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TAXONOMY OF SOME CRETACEOUS SPORES AND POLLEN GRAINS FROM EASTERN AUSTRALIA

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Abstract

Twenty-five species of plant microfossils from various Cretaceous sections in eastern Australia are systematically examined and illustrated. Of these, one Neocomian spore type is instituted as a new species; eight new species of spores and pollen grains from the late Albian-Upper Cretaceous are proposed; and the remaining forms, all from post-Aptian sediments, are assignable to existing Australian and overseas species of Cretaceous and Tertiary age. Particular attention is given to the nature, distribution, and stratigraphic significance of Australian schizaeaceous trilete spores (allocated to *Cicatricosisporites* and *Appendicisporites*); and to the oldest pollen representatives of the angiosperms. Pollen of the *Nothofagus brassi* type is recorded and described for the first time from the Australian Cretaceous, where it appears (as *Nothofagidites senectus* sp. nov.) initially in Senonian strata.

Introduction

During the course of a palynological review of the Australian Cretaceous System (Dettmann & Playford 1968), it became obvious that, while palynological contents of the Lower Cretaceous are well known, few published data existed on spore-pollen composition of Upper Cretaceous deposits. Accordingly, the purpose of the present paper is to describe, formally designate, and illustrate certain species of spores and pollen, the majority of which have stratigraphic and/or palaeobotanical significance in the mid-late Cretaceous of the eastern Australian region. Although these comprise only a minor proportion of the number of spore-pollen types present in the Upper Cretaceous, they are selected here to illustrate qualitative changes in the microfloral sequence, and to provide a systematic basis for the palyno-stratigraphic zonation (proposed by Dettmann & Playford 1968) of this lesser known part of the Cretaceous section. Clearly therefore this paper is to be regarded as a taxonomic complement to the Dettmann & Playford review paper (in press).

Forms described herein have been recovered from various subsurface sections in Victoria, South Australia, and Queensland. The precise localities of all type and other illustrated species are listed in the systematic section under each species and in the plate explanations. General indication of the known lateral and vertical distribution of each form is also given in the text, in which reference is made to the biostratigraphic units defined on spore-pollen criteria by Dettmann & Playford (1968). In ascending order these units, which span the Cretaceous System of eastern Australia, are: *Crybelosporites stylosus* Zone (?uppermost Jurassic-Valanginian); *Dictyotosporites speciosus* Zone (Valanginian-Upper Aptian), comprising *Cyclosporites hughesi* Subzone and *Crybelosporites striatus* Subzone; *Coptospora paradoxa* Zone (Upper Aptian-Upper Albian); *Tricolpites pannosus* Zone (Upper Albian-?Cenomanian); *Appendicisporites distocarinatus* Zone (?Cenomanian-?Turonian); *Clavifera triplex* Zone (?Turonian-?Coniacian); *Tricolpites* *pachyexinus* Zone (Santonian); and an informal unit containing the *Nothofagidites* Microflora (Santonian-uppermost Cretaceous).

The rock samples upon which this study is based were prepared according to the laboratory techniques described by Dettmann (1963).

Plant microfossil specimens that are illustrated herein have been lodged in one of the following institutions: National Museum of Victoria, Melbourne (specimen number prefixed 'P'); Mines Department of Victoria, Melbourne ('GSV'); Department of Geology & Mineralogy, University of Queensland, Brisbane ('Y'). Vernier readings quoted are those of Leitz Ortholux microscope no. Mx2188 in the University of Queensland. A master slide labelled with reference to this instrument accompanies the collections.

Systematic Palynology

Forms referable to the Anteturma Sporites are here categorized according to the scheme of Dettmann (1963); pollen conforming with the Anteturma Pollenites are classified within Potonié's (1958, 1960) suprageneric groups. Dimensional and nomenclatural terminology adopted by Dettmann (1963) is followed throughout; terms applicable to angiospermous pollen are those of Erdtman (1952). Unless stated otherwise, sizes quoted are based upon twenty suitably orientated specimens.

ANTETURMA SPORITES H. Potonié 1893

TURMA TRILETES Reinsch emend. Dettmann 1963

Suprasubturma ACAVATITRILETES Dettmann 1963

Subturma AZONOTRILETES Luber emend. Dettmann 1963

Infraturma LAEVIGATI Bennie & Kidston emend. Potonié 1956

Genus **Stereisporites** Pflug 1953

TYPE SPECIES (by original designation in Thomson & Pflug 1953: *Stereisporites stereoides* (Potonié & Venitz) Pflug 1953.

DISCUSSION: The Australian Upper Cretaceous spores of *Stereisporites viriosus* sp. nov. possess a distal circumpolar ridge and do not strictly conform with the genus as defined by Potonié (1956) and as used by many subsequent authors (e.g. Manum 1962). *S. viriosus* shows some similarity to *Staplinisporites* Pocock 1962 but lacks a distal polar thickening and radially arranged distal sculptural elevations. The faint distal radial striations exhibited by the species are considered to be a property of exine structure rather than of sculpture.

Krutzsch (1963b) allocates to *Stereisporites* a diversity of morphological types; clearly, those with well-developed sculpture and/or equatorial thickening are more appropriately placed within genera of the Apiculati and the Cingulati.

Stereisporites viriosus sp. nov.

(Pl. 6, fig. 1, 2)

DIAGNOSIS: Microspores radial, trilete, biconvex, the proximal surface pyramidal. Amb convexly subtriangular to subcircular. Laesurae straight, extending to equator with lips that are elevated extensions of exine. Lips 3-5μ high at pole, where they are sometimes flattened against laesurate margins; tapering in height towards equator. Exine 3-4μ thick. Proximal surface smooth to faintly scabrate. Distal surface with very fine, faint, radial striations and low, 2-3μ wide, circumpolar ridge that is concentric with, and two-thirds to five-sixths radius of, amb;

exine adjoining inner margin of ridge has coalescent grana and low verrucae 2-3μ in basal diameter.

DIMENSIONS: Equatorial diameter (15 specimens) 63 (74) 85μ.

HOLOTYPE: Preparation F368/4, 30·3 115·7, GSV 61863. Pl. 6, fig. 1, 2. Distal aspect. Amb convexly subtriangular, diameter 83μ; laesurae 42μ long; lips 5μ high at pole but flattened against laesurae at margins; exine 4μ thick; distal circumpolar ridge 2μ wide, encloses circular area 65μ in diameter; coalescent grana and verrucae adjacent to ridge's inner margin; faint fine striations radially arranged in distal exine.

TYPE LOCALITY: Victoria, F.B.H. Port Campbell No. 4 well, 3821-38 ft (core 7).

COMPARISON: This species is distinct from other Australian members of the genus in its larger size, radial striation, thick exine, and in the form of the distal circumpolar ridge. It resembles *Psilatriletes radiatus* Brenner 1963, the illustrated holotype (Pl. 20, fig. 7) of which appears to possess a distal circumpolar ridge. However, Brenner's species is smaller, has a thinner exine, and lacks well-developed laesurate lips. *Stereisporites maximus* Krutzsch 1963 resembles *S. viriosus* sp. nov. but lacks a distal circumpolar ridge. Other acingulate species assigned by Krutzsch (1963b) to the genus are considerably smaller than *S. viriosus* and differ in distal characteristics.

DISTRIBUTION: This form occurs infrequently, but appears to be of stratigraphic significance in the Upper Cretaceous of the Otway Basin. Its first appearance is within the *Tricolpites pachyexinus* Zone and it extends into the *Nothofagidites* Microflora.

Infraturma MURORNATI Potonié & Kremp 1954

Genus **Cicatricosisporites** Potonié & Gelletich 1933

TYPE SPECIES (by original designation): *Cicatricosisporites dorogensis* Potonié & Gelletich 1933.

DISCUSSION: Spores attributable to *Cicatricosisporites* Potonié & Gelletich 1933 are characterized by distal, equatorial, and sometimes proximal cicatricose sculpture. The majority of species included within the genus have been described from northern hemisphere Cretaceous and Tertiary sediments which often contain an almost overwhelming diversity of cicatricose elements. Many of the species apparently received only superficial examination, and were inadequately described and poorly typified. Because of this, some subsequent authors have incorrectly assigned diverse morphological types to the original specific categories; or have instituted a new taxon where an existing one was applicable. These practices have not only obscured the stratigraphic value of particular forms but have also contributed to the present state of taxonomic disorder that exists in relation to *Cicatricosisporites*. An obvious and relevant example is the allocation of innumerable Cretaceous and Tertiary forms to *C. dorogensis* Potonié & Gelletich 1933, which was originally described from the Eocene of Europe. It is now realized by some authors that few, if any, of the Cretaceous forms remotely resemble *C. dorogensis* (see Hughes & Moody-Stuart 1966, p. 287).

In Australia, the genus is almost invariably present in Lower and mid Cretaceous sediments, and is represented by only about ten distinct morphological types. The first record of Australian *Cicatricosisporites* is that of Cookson (1953b) who instituted the most commonly occurring species, *C. australiensis* (Cookson)

Potonié 1956. Later, Dettmann (1963) described three further species from the Australian Lower Cretaceous, all readily distinguishable from one another and from *C. australiensis*, and thus not forming links in a cicatricose morphological series. A fifth Australian species is described in this paper.

