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Author: Playford, Geoffrey

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Palynology of the Mount Johnstone Formation (Mississippian), southern New England Orogen, New South Wales, Australia

Geoffrey Playford

School of Earth and Environmental Sciences, The University of Queensland, Brisbane, Australia

ABSTRACT

This renewed palynological study of the Mount Johnstone Formation, at Balickera in the Hunter Valley region of New South Wales (eastern Australia), discloses a considerably more diverse palynoflora – termed the *Grandispora maculosa* Assemblage – than was reported in 1968. Represented are some 51 species of palynomorphs, comprising 46 species of trilete spores (distributed among 27 genera), three species of monolete spores (three genera), one species of hilate spores, and a single algal-cyst species. The following species are newly instituted: *Verrucosisporites adgeratus*, *V. johnstonense*, *V. pavimentatus*, *Anapiculatisporites robertsii*, *Convolutispora perplicata*, *Knoxisporites balickeraensis*, *Densoisporites argutus*, *Laevigatosporites demutabilis*, and *Latosporites durabilis*. Quantitatively important and/or consistently represented species include *Reticulatisporites magnidictyus* (particularly), *Punctatisporites* spp., *Verrucosisporites* spp., *Rattiganispora apiculata*, *Grandispora maculosa*, *Indotriradites kuttungensis*, *Velamisporites australiensis*, *Laevigatosporites demutabilis*, and *Psomospora detecta*. The absence of marine palynomorphs supports the previously envisaged, predominantly fluvial deposition of the Mount Johnstone Formation. Key palynostratigraphic indices, in conjunction with absolute-age determinations obtained from sub- and suprajacent rocks, indicate that the *G. maculosa* palynoflora and its hosting Mount Johnstone strata are Mississippian – specifically middle–late Visean – in age. This dating also applies to similarly palyniferous deposits in the northern Perth and Carnarvon basins of Western Australia. Beyond Eastern Gondwana, equivalents of the *G. maculosa* association have been reported from Western Gondwana (Brazil and Argentina in particular) and, to a lesser extent, from Northern Gondwana, thus attesting to its wide distribution and chronostratigraphic significance within the supercontinent and its distinctiveness *vis-à-vis* Euramerican regions.

KEYWORDS
palaeopalynology; systematics; biostratigraphy; Mississippian; Eastern Gondwana

1. Introduction

Palynological studies of largely nonmarine Mississippian successions in Gondwana have increased considerably in recent years, with emphasis on the stratigraphic and palaeogeographic significance of the palynofloras, underpinned by detailed taxonomic analyses. This applies mainly to Western Gondwana (principally Brazil and Argentina: Melo and Loboziak 2003; Playford and Melo 2012; Melo and Playford 2012; Césari et al. 2011; di Pasquo and Iannuzzi 2014; and references cited therein) and Eastern Gondwana (Australia: Jones and Truswell 1992; Playford 2015, 2017; Playford and Mory 2017).

Many of the species constituting the *Grandispora maculosa* miospore association – as described initially by Playford and Helby (1968) from the Italia Road Formation (now Mount Johnstone Formation) of the Hunter Valley region of New South Wales – have subsequently been identified in Middle to Upper Mississippian deposits elsewhere in Gondwana, thus enhancing chronostratigraphic correlations and palaeogeographic inferences over much of the supercontinent and, more particularly, between Eastern and Western Gondwana.

The Playford and Helby paper can be viewed essentially as an interim or reconnaissance study. Subsequent detailed palynological investigations of coeval or near-coeval strata elsewhere in Gondwana have provided the impetus and *raison d'être* for the current, more comprehensive examination of the Mount Johnstone Formation's palynoflora, thereby enhancing and strengthening its Gondwanan stratigraphic and other potentialities.

2. Geological setting, stratigraphy, and sampled section

The rural settlement of Balickera, New South Wales (Figure 1), whence the study samples derive, is located in the Lower Hunter Valley region, which lies within the southern part of the Devonian–Triassic New England Orogen (NEO; see, *inter alia*, Roberts et al. 2006; Rosenbaum 2012, fig. 1b). The orogen includes a Devonian–Carboniferous forearc basin: a curving, auriform, oroclinal structure (Shaanan et al. 2014, fig. 1c). The southernmost part of the NEO within the orocline comprises three blocks that are segregated by meridionally striking, syn-depositional faults (Roberts and Engel

CONTACT Geoffrey Playford g.playford@uq.edu.au School of Earth and Environmental Sciences, The University of Queensland, Brisbane, Queensland 4072, Australia.

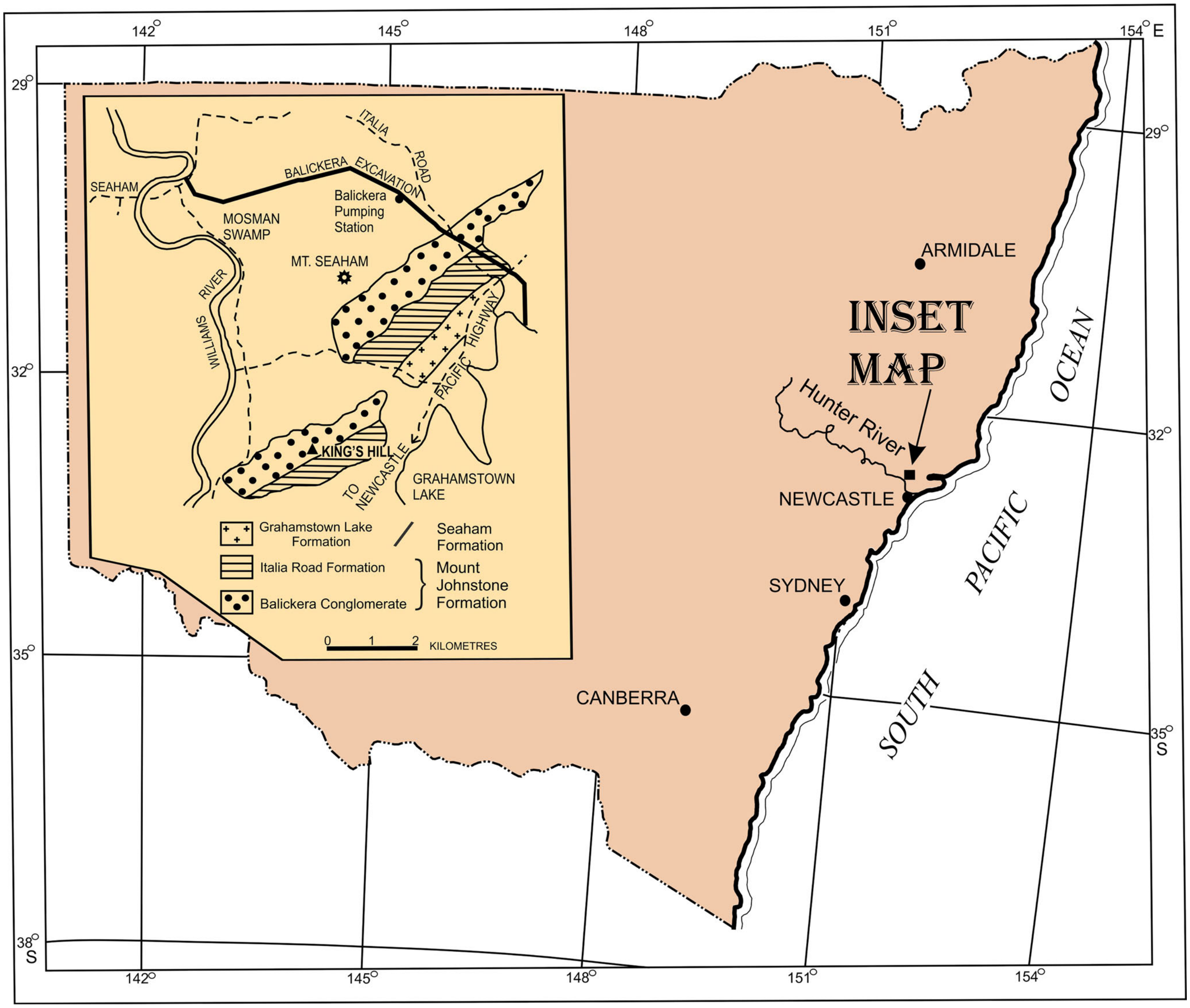

Figure 1. Locality map, New South Wales, with inset of Balickera area. Adapted from Playford and Helby (1968, fig. 1).

1987). From west to east these are the Rouchel, Gresford, and Myall blocks, the Gresford being bounded by the Karakurra and Williams River faults to the west and east, respectively (Phillips et al. 2016, fig. 1).

The Mount Johnstone Formation is exposed principally in the Rouchel and Gresford blocks (Geeve et al. 2002, fig. 2), and its 650-m-thick type section is located within the latter (Hamilton et al. 1974, p. 83; Roberts et al. 1991, p. 94). The Italia Road Formation and the conformably underlying Balickera Conglomerate – q.v. Rattigan (1967a, 1967b, 1967c) and adopted by Playford and Helby (1968) – are developed in the westernmost Myall Block immediately to the east of the aforementioned Williams River Fault (Rattigan 1967a, fig. 1). On lithostratigraphic grounds, these two formations were jointly subsumed nomenclaturally into the Mount Johnstone Formation (Roberts et al. 1991, p. 94–95), with the former Balickera Conglomerate termed informally the lower member of the Mount Johnstone Formation. Moreover, Rattigan's (1967a) Grahamstown Lake Formation, succeeding his Italia Road Formation, apparently conformably, was regarded by Roberts et al. (1991, p. 94) as being synonymous with the previously established Seaham Formation. These nomenclatural changes are followed here.

The Balickera section of the Mount Johnstone Formation (Rattigan 1967a, figs 1, 4; Figures 1, 2 herein) is more complete and informative than the type section. It was exposed as a continuous succession – transverse to the strike and dipping relatively steeply (30–55°) – during the 1958–early 1960s excavation of a canal, 8 km long, connecting the Williams River near Seaham to the Grahamstown Lake (aka Grahamstown Dam: a potable water reservoir serving the Lower Hunter region). Here, the Mount Johnstone Formation comprises 417 m of polymictic boulder conglomerates with interbeds of massive grey tuffs and ignimbrites (corresponding to Rattigan's Balickera Conglomerate), succeeded conformably by a rhythmic/cyclical unit (Rattigan's Italia Road Formation) comprising 360 m of mostly fine- to coarse-grained lithic sandstones and interbedded, variably carbonaceous shales and siltstones, and poor coal, together with minor tuffs, bentonites, and cherts. Note that Rattigan's (1967a, 1967b) usage of the term 'cyclothem' is at variance with accepted terminology: e.g. 'cyclothems result from

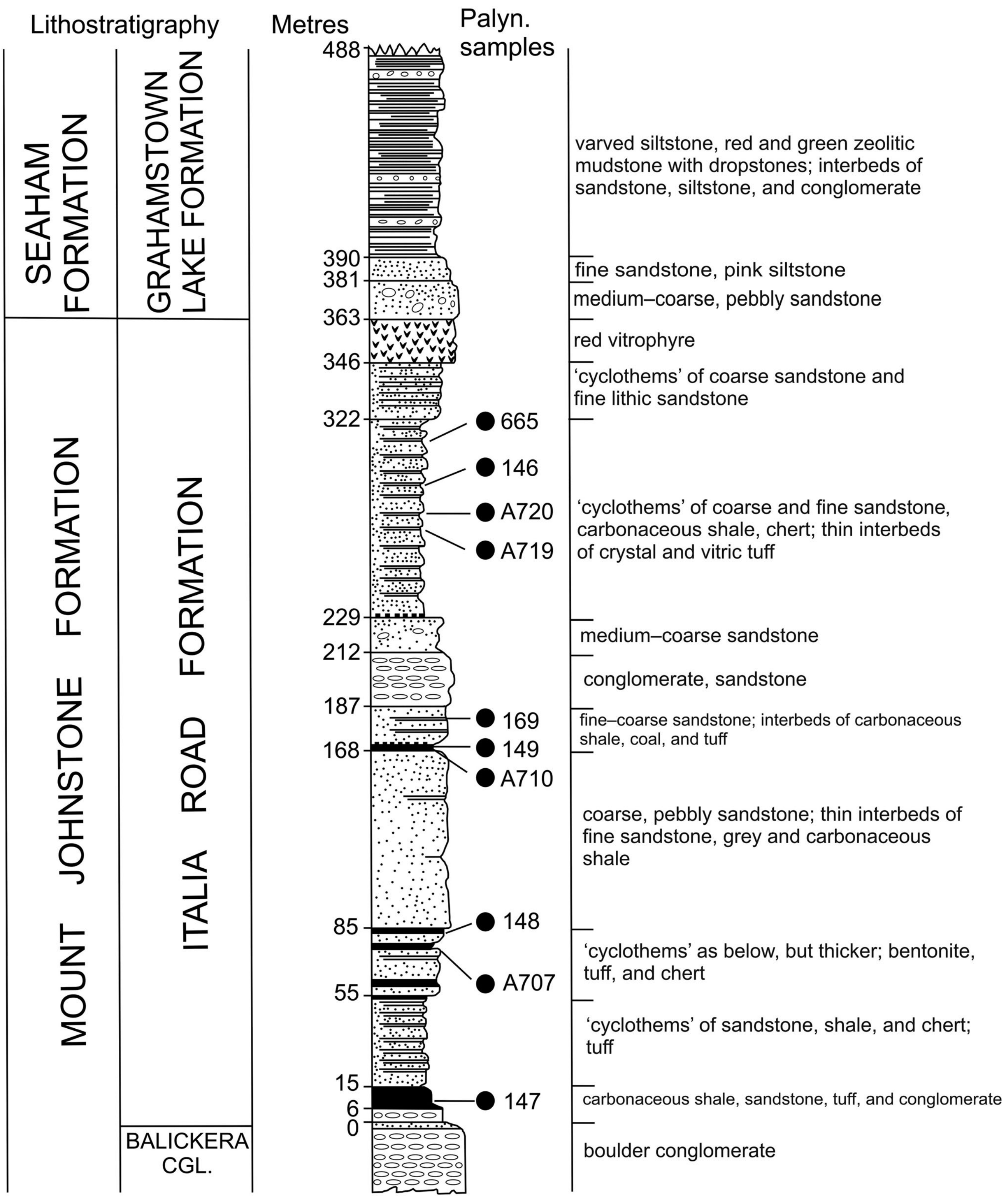

Figure 2. Stratigraphic section of the formerly named Italia Road Formation – now included with the underlying Balickera Conglomerate in the Mount Johnstone Formation – as exposed and measured (i.e. before flooding) in the Balickera canal excavation, whence the samples studied herein, as originally by Playford and Helby (1968), were collected. Based on Rattigan (1967a, fig. 4), but see text (section 2) regarding inapt usage of 'cyclothem'.

repeated alternations of deposition in marine and nonmarine environments', as exemplified by the Pennsylvanian of the Illinois Basin (Wicander and Monroe 2014, p. 225). According to Roberts et al. (1991, p. 98), the Mount Johnstone Formation accumulated in a wholly nonmarine fluvial environment, the conglomeratic lower part signifying a fan deposit from an uplifted source area, and the succeeding sandy, silty, carbonaceous sediments representing cyclically repetitive beds regarded as 'lateral accretionary units (deposited) by streams'. Earlier, Rattigan (1967b, p. 127) had envisaged that the cycles resulted from episodic flash-flooding generated by melted glaciers. Moreover, there is clear evidence of glacigene deposition in the overlying Seaham Formation (e.g. Süssmilch and David 1920; Roberts and Engel 1987; Fielding et al. 2008).

The samples studied herein, collected from levels indicated in Figure 2, are those investigated initially by Playford and Helby (1968). They represent the finer and palyniferous lithologies in the now-flooded Balickera excavation: mostly pale grey to black, carbonaceous siltstones, poor coal, and fine-grained sandstones.

3. Laboratory preparation, microscopy, and repository

Conventional palynological laboratory procedures were applied in the extraction and concentration of the palynomorphs from the samples (q.v. Playford and Helby, 1968, p. 105–106). The samples proved abundantly palyniferous, yielding spores in a very good to excellent state of preservation, as evidenced by Plates 1–11 herein.

The palynomorphs figured in the plates were captured as high-resolution (TIFF) images with an Olympus BH2 binocular microscope, using either a 40× or a 60× oil-immersion objective, with attached Olympus DP26 digital camera. The images were acquired via Olympus cellSens® software, and the plates were assembled by means of CorelDRAW® graphics suite.

All 168 palynomorphs figured herein are preserved in slides housed permanently in the Palaeontological Type Collection maintained by the Geological Survey of New South Wales, W.B. Clarke Geoscience Centre, 947–953 Londonderry Road, Londonderry, NSW 2753, Australia. Curatorial details are provided in Appendix 1.

4. Systematic palaeontology

Riding et al. (2018) have provided a useful and opportune commentary on the taxonomic-citation consequences of online vs. print publication (the latter, of course, normally post-dating the former). Providing that the online version is identical with the printed version (aside from differences in pagination), its date of issuance is accepted as the date of effective publication. This complies with the International Code of Nomenclature for algae, fungi, and plants (ICN; Turland et al. 2018, article 29) and had been followed earlier by Playford and Mory (2017, p. 280). Reference listings should, as they do herein, cite both modes of publication (where such exist).

4.1. Taxonomic inventory

The species identified in this study are listed below and arranged in accordance with the systematic order adopted in the ensuing descriptive section. Square-bracketed plate/figure citations refer to photomicrographs in the present paper. Asterisks denote species described by Playford and Helby (1968).

Calamospora spp. [Plate 1, figures 3, 4]
Leiotriletes ornatus Ishchenko, 1956 [Plate 1, figure 1]
Phyllothecotriletes golatensis Staplin, 1960 [Plate 1, figure 2]
**Punctatisporites lucidulus* Playford & Helby, 1968 [Plate 1, figures 9, 10]
**Punctatisporites subtritus* Playford & Helby, 1968 [Plate 1, figures 11–14]
Retusotriletes separatus Playford, 2015 [Plate 1, figure 5]
Cyclogranisporites firmus Jones & Truswell, 1992 [Plate 1, figures 6–8]
Verrucosisporites adgeratus sp. nov. [Plate 2, figures 1a, b–5a, b]
**Verrucosisporites aspratilis* Playford & Helby, 1968 [Plate 2, figures 6–8]
Verrucosisporites basiliscutis Jones & Truswell, 1992 [Plate 2, figure 9a, b]
Verrucosisporites gregatus Playford & Melo, 2012 [Plate 2, figures 10, 11]
Verrucosisporites iannuzzii di Pasquo in di Pasquo & Iannuzzi, 2014 [Plate 2, figures 12–15; Plate 3, figures 1a, b–3]
**Verrucosisporites italiaensis* Playford & Helby, 1968 [Plate 4, figures 13–15]
Verrucosisporites johnstonense sp. nov. [Plate 3, figures 12–15]
Verrucosisporites pavimentatus sp. nov. [Plate 3, figures 8–11]
**Verrucosisporites quasigobbettii* Jones & Truswell, 1992 [Plate 4, figures 1a, b–12a, b]
Verrucosisporites souzai di Pasquo in di Pasquo & Iannuzzi, 2014 [Plate 3, figures 4–7]
Anapiculatisporites amplus Playford & Powis, 1979 [Plate 5, figures 14–16]
Anapiculatisporites concinnus Playford, 1962 [Plate 5, figures 10–13]
Anapiculatisporites hispidus Butterworth & Williams, 1958 [Plate 5, figures 8, 9]
Anapiculatisporites robertsii sp. nov. [Plate 5, figures 1a, b–5]
Dibolisporites disfacies Jones & Truswell, 1992 [Plate 5, figures 6, 7]
**Raistrickia accincta* Playford & Helby, 1968 [Plate 7, figures 1–4]
**Raistrickia corymbiata* Playford in Playford & Mory, 2017 [Plate 7, figures 5, 6]
**Raistrickia radiosa* Playford & Helby, 1968 [Plate 7, figures 7, 8]
Brochotriletes diversifoveatus Playford & Satterthwait, 1985 [Plate 6, figure 9a, b]
Convolutispora perplicata sp. nov. [Plate 7, figures 16–18]
**Cordylosporites asperidictyus* (Playford & Helby, 1968) Dino & Playford, 2002 [Plate 6, figures 15–17]
**Foveosporites pellucidus* Playford & Helby, 1968 [Plate 6, figures 10–14a, b]
Microreticulatisporites sp. A [Plate 7, figures 13–15]
**Rattiganispora apiculata* Playford & Helby, 1968 emend. Playford, 1986 [Plate 7, figures 9a, b–12]
**Reticulatisporites magnidictyus* Playford & Helby, 1968 emend. Playford, 2017 [Plate 6, figures 1–8]
Diatomozonotriletes sp. A [Plate 9, figure 1]
Knoxisporites balickeraensis sp. nov. [Plate 8, figures 3a, b–8]
Knoxisporites sp. A [Plate 8, figure 1a, b]
Knoxisporites sp. B [Plate 8, figure 2a, b]
Densoisporites argutus sp. nov. [Plate 9, figures 5, 6]
Densosporites infacetus Daemon, 1974 [Plate 9, figures 7, 8]

