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THE PALYNOLOGY OF TERTIARY SEDIMENTS FROM A PALAEOCHANNEL IN NAMAQUALAND, SOUTH AFRICA.

by

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ABSTRACT

A site in Namaqualand, Western Cape Province, has yielded a diverse and well-preserved palynoflora. The site consists of a quarry, exposing a palaeochannel containing fluviatile sands, silts and clays with accompanying peat horizons. This paper presents a qualitative account of the pollen and spore assemblages extracted from the peats. Angiosperms were dominant both in terms of the number of individuals and the recognised types. Identifications were made where possible with reference to published illustrations and descriptions. There was a total of 69 palynomorph types, including spores, gymnosperm and angiosperm pollen.

KEYWORDS: Namaqualand, Tertiary, palynology

INTRODUCTION

To date, there has been limited palynological study of South Africa's Tertiary sediments. The major reason for the paucity of studies is that few suitable sites yielding positive results are known. The current investigation in Namaqualand concerns a new site from which much palynological data is available. The following descriptions represent the first published record of the palynomorphs from this locality.

Previous research on South Africa's Tertiary palynology includes work on the Arnot Pipe (Kirchheimer 1934), an analysis of the Knysna lignites (Thiergart *et al.* 1963), studies of coastal sequences from the south-western Cape (Coetzee 1978, 1980) and sampling by the Deep Sea Drilling Project of various offshore sites (McLachlan & Pieterse 1978, Morgan 1978, Partridge 1978). Scholtz (1985) re-examined sediments from the Arnot Pipe.

It was suggested that the sediments from the new site may be Pliocene in age (SACS 1980). They underlie marine and river terraces informally named as the Hondeklipbaai sandy gravels, which were dated as Pleistocene (SACS 1980) using warm-water faunas and transgression-regression analyses (Davies 1973). Palynology will assist in defining the age more closely.

SITE LOCALITY

The study area lies adjacent to the western coastline of South Africa (Figure 1), 490 km north of Cape Town on the coastal plain west of the Bokkeveld Mountains. It traverses the farms Koingnaas 475 and Zwart Lintjies Rivier 484 (Figure 2) and is referred to as 'Koingnaas' in this paper.

GEOLOGY

The local succession comprises the Hondeklipbaai sandy gravels which occur on overlapping marine terraces found between the Olifants River and Kleinsee (Figure 1).

The Koingnaas site consists of a quarry which was cut into a palaeochannel containing fluviatile sands, silts and clays with accompanying peat horizons. A geological section through the palaeochannel appears as Figure 3. The palynological work concentrated on three peat horizons, the 'channel peats', the 'main peat horizon' and peat stringers above the latter ('above main peat horizon').

The sedimentary sequence begins at the base of the channel, consisting of gritty, grey clays with few minor sedimentary structures. Sedimentary peat layers are found near the base of many of the channel scours and in-situ peats may be developed immediately above them. These were considered as the 'channel peats'. Occasionally macrofossil debris is found, such as poorly preserved pieces of wood. The later channel sediments comprise well-sorted and medium-grained sands with clays and peat layers as before. The 'main peat horizon' is found near the top of the channel deposits. It is an in-situ peat with several impersistent layers and recognisable seat earths containing rootlets. It may represent changing conditions and a major break in the sequence. Several stringers of peat were found above the main peat horizon. The succeeding deposits show a distinct change in lithology as they are dominated by medium-to-coarse grained sands, orange in colour with a much reduced clay content. The top of the sequence may be partly aeolian in origin and is unconfined by the channel. The sands are followed by an unconformity representing time during which

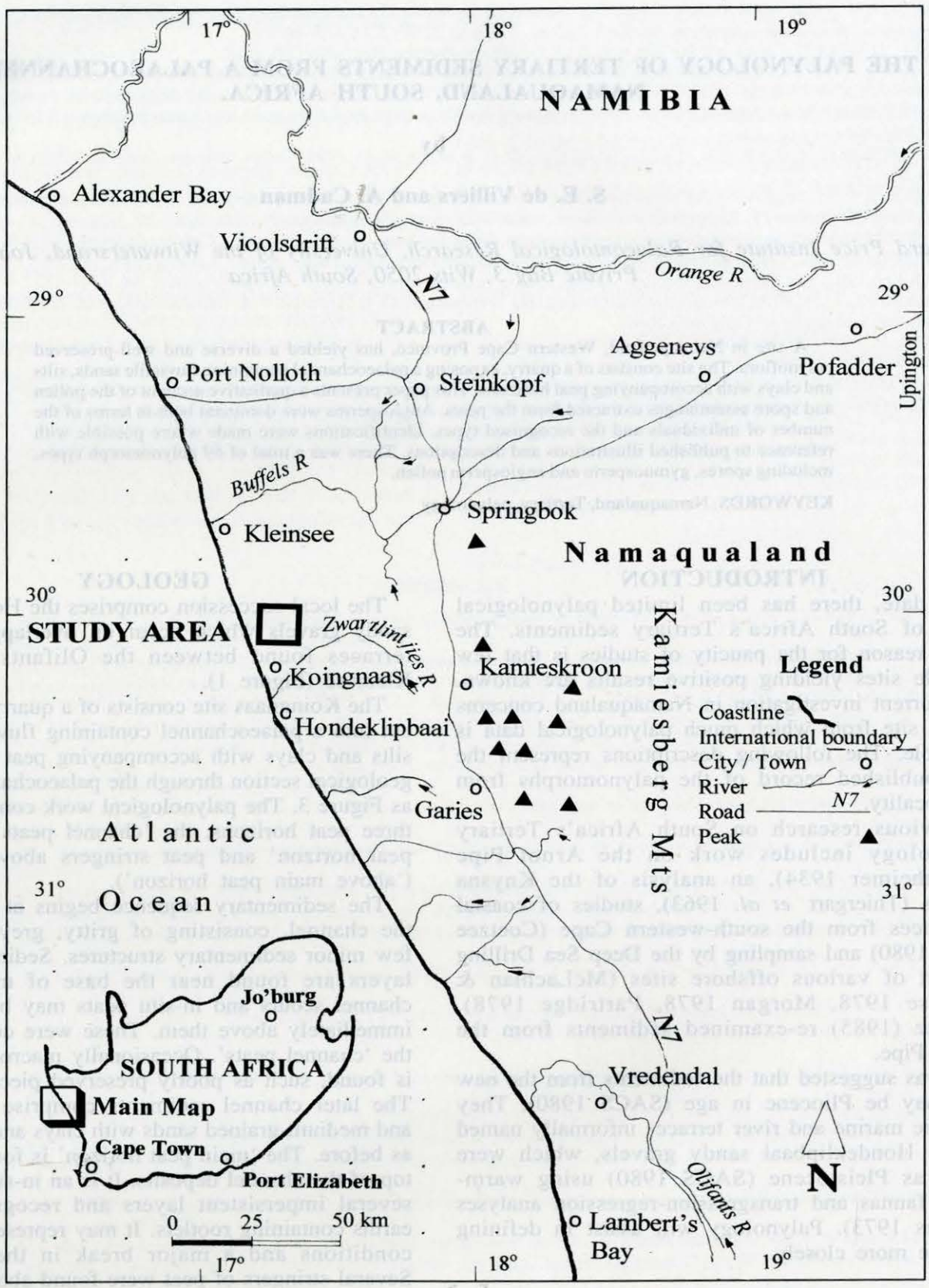


Figure 1. Locality Plan

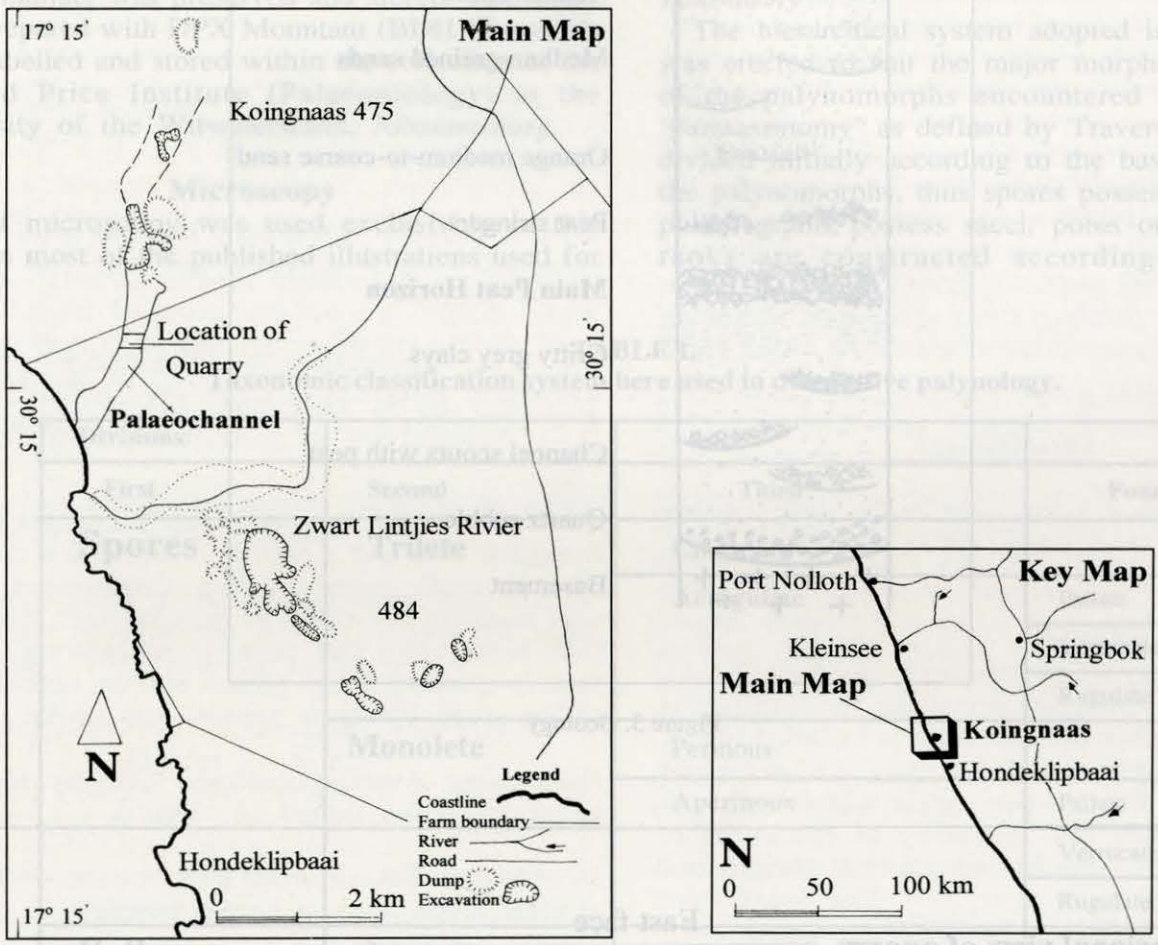


Figure 2. Site Locality

sea level changed considerably as the younger sediments are marine.

MATERIALS AND METHODS

Field techniques

A total of 45 samples was taken from the main peat horizon, stringers above it, and the channel peats. Some of the accompanying fine-grained sediments were sampled as well. The positions in the quarry face of those samples containing palynomorphs are given in Figure 4. Standard sampling procedures proposed by Faegri & Iversen (1964) were followed.

Laboratory methods

The extraction methods used in the laboratory combined those of Gray (1965) and Doher (1980). Approximately 25 g of each sample were processed. Twenty-five of the samples proved positive for palynomorphs.

Physical disaggregation and dispersal

Most of the samples were pounded with a mortar and pestle. Many of the Koingnaas samples included a clay fraction which proved difficult to work with. A slurry was made of the disaggregated material using distilled water.

Chemical extraction of minerals and organic matter

The slurry was chemically treated to remove the unwanted fractions. Carbonate removal was effected by 10% hydrochloric acid, clay minerals by 5% sodium pyrophosphate, silicates by 40% hydrofluoric acid and organic material by Schultz's solution.

Density separation

The heavy liquid used was zinc chloride with a specific gravity of 1.96. After centrifuging for 25 minutes at 2 500 rpm, the floating fraction was checked for palynomorphs. The sample was then

