PLANT MICROFOSSILS FROM THE LOWER TRIASSIC OF WESTERN AUSTRALIA

by B. E. BALME

ABSTRACT. Seventeen species of plant microfossils, made up of nine spores, six pollen grains, and two bodies of uncertain function, are described from the Kockatea Shale, a marine formation of early Triassic age, occurring in the Perth Basin, Western Australia. Nine new species are proposed and a new form genus *Lundbladispora* is instituted to include certain trilete spores of probable lycopodiaceous affinities. Species belonging to the genus *Taeniaesporites* (Leschik) are described for the first time from the southern hemisphere.

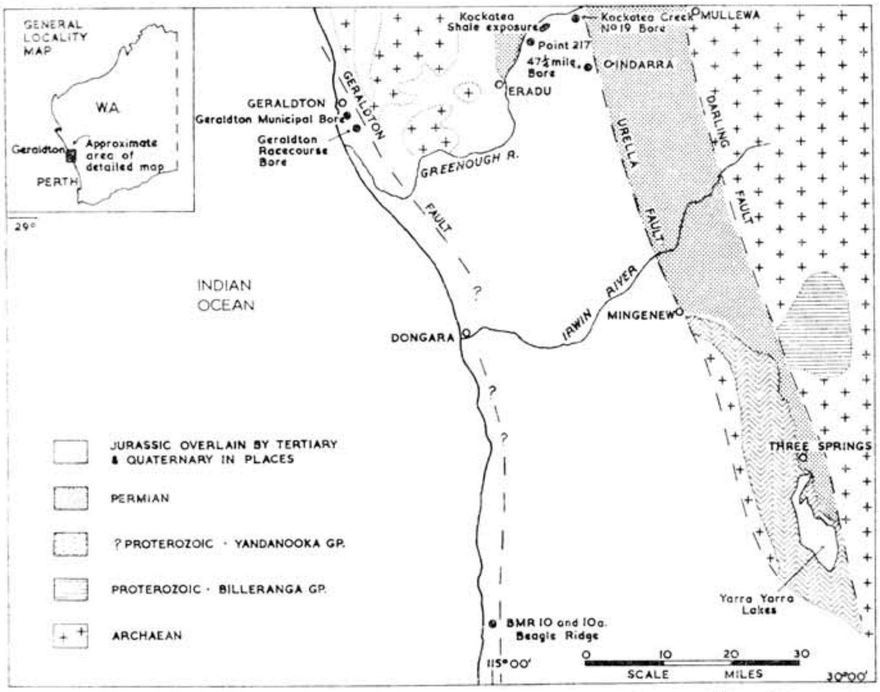
Microfloras from the Kockatea Shale differ completely from any known to occur in Australian Permian sediments and are considered to represent a specialized plant community which succeeded the *Glossopteris*-Flora at the end of Permian time. They resemble in some respects Upper Permian and Triassic microfloras from Europe, and Scythian assemblages from the Peace River area in Canada. The palaeofloristic and stratigraphical implications of the palynological data are discussed.

PERMIAN and older rocks in the northern part of the Perth Basin, Western Australia, are, in some places, overlain by the Kockatea Shale, a marine deposit of considerable stratigraphic importance. At two localities it contains ceratitic ammonoids and other marine invertebrate fossils of Lower Triassic (Scythian) age. It is, therefore, the only Triassic sequence in Australia which can so far be dated unequivocally in terms of the Austrian marine standard. The Kockatea Shale consists predominantly of greenish, grey, and red shale with occasional siltstone and sandstone units. It has been known for many years in bores near Geraldton, but its Triassic age was unsuspected until 1957, when Dr. P. E. Playford discovered ammonoids in a core from 1,470 feet in the Geraldton Racecourse Bore. One of these has been identified as an ophiceratid of uppermost Permian or basal Triassic age (Glenister and Furnish 1961). A rich and well-preserved assemblage of spores, pollen grains, and microplankton was recovered from the same core and on the basis of this, a correlation was proposed between the Kockatea Shale and the Blina Shale in the Canning Basin (McWhae, Playford, Lindner, Glenister, and Balme 1957). Refinement of the earlier age determinations became possible in 1959 following the drilling, by the Commonwealth Bureau of Mineral Resources, of a stratigraphic test bore at Beagle Ridge, about 80 miles south of Geraldton. This bore (BMR 10) penetrated over 1,000 feet of Kockatea Shale, and cores from the unit yielded marine faunas at several horizons. Palaeontologists of the Bureau of Mineral Resources, Canberra, are still studying this material, but identifications of some of the key genera have recently been published by Dickins (*in* Dickins, McTavish, and Balme 1961). They include the ophiceratid *Subinyoites* and the pelecypods *Claraia* and cf. *Bakevillia*, and demonstrate the Scythian age of the Kockatea Shale.

Proved exposures of the Kockatea Shale are known only from a small area in the upper reaches of the Greenough River (text-fig. 1) although it may correlate with part of the Chapman Group of Arkell and Playford (1954). It has been recognized in bores at Geraldton, Beagle Ridge, and in the vicinity of Indarra, a small township on the Mullewa road about 45 miles east of Geraldton. In coastal bores the Kockatea Shale has a thickness of up to 1,000 feet, but it thins rapidly to the east of Geraldton and is less

[Palaeontology, Vol. 6, Part 1, 1963, pp. 12–40, pl. 4–6.]

than 300 feet thick in bores close to the Urella Fault. Erosion in the Triassic and Lower Jurassic may partly explain this easterly attenuation but it seems that the Scythian shoreline lay to the west of the present line of the Darling Fault. Spores and pollen grains are most abundant and best preserved in sediments from the Eradu–Indarra district and it is unlikely that these were deposited far from the Lower Triassic coastline.



TEXT-FIG. 1. Generalized geological map of part of the Perth Basin showing localities of the samples examined.

Nevertheless, all samples so far examined from the Kockatea Shale contain hystrichosphaerids, usually in enormous numbers, and there can be little doubt that the unit is marine, even in its easterly occurrences.

Poor exposures and a scarcity of reliable sub-surface data obscure the stratigraphical relationships of the Kockatea Shale. It is clearly transgressive on the Permian, for it overlies Artinskian marine strata in Beagle Ridge Bore and continental Upper Permian sediments at Indarra. Below Geraldton it rests directly on Archaean metasediments.

Triassic beds of probable continental origin overlie the Kockatea Shale in Beagle Ridge Bore; elsewhere it is succeeded by marine or continental Jurassic.

Microfloras from the Kockatea Shale are intrinsically interesting, but their excellent preservation and the precision with which they can be dated, give them an especial stratigraphical and phytogeographical importance. They throw light on the fate of the *Glossopteris*-Flora in Western Australia and can be fairly closely compared with assemblages occurring in Lower Triassic sediments in other parts of the world. The emerging palynological evidence hints, therefore, that plant microfossils may provide a means of placing an upper limit on the Permian System in Australia.

Source and storage of samples. Seventeen samples from the Kockatea Shale provided the material for the present account. They were obtained from five boreholes and a shallow water-well in the northern part of the Perth Basin and their general localities are shown in text-fig. 1. Further details of the samples and their origin are as follows:

Well at Point 217 (28° 34′ 30″ S., 115° 7′ 10″ E.)
Sample 44070. Pale greenish-grey claystone. Depth 30 ft.
47¼ Mile Peg Bore (28° 39′ 55″ S., 115° 15′ 20″ E.)
Sample 43813. Greenish-grey shale. Depth 741–749 ft.
Sample 43815. Pale grey claystone. Depth 808–945 ft.
Sample 43816. Pale greenish-grey shale. Depth 948–968 ft.
Sample 43819. Brownish-grey sandy shale. Depth uncertain.
Sample 43820. Brownish-grey sandy shale. Depth uncertain.
Kockatea Creek No. 19 Bore (28° 33′ 40″ S., 115° 13′ 30″ E.)
Sample 43305. Pale greenish-grey claystone. Depth 139–190 ft.
Geraldton Racecourse Bore (28° 47′ 36″ S., 114° 39′ 16″ E.)
Sample 44342. Pale grey claystone. Depth 1,273 ft.
Sample 44497. Greenish-grey, red-stained, claystone. Depth 1,465 ft.
Geraldton Municipal Bore (28° 46′ 42″ S., 114° 35′ 50″ E.)
Sample 47563. Pale greenish-grey sandy shale. Depth 1,012–1,096 ft.
Sample 47564. Yellowish sandy shale. Depth 1,177–1344 ft.
Sample 47565. Pale greenish-grey calcareous shale. Depth 1,346–1,386 ft.
BMR. 10 (Beagle Ridge) Bore (29° 49′ 38″ S., 114° 58′ 30″ E.)
Sample 43938. Pale grey sandy siltstone. Depth 2,131–2,141 ft.
Sample 43939. Grey micaceous shale. Depth 2,223–2,233 ft.
Sample 43940. Grey micaceous shale with ammonoids. Depth 2,405–2,415 ft.
Sample 43941. Grey sandy shale. Depth 2,802–2,812 ft.
Sample 43942. Grey calcareous shale. Depth 3,203–3,213 ft.

Sample numbers in the above list, and throughout the text, refer to the general collection of the Department of Geology, University of Western Australia. Small reference samples of each of the sediments treated are lodged in this repository as are the slides of the type specimens and spore assemblages. The original samples, which provided the source of reference material, are held either by the Commonwealth Bureau of Mineral Resources, Canberra, or by the Geological Survey of Western Australia. Type specimens are mounted singly in glycerine jelly and sealed with bees-wax.

Techniques. Acid insoluble microfossils were extracted by boiling the crushed, carbonate-free sediment in 50 per cent. hydrofluoric acid and treating the residue by the modified Schulze method described by Balme and Hassell (1962). The residues were lightly stained with Safranin 'O' and examined by means of a Leitz 'Ortholux' microscope using a Pl Apo Oel 100/1·32 objective for detailed study of morphography. Photomicrographs were taken on Ilford Pan F film using the same oil immersion objective. They were developed in Kodak D76 and printed on Ilford 'Plastika' paper.

Acknowledgements. The author is indebted to the Director of the Commonwealth Bureau of Mineral Resources, Canberra (Mr. J. M. Rayner), for supplying material from the Beagle Ridge Bore and for permitting publication of the data obtained. The former Government Geologist of Western Australia (Mr. H. A. Ellis) also generously permitted the author access to the collections of the Geological Survey. Thanks are due to the Management of West Australian Petroleum Proprietary Limited, who virtually initiated the investigation and at all times were co-operative and helpful. The author is particularly grateful for the factual information and stimulating discussion provided by two geologists of that Company, Dr. P. E. Playford and Mr. S. P. Willmott. Dr. J. Jansonius, Calgary, Dr. Wilhelm Klaus, Vienna, and Mr. N. F. Hughes, Cambridge, have been patient and helpful correspondents, and the photomicrographs are the work of Mr. K. Bauer.