The criteria considered by Dettmann (1963, p. 52) to be of taxonomic significance are: "shape of muri, both in optical section and surface view; width of four adjacent muri and lumina in distal, interradial regions; relative width of muri and lumina; arrangement of muri; length of laesurae; and shape of amb". Some or all of these criteria have been used by Delcourt & Sprumont (1955), Kedves (1960, 1961), and Deák (1963, 1965), in the delineation of northern hemisphere species. Hughes & Moody-Stuart's (1966) study of *in situ* schizaeaceous spores conforming with *Cicatricosisporites* shows convincingly that the shape, spacing, and orientation of the muri together with laesurate features are valid taxonomic grounds for specific discrimination.

Documentation of these features at specific level involves detailed descriptions and adequate illustrations at critical orientations. Clear photographs of well-preserved specimens are of course essential; and supplementary idealized diagrams of the kind introduced by Deák (1963, Pl. 1, fig. 1-3) are most helpful in gaining a three-dimensional appreciation of the sculptural detail. Deák's diagrammatic procedure is applied here (Fig. 1) to the five named Australian species

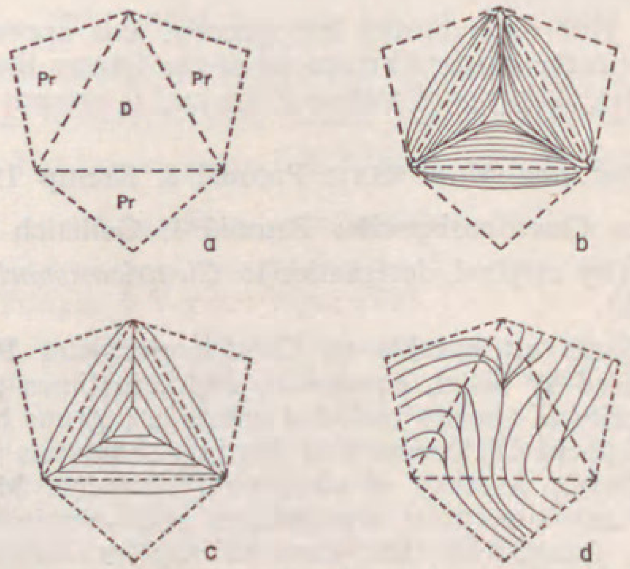

FIG. 1—Schematic distribution and orientation of sculptural elements (muri) in Australian *Cicatricosisporites*. a, Illustrative method (Pr = proximal surface, D = distal surface). b, *C. australiensis* (Cookson) Potonié 1956 and *C. ludbrooki* Dettmann 1963. c, *C. hughesi* Dettmann 1963 and *C. pseudotripartitus* (Bolkhovitina) Dettmann 1963. d, *C. cuneiformis* Pocock 1965. Note: Size of spores and muri not to scale.

of *Cicatricosisporites*. Sculptural patterns of these fall into three groups based upon orientation of muri and/or the nature in which the mural series coalesce or terminate. It can also be noted that species illustrated in Fig. 1b, c, are radially symmetrical; and that in Fig. 1d has bilateral symmetry. It seems possible that symmetry characteristics may enable objective subdivision of the genus.

DISTRIBUTION OF *CICATRICOSISPORITES* IN AUSTRALIA: The precise lower age limit of Australian *Cicatricosisporites* is difficult to establish because most initial appearances of this genus are in strata that lack associated faunal control. In eastern Australia the earliest occurrences are in non-marine sequences that may be either uppermost Jurassic or lowermost Cretaceous in age. To the north, in Papua, Evans (1966b) recorded *Cicatricosisporites* in beds containing a Neocomian fauna, and in immediately underlying sediments. From the Canning Basin, Western Australia, Balme (1957) and Evans (in Henderson, Condon, & Bastian 1963) report the genus at horizons immediately overlying strata containing *Buchia subpallasi* (Krumbeck) and considered to be no younger than Kimeridgian (Veevers & Wells 1961). Further, Mr. B. E. Balme (pers. comm.) has observed forms referable to *Cicatricosisporites* in Upper Jurassic sediments of the Carnarvon Basin (subsurface Barrow Island). Thus in Western Australia at least, the genus makes its initial appearance during late Jurassic times.

The first representatives to appear in eastern Australia are *C. australiensis* and *C. ludbrooki* Dettmann 1963; during the Aptian these are joined by *C. hughesi* Dettmann 1963. In Middle-Upper Albian times several other forms are introduced including *C. pseudotripartitus* (Bolkhovitina) Dettmann 1963 and *C. cuneiformis* Pocock 1965; these are sometimes associated with the inception of *Appendicisporites*.

Cicatricosisporites attains maximum abundance and diversity in late Albian and possibly early Cenomanian times. Its post-Cenomanian occurrences have been documented only in the Otway Basin, where it is infrequent in Turonian and early Senonian sediments. Isolated examples of the genus do occur in the post-Senonian sequence of the Otway Basin but these differ in physical condition (e.g. exine preservation) from the associated forms and are regarded as having been recycled. Moreover they are often accompanied by reworked Permian, Triassic, and early Cretaceous types. Thus it is probable that in Australia, *Cicatricosisporites* did not survive the Senonian.

Cicatricosisporites cuneiformis Pocock 1965

(Pl. 6, fig. 3-5; Fig. 1d)

DESCRIPTION: Microspores trilete, biconvex; amb convexly subtriangular to circular. Laesurae straight, length one-half to three-quarters of spore radius, lipped; lips comprise elevated exinal extensions, 3-4μ high at pole, tapering towards termini of laesurae. Exine 1-1·5μ thick with distal and proximal cicatricose sculpture. Distal sculpture bilaterally symmetrical, comprising a parallel series of muri; muri converge towards equatorial interradial regions and cross equator at 45° angle, to terminate at laesurate margins of each contact face. Proximal sculpture radially arranged. Muri 1·5-2μ wide, *ca.* 1μ high with rounded crests; separated by lumina 1-1·5μ wide. Total span of 4 muri and lumina is 9-11μ in equatorial interradial regions.

DIMENSIONS: Equatorial diameter 41 (50) 60μ; polar diameter (2 specimens) 32, 35μ.

REMARKS AND COMPARISON: The species exhibits overall bilateral symmetry, with a radiosymmetrical proximal face, and a bilaterally symmetrical distal face (Fig. 1d). The sculptural pattern conforms with that depicted by Deák (1963) in her fig. 1. Other forms having similar sculptural and symmetry attributes include Deák's (1963) species *Cicatricosisporites venustus* and *C. furcatus*; the specimens assigned by Pocock (1965) to *C. tersa* (Kara-Murza) and *C. mediostriatus* (Bolkhovitina); and forms that Brenner (1963) illustrated as *C. dorogensis* Potonié & Gelletich and *C. hallei* Delcourt & Sprumont. *C. cuneiformis* Pocock is distinct from these forms however in its size, in the size and shape of muri and lumina and also in the development and extension of laesurate lips. The species may be conspecific with forms allocated by Hedlund (1966, Pl. 3, fig. 5a, b) to *C. dorogensis*.

DISTRIBUTION: The species was described from late Middle Albian strata of Canada (Pocock 1965); similar forms illustrated by Hedlund (1966) are from the Cenomanian of Oklahoma. Although rarely common, the species is widely distributed in Australia in younger horizons of the *Coptospora paradoxa* Zone, and in the *Tricolpites pannosus* and *Appendicisporites distocarinatus* Zones; it is a rare constituent of the *Clavifera triplex* Zone.

Genus **Balmeisporites** Cookson & Dettmann 1958

TYPE SPECIES (by original designation): *Balmeisporites holodictyus* Cookson & Dettmann 1958.

Balmeisporites glenelgensis Cookson & Dettmann 1958
(Pl. 8, fig. 1)

1958 *Balmeisporites glenelgensis* Cookson & Dettmann, p. 43; Pl. 2, fig. 9, 10. [1958a]
1963 *Balmeisporites auriculatus* Hall, p. 433-34; Pl. 5, fig. 12-15.

DIMENSIONS: Equatorial diameter 83 (105) 123μ; overall polar diameter 101 (123) 150μ.

REMARKS: Hall (1963) distinguished his *Balmeisporites auriculatus* from *B. glenelgensis* on slight differences in the size of the mesh formed by the surface reticulum, and on the shape of the equatorial projections. However, such small variations fall within the morphographical range of Australian specimens referred to *B. glenelgensis*.

DISTRIBUTION: Known from the Great Artesian and Otway Basins, eastern Australia, as a component of the *Appendicisporites distocarinatus*, *Clavifera triplex*, and *Tricolpites pachyexinus* Zones (Cookson & Dettmann 1958a; Evans 1962, 1964; Dettmann 1963). Extra-Australian occurrences include Turonian of eastern Siberia (Mtchedlishvili & Samoilovich 1962, 1965), and Cenomanian of Iowa (Hall 1963) and Oklahoma (Hedlund 1966).

Subturma ZONOTRILETES Waltz 1935

Infraturma AURICULATI Schopf emend. Dettmann 1963

Genus **Appendicisporites** Weyland & Krieger 1953

SELECTED SYNONYMY:

1949 *Plicatella* Malyavkina (*pars*), *nom. nud*, p. 60.
1953 *Appendicisporites* Weyland & Krieger, p. 12.
1960 *Plicatella* Malyavkina ex Potonié, p. 50.