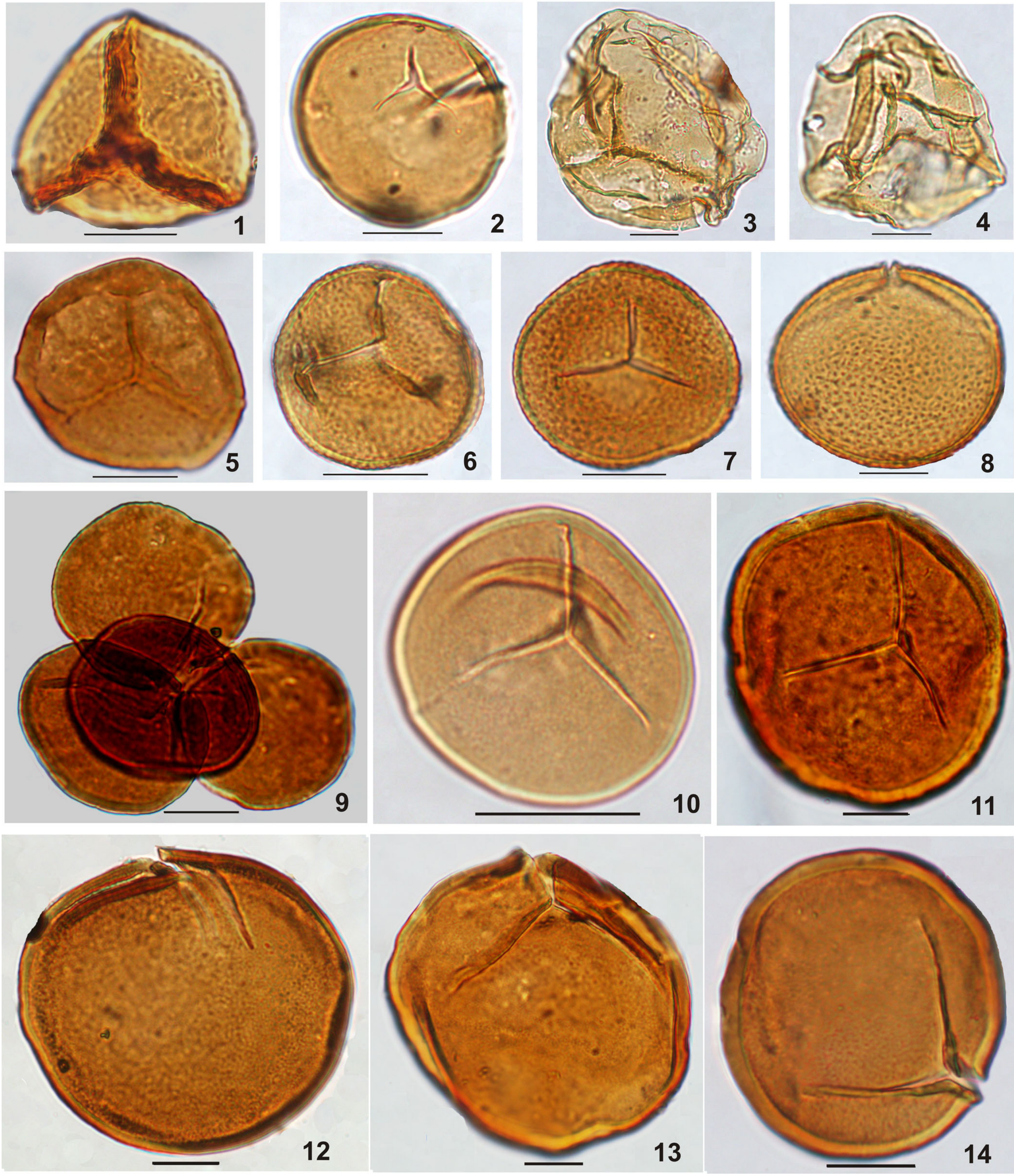

Plate 1. 1, *Leiotriletes ornatus* Ishchenko, 1958, median focus. 2, *Phyllothecotriletes golatensis* Staplin, 1960, proximal focus. 3, 4, *Calamospora* spp., medial foci. 5, *Retusotriletes separatus* Playford, 2015, medial focus. 6–8, *Cyclogranisporites firmus* Jones & Truswell, 1992; 6, proximal focus; 7, medial focus; 8, equatorial aspect. 9, 10, *Punctatisporites lucidulus* Playford & Helby, 1968; 9, tetrad; 10, medial focus. 11–14, *Punctatisporites subtritus* Playford & Helby, 1968; 11, proximal focus; 12, equatorial aspect; 13, proximo-equatorial aspect; 14, proximal focus. Scale bars = 20 μm. For slide locations and other curatorial details see Appendix 1.

Densosporites sp. A [Plate 9, figures 9a, b, 10]

***Indotriradites kuttungensis* (Playford & Helby, 1968) Playford, 1991 [Plate 9, figures 2–4]

Radiizonates arcuatus Loboziak, Playford & Melo, 2000 [Plate 9, figure 12a, b]

Vallatisporites sp. cf. *V. hystricosus* (Winslow, 1962) Wicander & Playford, 2013 [Plate 9, figure 13]

Diaphanospora sp. A [Plate 9, figure 11]

***Grandispora maculosa* Playford & Helby, 1968 [Plate 9, figures 14, 15]

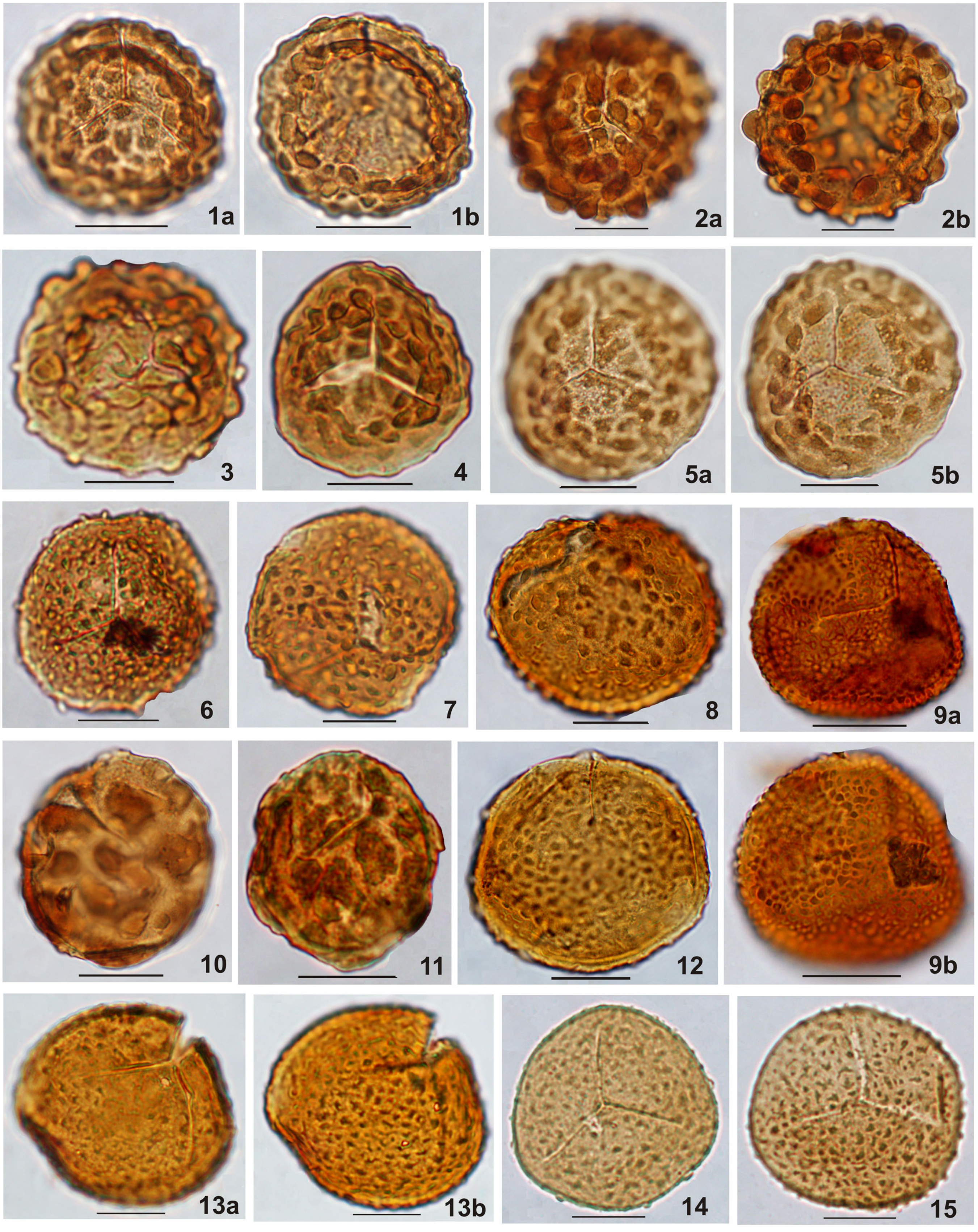

Plate 2. 1a, b–5a, b, *Verrucosisporites adgeratus* sp. nov.; 1a, b, holotype, proximal and distal foci; 2a, b, proximal and distal foci; 3, medial focus; 4, near-distal focus; 5a, b, proximal and distal foci. 6–8, *Verrucosisporites aspratilis* Playford & Helby, 1968; 6, proximal focus; 7, distal focus; 8, equatorial aspect. 9a, b, *Verrucosisporites basiliscutus* Jones & Truswell, 1992, proximal and distal foci. 10, 11, *Verrucosisporites gregatus* Playford & Melo, 2012; 10, equatorial aspect; 11, proximal focus. 12–15, *Verrucosisporites iannuzzii* di Pasquo in di Pasquo & Iannuzzi, 2014; 12, equatorial aspect; 13a, b, proximal-equatorial and distal-equatorial foci; 14, proximal focus; 15, distal focus. Scale bars = 20 µm. For slide locations and other curatorial details see Appendix 1.

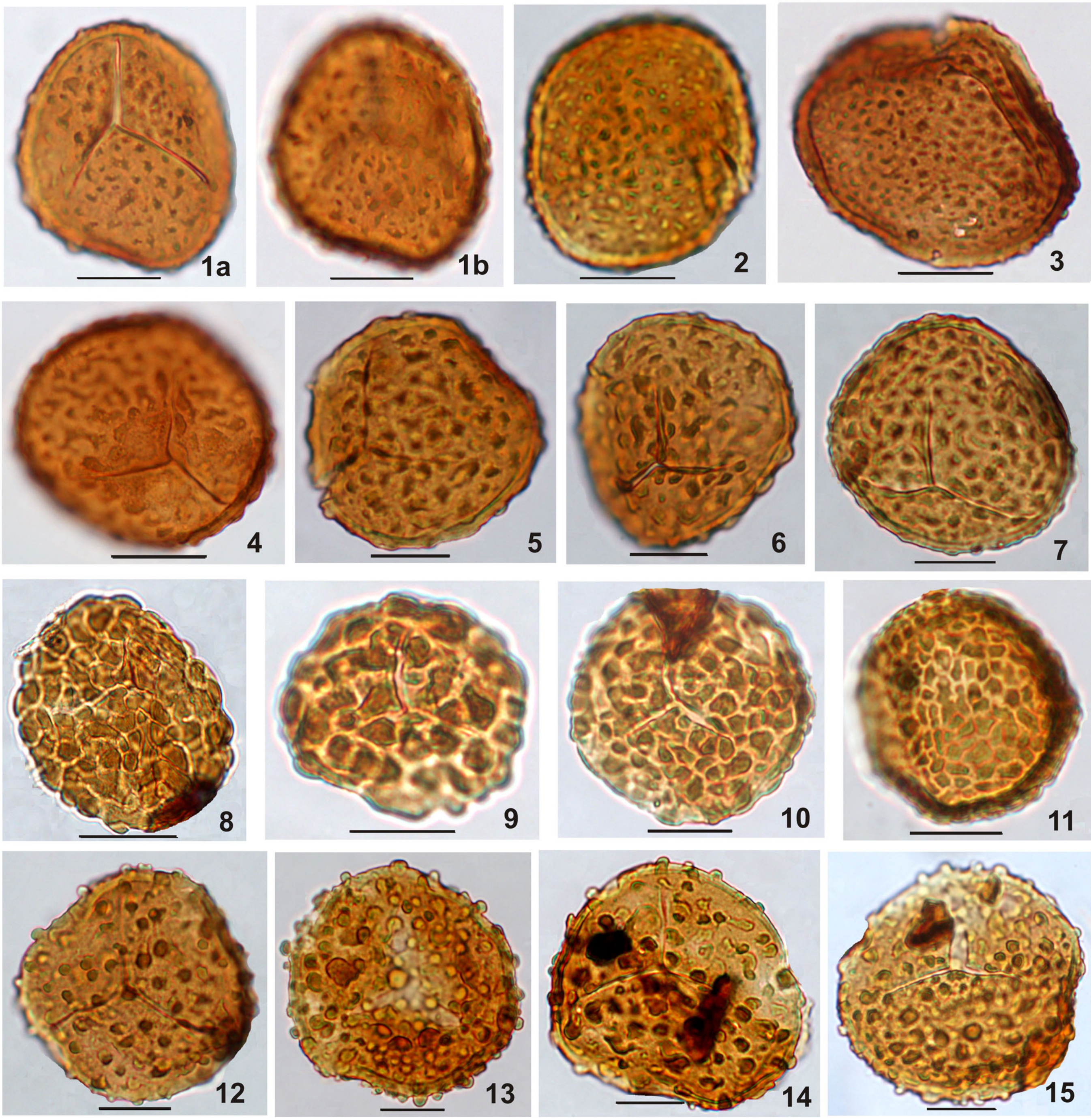

Plate 3. 1a, b–3. *Verrucosisporites iannuzzii* di Pasquo in di Pasquo & Iannuzzi, 2014; 1a, b, proximal and distal foci; 2, equatorial aspect; 3, equatorial aspect. 4–7, *Verrucosisporites souzai* di Pasquo in di Pasquo & Iannuzzi, 2014; 4, proximal focus; 5, medial focus; 6, proximal focus; 7, proximal focus. 8–11, *Verrucosisporites pavimentatus* sp. nov.; 8, holotype, medial focus; 9, proximal focus; 10, proximal focus; 11, distal focus. 12–15, *Verrucosisporites johnstonense* sp. nov.; 12, holotype, medial focus; 13, distal focus; 14, medial focus; 15, proximal focus. Scale bars = 20 µm. For slide locations and other curatorial details see Appendix 1.

**Velamisporites australiensis* (Playford & Helby, 1968) di Pasquo, Azcuy & Souza, 2003 [Plate 9, figures 16–18]

Velamisporites cortaderensis (Césari & Limarino, 1987) Playford, 2015 [Plate 10, figures 1–4]

Aratrisporites saharaensis Loboziak, Clayton & Owens, 1986 [Plate 11, figures 12, 13]

Laevigatosporites demutabilis sp. nov. [Plate 10, figures 5–12]

Latosporites durabilis sp. nov. [Plate 10, figures 13–18]

**Psomospora detecta* Playford & Helby, 1968 [Plate 11, figures 1a, b–11]

Tetraporina horologia (Staplin, 1960) Playford, 1963 [Plate 11, figure 14]

4.2. Descriptive systematics

The 'Turma' form-classificatory scheme for fossil spores and pollen grains (collectively, miospores) was initiated by Potonié and Kremp (1954). This scheme, including modifications by later authors, is followed in the systematics section

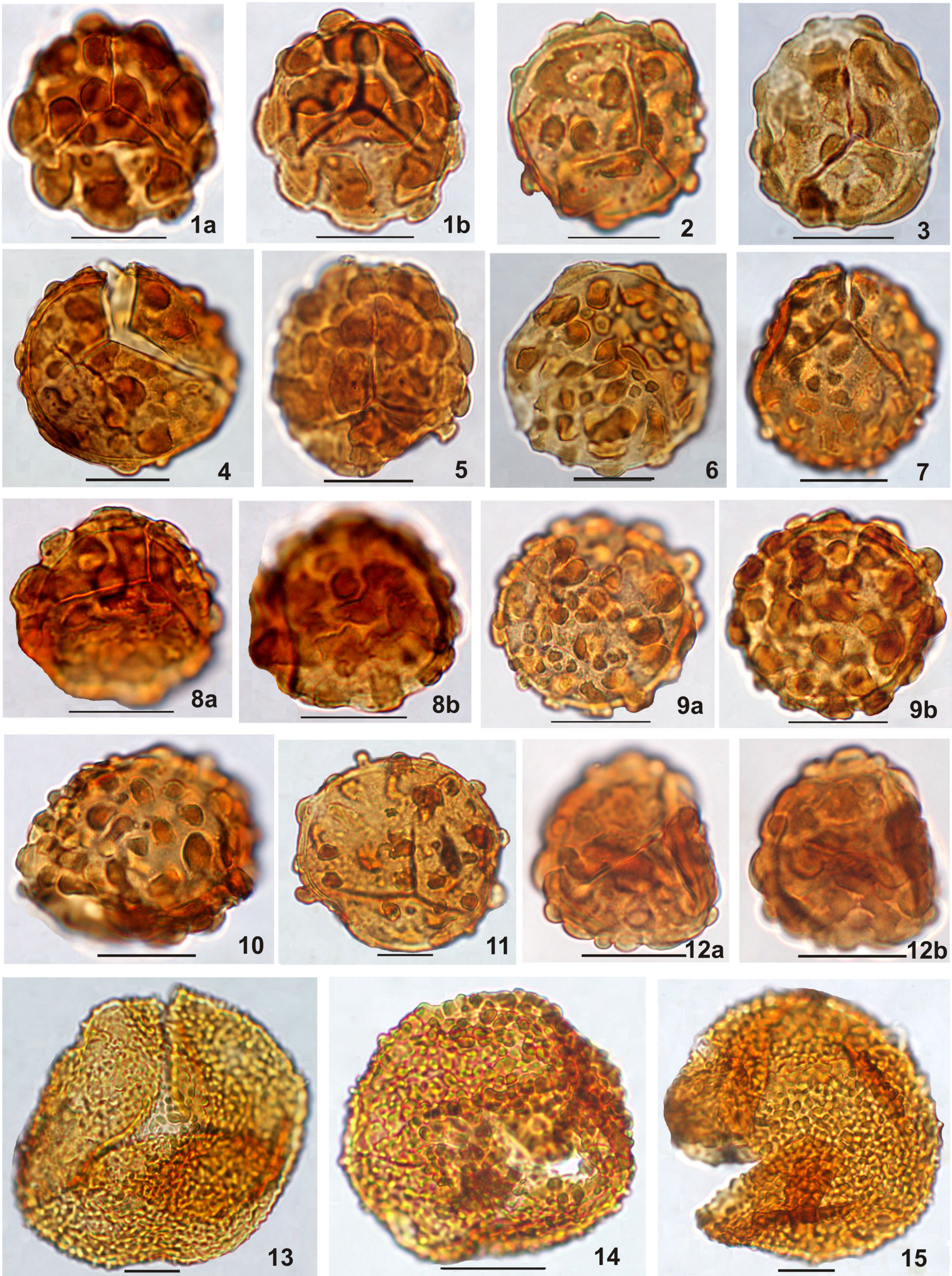

Plate 4. 1a, b–12a, b, *Verrucosisporites quasigobbettii* Jones & Truswell, 1992; 1a, b, proximal and distal foci; 2, medial focus; 3, medial focus; 4, proximal focus; 5, proximal focus; 6, distal focus; 7, proximal-equatorial focus; 8a, b, proximal and distal foci; 9a, b, medial and distal foci; 10, distal focus; 11, medial focus; 12a, b, proximal and distal foci. 13–15, *Verrucosisporites italiaensis* Playford & Helby, 1968; 13, proximal focus; 14, distal focus; 15, medial focus. Scale bars = 20 µm. For slide locations and other curatorial details see Appendix 1.

