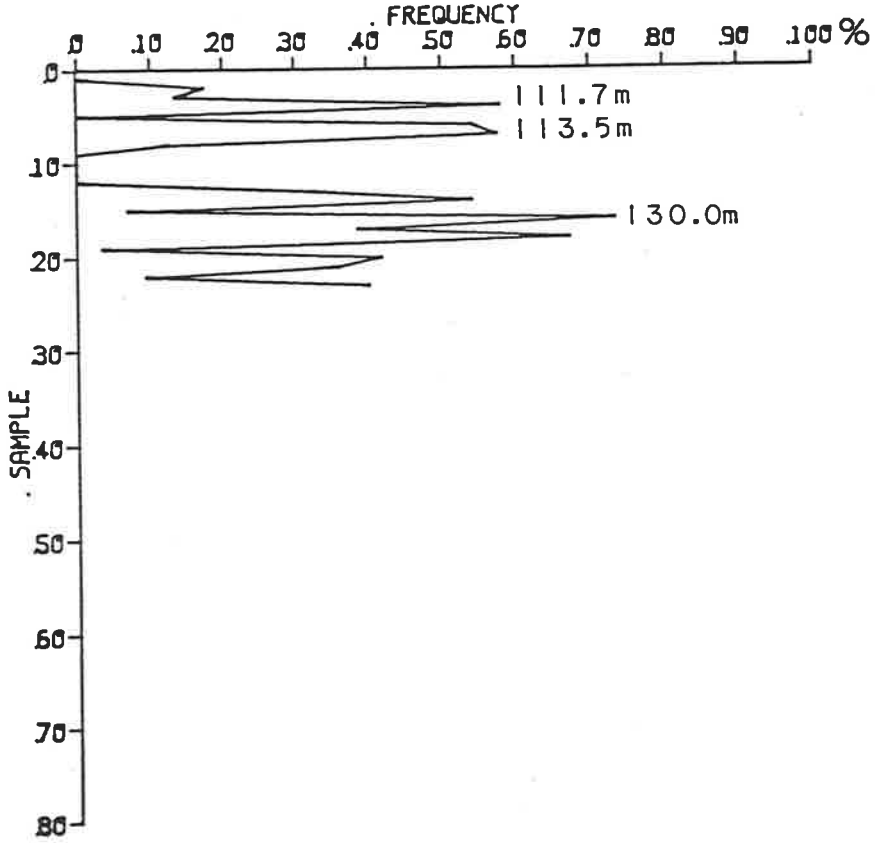
ERD 118 Monocot No.13



ERD 111 Monocot No.13



ERD 118 Monocot No.19

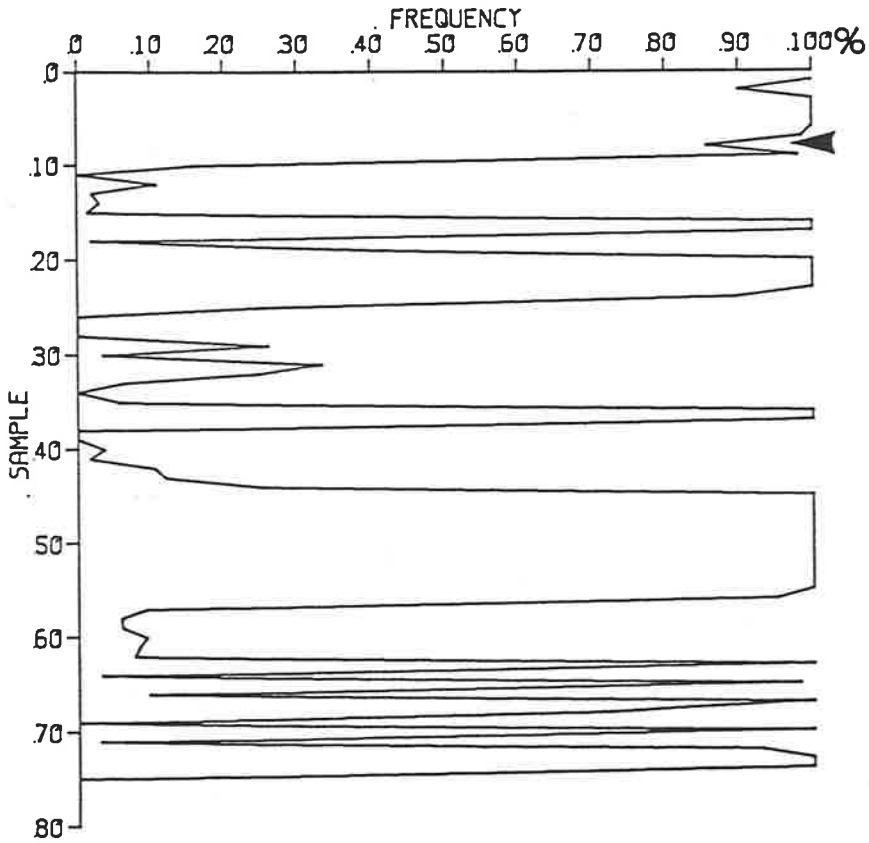


ERD 111 Monocot No.19

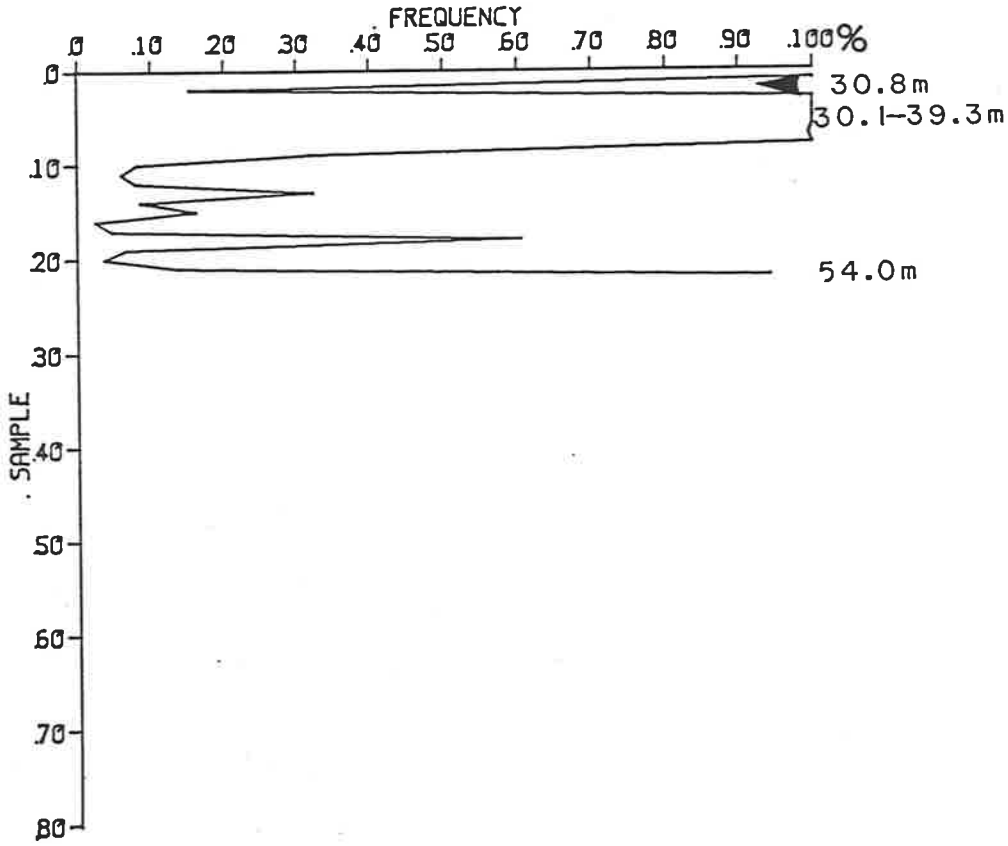
Figure 235: Comparison of the Dicot/gymnosperm Distribution Curves of ERD 118 and ERD 110.

Figure 236: Comparison of the Monocot No.13 Distribution Curves of ERD 118 and ERD 110.

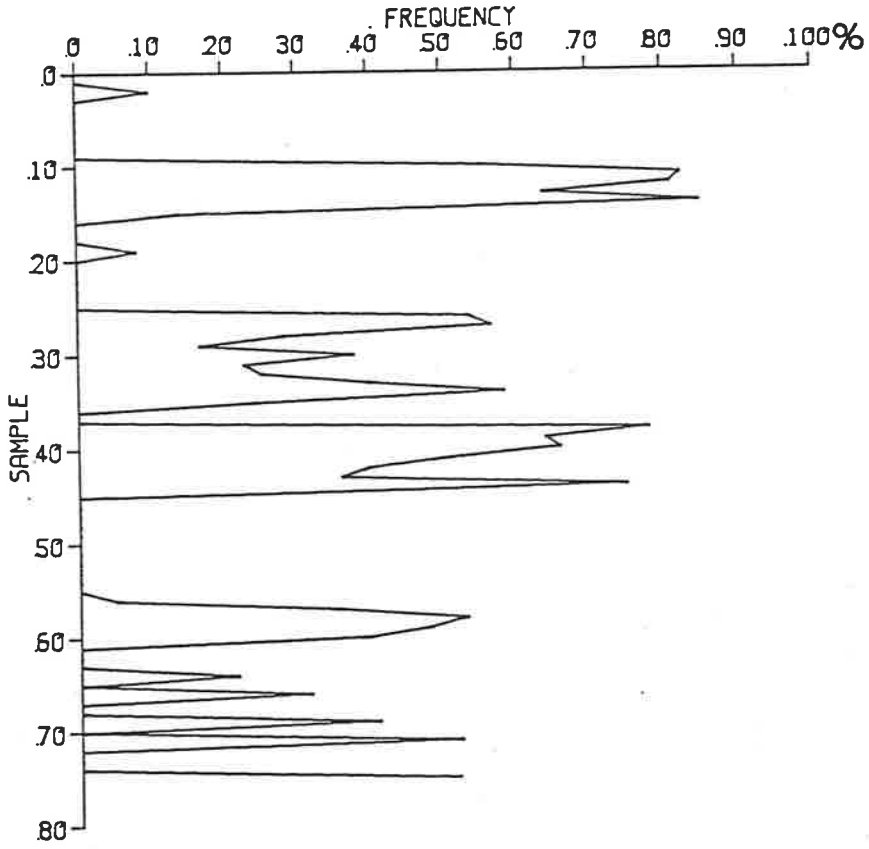
Figure 237: Comparison of the Monocot No.19 Distribution Curves of ERD 118 and ERD 110.



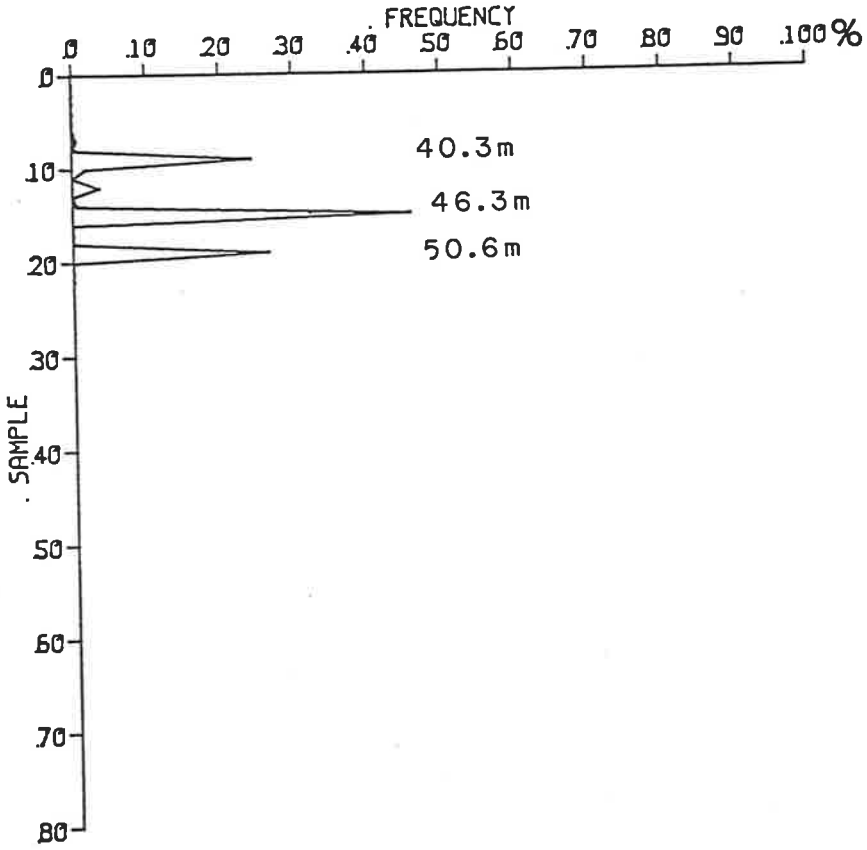
ERD 118 Dicot/Gymnosperm



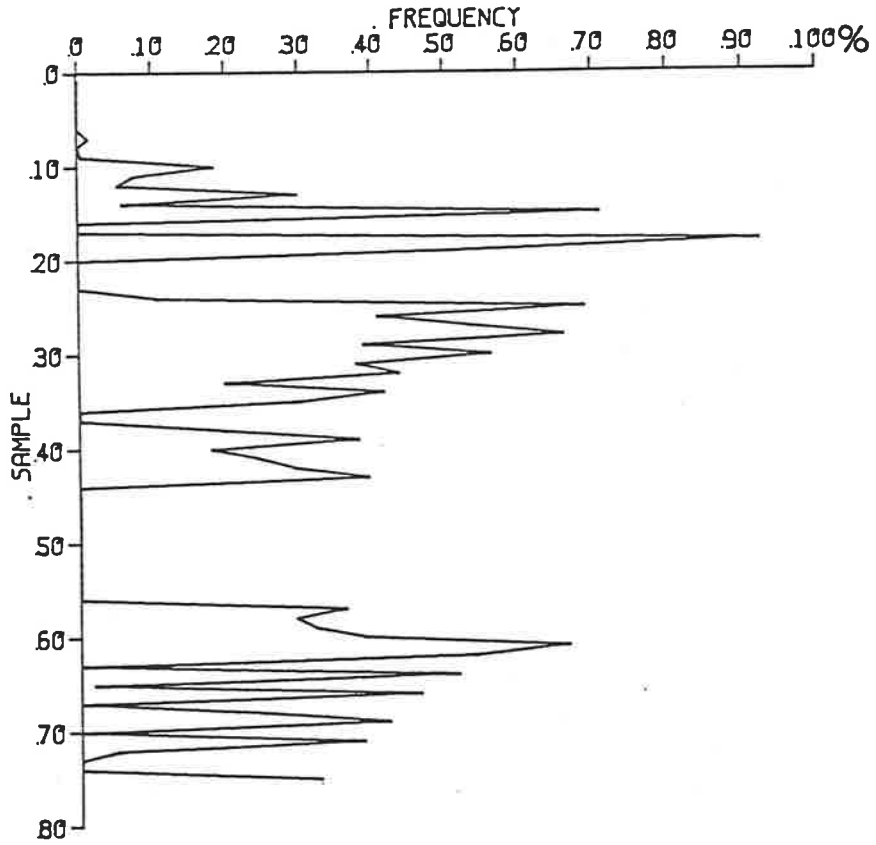
ERD 110 Dicot/Gymnosperm



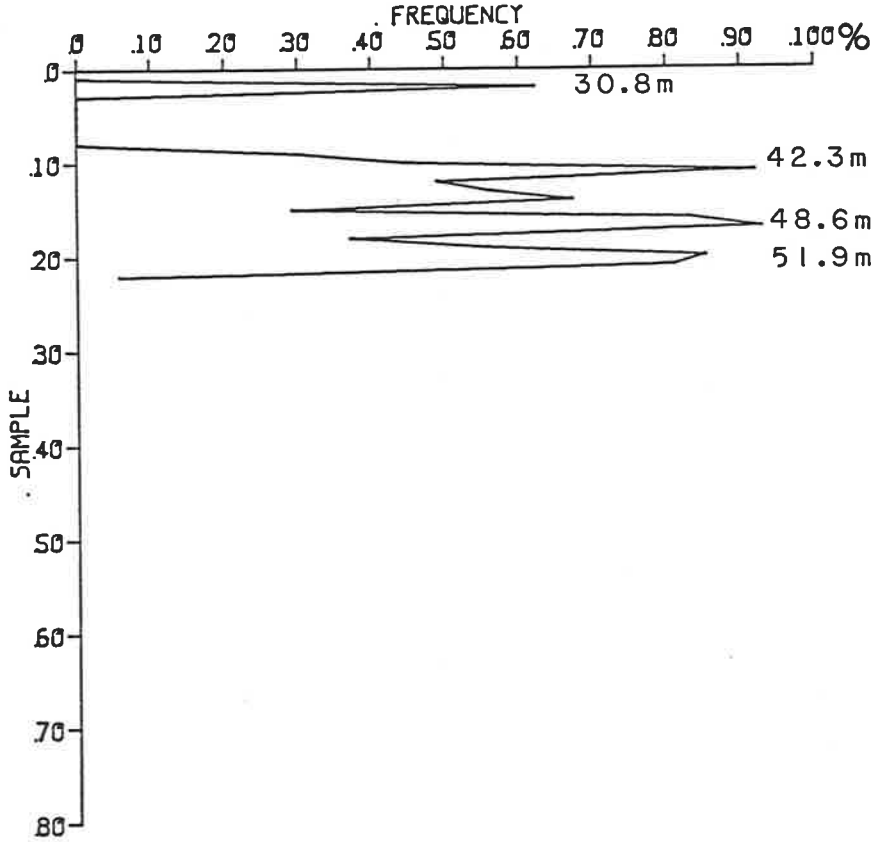
ERD 118 Monocot No.13



ERD 110 Monocot No.13



ERD 118 Monocot No.19



ERD 110 Monocot No.19

EXPLANATION OF MEGAFOSSIL FIGURES.

Most of the figures shown here are of either the dispersed cuticle parataxa recognised from the Curlew Formation or cuticles of species from related modern families. The best preserved fossil cuticles have been used to illustrate the Curlew parataxa which are not necessarily the type specimens. Many of these cuticles were mounted in association with other cuticles and therefore both the slide number and coordinates are included in the figure captions. The first three numbers of the Slide Number identify the core from which the cuticle was recovered. The depth at which the cuticle was recovered from the core is also listed. All cuticles have been photographed at a magnification of either 125X or 500X from a Zeiss research microscope (Bot. Res. No.10). The scale is defined on each Figure page.

The family affinity is also included in brackets after the slide coordinates. If the affinity is not known the term "Unknown" occurs in the brackets.

Figure 28: Parataxon No.1, Upper Epidermis. Slide No. 118-327, 100.2, 33.3. 40.3m. (Unknown)

Figure 29: Parataxon No.1, Lower Epidermis. Slide No. 118-327, 121.3, 36.0. 40.3m.

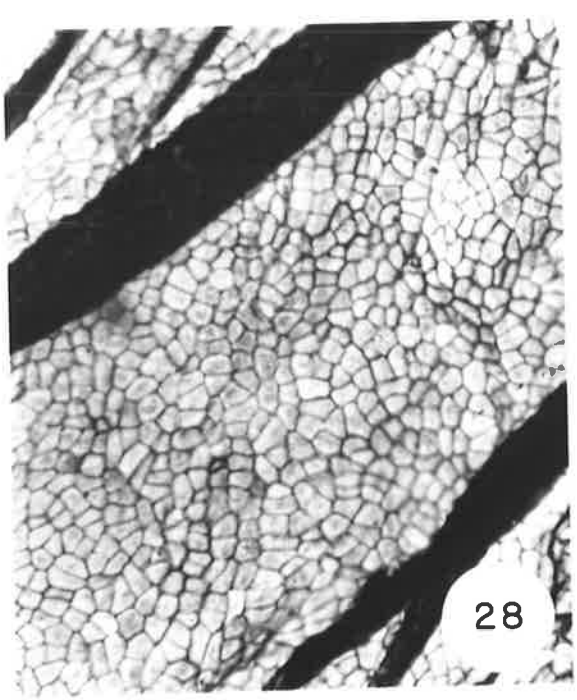
Figure 30: Parataxon No.2, Upper Epidermis. Slide No. 118-373, 90.0, 36.0. 58.0m. (Unknown)

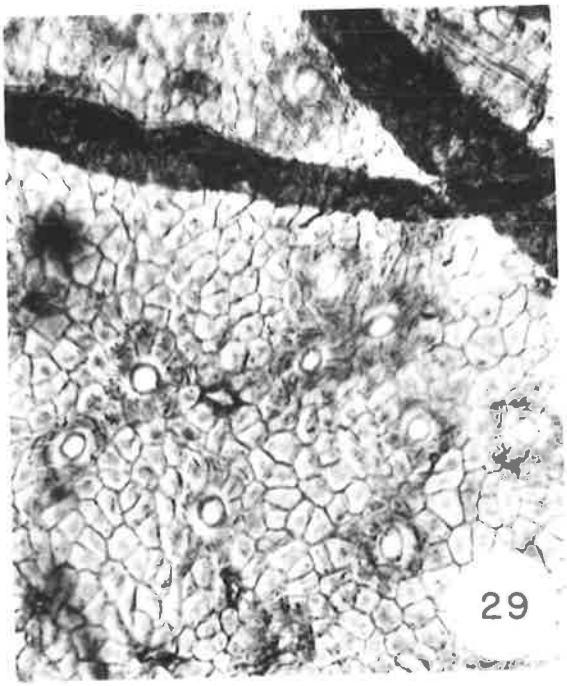
Figure 31: Parataxon No.2, Lower Epidermis. Slide No. 118-373, 95.0, 27.5. 58.0m.

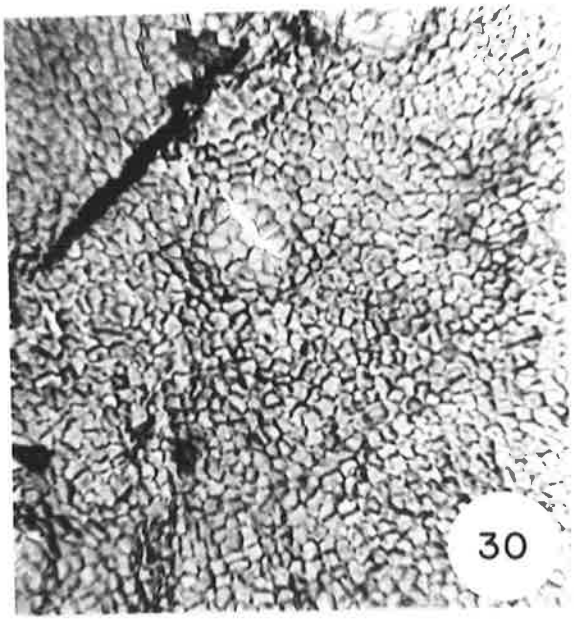
Figure 32: Parataxon No.3, Lower Epidermis. Slide No. 118-367, 106.2, 33.2. 56.5m. (Unknown)

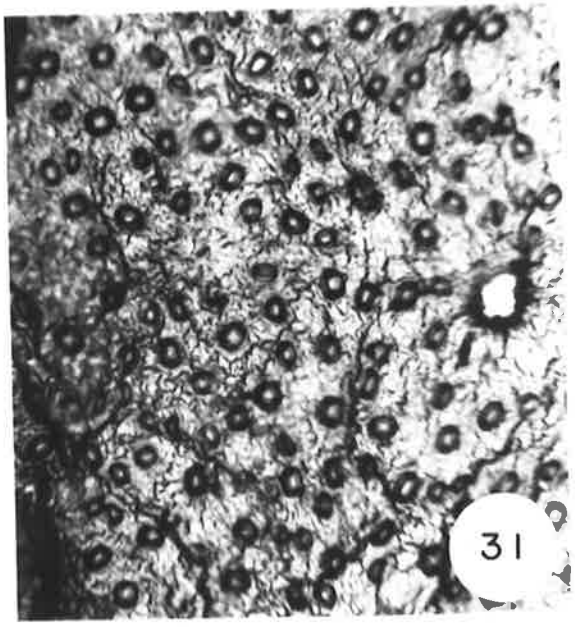
Figure 33: Parataxon No.4, Stomatiferous Surface. Slide No. 118-307, 92.0, 25.0. 31.0m. (Unknown)

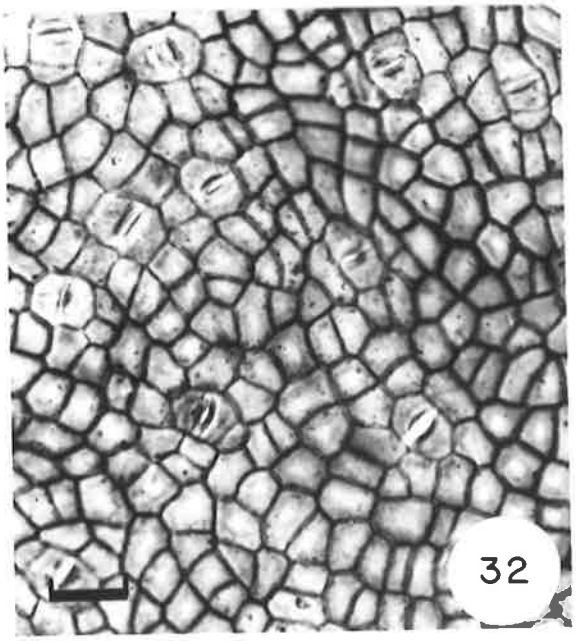
Scale Bar = 50um


28


29


30


31


32

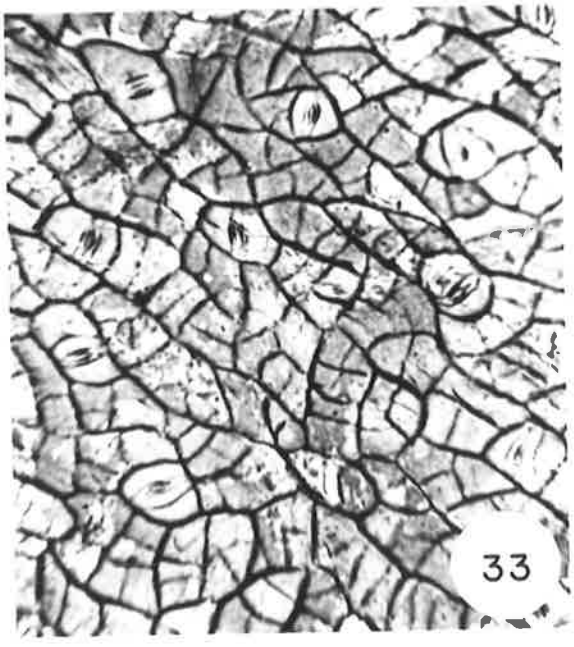

33

Figure 34: Parataxon No.5, Stomatiferous Surface. Slide No. 118-408, 99.0, 31.0. 69.8m. (Unknown)

Figure 35: Parataxon No.6, Upper Epidermis. Slide No. 118-338, 102.2, 32.2. 41.2m. (Unknown)

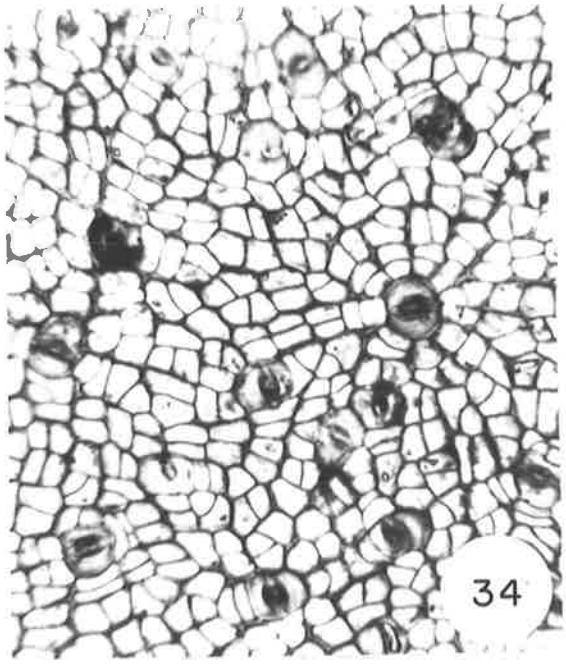
Figure 36: Parataxon No.6, Lower Epidermis. Slide No. 118-291, 100.8, 31.5. 29.0m.

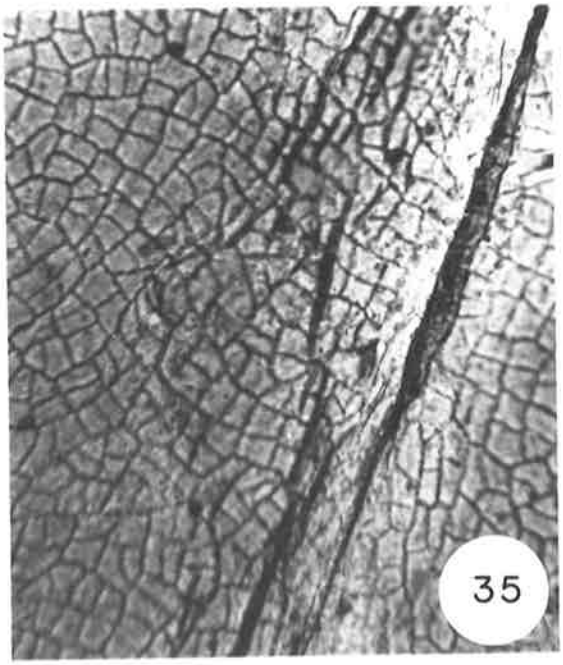
Figure 37: Parataxon No.7, Upper Epidermis. Slide No. 118-399, 82.9, 35.0. 75.0m. (Cyperaceae)

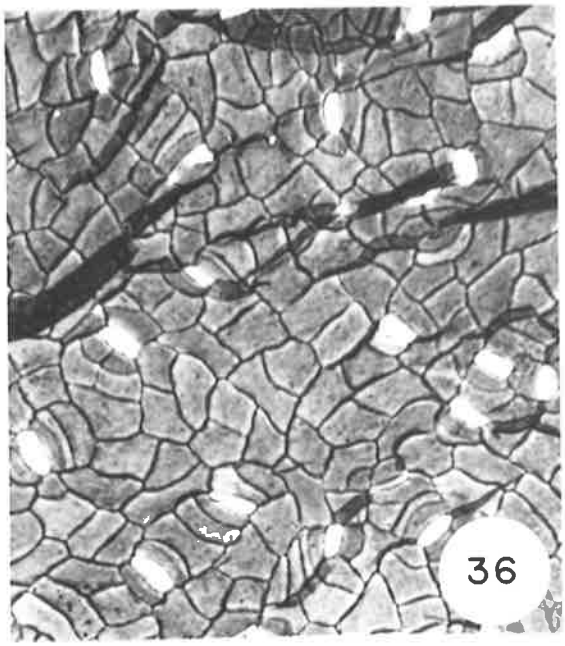
Figure 38: Parataxon No.7, Lower Epidermis. Slide No. 118-401, 96.0, 23.8. 75.0m.

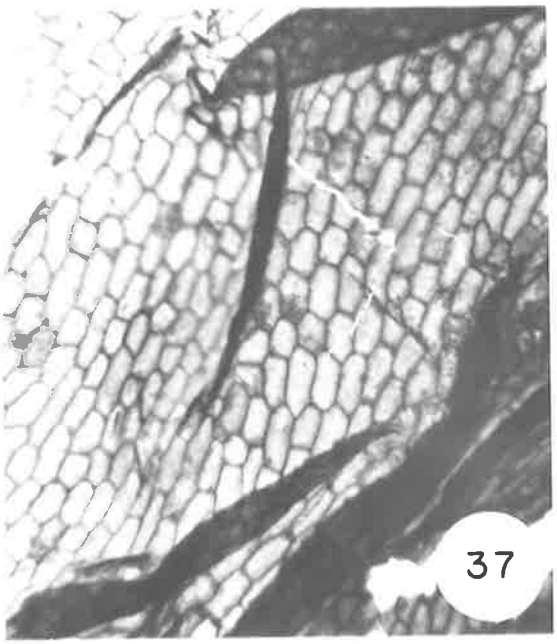
Figure 39: Parataxon No.8, Stomatiferous Surface. Slide No. 246-036, 104.0, 26.3. 37.3m. (Podocarpaceae)

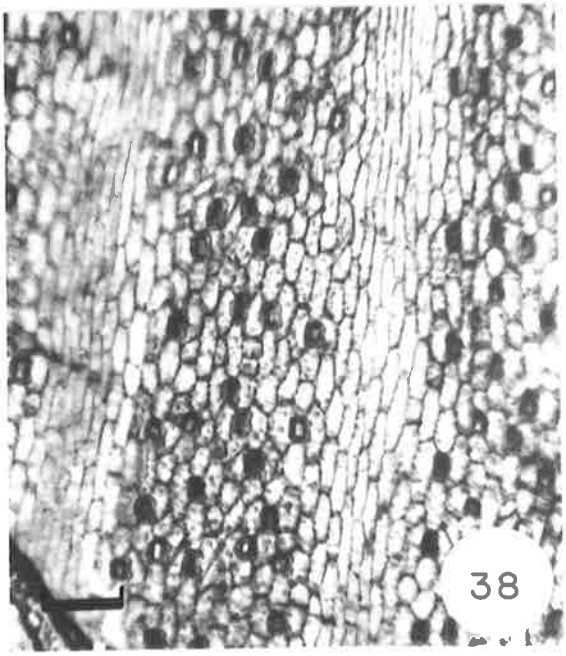
Scale Bar = 50um


34


35


36


37


38

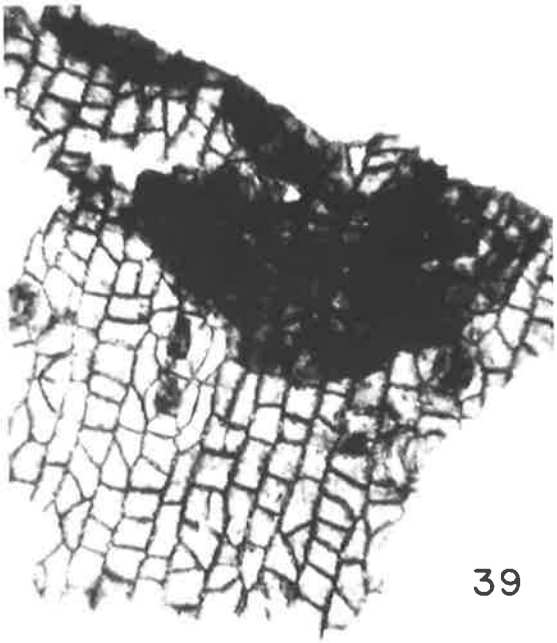

39

Figure 40: Parataxon No.9, Upper Epidermis. Slide No. 118-306,
85.1, 25.1. 31.0m. (Lauraceae)

Figure 41: Parataxon No.9, Lower Epidermis. Slide No. 118-306,
92.4, 31.0. 31.0m.

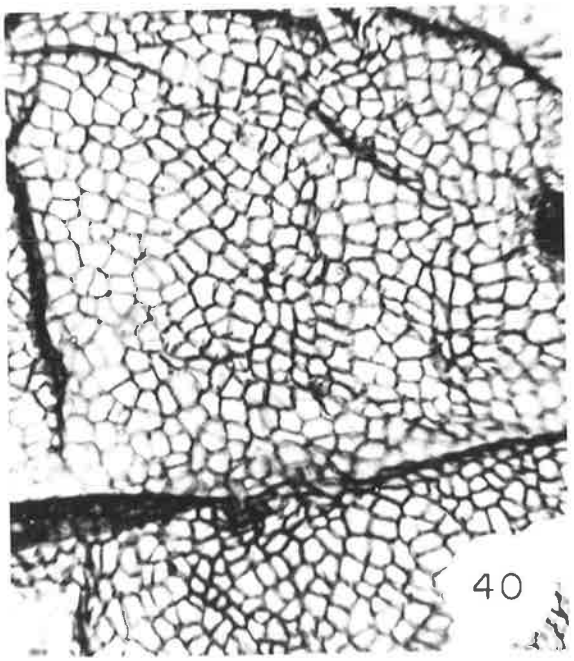
Figure 42: Parataxon No.10, Upper Epidermis. Slide No. 118-385,
88.3, 41,3. 61.0m. (Lauraceae)

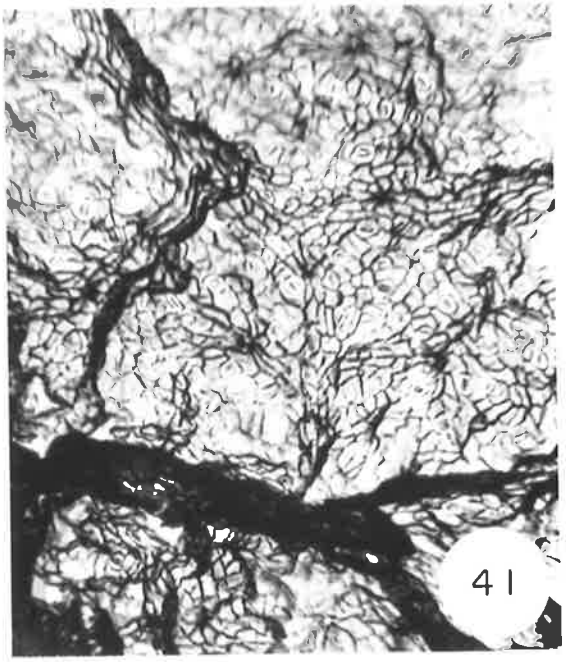
Figure 43: Parataxon No.10, Lower Epidermis. Slide No. 118-352,
85.7, 30.0. 50.9m.

