THE PALYNOLOGY OF EARLY TERTIARY SEDIMENTS NINETYEAST RIDGE INDIAN OCEAN

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With 8 plates, 2 text-figures, and 2 tables

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ABSTRACT. Assemblages of spores and pollen are recorded from volcanogenic sediments immediately above oceanic basement at drill sites on the Ninetyeast Ridge, Indian Ocean, and are believed to reflect the vegetation of islands which were emergent along the ridge crest in the Palaeogene. At Site 214, the assemblages were recovered from sediments interpreted, on foraminiferal, coccolith, and palynological evidence, as being of mid Palaeocene age. At Site 254, age estimates are ambiguous, but the palyniferous unit is overlain by units dated as middle to late Oligocene on foraminiferal evidence, and seems likely to be Oligocene itself. A total of seventy-one form-species has been identified from the sites. Fourteen of these are instituted as new species, and include *Arecipites insularis* Harris, *Cicatricosisporites teniatus* Harris, *Appendicisporites crassicarinatus* Harris, *Echiperiporites rotundus* Kemp, *Myrtaceidites oceanicus* Kemp, *Nyssapollenites deminutus* Harris, *Punctatosporites varigranulatus* Kemp, *Rhoipites grandis* Kemp, *R. isoreticulatus* Kemp, *R. microluminus* Kemp, *Sparganiaceaepollenites irregularis* Kemp, *Stoverisporites verrucolabrus* Kemp, *Simpsonipollis mulleri* Kemp, and *Tricolpites discus* Harris.

Assemblages from both sites have much in common with Early Tertiary microfloras from Australia and New Zealand; of the total number of form-species, forty-two have been previously described from Australia, seventeen from New Zealand. Families occurring in the island floras which have a general southern distribution include Myrtaceae, Proteaceae, Restionaceae, Gunneraceae, Chloranthaceae, Araucariaceae, and Podocarpaceae. Although reconstructions of the Indian Ocean suggest that the island sites were closer to southern land masses than they are now, it seems that they were truly oceanic in position, and it is argued that establishment of the floras must have occurred through long-distance dispersal mechanisms.

INTRODUCTION

RECENT drilling on the Ninetyeast Ridge in the Indian Ocean has established the presence of shallow water sediments at several sites on the ridge crest. At two of these sites, Deep Sea Drilling Project Sites 214 and 254 (see text-fig. 1), terrestrial to shallow-marine, volcanogenic sediments immediately overlying oceanic basement contain well-preserved spore and pollen assemblages. These, together with the deep-weathering profiles shown by the basement basalts, confirm that parts of the ridge have been emergent at differing times throughout its history. The pollen assemblages are interpreted as reflecting the vegetation of islands which existed along the ridge crest. An assemblage of Palaeocene age has been recovered from Site 214, in the northern sector, and one of probable late Oligocene age has been recorded from Site 254, at the southern extremity of the ridge. Preliminary accounts of these micro-floras have been published (Harris 1974; Kemp 1974); the present paper elaborates and formalizes the systematic description of the spore and pollen species present at
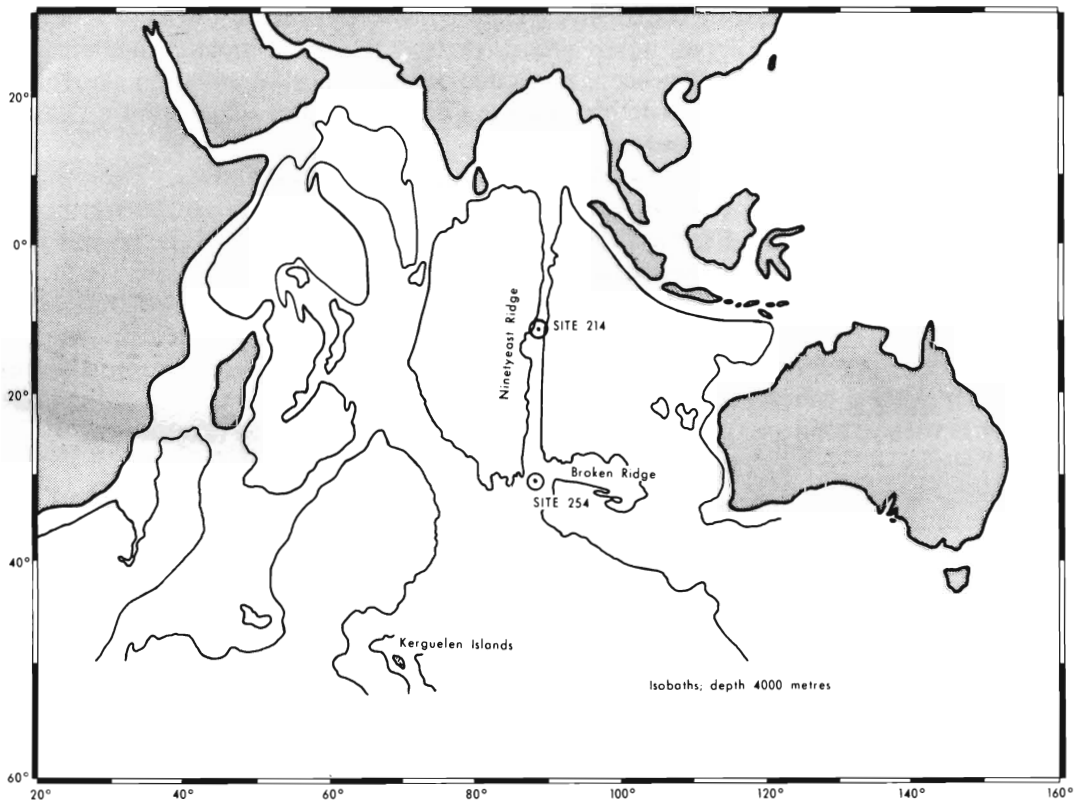
TEXT-FIG. 1. Locality map showing position of Deep Sea Drilling Project Sites 214 and 254.

each of the sites. Microfossils of fungal origin from Site 254 are treated in a separate publication (Kemp, in press). A full account of the phytogeographical implications of these ancient island floras is given elsewhere (Kemp and Harris 1975).

GEOLOGICAL SETTING

The Ninetyeast Ridge is a linear, presently submerged topographic feature which extends along the 90° E. meridian from approximately 9° N. to 32° S. It is a relatively straight, narrow feature, up to 100 km wide, rising some 1500–2000 m from the adjacent sea-floor, separating the Wharton Basin on the east from the Central Indian Basin to the west.

Recent interpretations of the origin of the Ninetyeast Ridge have drawn on data from magnetic anomalies in the adjacent sea-floor, from the stratigraphical succession in drill sites on the ridge crest, and from bathymetric data (Sclater and Fisher 1974; Sclater *et al.* 1974; Luyendyk *et al.* 1974). Correspondence of basement ages, where these have been established along the ridge crest, with those of the immediately adjacent sea-floor in the Central Indian Basin, suggests that the ridge belongs tectonically to the Indian plate. Although reasons for the present elevation of the ridge are not fully understood, the most likely explanation of its origin is that it represents the trace of an extrusive volcanic pile which accumulated at the junction of a former active spreading centre and a large transform fault. Movement along the transform, which was aligned north–south, parallel to, and almost coincident with the present Ninetyeast Ridge, accommodated relative motion between the Indian and Australian plates until probably the late Oligocene, after which motion ceased and fusion of these plates occurred.

The sedimentary sequences at drill sites along the ridge crest show a pattern which accords with the ridge being formed close to a spreading centre to the south, and subsiding in a northerly direction throughout its history. At each of the crestal sites, oceanic basement, where penetrated, is overlain by shallow water, clastic, frequently volcanogenic sediments. These pass upwards into shallow bank facies that are in turn overlain by coccolith oozes representing a pelagic, fully oceanic facies. The boundaries between these facies are diachronous, becoming older to the north; this, together with a general depth increase from south to north along the ridge crest, accords with a rapid sinking of the ridge in a northernly direction (Pimm *et al.* 1974).

SEQUENCES AT SAMPLE LOCALITIES

(i) *Site 214 (lat. 11° 20.2′ S., long. 88° 43.1′ E.); water depth 1665 m.* Five hundred metres of sediment and basalt were penetrated and all palyniferous samples were taken from the two basal units between cores 37 and 51 (text-fig. 2). The oldest unit comprises basalts and interbedded volcanogenic sediments and tuffs, grey and green clays and black and brown lignite. A terrestrial environment is indicated by the well-preserved spore and pollen assemblage. This unit is succeeded by glauconite-bearing silts and sands with foraminifera and other shelly fossils and these, together with the sedimentological data, point to a shallow shelf environment. Within this unit palyno-morphs become less abundant up sequence and are not found above core 37. Of

SITE 214
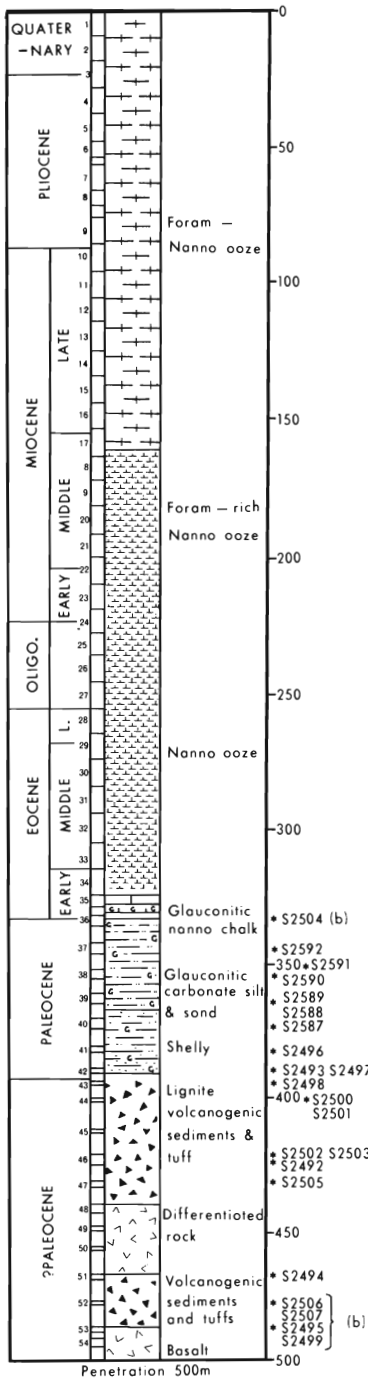
SITE 254
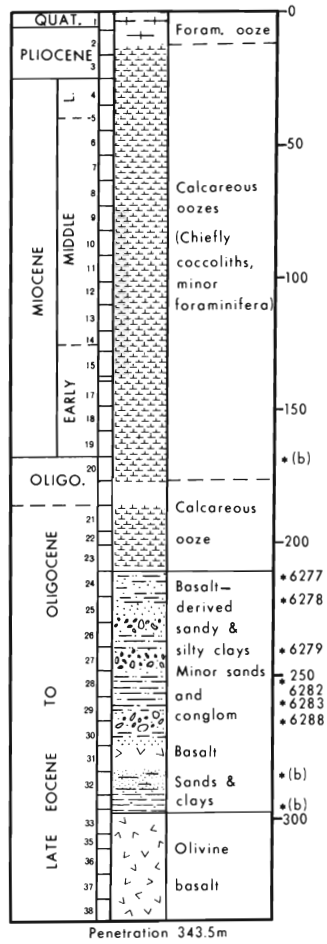
TEXT-FIG. 2. Sequences at Sites 214 and 254. Lithological information and age determinations are from von der Borch et al. (1974) and Davies et al. (1974). Palynological sampling horizons are shown by an asterisk and a number to the right of the column; barren samples are indicated by (b).

particular interest is the rapid decline in frequency of terrestrially derived palyno-
morphs concomitantly with a dominance of organic-walled microplankton. This is
attributed to a sudden submergence of the island system to oceanic depths (Harris
1974; Pimm *et al.* 1974).

Foraminifera and nannofossils in cores 36 and 41 indicate a Palaeocene age. In
particular, McGowran (1974) assigns a P4 age for cores 36 to 38 on the basis of rare
Planorotalites chapmani. In cores 40 and 41 benthonic foraminifera are of Palaeocene
age. Calcareous nannofossils from the top of core 37 are of mid Palaeocene age
(*Heliolithus kleinpelli* Zone), and possibly as old as the *Cyclococcolithina robusta*
Zone in core 41 (von der Borch *et al.* 1974). Below core 41 age assessment is based on
the palynological assemblages. The basis of assigning a Palaeocene age for these
sediments has been discussed by Harris (1974) and rests on correlation with the
Gambierina edwardsi Zone, which Harris (1971) erected in the Otway Basin of south-
eastern Australia, and for which a mid Palaeocene age has been faunally established.
The Palaeocene age thus rests in part on correlation with the Australian region and
with the marine assemblages in cores 38–41. There is no significant difference in the
terrestrial components between cores 41 and 42.

(ii) Site 254 (lat. 30° 58.15′ S., long. 87° 54.72′ E.); water depth 1253 m. All palyniferous
samples from Site 254 come from the basal sedimentary unit (text-fig. 2). This consists
of olive to black, poorly sorted silty clay and fine sandstone, with subordinate fine
conglomeratic bands (Davies *et al.* 1974). The sediments are primarily of volcanic
origin; pebbles consist of glassy or fine-grained porphyritic volcanics, and the
matrix contains abundant grains of altered volcanic glass. A marine influence
is evident through most of the unit; fragmentary molluscs are concentrated in its
upper part, and a restricted, but well-preserved assemblage of shallow-water fora-
minifera was recovered from cores 25 to 29. Shallow-water ostracodes and fragmentary
dinoflagellates occur through the same interval. Spore and pollen assemblages were
recovered from the upper part of the unit, viz. above a thin basalt at 277 m. Samples
taken below this level were barren, a condition probably associated with the increas-
ingly ferruginous nature of the sediments towards the base of the unit. The basal
ferruginous clays and fine sandstones conformably overlie a highly weathered basalt.
The sedimentary unit has been interpreted (Davies *et al.* 1974) as originating
through the weathering and erosion of a basaltic terrain and subsequent rapid
deposition of erosional products. The poor sorting, lack of current features, and
presence of a shallow marine fauna suggest deposition occurred rapidly in quiet
water; a lagoonal environment seems likely. Such an environmental interpretation
accords well with the palynological data. The spore and pollen assemblages are
diverse, with little local over-representation of species, a situation which suggests
derivation from a source area that may have been topographically diverse. The excel-
lence of preservation suggests that the grains have not travelled far, nor have they
suffered reworking from older sediments. Pollen densities are high in some Site 254
cores; a figure of approximately 20 000 grains per gram of sediment was estimated
for core 29. Comparably high figures were reported from the lagoons of Micronesian
islands (Leopold 1969) only when those islands were relatively large and high. On
Ponape, for example, which is some 90 square miles in extent, and 2500 feet high,

densities were of the order of 34 000 grains per gram; on low islands of only a few square miles, densities were many orders of magnitude lower.

Age assessments of the palyniferous unit based on varied fossil groups are ambiguous (Davies *et al.* 1974). The firmest age control comes from pelagic sediments above the unit; foraminifera in the calcareous oozes of core 30 have been identified as middle to late Oligocene in age. Foraminifera within the basal unit itself are long-ranging forms only, and unsuitable for age determination. The ostracodes could not be identified to species level, and could only be broadly interpreted as Eocene–Oligocene. The molluscs were identified as pre-Miocene, with the lack of definitive Eocene forms being conspicuous. Age assessment based on the palynological assemblage does little to clarify the ambiguity. Some of the difficulties in assigning an age on this basis were outlined by Kemp (1974) in a preliminary study; palynology is in general accord with an Oligocene age for the unit, i.e. not significantly older than the overlying calcareous oozes. The presence of Compositae grains, albeit in low numbers, at this site, suggests that the age may be as young as late Oligocene, as there is no evidence, on a global basis, for the appearance of the family before that date.

METHODS

Standard palynological techniques have been employed in the preparation of plant microfossils. Basically the technique is one of hydrofluoric acid digestion of mineral assemblages followed by ten to fifteen minutes oxidation of the residue with Schultze's solution and the removal of humic acids with a weak (1–2 per cent) hydroxide solution. All slides were made up in glycerine jelly, or Clearcol. Holotypes of new species, and all specimens on which new species descriptions are based, are housed in the palaeontological collections of two institutions; holotypes and figured specimens in the Bureau of Mineral Resources are prefixed CPC (Commonwealth Palaeontological Collection); holotypes in the Geological Survey of South Australia by Py. The following numbers refer to the catalogue number of the type. Topotype material from both localities is available at each depository. Photomicrographs with the light microscope were made on a Leitz Ortholux (No. BMR 724105) at the Bureau of Mineral Resources and a Zeiss Photomicroscope (No. 1953) at the Geological Survey of South Australia. Specimen co-ordinates are from these two microscopes. Specimens selected for examination by scanning electron microscope techniques were gold coated and photographed with a JEOL-JSM2 at the Bureau of Mineral Resources and a Siemens Autoscan at the Department of Geology, the University of Adelaide. With the exception of the long-ranging species *Cyathidites australis* Couper, *C. minor* Couper, and *Microcachryidites antarcticus* Cookson, all species recorded in the text are illustrated, if not in this publication then in the earlier, preliminary accounts of Kemp (1974) and Harris (1974).

SYSTEMATIC PALYNOLOGY

Tertiary palynology, even more than the palynology of older sedimentary rocks, has suffered from a marked ambiguity of approach. Authors have variously assigned

dispersed pollen and spores in Tertiary sediments to extant genera, or to purely artificial, morphological taxa; frequently, combinations of the two approaches have been utilized, with artificial categories employed only for those dispersed forms whose relationship to extant taxa is not immediately apparent. While the practice of broadly identifying dispersed pollen grains with extant genera may have some validity for the Neogene (although even this remains unsubstantiated), it is hazardous in the Palaeogene, without additional evidence for the existence of such genera at that time. The extension of this practice, that of combining the names of fossil pollen 'species' with those of extant plant genera, which is common enough in Tertiary palynological literature (see Traverse 1955; Elsik and Dilcher 1974; Martin 1973b), is unacceptable on similar grounds; identification of an extant genus implies the recognition of a whole group of characters, and these cannot be unequivocally inferred from dispersed pollen grains, especially in older Tertiary sediments. For the palynomorphs recovered from the Palaeogene sediments of the Ninetyeast Ridge, therefore, we have used a nomenclatural system which is purely morphographic, while we have attempted to indicate botanical affinities in an informal fashion where this is possible.

Within this framework, we have adhered to conventional binomial names, with their attendant type specimens. We are in full agreement with the basic tenets expressed by Hughes and his co-workers (summarized by Hughes 1975), concerning the inadequacies of many published descriptions of taxa, and of the stratigraphic disadvantages of 'balloon' taxa; we do not, however, for reasons outlined below, feel that the use of 'biorecords' to replace form-species as suggested by Hughes, would serve our purposes better than conventional nomenclature.

This study has as its aim the provision of basic descriptive data which are presented in support of previously published discussions of the palaeobiogeography of these island floras (Kemp and Harris 1975); reference of pollen grains to nomenclatural systems other than the currently accepted binomial scheme would, in this instance as in many others, make comparison with previously described microfloras extremely difficult. Further, the proposal to dispense with conventional binomial nomenclature had its origins in the alleged failure of that nomenclature to serve stratigraphy. Our aims in this study are not primarily stratigraphical, although it is relevant to point out in this context that we do not feel that the ascribing of binomial names to palynological taxa in any way restricts their stratigraphical usefulness—provided of course that original descriptions are based on adequate material from stated stratigraphical intervals.

In the following systematic section, form-species proposed as new have been based on a stated number of specimens (not less than twenty well-preserved individuals) that have been drawn from a single 'sample'—a sample in our case being a cored interval not more than 2·5 cm thick—and all specimens are available, with the types, for re-examination. Additionally, all new species are supported by high magnification scanning electron microscope (SEM) data. It is arguable that the erection of new form-species for common morphological types, for instance, for tricolporate grains of reticulate exine pattern, serves no useful purpose, and only adds to the already unwieldy agglomeration of names. Countering this, we feel that, if a literature search suggests that the forms are indeed previously undescribed, and, provided adequate specimens from a defined interval are available, then formal naming as a new taxon

ensures that the information gathered will be retained. The alternative, of giving the types an informal, open designation, offers no such guarantee, especially as the currently available cataloguing systems used to disseminate information (such as the Catalogue of Fossil Spores and Pollen), list only formally named species. Should the forms designated as new species eventually be proven to be synonymous with previously described forms, many of which are difficult to compare because of brief description and illustration, then, at worst, some inconvenience will have been incurred; no information will have been lost.

The addition of new morphological data as a result of technological improvements presents a continuing problem of comparison with previously described taxa, especially those which were briefly described and poorly illustrated. In this study, species for which we were able to obtain a large amount of high magnification detail have only been placed in comparison with similar, previously described forms which were based on much less. In this regard, the system of crudely quantitative, graded comparisons proposed by Hughes and his co-workers has considerable value in assessment of the stratigraphical utility of particular forms; we have not used it in our study, however, as it can only be realistically applied when descriptions of the taxa concerned have been presented in comparable detail. In assigning fossil species to form-genera, we have attempted to use the earliest named, appropriate taxa which have validity under the International Code of Botanical Nomenclature. It is evident that a distinct regional bias exists in the application of names in Tertiary palynology; Australian workers, for instance, have been influenced by the work of Cookson, and the names she erected; workers in tropical areas by van der Hammen and co-workers; while those in the northern hemisphere are more cognizant of the work of Potonié and other early palynologists. An example of the regional bias is evident in the usage of the form-genus *Tricolporites*, which was proposed by Cookson in 1947, and has been widely used in Australasia to accommodate a variety of tricolporate, frequently reticulate pollen types. The category, at the time of its erection, was not differentiated from the morphologically similar *Rhoipites* Wodehouse, 1933; nor has it subsequently been clearly separated from the latter form-genus, which we believe has priority, and so we have applied the name on those grounds.

The genera erected by van der Hammen (1956) and typified by pollen of extant plant species, have been widely used, especially in palynological studies of tropical Tertiary sequences (see Leidelmeyer 1966; Guzman 1967; van Hoeken-Klinkenberg 1965, 1966; Germeraad *et al*. 1968, and others). Attempts have been made by a number of these workers to regularize the typification of van der Hammen's genera, by selecting a fossil species as lectogenotype. This procedure, however, according to Srivastava (1966, p. 56), and echoed by Dettmann (1973, p. 12), does not appear to have been successful, as type species can only be replaced if the originals are lost or found to be wrong; in the present case, the fossil genera technically remain junior synonyms of the extant taxa originally used to typify them. Because of the doubts remaining as to the validity of these genera, we have avoided using them in this study.

Genus CYATHIDITES Couper, 1953

Type species. Cyathidites australis Couper, 1953.

Cyathidites australis Couper, 1953

(Not figured)

Dimensions. Equatorial diameter 53 (60) 68 μm (fifteen specimens).

Remarks. C. australis is separated from *C. minor* on a size basis; straight to slightly concave sides and non-labrate laesurae are further distinguishing features.

Affinity. The possible relationship of this type of fossil spore to the Cyatheaceae (including the Dicksoniaceae) has been discussed by Couper (1953, 1958).

Distribution. C. australis is widely distributed in the Mesozoic and Tertiary of Australia, New Zealand, and the northern hemisphere. It occurs in most samples from Sites 214 and 254, reaching maximum frequencies of 8 per cent.

Cyathidites minor Couper, 1953

(Not figured)

Dimensions. Equatorial diameter 23 (25) 29 μm (fifteen specimens).

Remarks. These forms from Site 254 which are here referred to *C. minor* are slightly smaller than those originally described from New Zealand, but are distinguished by the same concave-sided amb, weakly developed laesurae, and thin exine.

Distribution. Present in most samples from Sites 214 and 254, with a maximum abundance of 40 per cent.

Cyathidites sp. cf. *C. kerguelensis* (Cookson) comb. nov.

Plate 1, fig. 8

cf. *Trilites (Alsophilidites) kerguelensis* Cookson, 1947, p. 136, pl. 16, fig. 69.

Dimensions. Equatorial diameter 29 (33) 37 μm (fifteen specimens).


EXPLANATION OF PLATE 1

Figs. 1–5. *Stoverisporites verrucolabrus* Kemp sp. nov. Site 254. 1, 2, holotype, CPC 15654, Sample 6283, separate mount, 106.8, 37.3, $\times$ 1250. 1, median focus, showing verrucate labra and 'crescentic muri' around depressions on the distal face. 2, Nomarski interference contrast, focus on proximal face. 3, CPC 15656, Slide 6283/7, 103.0, 29.6. Focus on distal face, $\times$ 1250. 4, 5, scanning electron micrographs, Sample 6283. 4, distal surface showing circular shape of depressions, $\times$ 1400. 5, proximal face of another specimen, $\times$ 1600.

Figs. 6, 7. *Polypodiaceoisporites* cf. *P. tumulatus* Partridge, 1973. Site 254. 6, CPC 15657, Slide 6283/5, 107.8, 30.9. Specimen showing abrupt widening of cingulum interradially. 7, scanning electron micrograph, sample 6283. Distal aspect, $\times$ 1200.