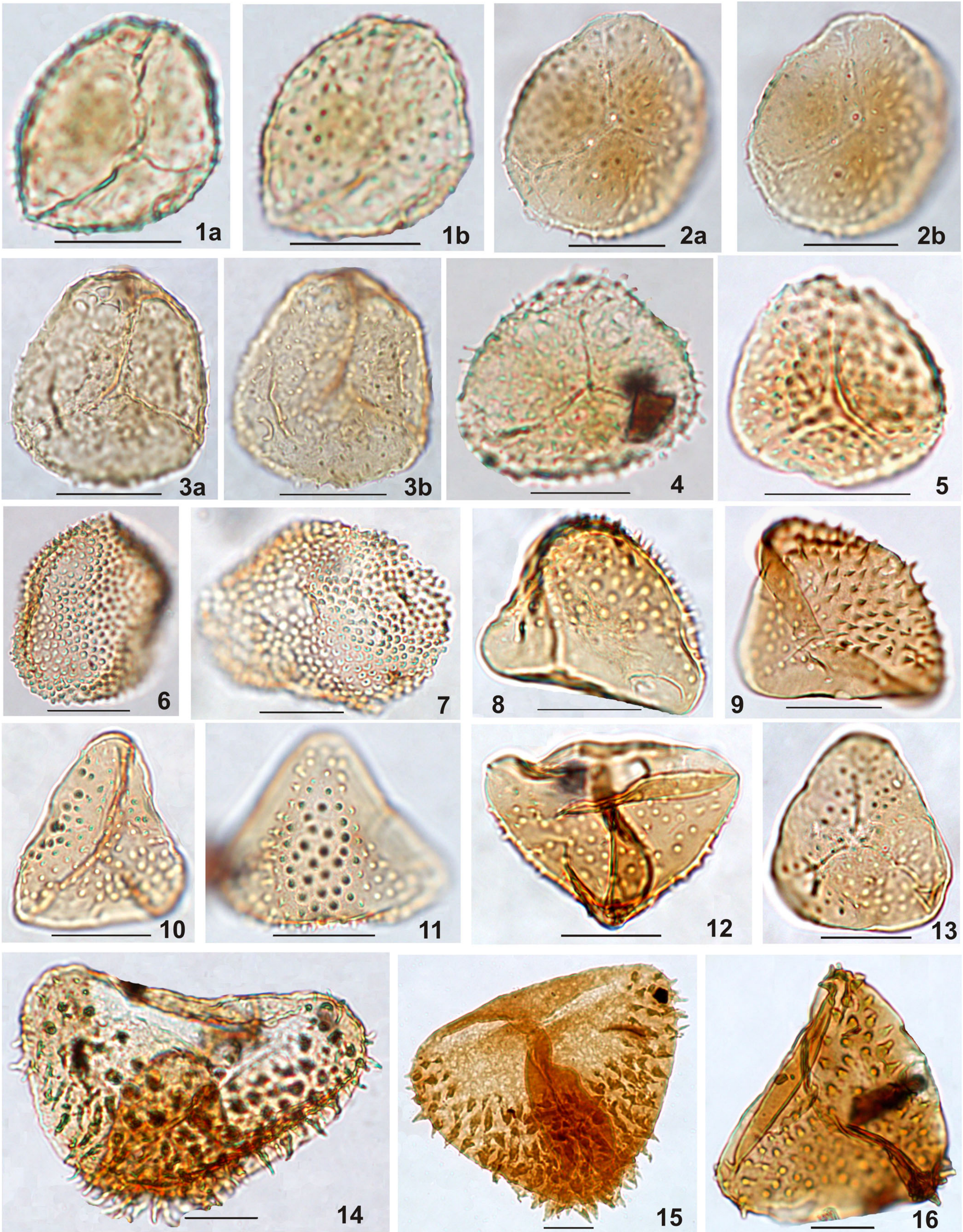

Plate 5. 1a, b–5, *Anapiculatisporites robertsii* sp. nov.; 1a, b, proximal and distal foci; 2a, b, distal and medial foci; 3a, b, holotype, proximal and distal foci; 4, proximal focus; 5, near-proximal focus. 6, 7, *Dibolisporites disfacies* Jones & Truswell, 1992; 6, medial focus; 7, distal focus of deformed specimen. 8, 9, *Anapiculatisporites hispidus* Butterworth & Williams, 1958; equatorial aspects. 10–13, *Anapiculatisporites concinnus* Playford, 1962; 10, medial focus; 11, distal focus; 12, equatorial aspect; 13, proximal focus. 14–16, *Anapiculatisporites amplus* Playford & Powis, 1979; 14, 15, equatorial aspects; 16, medial focus. Scale bars = 20 μm. For slide locations and other curatorial details see Appendix 1.

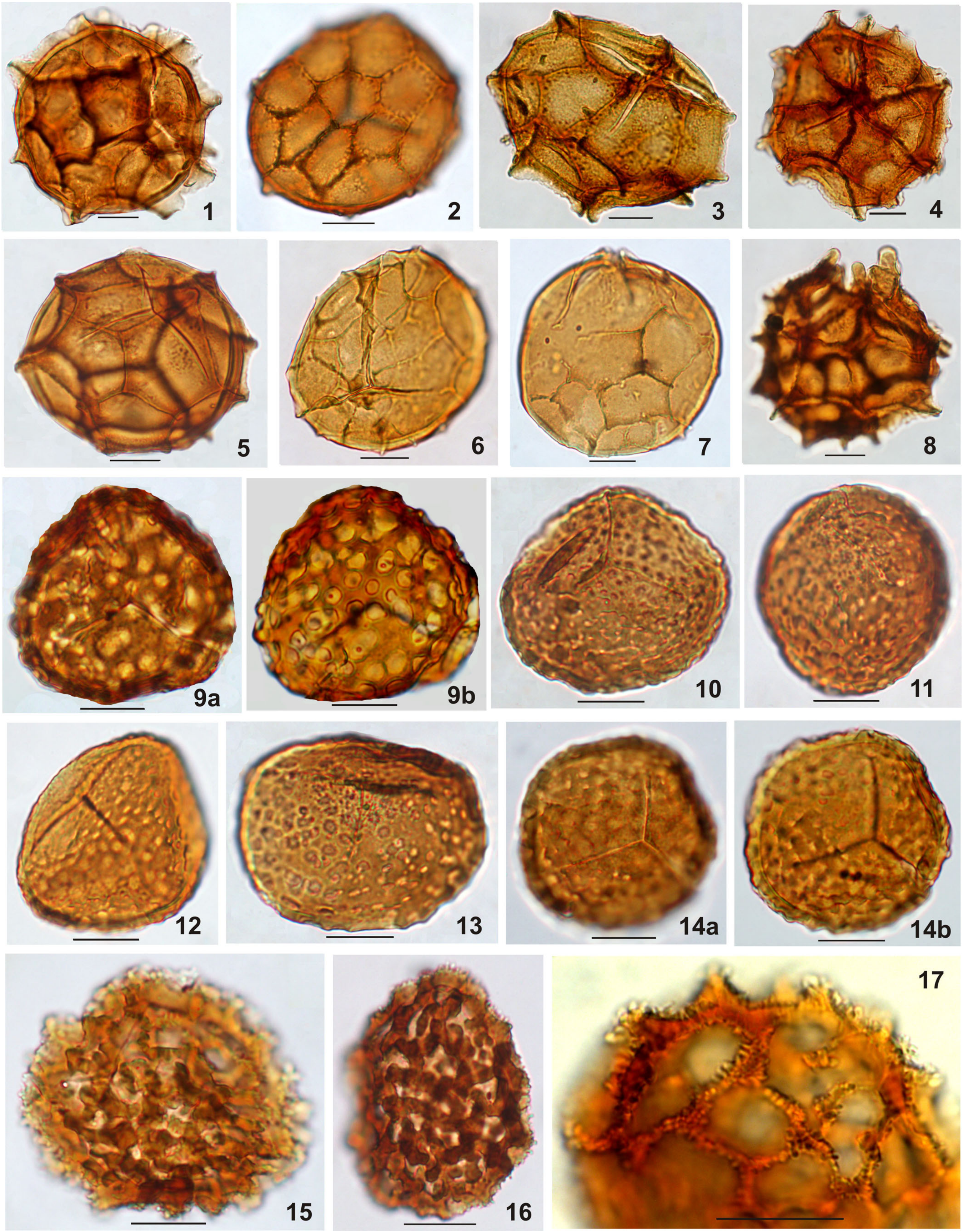

Plate 6. 1–8, *Reticulatisporites magnidictyus* Playford & Helby, 1968 emend. Playford, 2017; 1, proximal focus; 2, distal focus; 3, proximal-equatorial aspect; 4, medial focus; 5, proximal focus; 6, proximal focus; 7, equatorial aspect; 8, equatorial aspect. 9a, b, *Brochotriletes diversifoveatus* Playford & Satterthwait, 1985, proximal and distal foci. 10–14a, b, *Foveosporites pellucidus* Playford & Helby, 1968; 10, proximal focus; 11, equatorial aspect; 12, medial focus; 13, equatorial aspect; 14a, b, proximal and distal foci. 15–17, *Cordylosporites asperidictyus* (Playford & Helby, 1968) Dino & Playford, 2002; 15, near-proximal focus; 16, medial focus; 17, distal focus. Scale bars = 20 μm. For slide locations and other curatorial details see Appendix 1.

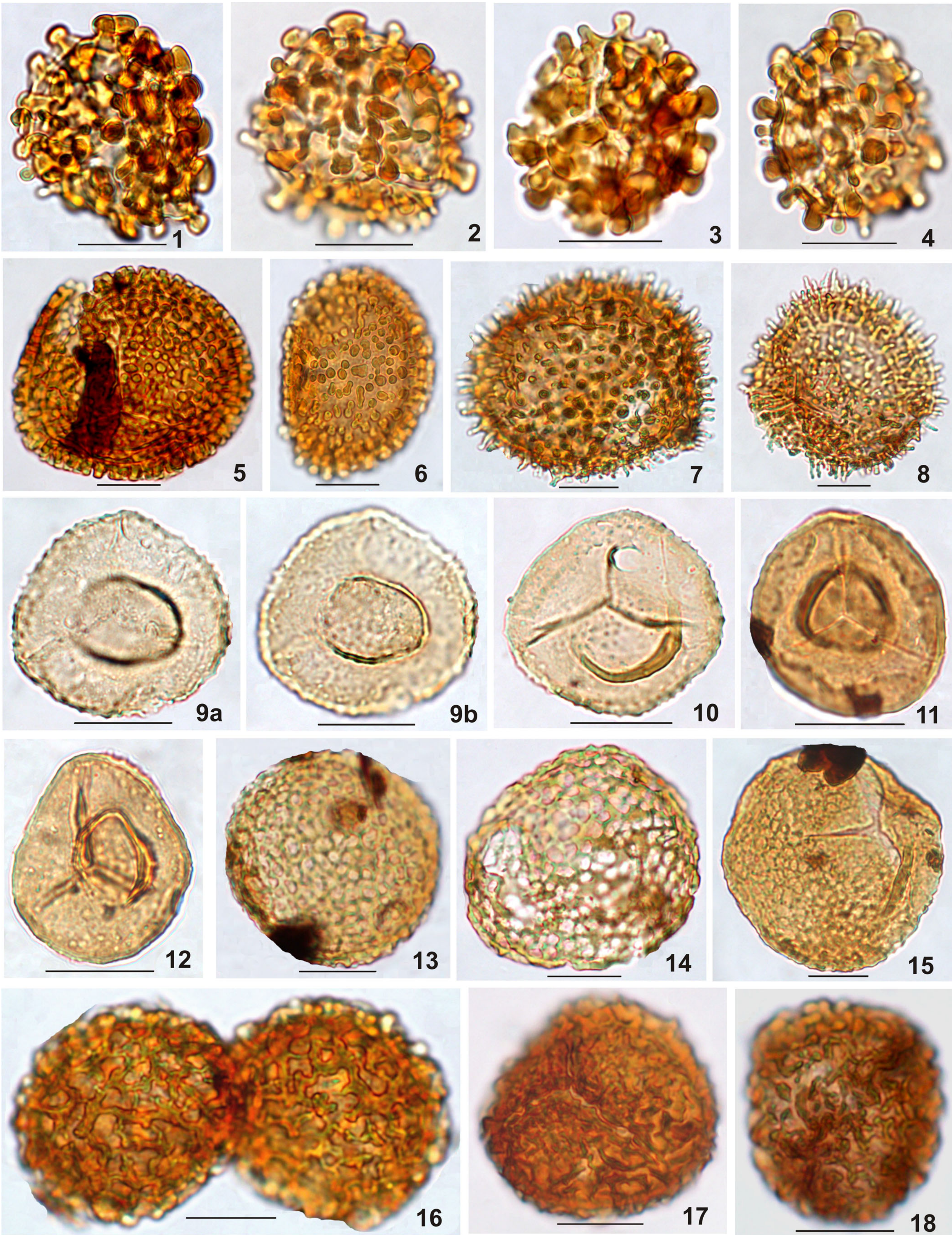

Plate 7. 1–4, *Raistrickia accincta* Playford & Helby, 1968; 1, medial focus; 2, medial focus; 3, proximal focus; 4, distal focus. 5, 6, *Raistrickia corymbiata* Playford in Playford & Mory, 2017, proximal and distal foci. 7, 8, *Raistrickia radiosa* Playford & Helby, 1968, distal and proximal foci. 9a, b–12, *Rattiganispora apiculata* Playford & Helby, 1968 emend. Playford, 1986; 9a, b, proximal and distal foci; 10, medial focus; 11, proximal focus; 12, medial focus. 13–15, *Microreticulatisporites* sp. A; 13, medial focus; 14, distal focus; 15, proximal-equatorial aspect. 16–18, *Convolutispora perplicata* sp. nov.; 16, two conjoined specimens, distal aspect; 17, holotype, proximal focus; 18, distal focus. Scale bars = 20 µm. For slide locations and other curatorial details see Appendix 1.

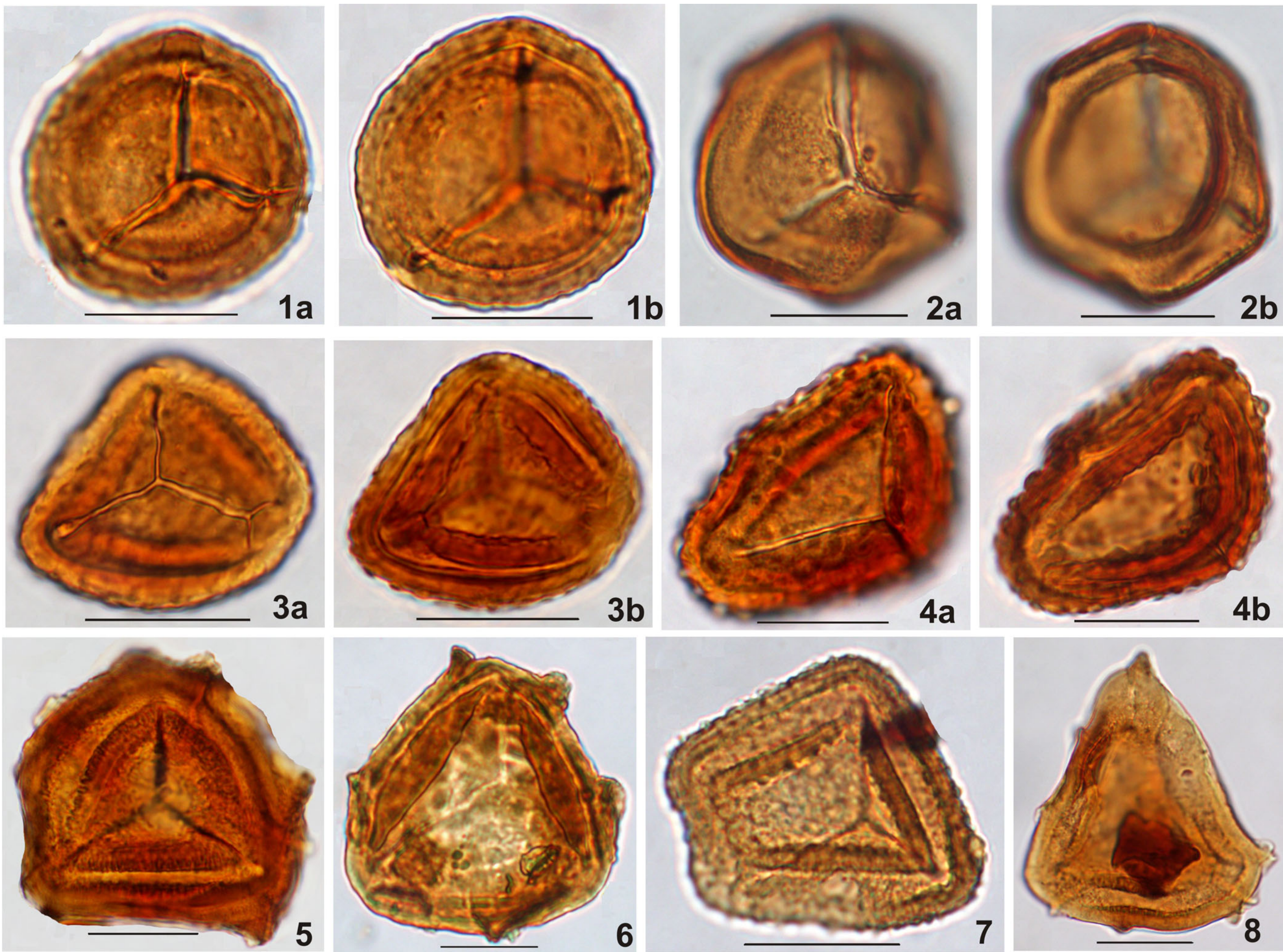

Plate 8. 1a, b, *Knoxisporites* sp. A, proximal and distal foci. 2a, b, *Knoxisporites* sp. B, proximal and distal foci. 3a, b–8, *Knoxisporites balickeraensis* sp. nov.; 3a, b, holotype, proximal and distal foci; 4a, b, proximal and distal foci; 5–8, medial foci. Scale bars = 20 µm. For slide locations and other curatorial details see Appendix 1.

below. The form genera and species of palynomorphs are subject to provisions of the ICN (Turland et al. 2018).

The basionym is cited for all previously instituted species, followed where appropriate either by synonyms and generic re-combinations or by direct reference (*cum syn.*) to synonymy listings in prior publications. Whereas most of the species identified are described in detail, some species that have been satisfactorily circumscribed in published accounts are documented without comprehensive descriptions. In many such cases, supplementary morphological information is included, based on specimens observed during the present study.

Descriptive terminology follows definitions furnished by such authors as Kremp (1965), Smith and Butterworth (1967), Playford and Dettmann (1996), Punt et al. (2007), and Traverse (2007). Exinal sculptural elements termed 'minute' are appreciably less than 1 µm in height, thus making their precise form difficult to determine precisely. Equatorial diameters are specified by lowest and highest values, in most cases with intervening bracketed arithmetic mean – e.g. 45 (59) 72 µm. Type-species designations are abbreviated as follows: OD, original designation; SD, subsequent designation; and M, monotypy. Appendix 1 provides curatorial details pertaining to each species identified herein.

4.2.1. Miospores

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.
Plate 1, figures 3, 4

Remarks. Representatives of this genus are only minor elements in the palynoflora and are of negligible stratigraphic import.

Genus *Leiotriletes* Naumova, 1939 ex Ishchenko, 1952
emend. R. Potonié & Kremp, 1954

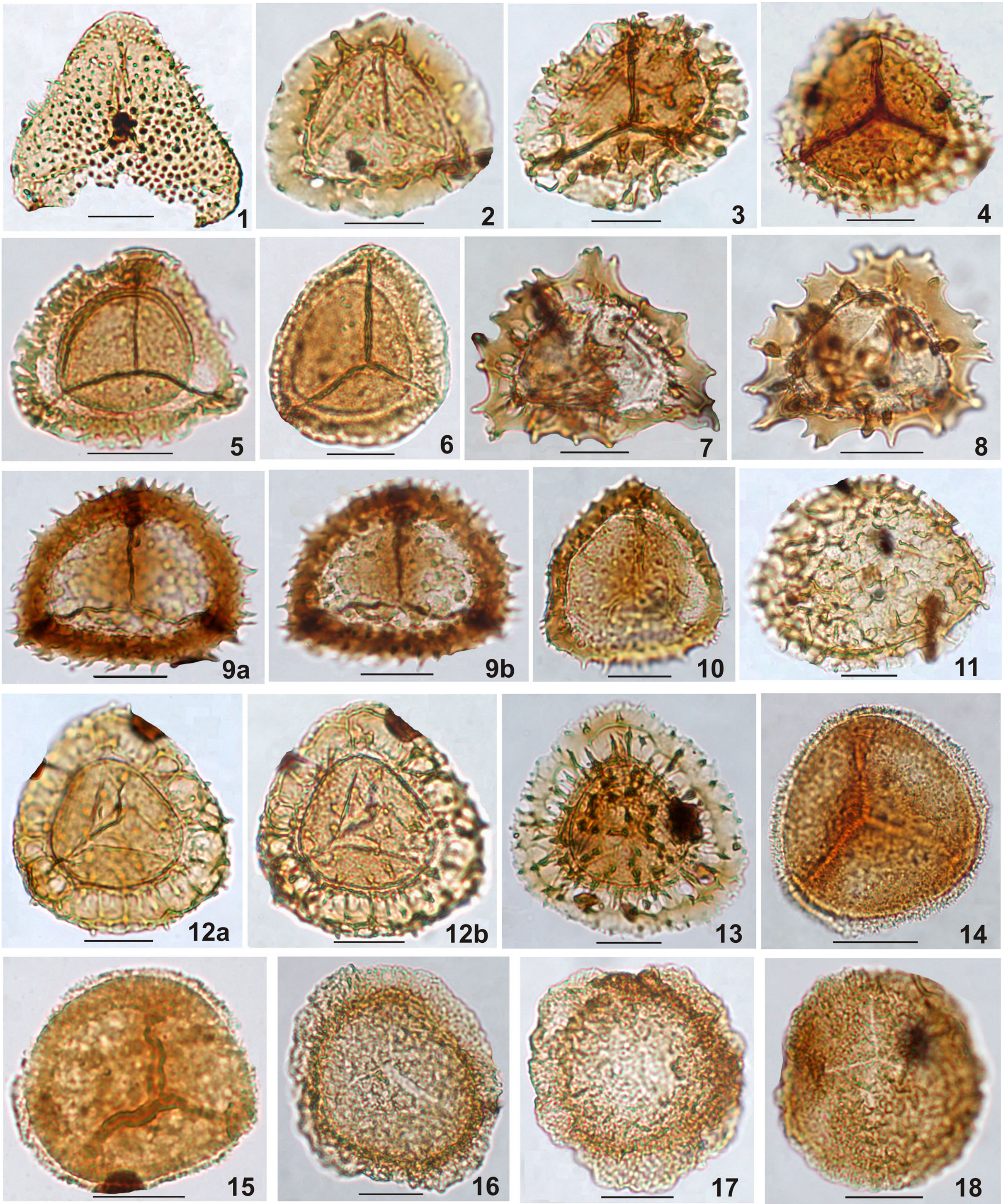

Plate 9. 1, *Diatomozonotriletes* sp. A, medial focus. 2–4, *Indotriradites kuttungensis* (Playford & Helby, 1968) Playford, 1991; 2, distal focus; 3, 4, medial foci. 5, 6, *Densoisporites argutus* sp. nov.; 5, medial focus; 6, holotype, medial focus. 7, 8, *Densosporites infacetus* Daemon, 1974, medial foci. 10a, b, 11, *Densosporites* sp. A; 9a, b, proximal and distal foci; 10, medial focus. 11, *Diaphanospora* sp. A, medial focus. 12a, b, *Radiizonates arcuatus* Loboziak, Playford & Melo, 2000, proximal and distal foci. 13, *Vallatisporites* sp. cf. *V. hystricosus* (Winslow, 1962) Wicander & Playford, 2013, distal focus. 14, 15, *Grandispora maculosa* Playford & Helby, 1968, distal and proximal foci. 16–18, *Velamisporites australiensis* (Playford & Helby, 1968) di Pasquo, Azcuy & Souza, 2003; 16, proximal focus; 17, medial focus; 18, proximal focus. Scale bars = 20 µm. For slide locations and other curatorial details see Appendix 1.