TYPE SPECIES (by original designation): *Appendicisporites tricuspidatus* Weyland & Griefeld 1953.

DISCUSSION: This genus was validly instituted by Weyland & Krieger (1953) and incorporates trilete spores having a cicatricose sculpture of one or several sets of parallel muri together with exinal thickenings (appendices) in the equatorial radial regions. The type species possesses three sets of muri that parallel the equator and fuse to form an appendix at each equatorial radial position.

Plicatella was proposed by Malyavkina (1949) but remained invalid until 1960 when Potonié selected a type species, *P. tricacantha* Malyavkina 1949. The latter has all the diagnostic characters of *Appendicisporites*, but Potonié argued that the two genera are separable according to relative length and shape of the equatorial appendices. The present authors do not regard such criteria as providing a sufficiently objective basis for the retention of *Plicatella*.

It should be noted that the type materials of *Appendicisporites* and *Plicatella* have not been illustrated or described in lateral aspect, an orientation which shows most clearly the precise form and extent of the appendices. As illustrated in lateral aspect, the Australian spores here allocated to *Appendicisporites* possess fin-like appendices that are developed in the disto-equatorial regions. In full polar views these appendices appear to be conical in shape and simulate purely equatorial, not distal developments. Several authors (e.g. Bolkhovitina 1961, Markova in Samoilovich *et al.* 1961, Pocock 1965, Burger 1966, Norris 1967) illustrate and describe in varying detail the shape of the appendices as seen in both polar and equatorial aspects, but the great majority of species attributable to *Appendicisporites* are known only in polar aspects.

Appendicisporites is similar in morphology to the spores produced by some extant species of the schizaeaceous fern *Anemia* Swartz, such as those of *A. glareosa* Gardn. (see Bolkhovitina 1961, Pl. 9, fig. 3a-e). In view of this, some authors have indiscriminately applied *Anemia* to dispersed plant microfossils of the *Appendicisporites* type. The spores found in the Cretaceous schizaeaceous megafossil *Pelletieria valdensis* Seward (see Hughes & Moody-Stuart 1966) appear to be comparable to *Appendicisporites* as discussed herein, notably in the development of exinal thickening in equatorial radial and distal regions. Hughes & Moody-Stuart believe however that the thickenings shown by their illustrated forms are due largely to compression during diagenesis. The thickenings of the species described below are considered to be a primary characteristic of the exine; accordingly the form is appropriately assigned to *Appendicisporites*.

Distribution of *APPENDICISPORITES* in Australia: Spores comparable to *Appendicisporites* are unknown in pre-Middle Albian Australian deposits. Their first appearance in the southern Eromanga Basin is within upper Albian-?Cenomanian horizons of the Oodnadatta Formation. They also occur in the Styx Coal Measures of Queensland, which on micro- and megafloral evidence are of Upper (or possibly Middle) Albian age. In the Otway Basin the genus appears initially in association with Upper Albian microfloras and ranges into sediments of Turonian and early Senonian age, but apparently no higher.

Appendicisporites has been reported from Papua (Evans 1966b) in sediments that could be as old as the Lower Albian; and, from the same area, we have observed a variety of representatives in Omati No. 1 well, sample 2, the age of which is Albian (Cookson & Dettmann 1958b).

Appendicisporites distocarinatus sp. nov.

(Pl. 6, fig. 13-20)

Diagnosis: Microspores trilete, biconvex, with strongly arched distal surface; amb convexly subtriangular; semicircular in equatorial view. Laesurae straight, three-quarters radius of amb; enclosed within membraneous lips, 3-4μ high. Exine 1·5-2μ thick, thicker (4-8μ) in disto-equatorial radial regions where 3 fin-like exinal projections are developed. Projections highest and widest at equator (up to 8μ high, 3-4μ wide) tapering in both height and width to within 14-17μ of distal pole where they are absent. Distal and equatorial exine sculptured with 3 series of 7-10 muri disposed parallel to equator and coalescing with thickened projections in disto-equatorial radial regions. Muri have straight or tapering sides (1·5-2μ high) and flat crests; equal in width or slightly wider (2-2·5μ) than adjacent lumina (1·5-2·5μ). Four muri and intervening lumina span 14-17μ. Contact faces smooth.

DIMENSIONS: Equatorial diameter (including projections) 41 (57) 75μ; polar diameter (11 specimens) 27 (41) 49μ.

HOLOTYPE: Preparation F270/5, 41·7 114·6, GSV 61871. Pl. 6, fig. 16-18. Distal aspect. Amb convexly triangular, diameter 55μ; laesurae 22μ long; sculpture of 3 series of 8 parallel muri, each murus 2μ wide, 1·5μ high, spaced 2μ apart; 4 muri and lumina span 15μ in distal interradial region; fin-like projections 24μ long, 6μ high and 5μ wide at equator; exine 1·5 thick in equatorial interradial region.

TYPE LOCALITY: Victoria, F.B.H. Fergusons Hill No. 1 well, at 2427-37 ft (core 5).

COMPARISON: A close sculptural resemblance is evident between this species and the spores assigned to *Appendicisporites tricornitatus* Weyland & Griefeld 1953 by Hedlund (1966), Pl. 4, fig. 4a, b) and by Singh (1964, Pl. 2, fig. 1). However, the form and extent of the appendices of the latter specimens are not precisely known, thus precluding accurate comparison with *A. distocarinatus* sp. nov. The type of *A. erdtmanii* Pocock 1965 appears to be similar to the Australian species in arrangement of muri and in form of the fin-like appendices, but has considerably wider (up to 4μ) muri and narrower (1μ) lumina. Other similar forms include *A. potomacensis* Brenner 1963, which has more strongly developed proximal sculpture and wider spaced muri; *A. stylosus* (Thiergart) Deák 1963, which has broader, closely spaced muri and higher disto-equatorial appendices; *Plicatella problematica* Burger 1966, which has considerably higher (4-5μ) muri; and *Anemia macrorhyza* (Malyavkina) Bolkhovitina 1953, which, as described by Bolkhovitina (1961) and Markova (in Samoilovich *et al.* 1961), possesses sculpture on the contact faces.

DISTRIBUTION: Sometimes common in the *Tricolpites pannosus* and *Appendicisporites distocarinatus* Zones, rarely present in the uppermost part of the *Coptospora paradoxa* Zone. Evans (1966b, Pl. 1, fig. 4) has figured a possible representative of this species from his *Odontochitina operculata* Zone (Albian) at Archer River, Papua.

Infraturma TRICRASSATI Dettmann 1963

Genus **Clavifera** Bolkhovitina 1966

1953 *Gleichenia* Smith: Bolkhovitina (*pars*) p. 53-5.
1959 *Gleicheniidites* Ross subgenus *Triplexisporis* Krutzsch, p. 114.
1961 *Gleicheniidites* Grigorjeva (*pars*) in Samoilovich *et al.*, p. 59-63. [non *Gleicheniidites* Ross]
1966 *Clavifera* Bolkhovitina, p. 68.

TYPE SPECIES (by original designation): *Clavifera triplex* (Bolkhovitina) Bolkhovitina 1966.

DISCUSSION: Bolkhovitina's (1966) diagnosis of this genus embraces gleicheniaceous-type trilete spores having essentially smooth exines in which radial and interradial thickenings (distinct from one another) are developed equatorially. These features are displayed by the Australian spores here allocated to the type species. However, as discussed subsequently, the exine is probably only weakly thickened in the equatorial radial regions; the apparent strong development of radial thickening appears to be related to the shape characteristics of the distal surface.

As the subgenus *Triplexisporis* Krutzsch 1959 has not been elevated to generic status, the correct name for the spores at generic level is *Clavifera*. Bolkhovitina notes that *Gleicheniidites* Ross ex Delcourt & Sprumont 1955 lacks radial thickenings at the equator and as such is separable from her *Clavifera*. She suggests affinity between *Clavifera* and extant members of the Gleichenioideae on the grounds of spore morphology.

Clavifera triplex (Bolkhovitina) Bolkhovitina 1966
(Pl. 6, fig. 6-8)

SELECTED SYNONYMY:

1953 *Gleichenia triplex* Bolkhovitina, p. 54; Pl. 8, fig. 10-13.
1959 *Gleicheniidites* (*Triplexisporis*) *triplex* (Bolkhovitina) Krutzsch, p. 114.
1961 *Gleicheniidites triplex* (Bolkhovitina) Grigorjeva in Samoilovich *et al.*, p. 63; Pl. 16, fig. 8-10.
1966 *Clavifera triplex* (Bolkhovitina) Bolkhovitina, p. 68; Pl. 1, fig. 6 a-c.

DESCRIPTION: Microspores trilete; distal surface strongly arched or flattened with 3 arcuate folds that project beyond equator giving 'knobbed' or bulbous appearance to amb apices; proximal surface pyramidal. Amb triangular with straight or slightly concave sides. Laesurae straight, length approximately equal to spore radius; with membraneous lips 1-2μ high. Exine 1-2μ thick, thicker at equator. Equatorial thickenings constitute interradial crassitudes, 4-6μ wide, with sinuous periphery. In equatorial radial regions exine is also slightly thickened; here the true degree of thickening is best observed in specimens lacking distal arcuate folds (i.e. in relatively uncompressed examples). Specimens with well-developed distal folds show an apparently abrupt thickening at each amb apex; these 'thickenings' are, however, exaggerated in polar view by oblique optical sections through the distal arcuate folds. Proximal exine smooth adjacent to laesurae; faintly scabrate in semi-circular area located in each equatorial interradial region. Distal exine smooth.

