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# COMPOSITION AND OCCURRENCE OF THE *GRANDISPORA MACULOSA* ZONAL ASSEMBLAGE (MISSISSIPPIAN) IN THE SUBSURFACE OF THE CARNARVON BASIN AND THE COOLCALALAYA SUB-BASIN OF WESTERN AUSTRALIA, AND ITS GONDWANAN DISTRIBUTION

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*Abstract*. The *Grandispora maculosa* miospore assemblage – initially described in 1968 from Middle-Late Mississippian strata of New South Wales (eastern Australia) – is well represented in samples examined herein from 10 Western Australian subsurface sections located in the northern Perth Basin (Coolcalalaya Sub-basin) and, to its immediate north, in several sub-basins of the southern and northern sectors of the Carnarvon Basin. Of particular stratigraphic-correlative importance is the presence of the eponymous *G. maculosa* together with, inter alia, *Reticulatisporites magnidictyus, Verrucosisporites quasigobbettii, V. gregatus, Apiculiretusispora tersa, Raistrickia accinta, R. radiosa, Foveosporites pellucidus*, and *Cordylosporites asperidictyus*. Four species are newly described herein: *Apiculatasporites spiculatus, Dibolisporites sejunctus, Raistrickia corymbiata,* and *Vallatisporites valentulus*. Published accounts from elsewhere in Gondwana collectively signify the widespread dissemination of the *G. maculosa* palynoflora, particularly through northern and western regions of the supercontinent, thus affording an effective means of intra-Gondwanan stratal correlation. Limited absolute dating and stratigraphic-successional considerations across Gondwana indicate that the age of the *G. maculosa* Assemblage can be bracketed within the middle Visean-early Serpukhovian of the Middle-Late Mississippian. This age is supported by the complete absence of bilaterally symmetrical, non-striate, saccate pollen grains, produced by walchian conifers, which were introduced globally (including in Australia) and near-synchronously late in the Serpukhovian. Cryptogamic land plants (ferns, articulates, lycophytes) are the inferred source of the palynoflora.

## Introduction

The palynostratigraphy of Australian Carboniferous (particularly Pennsylvanian) successions is currently incompletely documented. This is due mainly to dependence on incompletely or fortuitously cored drillholes through facies that cannot readily be correlated, and to intensive Cenozoic weathering across the continent that has rendered most surface exposures unproductive palynologically. However, there are exceptions in the case of terranes sufficiently incised below the zone of oxidization; e.g., the Balickera section, Southern New England Orogen, New South Wales (Rattigan 1967a-c; Playford & Helby 1968). Moreover, much remains to be achieved in terms of the taxonomy of the palynofloras if a rigorous and effective Carboniferous palynostratigraphy is to eventuate.

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Palynologically-based zonal schemes covering part or much of the Australian Carboniferous succession have been proposed, with varying degrees of temporal resolution, notably by Kemp et al. (1977), Playford (1985), Jones & Truswell (1992), Jones (1996), and Jones et al. (2000). The present paper focuses on one of the better defined, Mississippian miospore zonal units – the *Grandispora maculosa* Assemblage – as represented in Western Australian subsurface sections in the Coolcalalaya Sub-basin (northern Perth Basin), the Gascoyne Platform and Merlinleigh Sub-basin (Southern Carnarvon Basin), and the Peedamullah Shelf (Northern Carnarvon Basin). The morpho-taxonomy and prior reports (where applicable) of the miospore components of this distinctive palynoflora are detailed herein, thereby augmenting the accounts by Playford & Helby (1968) and Playford (2015). The distribution of the *G. maculosa* Assemblage through much of Gondwana is further documented.

## Geological setting

The longitudinally elongate Perth Basin and the contiguous Carnarvon Basin to the north are major Phanerozoic sedimentary basins that occupy a substantial portion of Western Australia's coastal regions (Hocking 1994). The westward extension of these basins beneath the Indian Ocean coincides with a marked thickening of the Mesozoic and younger strata; hence the Palaeozoic is best known from onshore or nearshore wells and outcrop. To the east, the basins are flanked by the Precambrian West Australian Craton, against which the Perth Basin abuts along the ca 1000 km-long Darling Fault, whereas the Carnarvon Basin largely onlaps the craton.

The northernmost onshore subdivision of the Perth Basin, the Coolcalalaya Sub-basin, lies between the northern end of the Darling Fault to the east, and the Proterozoic Northampton Inlier and its northern extension, the Ajana Ridge, to the west (Fig. 1). Exposures in the sub-basin are poor, but a combination of shallow drilling and seismic lines indicates a Palaeozoic sedimentary succession up to 8.5 km thick (Mory et al. 1998). The sub-basin is regarded by some authors (e.g., Crostella 1995; Mory et al. 1998; Mory & Haig 2011) as depositionally transitional with the Byro Sub-basin at the southeastern end of the Carnarvon Basin. Of the 10 wells sampled for the present study, one (YCH-2) lies in the Coolcalalaya Sub-basin, 77 km northwest of BHP CL5 on the Irwin Terrace that has been documented palynologically by Playford (2015). Hence, the core samples from these two wells currently provide the only definitive evidence, exclusively palynological, of the presence of (unnamed) Mississippian-age strata in the northern Perth Basin. The succeeding, glacial-marine/continental Nangetty Formation – known from intermittent outcrop and the subsurface – is of ca late Pennslyvanian-early Cisuralian age (Mory & Haig 2011: fig. 6).

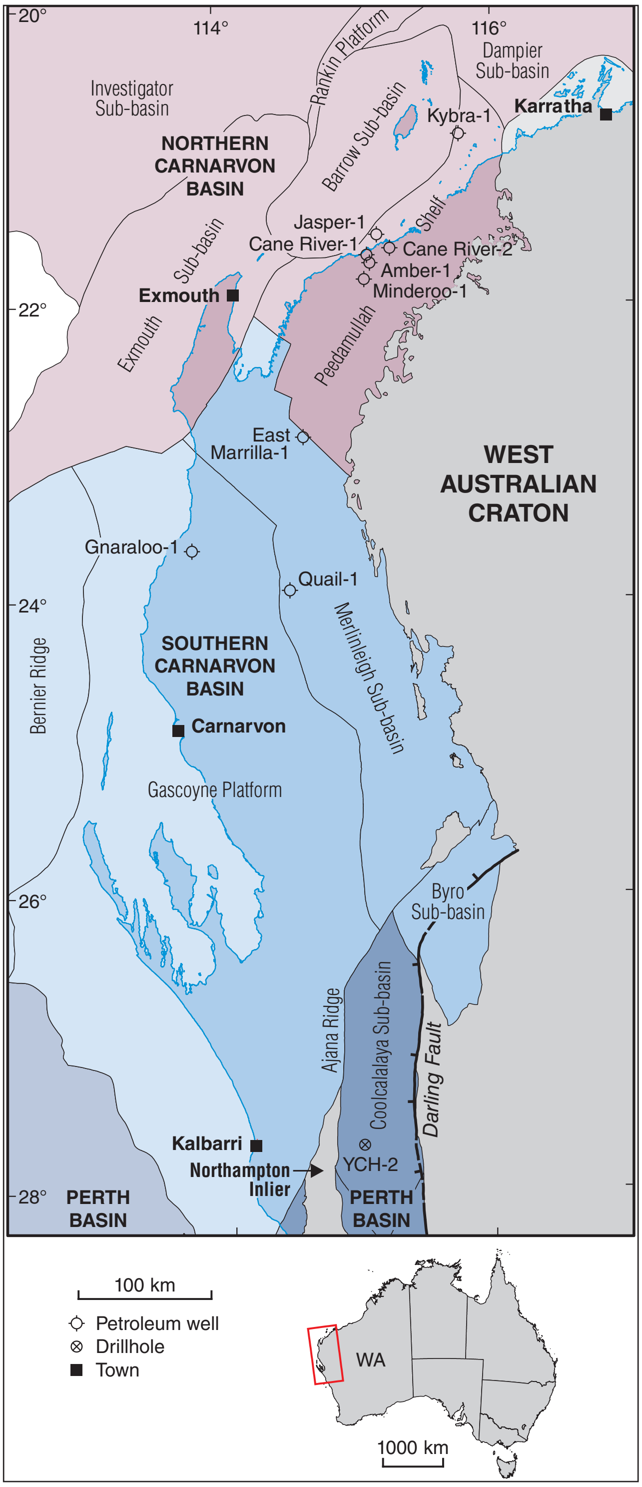



Fig. 1 - Locality map and geological setting of the Carnarvon Basin (less its westerly offshore extent) with its constituent sub-basins and of the northern Perth Basin (Coolcalalaya Sub-basin), Western Australia, showing location of wells on which the present study is based. See Tab. 1 for details of sampled material from each of the 10 wells. Adapted from Hocking (1994) and Martin et al. (2016).

The Carnarvon Basin, covering ca 115,000 km$^2$ onshore and 535,000 km$^2$ offshore, contains a Phanerozoic sedimentary infill up to 15 km thick. It

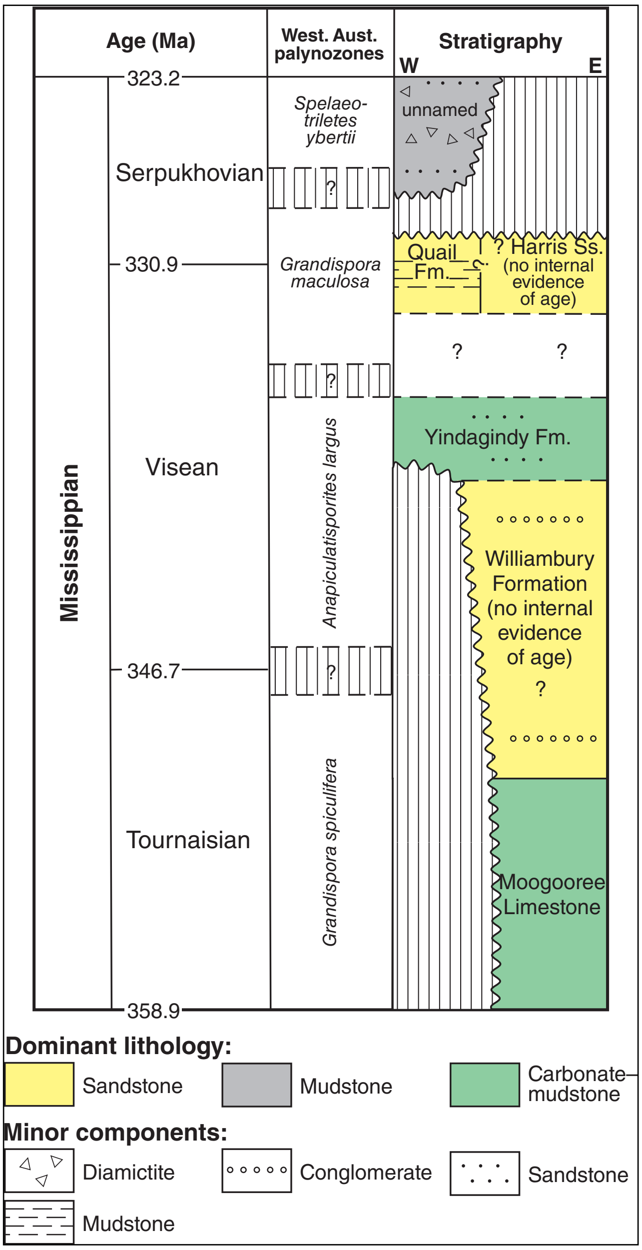



Fig. 2 - Mississippian chronostratigraphy of the Southern–Northern Carnarvon basins, Western Australia. Adapted from Vachard et al. (2014: fig. 3).

stretches for about 1000 km along the western and northwestern coastline of Western Australia (Fig. 1). The basin is subdivided into the Southern Carnarvon Basin and the Northern Carnarvon Basin (Hocking et al. 1994). The mainly Palaeozoic sediments of the Southern Carnarvon Basin are up to 7 km thick. The Northern Carnarvon Basin – Australia's premier oil- and gas-producing basin – contains a much greater thickness of predominantly Mesozoic–Cenozoic sediments (ca 15 km maximum, particularly offshore). These strata effectively obscure the underlying Palaeozoic section west of the basin's easternmost structural shelves (Hocking 1994).

The Southern and Northern Carnarvon basins have each been subdivided into a series of sub-basins (largely shown in Fig. 1; Hocking et al. 1987, 1994; Hocking 1990). Those subdivisions, from which the large majority of samples of this study were sourced, are mentioned below and are listed in Tab. 1. The Mississippian stratigraphy of the basin, as a whole and as currently known from limited outcrop and borehole sections, is shown in Fig. 2, together with the palynozonation that has been applied in Western Australia (e.g., Kemp et al. 1977: 179-180, fig. 2).

The Gascoyne Platform, the largest structural unit of the Southern Carnarvon Basin, contains mainly Palaeozoic (principally Ordovician-Mississippian) strata (Iasky et al. 1998: fig. 2; Mory et al. 2003: fig. 2) and abuts against half-grabens of the Merlinleigh and Byro sub-basins to the east. Devonian and Mississippian strata outcrop in the Merlinleigh's northeasterly sector and are inferred to be extensive in the subsurface.

The Northern Carnarvon Basin includes the marginal, mainly onshore Peedamullah Shelf (Fig. 1; Iasky et al. 2002) in which Mesozoic strata and younger sediment constitute a relatively thin cover, as opposed to the remainder of the basin, such that the Palaeozoic succession has been reached by petroleum-exploration wells only in the north and west of the Peedamullah Shelf (Hocking 1990).

## Samples studied, methods, and general observations

Apart from the effects of local tectonism, the sedimentary contents of most Western Australian Phanerozoic basins are essentially undeformed apart from fault displacements (Trendall & Cockbain 1990: fig. 4.1). This ensures the good to excellent – almost pristine – quality of palynomorph preservation, as shown by many publications documenting the palynofloras, even from older Palaeozoic strata. The miospore yields of the samples from the 10 boreholes listed below do exhibit some variation in preservation, but that generally presents no hindrance to reliable taxonomic identification.

Conventional laboratory procedures were adopted in the extraction and concentration of the palynomorphs from the study samples (e.g., Phipps

Tab. 1 - Data on samples studied. SWC = sidewall core/s.

| Basin | | Subdivision | Well | Latitude/ longitude | Sample type | Depth (*m*) | Total depth (*m*) |
|---|---|---|---|---|---|---|---|
| northern PERTH BASIN | | Coolcalalaya Sub-basin | *CRAE* YCH-2 | 27°43′06″S 114°59′45″E | core | 118.8 170.1 231.5 241.3 | 242 |
| CARNARVON BASIN | Southern | Gascoyne Platform | *WAPET* Gnaraloo-1 | 23°40′32″S 113°47′10″E | core | 476.4 | 500 |
| | | Merlinleigh Sub-basin | *WAPET* Quail-1 | 23°57′04″S 114°30′09″E | core | 2230.8-2231.4 | 3580 |
| | | Merlinleigh Sub-basin | *WAPET* East Marrilla-1 | 22°55'44"S 114°37'03"E | SWC, cuttings | 408-638 | 638 |
| | Northern | Peedamullah Shelf | *WAPET* Minderoo-1 | 21°50′45″S 115°04′47″E | core | 607.2 | 610 |
| | | Peedamullah Shelf | *Pan Pacific Petroleum* Amber-1 | 21°44'02"S 115°07'14"E | cuttings, SWC | 400-670 | 683 |
| | | Peedamullah Shelf | *Hematite Petroleum* Cane River-1 | 21°40'46"S 115°05'59"E | SWC, cuttings | 631.9-634.0 | 694 |
| | | Peedamullah Shelf | *Hematite Petroleum* Cane River-2 | 21°38′08″S 115°15′55″E | cuttings | 118.9-371.8 | 413 |
| | | Peedamullah Shelf | *Pan Pacific Petroleum* Jasper-1 | 21°32′35″S 115°10′18″E | SWC, cuttings | 456-545 | 549 |
| | | Peedamullah Shelf | *Bond Corp.* Kybra-1 | 20°51′47″S 115°46′14″E | SWC | 2170-2542 | 2562 |

& Playford 1984; Wood et al. 1996). The strew slides were examined with an Olympus BH2 binocular microscope, under bright-field illumination. Representative specimens were photographed (mainly via a x60 oil-immersion objective), with an Olympus DP26 digital camera linked to Olympus cellSens® software.

Locality and other details for the samples studied are listed in Tab. 1; most contain representatives of the *Grandispora maculosa* Assemblage preserved in fluviodeltaic to paralic sedimentary facies. Generalized observations and documentation are given below.

**YCH-2**, 118.8, 170.1, 231.5, 241.3 m (cores) - All four siltstone/claystone samples yielded abundant and very well preserved miospores. The final (unpublished) company report on this coal-exploratory diamond drillhole speculated that the 69-242 m cored section represented the "Lower Permian (Sakmarian) Nangetty Formation", but without any supporting palaeontological data. That stratigraphic designation is not supported by the present study.

**Gnaraloo-1**, 476.4 m (core) - This sample (core #2, grey siltstone) yielded moderately abundant and fairly well preserved miospores. From higher in the section (at 458 m), Backhouse (2002; unpublished) reported a sparse yield of miospores dated as ?Namurian. The Carboniferous strata in this well are possibly referable to the Quail Formation (Iasky & Mory 1999: 15).

**Quail-1**, 2230.8-2231.4 m (core) - A low yield of ill-preserved miospores, albeit of moderate diversity, characterizes this sample (core #12; fine-grained, silty, calcareous sandstone), as stated by B. E. Balme in the 1964 well completion report and by Powis (1981; unpublished). The latter's and the first author's more detailed observations (herein) are clearly indicative of *Grandispora maculosa* zonal representation at this level, which has been attributed to either the Quail Formation (Nicoll & Gorter 1995: fig. 2) or the Williambury Formation (well completion report, appendix 1).

**East Marrilla-1,** 498, 534, 542 m (sidewall cores); 408-638 m (cuttings) - The samples – mostly grey to dark grey siltstone interbedded within the putative Moogooree Limestone (but, most likely, the Quail Formation) – proved virtually barren with few, indeterminate (carbonized, ill- preserved) miospores (i.e., apart from Lower Cretaceous contaminants, including dinocysts). Powis (1981; unpublished) noted that identification of palynomorphs was "severely hindered" by their adverse condition, especially those from the pre-Permian succession.

**Minderoo-1**, 607.2 m - This lowermost core sample (#12; pale grey, consolidated, micaceous siltstone) produced a rich, varied, and well-preserved assemblage of miospores. West Australian Petroleum's well completion report (July 1963), assigned the so-called "Unit B" (1558-2000 ft/475-609 m) to the lower part of an "unnamed formation (Upper Carboniferous)" below 1270 ft (387 m), whereas Crostella et al. (2000: 58) assigned the interval to the Lyons Group. The assemblage clearly indicates equivalence with the Upper Mississippian Quail Formation.

**Amber-1**, 400 m (sidewall core); 505-510, 600-606, 665-670 m (cuttings) - This interval contains pale to medium grey siltstones interbedded within a predominantly limestone succession. Apart from Cretaceous contaminants in the cuttings samples, palynomorphs retrieved from the sidewall core and cuttings comprise carbonized, black-brown miospores and few simple acritarchs and scolecodonts. The lithostratigraphic unit, according to the well completion report, is the Quail Formation/Moogooree Limestone. Present observations largely confirm those of Purcell (1995a; unpublished) and favour correlation with the Quail Formation.

**Cane River-1**, 631.9-634.0 m (sidewall core/cuttings; siltstone, claystone) - These samples contain a moderately well preserved and fairly diverse palynoflora, together with some downhole contaminants (Cretaceous spores/pollen, dinocysts). In the well completion report, 1358-2277 ft (414-694 m) is referred to as "Carboniferous – Undifferentiated." Balme's (1972) very brief appendix, based on two sidewall cores and one cuttings sample, tentatively dated the palynoflora as late Early Carboniferous.

**Cane River-2**, 118.9-134.1, 182.9-192.0, 259.1-289.6, 335.3-344.4, 362.7-371.8 m (cuttings; predominantly medium to dark grey siltstones) - The base of the Cretaceous is at 305 m; hence the three upper samples contain in situ dinocysts and miospores of that age plus some Cenozoic downhole contaminants. The two lower samples yielded sparse, fine, black-brown organic matter along with very poorly preserved miospores of similar colouration and likely affiliation with the *Grandispora maculosa* Assemblage admixed with pale, relatively well preserved, post-Jurassic palynomorphs. This confirms a brief assessment by Ingram (1991; unpublished).

**Jasper-1,** 456 m (sidewall core), 540-545 m (cuttings) - The samples, comprising mainly medium to dark grey claystone, span much of the pre-Cretaceous section (452.7-549.7 m) attributed, in the well completion report, to the Quail Formation. Observation herein of abundant and generally well preserved miospores in the samples confirms Purcell's (1995b) *Grandispora maculosa* zonal assignment.

**Kybra-1**, 2170, 2192, 2215, 2286, 2347, 2395, 2542 m (sidewall cores; grey siltstones-fine grained sandstones) - The uppermost sample (at 2170 m) contains abundant, diverse, black-brown, indifferently preserved miospores that are clearly representative of the *Grandispora maculosa* Assemblage, in agreement with Purcell & Ingram's (1988) finding. The other samples (2192-2542 m) host sparse, carbonized, and ill-preserved miospores indicative of the preceding Visean *Anapiculatisporites largus* Assemblage, thereby confirming Purcell & Ingram's (1988) assignment. The presence of rare, mainly spinose acritarchs in the samples from 2192-2542 m is indicative of a marginal marine or brackish depositional environment. According to Bentley (1988), 2146.5-2170 m belongs to the Quail Formation, which is considered to overlie either the Yindagindy Formation or the Moogooree Limestone (cf. Nicoll & Gorter 1995: 416; Kybra-1 well completion report). Uncertainties relating to lithostratigraphic correlation of outcrop to subsurface are evident from some of the borehole reports. For instance, it was originally suggested (per well completion report) that the Quail-1 core sample (at 2230.8-2231.4 m) could be representative of the Williambury Formation (Fig. 2). But the core was later attributed (justifiably, vis-à-vis the present palynological evidence) to the Quail Formation (Nicoll & Gorter 1995: fig. 2).