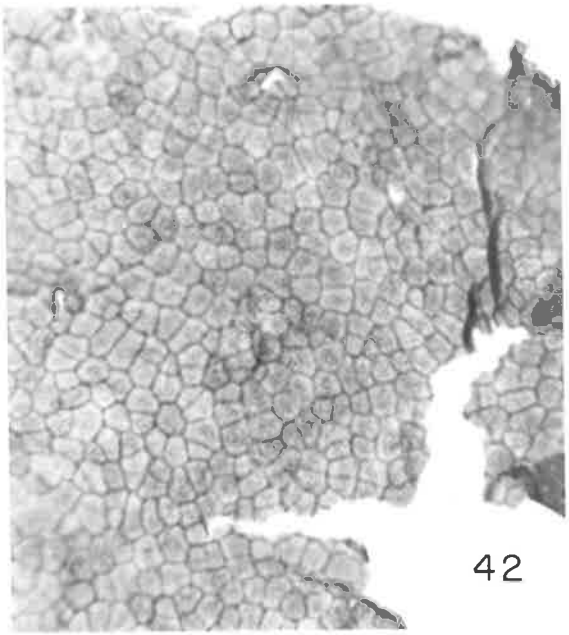
Figure 44: Parataxon No.11, Upper Epidermis. Slide No. 118-266,
99.8, 29.2. 27.5m. (Scale Bar = 12.5um) (Proteaceae)

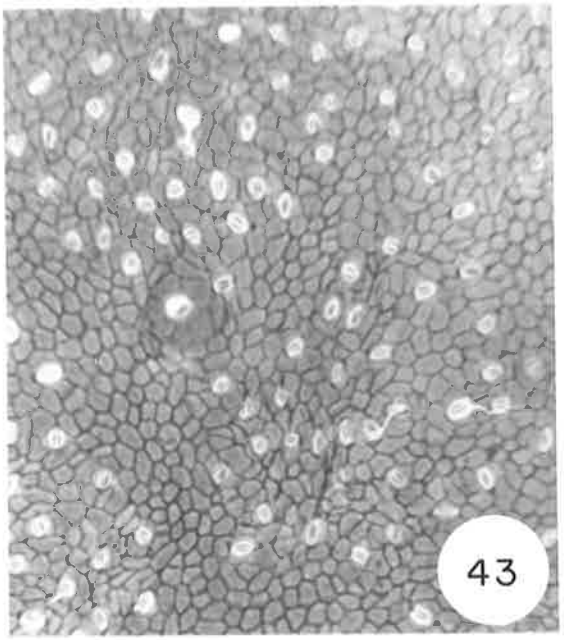
Figure 45: Parataxon No.11, Lower Epidermis. Slide No. 118-265,
97.6, 29.1. 27.5m.

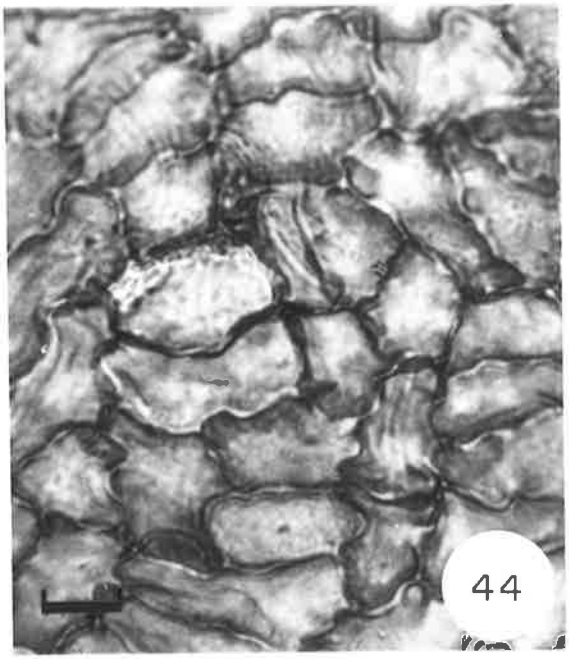
Scale Bar = 50um


40


41


42


43


44

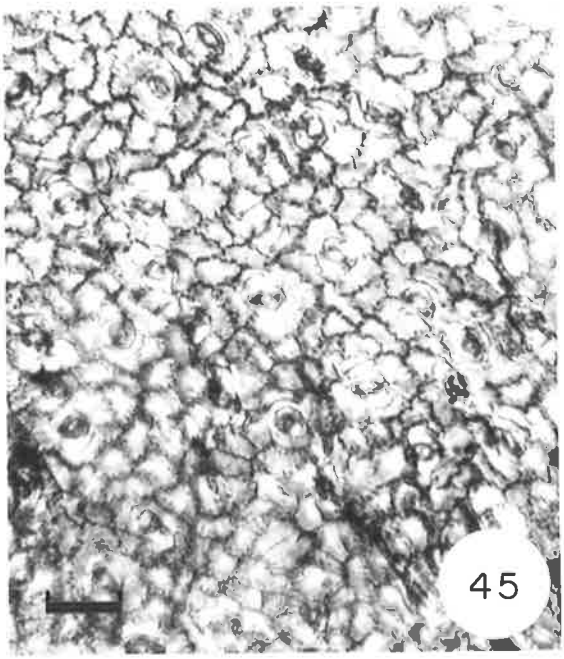

45

Figure 46: Parataxon No.12, Upper Epidermis. Slide No. 118-351, 104.0, 26.4. 50.9m. (Proteaceae)

Figure 47: Parataxon No.12, Lower Epidermis. Slide No. 118-368, 107.5, 27.4. 56.7m.

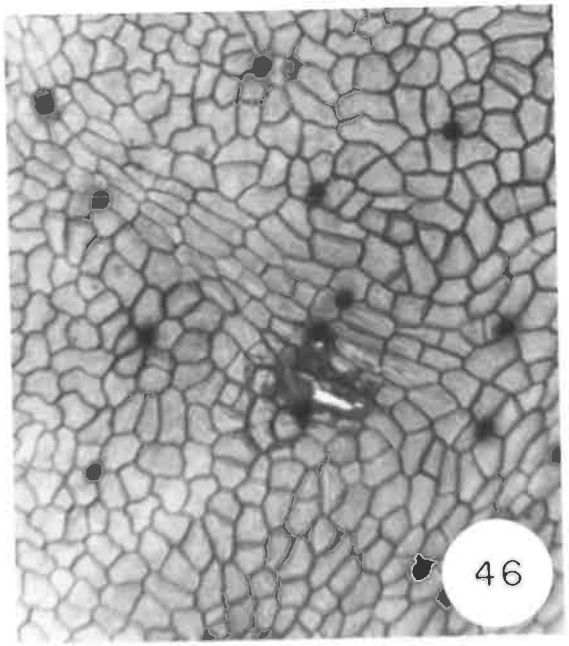
Figure 48: Parataxon No.13, Non-stomatiferous Cuticle. Slide No. 246-006. 37.3m. (Monocotyledonae)

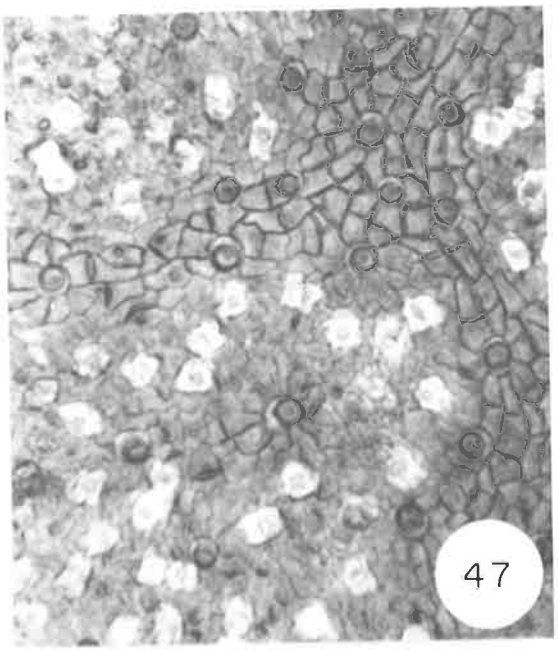
Figure 49: Parataxon No.14, Upper Epidermis. Slide No. 118-379, 94.3, 35.0. 60.3m. (Lauraceae)

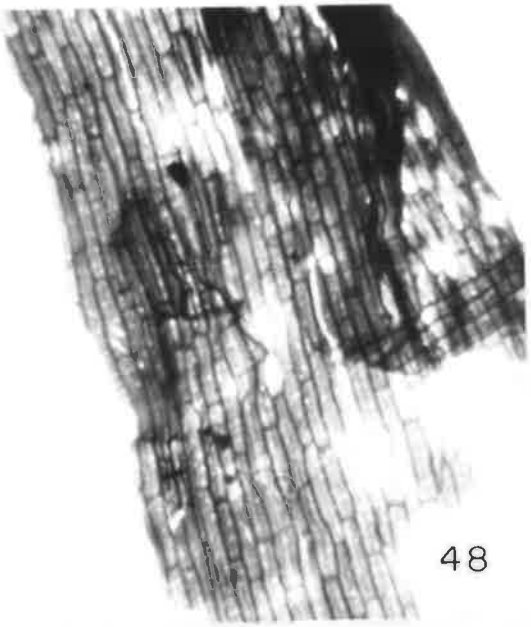
Figure 50: Parataxon No.14, Lower Epidermis. Slide No. 118-295, 88.0, 32.5. 30.7m.

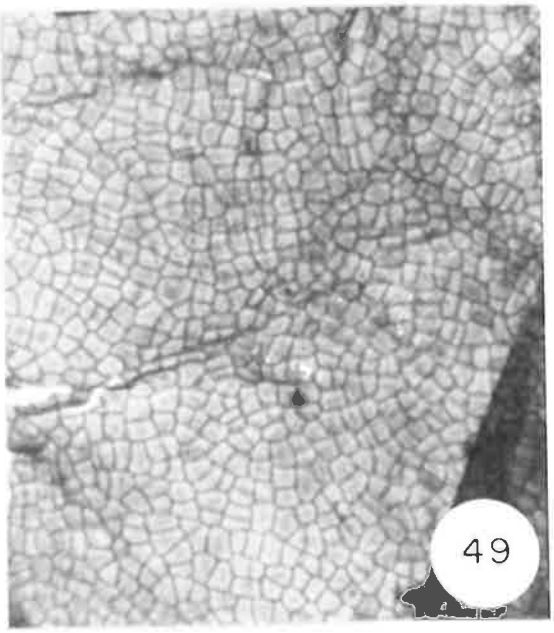
Figure 51: Parataxon No.15, Upper Epidermis. Slide No. 118-407, 107.2, 26.8. 73.6m. (Lauraceae)

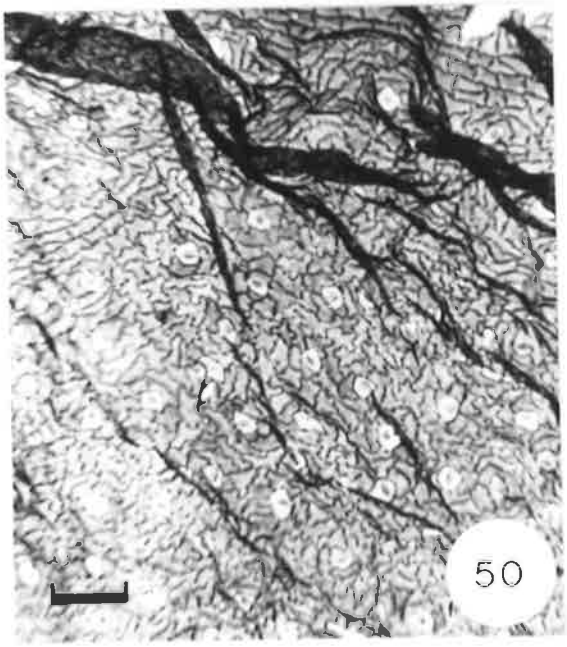
Scale Bar = 50um


46


47


48


49


50

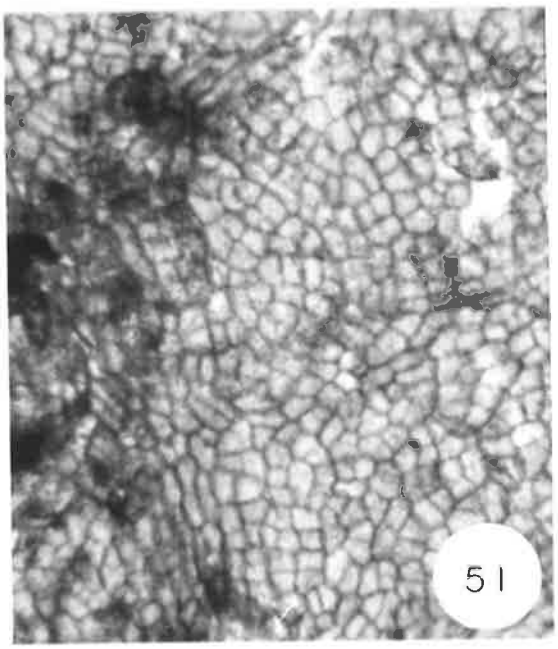

51

Figure 52: Parataxon No.15, Lower Epidermis. Slide No. 118-407, 83.6, 23.8. 73.6m. (Lauraceae)

Figure 53: Parataxon No.16, Upper Epidermis. Slide No. 118-369, 113.0, 29.3. 56.7m. (Lauraceae)

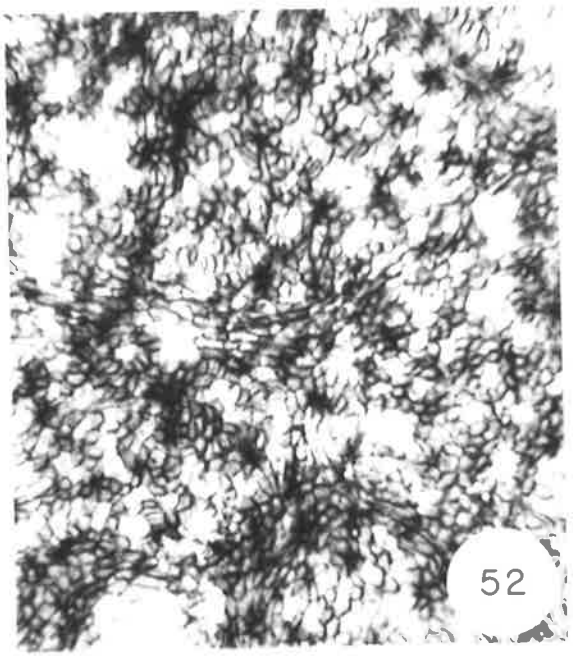
Figure 54: Parataxon No.16, Lower Epidermis. Slide No. 118-369, 111.2, 29.3. 56.7m.

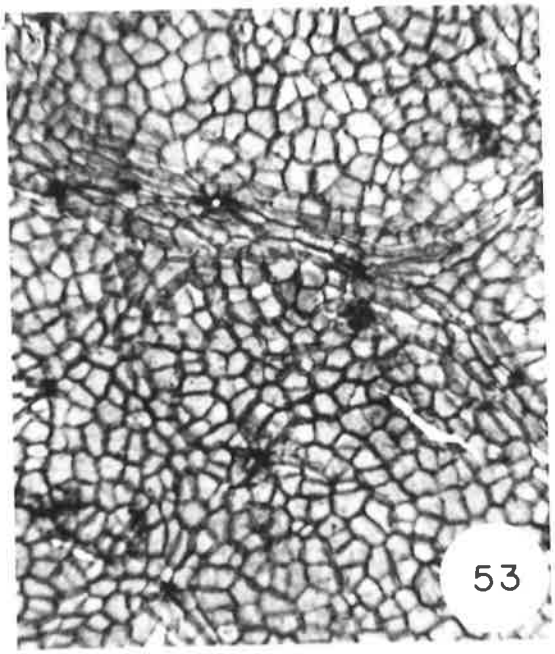
Figure 55: Parataxon No.17, Stomatiferous Surface. Slide No. 118-270, 104.1, 35.0. 27.5m. (Scale Bar = 12.5um) (Unknown)

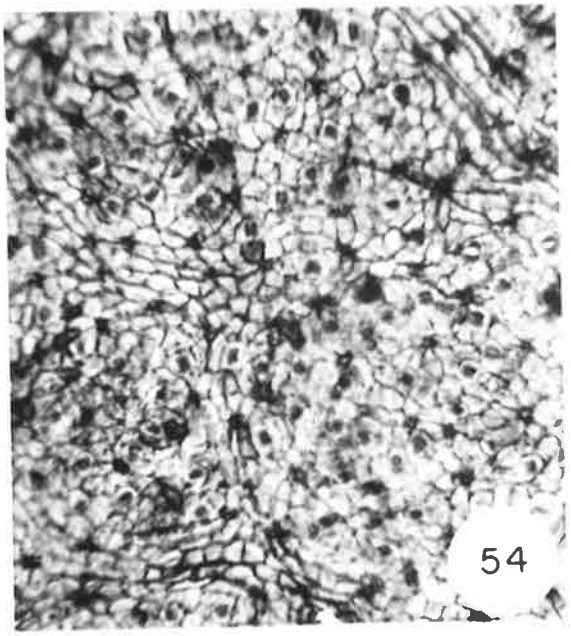
Figure 56: Parataxon No.18, Stomatiferous Surface. Slide No. 118-214, 97.7, 36.0. 26.0m. (Lauraceae)

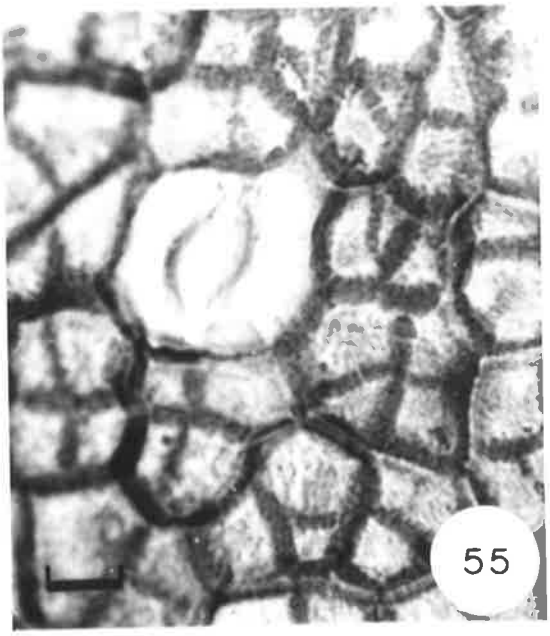
Figure 57: Parataxon No.19, Stomatiferous Surface. Slide No. 118-273, 96.0, 34.7. 28.2m. (Monocotyledonae)

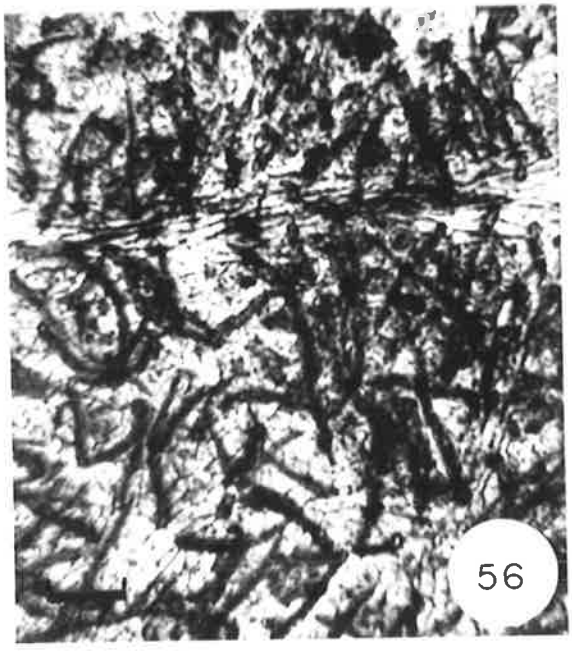
Scale Bar = 50um


52


53


54


55


56

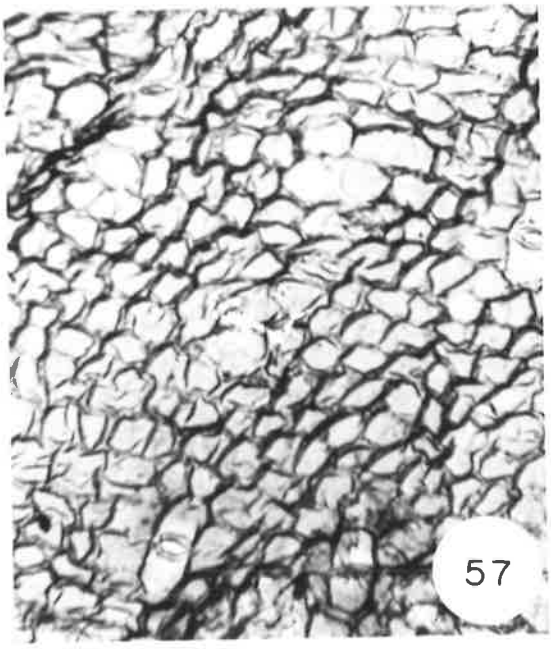

57

Figure 58: Parataxon No.20, Stomatiferous Surface. Slide No. 118-272, 96.5, 32.5. 27.5m. (Monocotyledonae)

Figure 59: Parataxon No.21, Stomatiferous Surface. Slide No. 118-280, 102.0, 19.9. 27.7m. (Monocotyledonae?)

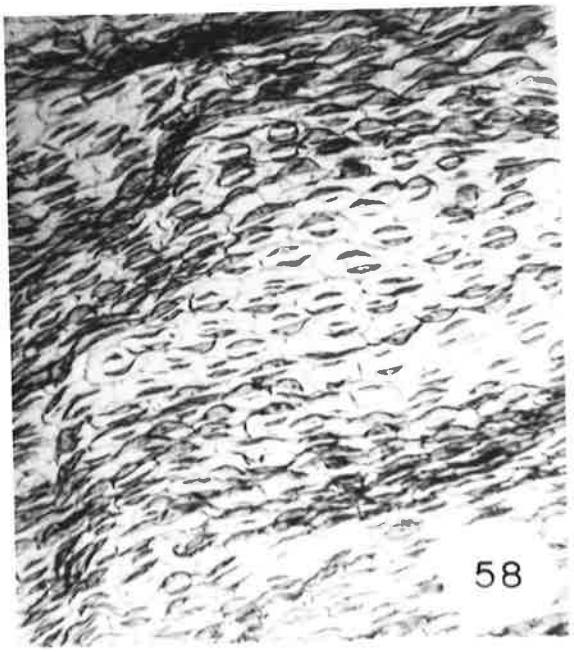
Figure 60: Parataxon No.22, Featureless Cuticular Surface. Slide No. 118-336, 95.0, 26.2. 41.0m. (Unknown)

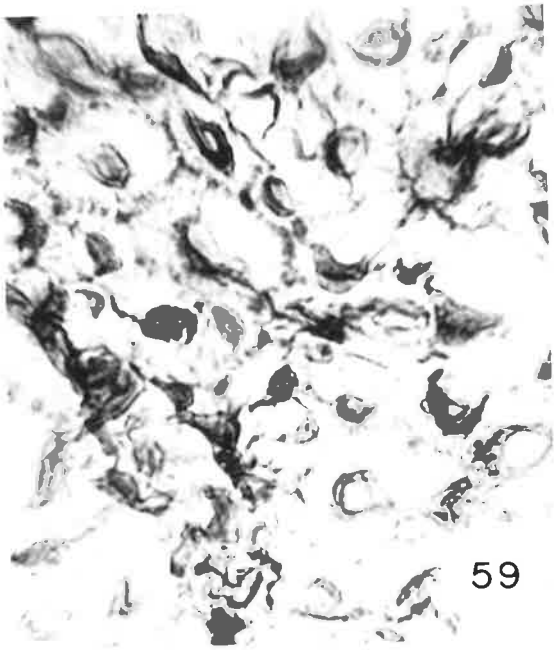
Figure 61: Parataxon No.23, Upper Epidermis. Slide No. 118-415. 75.8m. (Zamiaceae)

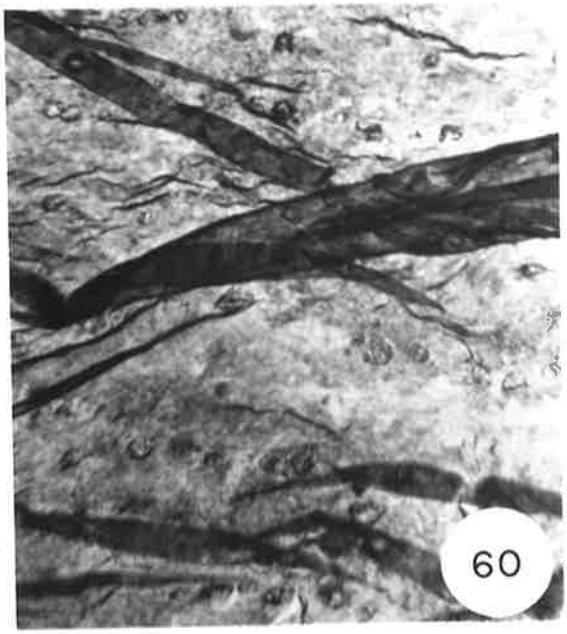
Figure 62: Parataxon No.23, Lower Epidermis. Slide No. 118-415. 75.8m.

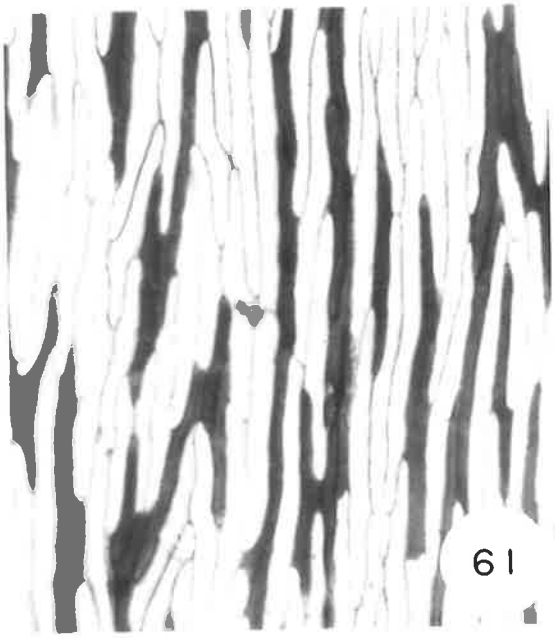
Figure 63: Parataxon No.17, Stomatiferous Surface. Slide No. 118-297, 87.0, 21.9. 30.7m.

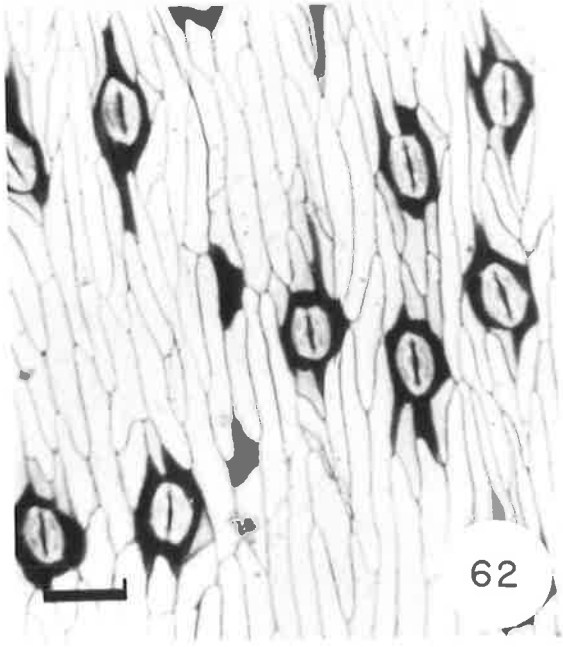
Scale Bar = 50um


58


59


60


61


62

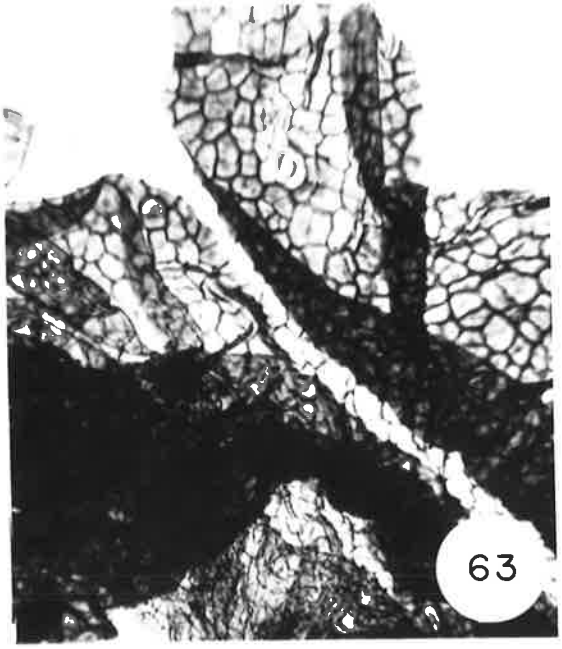

63

Figure 64: Parataxon No.24, Non-stomatiferous Surface.
Slide No. 118-370, 97.4, 37.6. 58.0m. (Unknown)

Figure 65: Parataxon No.25, Stomatiferous Surface. Slide No. 118-310,
93.5, 34.7. 31.0m. (Ebenaceae)

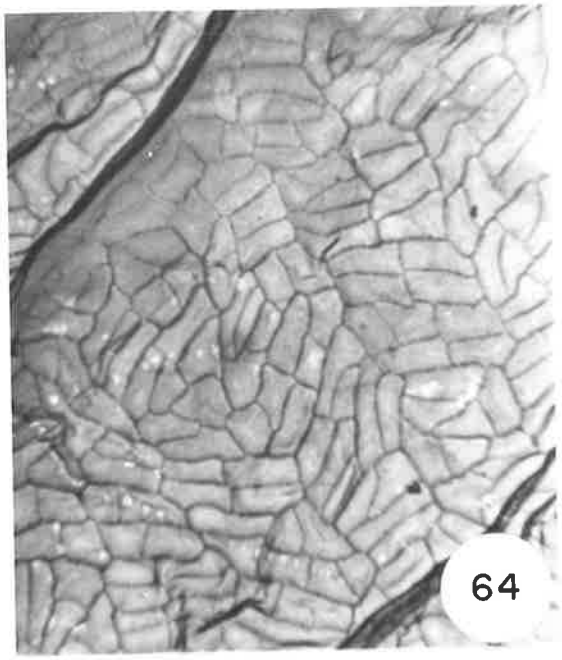
Figure 66: Parataxon No.26, Mesophyll ?. Slide No. 118-325. 37.0m.
(Unknown)

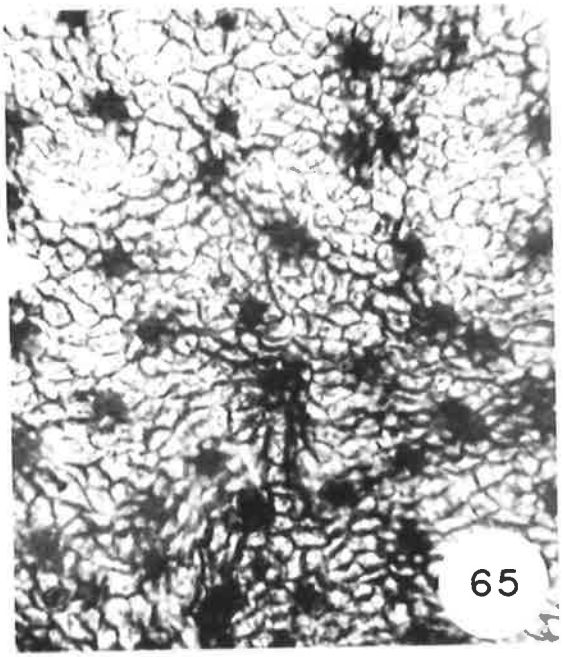
Figure 67: Parataxon No.27, Stomatiferous Surface. Slide No. 118-248,
89.9, 35.9. 27.0m. (Unknown)

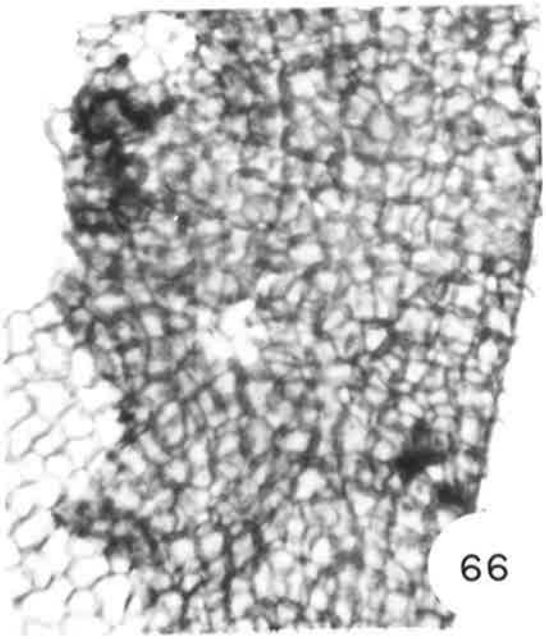
Figure 68: Parataxon No.28, Upper Epidermis. Slide No. 118-332,
92.3, 30.6. 40.3m. (Unknown)

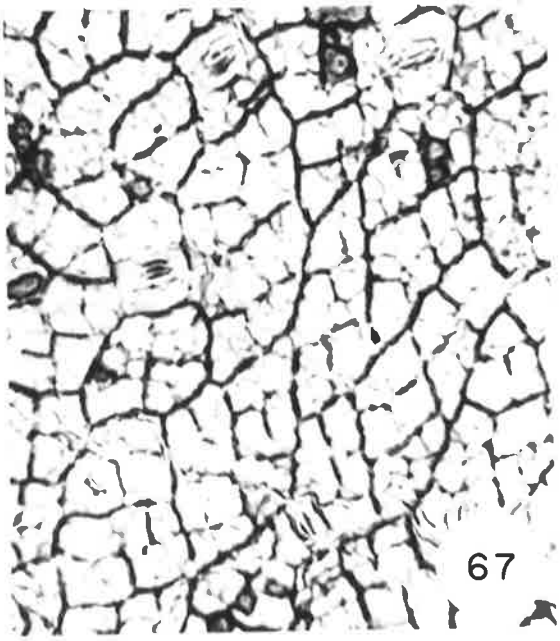
Figure 69: Parataxon No.28, Lower Epidermis. Slide No. 118-384,
116.4, 34.4. 61.0m.