Fig. 8. *Cyathidites* cf. *C. kerguelensis* Cookson, 1947. Site 254. CPC 15658, Slide 6283/6, 101.7, 45.2, $\times$ 1250.

Fig. 9. *Baculatisporites* sp. Site 254. CPC 15659, Slide 6282/3, 103.7, 38.3, $\times$ 1250. Proximal focus.

Figs. 10–12. *Deltoidospora* sp. Site 254. 10, CPC 15660, Slide 6282/7, 98.7, 37.2. Lateral compression showing thickening about trilete scar. $\times$ 1000. 11, 12, CPC 15661, Slide 6282/2, 94.3, 30.8. High and median foci, $\times$ 1000.
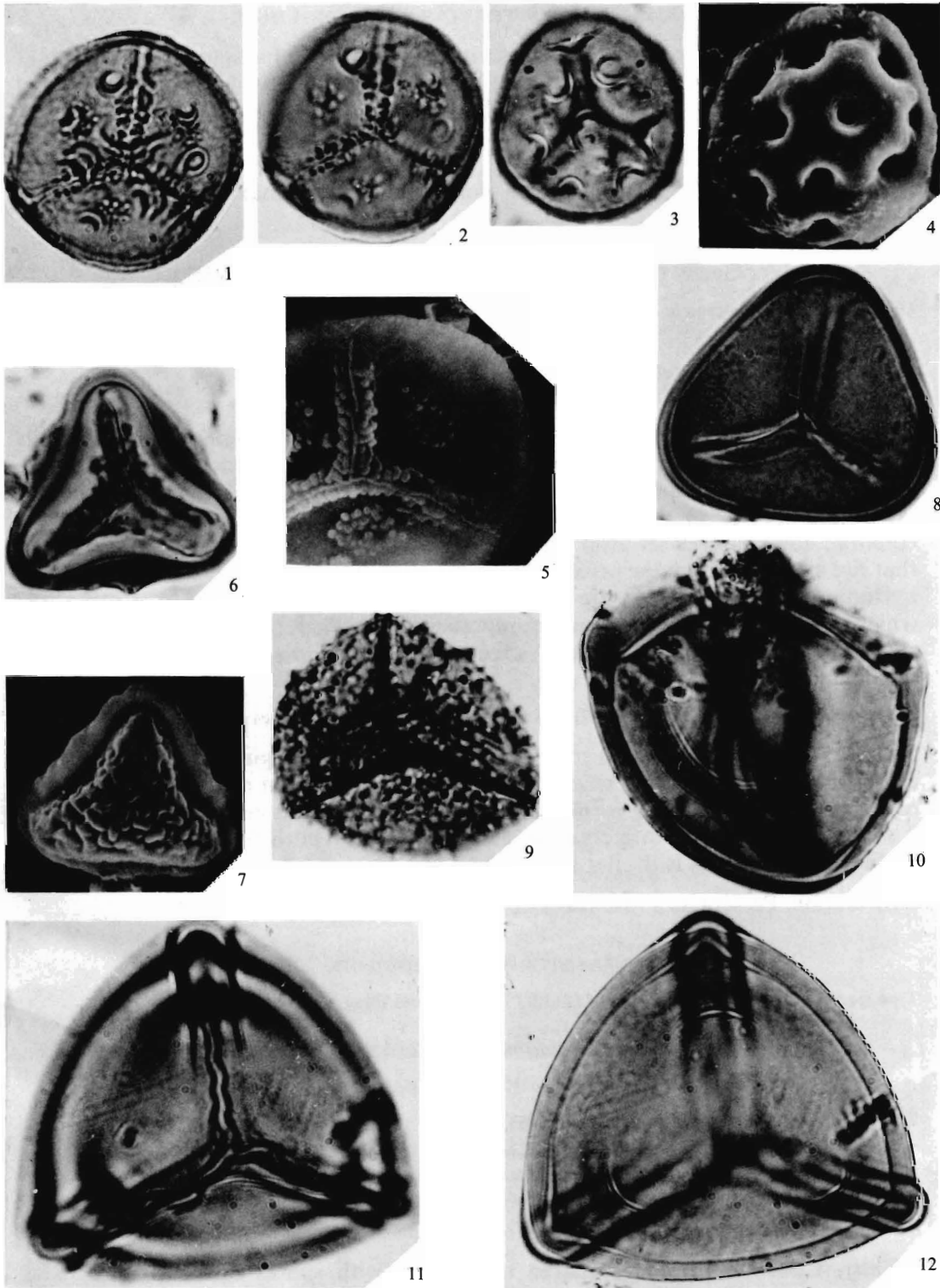
KEMP and HARRIS, Indian Ocean Tertiary spores

Remarks. This species conforms to Cookson's species, being characterized by a straight or convex-sided amb, weakly developed laesurae, and a relatively thick (1·5–2·0 μm) exine. It is, however, considerably smaller than the Kerguelen specimens.

Affinity. Unknown.

Distribution. Site 254, present in all cores, reaching a maximum frequency of 12 per cent.

Genus DELTOIDOSPORA Miner emend. Potonié, 1956

Type species. Deltoidospora hallii Miner, 1935.

Deltoidospora sp.

Plate 1, figs. 10–12

Description. Microspore trilete, radially symmetrical; amb rounded triangular with convex sides. Grain angles protruding beyond the line of the interradial wall. Two thirds of the observed specimens were compressed in a triplanar configuration, reflecting strong arching of the distal face. Laesurae straight, extending full distance to equator; commissures set atop prominent ridges 5–6 μm high and 8–10 μm wide, that rise smoothly from the proximal face, i.e. they are not abruptly delineated as are kyrtomes. These elevations are formed by gross thickening of the proximal wall, which is clearly shown in triplanar compressions (see Pl. 1, fig. 10). Exine uniformly smooth, approximately 2 μm thick, except for the proximal thickenings where the thickness reaches 5–6 μm.

Dimensions. Equatorial diameter 47 (49) 53 μm; polar diameter 44 (49) 58 μm (sixteen specimens).

Remarks. This species, which may be a new form, is distinguished by the marked exine thickenings about the trilete scar, and by the extension of the laesurae to the equator, with the resulting formation of prominent projections at the grain angles. The form identified from Kerguelen as *T.* cf. *neddeni* Potonié by Cookson (1947, p. 136, pl. 16, fig. 60) is similar in form and size range, and may be conspecific.

Distribution. Present as a rare form (less than 1 per cent) in two samples at Site 254.

Genus BACULATISPORITES Thomson and Pflug, 1953

Type species. Baculatisporites primarius (Wolff) Thomson and Pflug, 1953.

Baculatisporites comaumensis (Cookson) Potonié, 1956

(Figured in Harris 1974, pl. 1, fig. 6)

For synonymy prior to 1962 see Dettmann 1963, p. 35.

   1963   *Baculatisporites comaumensis* (Cookson); Dettmann, p. 35, pl. 3, figs. 22, 23.
   1972   *Baculatisporites comaumensis* (Cookson); Archangelsky, p. 76, pl. 3, fig. 3.
   1974   *Baculatisporites comaumensis* (Cookson); Harris, p. 511, pl. 1, fig. 6.

Dimensions. Equatorial diameter 32 (52) 60 μm (seven specimens).

Affinity. Cookson (1953) compared the species with spores of *Todea* Wild and

Leptopteris Presl., and Dettmann (1963) indicated comparison with certain species of *Osmunda* L.

Distribution. A rare species at Site 214.

Baculatisporites sp.

Plate 1, fig. 9

Dimensions. Equatorial diameter 33 (40) 45 μm (ten specimens).

Remarks. Reference to *Baculatisporites* is made tentatively since the sculptural elements, although showing marked variation, are preponderantly coni. Setae, bacula, and grana are also present. The forms are further distinguished by a rounded triangular amb, by slightly sinuous laesurae extending to the equator, and by labra. The species possibly represents a new taxon, but is too rare for formal description. Some resemblance to *B. turbioensis* Archangelsky (1972, pl. 3, fig. 3) is evident, except for the flat-topped processes shown by the southern Argentinian form.

Distribution. Site 254; present as a rare form in four samples.

Genus OSMUNDACIDITES Couper, 1953

Type species. Osmundacidites wellmanii Couper, 1953.

Osmundacidites wellmanii Couper, 1953

(Figured in Harris 1974, pl. 1, fig. 7)

For synonomy prior to 1962 see Dettmann 1963, p. 32.

     1963   *Osmundacidites wellmanii* Couper; Dettmann, p. 32, pl. 3, figs. 19–21.
     1974   *Osmundacidites wellmanii* Couper; Harris, p. 511, pl. 1, fig. 7.

Dimensions. Equatorial diameter 32 (48) 60 μm (twenty specimens).

Affinity. Couper (1960) placed this species in the Osmundaceae.

Distribution. A common species in most samples below the marine interval at Site 214.

Genus POLYPODIACEOISPORITES Potonié, 1956

Type species. Polypodiaceoisporites speciosus (Potonié) Potonié, 1956.

Polypodiaceoisporites sp. cf. *P. tumulatus* Partridge, 1973

Plate 1, figs. 6, 7

  cf. 1973   *Polypodiaceoisporites tumulatus* Partridge, in Stover and Partridge, p. 250, pl. 16, fig. 4.
     1974   *Polypodiaceoisporites* sp. cf. *P. retirugatus* Muller, in Kemp, p. 818, pl. 2, figs. 21, 22.

Dimensions. Equatorial diameter 25 (33) 44 μm (including cingulum); cingulum width 2–4 μm apically, 3–8 μm interradially.

Remarks. The Ninetyeast Ridge form differs from *P. tumulatus* in the range of equatorial structures; this population ranges from specimens in which the cingulum is of roughly uniform width (which is close to *P. tumulatus*), to those showing an abrupt

increase in cingulum thickness interradially (Pl. 1, fig. 6). The species was compared to *P. retirugatus* Muller in a preliminary study (Kemp 1974). It is, however, clearly distinct from the Sarawak Palaeocene species, which does not show a concentration of the sculptural elements in the distal pole area, and which is much larger.

Affinity. Muller (1968) likened the dispersed species *P. retirugatus* to the spores of *Pteris*; the basic similarity of morphology shown by *P.* sp. cf. *tumulatus* suggests a similar relationship.

Distribution. *P. tumulatus* appears in the Gippsland Basin of south-eastern Australia in the late Miocene. At Site 254, *P.* sp. cf. *tumulatus* is present in most samples, locally reaching abundances in excess of 5 per cent.

Genus CAMAROZONOSPORITES Pant ex Potonié, 1956 emend. Klaus, 1960

Type species. Camarozonosporites cretaceus (Weyland and Krieger); subsequent designation by Potonié 1956.

Camarozonosporites sp. indet.
(Not figured, see Harris 1974, pl. 1, fig. 16)

Dimensions. Equatorial diameter 32 (48) 56 μm (seven specimens).

Affinity. *Lycopodium* spores of Harris's (1955) Group V are similar.

Distribution. A rare species but present in most samples at Site 214 below the marine sequence.

Genus KRAEUSELISPORITES Leschik emend. Jansonius, 1962

Type species. Kraeuselisporites dentatus Leschik, 1955.

Kraeuselisporites papillatus Harris, 1965
(Figured in Harris 1974, pl. 1, fig. 15)

1965   *Kraeuselisporites papillatus* Harris, p. 83, pl. 25, figs. 15, 16.
1974   *Kraeuselisporites papillatus* Harris; Harris, p. 504, pl. 1, fig. 15.

Affinity. Probably with *Selaginella*.

Distribution. A very rare species at Site 214. In southern Australia it is a common form in Paleocene sediments.

Genus CLAVIFERA Bolkovitina, 1966

Type species. Clavifera triplex (Bolkovitina) Bolkovitina, 1966.

Clavifera triplex (Bolkovitina) Bolkovitina, 1966
(Figured in Harris 1974, pl. 1, fig. 10)

See Dettmann and Playford 1968, p. 77, for selected synonomy.

1968   *Clavifera triplex* (Bolkovitina); Dettman and Playford, p. 77, pl. 6, figs. 6–8.
1973   *Clavifera triplex* (Bolkovitina); Archangelsky, p. 348, pl. 2, figs. 4–6.
1974   *Clavifera triplex* (Bolkovitina); Harris, p. 511, pl. 1, fig. 10.

Dimensions. Equatorial diameter 25 (32) 37 μm (ten specimens).

Remarks. Spores of this type appear to intergrade with *Gleicheniidites*. The species from Site 214 have weakly thickened apices in contrast to Australian Late Cretaceous and Early Tertiary forms.

Affinity. Probably Gleicheniaceae.

Distribution. Infrequent in most samples from Site 214.

Genus STOVERISPORITES Burger, 1976 emend. Kemp

Type species. Stoverisporites microverrucatus Burger, 1976.

Remarks. Trilete spores bearing a distal sculpture interpreted as circular depressions bounded by crescentic, murus-like elevations, were included within the genus *Kuylisporites* Potonié by Cookson and Dettman (1958). Dettmann (1963), however, subsequently pointed out that *K. lunaris*, which is weakly thickened equatorially, is not strictly conformable with *Kuylisporites* as originally conceived. In addition, the type species, *K. waterbolki* Potonié, 1956, bears exinal depressions in interradial, equatorial areas, features which are lacking in *K. lunaris*. Burger (1976) erected the genus *Stoverisporites* to accommodate forms morphologically similar to *K. lunaris*, designating *K. microverrucatus* Burger as type species.

All previous interpretations of the distal sculpture of this group of species have relied on light microscopy. Scanning electron microscopy, used here, shows the distal face to be in fact sculptured with large, circular to oval foveolae, with no crescentic muri at their margins. The optical effect suggesting such structures results, apparently, from compression acting on the steeply arched distal face. This thickens the spore wall differentially on one side of the foveolae; this thickening is visible in optical section, but is not evident on the outer surface of the grain. The diagnosis of *Stoverisporites* given by Burger is, therefore, emended to incorporate these new observations.

Emended diagnosis. Azonate to weakly cingulate trilete spores with a strongly arched distal face bearing eight to twelve circular to oval depressions, each floored by exine which is thinned with respect to the rest of the distal face. In optical section the foveolae appear to be partially bounded by crescentic elevations (the 'scutulae' of Potonié 1956), but these are not apparent on the grain surface, and may be due to exine thickening under compression. Remainder of distal face, and proximal face may be smooth, or bear small verrucae or grana.

Stoverisporites verrucolabrus Kemp sp. nov.

Plate 1, figs. 1–5

Diagnosis. Spores trilete, weakly cingulate, amb generally circular, rarely rounded triangular. Laesurae extend to spore margins; there is a row of verrucae bounding the commissures and averaging 1·5–2·0 μm in diameter. Each proximal face bears a cluster of small verrucae or grana in its centre; these elements are also 1·5–2·0 μm in diameter. Cingulum development weak, with the cingulum generally 2–3 μm wide, thinning to a slightly ragged equatorial margin. Distal face strongly arched, sculptured with eight to twelve circular to oval foveolae, 3–4 μm in diameter. Under the

light microscope these appear as depressions bounded on one side by a crescentic murus. Grana or small verrucae are sparsely scattered on the distal exine surface between the foveolae.

Dimensions. Equatorial diameter (including cingulum) 25 (31) 35 μm (twenty-two specimens).

Holotype. Plate 1, figs. 1, 2. Sample 6283; separate mount, 106.8, 37.3 (CPC 15654). Holotype 31 μm in diameter, proximo-distally compressed, amb sub-circular; cingulum clearly present, 2·0-2·5 μm wide, tapering to a thin edge. Laesurae extend to angles, with verrucate labra 1·5 μm wide. Clustered grana distinct on contact faces. Nine foveolae on distal face.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Sample 6283. Core 29, section 1 at 128–130 cm, 258 m sub-bottom. ?Oligocene.

Remarks and comparison. The appearance of bounding crescentic muri about the foveolae in optical section is strongest in those near the grain equator, presumably because the grain face is more strongly arched there than at the distal pole, and compression of the sculptural features is most oblique. *S. verrucolabrus* is distinguished by the presence of labrate structures made up of very closely spaced verrucae, and by the cluster of verrucae or grana in each of the contact faces. This last feature is shared by the Early Cretaceous species *S. lunaris* (Cookson and Dettmann) Burger, 1976, to which the Early Tertiary form is morphologically close. *S. microverrucatus* Burger differs only in the less regular distribution of verrucae on the proximal face.

Affinity. Unknown.

Distribution. The Ninetyeast Ridge occurrence appears to be the first record of this morphological type outside the Cretaceous. *S. lunaris* occurs widely in the Australian Early Cretaceous (Dettmann 1963) and similar forms occur in strata of comparable age in the U.S.S.R. and Canada. In this study, *S. verrucolabrus* was recorded only from Site 254, where it was rare.

Genus FOVEOSPORITES Balme, 1957

Type species. Foveosporites canalis Balme, 1957.

Foveosporites sp.

Plate 2, fig. 4

Dimensions. Equatorial diameter 35–44 μm (six specimens).

EXPLANATION OF PLATE 2

Figs. 1–3. *Punctatosporites* sp. Site 254. 1, CPC 15662, Slide 6283/2, 109.5, 41.9. Nomarski interference contrast, ×1250. 2, 3, CPC 15663, Slide 6283/5, 91.8, 37.0. High and median foci, ×1250.

Fig. 4. *Foveosporites* sp. Site 254. CPC 15664, Slide 6283/5, 112.5, 45.6. Nomarski interference contrast; high focus on proximal face, ×1250.

Figs. 5, 6. *Triletes* cf. *T. tuberculiformis* Cookson, 1947, CPC 15665, Slide 6282/2, 98.7, 30.7. Proximal and distal foci, ×1250.

Fig. 7. *Foveotriletes palaequetrus* Partridge, 1973. CPC 15666, Slide 6283/6, 95.8, 35.2, ×1250.

Figs. 8, 9. *Cicatricosisporites teniatus* Harris sp. nov. Site 214. 8, 9, holotype, Slide ST2498/14, 15.0, 108.7 (GSSA Py 1020). Distal and median foci, ×1250.

Figs. 10–13. *Appendicisporites crassicarinatus* Harris sp. nov. Site 214. 10, holotype, Slide ST2498/4, 11.4, 106.7. Proximal focus, ×1250. 11, ST2498/8, 11.7, 106.3. Nomarski interference contrast, proximal aspect, ×1250. 12, 13, scanning electron micrographs, Sample S2498. 12, distal view, ×1000. 13, proximal view, ×1300.
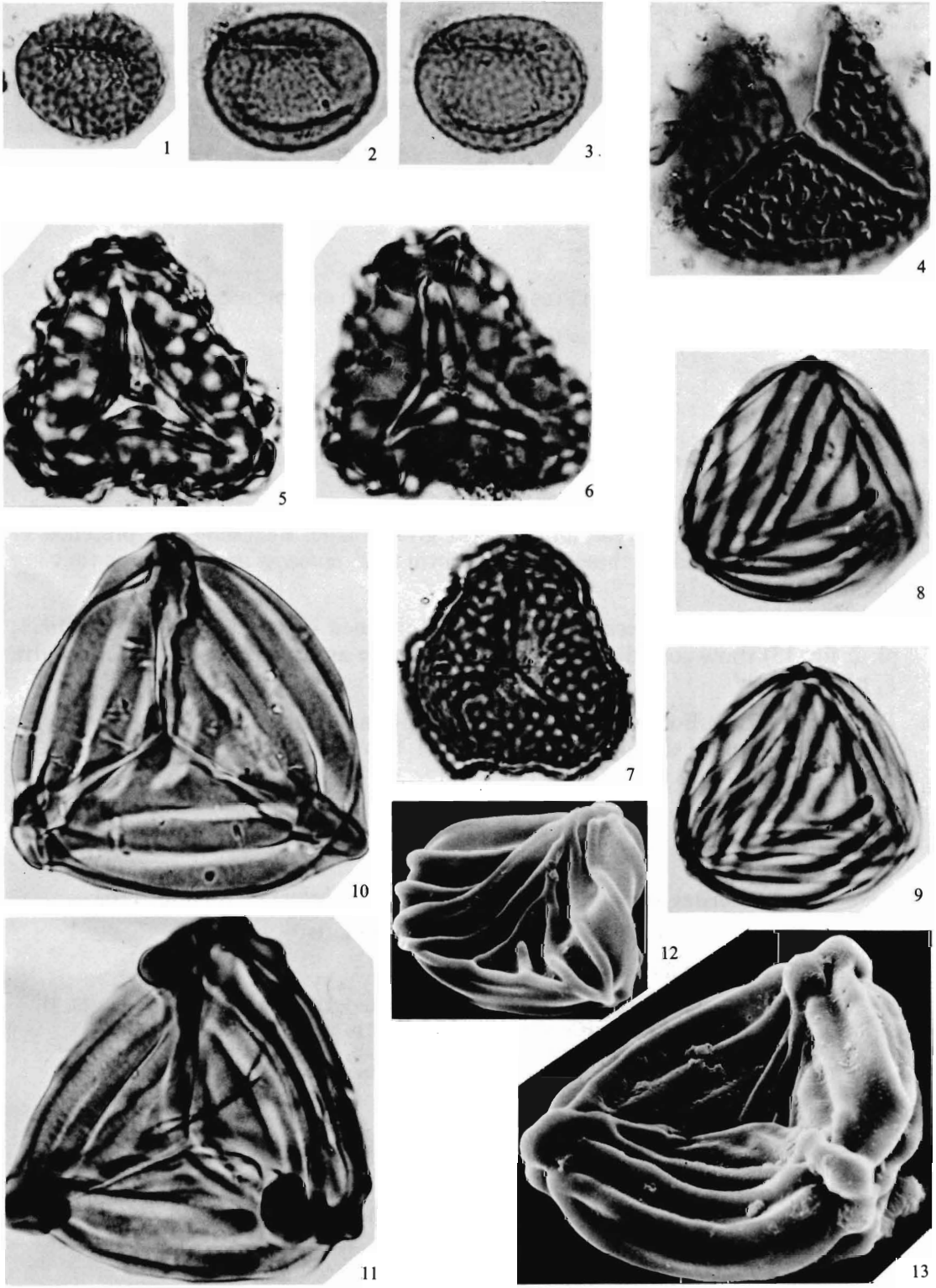
KEMP and HARRIS, Indian Ocean Tertiary spores

Remarks. This form, which is distinguished by a thick exine sculptured on proximal and distal faces with sinuous canals, may be a new species of *Foveosporites*, but too few specimens were recovered to characterize it as such. Among previously described species, the Early Cretaceous *F. canalis* Balme is morphologically closest, but is less robust and more circular in outline than the Ninetyeast Ridge form.

Affinity. Possibly Lycopodiaceae.

Distribution. Site 254, rare.

Genus FOVEOTRILETES van der Hammen ex Potonié, 1956

Type species. Foveotriletes scrobiculatus (Ross) Potonié, 1956.

Foveotriletes palaequetrus Partridge, 1973

Plate 2, fig. 7

1973   *Foveotriletes palaequetrus* Partridge, in Stover and Partridge, p. 248, pl. 14, figs. 4, 5.

Dimensions. Equatorial diameter 27–33 μm (eight specimens).

Remarks. In sculptural type and general grain shape, including the presence of distinct apical shoulders, these grains conform to *F. palaequetrus*, although they are slightly smaller.

Affinity. Spores of *Lycopodium fuegianum* Roivainen (illustrated in Heusser 1971, pl. 2, fig. 13) show considerable similarity in shape and sculpture to the fossil form *F. palaequetrus*.

Distribution. Late Eocene–early Miocene, Gippsland Basin, Victoria. A rare form (up to 1 per cent) in six samples from Site 214, two from Site 254.

Genus STEREISPORITES Pflug, 1953

Type species. Stereisporites steroides (Potonié and Venitz) Pflug, 1953.

Stereisporites antiquasporites (Wilson and Webster) Dettmann, 1963

(Figured in Harris 1974, pl. 1, fig. 11)

See Dettmann 1963, p. 25 for selected synonymy.

1963   *Stereisporites antiquasporites* (Wilson and Webster); Dettmann, p. 25, pl. 1, figs. 20, 21.
1972   *Cingutriletes australis* (Cookson); Archangelsky, p. 86, pl. 6, figs. 1–3.
1973   *Cingutriletes australis* (Cookson); Archangelsky, p. 347, pl. 2, figs. 7, 8.
1974   *Stereisporites antiquasporites* (Wilson and Webster); Harris, p. 511, pl. 1, fig. 11.

Affinity. Probably Sphagnaceae.

Distribution. A very rare species at Site 214.

Genus CERATOSPORITES Cookson and Dettmann, 1958

Type species. Ceratosporites equalis Cookson and Dettmann, 1958.

Ceratosporites equalis Cookson and Dettmann, 1958

(Figured in Harris 1974, pl. 1, fig. 14)

1958   *Ceratosporites equalis* Cookson and Dettmann, p. 101, pl. 14, figs. 17–19.
1963   *Ceratosporites equalis* Cookson and Dettmann; Dettmann, p. 36, pl. 5, figs. 6–8.
1974   *Ceratosporites equalis* Cookson and Dettmann; Harris, p. 511, pl. 1, fig. 14.

Affinity. Cookson and Dettmann (1958) compared the species with spores of the *Selaginella latifrons* group of Knox (1950).

Distribution. Recorded as a rare form in two samples at Site 214, and in one at Site 254.