SYSTEMATIC PALYNOLOGY

With the exception of a short paper by Hennelly (1958) and the recent contribution on megaspores by Dettmann (1961), no formal papers have been published on Australian Triassic palynology. Preliminary descriptions of microfloras from the Leigh Creek and Ipswich coals have been presented by Taylor (1953) and de Jersey (1949) respectively, but neither of these authors attempted to apply a binomial nomenclature to their plant microfossils. In the northern hemisphere, however, palynologists have been increasingly occupied with Upper Permian and Triassic sediments during the past five or six years, and papers from Russia, western Europe, and North America have proved surprisingly relevant to the present account. Malyavkina (1953) was the first to describe a varied assemblage of Triassic spores. These came from the Keuper of the Russian Pre-Urals, but Malyavkina used no photographs and adopted a rather informal taxonomy. Her account is, therefore, less useful as a systematic reference than the subsequent papers of Potonié and Klaus (1954), Leschik (1955, 1956), Klaus (1960), and Jansonius (1962).

Leschik's papers are well illustrated and provide a basis for the classification and comparison of isolated spores and pollen grains of Triassic age. Nevertheless, they contain certain nomenclatural inconsistencies, and some of the new genera and species proposed were poorly defined or based on misinterpretation of morphographic features. Critical revision of Leschik's systematics has been undertaken by Potonié (1958), Klaus (1960), and Jansonius (1962), but no stable taxonomy has yet evolved. This applies particularly to the classification of disaccate pollen grains assignable to the Infraturma Striatiti of Pant. Further discussion of this and other taxonomic problems will be found in subsequent sections of the present paper.

Taxonomic criteria are based on the publication of Potonié and Kremp (1954), and subsequent papers by Potonié. Certain of the suprageneric form taxa proposed by Potonié and Kremp and later authors have also been adopted. However, no attempt has been made to apply the all-embracing scheme of higher form categories favoured by many recent workers. This system has certain advantages in bringing apparent order to the bewildering variety of trilete spores in Upper Devonian and Carboniferous microfloras. Nevertheless, it seems unwise, at this stage of our knowledge of the morphology and affinities of fossil spores, to obscure possible natural relationships by over-rigid codification.

Terminology. With few exceptions morphographic terms have been taken from the glossaries provided by Potonié and Kremp (1955) and Couper (1958). *Amb* was defined by Erdtman as the outline of a spore or pollen grain viewed from the direction of the polar axis, and the term *cavate* is used in the sense of Dettmann (1961), to describe a spore in which the exoexine and intexine have become detached.

Measurements, unless otherwise stated, are taken on specimens preserved in full polar view, and the dimensional nomenclature is based on that of Couper (1958, text-fig. 7, p. 101).

Anteturma SPORITES H. Potonié

Turma TRILETES Reinsch

Genus PUNCTATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. Punctatisporites punctatus Ibrahim, Upper Carboniferous, West Germany.

Punctatisporites fungosus sp. nov.

Plate 4, figs. 10, 11

Holotype. Slide 47544. *Paratype.* Slide 47545.

Diagnosis. Amb circular, periphery smooth, off-polar compressions common and exine frequently ruptured. Trilete, scar distinct, laesurae straight and often of unequal length but seldom extending more than about half-way to the equatorial margin. Groove of commissure visible in some specimens. Exine very thick, with fine irregularly distributed pits visible under oil immersion. Narrow anastomosing pits and channels sometimes developed, particularly in the area of the proximal pole (Pl. 4, fig. 11). These channels are probably due to partial destruction of the exine, either during fossilization or as a result of the maceration process.

Dimensions. Diameter 83–119 μ; 15 specimens.

Locus typicus. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. Latin *fungosus* = 'spongy', from the texture of the exine.

Description. Holotype diameter 114 μ in slightly off-polar view. Exine 6–7 μ thick with irregularly disposed shallow pits less than 1 μ in diameter. The pitting is slightly more pronounced in the vicinity of the proximal pole.

Remarks and comparisons. Punctatisporites fungosus may be distinguished from the Lower Permian species *P. gretensis* Balme and Hennelly by its larger size and relatively thicker, finely pitted exine. It occurred, usually in small numbers, in all the samples examined and has also been found in the Blina Shale (Canning Basin, Western Australia).

Known stratigraphical range in Australia. Lower Triassic.

Genus OSMUNDACIDITES Couper 1953

Type species. Osmundacidites wellmanii Couper, Upper Jurassic, New Zealand.

EXPLANATION OF PLATE 4

Magnifications $\times 600$

Figs. 1–2. *Osmundacidites senectus.* 1, Holotype. 2, Paratype 47542.

Fig. 3. *Tetraporina sp.* cf. *Azonotetraporina? horologia* Staplin.

Figs. 4–5. cf. *Schizosporis sp.*

Fig. 6. *Lycopodiacidites pelagius*, holotype.

Fig. 7. *Lycopodiacidites sp.*

Figs. 8–9. *Lundbladispora brevicula.* 8, Paratype 47547. 9, Holotype.

Figs. 10–11. *Punctatisporites fungosus.* 10, Holotype. 11, Paratype, showing pitted and channelled exine.

Osmundacidites senectus sp. nov.

Plate 4, figs. 1, 2

Holotype. Slide 47541. *Paratypes*. Slides 47542 and 47543.

Diagnosis. Amb circular, periphery finely notched. Trilete, scar distinct, laesurae straight and extending about three-quarters of the distance to the distal margin. Exine 1–2 μ thick, sculptural elements small and varied, including cones, grana, and sub-baculate processes. Basal diameter of individual processes 1–3 μ, height 1–2 μ. Off-polar compressions common, suggesting that the spore was originally spherical, and the flattened exine usually has one or more broad, crescentic, folds.

Dimensions. Diameter 58–79 μ; 25 specimens.

Locus typicus. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. Latin *senectus* = 'aged'.

Description. Holotype preserved in full polar view. Diameter 72 μ, exine about 2 μ thick with irregularly distributed but fairly closely spaced sculptural elements. Among these, short cones predominate but grana and sub-baculae also occur; eighty-nine processes were counted around the periphery. In the holotype sculptural elements were less prominent in the region of the proximal pole, but this reduction was not obvious in the paratypes.

Remarks and comparisons. This species is assigned to *Osmundacidites* because of the variability in form of its sculptural elements and its general conformity with Couper's diagnosis. Some hesitation is felt in extending so considerably the stratigraphical range of a 'half-natural' genus, but Klaus (1960) has assigned Carnian spores to *Osmundacidites* and the known antiquity of the family Osmundaceae may be invoked in justification of the use of Couper's genus.

Osmundacidites senectus has finer and more regular sculptural elements than *O. wellmanii* Couper or *O. comaumensis* (Cookson) and is larger than *O. alpina* Klaus. It is fairly common in most samples from the Kockatea Shale and occurs also in the Blina Shale and in the Erskine Sandstone, a continental Triassic formation which overlies the Blina Shale. Occasional specimens have also been found in sediments from the Narrabeen Group in New South Wales.

Known stratigraphic range in Australia. Lower to (?) Middle Triassic.

Genus LYCOPODIACIDITES (Couper) R. Potonié 1956

Type species. *Lycopodiacidites bullerensis* Couper, Upper Jurassic, New Zealand.

Lycopodiacidites pelagius sp. nov.

Plate 4, fig. 6

Holotype. Slide 47551. *Paratype*. Slide 47550.

Diagnosis. Amb subtriangular to circular, periphery undulate. Trilete, scar clearly defined, laesurae straight and extending about three-quarters of the distance to the equatorial margin. Exine 4–7 μ thick on the distal side, slightly thinner on the proximal. Proximal face smooth or slightly rugulose. Distal face sculptured into low, rounded, irregular and rather indistinct ridges. Ridges 2–7 μ wide and 1–3 μ high, occasionally anastomosing to form a crude reticulum but usually separate from one another, giving the distal surface an irregular rugose pattern.

Dimensions. Diameter 86–100 μ; 10 specimens.

Locus typicus. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. Latin *pelagius* = 'pertaining to the sea', from the wavy appearance of the distal surface.

Description. Holotype diameter 97 μ, exine 6–8 μ thick, measured in optical section along the equatorial margin. Laesurae about 35 μ long and closed along their entire length. Distal ridges 1–3 μ high and 3–6 μ wide, occasionally anastomosing and enclosing rounded lumina.

Remarks and comparisons. Lycopodiacidites kuepperi Klaus, from the Upper Triassic of Austria, is slightly smaller and has more clearly defined distal rugae. *L. pelagius* was not common in the Kockatea Shale, but occasional specimens were recognized in most samples. It has not been found in any other deposit.

Known stratigraphic range in Australia. Lower Triassic.

Lycopodiacidites sp.

Plate 4, fig 7

Figured specimen. Slide 47557.

Description. Amb strongly rounded triangular, periphery undulate. Trilete, scar strongly defined, laesurae extending about half-way to the equatorial margin. Edges of laesurae turned outwards forming a triangular opening at the proximal pole. Exine about 6 μ thick, with an indistinctly rugose distal surface; proximal face perforate. Perforations less than 1 μ in diameter, irregularly distributed, and particularly concentrated around the proximal polar area.

Dimensions. Diameter 79–91 μ; 5 specimens.

Locality of figured specimen. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

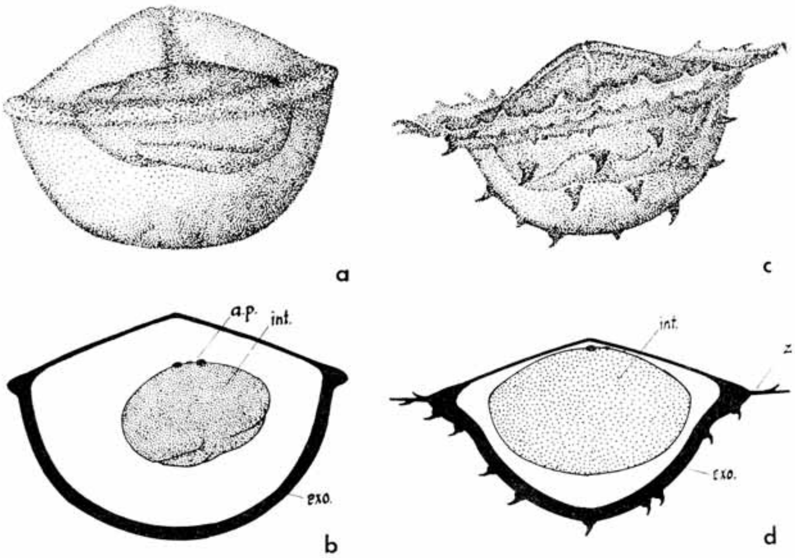
Remarks and comparisons. Lycopodiacidites sp. may represent *L. pelagius* in a corroded condition, but it was too rare adequately to assess this possibility. It has not therefore been named formally, but specimens maintaining the characters described above occurred sporadically in several of the assemblages.

Known stratigraphic range in Australia. Lower Triassic.

Genus KRAEUSELISPORITES (Leschik) Jansonius 1962

Type species. Kraeuselisporites dentatus Leschik, Keuper, Switzerland.