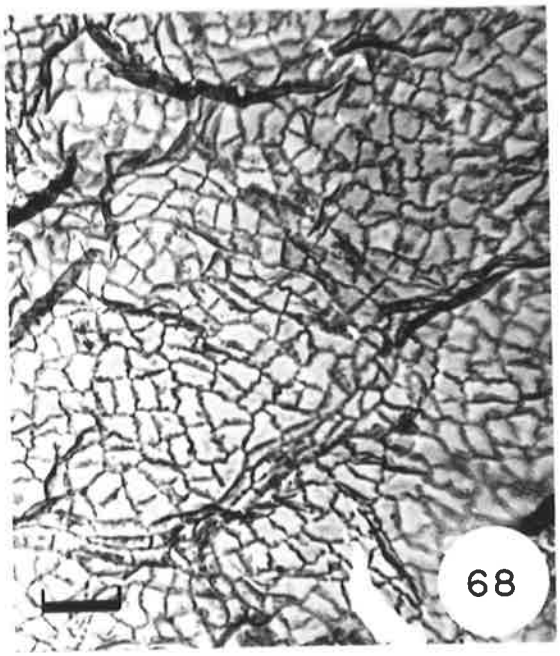
Scale Bar = 50um


64


65


66


67


68

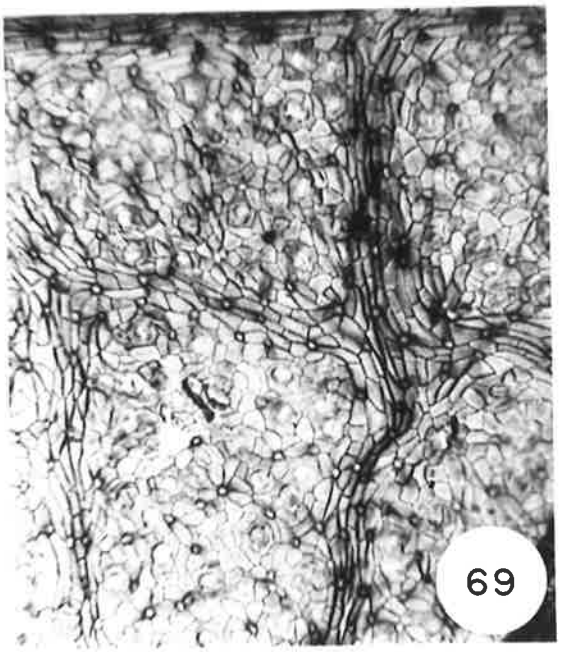

69

Figure 70: Parataxon No.29, Stomatiferous Surface. Slide No. 118-294, 92.2, 22.0. 30.7m. (Lauraceae)

Figure 71: Parataxon No.30, Non-stomatiferous Surface. Slide No. 118-324, 102.8, 39.7. 36.5m. (Unknown)

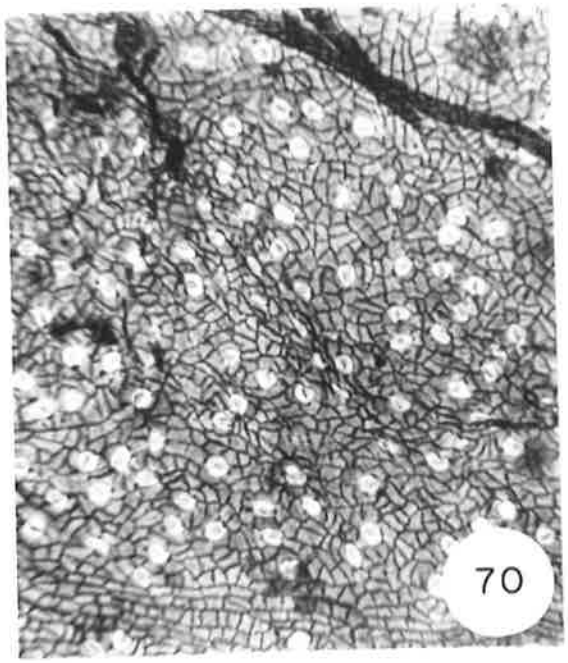
Figure 72: Parataxon No.31, Stomatiferous Cuticle. Slide No. 117-029, 108.7, 40.3. 47.2m. (Casuarinaceae)

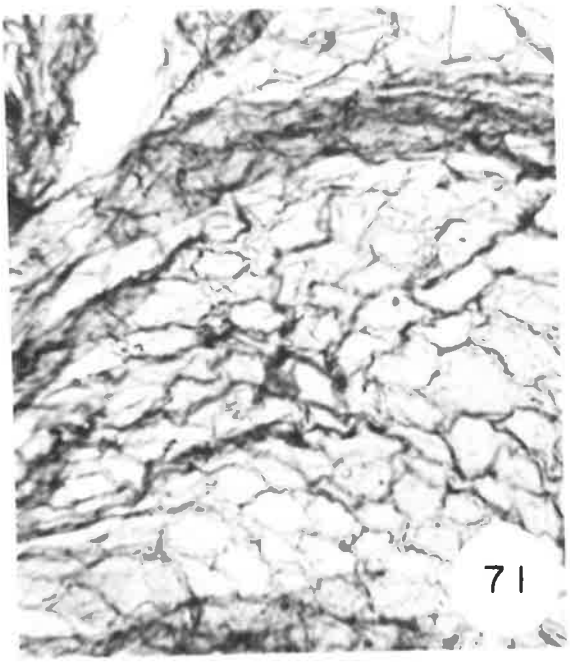
Figure 73: Parataxon No.32, Petiole Cuticle ?. Slide No. 118-401, 104.2, 34.2. 75.0m. (Unknown)

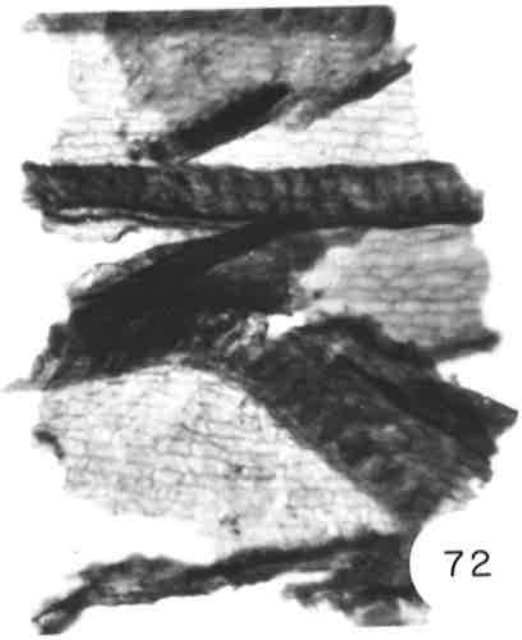
Figure 74: Parataxon No.33, Petiole Cuticle ?. Slide No. 118-358, 103.0, 29.4. 55.0m. (Unknown)

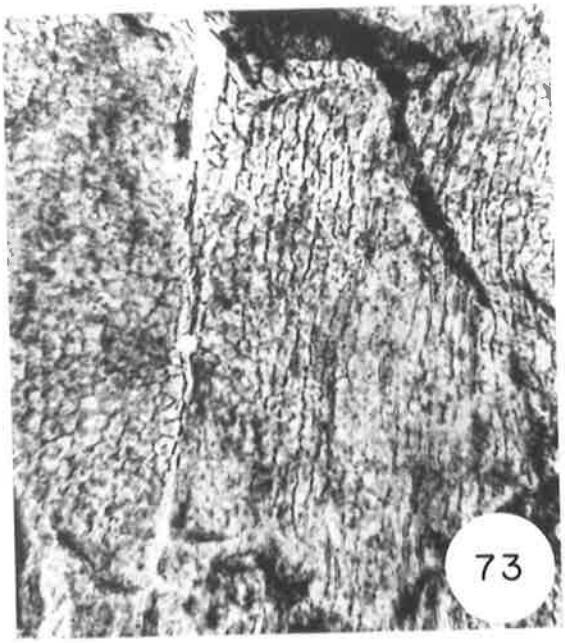
Figure 75: Parataxon No.34, Non-stomatiferous Surface. Slide No. 118-245, 104.0, 36.3. 27.3m. (Scale Bar = 12.5um). (Unknown)

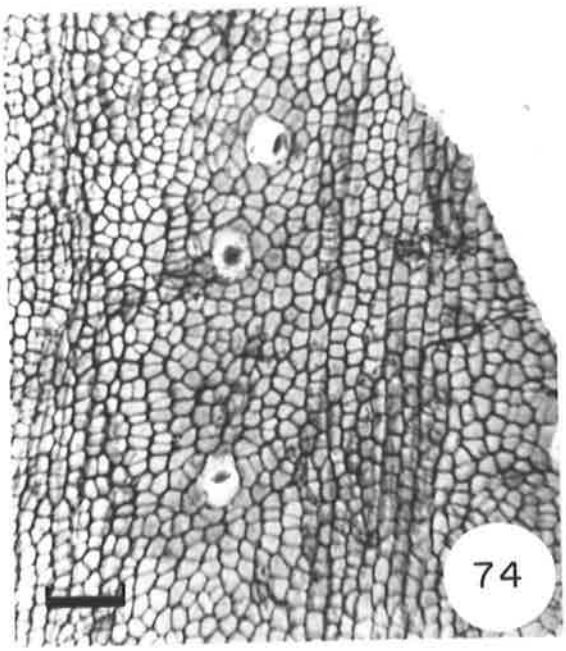
Scale Bar = 50um


70


71


72


73


74


75

Figure 76: Parataxon No.35, Stomatiferous Surface. Slide No. 110-014, 111.8, 40.8. 30.7m. (Unknown)

Figure 77: Parataxon No.36, Upper Epidermis. Slide No. 118-365, 104.1, 29.7. 56.5m. (Proteaceae)

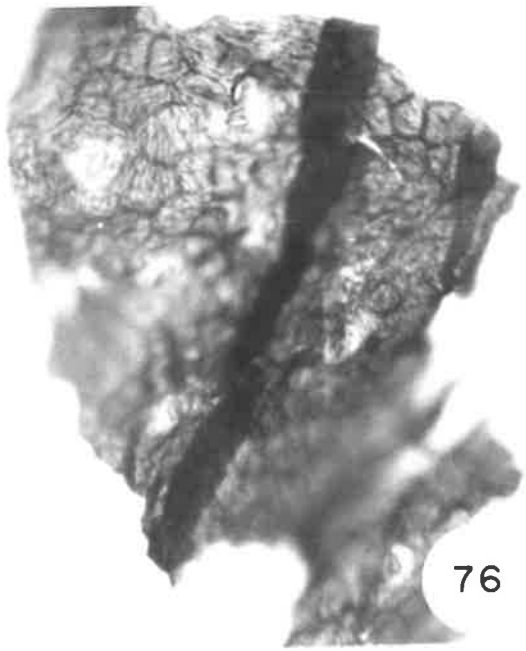
Figure 78: Parataxon No.36, Lower Epidermis. Slide No. 118-363, 110.0, 23.7. 56.5m.

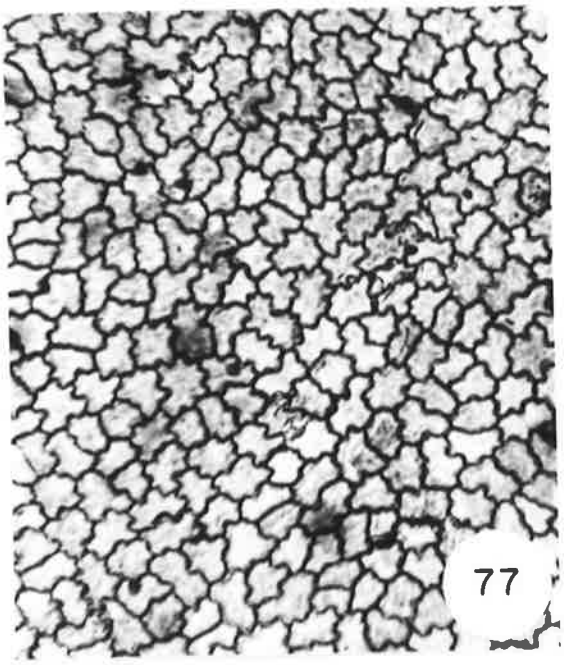
Figure 79: Parataxon No.37, Stomatiferous Surface. Slide No. 117-037, 89.7, 40.5. 90.7m. (Unknown)

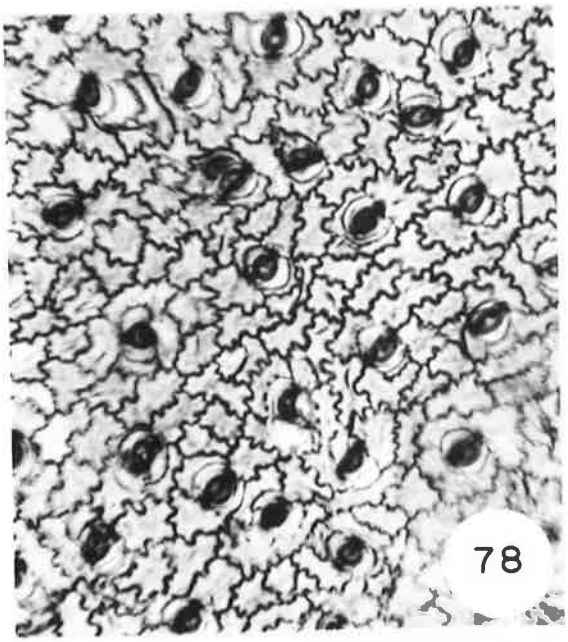
Figure 80: Parataxon No.38, Upper Epidermis. Slide No. 110-010, 85.0, 26.5. 39.9m. (Lauraceae)

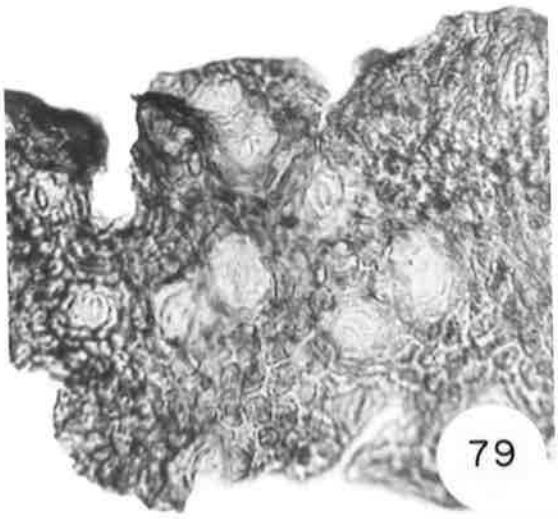
Figure 81: Parataxon No.38, Lower Epidermis. Slide No. 110-010, 91.4, 29.7. 39.9m.

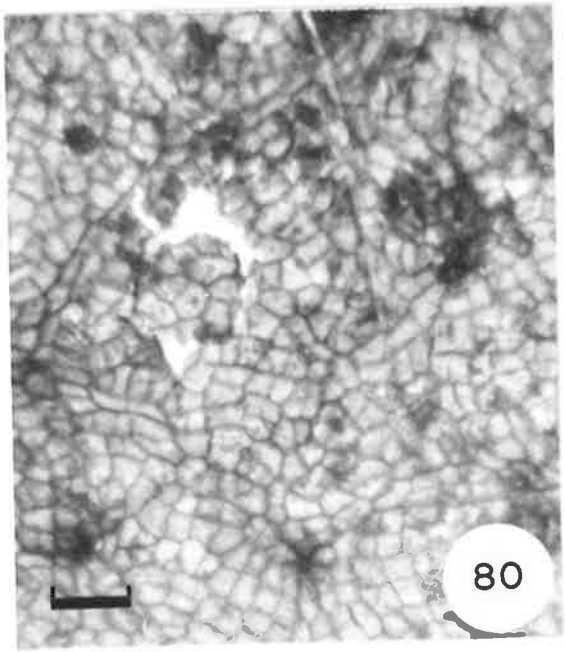
Scale Bar = 50um


76


77


78


79


80

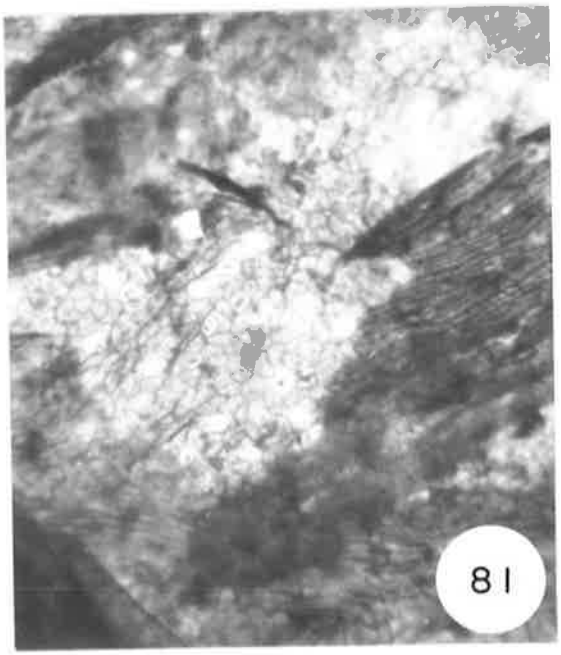

81

Figure 82: Parataxon No.39, Stomatiferous Surface. Slide No. 118-310, 104.6, 32.6. 31.0m. (Unknown)

Figure 83: Parataxon No.40, Upper Epidermis. Slide No. 118-283, 88.8, 30.6. 29.2m. (Proteaceae)

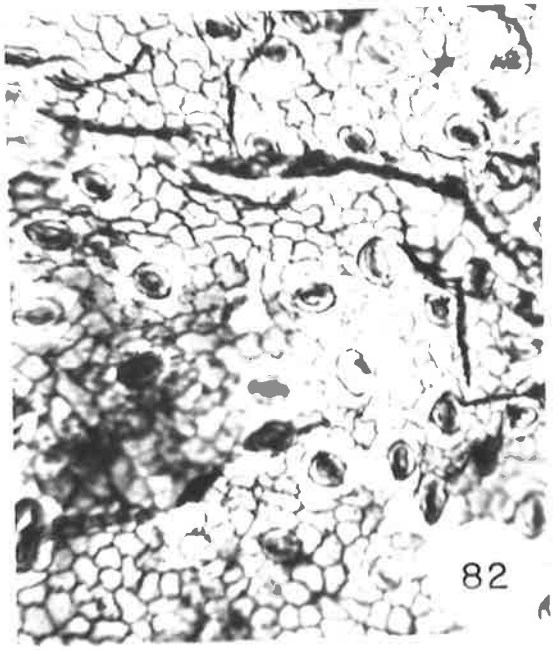
Figure 84: Parataxon No.40, Lower Epidermis. Slide No. 118-283, 100.0, 35.0. 29.2m.

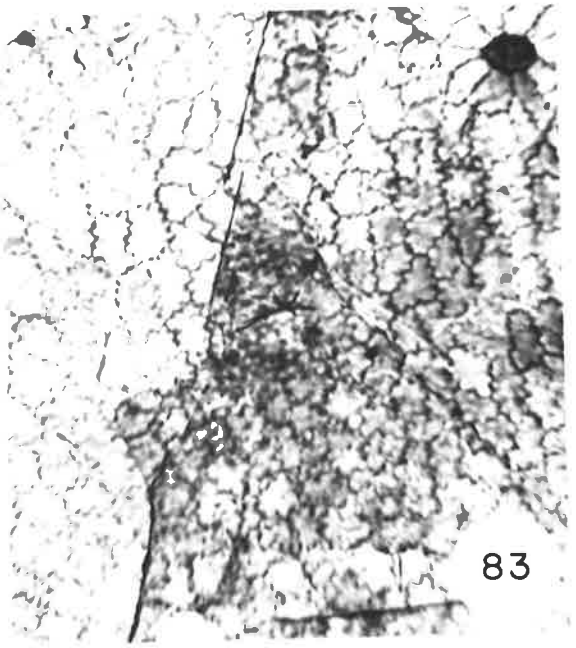
Figure 85: Parataxon No.41, Stomatiferous Surface. Slide No. 118-318, 93.0, 34.0. 31.6m. (Lauraceae)

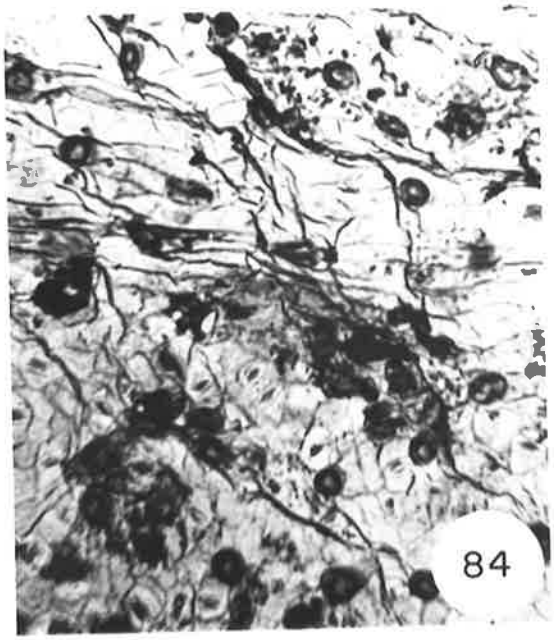
Figure 86: Parataxon No.42, Non-stomatiferous Surface. Slide No. 117-001, 102.0, 32.9. 46.1m. (Unknown)

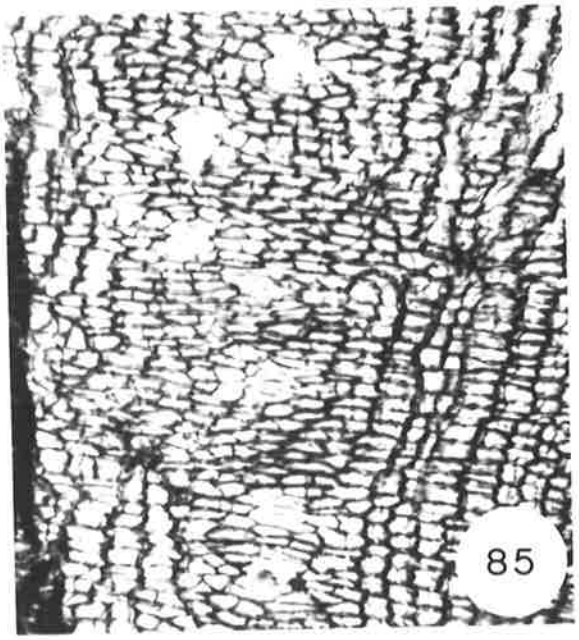
Figure 87: Parataxon No.43, Upper Epidermis. Slide No. 117-025, 100.1, 33.7. 59.5m. (Zamiaceae)

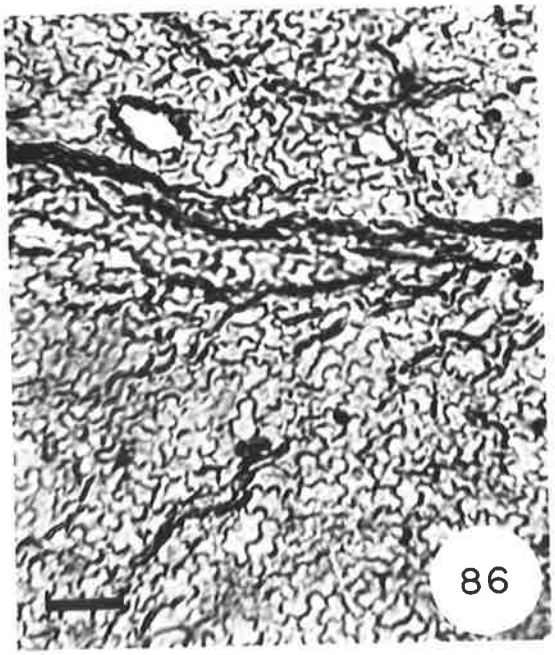
Scale Bar = 50um


82


83


84


85


86

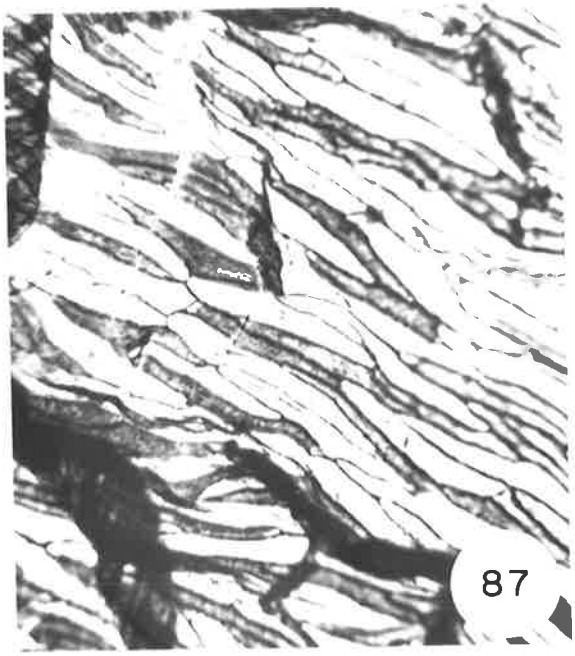

87

Figure 88: Parataxon No.43, Lower Epidermis. Slide No. 117-003, 80.5, 33.8. 47.9m. (Zamiaceae)

Figure 89: Parataxon No.44, Stomatiferous Surface. Slide No. 117-004, 98.3, 41.6. 47.9m. (Unknown)

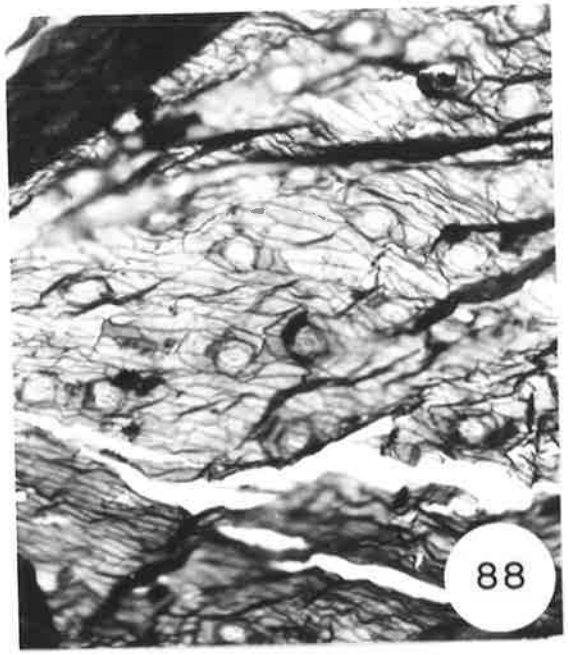
Figure 90: Parataxon No.45, Stomatiferous Surface. Slide No. 117-005, 82.7, 24.5. 59.2m. (Unknown)

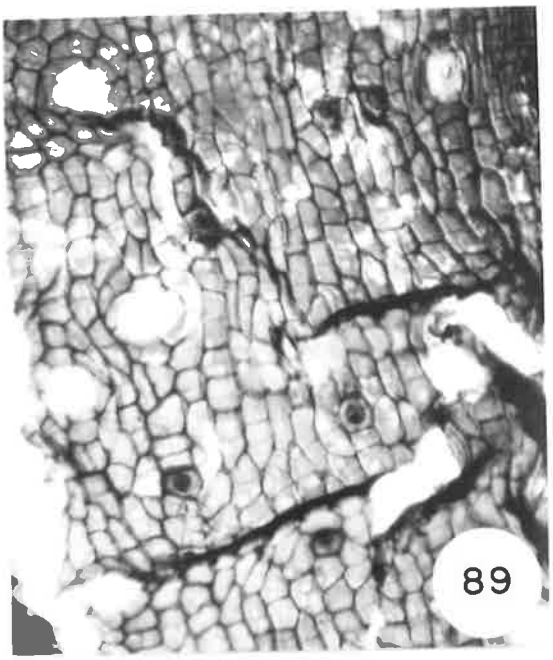
Figure 91: Parataxon No.46, Stomatiferous Surface. Slide No. 117-006, 98.0, 24.3. 59.2m. (Unknown)

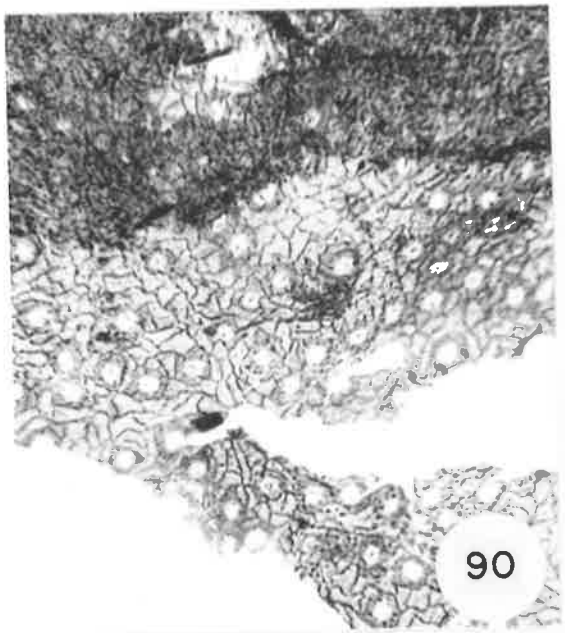
Figure 92: Parataxon No.47, Stomatiferous Surface. Slide No. 117-022, 82.3, 24.6. 60.0m. (Unknown)

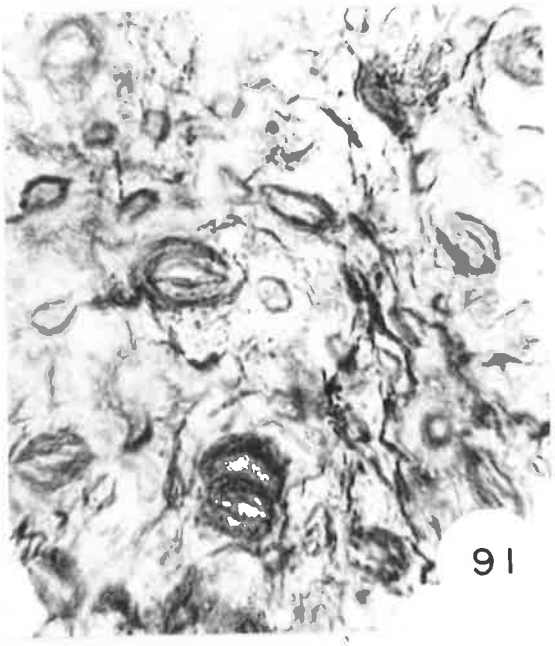
Figure 93: Parataxon No.48, Stomatiferous Surface. Slide No. 139-003, 100.1, 30.0. 110.0m. (Lauraceae)

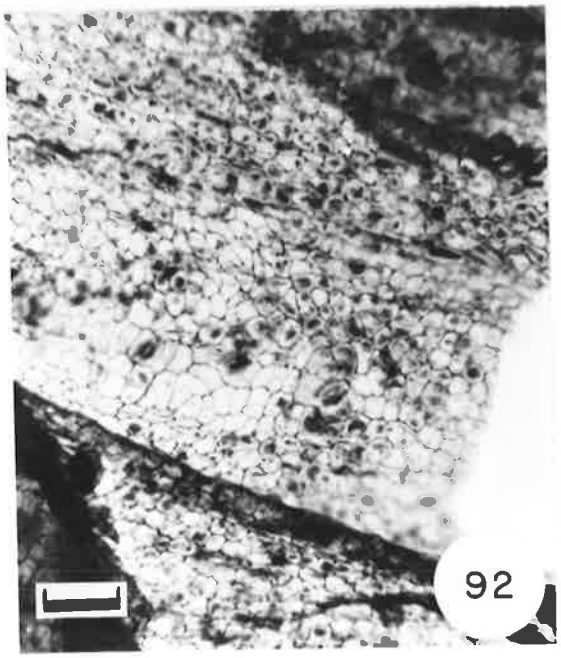
Scale Bar = 50um


88


89


90


91


92

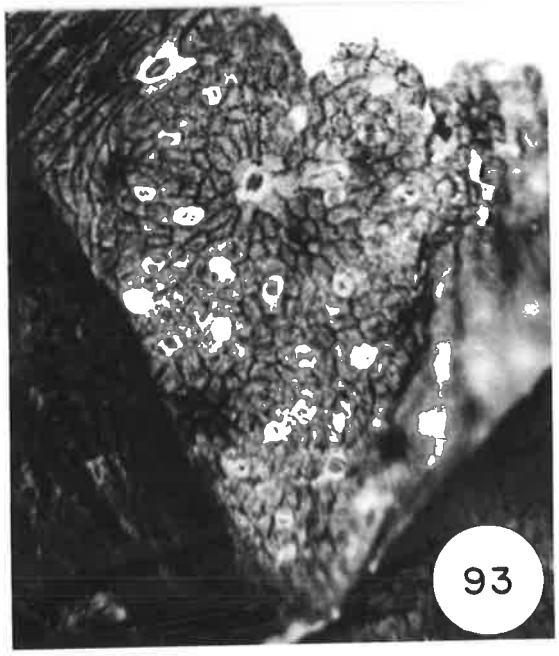

93

Figure 94: Parataxon No.49, Non-stomatiferous Surface.
Slide No. 111-002, 135.1m. (Monocotyledonae)

Figure 95: Parataxon No.50, Stomatiferous Surface. Slide No. 111-001,
106.4, 21.1. 119.3m. (Cunoniaceae?)

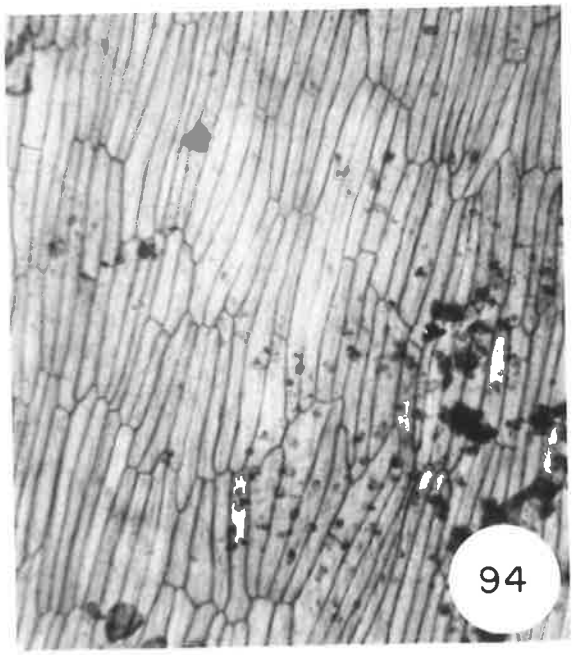
Figure 96: Parataxon No.51, Non-stomatiferous Surface.
Slide No. 117-016, 92.5, 26.0. 57.0m. (Unknown)

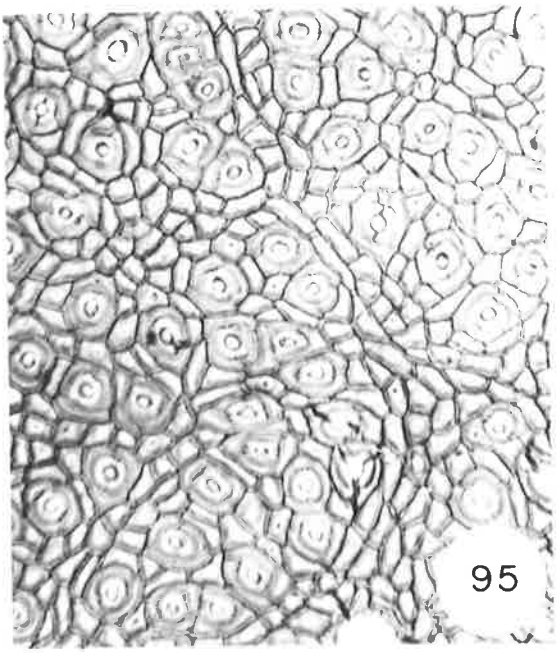
Figure 97: Parataxon No.52, Upper Epidermis. Slide No. 118-289,
103.0, 32.5. 29.0m. (Proteaceae)

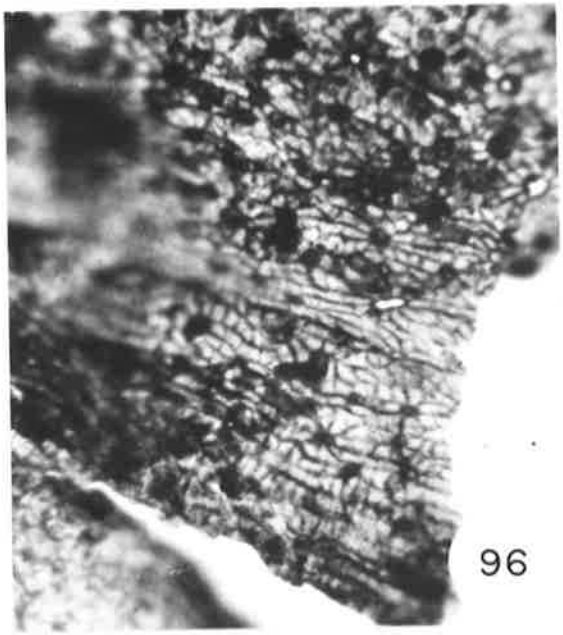
Figure 98: Parataxon No.52, Lower Epidermis. Slide No. 118-289,
101.4, 28.5. 29.0m.