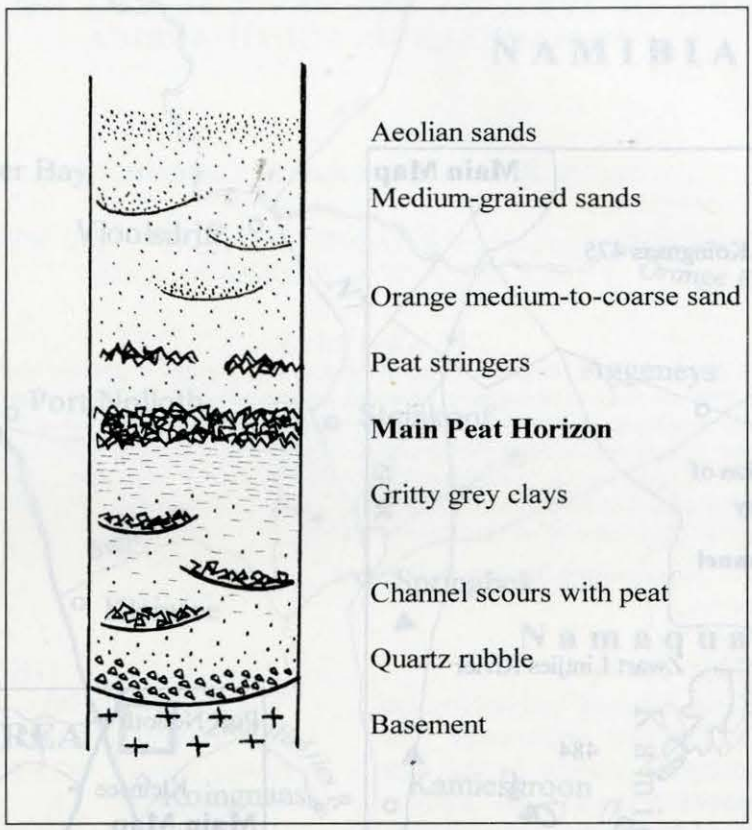


Figure 3. Geology

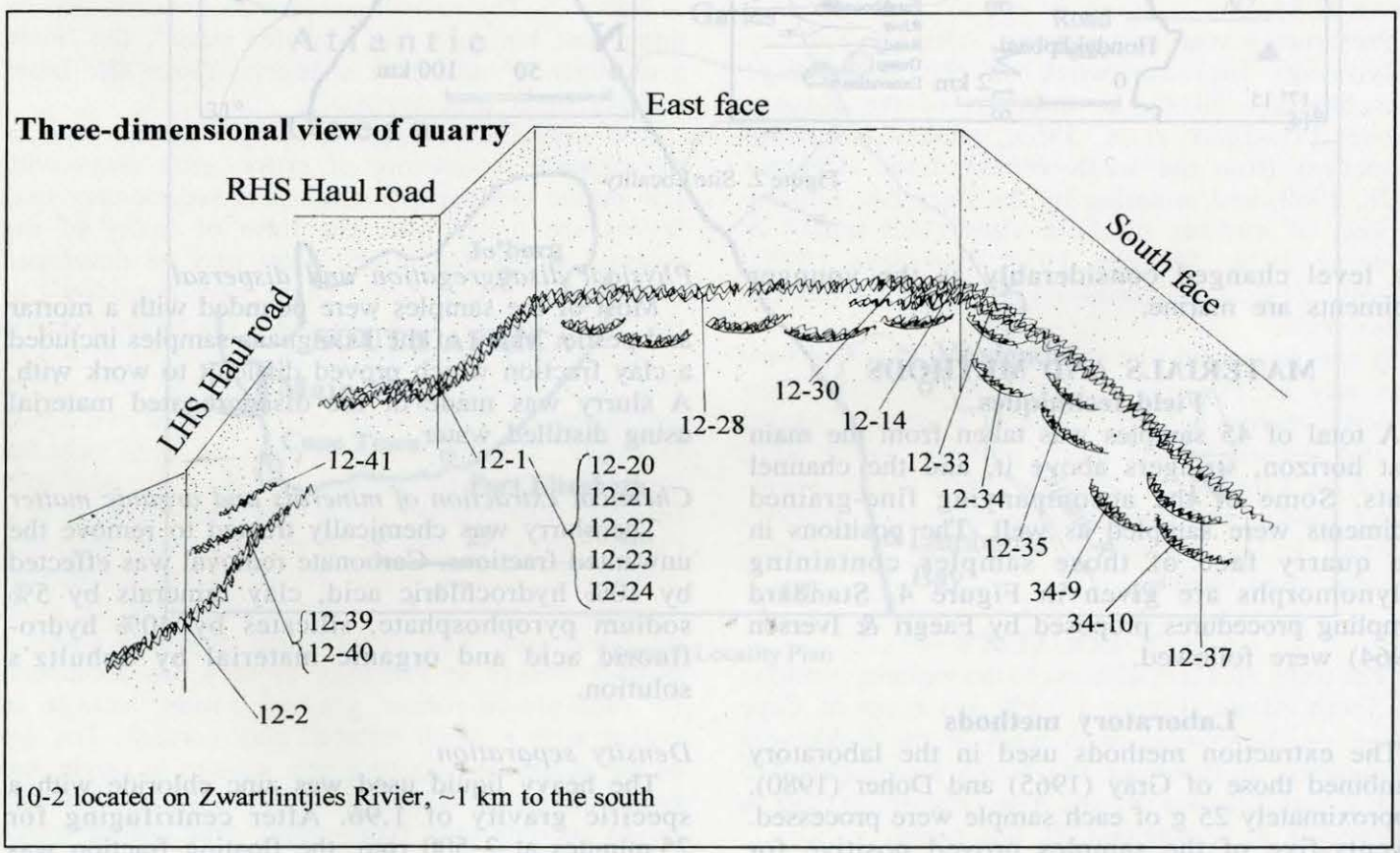


Figure 4. Sample Locations

judged to have a positive or negative palynomorph content.

Cleaning of residue and slide mounting

Positive residues were washed clean of zinc chloride and 1 cm^3 was used for slide mounting. The remainder was preserved and stored. The slides were prepared with DPX Mountant (BDH Chemicals UK), labelled and stored within the collection of the Bernard Price Institute (Palaeontology) at the University of the Witwatersrand, Johannesburg.

Microscopy

Light microscopy was used exclusively in this study as most of the published illustrations used for comparison were photomicrographs produced by light microscopy. Photomicrographs were taken of all representative specimens.

SYSTEMATIC PALYNOLOGY

Classification system

Taxonomy

The hierarchical system adopted in this research was erected to suit the major morphologic features of the palynomorphs encountered and is thus a 'parataxonomy' as defined by Traverse (1996). It is divided initially according to the basic structure of the palynomorphs, thus spores possess laesurae and pollen grains possess sacci, pores or colpi. Lower ranks are constructed according to mutually

TABLE 1.
Taxonomic classification system here used in descriptive palynology.

Divisions:			
First	**Second**	**Third**	**Fourth**
Spores	**Trilete**	Cingulate	
		Acingulate	Psilate
			Verrucate
			Rugulate
	Monolete	Perinous	
		Aperinous	Psilate
			Verrucate
			Rugulate
Pollen	**Saccate**	Bisaccate	
		Polysaccate	
	Porate	Monoporate	
		Triporate	
		Periporate	
		Stephanoporate	
	Colpate	Monocolpate	
		Trichotomocolpate	
		Tricolpate	
		Stephanocolpate	
	Colporate	Tricolporate	
		Stephanocolporate	
		Suncolporate	
Tetrads & Polyads			
Incertae sedis			

exclusive taxonomic features which include sculpturing elements and aperture construction (See Table 1).

Nomenclature

Individual palynomorph types were identified where possible with published illustrations and descriptions. Literature based on strata of similar age from regions which previously constituted western Gondwana were consulted initially, as this was the relevant phytogeographic province. Taxa from further away were only considered when other alternatives seemed implausible.

Palynomorph types which were unknown in the literature consulted were described and illustrated as completely as possible. Formal names will be assigned later, pending more specimens becoming available with continuing research on other local sites.

Terminology

Technical terms

All the technical terms used in the current paper are explained in Kremp (1965) and Punt *et al.* (1994).

Quantitative statements

A wide variety of palynomorph types was found. A quantitative statement concerning the distribution of each type within the sediments is included as part of the descriptive palynology. An array of approximately 30 types per sample was found, with a correspondingly low frequency of specimens in most cases. Few samples were found wherein one type constituted more than 25%. The quantitative statements are based on the following format:-

Rare - Less than 3% of one sample
Little known – 3 - 5% of one sample
Well known – 5 - 10% of one sample
Common – 10 - 20% of one sample
Significant – 20 - 50% of one sample
Dominant – At least 50% of one sample

Note: Palynomorph types presenting less than 5 specimens were not included in this paper.

Descriptive palynology

First division category (spores)

Morphologically, spores are recognised according to the character of the aperture. They possess laesurae, either trilete or monolete, as defined by Dettmann (1963).

Second division category (trilete spores)

Trilete spores possess a three-pronged 'trilete' mark (consisting of three laesurae) on the proximal face and are triradially symmetrical. The trilete spores found at Koingnaas are further classified according to the presence or absence of an equatorial cingulum.

Third division category (cingulate trilete spores)

Cingulate trilete spores possess a flange-like extension of the exine around the equatorial region of the spore, as defined by Kremp (1965).

Genus *Interulobites* Paden Phillips & Felix 1971

Type species: *I. intraverrucatus* (Brenner) Paden Phillips 1971

Remarks: Spores were placed into this genus if they possessed a narrow cingulum and large, flat verrucae on the distal face.

Interulobites sp – Figure 5.8

Literature: Ioannides & Colin 1974 p 896 Pl 4 no 3 & 4, Jansonius & Hills 1976 p 1334, McLachlan & Pieterse 1978.

Description: Trilete spores with a circular to sub-triangular amb and a narrow, structureless cingulum of even width, averaging 2µm. Commissure closed, rays reaching two-thirds to the cingulum. The distal face bears large flat verrucae sculpturing, approx 5µm in diameter which project into the central cavity of the spore. Exospore approx 2µm thick.

Dimensions: Average equatorial diameter, including cingulum 28µm, (range 16 - 39µm).

Distribution: Rare in main peat horizon. Not found at other levels. Present in two samples.

Genus *Polypodiaceoisporites* Potonié 1951 ex Potonié 1956

Type species: *P. speciosus* Potonié (1951) 1956

Remarks: These spores were identified as *Polypodiaceoisporites* despite some similarity with the genus *Muricingulisporis*, as both are cingulate with robust sculpturing. In *Muricingulisporis*, the elements are fused into muri whereas in the Koingnaas specimens the sculpturing is verrucate/rugulate. However, they show fused elements which completely surround the laesurae, as seen in *Muricingulisporis*.

Botanical affinity: This spore type was probably produced by a fern species related to the genus *Pteris* (Muller 1968).

Polypodiaceoisporites retirugatus Muller 1968 Figures 5.1 & 5.2

Literature: Potonié 1951, Potonié 1956, Muller 1968 p 7 Pl 1 Figure 8, Hekel 1972 p 5 Pl 2 Figure 2

& 3, Jansonius & Hills 1976 p 2098, Kemp 1974 p 818 Pl 2 Figure 21 & 22, Partridge 1978 Pl 1 Figures 9a & 9b.

Description: Trilete spores with a convexly triangular amb and a broad, structureless cingulum of even width, averaging 4µm. Commissure closed with an adjacent well-marked margo and rays reaching halfway to the equator. The proximal surface bears small verrucae (<2µm) in the interradial areas and the distal face bears robust rugulate-verrucate sculpturing, approx 3-5µm in diameter or width. Exospore approx. 2µm thick. Anisopolar in equatorial view.

Remarks: The Koingnaas specimens are smaller, possess longer laesurae, and have a slightly wider cingulum than those Figured in Muller (1968). Two illustrations of the same spore are shown. Figure 5.1 shows the interradial sculpturing on the proximal face and Figure 5.2 focusses on the laesurae.

Dimensions: Average equatorial diameter, including cingulum 36µm (range 25-45µm).

Distribution: Rare in the channel peats, little known in the main peat horizon, not seen above the main peat horizon. Present in six samples.

Polypodiaceoisporites cf *tumulatus* Partridge 1973
Figures 5.4 & 5.5

Literature: Potonié 1956, Jansonius & Hills 1976 p 2098, Kemp & Harris 1977 p 11 Pl 1 Figures 6 & 7.

Description: Trilete spores with a straight triangular amb and a narrow, structureless cingulum 3µm wide. Cingulum appears wider in interradial areas (up to 5µm). Commisssure may gape and is surrounded by a wide kyrtome bearing finely scabrate sculpturing. Well-defined laesurae measure in excess of two-thirds spore radius. Proximal surface psilate but distal face bears robust rugulate-to-verrucate sculpturing (3µm in width). Exosposre approximately 2µm thick.

Remarks: *Polypodiaceoisporites* cf *tumulatus* differs from *P. retirugatus* in having a cingulum which may vary in width, being wider in the interradial areas (Kemp & Harris 1977). The Koingnaas specimens differ in their overall shape (*P. retirugatus* has a roundly triangular amb and *P.* cf *tumulatus* straight sides) and their sculpturing (*P. retirugatus* has verrucate/rugulate sculpturing on both faces while *P.* cf *tumulatus* has robust rugulae on the distal face only while the proximal face is psilate). Two illustrations of the same spore are shown. Figure 5.4 shows the sculpturing on the distal face and Figure 5.5 focusses on the laesurae.

Dimensions: Average equatorial diameter, including cingulum 34µm (range 23 - 44µm).

Distribution: Little known in the main peat horizon and rare above. Not known in the channel peats. Present in 3 samples.

Genus *Verrucingulatisporites* Kedves 1961
Type species: *V. verrucatus* Kedves 1961

Remarks: Both sides of the central body and cingulum are ornamented with relatively large elements. The sculpture is 'corrugate' or verrucose.

Verrucingulatisporites sp – Figure 5.12
Literature: Kedves 1961 p 140 Pl 8 Figure 10, Jansonius & Hills 1976 p 3178.

Description: Trilete spores with a roundly triangular-to-circular amb with a relatively narrow cingulum, 3µm in width. Laesurae indistinct due to the nature of the sculpturing, but they may be surrounded by a narrow margo. Commissure gapes in some of the specimens studied. Sculpturing consists of very robust verrucae and rugulae. Verrucae closely placed, 2-4µm at base, 3-5µm high and may be pointed. Rugulae 2-4µm wide, may extend more than 10µm in length. Rugulae may form ridge in apical area.

Dimensions: Average equatorial diameter, including cingulum 38µm (range 28 - 54µm).

Distribution: Rare at all levels. Present in 8 samples.

Third division category (acingulate trilete spores)

These spores lack a cingulum as defined above. They are further classified according to their sculpture type.

Fourth division category (psilate acingulate trilete spores)

Spores with a surface which is more or less smooth.

Genus *Cyathidites* Couper 1953
Type species: *C. australis* Couper 1953

Remarks: Dettmann (1963) discussed the distinguishing features of the genus. Spores were identified as *Cyathidites* if they possessed a concavely-triangular amb with broadly rounded apices, convex proximal and distal surfaces and clearly defined laesurae measuring over two-thirds the spore radius.

Botanical affinity: Probably Dicksoniaceae (tree ferns) (Traverse 1988). Dettmann (1963) summarized the known botanical affinites of various species.

Cyathidites australis Couper 1953 – Figure 5.11
Literature: Couper 1953 p 27 Pl 2 Figures 11 & 12, Dettmann 1963 p 22 Pl 1 Figures 1-3, Harris 1965 p 79 Pl 24 Figure 11, Sah & Dutta 1972 p 43, Harris 1974 Pl 1 Figure 9, Jansonius & Hills 1976 p 692, Burger 1976 p 116 Pl 18 Figures 3 - 5, Kemp & Harris 1977 p 8, Kar 1979 p 19 Pl 1 Figure 1, Kar 1985 Pl 1 Figure 1 & 2 Pl 22 Figure 12 Pl 17 Figure 3 Pl 28 Figure 1, Scholtz 1985 p 19 Figure 4E, El Beialy 1995 p 315 Pl 4 Figure 1.

Description: Trilete spores with a roundly triangular amb having concave sides. Laesurae long, measuring two-thirds spore radius, clearly defined. Some specimens possess a gaping commissure. Exospore relatively thin (1-2µm) with a psilate surface.

Remarks: Harris (1974) found that *C. australis* appears to intergrade with *C. minor*. The Koingnaas specimens have been differentiated on the basis of exine thickness and relative size.

Dimensions: Average equatorial diameter 39µm (range 19-72µm).

Distribution: Little known in the channel peats, well known in the main peat horizon and rare above the main peat horizon. Present in 13 samples.

Cyathidites minor Couper 1953 – Figure 5.6
Literature: Couper 1953 Pl 2 Figure 13, Dettmann 1963 p 22 Pl I Figure 4 & 5, Harris 1965 p 79 Pl 24 Figure 12, Burger 1966 p 237 Pl 4 Figure 1, Brenner 1968 p 349 Pl 1 Figure 4, Hekel 1972 p 3 Pl 2 Figure 4, Ioannides & Colin 1974 p 896 Pl 4 Figure 1, Harris 1974 Figure 9, Hos 1974 p 7 Figure 13, Burger 1976 p 116 Pl 18 Figure 6 &7, Jansonius & Hills 1976 p 692, Kemp & Harris 1977 p 8, McLachlan & Pieterse 1978 Pl 1 Figure 1, Salard-Cheboldaeff 1979 p 368, Herngreen & Chlonova 1981 Pl 3 Figure 12, Kar 1985 Pl 1 Figure 2 Pl 6 Figure 1 Pl 28 Figure 2, Kar 1979 p 19 Pl 1 Figure 2, Traverse 1988 p 215 Figure 11.2 a, Saxena & Misra 1990.