Generic name. The inclusion of *Kraeuselisporites* in the Unterabteilung Zonaletes by Leschik (1955) has led to difficulties in the application of his generic name. It was rejected by Klaus (1960, p. 142), in favour of *Styxisporites* Cookson and Dettmann, on the ground that Leschik's description and interpretation were incorrect. Certainly the original diagnosis of *Kraeuselisporites* was inadequate but the illustrations were fairly clear, and, as Jansonius has noted, a weak trilete scar is visible on some of Leschik's figured specimens. *Styxisporites* and *Kraeuselisporites* have a similar structure, but the



TEXT-FIG. 2. *a*, *Lundbladispora playfordi* gen. et sp. nov. lateral view. *b*, *L. playfordi* diagrammatic section parallel to the polar axis. *c*, *Kraeuselisporites cuspidus* sp. nov., lateral view. *d*, *K. cuspidus* diagrammatic section parallel to polar axis. All ×800 approx. *a.p.* apical papillae; *exo.* exoexine; *int.* intexine.

form of the flange and lips seems to provide a means of distinguishing between the two genera. In *Styxisporites* the flange is translucent to almost transparent and clearly delimited from the central body, and the prominent laesurae are bordered by fairly strong lips.

Kraeuselisporites cuspidus sp. nov.

Plate 5, figs. 9, 10, 11; text-figs. 2*c*, *d*

Holotype. Slide 47552. *Paratypes*. Slides 47553 and 47554.

Diagnosis. Amb rounded triangular, periphery dentate. Exine cavate consisting of a zonate exoexine enclosing a thin intexine. Trilete, scar weak but usually clearly visible, laesurae extending to the inner margin of the zona. Distal side hemispherical, proximal flattened pyramidal. Exoexine 2–3 μ thick on distal side and 1 μ or less on the proximal.

Surface of exoexine (including zona) scabrate; distal surface and zona bearing heavy irregularly disposed spines 5–10 μ long, 5–6 μ in basal diameter, and 3–15 μ apart. Intexine thin, smooth, partially or completely detached from the exoexine, and usually folded.

Dimensions. Total diameter 71–112 μ, width of zona 9–25 μ; 25 specimens.

Locus typicus. Kockatea Creek No. 19 Bore, 139–190 ft. (sample 43305), Upper Greenough River area, Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. Latin *cuspis* = 'a point'.

Description. Holotype diameter 91 μ, zona 12–16 μ wide. Distal surface and zona bearing about forty heavy spines. Spines about 8 μ long with a basal diameter ranging from 3 to 5 μ. In the holotype the intexine is detached from the exoexine but unfolded. Paratype 47553 has a zona of irregular width and a shrunken, rather crumpled intexine.

Remarks and comparisons. Kraeuselisporites cuspidus is much larger than any of the forms of *Kraeuselisporites* described by Leschik. *Styxisporites cooksonae* Klaus is of comparable size, but its spines are confined to the distal surface and do not occur on the zona. *K. apiculatus* Jansonius is smaller and has more numerous spines than *K. cuspidus*.

Kraeuselisporites cuspidus was recorded from all the samples examined but was generally most common in material from the Upper Greenough River–Indarra area. It occurs also in the Blina Shale but undoubted specimens have not been recognized in other Triassic deposits. Other species of *Kraeuselisporites* occur in the Australian Permian.

Known stratigraphic range in Australia. Lower Triassic.

Kraeuselisporites saeptatus sp. nov.

Plate 6, figs. 8, 9, 10

Holotype. Slide 47549. *Paratypes.* Slides 47555, 47556, and 47561.

Diagnosis. Amb rounded triangular, periphery slightly ragged. Exine cavate consisting of a zonate exoexine enclosing a thin intexine. Trilete, scar usually distinct, laesurae straight with weak lip development visible on some specimens and extending to the inner margin of the zona. Distal hemisphere strongly inflated, proximal face forming a low pyramid (see Pl. 6, fig. 8). Exoexine 2–3 μ thick on the distal side, less than 1 μ thick on the proximal. Surface of exoexine (including zona) scabrate with a 'scaly' texture,

EXPLANATION OF PLATE 5

Magnifications ×600, except fig. 7.

Figs. 1–3. *Lundbladispora willmotti.* 1, Holotype, distal surface showing sculpture. 2, Holotype, proximal surface. 3, Paratype 47533, showing ruptured proximal face and spinose sculpture.

Figs. 4–8. *L. playfordi.* 4, Holotype. 5, Paratype 47838, with indistinct scar and faint apical papillae. 6, Paratype 47536, small specimen with slight lip development. 7, Specimen dissected intexine showing apical papillae. ×700. 8, Adherent tetrad showing free intexine and equatorial thickening, Paratype 47539.

Figs. 9–11. *Kraeuselisporites cuspidus.* 9, Holotype. 10, Paratype 47553, with irregular zona. 11, Paratype 47554.

irregularly disposed grana sometimes present on the distal hemisphere. Zona gradually becoming thinner towards its outer periphery. Intexine thin, smooth, with occasional fine marginal folds but rarely crumpled.

Dimensions. Diameter 51–76 μ, width of zona 6–18 μ; 25 specimens.

Locus typicus. Geraldton Racecourse Bore, 1,465 ft. (sample 44497), Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. Latin *saeptum* = 'an enclosure'.

Description. Holotype diameter 72 μ, zona 10–13 μ wide, diameter of intexine 42 μ. Intexine weakly folded around its margin and probably still adhering to the exoexine on the proximal side. Paratype 47555 is preserved in lateral view and has a polar diameter of 53 μ.

Remarks and comparisons. Kraeuselisporites saeptatus differs from any species previously assigned to *Kraeuselisporites* in its lack of distinct sculptural elements. However, Jansonius (1962) has included in the genus forms with weakly developed distal grana (cf. *K. punctatus* Jansonius) and the present assignation does not seem an undue extension of his interpretation of *Kraeuselisporites*. Eventually it may become expedient to create a new form genus for unsculptured forms of the *K. saeptatus*-type, but this has been deferred here in order to avoid excessive monotypy.

In lateral compressions *K. saeptatus* is easily distinguished from *Densosporites* by its strongly inflated distal hemisphere and flattened proximal surface. *Simplicisporites laciniatus* Leschik appears, from the original illustration (Leschik 1955, pl. 5, fig. 5), to have a similar structure to *K. saeptatus*, and so do the two forms referred to *Aequitriradites* by Nilsson (1958, p. 47). Rogalska (1956, pl. 31) also has illustrated comparable types from the Liassic of Poland.

Kraeuselisporites saeptatus is one of the most common species in the Kockatea Shale, especially in the sediments from BMR 10 (Beagle Ridge) Bore. It occurs also in the Blina Shale.

Known stratigraphical range in Australia. Lower Triassic.

Genus LUNDBLADISPORA gen. nov.

Type species. Lundbladispora willmotti sp. nov., Lower Triassic, Western Australia.

Diagnosis. Trilete spores with a maximum diameter of less than about 150 μ. Exine cavate with a finely structured exoexine enclosing a thin-walled intexine. Exoexine thinner on the proximal than on the distal side and with a narrow equatorial thickening. Surface of exoexine scabrate with a spongeous appearance. Distal side devoid of sculpture or bearing small cones, spines, or grana. Sculptural elements absent or considerably reduced on the proximal surface. Intexine thin-walled, smooth, with three apical papillae (cf. Bharadwaj 1958) in the area of the proximal pole. Intexine often eccentrically placed with respect to the equatorial margin of the exoexine.

Remarks and comparisons. The distinctive characters of *Lundbladispora* are as follows:

(*a*) The relatively thick finely textured exoexine with an equatorial thickening.

(*b*) The presence of a thin, frequently eccentrically placed, papillate intexine.
(*c*) Virtual restriction of sculptural elements, when they occur, to the distal surface and equatorial region.

Dispersed megaspores of comparable structure to *Lundbladispora* have been described from Palaeozoic and Mesozoic sediments and assigned to a number of form genera. These include *Duosporites* Høeg, Bose, and Manum, *Banksisporites* Dettmann, and *Bacutriletes* (van der Hammen). Few previously described microspores closely resemble *Lundbladispora*, but a possible exception is *Aculeisporites variabilitis* Jansonius, which possesses a papillate intexine and a finely granulose and spinose exoexine. Microspores illustrated by Lundblad (1948) from the Lower Triassic of Greenland appear indistinguishable from *Lundbladispora playfordi*; they were associated with the lycopodiaceous strobilis *Selaginellites polaris* and may be its microspores.

Cavate exines occur frequently in the spores of modern species of *Selaginella* (Knox 1950, Harris 1955) and they are known also in fossil spores obtained from lycopodiaceous strobili (Lundblad 1948, 1950, Bharadwaj 1958). Another lycopodiaceous character of *Lundbladispora* is the restriction of sculptural elements to the distal face (see Couper 1958, p. 105). In so far as one is justified in inferring affinities from spore morphography the evidence favours lycopodiaceous, and possibly selaginellid, affinities for *Lundbladispora*.

The genus is named after Dr. B. Lundblad, Stockholm University, in recognition of her contributions to our knowledge of Triassic floras.

Lundbladispora willmotti sp. nov.

Plate 5, figs. 1, 2, 3

Holotype. Slide 47532. *Paratypes*. Slides 47533, 47534.

Diagnosis. Amb circular or strongly rounded triangular, periphery spinose, exine cavate. Trilete, scar indistinct, laesurae poorly defined, extending about two-thirds of the distance to the equatorial margin. Exoexine 4–6 μ thick on the distal side, about 1 μ thick, and sometimes ruptured, on the proximal. Slightly depressed contact areas sometimes visible on the proximal face. Exoexine scabrate, distal surface and narrow equatorial thickening ornamented with cones or spines. Sculptured elements 1–2 μ in basal diameter, 1–3 μ long and 1–10 μ apart, absent or much reduced in size on the proximal face. Intexine smooth and thin-walled, bearing weak tetrad markings with three apical papillae, one in each inter-radial area.

Dimensions. Total diameter 71–86 μ, diameter of intexine 49–65 μ; 25 specimens.

Locus typicus. Kockatea Creek No. 19 Bore, 139–190 ft., Upper Greenough River area (sample 43305), Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. After Mr. S. P. Willmott, geologist of West Australian Petroleum Pty. Ltd.

Description. Holotype diameter 78 μ, diameter of intexine 53 μ. Proximal face extremely thin and translucent, bearing a faint, slightly sinuous tetrad scar. Sculptural elements 2 μ in basal diameter, 1–3 μ high and irregularly disposed. In paratype 47533 the proximal face is ruptured and the spines are fewer and more prominent, ranging up to 6 μ long.

Paratype 47534 is preserved in semi-lateral view and has a total diameter of 86 μ and a polar diameter of about 81 μ.

Remarks and comparisons. Lundbladispora willmotti is distinguished from *L. playfordi* by its spinose sculpture, larger size, and the coarser texture of its exoexine. It was present in all samples from the Kockatea Shale and occurs also in the Blina Shale.

Known stratigraphical range in Australia. Lower Triassic.

Lundbladispora playfordi sp. nov.