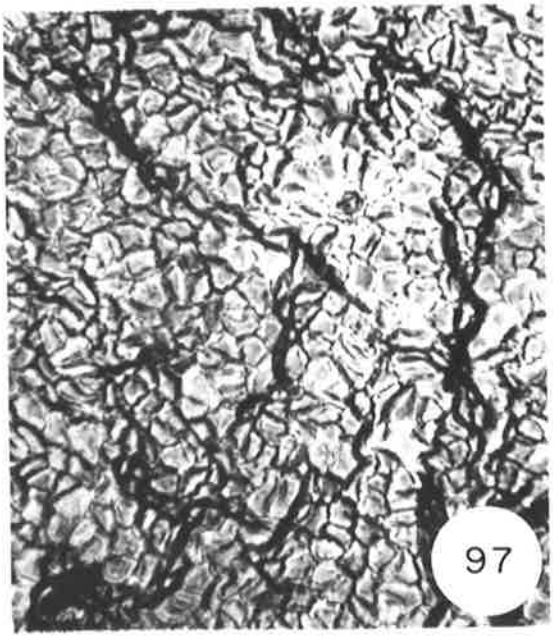
Figure 99: Parataxon No.1, Stomate. Slide No. 118-326,
111.1,33.9. 40.0m. (Scale Bar = 12.5um). (Unknown)

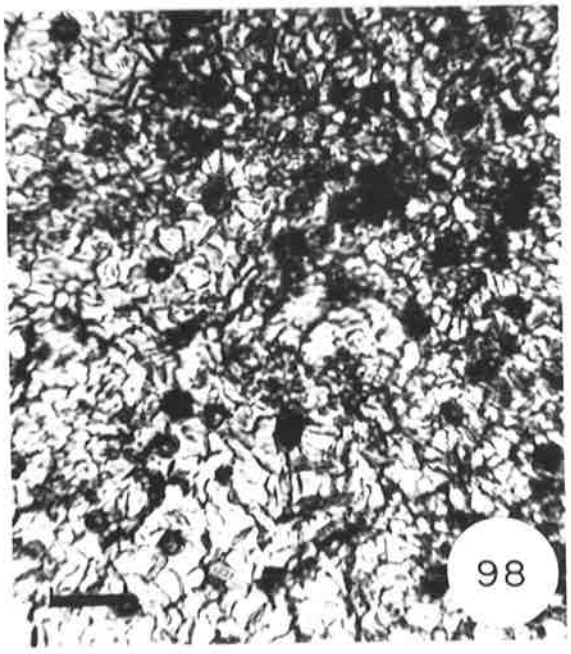
Scale Bar = 50um


94


95


96


97


98

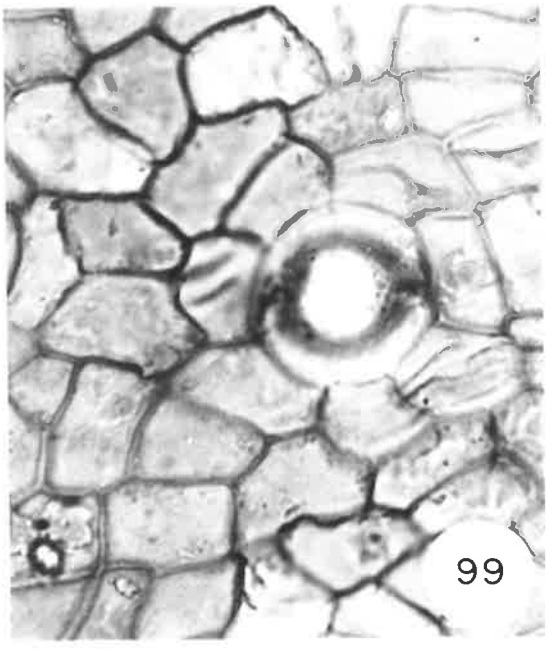

99

Figure 100: Parataxon No.2, Stomate. Slide No. 118-285, 87.3, 29.4. 29.2m. (Unknown)

Figure 101: Parataxon No.3, Stomate. Slide No. 118-367, 86.4, 28.3. 56.5m. (Unknown)

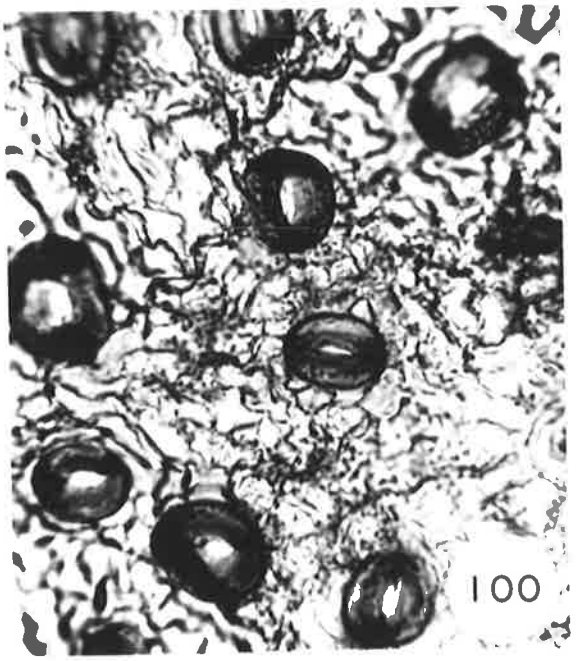
Figure 102: Parataxon No.4, Stomate. Slide No. 118-307, 89.7, 26.8. 31.0m. (Unknown)

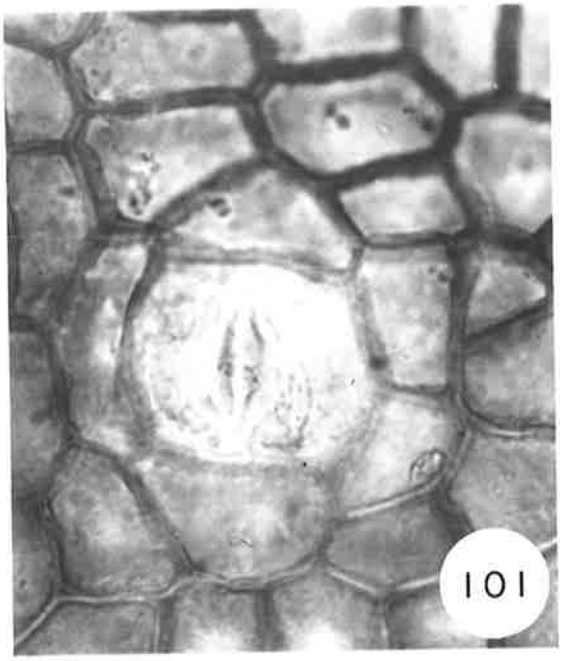
Figure 103: Parataxon No.5, Stomate. Slide No. 118-408, 90.3, 28.3. 69.8m. (Unknown)

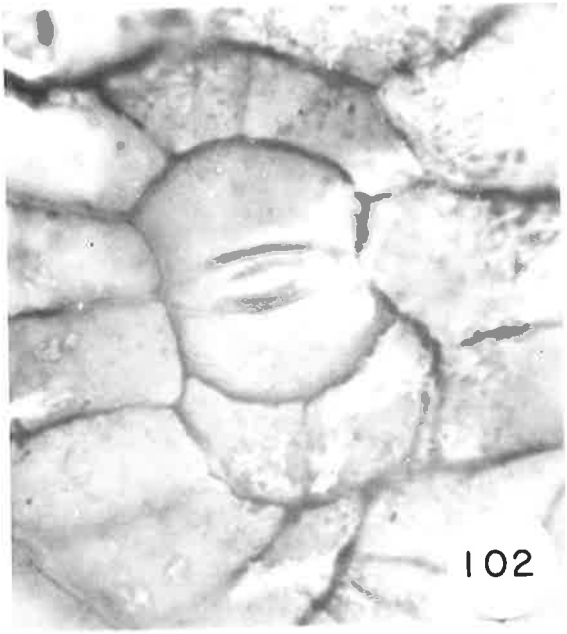
Figure 104: Parataxon No.6, Stomate. Slide No. 118-291, 100.8, 31.5. 29.0m. (Unknown)

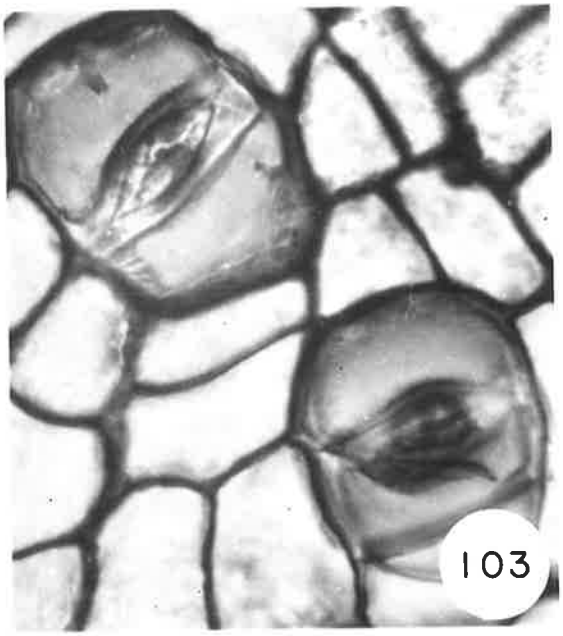
Figure 105: Parataxon No.7, Stomate. Slide No. 118-401, 96.0, 23.8. 75.0m. (Cyperaceae)

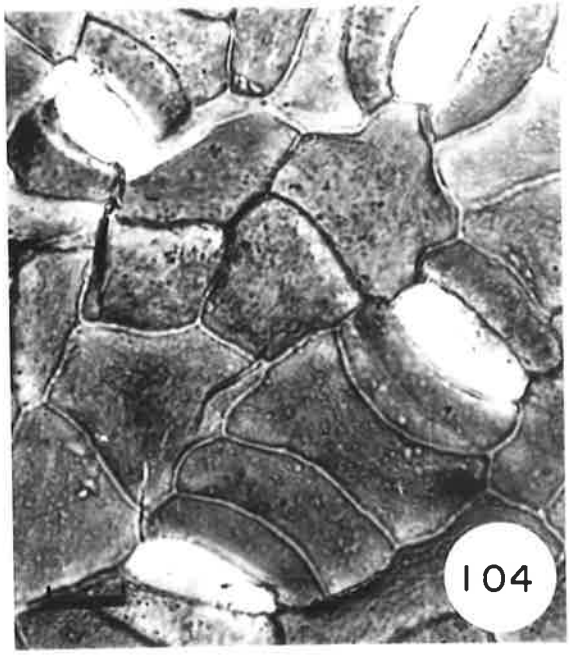
Scale Bar = 12.5um


100


101


102


103


104

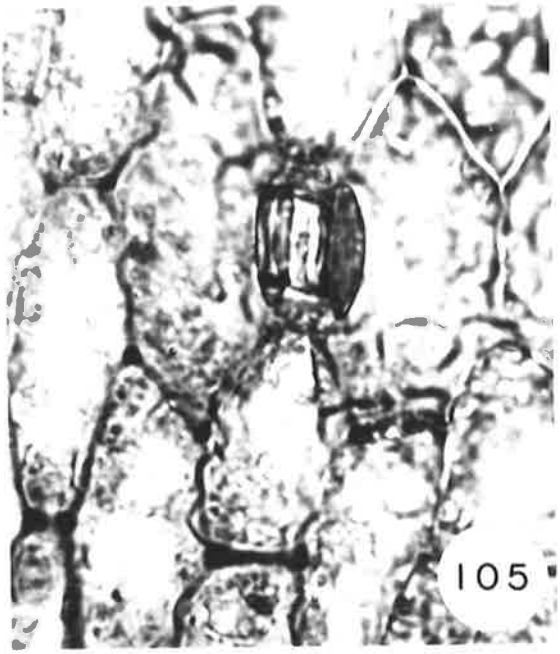

105

Figure 106: Parataxon No.8, Stomate. Slide No. 246-036,
104.0, 26.3. 37.3m. (Podocarpaceae)

Figure 107: Parataxon No.9, Stomate. Slide No. 118-260,
100.5, 29.0. 26.9m. (Lauraceae)

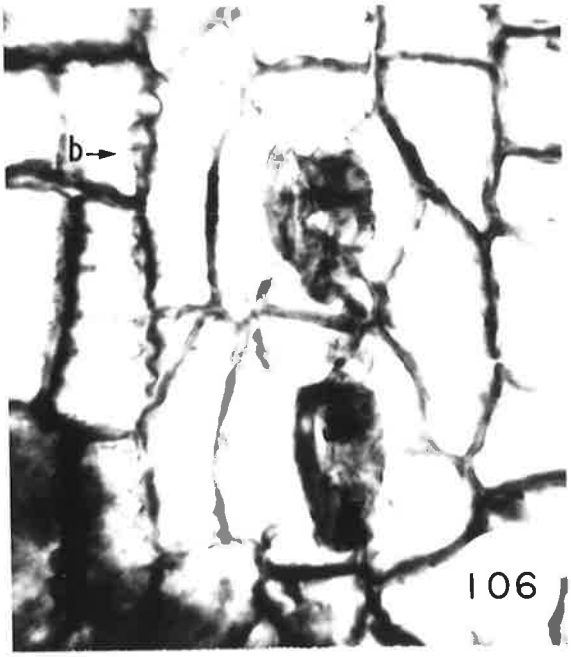
Figure 108: Parataxon No.10, Stomate. Slide No. 118-352,
98.3, 28.1. 50.9m. (Lauraceae)

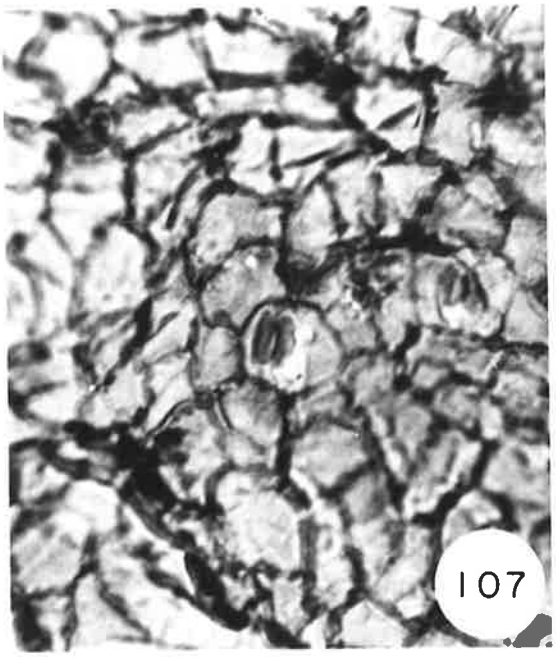
Figure 109: Parataxon No.11, Stomate. Slide No. 118-296,
106.2, 23.4. 30.7m. (Proteaceae)

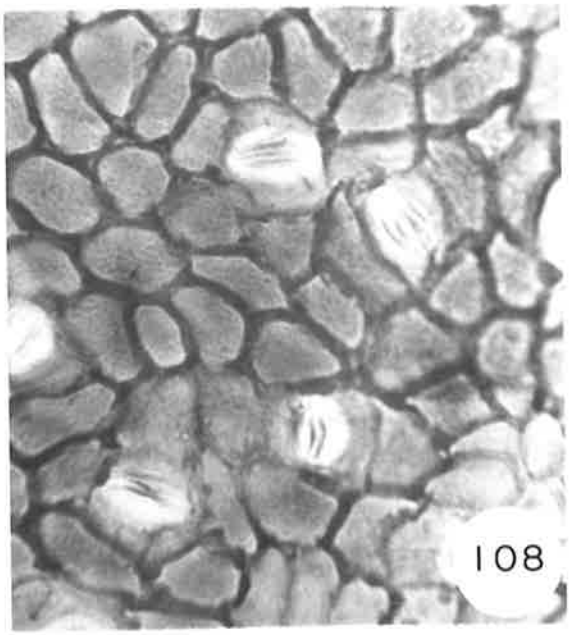
Figure 110: Parataxon No.11, Trichome Base on the Upper Epidermis.
Slide No. 118-390, 107.6, 32.6. 62.1m.

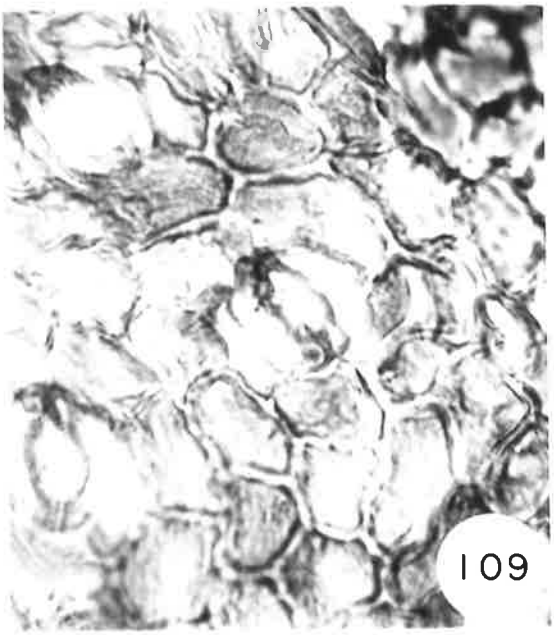
Figure 111: Parataxon No.12, Stomate. Slide No. 118-413,
98.8, 29.5. 62.1m. (Proteaceae)

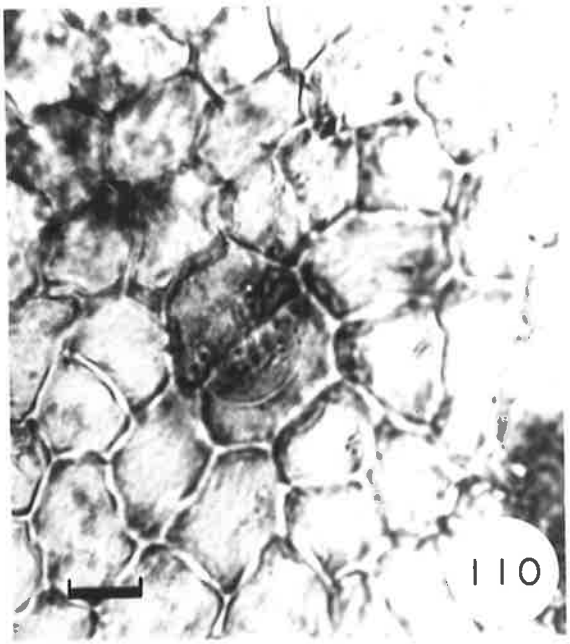
Scale Bar = 12.5um


b
106


107


108


109


110

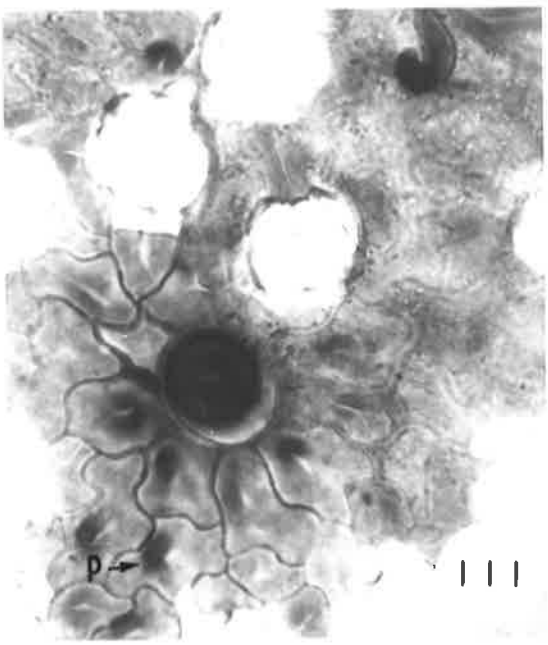

p
111

Figure 112: Parataxon No.12, Trichome Base on the Upper Epidermis.
Slide No. 118-281, 96.3, 29.7. 27.6m. (Proteaceae)

Figure 113: Parataxon No.14, Stomate. Slide No. 118-295,
88.5, 32.7. 30.8m. (Lauraceae)

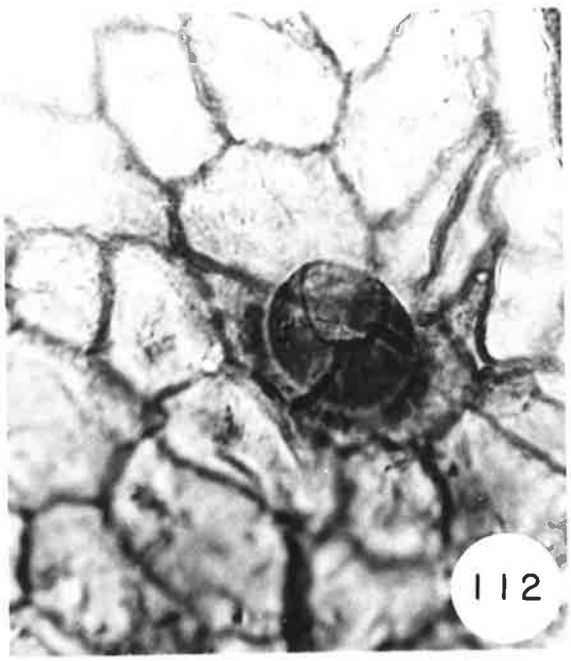
Figure 114: Parataxon No.15, Stomate. Slide No. 118-236,
107.5, 28.4. 26.0m. (Lauraceae)

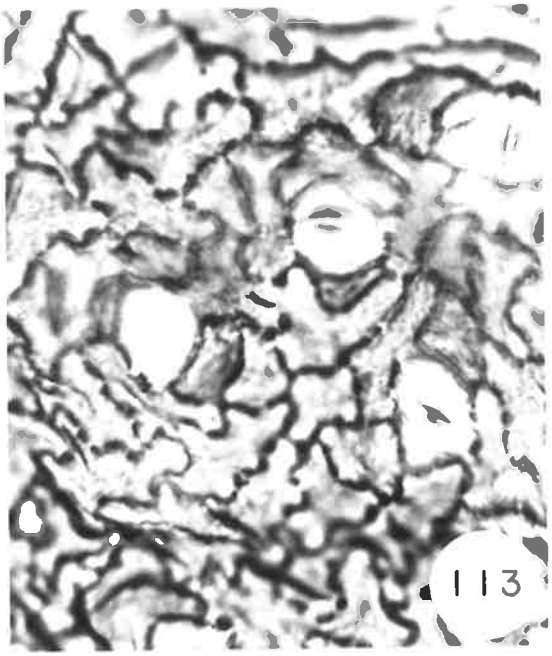
Figure 115: Parataxon No.16, Stomate. Slide No. 118-200,
95.2, 32.6. 26.0m. (Lauraceae)

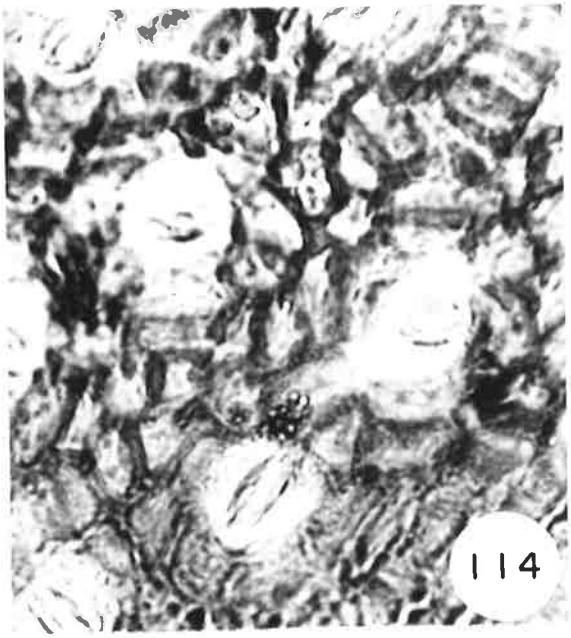
Figure 116: Parataxon No.18, Stomate. Slide No. 118-233,
104.7, 31.7. 26.7m. (Lauraceae?)

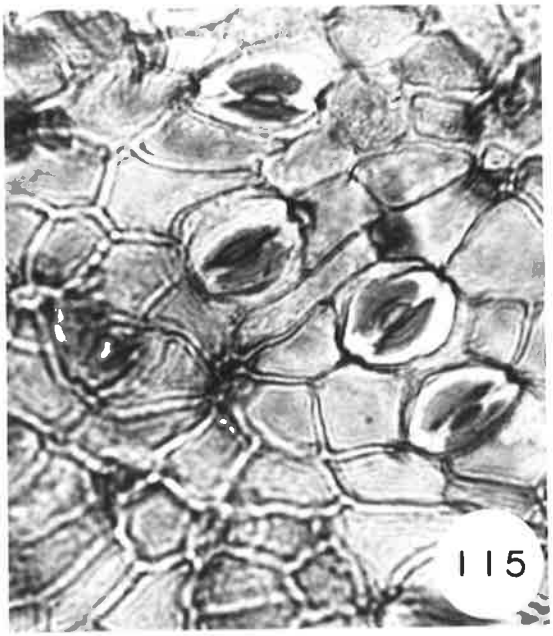
Figure 117: Parataxon No.19, Stomate. Slide No. 118-277,
77.4, 38.3. 28.0m. (Monocotyledonae)

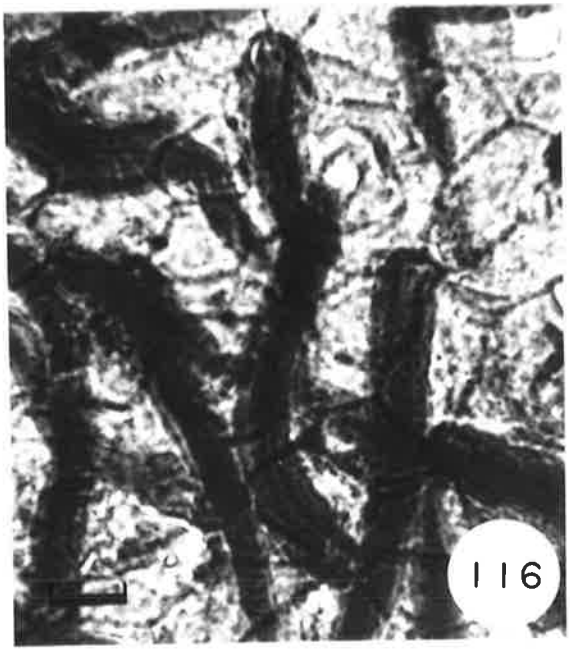
Scale Bar = 12.5um


112


113


114


115


116


117

Figure 118: Parataxon No.21, Stomate. Slide No. 118-340,
101.0, 24.8. 41.5m. (Monocotyledonae?)

Figure 119: Parataxon No.23, Leaf Margin Tooth.
Slide No. 118-415, 78.5m. (Scale Bar = 500um).
(Zamiaceae)

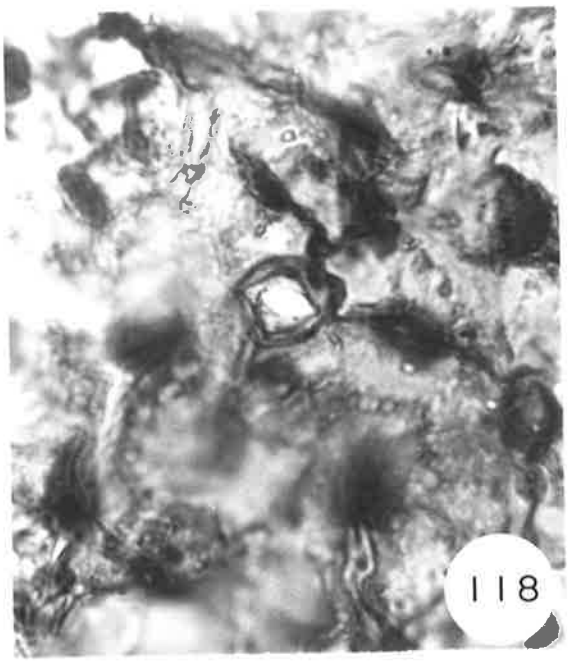
Figure 120: Parataxon No.23, Stomate on the Upper Epidermis.
Slide No. 118-500, 75.8m. (Scale Bar = 50um).

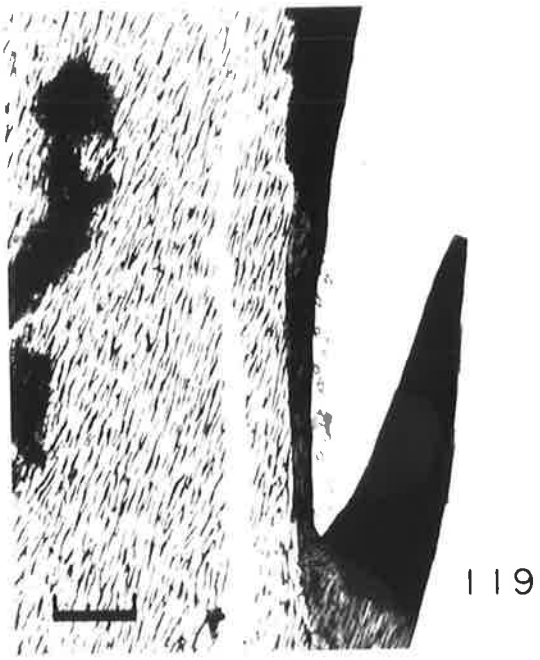
Figure 121: Parataxon No.23, Stomate On the Upper Epidermis.
Slide No. 118-500, 75.8m.

Figure 122: Parataxon No.23, Stomate on the Lower Epidermis.
Slide No. 118-500, 75.8m.

Figure 123: Parataxon No.23, Trichome Base on the Upper Epidermis.
Slide No. 118-414, 75.8m.

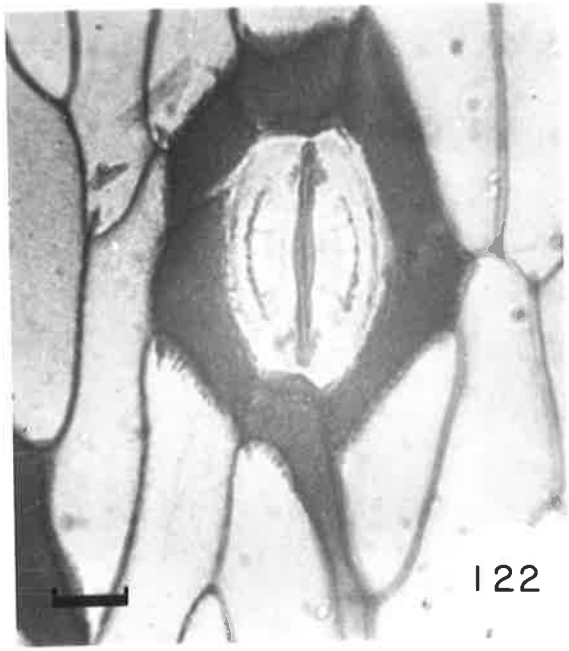
Scale Bar = 12.5um


118


119


120


121


122

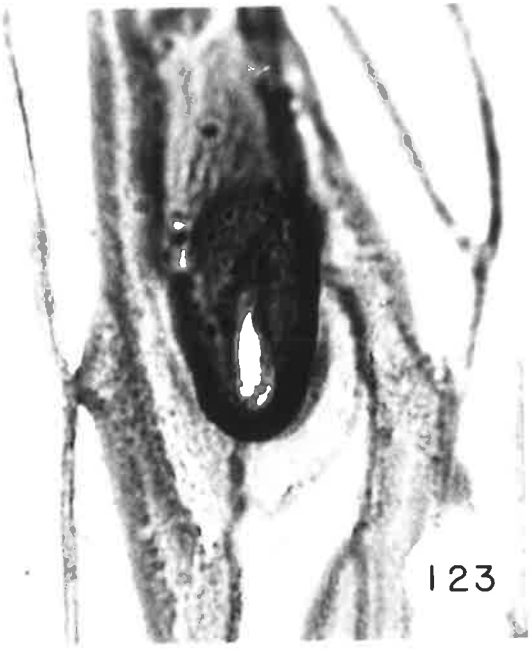

123

Figure 124: Parataxon No.17, Stomate. Slide No. 118-297, 90.1, 32.4. 30.7m. (Unknown)

Figure 125: Parataxon No.25, Stomate. Slide No. 118-310, 101.0, 25.9. 31.0m. (Ebenaceae)

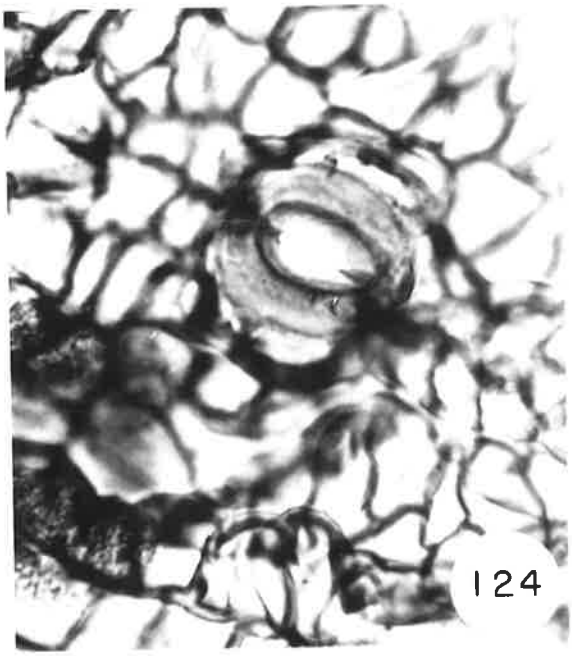
Figure 126: Parataxon No.27, Stomate. Slide No. 118-248, 89.9, 35.9. 27.0m. (Unknown)

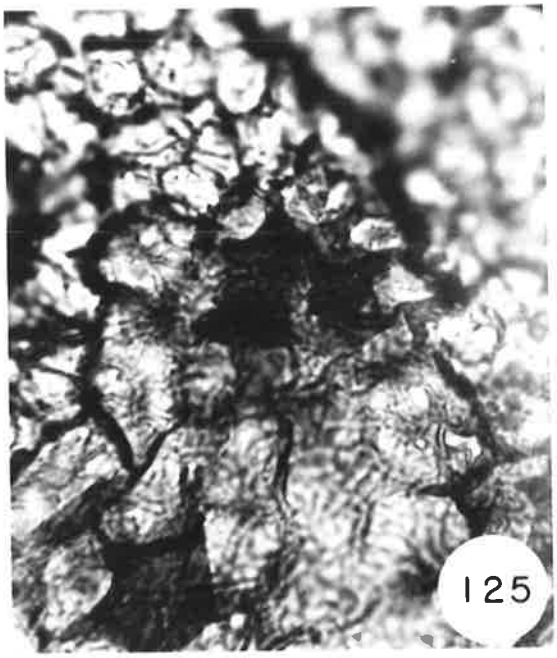
Figure 127: Parataxon No.28, Stomate. Slide No. 118-332, 92.3, 30.6. 40.3m. (Unknown)

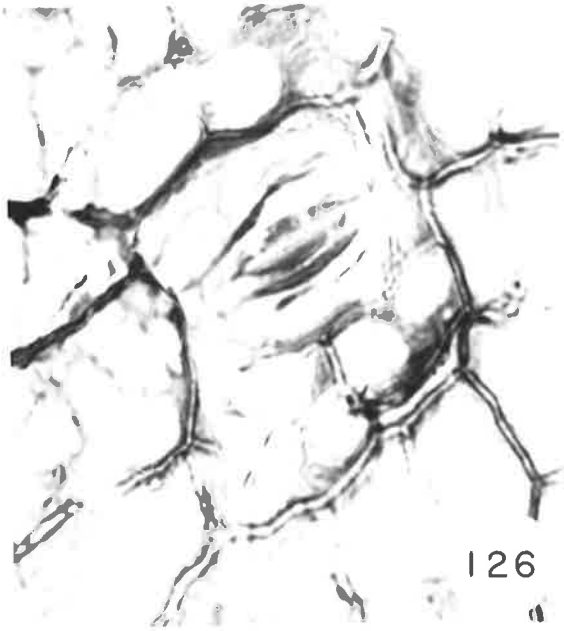
Figure 128: Parataxon No.29, Stomate. Slide No. 118-216, 98.1, 29.7. 26.0m. (Lauraceae)

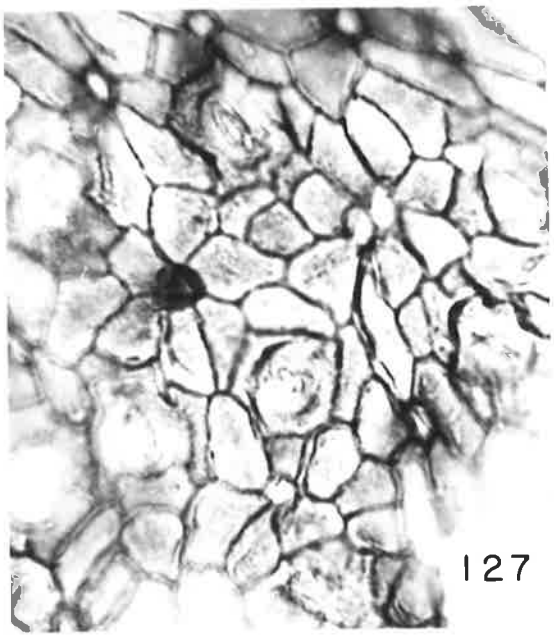
Figure 129: Parataxon No.31, Stomate. Slide No. 110-014, 112.3, 39.5. 37.3m. (Casuarinaceae)

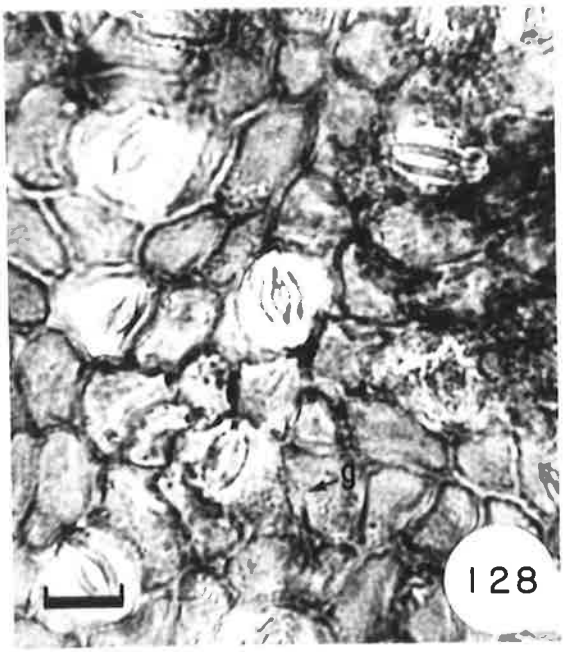
Scale Bar = 12.5um


124


125


126


127


g
128


129

Figure 130: Parataxon No.33, Stomate. Slide No. 118-235,
101.3, 27.7. 26.0m. (Unknown)

Figure 131: Parataxon No.35, Stomate. Slide No. 110-014,
111.8, 40.8. 37.3m. (Unknown)

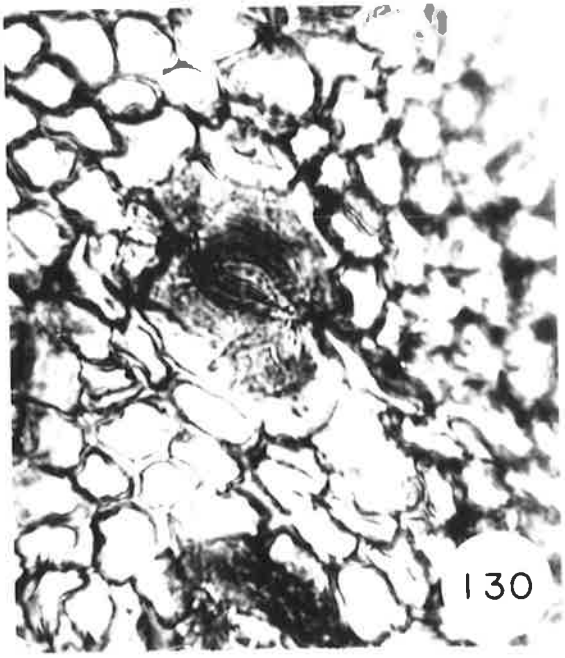
Figure 132: Parataxon No.36, Stomate. Slide No. 118-363,
82.1, 39.2. 56.5m. (Proteaceae)

Figure 133: Parataxon No.36, Trichome Base on the Upper Epidermis.
Slide No. 118-365, 104.1, 29.7. 56.5m.

