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A rich Middle Eocene Microflora at Arroyo de los Mineros, near Cañadón Beta, NE Tierra del Fuego Province, Argentina

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2 Text-Figures,1 Table and 9 Plates

This paper is devoted to the memory of Univ. Prof. Dr. WILHELM KLAUS

Middle Eocene,
Argentina,
Tierra del Fuego,
palynology,
Nothofagus rainforest,
mesothermal

Contents

Abstract

In northeastern Tierra del Fuego, Tertiary silty to sandy sediments in a coastal cliff at Arroya de los Mineros, near Cañadón Beta are rich in macrofossils, such as logs and *Nothofagus* leaves, and carbon rich sediments contain a well preserved microflora comprising pollen, spores and dinoflagellates. Over 90 taxa have been found; 45 are here described, based on light microscopy and SEM investigations. The most abundant taxa are *Nothofagus* spp., *Podocarpus* spp., and ferns. Most of the preserved taxa could have been affiliated to modern genera or families. The stratigraphical range of dinoflagellate cysts and the pollen and spore assemblages constrain the age of the locality to Middle Eocene. Palaeoclimatic conditions were humid and mesothermal, leading to the development of a relatively diverse *Nothofagus* dominated rainforest and related biohabitats.

Rica microflora del Eoceno medio en el Arroyo de los Mineros, cerca de Cañadón Beta, NE de la Provincia de Tierra del Fuego, Argentina

Resumen

Al noreste de Tierra del Fuego, próximo al Cañadón Beta, sobre una barranca costera del Océano Atlántico Sur, se exponen sedimentos areno-arcillosos pertenecientes a la sección basal de la Formación Cullen (PETERSEN, en PETERSEN y METHOL, 1948). Contienen una rica ma-

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croflora de maderas y hojas de *Nothofagus* y abundante microflora que comprende polen, esporas y microplancton. Se han encontrado más de 90 taxa; 45 han sido descriptos con microscopio óptico y electrónico de barrido (SEN).

Los taxa mejor representados son *Nothofagus* spp., *Podocarpus* spp. Y helechos. De la mayoria se han reconocido sus afinidades botánicas.

Estratigráficamente la asociación encontrada sugiere una edad eocena media temprana para dicho afloramiento. Las condiciones paleoclimáticas habrían sido húmdedas y mesotermal permitiendo el desarollo de una relativa dominancia de Nothofagus en um bosque lluvioso subtropical y biohabitat relacionados.

Eine reiche mitteleozäne Mikroflora von Arroyo de los Mineros, nahe Cañadón Beta, NE Feuerland, Argentinien

Zusammenfassung

Siltig bis sandige Sedimente der tieferen Cullen Formation, welche an der Nordostküste von Tierra del Fuego in der Nähe von Cañadón Beta ausstreichen, enthalten neben Hölzern und *Nothofagus* blättern, in organisch reichen Horizonten auch eine gut erhaltene Mikroflora mit Pollen, Sporen und Dinoflagellaten. Es konnten über 90 Taxa bestimmt werden, davon wurden 45 beschrieben und lichtmikroskopisch sowie rasterelektronenmikroskopisch abgebildet. Die häufigsten Taxa sind *Nothofagus* spp., *Podocarpus* spp. und Farne, die einen *Nothofagus* dominierten Regenwald bildeten. Fast alle Formen konnten botanisch Familien und Gattungen zugeordnet werden. Die stratigraphische Einstufung zusammen mit Dinoflagellaten ergibt ein Mittel Eozänes Alter. Die paläoklimatischen Bedingungen werden als feucht und mesothermal interpretiert.

1. Introduction

Samples of clastic sediments underlying and grading into the Cullen Formation of Tierra del Fuego have revealed a diverse and predominantly new palynoflora.

The samples were collected 1971 by F. VERVOORST from the Fundacion Miguel Lillo, Tucumán, Argentina (Lillo collection, LIL Pb: Nº. 5989-5999). The stubs of the palynological preparation are housed at the Pb-Palino, Tucumán, Argentina.

The sediments belong to an up to 4000m thick Tertiary sedimentary sequence, deposited in the Magellanes basin complex (BIDDLE et al., 1986), which is associated with the peripheral sedimentary basins related to both post-rift Gondwana break-up and the retroarc foreland of the southermost Andes.

Although palynological-stratigraphic and sedimentological examinations of Tertiary sediments of Tierra del Fuego have been made previously (e.g. CODIGNOTTO & MALUMIÁN, 1981; VERGEL & DURANGO DE CABRERA, 1988; PALMA et al., 1992; ZAMALOA & ROMERO, 1990; PETERSEN & METHOL, 1948; PÖTHE DE BALDIS, 1966) the stratigraphic age of the Cullen Fm. remains relatively unclear, having been variously estimated at Middle Eocene to Late Miocene.

Additional to the standard light-microscopy techniques that were applied by former authors during investigation of the palynofloras preserved here, in this study SEM photography has also been used to produce good quality high magnification images of palynomorphs. This technique is excellent for observing of micro-morphological features of the palynomorphs, thus contributing greatly to the mainly botanically based identification and stratigraphic and palaeoclimatic interpretation.

2. Geographical Position and Geology

Tierra del Fuego province lies at the southeastern end of the American continent and represents the southernmost part of Patagonia, Argentina. Samples were collected from the north-eastern part of Tierra del Fuego, from the lowermost Cullen Fm, which crops out along the coast of the Gulf of San Sebastian, near the Arroyo de los Mineros ("stream of the miners") adjacent to Canadon Beta (Text-Fig. 1).

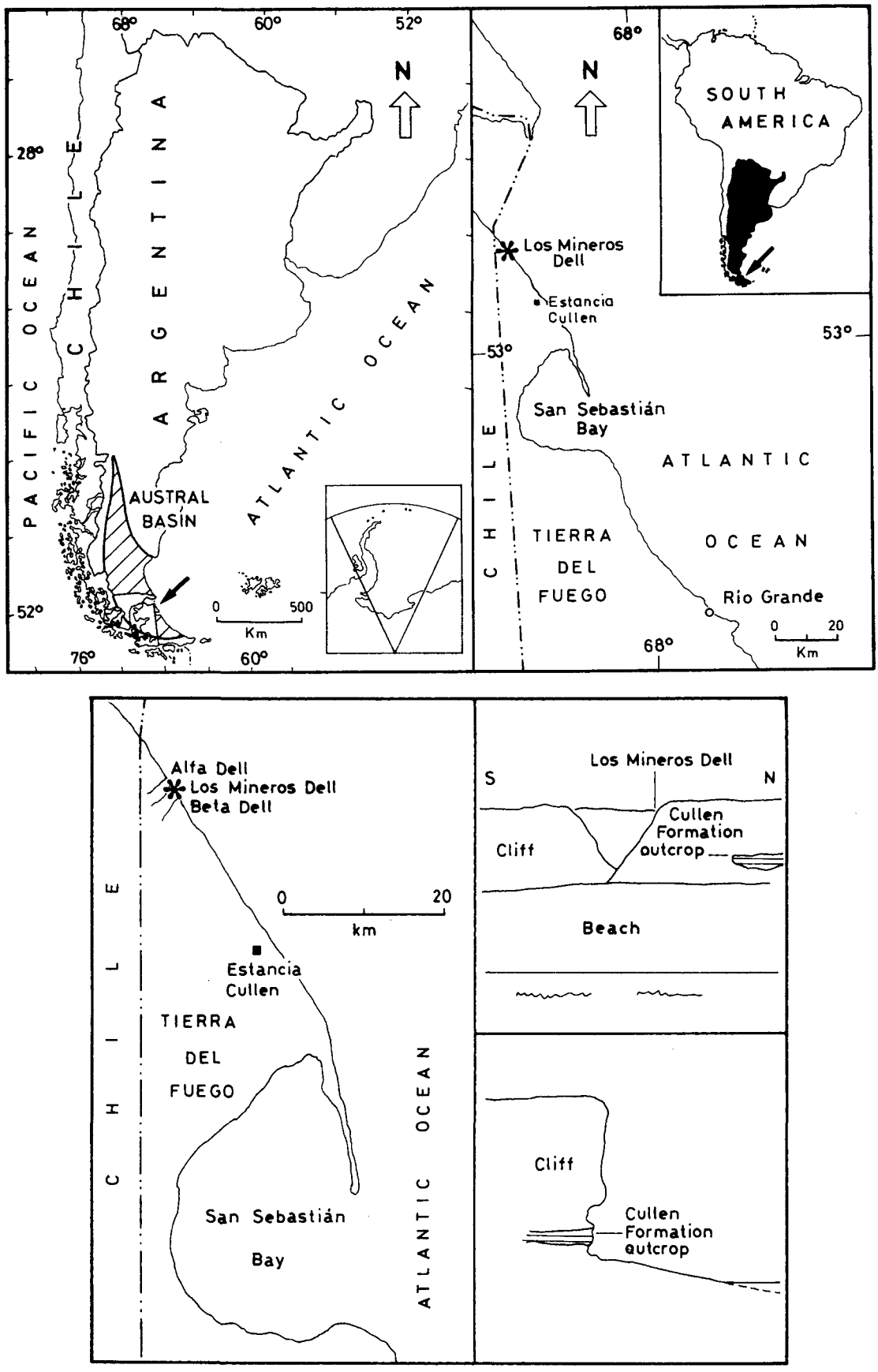
The post-Palaeozoic geological history of Patagonia is closely related to both the opening of the South Atlantic Ocean, due to the extensional break-up of Gondwana in the east and the subduction related compressional stress regime which developed during Jurassic times in the west (REIMER et al., 1996). Between these two different tectonic regimes, a transitional basin complex developed, including the onshore Austral/Magellanes basin in the Cuenca Austral and the offshore Malvinas basin situated between the mainland and the Falkland islands (BIDDLE et al., 1986; RICHARDS et al., 1996).

In contrast to the Central Andes of northern Chile and Perú, the Andes of South Argentina and Chile are characterized by a much lower topographic elevation of the magmatic arc (max. 2000m height) and a considerably thinner crust (HERVÉ, 1994). This has been explained by the tectonic situation, in which, first, the position of the magmatic arc remained more or less stationary during subduction from the Jurassic to Miocene, and, second, towards the east of Patagonia, the magmatic and tectonic evolution was strongly controlled by a N-S trending dextral strike slip fault system, active since Eocene times, which inhibited the development of a crustal thickening back-arc fold and thrust belt (HERVÉ, 1994).

After uplift of the magmatic arc in the Late Cretaceous, erosion and denudation initiated sedimentation in the eastern back arc-areas (HERVÉ, 1994). Subsidence of the Austral/Magellan basin is assumed to have started during the Eocene, with initial marine sedimentation, although later brackish to fluvial (Cullen Fm.) sediments also accumulated; these are assumed to have formed in an estuarine setting (CODIGNOTTO & MALUMIÁN, 1981; PETERSEN & METHOL, 1948; YRIGOYEN, 1969).