Description: Trilete spores with a concavely triangular amb and rounded apices. The laesurae are distinct with long narrow rays measuring two-thirds spore radius. Commissure may gape. Exospore thin (1µm) with psilate surface.

Remarks: *C. minor* is generally smaller and more delicate than *C. australis* and is often found crumpled.

Dimensions: Average equatorial diameter 25µm (range 20-30µm).

Distribution: Little known in the channel peats. Well known in the main peat horizon but not found above it. Present in 5 samples.

Cyathidites splendens Harris 1965 – Figure 5.13
Literature: Harris 1965 p 79 Pl 24 Figure 13-15, Jansonius & Hills 1976 p 692.

Description: Large trilete spores with a concavely sided triangular amb in polar view. Anisopolar in lateral view with polar length equal to equatorial diameter. Spores found in all orientations. Laesurae well marked with a faint margo. Rays measure two-thirds the spore radius, commissure may gape. Exospore relatively thin (2µm). Surface psilate to faintly scabrate.

Remarks: The Koingnaas specimens bear some resemblance to the published illustration of *Cyathidites giganticus* in Saxena & Misra (1990 p 265 Pl 1 Figure 17). Where found, large trilete spores were often numerous in the Koingnaas samples. Harris (1965) commented that spores of similar morphology to the new species he was proposing occurred in the modern *Lygodium*. *C. splendens* is differentiated from *Lygodiumsporites* on the proximal view, the length of the laesurae and overall size.

Dimensions: Average equatorial diameter 108µm (range 90-120µm).

Distribution: Rare. Found in the main peat horizon and the channel peats. Present in 3 samples.

Genus *Deltoidospora* (Miner 1935) Potonié 1956
Type species: *D. hallii* Miner 1935

Remarks. *Deltoidospora* was erected as a portmanteau genus for the reception of small trilete spores which were not otherwise assignable to another genus. The same approach has been taken when dealing with the Koingnaas specimens. Those included here bear a resemblance to several published illustrations and descriptions. They were not placed into species as little palaeobotanical or biostratigraphical information would be gained.

Botanical affinities: *Deltoidospora*-like spores were obtained from Lower Cretaceous *Onychiopsis* ferns as well as Eocene – Oligocene polypodiaceous ferns (*Acrostichum*) (Traverse 1988). Small trilete spores of this type are commonly found associated with many Mesozoic ferns (Jansonius & Hills 1976).

Deltoidospora sp – Figure 5.10
Literature: Miner 1935 p 618 Pl 24 Figure 7, Potonié 1956, Burger 1966 p 238 Pl 4 Figure 3, Martin 1973 p 9 Figure 33, Jansonius & Hills 1976 p 748, Kemp & Harris 1977 p 10 Pl 1 Figure 10-12, McLachlan & Pieterse 1978 Pl 1 Figure 3 & 4, Traverse 1988 p 219 & 233 & 311 Figure 14.3 b & 13.1c.

Description: Trilete spores with a triangular to subcircular amb, apices rounded. Laesurae long, reaching the equator. Commissure closed. Exospore thin (1-2µm), surface psilate.

Dimensions: Average equatorial diameter 45µm (range 13-70µ)

Distribution: Little known in the channel peats and the main peat horizon. Rare above the main peat horizon. Present in 10 samples.

Genus *Dictyophyllidites* Couper 1958 emend. Dettmann 1963

Type species: *D. harrisii* Couper 1958

Remarks: Spores were assigned to *Dictyophyllidites* if they possessed a thickened and faintly sculptured margo. The genus is discussed in Dettmann (1963).

Botanical affinity: Couper (1958) related the genus to spores of the Jurassic fern *Dictyophyllum*. Spores of this type were obtained from Jurassic *Phlebopteris* and Lower Cretaceous *Weichselia* ferns (Traverse 1988).

Dictyophyllidites sp – Figure 5.7

Literature: Couper 1958 p 140 Pl 21 Figure 6, Dettmann 1963 p 27, Harris 1965 p 80 Pl 24 Figure 18 & 19, Hekel 1972 p 3 Pl 2 Figure 8, Martin 1973 p 8 Figure 30, Jansonius & Hills 1976 p 786, McLachlan & Pieterse 1978 Pl 1 Figure 12, Pocknall & Mildenhall 1984 p 18 Pl 1 Figure 2-5, Traverse 1988 Figure 11.2 Figure 11.5 Figure 13.1.

Description: Trilete spores with a straight triangular amb. Laesurae long, in excess of two-thirds the spore radius, surrounded by a wide margo, with a scabrate surface. Exospore thin (1-2µm).

Dimensions: Average equatorial diameter 23µm (range 11 - 26µm).

Distribution: Rare at all levels. Present in 8 samples.

Genus *Gleicheniidites* Ross 1949

Type species: *G. senonicus* Ross 1949.

Remarks: The genus is discussed in Dettmann (1963) and Jansonius & Hills (1976).

Botanical affinity: Gleicheniaceae (Jansonius & Hills 1976).

Gleicheniidites sp – Figure 5.9

Literature: Cookson 1953 p 464 Pl 1 Figure 5 & 6, Dettmann 1963 p 64 Pl 13 Figure 6-10, Harris 1965 p 82 Pl 25 Figure 17, Jansonius & Hills 1976 p 1123, Martin 1973 p 6 Figure 9, Burger 1976 p 125 Pl 22 Figure 3-7, McLachlan & Pieterse 1978 Pl 1 Figure 41, Dettmann & Thomson 1987 Figure 4e.

Description: Trilete spores with a triangular amb, usually with concave sides and rounded apices. Laesurae long, reaching the equator. Exospore thin (1-2µm), but thickened slightly in interradial areas. Surface psilate.

Dimensions: Average equatorial diameter 27µm (range 19-35µm).

Distribution: Rare in the main peat horizon and channel peats. Found in two samples.

Genus *Lygodiumsporites* (Potonié, Thomson & Thiergart 1950) Potonié 1956

Type species: L. adriennis Potonié & Gelletich 1933.

Remarks: General similarities exist between specimens assigned to this genus and those included as *Cyathidites splendens*. The Koingnaas specimens resemble *Lygodiumsporites lakiensis* Sah & Kar 1969.

Botanical affinity: Produced by schizaeaceous ferns (Venkatachala & Rawat 1973).

Lygodiumsporites sp – Figure 5.3

Literature: Potonié, Thomson & Thiergart 1950, Potonié 1956, Jardine & Magloire 1965 Pl 1 Figure 8, Jansonius & Hills 1976 p 1561, Rao 1989 Pl 1 Figure 20 & 21, Saxena & Misra 1990 p 273 Pl 3 Figure 1.

Description: Large trilete spores with a very roundly triangular amb, spherical in lateral view. Laesurae short, measuring half the spore radius, with gaping commissure, surrounded by a well-marked margo. The illustrated specimen also shows 'pseudotoroid claws' which are fold-features of the margo. Exospore thin (1-2µm), surface psilate.

Dimensions: Average equatorial diameter 77µm (range 55 - 120µm).

Distribution. Well known in the channel peats and above the main peat horizon. Significant in the main peat horizon. Present in 8 samples.

Genus *Todisporites* Couper 1953

Type species. T. major Couper 1953.

Remarks. Genus erected to accommodate spores similar to those of *Todites* (Jansonius & Hills 1976).

Todisporites sp – Figure 5.15
Literature: Couper 1958 p 134 Pl 16 Figure 6, Jansonius & Hills 1976 p 2909, Martin 1973 p 6 Figure 7&8, McLachlan & Pieterse 1978 Pl 1 Figure 11.

Description: Trilete spores with a circular or roundly triangular amb. Laesurae long and narrow with raised lips, reaching the equator, commissure closed. Exospore thin (1-2µm), surface psilate. Spores often folded.

Dimensions: Average equatorial diameter 35µm (range 15-62µm).

Distribution: Rare in the main peat horizon and above. Present in 2 samples.

Type A – Figure 5.16
Remarks: The Koingnaas specimens did not resemble any illustrations or descriptions in the literature consulted. They appeared somewhat similar to *Laroccatriletes* Burger 1966 in Jansonius & Hills (1976).

Description: Trilete spores with a triangular amb having concave or straight sides, apices broadly rounded. Laesurae measure half the spore radius, commissure gapes very widely. Exospore (1-3µm), surface psilate.

Dimensions: Average equatorial diameter 31µm (range 22-53µm).

Distribution: Rare in the channel peats and above the main peat horizon. Little known in the main peat horizon. Present in 14 samples.

Fourth division category (granulate acingulate trilete spores)
Spores with surface sculpturing consisting of small granulae, the basal diameters of which do not exceed their height as defined by Kremp (1965).

Genus *Osmundacidites* Couper 1953
Type species: *O. wellmanii* Couper 1953

Botanical affinity: Jurassic osmundaceous ferns (Couper 1953). Found in *Todites* sporangia of Triassic age (Traverse 1988).

Osmundacidites wellmanii Couper 1953 – Figure 5.14
Literature: Couper 1953 Pl 1 Figure 5, Couper 1960 p 38 Pl 1 Figure 1, Dettmann 1963 p 31 Pl 3 Figure 19-21, Burger 1966 p 251 Pl 20 Figure 3, Hekel 1972 p 4 Pl 2 Figure 10, Martin 1973 p 5 Figure 5, Harris 1974 Pl 1 Figure 7, Jansonius & Hills p 1833, Kemp & Harris 1977 p 11, McLachlan & Pieterse 1978 Pl 1 Figure 7, Saxena & Misra 1990.

Description: Granulate trilete spores with circular amb, often folded. Laesurae narrow, very long and sometimes indistinct, reaching the equator. Exospore thin (1-2µm).

Remarks: Dettmann (1963) discusses the species and compares it with similar types, noting that Australian specimens are often distorted with arcuate folds. This feature was noted in the Koingnaas specimens. The spores of *Todea barbara*, a recent representative of the Osmundaceae in New Zealand, are very similar to *O. welmanii* but are smaller and more lightly sculptured (Couper 1953).

Dimensions: Average equatorial diameter 58µm (range 42 - 78µm).

Distribution: Rare in the channel peats, common in the main peat horizon but not known above it. Present in 4 samples.

Second division category (monolete spores)
Morphologically, these spores were recognised by the presence of a monolete mark on the proximal face which has its centre at the pole, as defined by Dettmann (1963). They are bilaterally symmetrical. The Koingnaas monolete spores are further classified according to the presence or absence of a perinous outer layer.

Third division category (perinous monolete spores)
Bearing an extra-exosporous layer, as defined by Kremp (1965).

Genus *Peromonolites* Couper 1953
Type species: P. bowenii Couper 1953

Remarks: Genus originally nominated by Erdtman (1947) for fossil monolete spores with a perine. All monolete spores with a perine found at Koingnaas were assigned to this genus.

Peromonolites sp – Figure 6.1
Literature: Couper 1953 p 32 Pl 3 Figure 31, Couper 1960 p 40 Pl 2 Figure 1, Jansonius & Hills 1976 p 1970.

Description: Monolete spores with a plano- to concavo-convex (bean-shaped) amb. Laesura indistinct, measuring half spore length. Exospore relatively thick, (2-5µm), probably smooth. Perine variously sculptured, from granulate to verrucate or rugulate.

Remarks: The illustrated specimen has a perine with loose folds arranged in a rugulate to hamulate pattern.

Dimensions: Average length 38µm (range 22-56µm). Average height 23µm (range 17-35µm).

Distribution: Rare at all levels. Present in 7 samples.

Third division category (aperinous monolete spores)

Lacking the extra-exosporous layer described above. Spores belonging to this category are further classified according to sculpture.

Fourth division category (psilate aperinous monolete spores)

Spores with a surface which is more or less smooth.

Genus *Laevigatosporites* (Ibrahim 1933) Schopf, Wilson & Bentall 1944

Type species: *L. vulgaris* (Ibrahim) Ibrahim 1933

Remarks: Smooth-walled monolete spores with broadly bean-shaped amb. Several genera to accommodate such spores may be found in the literature. However, many of them are junior synonyms of *Laevigatosporites* (Schopf, Wilson & Bentall 1944). Dettmann (1963) states that 'similar, if not identical, spores have been recorded frequently from other parts of the world in sediments ranging from Devonian to Recent' which possibly accounts for the plethora of names.

Botanical affinity: Ferns (Harris 1965).

Laevigatosporites sp – Figure 6.5

Literature: Jansonius & Hills 1976 p 1436. (*L. major*) – Ibrahim 1933, Krutsch 1959, Harris 1965 p 83 Pl 24 Figure 1, Hekel 1972 p 5 Pl 1 Figure 5, Harris 1974 Pl 1 Figure 1. (*L. ovatus*) – Dettmann 1963 p 86 Pl19 Figure 9-11, Martin 1973 p 13 Figure 50, Herngreen & Chlonova 1981Pl 3 Figure 11, Barnett 1989 Pl 3 Figure 2, Rao 1989 Pl 1 Figure 8.

Description: Monolete spores biconvex to concavo-convex in lateral view, oval in polar view. Laesura not lipped, measuring more than half spore length. Exospore thin to relatively thick (1-3µm) and smooth.

Dimensions: Average length 35µm (range 14-77µm). Average height 25µm (range 11-49µm). Average breadth 24µm (range 19-28µm).

Remarks: All psilate monolete spores found at Koingnaas were assigned to this genus, but not to any particular species. The reasons for this are firstly, the confusion caused by the creation of numerous genera which appear to be synonomous with *Laevigatosporites*; secondly, many brief and conflicting species' descriptions which do not encourage identifications to species level; thirdly, the vast geological range of such spores which supplies no useful stratigraphic information; and finally, the fact that they may be affiliated with many different plants does not aid palaeobotanical interpretation.

Distribution: Well known in the channel peats and above the main peat horizon. Common in the main peat horizon. Present in all samples.

Fourth division category – verrucate aperinous monolete spores

Possessing a surface which has wart-like, equidimensional sculpturing elements which measure more than 1µm at the base.

Genus *Polypodiidites* (Ross 1949) Couper 1953

Type species: P. senonicus Ross 1949.

Remarks: Monolete spores with very thick exospore bearing sub- to per-verrucate sculpturing diminishing on the proximal surface. Although Potonié (1956) incorporated *Polypodiisporites* in the genus *Polypodiidites*, Playford & Dettmann (1965) stated that *Polypodiidites* is distinguishable from *Polypodiisporites* in possessing markedly reduced proximal sculpture. Hekel (1972) reports that according to Potonié (1966), *Verrucatosporites* Thomson & Pflug (1953) should be included in *Polypodiidites* Ross (1949). When these spores are abundant, the various forms intergrade (Martin 1973).

Botanical affinity: Polypodiaceous affinities (Couper 1953).