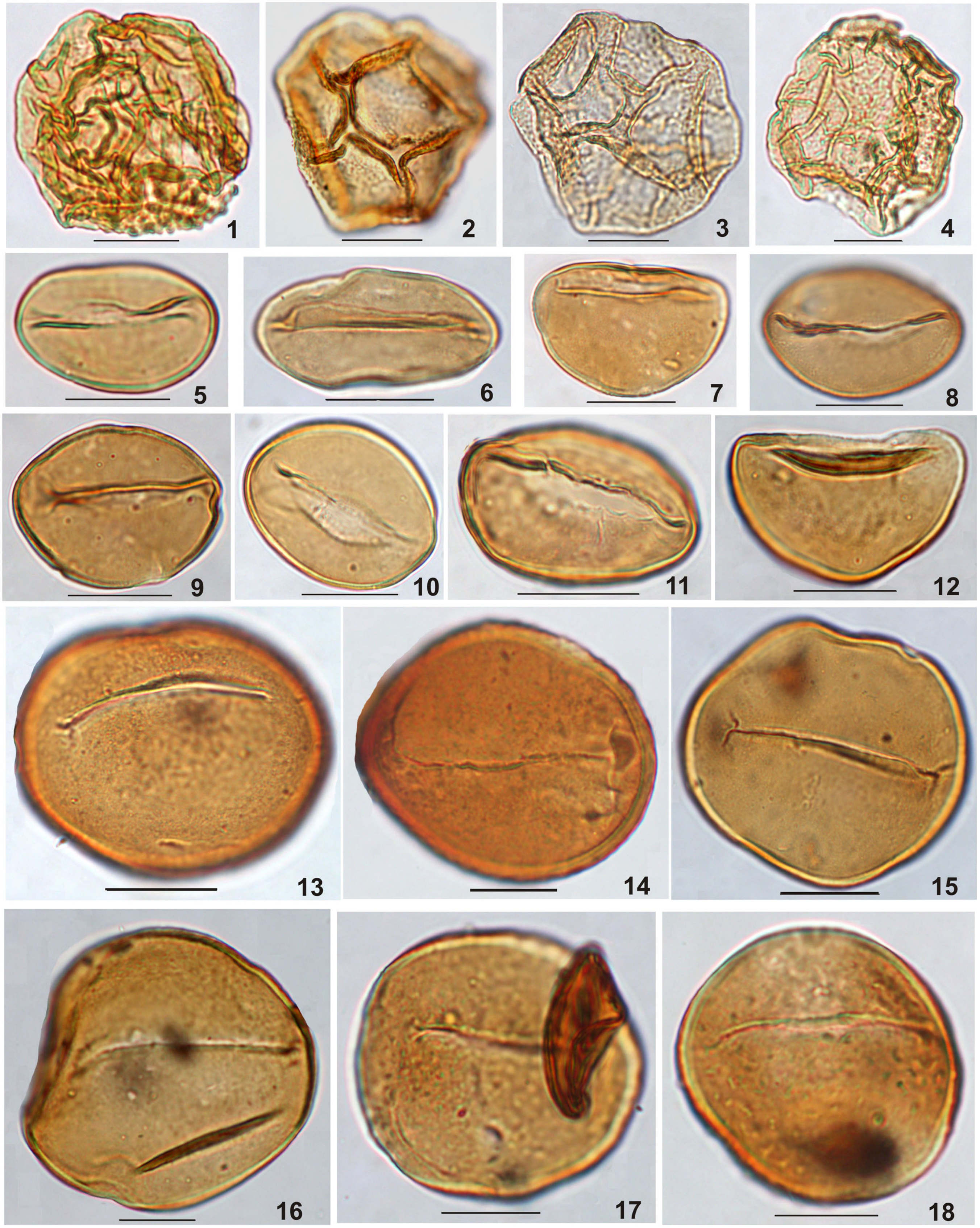

Plate 10. 1–4, *Velamisporites cortaderensis* (Césari & Limarino, 1987) Playford, 2015; 1, medial focus; 2, distal focus; 3, 4, medial foci. 5–12, *Laevigatosporites demutabilis* sp. nov.; 5, holotype, medial focus; 6, medial focus; 7, equatorial aspect; 8, proximal focus; 9, medial focus; 10, equatorial aspect; 11, proximal focus; 12, equatorial aspect. 13–18, *Latosporites durabilis* sp. nov.; 13, holotype, proximo-equatorial aspect; 14, medial focus; 15, 16, proximal foci; 17, medial focus; 18, proximal focus. Scale bars = 20 μm. For slide locations and other curatorial details see Appendix 1.

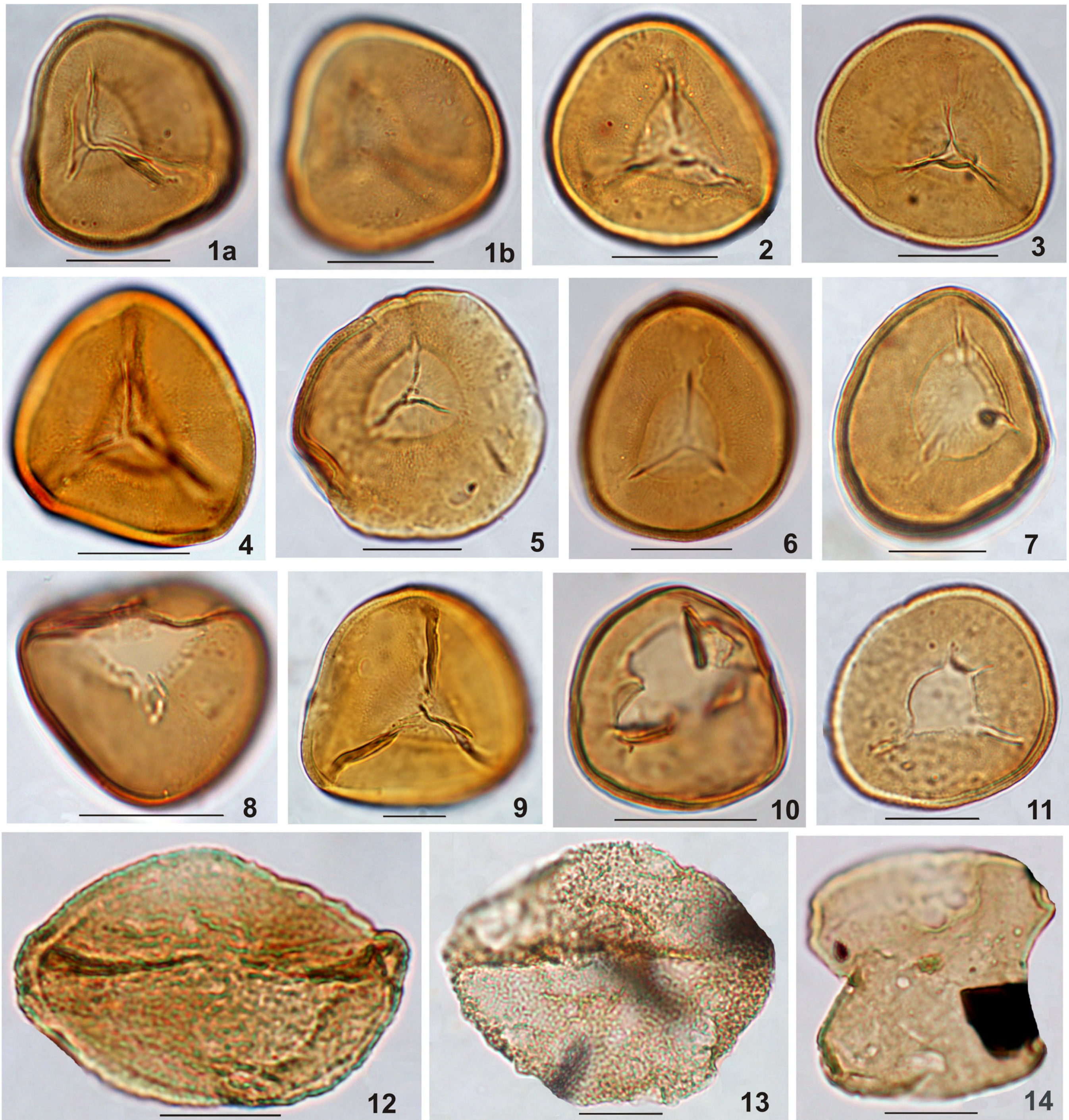

Plate 11. 1a, b–11, *Psomospora detecta* Playford & Helby, 1968; 1a, b, proximal and distal foci; 2, medial focus; 3, proximal focus; 4, medial focus; 5–7, proximal foci; 8, equatorial aspect; 9, medial focus; 10, 11, proximal foci. 12, 13, *Aratrisporites saharaensis* Loboziak, Clayton & Owens, 1986, medial foci. 14, *Tetraporina horologia* (Staplin, 1960) Playford, 1963. Scale bars = 20 μm. For slide locations and other curatorial details see Appendix 1.

Type species. *Leiotriletes sphaerotriangulus* (Loose, 1932) R. Potonié & Kremp, 1955 [SD; Potonié & Kremp 1954, p. 120].

Leiotriletes ornatus Ishchenko, 1956
Plate 1, figure 1

Synonymy.
1956 *Leiotriletes ornatus* Ishchenko, p. 22, pl. 2, figs 18–21.
For other synonymy see Playford and Melo (2012, p. 13).

Remarks. The few specimens encountered herein accord with those described by previous authors, most recently by Playford (2015, p. 6).

Previous records. Essentially cosmopolitan in rocks of late Palaeozoic, commonly Mississippian, age.

Genus *Phyllothecotriletes* Luber, 1955 ex R. Potonié, 1958

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

Phyllothecotriletes golatensis Staplin, 1960
Plate 1, figure 2

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

Remarks. Very rare in the present palynoflora; the specimens observed closely resemble those described previously (e.g. Playford and Mory 2017, p. 281, pl. 1, figs 7, 8).

Previous records. From the Upper Mississippian of Alberta, Canada (Staplin 1960); and recorded by Playford (2015) and Playford and Mory (2017) from Western Australian strata of the northern Perth Basin and contiguous Carnarvon Basin in strata containing the *Grandispora maculosa* Assemblage.

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

Type species. *Punctatisporites punctatus* (Ibrahim, 1932) Ibrahim, 1933 [OD].

Punctatisporites lucidulus Playford & Helby, 1968
Plate 1, figures 9, 10

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

Remarks. This species is relatively abundant, including as tetrads, in the Mount Johnstone Formation samples. Present specimens accord with those described originally (Playford and Helby 1968) and subsequently (Playford 2015, p. 6, fig. 2L, M).

Dimensions (37 specimens). Equatorial diameter 39 (52) 63 µm.

Previous records. Reported widely from middle Visean–Upper Mississippian successions of Eastern and Western Gondwana (Playford and Melo 2012, p. 14; Playford 2015; Playford and Mory 2017). Jones and Truswell (1992) indicated a range extension into the Pennsylvanian–?Lower Permian of Queensland's Galilee Basin, but they neither described nor illustrated any specimens they considered referable to the species.

Punctatisporites subtritus Playford & Helby, 1968
Plate 1, figures 11–14

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

Remarks and comparison. *Punctatisporites subtritus* Playford & Helby, 1968 is a conspicuous component of the palynoflora and is distinguishable from the accompanying *P. lucidulus* Playford & Helby, 1968 by its generally much larger size and thicker, intragranulate/intrapunctate exine. It is commonly preserved as off-polar compressions.

Dimensions (32 specimens). Equatorial diameter 57 (88) 112 µm.

Previous records. *Punctatisporites subtritus* and *P. lucidulus* share closely comparable stratigraphic and palaeogeographic distributions (q.v. Playford and Mory 2017, p. 281).

Infraturma RETUSOTRILETI Streel in Becker, Bless, Streel & Thorez, 1974

Genus *Retusotriletes* Naumova, 1953 emend. Streel, 1964

Type species. *Retusotriletes simplex* Naumova, 1953 [SD; Potonié 1958, p. 13].

Retusotriletes separatus Playford, 2015
Plate 1, figure 5

Synonymy.
2015 *Retusotriletes separatus* Playford, p. 7, fig. 3A–K.

Remarks. The few specimens encountered conform with the specific diagnosis as per above synonymy.

Dimensions (two specimens). Equatorial diameter 49, 56 µm.

Previous records. From Western Australian sediments bearing the *Grandispora maculosa* Assemblage (Playford 2015; Playford and Mory 2017), hence correlative with the Mount Johnstone Formation of the present study.

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
Plate 1, figures 6–8

Synonymy.
1992 *Cyclogranisporites firmus* Jones & Truswell, p. 163, figs 8S, 9K, L, O–V.

Remarks. The numerous specimens of this study are consonant with those diagnosed by Jones and Truswell (1992) and later described by Playford (2015, p. 10, fig. 4J–N).

Dimensions (42 specimens). Equatorial diameter 41 (58) 69 µm.

Previous records. In the Galilee Basin, Queensland, this species was originally reported (Jones and Truswell 1992) as ranging through zones A–D (Upper Mississippian–Lower Permian). Western Australian occurrences (Playford 2015; Playford and Mory 2017) are from strata hosting the *Grandispora maculosa* Assemblage and hence coeval with the Mount Johnstone Formation studied here. In Western Gondwana, the possible or likely presence of *Cyclogranisporites firmus* Jones & Truswell, 1992 in the Argentine Carboniferous was noted by Playford (2015, p. 10).

Subinfraturma VERRUCATI Dybová & Jachowicz, 1957

Genus *Verrucosisporites* Ibrahim, 1933 emend. Smith & Butterworth, 1957

Type species. *Verrucosisporites verrucosus* (Ibrahim, 1932) Ibrahim, 1933 [OD].

Discussion. Quantitatively and qualitatively, this acavate, verrucate genus is conspicuously and diversely represented in the study samples. Main interspecific variables are size, spacing, and distribution of verrucae; haptotypic character; exine thickness; and overall dimensions. In some instances, speciation is not entirely unequivocal insofar as a morpho-continuum could conceivably exist among some species (e.g. *Verrucosisporites iannuzzii*, *V. souzai*, and *V. roncadorense* as described and provisionally maintained separately herein). Conversely, *V. quasigobbettii* – the most abundant representative of the genus in the Mount Johnstone Formation – incorporates an appreciable range of comprehensively verrucate forms that are demonstrably intergradational.

Verrucosisporites adgeratus sp. nov.
Plate 2, figures 1a, b–5a, b

Synonymy.
1992 *Verrucosisporites nitidus* (Naumova; *sic*) *auct. non* Playford, 1964; Jones & Truswell, p. 161, fig. 8I.

Diagnosis. Spores radial, trilete; amb circular or nearly so. Laesurae distinct, simple, straight, length two-thirds of to almost equalling spore radius. Exine 1–2 μm thick, sculptured proximally and on marginal distal region with discrete or basally coalescent verrucae up to 6 μm apart. Verrucae circular, subcircular, or roundly polygonal in basal outline; 1.5–6.5 μm broad at base, height 0.8–2 μm. Distinct pole-centred area essentially devoid of sculpture, occupying ca. one-third to three-quarters of distal face, and bordered by circular to subcircular disposition of verrucae.

Dimensions (50 specimens). Equatorial diameter 40 (50) 63 μm, sculpture excluded.

Holotype. Slide K40/33, L30/3 (Plate 2, figure 1a, b). Distal aspect. Amb circular, diameter 46 μm; distinct, simple laesurae, length almost equal to spore radius; exine 1.7 μm thick; verrucate sculpture well developed, excluding unsculptured circular distal polar area, 32 μm in diameter, circumscribed by rampart-like circlet composed of close-spaced to fused verrucae.

Type locality. New South Wales, Balickera excavation, sample A720; Mount Johnstone Formation.

Etymology. Latin, *adger*: rampart.

Remarks. This species is readily distinguishable from others of the genus in featuring sculpture-free exine of a well-circumscribed area occupying much of its distal face.

Previous records. The single specimen recorded by Jones and Truswell (1992, as per above synonymy) was from an unspecified unit in the Galilee Basin, Queensland.

Verrucosisporites aspratilis Playford & Helby, 1968
Plate 2, figures 6–8

Synonymy.
1968 *Verrucosisporites aspratilis* Playford & Helby, p. 108, pl. 9, figs 3–5.
non 2012 *Verrucosisporites aspratilis* Playford & Helby 1968; Playford & Melo, p. 21, pl. 3, figs 8, 9.

Description. Spores radial, trilete with circular to very broadly rounded subtriangular amb. Laesurae distinct, simple, straight, length at least two-thirds of spore radius, uncommonly extending almost to equator. Exine 1.5–2.2 μm thick; sculptured comprehensively with mostly discrete verrucae commonly 2–4 μm apart. Verrucae subcircular to roundly or irregularly elongate in basal outline, basal diameter ca. 1–5.5 μm, height 0.5–3 μm. Few grana and minute coni interspersed among verrucae in some specimens.

Dimensions (17 specimens). Equatorial diameter, excluding sculptural projections, 40 (55) 66 μm.

Previous records. From the Mount Johnstone Formation, New South Wales (Playford and Helby 1968), and to the north in the Galilee Basin (zones A–D, Upper Mississippian through Lower Permian; Jones and Truswell 1992). Playford and Melo (2012, p. 21) noted other records from elsewhere in Gondwana, but the specimen they illustrated reflected a *sensu lato* perspective of the species; it is here considered probably attributable to *Verrucosisporites souzai* di Pasquo in di Pasquo and Iannuzzi, 2014 (described below).

Verrucosisporites basiliscutis Jones & Truswell, 1992
Plate 2, figure 9a, b

Synonymy.
1992 *Verrucosisporites basiliscutis* Jones & Truswell, p. 161, fig. 8C, E–H, J–L.

Description. Spores radial, trilete. Amb circular to subcircular. Laesurae perceptible to distinct, simple, straight, length one- to two-thirds of spore radius. Exine 1.5–3.5 µm thick, sculptured densely, uniformly, and comprehensively with discrete, close-spaced verrucae ca. 0.5–1 µm apart, thereby defining negative reticulum; basal diameter of verrucae mostly 1.5–2.5 µm, basal outline variable (circular, subcircular, ovaloid, polygonal, irregularly elongate), height 0.5–0.8 µm.

Dimensions (12 specimens). Equatorial diameter 39 (50) 61 µm.

Remarks. See Playford (2015, p. 11).

Previous records. Reported initially by Jones and Truswell (1992) from the Upper Mississippian through Lower Permian (zones A–D) of the Galilee Basin, Queensland, and subsequently by Playford (2015) and Playford and Mory (2017) from Western Australian strata of the northern Perth Basin and contiguous Carnarvon Basin containing the *Grandispora maculosa* Assemblage.

Verrucosisporites gregatus Playford & Melo, 2012
Plate 2, figures 10, 11

Synonymy.
2012 *Verrucosisporites gregatus* Playford & Melo, p. 23, pl. 4, figs 4–11.
2014 *Verrucosisporites roncadorense* di Pasquo in di Pasquo & Iannuzzi (*partim*), p. 419, fig. 7.8 (only).

Description. Spores radial, trilete, with circular or subcircular amb. Laesurae commonly indistinct, simple, straight, length at least two-thirds of spore radius. Exine sculptured irregularly, on distal surface and less prominently on proximal surface, with variably shaped, mostly discrete verrucae 1–3 µm high; basal outlines of verrucae subcircular to irregularly rounded-polygonal, 2–12 µm in maximum width; height of verrucae 0.8–3 µm, spaced up to 10 µm apart. Unsculptured exine 1.5–3 µm thick.

Dimensions (16 specimens). Equatorial diameter 40 (44) 52 µm.

Remarks. As noted by Playford and Melo (2012) and Playford and Mory (2017), *Verrucosisporites gregatus* Playford & Melo, 2012 is commonly preserved as partial or complete tetrads.

Previous records. This species has been recorded widely from Middle–Upper Mississippian strata of Western, Eastern, and Northern Gondwana (q.v. Playford and Melo 2012, p. 23; Playford 2015, p. 11; Playford and Mory 2017, p. 286).