Genus TRILITES Erdtman ex Couper emend. Dettmann, 1963

Type species. Trilites tuberculiformis Cookson, 1947.

Trilites sp. cf. *T. tuberculiformis* Cookson, 1947

Plate 2, figs. 5, 6

1963   *Trilites* sp. cf. *T. tuberculiformis* Cookson, 1947; Dettmann, p. 63, pl. 11, figs. 16–19.

Dimensions. Equatorial diameter 36 (39) 41 μm (eight specimens).

Remarks. Dettmann (1963) rephotographed and redescribed type material of *T. tuberculiformis* from Kerguelen. She placed Australian Early Cretaceous forms, which are smaller than the type species, in comparison with *T. tuberculiformis*. Specimens from the Ninetyeast Ridge sites are similar in both size and sculpture to the Australian Cretaceous ones, with which they may be conspecific.

Affinity. Some species of the extant genus *Dicksonia* (Cyatheaceae) have comparable trilete spores with rugulo-verrucate distal sculpture (e.g. *Dicksonia berteroana* Hooker).

Distribution. Site 254, recorded as a rare element from two samples. At Site 214 it is a common component in most samples.

Genus APPENDICISPORITES Weyland and Krieger, 1953

Type species. Appendicisporites tricuspidatus Weyland and Krieger, 1953.

Appendicisporites crassicarinatus Harris sp. nov.

Plate 2, figs. 10–13

1974   *Appendicisporites* sp. Harris, p. 511, pl. 1, fig. 17.

Diagnosis. Microspores free, trilete, biconvex, anisopolar with a radial symmetry. Shape in polar aspect sub-triangular; semi-circular in equatorial view. Laesurae straight, three-quarters of the amb radius, and enclosed in membranous lips 4–5 μm high. Exine 3–4 μm thick, apparently single-layered, sculptured in distal and equatorial regions with three sets of muri parallel to the equator. Exine thicker (to 9 μm) in distal equatorial radial regions where muri coalesce, forming a radially aligned murus

bisecting each amb angle (Pl. 2, fig. 12). Projections formed thus at the amb angles are highest and widest at the equator and taper gradually towards the distal pole. Muri are up to 5 μm wide, have straight or gently sloping sides, and are 2–3 μm high with rounded crests. Muri widths approximate those of adjacent lumina. Four muri and intervening lumina span 30–38 μm. Contact faces smooth.

Dimensions. Equatorial diameter (including projections) 55 (73) 87 μm (twenty specimens); polar diameter 38 (50) 61 μm (six specimens).

Holotype. Plate 2, fig. 10. Slide ST2498/4; 11.4, 106.7 (GSSA Py 1019). Grain in proximal polar aspect. Equatorial diameter 72 μm. Exine 3·6 μm thick at equator.

Type locality. Site 214, Indian Ocean, 11° 20.2′ S., 88° 43.1′ E. Core 43, core catcher sample, 402 m sub-bottom.

Remarks and comparison. This species has a similar ornament pattern to *Cicatricosisporites hughesi* Dettmann, 1963, but differs in its semi-circular amb, and thicker, round-crested muri, and in the more robust projections formed by the intersection of these at the grain angles. *Appendicisporites* is known only from pre-Senonian sediments in Australia (Dettmann and Playford 1968). This species has fewer wider-spaced muri than in *A. distocarinatus* Dettmann and Playford, 1968.

Affinity. Microspores of this type are characteristic of the Schizaeaceae.

Distribution. A common species in most samples from Site 214, with frequencies up to 6 per cent.

Genus *Cicatricosisporites* Potonié and Gelletich, 1933

Type species. Cicatricosisporites dorogensis Potonié and Gelletich, 1933.

Cicatricosisporites teniatus Harris sp. nov.

Plate 2, figs. 8, 9

1974   *Cicatricosisporites* sp. Harris, p. 511, pl. 1, fig. 18.

Diagnosis. Microspores free, trilete, biconvex; anispolar with a radial symmetry. Amb rounded triangular and shape sub-circular in equatorial aspect. Laesurae straight, three-quarter radius of amb in length, and enclosed in membranous lips 2–3 μm high. Exine 3–4 μm thick, apparently single layered. Distal and equatorial exine sculptured with three series of six to seven muri disposed parallel to equator. Muri 3–4 μm wide, 2–3 μm high with straight or tapering sides and rounded crests. Muri equal or slightly narrower in width than adjacent lumina. Four muri and intervening lumina span 20–25 μm. Contact faces smooth.

Dimensions. Equatorial diameter 32 (53) 65 μm (twenty specimens); polar diameter 38 (46) 52 μm (six specimens).

Holotype. Plate 2, figs. 8, 9. Slide ST2498/14; 15.0, 108.7 (GSSA Py 1020). Grain in distal polar aspect. Equatorial diameter 49 μm. Exine 4 μm thick at equator.

Type locality. Site 214, Indian Ocean, 11° 20.2′ S., 88° 43.1′ E. Core 43, core catcher sample, 402 m sub-bottom.

Remarks. This species follows the ornament pattern of *C. hughesi* Dettmann, 1963 but differs from this species in the shape of the amb and in having straight rather than

sinuous muri. *C. ludbrooki* Dettmann, 1963 is similar but muri are separated by narrower lumina in this species. Spores of this type occur only as remanié Cretaceous fossils in the Early Tertiary of southern Australia.

Affinity. Schizaeaceae.

Distribution. An uncommon species in the lower part of the non-marine sequence at Site 214.

<p align="center">Genus PEROMONOLITES Couper, 1953</p>

Type species. Peromonolites bowenii Couper, 1953.

<p align="center">*Peromonolites vellosus* Partridge, 1973</p>

<p align="center">Plate 3, figs. 1-3</p>

1973 *Peromonolites vellosus* Partridge, in Stover and Partridge, p. 251, pl. 15, fig. 6; pl. 16, fig. 1.
1974 *Peromonolites* sp. Kemp, p. 819, pl. 2, fig. 23.

Dimensions. Over-all grain length (including perispore) 34 (36) 42 μm (twenty specimens); grain depth 23 (27) 29 μm, width 23–29 μm.

Remarks. Ninetyeast Ridge specimens are morphologically very close to *P. vellosus* Partridge and show a clear two-layered exine with frequent separation of the exine layers. The outer layer forms a fibrous mat, 3–4 μm thick; the densely woven character of the fibres is distinct at high magnification (see Pl. 3, fig. 3). The inner layer, up to 2 μm thick, is lamellated. *Peromonolites* sp. from the Eocene Rio Turbio Formation of southern Argentina (Archangelsky 1972, pl. 7, figs. 6, 7) may be conspecific.

Affinity. Unknown.

Distribution. Middle Palaeocene to late Miocene, Gippsland Basin, Victoria (Stover and Partridge 1973). At Site 254, it was recorded from five samples, and reached relative abundance figures in excess of 5 per cent in one core.

<p align="center">*Peromonolites densus* Harris, 1965</p>

<p align="center">(Figured in Harris 1974, pl. 1, fig. 5)</p>

1965a *Peromonolites densus* Harris, p. 84, pl. 24, figs. 3–5.
1973 *Peromonolites densus* Harris; Stover and Evans, pl. 2, fig. 7.
1973 *Peromonolites densus* Harris; Stover and Partridge, p. 251.
1974 *Peromonolites densus* Harris; Harris, p. 511, pl. 1, fig. 5.

Affinity. Unknown.

Distribution. Middle Palaeocene through Miocene, Gippsland Basin, Victoria (Stover and Partridge 1973). At Site 214 it is a rare species.

Genus PUNCTATOSPORITES Ibrahim, 1933

Type species. Punctatosporites minutus Ibrahim, 1933.

Punctatosporites varigranulatus Kemp sp. nov.

Plate 3, figs. 10–13

Diagnosis. Spores bilateral, monolete, plano-convex in equatorial view. Laesura straight, with length equal to *c.* three-quarters of grain length. Proximal and distal surfaces uniformly covered with processes among which bacula predominate, but which include coni and grana. Smaller processes ($0.4-1.0$ μm in basal diameter) tend to be circular in plan; the larger forms are elongate and/or sinuous, up to 3.0 μm long and 0.5 μm wide. Elements vary in profile, with height slightly in excess of basal diameter in most cases, but equal in others. The profile of the distal end of the processes is usually squarish. Sculptural elements sparsely distributed, separated by areas of exine bearing low rugae arranged in an indistinct reticulate pattern. Exine $1.0-1.5$ μm thick, two-layered, although the layers are closely adpressed and difficult to discern. The outer, ornamented layer is thin and translucent, and extends for $3-4$ μm beyond the profile of the proximal face in equatorial compressions. It is presently unclear whether this feature represents random detachment of the outer layer, or whether it is a membranous labra.

Dimensions. Length 41 (45) 51 μm, depth 27 (30) 36 μm (twenty specimens). All specimens observed in equatorial compression.

Holotype. Plate 3, fig. 10. Sample 6283, separate mount, 103.5, 36.7 (CPC 15671). Grain compressed in equatorial aspect. Grain length 52 μm, depth 31 μm, membranous proximal extension 2 μm high, exine 1.5 μm thick, processes $1-2$ μm in height.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Core 29, section 1 at 128–130 cm, 258 m sub-bottom. ?Oligocene.

Remarks. The species recorded as ?*Peromonolites* sp. by Hekel (1972) from the early Miocene of Queensland bears some resemblance to *P. varigranulatus*, but differs in

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EXPLANATION OF PLATE 3

Figs. 1–3. *Peromonolites vellosus* Partridge, 1973. Site 254. 1, CPC 15667, Slide 6283/1, 100.6, 31.4. Equatorial aspect, median focus showing exine stratification, ×1000. 2, 3, scanning electron micrograph, Sample 6283. 2, equatorial aspect, ×1100. 3, detail of specimen in fig. 2, ×2500.

Fig. 4. *Laevigatosporites ovatus* Wilson and Webster, 1946. CPC 15668, Slide 6283/6, 112.3, 31.0, ×1250. Equatorial aspect.

Fig. 5. *Polypodiisporites* cf. *P. rugufavus* (Krutzsch) comb. nov. CPC 15669, Slide 6283/6, 101.8, 45.1. Equatorial aspect, ×1000.

Fig. 6. *Polypodiisporites* cf. *P. histiopteroides* (Krutzsch) comb. nov. CPC 15670, Slide 6283/6, 99.5, 31.0. Equatorial aspect, ×1000.

Figs. 7–9. *Polypodiisporites* sp. 7, Slide ST2498/4, 11.4, 102.0. Equatorial aspect, Nomarski interference contrast, ×750. 8, Slide ST2498/2, 8.7, 109.5 (GSSA Py 1021). Equatorial aspect, Nomarski interference contrast, ×1250. 9, scanning electron micrograph, Sample S2498, ×2600.

Figs. 10–13. *Punctatosporites varigranulatus* Kemp sp. nov. 10, holotype, CPC 15671, Sample 6283, separate mount, 103.5, 36.7. Equatorial aspect, median focus, ×1250. 11, CPC 15672, Slide 6282/3, 95.5, 37.8. Equatorial aspect, Nomarski interference contrast, ×1250. 12, 13, scanning electron micrographs. 12, ×900. 13, detail of specimen in fig. 12, ×2500.
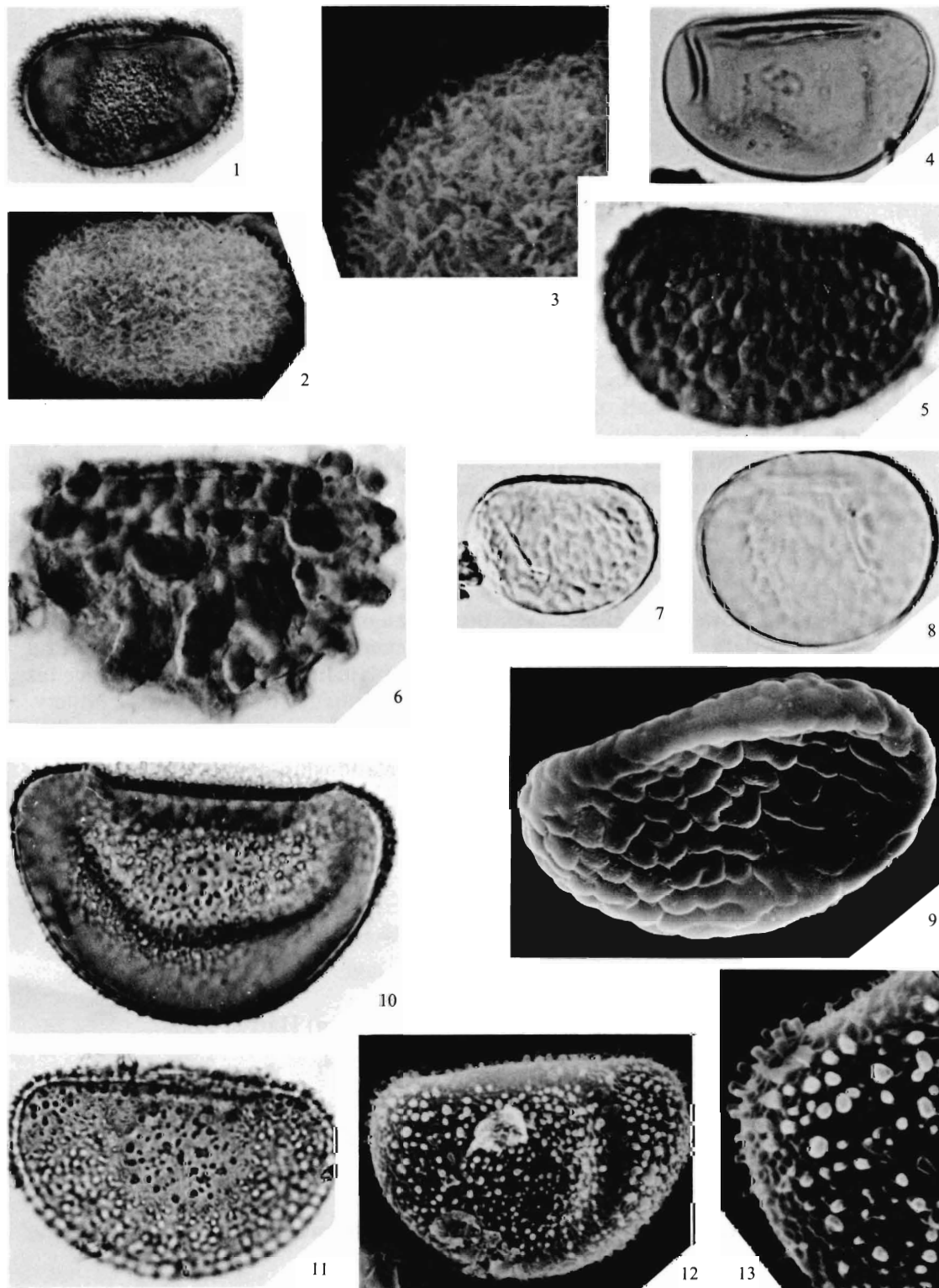
KEMP and HARRIS, Indian Ocean Tertiary spores

shape, being shorter and deeper than the Ninetyeast Ridge form. Species recovered from the European Tertiary and referred to *Echinosporis* by Krutzsch (1967) differ in that spinae and coni are the commonest sculptural elements, with bacula subordinate.

Affinity. Unknown, possibly Polypodiaceae.

Distribution. Site 254, present as a rare (less than 1 per cent) component in five samples.

Punctatosporites sp.

Plate 2, figs. 1–3

Description. Monolete, bilaterally symmetrical spores, amb oval. Laesura straight, simple, length equal to half or three quarters grain length. Exine 0·5–0·8 μm thick, without visible stratification; ornamented on both proximal and distal faces by sparsely distributed grana which are between 0·5 and 0·8 μm in both height and basal diameter. Grana show occasional coalescence to form short, discrete ridges; anatomosing of elements is insufficient to form a complete reticulum.

Dimensions. Spore length 19 (21) 27 μm, width 16 (17) 19 μm, depth 10 (15) 19 μm (twenty specimens).

Remarks. This dispersed species does not appear to match any previously described type. We have, however, retained an informal designation as we presently lack high magnification data. The dimensions and the general sparseness of the sculptural elements is similar to *P. scabratus* (Couper), from the late Jurassic and Early Cretaceous of Great Britain (Couper 1958), but the tendency of elements to coalesce in the Ninetyeast Ridge form is distinctive.

Affinity. Couper drew attention to the possible relationship of this type of grain to the order Marattiales.

Distribution. Common in two samples from Site 254 (relative abundances in excess of 7 per cent): rare in two others.

Genus MICROFOVEOLATOSPORITES Krutzsch, 1959

Type species. Microfoveolatosporites pseudodentatus Krutzsch, 1959.

Microfoveolatosporites fromensis (Cookson) Harris, 1965

(Figured in Harris 1974, pl. 1, figs. 3, 4)

1965   *Schizaea fromensis* Cookson, p. 43, pl. 8, fig. 3.
1965a *Microfoveolatosporites fromensis* (Cookson); Harris, p. 84, pl. 24, fig. 7.
1974   *Microfoveolatosporites* cf. *M. fromensis* (Cookson) Harris; Harris, p. 504, pl. 1, figs. 3, 4.

Affinity. Schizaeaceae.

Distribution. A very rare species at Site 214. It is also present rarely in Palaeocene sediments in southern Australia.

Genus POLYPODIISPORITES Potonié, 1933 emend. Khan and Martin, 1971

Type species. Polypodiisporites favus Potonié and Gelletich, 1933.

Polypodiisporites sp. cf. *P. rugufavus* (Krutzsch) comb. nov.

Plate 3, fig. 5

cf. 1967   *Verrucatosporites rugufavus* Krutzsch, p. 194, pl. 73, figs. 1-4.
    1974   *Verrucatosporites* sp. cf. *V. speciosus* Harris, 1965; Kemp, p. 818, pl. 2, fig. 24.

Dimensions. Length 38 (47) 58 μm, depth 25 (31) 38 μm (thirty specimens), width 30 (31) 36 μm. Verrucae have maximum diameter of 4-5 μm (distal face), maximum height of 1-2 μm. Exine thickness 2-3 μm; verrucae twenty to thirty in number around polar profile.

Remarks. This species resembles *V. rugufavus*, from the Miocene of Germany, in the densely crowded verrucae showing distinct radial alignment of their long axes. The verrucae in the Ninetyeast Ridge specimens are somewhat smaller, and consequently more abundant. *V. inangahuensis* (Couper), from the Miocene of New Zealand, is larger than the specimens described here, and has smaller verrucae.

Affinity. Polypodiaceae. Spores produced by the extant genera *Davallia*, and by some species of *Polypodium* resemble these fossil forms.

Distribution. Present in low frequencies in all samples from Site 254.

Polypodiisporites sp.

Plate 3, figs. 7-9

1974   *Polypodiidites* sp. Harris, p. 511, pl. 1, fig. 2.

Description. Spore free, anisopolar with bilateral symmetry. Shape in equatorial aspect sub-rounded, elliptical in full polar aspect. Laesura straight, extending half to two-thirds length of the major equatorial axis. Ornament consists of very low (1-2 μm high) contiguous verrucae from 2 to 4 μm in diameter and of irregular shape. Exine 1·8 μm thick.

Dimensions. Equatorial diameter, long axis 22 (27) 33 μm, short axis 17 (20) 25 μm (fifteen specimens).

Remarks. The rounded shape of the amb in equatorial view, the low verrucae and small size distinguish this species from *V. speciosus* Harris. *Verrucatosporites tenellis* (Krutzsch) Krutzsch, 1967, from European Eocene–Miocene sediments, is similar in shape and ornamentation, but is larger (35-40 μm equatorial diameter, long axis). The Ninetyeast Ridge form is given an informal designation here as the significance of this size difference cannot be assessed.

Affinity. Polypodiaceae.

Distribution. An infrequent species in the lower section of the non-marine sediments from Site 214; up to 5·5 per cent in one sample.

Polypodiisporites sp. cf. *P. histiopteroides* (Krutzsch) comb. nov.

Plate 3, fig. 6

cf. 1967   *Verrucatosporites histiopteroides* Krutzsch, p. 200, pl. 76, figs. 1-3.

Dimensions. Spore length 46–72 μm, grain depth 26–46 μm (five specimens).

Remarks. In the squarish, or 'bastion-shaped' verrucae, and in its size range, the species is close to the subspecies *V. histiopteroides histiopteroides* Krutzsch, originally described from Miocene brown coals of Germany; the verrucae, however, are more sparsely distributed in the Indian Ocean form.

Affinity. Probably Polypodiaceae; comparable spores are known from the genus *Histiopteris* (see Erdtman 1957, p. 63).

Distribution. Site 254, present as a rare element in five samples.

Genus LAEVIGATOSPORITES Ibrahim, 1933

Type species. Laevigatosporites vulgaris (Ibrahim) Ibrahim, 1933.

Laevigatosporites ovatus Wilson and Webster, 1946

Plate 3, fig. 4

Dimensions. Length 24 (34) 46 μm, depth 15 (23) 36 μm, breadth 23–27 μm.

Affinity. Smooth-walled monolete spores, or those with a readily shed perispore, occur in a number of fern genera, e.g. *Asplenium, Athyrium, Blechnum, Dryopteris,* etc.

Distribution. Common—present in all samples at Site 254, with relative frequencies up to 12 per cent; at Site 214, in frequencies up to 16 per cent.

Laevigatosporites major (Cookson) Krutzsch, 1959

(Figured in Harris 1974, pl. 1, fig. 1)

For previous synonomy see Harris 1965a.

    1965a *Laevigatosporites major* (Cookson); Harris, p. 83, pl. 24, fig. 1.
    1968   *Laevigatosporites major* (Cookson); Dettmann and Playford, p. 82, pl. 8, fig. 2.
    1974   *Laevigatosporites major* (Cookson); Harris, p. 511, pl. 1, fig. 1.

Dimensions. Equatorial diameter, long axis 56 (70) 82 μm, short axis 37 (42) 48 μm (twenty specimens).

Affinity. Probably Polypodiaceae.

Distribution. A species common to most samples from Site 214, reaching a relative frequency of 17 per cent.

Genus ARAUCARIACITES Cookson, 1947 ex Couper, 1953

Type species. Araucariacites australis Cookson, 1947 (by subsequent designation, Couper 1953).

Araucariacites australis Cookson, 1947

Plate 4, figs. 15, 16

Dimensions. Grain diameter 55 (75) 94 μm (thirty-five specimens measured).

Remarks. Both sculpturally, and in the mean size of the individuals measured, the specimens from the Ninetyeast Ridge conform to *A. australis*, described originally from the Tertiary lignites of Kerguelen. The majority of observed grains were strongly crumpled. Although thin and fractured areas were present in the exine of most, it was not possible to determine whether these represented functional apertures. Both interference microscopy and scanning electron microscopy were used to show details of the grain surface; the ornament consists of a dense cover of processes which are predominantly finely pointed coni, with subordinate grana (Pl. 4, fig. 16).

Affinity. The grains can be referred to Araucariaceae with some degree of confidence, but it is not possible to distinguish readily between *Araucaria* and *Agathis*, as has been remarked by Cookson (1947), Cookson and Duigan (1951), and Erdtman (1965). On the basis of size range alone, affinity with *Araucaria* seems most likely for the Ninetyeast Ridge specimens, as it does for those from Kerguelen, although the insecurity of this criterion is acknowledged.

Distribution. Site 254 only; present in nearly all samples, and locally reaching relative abundances of 8 per cent. Although *A. australis* has a wide distribution in Mesozoic sediments of both northern and southern hemispheres, Tertiary records are more restricted. From eastern Australia, in addition to the occurrences in New South Wales, Victoria, and South Australia documented by Cookson and Duigan (1951), it has been recorded from the Palaeocene of Victoria (Harris 1965a), the ?Palaeocene-Pliocene of Queensland (Hekel 1972), and the probable Miocene of western New South Wales (Martin 1973b). From Western Australia there are, perhaps remarkably, no records of *Araucaria*—like pollens in Tertiary sequences (Cookson 1954; Balme and Churchill 1959; Hos 1975), although they are present in the Cretaceous (Balme 1957). From Antarctica, there are Tertiary records from the Ross Sea and Antarctic Peninsula (McIntyre and Wilson 1966; Cranwell 1969), but none from the coastal region facing the Indian Ocean (Kemp 1972), although the fossil record is admittedly meagre in that area. *A. australis* has also been recorded from Borneo (Muller 1968), but it is scarce and possibly recycled in sediments younger than Senonian.

Genus LYGISTEPOLLENITES Stover and Evans, 1973

Type species. Lygistepollenites balmei (Cookson) Stover and Evans, 1973.

Lygistepollenites florinii (Cookson and Pike) Stover and Evans, 1973

(Figured in Harris 1974, pl. 2, figs. 3, 4)

1953   *Dacrydiumites florinii* Cookson and Pike, p. 479, pl. 3, figs. 20-35.
1965a   *Dacrydiumites florinii* Cookson and Pike; Harris, p. 87, pl. 26, fig. 18.

1973   *Lygistepollenites florinii* (Cookson and Pike); Stover and Evans, p. 64.
1973   *Lygistepollenites florinii* (Cookson and Pike); Stover and Partridge, p. 252.
1974   *Lygistepollenites florinii* (Cookson and Pike); Harris, p. 513, pl. 2, figs. 3, 4.