Plate 5, figs. 4–8; text-fig. 2*a*, *b*

Holotype. Slide 47537. *Paratypes.* Slides 47538, 47536, and 47839 (tetrad).

Diagnosis. Amb circular or strongly rounded triangular, periphery smooth, exine cavate. Trilete, scar indistinct or clearly defined, lips sometimes present, laesurae straight or slightly curved, length variable but usually extending almost to the equatorial margin. Exoexine scabrate, 2–4 μ thick on the distal face, slightly thinner on the proximal, thickened equatorially in a zone about 3–5 μ wide. Intexine thin, smooth, frequently folded, and bearing three apical papillae in the region of the proximal pole (Pl. 5, fig. 7). In polar compressions the intexine is usually eccentrically placed with respect to the equatorial margin of the exoexine. Exoexine and intexine detached (Pl. 5, fig. 8).

Dimensions. Total diameter 40–71 μ, diameter of intexine 24–48 μ; 25 specimens.

Locus typicus. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. After Dr. P. E. Playford, now of the Geological Survey of Western Australia.

Description. Holotype diameter 66 μ, diameter of intexine 42 μ, equatorial thickening 2–3 μ wide. Laesurae poorly defined, 20–22 μ long, and curved. Paratype 47839 consists of four spores in an adherent tetrad; these show the species to be biconvex with a polar diameter of about 60 μ. In Paratype 47838 the tetrad scar is scarcely visible but the proximal face is ruptured, exposing the papillate intexine.

Remarks and comparisons. Lundbladispora playfordi was abundant in all the samples examined from the Kockatea Shale and has also been found in the Blina Shale and rarely in the Erskine Sandstone. Its resemblance to spores from the Lower Triassic of Greenland has already been noted, but no other obviously similar forms have been previously described. *Endosporites papillatus* Jansonius has a detached, papillate intexine, but the Canadian species is said to have an extremely thin exoexine and is devoid of equatorial thickening.

Known stratigraphical range in Australia. Lower to (?) Middle Triassic.

Lundbladispora brevicula sp. nov.

Plate 4, figs. 8, 9

Holotype. Slide 47546. *Paratypes.* Slides 47547 and 47548.

Diagnosis. Amb rounded triangular, periphery spinose, exine cavate. Trilete, scar distinct, laesurae curved or sinuous, with narrow elevated lips and extending almost to the equatorial margin. Exoexine 2–3 μ thick on distal side, 1 μ or less on the proximal with an equatorial zone of thickening 2–4 μ wide. Surface of the exoexine finely spongeous; ornamented on the distal side and along the equatorial margin, with sparsely distributed cones and spines. Sculptural elements about 2 μ in basal diameter, 1–4 μ high. Intexine thin, smooth and with three faint apical papillae sometimes visible. The intexine is never notably eccentric and is apparently attached proximally to the exoexine.

Dimensions. Total diameter 41–56 μ, diameter of intexine 29–39 μ; 20 specimens.

Locus typicus. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. Latin *breviculus* = 'rather small'.

Description. Holotype diameter 51 μ, diameter of intexine 36 μ. Laesurae sinuous with raised lips about 2 μ wide on either side of the commissure. Sculpture consists of about sixty irregularly disposed cones and spines, 1–3 μ in basal diameter and 2–4 μ high. Except for slight size differences the paratypes show little variation from the holotype.

Remarks and comparisons. Lundbladispora brevicula is distinguished from *L. willmotti* by its smaller size, prominent tetrad scar, and relatively larger spines. It was present in all the samples examined and most common in material from the Upper Greenough River area. The only other Australian sediment in which it is known to occur is the Blina Shale.

Known stratigraphical range in Australia. Lower Triassic.

Anteturma POLLENITES R. Potonié
Turma SACCITES Erdtman
Subturma DISACCITES Cookson

Genus VITREISPORITES Leschik 1955 (= *Caytonipollenites* Couper 1958)

Type species. Vitreisporites signatus Leschik, Keuper, Switzerland.

Vitreisporites pallidus (Reissinger) Nilsson 1958

Plate 6, fig. 7

1938 *Pityopollenites pallidus* Reissinger, *Palaeontographica*, **84B**, 84.
1950 *Pityosporites pallidus* (Reiss.) Reissinger, *Palaeontographica*, **90B**, 109; pl. 15, figs. 1–5.
1958 *Caytonipollenites pallidus* (Reiss.) Couper, p. 150; pl. 26, figs. 7–8.
1958 *Vitreisporites pallidus* (Reiss.) Nilsson, p. 78; pl. 7, figs. 12–14.

Figured specimen. Slide 47529.

Description. Disaccate pollen grain. Central body elongate oval, proximal face infragranulate, distal germinal area smooth and very thin. Sacci microreticulate, slightly inclined distally, and a little longer than the central body.

Dimensions. Length of body 16–25 μ, breadth of body 12–21 μ, total breadth of grain 26–40 μ; 4 specimens.

Locality of figured specimen. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Remarks and comparisons. In form and size these Triassic specimens fall within the range of Couper's diagnosis of *Caytonipollenites pallidus*. Quantitatively the species is unimportant in the Kockatea Shale, but has been recorded because of its possible palaeobotanical interest. *Vitreisporites* was described by Jansonius from the Scythian of Canada, but in Europe the oldest clear record is in Keuper strata (Leschik 1955). Pollens similar to *Vitreisporites pallidus* occur rarely in Upper Permian strata in the Canning Basin, but are not common before the Lower Jurassic.

Known stratigraphical range in Australia. Upper Permian to Lower Cretaceous.

Genus PLATYSACCUS (Naumova) R. Potonié and Klaus 1954

Type species. Platysaccus papilionis R. Potonié and Klaus, Zechstein, Austria.

Platysaccus sp. cf. *P. papilionis* R. Potonié and Klaus 1954

Plate 6, fig. 12

1954 *Platysaccus papilionis* R. Potonié and Klaus, p. 539; pl. 10, figs. 11, 12.
1955 *Lueckisporites fusus* [pars] Balme and Hennelly, p. 92; pl. 1, figs. 6, 9.

Figured specimen. Slide 47527.

Description. Disaccate, strongly diploxinoid pollen grain. Central body subcircular, thick-walled, proximal surface smooth or slightly rugulose. Sacci much larger than the central body, microreticulate, attached distally with their inner bases separated by a narrow germinal area.

Dimensions. Diameter of central body 47–53 μ, length of sacci 71–87 μ, total breadth of grain 104–127 μ; 8 specimens.

Locality of figured specimen. Kockatea Creek No. 19 Bore, 139–190 ft., Upper Greenough River area (sample 43305), Western Australia. Kockatea Shale, Lower Triassic.

Remarks and comparisons. Platysaccus cf. *papilionis* falls within the broad limits proposed for the original species by Potonié and Klaus. It occurred sporadically in the Kockatea Shale and provides one of the few links between Permian and Triassic microfloras in Western Australia.

Platysaccus papilionis has been recorded by Jansonius from the Scythian of Canada and by several authors from the European Zechstein. Pollen grains of apparently similar structure occur also in the Polish Liassic (Rogalska 1956, pl. 21, fig. 1).

Known stratigraphical range in Australia. Lower Permian to (?) Middle Triassic.

Infraturma STRIATITI Pant

Genus STRIATITES (Pant) Pant 1955

Type species (designated by Pant). *Pityosporites sewardi* Virkki, Upper Permian, New South Wales, Australia.

Generic name. Striatites is one of the genera assigned by Potonié (1958) to the Infraturma Striatiti which includes all fossil, disaccate pollen grains bearing transverse bands of exoexinal thickening on their proximal faces. Such pollen grains are particularly characteristic of Permian microfloras from the 'Gondwanaland' countries and are common also in Permian and Triassic sediments from the northern hemisphere. Because of their great variety and abundance it is difficult to establish a satisfactory systematic scheme for the Striatiti and many ill-conceived and inapplicable taxa have appeared in palynological literature. It is obvious that the taxonomy of the whole group needs revision, but this cannot be attempted without considering the great diversity of Permian forms. In the present account the generic name *Striatites* is used to accommodate members of the Striatiti with well-developed sacci and more than about six bands of proximal thickening. It therefore includes forms which Potonié placed in *Striatites*, *Lunatisporites*, and *Striatopodocarpidites*.

Striatites sp. cf. *Taeniaesporites antiquus* Leschik 1956

Plate 6, fig. 13

1956 *Taeniaesporites antiquus* Leschik, p. 134; pl. 22, fig. 4.

Figured specimen. Slide 47526.

Description. Disaccate, sacci joined equatorially in some specimens, haploxinoid pollen grains. Central body oval in polar view. Proximal face of central body bearing about fifteen transverse bands of exoexinal thickening separated by narrow clefts in which the intexine is exposed. Proximal bands scabrate and 5–9 μ wide. Sacci fairly large, attached and inclined distally, separated on the distal side by a thin germinal area consisting of exposed intexine. Sacci microreticulate with clearly defined, slightly radially elongate lumina.

Dimensions. Length of body 76–114 μ, breadth of body 58–88 μ, length of sacci 81–116 μ; breadth of sacci 49–61 μ; 5 specimens.

Locality of figured specimen. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Remarks and comparisons. In its large size and occasional pseudo-monosaccate appearance *Striatites sp.* resembles *Lueckisporites richteri* Klaus from the German Zechstein. However, Klaus's species has heavier and better-defined proximal thickenings. The specimens of *Taeniaesporites antiquus* illustrated by Leschik look similar to some examples of *Striatites sp.*, but Leschik's diagnosis is imprecise and detailed comparisons are not possible.

EXPLANATION OF PLATE 6

Magnifications $\times$ 600, except fig. 13.

Figs. 1–3. *Taeniaesporites obex*. 1, Holotype, proximal side. 2, Holotype, distal side. 3, Paratype 47558, showing transverse, proximal scar.

Figs. 4–6. *Taeniaesporites sp.* cf. *T. noviaulensis* Leschik.

Fig. 7. *Vitreisporites pallidus* (Reissinger).

Figs. 8–10. *Kraeuselisporites saeptatus*. 8, Holotype. 9, Paratype 47555, lateral view. 10, Specimen showing outline of the intexine.

Fig. 11. *Crustaesporites sp.*

Fig. 12. *Platysaccus sp.* cf. *P. papilionis* Potonié and Klaus.

Fig. 13. *Striatites sp.* cf. *Taeniaesporites antiquus* Leschik. $\times$ 440.

Striatites sp. is assignable to *Lunatisporites* as that genus was interpreted by Potonié (1958), but recent doubts have been expressed as to the validity of *Lunatisporites* (Klaus 1960, Dr. G. F. Hart, personal communication) and use of the name should be discontinued pending clarification of its status. No form clearly identical with *Striatites sp.* is known from the Australian Permian, but similar types occur rarely in the Blina Shale.

Known stratigraphical range in Australia. Lower Triassic.

Genus TAENIAESPORITES (Leschik) Jansonius 1962

Type species. Taeniaesporites kraeuseli Leschik, Keuper, Switzerland.