As would be anticipated, spore colouration shows an increase in thermal maturity (TAI) corresponding to increasing sample depth. For example, samples from YCH-2 (118.8-243.3 m) and Gnaraloo-1 (476.4 m) yielded pale, very well preserved spores (TAI ~1+/2-; Pearson 1984); contrasting with those from Kybra-1 (2170-2542 m) and Quail-1 (2230.8-2231.4 m) with estimated TAI of 3-4. However, the relatively shallow East Marrilla-1 (498-638 m) and Cane River-2 (118.9-371.8 m) samples, all poorly palyniferous with TAI ~3, are clearly not concomitant with the trend, presumably due to tectonic or other post-depositional factors such as significant erosion.

## Systematic palaeontology

**Taxonomic inventory.** Miospore species identified in the study samples are listed below and are arranged in accordance with the systematic order applied in the descriptive section. Square-bracketed plate/figure citations refer to photomicrographs comprising the 10 plates of the present paper.

*Calamospora* spp. [Pl. 1, figs 1-3]
*Phyllothecotriletes golatensis* Staplin, 1960 [Pl. 1, figs 7, 8]
*Punctatisporites lucidulus* Playford & Helby, 1968 [Pl. 1, fig. 4]
*Punctatisporites subtritus* Playford & Helby, 1968 [Pl. 1, figs 5, 6]
*Apiculiretusispora tersa* Playford, 2015 [Pl. 2, figs 1, 2]
*Retusotriletes separatus* Playford, 2015 [Pl. 2, figs 3, 6]
*Retusotriletes* sp. A [Pl. 1, fig. 9]
*Verruciretusispora* sp. A [Pl. 1, figs 10, 11]
*Cyclogranisporites firmus* Jones & Truswell, 1992 [Pl. 1, fig. 12]
*Waltzispora* sp. A [Pl. 2, fig. 9]
*Converrucosisporites* sp. A [Pl. 2, figs 4, 5]
*Verrucosisporites basiliscutis* Jones & Truswell, 1992 [Pl. 3, fig. 4]
*Verrucosisporites gregatus* Playford & Melo, 2012 [Pl. 2, figs 7, 8]
*Verrucosisporites quasigobbettii* Jones & Truswell, 1992 [Pl. 3, figs 1-3]
*Verrucosisporites* sp. cf. *V. italiaensis* Playford & Helby, 1968 [Pl. 2, fig. 10]
*Anapiculatisporites amplus* Playford & Powis, 1979 [Pl. 4, figs 9-12]
*Anapiculatisporites concinnus* Playford, 1962 [Pl. 3, figs 5-7]
*Apiculatasporites spiculatus* Playford sp. n. [Pl. 3, figs 9-12]
*Claytonispora distincta* (Clayton, 1971) Playford & Melo, 2012 [Pl. 3, fig. 8]
*Dibolisporites disfacies* Jones & Truswell, 1992 [Pl. 4, figs 2, 3]
*Dibolisporites sejunctus* Playford sp. n. [Pl. 4, figs 4, 5]
*Tricidarisporites* sp. A [Pl. 2, figs 11, 12]
*Raistrickia accincta* Playford & Helby, 1968 [Pl. 4, fig. 1]
*Raistrickia corymbiata* Playford sp. n. [Pl. 5, figs 1-5]
*Raistrickia radiosa* Playford & Helby, 1968 [Pl. 4, figs 6-8]
*Raistrickia* sp. A [Pl. 5, fig. 6]
*Brochotriletes diversifoveatus* Playford & Satterthwait, 1985 [Pl. 5, figs 11-13]
*Cordylosporites asperidictyus* (Playford & Helby, 1968) Dino & Playford, 2002 [Pl. 5, figs 7-10]
*Foveosporites pellucidus* Playford & Helby, 1968 [Pl. 5, fig. 14]
*Reticulatisporites magnidictyus* Playford & Helby, 1968 [Pl. 6, figs 8-13]
*Ahrensisporites cristatus* Playford & Powis, 1979 [Pl. 6, figs 1-4]
*Diatomozonotriletes birkheadensis* Powis, 1984 [Pl. 6, figs 5-7]
*Diatomozonotriletes daedalus* Playford & Satterthwait, 1986 [Pl. 7, figs 1-8]
*Densoisporites truswelliae* Stephenson, Al Rawahi & Casey, 2008 [Pl. 7, figs 9-12]
*Densosporites claytonii* Ravn, McPhilemy, Rutherford, Talli & Bahra, 1994 [Pl. 8, Fig. 6; Pl. 9, fig. 7]
*Indotriradites daemonii* Loboziak, Melo, Playford & Streel, 1999 [Pl. 7, figs 13, 14]
*Indotriradites dolianitii* (Daemon, 1974) Loboziak, Melo, Playford & Streel, 1999 [Pl. 8, figs 1-5]
*Indotriradites kuttungensis* (Playford & Helby, 1968) Playford, 1991 [Pl. 8, figs 7-12]
*Vallatisporites valentulus* Playford sp. n. [Pl. 9, figs 8-12]
*Auroraspora solisorta* Hoffmeister, Staplin & Malloy, 1955 [Pl. 9, figs 1-6]
*Endosporites* sp. cf. *E. micromanifestus* Hacquebard, 1957 [Pl. 10, fig. 1]
*Grandispora maculosa* Playford & Helby, 1968 [Pl. 10, figs 2, 3]
*Velamisporites cortaderensis* (Césari & Limarino, 1987) Playford, 2015 [Pl. 10, figs 4-6]
*Aratrisporites saharaensis* Loboziak, Clayton & Owens, 1986 [Pl. 10, figs 7-12]
*Psomospora detecta* Playford & Helby, 1968 [Pl. 10, figs 13-15]
*Emphanisporites rotatus* McGregor, 1961 [Pl. 10, fig. 16]
*Retispora lepidophyta* (Kedo, 1957) Playford, 1976 [Pl. 10, fig. 17]

Note that two of the above-listed species (*Apiculiretusispora tersa* and *Retusotriletes separatus*) were newly insituted by Playford (2015) and *Velamisporites cortaderensis* was proposed therein as a new combination. As specified in the list of references, the paper was first published (hence publicly available/effectively published) online (electronically as DOI) on 30 October 2015; it was later issued, in December 2016, in print mode. Accordingly, in compliance with the International Code of Nomenclature for algae, fungi, and plants (ICN; McNeill et al. 2012, chapter IV, effective publication), the above new species and new combination are dated 2015 (not 2016).

**Repository.** The strew slides containing the 122 miospore specimens illustrated herein (Plates 1-10) are housed permanently in the Paleontological Type Collection maintained by the Geological Survey of Western Australia, 37 Harris Street, Carlisle, Perth, WA 6101, Australia (see Appendix 1).

**Descriptive systematics.** The 'Turma' form-classificatory scheme introduced by Potonié & Kremp (1954), and modified by later authors, is followed in the systematic section below. In accordance with that scheme, genera and species of dispersed spores and pollen grains are subject to provisions of the ICN (McNeill et al. 2012).

The basionym is cited for all previously instituted species, followed where appropriate either by synonyms and generic re-combinations or by direct reference to synonymy listings in previous publications. The majority of the species identified are described in detail. However, certain species that have been circumscribed satisfactorily in the literature are documented without full descriptions. In many such cases, supplementary morphological information is provided, based on specimens observed during the present study.

Descriptive terminology follows that provided by such authors as Kremp (1965), Smith & Butterworth (1967), Playford & Dettmann (1996), Punt et al. (2007), and Traverse (2007). Exinal sculptural elements described as 'minute' are appreciably less than 1 μm high and so their precise form is not always clearly discernible. Equatorial diameters are specified by lowest and highest values, in most cases with intervening bracketed arithmetic mean; e.g., 30 (38) 45 μm. Type-species designations are abbreviated thus: OD, original designation; SD, subsequent designation; and M, monotypy.

For each miospore species recorded below, details of source sample (well and depth therein), slide number and England Finder™ (EF) coordinates, and type category, the reader is referred to Appendix 1.

Anteturma **Proximegerminantes**
R. Potonié, 1970
Turma **Triletes** Reinsch, 1881
emend. Dettmann, 1963
Suprasubturma **Acavatitriletes** Dettmann, 1963
Subturma **Azonotriletes** Luber, 1935
emend. Dettmann, 1963
Infraturma **Laevigati** Bennie & Kidston, 1886
emend R. Potonié, 1956
Genus *Calamospora* Schopf, Wilson & Bentall, 1944
Type species: *Calamospora hartungiana* Schopf in Schopf, Wilson & Bentall, 1944 [OD].

***Calamospora*** spp.
Pl. 1, figs 1-3

**Remarks**. Simple, laevigate, relatively thin walled, trilete spores assignable to *Calamospora* Schopf, Wilson & Bentall, 1944 are a fairly minor component of the palynofloral assemblages of this study. Ranging in equatorial diameter from 55 to 103 µm, they resemble several named and not clearly differentiated Carboniferous species (including the type species), and hence are not binomially designated here.

Genus *Phyllothecotriletes* Luber, 1955
ex R. Potonié, 1958
Type species: *Phyllothecotriletes nigritellus* (Luber in Luber & Waltz, 1941) Luber, 1955 [SD; Potonié 1958: 17].

***Phyllothecotriletes golatensis*** Staplin, 1960
Pl. 1, figs 7, 8

1960 *Phyllothecotriletes golatensis* Staplin: 9, pl. 1, fig. 27.
2015 *Phyllothecotriletes* sp. A Playford: 6, fig. 2N.

**Description**. Spores radial, trilete, with circular-subcircular amb. Laesurae straight to slightly undulant, length 0.25-0.4 of spore radius. Exine laevigate, 1.5-3 µm thick.

**Dimensions** (12 specimens). Equatorial diameter 44 (57) 84 µm.

**Comparision**. *Phyllothecotriletes rigidus* Playford, 1963 (p. 580-581, pl. 79, figs 5, 6) differs from *P. golatensis* Staplin, 1960 in possessing a finely granulate and generally thicker exine. Staplin's species is considered to embrace the three specimens described by Playford (2015, as per above synonymy).

**Previous records**. From the Upper Mississippian of Alberta, Canada (Staplin 1960) and from a core sample, similarly dated, of the northern Perth Basin (CL5 borehole; Playford 2015).

Genus *Punctatisporites* Ibrahim, 1933
emend. R. Potonié & Kremp, 1954
Type species: *Punctatisporites punctatus* (Ibrahim, 1932) Ibrahim, 1933 [OD].

***Punctatisporites lucidulus*** Playford & Helby, 1968
Pl. 1, fig. 4

1968 *Punctatisporites lucidulus* Playford & Helby: 107, pl. 9, figs 1, 2.

**Dimensions** (six specimens). Equatorial diameter 42 (51) 66 µm.

**Previous records**. Reported from middle-upper Visean strata of Eastern and Western Gondwana (Playford & Helby 1968; Playford & Melo 2012; Playford 2015). Jones & Truswell's (1992: 160) identification of this species from their zones A-E (Galilee Basin, Queensland) was documented neither descriptively nor illustratively.

***Punctatisporites subtritus*** Playford & Helby, 1968
Pl. 1, figs 5, 6

1968 *Punctatisporites subtritus* Playford & Helby: 107; pl. 9, figs 11, 12.
1992 *Punctatisporites gretensis auct. non* Balme & Hennelly 1956; Jones & Truswell, partim: 160, fig. 8O.

**Dimensions** (10 specimens). Equatorial diameter 63 (72) 101 µm.

**Previous records**. This species and *P. lucidulus* have a similar stratigraphic and palaeogeographic distribution (Playford & Helby 1968; Playford & Melo 2012; Playford 2015).

Infraturma **Retusotrileti** Streel in Becker, Bless, Streel & Thorez, 1974
Genus *Apiculiretusispora* Streel, 1964
emend. Streel, 1967
Type species: *Apiculiretusispora brandtii* Streel, 1964 [OD].

***Apiculiretusispora tersa*** Playford, 2015
Pl. 2, figs 1, 2

2015 *Apiculiretusispora tersa* Playford: 7, 10, figs 3L, M, 4A-H.

**Dimensions** (eight specimens). Equatorial diameter 35 (48) 60 µm.

**Remarks**. The present specimens are in close morphological accord with those described originally (Playford 2015) as *Apiculiretusispora tersa* – in particular, by featuring well-defined contact faces with diminutive or non-existent sculpture; and fine, densely distributed spinae and coni sculpturing the substantial remainder of the exoexine, which moreover is consistently single-layered (acavate).

**Previous records**. The only previous report of *Apiculiretusispora tersa* is from the CL5 core sample, northern Perth Basin, of likely middle-late Visean age (Playford 2015).

Genus *Retusotriletes* Naumova, 1953
emend. Streel, 1964
Type species: *Retusotriletes simplex* Naumova, 1953
[SD; Potonié, 1958: 13].

***Retusotriletes separatus*** Playford, 2015
Pl. 2, figs 3, 6

2015 *Retusotriletes separatus* Playford: 7, fig. 3A-K.

**Dimensions** (30 specimens). Equatorial diameter 38 (48) 68 µm.

**Remarks**. Specimens of *Retusotriletes separatus* are relatively common in the material of this study and are exclusively trilete; i.e., no monolete variants were observed (cf. Playford 2015: 7).

**Previous records**. As for *Apiculiretusispora tersa*.

***Retusotriletes*** sp. **A**
Pl. 1, fig. 9

**Description**. Spores radial, trilete. Amb circular. Laesurae simple, straight, length ca 0.8-0.9 of spore radius, terminating at curvaturate invaginations. Contact areas well defined, exine thinner than in curvaturate-equatorial regions (ca 1.2 vs. 2-3 µm). Exine laevigate, apart from irregular pitting (corrosion effect).

**Dimensions** (three specimens). Equatorial diameter 74, 82, 87 µm.

**Comparison**. This form shows no close similarity to species of this genus that have been recorded from the Australian Upper Devonian-Carboniferous.

Genus *Verruciretusispora* Owens, 1971
Type species: *Verruciretusispora robusta* Owens, 1971 [OD].

***Verruciretusispora*** sp. **A**
Pl. 1, figs 10, 11

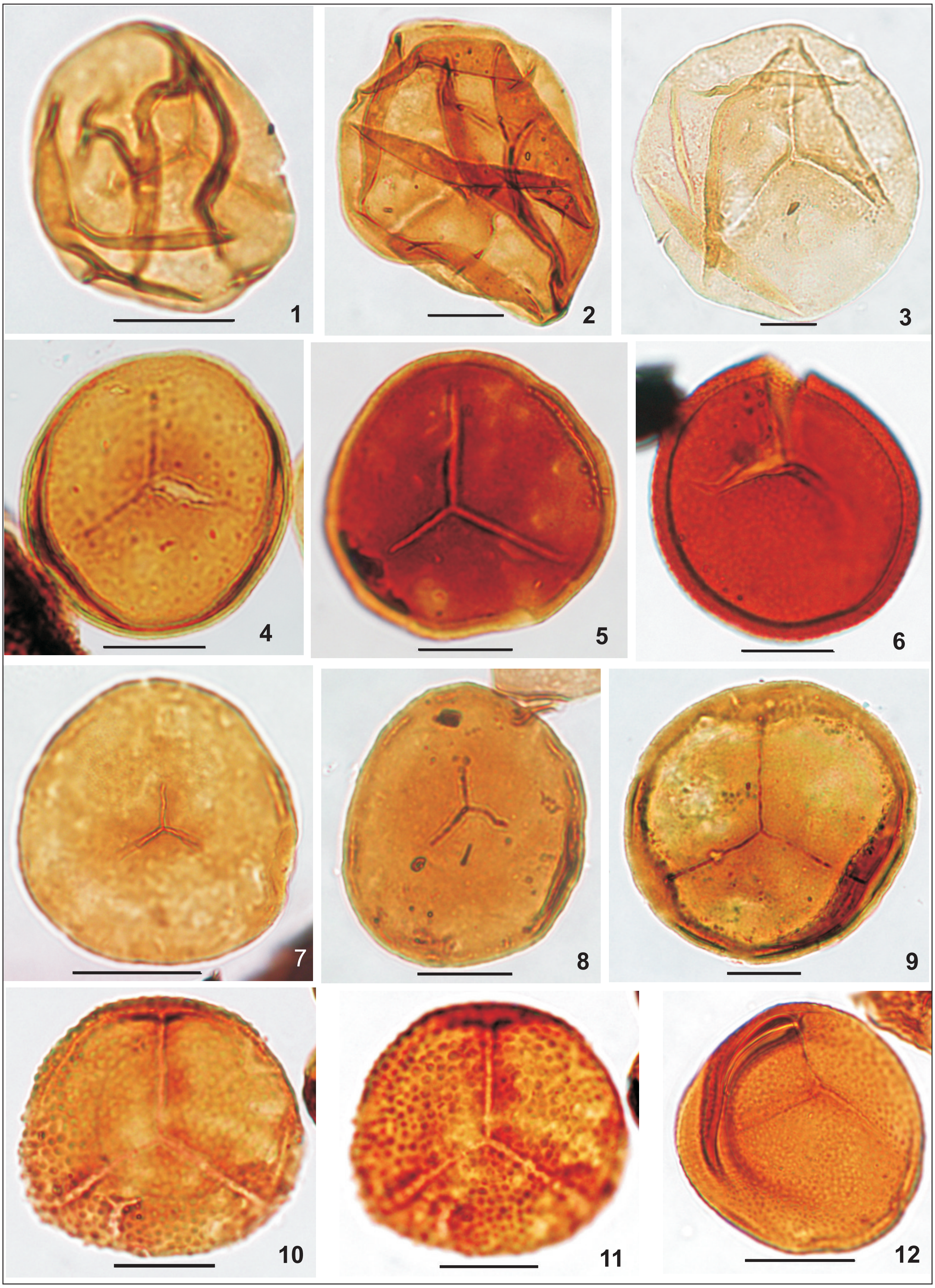
**Description**. Spores radial, trilete; amb subtriangular-subcircular, sides convex, apices obtusely rounded. Laesurae distinct, simple, straight, extending almost to equator, terminating at curvaturate invaginations. Contact areas, defined by curvaturae perfectae, laevigate. Exine ca 2.4-3 µm thick; sculptured distally and equatorially or near-equatorially with well-defined verrucae having circular-subcircular bases 1.5-2 µm in diameter, 1-1.8 µm high, spaced ± regularly ca 0.5-1.5 µm apart.

**Dimensions** (three specimens). Equatorial diameter 43, 47, 58 µm.

**Comparison**. This rare form bears scant resemblance to previously described representatives of the genus. *Verruciretusispora* sp. A of Playford (2015: 10, fig. 4I) features a circular amb, more distinct curvaturae, and coarser verrucae that are less uniformly distributed on the distal surface. *Verruciretusispora loboziakii* Higgs, Finucane & Tunbridge, 2002 (p. 145, 147, pl. I, 1-5, 9, 11) also has less regularly distributed sculptural elements that include rugulae.

PLATE 1

Figs 1-3 - *Calamospora* spp. 1, 2) medial foci. 3) proximal focus.
Fig. 4 - *Punctatisporites lucidulus* Playford & Helby, 1968, medial focus.
Figs 5, 6 - *Punctatisporites subtritus* Playford & Helby, 1968, near-proximal foci.
Figs 7, 8 - *Phyllothecotriletes golatensis* Staplin, 1960, proximal and medial foci, respectively.
Fig. 9 - *Retusotriletes* sp. A, proximal focus.
Figs 10, 11 - *Verruciretusispora* sp. A, near-proximal and distal foci, respectively.
Fig. 12 - *Cyclogranisporites firmus* Jones & Truswell, 1992, medial focus.
Space bars represent 20 µm; for locality and other curatorial details, see Appendix 1.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Infraturma **Apiculati** Bennie & Kidston, 1886 emend. R. Potonié, 1956
Subinfraturma **Granulati** Dybová & Jachovicz, 1957
Genus *Cyclogranisporites* R. Potonié & Kremp, 1954
Type species: *Cyclogranisporites leopoldii* (Kremp, 1952) R. Potonié & Kremp, 1954 [OD].

***Cyclogranisporites firmus*** Jones & Truswell, 1992
Pl. 1, fig. 12

1992 *Cyclogranisporites firmus* Jones & Truswell: 163, figs 8S, 9K, L, O-V.

**Dimensions** (eight specimens). Equatorial diameter 37 (45) 53 µm.

**Remarks**. Relatively thick (ca 3.5-4 µm) exine sculptured comprehensively with a combination of grana and small verrucae/rugulae characterizes this species, as described by Jones & Truswell (1992) and Playford (2015: 10, fig. 4J-N).

**Previous records**. In the Galilee Basin, Queensland, Jones & Truswell (1992) reported that the range of *Cyclogranisporites firmus* encompasses their biozones A-D (Upper Mississippian through Lower Permian). Playford (2015) recorded the species from a core considered datable as middle-late Visean in the northern Perth Basin, and noted its possible presence in the Argentinian Carboniferous.

Genus *Waltzispora* Staplin, 1960
Type species: *Waltzispora lobophora* (Waltz in Luber & Waltz, 1938) Staplin, 1960 [OD].

***Waltzispora*** sp. **A**
Pl. 2, fig. 9

**Description.** Spore radial, trilete. Amb subtriangular with concave to almost straight sides and relatively wide, broadly obtuse to slightly pointed apices. Simple, straight laesurae extending ca four-fifths of distance to equatorial margin. Exine 1.7 µm thick, essentially laevigate apart from irregular pitting due to corrosion.

**Dimensions** (one specimen). Equatorial diameter 33 µm.

**Comparison**. The specimen is morphologically similar to several previously described species from Mississippian deposits of the northern hemisphere – viz., *Waltzispora polita* (Hoffmeister, Staplin & Malloy, 1955) Smith & Butterworth, 1967, *W. sagittata* Playford, 1962, and *W. planiangulata* Sullivan, 1964. However, pending discovery of further and better preserved specimens, it is placed in open nomenclature.