Dimensions. Corpus diameter 28 (42) 55 μm (thirty specimens).

Remarks. Specimens assigned to this species show the same wide range of form accepted for the Australian members of the species.

Affinity. Pollen of a species of *Dacrydium*.

Distribution. A very common species in most samples at Site 214, reaching a relative frequency of 29 per cent.

Genus PHYLLOCLADIDITES Cookson ex Couper, 1953 emend. Stover and Evans, 1973

Type species. Phyllocladidites mawsonii Cookson, 1947 (designated by Couper 1953).

'*Phyllocladidites*' *paleogenicus* Cookson and Pike, 1954

(Figured in Harris 1974, pl. 2, figs. 8, 9)

1954   *Phyllocladidites paleogenicus* Cookson and Pike, p. 63, pl. 2, figs. 1–6.
1965a *Phyllocladidites paleogenicus* Cookson and Pike, in Harris, p. 86, pl. 26, fig. 19.
1974   '*Phyllocladidites*' cf. '*P*' *paleogenicus* Cookson and Pike; Harris, p. 513, pl. 2, figs. 8, 9.

Dimensions. Equatorial diameter of corpus, long axis 28 (42) 53 μm (thirty specimens).

Remarks. Pollen of this morphological type does not fit the diagnosis of *Phyllocladidites* as emended by Stover and Evans. These authors restrict to the genus those species with localized thickenings of the exine between the proximal roots of the sacci

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EXPLANATION OF PLATE 4

Figs. 1, 2. *Milfordia homeopunctata* (McIntyre) Partridge, 1973. Site 254. 1, CPC 15648, Slide 6283/3, 93.3, 38.9, ×1250. 2, CPC 16522, Slide 6282/4, 96.8, 33.5. Focus on pore, ×1250.

Figs. 3, 4. *Spinizonocolpites prominatus* (McIntyre) Stover and Evans, 1973. Site 254. CPC 15649, Slide 6283/6, 100.3, 45.2, ×1250. 3, median focus, showing processes in profile. 4, high focus on finely reticulate sexine.

Figs. 5, 6. *Arecipites insularis* Harris sp. nov. Site 214. 5, holotype, Slide ST2498/1, 11.8, 109.3 (GSSA Py 1018). Grain in polar aspect, sulcus gaping, ×1250. 6, Sample S2498, scanning electron micrograph, proximal face, ×2000.

Figs. 7–9. *Clavatipollenites* sp. cf. *C. hughesii* Couper, 1958. 7, 8, CPC 15650, Slide 6283/1, 101.4, 32.1, Site 254. High and median focus showing breakdown of sexine across the sulcus, ×1250. 9, scanning electron micrograph, Sample S2498, Site 214. Distal face. Breakdown of sexine reticulum in sulcal area visible, ×3000.

Figs. 10, 11. *Polycolpites* sp. Site 254. CPC 15651, Slide 6283/2, 93.5, 37.7. Polar aspect, ×1250. 10, median focus, showing elongated columellae around equator. 11, high focus on polar region.

Figs. 12, 13. *Schizocolpus marlinensis* Stover, 1973. Site 254, CPC 15652, Slide 6282/7, 105.9, 39.4. Oblique polar aspect, ×1250. 12, median focus showing loose attachment of sexine reticulum. Deep focus on pore in colpus at top right. 13, high focus, shows second pore in colpus at top right.

Fig. 14. *Podocarpidites* sp. Sample 6283, Site 254. Scanning electron micrograph, ×1300.

Figs. 15, 16. *Araucariacites australis* Cookson, 1947. Site 254. 15, CPC 15653, Slide 6283/2, 94.3, 27.6. Nomarski interference contrast, ×1250. 16, scanning electron micrograph of specimen from Sample 6283, showing detail of surface ornament, ×2500.
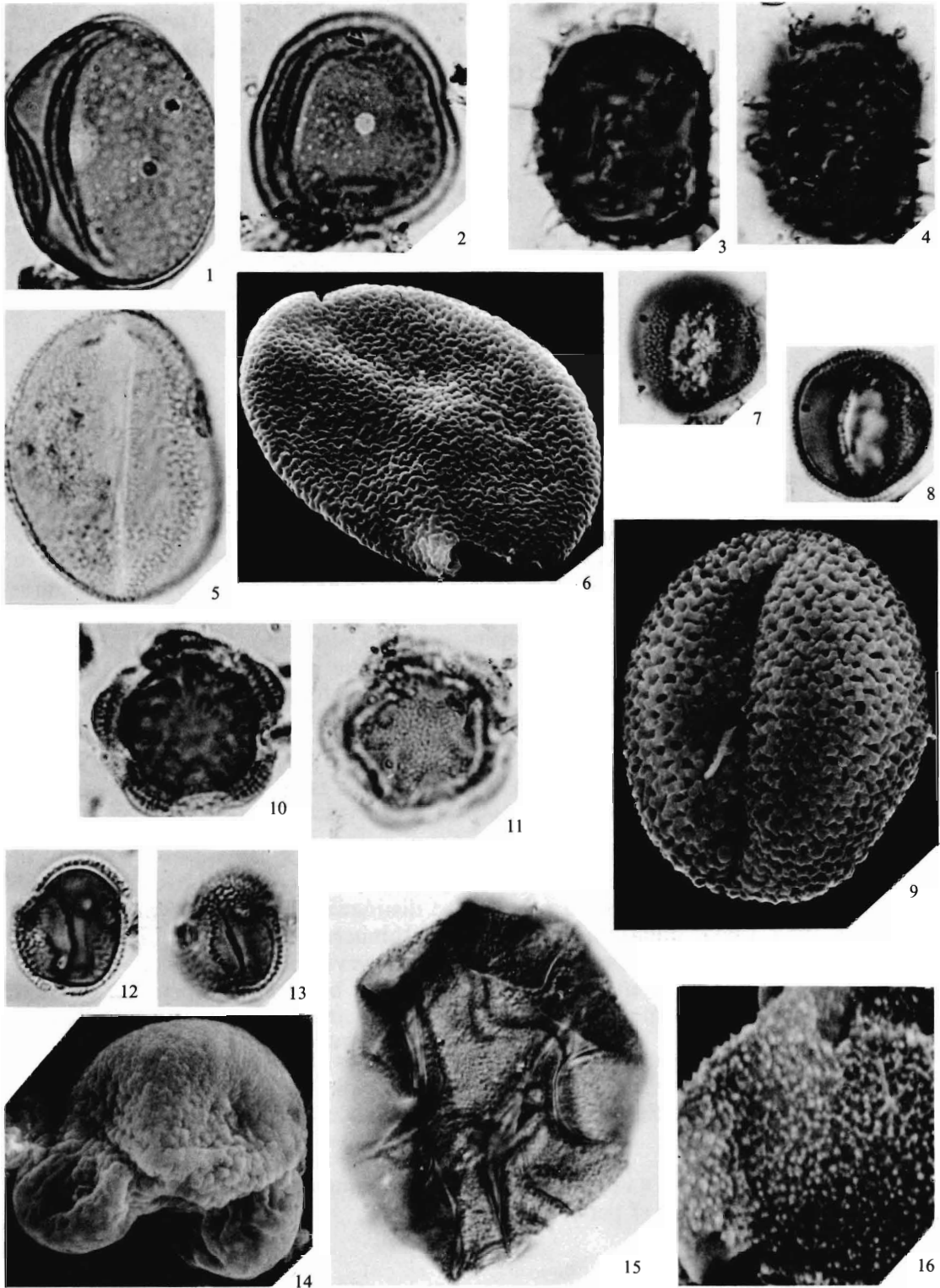
KEMP and HARRIS, Indian Ocean Tertiary spores

and the body cap. The morphology of this species is closely similar to *Podosporites microsaccatus* (Couper), except for the number of sacci.

Affinity. Cookson and Pike (1954*a*) refer grains of this type to *Phyllocladus*.

Distribution. A very common species at Site 214 below the marine sequence, reaching a relative frequency of 18 per cent.

Genus PODOCARPIDITES Cookson ex Couper, 1953

Type species. Podocarpidites ellipticus Cookson, 1947 (subsequent designation by Couper 1953).

Podocarpidites sp.

Plate 4, fig. 14

1974   *Podocarpidites* sp., in Kemp, p. 817, pl. 2, figs. 17, 18.

Description. Disaccate pollen grains, sacci distally pendant. Corpus slightly broader than long, strongly arched proximally. Sacci small in relation to corpus, with saccus length in excess of breadth. Corpus densely infrareticulate proximally, with proximal exine 2–3 μm thick; proximal surface elevated into densely packed, flattish rugulae or verrucae (see SEM, pl. 4, fig. 14); these overlap 2–3 μm on to the distal face in proximo-distal compressions. Sacci supported by a radially aligned infrareticulum; endo-sexinous rods within the sacci are continuous from saccus floor to distal surface; in surface view the rods show the blind-ended branching described by Sivak (1975) as typical of Podocarpaceae. Saccus surface shows radially aligned broad folds, but is otherwise smooth. Distal tenuitas, between the sacci roots, is thin walled and smooth (see illustration in Kemp 1974, pl. 2, fig. 18).

Dimensions. Over-all grain breadth 25 (36) 44 μm; corpus breadth 25 (28) 32 μm; corpus length 22 (33) 38 μm; saccus length 18 (21) 30 μm; saccus breadth 11 (13) 15 μm (eight specimens).

Remarks. This species differs from *P. ellipticus* in having smaller sacs in relation to the corpus, and in possessing a more densely verrucate or regulate proximal cap. The same relationships of saccus to corpus size distinguish the form from *P. exiguus* Harris, 1965, which, additionally, has a much thinner exine. It seems likely that the form described above represents a new species; however, although it was common at Site 254, well-preserved specimens were rare, most being either corroded or fragmented, so that informal nomenclature has been retained.

Affinity. Podocarpaceae. Surface views of the grains show a marked similarity to pollen of *Podocarpus madagascariensis* Baker (Sivak 1975, pl. 34, figs. 4–6), but identification of these Early Tertiary forms with extant taxa at species level is not implied.

Distribution. Sites 214 and 254, present in all samples; locally reaches relative frequencies in excess of 17 per cent.

Genus MICROCACHRYIDITES Cookson, 1947 ex Couper, 1953

Type species. Microcachryidites antarcticus Cookson, 1947 (subsequent designation by Couper 1953).

Microcachryidites antarcticus Cookson, 1947

(Not figured)

Dimensions. Over-all grain diameter 25–44 μm; corpus length 21–27 μm; corpus breadth 25–28 μm; saccus length 8–24 μm; saccus breadth 11–15 μm (five specimens).

Remarks. (Based on Site 254.) Bisaccate forms of this species strongly outnumbered trisaccate; a similar ratio was noted in the Tertiary lignites of Kerguelen by Cookson (1947).

Affinity. Podocarpaceae—possibly with affinity to *Microcachrys* (see discussion in Cookson 1947).

Distribution. Occurs as a rare component (up to 1 per cent) in most samples at Site 254, and is present in similar frequencies in most samples from Site 214 below the marine sequence.

· Genus SCHIZOSPORIS Cookson and Dettmann, 1959

Type species. Schizosporis reticulatus Cookson and Dettmann, 1959.

Schizosporis sp. indet.

(Figured in Harris 1974, pl. 2, figs. 1, 2)

Remarks. This species shows affinities with one that occurs rarely in southern Australian and Queensland Palaeocene sediments (Harris 1965*b*, fig. 10).

Affinity. Unknown.

Distribution. A very rare species at Site 214.

Genus TRICOLPITES Cookson ex Couper, 1953

Type species. Tricolpites reticulatus Cookson, 1947 (subsequent designation by Couper 1953).

Remarks. It has been recommended by some authors (Srivastava 1966, 1972, 1975; Dettmann 1973) that the form-genus *Tricolpites* should be used only for dispersed grains having the characters displayed by the genotype, *T. reticulatus* Cookson, rather than being used as a broad catch-all type of category. This suggestion, which would mean the restriction of the taxon to cover only tricolpate grains with simple colpi and a uniform surface reticulum of mesh diameter not exceeding 1–2 μm, has much merit. We have, however, used it here in a broader sense, and have included within it types with psilate and spinose exine surfaces, chiefly because there are no alternative genera which could satisfactorily accommodate those types, and, as we are only using informal designations for the species involved, we were not prepared to erect new categories.

Tricolpites reticulatus Cookson, 1947

Plate 5, figs. 1, 2

Selected synonymy.

      1974   *Tricolpites* sp. cf. *T. reticulatus* Cookson; Kemp, p. 816, pl. 1, figs. 1–5.

      1974   *Tricolpites* sp. cf. *T. waiparensis* Couper; Harris, pl. 2, fig. 19; pl. 3, fig. 1.

Dimensions. Polar diameter 17–29 μm (five specimens); equatorial diameter 18 (23) 29 μm (twenty specimens).

Remarks. Scanning electron microscopy of grains recovered from both sites shows the lumina of the sexine reticulum to be uniform across the entire grain surface, and the mesh diameter to be 0·3–0·4 μm. Rare grains observed in this study show a slight thickening of the sexine adjacent to the colpus, but this feature is not consistently present. The specimens figured by Kemp (1974) were only placed in synonymy with *T. reticulatus* because of the difficulty of comparing this relatively well-preserved material (which was viewed both with the light microscope and the SEM) with the brief descriptions and illustrations of Cookson (1947). However, Dettmann (1974, pers. comm.) has re-examined material from the Kerguelen type locality at high magnification, and we were able to compare our material with Dettmann's unpublished photographs of topotype material, and confirm that the Ninetyeast Ridge specimens are indeed *T. reticulatus*.

Comparison. The species *T. waiparensis* Couper, 1960 and *T. microreticulatus* Belsky, Boltenhagen, and Potonié, 1965 are both morphologically very similar to *T. reticulatus*, and both were published without differential diagnoses. In *T. waiparensis*, the grain outline appears more deeply trilobate than *T. reticulatus*, and the reticulum may be coarser, but these distinctions are slight. For *T. microreticulatus*, the distinctions are even more obscure; the lumen diameter was described as 0·5 μm which is very close to that observed for *T. reticulatus* in this study. *T. medius* Sah, from the central African Neogene (Sah 1967, p. 63, pl. 5, fig. 6) is another species lacking clear distinction from *T. reticulatus*. *T. dubhensis* Srivastava, from the Maastrichtian of Mull (Srivastava 1975), is distinguishable from *T. reticulatus* by the irregular nature of the lumina.


EXPLANATION OF PLATE 5

Figs. 1, 2. *Tricolpites reticulatus* Cookson, 1947. 1, Sample 5274/6283, Site 254, CPC 15624, × 1250. 2, scanning electron micrograph, S2498, Site 214, × 2800.

Figs. 3, 4. *Tricolpites asperamarginis* McIntyre, 1968. Site 254. 3, Sample 5274/6283, CPC 15625, × 1250. 4, scanning electron micrograph, Sample 6283, × 1200.

Figs. 5–8. '*Tricolpites*' sp. 2. Site 214. 5, Slide ST2498/13, 12.4, 106.3 (GSSA Py 1015). Grain in polar aspect, colpi indistinct, × 1250. 6, Nomarski interference contrast; Slide S2498/4, 11.1, 99.6. Grain in polar aspect, colpi distinct, × 750. 7, 8, scanning electron micrographs, Sample S2498. 7, × 11 000; 8, × 2800.

Figs. 9–15. *Tricolpites discus* Harris sp. nov. Site 214. 9, Slide S2492/1, 38.9, 106.2. Polar aspect, median focus, × 1250. 10, 11, Slide ST2498/4, 17.5, 106.2. High and median foci, grain in equatorial view, × 1250. 12, Slide S2498/17, 13.9, 108.7. Grain in equatorial view, median focus, × 1250. 13, 14, holotype, Slide ST2498/6, 12.2, 105.0 (GSSA Py 1012). Grain in polar view, high and median foci, × 1250. 15, scanning electron micrograph, Sample S2498, × 2500.
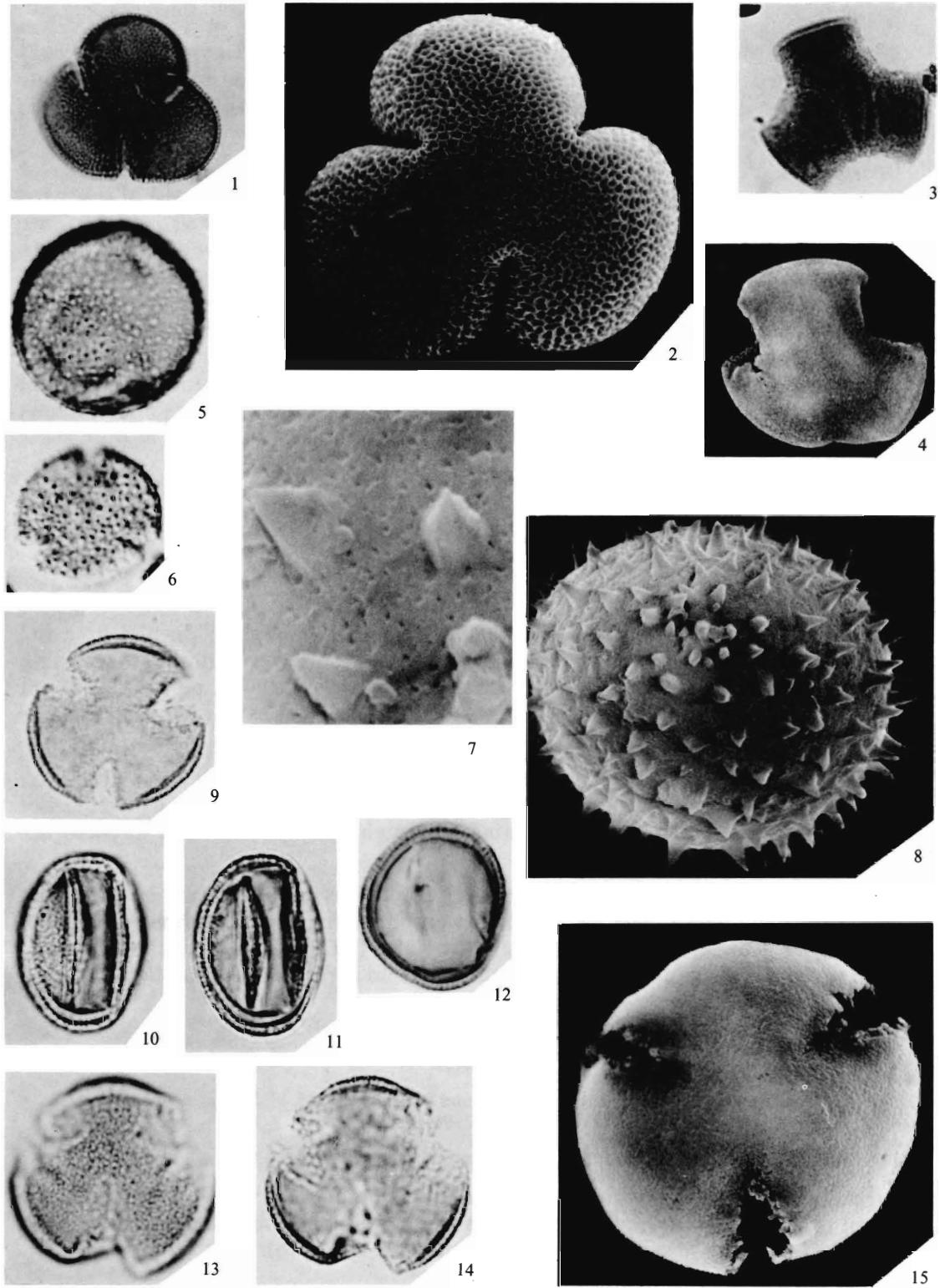
KEMP and HARRIS, *Tricolpites*

Affinity. The similarity of *T. reticulatus* to pollen of extant *Gunnera* (Gunneraceae) was confirmed by Cookson and Pike (1954*b*). The resemblance is further demonstrated in the illustrations of Chilean species of *Gunnera* shown by Heusser (1971, pl. 30, figs. 361–363).

Distribution. *T. reticulatus* was described originally from the middle Miocene of Kerguelen (Cookson 1947); it has since been identified from the Eocene of southern South America (Archangelsky 1973) and Antarctica (Cranwell 1969), and the Late Cretaceous of western Canada (Jarzen and Norris 1975). *Tricolpites* sp. I of Fasola (1969, pl. 7, figs. 13–15) may also be conspecific. *T. waiparensis* was described from the Late Cretaceous of New Zealand (Couper 1960), and has been recorded from Australia (Stover and Evans 1973). *T. microreticulatus* had its origin in the Senonian of West Africa (Belsky, Boltenhagen, and Potonié 1965), and has since been recorded from the Late Cretaceous of Wyoming (Leffingwell 1970), Montana (Norton and Hall 1967), and Canada (Srivastava 1969). On the Ninetyeast Ridge, *T. reticulatus* occurs in all samples, reaching relative abundance figures of 3 per cent at both sites.

Tricolpites asperamarginis McIntyre, 1968

Plate 5, figs. 3, 4

1968   *Tricolpites asperamarginis* McIntyre, p. 186, figs. 20–22.

Dimensions. Equatorial diameter 18 (23) 28 μm (ten specimens).

Remarks. *T. asperamarginis* is distinguished by widely gaping colpi, and by exine patterns that appear scabrate under optical microscopy, finely granulose with scanning electron microscopy. The exine stratification is obscure; the exine is 0·8–1·0 μm thick over all, thinning to a ragged colpus margin. To what extent the nature of the colpus margin is a preservational artifact is uncertain.

Affinity. Uncertain: exine patterns in members of the Violaceae show some similarity. Pollen in this family, however, is dominantly tricolporate, a condition which has not been recognized in the dispersed grains, although apertural features in these are difficult to discern.

Distribution. Palaeocene of New Zealand (McIntyre 1968). Forms with smaller apocolpia and slightly coarser sculpture were identified as *T. asperamarginis* from the Oligocene to Miocene of Queensland by Hekel (1972). On the Ninetyeast Ridge, it occurs as a rare component of assemblages from cores 28 and 29 at Site 254.

Tricolpites phillipsii Stover, 1973

Plate 6, fig. 16

1973   *Tricolpites phillipsii* Stover, in Stover and Partridge, p. 255, pl. 17, figs. 6, 7.
1974   *Tricolpites phillipsii* Stover; Harris, p. 506, pl. 3, fig. 2.

Dimensions. Equatorial diameter 22 (32) 38 μm (twenty specimens).

Remarks. The general form and sculpture of the exine agree closely with the Australian forms of the species. Scanning electron photomicrography shows the ornament to be more or less evenly distributed small granules (Pl. 6, fig. 16).

Affinity. Unknown.

Distribution. A common species in most samples from Site 214. Relative frequency up to 12 per cent.

Tricolpites discus Harris sp. nov.

Plate 5, figs. 9–15

1974   *Tricolpites* sp. 1, Harris, p. 513, pl. 2, figs. 17, 18.
1974   *Tricolpites* sp. 2, Harris, p. 515, pl. 3, fig. 3.

Diagnosis. Pollen grains free, tricolpate, prolate to oblate, isopolar. Amb circular, slightly trilobate, fossaperturate. Outline in equatorial aspect oval. Colpi three-quarters of polar diameter in length. In polar aspect these are seen to have characteristic torn margins, with both nexine and sexine splitting to form the aperture. The ragged appearance derives from the overhang of elements of the tectum into the colpus gape. Exine clearly stratified, tectate; sexine about as thick as nexine and both tapering rapidly toward colpi margins. Exine *c.* 2·5 μm thick and not thickening in polar areas. Exine structure tectate-perforate, appearing finely reticulate in surface view (Pl. 5, fig. 15) with uniform size lumina about 1 μm in diameter, separated by slightly wider muri.

Dimensions. Equatorial diameter 17 (19) 22 μm; polar diameter 16 (21) 25 μm (twenty specimens).

Holotype. Plate 5, figs. 13, 14. Slide ST2498/6, 12.2, 105.0 (GSSA Py 1012). Grain in polar aspect. Equatorial diameter 23 μm. Colpi distinct. Exine 2·5 μm thick.

Type locality. Site 214, Indian Ocean, 11° 20.2′ S., 88° 43.1′ E. Core 43, core catcher sample, 402 m sub-bottom. Palaeocene.

Remarks. This species displays a wide variation in shape and size but examination of a large number of specimens indicates that there are no grounds for separating either extremes of shape or size. The exine stratification, the ornament and the aperture style remain constant. The shape of the grain in polar aspect and the tectate-perforate nature of the sexine are distinctive.

Affinity. Unknown.

Distribution. A very common species occurring at Site 214, with a frequency in one sample of 55 per cent.

Tricolpites sp. 1

Plate 6, figs. 1, 2

1974   *Tricolpites* sp. 3, Harris, p. 513, pl. 2, fig. 16.

Description. Pollen grains free, tricolpate, oblate to spheroidal in shape; amb circular, slightly trilobate; equatorial view sub-circular. Colpi half to two-thirds polar diameter in length, with a definite, but unthickened margin. Exine 2 μm thick, obscurely stratified. Sexine psilate under light microscopy.

Dimensions. Equatorial diameter 17 (25) 32 μm (fifteen specimens).