Generic name. The genus *Taeniaesporites* was proposed by Leschik (1955, p. 38) on the basis of the following brief diagnosis: 'Mikrosporen mit zwei Luftsäcken. Der sporenkörper ist durch 6 und mehr Streifen zerlegt.' These characters scarcely justified the establishment of a new genus, for they do not distinguish *Taeniaesporites* from several pre-existing form genera. Leschik's subsequent attempt (Leschik 1956) to change the type species of *Taeniaesporites* did nothing to clarify the application of his generic name.

Potonié did not accept *Taeniaesporites* on the ground that Leschik had misconstrued the structure of *T. kraeuseli*, which, Potonié argued, had only three proximal striae and belonged in *Lueckisporites* R. Potonié and Klaus. Leschik's photographs bear out Potonié's interpretation and any attempt to prevent the proliferation of generic names among the Striatiti commands sympathy. Nevertheless, *T. kraeuseli* was adequately illustrated and is a well-characterized and distinctive species. It could certainly have been included in *Lueckisporites* as that genus was originally conceived, but having accepted the restriction of *Lueckisporites* to pollens of the *L. virkkiae* type, it was not altogether consistent for Potonié to reject *Taeniaesporites*.

Leschik's views on the scope of his genus have never been clearly expressed, but he has vigorously defended the separation of *Taeniaesporites* and *Lueckisporites* on morphographic and stratigraphic grounds. His arguments are strongly supported by the evidence from Western Australia. Here forms similar to *Taeniaesporites kraeuseli* and *T. noviaulensis* are common in Lower Triassic sediments, but pollens resembling *Lueckisporites virkkiae* have never been observed.

Jansonius (1962) has recently proposed an emendation of *Taeniaesporites* which restricts and clarifies the genus. In this the generic name *Taeniaesporites* is restricted to striatitid forms with less than six, and most commonly four, bands of transverse proximal thickening. These exoexinal bands are commonly inflated and separated by transverse clefts in which the intexine is exposed. The clefts are wider and more clearly defined than in other genera of the Striatiti. Under the diagnosis proposed by Jansonius both haploxinoid and diploxinoid forms may be assigned to *Taeniaesporites*, for he minimizes the relative size of body and bladder as a criterion in the classification of the Striatiti. One may agree with Jansonius that many Russian authors have over-emphasized this character, without subscribing unreservedly to his view. In the future it may prove convenient to reserve *Taeniaesporites* for haploxinoid forms and create a new genus for thick-walled diploxinoid species such as *Taeniaesporites transversundatus* Jansonius and *T. obex* sp. nov.

Taeniaesporites sp. cf. *T. noviaulensis* Leschik 1956

Plate 6, figs. 4–6

1956 *Taeniaesporites noviaulensis* Leschik, p. 134; pl. 22, figs. 1, 2.
?1962 *Taeniaesporites novimundi* Jansonius, p. 63.

Figured specimens. Slides 47522, 47523, and 47524.

Description. Disaccate pollen grain. Central body subcircular or oval in polar view, intexine thin and translucent, exoexine confined to the proximal side, infrareticulate and slightly thicker than the intexine. Exoexine divided by three, or sometimes four, transverse clefts in which the intexine is exposed; the proximal side, therefore, has four or five bands of transverse exoexinal thickening. A short, transverse, linear, scar is usually visible within the cleft which passes through the proximal pole and from this it is inferred that the species was formed in planar tetrads. Sacci attached, and slightly inclined distally. Structure of sacci microreticulate; mesh lumina fine near the bases of the sacci, becoming coarser towards their peripheries. Distal germinal area fairly broad, consisting of thin, smooth intexine.

Dimensions. Maximum diameter of central body 42–62 μ, breadth of sacci 26–36 μ, length of sacci 43–70 μ, total breadth 72–90 μ; 30 specimens.

Locality of figured specimens. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Remarks and comparisons. Specific discrimination within the genus *Taeniaesporites* is not easy, partly because of the rigidity of the emended diagnosis and partly because the forms encountered have a fairly wide range of apparently continuous variation, both in size and in the arrangement of the proximal thickenings. Jansonius recognized nine species from the Canadian Lower Triassic, but some of these are rather arbitrarily characterized and may prove difficult to maintain. A comparatively wide range of variation has been allowed in the specimens assigned here to *Taeniaesporites* cf. *noviaulensis* and this latitude may be gauged from the three specimens illustrated in Plate 6, figs. 4–6.

The Western Australian form is similar in size to Leschik's species which it also resembles in arrangement and structure of its proximal thickenings and the presence of a short, transverse, tetrad scar. A possible distinction lies in the internal structure of the sacci. In *Taeniaesporites noviaulensis* the lumina are radially elongate. The mesh is variable in the Australian species and appears coarser in poorly preserved specimens. There is some uncertainty, therefore, concerning its reliability as a specific character.

Taeniaesporites cf. *noviaulensis* is a key species in the microflora of the Kockatea Shale. It is easily recognized and occurred in all samples, usually making up between 3 and 10 per cent. of the total spore–pollen assemblage. It occurs commonly in the Blina Shale, less frequently in the Erskine Sandstone and in continental Triassic sediments overlying the Kockatea Shale in BMR 10 (Beagle Ridge) Bore. Rare specimens have been found in Triassic coals from the Springfield Basin, South Australia, but no representatives of *Taeniaesporites* have been recorded from the Leigh Creek Coal Measures. In the Sydney Basin, New South Wales, a few examples have been recognized in assemblages from the Collaroy Claystone (Middle Narrabeen Group), and similar forms occur red fairly commonly in a sample from the base of the Narrabeen Group, collected in the Nattai River area.

The distribution of *Taeniaesporites* is discussed further in a subsequent section of this paper.

Known stratigraphical range in Australia. Lower to (?) Upper Triassic (mainly Lower Triassic).

Taeniaesporites obex sp. nov.

Plate 6, figs. 1–3

Holotype. Slide 47531. *Paratype.* Slide 47558.

Diagnosis. Disaccate, more or less diploxinoid pollen grain. Central body circular in polar view, intexine very thin, translucent and faintly punctate. Proximal face bearing four prominent transverse bands of heavy exoexinal thickening, separated by clefts in which the intexine is exposed. Subsidiary clefts sometimes present in the thickenings giving rise to isolated patches of discontinuous exoexine. Thickenings infragranulate and about 2 μ thick. A short transverse, linear scar passes through the proximal pole. Sacci crescentic in polar compressions, longer than the central body, attached and inclined distally. Sacci microreticulate, mesh clearly defined, lumina radially elongated near the base of the sacci, becoming more equidimensional towards their outer margins.

Dimensions. Diameter of central body 36–43 μ, breadth of sacci 25–37 μ, length of sacci 43–57 μ, total breadth 69–81 μ.

Locus typicus. Well at Point 217, Upper Greenough River area (sample 44070), Western Australia. Kockatea Shale, Lower Triassic.

Derivatio nominis. Latin *obex* = 'a barred gate', from the appearance of the proximal surface.

Description. Holotype dimensions—diameter of central body 38 μ, sacci 30 $\times$45 μ and and 29 $\times$46 μ, total breadth 72 μ. The holotype is only slightly compressed and bears four bands of thickened exoexine. An elongated patch of discontinuous thickening occurs between the two major bands and is visible at the right-hand side of the central body in Plate 6, fig. 1. Thickenings 6–8 μ wide, with notched margins, and infragranulate sculpture. The paratype has a wider polar cleft than the holotype and displays a clear transverse scar.

Remarks and comparisons. Taeniaesporites obex is fairly rare in the Kockatea Shale and did not occur in all the samples. It is known from the Blina Shale and similar forms occur in the lower part of the Narrabeen Group in New South Wales. The circular central body and heavier proximal thickenings distinguish it from *T. noviaulensis*.

No species obviously resembling *Taeniaesporites obex* has been described from European sediments, but Jansonius (1962) has recorded forms with heavy discontinuous proximal thickenings from the Scythian of Canada. Of these, *T. transversundatus* is closest to the Australian species but it is smaller than *T. obex* and its proximal thickenings are markedly constricted away from the pole.

Known stratigraphical range in Australia. Lower Triassic.

Genus CRUSTAESPORITES Leschik 1956

Type species. Crustaesporites globosus Leschik, Zechstein, Germany.

Crustaesporites sp.

Plate 6, fig. 11

Figured specimen. Slide 47525.

Description. Trisaccate or irregularly disaccate pollen grain. Central body oval, intexine thin, finely punctate and translucent; proximal side bearing faint, roughly parallel bands of exoexine. Bands infrareticulate, 2–5 μ wide and about 1 μ apart. Sacci attached marginally slightly on the distal side of the equator and inclined distally. Sacci narrow and elongate, occasionally lobed; microreticulate with a clearly defined mesh.

Dimensions. Central body 91 ×78 μ, sacci 73 ×31 μ, 76 ×27 μ, 90 ×27 μ, figured specimen only.

Locality of figured specimen. Kockatea Creek No. 19 Bore, 139–190 ft., Upper Greenough River area (sample 43305), Western Australia. Kockatea Shale, Lower Triassic.

Remarks and comparisons. Crustaesporites sp. is rare in the Kockatea Shale. Representatives of the genus have been found in Australian Upper Permian deposits (cf. Balme and Hennelly 1955, pl. 4, fig. 44) and are known also from the German Zechstein (Leschik 1955, Klaus 1955, Grebe 1957) and the Lower Triassic of Canada (Jansonius 1962).

Jansonius interpreted *Crustaesporites* as a monosaccate form in which the sacci were irregularly constricted to give a multisaccate appearance. In the few specimens seen in microfloras from the Kockatea Shale the sacci were clearly separated, but the species was too rare to judge its range of variation. However, it is certainly possible to envisage a graduation from monosaccate to multisaccate specimens. *Crustaesporites* has clear affinities with the striatitid pollens and not, as Leschik suggested, with the *Podosporites–Microcachryidites* group.

INCERTAE SEDIS

Genus SCHIZOSPORIS Cookson and Dettmann 1958

Type species. Schizosporis reticulatus Cookson and Dettmann, Cretaceous, South Australia.

cf. *Schizosporis sp.*

Plate 4, figs. 4, 5

Figured specimens. Slide 47530.

Description. Spheroidal body of uncertain function. Body wall 2–4 μ thick, two-layered, inner layer very thin and smooth. Outer layer unsculptured, sometimes with occasional scattered pores. Most specimens are split roughly into two halves, along a line of weakness in the body wall. Some, however, are unruptured and in others the incipient split appears as a faint line. The form resists compression and most specimens are strongly three-dimensional.

Dimensions. Diameter 18–41 μ; 60 specimens.

Locality of figured specimens. Geraldton Racecourse Bore, 1,465 ft. (sample 44497), Western Australia. Kockatea Shale, Lower Triassic.