DIMENSIONS: Equatorial diameter 27 (39) 49μ.

COMPARISON AND AFFINITY: The Australian specimens described above appear to be identical with *Clavifera triplex* (Bolkhovitina) Bolkhovitina 1966 as originally diagnosed and as reported by Grigorjeva (in Samoilovich *et al.* 1961) and Döring (1965). '*Gleicheniidites*' *posttriplex* Döring 1965 appears to differ from *C. triplex* only in shape, a feature which Skarby (1964) considers to be unreliable in the discrimination between gleicheniaceous spore species. Wider interradial crassitudes and the presence of thickening at amb apices distinguish *C. triplex* from spores assigned by Balme (1957) and Dettmann (1963) to *Gleicheniidites* cf. *G. circinidites* (Cookson) Dettmann 1963.

On the basis of spore morphology, Bolkhovitina (1966) allies *C. triplex* with the extant Gleichenioideae, in particular with *Dicranopteris rigida* (Kunze) Nakai.

DISTRIBUTION: Widely distributed in U.S.S.R. with records from Aptian-Paleocene sediments (Bolkhovitina 1953, 1966; Samoilovich *et al.* 1961). Döring (1965) reports *C. triplex* from the German Neocomian. In the eastern Australian Cretaceous the species is a consistent component of the *Clavifera triplex* Zone with less frequent representation in the *Tricolpites pachyexinus* Zone and in sediments containing the *Nothofagidites* Microflora.

Genus **Ornamentifera** Bolkhovitina 1966

1953 *Gleichenia* Smith: Bolkhovitina (*pars*), p. 53-5.
1959 *Gleicheniidites* Ross subgenus *Peregrinisporis* Krutzsch, p. 114.

1961 *Gleicheniidites* Grigorjeva (*pars*) in Samoilovich *et al.*, p. 59-63. [non *Gleicheniidites* Ross]
1966 *Ornamentifera* Bolkhovitina, p. 69.

TYPE SPECIES (by original designation): *Ornamentifera echinata* (Bolkhovitina) Bolkhovitina 1966.

DISCUSSION: *Ornamentifera* was diagnosed by Bolkhovitina (1966) to incorporate trilete spores of presumed gleicheniaceous affinity, having interradial thickenings at the equator and sculptural projections of spinae, coni, &c. Morphologically comparable types had previously been allocated to the extant plant genus *Gleichenia* Smith by Bolkhovitina (1953 and later); to the subgeneric category *Peregrinisporis* by Krutzsch (1959) and Döring (1965); and to *Gleicheniidites* Grigorjeva (non Ross) by Grigorjeva in Samoilovich *et al.* (1961). Of these spore taxa, only *Ornamentifera* bears a correct generic name, because *Peregrinisporis* has subgeneric status, and *Gleicheniidites* Grigorjeva is a later homonym of *Gleicheniidites* Ross ex Delcourt & Sprumont 1955 (see Dettmann 1963, p. 65; Skarby 1964, p. 64).

The type species of *Ornamentifera*, *O. echinata* (Bolkhovitina) Bolkhovitina 1966, which is also the designated type of *Gleicheniidites* Grigorjeva, is regarded by Skarby (1964, p. 64) as being 'very similar to the spore (sic) described by Ross as *Anemiidites echinatus* (1949, p. 32; Pl. 1, fig. 17-18)'. If in fact these two forms prove to be identical then *O. echinata* (Bolkhovitina) is both a later homonym and synonym of Ross's species; and *Anemiidites* Ross 1949 would have priority over *Ornamentifera* Bolkhovitina 1966. However it should be noted that Ross's illustrations do not convincingly show equatorial interradial thickenings and as morphological doubt exists *Ornamentifera* is used herein.

The type of *Trubasporites* Vavrdova 1964 differs from *Ornamentifera* in having a foveolate exine.

Ornamentifera sentosa sp. nov.
(Pl. 6, fig. 9-12)

DIAGNOSIS: Microspores trilete, tricrassate, biconvex, the distal surface strongly arched. Amb triangular with straight or slightly concave sides and acutely rounded angles. Laesurae straight, length approximating spore radius, with membraneous lips, 1-2μ high. Exine 2-3μ thick, thicker at interradial regions of equator where 5-8μ broad crassitudes are developed. Crassitudes have distinctly serrate equatorial margins. Proximal contact areas bear diverse, usually coalescent sculptural elevations with flat, rounded, or pointed crests (2-3μ high) and irregular bases (2-6μ in diameter); elevations thus comprise verrucae, rugulae, spinae, and bacula. On distal surface, similar coalescent sculptural elevations are developed but confined to a concavely triangular area which has its centre at the pole and its apices in the equatorial radial regions.

DIMENSIONS: Equatorial diameter 36 (43) 52μ.

HOLOTYPE: Preparation F368/6, 37·1 119·8, GSV 61867. Pl. 6, fig. 11, 12. Proximal aspect. Amb triangular, diameter 44μ; laesurae 22μ long; proximal (contact) areas with discrete or coalescent, irregularly based sculptural projections, 1-5μ in basal diameter; distal exine sculptured with coalescent elevations in a triangular polar area, the sides of which parallel amb; equatorial crassitudes 6μ in maximum width, margins incised.

TYPE LOCALITY: Victoria, F.B.H. Port Campbell No. 4 well at 3821-38 ft (core 7).

COMPARISON: Species assigned by Bolkhovitina (1966) to *Ornamentifera* possess sculptural projections (spinae, coni, grana) that are discrete and uniformly distributed, and are thus distinct from *O. sentosa* sp. nov. with its differentially distributed, coalescent sculptural elements. Döring's (1965) species *Trubasporites nudowensis* and *T. verrutorosus* occasionally have coalescent projections but these constitute verrucae and rugulae with rounded crests. *Gleicheniidites* (*Peregrinisporis*) f. sp. A. of Döring (1965) has less conspicuous equatorial thickening than *O. sentosa* and its distal sculpture is uniformly distributed.

DISTRIBUTION: The species is restricted to horizons of the *Tricolpites pachyexinus* Zone and those containing the *Nothofagidites* Microflora.

Genus **Camarozonosporites** Pant ex Potonié 1956 emend. Klaus 1960

TYPE SPECIES (by subsequent designation of Potonié 1956, p. 65): *Camarozonosporites cretaceus* (Weyland & Krieger) Potonié 1956.

DISCUSSION: The type species is clearly tricrassate (thickened in the equatorial interradial regions) although its sculptural features have not yet been fully described or clearly illustrated. Klaus regarded the genus as rugulate distally and with reduced proximal sculpture; this emendation is followed here. Krutzsch (1959) used the genus in a similar sense and later (1963a) recognized that his *Hamulatisporis* is synonymous with Klaus's emended version of *Camarozonosporites*.

Of the Australian spores here referred to *Camarozonosporites* those of *C. amplus* (Stanley) comb. nov. and *C. ohaiensis* (Couper) comb. nov. show only slight exinal thickening in their equatorial radial regions. The other species, *C. bullatus* Harris 1965, recorded by us from the Victorian Upper Cretaceous sequence, has strongly thickened interradial crassitudes, but its distal exine possesses features not explicitly diagnosed for *Camarozonosporites*.

Camarozonosporites amplus (Stanley) comb. nov.

(Pl. 7, fig. 1-3)

1965 *Rugulatisporites* sp. indet.: Harris, Pl. 25, fig. 12 (no description). [1965a]
1965 *Hamulatisporis amplus* Stanley, p. 242; Pl. 29, fig. 1-6.
1966 *Perotrilites rugulatus* Couper: Gray & Groot, p. 124; Pl. 42, fig. 13, 14.

DESCRIPTION: Microspores trilete, biconvex; amb convexly subtriangular to circular. Laesurae straight, length at least three-quarters spore radius. Exine 2-3μ thick; thicker in equatorial interradial regions where narrow (3-6μ) crassitudes are developed. Distal and equatorial exine sculptured with low, strongly sinuous elevations (rugulae) that occasionally anastomose to enclose irregularly elongate lumina 2-8μ in maximum length; elevations 3-4μ broad at base, 1-2μ high, with broadly rounded crests. Circular area (diameter 6-8μ) about distal pole devoid of rugulae but with coarse grana. Proximal sculpture consists of low (*ca.* 1μ high), narrow (1-2μ wide) elongate sinuous elevations that emanate from laesurate margins and occasionally bifurcate towards equator.

DIMENSIONS: Equatorial diameter 55 (73) 109μ.

REMARKS AND COMPARISON: The holotype (Stanley 1965, Pl. 29, fig. 1-3) is situated in an off-polar aspect, but its illustrations show the narrow interradial crassitudes and a circular granulate area of exine in the distal polar region. Closely comparable features are exhibited by the specimens here assigned to the species.

Camarozonosporites helenensis Krutzsch 1963 and *Lygodium reticulatiformis*

Bolkhovitina 1961 may be conspecific with *C. amplus* (Stanley) comb. nov., but neither species apparently is granulate about the distal pole. *C. amplus* is distinct from *Perotrilites rugulatus* Couper 1958 which has a thicker exine and narrower flat-topped rugulae; and from *C. hammenii* van Ameron 1965 which has a stronger development of equatorial thickening.