2.1 Stratigraphic and Palaeogeographic Position

The today status of scientific knowledge of dinoflagellates together with the pollen and spore assemblage indicate a stratigraphic range from Lower to Middle Eocene. Because of the diversity and richness of the dinoflagellate flora and be-

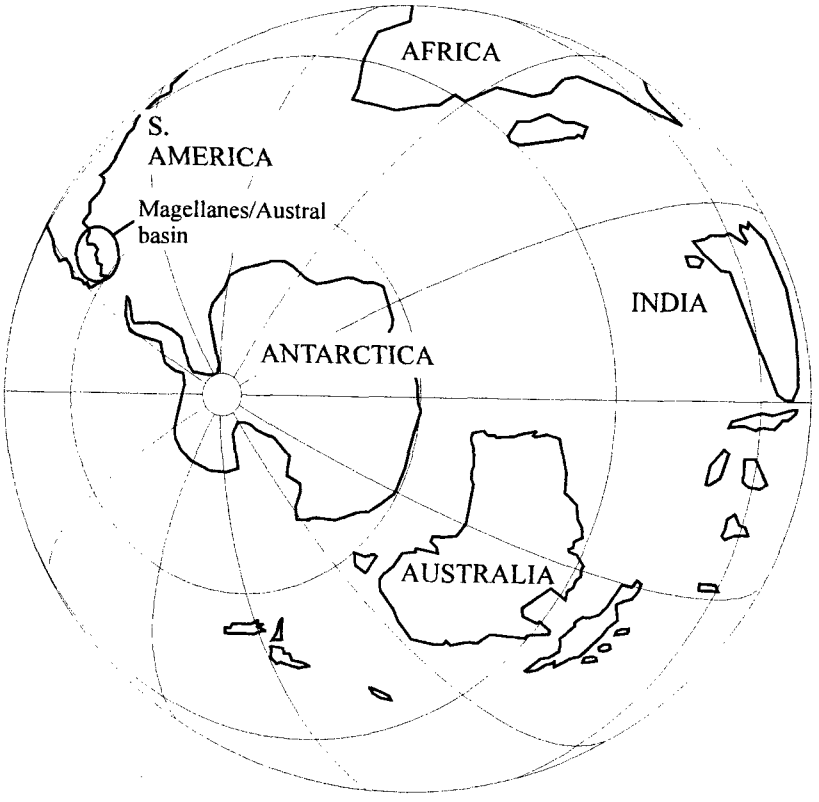


Text-fig.1
Sketches demonstrating the geographical position of the sample locality on NE Tierra del Fuego, in the Austral/Magellanes Basin, Argentina, South America.

Table 1
List and percentage distribution of all found taxa and their climatic requirements. Number of taxa; micro = microthermal, meso = meso-thermal, and mega = megathermal. Fossil genera are marked by "".

Family/Group	Genus/Type	N	%	micro	meso	mega
Bryophyta						
	Sphagnum	2	<1 %	x	x	x
Rebouliaceae	*Reboulisporites*		acces.			
Pteridophyta						
Gleicheniaceae	gen. indet.	3	5 %			x
Polypodiaceae	gen. indet.	?	5,3 %	x	x	x
Dryopteridaceae	gen. indet.	1	acces.	x	x	
Lophosoriaceae	*Lophosoria*		acces.			x
Marattiaceae	gen. indet.	1	4,2 %			x
Osmundaceae	*Osmunda*	1	<1 %		x	
Cyatheaceae	*Cnemidaria*	1	<1 %			x
	Trichipteris	1	<1 %			
fam. indet.	*"Ischyosprorites"*		acces.			
Lycopodiaceae	*Lycopodium*	2	1 %	x	x	x
fam. indet	gen. indet.	4	2,5 %			
Gymnospermae						
Ephedraceae	*Ephedra*	2	acces.		x	
Araucariaceae	*Araucaria*	2	3,4 %		x	x
Podocarpaceae	*"Podocarpidites marwickii"*		11,3 %		x	
	"P. elegans"		5 %		x	
	"P. magnus"		2,2 %		x	
	Dacrydium		acces.	x	x	
	Microcachrys		acces.		x	
	"Phyllocladidites"		5,3 %		x	
Angiospermae dicot.						
Anacardiaceae	*Campnosperma*		acces.			x
Apiaceae	gen. indet.	4	acces.	x	x	x
Aquifoliaceae	*Ilex*		acces.		x	x
Araliaceae	gen. indet.		acces.	x	x	x
Asteraceae	Centauridae type		1 %	x	x	x
	tubuliflore types	2	<1 %	x	x	x
Bignoniaceae	gen. indet.		acces.			x
Bombacaceae	*Bombax* s.l.		acces.			x
Caesalpinaceae	*Cassia*		acces.			x
	"Margocolporites"		acces.			x
	gen. indet.	1	acces.			x

Casuarinaceae	*Casuarina*		acces.		x		
Convolvulaceae	*Convolvulus*		acces.		x	x	
Ericales/Epacridaceae	gen. indet.	2	acces.	x	x	x	
Euphorbiaceae	gen. indet.		acces.	x	x	x	
	"Malvacipollis"		acces.				
Gunneraceae	*Gunnera*	2	<1 %		x		
Haloragidaceae	*Myriophyllum*		acces.	x	x	x	
Hydrocharitaceae	*Elodea*		acces.	x	x	x	
Loranthaceae	gen. indet.		acces.		x	x	
Lythraceae	gen. indet.		acces.		x		
Malvaceae	gen. indet.	3	<1 %		x	x	
Myrtaceae	gen. indet.	1	acces.		x		
	Myrceugenia		acces.		x		
Nothofagaceae	*"Nothofagidites"*	3	5 %		x		
	"N. suggatei"/menziesi type		11,6 %		x		
	"N. cincta"		7 %		x		
	"N. cranwellae"		acces.		x		
	"N. fortispinulosus"		2,5 %		x		
	"N. micromarginata"		<1 %		x		
	"N. saraensis"/fusca type		7,6 %		x		
Nyctaginaceae	gen. indet.		acces.			x	
Onagraceae	*Fuchsia*		acces.		x		
Polygonaceae	*Polygonum persicaria* type		acces.		x	x	
Proteaceae	*"Proteacidites"*	3	1		x		
	"P. pseudomoides"		acces.		x		
Restoniaceae	gen. indet.		acces.		x	x	
Rosaceae	*Polylepis/Acaena*		3,4	x	x		
	Rubus type	2	acces.	x	x		
	gen. indet	3	1,6 %	x	x		
Salicaceae	*Salix*		acces.	x	x		
Sapindaceae	*Paullinieae* indet.	2	acces.			x	
	Cupania	1	acces.			x	
	Serjania	1	acces.			x	
Sterculiaceae	gen. indet.		acces.			x	
Winteraceae	*Drimys*		acces.		x		
Angiospermae monocot.							
Arecaceae	gen. indet.		acces.			x	
Sparganiaceae	*Sparganium*		<1 %		x		
fam. indet.	gen. indet.		2,5 %				



Text-fig.2
Sketch of the Southern Hemisphere during Middle Eocene times(ca. 50Ma), showing the Paleogeographical position of South America, Antarctica, Australia, and Africa. Modified after WILFORD & BROWN (1994).

cause we think that many forms have not yet been described in detail, further work must be undertaken to enhance the taxonomy of this group. In this paper only the preliminary results are presented.

Achilleodinium biformoides (EISENACK) EATON Early Eocene
Membranophoridinium aspinatum GERLACH Middle Eocene
Ceratiopsis dartmooria (COOKSON & EISENACK) LENTIN & WILLIAMS Early Eocene
Ceratiopsis speciosa (ALBERTI) LENTIN & WILLIAMS Ear/Mid. Eocene
Ceratiopsis wardenensis (WILLIAMS & DOWNIE) STOVER & EVITT Early Eocene
Thalassiphora patulata (WILLIAMS & DOWNIE) STOVER & EVITT Early Eocene
Thalassiphora pelagica (EISENACK) EISENACK & GOCHT Early Eocene
Paralecaniella identata (DEFLANDRE & COOKSON) Ear/Mid. Eocene

The palaeogeographic position of southernmost South America during Middle Eocene times is shown on Text-figure 2.

2.2 Description of the Sample Material

The sample material consists of medium-grey to beige clayey siltstones, locally enriched with a minor fine-grained sand content, and horizons of concentrated, clearly recognizable, plant fragments and detritus. Microscopic examination of the organic matter revealed abundant woody tissues and cuticles, both mostly originating from leaf material, lots of epiphyllous leaf fungi, and common spores and hyphen of saprophytic fungi. Anther material of as yet indeterminate pollen and *Nothofagus* spp. have been found frequently, whilst small fragments of fusinitic matter are rare. The palynomorph content is characterized by approximately one third dinoflagellate cysts and two thirds pollen and spores. In the latter, the sum of spores make up 24%, the gymnosperm pollen 28%, and angiosperm pollen 48%. The composition of the palynoflora is summarized in Table 1.

Plate 1

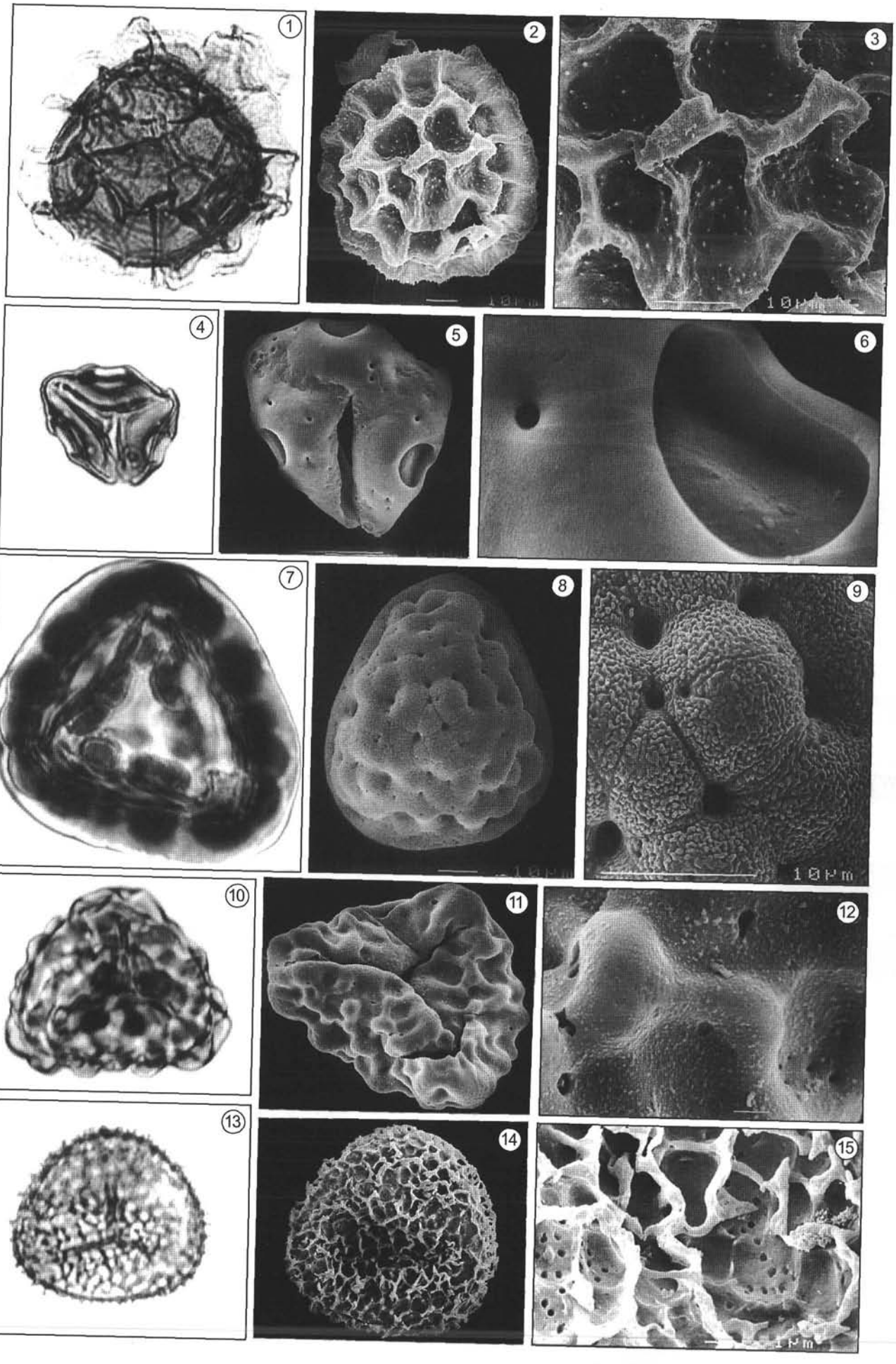
Reboulisporites fuegiensis
Fig. 1: Proximal view; 850x LM.
Fig. 2: Distal view; 600x SEM.
Fig. 3: Detail; 1950x SEM.