Polypodiidites inangahuensis Couper 1953 Figure 6.6

Literature: Ross 1949, Couper 1953 Pl 2 Figure 16, Couper 1960 p 39 Pl 1 Figure 7, Harris 1965 p 83 Pl 24 Figure 8 & 9 & 10, Jansonius & Hills p 2101, Pocknall & Mildenhall 1984 p 21 Pl 4 Figure 1,2.

Description: Monolete spores with a plano- to concavo-convex amb in lateral view. Laesura relatively short, measuring half spore length; narrow and usually closed. The exospore is very thick (3-4µm) with robust verrucate sculpturing, diminishing towards the laesura. Verrucae 1µm high, maximum 3µm diameter in plan view and may be elongated perpendicular to laesura. Spaced 1-3µm apart forming a negative reticulum.

Dimensions: Average length 69µm (range 43-105µm). Average height 38µm (range 27-69µm).

Distribution: Little known in the channel peats and main peat horizon. Well known above main peat horizon. Present in 11 samples.

Genus *Polypodiisporites* (Potonié 1931) Potonié 1956 emend. Khan & Martin 1972
Type species: *P. favus* Potonié 1931

Remarks: Monolete spores possessing verrucate to gemmate or bluntly baculate sculpturing elements. The verrucae are flat, plate-like and crowded, forming an appearance of a negative reticulum. The spore outline may thus appear crenate, undulate or with isolated projections. Jansonius & Hills (1976, p 2102) discussed at length the validity or otherwise of the genus, its type species and particular diagnosis. The diagnosis followed here is that of Khan & Martin 1972. Playford & Dettmann (1965) add that the sculpturing elements are evenly spaced on the exospore.

Botanical affinity: Polypodiaceous ferns.

Polypodiisporites sp – Figure 6.2
Literature: Potonié 1934, Harris 1965 p 83 Pl 24 Figure 8-10, Harris 1974 Figure 2, Jansonius & Hills 1976 p 2102, Kemp & Harris 1977 p 23 Pl 3 Figure 5, 7-9, Pocknall & Mildenhall 1984 p 22 Pl 3 Figure 1-5 Pl 4 Figure 3,4 Pl 54 Figure 1-3, Saxena & Misra 1990 p 266 Pl 1 Figure 5.

Description: Verrucate monolete spores with a plano- to concavo-convex (bean-shaped) amb. Laesura well marked, measuring more than half the spore length. Exospore relatively thick (2-4μm) with flat, closely placed and evenly spread verrucae. Individual elements 1μm high, 1-3μm at base, 1-3μm apart forming negative reticulum.

Remarks: A range of forms was found in the Koingnaas specimens, varying in size and shape, bearing coarser or finer sculpturing. As little biostratigraphic or palaeobotanical information would be gained by further splitting the group, *Polypodiisporites* sp was used as a 'portmanteau' species, including all verrucate monolete spores which could not be more accurately placed.

Dimensions: Average length 45μm (range 22-96μm). Average height 29μm (range 15-56μm). Average breadth 26μm (range 18-34μm).

Distribution: Rare in the channel peats and above the main peat horizon. Well known in the main peat horizon. Found in 12 samples.

First division category (pollen)
Morphologically, pollen grains are recognised according to the nature of the apertures or the possession of sacci (air bladders). The apertures take the form of pores or colpi which are arranged on the surface of the exine. The sacci may vary in number.

Second division category (saccate pollen)
Possessing at least one saccus (or bladder), for the purposes of flotation in air or water, as defined by Traverse (1988).

Third division category (bisaccate pollen)
Possessing two sacci.
Remarks: Most of the bisaccate specimens found in the Koingnaas sediments were poorly preserved.

Genus *Alisporites* Daugherty 1941
Type species: A. opii Daugherty 1941

Remarks: Bisaccate, sulcate pollen grains with equatorial outline oval to broadly oval. Sacci relatively narrow, distally attached along entire length. Palynomorphs assigned to *Alisporites* were distinguished from Podocarpaceous pollen by their 'haploxylonoid' appearance and oval corpus.

Botanical affinity: Coniferae (Jansonius 1971). Daugherty proposed the genus for all bisaccate pollen types that are not related to the Abetineae or Podocarpineae.

Alisporites sp – Figure 6.4
Literature: Daugherty 1941, Dettmann 1963 p 102 Pl 25 Figure 1-4 5-7, Muller 1968 Pl 2 Figure 1, Jansonius & Hills 1976 p 69, McLachlan & Pieterse 1978 Pl 4 Figure 6,7.

Description: Bisaccate pollen grains with corpus longer than broad in polar view. Large sacci attached laterally, possessing a large meshed reticulum. Length of sacci approximately equal to the length of corpus.

Dimensions: Average length grain 41μm (range 27-52μm).

Remarks: The featured specimen bears a good resemblance to the specimen illustrated in Muller (1968) as *Alisporites similis*. Due to the poor preservation and relative rarity of specimens, palynomorphs assigned to *Alisporites* will not be placed into particular species. Scholtz (1985) discussed the existence of expanded and collapsed states, which tend to make several different types appear similar. To date, too few specimens have been observed to make distinctions.

Distribution: Rare at all levels. Present in 5 samples.

Genus *Podocarpidites* (Cookson 1947) ex Couper 1953
Type species: *P. ellipticus* Cookson 1947

Remarks: Fossil bisaccate pollen grains of the type found in the modern *Podocarpus*. Both sacci extend beyond equatorial outline, longest dimension longer than that of corpus.

Botanical affinity: Podocarpaceous conifers (Traverse 1988).

Podocarpidites marwickii Couper 1953 Figure 6.3
Literature: Cookson 1947 p 131 Pl 13 Figure 5-7, Couper 1953 Pl 4 Figure 39, Couper 1960 p 45 Pl 4 Figure 10 & 11, Jansonius & Hills 1976 p2055, McLachlan & Pieterse 1978 p878 Pl4 Figure 2.

Description: Bisaccate pollen grains with corpus circular in proximal view. Corpus distinct from sacci, details of cap not observed. Large sacci attached laterally, semi-circular in shape, possessing widely meshed reticulum.

Remarks: Specimens having laterally attached sacci longer than the corpus were placed within this species. *P. marwickii* is similar to *P. major*; the difference being that *P. major* is larger and has finely reticulate sacci. The Koingnaas specimens may comprise intermediate forms between these two species.

Dimensions: Average length of grain 45µm (range 32-72µm).

Distribution: Well known at all levels. Present in 18 samples.

Podocarpidites sp – Figure 6.8
Literature: Cookson 1947, Jansonius & Hills 1976 p 2055.

Description: Bisaccate pollen grains. Corpus generally circular in distal view, polygonal in lateral view. Sacci attached distally, pendant, with a fine or wide-meshed reticulum. Some specimens show crassitudes at attachment sites of sacci.

Remarks: All bisaccate pollen grains which could not be more accurately placed were assigned to this species.

Dimensions: Average length of grain 45µm (range 20-70µm).

Distribution: Rare in the channel peats, well known in the main peat horizon and above. Found in 16 samples.

Genus *Microcachrydites* Cookson ex Couper 1953
Type species: M. antarcticus Cookson ex Couper 1953

Remarks: Fossil bisaccate pollen grains of the type found in the modern *Microcachrys*, having several sacci. According to Jansonius & Hills (1976) most specimens from the type locality possess two sacci, however in the literature consulted, most illustrated grains had three.

Botanical affinity: *Microcachrys* (Cookson 1947). Podocarpaceae (Kemp & Harris 1977).

Microcachrydites antarticus Cookson ex Couper 1953 – Figure 6.11 & 6.15
Literature: Cookson 1947 p 132 Pl 14 Figure 9, Couper 1953 Pl 9 Figure 134, Couper 1960 p 43 Pl 3 Figure 9, Dettmann 1963 p 103 Pl 26 Figure 1-5, Harris 1965 p 87 Pl 26 6&7, Martin 1973 p 16 Figure 63, Hos 1974 p 7 Figure 14, Harris 1974 Figure 7, Burger 1976 p 140 Pl 28 Figure 9, Khan 1976 p 787 Figure 6, Jansonius & Hills 1976 p 1648, Kemp & Harris 1977 p 29, Martin 1978 p 187 Figure H, Mc Lachlan & Pieterse 1978 Pl 4 no 4, Coetzee 1980 p 200, Coetzee & Rogers 1982 p 80 Pl 1 no 2, Coetzee 1983 p 349 Figure 2 no 2.

Description: Trisaccate pollen grains. Corpus generally circular in distal view, oval in lateral view, dipoloxylonoid, wide furrow. Small sacci, pendant, attached distally, with a coarsely-meshed reticulum. Rarely extend beyond outline of corpus.

Dimensions: Average length of grain 23µm (range 20-27µm).

Distribution: Rare above the main peat horizon. Only found in one sample.

Second division category (porate pollen)

Porate pollen has isodiametric germinal apertures (larger axis of opening less than twice the smaller axis) including forms with complex apertures, as defined by Traverse (1988). The porate pollen found at Koingnaas was further classified according to the number and position of the pores.

Third division category (triporate pollen)

Pollen grains included in this category possessed three equatorial pores separated in polar view by more or less 120°.

There is considerable confusion in the literature concerning the identification of those types of triporate pollen having a basically triangular amb. At least four genera have been erected to accommodate them, but the generic diagnoses do not appear to be mutually exclusive, as noted by Dettmann (1973) and Scholtz (1985). Descriptions and illustrations of pollen with this morphology have been published in many papers. Quite often, a particular species does not comply with the diagnosis of the genus to which it has been assigned, for instance, *Triorites festatus* (Muller 1968) contradicts

the generic diagnosis given by Erdtman (1947) in that it has a thin not a thick exine and it has a spherical rather than a triangular amb. The most important features of the generic diagnoses for the triangular triporate forms are summarized below.

Genus *Propylipollis* Martin & Harris 1975
Type species: *P. reticuloscabratus* Harris 1965

Remarks: Triporate pollen grains with triangular amb. Differentiated from *Proteacidites* and *Triorites* by the complex pores with post-atria.

Botanical affinity: Proteaceae subfamilies Grevilleoideae and Persoonioideae (Scholtz 1985).

Propylipollis sp – Figure 6.3
Literature: Martin & Harris 1974 p 110 Figure 2C & D 2H, Jansonius & Hills 1976 p 2150, Stover & Partridge 1982, Pl 2 Figure 15 Pl 6 no 9, Scholtz 1985 p 61-62, Figure 14 F-J Figure 15 A & B, Dettmann & Thomson 1987 Figure 6.

Description: Triporate pollen grains, triangular in polar view. Pores angulaperturate, 2-3µm in diameter, with striate post-atrium. Exine tectate, 1.5-2.5µm thick, does not vary in thickness across grain. Sculpturing psilate to scabrate.

Dimensions: Average equatorial diameter 26µm (range 17-40µm).

Distribution: Well known in the main peat horizon, rare in the channel peats and above the main peat horizon. Found in 6 samples.

Genus *Proteacidites* Cookson 1950 ex Couper 1953 emend. Martin & Harris 1974
Type species: *P. adenanthoides* (Cookson 1950) ex Couper 1953.

Remarks: Triporate pollen grains with a triangular or sub-triangular amb having concave to convex sides. Differentiated from *Propylipollis* and *Triorites* in having simple pores. Sculpturing may be very variable, including baculate, clavate and tuberculate types, which form a pitted-reticulate or pseudo-reticulate sculpture.

Botanical affinity: Proteaceous affinities (Couper 1953). Martin & Harris (1974) state that it should not be concluded that all the species of *Proteacidites* are true Proteaceae as the morphology of some types cannot be matched in any existing family.

Proteacidites sp – Figure 6.9
Selected literature: Cookson 1950 p 172 Pl 2 Figure 21, Couper 1953 p 42 Pl 5 Figure 52, Germeraad *et al* 1966 p 312 Pl 9 Figure 3 & 4, Martin & Harris 1974 p109, Jansonius & Hills 1976 p 2152 - 4, Coetzee & Rogers 1982, Scholtz 1985 p 61 Figure 13 O-P.

Description: Triporate pollen grains, amb triangular with straight sides. Pores simple, circular to oval in shape, angulaperturate, 2-5µm diameter. Exine tectate, 1-3µm thick, endexine thicker than ektexine, particularly in interporal areas. Sculpturing psilate to granulate.

Remarks: When compared to the literature, the diversity of forms found at Koingnaas is not vast. Kemp (1975) comments that in New Zealand, and especially in Australia, large reticulate and granulate types characterise the assemblages. The Koingnaas sediments appear to follow those from Antarctica in producing small proteaceous grains with smooth or faintly scabrate surfaces. The pollen grains assigned to this genus were not speciated further because of the plethora of published illustrations and descriptions that bear some resemblance to the range of forms found.

Dimensions: Average equatorial diameter 21µm (range 10 - 47µm).

Distribution: Common in the channel peats, well known in the main peat horizon and above. Found in every sample.

Genus *Triorites* Erdtman 1947 ex Cookson 1950 emend Potonié 1960
Type species: T. magnificus Cookson 1950.

Remarks: Triporate pollen grains with a triangular to sub-triangular amb having straight or concave sides. Differentiated from *Propylipollis* and *Triorites* by its complex pores, placed equatorially at the base of a cavity formed by forward annular extensions of the exine.

Botanical affinity: No definite botanical affinity is implied. Pollen grains of this type are found in a number of families (Couper 1953). Possible affinity of some species exists with Proteaceae or with ancestors of the family (Dettmann 1973).

Triorites sp – Figure 6.12
Literature: Cookson 1950 p 175 Pl 3 Figure 32-35, Couper 1953 Pl 7 Figure 110, Jansonius & Hills p 3038.

Description: Triporate pollen grains with a triangular amb. Complex pores with atria, annulae or costae pori, angulaperturate, apices may be truncated. Size of pores varies from small to large (2-5µm diameter). Exine tectate, 1-3µm thick, may vary from polar to

apicular areas. Sculpturing psilate to scabrate/ granulate.

Remarks: Specimens were assigned to this 'portmanteau' type if they were triporate with other than simple pores and could not be more accurately placed.

Dimensions: Equatorial diameter average 18µm.

Distribution: Rare in the channel peats and above the main peat horizon. Little known in the main peat horizon. Present in 10 samples.

Genus *Cricotriporites* Leidelmeyer 1966
Type species: *C. guianensis* Leidelmeyer 1966

Remarks: The Koingnaas specimens also bear a resemblance to *Annutriporites* Gonzales Gusman 1967.

Cricotriporites sp – Figure 6.17
Literature: Leidelmeyer 1966 p 54 Pl 4 Figure 4, Jansonius & Hills 1976 p 655.

Description: Triporate pollen grains with a circular amb. Pores placed equatorially, circular to oval in shape, may be 6µm in diameter. Possess annulae or costae pori, sometimes operculate. Exine tectate, 1-2µm thick. Sculpturing psilate to scabrate/ granulate.

Dimensions: Average equatorial diameter 25µm (range 20-31µm).

Distribution: Rare at all levels. Found in 6 samples.