AFFINITY: *C. amplus* is morphologically similar to extant *Lycopodium* spores belonging to Group V of Harris (1955).

DISTRIBUTION: Previously recorded from late Upper Cretaceous and Lower Paleocene of Dakota (Stanley 1965), Senonian of Delaware and New Jersey (Gray & Groot 1966), and Middle Paleocene of Australia (Harris 1965a). The similar forms described by Krutzsch (1963a) and Bolkhovitina (1961) are from Oligocene-Pliocene of Europe and Santonian of Kazakhstan respectively. Although rarely abundant, *C. amplus* is almost invariably a constituent of the *Tricolpites pachyexinus* Zone and of the *Nothofagidites* Microflora.

Camarozonosporites ohaiensis (Couper) comb. nov.

(Pl. 7, fig. 6, 7)

1953 *Trilites ohaiensis* Couper (*pro parte*), p. 30; Pl. 3, fig. 23.
1960 *Trilites ohaiensis* Couper emend. Couper, p. 41; Pl. 2, fig. 7, 8 (Emendation based upon type and additional specimens. [1960a]

DESCRIPTION: Microspores trilete, biconvex; amb subcircular to circular. Laesurae straight, extending about half the distance to equator. Exine 1·5-3μ thick; differentially thickened at equator where narrow (3-5μ wide) interradial crassitudes are developed. Distal and equatorial exine with low (1-2μ high), narrow (1-2μ broad), closely spaced, sinuous rugulae that occasionally anastomose to enclose irregularly elongate lumina 2-5μ in length. Circular area (10-12μ in diameter) about distal pole devoid of rugulae but granulate. Proximal exine with markedly reduced rugulate sculpture.

DIMENSIONS: Equatorial diameter 60 (75) 99μ.

COMPARISON AND AFFINITIES: The species differs from *Camarozonosporites amplus* (Stanley) comb. nov. in possessing relatively shorter laesurae and narrower, more closely spaced sculptural elevations. The large size and narrow interradial crassitudes enable distinction of *C. ohaiensis* (Couper) comb. nov. from other members of the genus. *Lycopodium*-spores assigned to Harris's (1955) Group V display similar sculptural and equatorial features.

DISTRIBUTION: Described originally from New Zealand where it is apparently restricted to sediments of probable Senonian and Maestrichtian age (Couper 1960a, p. 41; table 2). *C. ohaiensis* is a rare component of the *Tricolpites pachyexinus* Zone and of the *Nothofagidites* Microflora.

Camarozonosporites bullatus Harris 1965

(Pl. 7, fig. 4, 5)

1965 *Camarozonosporites bullatus* Harris, p. 82; Pl. 26, fig. 2, 3. [1965a]
1965 Gen. et sp. indet. Harris, Pl. 25, fig. 20 (no description). [1965a]

DESCRIPTION: Microspores trilete, biconvex; amb convexly subtriangular. Laesurae straight, length three-quarters spore radius, lipped; lips constitute low, 3-4μ wide exinal thickenings. Exine conspicuously tricrassate at equator; crassitudes 9-14μ wide in interradial regions, narrowing to 4μ at radii. Distal exine with a set of 3 low muri (3-5μ wide) that parallel sides of spore cavity and coalesce radially to enclose a triangular to subcircular area (diameter 12-20μ)

about distal pole. Distal polar exine thickened with a small circular crassitude 3-5μ in diameter. Exine otherwise smooth or faintly scabrate.

DIMENSIONS (10 specimens): Overall equatorial diameter 45 (57) 69μ; diameter of spore cavity 36 (43) 55μ.

REMARKS AND COMPARISON: The distal elevations that enclose a triangular to subcircular area in which a polar crassitude is developed are clearly evident in the holotype (Harris 1965a, Pl. 26, fig. 3) and in another specimen illustrated by Harris (Pl. 25, fig. 20) that is here assigned to *Camarozonosporites bullatus*.

Retitriletes triradiatus Pierce 1961 (p. 30; Pl. 1, fig. 18) strongly resembles *C. bullatus*, such that the two species may well prove to be conspecific.

The species is not altogether conformable with *Camarozonosporites* as emended by Klaus (1960). Assignment to *Coronatispora* Dettmann 1963 or *Zebrasporites* Klaus 1960 was considered but the former is characterized by comprehensive foveolate-reticulate sculpture, and the latter has radially arranged distal elevations.

AFFINITY: Harris (1965a) suggested a morphological resemblance to spores of *Lycopodium*.

DISTRIBUTION: Described from the Middle Paleocene of western Victoria (Harris 1965a) and recorded (Harris 1965b) from the Lower Tertiary of Queensland. In the present study it was found in the Otway Basin in sediments containing the late Cretaceous *Nothofagidites* Microflora. The similar spores of *Retitriletes triradiatus* occur in the early Upper Cretaceous of Minnesota (Pierce 1961).

Infraturma CINGULATI Potonié & Klaus emend. Dettmann 1963

Genus **Kraeuselisporites** Leschik emend. Jansonius 1962

TYPE SPECIES (by original designation): *Kraeuselisporites dentatus* Leschik 1955.

Kraeuselisporites jubatus sp. nov.
(Pl. 7, fig. 8-12)

DIAGNOSIS: Microspores trilete, zonate, biconvex; amb convexly subtriangular to subcircular. Spore cavity outline (polar view) triangular with straight to slightly convex sides. Laesurae straight, more or less reaching equator, with membraneous lips that are highest at pole (16-20μ) and have finely serrate crests. Exine 1-2μ thick, smooth to faintly scabrate proximally and distally. Distal exine additionally sculptured with 3-6μ high, membraneous muri that have strongly spinose crests; spine-like elements 2-3μ high, 1-3μ in maximum basal diameter. Muri anastomose about pole to delimit 1 to 5 pentagonal-hexagonal lumina (diameter 10-20μ), freely terminate towards inner margin of zona. Zona membraneous, 14-25μ wide (uniformly wide on given specimen), faintly scabrate, equatorial margin finely serrate.

DIMENSIONS: Overall equatorial diameter 70 (85) 110μ; diameter of spore cavity 41 (48) 60μ. Polar diameter (2 specimens) 46μ, 49μ.

HOLOTYPE: Preparation F235/1, 47·4 119·9, GSV 61879. Pl. 7, fig. 10, 11. Distal aspect. Amb subcircular, diameter 74μ; spore cavity convexly triangular, diameter 49μ; laesurae straight, 27μ long, with membraneous elevated lips; distal reticulum of high (up to 11μ), membraneous muri having deeply incised crests;

muri anastomose to form one lumen surrounding pole and terminate freely in radial regions near inner margin of zona.

TYPE LOCALITY: Victoria, Mines Dept. Vic. Timboon No. 5 bore, 3500-04 ft (core BB).

COMPARISON: The species differs from *Kraeuselisporites majus* (Cookson & Dettmann) Dettmann 1963 in being larger and in having high, widely spaced, membraneous muri that enclose one or several lumina in the distal polar area.

DISTRIBUTION: Present, and sometimes common, in the *Tricolpites pannosus* and *Appendicisporites distocarinatus* Zones; infrequent in the *Clavifera triplex* Zone and the uppermost horizons of the *Coptospora paradoxa* Zone.

TURMA MONOLETES Ibrahim 1933

Suprasubturma ACAVATOMONOLETES Dettmann 1963

Subturma AZONOMONOLETES Luber 1935

Infraturma LAEVIGATOMONOLETI Dybová & Jachowicz 1957

Genus **Laevigatosporites** Ibrahim 1933

TYPE SPECIES (by original designation): *Laevigatosporites vulgaris* (Ibrahim) Ibrahim 1933.

Laevigatosporites major (Cookson) Krutzsch 1959

(Pl. 8, fig. 2)

For synonymy see Harris 1965a, p. 83.

DIMENSIONS: Equatorial diameter: length 52 (65) 74μ, breadth 38 (45) 50μ. Polar diameter 30 (42) 49μ.

DISTRIBUTION: First appearances in the uppermost part of the *Coptospora paradoxa* Zone; infrequent throughout the Upper Cretaceous. Cookson (1947) and Harris (1965a) report the species from the Lower Tertiary of Kerguelen and Victoria respectively.

TURMA HILATES Dettmann 1963

Genus **Aequitriradites** Delcourt & Sprumont emend. Cookson & Dettmann 1961

TYPE SPECIES (by original designation): *Aequitriradites dubius* Delcourt & Sprumont emend. Delcourt, Dettmann, & Hughes 1963.

Aequitriradites hispidus sp. nov.

(Pl. 7, fig. 13)

1963 *Aequitriradites* sp. Dettmann, p. 95; Pl. 22, fig. 14, 15.

DIAGNOSIS (Dettmann 1963, p. 95): 'Microspores zonate; inaperturate or hilate; amb of spore cavity triangular with straight sides. Exine 2·5-3μ thick; distal polar exine composed of discrete, polygonal-based (2-3μ diameter), low (2μ high) coni and may be ruptured (hilate); remainder of exine sculptured with small (1μ basal diameter, 1-2μ high), sparsely disposed spinules. Zona membraneous, 14-17μ wide, irregular in outline. Tetrad mark occasionally present in form of narrow, low ridges which extend from equator to just beyond inner margin of zona'.