Remarks and comparisons. The generic assignation is tentative as the Triassic form is considerably smaller than any included in *Schizosporis* by Cookson and Dettmann (1958). It is similar in general structure to *Schizosporis spriggi* Cookson and Dettmann, but is smaller and has a relatively thicker body wall. Jansonius (1962) has assigned similar bodies to the genus *Spheripollenites* (Couper) Jansonius, but judging from Couper's original diagnosis and illustrations (Couper 1958, p. 158, pl. 31, fig. 12) the propriety of Jansonius's emendation is dubious. *Spheripollenites scabratus* Couper, the type species, was said by Couper to resemble the pollen grain of *Pagiophyllum connivens*, except in its lack of a thickened equatorial zone. From this comment, and from the original specific diagnosis, *S. scabratus* appears close to the Western Australian Jurassic species *Exesipollenites tumulus* Balme, and is certainly distinct from *Laevigatosporites scissus* Balme and Hennelly, which Jansonius includes in *Spheripollenites*.

From its morphography and its distribution in the Kockatea Shale cf. *Schizosporis sp.* is unlikely to be the spore or pollen grain of a vascular plant. It is usually extremely abundant in samples with a high microplankton content, and is rare or absent elsewhere.

Spheripollenites balmei Jansonius may be identical with *Schizosporis sp.*, but the Canadian species is said to have a faint intrapunctate or interpunctate pattern within the body wall. This feature was not convincingly exhibited by any specimens of cf. *Schizosporis sp.* which have been closely studied.

Known stratigraphical range in Australia. Lower Triassic.

Genus TETRAPORINA Naumova 1950

Type species. *Tetraporina antiqua* Naumova 1950, Lower Carboniferous, U.S.S.R. (designated Potonié 1960, p. 130).

Tetraporina sp. cf. *Azonotetraporina* ? *horologia* Staplin 1960

Plate 4, fig. 3

1960 *Azonotetraporina* ? *horologia* Staplin, p. 6; pl. 1, figs. 4, 6.

Figured specimen. Slide 47528.

Description. Test quadrilateral, two opposite sides concave, others straight or slightly convex. Surface smooth or faintly punctate, thickness of test about 1 μ. Arcuate folds about 10 μ long at each corner of the test.

Dimensions. Maximum length 36–46 μ; 8 specimens.

Locality of figured specimen. Geraldton Racecourse Bore, 1,465 ft. (sample 44497), Western Australia. Kockatea Shale, Lower Triassic.

Remarks and comparisons. *Tetraporina sp.* belongs to a group of morphographically similar bodies, of obscure origins, which is widely distributed in Carboniferous sediments (Naumova 1950, Teteriuk 1958, Staplin 1960). It is rare in the Kockatea Shale, but its occurrence extends the stratigraphical and geographical range of *Tetraporina*. Churchill (1960) has reported the presence of a form closely resembling *Tetraporina sp.*

in modern lake sediments and considers that it is the aplanospore of a member of the Cyanophyceae.

Known stratigraphical range in Australia. Permian to (?) Recent.

MICROPLANKTON

Except in one core (2,131–2,141 ft.) from BMR 10 (Beagle Ridge) Bore, all samples from the Kockatea Shale were characterized by extraordinarily large numbers of microplankton. Almost invariably they were many times more plentiful than spores or pollen grains, and a single slide from Gerldton Raceourse Bore (sample 44497) was estimated to contain over 25,000 specimens of hystrichosphaerids and leiospheres. Considered individually the various forms present are not particularly distinctive, for they are simple, spinose hystrichosphaerids, not differing obviously from species known to range from the Silurian onwards. On the other hand, both de Jekhowsky (1961) and Jansonius (1962) have noted that microplankton are particularly common in Lower Triassic marine sediments from widely separated parts of the world. Jansonius has already remarked on similarities between the microplankton suites of the Kockatea Shale and the Canadian Toad-Grayling Formation. All the common Western Australian forms are closely similar to species described by Jansonius, although the Canadian suites are more diverse, and in addition to hystrichosphaerids contain dinoflagellate tests. The following list includes all the common microplankton types in the Kockatea Shale, and is presented without taxonomic comment.

Wilsonastrum colonicum Jansonius	abundant
Wilsonastrum spp.	abundant
Micrhystridium setasessitante Jansonius	common
M. breve Jansonius	common
M. sp. cf. *M. inconspicuum* (Deflandre)	common

Colonial unicellular thallophytes similar to *Botryococcus* were common in some samples, particularly those from the Upper Greenough River area.

COMPOSITION OF THE ASSEMBLAGES

Text-fig. 3 shows the quantitative distribution of spore and pollen species in the seventeen samples studied. These figures are based on counts of about 200 specimens, except for three samples in which spores were rare and poorly preserved. In addition, the relative proportions of spores (including pollen grains) to microplankton have been estimated for each assemblage and these are expressed as a fractional ratio in the final column of text-fig. 3.

Except in the uppermost sample from BMR 10 Bore microplankton always outnumber spores, although their relative dominance varies within wide limits. The assemblages from BMR 10 Bore show gradually decreasing microplankton proportions towards the upper part of the section and a similar trend is present in the Geraldton Racecourse and Municipal Bores and in the 47¼ Mile Peg Bore; although these were not sampled in sufficient detail to enable confident interpretations. Frequency of microplankton in a sediment may be influenced by a variety of factors the relative importance

	LOCALITY	Point 217 Bore	Kockatea Creek No. 19 Bore	47¼ Mile Peg Bore					Geraldton Racecourse Bore		Geraldton Municipal Bore			B.M.R. 10 Beagle Ridge Bore				
	SPECIES / DEPTH IN FEET	30	139—190	uncertain	uncertain	741—749	808—945	948—968	1273	1465	1012—1096	1177—1344	1346—1386	2131—2141	2223—2233	2405—2415	2802—2812	3203—3213
SPORES	Punctatisporites fungosus	5	3	X	2	5	1	5	6	12	4	9	7	4	34	5	3	2
	Osmundacidites senectus	26	6	3	6	2	X	3	11	10	4	6	4	4	24	4	3	3
	Lycopodiacidites pelagius	2	2		2	1	X	1	1	1	2	2	1	2	2	1	1	1
	Lycopodiacites sp.	1	1	X	1	1				1	1	1	2	1		X	X	1
	Kraeuselisporites cuspidus	1	10	16	13	10	X	8	3	16	4	4	8	4	10	5	5	1
	K. saeptatus	3	36	20	24	36	9	24	21	58	76	34	39	76	106	104	31	5
	Lundbladispora playfordi	42	98	101	85	129	52	125	127	43	71	98	89	71	91	63	58	15
	L. willmotti	24	13	7	9	7	2	13	24	12	31	13	21	31	11	7	9	5
	L. brevicula	39	16	26	38	6	1	18	5	4	18	2	6	18	8	2	8	2
POLLEN GRAINS	Vitreisporites pallidus	1		1				X			1	2	X	1	1			
	Platysaccus cf. papilionis	1	X	2	1	1			X	1		X	1					
	Striatites sp.	4	1	4	1	X		1	4	3	4	2	5	4	4	X	X	1
	Taeniaesporites cf. noviaulensis	60	22	23	34	7	3	11	16	19	16	20	17	16	11	14	5	7
	T. obex	4	4	6	9	1	1	2	3	1	3	6	5	3	5	4	1	2
	Crustaesporites sp.	4	1	1	X	1		X		X		X		X	X			
TOTAL COUNT		217	215	210	225	207	69	211	221	181	235	199	205	235	307	209	124	45
SPORE / MICROPLANKTON RATIO		1/24	1/15	1/7	1/2	1/2	1/16	1/10	1/16	1/37	1/6	1/35	1/60	3/1	1/2	1/17	1/15	1/65

TEXT-FIG. 3. Distribution of spore and pollen species in samples from the Kockatea Shale.

of which is difficult to assess, particularly when dealing with a group of such divergent origins as the Hystrichosphaeridae. Recent studies (Muller 1959, Staplin 1961) suggest that the most favourable environment for the preservation of large numbers of hystrichosphaerids is a fairly deep, offshore basin in which turbidity is low. The most direct environmental interpretation of the palynological data from BMR 10 Bore is that the depositional basin gradually shallowed during the formation of the Kockatea Shale. Lithological evidence presented by McTavish (1960) favours the same concept, for coarser-grained sediments become more common in the upper part of the section, and the uppermost 100 feet or so are characterized by lingulid brachiopods, worm tubes, wood fragments, and other concomitants of the deltaic environment.

A singular feature of both the microplankton suites and the accompanying spore–pollen assemblages is their remarkable lack of diversity. Almost invariably *Wilsonastrum* was the dominant microplankton genus and in most samples the only other common forms were one or two species of *Micrhystridium*. The microplankton suite, consisting of few species and enormous numbers of individuals, suggests, therefore, a restricting but highly productive environment. High salinity may have been the main cause of this restriction, and could also be invoked to explain the general paucity of invertebrate fossils in the Kockatea Shale. Nevertheless, it would be unwise to imply that salinity was the only possible controlling factor.

Lack of variety in the spore–pollen assemblages is even more marked than a casual glance at text-fig. 3 would suggest, for of the fifteen species described only nine were present in every sample. *Lundbladispora playfordi* was almost always the most abundant species, and spores, especially forms with cavate exines, always outnumber pollen grains. In both paucity of species and relative abundance of pteridophyte spores, microfloras from the Kockatea Shale contrast notably with those from Australian Permian sediments. Assemblages from the Upper Permian in particular, are characterized by their heterogeneity and by a high content of striatitid, disaccate pollen grains (Balme 1962).

It may be argued that impoverishment of the Lower Triassic microfloras is a function of the conditions of deposition of the Kockatea Shale and does not necessarily imply specialization of their parent floras. Almost certainly the plant microfossils have been carried long distances from their sources and selective forces undoubtedly operated during transportation. The abundance of *Kraeuselisporites* and *Lundbladispora*, genera of probable lycopsid origin, suggests, for example, that elements of coastal swamp floras were heavily represented in the plant microfossil assemblages.

Even allowing for the possibility of selective transportation and preservation, however, it seems unlikely that these factors alone can explain the impoverishment in species of these Lower Triassic microfloras. Such impoverishment characterizes assemblages from the Kockatea Shale wherever it has been sampled, even in areas which must have lain close to the shoreline. Qualitatively similar microfloras have, in addition, been recovered from the Blina Shale, the closest outcrop of which lies about 1,000 miles north of Geraldton. Inadequate as the palynological data may be from the phytogeographic point of view, they can most reasonably be interpreted as recording the presence of highly specialized floras in western marginal areas of the Australian continent during early Triassic times.

Phytogeographic changes of the magnitude postulated can only have resulted from major climatic changes at the end of the Permian. It would be rash to attempt a dogmatic inference on the direction of these changes from the palynological evidence alone, although the sudden appearance, in the Western Australian Scythian, of *Taeniaesporites* and other European Zechstein and Triassic forms suggests increasing aridity. The lithology of the Kockatea Shale is compatible with a desertic climate in the adjoining mainland, as it is predominantly fine-grained and contains red layers in Geraldton Racecourse Bore. Clearly this ferric iron cannot have resulted from conditions within the basin of deposition, for even the red shales contain abundant plant microfossils which could not have survived prolonged oxidation. It may be concluded that most of the iron was transported in the ferric state, and partially or completely reduced after deposition in a marine environment.