Verrucosisporites iannuzzii di Pasquo in di Pasquo & Iannuzzi, 2014
Plate 2, figures 12–15; Plate 3, figures 1a, b–3

Synonymy.
2014 *Verrucosisporites iannuzzii* di Pasquo in di Pasquo & Iannuzzi, p. 415, 419, fig. 7.1–4.
2014 *Verrucosisporites souzai* di Pasquo in di Pasquo & Iannuzzi (*partim*), p. 419, fig. 7.7 (only).

Description. Spores radial, trilete. Amb circular to subcircular. Distinct, simple, straight laesurae extending ca. two-thirds to three-quarters of distance to equator. Exine 1.2–2.5 µm thick, bearing relatively fine and irregular verrucate sculpturing elements both distally and proximally. Verrucae variable in basal outline (subcircular, irregularly elongate, or subpolygonal), maximum width 1.2–3.5 µm, height up to 1.2 µm; mainly discrete, up to ca. 2.5 µm apart.

Dimensions (47 specimens). Equatorial diameter 38 (49) 62 µm.

Remarks and comparison. This species and *Verrucosisporites souzai*, both instituted by di Pasquo (in di Pasquo and Iannuzzi 2014), are clearly very similar, perhaps conspecific via morphological intergradation. A possible distinction is that the *V. iannuzzii* is more finely/less obtrusively and more densely verrucate than *V. souzai*.

Previous records. From the Poti Formation (Mag zone; late Visean) in the Parnaíba Basin, north-eastern Brazil (di Pasquo and Iannuzzi 2014).

Verrucosisporites italiaensis Playford & Helby, 1968
Plate 4, figures 13–15

Synonymy.
1968 *Verrucosisporites italiaensis* Playford & Helby, p. 108, pl. 9, figs 15, 16.
2017 *Verrucosisporites* sp. cf. *V. italiaensis* Playford & Helby, 1968; Playford & Mory, p. 288, pl. 2, fig. 10.

Description. Spores radial, trilete. Amb circular to subcircular (commonly irregularly so due to large-scale exinal folding). Laesurae distinct to perceptible, simple or with minor lip development, length one-half to three-quarters of spore radius. Exine 2–3.5 µm thick, bearing comprehensive, ± uniform, and dense verrucate sculpture. Verrucae rounded in profile; basal outline circular to subcircular, uncommonly lobate; basal diameter 1–4.5 µm; height 1.2–4 µm; mostly discrete and ca. 1–2 µm apart (uncommonly up to 9 µm apart).

Dimensions (16 specimens). Equatorial diameter 62 (94) 128 µm.

Remarks. The specimens figured by Playford and Mory (2017; q.v. above synonymy) were given only a cf. specific designation because the equatorial diameter of their three specimens fell well below the size range stated by Playford and Helby (1968) for *Verrucosisporites italiaensis*. However, topotypic specimens described above effectively bridge the apparent dimensional disparity.

Previous records. Mount Johnstone Formation, New South Wales, and approximately coeval core sample from the Coolcalalaya Sub-basin, Western Australia (Playford and Mory 2017).

Verrucosisporites johnstonense sp. nov.
Plate 3, figures 12–15

Diagnosis. Spores radial, trilete, with circular to subcircular amb. Laesurae distinct, simple, straight, extending at least two-thirds of distance to equator. Exine 2.3–3.2 μm thick with comprehensive, somewhat loosely distributed verrucate sculpture. Verrucae 0.5–12 μm apart; basal outlines circular, subcircular, or (much less commonly) rounded-elongate; basal diameter 1.5–6 μm; height 1.3–4 μm. Some specimens with rare grana interspersed among verrucae.

Dimensions (20 specimens). Equatorial diameter 62 (69) 78 μm (sculpture excluded).

Holotype. Slide K40/33, M29/1 (Plate 3, figure 12). Distal aspect. Amb near-circular, diameter 66 μm; laesurae distinct, simple, ± straight, length ca. four-fifths of spore radius; comprehensively distributed, predominantly discrete verrucae 1.5–3 μm high, bases mostly circular to subcircular in outline, diameter 2–4 μm, up to 12 μm apart (mostly ca. 4 μm); exine 2.5 μm thick.

Type locality. New South Wales, Balickera excavation, sample A720; Mount Johnstone Formation.

Etymology. After the Mount Johnstone Formation.

Comparison. *Verrucosisporites johnstonense* sp. nov. is similar to *V. quasigobbettii* Jones & Truswell, 1992 (recorded below), but is distinguishable mainly in featuring more uniform, commonly finer, and less crowded verrucae.

Verrucosisporites pavimentatus sp. nov.
Plate 3, figures 8–11

Diagnosis. Spores radial, trilete, with circular to subcircular amb. Laesurae distinct, simple, length ca. 0.5–0.7 of spore radius. Exine 1–2 μm thick, bearing comprehensively distributed, closely set, discrete verrucae, broadly rounded in profile to almost flat topped, 1–2 μm high; variably shaped (in plan view: irregularly polygonal, rectangular, elongate, subcircular; ca. 1–10 μm in maximum dimension); negative reticulum resulting from close spacing of verrucae (0.1–3.5 μm apart, commonly ca. 1 μm).

Dimensions (21 specimens). Equatorial diameter, excluding sculpture, 45 (52) 59 μm.

Holotype. Slide K40/11, W57/3 (Plate 3, figure 8). Proximal aspect. Amb subcircular, 48 μm in diameter; distinct, simple laesurae ca. one-half spore radius in length; exine 1 μm thick, with comprehensive verrucate sculpture; verrucae close-spaced distally, slightly lesser so proximally, defining negative reticulum; verrucae $<$ 1.4 μm apart, very variable basal outline (mostly irregularly polygonal, rectangular, subcircular; maximum breadth 2–8 μm), obtusely rounded in profile, height up to 1.5 μm.

Type locality. New South Wales, Balickera excavation, sample A720; Mount Johnstone Formation.

Etymology. Latin, *pavimentatus*: furnished with pavement.

Comparison. This species shows scant resemblance to other members of the genus, by reason of the distinctive pavement-like configuration of its sculpturing elements. *Verrucosisporites* sp. A of Playford and Melo (2012, p. 27, pl. 5, figs 4a, b) has a thicker exine with less variable, more protrusive, and less confined verrucae, particularly in contact areas.

Verrucosisporites quasigobbettii Jones & Truswell, 1992
Plate 4, figures 1a, b–12a, b

Synonymy.

1968 *Verrucosisporites* sp. cf. *V. gobbettii* Playford & Helby, p. 108–109, pl. 9, figs 6, 7.

1992 *Verrucosisporites quasigobbettii* Jones & Truswell, p. 161, fig. 8N, P, Q.

1992 *Verrucosisporites* sp. Jones & Truswell, p. 161, 163, fig. 8M, ?R.

2012 *Verrucosisporites quasigobbettii* Jones & Truswell, 1992; Playford & Melo, p. 26–27 (*cum syn.*), pl. 5, figs 7–9.

Description. Spores radial, trilete. Amb circular to subcircular or (less frequently) broadly rounded subtriangular; commonly modified irregularly by protrusive verrucae. Laesurae distinct, simple, straight, ca. two-thirds to four-fifths of spore radius in length. Exine 2–4 μm thick, with prominent, well-developed verrucate sculpture borne ± irregularly over proximal and distal surfaces. Verrucae mostly discrete and rounded (less commonly ± pila-like) in profile; basal outline variable, mainly circular, subcircular, or (infrequently) irregularly roundly polygonal, maximum basal width 2.5–14 μm, height 1–6 μm, basal separation commonly 4–8 μm, but may attain as much as 15 μm.

Dimensions (100 specimens). Equatorial diameter (excluding sculptural projections) 35 (54) 76 μm.

Remarks. The above description, based on the prolific representation of *Verrucosisporites quasigobbettii* Jones & Truswell, 1992 in the Mount Johnstone Formation samples, essentially replicates that given by Playford (2015, p. 13, fig. 5G–T) from correlative subsurface deposits of the Coolcalalaya Sub-basin, Western Australia. Those accounts together demonstrate the morpho-continuum linking specimens which, if encountered in appreciably lesser abundance, might be (mis)construed as constituting two or even more form species.

Previous records. First reported (Playford and Helby 1968) from the Mount Johnstone Formation of the present study, and subsequently by Jones and Truswell (1992) from the Galilee Basin, Queensland, in strata incorporating their zones A–E (uppermost Mississippian through Lower Permian) and by Playford (2015, as cited above). Recorded widely elsewhere in extra-Australian Gondwanan deposits mainly attributed to the Upper Mississippian (Playford and Melo 2012, p. 26–27; Playford 2015, p. 13).

Verrucosisporites souzai di Pasquo in di Pasquo & Iannuzzi, 2014
Plate 3, figures 4–7

Synonymy.
cf. 2012 *Verrucosisporites aspratilis auct. non* Playford & Helby, 1968; Playford & Melo, p. 21, pl. 3, figs 8, 9.
2014 *Verrucosisporites souzai* di Pasquo in di Pasquo & Iannuzzi, p. 419 (*partim*), fig. 7.5, 6, 11–13 (non fig. 7.7).

Description. Spores radial, trilete. Amb circular to subcircular with entire or slightly/irregularly undulating margin. Laesurae distinct, simple, straight, length ca. two-thirds to three-quarters of spore radius. Exine 2–3 µm thick; sculptured comprehensively and somewhat loosely with low verrucae of disparate shape (basal outline pentagonal, triangular, subcircular, elongate) and size (maximum basal diameter mostly 1.5–3.5 µm; height 0.5–2 µm); spacing between verrucae ca. 1–3 µm.

Dimensions (25 specimens). Equatorial diameter 33 (51) 62 µm.

Remarks. While generally larger (thus extending the size range), these specimens are in close morphological accord with *Verrucosisporites souzai* di Pasquo in di Pasquo & Iannuzzi, 2014. As mentioned above, this species could conceivably be merged with *V. iannuzzii*.

Previous records. *Verrucosisporites souzai* was described from the upper Visean Poti Formation, Parnaíba Basin, in Brazil's north-east (di Pasquo and Iannuzzi 2014).

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
Plate 5, figures 14–16

Synonymy.
1979 *Anapiculatisporites amplus* Playford & Powis, p. 381–382, pl. I, fig. 8, pl. II, figs 1–5.

Remarks. The few specimens recorded here conform to those described by previous authors, most recently Playford and Mory (2017, p. 288, pl. 4, figs 9–12).

Dimensions (six specimens). Equatorial diameter, excluding apiculate projections, 60 (88) 113 µm.

Previous records. Reported hitherto from Gondwanan strata of Visean through early Pennsylvanian age (Playford and Melo 2012, p. 27; Playford and Mory 2017, p. 288).

Anapiculatisporites concinnus Playford, 1962
Plate 5, figures 10–13

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

Description. Spores radial, trilete. Amb subtriangular; apices obtusely (commonly) to acutely rounded, sides nearly straight, slightly concave, or slightly convex. Laesurae distinct, ± straight, extending three-quarters to four-fifths of distance to equator, simple or with slight, narrow lip development. Exine 0.8–1.5 µm thick; entire proximal surface and marginal interradial regions of distal surface laevigate. Remainder (i.e. bulk) of distal surface sculptured with small, discrete, scattered coni, 1–1.5 µm high, bases 1–1.5 µm in diameter and 0.5–2.5 µm apart, ± evenly distributed; uncommonly projecting from equatorial radii (i.e. from amb apices).

Dimensions (10 specimens). Equatorial diameter 31 (40) 50 µm.

Previous records. As noted by Playford and Melo (2012, p. 29), *Anapiculatisporites concinnus* Playford, 1962 is widely distributed globally, with first appearances in the Visean and extending, particularly in Gondwanan regions, into the Lower Permian. A recent report of the species is from the Paganzo Basin (Argentina) in strata dated (by U-Pb CA-IDTIMS/Refined Chemical Abrasion-Isotope Dilution Thermal Ionisation Mass Spectrometry) as late Serpukhovian–Bashkirian (Césari et al. 2019).

Anapiculatisporites hispidus Butterworth & Williams, 1958
Plate 5, figures 8, 9

Synonymy.
1958 *Anapiculatisporites hispidus* Butterworth & Williams, p. 364, pl. I, figs 30, 31.

Description. Spores radial, trilete, with subtriangular amb. Laesurae distinct, simple or flanked by minor marginal folds, length 0.6–0.8 of spore radius. Exine ca. 1 µm thick, proximally laevigate. Distal exine bearing discrete apiculate projections (coni and short spinae), 1.5–3 µm in length, bases 0.8–1.2 µm broad, 1–2 µm apart. Projections shortening towards equator.

Dimensions (four specimens). Equatorial diameter, excluding sculptural projections, 35, 38, 40, 45 µm.

Remarks. Specimens are commonly preserved as lateral compressions, as in the Scottish type material.

Previous records. From the Upper Mississippian–Lower Pennsylvanian of Europe (e.g. Butterworth and Williams 1958; Smith and Butterworth 1967; Jachowicz 1972; Owens et al.

1977, 2004; Kmiecik 1978, 1986) and from an ?upper Visean core sample from the Gulf of Suez region (Sultan 1986).

Anapiculatisporites robertsii sp. nov.
Plate 5, figures 1a, b–5

Diagnosis. Spores radial, trilete. Amb roundly subtriangular to subcircular, apices commonly broadly obtuse, sides convex to almost straight. Laesurae perceptible to ± distinct, straight to slightly undulant; with or without narrow lips; commonly extending almost to equatorial margin with ± indistinct curvaturate termini. Exine thin, not exceeding ca. 1 μm in thickness. Distal surface sculptured with very fine, discrete, apiculate elements (minute coni and spinae) 0.5–1.6 μm high, 0.4–0.8 μm in basal diameter, loosely/variably distributed (bases ca. 0.7–4 μm apart). Apices of elements variable when viewed via ×100 oil-immersion objective: acute, slightly expanded ('knobbly'), uncommonly ± truncate. Proximal surface essentially laevigate, commonly showing slight darkening (polar-centred, indistinctly defined thickening).

Dimensions (31 specimens). Equatorial diameter 30 (43) 58 μm.

Holotype. Slide K30/1, O33 (Plate 5, figure 3a, b). Distal aspect. Amb roundly subtriangular, sides straight to convex, diameter 40 μm; very narrowly lipped laesurae extending close to equator with minor, weakly defined curvaturae imperfectae; exine ca. 0.9 μm thick; minute apiculate elements (coni, spinae) loosely dispersed over distal surface, very few projecting equatorially.

Type locality. New South Wales, Balickera excavation, sample A707; Mount Johnstone Formation.

Etymology. In memoriam, Professor Emeritus John Roberts (1938–2018), major contributor to knowledge of Australian Carboniferous stratigraphy and palaeontology, particularly of the southern NEO; q.v. Pickett et al. (2018), Metcalfe (2018).

Remarks and comparison. *Anapiculatisporites robertsii* sp. nov. is distinguished by its minute apiculate elements projecting from the distal surface, and, more sparsely, equatorially; and by the variable nature of the projections' apical termini. The species shows some similarity to *Stenozonotriletes coronatus* Sullivan & Marshall, 1966 (p. 273, pl. 3, figs 1–5) but differs in being acingulate.

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

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

Dibolisporites disfacies Jones & Truswell, 1992
Plate 5, figures 6, 7

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

Remarks. Rarely encountered during the present study, this species is characterised by indistinctness or absence of proximal face, together with conspicuous distal sculpture of biform apiculate projections as described by Jones and Truswell (1992) and Playford (2015).

Dimensions (seven specimens). Equatorial diameter 46 (49) 56 μm, excluding sculpture.

Previous records. As summarised by Playford (2015, p. 15), *Dibolisporites disfacies* Jones & Truswell, 1992 is known widely and exclusively from Gondwanan strata ranging from Upper Mississippian through Lower Permian.

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
Plate 7, figures 1–4

Synonymy.
1968 *Raistrickia accincta* Playford & Helby, p. 109, pl. 9, figs 13, 14.
2017 *Raistrickia accincta* Playford & Helby, 1968; Playford & Mory, p. 291–292 (*cum syn.*), pl. 4, fig. 1.

Description. Spores radial, trilete, with subcircular to ovaloid amb. Laesurae simple, ± straight, extending two-thirds to four-fifths of distance to equator. Exine 1–2 μm thick; sculptured comprehensively with blunted heterogeneous projections comprising pila (predominantly), together with bacula, coni, and verrucae. Projections having circular to subcircular to rounded-polygonal bases ca. 1–5 μm in diameter, length 1–9 μm, basal separation up to 6 μm (commonly ca. 1–2 μm).

Dimensions (16 specimens). Equatorial diameter, excluding sculptural projections, 33 (38) 45 μm.

Previous records. Playford and Helby (1968) first described *Raistrickia accincta* from the Mount Johnstone Formation; it was recently reported from age-equivalent (mid to late Visean) sediments of the northern Perth Basin and the Carnarvon Basin, Western Australia (Playford and Mory 2017). Two specimens figured as *R. accincta* by Kora (1993, pl. 2, figs 11, 12) from the putative Lower Pennsylvanian of Sinai, Egypt, may be authentic representatives of the species, but the photomicrographs lack clarity. The same would seem applicable to specimens from the Serpukhovian–lower Bashkirian of the Paganzo Basin, Argentina (Césari et al. 2019, fig. 7.12; Colombi et al. 2018, fig. 15, f–h).

Raistrickia corymbiata Playford in Playford & Mory, 2017
Plate 7, figures 5, 6

Synonymy.
1968 *Raistrickia radiosa* Playford & Helby, 1968, p. 109 (*partim*), pl. 9, fig. 8 (only).
?2002 *Raistrickia* sp. cf. *R. accincta* Playford & Helby, 1968; Césari & Limarino, p. 166, fig. 5 D, G, H.
2017 *Raistrickia corymbiata* Playford in Playford & Mory, p. 292 (*cum syn.*), pl. 5, figs 1–5.

Description. Spores radial, trilete. Amb circular to subcircular to ovoid or roundly subtriangular. Laesurae distinct to perceptible, simple, straight, extending at least three-quarters of distance to equator. Exine ca. 1.5 μm thick, proximally laevigate or scabrate. Relatively short, squat, terminally expanded projections (pila) distributed over entire distal surface and projecting equatorially. Pila ± uniformly spaced (uncommonly conjoined) on given specimen, but variable among specimens (up to 5 μm apart); height and basal diameter of pila likewise ± uniform on individual specimen but variable among specimens (1.5–4.5 μm); bases circular to subcircular in outline; terminal expansion (caput) 2–4 μm in diameter.

Dimensions (32 specimens). Equatorial diameter, excluding sculptural projections, 39 (64) 100 μm.

Comparison. See Playford and Mory (2017, p. 292).

Previous records. From Australian middle to late Visean sediments containing the *Grandispora maculosa* palynoflora (Playford and Helby 1968; Playford 2015, misidentified as *R. accincta*, q.v. Playford & Mory, 2017).

Raistrickia radiosa Playford & Helby, 1968
Plate 7, figures 7, 8

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

Description. Spores radial, trilete with circular to roundly subtriangular amb. Laesurae indistinct to perceptible, simple, two-thirds to three-quarters of spore radius in length. Exine, where unsculptured, 1.5–2.5 μm thick. Distal and proximo-equatorial exine bearing sculptural projections – bacula (mainly), also blunted spinae – 1–10 μm in length; sides parallel or slightly tapering towards truncate, bluntly rounded, or very weakly expanded tops; bases circular to subcircular in outline, diameter ca. 1–4.5 μm. Reduced sculpture on contact faces: commonly low irregular verrucae to almost laevigate or scabrate.

Dimensions (27 specimens). Equatorial diameter, excluding sculptural projections, 53 (74) 101 μm.

Comparison. See Playford and Helby (1968, p. 109–110) and Playford and Mory (2017, p. 292).

Previous records. This species has been identified in strata within the Visean–Pennsylvanian interval of Eastern and Western Gondwana (Playford 2015, p. 16).

Infraturma MURORNATI R. Potonié & Kremp, 1954

Genus *Brochotriletes* Naumova, 1939 ex Ishchenko, 1952

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

Brochotriletes diversifoveatus Playford & Satterthwait, 1985
Plate 6, figure 9a, b

Synonymy.
1985 *Brochotriletes diversifoveatus* Playford & Satterthwait, p. 141, pl. 4, figs 3–5.
2012 *Brochotriletes diversifoveatus* Playford & Satterthwait, 1985; Playford & Melo, p. 40–41 (*cum syn.*), pl. 13, fig. 6.

Description. Spores radial, trilete, with circular to convexly subtriangular amb. Laesurae ± distinct, simple, straight, length two-thirds to four-fifths of spore radius. Exine 3–4.5 μm thick; comprehensively incised to depths of 2.5–3.5 μm with foveolae (principally) and minor vermiculi. Foveolae of irregular shape in plan view (subcircular to roundly polygonal/elongate), 1–15 μm in maximum dimension, 1–9 μm apart.

Dimensions (six specimens). Equatorial diameter 63 (67) 74 μm.

Previous records. Reported from northern and Western Australian strata of mid Visean–early Serpukhovian age (Playford and Satterthwait 1985; Playford and Mory 2017); from coeval strata of the Amazonas and Parnaíba basins, northern Brazil (Playford and Melo 2012); and likely from the Algerian Sahara (Lanzoni and Magloire 1969, pl. II, figs 4, 5).

Genus *Convolutispora* Hoffmeister, Staplin & Malloy, 1955

Type species. *Convolutispora florida* Hoffmeister, Staplin & Malloy, 1955 [OD].