DIMENSIONS (15 specimens): Overall equatorial diameter 70 (83) 100μ; diameter of spore cavity 55 (66) 78μ.

HOLOTYPE: The specimen illustrated by Dettmann (1963, Pl. 22, fig. 15) and in present study is here designated the holotype. Preparation D234/5, P22136. Distal aspect. Amb irregular, diameter 98μ; spore cavity diameter 78μ, outline triangular; exine 3μ thick, spinulate except in an area (15μ in diameter) about distal pole where discrete polygonal-based coni are developed; tetrad mark comprises low ridges extending from equator 5-7μ towards pole; zona membraneous.

TYPE LOCALITY: South Australia, Kopperamanna No. 1 bore, at 2970 ft.

COMPARISON: This species differs from others assigned to *Aequitriradites* in its larger size and sculptural details, and in having a spore cavity that is triangular in polar view.

DISTRIBUTION: Known only from the *Crybelosporites stylosus* Zone of the Lake Frome Embayment, Eromanga Basin, and Surat Basin (Dettmann 1963; Evans 1966c; present study).

ANTETURMA POLLENITES Potonié 1931

TURMA SACCITES Erdtman 1947

Subturma DISACCITES Cookson 1947

Genus **Dacrydiumites** Cookson ex Harris 1965

TYPE SPECIES (by subsequent designation of Harris 1965a, p. 86): *Dacrydiumites florinii* Cookson & Pike 1953.

Dacrydiumites florinii Cookson & Pike 1953
(Pl. 8, fig. 3)

DIMENSIONS: Corpus: breadth 30 (38) 44μ; length 34 (42) 50μ; depth 25 (32) 37μ. Saccus: breadth 17 (22) 25μ; length 25 (32) 39μ.

DISTRIBUTION: Uncommon in the Upper Cretaceous of the Otway Basin, where it is observed in upper horizons containing the *Nothofagidites* Microflora. Evans (1966a, p. 27) notes a slightly older occurrence 'within or just before' his *Xenikoon australis* Zone, i.e. within the oldest horizons that have yielded the *Nothofagidites* Microflora. *D. florinii* occurs sometimes frequently in the Australian Tertiary (Cookson & Pike 1953, Harris 1965a).

Genus **Phyllocladidites** Cookson ex Couper 1953

TYPE SPECIES (by subsequent designation of Couper 1953, p. 38): *Phyllocladidites mawsonii* Cookson 1947.

Phyllocladidites mawsonii Cookson 1947
(Pl. 8, fig. 4)

DIMENSIONS: Corpus: breadth 22 (30) 42μ; length 22 (31) 39μ; depth 20 (25) 31μ. Saccus: breadth 8 (11) 14μ; length 12 (14) 17μ.

REMARKS: The Upper Cretaceous pollen here assigned to *Phyllocladidites mawsonii* Cookson appear to be comparable to the species as diagnosed by Cookson and as used by Couper (1953, 1960a) and Harris (1965a). They are smaller than, and lack the well-defined saccus reticulum of, *P. reticulosaccatus* Harris 1965.

DISTRIBUTION: In its initial south-eastern Australian appearances the species is associated with foraminiferal Zonule B of Taylor (1964). Within this zonule it has wide distribution in the Otway Basin. It becomes increasingly common in Senonian and later strata, assuming importance in Lower Tertiary sediments (Cookson 1953a, Harris 1965a). Extra-Australian occurrences include Lower Tertiary of Kerguelen (Cookson 1947); Senonian and Lower Tertiary of Antarctica (Cranwell 1964, fig. 2); and Senonian-Eocene or Oligocene of New Zealand (Couper 1953, 1960a).

TURMA PLICATES Naumova. emend. Potonié 1960

Subturma TRIPTYCHES Naumova emend. Potonié 1960

Genus **Tricolpites** Cookson ex Couper 1953

TYPE SPECIES (by subsequent designation of Couper 1953, p. 61): *Tricolpites reticulatus* Cookson 1947.

DISCUSSION: The genus is used here in Couper's (1953) sense for tricolpate grains having variable size, shape, and sculptural features.

Tricolpites pachyexinus Couper 1953
(Pl. 8, fig. 9, 10)

DIMENSIONS: Equatorial diameter 20 (24) 31μ.

REMARKS: The Australian grains here referred to *Tricolpites pachyexinus* Couper are somewhat smaller and have a generally thinner exine (1·5-3·0μ) than those described by Couper (1953, 1960a).

DISTRIBUTION: Rarely abundant, but a consistent element of Australian Upper Cretaceous assemblages of the *Tricolpites pachyexinus* Zone and the *Nothofagidites* Microflora. Couper (1953, 1960a) emphasizes the stratigraphic significance of the species (Senonian, Maestrichtian, and Danian of New Zealand).

Tricolpites gillii Cookson 1957
(Pl. 8, fig. 14)

DIMENSIONS: Equatorial diameter 20 (24) 31μ.

DISTRIBUTION: Cookson (1957) and Harris (1965a) report the species from Victorian sediments of Upper Cretaceous and Lower Tertiary age. In the present study it was found infrequently in Victorian Upper Cretaceous sediments that contain the *Nothofagidites* Microflora.

Tricolpites pannosus sp. nov.
(Pl. 8, fig. 5-8)

DIAGNOSIS: Pollen grains tricolpate, isopolar, prolate, to oblate spheroidal. Amb subcircular to convexly subtriangular. Exine 1μ thick, nexine thicker than sexine, finely and faintly scabrate in surface view (LO pattern). Colpi with ragged margins, 5-8μ long in polar view, 9-15μ long in equatorial view.

DIMENSIONS: Equatorial diameter 15 (24) 30μ; polar diameter 19 (22) 26μ.

HOLOTYPE: Preparation D359/2, 31·5 118·7, Y.353. Pl. 8, fig. 6. Polar aspect. Amb subcircular, diameter 19μ; colpi 5μ long, with ragged margins; exine 1μ thick, faintly scabrate.

TYPE LOCALITY: South Australia, Haddon Downs No. 5 well, 465 ft.

REMARKS AND COMPARISON: *Tricolpites pannosus* sp. nov. possesses a thin delicate exine that is often imperfectly preserved in sediments containing mildly carbonized organic matter. It resembles *T. fissilis* Couper 1960, but is considerably smaller and has shorter colpi. *T. errugatus* Hedlund 1966 is smaller than *T. pannosus* and its colpi extend the full length of the grain.

The specimen figured by Evans (1966a, Pl. 1, fig. 24) as *T. fissilis* shows the characters of *T. pannosus*, and its exine is torn about the polar ends of two colpi.

DISTRIBUTION: Usually abundant in its initial appearances where it is associated with youngest occurrences of *Coptospora paradoxa* (Cookson & Dettmann) Dettmann 1963 in sediments of late Albian (or ?Cenomanian) age. The species extends into the late Upper Cretaceous but has not been recorded from Tertiary sediments.

Tricolpites sabulosus sp. nov.

(Pl. 8, fig. 11-13)

DIAGNOSIS: Pollen grains isopolar, oblate, tricolpate (?tricolporate), anguloaperturate. Amb triangular with straight to strongly concave sides. Colpi short, narrow slits, 4-7μ long in polar view. Exine 1-1·5μ thick, 2-layered; nexine smooth, thicker than sexine which is granulate, with coarse and fine grana uniformly distributed over entire surface.

DIMENSIONS: Equatorial diameter 26 (32) 38μ; polar diameter (5 specimens) 20 (21) 23μ.

HOLOTYPE: Preparation F119/4, 34·1 118·4, GSV 61888. Pl. 8, fig. 11, 12. Polar aspect. Amb convexly triangular, diameter 30μ; colpi 4-5μ long; exine 1·5μ thick; grana 0·5-1μ in basal diameter, regularly distributed over whole surface.

TYPE LOCALITY: Victoria, F.B.H. Flaxmans No. 1 well, 4479-96 ft (core 5).

REMARKS AND COMPARISON: Grains situated in lateral aspect suggest that the apertures are colpate rather than colporate. Comparison may be drawn with *Beaupreaidites verrucosus* Cookson 1950, which differs sculpturally in possessing a finely pitted sexine that bears irregularly distributed grana and verrucae; and with *Tricolpites gillii* Cookson 1957 which is smaller than *T. sabulosus* and has much finer sculpture. The fossil pollen of *Psittacopollis* van Ameron 1965 and the grains of the living *Symplocus* (see Erdtman 1952, p. 424-5; fig. 242C) are superficially similar in morphology to *T. sabulosus* but their apertures are clearly tricolporate.

DISTRIBUTION: Sometimes common, and with restricted vertical distribution, in Otway Basin late Cretaceous sediments. It occurs only in the *Nothofagidites* Microflora.

TURMA POROSES Naumova emend. Potonié 1960

Subturma TRIPORINES Naumova emend. Potonié 1960

Genus **Triorites** Cookson ex Couper 1953

TYPE SPECIES (by subsequent designation of Couper 1953, p. 60): *Triorites magnificus* Cookson 1950.

DISCUSSION: Potonié (1960), perhaps justifiably, restricted the genus to those forms possessing sunken apertures and clavate-baculate sculpture. Of the many species that Cookson (1950, 1957), Cookson & Pike (1954), and Couper (1953, 1960a) assigned to *Triorites*, only *T. magnificus* Cookson 1950 and *T. clavatus* Cookson 1957 conform with the Potonié emendation. The remaining species were considered by Potonié to be morphologically similar to other validly instituted genera. It is apparent from the literature however that many triorate form genera are mutually overlapping and some are insecurely founded.