Genus *Momipites* Wodehouse 1933
Type species: *M. coryloides* Wodehouse 1933

Remarks: Triporate pollen grains with rounded triangular amb. Pores relatively small.

Botanical affinity: *Engelhardtia* and *Alfoaroa* (Jansonius & Hills 1976). Moraceae (Urticales) and Betulaceae (Fagales) (van Hoeken-Klinkenberg 1966).

Momipites sp – Figure 6.7
Literature: van Hoeken-Klinkenberg 1966, Wilson & Webster 1946 p 275 Figure 15, Jansonius & Hills 1976 p 1683, 3576.

Description: Triporate pollen grains, amb circular-roundly triangular in polar view. Pores small, simple structure, angulaperturate. Exine tectate, 1-2µm thick. Sculpturing psilate to granulate.

Dimensions: Average equatorial diameter 22µm (range 15-33µm).

Distribution: Rare in the channel peats and main peat horizon, not found above the main peat horizon. Present in 5 samples.

Third division category (stephanoporate pollen)
Pollen grains placed in this category possessed more than three equatorial, equally spaced pores, as defined by Traverse (1988).

Type B – Figure 6.16
Remarks: The Koingnaas specimens did not resemble *any* illustrations or descriptions in the literature consulted.

Description: 4-stephanoporate pollen grains with circular to almost square amb. Planaperturate pores, diameter 5µm, height 5µm, each with annulus and atrium. Ektexine thin (1µm) in interporal areas, thickening close to pores (3µm), columellate. Endexine usually thicker than ektexine (3µm), thickens slightly close to pores (4µm), appears structureless. Sculpturing psilate.

Dimensions: Average equatorial diameter 27µm (range 22-32µm).

Distribution: Rare at all levels. Found in 6 samples .

Third division category (periporate pollen)
Pollen grains placed in this category possessed more than three pores, randomly placed.

Genus *Byttneripollis* Konzalová 1976
Type species: *B. coronarius* Konzalová 1976

Remarks: The Koingnaas specimens were similar to the illustration in Jansonius & Hills (1976) for this genus.

Byttneripollis sp – Figure 6.10
Literature : Jansonius & Hills 1976 p 3452.

Description: 4-stephanoporate pollen grains, probably spherical but usually found crumpled. Five pores are occasionally seen. Pores have distinctly thickened annuli. Exine thin (1µm) and finely reticulate.

Dimensions: Average diameter 26µm (range 15-40µm).

Distribution : Well known in the channel peats and the main peat horizon, rare above main peat horizon. Present in 15 samples.

Genus *Cretaceiporites* Herngreen 1974
Type species: *C. (Mulitporopollenites) polygonalis* Jardine & Magloire 1965

Remarks: Genus proposed for spherical, periporate pollen of Cretaceous age.

Cretaceiporites sp – Figure 6.14
Literature: Jansonius & Hills 1976 p 652, Morgan 1978 p 923 Pl 8 Figure 3, McLachlan & Pieterse 1978 Pl 5 Figure 24, Schrank 1994 p 782 Figure 8n.

Description: Porate pollen grains with polygonal amb. Periporate, at least six large pores 5-7.5µm in diameter, each pore with membrane. Pores appear to be sunken. Ektexine columellate, 2-5µm thick, columellae taller in interporal areas. Endexine 3-4µm thick. Sculpturing psilate/scabrate.

Remarks: The Koingnaas specimens also resemble a form described in Kemp & Harris (1977) as *Polycolpites* sp.

Dimensions: Average diameter 19µm (range 14-30µm).

Distribution: Well known in the channel peats, little known in the main peat horizon. Found in two samples.

Second division category (colpate pollen)
Colpate pollen has germinal furrows with length approximately twice width. Some authors restrict the term 'colpi' to refer to equatorial, meridional apertures and contrast these with distal or proximal apertures termed 'sulci' (Punt *et al.* 1994). The Koingnaas specimens are further classified according to the number of colpi.

Third division category (monocolplate pollen)
These pollen grains possess a single longitudinal furrow.

Genus *Arecipites* (Wodehouse 1933) Anderson 1960
Type species: *A. punctatus* Wodehouse 1933.

Remarks: Nichols *et al.* (1973) examine this genus and compare it to several other monocolpate genera. *Arecipites* is characterised by a tapering colpus and a tectate exine.

Botanical affinity: Palmae (Nichols *et al.* 1973).
Arecipites sp – Figure 7.1
Literature: Wodehouse 1933 p 497 Figure 22, Anderson 1960 Pl 1 Figure 19 Pl 8 Figure 3 Pl 10 Figure 7, Nichols *et al* 1973 p 248 Pl 1 Figure 9-12, Jansonius & Hills 1976 p 166, Kemp & Harris 1977 p 54 Pl 4 Figure 5&6, Scholtz 1985 p 43 Figure 10 M-P, Christopher *et al* 1980 Pl 3 Figure 1&2.

Description: Monocolpate pollen grains oval in polar view, ends of grain rounded. Single long colpus with tapering ends, extends length of grain. Exine 1-2µm thick, with perforated tectum. Surface appears finely pitted, pits <0.5µm.

Dimensions: Average length 24µm (range 18-37µm), average width 15µm (range 11-27µm).

Distribution. Rare in the channel peats and main peat horizon, little known above the main peat horizon. Found in 7 samples.

Genus *Liliacidites* Couper 1953
Type species: *L. kaitangataensis* Couper 1953

Remarks: Couper (1953) established *Liliacidites* to accommodate fossil pollen with liliaceous affinities that cannot be more accurately placed. The genus is characterised by a tapering colpus and a fine reticulum. The morphological difference between *Liliacidites* and *Clavatipollenites* is subtle. In the former, the colpus extends through all the layers of the exine, while in the latter, it is only seen in the lower layer. The difference is difficult to see if the preservation is not good. A further distinction is the nature of the colpus, which is smooth in *Liliacidites* but 'ragged' in *Clavatipollenites* (Dettmann 1973). Also, *Liliacidites* seems to be reserved for pollen of late Cretaceous and Tertiary age, while *Clavatipollenites* is used for mid-Cretaceous pollen (McLachlan & Pieterse 1978).

Botanical affinity: Liliaceous affinities (Couper 1953, Pocknall 1982).

Liliacidites sp – Figure 7.2
Literature: Couper 1953 Pl 7 Figure 97& 100, Dettmann 1973 Pl 1 Figure 6-8 Pl 1 Figure 15, Hos 1974 p 11 Figure 48, Jansonius & Hills 1976 p 1489 & 4462, McLachlan & Pieterse 1978, Scholtz 1985.

Description: Monocolpate pollen grains, oval in polar view, ends of grain rounded. Single broad colpus, extends almost length of grain. Ends of colpus taper with smooth edges. Exine 1-3µm thick, columellae well seen, support reticulum. Lumina often larger in centre of grain.

Dimensions: Average length 37µm (range 15-63µm).

Distribution: Rare in the channel peats, common in the main peat horizon, well known above it. Found in 8 samples.

Genus *Monocolpopollenites* Pflug & Thomson in Thomson & Pflug 1953 emend. Nichols, Ames & Traverse 1973

Type species: *M.(Pollenites) tranquillus* Potonié 1934.

Remarks: Nichols *et al.* (1973) compare this genus to several other monocolpate genera. *Monocolpopollenites* is characterised by a long flaring colpus and reticulate exine.

Botanical affinity: Various Monocotyledonae and Cycadophyta (Nichols *et al.* 1973).

Monocolpopollenites sp – Figure 7.4

Literature: Jardine & Magloire 1965 Pl 8 Figure 31-35, Thomson & Pflug 1953, Nichols *et al.* 1973 p 51 Pl 2 Figure 2-5 p 53 Pl 2 Figure 6-9, Jansonius & Hills 1976 p 1681, Christopher *et al.* 1980 Pl 3 Figure 7.

Description: Monocolpate pollen grains, oval in polar view, ends of grain rounded. Single broad colpus, may extend length of grain. Ends of colpus flare and may be almost closed in the centre. Exine 1-3µm thick, columellae well seen, support reticulum. Lumina 1µm in diameter.

Dimensions: Average length 26µm (range 12-54µm). Average width 15µm (range 9-22µm).

Distribution: Rare in the channel peats and above the main peat horizon, well known in the main peat horizon. Found in 7 samples.

Genus *Striamonocolpites* Mather & Mather 1969

Type species: *S. longicolpatus* Mather & Mather 1969.

Remarks: A number of monocolpate grain are 'lumped' together in this group. *Striamonocolpites* is characterised by the striate exine.

Botanical affinity: ?Palmae (Jansonius & Hills 1976).

Striamonocolpites sp – Figure 7.5

Literature: Jansonius & Hills 1976 p 2730.

Description: Monocolpate pollen grains, oval in polar view, ends of grain usually pointed. Single colpus, closed or slightly gaping, extends length of grain. Ends of colpus may be slightly flared. Exine 1-3µm thick, striate surface, ribs vary from 0.5µm thick and relatively long to fine and short.

Dimensions: Average length 32µm (range 19-45µm).

Distribution: Rare at all levels. Found in 5 samples.

Third division category (tricolpate pollen)

Pollen grains included in this category possess three colpi separated in polar view by 120°. The colpi are placed on the meridians of the grain, bisected by the equator, as defined by Kremp (1965).

Genus *Cupuliferoidaepollenites* Potonié, Thomson & Thiergart 1950 ex Potonié 1960

Type species: *C. liblarensis* Thomson in Potonié, Thomson & Thiergart 1950.

Remarks: Specimens were placed within *Cupuliferoidaepollenites* if they were psilate. Dettmann (1973) discusses the validity of several genera erected to accommodate psilate tricolpate pollen.

Cupuliferoidaepollenites sp – Figure 7.3

Literature: Potonié, Thomson & Thiergart 1950, Groot & Penny 1960 p 232 Pl 2 Figure 8,9, Dettmann 1973 Pl 2 Figure 11-15, Jansonius & Hills 1976 p 684.

Description: Tricolpate pollen grains circular in polar view, almost spheroidal. Colpi simple in structure, may gape and are relatively short, reaching halfway to poles. Exine 2-3µm thick, surface psilate.

Dimensions: Average equatorial diameter 21µm (range 10-31µm).

Distribution: Well known in the channel peats and main peat horizon, not known above it. Found in 10 samples.

Genus *Retibrevitricolpites* van Hoeken-Klinkenberg 1966

Type species: *R. triangulus* van Hoeken-Klinkenberg 1966.

Remarks. The Koingnaas specimens were placed within *Retibrevitricolpites* rather than *Brevitricolpites* because of their reticulate nature.

Retibrevitricolpites sp – Figure 7.6

Literature: van Hoeken-Klinkenberg 1966 Pl 2 Figure 2&3, Jansonius & Hills 1976 p 2358, Salard-Cheboldaeff 1979 Pl 1 Figure 1.

Description: Tricolpate pollen grains triangular to circular in polar view. Colpi very short and gape slightly. Exine 2-4µm thick, ektexine thinner next to colpi. Surface reticulate, lumina 0.5µm.

Dimensions: Average equatorial diameter 20µm (range 13-34µm).

Distribution: Rare in the channel peats and main peat horizon, not known above it. Found in 4 samples.

Genus *Striatopollis* Krutzsch 1959
Type species: *S. sarstedensis* Krutzsch 1959.

Remarks: Specimens were placed within *Striatopollis* if they were striate. This is the only genus found in the literature consulted which accepts solely tricolpate pollen with striate sculpture.

Striatopollis sp – Figure 7.19
Literature: Burger 1976 p 152 Pl 34 Figure 4-9, Jansonius & Hills 1976 p 2775, McLachlan & Pieterse 1978, Salard-Cheboldaeff 1979 Figure13.

Description: Tricolpate pollen grains oval in equatorial view, poles may be pointed. Colpi extend almost to poles and may be closed. Exine 2-3µm thick, surface striate.

Dimensions: Average equatorial diameter 26µm (range 12-33µm).

Distribution: Rare in the channel peats and main peat horizon, not known above it. Found in 5 samples.

Genus *Tricolpites* (Cookson 1947) Couper 1953 emend Belsky, Boltenhagen & Potonié 1965
Type species: (by subsequent designation of Couper 1953) *T. reticulatus* Cookson 1947.

Remarks: The emended generic diagnosis prescribes that only pollen grains with a stratified exine of which the sexine (ektexine) has columellae forming a surface reticulum with a regular mesh size of 1µm should be included. The criteria of Dettmann & Jarzen (1989) were followed in this paper. Kemp and Harris (1977 p 29) note that the genus *Tricolpites* is often restricted to those grains which display the characteristics of the type species, while it may also be used in a broader sense to include other sculptured and psilate grains, as no valid alternative genera exist.

Botanical affinity: ?Gunneraceae (Dettmann & Jarzen 1989, Scholtz 1985).

Tricolpites reticulatus (Cookson 1947) Couper 1953 Figure 7.11
Literature: Cookson 1947 p 134 Pl 15 Figure 45, Couper 1953, Hekel 1972 p 9 Pl 4 Figure 23, Jansonius & Hills 1976 p 2970, Kemp & Harris 1977 p 29 Pl 5 Figure 1 & 2, Pocknall 1982 p 264 Figure 7, Scholtz 1985 p 64 Figure 15 C-G, Jarzen & Dettmann 1989 p 100 Pl 1 Figure 1-8 Pl2 Figure 1,2,4 Pl 3 Figure 7, Venkatachala *et al.* 1989 Pl 5 Figure 1-11.

Description: Tricolpate pollen grain, amb circular to trilobate in polar view. Colpi fossaperturate, often gaping, meridionally aligned. Long, reaching well into polar area. Exine stratified. Ektexine columellate, 1-1.5µm thick, supporting reticulum. Endexine 1µm. Lumina of mesh measure 1µm.

Dimensions: Average equatorial diameter 15µm (range 8-26µm), average polar length 15.5µm (range 9-27µm).

Distribution: Significant at all levels. Present in all samples.

Tricolpites asperamarginis Mc Intyre 1968 Figure 7.8
Literature: Kemp & Harris 1977 p 32 Pl 5 Figure 3 & 4.

Description: Tricolpate pollen grains triangular in polar view. Meridionally aligned colpi gape very widely, reaching halfway into polar area. Colpi have 'ragged' margins. Exine stratification not well seen, total thickness 1-3µm. Surface has fine reticulum.

Remarks: Specimens were assigned to this species if they were small and possessed widely gaping colpi.

Dimensions: Average diameter 14µm (range 12-17µm).

Distribution: Rare in the channel peats and above the main peat horizon. Little known above the main peat horizon. Found in 6 samples.

Tricolpites cooksonae Dettmann 1973 – Figure 7.9
Literature: Cookson 1947 p 134 Pl 15 Figure 45, Dettmann 1973 Figure 13-18.

Description: Tricolpate pollen grains, circular in polar view. Gaping colpi with simple margins, extending halfway into polar area. Exine thin (1-2µm in total), ektexine columellate and slightly thicker than endexine. Surface reticulum very marked, mesh >1µm diameter but slightly finer close to colpi; muri very thin and lumina large.