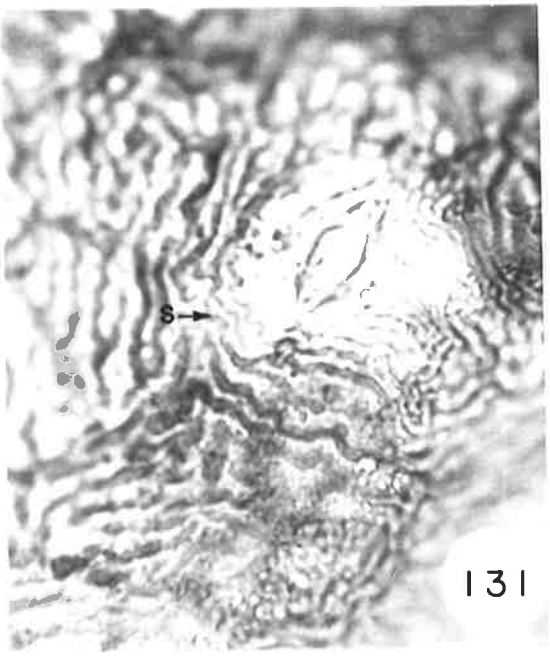
Figure 134: Parataxon No.38, Stomate. Slide No. 110-010,
91.4, 29.7. 39.9m. (Lauraceae)

Figure 135: Parataxon No.39, Stomate. Slide No. 118-310,
104.6, 32.6. 31.0m. (Unknown)

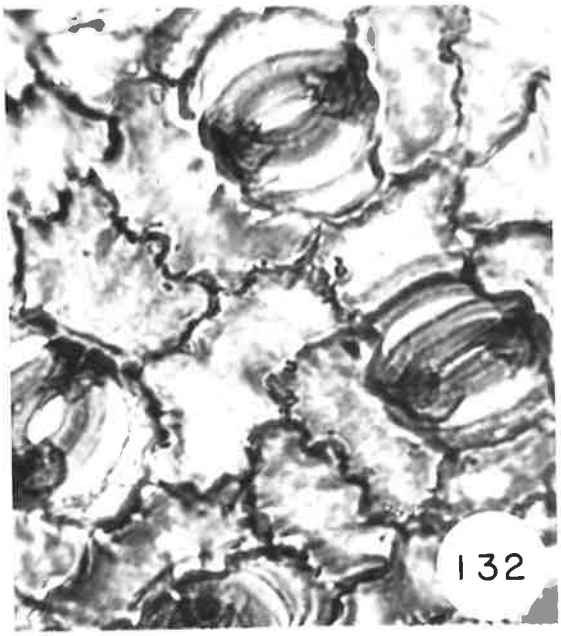
Scale Bar = 12.5um



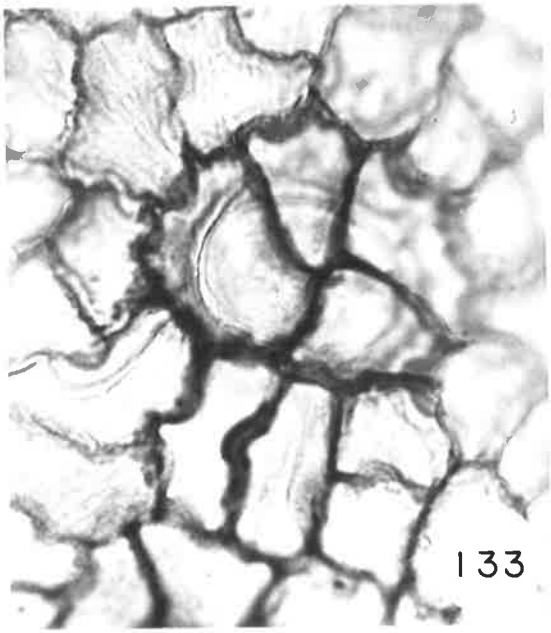
130



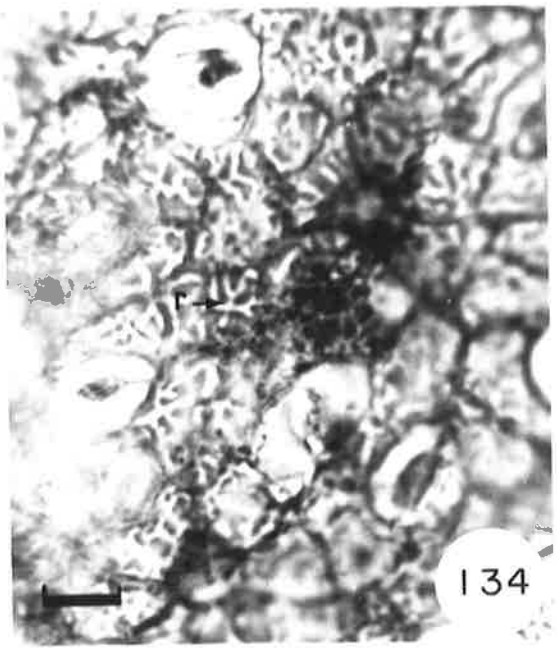
131



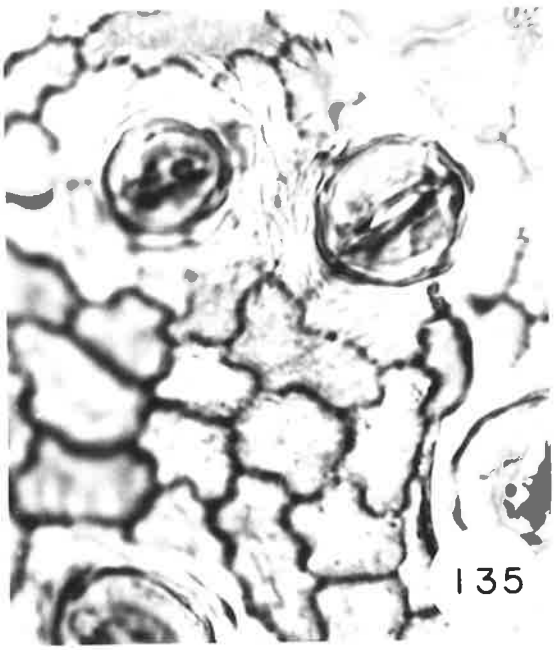
132



133



134



135

Figure 136: Parataxon No.40, Stomate. Slide No. 118-283, 99.7, 35.3. 29.2m. (Proteaceae)

Figure 137: Parataxon No.43, Stomate. Slide No. 117-003, 80.5, 33.8. 47.9m. (Zamiaceae)

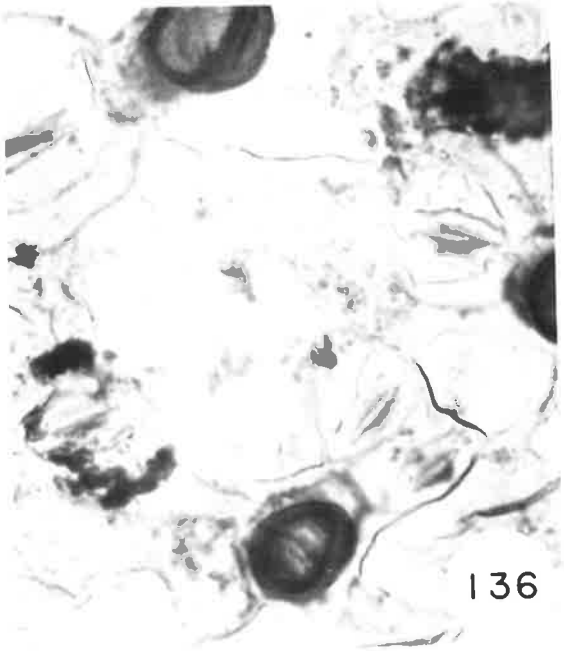
Figure 138: Parataxon No.44, Stomate. Slide No. 117-004, 98.3, 41.6. 47.9m. (Unknown)

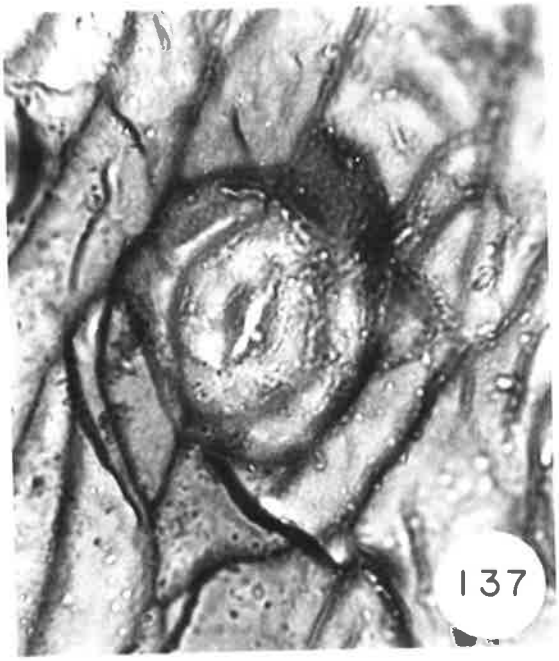
Figure 139: Parataxon No.45, Stomate. Slide No. 117-005, 82.7, 24.5. 59.2m. (Unknown)

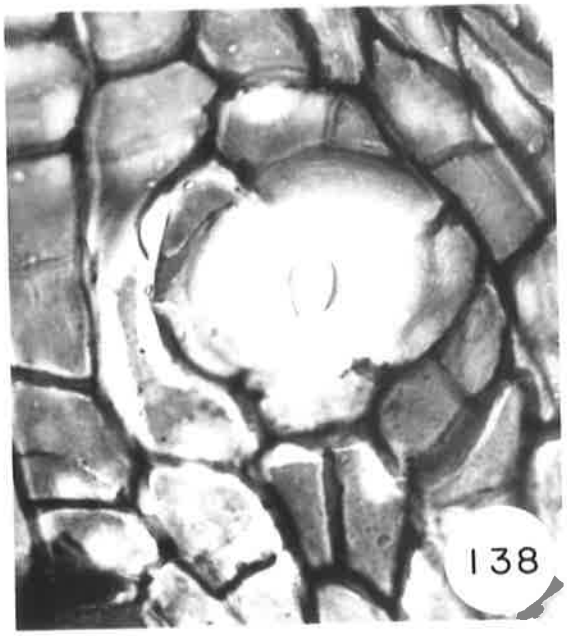
Figure 140: Parataxon No.47, Stomate. Slide No. 117-022, 82.3, 24.6. 60.0m. (Unknown)

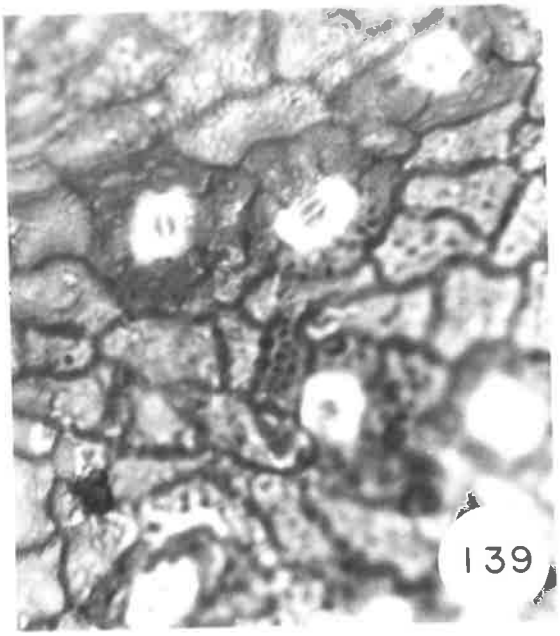
Figure 141: Parataxon No.48, Stomate. Slide No. 139-003, 100.1, 30.0. 128.0m. (Lauraceae)

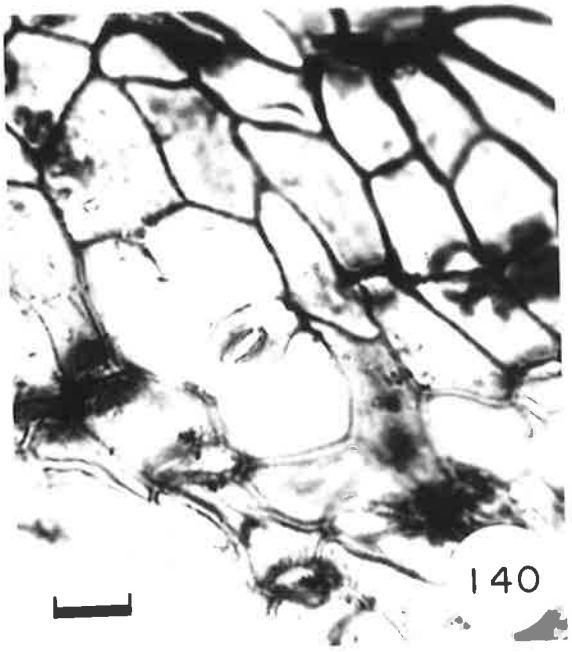
Scale Bar = 12.5um


136


137


138


139


140

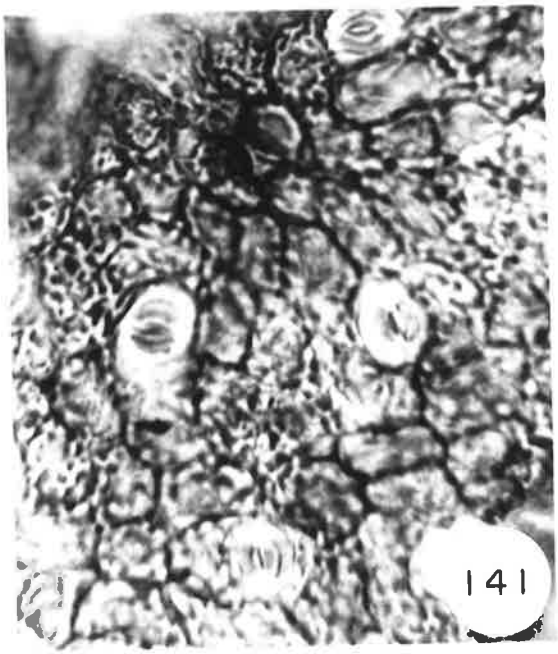

141

Figure 142: Parataxon No.50, Stomate. Slide No. 111-001, 106.4, 21.1. 119.3m. (Cunoniaceae?)

Figure 143: Lower Epidermis of Diospyros No.312, from Anglesea Deposit, Victoria. (Scale Bar = 50um).

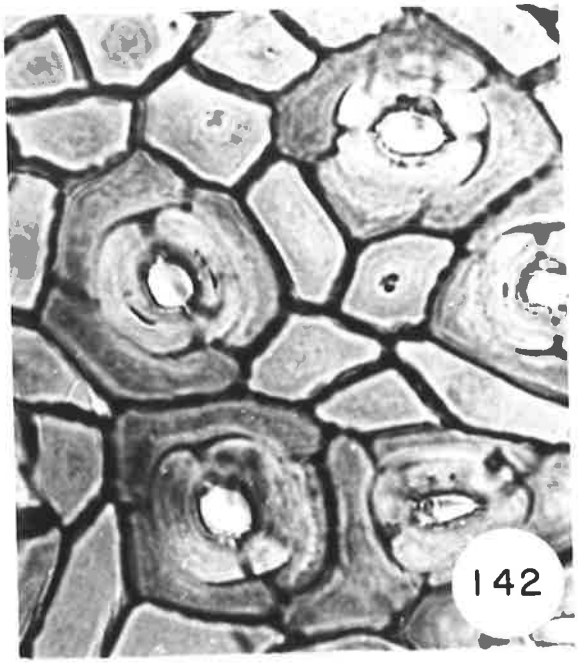
Figure 144: Stomate of Diospyros No.312, from Anglesea Deposit, Victoria.

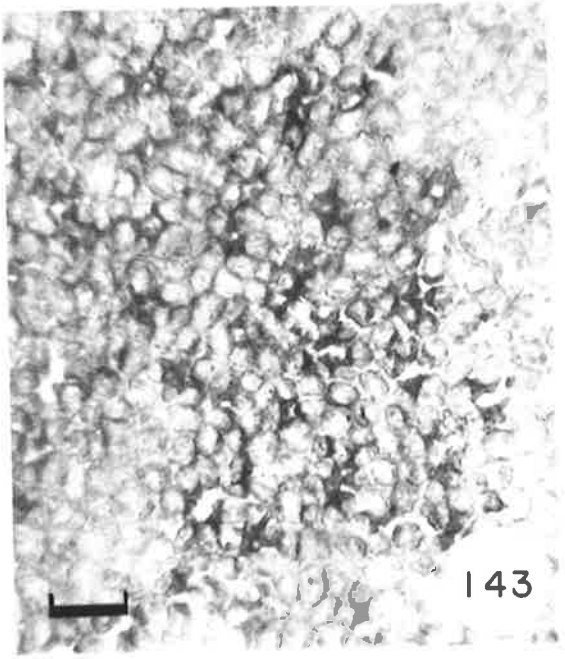
Figure 145: Stomate of Diospyros No.085, from Anglesea Deposit, Victoria.

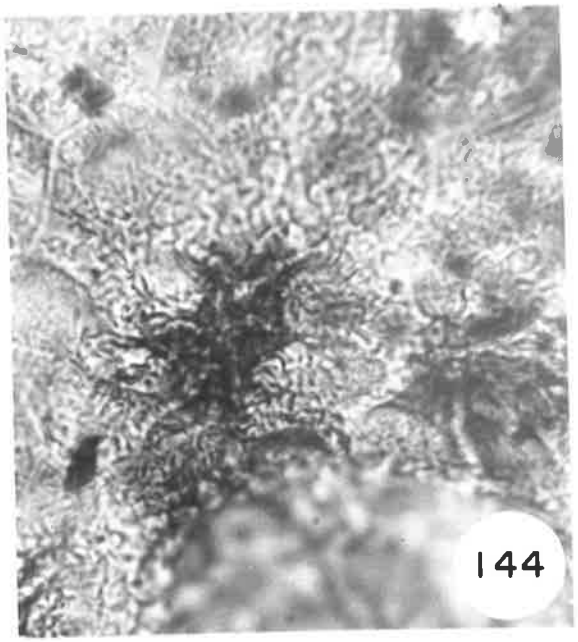
Figure 146: Azolla capricornica microspore massulae showing glochidia. ERD 118. 40.3/2, 72.9, 39.7.

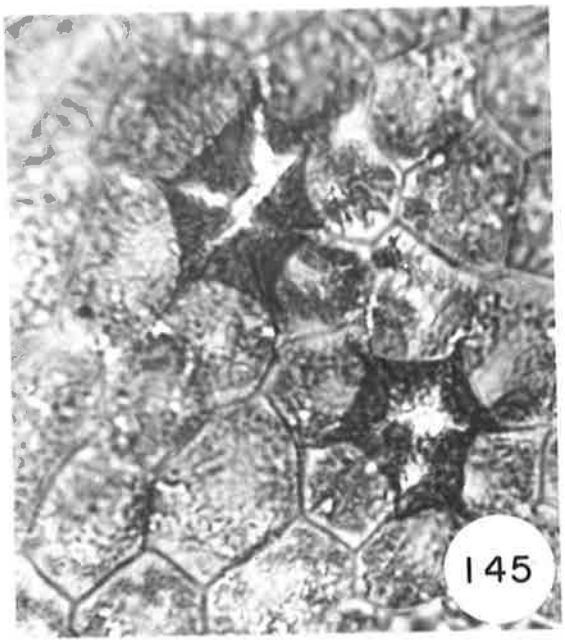
Figure 147: One of the larger Fossil Leaf Fragments recovered from the deposit. ERD 111. 106.8m . (Scale Bar = 21um).

Scale Bar = 12.5um


142


143


144


145


146


147

Figure 148: Seed Structure, CF 1. ERD 118, 33.4m.
(Scale Bar = 500um).

Figure 149: Seed Cuticle, CF 2. Slide No. 112-026,
90.5, 26.1. 127.2m. (Scale Bar = 90um).

Figure 150: Seed Cuticle, CF 4. Slide No. 117-015,
122.8, 32.9. 49.0m. (Scale Bar = 110um).

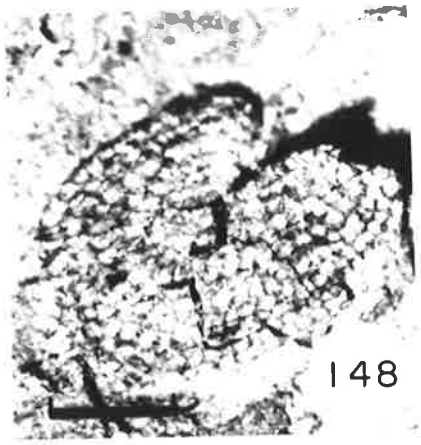
Figure 151: Scale-like Structure, CF 7. Slide No. 139-001,
97.5, 27.2. 110.0m. (Scale Bar = 240um).

Figure 152: Seed Cuticle, CF 5. Slide No. 118-276,
97.8, 30.4. 28.2m. (Scale Bar = 190um).

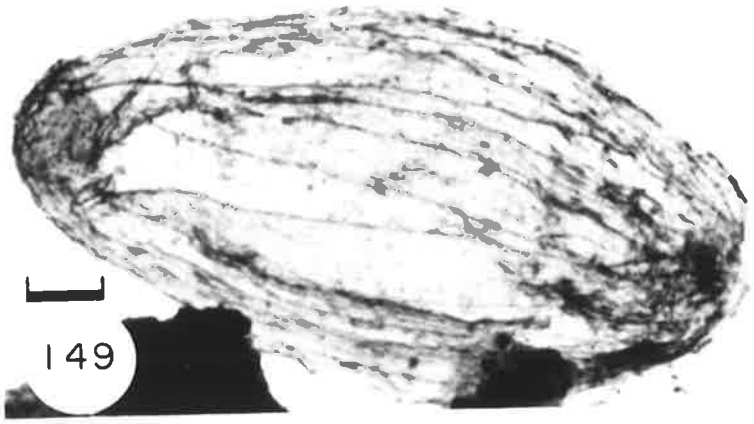
Figure 153: Azolla capricornica microspore massulae.
Slide No. 117-028, 75.5, 29.6. 68.7m. (Scale Bar = 43um).

Figure 154: Azolla capricornica megaspore float. ERD 118. 37.3m.
(Scale Bar = 35um).

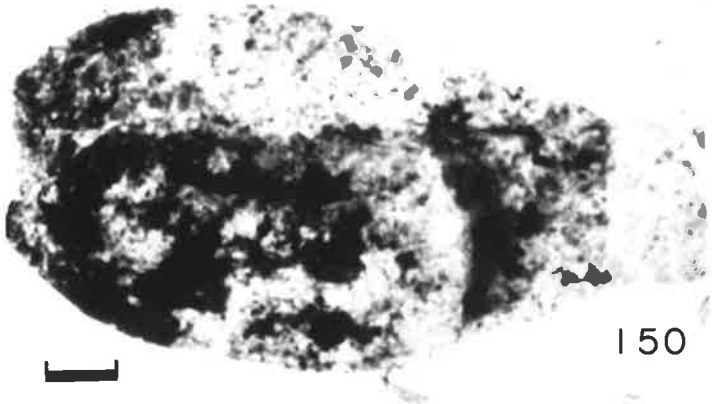
Figure 155: Seed Cuticle, CF 3. Slide No. 112-021,
95.1, 31.2. 108.3m. (Scale Bar = 38um)



148



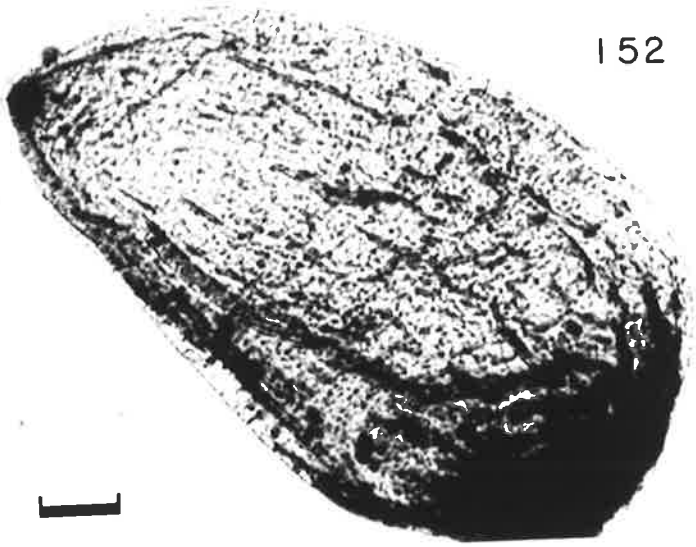
149

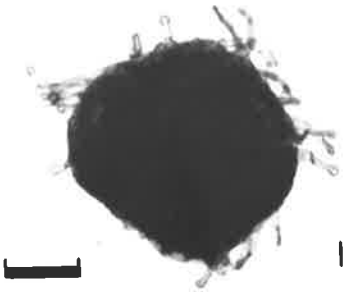


150

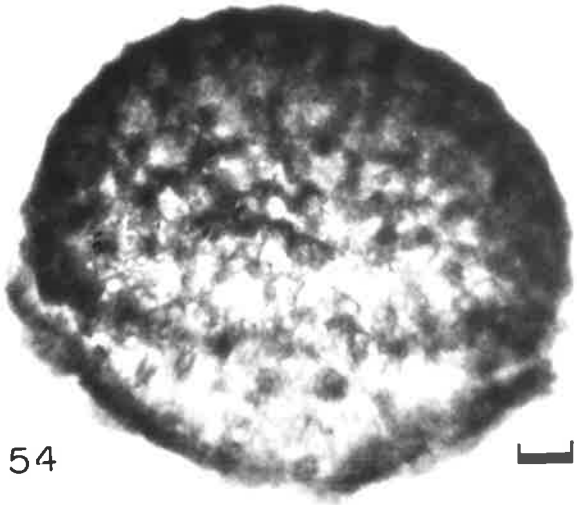
151

152

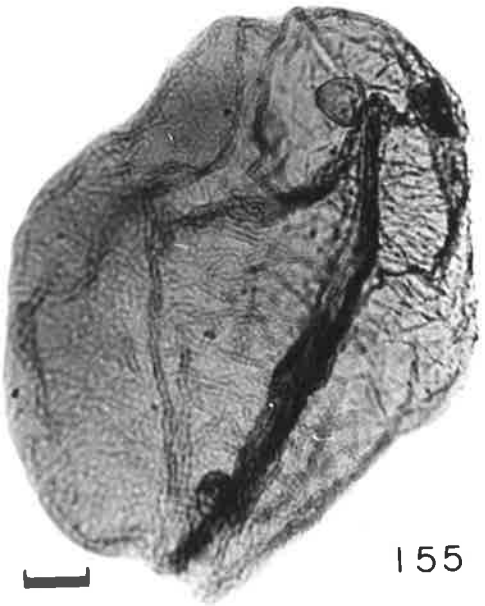




153



154



155

Figure 156: Rootlet, CF 9. Slide No.118-420,
93.4, 27.4. 33.4m. (Scale Bar = 170um).

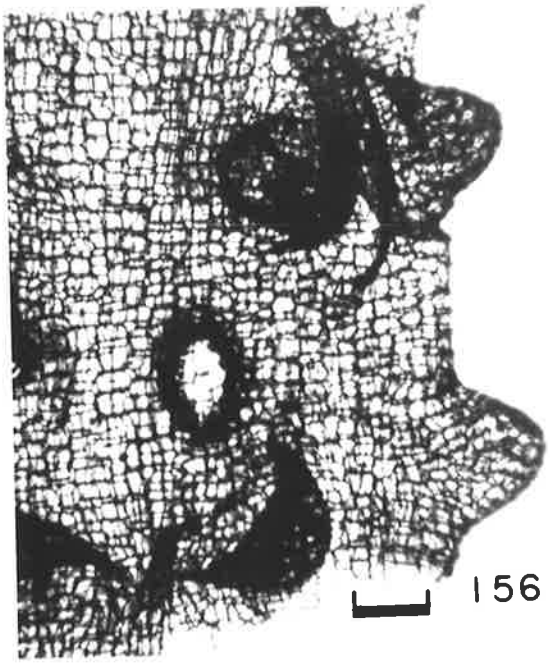
Figure 157: Rootlet, CF 6. Slide No. 118-383,
95.1, 28.0. 58.0m. (Scale Bar = 50um).

Figure 158: Manginuloid Hyphae marking on Proteaceae cuticle.
Slide No. 110-011, 112.8, 27.4. 39.5m. (Scale Bar = 50um).

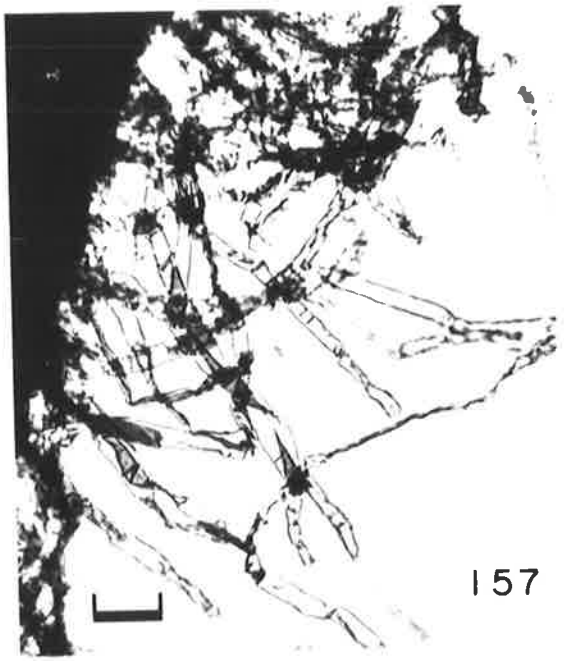
Figure 159: Epiphyllous Fungal Shield. Slide No. 112-021,
112.0, 35.7. 108.3m. (Scale Bar = 12.5um).

Figure 160: Beilschmiedia elliptica, Upper Epidermis.
(Scale Bar = 50um).

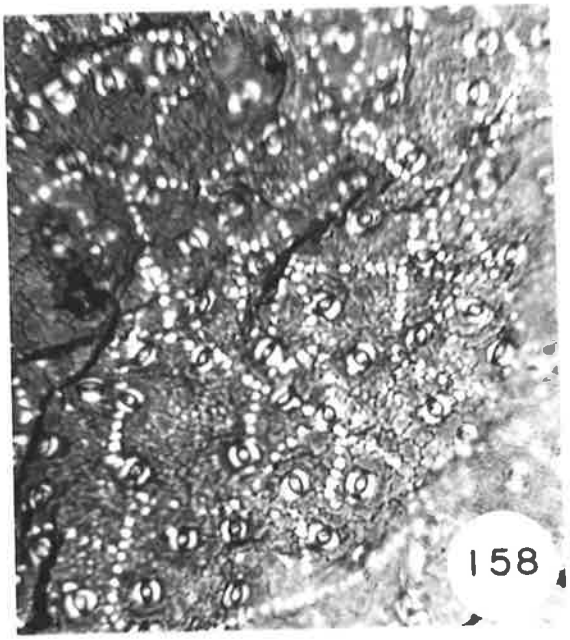
Figure 161: Beilschmiedia elliptica, Lower Epidermis.
(Scale Bar = 50um).



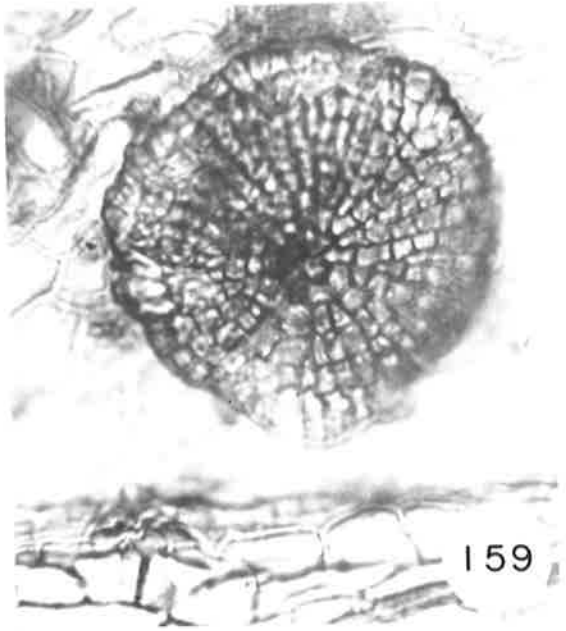
156



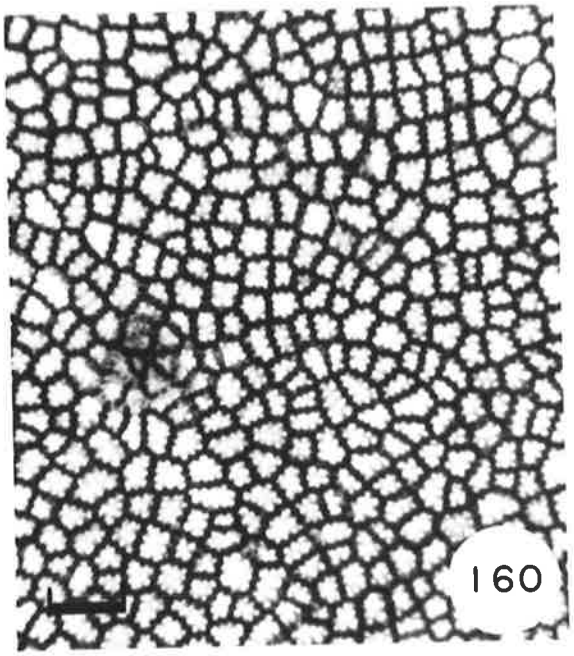
157



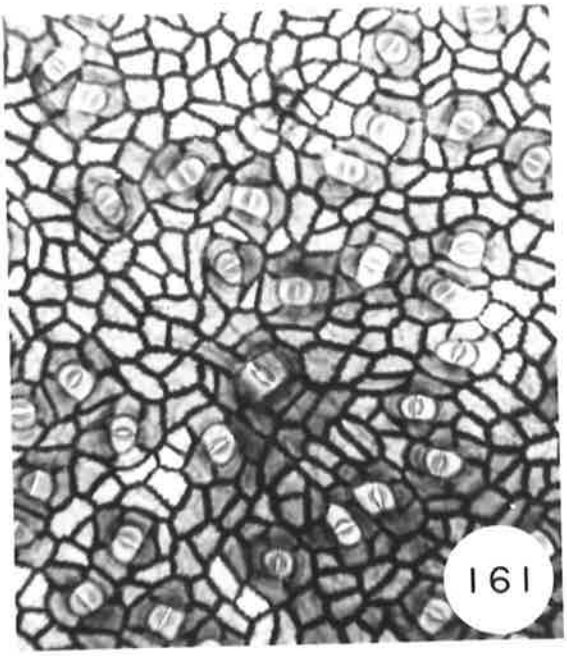
158



159



160



161

Figure 162: Beilschmiedia elliptica, Stomate.
(Scale Bar = 12.5um).