As an exhaustive review of triorate forms does not fall within the scope of this paper, Couper's (1953) diagnosis of *Triorites* is followed without modification. Moreover it is now known that Mr. W. K. Harris (pers. comm.) will publish a full review of *Triorites*, and it is understood that, in this, forms described by Cookson and Pike as *T. edwardsii* are to be allocated to a new generic category.

Triorites minor Couper 1953
(Pl. 8, fig. 22)

DIMENSIONS: Equatorial diameter 14 (20) 25μ.

DISTRIBUTION: Couper (1953) described this species from New Zealand where according to his subsequent (1960a) paper it ranges from Senonian to Upper Oligocene. *Triorites minor* is widely distributed, and in places is common, in the Upper Cretaceous of the Otway Basin. Its first appearances are within the *Appendicisporites distocarinatus* Zone and it extends into sediments containing the *Nothofagidites* Microflora.

Triorites edwardsii Cookson & Pike 1954
(Pl. 8, fig. 21)

1954 *Triorites edwardsii* Cookson & Pike (*pars*), p. 214-5; Pl. 2, fig. 101, 105, 106 (*non* fig. 102, 103, 104, 107).
1965 *Triorites edwardsii* Cookson & Pike 1954: Harris p. 94; Pl. 28, fig. 1. [1965a]

DIMENSIONS: Equatorial diameter 25 (33) 41μ.

REMARKS: Forms here referred to *Triorites edwardsii* possess strongly developed thickenings about the apertures and as such appear to be morphologically distinct from certain of the specimens allocated to the species by Cookson & Pike. A full morphological and taxonomic account of the species and related Australian forms is already in preparation (W. K. Harris, pers. comm.) and thus no description is provided herein. The specimen figured by Evans (1966a, Pl. 1, fig. 18), from his *Nelsoniella aceras* Zone, is now regarded by him (pers. comm.) as distinct from species here assigned to *T. edwardsii* and to aff. *T. edwardsii*.

DISTRIBUTION: Rarely common, but of undoubted stratigraphic importance, in Victorian Upper Cretaceous and Lower Tertiary. Its first appearances are in upper horizons of Taylor's (1964) Zonule A (Senonian); and Harris (1965a) illustrated a specimen from the Pebble Point Formation (Middle Paleocene). Examples depicted by Cookson & Pike (1954, Pl. 2, fig. 101, 105, 106) are from bores at Lal Lal and from the Pebble Point Formation. Mtchedlishvili & Samoilovich (1962) record, but do not describe or illustrate, *Triorites edwardsii* from the Senonian of Siberia.

aff. **Triorites edwardsii** Cookson & Pike 1954
(Pl. 8, fig. 20)

1954 *Triorites edwardsii* Cookson & Pike (*pars*), p. 104-5; Pl. 2, fig. 103, 107.

DIMENSIONS: Equatorial diameter (6 specimens) 20 (25) 29μ.

REMARKS: Uppermost Cretaceous pollen here assigned to the above category are comparable to certain specimens referred by Cookson & Pike to their *Triorites edwardsii*. However, the form is distinct from *T. edwardsii* s. st. in being unthickened about the apertures.

DISTRIBUTION: A rare type in the Upper Cretaceous, where it is restricted to the upper part of the sequence containing the *Nothofagidites* Microflora.

Genus **Proteacidites** Cookson ex Couper 1953

TYPE SPECIES (by subsequent designation of Couper 1953, p. 42): *Proteacidites adenathoides* Cookson 1950.

Proteacidites scaboratus Couper 1960

(Pl. 8, fig. 19)

DIMENSIONS: Equatorial diameter 25 (29) 35μ.

REMARKS: The south-eastern Australian specimens appear to be identical with those described by Couper (1960a, p. 52; Pl. 5, fig. 22, 23) under the above designation, apart from their slightly smaller size. Harris (1965a, p. 92; Pl. 29, fig. 13, 14) illustrates and comments upon examples which he says have 'a thicker exine around the apertures'. The specimens figured by Evans (1966a, Pl. 1, fig. 11, 20) as *Proteacidites* sp. and *Triorites minor* Couper 1953 respectively may be representatives of *P. scaboratus* Couper.

DISTRIBUTION: Described from New Zealand where it is reported to be restricted to Upper Senonian (or Maestrichtian) and Danian sediments (Couper 1960a); and reported by Harris (1965a) from the Lower Paleocene of Victoria. In the Otway Basin, it is fairly common in the *Tricolpites pachyexinus* Zone and in the *Nothofagidites* Microflora. Its initial appearances coincide with those of *Tricolpites pachyexinus* Couper 1953 and *Hexagonifera vermiculata* Cookson & Eisenack 1961 in Taylor's (1964) Zonule A (Senonian).

Proteacidites amolosexinus sp. nov.

(Pl. 8, fig. 15-18)

DIAGNOSIS: Pollen grains triorate, isopolar, peroblate, anguloaperturate. Amb triangular with straight to weakly convex or concave sides. Ora circular, 4-6μ in diameter. Exine 2-3μ thick, thickening slightly about apertures, 2-layered. Nexine 1·5-2·5μ thick, smooth. Sexine delicate, less than 1μ thick; sculpture finely granulate-pilate, forming a fine-meshed reticulum in surface view; lumina *ca.* 1μ in diameter, slightly smaller about apertures. The delicate sexine is sometimes absent, often imperfectly preserved. In imperfectly preserved specimens, the surface sexine pattern is finely granulate or almost smooth, and a radial lineation of the grana about the apertures is sometimes discernible (Pl. 8, fig. 16).

DIMENSIONS: Equatorial diameter 40 (54) 77μ.

HOLOTYPE: Preparation F363/1, 50·1 126·6, GSV 61893. Pl. 8, fig. 17, 18. Polar aspect. Amb triangular, diameter 46μ; ora 6μ in diameter; exine 2·5μ thick; nexine 2μ thick; sexine *ca.* 0·5μ thick, finely reticulate in surface view.

TYPE LOCALITY: Victoria, F.B.H. Port Campbell No. 4 well, 2892-2912 ft (core 2).

COMPARISON: The species is similar to *Proteacidites franktonensis* Couper 1960, but differs in having smaller ora and finer sculptural elements. *P. rectomarginis* Cookson 1950 has larger ora and thicker sexine.

DISTRIBUTION: Widely distributed in the Otway Basin where it occurs only in the *Nothofagidites* Microflora.

Subturma POLYPORINES Naumova emend. Potonié 1960

Genus **Nothofagidites** Erdtman ex Potonié 1960

TYPE SPECIES (by subsequent designation of Potonié 1960, p. 132): *Nothofagidites flemingii* (Couper) Potonié 1960.

DISCUSSION: From studies of extant *Nothofagus* material, Cranwell (1939, 1963, 1964), Cookson (1946), Cookson & Pike (1955), and Couper (1953, 1960a, b) have established that *Nothofagus*-pollen is widespread, often abundant, in Tertiary sediments of Australasia, Antarctica, and South America. Couper (1953, 1960a, b) and Cranwell (1963, 1964) have also confirmed that pollen of *Nothofagus* exists in Upper Cretaceous (Senonian and later) sequences of New Zealand and Antarctica.

The *Nothofagus*-like pollen described below are therefore of palaeobotanical and phytogeographic significance, for their occurrence in Senonian deposits of the Otway Basin establishes a pre-Tertiary occurrence of *Nothofagus* in south-eastern Australia.

These Victorian Upper Cretaceous pollen, assigned to *Nothofagidites senectus* sp. nov., are morphologically comparable with pollen of the *Nothofagus brassi* group (Cookson & Pike 1955). However, because of the reasons cited by Potonié (1960, p. 133) the grains are referred to the form generic category *Nothofagidites* Erdtman ex Potonié, rather than to the natural genus *Nothofagus* Blume.

Nothofagidites senectus sp. nov.
(Pl. 8, fig. 23-25)

DIAGNOSIS: Pollen grains, isopolar, polyorate, oblate to peroblate. Ora comprise 4-6 (usually 5) 'colpoid' apertures with straight sides and broadly rounded ends; length of apertures 5-8μ in lateral view, 2-4μ in polar view; oral rims unthickened. Amb subcircular to polygonal; sides convex or (rarely) straight between ora. Exine *ca.* 0·75μ thick, finely spinulate; spinules *ca.* 0·5μ high, 0·5μ in basal diameter, spaced 0·5-1μ apart over entire surface.

DIMENSIONS: Equatorial diameter 19 (23) 30μ; polar diameter 12 (14) 16μ.

HOLOTYPE: Preparation F119/9, 36·9 114·9, GSV 61898. Pl. 8, fig. 23, 24. Polar aspect. Amb pentagonal (interoral sides convex), diameter 19μ; exine *ca.* 0·75μ thick, spinulate; spinules 0·5μ in basal diameter, 0·5μ high, comprehensively and uniformly distributed; 5 ora, each 2-3μ long (polar view).

TYPE LOCALITY: Victoria, F.B.H. Flaxmans No. 1 well, 4479-96 ft (core 5).