Remarks: *T. cooksonae* is similar in general morphology to *Retitricolpites virgeus*, as noted by Dettmann (1973). The genus *Retitricolpites* is illegitimate (Jansonius & Hills 1976). Superficial similarities were seen with *T. angululuminosis* (Anderson 1960); however the colpi of that species are bordered.

Dimensions: Average diameter 17µm (range 11-28µm).

Distribution: Rare at all levels. Present in 6 samples.

Tricolpites gillii Cookson 1957 – Figure 7.10

Literature: Cookson 1947 p 134 Pl 15 Figure 45, Cookson 1957, Harris 1965 Pl 27 Figure 13, Stover & Evans 1973 Figure 6, Dettmann & Thomson 1987 Figure 5k.

Description: Tricolpate pollen grains triangular in polar view. Colpi anglulaperturate, extend halfway into polar area, usually closed or slightly gaping. Exine 1-3µm thick, thickest in intercolpal areas. Stratification not well seen. Sculpturing finely reticulate, coarser in intercolpal areas.

Remarks: The Koingnaas specimens also bear a similarity to *Tricolpites* sp 9 featured in McLachlan & Pieterse (1978).

Dimensions: Average diameter 19µm (range 12-43µm).

Distribution: Rare in the channel peats. Common in the main peat horizon and above. Present in 13 samples.

Tricolpites sp A – Figure 7.14

Literature: Anderson 1960 Pl 6 Figure 18, Stover & Evans 1973 Pl Figure 6, Jansonius & Hills 1976 p 2970 & 2985, Christopher *et al.* 1980.

Description: Tricolpate pollen grains circular in polar view. Colpi gape widely and extend well into polar area. Exine 1-1.5µm thick. Sculpturing finely reticulate.

Remarks: The Koingnaas specimens bear a similarity to *Tricolpopites* Biswas in Jansonius & Hills (1976).

Dimensions: Average diameter 22µm (range 12-29µm).

Distribution: Rare at all levels. Present in 5 samples.

Tricolpites sp B – Figure 7.13

Literature: Jansonius & Hills 1976 p 2970, Couper 1953 Pl 1 Figure 118, 119, Couper 1960 P 64 Pl 10 Figure 20, 21, Martin 1973 p 40 Figure 171.

Description: Tricolpate pollen grains triangular to trilobate in polar view. Colpi fossaperturate, extend well into polar area, closed and complex in structure. Exine thick, 2-4µm thickest in intercolpal areas. Columellae high but fine, coalesce to form perforated tectum. Surface of colpi psilate, ridged parallel to aperture.

Remarks: The Koingnaas specimens bear a similarity to *Tricolpites mataurаensis* featured in Couper (1953, 1960) and Martin (1973).

Dimensions: Average diameter 33µm (range 25-50µm).

Distribution: Rare in the channel peats. Not known at other levels. Present in 2 samples.

Genus *Tricolpopollenites* Pflug & Thomson in Thomson & Pflug 1953

Type species: *T. parmularius* (Potonié) Thomson & Pflug 1953

Remarks. *Tricolpopollenites* is treated as a 'portmanteau' genus for prolate tricolpate grains which could not be more accurately placed. Many grains were found with similar morphology, but they showed a range of details including rounded or pointed poles, reticulate or relatively smooth surfaces, long to relatively short or closed to gaping colpi. They were placed within *Tricolpopollenites* rather than *Tricolpites* beacuse the generic diagnosis of the former cites the prolate nature of the grains and does not specify sculpturing details.

Tricolpopollenites sp – Figure 7.18

Literature: Couper 1953 Pl Figure 122, Couper 1960 p 65 Pl 11 Figure 13-15, Jansonius & Hills 1976 p 2970, Pocknall & Mildenhall 1984.

Description: Tricolpate pollen grains, prolate in equatorial view. Colpi usually long and narrow, with simple margins. Exine thin (1-2µm) and finely columellate. Surface psilate to finely reticulate.

Remarks: The specimens bear some resemblance to the published illustrations mentioned above.

Dimensions: Average polar length 26µm (range 14-47µm).

Distribution: Rare in the channel peats and above the main peat horizon, significant in the main peat horizon. Found in 16 samples.

Third division category (stephanocoplate pollen)
Possessing more than three colpi.

Genus *Glencopollis* Pocknall & Mildenhall 1984

Type species: G. ornatus Pocknall & Mildenhall 1984.

Botanical affinities: Family Polygonaceae (Polygonales:Caryophyllidae) (Pocknall & Mildenhall 1984).

Glencopollis ornatus Pocknall & Mildenhall 1984 Figure 7.7

Literature: Pocknall & Mildenhall 1984 p 29 Pl 10 Figure 1-5, Barreda 1993 p 172 Pl 1 Figure 1-6.

Description: Tricolpate pollen grains, prolate in equatorial view, poles relatively pointed. Colpi long and narrow, with simple margins, extending virtually to poles. Exine thin (1µm) and finely columellate. Surface psilate to very finely reticulate.

Dimensions: Average diameter 32µm (range 20-47µm).

Distribution: Rare in the channel peats and the main peat horizon, not found above. Present in 3 samples.

Genus *Retistephanocolpites* Leidelmeyer 1966

Type species: *R. angeli* Leidelmeyer 1966.

Remarks: Stephanocolpate pollen grains with a reticulate sculpture.

Retistephanocolpites sp – Figure 7.12

Literature: Jansonius & Hills p 2393.

Description: Stephanocolpate pollen grains, circular to almost lobate in polar view. Colpi short, gaping, fossaperturate. Grains have large polar area. Exine thick (2-3µm), ektexine columellate. Surface reticulate, mesh diameter approx 1µm.

Dimensions: Average diameter 23µm (range 17-63µm).

Distribution: Rare at all levels, found in 5 samples.

Second division category (colporate pollen)

Pollen grains included in this category possess compound apertures, individually termed a 'colporus' which consists of a colpus with one or more pores.

Third division category (tricolporate pollen)

Possessing three such apertures defined above. Having three longitudinal colpi, all arranged on meridians, each having an equatorial transverse pore, as defined by Kremp (1965). Tricolporate pollen was the most abundant type found.

Genus *Gemmatricolporites* Leidelmeyer 1966

Type species: *G. berbicensis* Leidelmeyer 1966

Remarks: Specimens were assigned to this genus if they possessed gemmate sculpturing.

Gemmatricolporites berbicensis Leidelmeyer 1966 – Figure 7.17

Literature: Leidelmeyer 1966 p 55 Pl 4 Figure 5, Jansonius & Hills 1976 p 1097.

Description: Tricolporate pollen grains, prolate in equatorial view with rounded poles. Colpi long, slightly gaping, reach almost to poles. Pores circular to lalongate, 3-5µm diameter. Exine intectate, >2µm. Ektexine consists of densely distributed baculae, 2µm high, 1-1.5µm diameter, each with a large caput, producing gemmate appearance of surface.

Dimensions: Average polar length 37µm (range 25-42µm).

Distribution: Rare at all levels, found in 4 samples.

Genus *Rhoipites* Wodehouse 1933

Type species: *R. bradleyi* Wodehouse 1933.

Remarks: Kemp & Harris (1977) discuss the validity of this genus versus *Tricolporites* and *Tricolporopollenites*. A great many tricolporate, reticulate pollen grains were found within the Koingnaas sediments and most of them were placed within the genus *Rhoipites*. A number of types were recognised but they could not be confidently placed within any existing species described and illustrated in the literature consulted. Formal names have not yet been assigned, pending further research. Grains which were not assigned to any of the types mentioned above were included in the statistics as *Rhoipites* sp. They were significant at all levels.

Botanical affinities: Many groups of dicotyledonous plants.

Rhoipites sp A – Figure 7.20

Description: Tricolporate pollen grains, prolate in equatorial view, poles rounded. Colpi long, in excess of three-quarters grain length and may gape slightly. Pores lalongate, with distinctive 'eye' shape, measuring 6µm width, 14µm in extent. Ektexine <2µm, columellae higher at poles. Endoexine thin (1µm). Surface reticulum mesh size 0.5µm.

Remarks: Specimens were placed in this group if they were prolate with tapering, lalongate pores. They resemble the illustration of *Retitricolporites guianensis* in van der Hammen & Wymstra (1964).

Dimensions: Average polar length 26µm (range 15-50µm).

Distribution: Rare in the channel peats and the main peat horizon, not found above. Present in 8 samples.

Rhoipites sp B – Figure 7.15 & 7.16

Description: Tricolporate pollen grains, prolate in equatorial view. Colpi long and narrow, reaching almost to poles. Pores structurally complex, zonorate in endexine (7µm width), but 'H' shaped in endexine. Exine relatively thick, 3-5µm. Ektexine <2µm, columellae higher at pole. Surface reticulate, mesh 0.5-1µm diameter.

Remarks: Specimens were placed in this group if they possessed the characteristic 'H' shaped pore. Two illustrations of the same grain are included. Figure 7.15 shows the detail of the endopore structure and Figure 7.16 shows the equatorial zonaperturate structure. They are similar to *Tricolporopollenites* spp C & D in Scholtz (1985). The Koingnaas specimens were not identified as such because the grains featured by Scholtz were not zonorate.

Dimensions: Average polar length 29µm (range 15-52µm).

Distribution: Little known in the channel peats, rare in the main peat horizon and above. Found in 8 samples.

Rhoipites sp C – Figure 7.22

Description: Tricolporate pollen grains, prolate in equatorial view, poles very rounded. Colpi long and broad, almost reaching to equator. Lalongate pores 'bow' shaped, divided into two parts at equator. Ektexine 2-4µm, bulging at equator over the pores, columellae higher at poles. Endexine 1-1.5µm. Surface reticulate, mesh size 0.5µm.

Remarks: Specimens were placed in this group if they possessed 'bow' shaped pores, similar to that seen in *Pleurospermaepollenites* Kulková. Other features characteristic of this genus were not seen.

Dimensions: Average polar length 23µm (range 15-45µm), average equatorial diameter 18µm (range 10-38µm).

Distribution: Common in the channel peats, rare in the main peat horizon and above. Found in 8 samples.

Rhoipites sp D – Figure 7.23

Description: Tricolporate pollen grains, prolate in equatorial view, poles may be rounded or relatively pointed. Colpi long, reaching almost to poles. Pores slightly lalongate (<5µm diameter). Ektexine <2µm, height of columellae does not vary, endexine thinner. Sculpturing coarsely reticulate (lumina >1µm and muri 0.5µm), mesh size diminishes close to colpi. Lumina irregular in shape, slightly larger in polar area.

Remarks: Specimens with a coarse reticulum were placed in this group. They appear similar to grains identified as *Calodendrum* in Coetzee (1983).

Dimensions: Average polar length 29µm (range 20-46µm).

Distribution: Rare at all levels. Found in 6 samples.

Rhoipites sp E – Figure 7.21

Description: Tricolporate pollen grains, sub-prolate to circular in equatorial view. Colpi long and very broad (8µm). Pores large (5-8µm) and circular. Ektexine <2µm, columellae very fine and equal in height throughout grain. Endexine thin (1µm) surface finely reticulate.

Remarks: Specimens were placed in this group if they were approximately spherical, with a relatively thin exine and large circular pores. They resembled several published illustrations, such as *R. isoreticulatus* shown in Kemp & Harris (1977). They were not identified as such because the exine in the colpi was not seen to be smooth. They were also similar to *Rhoipites* sp E Christopher *et al.* (1980) and *Tricolporopollenites* sp El Beialy (1995).

Dimensions: Average polar length 27µm (range 10-55µm).

Distribution: Well known in the channel peats and main peat horizon, not known above. Present in 10 samples.

Rhoipites sp F – Figure 8.1

Description: Tricolporate pollen grains, prolate in equatorial view, poles usually rounded. Colpi long and narrow, reaching almost to poles. Pores lolongate, 2µm wide but 5µm in length, with costa pori. Exine relatively thin, ektexine <2µm, columellae very fine and equal in height all over grain. Endexine <1µm.

Remarks: Specimens were placed in this group if they possessed lolongate pores. They did not closely resemble any illustrations in the literature consulted.

Dimensions: Average polar length 24µm (range 17-53µm).

Distribution: Well known in the channel peats, little known in the main peat horizon, rare above the main peat horizon. Found in 12 samples.

Rhoipites sp G – Figure 8.13

Description: Tricolporate pollen grains, small and spheroidal. Colpi relatively long, reaching well into polar area, do not gape. Pores circular, 3µm diameter, simple structure. Ektexine <2µm, columellae may

be higher in intercolpal areas. Endexine 1µm. Surface fairly coarsely reticulate, mesh approx 1µm diameter. Lumina irregular in shape but evenly sized throughout grain.

Remarks: Small, spheroidal grains with a coarse reticulum were placed in this group. In polar view they may look much like *Tricolpites reticulatus*. However, to be included here, the colpi must be seen to contain pores. They are similar to *Tricolporopollenites arnotiensis* Scholtz (1985) but were not identified as such because the reticulum is coarser and the pores are larger.

Dimensions: Average polar length 13µm.

Distribution: Well known in the channel peats, rare in the main peat horizon and above. Found in 8 samples.

Rhoipites sp H – Figure 8.2

Description: Tricolporate pollen grains, prolate in equatorial view. Colpi long, reaching almost to poles with marked costa colpi, which extend to form costae pori. Lalongate pores, rectangular in shape with blunt ends, 2-3µm wide and approx 8µm in length. Do not coalesce into zonorate feature. Exine thin, <1µm. Surface very finely reticulate.

Remarks: Specimens were placed into this group if they possessed the characteristic rectangular pore. They did not closely resemble any illustrations in the literature consulted.

Dimensions: Average polar length 27µm (range 13-47µm).

Distribution: Well known in the channel peats, rare in the main peat horizon and above. Found in 6 samples.

Rhoipites sp J – Figure 8.14

Description: Tricolporate pollen grains, subprolate to circular in polar view. Colpi long, reaching almost to poles, sides well marked. Lalongate pores slit-like. Ektexine <2µm with fine columellae. Endexine 1-2µm, thickens adjacent to pores. Surface finely reticulate.

Remarks: Specimens were placed in this group if they possessed slit-like lalongate pores. They bore some resemblance to *Liangopollis* Song Zhi-Chen & Cao Liu 1980 in Jansonius & Hills (1976).

Dimensions: Average polar length 28µm (range 15-57µm).

Distribution: Rare in the channel peats and main peat horizon, not known above. Found in 7 samples.

Rhoipites sp K – Figure 8.5

Description: Tricolporate pollen grains, subprolate to circular in equatorial view, poles very rounded. Colpi long and relatively narrow, with costae colpi, reaching almost to poles. Pores small (2-3µm) and circular in shape. Exine relatively thin. Ektexine <1.5µm with fine columellae. Endexine >1µm. Surface finely reticulate, mesh <0.5µm.