Remarks. Detailed surface data at high magnification for this species is presently unavailable, so an informal designation has been retained. It differs from the oblate *T. gillii* Cookson, 1957 in having a circular amb. *T. asperamarginis* McIntyre has wider, thin-margined colpi and a distinctly scabtate exine surface.

Affinity. Unknown.

Occurrence. Occurs infrequently in most samples from Site 214.

'Tricolpites' sp. 2

Plate 5, figs. 5–8

1974   *Tricolporites* sp. 1, Harris, p. 515, pl. 3, fig. 8.

Description. Pollen grains free, tricolpate, oblate; isopolar with circular amb. The colpi are indistinct, about one-third of the polar diameter in length, and in most cases are more or less closed. Under the light microscope, the exine stratification is obscure. Exine *c.* 1·5 μm thick, ornamented with rather regularly distributed cone-shaped spinae about 1·5 μm high. Scanning electron microscopy (Pl. 5, fig. 7) shows that the spines sit atop what is probably a perforate tectum, in which the punctae are about 0·5 μm in diameter.

Dimensions. Equatorial diameter 20 (23) 25 μm (ten specimens).

Remarks. Tricolpate species with a spinose ornament conform to the form-genus *Echitricolpites*, which was proposed by van der Hammen (1956); this category, however, is invalid, so the species described here is assigned loosely to *Tricolpites*. This distinctive Ninetyeast Ridge form does not compare with any previously described form-species, as far as can be determined, but it has not been formally designated as a new taxon because the morphology of the colpi, and the exine stratification remain obscure.

Affinity. Unknown.

Distribution. At Site 214, 'Tricolpites' sp. 2 occurs in most samples with a frequency up to 3 per cent.

Genus TUBULIFLORIDITES Cookson, 1947 ex Potonié, 1960

Type species. Tubulifloridites antipodica Cookson, 1947 (subsequent designation by Potonié 1960).

Remarks. Tubulifloridites is used herein as a broadly circumscribed form-genus, in the sense in which it was originally defined by Cookson as a sporomorph taxon, and subsequently validated by Potonié. Although Cookson was confident that the Kerguelen material bore close affinities to the Tubuliflorae, she was unable to identify pores within the fossil grains, nor did she describe the complexity of exine stratification present in modern representatives of the group. *Compositoipollenites* Potonié 1951 suffers from a comparable vagueness of definition; in this case it is the presence of colpi that is in doubt. Until re-examination and redescription of material from Cookson's type locality has been made, the relationship between these two form genera remains problematical. More recently, grains of the Tubuliflorae type have

been assigned to *Echitricolporites* van der Hammen which Germeraad *et al.* (1968) attempted to validate by selecting a fossil lectogenotype in place of the extant species designated by van der Hammen; we consider, however, that the validity of the form-genus remains doubtful.

<div align="center">

Tubulifloridites sp. cf. *T. antipodica* Cookson, 1947

Plate 6, figs. 3, 4

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cf. 1947   *Tricolpites (Tubulifloridites) antipodica* Cookson, p. 134, pl. 15, fig. 44.
cf. 1960   *Tubulifloridites antipodica* Cookson; Potonié, p. 106.

Remarks. The rare specimens observed in this study appear to be better preserved than the Kerguelen types. The exine stratification is distinct, and elongated columellae are present at the spine bases. No pores were seen, but the few specimens observed were poorly orientated and partly obscured.

Dimensions. Equatorial diameter 18–23 μm (three specimens).

Affinity. Compositae: Tubuliflorae group.

Distribution. This record, from sediments underlying those dated as Oligocene at Site 254, is of particular interest, as occurrences of Compositae type grains are rare before the Miocene. From tropical areas, Germeraad *et al.* (1968) noted that the Tubuliflorae type of grain was the earliest Composite to appear, but that it had not been recorded from the pre-Miocene. From Australia, the earliest records of *T. antipodica* are in the *Triporopollenites bellus* Zone of the Gippsland Basin, which is now regarded as middle Miocene (Partridge, pers. comm. 1975). It has also been identified in the Pliocene (Martin 1973*a*). The Kerguelen type material seems likely, on radiometric evidence, to be middle Miocene (Nougier 1970).

<div align="center">

?*Tubulifloridites* sp.

Plate 6, figs. 5, 6

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Description. Pollen grains free, isopolar, tricolporate. Oblate, sub-circular to slightly trilobate, fossaperturate in polar view. Elliptical to sub-circular in equatorial aspect. Colpi clearly defined, length about three-quarters of polar diameter. Ora indistinct. Exine stratification indistinct, but with a clear thickening about the ora. Sexine 1·5 μm thick, ornamented by evenly distributed spinulae about 1 μm high.

Dimensions. Equatorial diameter 14 (17) 19 μm (seven specimens).

Remarks. *T. antipodica* is larger and has a coarser ornament; it also has ora which are even less distinct. Too few specimens were recovered for formal description of this form.

Affinity. This type of pollen grain is suggestive of Compositae.

Distribution. A rare species at Site 214 below the marine units.

Genus RHOIPITES Wodehouse, 1933

Type species. Rhoipites bradleyi Wodehouse, 1933.

Remarks. On the basis of definitions given by original authors, and by reference to illustrations of type species (designated by monotypy in each case), there appears to be little difference between the form genera *Rhoipites* Wodehouse and *Tricolporites* Cookson. The former name has priority, although *Tricolporites* has been widely used, especially by southern hemisphere workers, for tricolporate pollen with a reticulate exine pattern; the emended diagnosis given by Stover and Partridge (1973) extends *Tricolporites* to include non-reticulate tricolporate grains, which probably limits the usefulness of the category. Other genera, e.g. *Rhooidites* Potonié, Thomson, and Thiergart, *Rhooipollenites* Potonié, and *Tricolporopollenites* Pflug and Thomson, are accepted as synonyms of *Rhoipites* (Potonié 1960). Hekel (1972) emended *Retitricolporites* van der Hammen to include tricolporate, reticulate forms in which the lumina of the reticulum show a progressive decrease in size towards the colpi. The validity of this genus is, however, subject to the same reservations as those expressed by Srivastava (1966 and later) and Dettmann (1973) for *Retitricolpites*.

Rhoipites grandis Kemp sp. nov.

Plate 6, figs. 18–21

1974 *Rhoipites* sp. 2, Kemp, p. 817, pl. 1, figs. 21, 22, 27–30.

Diagnosis. Pollen grains tricolporate, free, prolate, oval in equatorial view. Colpi distinct, extending almost to poles, widest equatorially, tapering to poles. Ora clearly

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EXPLANATION OF PLATE 6

Figs. 1, 2. *Tricolpites* sp. 1. Harris sp. nov. Site 214. 1, Slide ST2498/12, 12.0, 104.6 (GSSA Py 1017). Grain in polar aspect, ×1250. 2, Slide ST2493/17, 36.6, 94.4. Polar aspect, ×750.

Figs. 3, 4. *Tubulifloridites* cf. *T. antipodica* Cookson. CPC 16521, Slide GJ274/2, 99.2, 26.3. 3, median focus showing wall in section. 4, high focus on spines (sexine partially detached).

Figs. 5, 6. ? *Tubulifloridites* sp. Site 214. 5, Slide ST2498/16, 12.1, 108.4 (GSSA Py 1013). Grain in polar aspect, apertures distinct, ×1250. 6, Slide ST2498/4, 8.7, 96.1. Polar aspect, median focus, ×1250.

Figs. 7–9, 17. *Rhoipites isoreticulatus* Kemp sp. nov. Site 254. 7, CPC 15628, Slide 6283/1, 101.1, 32.6. Equatorial aspect, median focus, ×1250. 8, 9, holotype, CPC 15629, Slide 6283/5, 91.8, 38.9. Nomarski interference contrast, ×1250. 10, median focus on apertures. 9, high focus on colpus membrane. 17, scanning electron micrograph, Sample 6283, grain in polar aspect, colpus membranes distinct, ×2500.

Figs. 10–13. *Rhoipites microluminus* Kemp sp. nov. Site 254. 10, Slide CPC 15626, Slide 6283/5, 97.7, 36.4. Equatorial aspect, ×1250. 11, 12, holotype, CPC 15627, Slide 6283/5, 106.0, 42.7. Equatorial aspect, median focus and high focus on colpus, ×1250. 13, scanning electron micrograph, Sample 6283, ×1500.

Figs. 14, 15. *Nyssapollenites* cf. *N. endobalteus* McIntyre comb. nov. Site 254. 14, CPC 15630, Slide 6283/6, 41.5, 108.5. Nomarski interference contrast. Grain in equatorial aspect, ×1250. 15, CPC 15631, Slide 6283/5, 95.2, 36.9, ×1250.

Fig. 16. *Tricolpites phillipsi* Stover, 1973, Site 214, Sample S2498, scanning electron micrograph, grain in polar compression, ×2000.

Figs. 18–21. *Rhoipites grandis* Kemp sp. nov. Site 254. 19, 20, holotype, CPC 15632, Slide 6283/6, 45.4, 100.7. 19, median focus. 20, high focus (Nomarski interference contrast), ×1250. 18, 21, scanning electron micrographs, Sample 6283. 18, detail of pore, ×3250. 21, ×1100.
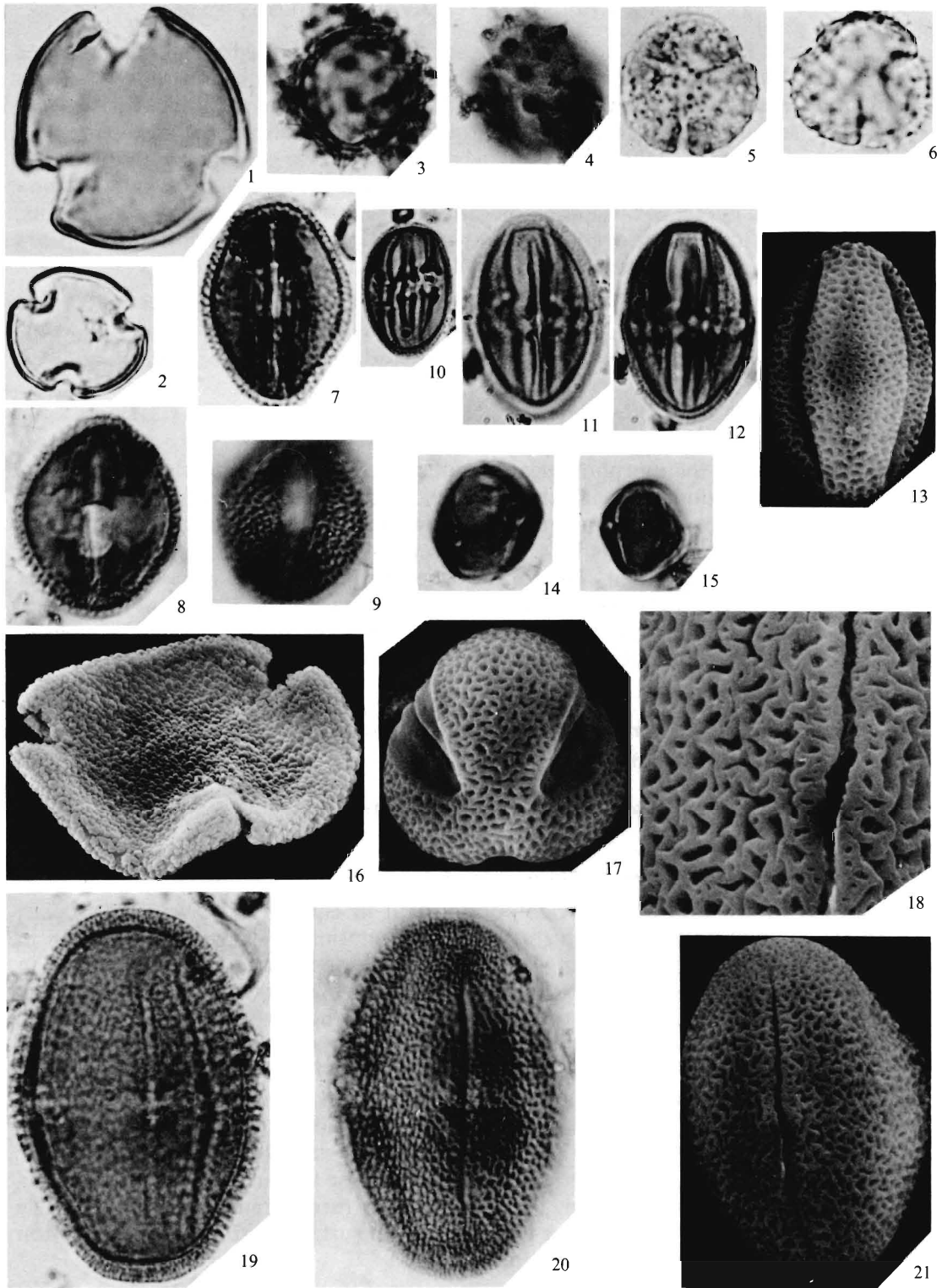
KEMP and HARRIS, Indian Ocean Tertiary spores

visible (except in collapsed, contracted grains), lalongate, bounded on polar margins by nexine thickenings defining an aperture 1·5–3·0 μm in polar diameter, 5–7 μm long in its equatorial extension. Exine stratification distinct at magnifications as low as ×250; sexine 2–3 μm thick, slightly thicker at poles than equator; nexine 0·5–0·8 μm thick, except for thickenings adjacent to ora. Sexine columellate, semitectate, with baculate heads fusing to form a reticulum of irregularly shaped polygonal lumina 2·5–3·0 μm in diameter near the equator, diminishing gradually in size in polar regions. No decrease in lumina size occurs adjacent to the colpi. Nexine flooring colpi appears finely granulate at high (greater than ×2000) magnifications.

Dimensions. Polar diameter 30 (41) 49 μm; equatorial diameter 15 (26) 35 μm (forty specimens).

Holotype. Plate 6, figs. 19, 20. Slide 6283/6; 45.3, 100.7 (CPC 15632). Grain in equatorial aspect. Polar diameter 48 μm, equatorial diameter 35 μm. Sexine approximately 2·0 μm thick at equator, 3·0 μm thick at poles; nexine 0·5 μm thick.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Core 29, section 1 at 128–130 cm, 258 m sub-bottom. ?Oligocene.

Remarks. Most of the morphological features listed above are clearly visible at the magnifications obtainable with the light microscope. All specimens observed in strew mounts are orientated in equatorial view, reflecting the strongly prolate grain shape. No comparable forms have been described from the Tertiary of Australia, New Zealand, or Kerguelen. The form-species *Retitricolporites guianensis* Van der Hammen and Wymstra, 1964 (figured also by Germeraad *et al.* 1968, pl. 17, figs. 8, 9) has a reticulate exine and comparable lalongate ora, but differs from *R. grandis* in showing a distinct diminution of lumina diameter towards the colpi.

Affinity. Unknown.

Distribution. Site 254, common. Present in all samples; has a relative abundance of 19 per cent in the type sample.

<div align="center">

Rhoipites isoreticulatus **Kemp** sp. nov.

Plate 6, figs. 7–9, 17

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1974   *Tricolpites* sp. Kemp, p. 816, pl. 1, figs. 6–8.

Diagnosis. Pollen grains free, tricolporate, oval in equatorial view; sub-circular, fossaperturate in polar view, which is a rare orientation in strew mounts. Colpi in excess of three-quarters grain length, broadest equatorially and tapering to poles in expanded specimens; collapsed grains show a narrowing equatorially, in the vicinity of the pore. Within each colpus the apertural suture is bordered by a zone of smooth exine, 4–5 μm wide at the equator and tapering towards the poles, suggestive of a colpus membrane. Ora relatively large, with margins forming an incomplete circle approximately one-third of colpus length in diameter. Exine columellate, semitectate; stratification distinct at magnifications of approximately ×250; sexine approximately twice as thick as nexine (1·5–2·0 μm to 0·5–1·0 μm). Distal ends of columellae unite to form the muri of the reticulum, which enclose irregularly polygonal, sometimes narrow and sinuous lumina, of diameter only rarely greater than 1·5 μm. The reticulum is constant in form over the entire grain surface, without any diminution of lumina size near the equator or poles.

Dimensions. Polar diameter 21 (27) 32 μm; equatorial diameter 16 (21) 26 μm (thirty specimens).

Holotype. Plate 6, figs. 8, 9. Slide 6283/5; 91.8, 38.9 (CPC 15629). Grain in equatorial aspect, expanded to show colpus membrane. Pores distinct, 6 μm diameter in polar measurement. Polar diameter 26 μm, equatorial 22 μm, exine 2 μm thick.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Core 29, section 1 at 128–130 cm, 258 m sub-bottom. ?Oligocene.

Remarks. The preservation of what may be a colpus membrane in this species is noteworthy, as this is a feature which is rarely recorded in fossil form. It was evident only in expanded grains, which were about half of those observed in this study; in collapsed grains (cf. those recorded by Kemp (1974, pl. 1, figs. 6–8) as *Tricolpites* sp.) the colpus margins tend to come into contact near the equator, leaving the extremities gaping. Scanning electron microscopy (Pl. 6, fig. 17) suggests that the surface of the smooth colpus zone is continuous with the sexinal reticulum, and that it is in fact part of the sexine. *R. cryptoporus* Srivastava from the Palaeocene of Alabama and Texas (Srivastava 1972, p. 270, pls. 21, 22) shows a basic similarity of form to *R. isoreticulatus*, but differs in its colpus features and shows reduction in reticulum mesh size towards the colpi.

Affinity. The dispersed grains show some resemblance to those of *Avicennia* (Verbeniaceae; see illustrations in Muller (1964, pl. 1, fig. 2) and van der Hammen (1963, pl. 6, figs. 1, 2)), which display a clear colpus membrane, although this is rarely preserved in fossil grains. Grains of *Avicennia* do, however, show a reduction in reticulum mesh size near the colpi.

Distribution. Common at Site 254; present in all samples, reaching a relative abundance in excess of 22 per cent in core 29.

Rhoipites microluminus Kemp sp. nov.

Plate 6, figs. 10–13

1974   *Rhoipites* sp. 1, Kemp, p. 817, pl. 1, figs. 16–18.

Diagnosis. Pollen grains free, tricolporate, prolate, elliptical to sub-circular in equatorial aspect. Polar views not recorded. Colpi extend nearly full length of grain, taper towards poles, expand at equator. Colpus formed in both nexine and sexine, bounded internally by thickenings of the nexine which increase in width from poles to equator, where they reach c. 1 μm wide. At the equator the thickenings are deflected transversely for 1–2 μm, to form well-defined polar margins for the ora. Ora 2–3 μm in diameter. Exine distinctly stratified, columellate, with the sexine slightly thicker than the nexine (1·0–1·5 μm to 0·5–0·8 μm), except in the colpi regions, where the nexine is the thicker layer. Sexine shows a slight increase in thickness near the poles. Columellae of the sexine unite distally to form a reticulum in which the shape of the lumina varies from trapezoidal to elongately sinuous; average lumina diameter c. 0·4–0·5 μm, with no size modification adjacent to the colpi or in the polar regions.

Dimensions. Polar diameter 13 (19) 25 μm; equatorial diameter 9 (14) 20 μm (thirty specimens).

Holotype. Plate 6, figs. 11, 12. Slide 6283/5; 106.0, 42.7 (CPC 15627). Specimen in equatorial aspect. Polar diameter 25 μm, equatorial diameter 17 μm. Ora 2·0–2·5 μm in diameter, exine finely reticulate.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Core 29, section 1 at 128–130 cm, 258 m sub-bottom. ?Oligocene.

Remarks. *R. microluminus* is distinguished by its fine, uniform surface reticulum and by the distinctive nexine thickenings adjacent to the ora. The strongly prolate grain shape meant that polar orientations were not recorded. Comparisons show that *Tricolporites microreticulatus* Harris, 1965 shows some similarity, but is much larger, has a coarser reticulum and more pronounced exinal thickening at the poles. The Ninetyeast Ridge form differs also from *Tricolporopollenites ivanhoensis* Martin, 1973 in possessing a more abrupt thickening about the ora.

Affinity. The basic pollen type is known from several dicotyledonous families, including, among others, Rutaceae, Umbelliferae, Euphorbiaceae, and Flacourtiaceae.

Distribution. Common in all Site 254 samples, ranging from 3 to 6 per cent.

Genus SIMPSONIPOLLIS S. K. Srivastava, 1975

Type species. *Simpsonipollis mullensis* (Simpson) S. K. Srivastava, 1975.

Remarks. Dispersed tricolporate pollen species in which the sexine is one of a pattern of ridges aligned approximately parallel to the polar axis have been accommodated in the past within the broadly circumscribed form genus *Tricolporites* Cookson, and within *Striatricolporites* (van der Hammen), among other genera. Srivastava (1975) argued that *Striatricolporites*, which on its initial erection by van der Hammen (1956), was typified by pollen of the extant *Tapirira guianensis* Abul., was invalid according to Article 7 of the botanical code, and has remained so in spite of the attempt by Leidelmeyer (1966) to validate it by naming the fossil *S. pimulus* as lectogenotype. Srivastava's arguments are accepted here, and the Ninetyeast Ridge forms with a 'striate' sexine pattern are referred to his new genus *Simpsonipollis*. This assignation is made with some reservation, however, as Srivastava, in his diagnosis, mentions a 'reticulate sculpture', with respect to the organization of the sexinal ridges, and it is arguable that the meridional arrangement of ridges in the Ninetyeast Ridge forms (or, indeed, in the type, *S. mullensis*) should be so described.

Simpsonipollis mulleri Kemp sp. nov.

Plate 7, figs. 3–6, 13

1974   *Striatricolporites* sp. Kemp, p. 817, pl. 1, figs. 9–13.

Diagnosis. Tricolporate pollen, free, isopolar, sub-prolate to prolate-spheroidal in shape; outline oval to sub-circular in equatorial view, and circular, trilobate, fossaperturate in polar view. Colpi approximately two-thirds of polar diameter in length, rarely longer. Ora conspicuous only in expanded specimens, well developed in the nexine, elliptical in shape with slight elongation in the plane of the equator. Polar diameter of pores 2·5–3·0 μm; equatorial 4·0–5·0 μm. Remainder of colpus is floored with slightly granular nexine (Pl. 7, fig. 13). Exine stratification obscure. Sexine pattern consists of fine ridges of irregular width and height, aligned parallel to the polar axis in a general way, but sometimes intersecting the colpus margins obliquely. The ridges

branch irregularly, and sometimes assume curved shapes in the polar regions. Ridges 0·5–1·0 μm wide, 0·5–0·8 μm in height. High magnifications (not less than ×2000) show the presence of small foveolae penetrating the sexine between the ridges.

Dimensions. Polar diameter 14 (17) 22 μm (eight specimens); equatorial diameter 10 (20) 21 μm (twenty specimens).

Holotype. Plate 7, fig. 3. Slide 6283/1; 111.0, 46.0 (CPC 15633). Grain in slightly oblique equatorial aspect. Polar diameter 22 μm; equatorial diameter 21 μm. Pore distinct, 3·5 μm in polar diameter, 4·0 μm equatorially. Exine 2·0 μm thick.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Sample 6283. Core 29 at 128–130 cm, 258 m sub-bottom. ?Oligocene.

Remarks. The exine structure suggested by the appearance of foveolae between the ridges at high magnification is columellar, with the conspicuous parallel ridges being developed atop a perforate tectum (Pl. 7, fig. 13). Grains observed under the light microscope vary in the definition of the ora; only in expanded grains are these prominent. *Simpsonipollis mulleri* differs from the Maastrichtian *S. mullensis* in its more spherical shape, and in the less regular, more widely spaced disposition of the sexine ridges. Striate, tricolporate pollen has been recorded from a number of Early Tertiary localities in Australasia and the modern tropics (Couper 1960; McIntyre 1968; Martin 1973*b*; Stover and Partridge 1973; Leidelmeyer 1966; Guzman 1967; Muller 1968). Some of these forms, for example *Tricolporites pseudostriatus* McIntyre, 1968 and *T. substriatus* Martin, 1973*b* are in fact pseudostriate, not displaying distinct sexine ridges at all, but deriving their pattern from the alignment of lumina or of distinct clavae. The Ninetyeast Ridge species differs from all of these published species in its combination of near-sphaeroidal shape, distinct, apparently solid ridges on the tectum, and the slight equatorial extension of the ora.

Affinity. Muller (1968) remarked on the difficulty of recognizing the relationship of tricolporate pollens with a striate exine pattern, as these occur in several modern families, including Leguminosae, Anacardiaceae, Sapindaceae, Cucurbitaceae, and Nolanaceae (cf. *Nolana*).

Distribution. Site 254; present as a rare (0·5–1·0 per cent) component in four samples.

Genus NYSSAPOLLENITES Thiergart, 1937

Type species. Nyssapollenites (al. *Pollenites*) *pseudocruciatus* (Potonié) Thiergart, 1937.

Remarks. Nyssapollenites was erected from German Eocene material to accommodate tricolporate pollen of suboblate shape, with an 'infrapunctate' exine. Singh (1971) used it for Late Cretaceous pollens in which the exine had a faintly roughened, or scarbrate appearance, and Dettmann (1973) applied it to Cenomanian and Turonian forms which appeared scabrate under the light microscope and covered with low, irregular elevations at high magnifications. These usages indicate that the original diagnosis of 'infrapunctate' must of necessity be interpreted to cover a wide range of exine morphology, the more so as high magnification studies clarify exine structure. The name is used here purely as a form genus, without implications of affinity.