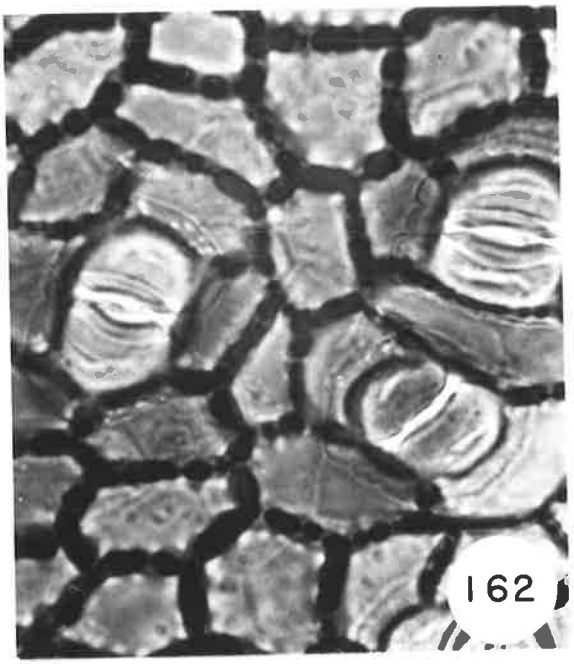
Figure 163: Beilschmiedia obtusifolia, Upper Epidermis.
(Scale Bar = 50um).

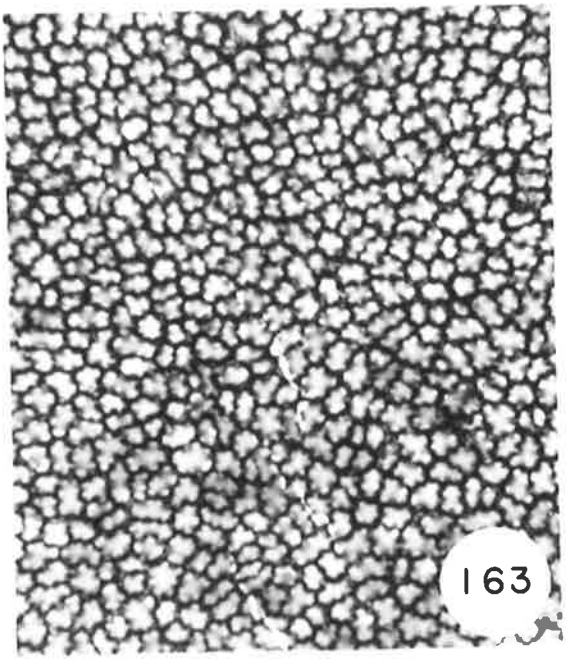
Figure 164: Beilschmiedia obtusifolia, Lower Epidermis.
(Scale Bar = 50um).

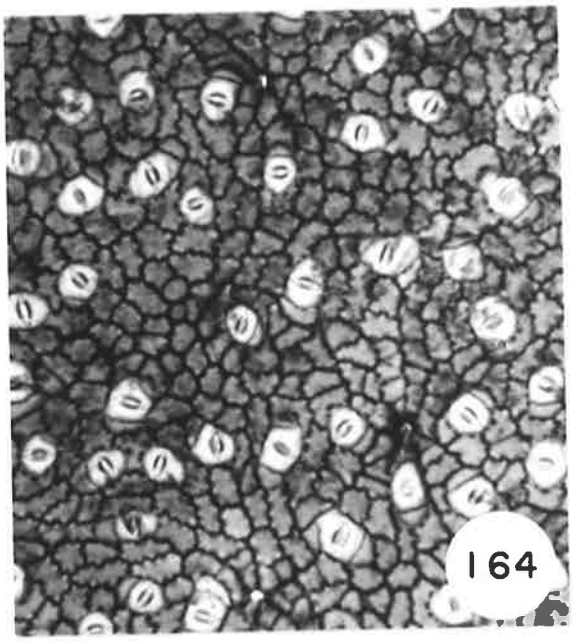
Figure 165: Beilschmiedia obtusifolia, Stomate.
(Scale Bar = 12.5um).

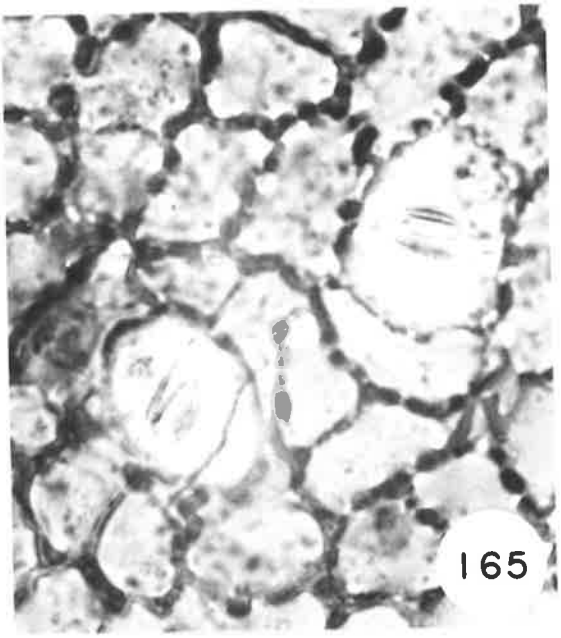
Figure 166: Beilschmiedia tawa, Upper Epidermis.
(Scale Bar = 50um).

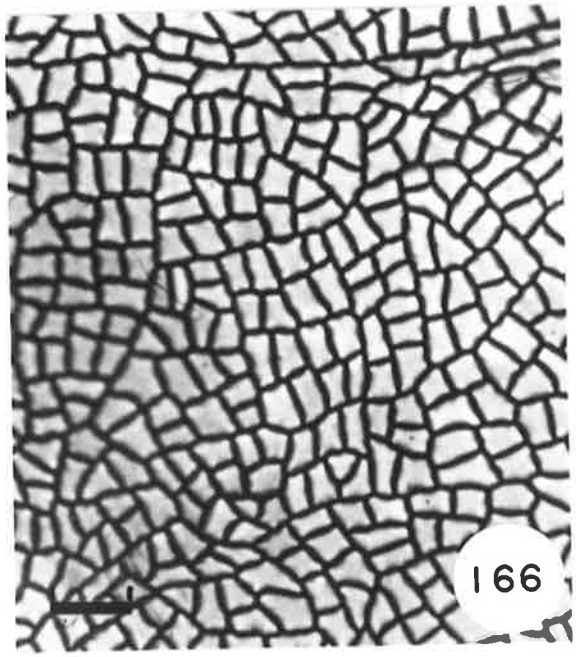
Figure 167: Beilschmiedia tawa, Lower Epidermis.
(Scale Bar = 50um).


162


163


164


165


166

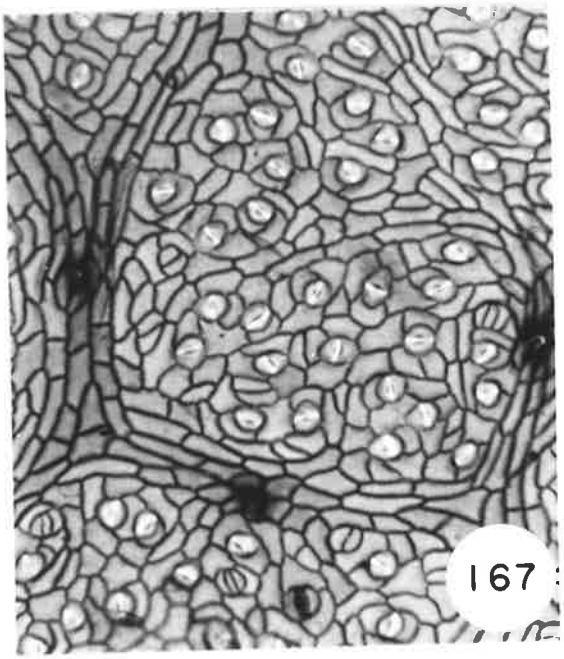

167

Figure 168: Endiandra discolor, Upper Epidermis.
(Scale Bar = 50um).

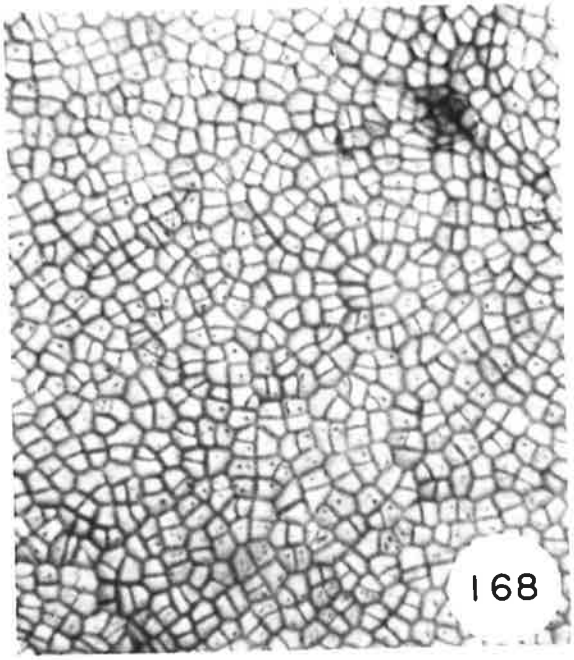
Figure 169: Endiandra discolor, Lower Epidermis.
(Scale Bar = 50um).

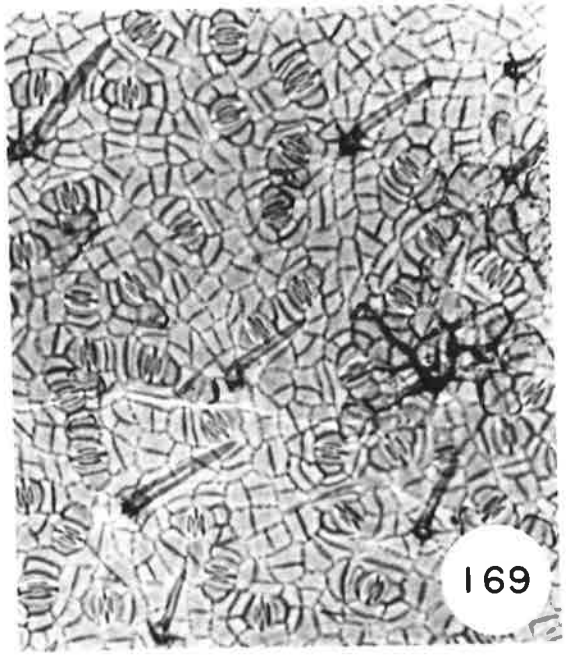
Figure 170: Endiandra discolor, Stomate.
(Scale Bar = 12.5um).

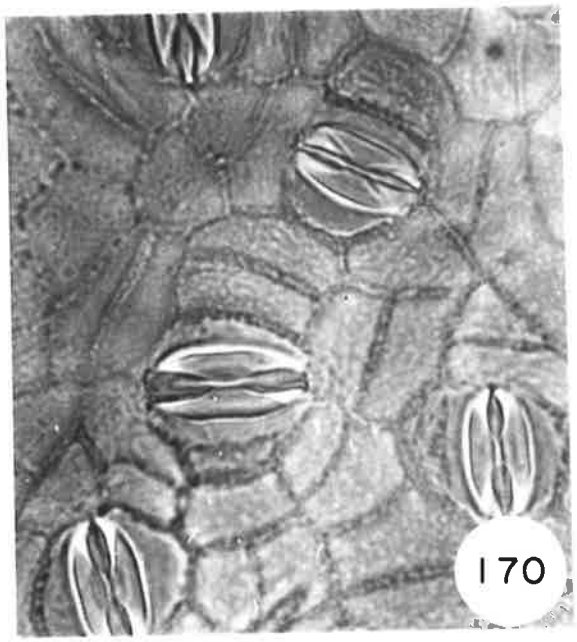
Figure 171: Endiandra polyneura, Upper Epidermis.
(Scale Bar = 50um).

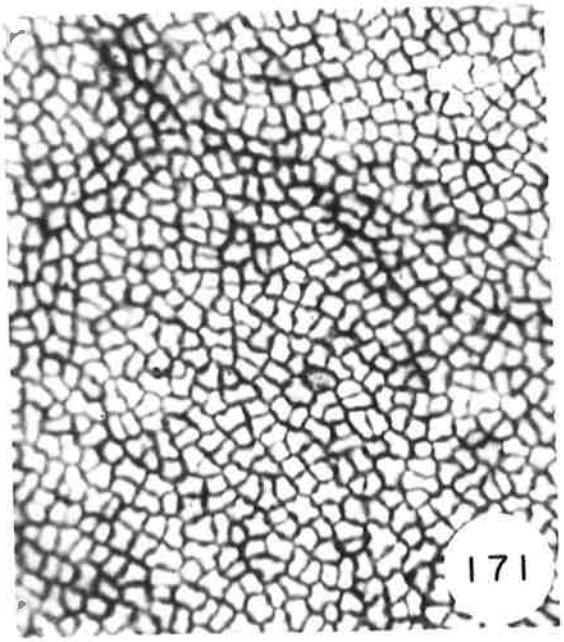
Figure 172: Endiandra polyneura, Lower Epidermis.
(Scale Bar = 50um).

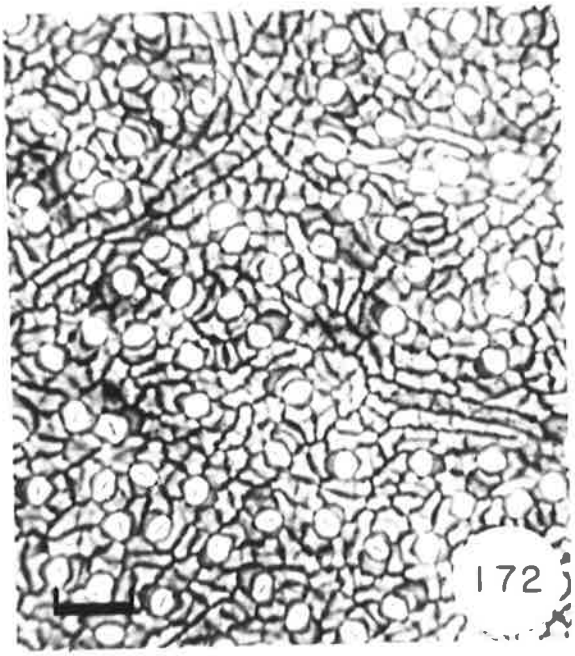
Figure 173: Endiandra aneityensis, Upper Epidermis.
(Scale Bar = 12.5um).


168


169


170


171


172

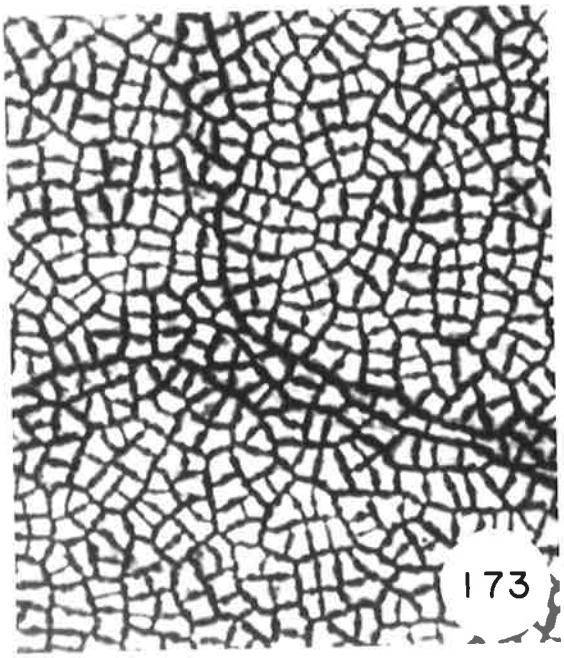

173

Figure 174: Endiandra aneityensis, Lower Epidermis.
(Scale Bar = 12.5um).

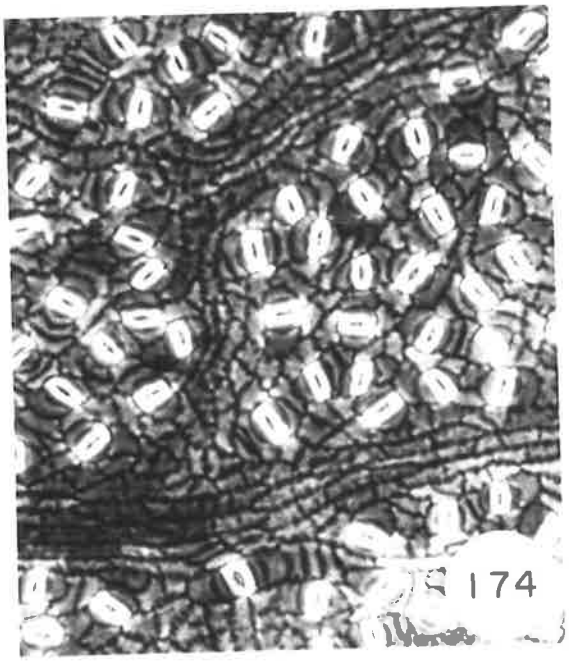
Figure 175: Endiandra pubens, Upper Epidermis.
(Scale Bar = 50um).

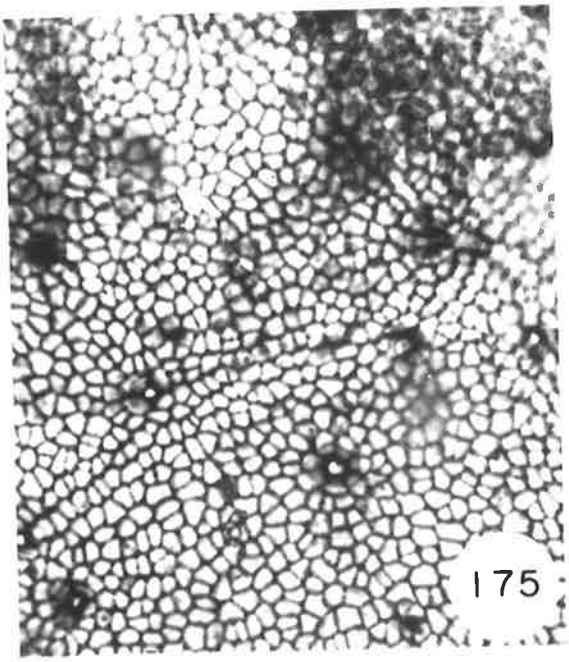
Figure 176: Endiandra pubens, Lower Epidermis.
(Scale Bar = 50um).

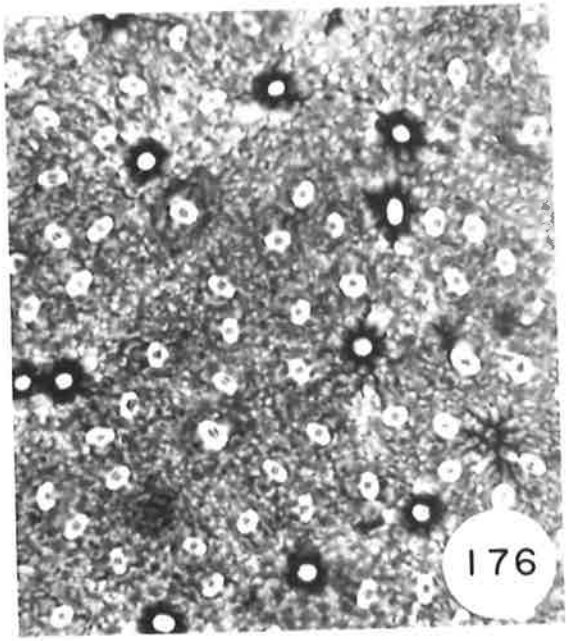
Figure 177: Endiandra pubens, Stomate.
(Scale Bar = 12.5um).

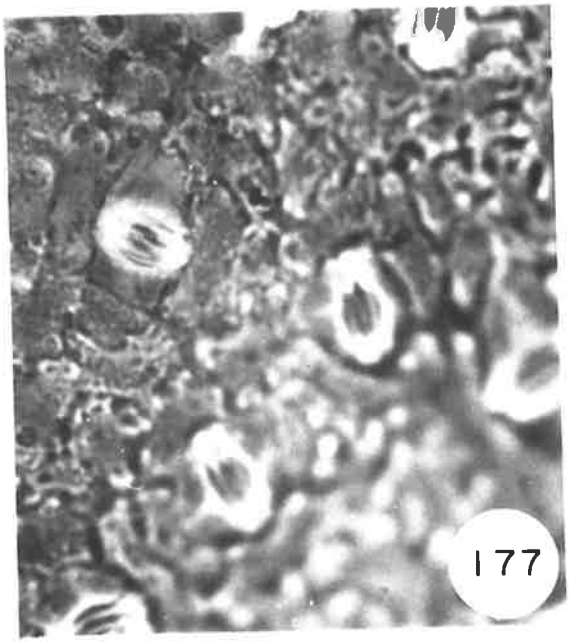
Figure 178: Endiandra crassiflora, Upper Epidermis.
(Scale Bar = 50um).

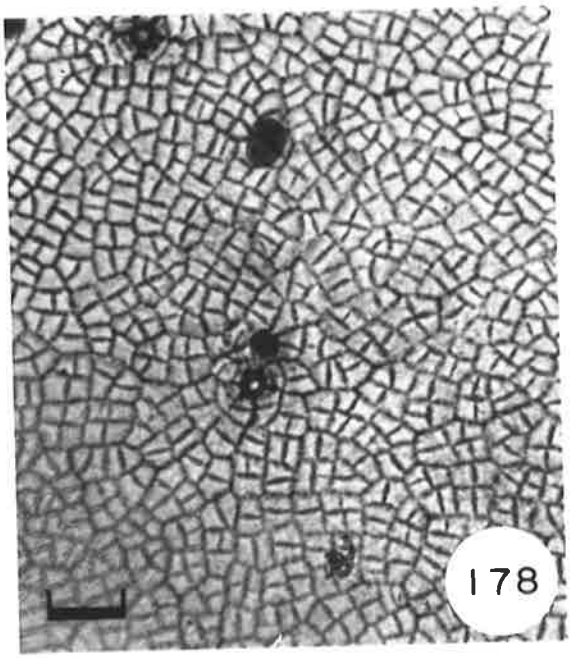
Figure 179: Endiandra crassiflora, Lower Epidermis.
(Scale Bar = 50um).


174


175


176


177


178

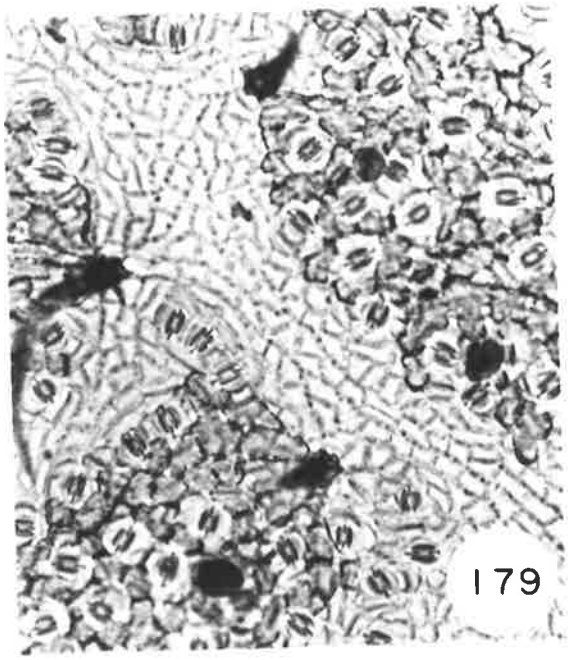

179

Figure 180: Endiandra crassiflora, Stomate.
(Scale Bar = 12.5um).

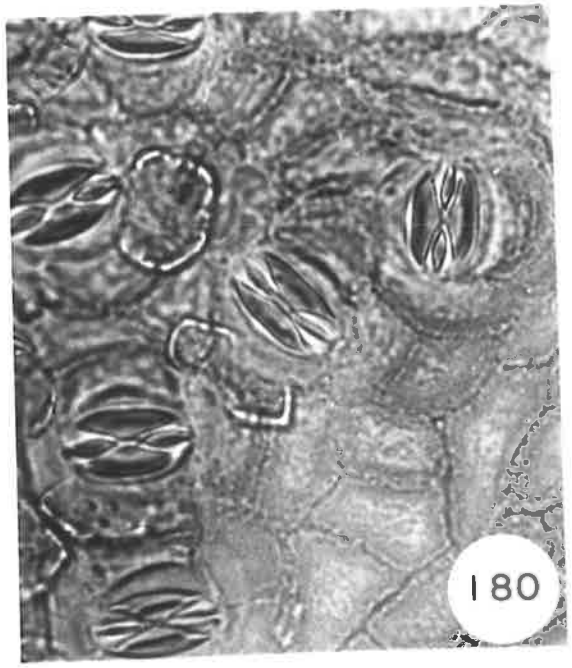
Figure 181: Endiandra hayesi, Upper Epidermis.
(Scale Bar = 50um).

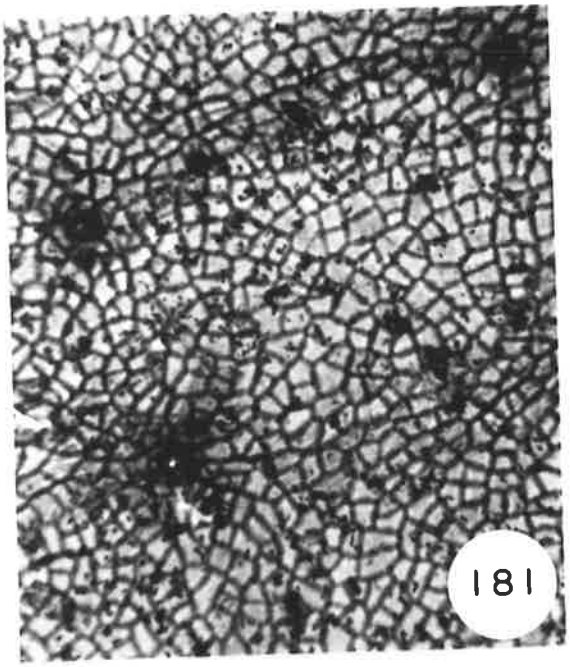
Figure 182: Endiandra hayesi, Lower Epidermis.
(Scale Bar = 50um).

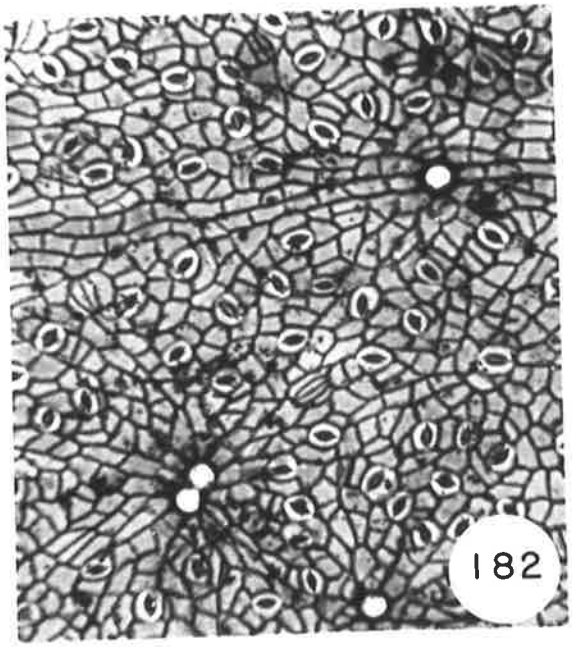
Figure 183: Endiandra hayesi, Stomate.
(Scale Bar = 12.5um).

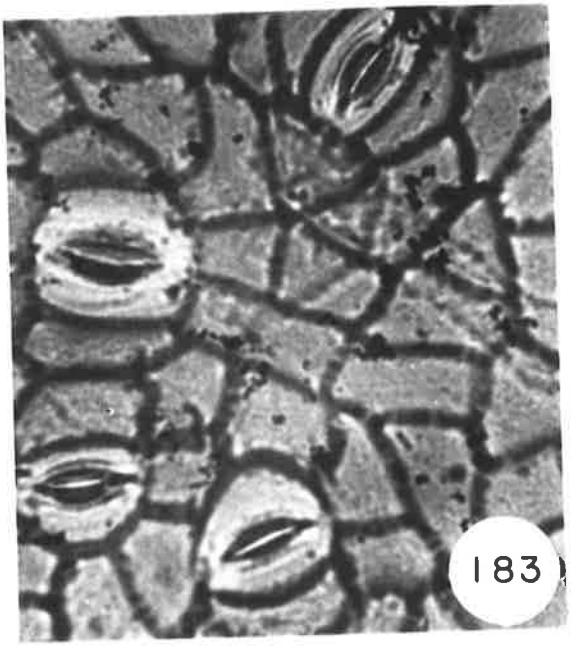
Figure 184: Endiandra introrsa, Upper Epidermis.
(Scale Bar = 50um).

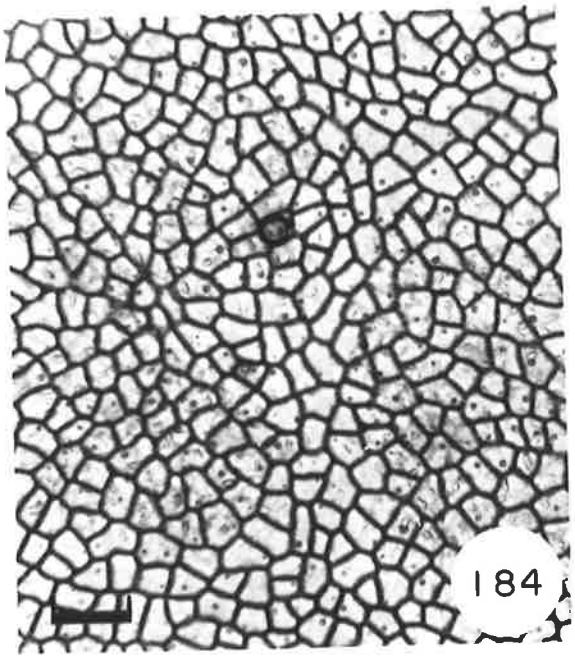
Figure 185: Endiandra introrsa, Lower Epidermis.
(Scale Bar = 50um).


180


181


182


183


184

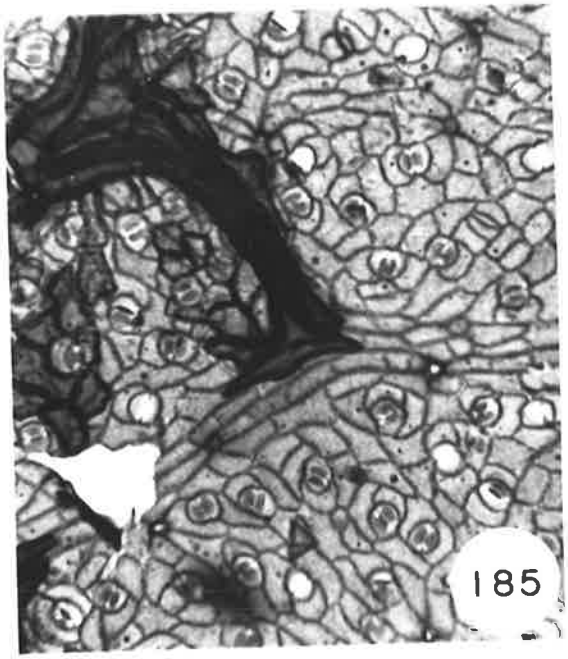

185

Figure 186: Endiandra introrsa, Stomate.
(Scale Bar = 12.5um).

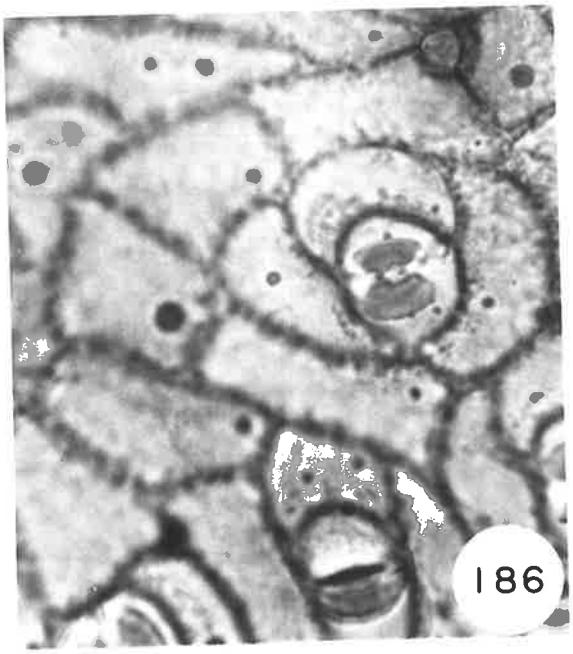
Figure 187: Endiandra muelleri, Upper Epidermis.
(Scale Bar = 50um).

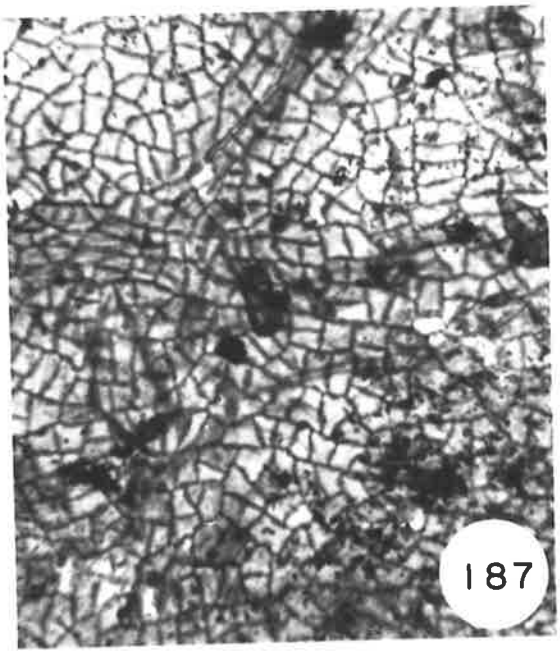
Figure 188: Endiandra muelleri, Lower Epidermis.
(Scale Bar = 50um).

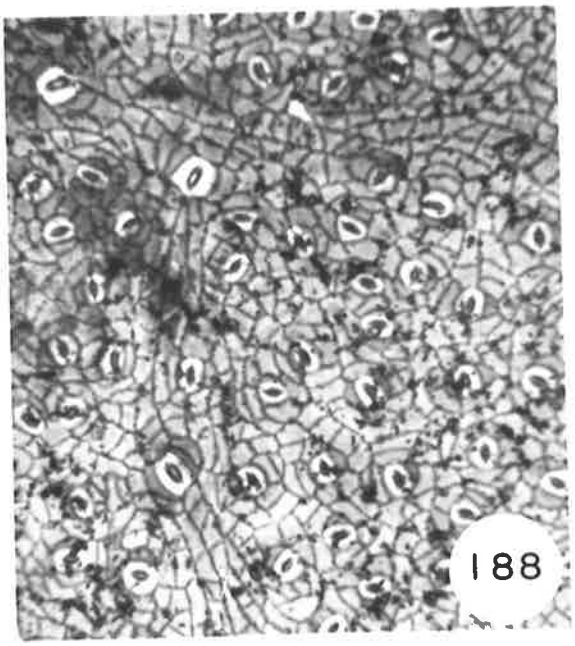
Figure 189: Endiandra muelleri, Stomate.
(Scale Bar = 12.5um).

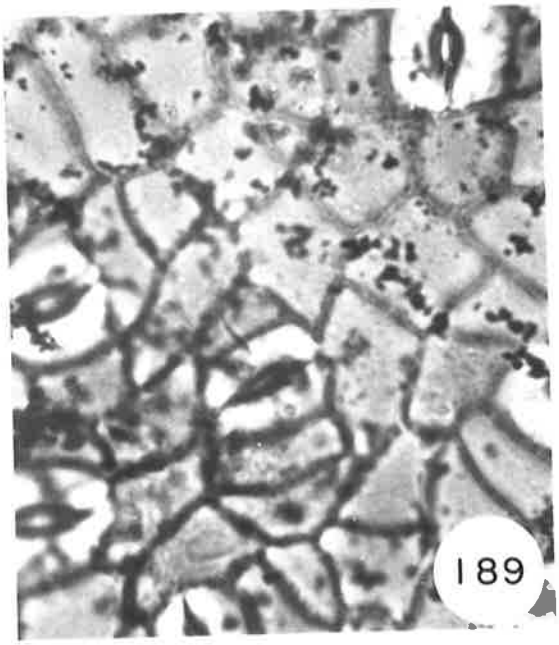
Figure 190: Deehasia incrassata, Upper Epidermis.
(Scale Bar = 50um).

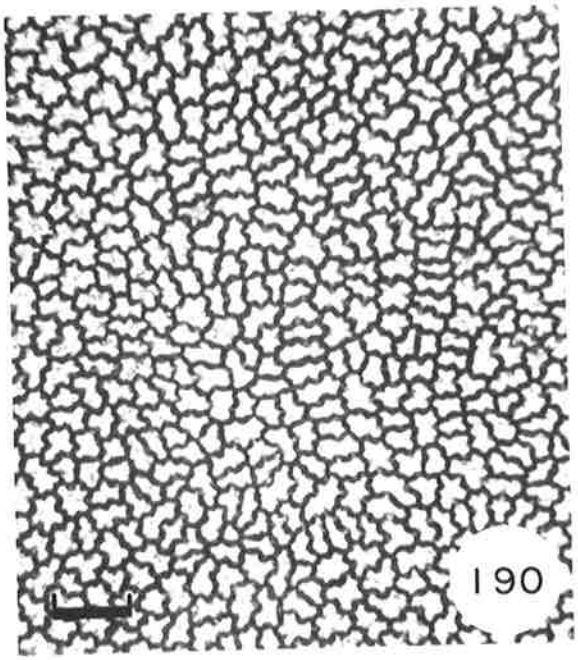
Figure 191: Deehasia incrassata, Lower Epidermis.
(Scale Bar = 12.5um).