Subinfraturma **Verrucati** Dybová & Jachowicz, 1957
Genus *Converrucosisporites* R. Potonié & Kremp, 1954
Type species: *Converrucosisporites triquetrus* (Ibrahim, 1933) R. Potonié & Kremp, 1954 [OD].

***Converrucosisporites*** sp. **A**
Pl. 2, figs 4, 5

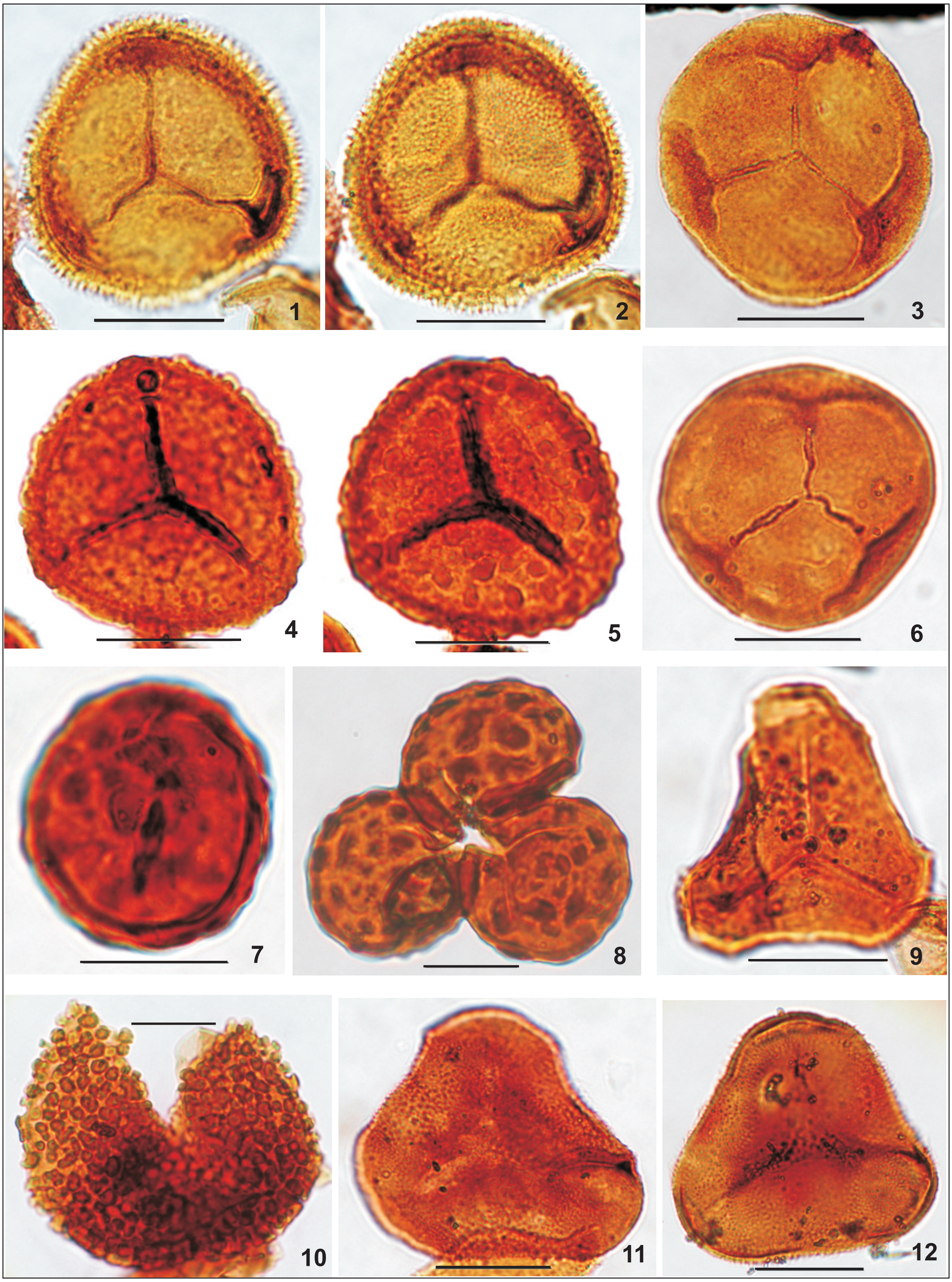
**Description**. Spores radial, trilete. Amb subtriangular with obtusely rounded apices and convex sides. Laesurae distinct, straight, length three-quarters to four-fifths of amb radius; flanked by dark (thickened), slightly elevated lips individually ca 0.6-1 µm wide and having entire to scalloped margins. Exine 1.5 µm thick, laevigate proximally. Distal exine conspicuously sculptured with mostly discrete, variably spaced verrucae, up to 1.6 µm high, bases of verrucae irregularly rounded, < 2.5 µm apart.

**Dimensions** (two specimens). Equatorial diameter 43, 44 µm.

**Remarks**. This distinctive form appears unassignable, nor closely comparable, to previously described species of the genus, but insufficient specimens are available for formal naming.

PLATE 2

Figs 1, 2 - *Apiculiretusispora tersa* Playford, 2015, proximal and distal foci, respectively.
Figs 3, 6 - *Retusotriletes separatus* Playford, 2015, medial and proximal foci, respectively.
Figs 4, 5 - *Converrucosisporites* sp. A, proximal and distal foci, respectively
Figs 7, 8 - *Verrucosisporites gregatus* Playford & Melo, 2012. 7) medial focus. 8) part tetrad.
Fig. 9 - *Waltzispora* sp. A, medial focus.
Fig. 10 - *Verrucosisporites* sp. cf. *V. italiaensis* Playford & Helby, 1968, distal-medial focus.
Figs 11, 12 - *Tricidarisporites* sp. A, medial foci.
Scale bars represent 20 µm; for locality and other curatorial details, see Appendix 1.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Subinfraturma **Verrucati** Dybová & Jachowicz, 1957
Genus *Verrucosisporites* Ibrahim, 1933
emend. Smith & Butterworth, 1967
Type species: *Verrucosisporites verrucosus* (Ibrahim, 1932) Ibrahim, 1933 [OD].

***Verrucosisporites basiliscutis*** Jones & Truswell, 1992
Pl. 3, fig. 4

1992 *Verrucosisporites basiliscutis* Jones & Truswell: 161, fig. 8C, E-H, J-L.

**Dimensions** (five specimens). Equatorial diameter (sculptural projections excluded) 41 (51) 60 µm.

**Remarks**. The few specimens encountered here are sculptured comprehensively with variously-shaped and -spaced verrucae, as described and illustrated by Jones & Truswell (1992) and Playford (2015: 11, fig. 5A-D).

**Previous records**. Reported initially by Jones & Truswell (1992) from Queensland's Galilee Basin, extending through their biozones A-E (uppermost Mississippian-Lower Permian); and subsequently by Playford (2015) from a northern Perth Basin core sample here ascribed to the middle-upper Visean.

***Verrucosisporites gregatus*** Playford & Melo, 2012
Pl. 2, figs 7, 8

2012 *Verrucosisporites gregatus* Playford & Melo: 23 (cum syn.), pl. 4, figs 4-11.
2014 *Verrucosisporites roncadorense* di Pasquo in di Pasquo & Iannuzzi, partim: 419, fig. 7.8 (only).

**Description**. Spores radial, trilete; commonly preserved as partial or complete tetrads. Amb circular or subcircular. Laesurae distinct or ± indistinct; simple, straight, extending at least 0.7 of distance to equator. Exine 1.5-3 µm thick, distal surface and proximo-equatorial region bearing coarse, broadly rounded, mostly discrete verrucae 0.8-3.5 µm high with circular to irregularly rounded-polygonal or -elongate basal outlines (maximum diameter 2.3-10 µm) spaced 10 µm or less apart. Contact faces not clearly demarcated apart from being either laevigate-scabrate or bearing much-diminished verrucate sculpture.

**Dimensions** (13 specimens). Equatorial diameter, including sculptural projections, 30 (38) 45 µm.

**Previous records**. *Verrucosisporites gregatus* Playford & Melo, 2012 is known from the Middle-Upper Mississippian of Western and Northern Gondwana, as documented by Playford & Melo (2012: 23). The first report from Eastern Gondwana is that of Playford (2015) from the northern Perth Basin.

***Verrucosisporites quasigobbettii***
Jones & Truswell, 1992
Pl. 3, figs 1-3

1968 *Verrucosisporites* sp. cf. *V. gobbettii* Playford, 1962; Playford & Helby: 108-109, pl. 9, figs 6, 7.
1992 *Verrucosisporites quasigobbettii* Jones & Truswell: 161, fig. 8N, P, Q.
1992 *Verrucosisporites* sp. Jones & Truswell: 161, 163, fig. 8M, R.
1995 *Verrucosisporites* sp. Clayton: pl. I, fig. 8 [no description].
2012 *Verrucosisporites quasigobbettii* Jones & Truswell, 1992; Playford & Melo: 26-27 (cum syn.), pl. 5, figs 7-9.
non 2016 *Verrucosisporites quasigobbettii* (Playford & Helby) [sic] Jones & Truswell; Aria-Nasab, Spina, Cirilli & Daneshian: pl. 3, fig. 9 [no description].

**Dimensions** (21 specimens). Equatorial diameter, excluding projecting verrucae, 33 (47) 63 µm.

**Remarks**. The present specimens accord with those detailed by previous authors (Jones & Truswell 1992, as per above synonymy; Playford & Melo 2012: 26, pl. 5, figs 7-9; Playford 2015: 13, fig. 5G-T).

**Previous records**. *Verrucosisporites quasigobbettii* Jones & Truswell, 1992 has been reported extensively from Eastern and Western Gondwana, particularly from Middle-Upper Mississippian strata (see summaries by Playford & Melo 2012: 26-27; Playford 2015: 13). Also figured by Kora & Schultz (1987; as *V. gobbettii* Playford, 1962) from similarly dated material from Sinai, Egypt.

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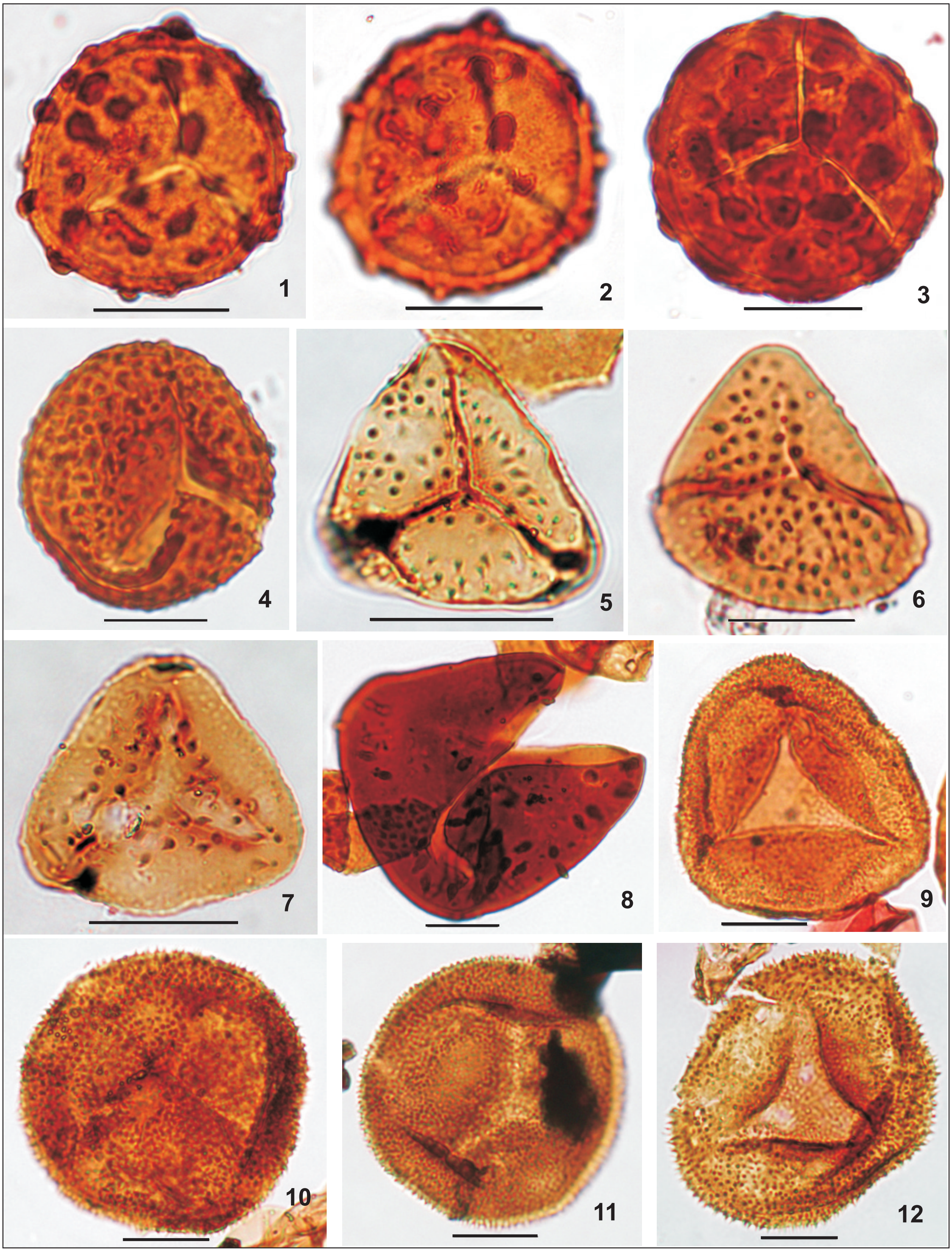
PLATE 3

Figs 1-3 - *Verrucosisporites quasigobbettii* Jones & Truswell, 1992. 1, 2) near-proximal and distal foci, respectively. 3) proximal focus.
Fig 4 - *Verrucosisporites basiliscutis* Jones & Truswell, 1992, proximal-medial focus.
Figs 5-7 - *Anapiculatisporites concinnus* Playford, 1962. 5, 7) medial foci. 6) distal focus.
Fig. 8 - *Claytonispora distincta* (Clayton, 1971) Playford & Melo, 2012, medial focus.
Figs 9-12 - *Apiculatasporites spiculatus* Playford sp. n. 9) holotype, proximal focus. 10, 11) medial foci. 12) medial-distal focus.
Scale bars represent 20 µm; for locality and other curatorial details, see Appendix 1.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### *Verrucosisporites* sp. cf. *V. italiaensis* Playford & Helby, 1968

Pl. 2, fig. 10

cf. 1968 *Verrucosisporites italiaensis* Playford & Helby: 108, pl. 9, figs 15, 16.

**Dimensions** (three specimens). Equatorial diameter (sculptural projections excluded) 65, 69, 80 µm.

**Remarks and comparison**. The few specimens closely resemble *Verrucosisporites italiaensis* Playford & Helby, 1968, the main difference being size, the equatorial diameter of the latter being 93-131 µm, with a mean of 108 µm. Hence, positive attribution to *V. italiaensis* is withheld. *Verrucosisporites patelliformis* (Menéndez, 1965) Gutiérrez & Césari, 2000 (p. 444, fig. 2.A), from the Upper Pennsylvanian-Lower Permian of Argentina (Césari et al. 2011), could be similar to the present specimens, but published photomicrographs of Menéndez's species are insufficiently clear for comparative purposes.

Subinfraturma **Nodati** Dybová & Jachowicz, 1957

Genus *Anapiculatisporites* R. Potonié & Kremp, 1954

Type species: *Anapiculatisporites isselburgensis* R. Potonié & Kremp, 1954 [OD].

### *Anapiculatisporites amplus* Playford & Powis, 1979

Pl. 4, figs 9-12

1979 *Anapiculatisporites amplus* Playford & Powis: 381-382, pl. I, fig. 8, pl. II, figs 1-5.

**Description**. Spores radial, trilete; biconvex, distal face markedly convex. Amb subtriangular, sides slightly concave to slightly convex, apices obtusely rounded. Laesurae distinct, almost attaining equator, commonly with lips individually ± 3 µm wide, locally emphasized by exinal folding. Exine 1.5-3.8 µm thick on proximal surface and unsculptured distal surface. Apart from the equatorial interradial regions, distal surface conspicuously sculptured with discrete, blunted or pointed, apiculate projections (coni/spinae) 2-5 µm high; bases circular-subcircular in outline, 1.5-5 µm in diameter, up to 8 µm apart.

**Dimensions** (14 specimens). Equatorial diameter, excluding sculptural projections, 62 (75) 84 µm.

**Previous records**. Playford & Melo (2012: 27) summarized the distribution of this species in Eastern, Western, and Northern Gondwana in strata of Visean through early Pennsylvanian age. Also reported by Kora (1993: 240, pl. 2, figs 1-3) from ?Lower Pennsylvanian of Sinai, Egypt.

### *Anapiculatisporites concinnus* Playford, 1962

Pl. 3, figs 5-7

1962 *Anapiculatisporites concinnus* Playford: 587-588, pl. 80, figs 9-12.
2012 *Anapiculatisporites concinnus* Playford, 1962; Playford & Melo: 28-29 (cum syn.), pl. 6, figs 1-4.

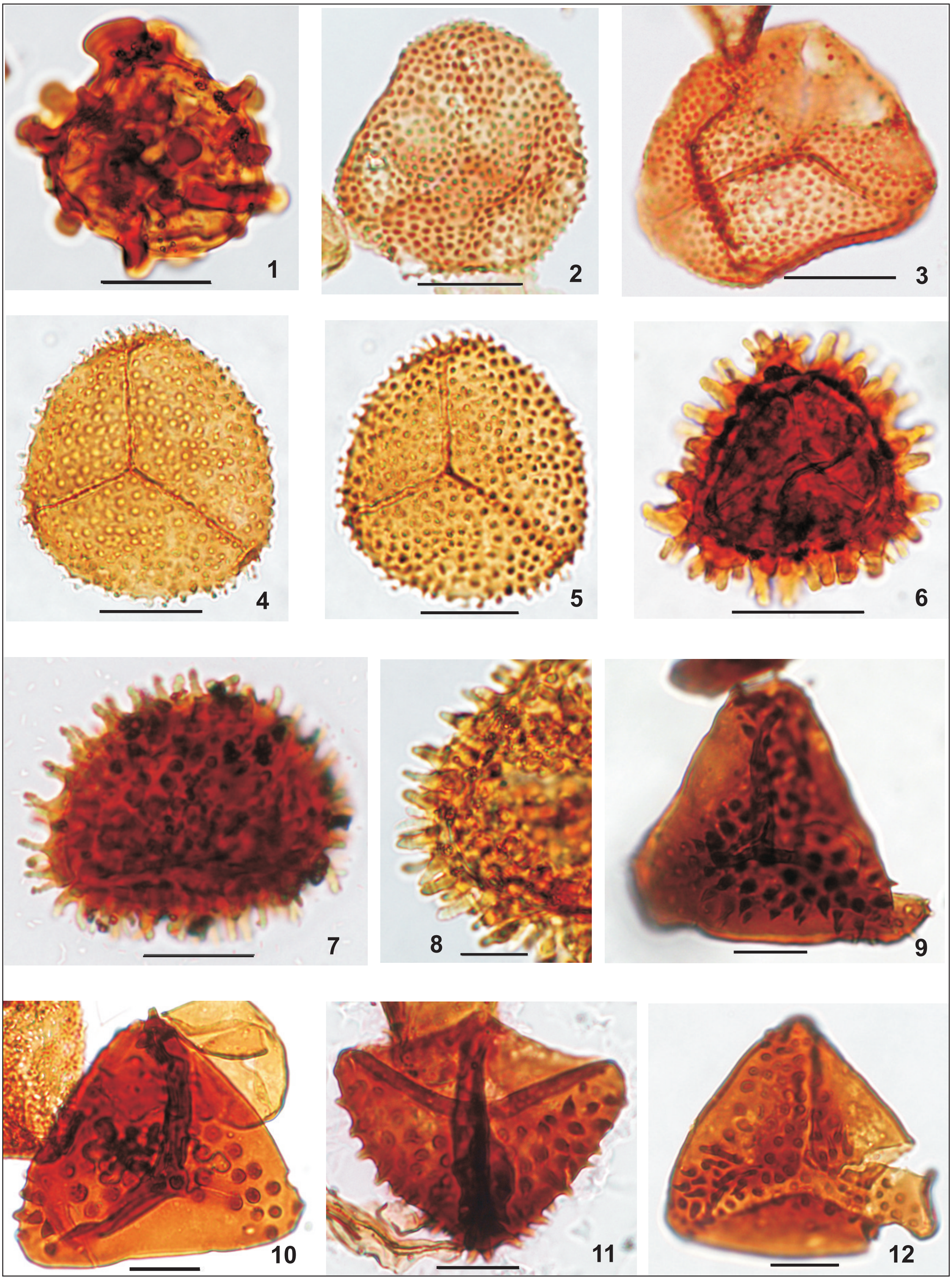
**Dimensions** (five specimens). Equatorial diameter 28 (33) 37 µm.

**Remarks**. The few specimens of *Anapiculatisporites concinnus* Playford, 1962 encountered during the present study exhibit the characteristic variation in the disposition of the coni, which are borne exclusively on the distal surface and commonly along the equatorial interradii.

**Previous records**. Reported extensively from Visean strata of both northern and southern hemispheres, and persisting locally into the upper Palaeozoic (Pennsylvanian, Lower Permian) of several Gondwanan regions (Playford & Melo 2012: 29).