Nyssapollenites sp. cf. *N. endobalteus* McIntyre comb. nov.

Plate 6, figs. 14, 15

cf. 1965   *Tricolporopollenites endobalteus* McIntyre, p. 211, figs. 27–29.

Remarks. T. endobalteus was erected to include small, near-spherical, tricolporate pollens with a relatively thick scabrate exine and lalongate ora. The forms identified from the Ninetyeast Ridge are not conspecific as they are slightly more prolate and have ora which are less elongated equatorially. The species *Dodonaea spherica* Martin (1973*b*, p. 18, figs. 72–74) is similar, but is less prominently thickened about the ora, and has a finely verrucate surface exine pattern.

Dimensions. Polar diameter 12 (19) 21 μm; equatorial diameter 11 (15) 17 μm (twelve specimens).

Affinity. Martin (1974) examined the New Zealand type material of the fossil species *T. endobalteus* and equated it with pollen of the living euphorbiaceous genera *Macaranga* and *Mallotus*. From the general similarity to *Dodonaea* species, however, relationship with Sapindaceae is also possible.

Distribution. Common in most samples from Site 254, with maximum relative abundance reaching 6 per cent.

Nyssapollenites deminutus Harris sp. nov.

Plate 7, figs. 1, 2

1974   *Tricolporites prolata* Cookson; Harris, p. 515, pl. 3, figs. 9, 10.

Diagnosis. Pollen grains free, isopolar with prolate elliptical amb in equatorial aspect. Colpi two-thirds of polar diameter in length. Ora conspicuous and well developed in

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EXPLANATION OF PLATE 7

Figs. 1, 2. *Nyssapollenites deminutus* Harris sp. nov. Site 214.   1, holotype, Slide ST2498/3, 0·5, 107·4 (GSSA Py 1014). Equatorial aspect, × 1250.   2, scanning electron micrograph, Sample S2498, grain in polar view, × 5000.

Figs. 3–6, 13. *Simpsonipollis mulleri* Kemp sp. nov. Site 254.   3, holotype, CPC 15633, Slide 6283/1, 111.0, 46.0. Nomarski interference contrast, grain in equatorial aspect, pore distinct, × 1250.   4, 5, CPC 15634, Slide 6283/1, 45/5, 29.1. Polar aspect, × 1250.   4, median focus.   5, high focus, Nomarski interference contrast, showing striae across polar region. 6, scanning electron micrograph, Sample 6283, grain in polar aspect, × 2500.   13, scanning electron micrograph, Sample 6283. Focus on aperture, with pore and finely granular nexine, × 3250.

Fig. 7. *Sapotaceoidaepollenites rotundus* Harris, 1972. Site 254, CPC 15635, Slide 6283/5, 98.2, 34.0. Equatorial aspect, × 1250.

Figs. 8–10. *Concolpites* cf. *C. leptos* Partridge, 1973. Site 214.   8, 9, Slide ST2498/18, 11.7, 106.5 (GSSA Py 1016). Polar aspect, × 1250.   9, phase contrast. 10, Slide ST2498/4, 4.8, 112.4. Nomarski interference contrast, × 1250.

Figs. 11, 12. *Myrtaceidites* cf. *M. mesonesus* Cookson and Pike, 1954.   11, CPC 15636, gold-coated specimen, Sample 6283, × 1250.   12, scanning electron micrograph of same specimen, polar aspect, × 2500.

Figs. 14–17. *Gothanipollis* cf. *G. gothani* Krutzsch, 1959. Site 254, CPC 15637.   14, Slide 6283/4, 104.5, 34.6. Polar aspect, × 1250.   15–17, scanning electron micrographs, Sample 6283.   15, polar view, × 1500. 16, detail of specimen in fig. 15, showing smooth areas adjacent to colpus, granulose intercolpia, × 3500. 17, polar aspect, × 1500.

Figs. 18–22. *Myrtaceidites oceanicus* Kemp sp. nov. Site 254.   18, CPC 15638, Slide 5274/2, 107.0, 31.1. Tetracolporate specimen, × 1250.   19, 20, CPC 15639, holotype, Slide 6283, separate mount, 102.0, 36.2, 19, median focus, vestibulum discernible at apertures. 20, high focus on sculpture, × 1250.   21, 22, scanning electron micrographs, specimens from Sample 6283, polar aspect, both at × 1600.
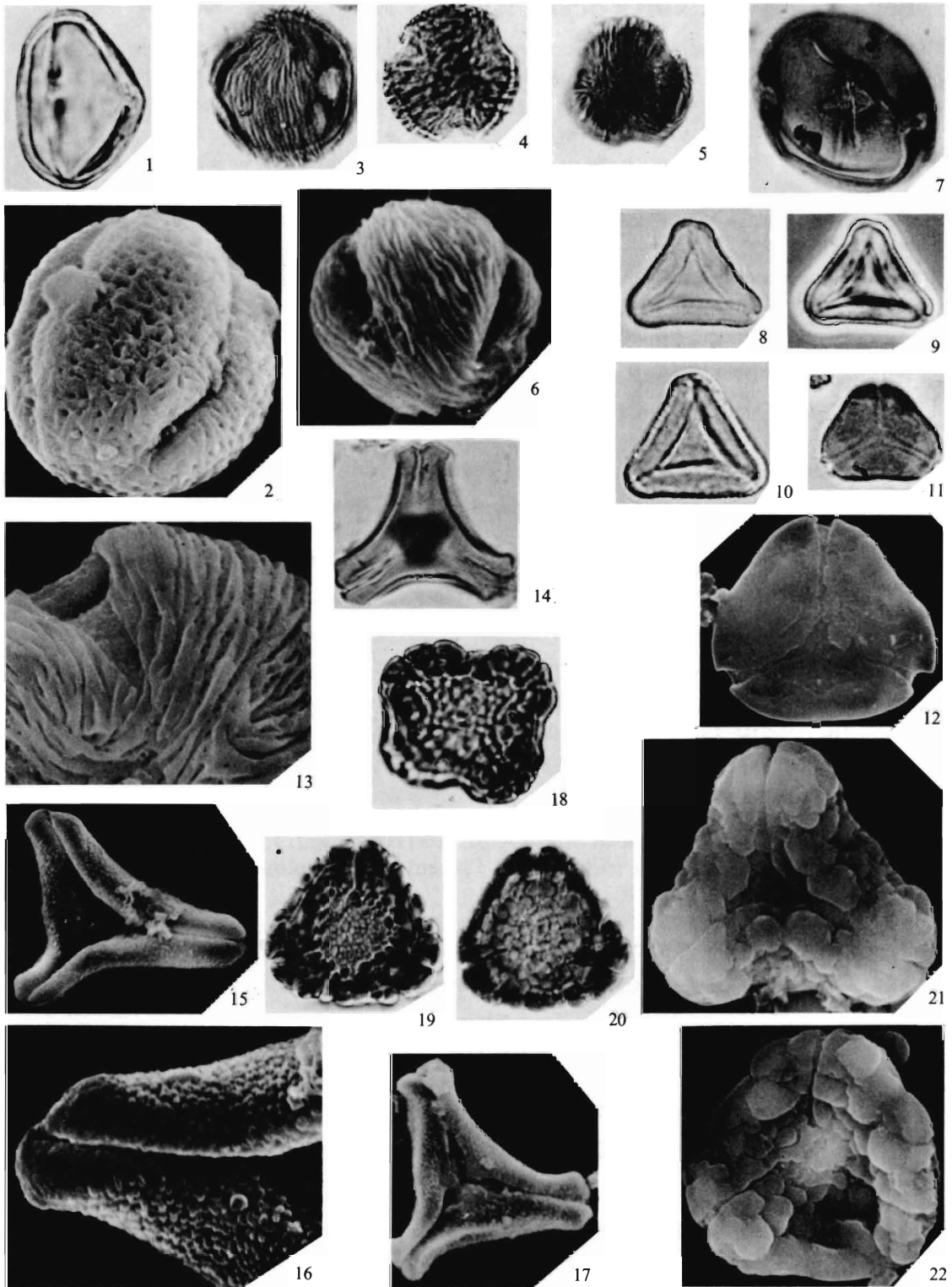
KEMP and HARRIS, Indian Ocean Tertiary spores

the nexine, 2 μm in diameter, circular in shape. Exine stratification obscure. Sexine tectate; the pattern is indistinct under the light microscope, but scanning electron microscopy shows it to be one of very fine, irregular, sometimes elongate punctae, which are less than 1 μm in diameter.

Holotype. Plate 7, fig. 1. Slide ST2498/3; 9.5, 107.4 (GSSA Py 1014). Grain in equatorial aspect. Polar diameter 22 μm; equatorial diameter 13 μm. Pore distinct, 2 μm in diameter. Exine 2 μm thick.

Type locality. Site 214, Indian Ocean, 11° 20.2' S., 88° 43.1' E. Core 43, core catcher sample, 402 m sub-bottom. Palaeocene.

Dimensions. Polar diameter 18 (23) 26 μm; equatorial diameter 11 (12) 15 μm (twenty specimens).

Remarks. This form is closely similar to *T. prolata* Cookson, but differs in having more prominent ora, punctate sexine, and a slightly smaller size.

Affinity. Unknown.

Distribution. Occurs in most samples from Site 214 with a frequency up to 16 per cent.

Genus SAPOTACEOIDAEPOLLENITES Potonié, Thomson, and Thiergart, 1950

Type species. Sapotaceoidaepollenites (al. *Pollenites*) *manifestus* (Potonié), 1931.

Sapotaceoidaepollenites rotundus Harris, 1972

Plate 7, fig. 7

1972 *Sapotaceoidaepollenites rotundus* Harris, p. 56, figs. 17, 18.

Dimensions. Polar diameter 21 (31) 44 μm; equatorial diameter 19 (26) 38 μm (eleven specimens).

Remarks. Specimens from Site 254 conform closely to *S. rotundus*, described originally from the middle Eocene of South Australia, although they extend the size range slightly.

Affinity. Possibly Sapotaceae.

Distribution. Middle Eocene of South Australia (Harris 1972); early Eocene–Miocene of Victoria (Stover and Partridge 1973). Present as a rare component in two samples from Site 254.

Genus MYRTACEIDITES Cookson and Pike, 1954 ex Potonié, 1960

Type species. Myrtaceidites mesonesus Cookson and Pike ex Potonié, 1960.

Myrtaceidites sp. cf. *M. mesonesus* Cookson and Pike, 1954

Plate 7, figs. 11, 12

Dimensions. Equatorial diameter 6 (10) 22 μm (100 specimens).

Remarks. Specimens from Site 254 have been compared to the Australian form species *M. mesonesus* as they show a distinctly scabrate exine pattern. The size range, however, is closer to that of *M. parvus* Cookson and Pike, 1954*b*. Scanning electron microscopy resolves the surface pattern into poorly defined, flattish, irregularly distributed grana. Under the light microscope, the Ninetyeast Ridge form appears

more conspicuously ornamented than *M. mesonesus*; the surface sculpture, however, is not as pronounced as that in *M. verrucosus* Partridge, 1973.

Affinity. Myrtaceae. Cookson and Pike (1954b) noted the similarity of the dispersed pollen *M. mesonesus* to that of certain species of *Eucalyptus*; *M.* cf. *mesonesus*, however, in possessing a more granulate exine shows more resemblance to members of the tribe Myrtinae—*Lophomyrtus* and *Rhodomyrtus*, for instance.

Distribution. Common at Site 254, reaching relative frequencies of 6 per cent.

Myrtaceidites oceanicus Kemp sp. nov.

Plate 7, figs. 18–22

1974   *Meyeripollis* sp. Kemp, p. 817, pl. 2, figs. 7–12.

Diagnosis. Pollen grains free, tricolporate, sometimes tetracolporate, isopolar, peroblate to oblate, syncolporate, angulaperturate. Amb triangular with rounded angles, sides straight to convex. In some specimens colpi bifurcate on polar surface and reunite to form a polar island 8–10 μm in diameter. Exine stratification obscure, except at the grain angles, where a small vestibulum may be formed by separation of sexine and nexine. Sexine thicker than nexine, especially adjacent to colpi. Sexine up to 4 μm thick at grain angles, decreasing in thickness interradially. Sexine surface elevated to form flattish verrucae; the largest of these are adjacent to the colpi and have a diameter of around 5 μm, and an elevation above their bases of 1·5–2·0 μm. The verrucae diminish markedly in size towards the poles, to diameters of 1–2 μm. In some grains there is a decrease in size away from the colpi margins at the equator; in others verrucae of similar size are distributed right around the equator.

Dimensions. Equatorial diameter 16 (19) 23 μm (thirty specimens); equatorial views not observed so no polar diameters were measured.

Holotype. Plate 7, figs. 19, 20. Sample 6283, separate mount, 102.0, 36.2 (CPC 15638). Grain in polar compression, equatorial diameter 23 μm, verrucae 4–5 μm in diameter at grain angles, diminishing to 1–2 μm at poles. Exine 3 μm thick adjacent to colpi, 1·5–2·0 μm interradially. No polar island.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Core 29, section 1 at 128–130 cm, 258 m sub-bottom.

Remarks and comparison. This form species, although distinctive, shows a considerable range of form; about 5 per cent of observed grains are tetracolporate (see Pl. 7, fig. 18); there is also variation in the degree of development of polar islands, and in the diameter and elevation of verrucae. The subsurface exine structure has not been determined.

The reference of these forms to *Meyeripollis* (by Kemp 1974) is revised here, as the original description of that genus (Baksi and Venkatachala 1970, p. 83) mentions 'broad prominent gemmae' at the grain angles. In the Ninetyeast Ridge species, the ornament is invariably one of verrucae; these are in some cases very prominent, particularly at the angles, but true gemmae, with constricted bases, have not been observed. Additionally, scanning electron microscopy of *Meyeripollis* specimens (Muller, pers. comm. 1975) has revealed a fine, striate microsculpture on the surface of the larger sculptural elements. No comparable sculpture is visible in *Myrtaceidites*

oceanicus. M. verrucosus Partridge, from the early Eocene through Miocene of the Gippsland Basin, has an exine pattern of smaller, more uniform size verrucae than those of *M. oceanicus.*

Distribution. Site 254 only, common, reaching a frequency of 5 per cent in core 29.

Genus CONCOLPITES Partridge, 1973

Type species. Concolpites leptos Partridge 1973, p. 256, pl. 18, fig. 1.

Concolpites sp. cf. *C. leptos* Partridge, 1973

Plate 7, figs. 8-10

1974   *Myrtaceidites* sp. Harris, p. 515, pl. 3, figs. 4, 5.

Description. Pollen grains free, tricolporate, syncolporate, isopolar, oblate. Amb triangular with rounded angles. Sides mostly straight, or slightly concave or convex. Colpi invariably bifurcate to form distinct polar islands, 4–6 μm in diameter. Pores indistinct, about 1 μm in diameter, without differential exine thickening. Exine *c.* 1 μm thick, without clear stratification. Ornament indistinct, but faintly granulate in the interradial regions.

Dimensions. Equatorial diameter 15 (18) 22 μm (ten specimens).

Remarks. This species closely resembles *C. leptos* but all specimens examined lack the large atria characteristic of that species and genus. A. Partridge has examined these specimens and is confident of this assignment.

Distribution. A rare species; up to 1·5 per cent of assemblages in samples from Site 214 below the marine units.

Genus CUPANIEIDITES Cookson and Pike, 1954 ex Krutzsch, 1959

Type species. Cupanieidites major Cookson and Pike, 1954 (subsequent designation by Krutzsch 1959).

Remarks. This history of the usage of the form-genera *Cupanieidites* and *Duplopollis* Krutzsch was recently outlined by Stover and Partridge (1973, p. 257). It should also be noted here that dispersed grains of comparable morphology continue to be assigned to the form-genus *Syncolporites* van der Hammen, which is probably invalid under the ICBN (see Potonié 1966, p. 171).

Cupanieidites orthoteichus Cookson and Pike, 1954

(Figured in Kemp 1974, pl. 2, fig. 1)

1954   *Cupanieidites orthoteichus* Cookson and Pike, p. 213, pl. 2, figs. 73–78.
1965   *Duplopollis orthoteichus* (Cookson and Pike); Krutzsch, p. 144.
1965   *Duplopollis orthoteichus* (Cookson and Pike) Krutzsch; Harris, p. 89, pl. 27, figs. 20, 21.
1973   *Duplopollis orthoteichus* (Cookson and Pike); Harris 1965; Martin, p. 19, fig. 77.
1973   *Cupanieidites major/orthoteichus* in Stover and Partridge, p. 257.
1974   *Cupanieidites orthoteichus* Cookson and Pike; Kemp, p. 817, pl. 2, fig. 1.

Dimensions. Equatorial diameter 15-24 μm (five specimens).

Affinity. Cookson and Pike fairly confidently places these forms within the tribe Cupanieae of the family Sapindaceae.

Distribution. Palaeocene to Pliocene in Australia (Harris 1965; Cookson and Pike 1954*b*; Martin 1973*a*; Stover and Partridge 1973; Hekel 1972) and New Zealand (Couper 1960). Closely similar forms, identified as *C. major* Cookson and Pike, 1954*b*, occur in the Late Cretaceous to Palaeocene in North America (Drugg 1967; Norton and Hall 1969). From Brazil, the species *Syncolporites triangularis*, described by Regali *et al.* (1974, p. 285, pl. 12, fig. 13), which has a Late Cretaceous range, appears very close to *C. orthoteichus*. Recorded from three samples at Site 254, reaching a relative abundance of 3 per cent in core 28.

Genus GOTHANIPOLLIS Krutzsch, 1959

Type species. Gothanipollis gothani Krutzsch, 1959.

Gothanipollis sp. cf. *G. gothani* Krutzsch, 1959

Plate 7, figs. 14–17

cf. 1959   *Gothanipollis gothani* Krutzsch, p. 237, pl. 47, figs. 564–569.

Dimensions. Equatorial diameter 13–17 μm (ten specimens).

Remarks. The pollen grains are syncolporate, with a finely granulate exine; at high magnifications (see Pl. 7, fig. 16) the ornamentation of the exine appears significantly coarser in the intercolpia, both in the equatorial and in the polar regions. The exine immediately adjacent to the colpi is almost smooth, as is that of the apical 'cushions'. The form resembles *G. gothani* subsp. *gothani* Krutzsch, from the middle Eocene of Germany, except that the apical cushion is less sharply delineated than in the European species. A closely similar form was referred to *G. gothani* in manuscript by Partridge (1971, p. 167, pl. 16, fig. 25); the other southern hemisphere species, *G. bassensis* Stover, 1973, from the Gippsland Basin, differs in shape and in the disposition of apical exine modifications.

Affinity. Elsik and Dilcher (1974) drew attention to the similarity of pollen of two genera of Loranthaceae, viz. *Gaiadendron* and *Phrygilanthus* to the dispersed form *Gothanipollis*. However, a close relationship to *Loranthus* is also possible; grains in *Loranthus elegans* are similar in shape and exine pattern to *G. gothani*.

Distribution. In Europe and the Gulf Coast of North America, *Gothanipollis* species first appear in the middle Eocene (the Lutetian in Europe); in Australia, the earliest records are likewise middle Eocene (Stover and Partridge 1973). From the Ninetyeast Ridge, the form occurs as a rare element at Site 254 only.

Genus HALORAGACIDITES Couper, 1953

Type species. Haloragacidites trioratus Couper, 1953.

Haloragacidites sp. cf. *H. harrisii* (Couper) Harris, 1971

Plate 8, figs. 17, 18

cf. 1971   *Haloragacidites harrisii* (Couper) Harris, in Mildenhall and Harris, 1971, p. 304, figs. 8–11.

Dimensions. Equatorial diameter 25–34 μm (six specimens).

Remarks. The exine stratification is clear in the grains examined, with a thicker, homogenous-looking tectum being distinguishable from a much thinner, granular, inner layer—which may be nexine—or may be an infratectal granular layer akin to those described by Doyle *et al.* (1975, fig. 1, p. 434). The tectum shows a distinct inwards thickening at the base of the pore protrusion (Pl. 8, fig. 17); the same specimen clearly shows reduction of the inner layer to irregular patches of granules in the aspid area. Under the light microscope, these grains agree closely with Couper's illustration of *H. harrisi* (Couper 1953, pl. 7, fig. 111) and with subsequent, better illustrated identifications of the form from Australia (Cookson and Pike 1954*b*; Harris 1965; Hekel 1972; Martin 1973*a*; Stover and Evans 1973) and New Zealand (Couper 1960). Scanning electron microscopy, however, reveals a surface ornament (Pl. 8, fig. 18), of regularly spaced, minute grana borne on or at the intersections of vaguely defined linear elevations. Observations of similar surface sculpture have been made on Eocene specimens from Western Australia (D. Hos, pers. comm.). The form cannot be firmly identified with *H. harrisii* until surface data at an equivalent magnification are available from the New Zealand type material.

Affinity. Most Australian accounts have equated similar dispersed forms with pollen of extant Casuarinaceae, although Cookson and Pike (1954) pointed to a close agreement with grains of *Canacomyrica* (Myricaceae). Martin (1973*a*) however, suggested that this affinity was not supported by the macrofossil records in Australia. Relationship to Haloragaceae, as originally suggested by Couper (1953) seems unlikely on morphological grounds; pollen in this family frequently has more than three apertures, and the exine adjacent to these shows pronounced thickening, as distinct from the aspidate condition. Dispersed forms from the Ninetyeast Ridge show closest resemblance to pollen in the division Cryptosomae of the Casuarinaceae; grain shape and pore protrusion are closest to members of this group (see Kershaw 1970). Identifications of *Casuarina* from northern hemisphere Tertiary sediments remain suspect; most are probably Betulaceae, although review of the problem is beyond the scope of this paper. Srivastava (1972) referred a number of form-species which had been previously described from North America and Britain to *Casuarinidites* Cookson and Pike, suggesting, according to the original definition of that form-genus, affinity with *Casuarina*. All of these forms, however, differ from the Ninetyeast Ridge forms, and probably from most extant *Casuarina* pollens, in the nature of the exine structure about the base of the pore protrusion.

Distribution. The Australian and New Zealand records suggest a total range for the species of Palaeocene to Recent. At Site 254, the species reached a relative abundance of 3 per cent in core 28; at Site 214 it was very rare.

<div align="center">

Genus PROTEACIDITES Cookson ex Couper, 1953

</div>

Type species. Proteacidites adenanthoides Cookson, 1950 (subsequent designation by Couper 1953).

<div align="center">

Proteacidites sp. cf. *P. symphonemoides* Cookson, 1950

Plate 8, fig. 19

</div>

cf. 1950 *Proteacidites symphonemoides* Cookson, p. 172, pl. 2, fig. 17.

Dimensions. Equatorial diameter 19 (23) 25 μm (seven specimens).

Remarks. The exine of the Ninetyeast Ridge form is thinner than in *P. symphonemoides*. *P. pseudomoides* Stover (see Stover and Partridge 1973, p. 266, pl. 25, fig. 3) has a comparably thin wall, but a much finer reticulum.

Affinity. Proteaceae.

Distribution. Site 254, in core 28 only, extremely rare.

Proteacidites sp.

Plate 8, fig. 20

Remarks. Only two specimens of *Proteacidites* sp. have been isolated from Site 214. The form is not specifically identified.

Genus ECHIPERIPORITES van der Hammen and Wymstra, 1964

Type species. Echiperiporites akanthos van der Hammen and Wymstra, 1964.

Echiperiporites rotundus Kemp sp. nov.

Plate 8, figs. 1–7

1974   *Malvacipollis* sp., in Kemp, p. 817, pl. 1, figs. 23–26.

Diagnosis. Pollen grains triporate, isopolar, radial, oblate-spheroidal to oblate. Amb sub-circular to rounded triangular with strongly convex sides. Definition of pores varies; in some specimens they are distinct, in others difficult to discern. Exine stratification distinct, even at $\times 250$ for some grains. Sexine *c.* 1·0 μm thick, slightly thicker than nexine. Nexine thins towards the pores. Sexine bears smooth spines, up to 1·0 μm in basal diameter, and 1·5–3·0 μm long. Spines may taper abruptly to form a conical projection, or may taper at their tips only, with the spine base being essentially cylindrical (see high magnification illustration, Pl. 8, fig. 7). Spines are uniformly distributed over entire surface of grain. Exine surface between spines bears minute, irregularly scattered grana.

Dimensions. Equatorial diameter 14 (16) 19 μm (thirty-five specimens measured). Polar orientations not recorded.

Holotype. Plate 8, figs. 1–3, Slide 6283/5; 104.1, 31.9 (CPC 15640). Grain in polar view, all three pores distinct. Equatorial diameter of grain 15 μm (exclusive of spines); pores 3–4 μm in diameter; exine 1·5 μm thick, spines averaging 1·5 μm long.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Core 29, section 1 at 128–130 cm, 258 m sub-bottom. ?Oligocene.

Remarks. Variation in this form species is expressed in the definition and in the form of the germinal apertures; rarely, the tricolporate condition is approached, with the development of short colpi—in some specimens, only one of the three apertures shows this feature, so that it may be an artifact, caused by splitting during compression. *E. rotundus* does not show close resemblance to any previously described Early Tertiary forms. It is distinguishable from forms assigned to *Echitriporites* van der Hammen ex van Hoeken-Klinkenberg on the basis of its rounded amb and more spheroidal shape.