186


187


188


189


190

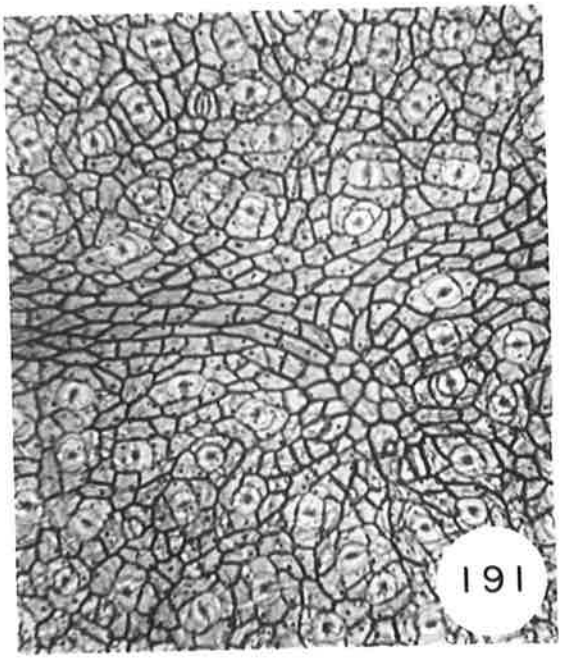

191

Figure 192: Cinnamomum oliveri, Upper Epidermis.
(Scale Bar = 50um).

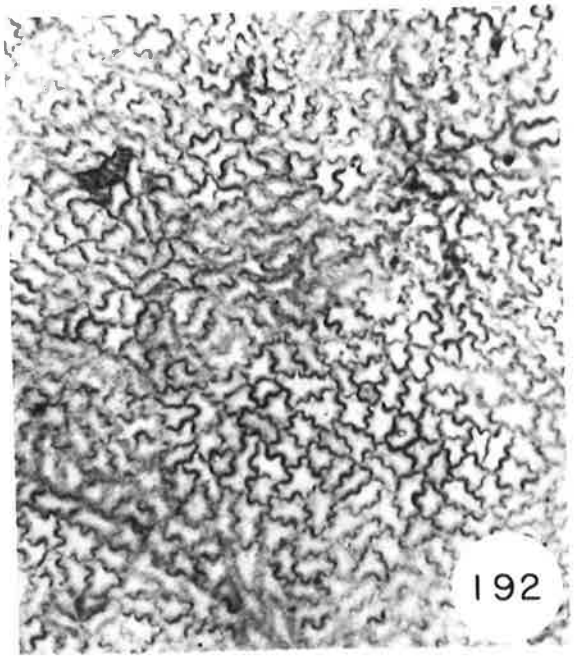
Figure 193: Cinnamomum oliveri, Lower Epidermis.
(Scale Bar = 50um).

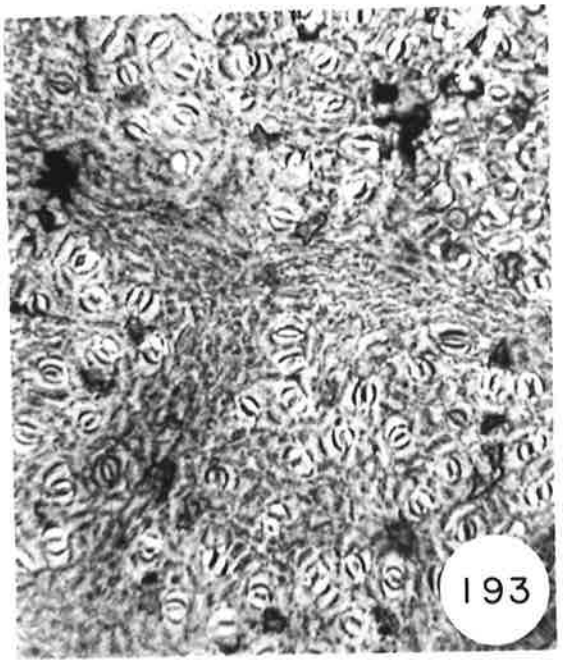
Figure 194: Cryptocarya murrayi, Upper Epidermis.
(Scale Bar = 50um).

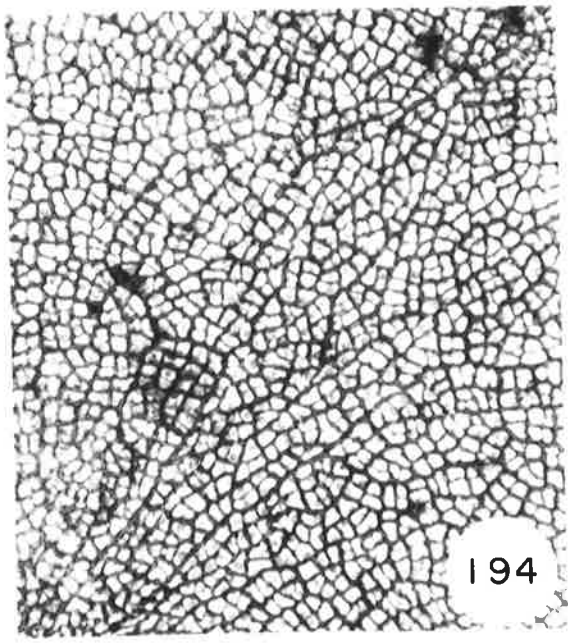
Figure 195: Cryptocarya murrayi, Lower Epidermis.
(Scale Bar = 50um).

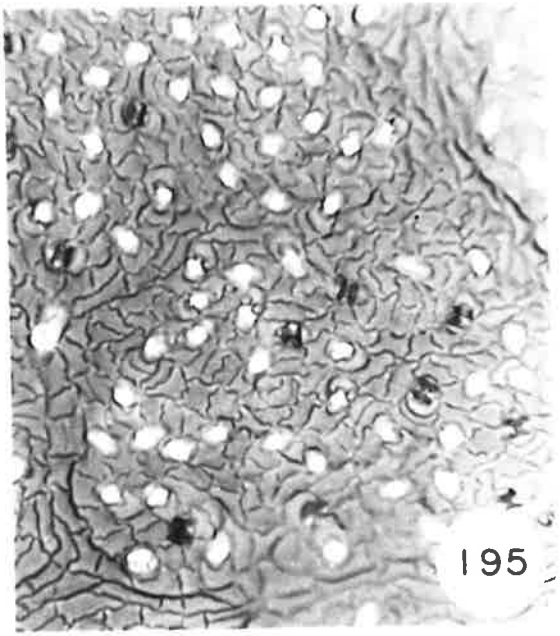
Figure 196: Cryptocarya glaucescens, Upper Epidermis.
(Scale Bar = 50um).

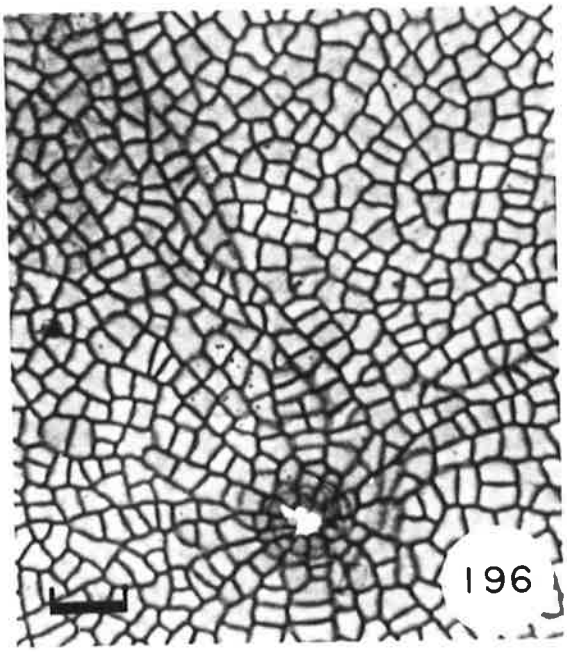
Figure 197: Cryptocarya glaucescens, Lower Epidermis.
(Scale Bar = 50um).


192


193


194


195


196

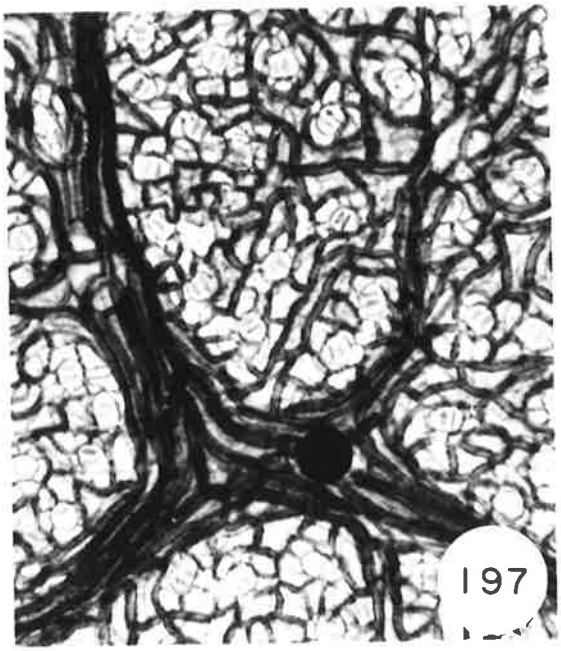

197

Figure 198: Cryptocarya glaucescens, Stomate.
(Scale Bar = 12.5um).

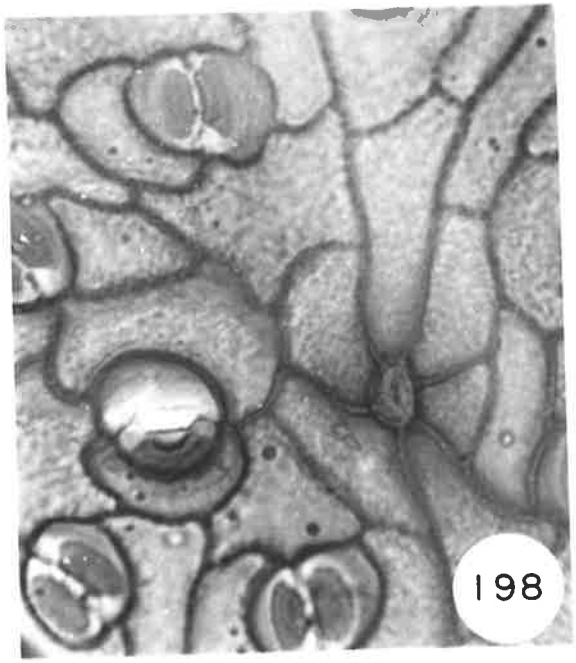
Figure 199: Cryptocarya erythoxylon, Upper Epidermis.
(Scale Bar = 50um).

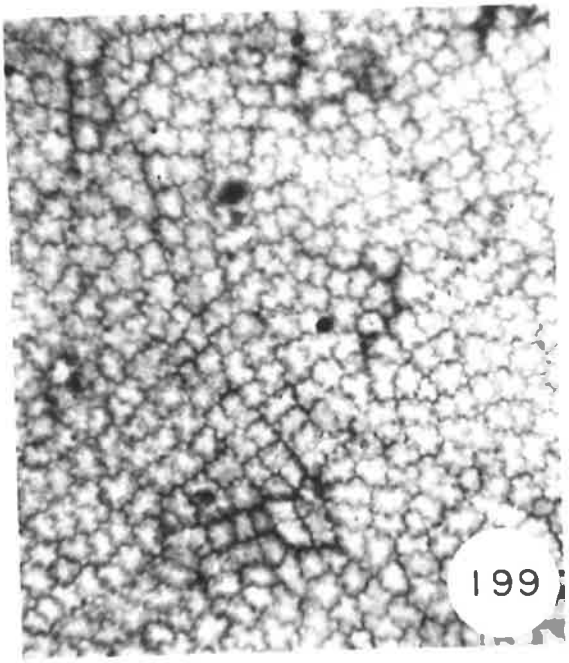
Figure 200: Cryptocarya erythoxylon, Lower Epidermis.
(Scale Bar = 50um).

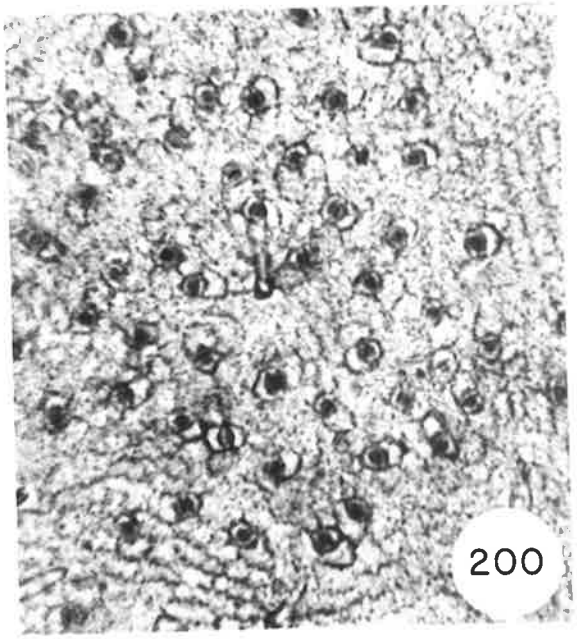
Figure 201: Cryptocarya ilocana, Upper Epidermis.
(Scale Bar = 50um).

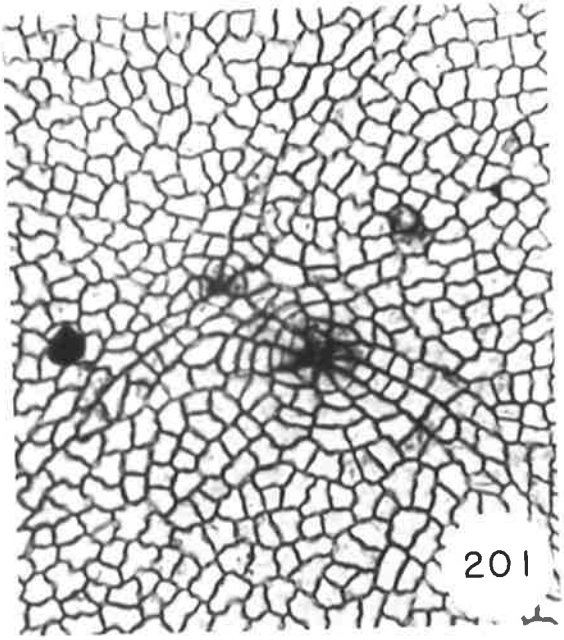
Figure 202: Cryptocarya ilocana, Lower Epidermis.
(Scale Bar = 50um).

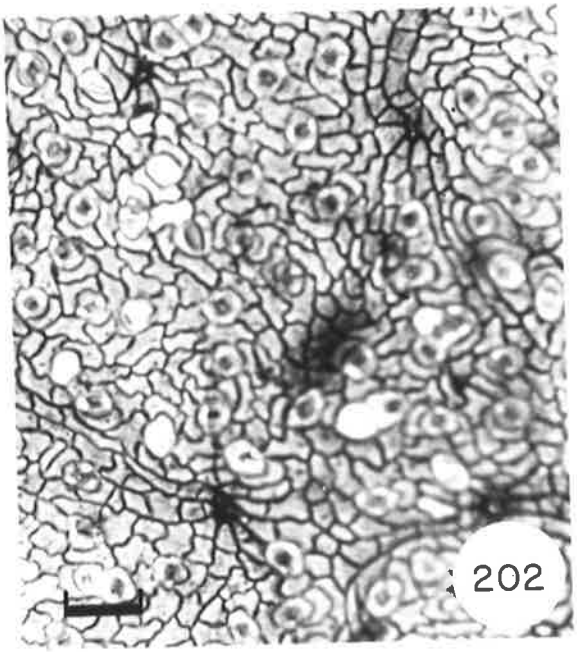
Figure 203: Cryptocarya cinnamomifolia, Upper Epidermis.
(Scale Bar = 50um).


198


199


200


201


202

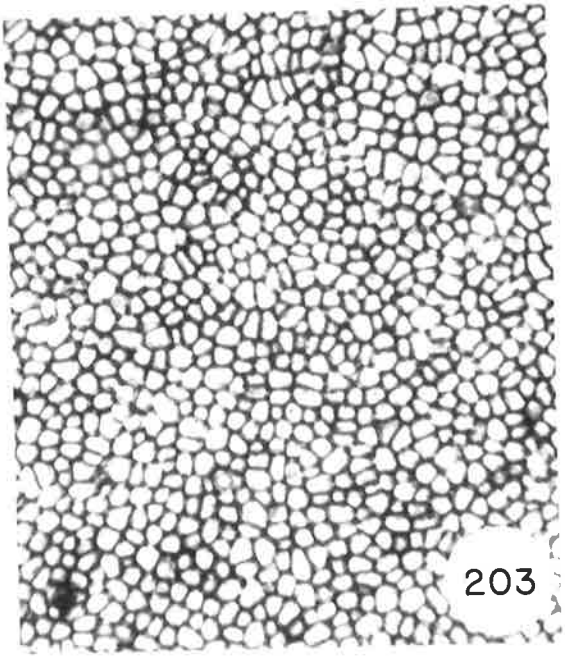

203

Figure 204: Cryptocarya cinnamomifolia, Lower Epidermis.
(Scale Bar = 50um).

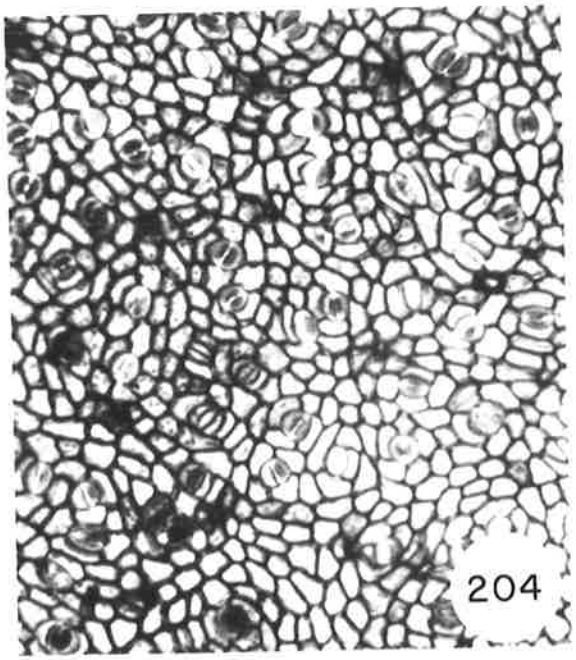
Figure 205: Cryptocarya cinnamomifolia, Stomate.
(Scale Bar = 12.5um).

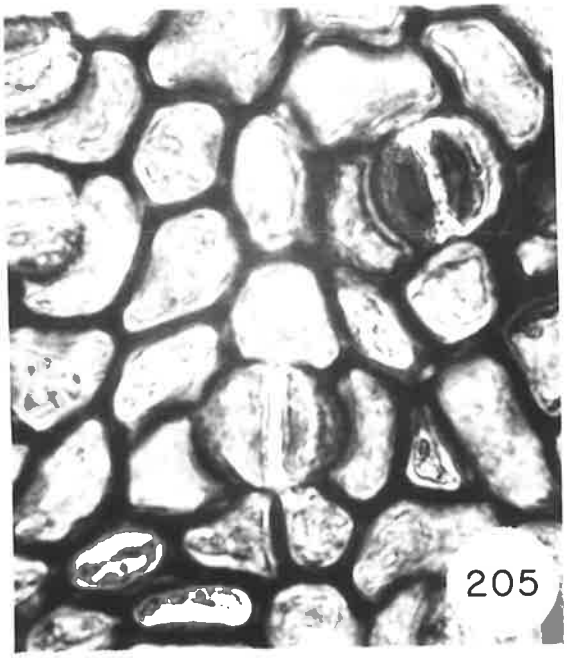
Figure 206: Cryptocarya oblata, Upper Epidermis.
(Scale Bar = 50um).

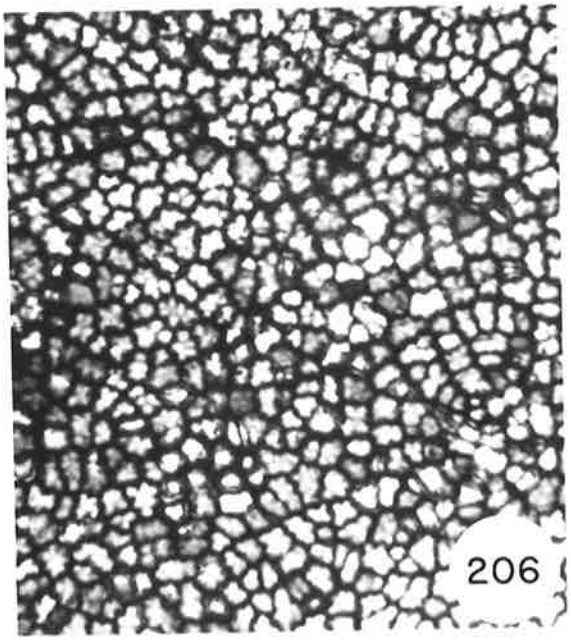
Figure 207: Cryptocarya oblata, Lower Epidermis.
(Scale Bar = 50um).

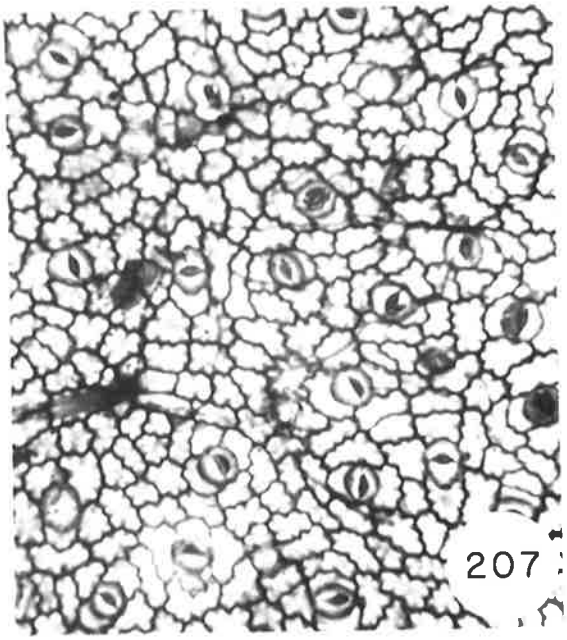
Figure 208: Cryptocarya oblata, Stomate.
(Scale Bar = 50um).

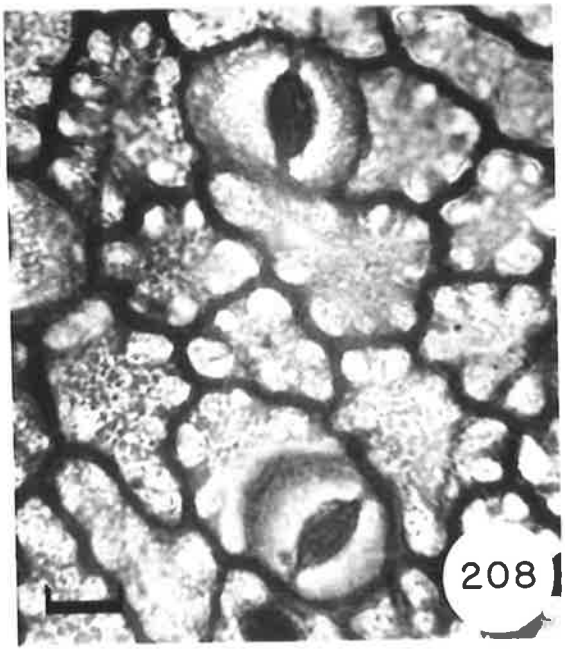
Figure 209: Cryptocarya triplinervis, Upper Epidermis.
(Scale Bar = 12.5um).


204


205


206


207


208

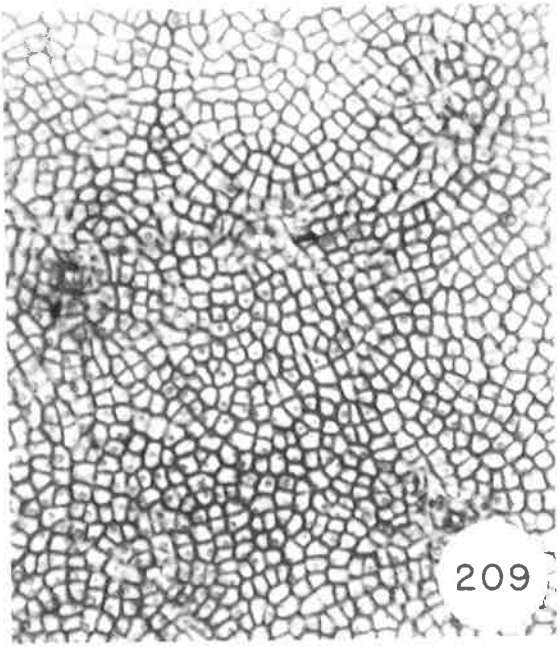

209

Figure 210: Cryptocarya triplinervis, Lower Epidermis.
(Scale Bar = 50um).

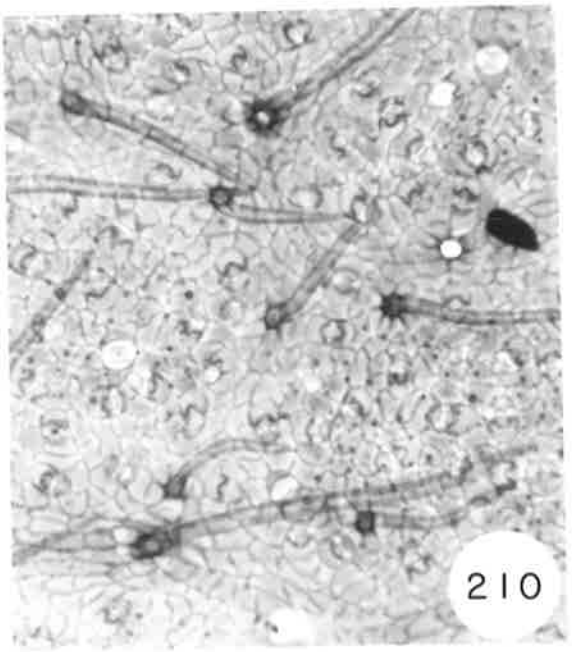
Figure 211: Cryptocarya triplinervis, Stomate.
(Scale Bar = 12.5um).

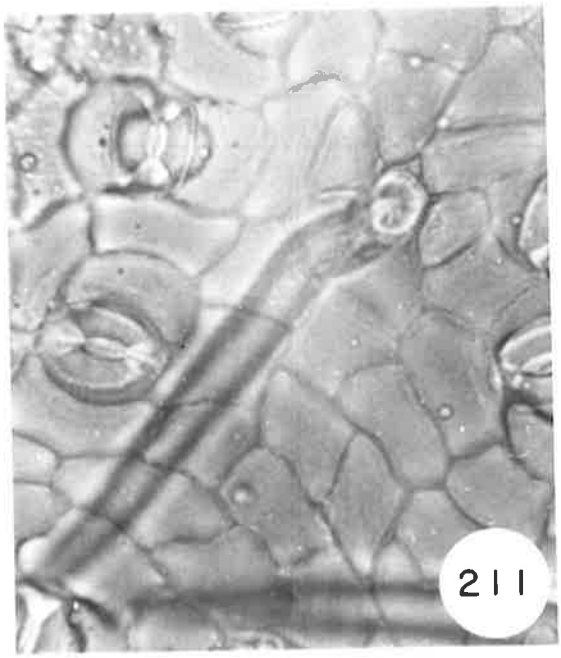
Figure 212: Litsea leefeana, Upper Epidermis.
(Scale Bar = 50um).

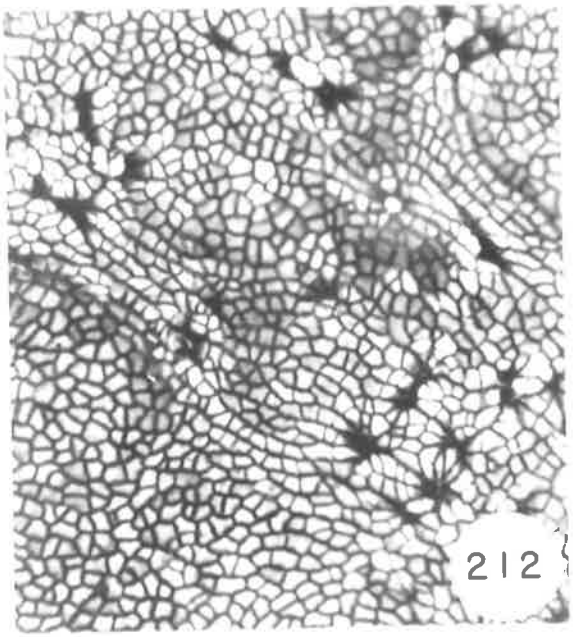
Figure 213: Litsea leefeana, Lower Epidermis.
(Scale Bar = 50um).

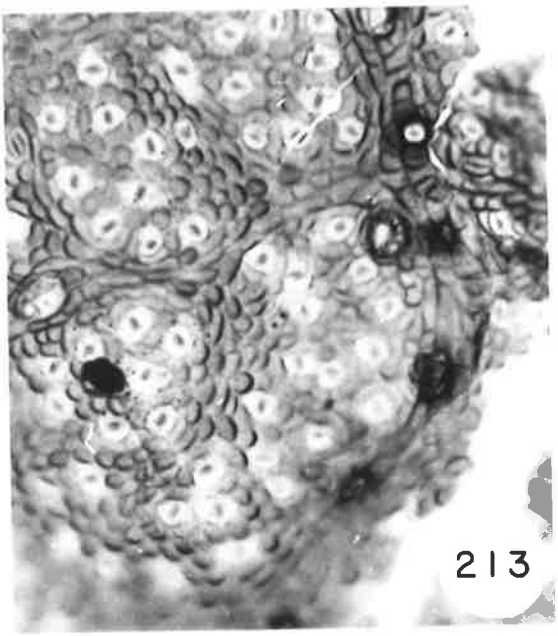
Figure 214: Litsea leefeana, Stomate.
(Scale Bar = 12.5um).

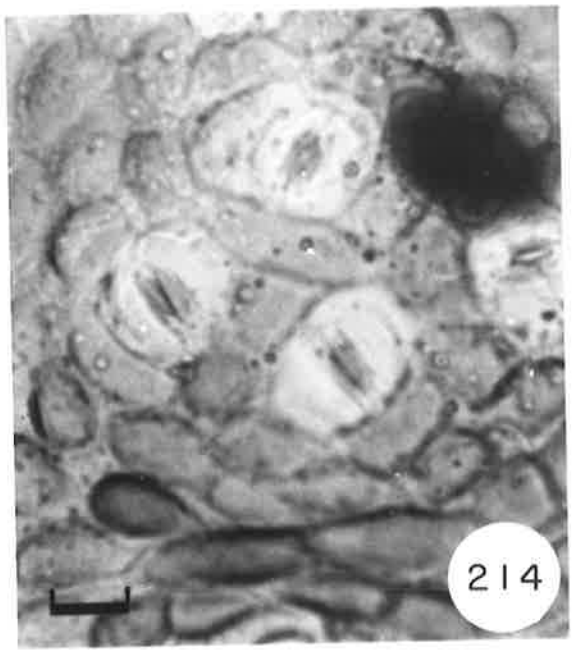
Figure 215: Litsea ferruginea, Upper Epidermis.
(Scale Bar = 50um).


210


211


212


213


214

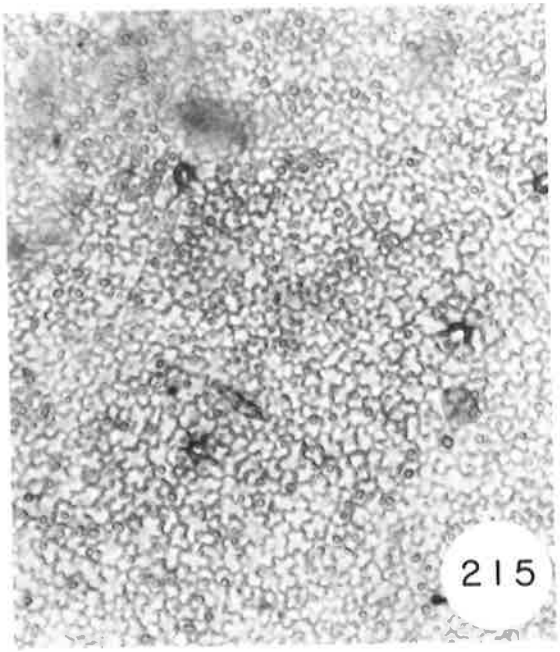

215

Figure 216: Litsea ferruginea, Lower Epidermis.
(Scale Bar = 50um).

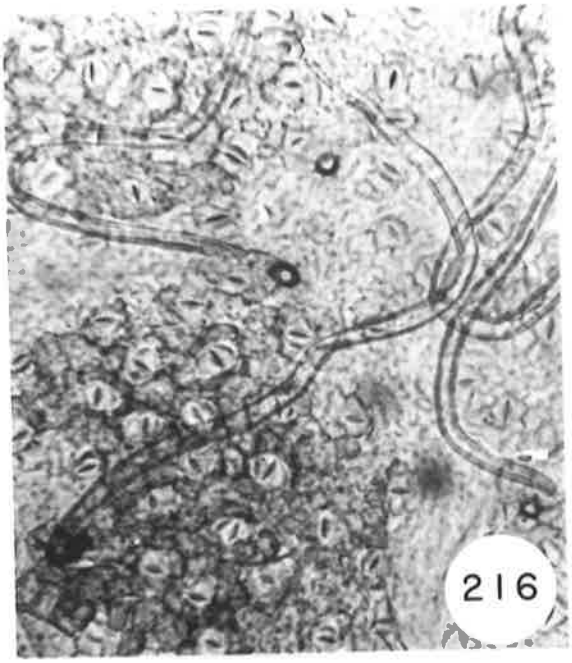
Figure 217: Litsea ferruginea, Stomate.
(Scale Bar = 12.5um).

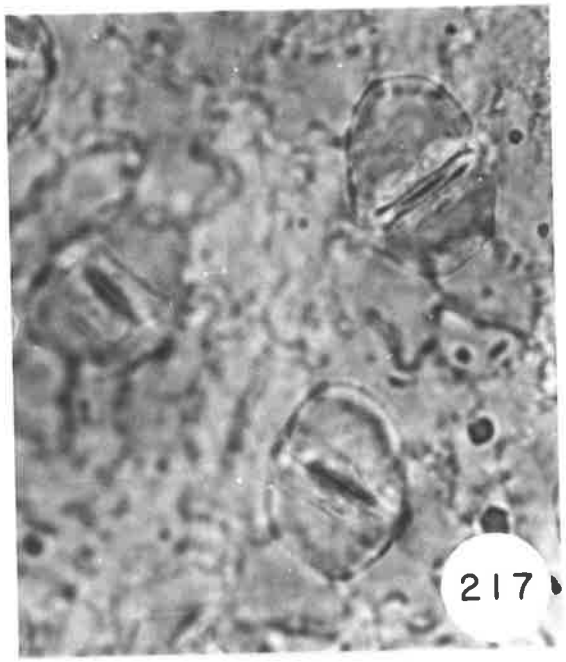
Figure 218: Litsea reticulata, Upper Epidermis.
(Scale Bar = 50um).

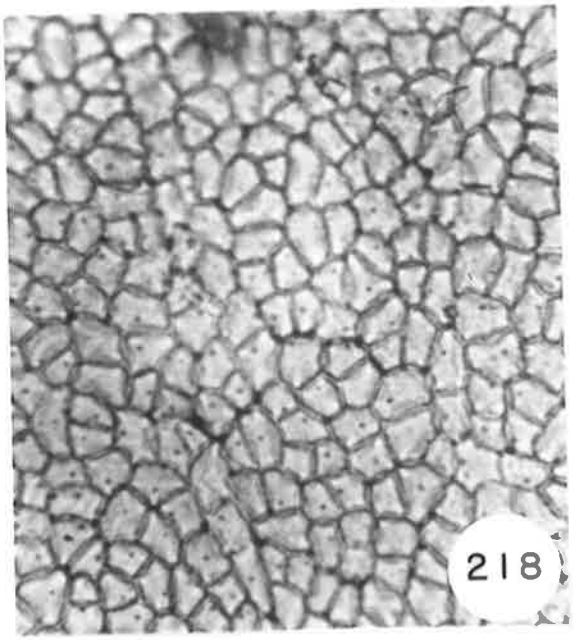
Figure 219: Litsea reticulata, Lower Epidermis.
(Scale Bar = 50um).