PLATE 4

Fig. 1 - *Raistrickia accincta* Playford & Helby, 1968, near-distal focus.
Figs 2, 3 - *Dibolisporites disfacies* Jones & Truswell, 1992. 2) distal focus. 3) medial focus.
Figs 4, 5 - *Dibolisporites sejunctus* Playford sp. n., holotype, proximal and distal foci, respectively.
Figs 6-8 - *Raistrickia radiosa* Playford & Helby, 1968. 6) proximo-equatorial focus. 7) medial focus. 8) sculptural detail (scale bar = 10 µm).
Figs 9-12 - *Anapiculatisporites amplus* Playford & Powis, 1979. 9, 12) distal foci. 10) medial focus. 11) equatorial aspect.
Scale bars represent 20 µm, unless otherwise indicated; for locality and other curatorial details, see Appendix 1.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Genus *Apiculatasporites* Ibrahim, 1933 emend. Smith & Butterworth, 1967

Type species: *Apiculatasporites spinulistratus* (Loose, 1932) Ibrahim, 1933 [M].

***Apiculatasporites spiculatus*** Playford sp. n.

Pl. 3, figs 9-12

**Holotype**: Slide F49776/1, D23 (Pl. 3, fig. 9). Proximal aspect. Equatorial diameter 61 μm; subtriangular/subcircular amb with convex sides and obtusely rounded apices; gaping laesurae extending ca three-quarters of distance to equator; exine 1.4 μm thick, contact areas ± laevigate, elsewhere (distal face and proximo-equatorial region) very finely and densely apiculate (coni and spinae ca 0.5-0.9 μm high, basal diameter < 0.5 μm).

**Type locality**: Western Australia, northern Perth Basin, Coolcalalaya Sub-basin; CRAE DDH YCH-2, core, 118.8 m.

**Etymology**: Latin, *spiculatus*, prickly, bearing small spikes.

**Diagnosis**: Spores radial, trilete. Amb circular-subcircular or very broadly roundly subtriangular. Laesurae distinct, simple, straight, length ca three-quarters of spore radius, commonly gaping. Distal and proximo-equatorial exine 1.5-2 μm thick, densely sculptured with minute apiculate elements (predominantly coni, some spinae) < 1 μm high, < 0.5 μm broad basally, ca 0.3-0.7 μm apart. Laevigate to scabrate contact areas occupying bulk of proximal face.

**Dimensions** (11 specimens). Equatorial diameter 48 (61) 78 μm.

**Comparison.** *Apiculatasporites spiculatus* sp. n. shows some resemblance to *Apiculiretusispora tersa* Playford, 2015 (p. 7, 10, fig. 3L, M, fig. 4A-H), differing in featuring unlipped, often gaping laesurae and in lacking distinct curvaturae. It is also similar to the Devonian species *Apiculiretusispora brandtii* Streel, 1964 (p. B8, pl. 1, figs 6-10; (text)fig. 2), which is generally larger, distinctly curvaturate, and sculptured with a range of minute projections (grana, coni, spinae). Moreover, for those reasons, the present form is incompatible with Breuer & Steeman's (2013) *Apiculiretusispora brandtii* Morphon. *Apiculatasporites spiculatus* differs from *A. quadrosii* Playford & Melo, 2012 (p. 30-31, pl. 6, figs 11-16, pl. 7, figs 14, 15), which has generally shorter, non-gaping laesurae and somewhat coarser (albeit still diminutive and densely distributed) conate sculpture.

Genus *Claytonispora* Playford & Melo, 2012

Type species: *Claytonispora distincta* (Clayton, 1971) Playford & Melo, 2012 [OD].

2012 *Claytonispora* Playford & Melo: 31, 33 (cum syn.).

**Discussion**. See Playford & Melo (2012: 31-33, text-fig. 4) for a detailed account of the diagnostic attributes of *Claytonispora* and its differentiation from sculpturally comparable genera.

***Claytonispora distincta*** (Clayton, 1971) Playford & Melo, 2012

Pl. 3, fig. 8

1971 *Umbonatisporites distinctus* Clayton: 591-592, pl. 4, figs 4-6.
2012 *Claytonispora distincta* (Clayton, 1971) Playford & Melo: 33 (cum syn.), pl. 6, fig. 17, pl. 7, figs 1, 2, text-figs 4D, E.

**Dimensions** (two specimens). Equatorial diameter, excluding sculptural projections, 79, 92 μm.

**Remarks and comparison**. The few specimens of *Claytonispora distincta* (Clayton, 1971) Playford & Melo, 2012 identified here are clearly congruent with the detailed descriptions and illustrations provided by, inter alia, Clayton (1971), Playford (1971, 1972, 1976, 1991), Playford & Satterthwait (1986), and Higgs (1996).

**Previous records**. This distinctive species has been reported globally from Mississippian rocks (Playford 1991; Playford & Melo 2012).

Genus *Dibolisporites* Richardson, 1965 emend. Playford, 1976

Type species: *Dibolisporites echinaceus* (Eisenack, 1944) Richardson, 1965 [OD].

***Dibolisporites disfacies*** Jones & Truswell, 1992

Pl. 4, figs 2, 3

1992 *Dibolisporites disfacies* Jones & Truswell: 167 (partim), fig. 11A-F, I, J (non fig. 11G, H, K-M).
2015 *Dibolisporites disfacies* Jones & Truswell; Playford, 14-15 (cum syn.), fig. 6A-L.

**Dimensions** (eight specimens). Equatorial diameter, excluding sculptural projections, 38 (47) 52 μm.

**Remarks and comparison**. Jones & Truswell (1992: 167) noted and included broadly within their species *Dibolisporites disfacies* "a variant in which the processes are finer than average; in these, the basal section of the biform element is elongated, and the surmounting spine much longer in relation to the total length of the projection." This sculptural distinction is well illustrated and confirmed by their scanning electron micrographs: viz., Jones & Truswell 1992, fig. 11J (characteristic *D. disfacies*) vs. fig. 11L ('variant'). Playford (2015) recorded the former but not the latter in his CL5 assemblage, hence foreshadowing that the 'variant' be accorded separate specific status. This is proposed below as *D. sejunctus* sp. n. The two species, represented in several samples of the present study, are readily distinguishable; i.e., absent any evidence of morphological intergradation. Note that Jones & Truswell's (1992) diagnosis of *D. disfacies* did not embrace the variant morphology and thus requires no formal modification or emendation.

As stated by Jones & Truswell (1992), *D. disfacies* differs from *D. microspicatus* Playford, 1978 (p. 121-122, pl. 5, figs 1-9, text-fig. 6) in having a thinner exine and a less durable proximal face. Furthermore, the distal biform elements – commonly coalescent in *D. microspicatus* – are discrete and more uniformly distributed in *D. disfacies*.

**Previous records**. Exclusively Gondwanan distribution in strata encompassing the uppermost Mississippian to Lower Permian, as summarized by Playford (2015: 15).

### ***Dibolisporites sejunctus*** Playford sp. n.

Pl. 4, figs 4, 5

1992 *Dibolisporites disfacies* Jones & Truswell: 167 (partim), fig. 11G, H, K-M (only).

**Holotype**: Slide F49776/1, X53/3 (Pl. 4, figs 4, 5). Proximal aspect. Equatorial diameter 51 μm; amb broadly rounded subtriangular; distinct laesurae almost attaining equator; proximal face laevigate; relatively broadly based, biform, apiculate sculptural projections borne regularly and discretely on distal face and projecting equatorially, up to 3.5 μm long and 2 μm broad at base; unsculptured exine ca 1.3 μm thick.

**Type locality**: Western Australia, northern Perth Basin, Coolcalalaya Sub-basin; CRAE DDH YCH-2, core, 118.8 m.

**Etymology**: Latin, *sejunctus*, disjoined, separated.

**Diagnosis**: Spores radial, trilete. Amb subtriangular with convex sides and broadly rounded apices. Laesurae distinct, simple, straight, extending close to equatorial margin. Exine, where unsculptured, 0.8-1.4 μm thick. Proximal surface laevigate. Distal surface and equator bearing apiculate biform projections, up to ca 3.5 μm long, close-spaced (0.5-4 μm apart), each having hemispherical (verruca-like) basal portion (typically ca 0.8-1.6 in diameter) surmounted by slender spina or bacula with truncate or slightly expanded termini.

**Dimensions** (11 specimens). Equatorial diameter, excluding sculptural projections, 38 (49) 60 μm.

**Comparison**. See above for distinctions à propos of *Dibolisporites disfacies* and *D. microspicatus*.

**Previous records**. From within the Upper Mississippian/Lower Pennsylvanian through Lower Permian succession of the Galilee Basin, Queensland (Jones & Truswell 1992), but precise range of their putative 'variant' of *D. disfacies* unspecified.

### Genus *Tricidarisporites* Sullivan & Marshall, 1966 emend. Gueinn, Neville & Williams in Neves et al., 1973

Type species: *Tricidarisporites balteolus* Sullivan & Marshall, 1966 [OD; for discussion see Playford 1978: 121]

### ***Tricidarisporites*** sp. **A**

Pl. 2, figs 11, 12

**Description**. Spores radial, trilete. Amb subtriangular; sides concave to almost straight; apices very broadly rounded. Laesurae ± distinct, straight, length ca three-quarters of spore radius, simple or with irregularly and slightly thickened margins. Exine ca 1 μm thick; proximal surface essentially laevigate; distal surface densely sculptured with minute, discrete spinae < 0.4 μm in basal diameter and basal separation, length commonly ca 0.5-1 μm but attaining up to 1.6 μm along amb interradii; broad apical regions of amb laevigate.

**Dimensions** (two specimens). Equatorial diameter 44, 45 μm.

**Comparison**. This form, unnamed because of its scant representation, resembles superficially two finely sculptured species from the British Lower Carboniferous; viz., *Tricidarisporites fasciculatus* (Love, 1960: 112, pl. 1, fig. 2, text-fig. 2) Sullivan & Marshall, 1966 and *T. arcuatus* Neville in Neves et al. 1973 (p. 32, pl. 1, figs 7, 8). However, *Tricidarisporites* sp. A differs from these chiefly in possessing spinose not granulate sculpture.

### Subinfraturma **Baculati** Dybová & Jachowicz, 1957
### Genus *Raistrickia* Schopf, Wilson & Bentall, 1944 emend. R. Potonié & Kremp, 1954

Type species: *Raistrickia grovensis* Schopf in Schopf, Wilson & Bentall, 1944 [OD].

### ***Raistrickia accincta*** Playford & Helby, 1968

Pl. 4, fig. 1

1968 *Raistrickia accincta* Playford & Helby: 109, pl. 9, figs 13, 14.
?1993 *Raistrickia accincta* Playford & Helby, 1968; Kora: 242, pl. 2, figs 11, 12 [no description].
non 2015 *Raistrickia accincta* Playford & Helby, 1968; Playford, fig. 7A-C.

**Dimensions** (three specimens). Equatorial diameter, excluding sculptural projections, 36, 38, 41 µm.

**Remarks**. This species – rare in the present material – is distinguished chiefly by its sculptural diversity. The predominant elements are pila of variable shape and size. Other projections include bacula, verrucae, and grana, as described originally (Playford & Helby 1968). Specimens attributed to *Raistrickia accincta* Playford & Helby, 1968 by Playford (2015) are here re-assigned to *R. corymbiata* sp. n.

**Previous records.** From the Southern New England Orogen, New South Wales (Playford & Helby 1968) in the Italia Road (Mount Johnstone) Formation (middle to late Visean; see Age of palynoflora, below); and possibly from the Lower Pennsylvanian of Sinai, Egypt (Kora 1993).

### ***Raistrickia corymbiata*** Playford sp. n.

Pl. 5, figs 1-5

1968 *Raistrickia radiosa* Playford & Helby: 109 (partim), pl. 9, fig. 8 (only).
?2002 *Raistrickia* sp. cf. *R. accincta* Playford & Helby, 1968; Césari & Limarino: 166, fig. 5D, G, H.
2015 *Raistrickia accincta* auct. non Playford & Helby, 1968; Playford: fig. 7A-C.

**Holotype**: Slide F49777/4, M48 (Pl. 5, fig. 2). Amb circular, diameter 48 µm; laesurae four-fifths of spore radius in length; exine 1.5 µm thick; pila up to 4.7 µm high and in basal diameter, distributed densely, if somewhat irregularly, on distal face and projecting prominently equatorially, bases and tops mostly discrete.

**Type locality**: Western Australia, northern Perth Basin, Coolcalalaya Sub-basin; CRAE DDH YCH-2, core, 170.1 m.

**Etymology**: Latin, *corymbiatus*, clustered (sculptural elements).

**Diagnosis**: Spores radial, trilete. Amb circular-subcircular, uncommonly convexly subtriangular. Laesurae ± distinct, simple, straight, length ca 0.7-0.9 of spore radius. Exine ca 1.2-1.7 µm thick, uncommonly showing coarse arcuate compression folding; bulk of proximal face (i.e., contact faces) laevigate or scabrate. Distinct, ± irregularly crowded, squat, sculptural projections (pila) borne distally and equatorially. Pila with circular to irregularly rounded bases 1-5 µm in diameter, up to 4-5 µm apart, uncommonly fused basally; height of pila commonly 2-5 µm, sides ± straight to constricted (concave); very slightly to distinctly expanded club-like tops 2-4 µm in diameter, commonly discrete, locally conjoined in groups of 2-3.

**Dimensions** (28 specimens). Equatorial diameter, exluding sculptural projections, 32 (50) 68 µm.

**Comparison**. Availability of numerous specimens in the present samples facilitates unequivocal differentiation of *Raistrickia corymbiata* sp. n. from *R. accincta* (see above) and from other similarly sculptured species such as *R. baculosa* Hacquebard, 1957 (p. 310, pl. 1, figs 23, 24) and *R. rotunda* Azcuy, 1975 (p. 60, 62, pl. XVII, figs 110-113, pl. XVIII, fig. 118).

**Previous records**. From Australian middle-late Visean strata containing the *Grandispora maculosa* palynoflora: viz., in the Southern New England Orogen, New South Wales (Playford & Helby 1968) and northern Perth Basin, Western Australia (Playford 2015; as *R. accincta*).

### ***Raistrickia radiosa*** Playford & Helby, 1968

Pl. 4, figs 6-8

1968 *Raistrickia radiosa* Playford & Helby: 109-110, pl. 9, figs 9, 10 (non fig. 8).

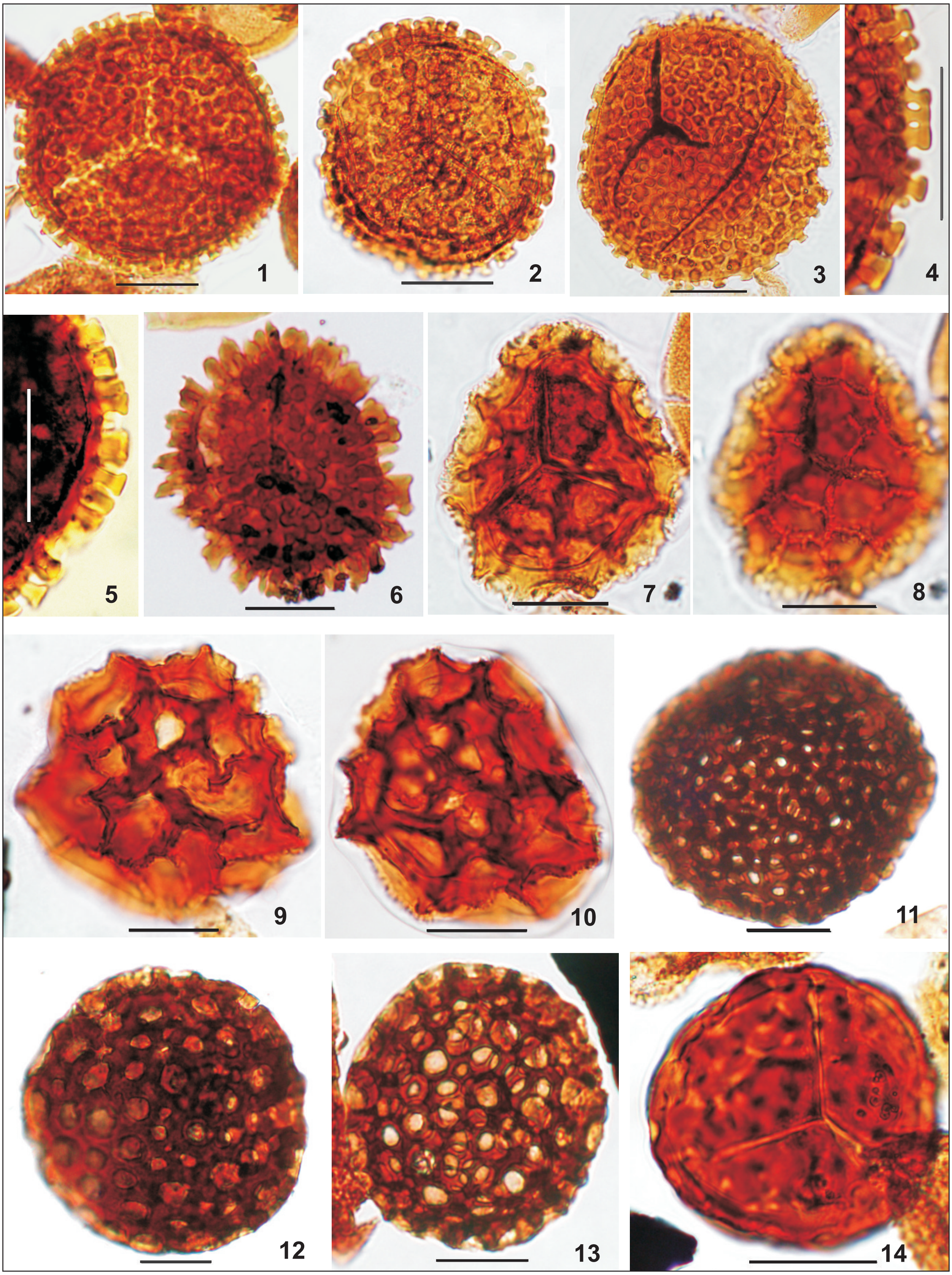
**Dimensions** (17 specimens). Equatorial diameter, excluding bacula, 33 (59) 70 µm.

**Remarks and comparison**. The present specimens conform to those detailed by Playford (2015: 15-16, fig. 7D-G). They are distinguishable sculpturally from specimens belonging to *R. corymbiata*, their bacula being more slender and lacking any distinct tendency toward terminal expansion.

**Previous records**. From within the Middle Mississippian-Lower Pennsylvanian of Australia and South America (see Playford, 2015: 16).

PLATE 5

Figs 1-5 - *Raistrickia corymbiata* Playford sp. n. 1) medial focus. 2) holotype, near-distal focus. 3) proximal focus. 4, 5) sculptural detail.
Fig. 6 - *Raistrickia* sp. A, distal-medial focus.
Figs 7-10 - *Cordylosporites asperidictyus* (Playford & Helby) Dino & Playford, 2002. 7, 8) proximal and distal foci, respectively. 9) distal focus. 10) medial focus.
Figs 11-13 - *Brochotriletes diversifoveatus* Playford & Satterthwait, 1985, medial foci.
Fig. 14 - *Foveosporites pellucidus* Playford & Helby, 1968, proximal focus.
Scale bars represent 20 µm; for locality and other curatorial details, see Appendix 1.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### ***Raistrickia* sp. A**

Pl. 5, fig. 6

**Description**. Spore radial, trilete. Amb subcircular. Laesurae ± distinct , extending to equatorial periphery; accompanied by lips 1-2 µm in overall width. Exine ca 1.7 µm thick, laevigate proximally. Distal exine sculptured ± irregularly with coarse projections of irregular but generally baculate form, projecting prominently around equator. Sculptural elements 3-6.5 µm long, bases circular to subcircular, 1.3-3.5 µm broad, discrete or basally coalescent, up to 4 µm apart; length of projections 3-6.5 µm, tops flat, undulant, or pointed.

**Dimensions** (one specimen). Equatorial diameter, sculpture excluded, 45 µm.

**Comparison**. The diverse form and irregularity of the sculptural projections of this single, hence informally designated spore appear to bear no close similarity to described species of the genus.

Infraturma **Murornati** R. Potonié & Kremp, 1954
Genus *Brochotriletes* Naumova, 1938
ex Ishchenko, 1952

Type species: *Brochotriletes magnus* Ishchenko, 1952 [M].

### ***Brochotriletes diversifoveatus***
Playford & Satterthwait, 1985

Pl. 5, figs 11-13

1969 *Reticulatisporites* sp. nº 2571 Lanzoni & Magloire, pl. II, figs 4, 5 [no description].
1985 *Brochotriletes diversifoveatus* Playford & Satterthwait: 141, pl. 4, figs 3-5.

**Description**. Spores radial, trilete. Amb circular to oval, uncommonly convexly subtriangular. Laesurae perceptible, simple, straight, length ca 0.7-0.9 of spore radius. Exine 2.8-5.5 µm thick and laevigate where unincised. Foveolate sculpture developed comprehensively; foveolae of variable outline (circular to irregularly rounded or elongate), 1.5-8 µm in maximum width and 2-3.7 µm deep.

**Dimensions** (26 specimens). Equatorial diameter 48 (66) 92 µm.

**Previous records**. From Visean strata of the Bonaparte Basin, Western Australia (Playford & Satterthwait 1985), the Amazonas Basin, northern Brazil (Playford & Melo 2012), and the Algerian Sahara (Lanzoni & Magloire 1969).

Genus *Cordylosporites* Playford & Satterthwait, 1985

Type species: *Cordylosporites sepositus* Playford & Satterthwait, 1985 [OD].

### ***Cordylosporites asperidictyus***
(Playford & Helby, 1968) Dino & Playford, 2002

Pl. 5, figs 7-10

1968 *Reticulatisporites asperidictyus* Playford & Helby: 110, pl. 9, figs 17, 18, pl. 10, fig. 1.
2002 *Cordylosporites asperidictyus* (Playford & Helby) Dino & Playford: 344-345, pl. 1, figs 8, 9.

**Dimensions** (six specimens). Equatorial diameter, sculpture excluded, 48 (59) 65 µm.

**Remarks**. The specimens collectively exhibit the characteristic variation in the gross form of the reticulate sculpture (perfectum or imperfectum) and in the nature of the minute supramural projections (verrucae, pila, bacula, spinae, coni).