Convolutispora perplicata sp. nov.
Plate 7, figures 16–18

Diagnosis. Spores radial, trilete with circular to subcircular amb. Laesurae perceptible to ± distinct; length ca. two-thirds to three-quarters of spore radius. Exine 1.2–1.8 μm thick where unsculptured. Comprehensive murornate sculpture comprising muri/rugulae 0.5–2.5 μm wide, both freely terminating and anastomosing, 0.7–1.2 μm high, 0.5–5 μm apart.

Dimensions (23 specimens). Equatorial diameter 45 (59) 72 μm overall.

Holotype. Slide K40/12, D58/1 (Plate 7, figure 17). Proximal aspect. Amb subcircular, diameter 53 μm; laesurae discernible, straight, simple, length ca. 0.7 of spore radius; exine 1.3 μm thick, bearing convolute to rugulate sculpture distally and proximally; muri anastomosing and freely terminating, 0.5–1 μm wide, 0.7–1 μm high, 0.5–3.5 μm apart.

Type locality. New South Wales, Balickera excavation, sample A720; Mount Johnstone Formation.

Etymology. Latin, *perplicatus*: intricate, entangled.

Comparison. *Convolutispora venusta* Hoffmeister, Staplin & Malloy, 1955 (p. 385, pl. 38, fig. 11) and C. *perplicata* sp. nov. are similar, but the latter is differentiable mainly in possessing less crowded and more variable murornate sculpture and probably a somewhat thinner exine. *Convolutispora* sp. A of Playford (1971, p. 28, pl. 9, fig. 6) is larger and more densely and uniformly rugulate than *C. perplicata*.

Genus *Cordylosporites* Playford & Satterthwait, 1985

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

Cordylosporites asperidictyus (Playford & Helby, 1968) Dino & Playford, 2002
Plate 6, figures 15–17

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

Description. Spores radial, trilete; amb circular to subcircular. Laesurae perceptible to ± distinct, straight, length two-thirds to three-quarters of spore radius. Exine comprehensively reticulate; muri variable in basal width (1.5–4 μm) and height (1.5–6.5 μm) enclosing subcircular, polygonal, or elliptical lumina 3–20 μm in maximum diameter (smaller lumina commonly proximal). Crests of muri fimbriate, being modified by very fine and close-spaced projections (diminutive grana, verrucae, spinae, bacula) $<$ 2 μm high). Non-reticulate exine 2–3 μm thick.

Dimensions (22 specimens). Overall equatorial diameter 55 (65) 75 μm.

Previous records. From Eastern Gondwana (Western Australia, New South Wales; Playford and Helby 1968; Playford 2015; Playford and Mory 2017) and Western Gondwana (Brazil, Argentina; q.v. Dino and Playford 2002, p. 345; Perez Loinaze 2009; Perez Loinaze et al. 2010; Perez Loinaze and Césari 2012; Césari et al. 2019; Colombi et al. 2018), in strata mainly of middle Visean–early Serpukhovian age.

Genus *Foveosporites* Balme, 1957

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

Foveosporites pellucidus Playford & Helby, 1968
Plate 6, figures 10–14a, b

Synonymy.
1968 *Foveosporites pellucidus* Playford & Helby, p. 111, pl. 10, figs 2–6.

Description. Spores radial, trilete, with circular to convexly subtriangular amb. Laesurae simple, straight, ± distinct, extending for two-thirds to four-fifths of distance to equator. Distal and proximo-equatorial exine densely foveo-vermiculate, elements ± regularly/densely distributed, incising exine by ca. 0.5–1.5 μm. Vermiculi simple or branching, non-anastomosing, very narrow (ca. 0.4–0.7 μm wide), up to ca. 10 μm long; foveolae discrete, circular, subcircular, or roundly elongate in outline and 1.5–8.5 μm in maximum diameter. Unsculptured exine 2–3.5 μm thick.

Dimensions (39 specimens). Equatorial diameter 50 (64) 80 μm.

Previous records. Characteristic component of the *Grandispora maculosa* Assemblage of eastern and Western Australia, and coevally (mid Visean–lower Serpukhovian) in South America (Playford and Melo 2012, p. 49–50).

Genus *Microreticulatisporites* Knox, 1950 emend. R. Potonié & Kremp, 1954 *sensu* Smith & Butterworth, 1967

Type species. *Microreticulatisporites lacunosus* (Ibrahim, 1933) Knox, 1950 [SD; Potonié & Kremp 1954, p. 143].

Microreticulatisporites sp. A
Plate 7, figures 13–15

Description. Spores radial, trilete; amb circular to subcircular, margin slightly undulant to almost entire. Laesurae perceptible to ± distinct, simple, length two-thirds to three-quarters of spore radius. Exine 1–1.5 μm thick; with fine, comprehensive reticulum perfectum; muri 0.5–1.5 μm wide, 0.5–1.2 μm high, enclosing circular to subcircular lumina 0.7–5 μm in maximum diameter.

Dimensions (three specimens). Equatorial diameter 57, 66, 78 μm.

Comparison and remarks. *Dictyotriletes* sp. B of Playford (1978, p. 128, pl. 8, figs 8–10) is smaller than *Microreticulatisporites* sp. A and its reticulum is vestigial proximally. *Microreticulatisporites punctatus* Knox, 1950, as described and figured by Perez Loinaze and Césari (2004, p. 420, pl. 3, figs 2, 3), is more finely reticulate than the present form. Although favourably preserved, the three specimens encountered are clearly insufficient for other than informal specific designation.

Genus *Rattiganispora* Playford & Helby, 1968 emend. Playford, 1986

Synonymy.
1968 *Rattiganispora* Playford & Helby, p. 111.
1983 *Diademaspora* Playford, p. 272–273.

1986 *Rattiganispora* Playford & Helby, 1968 emend. Playford, p. 85–86.

Type species. *Rattiganispora apiculata* Playford & Helby, 1968 emend. Playford, 1986 [OD; M].

Discussion. See Playford (1986, p. 86, 91) and Jones and Truswell (1992, p. 169).

Rattiganispora apiculata Playford & Helby, 1968 emend. Playford, 1986
Plate 7, figures 9a, b–12

Synonymy.
1968 *Rattiganispora apiculata* Playford & Helby, p. 111–112, pl. 11, figs 1–3.
1986 *Rattiganispora apiculata* Playford & Helby, 1968 emend. Playford, p. 86–91, pl. I, figs 1–9, pl. II, figs 1–7, pl. III, figs 1–6, text-fig. 1a.

Description. Spores radial, trilete; amb convexly subtriangular to subcircular. Laesurae perceptible to distinct, ± straight, simple or narrowly lipped, length at least two-thirds of spore radius, commonly extending close to equatorial margin. Contact areas, comprising bulk of proximal face, essentially laevigate. Distal surface featuring (i) a distinct, rounded to somewhat flattened, polar-centred, boss-like prominence, basal outline circular to subcircular, circumscribed by (ii) a continuous, moat-like depression, the latter flanked by (iii) the outer equatorial zone. Depression (ii) laevigate or scabrate; (i) and (iii) finely apiculate, bearing scattered, minute, discrete spinae and coni, 0.5–3 μm long, 0.5–1.2 μm broad basally, 1–10 μm apart. Exine thickness, measured equatorially, 0.6–1.5 μm.

Dimensions (40 specimens). Equatorial diameter 32 (39) 46 μm; diameter of distal polar boss 13 (18) 23 μm.

Comparison. This species is readily distinguishable from *Rattiganispora acuminata* (Playford, 1983, p. 273–274, pl. I, figs 1–9, pl. II, figs 1–3) Playford, 1986 (p. 91–92, pl. IV, figs 1–10, text-fig. 1 b) on criteria detailed by Playford (1986).

Previous records. In Australia, originally (Playford and Helby 1968) from the Italia Road/Mount Johnstone Formation of this study; subsequently from correlative strata in the Clarke River Basin, Queensland (Playford 1986), and from the Galilee Basin, Queensland, zones C–?E (upper Mississippian–Pennsylvanian: Jones and Truswell 1992). Dino and Playford (2002, p. 345) summarised occurrences reported from Brazil and Argentina. These, together with ensuing South American reports (e.g. Césari and Gutiérrez 2001; Perez Loinaze et al. 2011), signify that *Rattiganispora apiculata* has a closely comparable chronostratigraphic range in Eastern and Western Gondwana.

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

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

Reticulatisporites magnidictyus Playford & Helby, 1968 emend. Playford, 2017
Plate 6, figures 1–8

Synonymy.
1968 *Reticulatisporites magnidictyus* Playford & Helby, p. 110–111, pl. 10, figs 7–10.
2017 *Reticulatisporites magnidictyus* Playford & Helby, 1968 emend. Playford, p. 5 (*cum syn.*), fig. 2a, b; pl. 1, figs 1–12; pl. 2, figs 1–11.

Remarks. The recent diagnostic emendation (Playford, 2017) is based on many more specimens than originally examined by Playford and Helby (1968). Accordingly, it constitutes an appreciably broader morphological spectrum (Playford 2017, pls 1, 2; pl. 6, figs 1–8 herein). Main variables are overall size; reticulum (strongly developed to, much less commonly, vestigial); and complete absence (commonly) or presence of perceptible to well-developed pronged apical prominence (cf. Playford 2017, pl. 2; pl. 6, figs 7, 8 herein).

Dimensions (270 specimens). Equatorial diameter, excluding reticulum, 64 (94) 130 μm. *Note.* This incorporates 200 specimens measured during the present study plus the original 20 specimens (Playford and Helby 1968, p. 110) and the 50 topotypic specimens recorded by Playford (2017, p. 5).

Previous records. The exceptionally widespread dissemination of this species in Eastern, Western, and Northern Gondwanan strata of mid Visean through early Serpukhovian age – as a characteristic component of the *Grandispora maculosa* Assemblage and of Melo and Loboziak's (2003) Mag Zone – was documented in Playford (2017, p. 6–7, figs 1, 3). A subsequent record by Césari et al. (2019) is from the Paganzo Basin (Argentina) in strata attributed to their Stage 5 (dated as Bashkirian).

Subturma ZONOTRILETES Waltz in Luber & Waltz, 1938
Infraturma TRICRASSATI Dettmann, 1963

Genus *Diatomozonotriletes* Naumova, 1939 emend. Playford, 1963

Type species. *Diatomozonotriletes saetosus* (Hacquebard & Barss, 1957) Hughes & Playford, 1961 [SD; Playford 1963, p. 646].

Diatomozonotriletes sp. A
Plate 9, figure 1

Description. Spore radial, trilete. Amb subtriangular with obtusely rounded apices and straight to slightly concave sides. Laesurae perceptible, straight, extending to near-vicinity of equator, partly flanked by low, narrow, discontinuous exinal folds or thickenings. Exine ca. 1 μm thick, proximal surface essentially laevigate. Distal surface sculptured with discrete, minute coni-spinae up to 1.5 μm long, 0.7–1.4 μm broad basally, 1–3 μm apart. Equatorially coronate: each interradial region marked by a single row of discrete spinae up to 3.5 μm long and 1.2 μm broad basally, in central interradii, gradually diminishing towards amb apices near or where minute coni (ca. 0.5 μm high) are present.

Dimensions (one specimen). Equatorial diameter, excluding corona, 68 μm.

Comparison and remarks. This single incomplete but otherwise well-preserved specimen appears to show no close resemblance to previously instituted species of the genus. The clear size distinction between the distal apiculate projections and those of the equatorial corona warrants the generic assignment, rather than to *Tricidarisporites* Sullivan & Marshall, 1966 emend. Gueinn, Neville & Williams in Neves et al., 1973.

Infraturma CINGULATI R. Potonié & Klaus, 1954 emend. Dettmann, 1963

Genus *Knoxisporites* R. Potonié & Kremp, 1954 emend. Neves, 1961

Type species. *Knoxisporites hagenii* R. Potonié & Kremp, 1954 [OD].

Knoxisporites balickeraensis sp. nov.
Plate 8, figures 3a, b–8

Diagnosis. Spores radial, trilete. Amb variably triangular, subtriangular, quadrilateral; periphery entire, undulating, or with commonly irregular, broad-based projections. Laesurae distinct, simple, straight, extending for ca. three-quarters of distance to equator. Cingulum of uniform or variable width, within range of 2.5–10 μm. Distal surface bearing a continuous or near-continuous ridge, 2.5–7 μm wide, encompassing a substantial polar region and with outline conforming to equator. Proximal surface largely scabrate or minutely granulate; proximo-equatorial and distal surfaces densely granulate with elements mostly < 1 μm in height and basal diameter.

Dimensions (10 specimens). Equatorial diameter 34 (46) 56 μm.

Holotype. Slide K40/16, X54/1 (Plate 8, fig. 3a, b). Proximal aspect. Equatorial diameter 36 μm; amb subtriangular with convex to almost straight sides, margin entire; distinct, straight, simple laesurae, three-quarters of spore radius in length; exine laevigate to weakly/indistinctly granulate; cingulum 3.5 μm wide; distal circumpolar ridge 3.5–4 μm wide.

Type locality. New South Wales, Balickera excavation, sample A720; Mount Johnstone Formation.

Etymology. From the rural settlement of Balickera in the Hunter Valley, New South Wales.

Comparison. Three main attributes of *Knoxisporites balickeraensis* sp. nov., separately and together, serve to distinguish it from previously instituted species of the genus – viz., the variable overall amb configuration; the variable equatorial margin of the cingulum (± coarse projections); and the (predominantly distal) granulate sculpture.

Knoxisporites sp. A
Plate 8, figure 1a, b

Description. Spore radial, trilete. Amb circular. Laesurae distinct, straight to curved, extending to cingulum's inner margin, with lips 1–1.6 μm wide overall. Exine laevigate. Cingulum uniformly 4.5 μm wide. Distal surface bearing continuous ring-like thickening 3 μm wide circumscribing polar region 23 μm in diameter.

Dimensions (one specimen). Overall equatorial diameter 38 μm.

Remarks. Only one, albeit well-preserved, specimen was encountered. It appears consonant with *Knoxisporites* R. Potonié & Kremp, 1954 emend. Neves, 1961, but shows no clear similarity to established species of the genus.

Knoxisporites sp. B
Plate 8, figure 2a, b

Description. Spore radial, trilete, with near-circular amb. Laesurae distinct, simple, straight, attaining cingulum's inner margin. Cingulum uniform, very narrow (1.7 μm wide). Distal polar region, 26 μm in diameter, circumscribed by narrow, continuous ring-like thickening 2.5 μm wide. Cingulum and distal ring laevigate; elsewhere exine laevigate to scabrate.

Dimensions (one specimen). Overall equatorial diameter 43 μm.

Comparison. The sole, well-preserved specimen resembles the widely reported Mississippian species *Knoxisporites ruhlandii* Doubinger & Rauscher, 1966 (p. 384, 386; pl. VI, figs 4–7; pl. pl. VII, figs 1, 2; text-fig. 3), but differs from the latter chiefly in lacking a distal polar boss, and in having a circular amb and simple (unlipped) laesurae.

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 in Samoilovitch & Mtchedlishvili, 1961 [OD; M].

Densoisporites argutus sp. nov.
Plate 9, figures 5, 6

Diagnosis. Spores radial, trilete, cingulicavate; amb convexly subtriangular. Laesurae distinct, straight to slightly curved, narrowly lipped (1.5–2.5 µm wide overall), extending almost to equator. Intexine laevigate, 1–1.5 µm thick, forming well-defined inner body with or without marginal folding, outline (in polar aspect) conforming to amb and contracted from spore-cavity margin by up to 6 µm. Exoexine laevigate to scabrate, but outer equatorial region (flange) irregularly or somewhat radially dissected-cum-fimbriate (possible corrosion effect in part).

Dimensions (10 specimens). Overall equatorial diameter 52 (68) 84 µm; diameter of spore cavity, in polar view, 33 (45) 54 µm.

Holotype. Slide K30/1, V51/3 (Plate 8, figure 6). Distal aspect. Amb 40 µm in diameter, subtriangular with convex sides and obtuse to rounded-acute apices; laesurae distinct, ± straight, narrowly lipped, almost reaching equatorial margin; laevigate intexine ca. 1 µm thick, outline conformable with amb, slightly excentrically disposed, diameter 38 µm; exoexine scabrate, flange 3–9 µm wide.

Type locality. New South Wales, Balickera excavation, sample A707; Mount Johnstone Formation.

Etymology. Latin, *argutus*: distinct, clear.

Remarks and comparison. Attribution to the genus is perhaps questionable, given that *Densoisporites argutus* sp. nov. lacks a uniformly thickened equatorial margin. Of the few established Carboniferous species, *D. truswelliae* Stephenson, Al Rawahi & Casey, 2008 (q.v. Playford 2015, p. 19–20, fig. 9A–I) differs from the present specimens in its shorter laesurae and distinctly cingulate equatorial margin.

Genus *Densosporites* Berry, 1937 emend. R. Potonié & Kremp, 1954

Type species. *Densosporites covensis* Berry, 1937 [OD].

Densosporites infacetus Daemon, 1974
Plate 9, figures 7, 8

Synonymy.

1974 *Densosporites infacetus* Daemon, p. 569–570, pl. VII, figs 6, 7.

2012 *Densosporites infacetus* Daemon, 1974; Melo & Playford, p. 107–108 (*cum syn.*), pl. 3, figs 9–12.

Description. Spores radial, trilete, cingulicavate. Amb convexly subtriangular. Laesurae perceptible, simple or with very narrow lips, extending to or close to cingulum's inner margin. Intexine very thin and featureless, variably contracted from exoexine by up to ca. 8 µm. Exoexine laevigate proximally, thickened equatorially to form well-defined cingulum. Distal surface sculptured prominently with discrete or basally coalescent coni and spinae that project equatorially, thus producing a coarsely jagged margin. Sculptural elements broad-based (diameter 3–5 µm), height 4–10.5 µm.

Dimensions (eight specimens). Equatorial diameter (excluding sculptural projections) 48 (58) 72 µm; spore-cavity diameter (polar view) 35 (43) 54 µm.

Previous records. As summarised by Melo and Playford (2012, p. 108), *Densosporites infacetus* Daemon, 1974 has been reported principally from the uppermost Devonian–Mississippian of the Amazonas Basin, northern Brazil, and from the Strunian of the Algerian Sahara (Lanzoni and Magloire 1969).

Densosporites sp. A
Plate 9, figures 9a, b, 10

Description. Spores radial, trilete, cingulicavate. Amb subtriangular with convex sides and obtusely to acutely rounded apices. Laesurae distinct to perceptible, straight or weakly undulant, extending to or just beyond inner margin of cingulum, accompanied by very narrow lips (ca. 1 µm wide overall). Proximal surface essentially laevigate. Distal surface of exoexine apiculate: sculptured with spinae and, much less commonly, coni, loosely and irregularly distributed on non-cingulate (polar/subpolar) region; closer spaced, including some basal coalescence, on cingulum and projecting prominently equatorially. Dimensions of sculptural elements: length 2–6.5 µm, bases 0.5–3.5 µm in diameter, up to 4 µm apart. Distal exoexine showing slight thickening in polar region. Intexine very thin, in contact with or slightly contracted from exoexine.

Dimensions (five specimens). Equatorial diameter (excluding sculptural projections) 59 (70) 82 µm; cingulum width 5–11 µm.

Comparison. These specimens appear to show no close similarity to previously instituted species of the genus, but their numbers are clearly insufficient for formal designation as new. *Densosporites spinosus* Dybová & Jachowicz, 1957 (p. 164–166, pl. XLIX, figs 1–4) is smaller with a proportionately wider cingulum and more strongly lipped laesurae.

Genus *Indotriradites* Tiwari, 1964 emend. Foster, 1979

Type species. *Indotriradites korbaensis* Tiwari, 1964 [OD].

Indotriradites kuttungensis (Playford & Helby, 1968) Playford, 1991
Plate 9, figures 2–4

Synonymy.

1968 *Kraeuselisporites kuttungensis* Playford & Helby, p. 112–113, pl. 11, figs 6, 7.

1991 *Indotriradites kuttungensis* (Playford & Helby, 1968) Playford, p. 104.

non 1992 *Cristatisporites* sp. cf. *kuttungensis* (Playford & Helby, 1968) Jones & Truswell, p. 171, 173, fig. 14 A–F.

Remarks. The species' diagnostic features have been amplified and illustrated in detail by Playford (2015, p. 21, fig. 11A–T) based on its abundant representation in the northern Perth Basin, Western Australia.

Dimensions (51 specimens). Overall equatorial diameter, excluding spinose projections, 49 (65) 86 µm; diameter of spore cavity, in polar view, 31 (41) 55 µm.

Comparison. From the Agua Colorada Formation (Paganzo Basin, Argentina), dated as late Serpukhovian–Bashkirian, Césari et al. (2019, p. 412–413, fig. 6.8–11) recorded abundant specimens of *Indotriradites stellatus* (Azcuy, 1975) Césari & Perez Loinaze in Césari et al., 2019. While noting its similarity to *I. kuttungensis* (Playford & Helby, 1968) Playford, 1991 in terms of preservationally variable distal sculpture, Césari et al. (2019, p. 413) stated that favourably preserved specimens of *I. stellatus* feature 'spaced acuminate verrucae and bacula', whereas *I. kuttungensis* is characterised by 'a uniform and predominate [*sic*] spinose sculpture with subordinate coni …'.

Previous records. Originally described from the Mount Johnstone Formation by Playford and Helby (1968), and reported subsequently from age-equivalent (*Grandispora maculosa*-zonal) deposits of the northern Perth Basin and Carnarvon Basin, Western Australia (Playford 2015; Playford and Mory 2017).