***Cnemidaria* sp.**
Fig. 4: Proximal view; 850x LM.
Fig. 5: Distal view; 1600x SEM.
Fig. 6: Detail; 9000x SEM.

***Lophosoria* sp.**
Fig. 7: Proximal view; 850 LM.
Fig. 8: Distal view; 720x SEM.
Fig. 9: Detail; 2900x SEM.

***Ischyosporites* sp.**
Fig. 10: Proximal view; 850x LM.
Fig. 11: Proximal view; 850x SEM.
Fig. 12: Detail; 1150x SEM.

***Lycopodium* sp.**
Fig. 13: Proximal view; 850x LM.
Fig. 14: Distal view; 1000x SEM.
Fig. 15: Detail; 4100x SEM.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3. Methods

Sample preparation essentially followed the classical standard treatment, with minor differences, which we consider to yield better results. Non-oxidized samples were chosen, because they should provide the best preserved pollen for light-microscopy and SEM photography, resulting in high quality photographs which allow reliable botanical identifications and which can later be used by other workers for comparison. We believe that high quality photographs, particularly SEM images, are essential for comparison with other fossil palynofloras, even, or in particular, when the material is not yet botanically identified.

The first stage involves breaking up the samples by hand, followed by crushing with an mortar and pestle, producing a relatively coarse powder. The samples were not washed or sieved, because we wanted to retain small palynomorphs (<10µ), for example Myrtaceae. The powder was then treated by standard wet chemical processes with HCL, HF and subsequent acetolysis. Light microscopic (LM) investigation of the preparations was carried out without a coverslip, for two reasons both related to the further examination of individual grains: First, a fine hair mounted on a needle functioned as an easy handling micro-manipulator to move and turn palynological objects around to obtain the optimal position for identification and photography and, second, with the help of the hair, particles were transported to a SEM stub for further investigation or to a clean glycerine drop, thus providing better quality LM photographs without bits and pieces obstructing the view. These micro-manipulations were simplified by using a LM in which the field of view is not optically reversed (ZETTER, 1989). Excess glycerine on the SEM stub was washed away with absolute ethanol to prevent the micromorphological features of the pollen wall being smeared over. The last handling was done with the stub positioned under a binocular. The stubs with the mounted palynomorphs were then sputtered with gold and underwent SEM analysis and photography. Palynomorphs figured on photographic plates are represented by at least one LM image, one SEM overview image and one SEM image of the micro-morphology with all images coming from the same grain.

4. Systematic Description

Bryophyta

Family: Rebouliaceae EVANS
Genus: *Reboulisporites fuegiensis* ZAMALOA & ROMERO, Pl. 1, Fig.1–3
Shape: Oblate and spheroidal.
Size: 65–75µ.
Apertures: Trilete.
Wall thickness: 1–1,5µ.
Surface: The exospore forms a well defined polygonal reticulate surface, covered with widely spaced nannospinulae.

Pteridophyta

Family: Cyatheaceae KAULFUSS
Genus: *Cnemidaria* PRESL, Pl. 1, Fig. 4–6
Shape: Oblate, triangular in polar view.
Size: 25–39µ.
Aperture: Trilete; the arms nearly reach the equator.
Wall thickness: 1.5–2µ.
Surface: Three large piths in the equatorial area between the aperture arms; smaller piths are scattered over all the distal area.

Family: Lophosoriaceae PICHI-SERMOLLI
Genus: *Lophosoria* PRESL, Pl. 1, Fig. 7–9
Shape: Oblate to spheroidal; triangular obtuse in polar view; well defined zona.
Size: 50–90µ.
Aperture: Trilete.
Wall thickness: >2µ.
Surface: Wavy and perforate with micro-rugulae.

Family indet.
Fossil genus: *Ischyosporites* STUCHLIK, Pl. 1, Fig. 10–12
Shape: Oblate; triangular in polar view.
Size: 40–50µ.
Aperture: Trilete; aperture arms nearly reach the equator.
Wall thickness: 2–4µ.
Surface: The surface is characterized by ridges and wide grooves and irregularly distributed perforations. The whole surface is covered by irregularly shaped sporopollenine flakes.

Family: Lycopodiaceae MIRBEL
Genus: *Lycopodium* LINNÉ, Pl. 1, Fig. 13–15
Shape: Oblate to subglobular; triangular obtuse in polar view.
Size: 35–50µ.
Aperture: Trilete, with relatively short aperture arms.
Surface: The distal area is characterized by an irregular and incomplete reticulate surface and irregularly scattered perforations.

Gymnosperms

Family: Araucariaceae HENKEL & HOCHSTETTER
Genus: *Araucaria* JUSSIEU, Pl. 2, Fig. 1–3
Fossil genus: *Araucaricidites* COOKSON
Shape: Oblate to spheroidal.
Size: 40–60µ.
Apertures: Nonaperturate.
Wall thickness: 2µ; the nexine is as thick as the sexine.

Plate 2

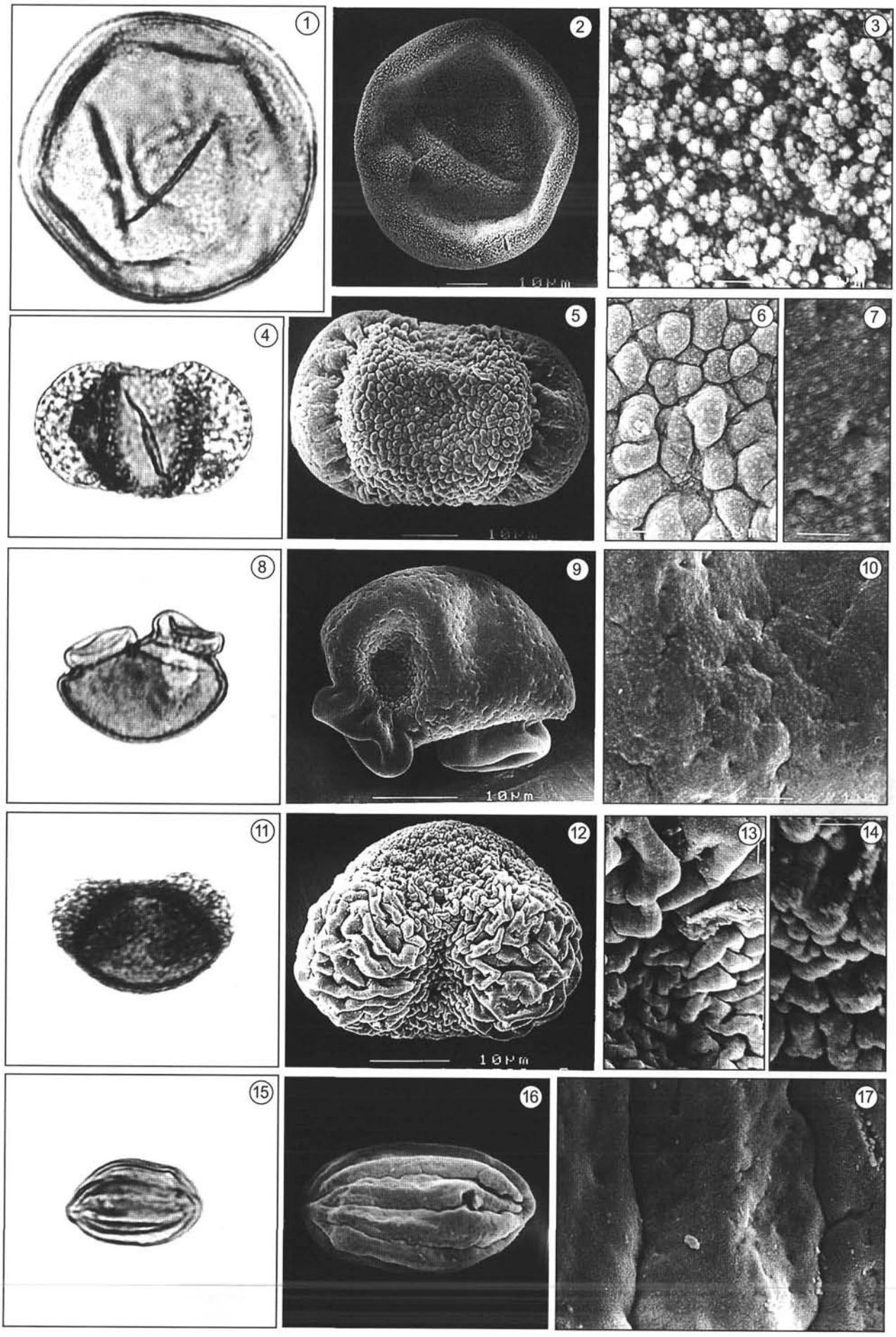
***Araucaria* sp.**
Fig. 1: 850x LM.
Fig. 2: 750x SEM.
Fig. 3: Detail; 1120x SEM.

Podocarpus* sp. *1 (Podocarpidites marwickii)
Fig. 4: Proximal view; 850x LM.
Fig. 5: Proximal view; 1200x SEM.
Fig. 6: Detail cappa; 5500x SEM.
Fig. 7: Detail saccus; 10 000x SEM.

Dacrydium* sp. *1 (Phyllocladidites mawsonii)
Fig. 8: Equatorial view; 850x LM.
Fig. 9: Equatorial view; 1600x SEM.
Fig.10: Detail cappa; 7000x SEM.

Dacrydium* sp. *2 (Dacrydiumites florinii)
Fig. 11: Equatorial view; 850x LM.
Fig. 12: Equatorial view; 1500x SEM.
Fig. 13: Detail cappula 6000x SEM.
Fig. 14: Detail cappa 11 000x SEM

***Ephedra* sp.**
Fig. 15: Polar view; 850x LM.
Fig. 16: Polar view; 1600x SEM.
Fig. 17: Detail; 9000x SEM.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Exine: Tectate.
Sculpture: Micro-verrucate; micro-verrucae are differently shaped and dissected into a cauliflower pattern.

Family: Podocarpaceae ENDLICHER
Genus: *Podocarpus* L'HÉRITIER ex. PERSOON
Podocarpus sp. 1, Pl. 2, Fig. 4–7
Fossil genus: *Podocarpidites marwickii* COOPER
Shape: Bisaccate, elliptical in distal view. The sacci are hemispherical and incompletely alveolate.
Size: 50–55µ in equatorial diameter; the attachment area of the sacci to the corpus is broad.
Aperture: Leptoma
Exine: Tectate
Sculpture: Distal cappula with leptoma is thinned out and displays a flaky uneven surface. The cappa is strongly rugulate to verrucate and separated by fissures. The sacci and corpus are covered with regularly distributed blunt nannospinulae and irregularly distributed fovae can be observed on the sacci.