**Previous records.** From middle-late Visean strata of the Southern New England Orogen, New South Wales (Playford & Helby 1968) and northern Perth Basin, Western Australia (Playford 2015). Reported also from South American rocks of similar or slightly younger (Pennsylvanian) age (Césari & Bercowski 1998; Dino & Playford 2002; Perez Loinaze et al. 2010, 2011; Perez Loinaze & Césari 2012).

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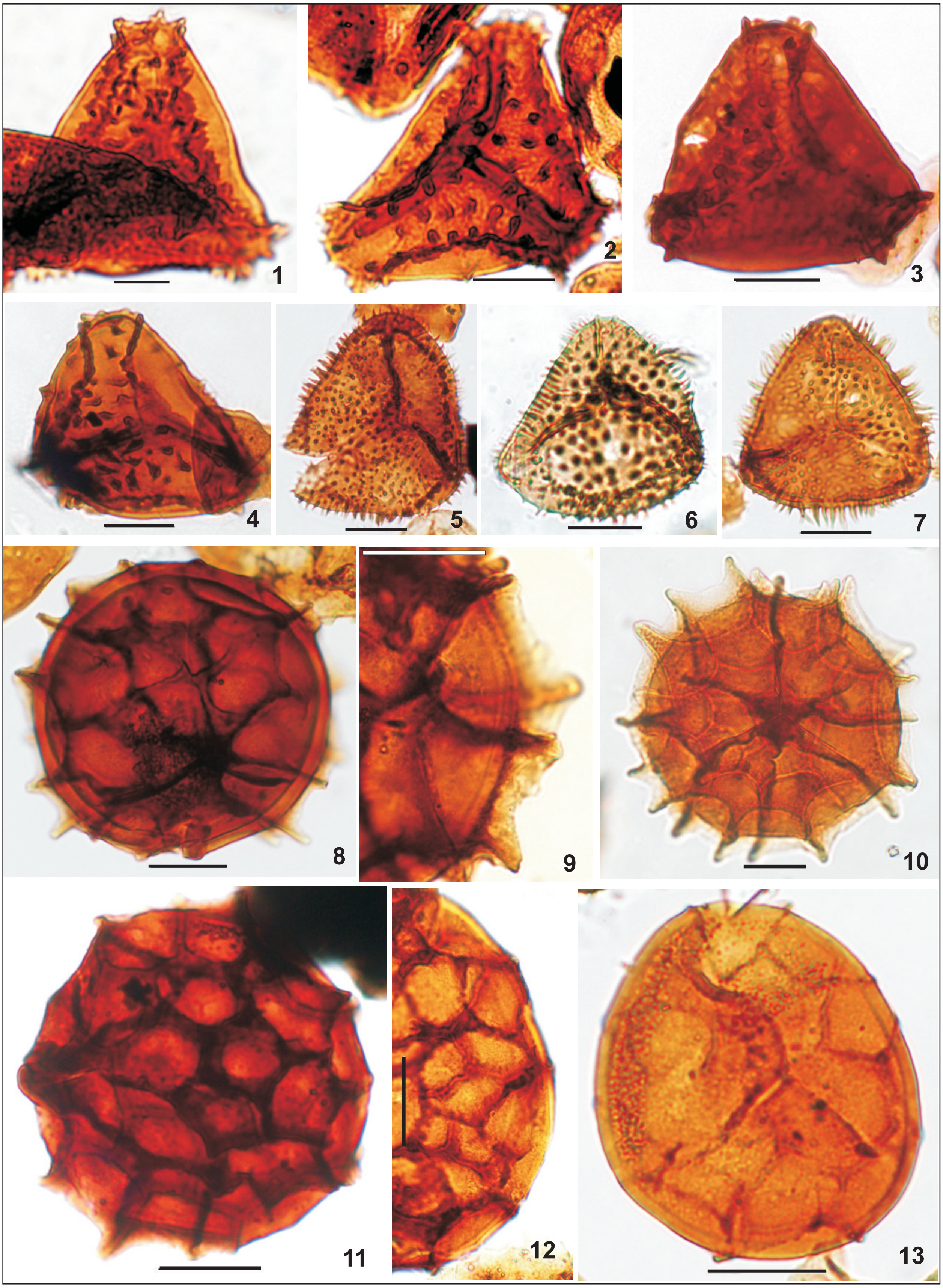
PLATE 6

Figs 1-4 - *Ahrensisporites cristatus* Playford & Powis, 1979. 1) distal focus. 2, 4) medial-distal foci. 3) near-proximal focus.
Figs 5-7 - *Diatomozonotriletes birkheadensis* Powis, 1984. 5) distal focus. 6, 7) medial focus.
Figs 8-13 - *Reticulatisporites magnidictyus* Playford & Helby, 1968. 8) medial focus. 9, 12) sculptural detail. 10) proximal focus. 11) distal focus. 13) degraded or immature specimen, medial focus.
Scale bars represent 20 µm; for locality and other curatorial details, see Appendix 1.



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Genus *Foveosporites* Balme, 1957

Type species: *Foveosporites canalis* Balme, 1957 [OD; M].

***Foveosporites pellucidus*** Playford & Helby, 1968

Pl. 5, fig. 14

1968 *Foveosporites pellucidus* Playford & Helby: 111, pl. 10, figs 2-6.
2000 *Foveosporites appositus* auct. non Playford, 1971; Melo & Loboziak, pl. II, 2 [no description].
2003 *Foveosporites appositus* auct. non Playford, 1971; Melo & Loboziak, pl. III, 11 [no description].
2011 *Foveosporites hortonensis* (auct. non Playford, 1964) Azcuy, 1975; Perez Loinaze, Limarino & Césari: fig. 6.9 [no description].

**Dimensions** (28 specimens). Equatorial diameter 38 (56) 70 µm.

**Comparison**. *Foveosporites appositus* Playford, 1971 (p. 28-29, pl. 10, figs 1-8) differs from *F. pellucidus* mainly in possessing a comprehensive, predominantly vermiculate sculpture (see Playford & Helby 1968; Playford 2015: fig. 7L-O).

**Previous records**. Australian reports are from middle-late Visean strata containing the *Grandispora maculosa* palynoflora of the Southern New England Orogen, New South Wales (Playford & Helby 1968) and northern Perth Basin, Western Australia (Playford 2015). Also identified in South American deposits of comparable and slightly younger age (see Playford & Melo 2012: 49-50).

Genus *Reticulatisporites* Ibrahim, 1933 emend. R. Potonié & Kremp, 1954

Type species: *Reticulatisporites reticulatus* (Ibrahim, 1932) Ibrahim, 1933 [OD].

***Reticulatisporites magnidictyus*** Playford & Helby, 1968

Pl. 6, figs 8-13

1968 *Reticulatisporites magnidictyus* Playford & Helby: 110-111, pl. 10, figs 7-10.
1987 *Raistrickia baculosa* (auct. non Hacquebard, 1957) Kora & Schultz: fig. 5 (14) [no description].
1987 *Acinosporites spiritensis* (auct. non Playford, 1971) Kora & Schultz: fig. 5 (15) [no description].
2012 *Reticulatisporites magnidictyus* Playford & Helby, 1968; Playford & Melo: 50 (cum syn.), pl. 13, figs 1-5.
2015 *Reticulatisporites magnidictyus* Playford & Helby, 1968; Playford: 17-18 (cum syn.), fig. 8A-F.

**Dimensions** (27 specimens). Equatorial diameter 48 (70) 101 µm, excluding projecting muri.

**Remarks**. As a cohort, the numerous specimens of *Reticulatisporites magnidictyus* Playford & Helby, 1968 encountered during this study exemplify the range of morphological variation evident from earlier studies (viz., publications cited in above synonymy). The chief variables are equatorial diameter, diameter of lumina, and height of muri. Additionally, Playford (in press), during an ongoing re-investigation of the Mount Johnstone Formation, reports the presence of a gula-like apical prominence in a minority of specimens belonging to this species. These were not encountered in the present study.

**Previous records**. *Reticulatisporites magnidictyus* is widely distributed through Western, Eastern, and Northern Gondwanan deposits of middle Visean through early Serpukhovian age (Playford & Melo 2012: 51; Playford 2015: 26).

Subturma **Auritotriletes** R. Potonié & Kremp, 1954
Infraturma **Auriculati** Schopf, 1938 emend. Dettmann, 1963
Genus *Ahrensisporites* R. Potonié & Kremp, 1954

Type species: *Ahrensisporites guerickei* (Horst, 1943) R. Potonié & Kremp, 1954 [OD].

***Ahrensisporites cristatus*** Playford & Powis, 1979

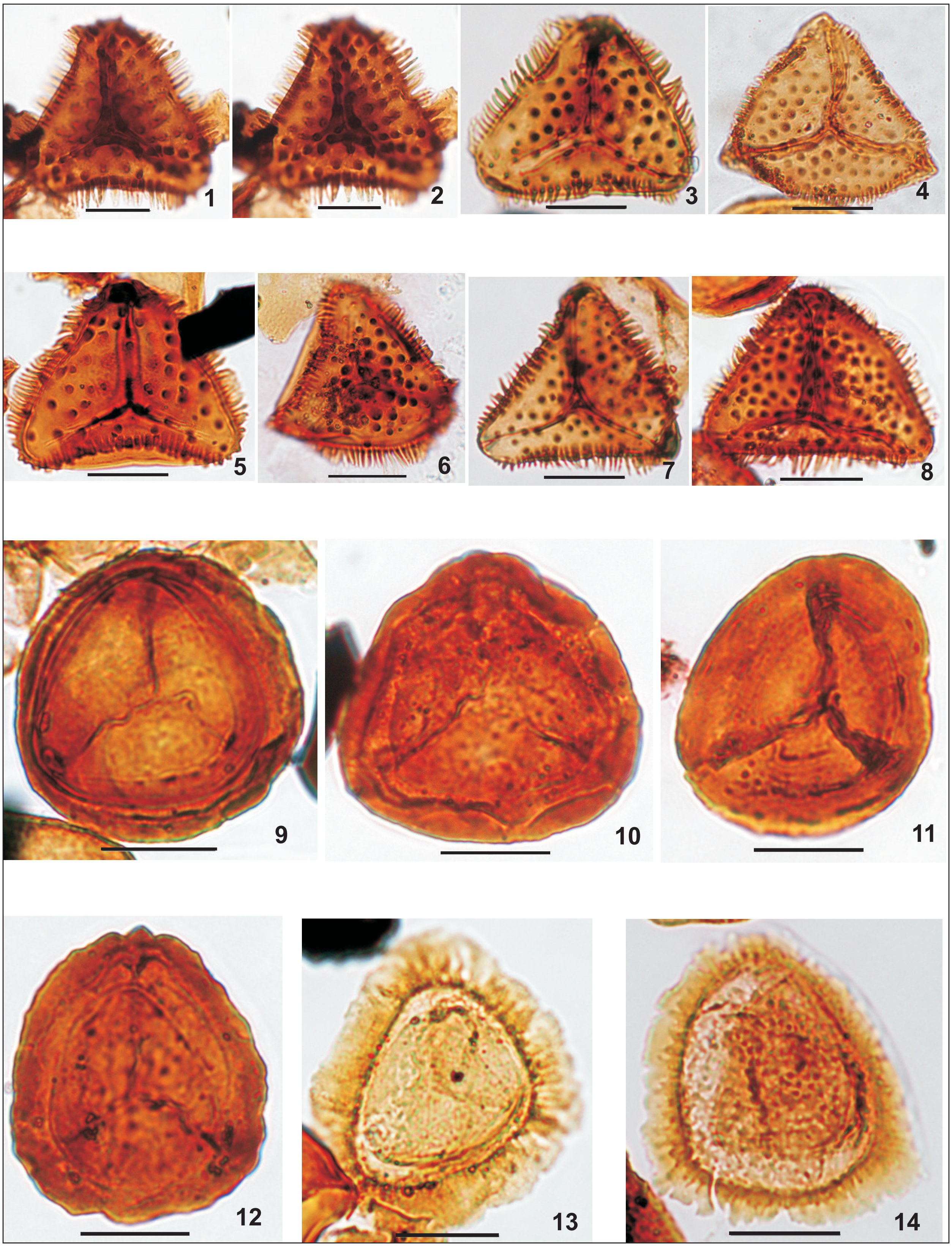
Pl. 6, figs 1-4

1979 *Ahrensisporites cristatus* Playford & Powis: 384-385, fig. 2, pl. II, fig. 6, pl. III, figs 1-7.

**Description**. Spores radial, trilete. Amb subtriangular with obtusely rounded or truncate apices and ± straight to slightly convex sides. Laesurae ±

PLATE 7

Figs 1-8 - *Diatomozonotriletes daedalus* Playford & Satterthwait, 1986. 1, 2) proximal and distal foci, respectively. 3, 7) proximal-medial foci. 4) proximal focus. 5, 6) medial-distal foci. 8) near-proximal focus.
Figs 9-12 - *Densoisporites truswelliae* Stephenson, Al Rawahi & Casey, 2008, medial foci.
Figs 13, 14 - *Indotriradites daemonii* Loboziak, Melo, Playford & Streel, 1999. 13) near-proximal focus. 14) distal focus.
Scale bars represent 20 µm; for locality and other curatorial details, see Appendix 1.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distinct, extending near to equator, commonly associated with conspicuous or inconspicuous fold-like lips individually up to 5 μm wide. Exine 1.3-2.6 μm thick (i.e., where unsculptured); distally kyrtomate and apiculate. Kyrtome comprising three, ± straight to concave, cristate/apiculate, exinal ridges, ca 2.5-6 μm wide and high, prescribing substantial subtriangular portion of distal surface and joining close to amb apices. Mostly discrete, relatively coarse coni and spinae (1.4-4 μm broad basally; 2-7 μm high; < 8 μm apart) borne on distal exine enclosed by kyrtome and less commonly and more sparsely outside the latter and projecting equatorially.

**Dimensions** (eight specimens). Equatorial diameter 58 (68) 84 μm.

**Previous records**. *Ahrensisporites cristatus* Playford & Powis, 1979 is a typically, and evidently exclusively, Gondwanan species. It has been reported from Australian and South American deposits ranging from Middle or Upper Mississippian through middle or upper Pennsylvanian as summarized by Dino & Playford (2002), and has been recorded subsequently from within that stratigraphic interval by such authors as Souza & Marques-Toigo (2003) and Souza (2006) from the Paraná Basin, Brazil; Gutiérrez & Barreda (2006) and Perez Loinaze et al. (2014) from the Paganzo Basin, Argentina; Kora (1993) from Sinai, Egypt; and Stephenson & Al-Mashaikie (2011) from Yemen.

Subturma **Zonotriletes** Waltz, 1935
Infraturma **Tricrassati** Dettmann, 1963
Genus *Diatomozonotriletes* Naumova, 1939
emend. Playford, 1963
Type species: *Diatomozonotriletes saetosus* (Hacquebard & Barss, 1957) Hughes & Playford, 1961 [SD; Playford 1963: 646].

***Diatomozonotriletes birkheadensis*** Powis, 1984
Pl. 6, figs 5-7

1984 *Diatomozonotriletes birkheadensis* Powis: 436, 438, pl. 1, figs 4-6.

**Dimensions** (18 specimens). Equatorial diameter 43 (54) 71 μm, excluding coronal spinae.

**Remarks**. The present specimens, preserved in both polar and equatorial aspects, conform to those detailed by Playford (2015: 18-19, fig. 10I-N).

**Previous records**. From Australian strata spanning the middle-upper Visean through Lower Permian (Playford 2015: 19).

***Diatomozonotriletes daedalus***
Playford & Satterthwait, 1986
Pl. 7, figs 1-8

1986 *Diatomozonotriletes daedalus* Playford & Satterthwait: 20, pl. 7, figs 10-14.
2015 *Diatomozonotriletes daedalus* Playford & Satterthwait, 1986; Playford: 19 (cum syn.), fig. 10O-T.

**Dimensions** (23 specimens). Equatorial diameter 41 (50) 65 μm, excluding coronal spinae.

**Remarks**. *Diatomozonotriletes daedalus* Playford & Satterthwait, 1986 is readily identifiable from its commonly lipped laesurae and prominent corona, the spinae of which contrast with the distal sculpturing elements (typically coni with mammoid bases): Playford & Satterthwait (1986) and Playford (2015).

**Previous records**. From Visean deposits of Australia (Playford, 1971, 2015; Playford & Satterthwait, 1986).

Suprasubturma **Laminatitriletes**
Smith & Butterworth, 1967
Subturma **Zonolaminatitriletes**
Smith & Butterworth, 1967
Infraturma **Cingulicavati**
Smith & Butterworth, 1967
Genus *Densoisporites* Weyland & Krieger, 1953
emend. Dettmann, 1963
Type species: *Densoisporites velatus* Weyland & Krieger, 1953 emend. Krasnova, 1961 [OD; M].

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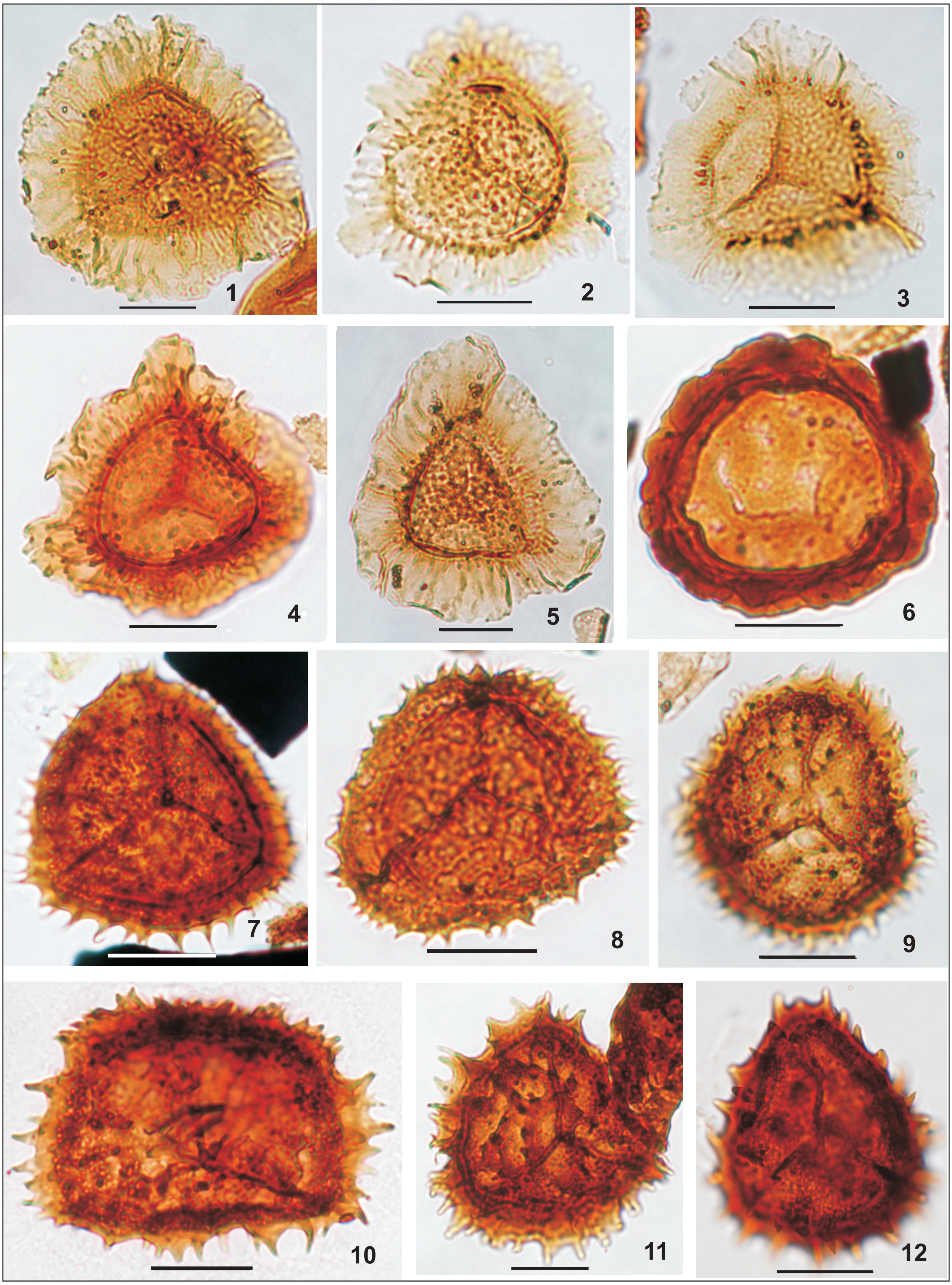
PLATE 8

Figs 1-5 - *Indotriradites dolianitii* (Daemon, 1974) Loboziak, Melo, Playford & Streel, 1999. 1, 5) medial foci. 2, 4) distal foci. 3) proximal focus.
Fig. 6 - *Densosporites claytonii* Ravn, McPhilemy, Rutherford, Talli & Bahra, 1994, medial focus.
Figs 7-12 - *Indotriradites kuttungensis* (Playford & Helby, 1968) Playford, 1991. 7, 10, 12) proximal foci. 8) medial focus. 9, 11) near-distal focus.
Scale bars represent 20 μm; for locality and other curatorial details, see Appendix 1.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### *Densoisporites truswelliae* Stephenson, Al Rawahi & Casey, 2008
Pl. 7, figs 9-12

1992 *Densoisporites* sp. Jones & Truswell: 175, fig. 12X, Y.
2008 *Densoisporites truswellii* [sic] Stephenson, Al Rawahi & Casey: 31, pl. 3, figs a-l.
2015 *Densoisporites truswelliae* Stephenson, Al Rawahi & Casey, 2008; Playford: 19-20, fig. 9A-I. [nom. corr. pro *truswellii*].

**Dimensions** (19 specimens). Overall equatorial diameter 43 (55) 67 µm; diameter of intexine, in polar view, 32 (38) 49 µm.

**Remarks**. The equatorial thickening of the exoexine varies in width (ca 1.5-5.5 µm) and its inner margin is commonly and somewhat irregularly scalloped, particularly in specimens with the wider thickening. Intexinal body is thin (ca 0.5-2.5 µm thick) but commonly well-defined with irregular marginal folding; its outline approximately conforms with amb. Laesurate lip development is conspicuous or relatively minor.