Genus *Radiizonates* Staplin & Jansonius, 1964

Type species. *Radiizonates aligerens* (Knox, 1950) Staplin & Jansonius, 1964 [OD].

Radiizonates arcuatus Loboziak, Playford & Melo, 2000
Plate 9, figure 12a, b

Synonymy.

2000 *Radiizonates arcuatus* Loboziak, Playford & Melo, p. 272, 274 (*cum syn.*), pl. I, figs 1–18.

2012 *Radiizonates arcuatus* Loboziak, Playford & Melo, 2000; Melo & Playford, p. 113–114 (*cum syn.*), pl. 6, figs 15–17.

Dimensions (two specimens). Overall equatorial diameter 67, 72 µm; spore-cavity diameter, in polar view, 38, 40 µm.

Previous records. The two specimens represent the first Australian report of *Radiizonates arcuatus* Loboziak, Playford & Melo, 2000, which is well known from the Mississippian of Western and Northern Gondwana (Melo and Playford 2012, p. 113–114).

Genus *Vallatisporites* Hacquebard, 1957

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

Vallatisporites sp. cf. *V. hystricosus* (Winslow, 1962)
Wicander & Playford, 2013
Plate 9, figure 13

Synonymy.

cf. 1962 *Cirratriradites hystricosus* Winslow, p. 41–42, pl. 18, fig. 5.

cf. 1962 *Cirratriradites* sp. A Winslow, p. 42, pl. 18, figs 1,? 2.

cf. 1988 *Vallatisporites hystricosus* (Winslow) Byvscheva, 1985 (comb. invalid); Avchimovitch, Byvscheva, Higgs, Streel & Umnova, p. 175 (*cum syn.*), pl. 5, fig. 14.

cf. 2006 *Vallatisporites hystricosus* (Winslow) Byvscheva, 1985; Dueñas & Césari, p. 33, pl. II, fig. 12. [no description]

cf. 2013 *Vallatisporites hystricosus* (Winslow, 1962) Wicander & Playford, p. 614, pl. 6, fig. 1.

Description. Spores radial, trilete, cingulicavate. Amb convexly subtriangular. Laesurae ± distinct, simple, straight, extending four-fifths of distance to equator. Intexine ca. 0.5 µm thick, forming distinct internal body slightly contracted from spore-cavity margin. Exoexine forming zona of ± uniform thickness; inner part, constituting ca. 35–50% of zona width, occupied by uniserially disposed, radially elongate to subcircular vacuoles. Proximal exoexine laevigate to scabrate. Distal exoexine sculptured with discrete apiculate elements (predominantly spinae) 2–10 µm long, tapering regularly from circular bases (diameter 1.2–3.5 µm; mostly 2–8 µm apart) to acutely pointed apices; outer equatorial (non-vacuolate) zonal region bearing diminished, scattered elements (short spinae, coni).

Dimensions (two specimens). Equatorial diameter 74, 75 µm; diameter of spore cavity (polar view) 44, 51 µm.

Remarks and comparison. Of currently recognised species of *Vallatisporites* Hacquebard, 1957, these two well-preserved specimens most closely resemble *V. hystricosus* (Winslow, 1962) Wicander & Playford, 2003, but differ in that the apiculate distal exoexine bears more delicate spinae featuring no or only minor basal expansion (i.e. they are essentially non-galeate). The undescribed spore figured by Dueñas and Césari (2006, as per above synonymy) is sculpturally similar to, and could conceivably be conspecific with, the present specimens. Another illustrated but undescribed specimen (Melo and Loboziak 2003, pl. VIII, fig. 7), labelled *Vallatisporites hystricosus* (Winslow) Byvscheva, 1985, differs mainly in being less prominently vacuolate.

None of the spores figured by Kedo and Golubtsov (1971, pl. III, figs 1–19) as *Hymenozonotriletes pusillites* Kedo, 1957 *sensu lato* (i.e. including *V. hystricosus* as synonym) resembles the present specimens or that illustrated by Dueñas and Césari (2006).

Previous record. (possible). Dueñas and Césari's (2006) specimen is from the Lower Mississippian of the Llanos Orientales Basin, Colombia.

Suprasubturma PSEUDOSACCITITRILETES Richardson, 1965

Infraturma MONOPSEUDOSACCITI Smith & Butterworth, 1967

Genus *Diaphanospora* Balme and Hassell, 1962

Synonymy. See Playford (1976, p. 40).

Type species. *Diaphanospora riciniata* Balme and Hassell, 1962 [OD].

Diaphanospora sp. A
Plate 9, figure 11

Description Spores radial, trilete. Amb subcircular to convexly subtriangular. Laesurae simple, straight, extending for ca. one-half to two-thirds of distance to intexinal body margin. Exine two-layered, cavate; intexine periphery ± conformable with amb. Intexine laevigate, darker than enveloping exoexine, thickness 1–1.2 µm. Exoexine very thin, ca. 0.5 µm thick, diaphanous, surface finely rugulate to imperfectly reticulate; muri ca. 0.7 µm wide and high; lumina mostly irregularly polygonal, 3–18 µm in maximum dimension.

Dimensions (two specimens). Overall equatorial diameter 79, 86 µm; diameter of intexine (polar view) 64, 76 µm.

Comparison. This informally designated species shows some resemblance to *Diaphanospora angusta*? (Hacquebard, 1957) Playford & McGregor, 1993 (p. 36–37, pl. 16, figs 1, 2) but differs mainly in featuring a more finely wrinkled, quasi-reticulate exoexine.

Genus *Grandispora* Hoffmeister, Staplin & Malloy, 1955 emend. McGregor, 1973

Type species. *Grandispora spinosa* Hoffmeister, Staplin & Malloy, 1955 [OD; M].

Grandispora maculosa Playford & Helby, 1968
Plate 9, figures 14, 15

Synonymy.
1968 *Grandispora maculosa* Playford & Helby, p. 113, pl. 11, figs 4, 5.
non 1997 *Grandispora maculosa* Playford & Helby; Coquel, Loboziak, Stampfli & Stampfli-Vuille, pl. 3, 3. [no description]

Remarks. The present topotypic specimens replicate the morphology of this species as detailed originally (Playford and Helby 1968) and subsequently from age-equivalent Western Australian strata (Playford 2015, p. 24, fig. 12A–C).

Dimensions (15 specimens). Overall equatorial diameter 34 (52) 74 µm; diameter of intexine (polar view) 28 (43) 63 µm.

Previous records. Reported widely from Eastern and Western Gondwanan sediments dated within the Middle–Late Mississippian interval (Melo and Playford 2012, p. 120–121; di Pasquo and Iannuzzi 2014; Playford 2015; Playford and Mory 2017).

Genus *Velamisporites* Bharadwaj & Venkatachala, 1962

Synonymy.
1962 *Velamisporites* Bharadwaj & Venkatachala, p. 24–25.
2012 *Velamisporites* Bharadwaj & Venkatachala, 1962; Melo & Playford, p. 125 (*cum syn.*).

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

Discussion. As posited by Ravn (1991, p. 95–96), and discussed in some detail by Melo & Playford (2012, p. 125–126), *Rugospora* Neves & Owens (1966, p. 350, 352) is regarded here as a junior synonym of *Velamisporites* Bharadwaj & Venkatachala, 1962.

Velamisporites australiensis (Playford & Helby, 1968) di Pasquo, Azcuy & Souza, 2003
Plate 9, figures 16–18

Synonymy.
1968 *Wilsonites australiensis* Playford & Helby, p. 114–115, pl. 11, figs 15–19.
1992 *Rugospora australiensis* (Playford & Helby, 1968) Jones & Truswell, p. 175–176, fig. 10 O–T.
2003 *Velamisporites australiensis* (Playford & Helby) di Pasquo, Azcuy & Souza, p. 290. [no description or illustration]
?2009 *Velamisporites australiensis* (Playford & Helby) di Pasquo, Azcuy & Souza; di Pasquo, pl. 3, fig. F. [no description]

Description. Spores radial, trilete, with circular to subcircular amb, less commonly convexly subtriangular. Laesurae distinct or indistinct, simple, straight, length ca. one-half to two-thirds of spore radius. Intexinal body commonly indistinct, thin, outline ± conformable with equator. Exoexine loosely enveloping intexine; finely, intensely folded and granulate.

Dimensions (36 specimens). Overall equatorial diameter 57 (73) 85 µm; diameter of intexine (polar view) 43 (58) 69 µm.

Previous records. Mount Johnstone Formation, New South Wales (Playford and Helby 1968); Galilee Basin, Queensland, zones A–E, Upper Mississippian–Lower Permian (Jones and Truswell 1992).

Velamisporites cortaderensis (Césari & Limarino, 1987) Playford, 2015
Plate 10, figures 1–4

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

Remarks. Specimens encountered herein are fully compatible with those described in detail from Western Australia by Playford (2015) and illustrated by Playford and Mory (2017).

Dimensions (15 specimens). Overall equatorial diameter 51 (62) 78 µm; intexine diameter, in polar view, 34 (51) 60 µm.

Previous records. Not previously reported from the Mount Johnstone Formation, *Velamisporites cortaderensis* (Césari &

Limarino, 1987) Playford, 2015 is well represented in coeval strata of Western Australia's Perth and Carnarvon basins (Playford 2015; Playford and Mory 2017) and in Western Gondwana with a range of 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
Plate 11, figures 12, 13

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

Dimensions (three specimens in polar aspect). Overall length 56, 66, 80 μm; length of intexinal body 46, 55, 62 μm. Overall width 44, 62, 70 μm; width of intexinal body 37, 49, 52 μm.

Previous records. The three specimens constitute the first known occurrence of this species in the Mount Johnstone Formation, but it has recently been described from correlative Western Australian deposits (Playford 2015; Playford and Mory 2017). Prior reports – from Northern and Western Gondwana – are extensive, in successions dated within the Tournaisian–?early Serpukhovian interval (Clayton 1996; Melo and Playford 2012, p. 128).

Genus *Laevigatosporites* Ibrahim, 1933

Type species. *Laevigatosporites vulgaris* Ibrahim, 1933 [OD].

Laevigatosporites demutabilis sp. nov.
Plate 10, figures 5–12

Diagnosis. Spores bilateral, monolete. Amb oval to elongate-elliptical; plano-convex, strongly arched distally. Laesura distinct, straight; flanked, at least in part, by narrow exinal folds; length ca. four-fifths to nine-tenths of spore length. Exine laevigate, 0.8–1.5 μm thick.

Dimensions In polar aspect (61 specimens), length 38 (52) 70 μm; width 21 (36) 48 μm. In equatorial aspect (33 specimens), polar axis 25 (32) 42 μm.

Holotype. Slide K40/33, Y61/1 (Plate 10, figure 5). Proximal aspect. Amb oval, 39 × 25 μm; laesura extending close to equator, 33 μm long, margin irregularly folded; laevigate exine 0.9 μm thick.

Type locality. New South Wales, Balickera excavation, sample A720; Mount Johnstone Formation.

Etymology. Latin, *demutabilis*: variable, changeable.

Remarks. The continuously variable amb configuration characterises this morphologically simple monolete species. It differs from the Permian species *Laevigatosporites colliensis* (Balme & Hennelly, 1956, p. 55–56, pl. 1, figs 1–5) Venkatachala & Kar, 1968 in being generally smaller with a more variable amb, and in its exinal folding associated with the laesura (see also Backhouse 1991, p. 282, 284, pl. XIII, figs 1–4).

Genus *Latosporites* R. Potonié & Kremp, 1954

Type species. *Latosporites latus* (Kosanke, 1950) R. Potonié & Kremp, 1954 [OD].

Discussion. The main distinction from *Laevigatosporites* Ibrahim, 1933 is that *Latosporites* R. Potonié & Kremp, 1954 has a circular to oval equatorial outline. Moreover, following Jansonius and Hills (1976, card 1462), the genus is applied here *sensu* Potonié (1966, p. 98): viz. 'wall laevigate, but may be minutely granular or punctate'.

Latosporites durabilis sp. nov.
Plate 10, figures 13–18

Diagnosis. Spores bilateral, monolete; plano-convex, strongly arched distally. Amb circular or almost so. Laesura distinct, simple, straight, length at least three-quarters of spore length, with or without short bifurcation at one or both ends. Exine 2–3.6 μm thick; laevigate, scabrate, or minutely granulate.

Dimensions (12 specimens, polar view). Length 52 (62) 78 μm, width 44 (52) 77 μm.

Holotype. Slide K40/32, D16 (Plate 10, figure 13). Proximo-equatorial aspect. Amb near-circular, 56 × 46 μm; laesura 37 μm long, with small bifurcation at one end; exine scabrate, 2.3 μm thick.

Type locality. New South Wales, Balickera excavation, sample A720; Mount Johnstone Formation.

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

Comparison. This species is readily distinguishable from *Laevigatosporites demutabilis* sp. nov. in being generally larger, thicker walled, and in having an essentially circular amb.

Turma HILATES Dettmann, 1963

Genus *Psomospora* Playford & Helby, 1968

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

Psomospora detecta Playford & Helby, 1968
Plate 11, figures 1a, b–11

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

Description. Spores radial, proximally hilate; plano-convex, strongly arched distally. Tetrahedral tetrad mark perceptible to distinct, manifested by continuous or discontinuous, narrow exinal folds of variable radial extent (reaching one-third to four-fifths of distance to equator). Exine laevigate; thickness 1.4–2.5 μm as measured equatorially and distally. Very fine, close-spaced intrastriae, extending radially from hilum margin, evident proximally in well-preserved specimens. Hilum, centred at proximal pole, comprising a triangular to subtriangular area of very thin, hence fragile exine, intact (margin entire) or variously fragmented (margin commonly irregular).

Dimensions (44 specimens). Equatorial diameter 32 (48) 76 μm; diameter of proximal polar aperture (hilum) 15 (21) 32 μm.

Previous records. *Psomospora detecta* Playford & Helby, 1968 is common to the Mount Johnstone Formation and age-equivalent strata in Western Australia (Playford and Helby 1968; Playford 2015; Playford and Mory 2017). Jones and Truswell (1992) reported the species from younger Carboniferous–Early Permian strata in the Galilee Basin, Queensland. Melo and Playford (2012, p. 129) documented the extensive Late Mississippian–Middle Permian distribution of *P. detecta* in Western and Northern Gondwana, noting its confinement to the supercontinent. Vergel et al. (2015, table 1, fig. 4.7) reported this species from late Serpukhovian–Bashkirian strata of the Calingasta-Uspallata Basin (north-west Argentina), but their illustrated specimen is indifferently preserved such that its identity is problematic.

4.2.2. Algal cysts (zygospores)

Division CHLOROPHYTA Pascher, 1914
Class ZYGNEMAPHYCEAE Round, 1971

Genus *Tetraporina* Naumova, 1939

Type species. *Tetraporina antiqua* Naumova, 1950 [neotype; OD, Potonié, 1960, p. 130].

Discussion. Jansonius and Hills (1976, 1977, 1981; cards 2877, 3416, 3917–3919) systematically elaborated on the convoluted nomenclatural history of this quadrate genus, the scope and status of which still await satisfactory resolution. It was originally regarded (Naumova 1939; Bolkhovitina 1953) as a form of porate angiospermous pollen. However, numerous fossil records dating from the Mississippian onwards are distinctly aporate and are considered representative of the acid-resistant zygospores of freshwater zygnemataceous chlorophytes (e.g. Head 1992; Colbath and Grenfell 1995; van Geel and Grenfell 1996; Worobiec and Worobiec 2008).

Tetraporina horologia (Staplin, 1960) Playford, 1963
Plate 11, figure 14

Synonymy.
1960 *Azonotetraporina*? *horologia* Staplin, p. 6, pl. 1, figs 4, 6.
1963 *Tetraporina horologia* (Staplin) Playford, p. 659, pl. 95, figs 14, 15.

Description. Cysts inaperturate; quadrangular (approximately square), opposing sides ± straight or concave; corners rounded, unthickened, slightly folded. Wall essentially laevigate or scabrate, 1.2–1.5 μm thick.

Dimensions (two specimens). Length of sides 51 × 47 μm, 55 × 49 μm.

Remarks. The specimen figured by del Papa and di Pasquo (2007, fig. 9J) as *Tetraporina punctata* (Tiwar & Navale) Kar & Bose, 1976 could be representative of *T. horologia* (Staplin, 1960) Playford, 1963.

Previous records. Following its description from nonmarine Mississippian rocks of Western Canada and Spitsbergen (Staplin 1960; Playford 1963), the species has been reported elsewhere from Mississippian and later Palaeozoic deposits (e.g. Hemer and Nygreen 1967; Cazzulo-Klepzig et al. 2002, 2005; di Pasquo 2003; Mullins and Servais 2008; Barbolini et al. 2016; Lopes et al. 2016).

5. Composition of palynoflora

The diverse, well-preserved, and wholly nonmarine palynoflora of the Mount Johnstone Formation comprises predominantly trilete spores (at least 47 species, the number of *Calamospora* species being undetermined), three species of monolete spores, and one species of hilate spores, together with a single species of algal cysts. Based on systematic counting of 250 specimens in two representative samples, Figure 3 depicts appreciable variation from both qualitative-taxonomic and quantitative perspectives. This accords with Playford and Helby's (1968, p. 115) statement pointing to some inconsistency in species occurrences. The most abundant species in both samples is *Reticulatisporites magnidictyus*, joined by similar high frequencies of *Velamisporites australiensis* and *Rattiganispora apiculata* in A707 and of *Psomospora detecta* and *Laevigatosporites demutabilis* in A720. Other species, including *Indotriradites kuttungensis*, *Punctatisporites lucidulus*, *P. subtritus*, *Verrucosisporites quasigobbettii*, *Grandispora maculosa*, and *Raistrickia* spp., are more or less consistently represented, albeit in lesser abundances, in both samples. Detailed examination of the other samples studied here show similar compositional variations. Consistently lacking throughout are any pollen grains or prepollen, a circumstance of chronostratigraphic significance, as discussed below (section 6.1).

6. Correlation and age of palynoflora

The distribution of the *Grandispora maculosa* palynoflora in Australia and elsewhere in Gondwana – particularly in Brazil and Argentina; also in North Africa/the Middle East – is discussed below, followed by a consideration of its age.

Taxa	sample A707	sample A720
Calamospora spp.	u	u
Leiotriletes ornatus	r	
Phyllothecotriletes golatensis		x
Punctatisporites lucidulus	u	a
Punctatisporites subtritus	c	c
Retusotriletes separatus	r	
Cyclogranisporites firmus	u	u
Verrucosisporites adgeratus	r	u
Verrucosisporites aspratilis	x	x
Verrucosisporites basiliscutis		r
Verrucosisporites gregatus	x	
Verrucosisporites iannuzzii	x	u
Verrucosisporites italiaensis	x	r
Verrucosisporites johnstonense	x	u
Verrucosisporites pavimentatus	x	u
Verrucosisporites quasigobbettii	u	u
Verrucosisporites souzai		u
Anapiculatisporites amplus	x	r
Anapiculatisporites concinnus	u	r
Anapiculatisporites hispidus		x
Anapiculatisporites robertsii	u	r
Dibolisporites disfacies	c	r
Raistrickia accincta	u	r
Raistrickia corymbiata	u	r
Raistrickia radiosa	r	x
Brochotriletes diversifoveatus	x	
Convolutispora perplicata	r	r
Cordylosporites asperidictyus	x	r
Foveosporites pellucidus	u	r
Microreticulatisporites sp. A	x	x
Rattiganispora apiculata	va	r
Reticulatisporites magnidictyus	va	va
Diatomozonotriletes sp. A	x	
Knoxisporites balickeraensis	x	u
Knoxisporites sp. A		x
Knoxisporites sp. B		x
Densoisporites argutus	x	x
Densosporites infacetus		x
Densosporites sp. A	x	x
Indotriradites kuttungensis	c	c
Radiizonates arcuatus	x	r
Vallatisporites cf. *V. hystricosus*		x
Diaphanospora sp. A	x	
Grandispora maculosa	u	u
Velamisporites australiensis	va	r
Velamisporites cortaderensis	r	u
Aratrisporites saharaensis		x
Laevigatosporites demutabilis	u	va
Latosporites durabilis	r	u
Psomospora detecta	x	c
Tetraporina horologia		

Figure 3. Quantitative distribution of palynomorph species in two representative samples of the Mount Johnstone Formation. Relative abundances are based on systematic counts of 250 specimens per strew slide from each sample. Relative abundances are denoted as follows: va, very abundant (> 25% of content); a, abundant (>10–25%); c, common (>5–10%); u, uncommon (1–5%); r (< 1%); 'x' indicates observed presence in sample, but not in actual count-traverse.

6.1. Correlation within Australia

The clear correlation between the Mount Johnstone Formation's *Grandispora maculosa* Assemblage, as originally reported (Playford and Helby, 1968), and the Western Australian palynofloras from the northern Perth Basin and the Carnarvon Basin described by Playford (2015) and Playford and Mory (2017) was highlighted by the latter authors (p. 28–29 and p. 308 respectively). The current, more detailed Mount Johnstone study reinforces that correlation. The shared species in the Western Australian strata now number 26 out of the 51 recorded herein (cf. section 4.1 Taxonomic inventory and Table 1). This may seem, *prima facie*, not particularly persuasive from a correlative perspective. However, most of the Western Australian 'absentees' – such as *Verrucosisporites souzai*, *V. iannuzzii*, *Convolutispora perplicata*, *Radiizonates arcuatus*, *Aratrisporites saharaensis*, *Rattiganispora apiculata*, and *Velamisporites australiensis* – are only sparingly and/or very inconsistently represented in the Mount Johnstone Formation.