Remarks: Specimens were placed in this group if they were relatively large but possessed small, circular pores. They did not closely resemble any illustrations in the literature consulted.

Dimensions: Average polar length 25µm (range 14-36µm).

Distribution: Rare in the channel peats and above the main peat horizon, well known in the main peat horizon. Found in 10 samples.

Genus *Simpsonipollis* Srivastava 1975

Type species: *S. mullensis* (Simpson) Srivastava 1975

Remarks: Kemp & Harris (1977 p 40) discussed the validity of the genus. All striate tricolporate grains were included here.

Botanical affinity: Muller (1968) remarked on the difficulty of recognising the relationship of striate tricolporate pollen as this type occurs in several modern families.

Simpsonipollis sp – Figure 8.10

Literature: S K Srivastava 1975, Jansonius & Hills 1976 p 2604 & 2726, Kemp & Harris 1977 p 40 Pl 7 Figure 3-6 & 13.

Description: Tricolporate pollen grains, prolate in equatorial view. Colpi long, measuring two-thirds polar length. Pores usually circular, 4µm in diameter. Exine striate, thin wavy ridges of irregular width and height (<0.5µm wide, more than 5µm in length), usually aligned parallel to polar axis, shorter in equatorial region.

Dimensions: Average polar length 31µm (rare 17-43µm).

Distribution: Rare at all levels. Present in 8 samples.

Genus *Tricolporites* Cookson 1947

Type species: *T. sphaericus* Cookson 1947

Remarks: *Tricolporites* is probably the only valid genus in which psilate, tricolporate grains may be

accommodated. Jansonius & Hills (1976) discuss the validity of this and other genera.

Tricolporites sp – Figure 8.3

Description: Tricolporate pollen grains, prolate to sub-prolate in equatorial view. Colpi long, reaching almost to poles. Pores usually circular, may be lalongate. Ektexine 2-5µm, appears to be structureless. Endexine thinner. Surface appears psilate.

Remarks: Specimens were placed in this group if they were psilate.

Dimensions: Average polar length 30µm (range 10-65µm).

Distribution: Common in the channel peats, significant in the main peat horizon, rare above the main peat horizon. Found in 12 samples.

Type C – Figure 8.11

Description: Tricolporate pollen grains, triangular in polar view, oblate in equtorial view. Apices very rounded, sides concave or straight. Colpi short or very short, only faintly discernible as very shallow and narrow, thus grain has large, flat polar area. Pores lolongate, sometimes appear to occupy whole of colpus. Exine thick (2-3µm), especially in intercolpal areas. Ektexine appears to be structureless. Surface psilate.

Remarks: As the colpi are so short that grains appear to be triporate rather than tricolporate. The Koingnaas specimens were not similar to any published illustration in the literature consulted for either category. Couper (1953) found grains similar to *Elytranthe*; however these were striate.

Dimensions: Average polar diameter 15µm (range 12-28µm).

Distribution: Well known in the channel peats and the main peat horizon, rare above. Found in 15 samples.

Third division category (stephanocolporate pollen)

Specimens were placed in this category if they possessed four or more colpi each with an equatorial pore.

Genus *Sapotaceoidaepollenites* Potonié, Thomson & Thiergart 1950 ex Potonié 1960

Type species: *S. manifestus* Potonié 1950

Remarks: Psilate or very finely reticulate stephanocolporate grains were assigned to this genus.

Botanical affinities: Possibly Sapotaceae (Kemp & Harris 1977).

Sapotaceoidaepollenites sp – Figure 8.4

Literature: Jansonius & Hills 1976 p 2500, Kemp & Harris 1977 p 44 Pl 7 Figure 7, Martin 1978 p 188 Figure 6C & 6D, Stover & Partridge 1982 Pl 1 Figure 6.

Description: Stephanocolporate grains, prolate in equatorial view with blunt poles. Grains are 'barrel-shaped'. Four colpi, relatively short and broad. Pores circular, 4-5µm diameter, simple construction. Exine relatively thick. Ektexine >2µm, columellae very fine. Endexine 1-1.5µm. Scurface appears psilate or very finely reticulate.

Remarks: Some of the Koingnaas specimens closely resembled *S. rotundus* Harris (1972).

Dimensions: Average polar length 27µm (range 13-68µm).

Distribution: Little known in the channel peats and main peat horizon, rare above. Found in 11 samples.

Genus *Stephanocolporites* van der Hammen 1954

Type species: None designated.

Remarks: Reticulate stephanocolporate grains were assigned to this genus. It may not be valid under the rules of the ICBN as no type species was designated (Jansonius & Hills 1976). An alternative genus for this group, *Retistephanocolporites*, was not used as its generic diagnosis specified a brevicolpate condition, which was not seen in the Koingnaas specimens.

Botanical affinities: Possibly Polygalaceae (Jansonius & Hills 1976).

Stephanocolporites sp – Figure 8.6

Literature: Jansonius & Hills 1976 p 2700.

Description: Stephanocolporate pollen grains, prolate in equatorial view, poles rounded. Four or more colpi, long and broad, may gape. Four or more pores, circular or slightly lalongate, 3µm diameter, simple construction. Ektexine 2µm thick, columellae slightly taller at poles. Endexine 1-1.5µm, structureless. Surface reticulate, mesh >0.5µm.

Dimensions: Average polar length 33µm (range 17-62µm).

Distribution: Little known in the channel peats, rare in the main peat horizon and not known above it. Present in 4 samples.

Third division category (syncolporate pollen)
Having colpi, containing pores, which anastomose at the poles, as defined by Kremp (1965).

Genus *Cupaniedites* (Cookson & Pike 1954) Krutzsch 1959
Type species: *C. major* Cookson & Pike 1954

Botanical affinities: Sapindaceae tribe Cupanieae (Cookson & Pike 1954).

Cupaniedites major – Figure 8.7
Literature: Cookson & Pike 1954 p 212 Pl 2 Figure 83-85, Couper 1960 p 58 Pl 8 Figure 21, Jansonius & Hills p 679.

Description: Syncolporate pollen grains, amb triangular in polar view with straight sides. Colpi anastomose at the poles but do not form polar triangle. Pores not seen well due to apical position. Exine thin (1-2µm) structure not seen well. Surface appears psilate but may be weakly verrucate.

Dimensions: Average diameter 20µm (range 15-33µm).

Distribution: Rare in the channel peats and main peat horizon, not known above. Present in 7 samples.

Cupaniedites orthoteichus – Figure 8.8
Literature: Cookson & Pike 1954 p 210 Pl 2 Figure 73-78, Couper 1960 p 58 Pl 8 Figure 19&20, Boltenhagen 1967 p 349 Pl 4 Figure 3-5, Stover & Evans 1973, Hos 1974 p 9 Figure 28, Kemp & Harris 1977, Martin 1978 p 191 Figure H, Coetzee & Rogers 1982 Pl 1 no 8, Stover & Partridge 1982 Pl 2 no 13, Pocknall 1985 Figure 25 & 26.

Description: Syncolporate pollen grains, amb triangular in polar view with straight to convex sides. Colpi anastomose at the poles forming polar triangle. Pores not seen well due to apical position. Exine thin (1-2µm) structure not seen well. Surface psilate.

Dimensions: Average diameter 19µm (range 16-29µm).

Distribution: Rare in the channel peats and the main peat horizon, not known above. Found in 5 samples.

Genus *Retisyncolporites* Gonzales Gusman 1967
Type species: *R. aureus* Gonzalez Gusman 1967
Remarks: Specimens were placed in this genus if they possessed a coarse reticulum.

Retisyncolporites sp – Figure 8.12
Literature: Jansonius & Hills p 2397.

Description: Syncolporate pollen grains, amb triangular in polar view with straight sides. Colpi anastomose at the poles forming polar triangle. Pores not seen well due to apical position. Exine 1-3µm, ektexine robustly columellate. Surface reticulate, lumina >1µm, muri as wide as lumina.

Dimensions: Average diameter 26µm (range 19-34µm).

Distribution: Rare at all levels, found in 4 samples.

Second division category (inaperturate pollen)
The palynomorphs included in this group have no sacci, pores or colpi of the type recognised in other groups.

Genus Araucariacites (Cookson 1947) Couper 1953
Type species: *A. australis* Cookson ex Couper 1953

Remarks: Spherical non-aperturate grains with granular exines similar to recent menbers of the Araucariaceae.

Botanical affinity: Araucariaceae.

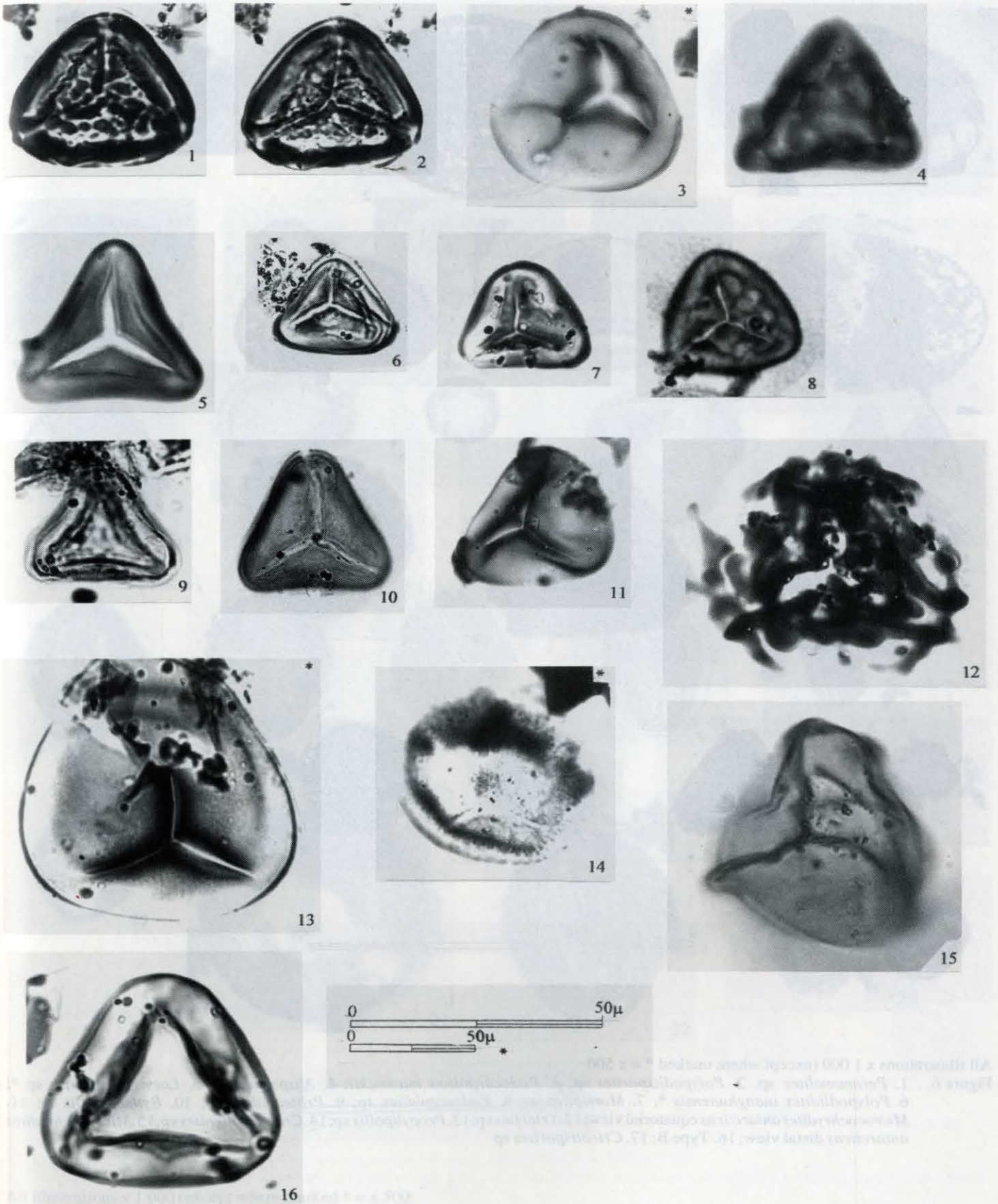
Araucariacites australis Cookson 1947 – Figure 8.15
Literature: Cookson 1947 p130 Pl 13 Figure1-4, Couper 1953, Dettmann 1963 p 105 Pl 26 Figure 15, Harris 1965 p 88 Pl 26 Figure 24, Muller 1966 Pl 2 Figure 10, Brenner 1968 p 359 Pl 13 Figure 1-4, Martin 1973 p 16 Figure 64, Jansonius & Hills 1976 p 151, Khan 1976 p 783 Figure 1, Kemp & Harris 1977 p 25 Pl 4 Figure 15 & 16, McLachlan & Pieterse 1978.

Description: Large inaperturate pollen grains, outline circular. Invariably crumpled. Exine thin (approx 1µm). Surface with finely granulate sculpturing, elements are closely packed. Some grains have small echinae.

Dimensions: Average diameter 28µm (range 20-42µm).

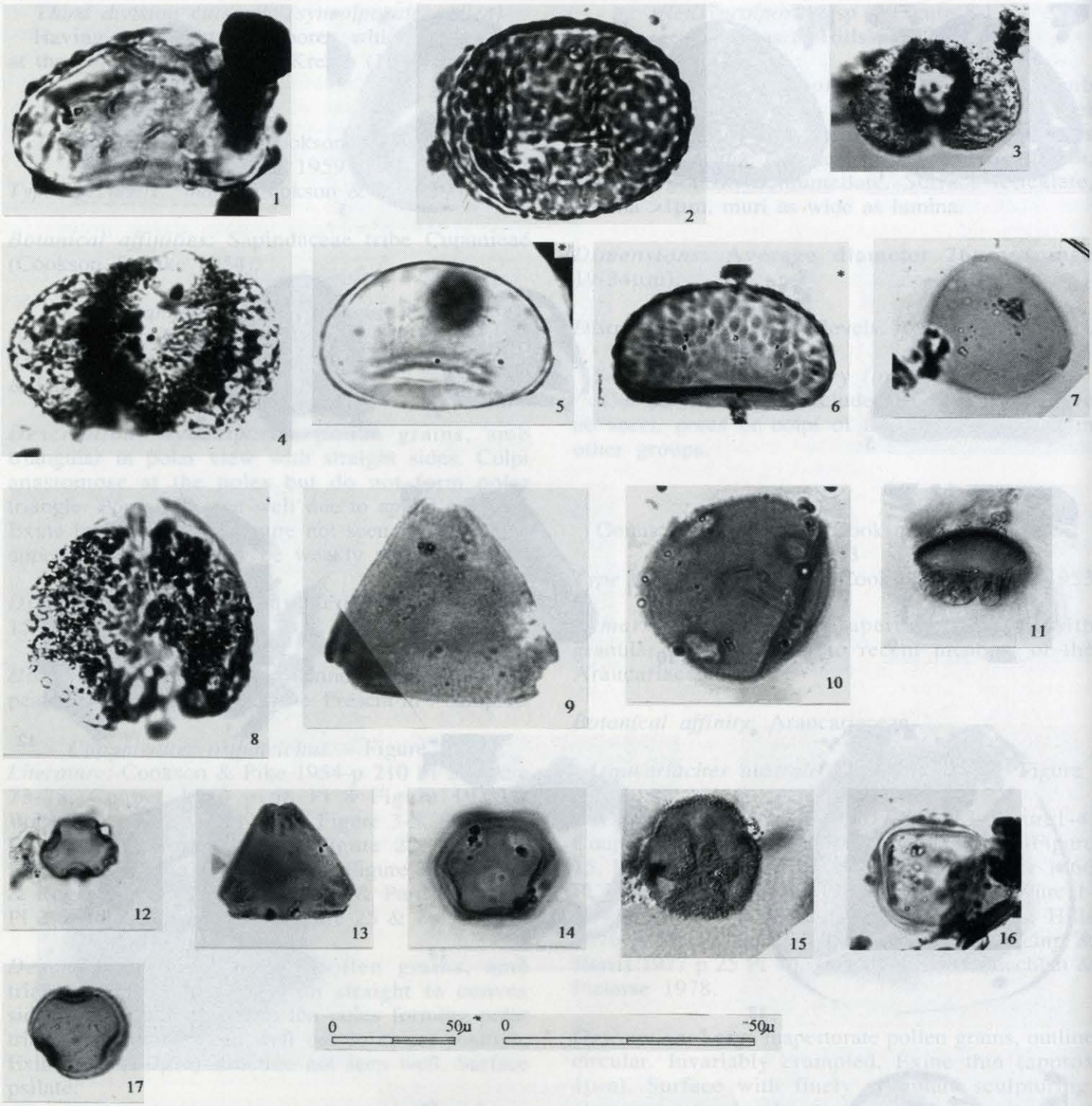
Distribution: Rare in the channel peats and above the main peat horizon. Well known in the main peat horizon. Present in 7 samples.