**Previous records**. This species is known from Australian strata of middle Visean to Early Permian age (Jones & Truswell 1992; Playford 2015); from cuttings samples, reputedly Lower Permian, of Oman (Stephenson et al. 2008); and from core samples, dated as Westphalian, of western Iraq (Stephenson et al. in press).

### Genus *Densosporites* Berry, 1937 emend. R. Potonié & Kremp, 1954
Type species: *Densosporites covensis* Berry, 1937 [OD].

### *Densosporites claytonii* Ravn, McPhilemy, Rutherford, Talli & Bahra, 1994
Pl. 8, fig. 6; Pl. 9, fig. 7

1994 *Densosporites claytonii* Ravn, McPhilemy, Rutherford, Talli & Bahra: 15, pl. 2.A.1, figs 1-9.
2012 *Densosporites claytonii* Ravn, McPhilemy, Rutherford, Talli & Bahra, 1994; Melo & Playford: 106-107 (cum syn.), pl. 4, figs 1, 2a, 2b.

**Dimensions** (five specimens). Overall equatorial diameter 51 (58) 71 µm; diameter of spore cavity (in polar view) 28 (37) 51 µm.

**Previous records**. This rare component of the present material, not previously reported from Australia, is known from Mississippian rocks of various parts of Western and Northern Gondwana (Melo & Playford 2012: 107).

### Genus *Indotriradites* Tiwari, 1964 emend. Foster, 1979
**Type species**: *Indotriradites korbaensis* Tiwari, 1964 [OD].

### *Indotriradites daemonii* Loboziak, Melo, Playford & Streel, 1999
Pl. 7, figs 13, 14

1999 *Indotriradites daemonii* Loboziak, Melo, Playford & Streel: 20 (cum syn.), pl. I, 1-5.
2015 *Indotriradites daemonii* Loboziak, Melo, Playford & Streel, 1999: Playford: 21 (cum syn.), fig. 10A-H.

**Dimensions** (12 specimens). Overall equatorial diameter 50 (66) 79 µm; spore-cavity diameter (polar view) 36 (41) 47 µm.

**Previous records**. This species was identified in the middle-upper Visean palynoflora (CL5 core) from the northern Perth Basin as documented by Playford (2015), who noted prior reports of its widespread distribution elsewhere in coeval Gondwana successions.

### *Indotriradites dolianitii* (Daemon, 1974) Loboziak, Melo, Playford & Streel, 1999
Pl. 8, figs 1-5

1974 *Hymenozonotriletes dolianitii* Daemon: 572, pl. VIII, figs 7, 8.
1999 *Indotriradites dolianitii* (Daemon, 1974) Loboziak, Melo, Playford & Streel: 18, 20, pl. I, 6-14.
2012 *Indotriradites dolianitii* (Daemon, 1974) Loboziak, Melo, Playford & Streel, 1999: Melo & Playford: 109 (cum syn.), pl. 4, figs 10, 11, pl. 6, fig. 7.

**Description**. Spores radial, trilete, cingulicavate. Amb convexly subtriangular, commonly with

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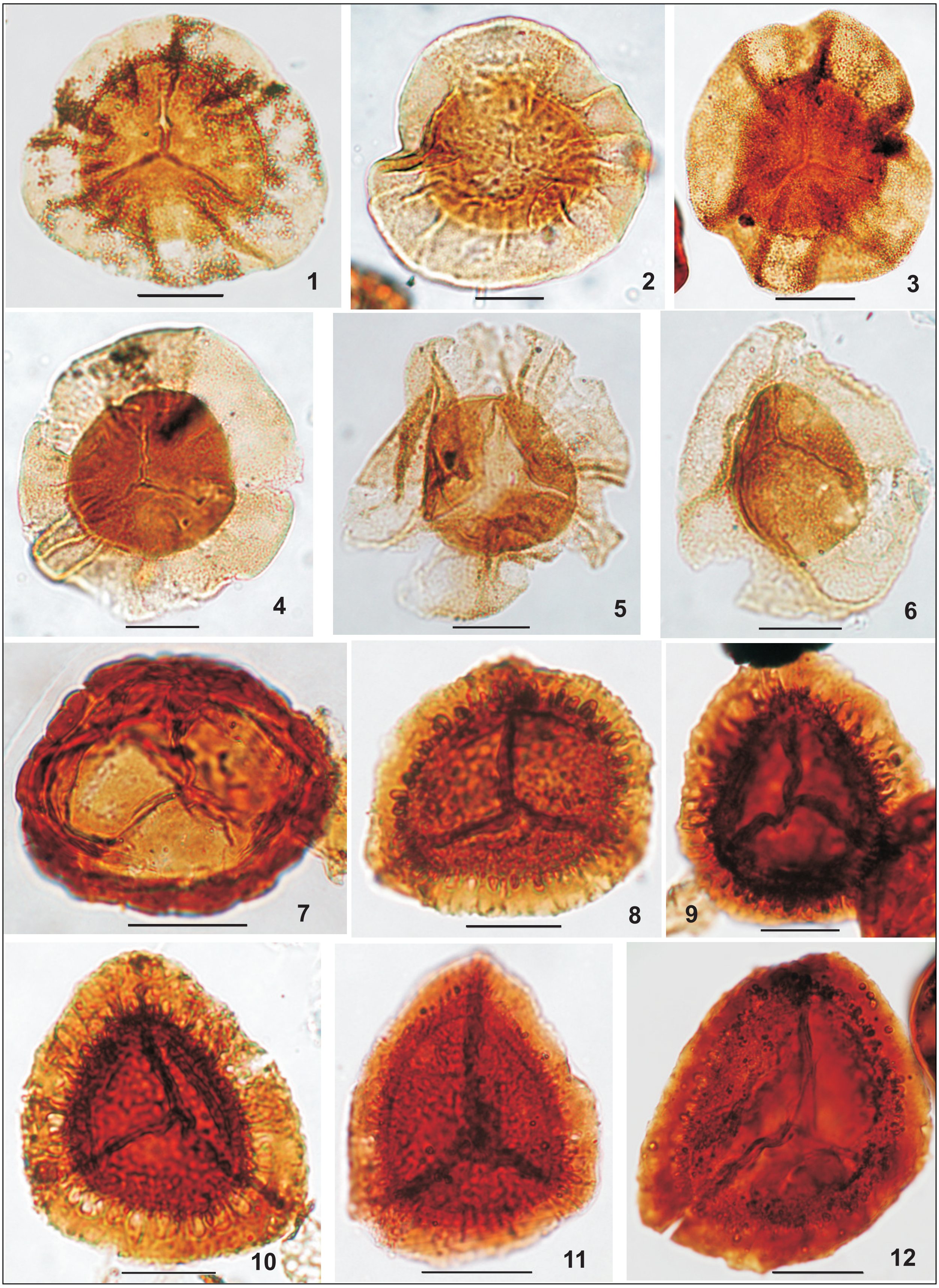
PLATE 9

Figs 1-6 - *Auroraspora solisorta* Hoffmeister, Staplin & Malloy, 1955. 1, 2, 4, 5, 6) proximal foci. 3) medial focus.
Fig. 7 - *Densosporites claytonii* Ravn, McPhilemy, Rutherford, Talli & Bahra, 1994, medial-proximal focus.
Figs 8-12 - *Vallatisporites valentulus* Playford sp. n. 8, 9, 12) proximal foci. 10) holotype, proximal focus. 11) medial focus.
Scale bars represent 20 µm; for locality and other curatorial details, see Appendix 1.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irregularly undulating, crenulated, or embayed margin. Laesurae commonly distinct, simple or narrowly lipped, extending to inner margin of zona. Distal surface of exoexine, including zona, bearing scattered to somewhat crowded spinae and small verrucae, typically radially oriented, imparting a strutted appearance to zona. Intexine, where clearly visible, commonly contracted slightly from exoexine.

**Dimensions** (22 specimens). Overall equatorial diameter 52 (69) 92 µm; spore-cavity diameter (polar view) 31 (42) 55 µm.

**Previous records**. From the Amazonas Basin, northern Brazil, in strata assigned to the Mag Range Zone (Loboziak & Melo 2003) and dated as late middle-early late Visean (Melo & Playford 2012).

### ***Indotriradites kuttungensis*** (Playford & Helby, 1968) Playford, 1991

Pl. 8, figs 7-12

1968 *Kraeuselisporites kuttungensis* Playford & Helby: 112-113, pl. 11, figs 6, 7.
1991 *Indotriradites kuttungensis* (Playford & Helby) Playford: 104.
non 1992 *Cristatisporites kuttungensis* (Playford & Helby, 1968) Jones & Truswell: 171, 173, fig. 14A-F.

**Dimensions** (50 specimens). Overall equatorial diameter, excluding spinose projections, 43 (60) 77 µm; diameter of spore cavity, in polar view, 31 (46) 62 µm.

**Previous records**. Described originally (Playford & Helby, 1968) from the Southern New England Orogen, New South Wales in strata now dated as middle to late Visean; and subsequently from a core sample, similarly datable, of the northern Perth Basin (CL5 borehole; Playford 2015: 21, 24, fig. 11A-T).

## Genus *Vallatisporites* Hacquebard, 1957

Type species: *Vallatisporites vallatus* Hacquebard, 1957 [OD].

### ***Vallatisporites valentulus*** Playford sp. n.

Pl. 9, figs 8-12

**Holotype**: Slide F49777/3, H43/1 (Pl. 9, fig. 10). Proximal aspect. Equatorial diameter 67 µm; spore-cavity diameter 44 µm. Amb subtriangular, sides moderately convex, apices obtusely rounded; narrowly lipped, slightly sinuous laesurae extending to inner margin of vacuolate ring; latter consisting of radially oriented, elongate-oval vacuoles 4-5 µm long, 1.6-3.2 µm in maximum width; exoexine of distal surface (bounded by equatorial flange) bearing variably disposed, irregularly shaped, sculptural elements (grana and verrucae < 4 µm in diameter).

**Type locality**: Western Australia, northern Perth Basin, Coolcalalaya Sub-basin; CRAE DDH YCH-2, core, 170.1 m.

**Etymology**: Latin, *valentulus*, strong, durable.

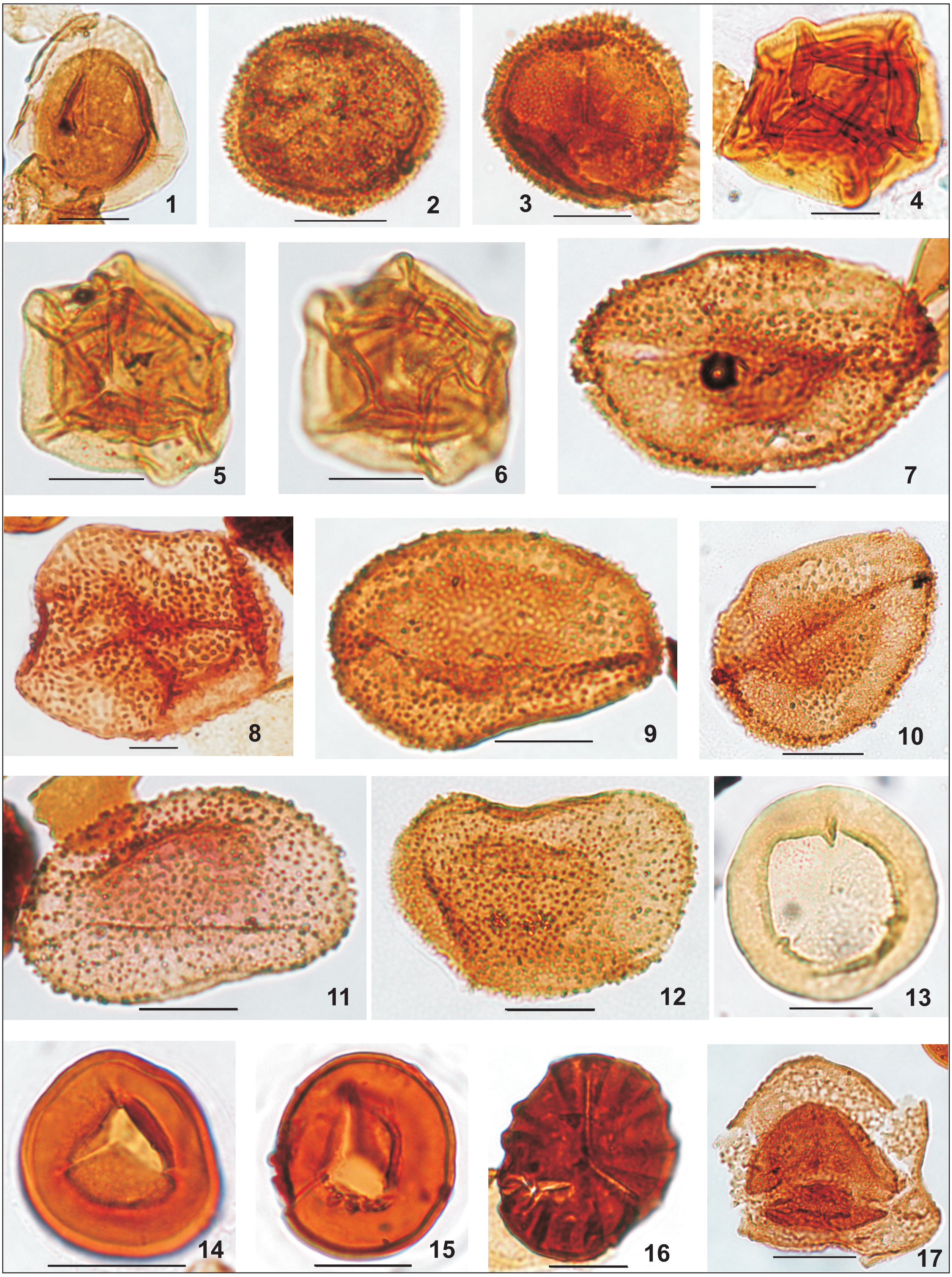
**Diagnosis**: Spores radial, trilete, cingulicavate, with convexly subtriangular to near-circular amb. Laesurae distinct, straight to irregularly undulating, with relatively narrow, thickened, slightly elevated, ± flexuous lips up to 4 µm in overall width, extending to or just beyond spore-cavity margin. Intexine very thin, subject to irregular folding marginally, attached to or slightly contracted from exoexine. Distinct uniserial ring of vacuoles constituting inner margin of exoexinal flange, thus prescribing spore cavity; vacuoles radially oriented, elongate-oval in outline, 3-5 µm long, 1.4-3.5 µm in maximum width. Distal exoexine over spore cavity irregularly sculptured with varying proportions of grana and irregularly shaped verrucae, discrete to coalescent, 0.2-8 µm in diameter. Flange laevigate, uncommonly with scattered minute coni.

**Dimensions** (37 specimens). Overall equatorial diameter 48 (69) 84 µm; spore-cavity diameter (in polar view) 35 (49) 60 µm.

**Remarks and comparison**. The distal exoexinal sculpture prescribed by the spore cavity is notably variable among specimens assigned to *Vallatisporites valentulus* sp. n. in regard to form (grana, verrucae), size, and disposition. This species is similar to *V. verrucosus* Hacquebard, 1957 (p. 313, pl. 2, fig. 13), but the latter features longer laesurae, more uniform verrucate sculpture, and generally narrower flange (see also Playford 1964, pl. X, fig. 8; Melo & Playford 2012, pl. 8, figs 21–24). Both

PLATE 10

Fig. 1 - *Endosporites* sp. cf. *E. micromanifestus* Hacquebard, 1957, medial focus.
Figs 2, 3 - *Grandispora maculosa* Playford & Helby, 1968. 2) medial focus. 3) proximal focus.
Figs 4-6 - *Velamisporites cortaderensis* (Césari & Limarino, 1987) Playford, 2015. 4) distal focus. 5, 6) proximal and distal foci, respectively.
Figs 7-12 - *Aratrisporites saharaensis* Loboziak, Clayton & Owens, 1986. 7-11) medial foci. 12) equatorial aspect.
Figs 13-15 - *Psomospora detecta* Playford & Helby, 1968. 13) medial focus. 14, 15) medial-distal foci.
Fig. 16 - *Emphanisporites rotatus* McGregor, 1961, proximal focus.
Fig. 17 - *Retispora lepidophyta* (Kedo, 1957) Playford, 1976, medial focus.
Scale bars represent 20 µm; for locality and other curatorial details, see Appendix 1.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*V. agadesensis* Loboziak & Alpern, 1978 (p. 58-59, pl. 2, figs 9-12) and *V. splendens* Staplin & Jansonius, 1964 (p. 113, pl. 21, figs 13, 14, text-fig. 2k) differ from *V. valentulus* chiefly in being sculptured distally with rugulae and vermiculi. Ravn's (1991: 96, pl. 23, fig. 20) *Vallatisporites* sp. 1 has a wider flange than the present species and its distal sculptural elements (verrucae, "pustules") are coarser.

Suprasubturma **Pseudosaccititriletes** Richardson, 1965
Infraturma **Monopseudosacciti** Smith & Butterworth, 1967
Genus *Auroraspora* Hoffmeister, Staplin & Malloy, 1955
Type species: *Auroraspora solisorta* Hoffmeister, Staplin & Malloy, 1955 [OD; M].

***Auroraspora solisorta*** Hoffmeister, Staplin & Malloy, 1955
Pl. 9, figs 1-6

1955 *Auroraspora solisortus* Hoffmeister, Staplin & Malloy: 381, pl. 37, fig. 3.

**Description**. Spores radial, trilete, cavate. Amb subcircular to convexly subtriangular; margin ± entire or irregularly undulating to embayed. Laesurae ± distinct, straight or slightly undulating, simple or very narrowly lipped; extending to or almost to margin of intexine. Intexine 1.2-1.5 μm thick, laevigate; outline (in polar view) ± conformable with amb; enveloped by thinner and much paler (more translucent) exoexine. Exoexine 0.3-0.5 μm thick; infragranulate and (less commonly, imperfectly, and locally) microreticulate. Conspicuous, ± irregularly developed, radial plications of the exoexine emanating from middle or outer region of intexinal body and extending to or close to equatorial periphery.

**Dimensions** (31 specimens). Overall equatorial diameter 43 (63) 84 μm; diameter of intexine (polar aspect) 26 (40) 52 μm.

**Remarks**. Hoffmeister et al. (1955) provided a reasonably explicit diagnosis of *Auroraspora solisorta* but figured only one specimen (the holotype). The present specimens accord with their circumscription, although are clearly better preserved and some show a patchy microreticulation of the very thin pseudosaccus (exoexine). The specific assignment of the present specimens, and of those described by Melo & Playford (2012: 117-118, pl. 9, figs 5-8), is considered appropriate, but could be reassessed pending availability of further information on the holotype and on possible topotypic specimens (i.e., from the Hardinsburg Formation, TC-082; Hoffmeister et al. 1955). Upper Mississippian specimens identified as *A. solisorta* by Clayton (1995, pl. II, fig. 2) from Saudi Arabia, and by Playford et al. (2008, pl. 6, figs 1, 2) from Morocco conform to those encountered in the present study.

**Previous records**. *Auroraspora solisorta* is distributed, virtually globally, in upper Famennian through Mississippian strata (Melo & Playford 2012; Playford 2015).

Genus *Endosporites* Wilson & Coe, 1940 ex Schopf, Wilson & Bentall, 1944
Type species: *Endosporites ornatus* Wilson & Coe, 1940 [SD; Schopf et al. 1944: 45].

***Endosporites*** sp. cf. ***E. micromanifestus*** Hacquebard, 1957
Pl. 10, fig. 1

2015 *Endosporites* sp. cf. *E. micromanifestus* Hacquebard, 1957; Playford: 24, fig. 12G, H.

**Dimensions** (four specimens) Overall equatorial diameter 52, 55, 57, 62 μm; diameter of intexine (polar view) 37, 39, 41, 42 μm.

**Remarks**. It seems probable that the present specimens, together with those illustrated by Playford (2015) from the northern Perth Basin, represent a species distinct from *Endosporites micromanifestus* Hacquebard, 1957 (p. 317, pl. 3, fig. 16), mainly because their pseudosaccus (exoexine) and intexinal body appear to be somewhat thicker than in Hacquebard's species. However, insufficient specimens are currently available for formal specific designation.

Genus *Grandispora* Hoffmeister, Staplin & Malloy, 1955 emend. McGregor, 1973
Type species: *Grandispora spinosa* Hoffmeister, Staplin & Malloy, 1955 [OD; M].

***Grandispora maculosa*** Playford & Helby, 1968
Pl. 10, figs 2, 3

1968 *Grandispora maculosa* Playford & Helby: 113, pl. 11, figs 4, 5.

**Dimensions** (21 specimens). Overall equatorial diameter 39 (47) 75 μm; diameter of intexine, in polar view, 28 (41) 60 μm.

**Previous records**. This species has been reported and fully described from Eastern and Western Gondwanan strata of Middle and Late Mississippian age (Playford & Helby 1968; Melo & Playford 2012; Playford 2015).

Genus *Velamisporites* Bharadwaj & Venkatachala, 1962

**Type species**: *Velamisporites rugosus* Bharadwaj & Venkatachala, 1962 [OD].

***Velamisporites cortaderensis***
(Césari & Limarino, 1987) Playford, 2015
Pl. 10, figs 4-6

1987 *Dictyotriletes cortaderensis* Césari & Limarino: 225, pl. 2, fig. 2.
2015 *Velamisporites cortaderensis* (Césari & Limarino, 1987) Playford: 26 (cum syn.), fig. 13D-I.

**Dimensions** (14 specimens). Overall equatorial diameter 43 (55) 72 μm; diameter of intexine (polar view) 29 (43) 55 μm.

**Previous records.** As summarized by Playford (2015: 26), *Velamisporites cortaderensis* (Césari & Limarino, 1987) Playford, 2015 is known from Western and Eastern Gondwanan deposits with a stratigraphic range of Middle or Upper Mississippian through Lower Permian.