Genus: *Dacrydium* LAMBERT/*Lagarostrobus franklinii* type QUINN
Dacrydium sp. 1, Pl. 2, Fig. 8–10
Fossil genus: *Phyllocladidites mawsonii* COOKSON
Shape: Bisaccate, elliptical, small sacci with very reduced aveoles.
Size: 35–55µ in distal equatorial view and 20–25µ from pole to pole
Apertures: Leptoma.
Exine: Tectate
Sculpture: The cappa is undulated, perforated and nannopunctate, the cappula with the leptoma is rugulate. The sacci are smooth and scarcely foveate.

Genus: *Dacrydium* LAMBERT
Fossil genus: *Dacrydiumites florinii* COOKSON & PIKE, Pl. 2, Fig. 11–14
Shape: Bisaccate, ellipsoidal in distal view; the sacci are characterized by well developed aveoles; SEM image of sacci displays a strongly folded surface.
Size: 35–40µ in equatorial diameter.
Apertures: Leptoma.
Exine: Tectate.
Sculpture: The corpus in the polar area is verrucate to rugulate; verrucae have different sizes (0,5–1,5µ). On the distal side the leptoma displays criss-cross smooth rugulae.

Family: Ephedraceae DUMORTIER
Genus: *Ephedra* LINNÉ, Pl. 2, Fig. 15–17
Shape: Oblate; elliptical in polar view.
Size: c-axis: 15–17µ, b-axis: 27–30µ.
Apertures: Polyplicate; furrows between plicae are not straight.
Wall thickness: 1–1,5µ; the nexine has the same thickness as the sexine.
Exine: Tectate to slightly perforate.
Sculpture: Smooth.

Angiosperms

Family: Bombacaceae KUNTH
Genus: *Bombax* LINNÉ, Pl. 3, Fig. 1–3
Shape: Oblate; triangular obtuse in polar view.
Size: 35–40µ.
Apertures: Brevitricolpate.
Wall thickness: 1–1,7µ; the nexine is slightly thinner than the sexine.
Exine: Semitectate.
Sculpture: Microreticulate; the microreticulum is very variable across the surface: the polar area is more striato-reticulate and the mesocolpium areas are characterized by a transition from microreticulate to foveate. The muri are smooth.

Family: Sapindaceae JUSSIEU
Genus: *Cupania* LINNÉ, Pl. 3, Fig. 4–6
Fossil genus: *Cupanieidites* COOKSON
Shape: Oblate; triangular in polar view.
Size: 20–22µ in equatorial diameter.
Apertures: Tricolporate, demi-syncolpate.
Wall thickness: 1–2µ; the nexine is thinner than the sexine.
Exine: Semitectate.
Sculpture: Reticulate, heterobrochate; muri are smooth and duplicolumellate and have various widths. Within the lumina, the top of the nexine displays protruding sexine material.

Genus *Serjania* MILLER, Pl. 3, Fig. 7–9
Shape: Oblate, triangular in polar view, heteropolar.
Size: 18–20µ in equatorial diameter.
Apertures: Tricolporate, demi-syncolpate.
Wall thickness: 1–1,5µ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Striate; in the mesocolpium areas the striae run more or less paralell to the outline of the grain and bend around at the colpi to run parallel to the colpi. Some striae tend to split and run across a set of striae. The syncolpium area is characterized by much shorter and thinner striae/rods producing a criss-cross pattern.

Family: Nyctaginaceae
Gen. indet., Pl. 3, Fig. 10–12
Shape: Oblate to spheroidal.
Size: Up to 40µ in equatorial diameter.
Apertures: Tricolpate; aperture membranes consist of masses of partly fused angular spinulae.
Wall thickness: 2,8–3µ; the nexine is much thinner than the sexine.
Exine: Tectate.

Plate 3

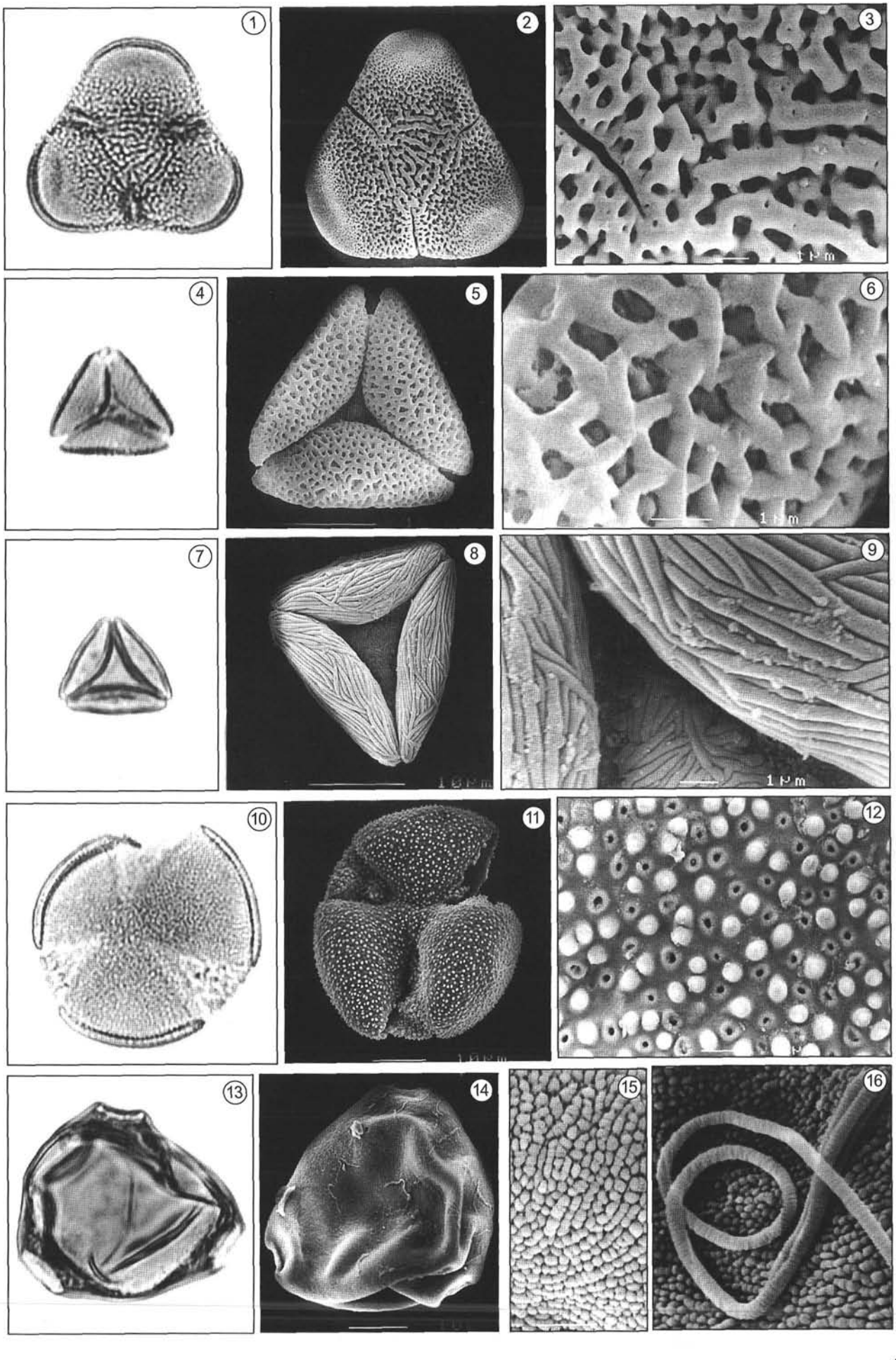
***Bombax* sp.**
Fig. 1: Polar view; 850x LM.
Fig. 2: Polar view; 1000x SEM.
Fig. 3: Detail; 5000x SEM.

***Cupania* sp.**
Fig. 4: Polar view; 850x LM.
Fig. 5: Polar view; 2000x SEM.
Fig. 6: Detail; 11 500x SEM.

***Serjania* sp.**
Fig. 7: Polar view; 850x LM.
Fig. 8: Polar view; 1800x SEM.
Fig. 9: Detail; 7000x SEM.

***Nyctaginaceae* gen. indet.**
Fig. 10: Polar view; 850x LM.
Fig. 11: Polar view; 1000x SEM.
Fig. 12: Detail; 6500x SEM.

***Fuchsia* sp.**
Fig. 13: Polar view; 850x LM.
Fig. 14: Polar view; 1100x SEM.
Fig. 15: Detail; 11 000x SEM.
Fig. 16: Detail of viscin threads 11 000x SEM.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Sculpture: Densely spaced micro-spinulae (max. 0,5μ in diameter); in between are fovae that are surrounded by slightly protruded rims.

Family: Onagraceae JUSSIEU
Genus: *Fuchsia* LINNÉ, Pl. 3, Fig. 13–16
Fossil genus: Crassiorites ZAMALOA & ROMERO
Shape: Oblate and triangular in polar view.
Size: 30–42μ.
Apertures: Triporate with protruding ectoapertures.
Wall thickness: 1,5μ; the nexine is as thick as the sexine.
Exine: Tectate.
Sculpture: Striae dissected into very fine bead-strings. Viscin threads are located in the proximal polar area. At higher magnification viscin threads display a faint annelid-like pattern.

Family: *Proteaceae* JUSSIEU
Fossil genus: *Proteacidites* COOKSON ex COUPER, Pl. 4, Fig. 1–3
Type 1 P. pseudomoides STOVER
Shape: Oblate; triangular, with cut off corners in polar view.
Size: 28–32μ.
Apertures: Triporate.
Wall thickness: 1,8–2μ; the nexine is thinner than the sexine.
Exine: Semitectate.
Sculpture: Reticulate, heterobrochate; muri are duplicolumellate, dissected by fissures and smooth.

Proteacidites Type 2, Pl. 4, Fig. 4–6
Shape: Oblate; triangular, with cut off corners in polar view.
Size: 30–34μ in equatorial diameter.
Apertures: Triporate; the pori do protrude.
Wall thickness: 2–3,5μ; the nexine is much thinner than the sexine.
Exine: Tectate.
Sculpture: Rugulate to verrucate; most of the tectum elements are disaggregated by irregular fissures and perforations. The surface is not smooth, a faint verrucate texture is discernable.

Proteacidites Type 3, Pl. 4, Fig. 7–9
Shape: Oblate; triangular, with cut off corners in polar view.
Size: 15–18μ in equatorial diameter.
Apertures: Triporate.
Wall thickness: 2μ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Verrucate; verrucae are irregularly shaped and disaggregated; around the apertures the verrucae are smaller than in the meso- and apocolpium areas.

Proteacidites Type 4, Pl. 4, Fig. 10–12
Shape: Oblate; triangular, with cut corners in polar view.
Size: 18–20μ in equatorial diameter.
Apertures: Triporate.
Wall thickness: 2–2,5μ; the nexine has the same thickness as the sexine.
Exine: Tectate.
Sculpture: Irregularly micro-verrucate; micro-verrucae are separated by fissures and fovae; predominantly in the polar area irregularly and widely spaced bigger verrucae (0,5μ in diameter) are distributed on top of the basal verucae layer.

Family: Myrtaceae JUSSIEU
Genus: *Myrceugenia* O. BERG, Pl. 4, Fig. 13–15
Shape: Oblate; triangular obtuse in polar view.
Size: 14–16μ in equatorial diameter.
Apertures: Trisyncolporate, the colpi have thickened margins.
Wall thickness: 0,8–1μ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Irregularly verrucate; the verrucae in the meso- and apocolpium areas are much bigger than those in the aperture areas.