Affinity. Pollen with some resemblance to *E. rotundus* occurs in certain general of Campanulaceae and Icacinaceae (i.e. *Iodes africana*), but interpretations of affinity remain speculative.

Distribution. Site 254; present in most cores, reaching a relative abundance of around 2 per cent.

Genus PSILODIPORITES Varma and Rawat, 1963

Type species. Psilodiporites hammenii Varma and Rawat, 1963.

Remarks. The original spelling of this generic name, as proposed by Varma and Rawat, is as above; subsequent authors (e.g. van der Hammen and Wymstra 1964; Guzman 1967) have adopted the spelling '*Psiladiporites*'.

Psilodiporites sp. cf. *P. redundantis* Guzman, 1967

Plate 8, figs. 8–11

cf. 1967 *Psiladiporites redundantis* Guzman, p. 54, pl. 16, fig. 3–3*e*.

Dimensions. Grain diameter 10 (13) 15 μm (fifteen specimens measured).

Remarks. Dispersed pollen grains from Site 254 resemble *P. redundantis* in general shape, in the scabrate and folded nature of the exine, and in the frequent presence of an annulus about each pore. Under the light microscope, the surface of the grains ranges in appearance from psilate to scabrate; with higher magnifications, however, the surface sculpture resolves into one of fine, uniformly distributed grana (Pl. 8, fig. 11). This feature has not yet been proven for *P. redundantis*, so that the Ninetyeast Ridge form is retained in comparison. *P. minimus* van der Hammen and Wymstra,

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EXPLANATION OF PLATE 8

Figs. 1–7. *Echiperiporites rotundus* Kemp sp. nov. Site 254. 1–3, holotype, CPC 15640, Slide 6283/5, 104.1, 31.9. Grain in polar view, × 1250. 1, median focus, pores distinct. 2, 3, higher focal levels, focus on spinae. 4, 5, CPC 15641, Slide 6283/1, 105.4, 33.4. High and median foci, ×1250. 6, 7, scanning electron micrographs, Sample 6283. 6, grain in oblique polar view, pore visible at bottom left, ×2500. 7, sculptural detail of specimen in fig. 6, × 5000.

Figs. 8–11. *Psilodiporites* cf. *P. redundantis* Guzman, 1967. Site 254. 8, CPC 15642, Slide 6282/1, 100.5, 32.2. Equatorial aspect, × 1250. 9, CPC 15643, Slide 6283/2, 109.2, 38.2. Equatorial aspect, scabrate surface, × 1250. 10, gold coated specimen illustrated in fig. 11, Sample 6283. 11, scanning electron micrograph, oblique equatorial aspect, ×2250.

Figs. 12–16. *Sparganiaceaepollenites irregularis* Kemp sp. nov. Site 254. 12, 13, holotype, CPC 15644, Slide 6283/2, 99.2, 32.3, × 1250. 12, median focus. 13, high focus on pore and surface sculpture, Nomarski interference contrast. 14, scanning electron micrograph, Sample 6283, pore visible near upper edge, × 1300. 15, detail of specimen in fig. 14, showing pore and duplibaculate muri, × 2500. 16, CPC 15645, Slide 6283/1, 91.7, 29.9. Nomarski interference contrast, duplibaculate nature of muri distinct, × 1250.

Figs. 17, 18. *Haloragacidites* cf. *H. harrisii* (Couper) Harris, 1971. 17, CPC 15646, Slide 6283/8, 99.3, 39.4. Nomarski interference contrast, × 1250. 18, scanning electron micrograph, Sample 6283, polar aspect, ×1500.

Fig. 19. *Proteacidites* cf. *P. symphonemoides* Cookson, 1950. Site 254, Slide 6283/1, CPC 15647, 110.8, 39.2. Polar aspect, × 1250.

Fig. 20. *Proteacidites* sp. Site 214. Scanning electron micrograph, polar aspect, × 2000.
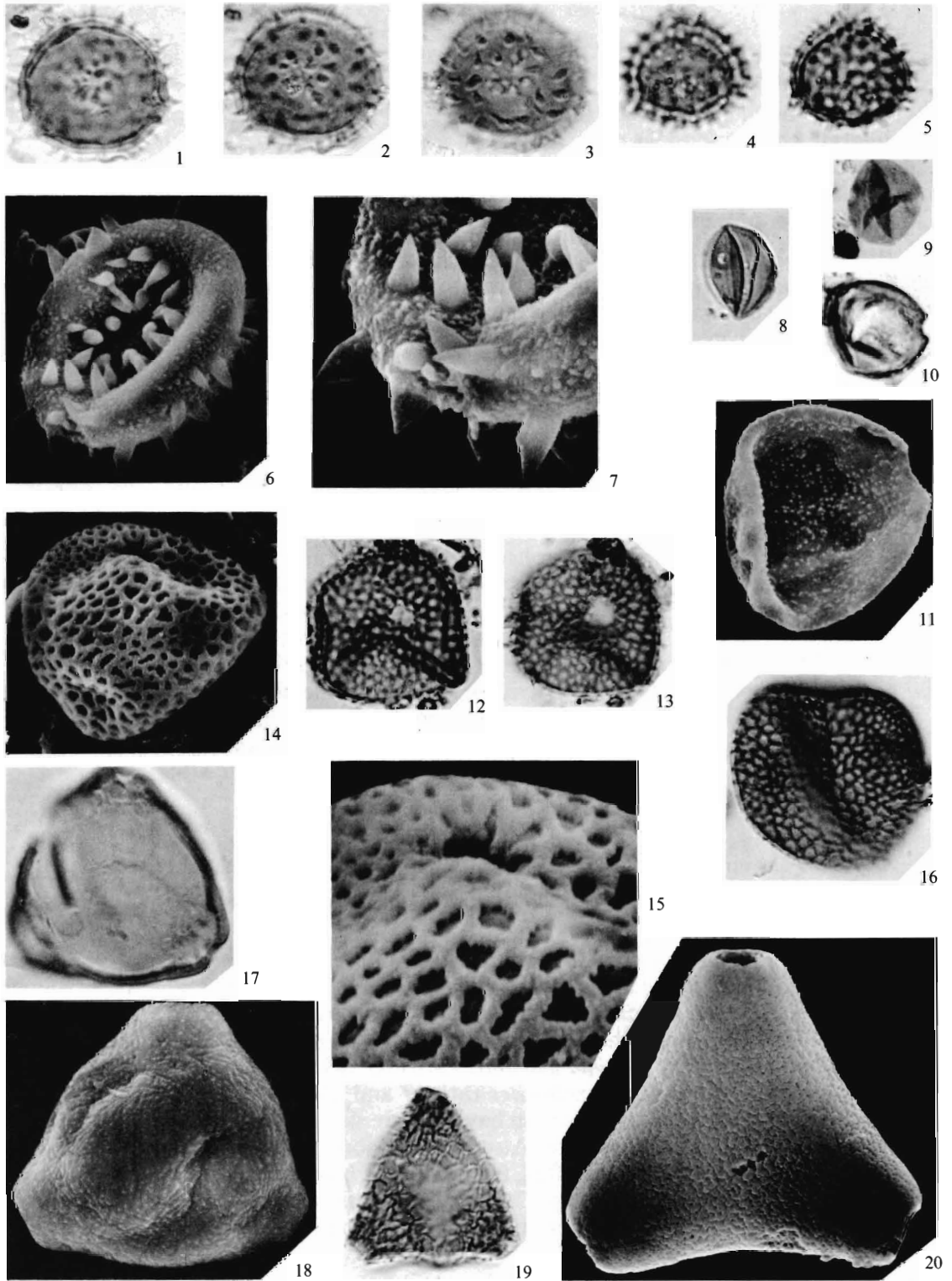
KEMP and HARRIS, Indian Ocean Tertiary spores

1954 is less frequently folded, appears to have a smoother wall, and lacks thickening about the pores.

Affinity. Germeraad *et al.* (1968) have pointed out the probable affinity of small diporate pollens to those of the family Moraceae, but stressed that the similarity of pollen in different genera within this family makes closer identification difficult. Relationship with Urticaceae cannot be ruled out; thin-walled, diporate grains occur in a number of members of this family, e.g. the tropical genus *Laportea.*

Distribution. P. redundantis occurs in the Eocene of Columbia (Guzman 1967). At Site 254, *P.* cf. *redundantis* is relatively common, reaching abundance figures of around 7 per cent in two samples. Its small size and translucency make it easily missed in light microscope counts.

<div align="center">Genus SPARGANIACEAEPOLLENITES Thiergart, 1937</div>

Type species. Sparganiaceaepollenites polygonalis Thiergart, 1937.

<div align="center">*Sparganiaceaepollenites irregularis* Kemp sp. nov.</div>

<div align="center">Plate 8, figs. 12-16</div>

Diagnosis. Pollen grains free, spheroidal, monoporate. Compressions show no preferred orientation with respect to the pore, but generally have a circular outline, modified by folding. Pore diameter ranges from 4–6 μm, with a ragged margin formed by breaking apart of the exinal elements. Exine 1·5 μm thick, distinctly stratified, columellate, with sexine slightly thicker than nexine. Muri of the surface reticulum are clearly duplibaculate, with individual baculae visible both in optical section and in surface view (see scanning electron micrographs, Pl. 8, figs. 14, 15). Lumina irregularly polygonal, 0·4–2·0 μm in diameter, with a wide variation in shape, but there are no modifications in the surface pattern in apertural or other areas.

Dimensions. Grain diameter 26 (30) 34 μm (thirty specimens).

Holotype. Plate 8, figs. 12, 13. Slide 6283/2; 99.2, 32.3 (CPC 15644). Specimen compressed with pore uppermost; distorted by transverse folds. Grain diameter 27 μm, pore 3 μm with ragged margin.

Type locality. Site 254, Indian Ocean, 30° 58.15′ S., 87° 53.72′ E. Core 29, section 1 at 128–130 cm, 258 m sub-bottom. ?Oligocene.

Comparison. S. irregularis is characteristically folded, reflecting a relatively thin exine, in contrast to the more robust *S. barungensis* Harris (1972, figs. 1–3), which also has a more clearly defined pore margin. *S. robustiporis* Martin (1973*b*, p. 36, figs. 154–157) has a pore which is less ragged at its margins, and smaller in relation to the grain diameter. *Aglaoreidia qualumis* Partridge, which might more approxiately be referred to *Sparganiaceaepollenites* (Stover and Partridge 1973, p. 261, pl. 20, figs. 8, 9) differs from *S. irregularis* in having more slender muri and distinct thickening about the pore. Outside the Australian region, the form-species *Monoporopollenites solaris* Weyland and Pflug, from Pliocene brown coals in Greece (Weyland and Pflug 1957, p. 103, pl. 22, figs. 36, 37) appears similar in size, shape, and broad exine pattern, but the description and illustrations are too brief for reliable comparison.

Affinity. Relationships lie with Typhaceae/Sparganiaceae; Martin (1973*b*) considers that the completeness of the reticulum in *S. robustiporis* (which is similar to that in *S. irregularis*) indicates closer affinity to *Sparganium* than to *Typha*.

Distribution. Site 254 only; present as a rare component in three samples.

Genus MILFORDIA Erdtman emend. Partridge, 1973

Type species. Milfordia hypolaenoides Erdtman, 1960.

Milfordia homeopunctata (McIntyre) Partridge, 1973

Plate 4, figs. 1, 2

1965   *Monoporopollenites homeopunctatus* McIntyre, p. 206, figs. 4, 5.
1968   *Restioniidites homeopunctatus* (McIntyre) Elsik, p. 313.
1972   *Restioniidites homeopunctatus* (McIntyre) Elsik; Hekel, p. 15, pl. 6, fig. 30.
1973   *Milfordia homeopunctata* (McIntyre) Partridge, in Stover and Partridge, p. 262, pl. 21, figs. 10, 11.

Dimensions. Grain diameter 26–36 μm (six specimens).

Affinity. Probably Restionaceae. The pollen of certain species of *Restio*, notably that of *R. subverticillatus* Mast. (see Chanda 1966, p. 413), shows a pronounced similarity to *M. homeopunctata*.

Distribution. Miocene of New Zealand (McIntyre 1968); ?Palaeocene to late Miocene in eastern Australia (Stover and Partridge 1973; Hekel 1972). In this study, it was recorded as a rare form in two cores from Site 254.

Genus GRAMINIDITES Cookson, 1947 ex Potonié, 1960

Type species. Graminidites media Cookson, 1947 (subsequent designation by Potonié 1960).

Graminidites sp. cf. *G. media* Cookson, 1947

(Figured in Kemp 1974, pl. 2, fig. 19)

cf. 1947   *Monoporites* (*Graminidites*) *media* Cookson, p. 134, pl. 15, figs. 41, 42.

Dimensions. Grain diameter 12–18 μm (five specimens).

Remarks. The form illustrated here resembles *G. media*, described originally from Kerguelen, but is considerably smaller. *G. media* was also recorded by Martin (1973*a*) from the Pliocene of western New South Wales, which is the only published record of the species from Australia.

Affinity. Grammineae.

Distribution. Site 254, very rare.

Genus ARECIPITES Wodehouse, 1933 emend. Anderson, 1960

Type species. Arecipites punctatus Wodehouse, 1933.

Remarks. Use of the genus *Arecipites* for Tertiary pollens of palm-like form and exine stratification is preferred over the more broadly circumscribed *Monosulcites* Cookson

ex Couper. Nicols *et al.* (1973) emended *Arecipites* yet again, and distinguished it from *Monocolpopopollenites* Pflug and Thomson on the basis of colpus form and exine stratification. They restricted *Arecipites* to forms in which the colpus extremities were tapered rather than flared, and placed types with rounded, flared colpus ends into *Monocolpollenites*. We have found this distinction difficult to apply; forms here compared to *A. waitakiensis* (McIntyre) show a range of shape in the colpus extremities, from specimens with distinctly flaring aperture ends to those in which the shape could most aptly be described as tapering. In all other respects the grains are identical, so they are here retained within a single form genus. Distinction between *Arecipites* and *Liliacidites* Couper remains unclear; Nicols *et al.* (1973) reserved *Arecipites* for species with a tectate exine, and assigned grains with a reticulate exine structure to *Liliacidites*. These two structural conditions are in fact gradational, as fusion of columellate heads may occur to any degree. It is interesting to note in this context that forms compared by Dettmann (1973) to *L. kaitangataensis* Couper, 1953, the type species of *Liliacidites*, show an exine surface pattern which is clearly tectate-perforate.

Arecipities sp. cf. *A. waitakiensis* (McIntyre) comb. nov.

(Figured in Kemp 1974, pl. 2, fig. 20)

cf. 1968   *Monosulcites waitakiensis* McIntyre, p. 201, figs. 78–81.

Dimensions. Equatorial diameter, long axis 24 (31) 36 μm, short axis 13 (16) 23 μm (fifteen specimens).

Remarks. M. waitakiensis McIntyre is similar in size, general form, and exine stratification to the Ninetyeast Ridge form; the sulcus shape in the Indian Ocean specimens, however, is more commonly key-hole shaped at its extremities, and more widely gaping than in the New Zealand specimens.

Affinity. Probably with the Palmae, although the eurypalynous nature of that family (see Sowunmi 1972) makes reference to even sub-families difficult. Similarity to the dispersed fossil form is shown by pollen of the extant genera *Jessenia* (subfamily Arecoideae) especially in sulcus shape, and by *Paralinospadix*, but true relationships remain speculative.

Distribution. Miocene, New Zealand (McIntyre 1968). Present in all samples from Site 254; reaching abundances of 8–9 per cent.

Arecipites insularis Harris sp. nov.

Plate 4, figs. 5, 6

1974   *Arecipites* sp. Harris, p. 513, pl. 2, figs. 10, 11.

Diagnosis. Pollen grains free, anisopolar, monosulcate, with a bilateral symmetry. Shape in polar aspect irregularly elliptical. Sulcus extends length of grain and is of variable width. Margins more or less well defined, but equatorial ends are frequently ragged. Exine tectate-perforate, 2·5 μm thick over entire grain, distinctly stratified. Sexine about as thick as nexine. Ornament a distinct reticulum, lumen up to 1·5 μm in diameter on proximal face, becoming distinctly finer on distal surface. Diameter

of the lumina is smaller than width of the muri walls separating them; these are up to 2 μm wide and are elevated to give the grain surface a rugulo-verrucate appearance (Pl. 4, fig. 6).

Holotype. Plate 4, fig. 5. Slide ST2498/1; 11.8, 109.3 (GSSA Py 1018). Grain in polar aspect. Equatorial diameter (long) 34 μm, (short) 25 μm. Exine 2·5 μm thick.

Type locality. Site 214, Indian Ocean, 11° 20.2′ S., 88° 43.1′ E. Core 43, core catcher sample, 402 m sub-bottom. Palaeocene.

Dimensions. Equatorial diameter, long axis 28 (35) 40 μm, short axis 20 (28) 32 μm (twenty specimens).

Remarks. The species differs from *A. waitakiensis* in having a coarser reticulum.

Affinity. Grains of this type are morphologically similar to pollen of the Palmae; some Arecoideae, such as *Kentia* and *Roscheria* have similar pollens.

Distribution. Common in most samples from Site 214 with relative frequencies up to 65 per cent.

Genus SPINIZONOCOLPITES Muller, 1968

Type species. Spinizonocolpites prominatus (McIntyre) Stover and Evans, 1973 (*S. echinatus* Muller, 1968, which was originally designated as type species, is considered by Stover and Evans to be synonymous with *S. prominatus*).

Spinizonocolpites prominatus (McIntyre) Stover and Evans, 1973

Plate 4, figs. 3, 4

For synonymy see Stover and Partridge 1973, p. 253.

Dimensions. Grain length 25–28 μm, width 21–24 μm (three specimens).

Remarks. The specimens from the Ninetyeast Ridge are smaller than those described originally from New Zealand. The form of the sulcus has not been clearly observed in the specimens recorded here.

Affinity. McIntyre (1965) commented on the resemblance of *S. prominatus* to pollen of the extant palm species *Lepidocaryum gracile.* However, affinity with the mangrove palm, *Nipa*, seems more likely. Both Erdtman (1952, p. 304) and Sowumni (1972, p. 25) have described pollen of *L. gracile*, and stress that it differs from that of *Nipa* in having deep-rooted spine bases; in both the New Zealand and the Ninetyeast Ridge specimens of *S. prominatus*, the spines are clearly supra-tectal, favouring *Nipa* rather than *L. gracile.*

Distribution. Palaeocene to middle Eocene, New Zealand (McIntyre 1965); early to mid Eocene, Victoria (Stover and Partridge 1973); Palaeocene, Tasmania (Cookson and Eisenack 1967); Late Cretaceous to Recent, Sarawak (as *S. echinatus* Muller). On the Ninetyeast Ridge, the species has been recorded as a rare element in only two samples from Site 254.

Genus CLAVATIPOLLENITES Couper, 1958

Type species. Clavatipollenites hughesii Couper, 1958.

Remarks. Dettmann (1973) suggested that distinction between the superficially similar genera *Clavatipollenites* and *Liliacidites* Couper could be related to the

presence of an equatorial zone of differentially thickened exine in *Liliacidites* and to morphological differences associated with sulcus development. In *Liliacidites* the sulcus is formed in both nexine and sexine and hence assumes a well-defined shape; in *Clavatipollenites* the sulcus shows definite development in the nexine only, and the sexine breaks down in an irregular fashion across the germinal aperture. This process forms an irregular opening with ragged, ill-defined margins. Applying this distinction, all reticulate, monosulcate pollens observed in this study have been referred to *Clavatipollenites*. Laing (1975) rejected both of Dettmann's grounds for retaining separation of the two genera, and treated *Clavatipollenites* as a junior synonym of *Liliacidites*. However, an examination of Couper's topotype material of *C. hughesii* made by Kemp (1968), reinforces the suggestion that the distinction made on sulcal type at least, is a fundamental and useful one. Most of the grains in the type material show a ragged sulcus of the type described by Dettmann; in the type specimen the sulcus is infolded and obscure, but even so, the type of sexine breakdown which Dettmann described is suggested—contrary to the opinion stated by Laing (1975, p. 780).

Clavatipollenites sp. cf. *C. hughesii* Couper, 1958 emend. Kemp, 1968

Plate 4, figs. 7-9

cf. 1958   *Clavatipollenites hughesii* Couper, pl. 31, figs. 19-22.

Dimensions. Grain length 16 (20) 25 μm; width 14 (17) 20 μm (twenty-five specimens); grain depth 16, 17 μm (two specimens).

Remarks. All specimens of *Clavatipollenites* observed at Sites 214 and 254 fall within the range of morphological variation shown by light microscope observations of *C. hughesii* from the Early Cretaceous of England (Couper 1958; Kemp 1968) in shape, size range, and sulcal form. However, there are presently no high magnification data available for *C. hughesii*, although photographs of closely comparable species from the Early Cretaceous of the Potomac Group, U.S.A. have recently been published (Doyle *et al.* 1975). Comparison of the Ninetyeast Ridge material (Pl. 4, fig. 9) with these photographs confirms a close similarity, although the 'lumpiness' shown by the muri is more pronounced than in the North American Cretaceous species. In view of the absence of data from the type locality of *C. hughesii*, and of the wide stratigraphic gap separating the northern and southern hemisphere records, the Ninetyeast Ridge forms are not identified directly with *C. hughesii*. *C. ascarinoides* McIntyre, 1968, from the New Zealand Miocene, was described as having clearly defined sulcal margins, which would clearly differentiate it from the Ninetyeast Ridge form. This feature is not, however, evident in all illustrations of *C. ascarinoides*; the specimen shown as fig. 4 by McIntyre appears to have an ill-defined, irregular sulcus. *C. evittii* Chmura, from the Late Cretaceous of California (Chmura 1973, p. 104, pl. 21, figs. 4-8) shows a similar granular sulcal membrane to the forms figured herein, but is significantly larger.

Affinity. The similarity of *Clavatipollenites* to the pollen of *Ascarina* (Chloranthaceae) was noted by Couper (1960). Whilst this suggestion of affinity may have relevance for the Tertiary forms, it seems doubtful that it can be taken to indicate the existence

of this family as far back in time as the Early Cretaceous, when these grains first appear.

Distribution. (Southern hemisphere only.) Late Eocene, Western Australia (Hos 1975); mid Eocene, Maslin Bay, South Australia, and Palaeocene, Otway Basin (W. K. Harris, unpublished data); Albian-Cenomanian, Great Artesian Basin; Cenomanian-Turonian, Bathurst and Melville Islands and Otway Basin (Dettmann 1973); Palaeocene-Recent, New Zealand (as *Ascarina*, in Couper 1960); Barremian-Aptian, Patagonia (Archangelsky and Gamerro 1967). On the Ninetyeast Ridge *Clavatipollenites* is a constant component in all samples from both Sites 214 and 254, reaching relative frequencies of up to 18 per cent in the former, and 3 per cent in the latter.

Genus POLYCOLPITES Couper, 1953

Type species. Polycolpites clavatus Couper, 1953 (by original designation).

Polycolpites sp.
Plate 4, figs. 10, 11

Description. Pollen grains oblate, stephanocolpate, five-lobed in polar view. Colpi 5, short, widest at equator. Exine shows a clear separation of sexine from nexine; sexine columellate, most distinctly so in the intercolpia, where the columellae reach their greatest height. The columellae decrease gradually in height towards the colpi, an arrangement that emphasises the distinctive five-lobed appearance. Tips of columellae are united into a reticulum of mesh diameter *c.* 0·5 μm; the reticulum extends across polar regions. Colpi appear to be developed in nexine only, and are covered with a granular, probably sexinous membrane.

Dimensions. Over-all grain diameter 15-24 μm (four specimens).

Remarks. This form differs from previously described species of *Polycolpites* in the presence of elongated columellae in the intercolpia, giving the distinctive five-lobed appearance in polar view. It is too rare to be formally designated as a new species.

Affinity. Unknown.

Distribution. Site 254, a very rare element in core 29.

Genus NOTHOFAGIDITES Potonié, 1960

Type species. Nothofagidites flemingii (Couper) Potonié, 1960.

Nothofagidites brachyspinulosus (Cookson)
(Figured in Harris 1974, pl. 3, fig. 14)

1959 *Nothofagus brachyspinulosus* Cookson, p. 26, pl. 4, fig. 4.
1965a *Nothofagidites brachyspinulosus* (Cookson); Harris, p. 96, pl. 29, fig. 24.
1974 *Nothofagidites* sp. Harris, p. 515, pl. 3, fig. 14.

Affinity. Pollen of a species of *Nothofagus*.

Distribution. Extremely rare at both sites.

Nothofagidites spp. *emarcidus-heterus* (Cookson)

(Figured in Harris 1974, pl. 3, figs. 12, 13)

1974   *Nothofagidites* spp. Harris, p. 515, pl. 3, figs. 12, 13.

Remarks. The species recorded here conform with the *emercidus-heterus* complex but are more closely related to *N. heterus* (Cookson) Stover and Evans, 1973.

Affinity. Pollen of one or more species of *Nothofagus.*

Distribution. Extremely rare at Site 214.