Turma **Monoletes** Ibrahim, 1933
Genus *Aratrisporites* Leschik, 1955 emend.
Playford & Dettmann, 1965

Type species: *Aratrisporites parvispinosus* Leschik, 1955 [OD].

***Aratrisporites saharaensis*** Loboziak,
Clayton & Owens, 1986
Pl. 10, figs 7-12

1986 *Aratrisporites saharaensis* Loboziak, Clayton & Owens: 498-499 (cum syn.), pl. 1, figs 1-20.

**Description**. Spores bilateral, monolete, cavate; plano- or concavo-convex in equatorial aspect (distal surface convex). Amb oval, elliptical or (uncommonly) subcircular with obtusely rounded or slightly pointed ends. Laesura distinct, straight, broadly curved or slightly kinked (geniculate), simple or flanked irregularly by narrow lips or exoexinal folds. Laesura almost attaining equatorial margin, commonly with curvaturate termini. Intexine thin, laevigate, constituting ± indistinctly defined inner body with outline ± conforming to amb. Exoexine mainly ca 1.5 μm thick, with or without slight equatorial thickening; sculptured distally and proximo-equatorially with a range of small, discrete, projecting elements (bacula, pila, coni, spinae, verrucae, grana), commonly up to 4 μm high and 3 μm broad basally.

**Dimensions** (26 specimens in polar aspect). Overall length 51 (72) 91 μm; length of intexinal body 25 (40) 55 μm. Overall width 27 (41) 60 μm; width of intexinal body 14 (27) 36 μm.

**Previous records**. Loboziak et al.'s (1986) original report of *Aratrisporites saharaensis* was as an abundant component of Mississippian strata, dated as late Tournaisian to early Namurian/Serpukhovian, in the northern Saharan region. This was followed by documentation of further occurrences of the species in North Africa and the Middle East, thus prompting the concept of the *Aratrisporites saharaensis* Microflora – composed of the eponymous species and several other miospore species – characterizing much of Northern Gondwana during Mississippian time (Clayton et al. 1991; Clayton 1996; González et al. 2011). However, *A. saharaensis* has more recently been identified extensively and coevally elsewhere, particularly in Western Gondwana, as summarized by Melo & Playford (2012: 128). The specimens described herein are the first of *A. saharaensis* to be reported from Australia or indeed from Eastern Gondwana.

Turma **Hilates** Dettmann, 1963
Genus *Psomospora* Playford & Helby, 1968

Type species: *Psomospora detecta* Playford & Helby, 1968 [OD; M].

***Psomospora detecta*** Playford & Helby, 1968
Pl. 10, figs 13-15

1968 *Psomospora detecta* Playford & Helby: 114, pl. 11, figs 8-14, fig. 3a-d.

**Dimensions** (six specimens). Equatorial diameter 31 (41) 51 μm.

**Previous records**. Melo & Playford (2012: 129) cited numerous published occurrences of *Psomospora detecta* Playford & Helby, 1968 over much of Gondwana, with a stratigraphic range of Middle or

Upper Mississippian through Guadalupian. To these can be added reports by Stephenson et al. (2003, Lower Permian, Oman), Stephenson (2004, ?upper Pennsylvanian-Lower Permian, Oman), and Playford (2015, middle-upper Visean, northern Perth Basin).

## Palynofloral composition

With the exception of material from 2192-2542 m in Kybra-1, all of the studied palyniferous samples have yielded, in varying abundance, representatives of the *Grandispora maculosa* zonal miospore assemblage. The best-preserved miospores are from the four core samples that collectively span 118.8-241.3 m in the YCH-2 borehole of the Coolcalalaya Sub-basin. Hence, the large majority of specimens illustrated in Plates 1-10 are from that particular interval (see Appendix 1 for details).

The following taxonomic categories of miospores are represented: 34 genera; 38 formally named species including three instituted as new species; two "cf." species; six informally designated species ("sp. A"); and one generically attributed but binomially undesignated species grouping (*Calamospora* spp.). Apart from one hilate form (*Psomospora detecta*), all other species are trilete. Two species, very rare and inconsistently represented, are *Retispora lepidophyta* (Kedo, 1957) Playford, 1976 and *Emphanisporites rotates* McGregor, 1961; both are clearly recycled from the Devonian.

The species represented most consistently are the following: *Verrucosisporites quasigobbettii, Indotriradites kuttungensis, I. daemonii, I. dolianitii, Reticulatisporites magnidictyus, Grandispora maculosa, Punctatisporites lucidulus, P. subtritus, Retusotriletes separatus, Raistrickia corymbiata, R. radiosa, Brochotriletes diversifoveatus, Cordylosporites asperidictyus, Foveosporites pellucidus, Ahrensisporites cristatus, Densoisporites truswelliae, Vallatisporites valentulus, Auroraspora solisorta,* and *Aratrisporites saharaenisis*.

Particularly noteworthy from a chronostratigraphic standpoint is that none of the samples contains prepollen, nor indeed pollen grains of any description.

## Intra- and extra-Australian correlation

The palynological suite described here complements and essentially replicates that reported by Playford (2015) from the CL5 diamond drillhole in the Irwin Terrace, which adjoins the Coolcalalaya Sub-basin in the northern Perth Basin (Playford 2015: fig. 1). Qualitatively, this is manifested by the substantial number of species shared with the CL5 palynoflora. This Western Australian palynoflora is closely comparable with that first described by Playford & Helby (1968) from the Italia Road Formation (now incorporated in the Mount Johnstone Formation) of the Southern New England Orogen, New South Wales, which constitutes the *Grandispora maculosa* Assemblage or Zone (e.g., Kemp et al. 1976; Playford 1985). Further studies (GP, in progress) on Mount Johnstone samples reinforce this east-west Australian palynostratigraphic correlation.

The Western Australian distribution of the *G. maculosa* Assemblage points to several lithostratigraphic misidentifications. Given the lack of glacial features that characterize the ca upper Pennsylvanian to lower Cisuralian Nangetty Formation, and the significantly older age from the boreholes in the Coolcalalaya Sub-basin (YCH-2) and adjacent Irwin Terrace (CL5), there is a strong case to reassign those *G. maculosa* Assemblage-bearing strata to a new unit. Moreover, the additional *G. maculosa* Assemblage reports of this study are all from pre-glacial strata below the Lyons Group (a lateral equivalent of the Nangetty Formation within the Southern Carnarvon Basin).

The *G. maculosa* Assemblage has also been reported from beyond Australia (i.e., beyond Eastern Gondwana) from many other regions of the supercontinent, thus affording an effective means of long-distance stratigraphic correlation, particularly of non-marine or nearshore marine strata (Melo & Playford 2012; Playford 2015: 29-31, tab. 1, fig. 15). Extra-Australian reports of numerous species diagnostic of the assemblage are from Western Gondwana (northern Brazil, Peru, Bolivia, and western Argentina) and also from the Falkland Islands/Islas Malvinas: see Fig. 3 (solid stars with captioned references). Furthermore, certain key species are represented, albeit subordinately, in palynofloras recorded from North Africa and the Middle Eastern region (Playford 2015: tab. 1), signifying a somewhat lesser alliance with the *G. maculosa* Assemblage in Northern Gondwana (see Fig. 3, outlined stars + references) than in eastern and western parts of the supercontinent.

Not cited in Playford (2015), but warranting mention here, are accounts by Kora & Schultz

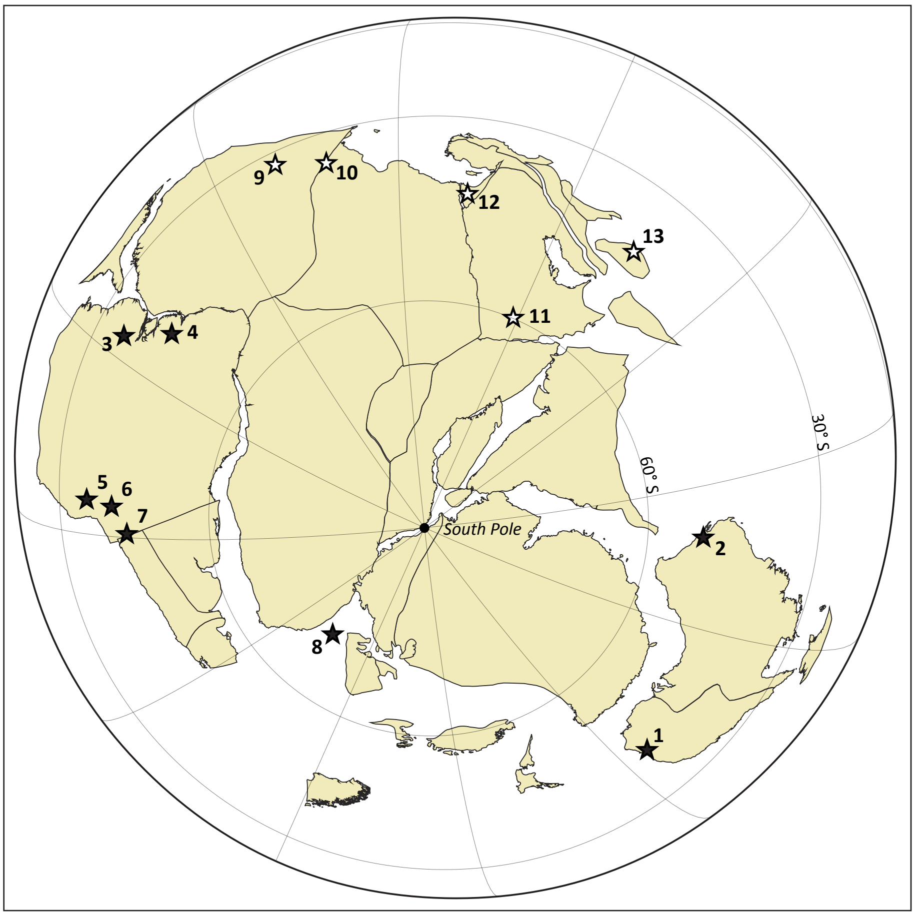


Fig. 3 - Occurrences of the *Grandispora maculosa* zonal Assemblage (solid stars) and of some components thereof (outlined stars) overlain on late Mississippian/330 Ma palaeogeographic reconstruction of Gondwana adapted from Domeier & Torsvik (2014; 3D orthographic projection centred on lat. 80°S, long. 20°E). Key to numbered locations (generalized) and respective sources of data: 1) Hunter Valley, Southern New England Orogen, New South Wales, Australia (Playford & Helby 1968). 2) Carnarvon Basin and northern Perth Basin, Western Australia (Playford 2015; present study). 3, 4) Amazonas and Parnaíba basins, respectively, northern Brazil (Melo & Playford 2012, and references therein). 5) Madre de Dios Basin, Peru (Azcuy & di Pasquo 2005, 2006). 6) Bolivia (see Melo & Playford 2012, p. 147). 7) Río Blanco Basin, western Argentina (Perez Loinaze 2007, 2008a, b; Césari et al. 2011). 8) West Falkland/Isla Gran Malvina (Hyam et al. 1997; palaeolocation after Marshall 1994). 9) Grand Erg Occidental, Algerian Sahara (Lanzoni & Magloire 1969; Coquel & Abdesselam-Rouighi 2000). 10) Ghadamis/Ghadames Basin, western Libya (Coquel & Moreau-Benoit 1986; Belhaj 2000). 11) Arabian Peninsula, various locations in Saudi Arabia, Oman, and Yemen (e.g., Besems & Schuurman 1987; Clayton 1995, 1996; Stephenson et al. 2003, 2008). 12) Sinai Peninsula, Egypt (Kora & Schultz 1987; Kora 1993). 13) Tabas, Central Iran Basin (Aria-Nasab et al. 2016; Playford et al. 2017).

(1987) and Kora (1993) of palynofloras from the Abu Thora Formation of Sinai (Egypt) that are dated, respectively, as late Visean and late Visean through early Westphalian (ca late Bashkirian). Those authors illustrated several miospore species from their older (late Visean) suite that are characteristic components of the *G. maculosa* Assemblage; viz., *Verrucosisporites quasigobbettii* (as *V. gobbettii* Playford, 1962), *Reticulatisporites magnidictyus* (as *Raistrickia baculosa* Hacquebard, 1957 and *Acinosporites spiritensis* Playford, 1971)*, Anapiculatisporites amplus, Raistrickia accincta, Ahrensisporites cristatus,* and *Auroraspora solisorta.* Hence, this older Sinai palynoflora (Fig. 3, locality 12) is affiliated with the other Northern Gondwanan palynofloras mentioned above regarding correlation with the *G. maculosa* Assemblage.

From southeast Tabas in the Central Iran Basin, Aria-Nasab et al. (2016) produced an account of the palynology (principally miospores) of the ~Middle to Late Mississippian Shishtu Formation. Notwithstanding the taxonomic misidentifications and other flaws in that publication (see Playford et al. 2017), the presence of the following species in the Shishtu assemblage signifies a *Grandispora maculosa*-palynofloral alliance, comparable to that reported previously from elsewhere in Northern Gondwana: *Reticulatisporites magnidictyus, Verrucosisporites quasigobbettii, Velamisporites cortaderensis, Indotriradites* *daemonii,* and *Aratrisporites saharaensis*. Additionally, Aria-Nasab et al. (2016) listed many species that would connote an extra-Gondwanan (i.e., Laurasian) affinity. However, Playford et al. (2017) noted that the majority of those binomial identifications were either unsupported by photomicrographs or were unconvincingly illustrated. Hence, the part-Laurasian affinity of the Shishtu palynoflora, although not to be ruled out, necessarily awaits objective confirmation.

Although the South American and Australian Mississippian palynofloras considered here have many miospore species in common – those that essentially define the *G. maculosa* Assemblage – it should be noted that certain species prominent coevally in South America are apparently unrepresented in Australia, and vice versa. For example, as yet unrecorded within the Australian Mississippian are, among others: *Neoraistrickia loganensis* (Winslow, 1962) Coleman & Clayton, 1987 (see Playford & Melo 2009); *Waltzispora lanzonii* Daemon, 1974 (Playford & Melo 2010); *Cyrtospora cristifera* (Luber in Luber & Waltz, 1941) emend. Van der Zwan, 1971 (Melo & Playford 2012); and *Schopfipollenites acadiensis* Utting, 1987 (Melo & Playford 2012). On the other hand, the following are some examples of species, recorded herein, that are as yet unreported from South American deposits: *Apiculiretusispora tersa* Playford, 2015; *Phyllothecotriletes golatensis* Staplin, 1960; *Diatomozonotriletes birkheadensis* Powis, 1984; *D. daedalus* Playford & Satterthwait, 1986; and *Densoisporites truswelliae* Stephenson, Al Rawahi & Casey, 2008.

Lastly, the following components of the *G. maculosa* Assemblage, as reported here and by Playford (2015), are notable for their particularly widespread distribution in Gondwana (single-asterisked * below) and, in fewer instances, beyond the supercontinent (double-asterisked**): *Verrucosisporites quasigobbettii**, *Reticulatisporites magnidictyus** *Aratrisporites saharaensis**, *Psomospora detecta**, *Claytonispora distincta***, *Anapiculatisporites concinnus***, and *Auroraspora solisorta***.

## Age of palynoflora

**Australian Eastern Gondwana.** The lithostratigraphic unit from which the *Grandispora maculosa* Assemblage was initially described – the Mount Johnstone Formation (aka Italia Road Formation: Playford & Helby 1968) in the Hunter Valley region of the Southern New England Orogen – has not itself been dated (or indeed proven datable) radiometrically. However, absolute ages of sub- and suprajacent ignimbritic formations have been reported during the past two decades, as discussed by Playford (2015: 31-32) and re-evaluated below.

• Base (i.e., Martins Creek Ignimbrite Member of Gilmore Volcanic Group), SHRIMP dating = 338.9 ± 2.2 Ma. Top (i.e., Paterson Volcanics), SHRIMP datings = 335.5 ± 4.3 Ma and 335.9 ± 3.9 Ma. References: Roberts et al. (1995a, p. 168), ages increased by 2% in accordance with Black et al. (2003). Middle Mississippian (middle to late Visean): Cohen et al. (2013/2016).

• Base (i.e., Martins Creek Ignimbrite Member of Gilmore Volcanic Group), SHRIMP dating = 338.9 ± 2.2 Ma. Top (i.e., Paterson Volcanics), SHRIMP dating = 335.1 ± 1.4 Ma. References: Roberts et al. (1995b, fig. 12), ages increased by 2% in accordance with Black et al. (2003). Middle Mississippian (Middle to late Visean): Cohen et al. (2013/2016).

Note that Roberts et al. (2006: 266, fig. 10) have SHRIMP AS3-calibrated the Elmswood Ignimbrite Member, which is within and ca 700 m above the base of the glaciogene Seaham Formation, which there disconformably overlies the Isismurra Formation [see Geeve et al. (2002: fig. 2) for stratigraphic relationships à propos of the Mount Johnstone Formation]. The Elmswood Member's date, at 326.4 ± 2.9 Ma, is indicative of Late Mississippian (ca middle Serpukhovian).

Notwithstanding the above, such authors as Black et al. (2003) and Metcalfe et al. (2015) have questioned the reliability of the standards adopted in obtaining SHRIMP ages and, ipso facto, the accuracy of the dates obtained thereby. According to these authors, U-Pb CA-IDTIMS (chemical abrasion-isotope dilution thermal ionisation mass spectrometry) methodology enhances precision in absolute-time calibration (e.g., vis-à-vis Australian Permian palynostratigraphy: Laurie et al. 2016), but has yet to be applied to the Carboniferous of the Southern New England Orogen.

From the most reliable radiometric-dating evidence currently available, and with reference to Cohen et al. (2013/2016), it appears that the

Mount Johnstone Formation is middle to late Visean in age. By palynostratigraphic correlation, this is applicable also to the Carnarvon and northern Perth basin palynoflora (Playford 2015; this study). However, CA-IDTIMS zircon dates from or relevant to the Mount Johnstone Formation are needed either to confirm or revise this age assignment.

**Extra-Australian Gondwana.** The widespread Western Gondwanan distribution of the *Grandispora maculosa* association, hence its chronostratigraphic significance, is documented in a previous section and in Playford (2015: 29-31), as is the presence of some of its constituents in Northern Gondwanan deposits. In few instances are these extra-Australian occurrences age-constrained by independent data (i.e., from absolute dating or faunal evidence).

In western Argentina's Río Blanco Basin, the *G. maculosa* zonal equivalent – known as the MQ (*Reticulatisporites magnidictyus-Verrucosisporites quasigobbettii*) Interval biozone of the Cortaderas Formation (Perez Loinaze 2007; Césari et al. 2011; Limarino et al. 2014) – has been dated as middle-late Visean. This attribution is supported by palynostratigraphic correlation within and beyond Western Gondwana; and by Gulbranson et al.'s (2010) $^{206}Pb/^{238}U$ 335.99 ± 0.06 Ma IDTIMS dating of an andesite from the uppermost Punta del Agua Formation, which is correlated to the upper part of the Cortaderas Formation (Césari et al. 2011: fig. 3). This absolute age dating is, in turn, closely compatible with that ascribed to Mount Johnstone Formation (see above).

Melo & Playford (2012) have discussed the various representations and nomenclature of *G. maculosa*-type palynofloral assemblages as reported from Mississippian strata of Western and Northern Gondwana. They (Melo & Playford 2012: 148, tab. 1) indicated ages for the extra-Australian correlative zones encompassing, or variously within, the middle to late Visean (?early Serpukhovian) interval. The complete lack of bilaterally symmetrical monosaccate pollen (notably *Potonieisporites* Bhardwaj, 1954 emend. Bharadwaj, 1964) that first appeared globally (including in Australia) and near-synchronously toward the close of the Serpukhovian (Playford 2015: 33, and references cited therein) supports a pre-late Serpukhovian age.

## Palaeobotanical and palaeogeographic implications

A diversity of terrestrial, cryptogamic plants is evidently represented in the study samples. Following Potonié (1962, etc.) and, in particular, Balme (1995), the main contributors to the palynoflora are identifiable as ferns, articulates, and lycophytes. Not unexpectedly, this mirrors the scenario connoted by the CL5 palynoflora from the Irwin Terrace, northern Perth Basin (Playford 2015). The rare and inconsistent presence of small, simple, spinose acritarchs implies possible brackish incursions in otherwise seemingly fresh-water depositional settings. The glacial origin of outcrops next to the Darling Fault 3-23 km southeast of CL5 was proposed by Playford et al. (1976), Mory et al. (2005, localities 12-15), and Eyles et al. (2006). Within this outcrop belt, the latter authors assigned a glacial origin to channelized sandstone-conglomerate facies, which included slumped and folded sandstone beds but contained no striated or faceted boulders (the majority of boulders being rounded). Nonetheless, Eyles et al. (2006: 623, fig. 5F) were cautious about the nature of the outcrops described as varves by Playford et al. (1976: 84, fig. 20), instead terming them laminated mudstone, albeit supposedly with 'striated dropstones.' Correlation of these outcrops with those farther west (including the 'glacier bed' of Maitland 1912; Mory et al. 2005, locality 10) where the glacial features are unambiguous, and into subsurface sections (as implied by Eyles et al.'s 2006 application of the term 'Wicherina Member' of the Nangetty Formation) requires drilling within the outcrop belt southeast of CL5 in order to establish the age of these strata.

Within the Southern and Northern Carnarvon Basins, the *G. maculosa* Assemblage is found in the Quail Formation or equivalent strata that extend for a considerable distance, ca 370 km, from the type section in Quail-1: 2100-2453 m, Nicoll & Gorter 1995) to the northernmost well (Kybra-1). These strata are regarded as mainly of shallow marine to fluvial origin, seemingly without obvious glaciogenic signature (Hocking 1990: 474).