Nowadays it would be reactionary to invoke a desertic climate to explain the origin of red coloration in sediments. On the other hand, many authorities (Dunham 1953, Dunbar and Rodgers 1958, p. 217) are agreed that arid conditions favour, and may even be essential to, the preservation of ferric oxides during prolonged transportation.

PHYTOGEOGRAPHIC AND STRATIGRAPHIC SIGNIFICANCE OF THE MICROFLORAS

Because of the precision with which the Kockatea Shale can be dated its microfloras have an intrinsic importance to both stratigraphers and palaeobotanists, and when the unusual composition of the assemblages is also taken into account, their significance is further enhanced. In Western Australia at least, it is probable that an upper limit to the Permian System can be established on a palynological basis, and that floral changes of great magnitude were initiated at the beginning of the Triassic Period. These changes involved the extinction of the major elements of the *Glossopteris*-Flora and their replacement by other plant groups, some of which possibly originated in the northern hemisphere during Upper Permian time.

To expand these conclusions on the fate of the *Glossopteris*-Flora a brief consideration of the main characteristics of Australian Permian microfloras is a necessary preliminary. Certain aspects of these microfloras have been discussed by Klaus (1958), Balme (1962) and more cursorily by other authors. Wherever sediments containing the typical *Glossopteris*-association of plant macrofossils have been examined palynologically, they have yielded well-defined and basically similar assemblages of spores and pollen grains. In post-glacial Permian sediments these microfloras are characterized generally by considerable diversity, and particularly by their high content of disaccate pollen grains with striate proximal faces. In Western Australia microfloras of this type make their first appearance in glacial deposits, which form the basal units of the Permian successions in each of the major sedimentary basins. With modifications they persist throughout the Artinskian and attain their maximum variety in Upper Permian times. It is uncertain whether the Upper Permian is completely represented in any Australian state and there is evidence of a break in sedimentation between Permian and basal Triassic sediments in both the Canning and Perth Basins in Western Australia. Nevertheless, the hiatus cannot be a long one, for the Hardman Member of the Liveringa Formation in the Canning Basin contains marine fossils which enable it to be correlated with the Upper Productus Limestone of the Salt Range (Dickins and Thomas 1954), in turn equivalent to the Dzhulfian or uppermost Permian of Russia. If a non-sequence exists in the Upper Permian of the Canning Basin it can, therefore, represent only part of the Dzhulfian Stage.

Typically Permian microfloras occur in the Liveringa Formation wherever it has been examined, and these compare closely with assemblages from the Indarra Beds in the Perth Basin, the Newcastle and Illawarra Coal Measures in New South Wales, the Upper Bowen Group and its equivalents in Queensland and the Cygnet Coal Measures in Tasmania. In other words the palynological evidence strongly implies the existence of a pan-Australian flora in Upper Permian times. This, in classic terms, was the *Glossopteris*-Flora.

Basal Triassic microfloras from Western Australia, represented by assemblages from the Kockatea Shale and Blina Shale, are quite unlike any known from Australian Permian strata. A few Palaeozoic types (e.g. *Platysaccus* cf. *papilionis*) occur rarely in the Mesozoic, but the most prominent Scythian forms, such as *Lundbladispora* and *Taeniaesporites*, have never been observed in Australian Permian sediments. Only one conclusion seems possible from the microfloral evidence, namely that, in Western Australia, Lower Triassic floras were quite distinct from those of the Upper Permian. From this it follows that the *Glossopteris*-Flora did not survive into the Mesozoic, at least in the western part of the present Australian continent.

Virtually nothing is known of the megascopic organs of these Lower Triassic plants which superseded the *Glossopteris*-Flora. No identifiable plant megafossils have so far been recorded from the Kockatea Shale, but plants occur rarely in the upper part of the Blina Shale at Erskine Range in the Canning Basin. These have not been studied in detail, but include equisetalean, and probably lycopodiaceous, stem fragments. *Dicroidium*, the frond genus which particularly characterizes Triassic continental sediments in eastern Australia, has been reported from the Erskine Sandstone, a continental Triassic unit conformably overlying the Blina Shale (Antevs 1913, Brunnschweiler 1954) but is not known to occur in the Perth Basin. On palynological grounds it is unlikely that the pteridospermous group which bore *Dicroidium*-foliage was an important component of the Scythian floras in Western Australia. Neither the Kockatea Shale nor the Blina Shale contains the pollen genus *Pteruchipollenites* (in the sense of Couper 1958), which is always abundant in association with *Dicroidium* in the Triassic of New South Wales, Queensland, and South Australia. *Pteruchipollenites* is present in the Erskine Sandstone, and in the Perth Basin its first known occurrence is in continental Triassic sediments which overlie the Kockatea Shale in BMR 10 (Beagle Ridge) Bore. If, as is implied here, *Pteruchipollenites* can be used as an index for the *Dicroidium*-Flora, it follows that this did not become established in Western Australia until after early Scythian time. Its first appearance cannot be dated unequivocably, but the sediments in which *Pteruchipollenites* occurs in Beagle Ridge Bore conformably overlie the Kockatea Shale, with an apparently transitional contact, and are likely to be late Scythian or early Middle Triassic. From the preceding discussion it is concluded that plant microfossils from the Kockatea Shale record the existence of a specialized and fairly short-lived flora which became established in the late Permian or early Triassic and was replaced by the *Dicroidium*-Flora, probably before the end of the Scythian Age.

Whether this flora existed in eastern Australia is conjectural, in view of the inadequacy of palynological data and the difficulties of correlating Australian Triassic sediments. On *a priori* grounds microfloras similar to those from the Kockatea Shale would be expected to occur in the lower part of the Narrabeen Group in New South Wales. However, from the scanty published evidence, and from the few samples examined by the present author, this is not so. *Taeniaesporites* was present in a shale collected from the base of the Narrabeen Group in the Nattai River district of New South Wales, but in other ways the microflora from this sample resembled those from the Erskine Sandstone rather than the Kockatea Shale. Hennelly (1958) described a rather poorly preserved microflora obtained from the bottom 75 feet of the Narrabeen Group in the Illawarra District of New South Wales. In this, disaccate pollen grains of the *Pteruchipollenites*-type (*Pityosporites reticulatus* Hennelly) were apparently dominant and in general composition the assemblages look younger than those from the Kockatea Shale. Two hypotheses may be advanced to explain the differences between microfloras from the base of the Triassic System in New South Wales and Western Australia. It is possible that a distinct floral province existed in the western part of the Australian continent during Scythian times and that elements of the *Dicroidium*-Flora migrated from eastern Australia late in the Lower Triassic. Alternatively, part of the Lower Triassic may be missing in the Sydney Basin and the conformable contact of the Narrabeen Group with the underlying Illawarra Coal Measures may obscure a sedimentary hiatus representing at least part of the Scythian Stage. Further speculation is unjustified on the published data available, but a convincing answer should follow the assessment of information on the Triassic of eastern Australia at present being accumulated by palynologists of the Bureau of Mineral Resources, Canberra.

The most obviously interesting record from the Kockatea Shale is that of the disaccate pollen genus *Taeniaesporites*, which had not previously been reported from the southern hemisphere. *Taeniaesporites* belongs to the diverse complex of disaccate pollen grains with transverse thickenings on their proximal faces, which have been assigned by Potonié to the Infraturma Striatiti. However, its structural characters set it apart from other genera of the Striatiti, and are so distinctive that it can hardly be doubted that at least the haploxinoid species of *Taeniaesporites* were derived from closely related plants. Such species have been reported from widely separated regions in the northern hemisphere, occurring in Upper Permian and Triassic strata.

In Australia *Taeniaesporites* has never been found in Permian sediments and appears to be confined to the Triassic. Rare specimens have been found in the upper part of the Narrabeen Group and in coals from the Springfield Basin, South Australia. These South Australian coals almost certainly correlate with the Leigh Creek Coal Measures and may be of Upper Triassic or Rhaetic age (Dettmann 1961). Although *Taeniaesporites* probably ranges into the Australian Upper Triassic, it appears to be particularly characteristic of Scythian strata, for it is only known in abundance from the Kockatea Shale and Blina Shale. Records from the northern hemisphere indicate that *Taeniaesporites* has a different stratigraphic distribution in western Europe. One of its oldest documented occurrences is in the Hilton Plant Beds in Westmorland (Jansonius 1962) and it is known also from the German Zechstein (Potonié and Klaus 1954, Leschik 1956). Little published information is available on the palynology of the Buntsandstein or Muschelkalk equivalents, but *Taeniaesporites* (*Lueckisporites*) *kraeuseli* was listed by Klaus from the Carnian of Austria, and similar species are known from the Keuper (Leschik 1955, Pautsch 1958). Post-Keuper records are dubious, but the species *Protosacculina* *glabrescens* Malyavkina from the Rhaetic of Kazakhstan may belong to *Taeniaesporites*, and a single poorly preserved specimen of the genus from the Swedish Liassic was illustrated by Nilsson (1958).

On the available evidence *Taeniaesporites* appeared earlier, and persisted longer, as a prominent microfloral element in Europe, than it did in Australia. Perhaps the apparent differences in the time of first appearance should not be stressed, in view of the possibility that strata homotaxial with the Upper Zechstein are not represented in Australia. The abundance of *Taeniaesporites* throughout the European Triassic, on the other hand, contrasts with its virtual restriction to the Lower Triassic in Australia and these discrepancies in distribution call for some explanation. One interpretation of the evidence is that the parent plants of *Taeniaesporites* were adapted to the more or less desertic environments which characterized the Triassic Period in western Europe. The occurrence of *Pleuromeia*, and other Triassic genera, in the Erskine Sandstone (Brunnschweiler 1954) suggests that desertic plant communities of the European type were stabilized in Western Australia during the early Triassic. These did not survive the extensive climatic changes which were initiated probably in the late Scythian, leading to the establishment of the *Dicroidium*-Flora and the formation of thick coal measures in many parts of the Australian continent.

The only detailed published palynological study of Lower Triassic strata from the northern hemisphere was carried out by Jansonius on sediments from the Scythian section of the Toad–Grayling Formation in Alberta, Canada. Assemblages from the Toad–Grayling Formation are more diverse than those from the Kockatea Shale and contain higher proportions of disaccate pollens, but clear similarities exist between the Western Australian and Canadian microfloras. *Taeniaesporites* is common in both and the Albertan assemblages also contain *Kraeuselisporites*, *Lundbladispora* (cf. *Aculeisporites variabilis* Jansonius), *Vitreisporites*, *Striatites*, *Crustaesporites*, and *Platysaccus*. Close resemblances between the microplankton suites have already been noted by Jansonius, and it seems reasonable to infer that the Australian and Canadian microfloras originated from basically similar communities of parent plants.

Disaccate pollen grains of the *Taeniaesporites*-type are known from the Lower Triassic of Madagascar (de Jekhowsky, personal communication), and the wide distribution of these forms in basal Mesozoic sediments suggests that the postulated late Permian phytogeographic changes were not confined to Western Australia. There is an urgent need for further information on early Mesozoic microfloras, particularly from India and the countries of the southern hemisphere, but the evidence at present available draws attention to the possibility of establishing a palynological basis for the inter-continental correlation of Lower Triassic strata.