Family: Asteraceae DUMORTIER
Gen. indet. tubuliflore 1, Pl. 5, Fig. 1–3
Shape: Spheroidal.
Size: 20–25μ in equatorial diameter.
Apertures: Tricolporate; colpi membranes are verrucate to microspinulose.
Wall thickness: 1,2μ; nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Densely spaced spinae of ca. 2,5–3μ length. Bases of ca. one third of the spinae have elongated perforations.

Gen. indet. tubuliflore 2, Pl. 5, Fig. 4–6
Shape: Subprolate to spheroidal.
Size: c-axis: 17–20μ, b-axis: 15–18μ.
Apertures: Tricolporate.
Wall thickness: 1,2μ; nexine is thinner than sexine.
Exine: Tectate.
Sculpture: Spinulose; the spinae are short (1–1,5μ) and have broad bases which are perforated. The surface of the tectum is faintly striate and perforate.

Gen. indet. tubuliflore 3, Pl. 5, Fig. 7–9
Shape: Subprolate; elliptical in equatorial view.
Size: c-axis: 30–32μ, b-axis: 20–25μ.
Apertures: Tricolporate.
Wall thickness: 2,5–3μ; the nexine is slightly thinner than the sexine.
Exine: Tectate perforate.
Sculpture: Short, relatively widely spaced spinulae.

Family: Caesalpinaceae LINNÉ
Genus: *Cassia* LINNÉ, Pl. 5, Fig. 10–13
Shape: Oblate, triangular obtuse in polar view.
Size: 40–45μ
Apertures: Tricolporate; broad colpi with finely verrucate colpi membranes.

Plate 4

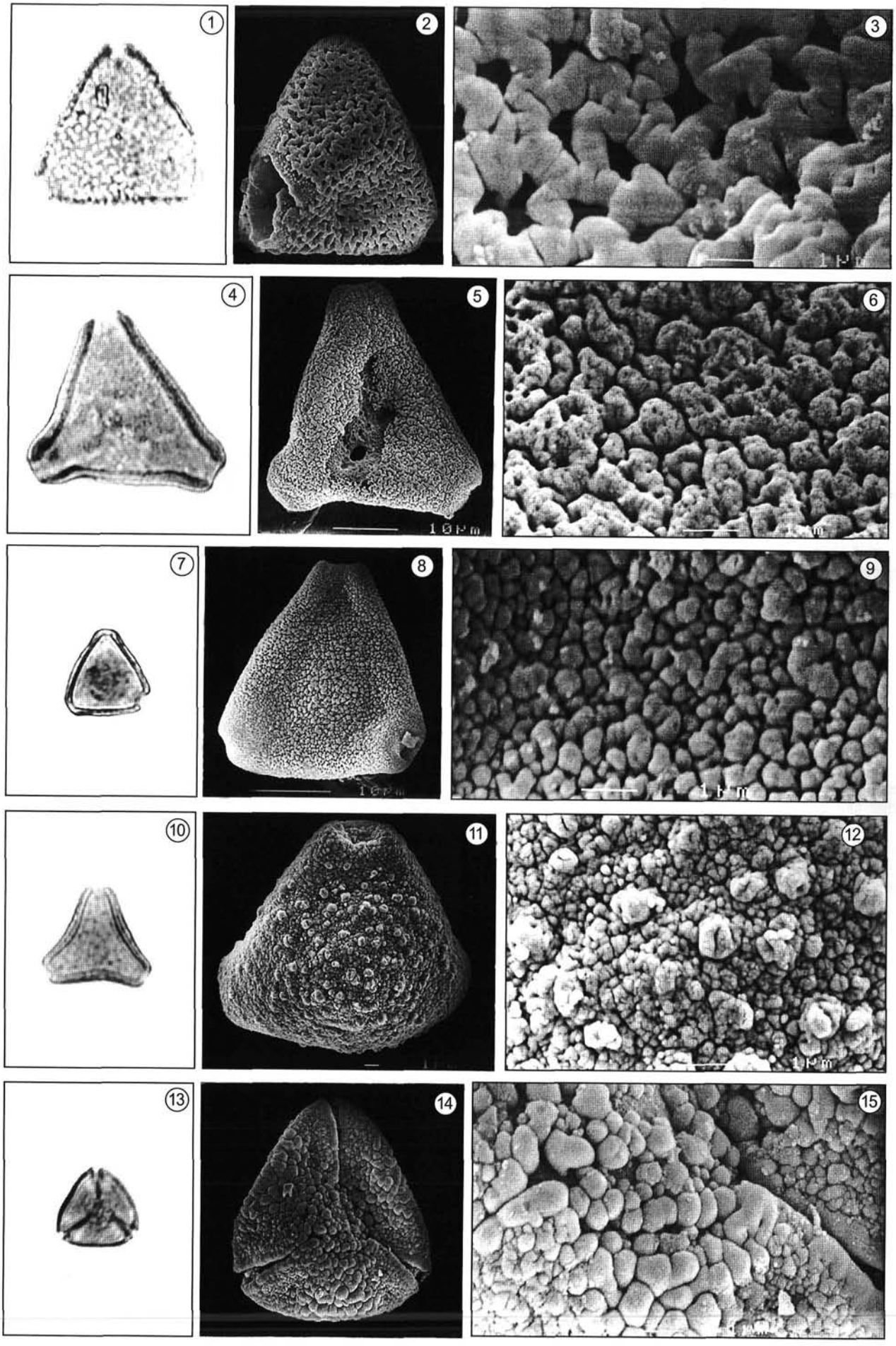
Proteacidites* sp. *1 (pseudomoides)
Fig. 1: Polar view; 850x LM.
Fig. 2: Polar view; 1200x SEM.
Fig. 3: Detail; 10 000x SEM.

Proteacidites* sp. *2
Fig. 4: Polar view; 850x LM.
Fig. 5: Polar view; 1200x SEM.
Fig. 6: Detail 10 000x SEM.

Proteacidites* sp. *3
Fig. 7: Polar view; 850x LM.
Fig. 8: Polar view; 1800x SEM.
Fig. 9: Detail; 10 000x SEM.

Proteacidites* sp. *4
Fig. 10: Polar view; 850x LM.
Fig. 11: Polar view; 3000x SEM.
Fig. 12: Detail; 10 000x SEM.

***Myrceugenia* sp.**
Fig. 13: Polar view; 850x LM.
Fig. 14: Polar view; 2500x SEM.
Fig. 15: Detail; 8000x SEM.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Wall thickness: 2μ; nexine is thinner than sexine.
Exine: Semitectate.
Sculpture: Foveate to microreticulate (tectum perforatum); the fovae are irregularly distributed and the tectum surface undulates. The fovae in the polar area and towards the colpi decrease in number whilst the tectum surface appears to be less undulated.

Fossil genus: *Margocolporites* GERMERAAD, HOPPING & MULLER, Pl. 5, Fig. 14–16
Shape: Oblate to spheroidal and circular in polar view.
Size: 40–42μ in equatorial diameter.
Apertures: Tricolporate.
Wall thickness: 2,5–3μ; the nexine is thinner than the sexine.
Exine: Semitectate.
Sculpture: Microreticulate, nearly homobrochate; muri are smooth. The costa colpi are densely packed with long, thin, nail-shaped clavae.

Family: Malvaceae JUSSIEU
Fossil genus: *Malvacipollis* HARRIS
Type 1, Pl. 6, Fig. 1–3
Shape: Oblate to spheroidal and circular in polar view.
Size: 40–42μ in equatorial diameter.
Apertures: Tetraporate.
Wall thickness: 1,8–2μ; the nexine has the same thickness as the sexine.
Exine: Tectate perforate.
Sculpture: Regularly distributed spinae of 1–1,5μ length; the bases of the spinae are globular. The space in between the spinae displays irregularly distributed microspinulae.

Type 2, Pl. 6, Fig. 4–6
Shape: Oblate to spheroidal and circular in polar view.
Size: 30–33μ in equatorial diameter.
Apertures: Triporate.
Wall thickness: 1,3–1,5μ; the nexine has the same thickness as the sexine.
Exine: Tectate perforate.
Sculpture: Regularly distributed spinae; the spinae sit on disc-like bases and are 2–3μ long. The tectum surface around and in between the discs is covered by irregularly distributed micro-spinulae.

Family: Euphorbiaceae JUSSIEU
Fossil genus: *Malvacipollis* HARRIS
Gen. indet. 1, Pl. 6, Fig. 7–9
Shape: Oblate to spheroidal; circular in polar view.
Size: 28–30μ in equatorial diameter.
Apertures: Stephanoporate (8)
Wall thickness: 1–1,5μ; the nexine is thinner than sexine.
Exine: Tectate perforate.
Sculpture: Widely and regularly spaced spinae of 2–3μ length; the surface of the spinae and tectum are finely striate; the perforations are cluttered with sporopollenine material.

Family: Euphorbiaceae JUSSIEU
Gen. indet. 2, Pl. 6, Fig. 10–12
Shape: Subprolate, elliptical in equatorial view.
Size: c-axis: 25–27μ, b-axis: 20–24μ.
Apertures: Tricolporate with long and narrow colpi; the colpi membranes are micro-verrucate.
Wall thickness: 1–1,5μ; the nexine is thinner than the sexine.
Exine: Semitectate.
Sculpture: Microreticulate, homobrochate where the lumina are funnel shaped and the reticulum is looking like an open honey-comb. In the colpi areas, the reticulum disappears abruptly, resulting in a 3–4μ wide tectate rim around the colpi.

Fam. indet. 1, Pl. 6, Fig. 13–16
Shape: Prolate; elliptical in equatorial view.
Size: c-axis: 30–35μ, b-axis: 25–30μ.
Aperture: Tricolpate.
Wall thickness: 2,5–3μ; the nexine is thinner than the sexine.
Exine: Semitectate.
Sculpture: Reticulate, heterobrochate; more microreticulate along the colpi; lumina in the mesocolpium areas big (2–4μ in diameter) and circular to polygonal in shape. Muri are duplicolumellate and smooth.

Family: Haloragidaceae R. BROWN
Genus: *Myriophyllum* LINNÉ, Pl. 7, Fig. 1–3
Shape: Oblate; quadrangular obtuse in polar view.
Size: 20–22μ in equatorial diameter.
Apertures: Tetraporate; the sexine in the aperture areas protrudes and forms an atrium.
Wall thickness: 1–1,5μ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Verrucate; densely spaced nanno-spinulae on top of verrucae layer.

Family: Gunneraceae MEISSNER
Genus: *Gunnera* LINNÉ, Pl. 7, Fig. 4–7
Shape: Oblate; triangular obtuse to circular in polar view.
Size: 22–25μ in equatorial diameter.
Apertures: Tricolpate; colpi membranes are granular to micro-verrucate.
Wall thickness: 1,5μ; the nexine has the same thickness as the sexine.
Exine: Semitectate.
Sculpture: Microreticulate, heterobrochate (0,5–0,8μ); lumina are polygonal; muri are simplicolumellate and smooth.

Family: Apiaceae LINDLEY
Gen. indet. 1, Pl. 7, Fig.8–10
Shape: Prolate to elliptical in equatorial view.
Size: c-axis: 12–15μ, b-axis: 10μ.