As depicted on a Gondwanan palaeocontinental reconstruction at around 330 Ma (Fig. 3), the presence of the *Grandispora maculosa* Assemblage beyond Australia has been comprehensively and convincingly documented in South America (viz., northern Brazil, Peru, Bolivia, western Argentina: Playford 2015: 29-31, tab. 1). According to the reconstruction, the palaeolatitudinal spread of the assemblage across Eastern and Western Gondwana is broadly within 30°-60° S. That would also apply to the reports from Northern Gondwana, which, though not fully representative of the *G. maculosa* Assemblage, do include some of its key components (Playford 2015, tab. 1). A seeming anomaly is the higher palaeolatitude indicated for the Falkland Islands/Islas Malvinas on Fig. 3. The archipelago might have been closer to the southern tip of Africa, although latest evidence (Ramos et al. 2017) signifies greater proximity to southern South America (Patagonia). There is some evidence of glacial/periglacial influence in eastern Australian strata containing the *G. maculosa* Assemblage, preceding the onset of glacial deposition in the early Pennsylvanian (Playford 2015 and references therein). Whereas no palaeoclimatic synthesis or information is currently available concerning the stratigraphic intervals represented by the subsurface samples of the present study, their glacial affinity appears tenuous. This may be due to the west Australian sections coming under a somewhat warmer Tethyan influence at that time compared to east Australia, which was possibly more strongly influenced by cold Panthalassan currents emanating from the southern polar region.

## Conclusions

1. Diversified and mostly well preserved, in situ palynofloral suites – hosted by non-marine and paralic subsurface samples from the northern Perth Basin and the Northern and Southern Carnarvon Basins in Western Australia – are attributable to a range of miospore (almost entirely trilete) taxa comprising 31 genera and 45 named and less formally designated species.

2. The palynofloras are characterized by key representatives of the *Grandispora maculosa* Assemblage, notably the eponymous species and *Reticulatisporites magnidictyus*, together with such species as *Verrucosisporites quasigobbettii, V. gregatus, Apiculiretusispora tersa, Raistrickia accinta, R. radiosa, R. corymbiata*, and *Cordylosporites asperidictyus*.

3. Australian (i.e., Eastern Gondwanan) strata containing the *Grandispora maculosa* Assemblage are considered middle to late Visean in age, although extension into the later Mississippian (early Serpukhovian) is not unlikely, given other occurrences elsewhere in Gondwana. The complete absence of bilaterally symmetrical, monosaccate pollen (e.g., *Potonieisporites*) derived from walchian conifers supports a pre-late Serpukhovian dating.

4. The widespread dissemination of the assemblage through successions of Middle to early Late Mississippian age elsewhere in Gondwana is shown by numerous palynological/palynostratigraphic publications, particularly from South America and North Africa, thereby demonstrating its stratigraphic significance over much of the supercontinent.

5. The *Grandispora maculosa* Assemblage derived from an exclusively cryptogamic, terrestrial vegetation, including ferns, articulates, and lycophytes.

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**Appendix 1**. Inventory of illustrated specimens. Slide locations of individual specimens are specified by coordinates derived from a standard England Finder™ (EF) slide. Specimen catalogue numbers (F53025-F53146, inclusive) are those of the permanent repository: Geological Survey of Western Australia, Paleontological Type Collection, 37 Harris Street, Carlisle, Perth, WA 6101, Australia. In left-hand column, type categories are parenthesized thus: Ho, holotype; Pa, paratype; Hy, hypotype. Abbreviations to well names: Y, YCH-2; Am, Amber-1; CR1, Cane River-1; Gn, Gnaraloo-1; Ja, Jasper-1; Ky, Kybra-1; Mi, Minderoo-1.

| Miospore species/type | Plate/ Figure | Well, depth (m) | Slide | EF | Photograph number | Catalogue number |
|---|---|---|---|---|---|---|
| *Calamospora* sp. | 1/1 | Y, 118.8 | F49776/1 | C24/3 | YCH2-55 | F53025 |
| *Calamospora* sp. | 1/2 | Y, 118.8 | F49776/1 | D34/2 | YCH2-95 | F53026 |
| *Calamospora* sp. | 1/3 | Mi, 607.2 | K314/2 | T30/4 | BA-196 | F53027 |
| *Phyllothecotriletes golatensis* (Hy) | 1/7 | Y, 118.8 | F49776/2 | E24/1 | YCH2-176 | F53028 |
| *Phyllothecotriletes golatensis* (Hy) | 1/8 | Y, 118.8 | F49776/1 | P35 | YCH2-106 | F53029 |
| *Punctatisporites lucidulus* (Hy) | 1/4 | Y, 118.8 | F49776/1 | K30/2 | YCH2-84 | F53030 |
| *Punctatisporites subtritus* (Hy) | 1/5 | Y, 170.1 | F49777/3 | J13 | YCH2-318 | F53031 |
| *Punctatisporites subtritus* (Hy) | 1/6 | Y, 170.1 | F49777/4 | G21/1 | YCH2-426 | F53032 |
| *Apiculiretusispora tersa* (Hy) | 2/1,2 | Y, 170.1 | F49777/5 | O31/4 | YCH2-492, 493 | F53033 |
| *Retusotriletes separatus* (Hy) | 2/3 | Y, 170.1 | F49777/1 | W17/3 | YCH2-256 | F53034 |
| *Retusotriletes separatus* (Hy) | 2/6 | Y, 170.1 | F49777/3 | D22/1 | YCH2-336 | F53035 |
| *Retusotriletes* sp. A | 1/9 | Y, 170.1 | F49777/1 | W47/3 | YCH2-290 | F53036 |
| *Verruciretusispora* sp. A | 1/10,11 | Y, 231.5 | F49778/2 | U48 | YCH2-618, 619 | F53037 |
| *Cyclogranisporites firmus* (Hy) | 1/12 | Y, 118.8 | F49776/1 | S36 | YCH2-108 | F53038 |
| *Waltzispora* sp. A | 2/9 | Y, 118.8 | F49776/2 | G54/4 | YCH2-238 | F53039 |
| *Converrucosisporites* sp. A | 2/4,5 | Y, 118.8 | F49776/1 | J43/1 | YCH2-124, 125 | F53040 |
| *Verrucosisporites basiliscutis* (Hy) | 3/4 | Y, 170.1 | F49777/1 | P39 | YCH2-282 | F53041 |
| *Verrucosisporites gregatus* (Hy) | 2/7 | Y, 118.8 | F49776/1 | J27/2 | YCH2-66 | F53042 |
| *Verrucosisporites gregatus* (Hy) | 2/8 | Y, 170.1 | F49777/3 | M32 | YCH2-350 | F53043 |
| *Verrucosisporites quasigobbettii* (Hy) | 3/1,2 | Y, 170.1 | F49777/3 | B43 | YCH2-365, 364 | F53044 |
| *Verrucosisporites quasigobbettii* (Hy) | 3/3 | Y, 231.5 | F49778/2 | Q59/2 | YCH2-638 | F53045 |
| *Verrucosisporites* sp. cf. *V. italiaensis* | 2/10 | Y, 118.8 | F49776/1 | E41/1 | YCH2-119 | F53046 |
| *Anapiculatisporites amplus* (Hy) | 4/9 | Ky, 2170 | 3 | C36/1 | CR-11 | F53047 |
| *Anapiculatisporites amplus* (Hy) | 4/10 | Y, 118.8 | F49776/1 | E34/2 | YCH2-96 | F53048 |
| *Anapiculatisporites amplus* (Hy) | 4/11 | Y, 118.8 | F49777/6 | W22 | YCH2-518 | F53049 |
| *Anapiculatisporites amplus* (Hy) | 4/12 | Y, 170.1 | F49777/1 | F25/3 | YCH2-263 | F53050 |
| *Anapiculatisporites concinnus* (Hy) | 3/5 | Y, 170.1 | F49777/4 | G45/2 | YCH2-450 | F53051 |
| *Anapiculatisporites concinnus* (Hy) | 3/6 | CR1, 631-634 | 2274/1 | F22/1 | CR-01 | F53052 |
| *Anapiculatisporites concinnus* (Hy) | 3/7 | Y, 118.8 | F49776/2 | E31 | YCH2-191 | F53053 |
| *Apiculatasporites spiculatus* (Ho) | 3/9 | Y, 118.8 | F49776/1 | D23 | YCH2-09 | F53054 |
| *Apiculatasporites spiculatus* (Pa) | 3/10 | Y, 118.8 | F49776/1 | C19 | YCH2-33 | F53055 |
| *Apiculatasporites spiculatus* (Pa) | 3/11 | Ja, 540-545 | 3 | T35 | CR-21 | F53056 |
| *Apiculatasporites spiculatus* (Pa) | 3/12 | Y, 231.5 | F49778/3 | D39 | YCH2-654 | F53057 |
| *Claytonispora distincta* (Hy) | 3/8 | Y, 118.8 | F49776/2 | T24/3 | YCH2-175 | F53058 |
| *Dibolisporites disfacies* (Hy) | 4/2 | Y, 170.1 | F49777/4 | P19 | YCH2-410 | F53059 |
| *Dibolisporites disfacies* (Hy) | 4/3 | Y, 170.1 | F49777/4 | M54/3 | YCH2-468 | F53060 |
| *Dibolisporites sejunctus* (Ho) | 4/4,5 | Y, 118.8 | F49776/1 | X53/3 | YCH2-142, 143 | F53061 |
| *Tricidarisporites* sp. A | 2/11 | Y, 118.8 | F49776/1 | J28 | YCH2-74 | F53062 |
| *Tricidarisporites* sp. A | 2/12 | Y, 241.3 | F49779/1 | D29/1 | YCH2-694 | F53063 |
| *Raistrickia accincta* (Hy) | 4/1 | Y, 170.1 | F49777/1 | P55 | YCH2-293 | F53064 |
| *Raistrickia corymbiata* (Pa) | 5/1 | Y, 170.1 | F49777/5 | N19 | YCH2-485 | F53065 |
| *Raistrickia corymbiata* (Ho) | 5/2 | Y, 170.1 | F49777/4 | M48 | YCH2-456 | F53066 |
| *Raistrickia corymbiata* (Pa) | 5/3 | Y, 170.1 | F49777/6 | P56/4 | YCH2-546 | F53067 |

| Miospore species/type | Plate/ Figure | Well, depth (m) | Slide | EF | Photograph number | Catalogue number |
|---|---|---|---|---|---|---|
| *Raistrickia corymbiata* (Pa) | 5/4 | Y, 231.5 | F49778/1 | Q55 | YCH2-594 | F53068 |
| *Raistrickia corymbiata* (Pa) | 5/5 | Y, 231.5 | F49778/2 | B23/3 | YCH2-606 | F53069 |
| *Raistrickia radiosa* (Hy) | 4/6 | Y, 118.8 | F49776/1 | V40 | YCH2-116 | F53070 |
| *Raistrickia radiosa* (Hy) | 4/7 | Y, 241.3 | F49779/1 | E51 | YCH2-706 | F53071 |
| *Raistrickia radiosa* (Hy) | 4/8 | Y, 170.1 | F49777/1 | S50/4 | YCH2-303 | F53072 |
| *Raistrickia* sp. A | 5/6 | Y, 231.5 | F49778/1 | V34/3 | YCH2-571 | F53073 |
| *Brochotriletes diversifoveatus* (Hy) | 5/11 | Am, 505-511 | 2 | O36 | CR-05 | F53074 |
| *Brochotriletes diversifoveatus* (Hy) | 5/12 | Gn, 476.4 | K209/6 | M41 | GN-07 | F53075 |
| *Brochotriletes diversifoveatus* (Hy) | 5/13 | Y, 170.1 | F49777/3 | S18/2 | YCH2-331 | F53076 |
| *Cordylosporites asperidictyus* (Hy) | 5/7,8 | Y, 118.8 | F49776/2 | X24 | YCH2-174, 173 | F53077 |
| *Cordylosporites asperidictyus* (Hy) | 5/9 | Y, 118.8 | F49776/2 | E39/3 | YCH2-207 | F53078 |
| *Cordylosporites asperidictyus* (Hy) | 5/10 | Y, 118.8 | F49776/2 | T38 | YCH2-205 | F53079 |
| *Foveosporites pellucidus* (Hy) | 5/14 | Y, 170.1 | F49777/4 | S51/2 | YCH2-461 | F53080 |
| *Reticulatisporites magnidictyus* (Hy) | 6/8 | Y, 170.1 | F49777/1 | U25/3 | YCH2-262 | F53081 |
| *Reticulatisporites magnidictyus* (Hy) | 6/9 | Y, 231.5 | F49778/3 | G42/3 | YCH2-657 | F53082 |
| *Reticulatisporites magnidictyus* (Hy) | 6/10 | Mi, 607.2 | K314/3 | L35 | BA-207 | F53083 |
| *Reticulatisporites magnidictyus* (Hy) | 6/11 | Y, 118.8 | F49776/1 | O51 | YCH2-137 | F53084 |
| *Reticulatisporites magnidictyus* (Hy) | 6/12 | Y, 231.5 | F49778/3 | J30 | YCH2-649 | F53085 |
| *Reticulatisporites magnidictyus* (Hy) | 6/13 | Y, 170.1 | F49777/4 | U43 | YCH2-449 | F53086 |
| *Ahrensisporites cristatus* (Hy) | 6/1 | Y, 118.8 | F49776/1 | K19 | YCH2-38 | F53087 |
| *Ahrensisporites cristatus* (Hy) | 6/2 | Y, 118.8 | F49776/1 | G21 | YCH2-47 | F53088 |
| *Ahrensisporites cristatus* (Hy) | 6/3 | Y, 118.8 | F49776/2 | P31/2 | YCH2-192 | F53089 |
| *Ahrensisporites cristatus* (Hy) | 6/4 | Y, 118.8 | F49776/2 | K25 | YCH2-183 | F53090 |
| *Diatomozonotriletes birkheadensis* (Hy) | 6/5 | Y, 118.8 | F49776/2 | N41/3 | YCH2-216 | F53091 |
| *Diatomozonotriletes birkheadensis* (Hy) | 6/6 | Gn, 476.4 | K209/5 | G41 | GN-04 | F53092 |
| *Diatomozonotriletes birkheadensis* (Hy) | 6/7 | Y, 170.1 | F49777/4 | V29 | YCH2-423 | F53093 |
| *Diatomozonotriletes daedalus* (Hy) | 7/1,2 | Ja, 540-545 | 2 | J27/1 | CR-14,15 | F53094 |
| *Diatomozonotriletes daedalus* (Hy) | 7/3 | Y, 170.1 | F49777/3 | N28/1 | YCH2-340 | F53095 |
| *Diatomozonotriletes daedalus* (Hy) | 7/4 | Y, 231.5 | F49778/2 | W44/4 | YCH2-616 | F53096 |
| *Diatomozonotriletes daedalus* (Hy) | 7/5 | Y, 118.8 | F49776/2 | K50/4 | YCH2-232 | F53097 |
| *Diatomozonotriletes daedalus* (Hy) | 7/6 | Y, 170.1 | F49777/6 | C29/3 | YCH2-525 | F53098 |
| *Diatomozonotriletes daedalus* (Hy) | 7/7 | Y, 170.1 | F49777/4 | P25/1 | YCH2-419 | F53099 |
| *Diatomozonotriletes daedalus* (Hy) | 7/8 | Y, 170.1 | F49777/6 | K20/4 | YCH2-513 | F53100 |
| *Densoisporites truswelliae* (Hy) | 7/9 | Y, 231.5 | F49778/1 | S23 | YCH2-565 | F53101 |
| *Densoisporites truswelliae* (Hy) | 7/10 | Y, 231.5 | F49778/3 | U47 | YCH2-671 | F53102 |
| *Densoisporites truswelliae* (Hy) | 7/11 | Y, 118.8 | F49776/1 | N30/2 | YCH2-83 | F53103 |
| *Densoisporites truswelliae* (Hy) | 7/12 | Y, 231.5 | F49778/1 | K51 | YCH2-586 | F53104 |
| *Densosporites claytonii* (Hy) | 8/6 | Y, 231.5 | F49778/1 | F22/2 | YCH2-563 | F53105 |
| *Densosporites claytonii* (Hy) | 9/7 | Y, 231.5 | F49778/3 | D58/2 | YCH2-687 | F53106 |
| *Indotriradites daemonii* (Hy) | 7/13 | Y, 170.1 | F49777/3 | E38/1 | YCH2-356 | F53107 |
| *Indotriradites daemonii* (Hy) | 7/14 | Y, 118.8 | F49776/1 | H33/1 | YCH2-103 | F53108 |
| *Indotriradites dolianitii* (Hy) | 8/1 | Y, 118.8 | F49776/2 | B21 | YCH2-165 | F53109 |
| *Indotriradites dolianitii* (Hy) | 8/2 | Y, 170.1 | F49777/1 | O55/1 | YCH2-294 | F53110 |
| *Indotriradites dolianitii* (Hy) | 8/3 | Y, 170.1 | F49777/4 | O53/3 | YCH2-466 | F53111 |

| Miospore species/type | Plate/ Figure | Well, depth (m) | Slide | EF | Photograph number | Catalogue number |
|---|---|---|---|---|---|---|
| *Indotriradites dolianitii* (Hy) | 8/4 | Y, 118.8 | F49776/2 | F31/2 | YCH2-195 | F53112 |
| *Indotriradites dolianitii* (Hy) | 8/5 | Y, 231.5 | F49778/1 | X22/1 | YCH2-562 | F53113 |
| *Indotriradites kuttungensis* (Hy) | 8/7 | Y, 170.1 | F49777/4 | H25 | YCH2-418 | F53114 |
| *Indotriradites kuttungensis* (Hy) | 8/8 | Y, 231.5 | F49778/1 | F55 | YCH2-596 | F53115 |
| *Indotriradites kuttungensis* (Hy) | 8/9 | Y, 170.1 | F49777/2 | O52 | YCH2-314 | F53116 |
| *Indotriradites kuttungensis* (Hy) | 8/10 | Y, 170.1 | F49777/6 | C55/1 | YCH2-541 | F53117 |
| *Indotriradites kuttungensis* (Hy) | 8/11 | Y, 231.5 | F49778/1 | B57/2 | YCH2-599 | F53118 |
| *Indotriradites kuttungensis* (Hy) | 8/12 | Y, 170.1 | F49777/3 | D27 | YCH2-341 | F53119 |
| *Vallatisporites valentulus* (Pa) | 9/8 | Y, 170.1 | F49777/4 | U26 | YCH2-420 | F53120 |
| *Vallatisporites valentulus* (Pa) | 9/9 | Y, 231.5 | F49778/2 | L50/1 | YCH2-622 | F53121 |
| *Vallatisporites valentulus* (Ho) | 9/10 | Y, 170.1 | F49777/3 | H43/1 | YCH2-359 | F53122 |
| *Vallatisporites valentulus* (Pa) | 9/11 | Y, 241.3 | F49779/1 | T51/4 | YCH2-703 | F53123 |
| *Vallatisporites valentulus* (Pa) | 9/12 | Y, 231.5 | F49778/3 | N51 | YCH2-679 | F53124 |
| *Auroraspora solisorta* (Hy) | 9/1 | Y, 231.5 | F49778/1 | H55 | YCH2-595 | F53125 |
| *Auroraspora solisorta* (Hy) | 9/2 | Gn, 476.4 | K209/4 | T42/3 | GN-01 | F53126 |
| *Auroraspora solisorta* (Hy) | 9/3 | Y, 118.8 | F49776/1 | J53 | YCH2-141 | F53127 |
| *Auroraspora solisorta* (Hy) | 9/4 | Gn, 476.4 | K209/6 | M46/2 | BA-230 | F53128 |
| *Auroraspora solisorta* (Hy) | 9/5 | Y, 170.1 | F49777/3 | C53/2 | YCH2-392 | F53129 |
| *Auroraspora solisorta* (Hy) | 9/6 | Y, 170.1 | F49777/1 | C28/2 | YCH2-266 | F53130 |
| *Endosporites* sp. cf. *E. micromanifestus* | 10/1 | Y, 231.5 | F49778/1 | L48 | YCH2-583 | F53131 |
| *Grandispora maculosa* (Hy) | 10/2 | Y, 170.1 | F49777/1 | M26 | YCH2-265 | F53132 |
| *Grandispora maculosa* (Hy) | 10/3 | Y, 231.5 | F49778/1 | G15/2 | YCH2-551 | F53133 |
| *Velamisporites cortaderensis* (Hy) | 10/4 | Y, 170.1 | F49777/6 | Q15/4 | YCH2-506 | F53134 |
| *Velamisporites cortaderensis* (Hy) | 10/5,6 | Y, 170.1 | F49777/1 | E47/1 | YCH2-286, 287 | F53135 |
| *Aratrisporites saharaensis* (Hy) | 10/7 | Y, 170.1 | F49777/4 | F34/3 | YCH2-430 | F53136 |
| *Aratrisporites saharaensis* (Hy) | 10/8 | Y, 118.8 | F49776/1 | P20 | YCH2-41 | F53137 |
| *Aratrisporites saharaensis* (Hy) | 10/9 | Y, 231.5 | F49778/1 | Q42/2 | YCH2-579 | F53138 |
| *Aratrisporites saharaensis* (Hy) | 10/10 | Y, 231.5 | F49778/1 | W51/2 | YCH2-587 | F53139 |
| *Aratrisporites saharaensis* (Hy) | 10/11 | Y, 170.1 | F49777/6 | G45/2 | YCH2-535 | F53140 |
| *Aratrisporites saharaensis* (Hy) | 10/12 | Y, 231.5 | F49778/3 | D36/1 | YCH2-652 | F53141 |
| *Psomospora detecta* (Hy) | 10/13 | Mi, 607.2 | B368/x1 | T28 | BA-136 | F53142 |
| *Psomospora detecta* (Hy) | 10/14 | Y, 118.8 | F49776/2 | M39 | YCH2-208 | F53143 |
| *Psomospora detecta* (Hy) | 10/15 | Y, 170.1 | F49777/5 | F43/3 | YCH2-500 | F53144 |
| *Emphanisporites rotatus* (Hy) | 10/16 | Y, 170.1 | F49777/1 | G17/4 | YCH2-257 | F53145 |
| *Retispora lepidophyta* (Hy) | 10/17 | Y, 231.5 | F49778/3 | R19/3 | YCH2-643 | F53146 |