First division category (incertae sedis)
Forms which could not be matched with published descriptions and/or illustrations and which could not be accommodated in any of the categories above remained as incertae sedis.



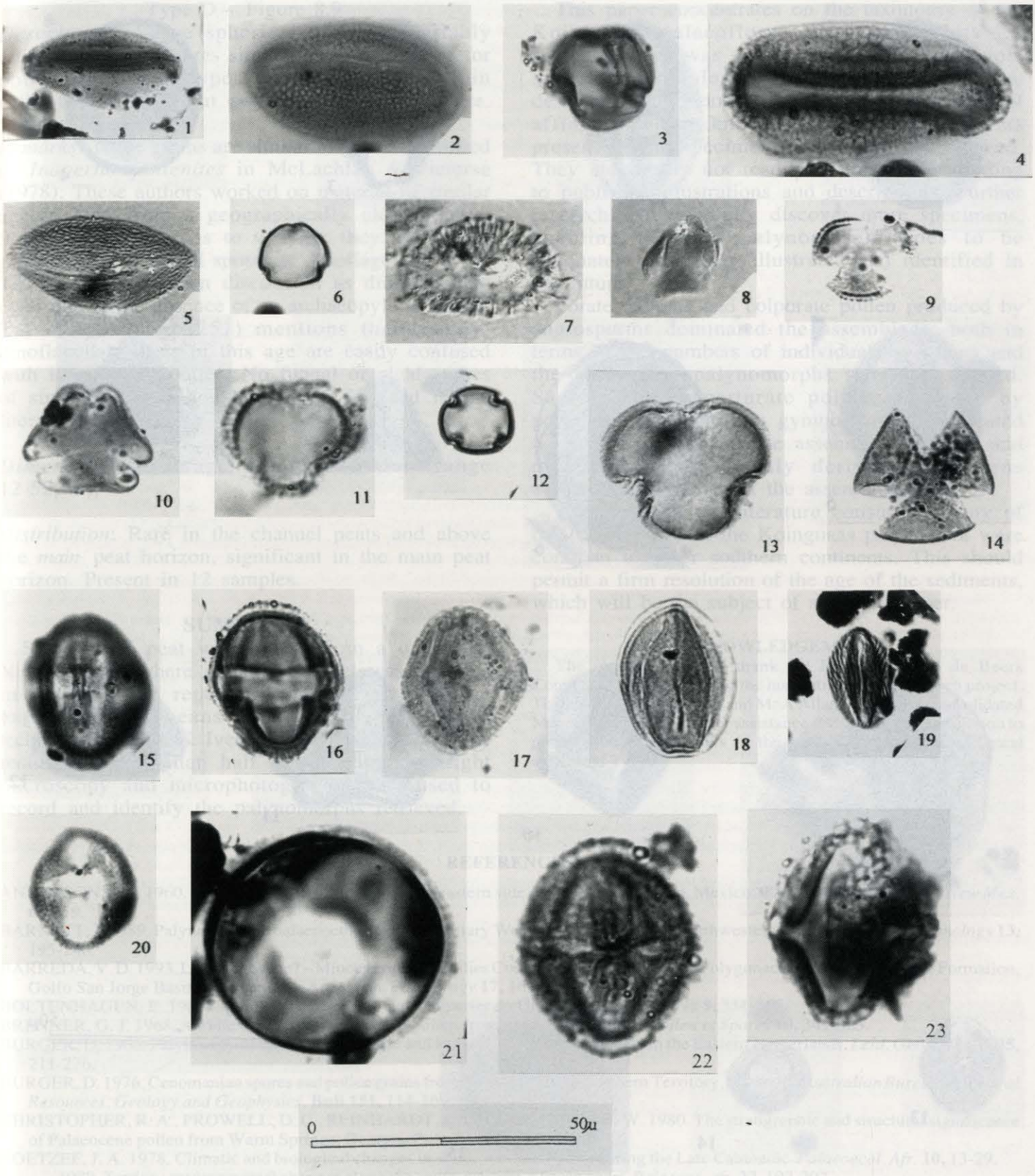
All illustrations x 1 000 (except where marked * = x 500)

Figure 5. 1. *Polypodiaceoisporites retirugatus* showing sculpturing on proximal face; 2. *Polypodiaceoisporites retirugatus* showing laesurae; 3. *Lygodiumsporites* sp *; 4. *Polypodiaceoisporites tumulatus* showing sculpturing on distal face 5. *Polypodiaceoisporites tumulatus* showing laesurae; 6. *Cyathidites minor*; 7. *Dictyophyllidites* sp; 8. *Interulobites* sp; 9. *Gleicheniidites* sp; 10. *Deltoidospora* sp; 11. *Cyathidites australis*; 12. *Verrucingulatisporites* sp; 13. *Cyathidites splendens* *; 14. *Osmundacidites wellmanii* *; 15. *Todisporites* sp; 16. Type A



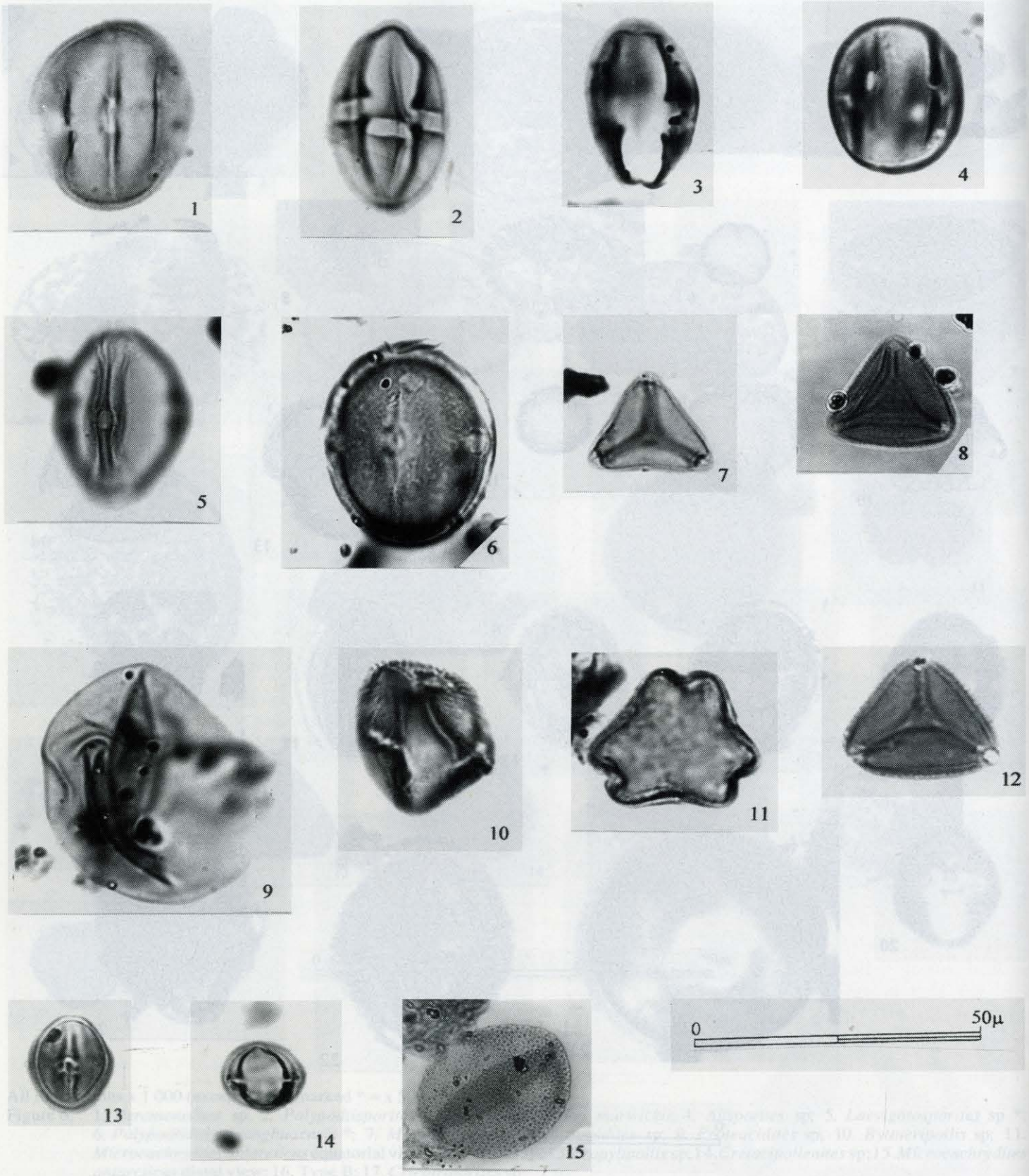
All illustrations x 1 000 (except where marked * = x 500

Figure 6. 1. *Peromonolites* sp; 2. *Polypodiisporites* sp; 3. *Podocarpidites marwickii*; 4. *Alisporites* sp; 5. *Laevigatosporites* sp *; 6. *Polypodiidites inanghuaensis* *; 7. *Momipites* sp; 8. *Podocarpidites* sp; 9. *Proteacidites* sp; 10. *Byttneripollis* sp; 11. *Microcachrydites antarcticus* equatorial view; 12. *Triorites* sp; 13. *Propylipollis* sp; 14. *Cretacipollenites* sp; 15. *Microcachrydites antarcticus* distal view; 16. Type B; 17. *Cricotriporites* sp



All illustrations x 1 000 (except where marked * = x 500

Figure 7. 1. *Arecipites* sp; 2. *Liliacidites* sp; 3. *Cupuliferoidaepollenites* sp; 4. *Monocolpopollenites* sp; 5. *Striamonocolpites* sp; 6. *Retibrevitricolpites* sp; 7. *Glencopollis ornatus*; 8. *Tricolpites aspermarginis*; 9. *Tricolpites cooksonae*; 10. *Tricolpites gillii*; 11. *Tricolpites reticulatus*; 17. *Gemmatricolpites berbicensis*; 18. *Tricolporopollenites* sp; 19. *Striatopollis* sp; 20. *Rhoipites* sp A; 21. *Rhoipites* sp E; 22. *Rhoipites* sp C; 23. *Rhoipites* sp D



All illustrations x 1 000 (except where marked * = x 500

Figure 8 1. *Rhoipites* sp F; 2. *Rhoipites* sp H; 3. *Tricolporites* sp; 4. *Sapotaceoidaepollenites* sp; 5. *Rhoipites* sp K; 6. *Stephanocolporites* sp; 7. *Cupaniedites major*; 8. *Cupaniedites orthoteichus*; 9. Type D; 10. *Simpsonipollis* sp; 11. Type C; 12. *Retisyncolporites* sp; 13. *Rhoipites* sp G; 14. *Rhoipites* sp J; 15. *Araucariacites* sp; 12. *Retistephanocolpites* sp; 13. *Tricolpites* sp B; 14. *Tricolpites* sp A; 15. *Rhoipites* sp B showing endopore; 16. *Rhoipites* sp B showing zonorate structure

Type D – Figure 8.9

Description: Large spherical grains, invariably crumpled. No apertures similar to those defined for pollen and spore types were seen. Exine thin (<0.1-0.2µm) without any discernible structure. Surface psilate.

Remarks: These grains are similar to grains identified as *Inaperturopollenites* in McLachlan & Pieterse (1978). These authors worked on material of similar age to ours from a geographically close source. Some doubt exists as to whether they are pollen grains, algal or fungal spores or dinoflagellate cysts. The grains have been discounted as dinoflagellete cysts due to the absence of an archaeopyle or plates. Traverse (1988 p 251) mentions that 'baggy' dinoflagellate cysts of this age are easily confused with inaperturate pollen. No fungal or algal spores of similar morphology have been featured in the literature consulted.

Dimensions: Average diameter 29µm (range 12-52µm).

Distribution: Rare in the channel peats and above the *main* peat horizon, significant in the main peat horizon. Present in 12 samples.

SUMMARY

Samples of peat were taken from a quarry in Namaqualand where a palaeochannel was exposed in sediments of reputedly Pliocene age. Pollen extraction by means of standard maceration techniques (Faegri & Iversen 1964) yielded positive results in more than half of the samples. Light microscopy and microphotography were used to record and identify the palynomorphs retrieved.

This paper concentrates on the taxonomy of the Koingnaas palaeoflora. A wide variety of palynomorphs was found, ranging from simple spores to complex pollen. Only 69 are here described and identified, including the botanical affinities where known. The remaining forms presented few specimens, often badly preserved. They are mostly not readily identifiable according to published illustrations and descriptions. Further research will hopefully discover more specimens, enabling the rare palynomorph types to be adequately described, illustrated and identified in the future.

Porate, colpate and colporate pollen produced by angiosperms dominated the assemblage, both in terms of the numbers of individual specimens and the number of palynomorphs types recognised. Saccate and inaperturate pollen, produced by podocarp and araucarian gymnosperms, constituted a small percentage of the assemblage. Trilete and monolete spores mostly derived from ferns accounted for a fifth of the assemblage.

According to the literature consulted, many of the forms found in the Koingnaas palynoflora were common to other southern continents. This should permit a firm resolution of the age of the sediments, which will be the subject of a second paper.

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