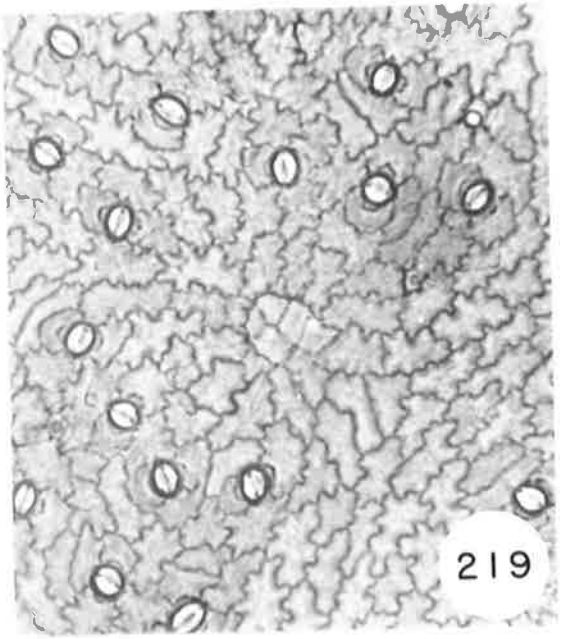
Figure 220: Litsea reticulata, Stomate.
(Scale Bar = 12.5um).

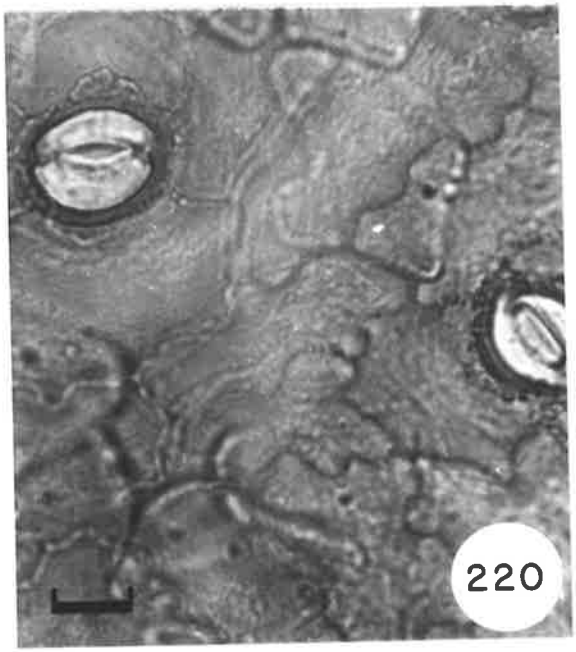
Figure 221: Litsea japonica, Upper Epidermis.
(Scale Bar = 50um).


216


217


218


219


220

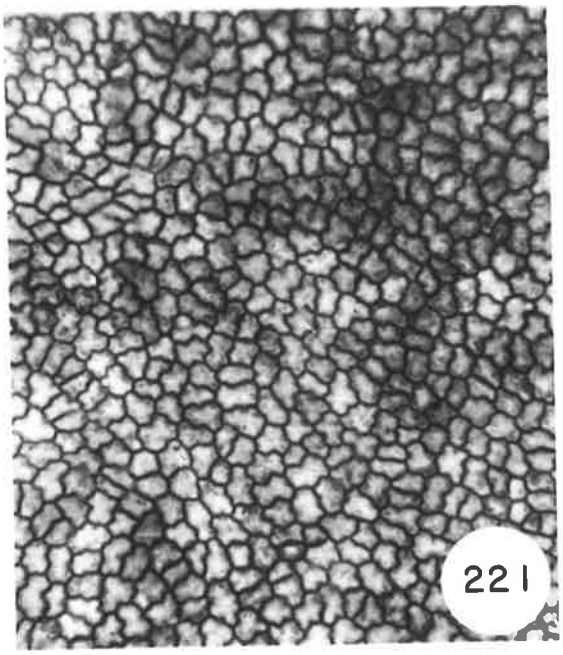

221

Figure 222: Litsea japonica, Lower Epidermis.
(Scale Bar = 50um).

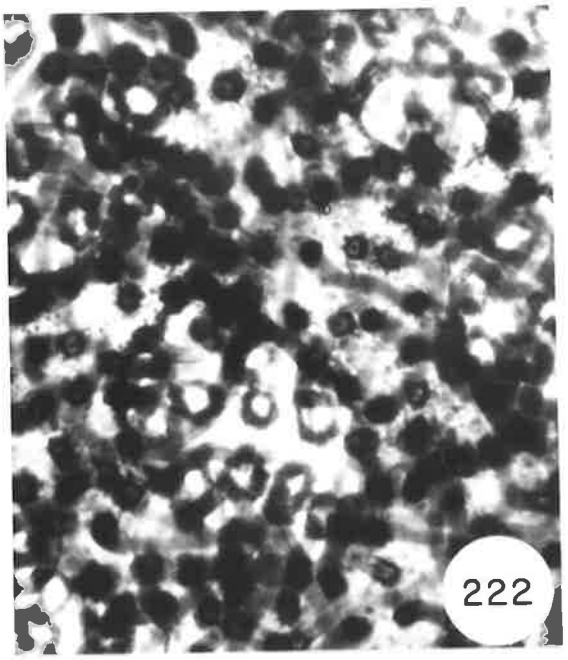
Figure 223: Litsea glutinosa, Upper Epidermis.
(Scale Bar = 50um).

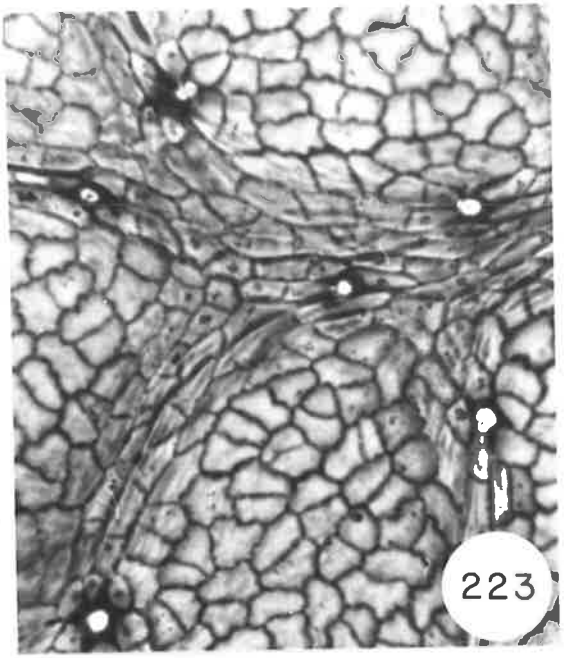
Figure 224: Litsea glutinosa, Lower Epidermis.
(Scale Bar = 50um).

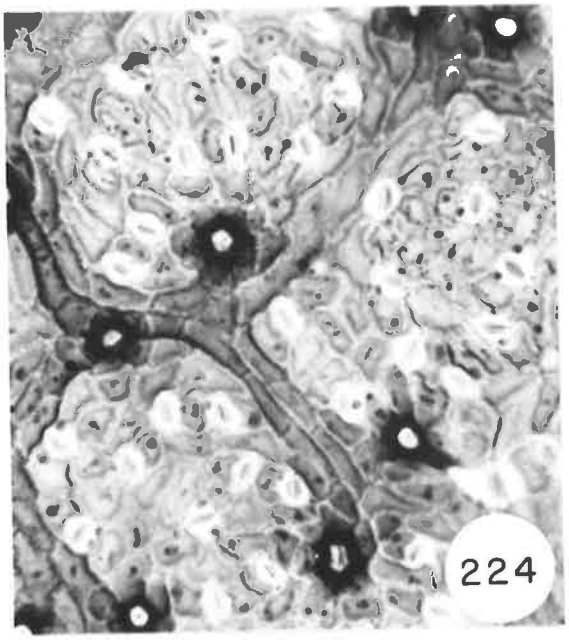
Figure 225: Litsea glutinosa, Stomate.
(Scale Bar = 12.5um).

Figure 226: Neolitsea dealbata, Upper Epidermis.
(Scale Bar = 50um).

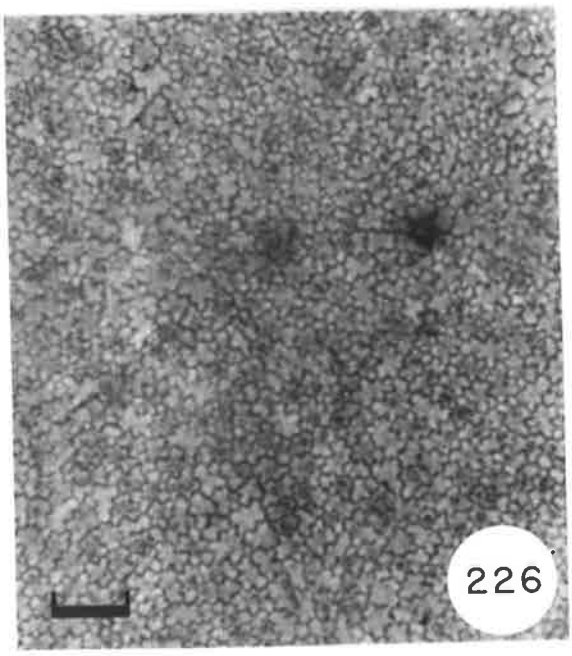
Figure 227: Neolitsea dealbata, Lower Epidermis.
(Scale Bar = 50um).


222


223


224


225


226

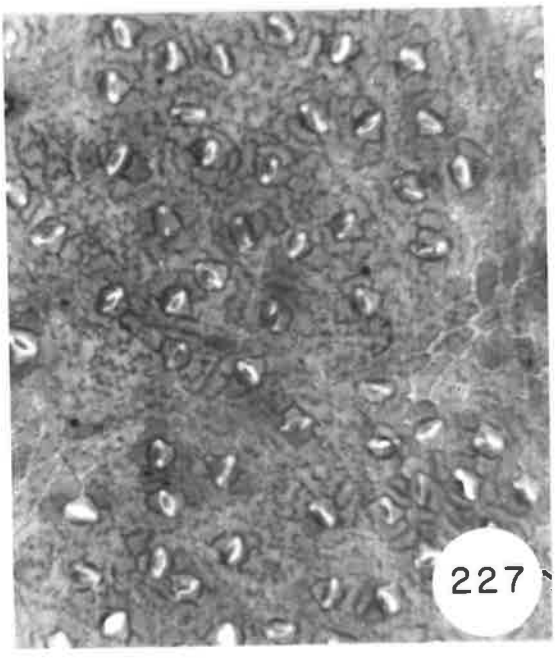

227

Figure 228: Darlingia ferruginea, Upper Epidermis.
(Scale Bar = 50um).

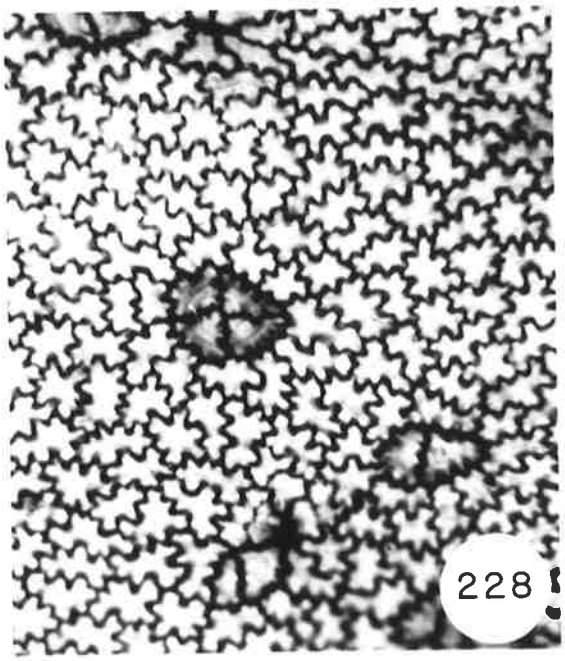
Figure 229: Darlingia ferruginea, Trichome Base on the Upper Epidermis. (Scale Bar = 12.5um).

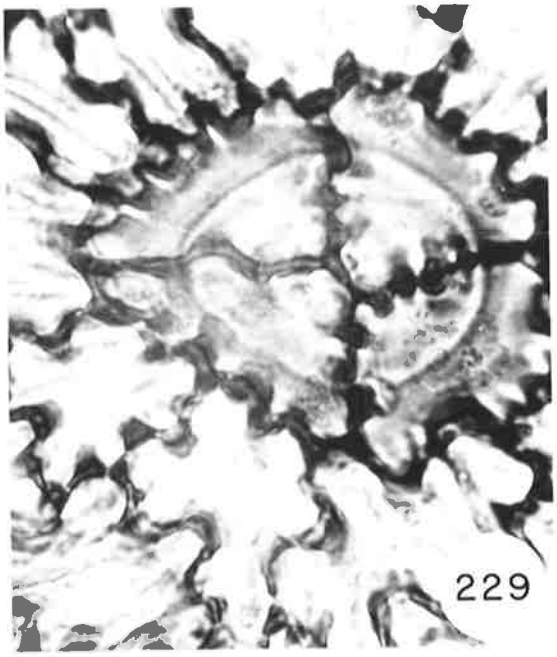
Figure 230: Darlingia ferruginea, Lower Epidermis.
(Scale Bar = 50um).

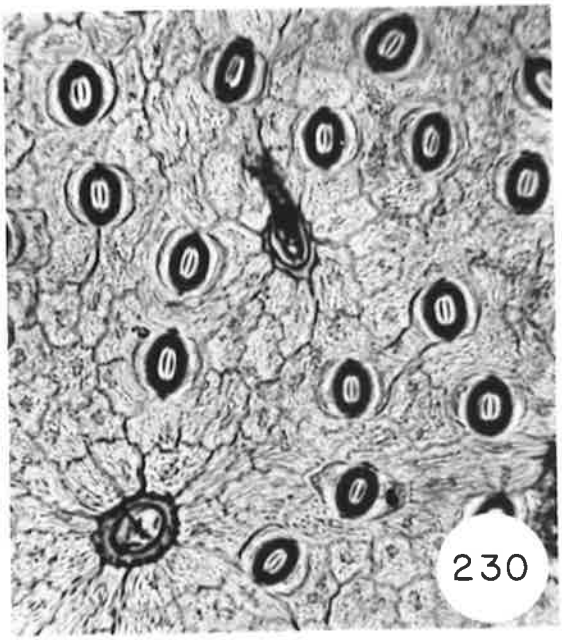
Figure 231: Cardwellia sublimis, Upper Epidermis.
(Scale Bar = 12.5um).

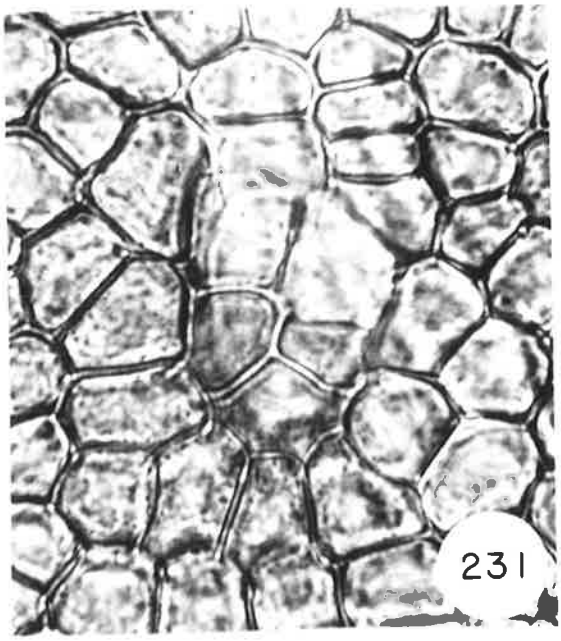
Figure 232: Cardwellia sublimis, Lower Epidermis.
(Scale Bar = 50um).

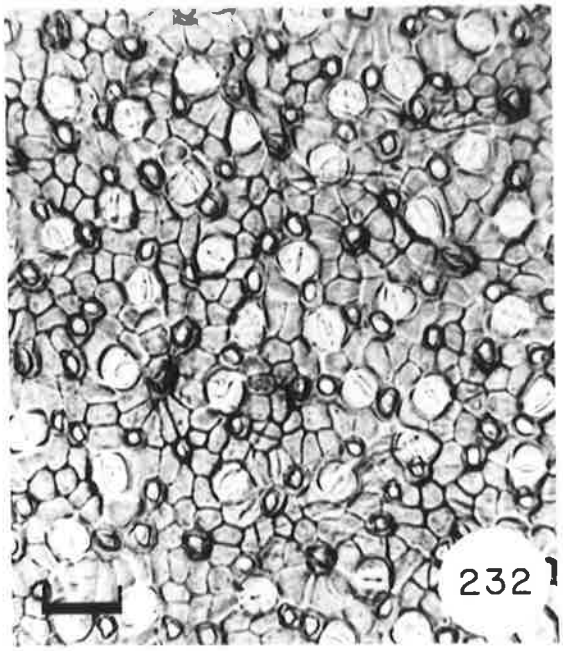
Figure 233: Cardwellia sublimis, Stomate.
(Scale Bar = 12.5um).

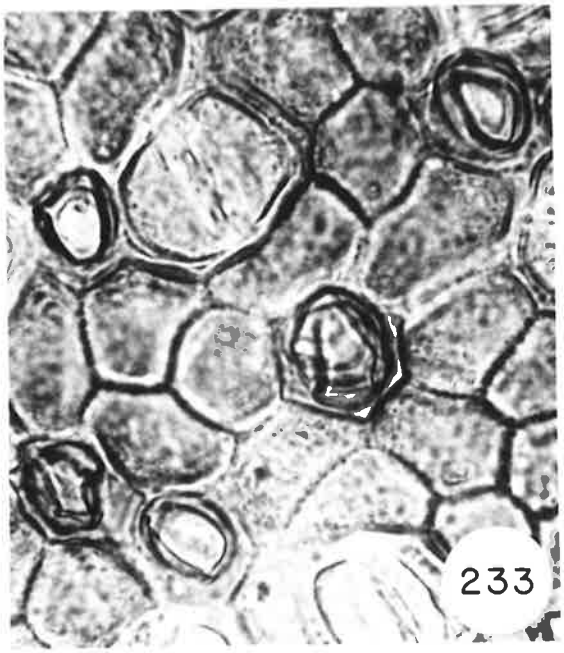

228


229


230


231


232


233

I have extensively reviewed my examiner's remarks and in consultation with my supervisor, Dr. David Christophel, the following amendments have been made to my thesis.

Each of the comments made by Prof. D. Dilcher, which dealt primarily with semantics and typographical errors, have been reviewed and the suggested amendments undertaken.

The other examiner arrived at a number of additional recommendations after review of my thesis. Some I accept as being valid and enhancing the overall content of the document. However he makes a number of points which I would like to contest and thank you for the opportunity to present my viewpoints.

Of the six major recommendations made by this examiner No. i (small typographic errors .....) and No ii (omissions.....) have been dealt with as suggested.

Recommendation No iii (Deficiencies in Identification)
The standard palaeobotanical practice is identification by comparison, either with other plant fossils or modern plant groups. Holotypes are exceedingly rare. It is standard practice to consult holotypes in taxonomic revisional work (e.g. monographs) but not for comparison/identifications as done in this thesis.
Dispersed cuticle analysis is a greatly neglected field of palaeobotanical research, particularly in Australia and this makes it extremely difficult to identify fossil cuticle types by comparsion, let alone using holotypes.

If identifications are to be made, workers have to use all available sources of information, and this includes the use of unpublished material in the form of Honours and Ph.D theses which represents an invaluable research resource. Otherwise the already small data base becomes even smaller and much valuable information is lost. A great majority of this material is eventually published allowing amendments to be made and published references cited. For example, Syber (1983), an unpublished work cited in my thesis to compare the Curlew Formation flora with a similarly aged flora from southern Australia has since gone to press and this has been noted in my thesis by a footnote (page 42) and the reference cited.

The second part of this recommendation refers to three specific identifications, i.e. the pollen type Graminidites and cuticle types Gymnostoma and Synaphea. These criticisms reflect a difference of opinion. The pollen grains I identified as Graminidites were confirmed by two other practising palynologists prior to the submission of the thesis. They were Mr. Wayne Harris who is internationally recognized for his work on Australian Tertiary Palynology and Dr. Clinton Foster who has also studied the palynoflora of the Curlew Formation and is therefore familiar with the state of preservation and the type of palynomorphs present. In recognition of the examiner's doubt concerning the identity of these grains I have changed the identification from positive to possible.

.../2

p 142 His criticism of Gymnostoma identification is unfounded. I am fully aware as to where stomates are located on this plant and the statement referring to an inability to distinguish an upper and lower epidermis has been deleted to avoid this misconception. The evidence available makes the identification of Gymnostoma beyond doubt. It is very similar to the same Anglesea fossil cuticles used by Christophel (1980) to first identify and describe the fossil Gymnostoma. Cell size and shape, stomatal arrangement, subsidiary cell position and number are features of the Curlew cuticle which compare very well with those of the southern Gymnostoma. Christophel himself has confirmed the Curlew fossil as Gymnostoma.

A comparative process was again used in the identification of Synaphea. The Curlew cuticle was shown to be very similar to the same fossil material identified by Lange (1978b) as having a strong affinity to Synaphea. Having established an affinity between the two fossil cuticles modern proteaceous cuticles were examined. It should be noted that the Proteaceae is a large family containing 75 genera and 1500 species, hence making it impossible to use the same method of examination employed for the Lauraceae. However, representatives of each of the nine genera most closely related to Synaphea, i.e. the tribe Conospermeae, were examined and it was shown that only the modern species of Synaphea were comparable to the Curlew cuticle. Based on this evidence I have no doubt this cuticle has a strong affinity to Synaphea.

Recommendation No. iv (Deficiencies in argument ....)
Considering Prof. Dilcher's comments on the thesis it is difficult to accept all criticisms made by this examiner. I have closely reviewed his list of " Comments, Corrections and Criticisms" and I have made several changes, however. I am hesitant to make such wholesale changes to the thesis as he suggests given that these would significantly alter the work from that which was commended by Prof. Dilcher.

The corrections and my comments regarding the examiner's criticisms are discussed below in reference to the page number cited by the examiner.

p 36 The criticism of the statement " absence of myrtaceous megafossils" is unfounded. There are a number of publications, i.e Johnston (1885), Ettingshausen (1888), Deane (1902) and Lange (1978) that claim to have identified myrtaceous megafossil remains, but the identifications have been based solely on impressions and cannot be confirmed by cuticular analysis. The only confirmed reports of Myrtaceae leaves are from the Oligocene (Hill and Macphail, 1983) and Miocene (Holmes et al, 1983), this is implied on page 36. To further clarify the fact that reference was being made to the Eocene period "Eocene" has been inserted in the above statement, i.e. "absence of Eocene myrtaceous megafossils"

In reference to Eucalyptus coccifera the species exhibits leaf features which are characteristic of the whole family and it is these features that are suggested as governing the dispersal ability of leaves and hence responsible for the scarcity of leaves in the fossil record. The climatic requirements of the species are quite irrelevant in this instance.

p48 The Mt. Larcom Range is dated as Lower Permian (Kirkegaard et al 1970) and therefore the drainage system was well established prior to the presence of the suggested Nothofagus forests.

p61 There is no denying that Malvacearumpollis and Malvacipollis are different genera. what is indicated in this instance is that Malvacipollis species from the Curlew Formation have in the past been incorrectly assigned to the genus Malvacearumpollis by Hekel (1972).

Almost all the identified parataxa of the Curlew megafossil flora are first occurences in the Queensland Tertiary but they are not new parataxa being identified for the very first time (except for the Lauraceae parataxa). The families to which these parataxa are related occurred throughout the Australian Tertiary and are well documented as are their relationships, i.e. Casuarinaceae (Christophel, 1980), Ebenaceae (Christophel and Basinger, 1982), Podocarpaceae (Greenwood, 1987), Proteaceae (Lange, 1978b; Blackburn, 1981) and Zamiaceae (Hill, 1978,1980). The type of examination suggested by the examiner is not warranted as these relationships have been confirmed in previous works and are now generally accepted throughout the Australian palaeobotanical community. However, each affinity must be established and this has been achieved by presenting a detailed description (including photographs) of each parataxon emphasising those cuticle features which determine its affinity and by discussing those diagnostic features of the related parataxa (either modern or extinct) which establish the strength of the relationship. If a relationship could not be confirmed using this procedure a tentative status has been applied to the relatioship, for example, Parataxon No. 7 (? Cyperaceace) and Parataxon No. 50 (? Cunoniaceae).

The Lauraceae parataxa have not been described from other Australian Tertiary localities therefore a more intensive analysis of these fossil types was undertaken to establish their modern affinites. As the Australian Lauraceae classification system was in the process of revision (Hyland, 1986) it was necessary to first discuss the present state of classification, develop a method of identification based on cuticle features (i.e key) and then discuss the relationships between the fossil and modern Lauraceae using a similar procedure to that discussed above.

Photographic evidence is provided for all suggested relationships either by myself or in referenced works. In the case of the Ebenaceae, Zamiaceae and Proteaceae the relationships are between two extinct fossil specimens. With access not available to the original type material for Bowenia (Zamiaceae, Hill 1978) and Synaphea (Proteaceae, Lange 1978) the use of published material was the only available method for illustrating the relationships between the fossils and their modern relative. Austrodiospyros (Christophel and Basinger, 1982) material was available and three examples of the Anglesea genus are presented.

The examiner suggests a close similarity in form may be a family feature rather than a generic one. This is true but when the possible affinities of fossil cuticles are discussed the characteristic features of family, genus and species are highlighted and explanations are provided as to why such a feature is regarded as diagnostic of a particular level (e.g. genus). In the published works of Hill (1978) and Lange (1978) those characteristics which associate the fossil parataxa with the modern genera Bowenia and Synaphea respectively are discussed in great detail allowing comparisons to be made with confidence.

I am fully conversant with the type of cuticle characters which best define a family, e.g. Trichome Base Type i.e. Complex/Simple and the type of stomatal arrangement, and those that are diagnostic of a genus, such as cuticle thickening of cell wall and position of stomate. A photograph will not be of any additional assistance in identification unless the cuticle features that distinguish the cuticle are highlighted in the text. A written description is far more informative than a photograph in this instance. Where an illustration is available and of better quality it would seem to be more appropriate to describe the distinctive features and reasons for making a particular association and then give the reader access to the best available photographic representation via a reference.

I am in agreement with the examiner's final comment on page 6 "A false sense of having finalised an identification is worse than a realistically tentative identification" and as a result of my research the identification of two parataxa No. 7 and 50 were only tentatively assigned to modern families.

p163 The reference cited presents the scale used to determine the type of cell wall undulation. This was pointed out in section 4.1.3 where the character set was defined for all cuticular descriptions.

p178 4.2.2 Chapter 4 is titled "Megafossil Descriptions", the comments in this section refer specifically to megafossils not pollen - pollen comparisons are discussed in chapter 6.

p216 Additions have been made to the Pollen Diagram. The absence of cores 116 and 139 from the analysis have been reported. Core 116 was situated right on a faultline and the Curlew sediments could not be identified. In Core 139 the Curlew sequence was incomplete and contained little plant material, it was also located outside the research area.

p245 This represents a difference of opinion between myself and my examiner. The Liliacidites pollen species have been confirmed by C. Foster who has worked on the Curlew Formation and W. Harris a Tertiary Palynologist. Reference is made to the fact that palms may have been associated with the Curlew vegetation in section 7.2.4. p285.

p248 This sentence has been deleted.

p258 The identification of Gymnostoma in the Curlew Formation is based on the examination of 185 cuticle fragments, all approximately 0.5mm and all recovered after maceration. An examination of every sample prior to maceration failed to reveal any sizeable fragments, therefore I consider the examiner's comments with regard the expected finding of short lengths of phylloclade are misplaced. It was stated in section 2.3, Fossil Preservation, that no intact fossils were recovered from the Curlew Formation. The presence of Gymnostoma in the deposit is beyond doubt. Cuticles were favourably compared with the type specimens used by Christophel (1980) to separate Gymnostoma from Casuarina. All Curlew cuticle fragments examined revealed hexagonal epidermal cells, 0 - 1 subsidiary cells, a glabrous vestiture and stomata in lateral leaf bands. Even though figures 72 and 129 are not of the same quality as those of the Anglesea fossils (Christophel, 1980) which were exceptionally well preserved, the diagnostic Gymnostoma characteristics are evident, for example, the stomata are not located in grooves (Figure 72) and they possess 0 - 1 subsidiary cells (Figure 129). The examiner's suggestion that double stomatal bands are characteristic of the Casuarinaceae is not diagnostically correct as is evident in a number of figures from Christophel (1980). To reaffirm the presence of Gymnostoma in the Curlew Formation Christophel has confirmed these identifications.

p260-277 Corrections have been made with reference to the examiner's remarks.

p279 This statement is based solely on palynological data. There is no evidence to indicate any of the Curlew palynomorphs are related to Synaphea which would warrant a modification to the suggested vegetation type, i.e. subtropical/tropical closed forest. The sclerophyllous proteaceous shrubs probably occurred on disturbed sites within this community. Anglesea (Christophel et al 1987) which has a higher proteaceous palynoflora is considered to be subtropical/tropical closed forest.

The evidence to support the statement that H.harrisii is attributable to Gymnostoma is strong. Not only do the Curlew pollen grains identified as H. harrisii compare favourably with those removed from an anther of a male cone identified as Gymnostoma (Christophel, 1980) but they also have a distinct morphology characteristic of modern Gymnostoma (Kershaw 1970a).

p280 The examiner's comments have been noted and corrections made.

p282 The easterly movement was in reference to the pollen. L 16 The logic is based on interpretations made from Luly et al (1980) whereby plants with a low habit tend to have local pollen dispersal, in which case it could be assumed that the source plants grew near the deposition site. As the examiner has indicated, some chenopods are long distance dispersers, although not directly stated by myself it was implied that the presence of these grains may have been the result of long distance dispersal.

.../6

p283 As stated in Chapter 3 the pollen Corsinipollenites oculus noctis is related to Epilobium (not Jussiaea) and therefore vegetation interpretations are based on the habits of plants within this genus.

p284 Of the numerous fern spores identified very few are recognized as having modern affinities beyond the family level, therefore I have restricted comments on habit to very general ones, i.e those of the family as a whole. I am fully aware of the exceptions mentioned by the examiner but consider the addition of more speculative information would only produce a more unrealistic interpretation of this group's contribution to the overall picture of the Curlew vegetation. A sentiment expressed earlier by the examiner himself.

It is agreed that ferns appear to reach their highest frequencies in the lignites and that these values may be the result of water carriage, however it cannot be assumed that the ferns are therefore part of an allochthonous vegetation. Transport by water is particularly abrasive and extensive damage may occur to plant material over long distances. Christophel and Blackburn, 1978 demonstrated that 2 km was sufficient to cause fragmentation of leaves. Fern spores are generally large and as a consequence are usually carried in the water column which may result in considerable buffetting both by other objects also in suspension and contact with the sides and bottom of the water course.

If spores are transported over a very short distance such as in the case of autochthonous spores, then little damage occurs, but if transported over a long distance such as in the case of allochthonous spores then the spores are distorted, broken and any ornamentation shows signs of abrasion. The excellent state of preservation of the Curlew fern palynomorphs suggests that they are part of the autochthonous flora of the Curlew Formation.

p285 L23 The identification of fossil relatives of Gymnostoma and Bowenia from the Curlew Formation adds to our knowledge of the Early Tertiary distribution of both genera. Gymnostoma and Bowenia are presently restricted to N.E. Queensland rainforest communities. These rainforests can be classified using Webb's (1959) Rainforest Classification: Gymnostoma occurs in association with Simple Mesophyll Vine Forest (SMVF) and Bowenia in association with Complex Notophyll Vine Forest (CNVF) The former (SMVF) is tropical and found in Queensland from Bundaberg at 25° S, to north of Cooktown at 15° S. The latter (CNVF) is subtropical and in Australia occurs from Kiama in N.S.W. at 35° S and as far north as Mackay, Queensland at 20° S. This evidence supports the view that a subtropical/tropical rainforest existed in the vicinity of the Curlew Formation locality during the Middle Eocene.

Gymnostoma is cited by the examiner as occupying infertile soils in New Caledonia, but soil infertility is a recognised feature of the rainforest community, therefore the presence of Gymnostoma in this environment is not an unusual situation. In Australia, Gymnostoma is found in association with waterways and disturbed sites (Christophel personal communication) where soil instability (a succesional phase leading to infertility) is common. Bowenia is a particularly small genus (represented by 4 species, two extant and two extinct). All four are considered morphologically distinct. The extant species are confined to either subtropical or tropical rainforest communities.

.../7

Wet sclerophyll forest is very similar in composition to subtropical rainforest, the major difference being the percentage of recognised rainforest taxa (e.g. Cupaniopsis) but environmental requirements are almost identical. I consider this evidence, which emphasises the Australian situation with regard to the modern relatives of the Gymnostoma and Bowenia fossils, is defencible and convincing enough to propose this reconstruction.

p288 Any reference to rainfall based on the fungal shield Callimothallus has been omitted. The rainfall figure was intended as a very broad estimate and was included only to highlight the fact that precipitation was in excess of that expected in a sclerophyllous woodland (i.e < 140 cm/year) and therefore within the rainfall range for rainforest vegetation.

p289 The topic of foliar physiognomy has not been raised until now because it has little relevance to this research project. Foliar physiognomy can only be used on intact fosil material not cuticle fragments, it is therefore discussed in Section 7.2 under Interpretative Approaches Available to researchers. Its benefits and shortcomings are discussed.

There is no obvious explanation as to why the monocot pollen frequencies are so low in the lignites. Possibly the computer analysis suggested by the examiner may provide some possible answers. Such an analysis would be undertaken prior to the publishing of any of this data. From my observations of such a correlation it could be suggested that the monocot flora was not as common as first indicated and that the eucalypts in the canopy of the autochthonous vegetation would probably have a more extra-local distribution. This could only be confirmed by carrying out the analysis, but it would appear only minor changes to the present vegetation reconstruction would be necessary. Such considerations are relevant to future work, but not required within the present thesis objectives.

The examiner's comments on my acceptance of Luly et al (1980) and Kershaws (1970) work is somewhat confusing. In one instance it is stated that I have failed to be critical of these works and in the next that their work is to be commended for its objectivity and authenticity. It was because of the objectivity, authenticity and integrity of these works that they were used to assist in reconstructing the past environment and vegetation of the Narrows Region. To quote Luly et al (1980) in reference to Table 3 which is concerned with pollen production and dispersal characteristics of selected taxa. "There is fairly good correspondence in the performance of individual taxa present in different regions despite the fact that they are often represented by different species or genera. This gives some confidence to the application of the data to Late Tertiary assemblages..." With the same confidence this data has been used to assist in interpreting the Eocene fossil flora of the Curlew Formation.

Recommendation No. v (Failure to separate....)
Judging by the examiner's comments there appears to be a misconception that Chapter 3 is intended as a purely taxonomic assessment of the Curlew palynoflora and for this reason a number of changes have been made to clarify my intentions. The title of the chapter was possibly misleading, i.e. Palynological Descriptions. This has been changed to Palynological Examinations to imply a much broader treatment of the palynomorphs. The principal emphasis of my scientific endeavour was to highlight the floristic trends which existed within the Curlew Formation and to develop these findings so that they would prove to be a useful foundation for palaeoenvironmental reconstructions.

Hence the data was not presented in the style suggested by the examiner, because to do so would have attached connotations not intended by myself nor by the proponents of this different technique.

I recognise and appreciate the importance of the application of scientific method to data handling in a document such as the one I have written and to the general advancement of ideas of scientific merit. However, in Chapter 3 I was not operating under the misconception that the data I had presented were in the scientific style of taxonomic classification but rather in the descriptive style of categorisation, which is an equally accepted scientific style for the concepts which I was trying to convey.

Therefore in Section 3.1.2 the broad classification system used has been termed a Categorisation to further impress my intentions. The specific reasons for establishing the eight categories are discussed in this section and have been further expanded to remove any further confusion. The category "Angiospermae" appears to have caused the examiner most concern. This category deals with all angiosperm pollen types excluding those discussed under the categories, Fagaceae, Myrtaceae, Proteaceae and Casuarinaceae and its title as been amended.

It was my objective in each category not to undertake an extensive taxonomic review but rather to discuss the floristic trends within the formation and compare these trends with similarly aged deposits from other parts of Australia, to extend the already comprehensive work of Luly et al (1980) and by doing this determine whether such concepts hold any promise in assisting palaeoenvironmental investigations.

Recommendation No. vi (Extensive use of unpublished ...)
I have already discussed this topic in my earlier comments on Recommendation No. iii. The example stated in this instance by the examiner again involves the work by Syber which has gone to press since I submitted my thesis. The only other reference made in my thesis to an Honours thesis (Wood,1981) concerns pollen frequencies, which can easily be confirmed by consulting the pollen data presented in this work. This information was used in the development of a distributional trend for pollen types from similarly aged deposits. Having confirmed this information I fail to see that being unpublished detracts from the merit of this work.

One further comment I would like to make is that the use of indelible ink and fluorescent marking pens by this examiner has rendered one of my submitted copies, which was quite expensive to produce, useless as a document and I urge the abolition of this practice in the future.