REMARKS AND COMPARISON: The specimen illustrated by Evans (1966a, Pl. 1, fig. 16) almost certainly belongs to *Nothofagidites senectus* sp. nov. The species is characterized by small grains lacking thickened rims around the apertures. These features indicate close relationship with extant grains of the *Nothofagus brassi*-type as described by Cookson & Pike (1955).

Nothofagidites senectus resembles *Nothofagus waiparensis* Couper 1960, but the exine of the latter is said to be thickened about the apertures. It is readily distinguishable from *Nothofagidites emarcidus* (Cookson) Harris 1965 in having shorter colpoid apertures and uniformly distributed spinules. *Nothofagus diminuta* Cookson 1959 has longer, more closely spaced spinules and its amb is concave between the apertures.

DISTRIBUTION: The species is widely distributed, though rarely common, in the late Cretaceous sediments of the Otway Basin containing the *Nothofagidites* Microflora. Its first appearances are within the upper part of Taylor's (1964) Zonule A (Senonian). Evans (1966a, p. 27) reports a similar first appearance within or just preceding his *Xenikoon australis* Zone.

Genus **Stephanoporopollenites** Pflug ex Pflug & Thomson 1953

TYPE SPECIES (by subsequent designation of Pflug & Thomson in Thomson & Pflug 1953, p. 90): *Stephanoporopollenites hexaradiatus* (Thiergart) Pflug & Thomson 1953.

Stephanoporopollenites obscurus Harris 1965
(Pl. 8, fig. 26-28)

DIMENSIONS: Equatorial diameter 27 (31) 38μ; polar diameter (3 specimens) 20, 27, 28μ.

DISTRIBUTION: Rarely common, but occurs in the majority of Upper Cretaceous samples examined from the Otway Basin. Harris (1965a) described the form from Victorian Lower Tertiary strata.

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Explanation of Plates

PLATE 6

All figures × 500 unless otherwise specified; from unretouched negatives

Fig. 1, 2—*Stereisporites viriosus* sp. nov. Holotype; proximal and distal foci.

Fig. 3-5—*Cicatricosisporites cuneiformis* Pocock 1965. Preparation B266/4, 33·3 118·6.

Y.352; Qld. Mines Dept. bore Styx N.S.24, 471 ft 3, 4, Proximal and distal foci, 5, Portion of distal exine (× 1000).

Fig. 6-8—*Clavifera triplex* (Bolkhovitina) Bolkhovitina 1966. 6, 7, Proximal and distal foci; preparation F336/1, 28·8 125·4, GSV 61864; Mines Dept. Vic. Mepunga No. 7 bore, 3413-28 ft 8, Median focus; preparation F237/14, 30·9 117·7, GSV 61865; Mines Dept. Vic. Timboon No. 5 bore, 3286-97 ft.

Fig. 9-12—*Ornamentifera sentosa* sp. nov. 9, 10, Proximal and distal foci; preparation F368/11, 38·4 122·1, GSV 61866; F.B.H. Port Campbell No. 4 well, 3821-38 ft. 11, 12, Holotype, proximal and median foci.

Fig. 13-20—*Appendicisporites distocarinatus* sp. nov. F.B.H. Fergusons Hill No. 1 well, 2427-37 ft 13, Proximal focus, preparation F270/9, 35·5 107·6, GSV 61868, 14, Distal focus, preparation F270/4, 33·5 117·6, GSV 61869. 15, Portion of distal exine (× 1000), preparation F270/13, 35·5 119·4, GSV 61870. 16-18, Holotype; Proximal and distal foci, and distal sculptural detail (× 1000), respectively. 19, 20 × 1000), lateral aspect; preparation F270/8, 33·9 120·6, GSV 61872.

PLATE 7

All figures × 500; from unretouched negatives

Fig. 1-3—*Camarozonosporites amplus* (Stanley) comb. nov. 1, 2, Proximal and distal foci; preparation F338/2, 18·3 118·7, GSV 61873; Mines Dept. Vic. Mepunga No. 7 bore, 3017-25 ft. 3, Median focus; preparation F240/6, 26·4 121·5, GSV 61874; Mines Dept. Vic. Timboon No. 5 bore, 2949-63 ft.

Fig. 4, 5—*Camarozonosporites bullatus* Harris 1965. Proximal and distal foci; preparation F317/3, 40·8 120·5, GSV 61875; Mines Dept. Vic. Wangoom No. 6 bore, 3065-72 ft.

Fig. 6, 7—*Camarozonosporites ohaiensis* (Couper) comb. nov. Mines Dept. Vic. Timboon No. 5 bore, 2949-63 ft. 6, Proximal focus; preparation F240/13, 31·9 115·8, GSV 61876. 7, Median focus; preparation F240/7, 34·7 114·7, GSV 61877.

Fig. 8-12—*Kraeuselisporites jubatus* sp. nov. 8, 9, Proximal and distal foci; preparation F235/5, 35·9 120·8, GSV 61878; Mines Dept. Vic. Timboon No. 5 bore, 3500-04 ft. 10, 11, Holotype; proximal and distal foci. 12, Lateral aspect; preparation F301/2, 48·1 124·2, GSV 61880; Mines Dept. Vic. Wangoom No. 2 bore, 3968-72 ft.

Fig. 13—*Aequitriradites hispidus* sp. nov. Holotype; distal focus.

PLATE 8

All figures × 750 unless otherwise specified; from unretouched negatives

Fig. 1—*Balmeisporites glenelgensis* Cookson & Dettmann 1958. Median focus (× 125); preparation F240/8, 34·1 110·1, GSV 61881; Mines Dept. Vic. Timboon No. 5 bore, 2949-63 ft.

Fig. 2—*Laevigatosporites major* (Cookson) Krutzsch 1959. Lateral aspect (× 500); preparation F338/9, 30·6 122·2, GSV 61882; Mines Dept. Vic. Mepunga No. 7 bore, 3017-25 ft.

Fig. 3—*Dacrydiumites florinii* Cookson & Pike 1953. Distal focus; preparation F316/1, 37·9 116·7, GSV 61883; Mines Dept. Vic. Wangoom No. 2 bore, 2834-39 ft.

Fig. 4—*Phyllocladidites mawsonii* Cookson 1947. Distal focus; preparation F119/8, 40·2 110·6, GSV 61884; F.B.H. Flaxmans No. 1 well, 4479-96 ft.

Fig. 5-8—*Tricolpites pannosus* sp. nov. 5, Polar view; preparation F235/1, 55·9 122·0 GSV 61885; Mines Dept. Vic. Timboon No. 5 bore, 3500-04 ft. 6, Holotype; polar view. 7, polar view, preparation D359/1, 45·8 119·2, Y.354; South Australia, Haddon Downs No. 5 bore, 465 ft. 8, Lateral aspect; preparation D359/2, 30·8 123·6, Y.355; loc. as fig. 7.

Fig. 9, 10—*Tricolpites pachyexinus* Couper 1953. 9, Polar view; preparation F367/7, 39·4 121·0, GSV 61886; F.B.H. Port Campbell No. 4 well, 3519-36 ft. 10, Oblique aspect; preparation F103/1, 36·6 118·8, GSV 61887; F.B.H. Port Campbell No. 1 well, 4862-69 ft.

Fig. 11-13—*Tricolpites sabulosus* sp. nov. 11, 12, Holotype; surface view and optical section of exine. 13, Polar view, preparation F119/3, 31·4 111·7, GSV 61889; loc. as fig. 4.

Fig. 14—*Tricolpites gillii* Cookson 1957. Polar view; preparation F119/7, 42·2 119·5, GSV 61890; loc. as fig. 4.

Fig. 15-18—*Proteacidites amolosexinus* sp. nov. Polar views (all × 500). 15, Preparation F108/2, 42·1 125·5, GSV 61891; F.B.H. Port Campbell No. 1 well, 3997-4009 ft. 16, Corroded specimen having imperfectly preserved sexine; preparation F367/11, 35·5 117·3, GSV 61892; loc. as fig. 9. 17, 18, Holotype.

Fig. 19—*Proteacidites scaboratus* Couper 1960. Polar view; preparation F367/10, 39·9 120·5, GSV 61894; loc. as fig. 9.

Fig. 20—Aff. *Triorites edwardsii* Cookson & Pike 1954. Polar view; preparation F363/1, 51·0 115·8, GSV 61895; F.B.H. Port Campbell No. 4 well, 2892-2912 ft.

Fig. 21—*Triorites edwardsii* Cookson & Pike 1954 *pars*. Polar view; preparation F118b/3, 35·1 121·3, GSV 61896; F.B.H. Flaxmans No. 1 well, 4309-16 ft.

Fig. 22—*Triorites minor* Couper 1953. Polar view; preparation F129/2, 43·9 120·9, GSV 61897; F.B.H. Flaxmans No. 1 well, 5543-46 ft.

Fig. 23-25—*Nothofagidites senectus* sp. nov. Polar views. 23, 24, Holotype. 25, Six-pored example; preparation F119/6, 28·8 126·0, GSV 61899; loc. as fig. 4.

Fig. 26-28—*Stephanoporopollenites obscurus* Harris 1965. 26, 27, High focus and optical section of oblique polar view; preparation F036/4, 50·6 120·0, GSV 61900; F.B.H. Eumeralla No. 1 well, 2835-49 ft. 28, Lateral aspect; preparation F401/1, 39·1 108·9, GSV61901; Mines Dept. Vic. Latrobe No. 1 bore, 1627-31 ft.