Plate 5

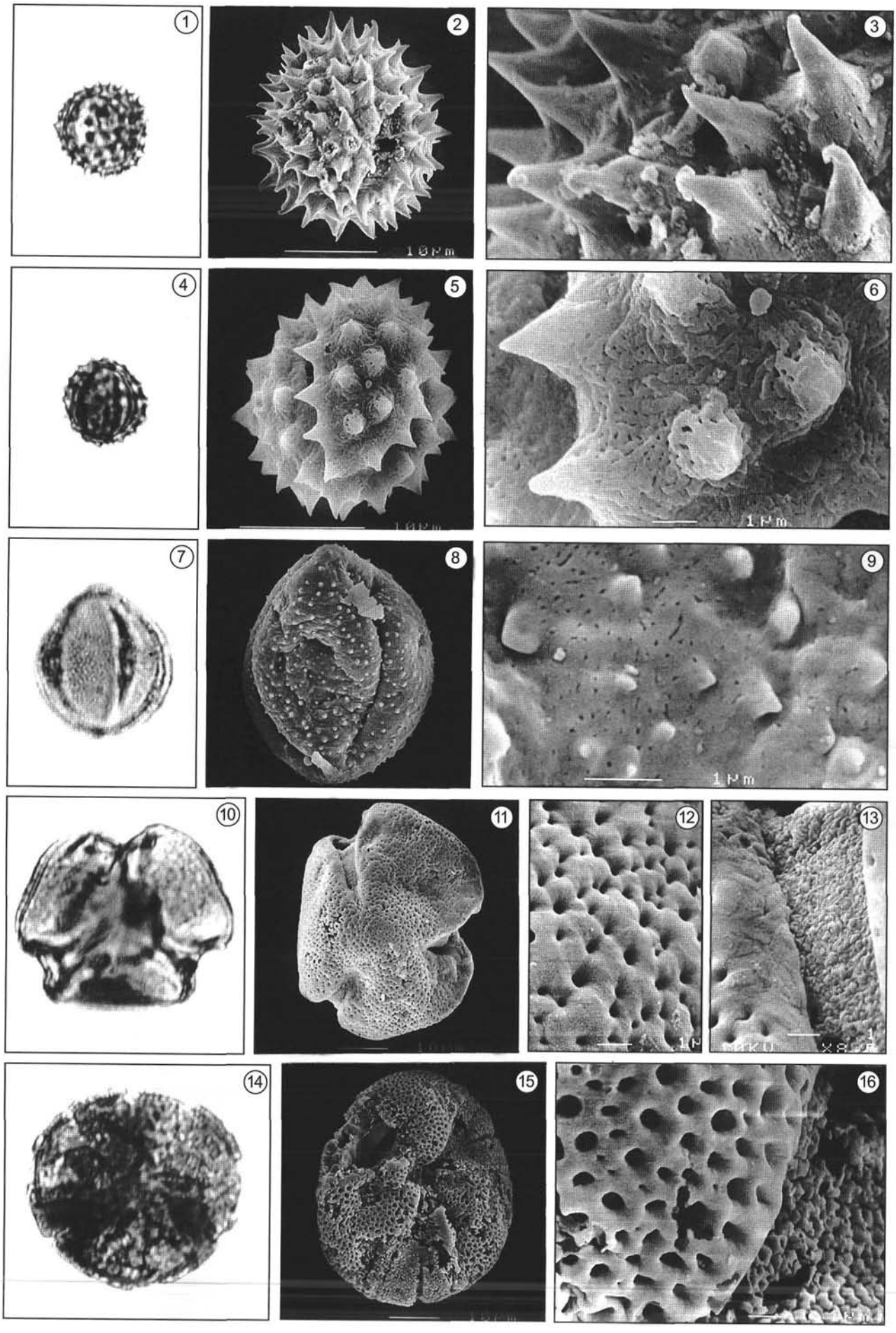
Tubuliflore Asteraceae sp. *1*
Fig. 1: Equatorial view; 850x LM.
Fig. 2: Equatorial view; 1750x SEM.
Fig. 3: Detail; 8000x SEM.

Tubuliflore Asteraceae sp. *2*
Fig. 4: Equatorial view; 850x LM.
Fig. 5: Equatorial view; 2400x SEM.
Fig. 6: Detail; 8000x SEM.

Tubuliflore Asteraceae sp. *3*
Fig. 7: Equatorial view; 850x LM.
Fig. 8: Equatorial view; 1500x SEM.
Fig. 9: Detail; 15 000x SEM.

***Cassia* sp.**
Fig. 10: Polar view; 850x LM.
Fig. 11: Polar view; 1000x SEM.
Fig. 12: Detail mesocolpium; 6500x SEM.
Fig. 13: Detail aperture area; 6500x SEM.

Caesalpinaceae *(Margocolporites* sp.)
Fig. 14: Polar view; 850x LM.
Fig. 15: Polar view; 1000x SEM.
Fig. 16: Detail; 7000x SEM.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Aperture: Tricolporate; colpi are narrow; the sexine in the aperture area protrudes slightly.
Wall thickness: The sexine is thickened in the polar areas (1,5–2µ); the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Rugulate; rod-like tectal elements display a criss-cross pattern in the polar areas, whilst
welded together in the aperture areas. In the mesocolpium areas, rods are shorter and densely packed; rods are smooth.

Gen. indet. 2, Pl. 7, Fig. 11–13
Shape: Prolate; elliptical in equatorial view.
Size: c-axis: 33–35µ, b-axis: 16–18µ.
Apertures: Tricolporate.
Wall thickness: 2,5–3µ; in the polar and aperture areas the sexine is considerable thickened.
Exine: Tectate.
Sculpture: Criss-cross pattern of short rods (width 0,3–0,5µ); the rods tend to split up and cross over each other. In the polar areas the rods get longer and flatter.

Gen. indet. 3, Pl. 7, Fig. 14–16
Shape: Prolate; elliptical to bone shaped in equatorial view.
Size: c- axis: 30–33µ, b-axis: 15–17µ
Apertures: Tricolporate; colpi are narrow, long and straight.
Wall thickness: 1,5–2µ; the nexine has the same thickness as the sexine.
Exine: Tectate.
Sculpture: Criss-cross pattern of shallow short rods.

Family: Rosaceae Jussieu
Genus: *?Polylepis* Ruíz & Pavón/?Acaena Mutis ex. Linné, Pl. 8, Fig. 1–3
Shape: Spheroidal, circular in polar view.
Size: 20–24µ in equatorial diameter.
Apertures: Tricolporate, operculate; the operculum above endoapertures is less verrucate and smoother.
Wall thickness: 1–1,3µ; the nexine is slightly thinner than the sexine.
Exine: Tectate.
Sculpture: Verrucate with microspinulae; verrucae are irregularly dissected.

Family: Rosaceae Linné
Genus: *Rubus* Linné, Pl. 8, Fig. 4–6
Shape: Subprolate and rhomboidal in equatorial view.
Size: 20–22µ in equatorial diameter.
Apertures: Tricolporate; the sexine protrudes slightly in the endoaperture areas and forms a bridge- like structure.
Wall thickness: 1,5µ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Striate; thick (1µ), short striae (2–4µ) that narrow considerably at the ends and run from pole to pole in the mesocolpium areas; the striae are arranged perpendicular to the colpi and are smooth. The polar and aperture areas display perforations between the striae.

Gen. indet. 1, Pl. 8, Fig. 7–9
Shape: Prolate and elliptical in equatorial view.
Size: c-axis: 32–34µ, b-axis: 18–29µ.
Apertures: Tricolporate; the sexine protrudes slightly in the endoaperture areas and forms a bridge- like structure.
Wall thickness: 1,5µ; the nexine has the same thickness as the sexine.
Exine: Tectate.
Sculpture: Striate; the striae are thin and run more or less perpendicular to the c-axis; they tend to split and thin out at the ends; some extremely thin striae cross over other striae

Gen. indet. 2, Pl. 8, Fig. 10–12
Shape: Prolate; elliptical in equatorial view.
Size: c-axis: 22–24µ, b-axis: 17–19µ.
Apertures: Tricolporate, operculate; the operculum displays shallow broad striae and fossulae.
Wall thickness: 1,3µ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Striate; striae and fossulae have the same width (0,2µ) and run more or less paralell to each other from polar area to polar area; fossulae are perforate.

Gen. indet. 3, Pl. 8, Fig. 13–15
Shape: Spheroidal; circular in equatorial view.
Size: 24–26µ in equatorial diameter.
Apertures: tricolporate; operculate.
Wall thickness: 1,4–1,6µ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Striate; very thin and flat striae that are combined mostly in pairs or triplets; these unit are separated by fossulae. The striae are smooth.

Family: Nothofagaceae
Genus: *Nothofagus menziesi* type Blume
Fossil genus: *Nothofagidites suggatei* Couper, Pl. 9, Fig. 1–3
Shape: Oblate and circular in polar view.
Size: 40–45µ in equatorial diameter.
Apertures: Stephanocolpate (8).
Wall thickness: 1–1,2µ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Regularly spaced short micro-spinulae of various sizes. Tectum displays faint fissures between spinae.

Fossil genus: *N. fortispinulosus* Menéndez & Caccavari
Type 1, Pl. 9, Fig. 4–6
Shape: Oblate; circular in polar view.
Size: 18–20µ in equatorial diameter.
Apertures: Stephanocolpate (8).

Plate 6

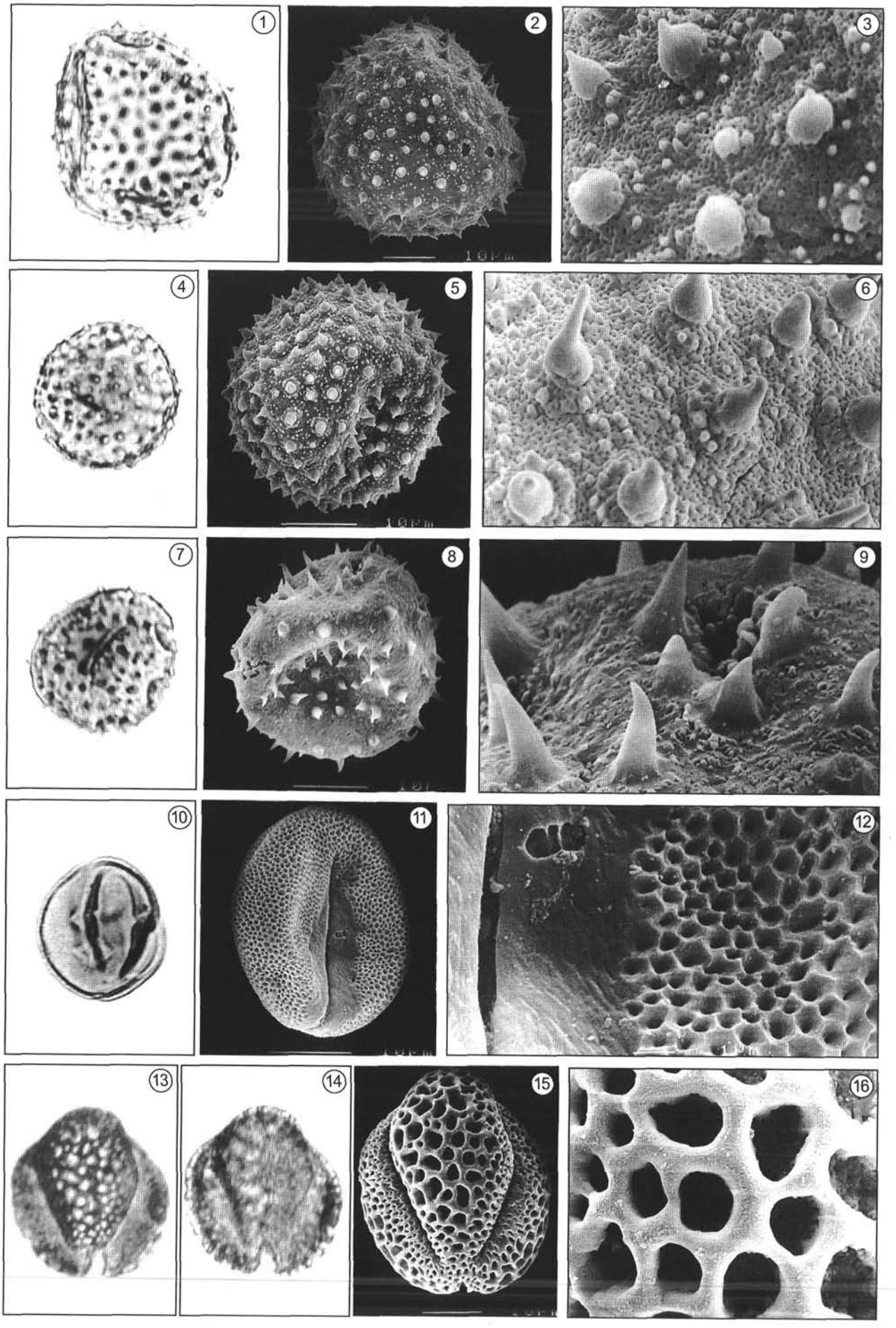
Malvaceae gen. indet. *1 (Malvacipollis* sp. *1)*
Fig. 1: Polar view; 850x LM.
Fig. 2: Polar view; 1000x SEM.
Fig. 3: Detail; 6000x SEM.