Genus SCHIZOCOLPUS Stover, 1973

Type species. Schizocolpus marlinensis Stover, 1973.

Schizocolpus marlinensis Stover, 1973

Plate 4, figs. 12, 13

1973   *Schizocolpus marlinensis* Stover, in Stover and Partridge, p. 258, pl. 18, figs. 3, 4.
1974   *Schizocolpus marlinensis* Stover; Harris, p. 505, pl. 3, fig. 15.

Remarks. Specimens from Sites 214 and 254 are conspecific with the Australian forms. The diorate, tricolporate apertures are clearly defined and the exine shows some tendency to separate from the nexine.

Affinity. Probably Didymelaceae (Stover and Partridge 1973). This family is now represented in Malagasy by *Didymeles.*

Distribution. Early to middle Eocene, Gippsland Basin, Victoria (Stover and Partridge 1973). Very rare in one sample at Site 214, two at Site 254.

Genus AUSTRALOPOLLIS Krutzsch, 1966

Type species. Australopollis obscurus (Harris) Krutzsch, 1966.

Australopollis obscurus (Harris) Krutzsch

(Figured in Harris 1974, pl. 3, fig. 11)

1965a   *Stephanoporopollenites obscurus* Harris, p. 95, pl. 29, figs. 15–17.
1966   *Australopollis obscurus* (Harris) Krutzsch, p. 38.
1973   *Australopollis obscurus* (Harris); Stover and Partridge, p. 270.
1974   *Australopollis obscurus* (Harris); Harris, p. 515, pl. 3, fig. 11.

Affinity. Unknown.

Distribution. Only one poorly preserved specimen was recorded from Site 214. The species which are rare enough to be wind-blown: *Nothofagus* spp. (Proteaceae), *Halo-*Australia.

SOURCE OF THE MICROFLORAS

The spore and pollen assemblages in these presently submerged sediments are interpreted as having been derived from the vegetation of islands which were emergent along the ridge crest in the Palaeocene and Oligocene. The existence of such islands is supported by the subaerially weathered nature of basalts at the sites, and by the lignitic character of some of the sediments immediately overlying them. That the spores and pollen reflect a vegetation source not far removed from the sites of deposition is attested by the high densities of plant microfossils in the sediments, by the excellence of their preservation, and by the additional occurrence in the cores of tracheids, cuticular fragments, and the fructifications of epiphyllous fungi. The bulk of the pollen recovered seems likely to be indigenous, rather than blown from distant sources. However, a wind-blown origin cannot be entirely ruled out for some taxa, particularly those whose parent plants are known to be high pollen producers, and which produce pollen well suited to long-distance dispersal by air currents. *Nothofagus* is the prime example of such a type, and the extremely rare grains reported in this study—no more than one or two per sample—are regarded as being derived from distant, probably continental forests.

COMPOSITION AND BOTANICAL AFFINITIES OF ASSEMBLAGES

Site 214. The detailed distribution of palynomorphs over a 116-m interval has been documented by Harris (1974). There are only minor variations in composition (apart from the introduction of microplankton in core 41) and the assemblages can be treated as one unit. There are, however, marked changes in frequency of several form-species which are in turn reflected in the relative frequencies of the major plant groups (see fig. 2, Harris 1974). These groups are represented by eighteen form-species of pteridophytes, four conifers, and fifteen form-species of angiosperms. The other major component of the assemblages at this site is the organic walled microplankton, dinoflagellate cysts, acritarchs, and green algae, occurring in and above core 41. These elements will be described elsewhere.

The dominant angiosperm pollen is that of *Arecipites*, a form which probably can be related to the modern palms. Equal in abundance is *Clavatipollenites*, a form with similarities to pollen of the New Zealand and New Caledonian genus *Ascarina* (Chloranthaceae). Pollen of *Gunnera* (*Tricolpites reticulatus*) is another consistent and commonly occurring species. Among the other angiosperm fossil species that are identifiable to family or generic level at this site there are Myrtaceae, and several species which are rare enough to be wind-blown: *Nothofagus* spp. (Proteaceae), *Haloragacidites harrisii* (which has affinities with Casuarinaceae), and *Schizocolpus marlinensis* (probably Didymelaceae). The other angiosperm pollen cannot be assigned to any extant genus or family.

The gymnosperm pollen are represented by common *Lygistepollenites florinii* (*Dacrydium*), *Microcachryidites antarcticus* (*Microcachrys*), *Phyllocladidites paleogenicus* (*Phyllocladus*), and pollen of *Podocarpus*. Fern spores are dominated by smooth-walled trilete spores of the Cyatheaceae. Other families recognized include Polypodiaceae, Gleicheniaceae, and Schizaeaceae. Spores of lycopods are not common but are represented by two species.

Site 254. Spore and pollen assemblages recovered throughout a sequence some 63 m thick at Site 254 showed only minor variations in composition, chiefly in the relative abundances of different form-species. For this reason assemblages through the sampled sequence are treated as a single unit in the following discussion.

TABLE 1. Frequency distribution of pollen and spores at Sites 214 and 254. Frequencies are based on counts of 250 grains per sample; × denotes observed in sample but not in count. At Site 214, samples S2493 and above are marine, and figures shown are percentages of the total palynomorph assembly, which includes dinoflagellates (see Harris 1974, fig. 2).

SAMPLE NOS. ANGIOSPERMS	2592	2591	2590	2589	2587	2496	2493	2497	2498	2500	2501	2502	2503	2492	2505	2494	6277	6278	6279	6282	6283	6288
ARECIPITES INSULARIS	2.0	2.0			3.0	7.0	6.0	2.5	2.0	2.0	0.5	14.0	25.5	17.0	65.5	28.0						
A. cf. WAITAKIENSIS																	3.5	X	X	8.5	X	0.5
AUSTRALOPOLLIS OBSCURUS			X																			
CLAVATIPOLLENITES cf HUGHESII			X	X	9.0	9.0	4.0	17.0	13.0	8.0	3.5	3.5	18.0	6.0	4.5	10.0	3.5	X	X	3.0	0.5	0.5
CUPANIEIDITES ORTHOTEICHUS																				3.0	1.0	1.0
ECHIPERIPORITES ROTUNDUS																	0.5			1.0	2.0	2.5
GOTHANIPOLLIS cf. GOTHANI																					0.5	
GRAMINIDITES cf. MEDIA																				0.5	0.5	
HALORAGACIDITES cf. HARRISSII				X											X		0.5			3.0	X	
MILFORDIA HOMOPUNCTATA																				X	X	
MYRTACEIDITES cf. MESONESUS																	0.5			4.0	6.0	3.5
M. OCEANICUS																	2.0		X	5.0	2.5	X
CONCOLPITES cf. LEPTOS							0.5	X		1.0	0.5			X		0.5						
NOTHOFAGIDITES SPP.				X		X				X					X					X	X	
PROTEACIDITES cf. SYMPHONEMOIDES																				X		
P. SP.		X																				
NYSSAPOLLENITES cf. ENDOBALTEUS																	6.0		X	5.5	4.0	4.5
N. DEMINUTUS		2.0	X			1.0	3.0	4.5	9.0	7.0	1.0	0.5	16.0	X	2.0	2.0				7.5	7.0	1.5
PSILODIPORITES cf. REDUNDANTIS																		X			X	
POLYCOLPITES SP.																						
RHOIPITES GRANDIS																	3.0	X	X	1.5	19.0	12.0
R. ISORETICULATUS																	5.0	X	X	4.5	2.0	22.5
R. MICROLUMINUS																	3.5	X	X	6.0	5.0	6.0
SAPOTACEAEPOLLENITES ROTUNDUS																				X	0.5	
SPARGANIACEAEPOLLENITES IRREGULARIS																				X	X	
SPINIZONOCOLPITES PROMINATUS																			X			
SCHIZOCOLPUS MARLINENSIS							0.5													0.5		
SIMPSONIPOLLIS MULLERI																	0.5			1.0	0.5	1.0
TRICOLPITES ASPERAMARGINUS																				X	0.5	
T. SP.2,			X			X	X	0.5	3.0	1.0	0.5	0.5	X		X							
T. DISCUS						5.0	2.0	30.0	15.5	8.0	5.0	55.0	19.5	5.0	8.0	8.5						
T. SP. 1								X	X	0.5	0.5		0.5	X	X							
T. PHILLIPSI					3.0		3.5	1.5	2.0	X		12.0	1.0	9.5	2.5	7.0						
T. RETICULATUS	1.0	1.0	X		1.0	3.0	1.0	1.5	1.5	0.5	X	0.5	2.5	X	X	3.0	1.5	X	X	2.0	3.0	2.5
TUBULIFLORIDITES cf. ANTIPODICA																	0.5					
?T. SP.						X		X		X	X	X										
GYMNOSPERMS																						
ARAUCARICITES AUSTRALIS																	0.5		X	1.5	7.0	8.0
LYGISTEPOLLENITES FLORINII		1.0	X	X	2.0	4.0	2.0	29.0	23.0	1.0	X	5.5	5.5	12.5	1.5	9.5						
MICROCACHRYIDITES ANTARCTICUS								1.0	X	1.0		X		0.5		0.5	1.0			0.5	X	0.5
PHYLLOCLADIDITES PALEOGENICUS								1.0	5.0	1.5	22.5	10.0	3.0	1.0	18.0	11.5	6.0					
PODOCARPIDITES ELLIPTICUS			1.0	X	2.0	1.0	3.0	0.5	3.5	9.5	1.0	2.0	X	6.5	0.5							
P. SP.																	17.5	X	X	5.0	5.0	11.0
PTERIDOPHYTES AND OTHERS																						
APPENDICISPORITES CRASSICARINATUS	1.0		X	X	1.0		3.0	X		1.0	1.5	X	X	6.0	X		1.0			X	X	
BACULATISPORITES COMAUMENSIS							X	X	X			0.5	X	X								
B. SP.																	1.0			2.0	X	X
CAMAROZONOSPORITES SP.							0.5		0.5			X	X	0.5						X		
CERATOSPORITES EQUALIS							1.0			0.5			X									
CICATRICOSISPORITES TENIATUS									2.0	X		X										
CLAVIFERA TRIPLEX					1.0		1.0		0.5	X		0.5										
CYATHIDITES AUSTRALIS						1.0	3.0	1.0	1.0	6.5	X	8.5	X	2.0	2.5	X	0.5		X	0.5	0.5	
C. MINOR	4.0	4.0	X	X	14.0	1.0	6.0	X		7.0	40.5		X		3.5	0.5	5.5			1.5	0.5	3.0
C. KERGUELENSIS																	12.5	X	X	8.5	8.0	2.5
DELTOIDOSPORA SP.																	0.5		X			
FOVEOTRILETES PALAEQUETRUS								1.0	0.5				0.5		0.5	X	0.5		X	X		
FOVEOSPORITES SP																	0.5					
KRAEUSELISPORITES PAPILLATUS							1.0			X					X							
LAEVIGATOSPORITES MAJOR		1.0	X	X	3.0	1.0	6.0	1.0	11.0	12.0	12.0	1.5	5.0	1.0	6.0							
L. OVATUS	10.	3.0	X	X	1.0					8.0	10.5	0.5	X	4.0		4.5	11.5	X	X	11.0	12.0	10.0
MICROFOVEOLATOSPORITES FROMENSIS										X												
OSMUNDACIDITES WELLMANII							X		0.5	1.0	X	0.5	2.0	1.5	2.0	0.5						
PEROMONOLITES DENSUS						1.0				0.5												
P. VELLOSUS																	1.0			X	2.0	X
POLYPODIACEOISPORITES cf TUMULATUS																	4.0	X		2.0	3.0	5.5
POLYPODIISPORITES cf HISTIOPTEROIDES																	X		X	0.5	X	
P. cf RUGUFAVUS																	3.0	X	X	1.5	1.5	1.5
P. SP.										0.5	3.0	X		X		5.5						
PUNCTATOSPORITES SP.																	1.5			7.5	4.5	0.5
P. VARIGRANULATUS																	X		X	X	X	0.5
STEREISPORITES ANTIQUASPORITES											0.5											
STOVERISPORITES VERRUCOLABRUS																				0.5		
TRILITES cf TUBERCULIFORMIS																	0.5				X	

There is a notable diversity in the spore and pollen spectrum recovered from this site; some twenty-six form-species of angiosperm pollen have been described, together with three conifers, seventeen pteridophytes, and two lycopods. Fungal remains, chiefly spores, but including some fructifications, are common in residues from the site (Kemp, in press); they occur in all samples, but show a marked concentration in some cores, for instance in residues from core 29, where they are the dominant microfossils. Such concentrations are probably attributable to selective preservation of fungal debris.

Among angiosperms, the most abundant forms are tricolporate pollens with a reticulate exine pattern, referred herein to the form-genus *Rhoipites*. The botanical affinities of this group remain obscure; one species, *R. isoreticulatus*, bears some similarity to pollen of the mangrove genus *Avicennia*, but the resemblance is not total. Next in relative abundance are syncolporate pollens of probable myrtaceous affinity; the small form which has been compared to the Australian Tertiary species *Myrtaceiidites mesonesus* Cookson and Pike is the most common in this group. The species *M. oceanicus* has the broad characteristics of the pollen of Myrtaceae, but no living forms are known with such pronounced verrucate ornament. *Cupanieidites orthoteichus* Cookson and Pike, a syncolpate form which also occurs in Australian Tertiary sequences, and which has close analogues in the Sapindaceae, occurs at Site 254 in slightly lower frequencies than myrtaceous pollen.

Small, thin-walled diporate pollen, referred to *Psilodiporites* sp. cf. *redundantis* Guzman is a common element, and may represent pollen of Moraceae, although Urticaceae cannot be ruled out. These grains reach relative abundances in excess of 7 per cent. Also locally abundant are monocolpate pollens—*Arecipites waitakiensis* McIntyre, morphologically close to pollen of some extant palm genera, and *Clavatipollenites* cf. *hughesii* Couper, which possibly indicates Chloranthaceae, occur in significant amounts in most samples.

It is among the less common angiosperm elements that forms of the greatest phytogeographical interest occur. The identification of *Gothanipollis*, for instance, represents only the second reported occurrence of this form-genus (which probably derives from a member of the Loranthaceae) in southern hemisphere Tertiary sediments. The form-species *Schizocolpus marlinensis* Stover, which is of restricted stratigraphical range in the Australian Eocene, and which occurs at Sites 214 and 254, is close to pollen of *Didymeles* (*Didymelaceae*), a genus presently confined to Madagascar. *Casuarina*, a genus presently little represented on oceanic islands, occurs (as *Haloragacidites* cf. *harrisii* (Couper) in frequencies of up to 3 per cent at Site 254 and is probably indigenous, rather than wind-blown. Pollen morphologically indistinguishable from that of *Gunnera*, another genus of widespread southern distribution, occurs in comparable frequencies. The presence of proteaceous pollen, albeit in low (less than one per cent) frequencies, is also of considerable interest. A possible aquatic or marshy element is represented by *Sparganiaceaepollenites irregularis*, which is close to the pollen of extant *Sparganium*. Another herbaceous component is reflected in *Milfordia homeopunctata* (McIntyre) which is akin to the pollen of certain species of *Restio* (Restionaceae).

Coniferous pollen make up around 20 per cent of the total assemblage in some cores. The large, folded, granulate pollen of *Araucaria* (as *Araucariacites australis*) is prominent among this group: the record from Site 254 is the second from an Indian Ocean island site, as both macrofossil remains and pollen are known from the Early Tertiary lignites of Kerguelen (Seward and Conway 1934; Cookson 1947). There are few records of the genus from Tertiary sequences on continents immediately bordering the Indian Ocean—it seems to be absent from Western Australia (Hos 1975) and from that portion of Antarctica south of the Indian Ocean (Kemp 1972); the only Tertiary record from India comes from Kutch (Sah and Kar 1970). Podocarpaceous

pollen from Site 254 is abundant but not diverse; all observed types are similar to that of extant *Podocarpus* or *Microcachrys*.

Fern spores are the third major element of the microflora, constituting 15–45 per cent of the total spore/pollen spectrum. Smooth-walled, trilete forms of the Cyatheaceae are the most abundant types, with other families being represented in a minor way. Representatives of Polypodiaceae, Gleicheniaceae, Schizaeaceae, and possibly Osmundaceae occur in low frequencies. Two form species, both of rare occurrence, may represent Lycopodiaceae. Fungal remains are diverse, but it is not possible to say how many modern groups are represented; only the epiphyllous Microthyriaceae can be confidently recognized as they are represented by their fruiting bodies (Kemp, in press).

COMPARISONS WITH OTHER TERTIARY MICROFLORAS

Spore and pollen species described from Sites 214 and 254 are listed in Table 2, together with those which are common to other southern hemisphere Tertiary localities. These data show clearly that a strong floristic relationship existed between the Ninetyeast Ridge floras and those of the Australian and New Zealand Early Tertiary, with weaker ties to southern South America and Antarctica, although comparative data are more sparse for these regions. Of a total of 37 form-species recognized at Site 214, some 28 have either been described from the Australian Tertiary, or have closely similar counterparts there. At Site 254, of 48 form-species described, again, 28 are known to occur in Australia, and 19 are known from New Zealand.

Similarities in composition are particularly strong among the coniferous elements; the mixture of podocarpaceous and araucarian pollens seen in the Site 254 assemblage is typical of Australian and New Zealand Early Tertiary sequences. Among the angiosperms, although a high percentage of species occurs in common between the islands of the ridge and the southern continents, quantitative differences are pronounced. The continental assemblages tend to be dominated by *Nothofagus* pollen types, which occur in considerable diversity; in the Ninetyeast Ridge microfloras, *Nothofagidites* is a rare component, rare enough for the grains to have been wind-transported, rather than locally produced. Proteaceous pollen too, occurs in great numbers and diversity on the continents, but is poorly represented on the island sites, although occurring in considerably higher frequencies than *Nothofagidites*. Among the other major shared groups, pollen of Myrtaceae occurs in the island microfloras in frequencies comparable to those of the continents, although the species differ, and may include an endemic island component.

TABLE 2. Spore and pollen species at Sites 214 and 254 and their known distribution in southern hemisphere sediments. Data for Australia drawn from publications of Cookson and co-workers, from Harris (1965*a*, 1971, 1972), Martin (1973*a*, *b*), Hekel (1972), Stover and Evans (1973), Stover and Partridge (1973); for New Zealand from Couper (1953, 1960) and McIntyre (1965, 1968); for South America from Archangelsky (1972, 1973) and Fasola (1969); for Antarctica from Cranwell (1959, 1969), McIntyre and Wilson (1966), and Kemp (1972, 1975).

	SITE 214	SITE 254	AUSTRALIA	NEW ZEALAND	S. AMERICA	ANTARCTICA
APPENDICISPORITES CRASSICARINATUS N.SP.	X	X				
ARAUCARIACITES AUSTRALIS		X	X	X		X
ARECIPITES INSULARIS N.SP.	X					
A. CF. WAITAKIENSIS		X		X		
AUSTRALOPOLLIS OBSCURUS	X			X		
BACULATISPORITES COMAUMENSIS	X		X	X	X	
BACULATISPORITES SP.	X					
CAMAROZONOSPORITES SP.	X			X		
CERATOSPORITES EQUALIS	X	X	X			
CICATRICOSISPORITES TENIATUS N.SP.	X					
CLAVATIPOLLENITES CF. HUGHESII	X	X	X	cf.	X	
CLAVIFERA TRIPLEX	X		X		X	
CYATHIDITES AUSTRALIS	X	X	X	X		X
C. KERGUELENSIS		X				
C. MINOR	X	X	X	X	X	X
CUPANIEIDITES ORTHOTEICHUS		X	X	X		
DELTOIDOSPORA SP.		X				
ECHIPERIPORITES ROTUNDUS N.SP.		X				
FOVEOTRILETES PALAEQUETRUS	X	X	X			
FOVEOSPORITES SP.		X				
GOTHANIPOLLIS CF. GOTHANI		X	X			
GRAMINIDITES CF. MEDIA		X	X			
HALORAGACIDITES HARRISII	X	X	X	X	X	X
KRAEUSELISPORITES PAPILLATUS	X		X			
LAEVIGATOSPORITES MAJOR	X		X			X
L. OVATUS	X	X	X		X	
LYGISTEPOLLENITES FLORINII	X		X	X		X
MICROCHRYIDITES ANTARCTICUS	X	X	X	X	X	X
MICROFOVEOLATOSPORITES FROMENSIS	X		X			
MILFORDIA HOMEOPUNCTATA		X	X	X	cf.	
MYRTACEIDITES CF. MESONESUS		X	X	cf.		cf.
M. OCEANICUS N.SP.		X				
CONCOLPITES CF. LEPTOS	X		cf.			
NOTHOFAGIDITES EMARCIDA-HETERA	X		X	X		X
N. BRACHYSPINULOSA	X	X	X	cf.		X
OSMUNDACIDITES WELLMANII	X		X	X		
PEROMONOLITES DENSUS	X		X			
P. VELLOSUS		X	X		cf.	
PHYLLOCLADIDITES PALEOGENICUS	X		X			
PODOCARPIDITES ELLIPTICUS	X	X	X	X	X	X
PODOCARPIDITES SP.		X		X		
POLYPODIACEOISPORITES CF. TUMULATUS		X	X			
POLYPODIISPORITES CF. HISTIOPTEROIDES		X				
P. RUGUFAVUS		X				
P. SP.	X					
PROTEACIDITES CF. SYMPHONEMOIDES			X	X	cf.	
P. SP.	X		X			
NYSSA POLLENITES CF. ENDOBALTEUS			X	X	cf.	
PSILODIPORITES CF. REDUNDANTIS			X			
PUNCTATOSPORITES SP.			X			
P. VARIGRANULATUS N.SP.			X			
POLYCOLPITES SP.			X			
RHOIPITES GRANDIS N.SP.			X			
R. ISORETICULATUS N.SP.			X			
R. MICROLUMINUS N.SP.			X			
SAPOTACEAEPOLLENITES ROTUNDUS			X	X		
SCHIZOCOLPUS MARLINENSIS	X		X	X		
SPARGANIACEAEPOLLENITES IRREGULARIS N.SP.			X	cf.		
SPINIZONOCOLPITES PROMINATUS			X	X	X	
STEREISPORITES ANTIQUASPORITES	X		X		X	X
STOVERISPORITES VERRUCOLABRUS N.SP.			X			
SIMPSONIPOLLIS MULLERI N.SP.			X			
TRICOLPITES ASPERAMARGINIS			X	X	X	
T. SP.2	X					
T. DISCUS N.SP.	X					
T. SP.2	X					
T. PHILLIPSI	X		X			
T. RETICULATUS	X	X	X	X	X	
TRILITES TUBERCULIFORMIS	X	X	X		X	
TUBULIFLORIDITES CF. ANTIPODICA		X	X	cf.		
?T. SP.	X					

Lignites from Kerguelen, which have been radiometrically dated as approximately middle Miocene (Nougier 1970), have yielded microfloras which share some features with the Ninetyeast Ridge assemblages. The coniferous component is similar, being composed of podocarps and araucarians, and there are similarities in the pteridophyte spores, but the angiosperm component is decidedly impoverished in comparison especially with that from Site 254. Of the other landmasses bordering the Indian Ocean, only in India has the Tertiary palynological record been extensively investigated. Tertiary microfloras are known from Assam (Baksi 1962, 1965; Sah and Dutta 1966, 1968), from Kutch (Venkatachala and Kar 1969; Sah and Kar 1970), from Peninsula India (Rao 1955; Ramanujam 1966), and from the Andaman Islands (Banerjee 1966). These assemblages have few elements in common with the Ninetyeast Ridge microfloras, either in the major pollen groups or at an individual species level. Palm-type pollens are shared by the Indian and the island assemblages, but are much more abundant and diverse in Indian regions. Assemblages from Assam contain rare pollens of possible myrtaceous origin, and very rare *Araucariacites*, already mentioned, occurs in Kutch, but the general level of resemblance to Indian Ocean microfloras is very low. The assemblages described from Sarawak by Muller (1968) also have little in common with the Ninetyeast Ridge assemblages. Indeed, the latter show little affinity with microfloras described from tropical regions as a whole (compare Germeraad *et al.* 1968); none of the forms listed as zonal indicators in tropical Tertiary sediments occur on the Ninetyeast Ridge sites.

Similarities between the Ninetyeast Ridge microfloras and those of Australia and New Zealand are probably related to the greater proximity of the ridge sites to these southern landmasses in the Early Tertiary, in comparison with their present position (Kemp and Harris 1975). Reconstructions of the positions of land areas bordering and within the Indian Ocean in the Palaeogene (Sclater and Fisher 1974) indicate that India lay far to the north of the island sites on the Ninetyeast Ridge when these were emergent in the Palaeocene and Oligocene, a factor which may account for the lack of any similarity to Indian Tertiary microfloras. Further, these reconstructions show that, although the island sites were then in relatively high southern latitudes, and closer to the southern continents than they are now, they were still truly oceanic in position, so that their colonization would have required the long-distance dispersal of propagules. Mechanisms for such long, trans-oceanic dispersal remain obscure. The same problems of colonization must have been shared by the Early Tertiary vegetation of Kerguelen; the differences between this microflora and that of Site 254 are perhaps related to latitudinal differences between the sites at the time of their emergence, and to progressive climatic deterioration in the Miocene.

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TAXONOMIC INDEX