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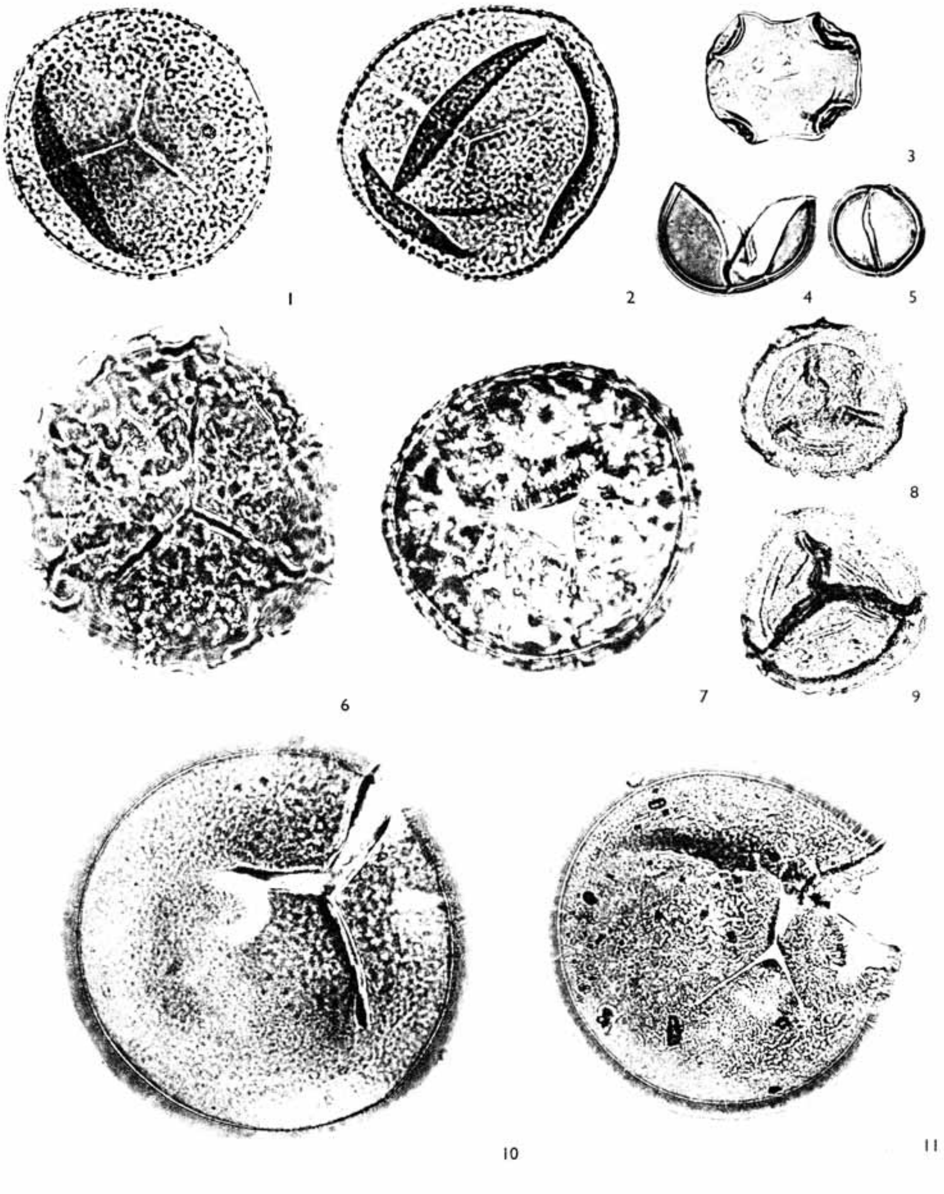
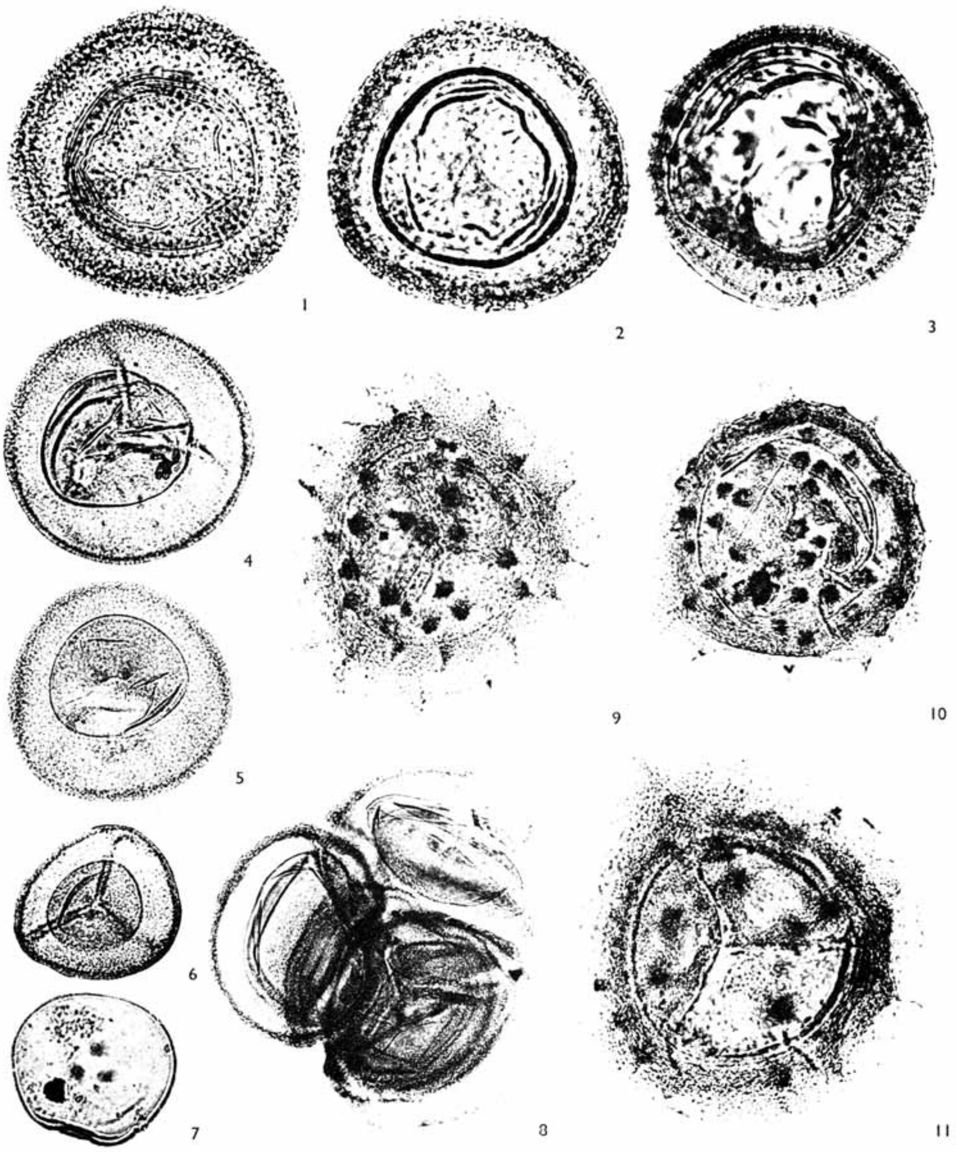
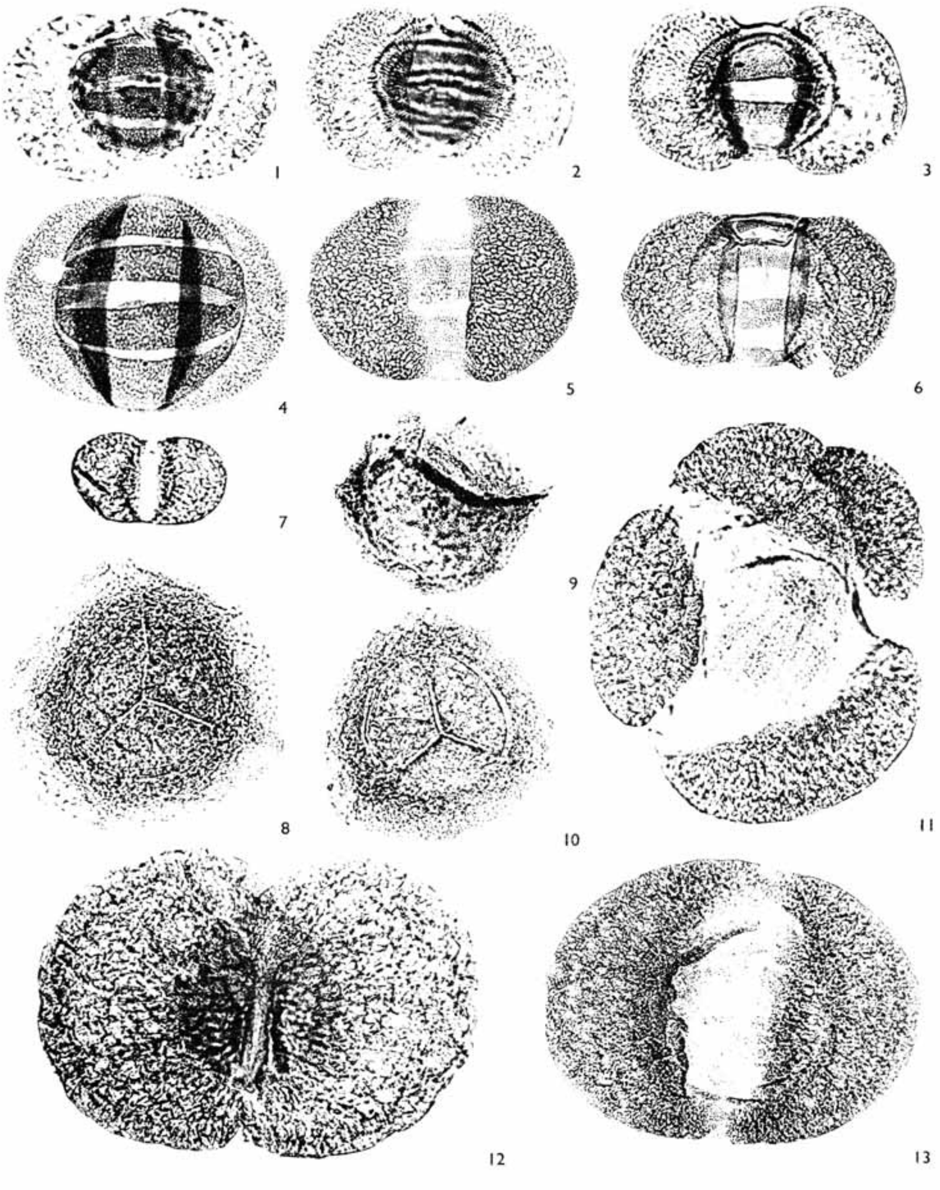
Manuscript received 20 March 1962



BALME, Triassic plant microfossils



BALME, Triassic plant microfossils



BALME, Triassic plant microfossils