Malvaceae gen. indet. *2 (Malvacipollis* sp. *2)*
Fig. 4: Polar view; 850x LM.
Fig. 5: Polar view; 1450x SEM.
Fig. 6: Detail; 6000x SEM.

Euphorbiaceae gen. indet. *1 (Malvacipollis* sp. *3)*
Fig. 7: Polar view; 850x LM.
Fig. 8: Polar view; 1400x SEM.
Fig. 9: Detail; 6000x SEM.

Euphorbiaceae gen. indet. *2*
Fig. 10: Equatorial view; 850x LM.
Fig. 11: Equatorial view; 1500x SEM.
Fig. 12: Detail; 8000x SEM.

Fam. indet. *1*
Fig. 13: Equatorial view; 850x LM.
Fig. 14: Equatorial view; 850x LM.
Fig. 15: Equatorial view; 1100x SEM.
Fig. 16: Detail; 5000x SEM.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Wall thickness: 1μ; the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Regularly densely spaced spinae of 0,3–0,5μ length. Surface of the tectum is uneven and coverd by flaky sporopollenine material.

Fossil genus: *N. fortispinulosus* MENÉNDEZ & CACCAVARI
Type 2, Pl. 9, Fig. 7–9
Shape: Oblate; circular in polar view.
Size: 22–24μ in equatorial diameter.
Apertures: Stephanocolpate (7).
Wall thickness: 1–1,2μ: the nexine is thinner than the sexine.
Exine: Tectate.
Sculpture: Regularly densely spaced spinae of 0,5–0,8μ length; most spinae have globular bases. Surface of the tectum is uneven and faintly fissured.

Fam. indet. 2, Pl. 9, Fig. 10–12
Shape: Oblate, circular in polar view.
Size: 22–25μ in equatorial diameter.
Apertures: Tricolpate
Wall thickness: 1,5μ; the nexine is thinner than the sexine,
Exine: Tectate.
Sculpture: Verrucate with nanno-spinulae, the verrucae are dissected by fossulae, the latter occasionally display perforations.

Family: Sterculiaceae BARTLING
Gen. indet. Pl. 9, Fig. 13–15
Shape: Spheroidal; circular in equatorial view.
Size: 19–22μ in equatorial diameter.
Apertures: Tricolporate; the colpi membranes display clustered microverrucae.
Wall thickness: 1–1,2μ; the nexine has the same thickness as the sexine.
Exine: Semitectate.
Sculpture: Reticulate, heterobrochate; shape of the lumina is polygonal; the muri are simplicolumellate, uneven and wavy and display more braided pattern and fovae. The rimms around the colpi are striato-microreticulate.

5. Discussion

5.1 Palaeoclimatic Interpretation and Biohabitat

The botanical information obtained from the diverse and rich microflora of the lowermost part of the Cullen Fm. has been used to model the palaeoclimatic conditions in the late Eocene. The broad temperature and ecological classification of Nix (*in* MACPHAIL et al., 1994) has been used to facilitate the modelling. In this, three thermal response groups are differentiated; megatherm (mean air temperature >24 °C); mesotherm (>14 °C, >20 °C), and microtherm (<12 °C). If the availability of both moisture and light are not restricted during one or more seasons, these divisions more or less correspond to the tropical, subtropical-warm temperate and cool-cold temperate categories, respectively.

Few, if any, of the plant taxa preserved in the studied samples are frost resistant and most require humid/moist conditions, with temperature requirements varying from microthermal to megathermal. For some families identified no specific climatic information can be inferred, due to the wide climatic range enjoyed by different species of these families (e.g. Apiaceae, Araliaceae, Ericales/Epacridaceae, Rosaceae, Convovulaceae, Polypodiaceae); further work has to be undertaken

Plate 7 ▶

***Myriophyllum* sp.**
Fig. 1: Polar view; 850x LM.
Fig. 2: Polar view; 1800x SEM.
Fig. 3: Detail; 1000x SEM.

***Gunnera* sp.**
Fig. 4: Polar view; 850x LM.
Fig. 5: Equatorial view; 850x LM.
Fig. 6: Polar view; 1600x SEM.
Fig. 7: Detail; 11500xSEM.

Apiaceae gen. indet 1
Fig. 8: Equatorial view; 850x LM.
Fig. 9: Equatorial view; 3000x SEM.
Fig. 10: Detail; 8000x SEM.

Apiaceae gen. indet. 2
Fig. 11: Equatorial view; 850x SEM.
Fig. 12: Equatorial view; 1300x SEM.
Fig. 13: Detail; 6000x SEM.

Apiaceae gen. indet. 3
Fig. 14: Equatorial view; 850x LM.
Fig. 15: Equatorial view; 1200x SEM.
Fig. 16: Detail; 7000x SEM.

Plate 8 (on page 458)

Polylepis/?Acaena
Fig. 1: Polar view; 850x LM.
Fig. 2: Polar view; 2000x SEM.
Fig. 3: Detail; 10 000x SEM.

Rubus sp.
Fig. 4: Equatorial view; 850x LM.
Fig. 5: Equatorial view; 1959x SEM.
Fig. 6: Detail; 6500x SEM.

Rosaceae gen. indet. 1
Fig. 7: Equatorial view; 850x LM.
Fig. 8: Equatorial view; 1500x SEM.
Fig. 9: Detail; 10 000x SEM.

Rosaceae gen. indet. 2
Fig. 10: Equatorial view; 850x LM.
Fig. 11: Equatorial view; 1700x SEM.
Fig. 12: Detail; 7000x SEM.

?Rosaceae gen. indet. 3
Fig. 13: Equatorial view; 850x LM.
Fig. 14: Equatorial view; 1600x SEM.
Fig. 15: Detail; 7000x SEM.

Plate 9 (on page 459)

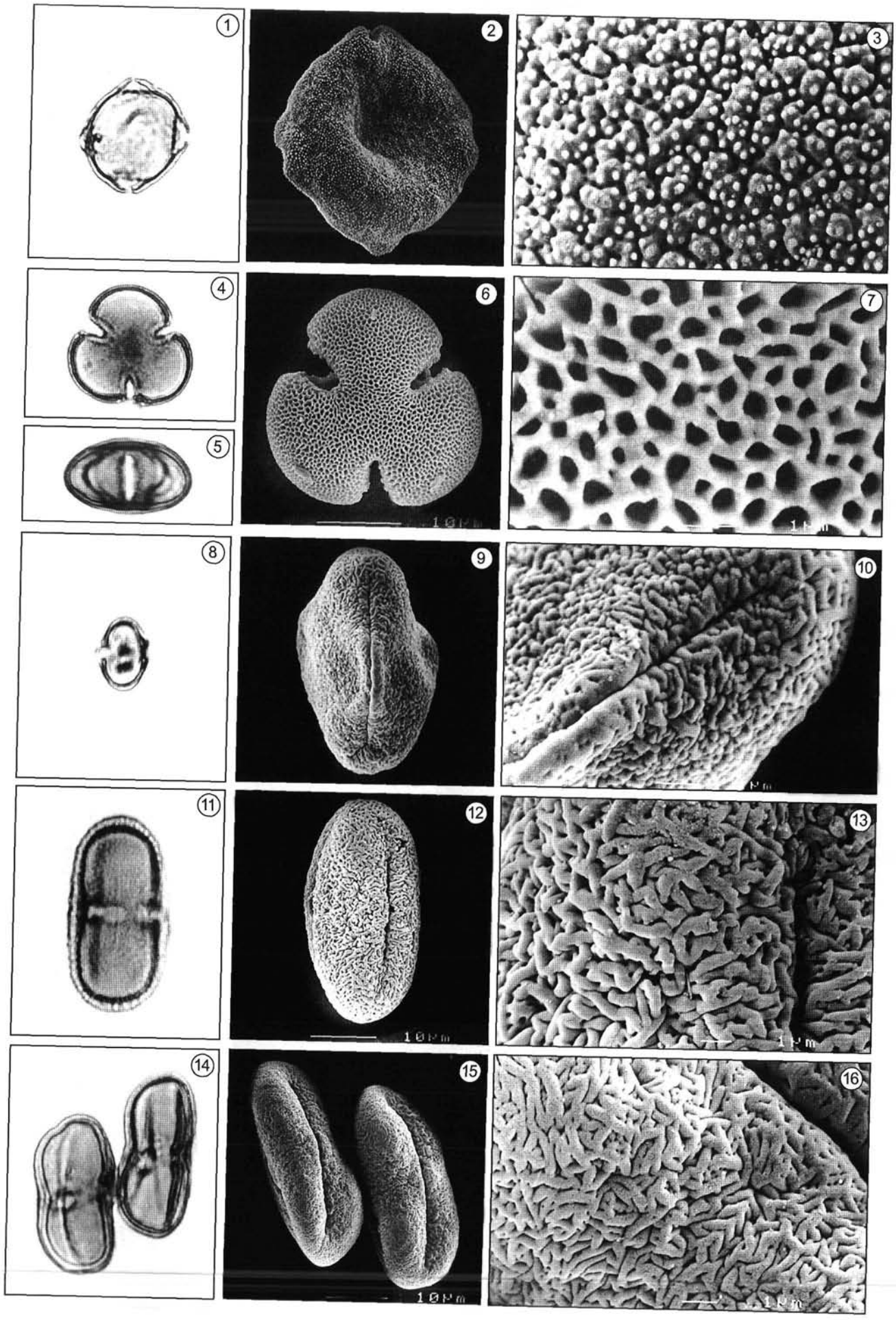
Nothofagus sp.1 (Nothofagidites suggatei)
Fig. 1: Polar view; 850x LM.
Fig. 2: Polar view; 1000x SEM.
Fig. 3: Detail; 12000x SEM.

Nothofagus sp. 2 (Nothofagidites fortispinulosus type 1)
Fig. 4: Polar view; 850x LM.
Fig. 5: Polar view; 1700x SEM.
Fig. 6: Detail; 12000x SEM.

Nothofagus sp. 3 (Nothofagidites fortispinulosus type 2)
Fig. 7: Polar view; 850x LM.
Fig. 8: Polar view; 1800x SEM.
Fig. 9: Detail; 12000x SEM.

Fam. indet. 2
Fig. 10: Polar view; 850x LM.
Fig. 11: Polar view; 1500x SEM.
Fig. 12: Detail 12000x SEM.

Sterculiaceae gen. indet.
Fig. 13: Equatorial view; 850x LM.
Fig. 14: Equatorial view; 2200x SEM.
Fig. 15: Detail; 12 000x SEM.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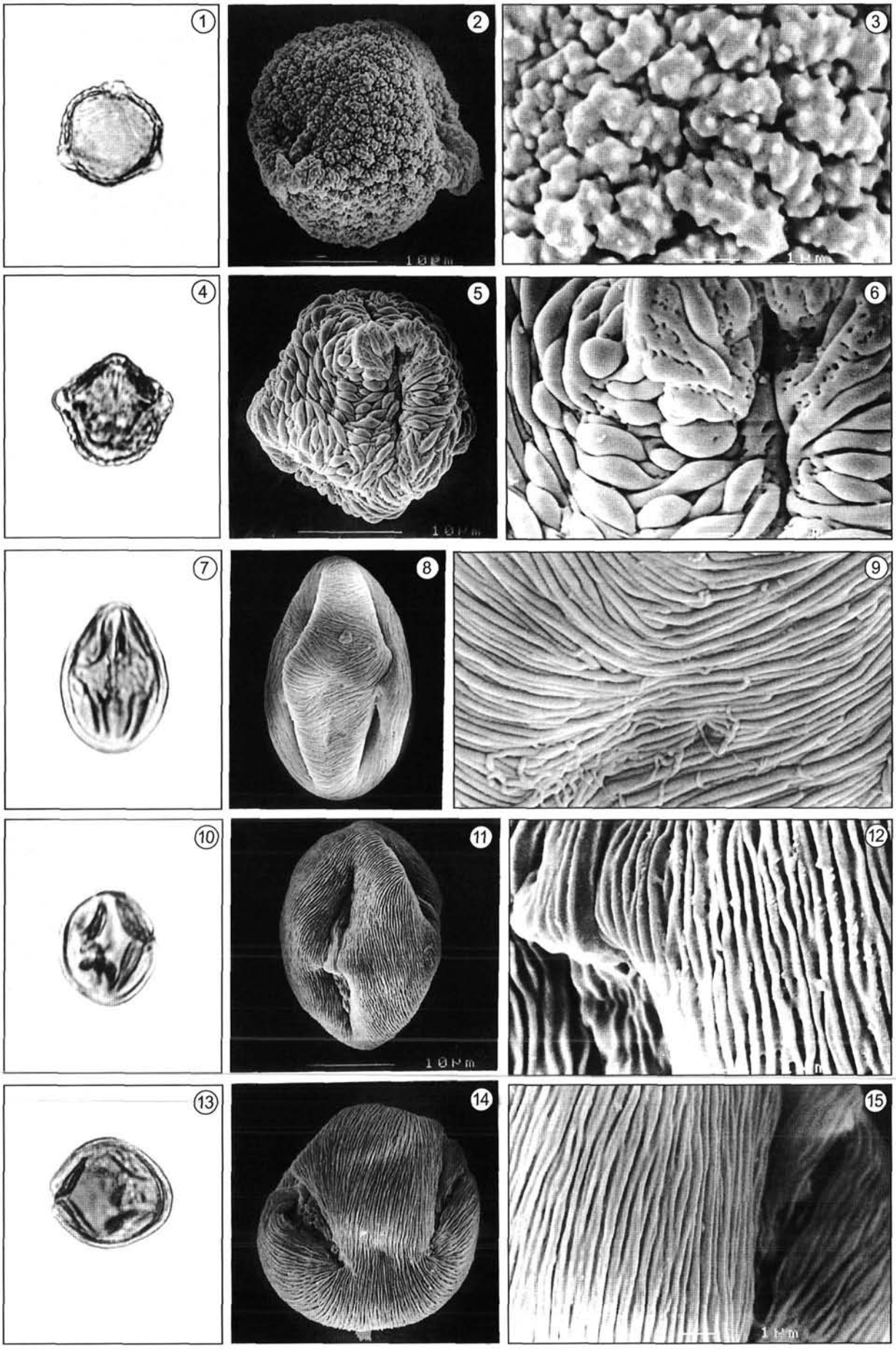

Plate 8: Explanation see on page 456.

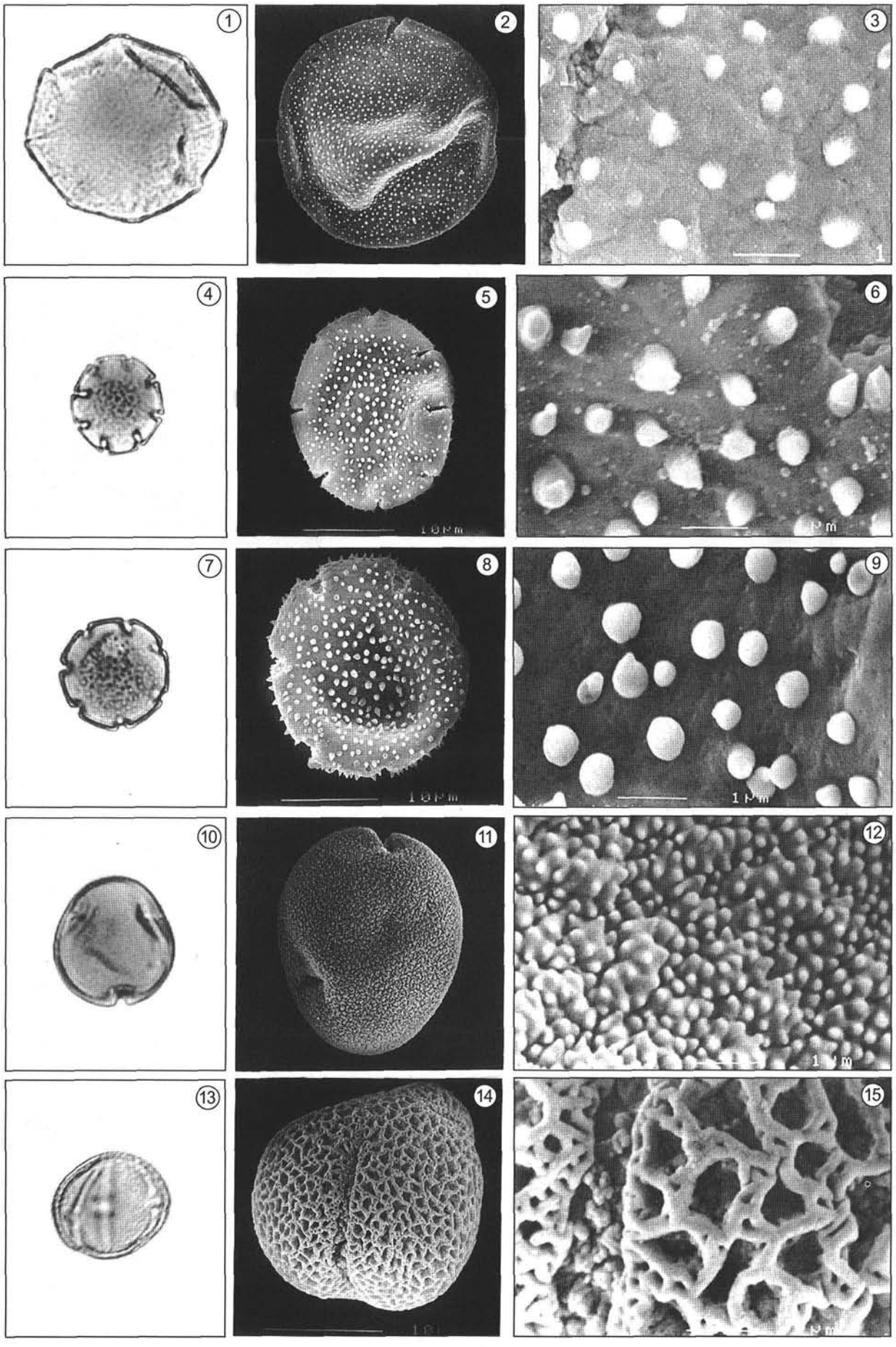

Plate 9: Explanation see on page 456.

to identify this material down to generic level. Taxa that prefer megathermal conditions only occur as accessory components, such as *Bombax, Campnosperma, Cassia, Cnemidaria, Cupania, Proteacidites, Serjania, Trichipteris,* and the members of the Arecaceae, Bignoniaceae, Nyctaginaceae, and Sterculiaceae. These are considered to be relicts of a previous warmer megathermal period and all, except *Proteacidites* spp., prefer humid conditions. *Phyllocladus* and *Dacrydium* prefer micro- to mesothermal conditions, and could have withstood neither frost nor dessication. The two most abundant genera, *Nothofagus* and *Podocarpus,* generally favour more mesothermal conditions (although some *Nothofagus* are more microthermal), as do the bulk of the remaining taxa preserved (e.g. *Fuchsia, Gunnera,* Araliaceae).

Numerous herbaceous and shrubby plant taxa have been identified in this region for the first time, some of which are described in detail. For example, three types of Asteraceae, three types of Malvaceae, four types of Apiaceae, six types of Rosaceae, one type of Valerianaceae, and one *Salix,* giving evidence for a vegetational change that is not only based on the disappearance of megathermal elements of the flora, but as well the evolution of modern families with light demanding taxa. This may be an indication that the dense forest vegetation opened up and gave way to clearings with higher light intensities.

The environment can be described as follows: The vegetation cover around the estuarine setting was dominated by humidity requiring, predominantly mesothermal taxa, forming a rainforest. This was probably dominated by a mixture of *Nothofagus* species, with an overstorey of *Podocarpus* species and a variable undergrowth. In particular, pterophytes and bryophytes are assumed to represent the more herbaceous undergrowth. Other synusia, for example the shrubby/small tree undergrowth, were inhabited by *Ilex, Myrceugenia, Salix* and Caesalpiniaceae such as *Cassia,* Rosaceae, Sterculiaceae. Seasonally, or permanently flooded sites were inhabited by *Gunnera* spp., *Sparganium, Myriophyllum,* Hydrocharitaceae, Restionaceae and Apiaceae. This flora is comparable with the *Nothofagus* association III of MARKGRAF et al. (1996) and has some similarities with the palynoflora of Rio Turbio (ROMERO, 1977).

6. Conclusions

Despite all previously conducted examinations, the palynoflora of the lowermost part of the Cullen Fm. is very diverse and rich; over 90 taxa have been distinguished and most of them botanically affiliated.

The microflora is characterized by approximately one third of dinoflagellate cysts and two thirds of pollen and spores. The amount of spores makes up 24%, those of the gymnosperm pollen 28%, and angiosperm pollen 48%.

The appearance of more modern families such as Apiaceae, Valerianaceae, Asteraceae, Malvaceae, Rosaceae, and *Salix,* the diversity within the genera of *Nothofagus* (>8) and *Podocarpus* (6) give evidence for a vegetational change over.

The stratigraphic position of the lowermost Cullen Fm. can be assigned to Middle Eocene.

The suggested climatic conditions were mesothermal and humid, leading to the development of a *Nothofagus* dominated rainforest vegetation and its associations.

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