Table 1. Compendium of miospore species identified in the Mount Johnstone Formation and their reported presence in coeval or near-coeval Mississippian strata from elsewhere in the Gondwana supercontinent. See systematic section for sources of data.

Eastern Gondwana			
Mt Johnstone Fm, New South Wales	West. Aust.	Western Gondwana	Northern Gondwana
Leiotriletes ornatus	•		
Phyllothecotriletes golatensis	•		
Punctatisporites lucidulus	•	•	
Punctatisporites subtritus	•	•	
Retusotriletes separatus	•		
Cyclogranisporites firmus	•		
Verrucosisporites aspratilis	•	•	?
Verrucosisporites basiliscutis	•		
Verrucosisporites gregatus	•	•	•
Verrucosisporites iannuzzii		•	
Verrucosisporites italiaensis	•		
Verrucosisporites quasigobbettii	•	•	•
Verrucosisporites souzai		•	
Anapiculatisporites amplus	•	•	•
Anapiculatisporites concinnus	•	•	•
Dibolisporites disfacies	•	•	•
Raistrickia accincta	•	?	?
Raistrickia corymbiata	•		
Raistrickia radiosa	•	•	
Brochotriletes diversifoveatus	•	•	•
Cordylosporites asperidictyus	•	•	•
Foveosporites pellucidus	•	•	
Rattiganispora apiculata		•	
Reticulatisporites magnidictyus	•	•	•
Densosporites infacetus		•	•
Indotriradites kuttungensis	•		
Radiizonates arcuatus		•	•
Vallatisporites sp. cf. *V. hystricosus*		?	
Grandispora maculosa	•	•	
Velamisporites cortaderensis	•	•	
Aratrisporites saharaensis	•	•	•
Psomospora detecta	•	•	•

From the southern Galilee Basin of Queensland, the lower part of Jones and Truswell's (1992) Carboniferous–Permian palynostratigraphic sequence includes several species in common with the Mount Johnstone Formation, including *Verrucosisporites quasigobbettii*, *Dibolisporites disfacies*, and *Velamisporites cortaderensis* (see Playford 2015, p. 28, table 1). However, the more characteristic components of the *Grandispora maculosa* Assemblage are notably absent. Moreover, the presence of bilaterally symmetrical monosaccate pollen grains (prepollen) and radially symmetrical monosaccate pollen grains throughout the Galilee Basin succession (zones A–E of Jones and Truswell, 1992), but unrecorded in the Mount Johnstone Formation and its Western Australian correlatives, signifies a younger age, dating from the later Serpukhovian (Playford 2015, p. 33; and references cited therein).

6.2. Extra-Australian correlation

With few exceptions, the Mount Johnstone Formation and age-equivalent Western Australian strata share their appreciable cohort of diagnostic spore species with palynofloras reported from South America (Western Gondwana) and from the North African/Middle Eastern region (Northern Gondwana), as summarised in Table 1. This attests to the widespread dispersal of the *Grandispora maculosa* Assemblage in terrestrial and nearshore marine deposits of Gondwana during mid- to Late Mississippian time, and hence to its efficacy for long-distance chronostratigraphic correlation.

The present study adds the following four species to the listing (Table 1; cf. Playford 2015; Playford and Mory, 2017) of trilete spores that are shared between Western and Eastern Gondwana: *Verrucosisporites iannuzzii*, *V. souzai*, *Densosporites infacetus*, and *Radiizonates arcuatus*.

6.3. Age

The Mount Johnstone Formation (including Italia Road Formation) was originally dated, somewhat tentatively, as Pennsylvanian (e.g. Rattigan 1967a; Playford and Helby 1968; Roberts and Engel 1987; Hamilton et al. 1974; Roberts et al. 1991). As discussed by Playford (2015) and Playford and Mory (2017), although it has not thus far been possible to date the formation directly with radiometric precision, cogent evidence in that regard has been forthcoming from sub- and suprajacent units since the mid-1990s. These data, based on K-Ar, Sensitive High-Resolution Ion Microprobe (SHRIMP), and U-Pb Refined Chemical Abrasion-Isotope Dilution Thermal Ionisation Mass Spectrometry (U-Pb CA-IDTIMS) analyses, indicate that the Mount Johnstone Formation – and, *ipso facto*, its northern Perth Basin and Carnarvon Basin palynologically correlative strata – are of middle to late Visean age.

In Western and Northern Gondwana, the correlatives of the *Grandispora maculosa* Assemblage are similarly datable, with a possible or likely extension into the early Serpukhovian (Melo and Playford 2012, p. 148, table 1; Playford 2015, p. 33).

7. Palaeogeographic and palaeobotanical inferences

The palaeogeographic and palaeofloristic significance of the *Grandispora maculosa* Assemblage and its widespread Gondwanan distribution have been discussed recently (Playford 2015, p. 29–31, table 1, fig. 15; Playford and Mory, 2017, p. 306–308, fig. 3) and hence require no reiteration here. One especially prominent component of the assemblage – *Reticulatisporites magnidictyus* – was highlighted by Playford (2017) *vis-à-vis* its distinctive and variable morphology and its extensive, exclusively Gondwanan palaeogeographic distribution.

In purely qualitative terms, the Mount Johnstone Formation's palynoflora consists chiefly of variously sculptured, acavate and cavate, trilete spores, associated with some simple monolete and hilate spores. Parental plant sources can be envisaged as a range of cryptogamic land plants – mostly lycopods, ferns, and articulates. Of these, lepidodendrids and '*Rhacopteris*' (aka *Pseudorhacopteris* Rigby, 1973, *Nothorhacopteris* Archangelsky, 1983) are the main megafossils preserved in the formation (Rattigan 1967a; Roberts et al. 1991). As mentioned previously, the absence of megascopic or palynological remains of gymnosperms, such as the walchian conifers, in strata hosting the *Grandispora maculosa* suite is particularly noteworthy.

8. Conclusions

- The Mount Johnstone Formation's well-preserved palynoflora – the *Grandispora maculosa* Assemblage – is considerably more diverse than originally reported some five decades ago. This applies particularly to its extensive range of trilete miospores; hitherto unreported are its content of two species of monolete spores.
- Deposition under nonmarine fluvial conditions is supported by the complete absence of marine palynomorphs.
- Precise intra-Gondwanan correlation is further accentuated by this Eastern Gondwana study, particularly with South America. Key species in that regard are, *inter alia*, *Reticulatisporites magnidictyus*, *Grandispora maculosa*, *Verrucosisporites quasigobbettii*, *Raistrickia radiosa*, *Cordylosporites asperidictyus*, *Rattiganispora apiculata*, and *Psomospora detecta*.
- Based on palynostratigraphic and (indirect) absolute-age determinations, the Mount Johnstone Formation is datable as middle through late Visean, certainly pre-late Serpukhovian as evidenced by the total lack of gymnospermous prepollen.

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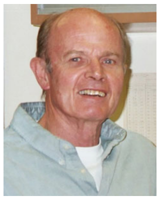
Disclosure statement

No potential conflict of interest was reported by the author.

Notes on contributor



GEOFFREY PLAYFORD is a graduate of the Universities of Western Australia (BSc Hons I, DSc) and Cambridge (PhD) and is currently a professor emeritus in the School of Earth and Environmental Sciences, The University of Queensland (UQ). While an honours student at The University of Western Australia (UWA), he was introduced to palynology by the inspirational Dr Basil Balme, then newly appointed to the university. Geoff's PhD research at Cambridge – supervised by Dr Norman Hughes – was undertaken during the tenure of a Robert & Maude Gledden Research Fellowship awarded by UWA. Subsequently, during tenure of a National Research Council of Canada Postdoctoral Fellowship, he worked with Dr Peter Hacquebard and Sedley Barss at the Geological Survey of Canada (Ottawa), followed by a lectureship appointment at UQ. During periods of sabbatical leave from UQ, he has conducted collaborative research, notably with the late Dr Francine Martin (Belgium); Dr Colin McGregor (Canada); Prof. Reed Wicander and Merrell Miller (USA); Prof. Marco Tongiorgi (Italy); Drs Felipe González and Carmen Moreno (Spain); and, in Brazil, with Drs Rodolfo Dino and José Henrique Gonçalves de Melo, at the Petrobras Research Centre in Rio de Janeiro and the State University of Rio de Janeiro (UERJ). Geoff has published extensively on a diverse range of Palaeozoic–Cenozoic palynomorphs, with main emphasis on their stratigraphic applications.

ORCID

Geoffrey Playford http://orcid.org/0000-0002-3876-7907

References

Note. In accordance with conventional practice, the listing below excludes 'taxa-only references'; i.e. those that appear in the text solely as adjuncts to taxonomic names (e.g. *Indotriradites* Tiwari, 1964 emend. Foster, 1979) and without page references.

Avchimovitch V, Byvscheva T, Higgs K, Streel M, Umnova VT. 1988. Miospore systematics and stratigraphic correlation of Devonian–Carboniferous boundary deposits in the European part of the USSR and western Europe. Courier Forschungsinstitut Senckenberg. 100:169–191.

Backhouse J. 1991. Permian palynostratigraphy of the Collie Basin, Western Australia. Review of Palaeobotany and Palynology. 67(3–4): 237–314.

Balme BE, Hennelly J. 1956. Monolete, monocolpate and alete sporomorphs from Australian Permian sediments. Australian Journal of Botany. 4(1):54–67.

Barbolini N, Bamford MK, Tolan S. 2016. Permo-Triassic palynology and palaeobotany of Zambia: a review. Palaeontologia Africana. 50:18–30.

Bharadwaj DC, Venkatachala BS. 1962. Spore assemblage out of a Lower Carboniferous shale from Spitzbergen. The Palaeobotanist. 10:18–47. [imprinted 1961]

Bolkhovitina NA. 1953. Characteristic spores and pollen from the Cretaceous of the central part of the USSR. Trudy Geologicheskogo Instituta, Akademiia Nauk SSSR. 145:1–84. [In Russian]

Butterworth MA, Williams RW. 1958. The small spore floras of coals in the Limestone Coal Group and Upper Limestone Group of the Lower Carboniferous of Scotland. Transactions of the Royal Society of Edinburgh LXIII. 63(2):353–392.

Cazzulo-Klepzig M, Guerra-Sommer M, Formoso NL, Calarge LM. 2002. Geochemical and palynological evidence for the age determination of Permian coals, southern Brazil. Journal of South American Earth Sciences. 15(3):375–380.

Cazzulo-Klepzig MI, Menegat RU, Guerra-Sommer MA. 2005. Palynology and palaeobotany in the reconstruction of landscape units from the Candiota Coalfield, Permian of Paraná Basin, Brazil. Revista Brasileira de Paleontologia. 8(1):83–98.

Césari SN, Gutiérrez PR. 2001. Palynostratigraphy of upper Paleozoic sequences in central-western Argentina. Palynology. 24:113–146.

Césari SN, Limarino CO. 1987. Análisis estratigráfico del perfil de la quebrada de La Cortadera (Carbonífero), Sierra de Maz, La Rioja, Argentina. IV Congreso Latinoamericano de Paleontología, Memorias. 1:315–330.

Césari SN, Limarino CO, Gulbranson EL. 2011. An Upper Paleozoic biochronostratigraphic scheme for the western margin of Gondwana. Earth-Science Reviews. 106(1–2):149–160.

Césari SN, Limarino CO, Spalletti LA, Piñol FC, Perez Loinaze VS, Ciccioli PL, Friedman R. 2019. New U–Pb zircon age for the Pennsylvanian in Argentina: implications in palynostratigraphy and regional stratigraphy. Journal of South American Earth Sciences. 92:400–416.

Clayton G. 1996. Mississippian miospores. In: Jansonius J, McGregor DC, editors, Palynology: principles and applications. Vol. 2. Dallas (TX): American Association of Stratigraphic Palynologists Foundation; p. 589–596.

Colbath GK, Grenfell HR. 1995. Review of biological affinities of Paleozoic acid-resistant, organic-walled eukaryotic algal microfossils (including "acritarchs"). Review of Palaeobotany and Palynology. 86(3–4): 287–314.

Colombi CE, Limarino CO, Césari SN. 2018. La sucesión carbonífera de la quebrada Agua de La Peña (Sierra De Valle Fértil): ambientes sedimentarios, contenido fosilífero e importancia estratigráfica. Latin American Journal of Sedimentology and Basin Analysis. 25:19–53.

Coquel R, Loboziak S, Stampfli GM, Stampfli-Vuille B. 1977. Palynologie du Devonien superieur et du Carbonifere inferieur dans l'Elburz oriental (Iran Nord-Est). Revue de Micropaléontologie. 20:59–71.

del Papa C, di Pasquo M. 2007. Paleoenvironmental interpretation and palynology of outcrop and subsurface sections of the Tarija Formation (Upper Carboniferous), northwestern Argentina. Journal of South American Earth Sciences. 23(1):99–119.

di Pasquo M. 2003. Avances sobre palinología, bioestratigrafía y correlación de los Grupos Macharetí y Manduyutí, Neopaleozoico de la Cuenca Tarija, Provincia de Salta, Argentina. Ameghiniana. 40:3–32.

di Pasquo M. 2009. Primer registro de megafloras y palinología en estratos de la Formación Tarija (Pennsylvaniano), Arroyo Aguas Blancas, Provincia de Salta, Argentina. Descripción de dos especies nuevas. Andean Geology. 36:95–123.

di Pasquo M, Iannuzzi R. 2014. New palynological information from the Poti Formation (upper Visean) at the Roncador Creek, Parnaíba Basin, northeastern Brazil. Boletin Geológico y Minero. 125:405–435.

di Pasquo M, Azcuy CL, Souza PA. 2003. Palinología del Carbonífero Superior del Subgrupo Itararé en Itaporanga, Cuenca Paraná, Estado de São Paulo, Brasil. Parte 1: sistemática de esporas y paleofitoplancton. Ameghiniana. 40:277–296.

Daemon RF. 1974. Palinomorfos-guias do Devoniano Superior e Carbonífero Inferior das bacias do Amazonas e Parnaíba. Anais da Academia Brasileira de Ciência. 46:549–587.

Dino R, Playford G. 2002. Miospores common to South American and Australian Carboniferous sequences: stratigraphic and phytogeographic implications. In: Hills LV, Henderson CM, Bamber EW, editors, Carboniferous and Permian of the World. Calgary, AB: Canadian Society of Petroleum Geologists, Memoir. Vol. 19; p. 336–359.

Doubinger J, Rauscher R. 1966. Spores du Viséen marin de Bourbach-le-Haut dans les Vosges du Sud. Pollen et Spores. 8:361–405.

Dueñas H, Césari SN. 2006. Palynological evidence of Early Carboniferous sedimentation in the Llanos Orientales Basin, Colombia. Review of Palaeobotany and Palynology. 138(1):31–42.

Dybová S, Jachowicz A. 1957. Mikrospory górno-śląskiego karbonu produktywnego (Microspores of the Upper Silesian Coal Measures). Prace Państwowego Instytutu Geologicznego. 23:1–328. [In Polish with Russian and English summaries]

Fielding CR, Frank TD, Birgenheier LP, Rygel MC, Jones AT, Isbell JL. 2008. Stratigraphic facies associations of the late Paleozoic ice age in eastern Australia (New South Wales and Queensland). In: Fielding CR, Frank TD, Isbell JL, editors, Resolving the late Paleozoic ice age in time and space. Boulder, CO: Geological Society of America, Special Paper 441; p. 41–57.

Geeve RJ, Schmidt PW, Roberts J. 2002. Paleomagnetic results indicate pre-Permian counter-clockwise rotation of the southern Tamworth Belt, southern New England Orogen, Australia. Journal of Geophysical Research (Solid Earth). 107(B9):EPM-4.

Hamilton G, Hall GC, Roberts J. 1974. The Carboniferous non-marine stratigraphy of the Paterson-Gresford district, New South Wales. Journal and Proceedings, Royal Society of New South Wales. 107:76–86.

Head MJ. 1992. Zygospores of the Zygnemataceae (Division Chlorophyta) and other freshwater algal spores from the uppermost Pliocene St. Erth Beds of Cornwall, southwestern England. Micropaleontology. 38(3):237–260.

Hemer DO, Nygreen PW. 1967. Algae, acritarchs and other microfossils incertae sedis from the Lower Carboniferous of Saudi Arabia. Micropaleontology. 13(2):183–194.

Ishchenko AM. 1956. Spores and pollen from the Lower Carboniferous sediments of the western extension of the Donetz Basin and their stratigraphic importance. Akademiia Nauk Ukrainskoi SSR, Trudy Instituta Geologicheskikh Nauk, Seriia Stratigrafii i Paleontologii, Kiev. 11:1–185. [in Russian]

Jachowicz A. 1972. A microfloristic description and stratigraphy of the productive Carboniferous of the Upper Silesian Coal Basin. Prace Instytut Geologiczny. 61:185–277.

Jansonius J, Hills LV. 1976–1981. Genera file of fossil spores. Alberta: Department of Geology, University of Calgary, Special Publication.

Jones MJ, Truswell EM. 1992. Late Carboniferous and Early Permian palynostratigraphy of the Joe Joe Group, southern Galilee Basin, Queensland, and implications for Gondwanan stratigraphy. BMR Journal of Australian Geology and Geophysics. 13:143–185.

Kedo GI, Golubtsov VK. 1971. Palynological criterion of the search for the determination of the Devonian-Carboniferous boundary in the Southern Urals. In: Palynology research in Byelorussia and other regions of the USSR. Minsk Nauka i Technika; p. 5–34. [in Russian]

Kmiecik H. 1978. Spore stratigraphy of the Carboniferous of central Eastern Poland. Rocznik Polskiego Towarzystwa Geologicznego. 48: 369–389.

Kmiecik H. 1986. Palynostratigraphy of the Carboniferous at the margin of the Polish part of the East-European Platform. Review of Palaeobotany and Palynology. 48(4):327–345.

Kora M. 1993. Carboniferous miospore assemblages from the Abu Rodeiyim boreholes, west-central Sinhai, Egypt. Revue de Micropaléontologie. 36: 235–255.

Kremp G. 1965. Morphologic encyclopedia of palynology: an international collection of definitions and illustrations of spores and pollen. Program in Geochronology, University of Arizona, Contribution. 100:i–xiii + 1–185. Tucson (AZ): University of Arizona Press.

Lanzoni E, Magloire L. 1969. Associations palynologiques et leurs applications stratigraphiques dans le Dévonien supérieur de Grand Erg occidental (Sahara algérien). Revue de L'Institut Français du Pétrole. 24: 441–469.

Loboziak S, Clayton G, Owens B. 1986. *Aratrisporites saharaensis* sp. nov.: a characteristic Lower Carboniferous miospore species of North Africa. Geobios. 19(4):497–503.

Loboziak S, Playford G, Melo J. 2000. *Radiizonates arcuatus*, a distinctive new miospore species from the Lower Carboniferous of Western Gondwana. Review of Palaeobotany and Palynology. 109(3–4): 271–277.

Lopes G, Mangerud G, Clayton G, Mørk A. 2016. New insights on East Finnmark Platform palynostratigraphy and paleogeography—a study of three shallow cores from a Mississippian succession in the Barents Sea, Norway. Palaeogeography, Palaeoclimatology, Palaeoecology. 450:60–76.

Melo JHG, Loboziak S. 2003. Devonian–Early Carboniferous miospore biostratigraphy of the Amazon Basin, northern Brazil. Review of Palaeobotany and Palynology. 124(3–4):131–202.

Melo JHG, Playford G. 2012. Miospore palynology and biostratigraphy of Mississippian strata of the Amazonas Basin, northern Brazil. Part Two. American Association of Stratigraphic Palynologists Foundation, Contributions Series. 47:91–201.

Metcalfe I. 2018. Vale: Emeritus Professor John Roberts (6th April 1938 – 6th May 2018). Newsletter on Carboniferous Stratigraphy. 34:4–5.

Mullins GL, Servais T. 2008. The diversity of the Carboniferous phytoplankton. Review of Palaeobotany and Palynology. 149(1–2):29–49.

Naumova SN. 1939. Spores and pollen of the coals of the USSR. Transactions of the 17th International Geological Congress, Moscow. 1:353–364.

Owens B, McLean D, Bodman D. 2004. A revised palynozonation of British Namurian deposits and comparisons with eastern Europe. Micropaleontology. 50(1):89–103.

Owens B, Neves R, Gueinn KJ, Mishell DR, Sabry HS, Williams JE. 1977. Palynological division of the Namurian of northern England and Scotland. Proceedings of the Yorkshire Geological Society. 41(3): 381–398.

Neves R. 1961. Namurian plant spores from the Southern Pennines, England. Palaeontology. 4:247–279.

Neves R, Owens B. 1966. Some Namurian camerate miospores from the English Pennines. Pollen et Spores. 8:337–360.

Perez Loinaze V. 2009. New palynological data from the Malanzán Formation (Carboniferous), La Rioja Province, Argentina. Ameghiniana. 46:495–512.

Perez Loinaze VS, Césari SN. 2004. Palynology of the Estratos de Mascasín Upper Carboniferous, Paganzo Basin, Argentina: systematic descriptions and stratigraphic considerations. Revista Española de Micropaleontología. 36:407–438.

Perez Loinaze VS, Césari SN. 2012. Palynology of late Serpukhovian glacial and postglacial deposits from Paganzo Basin, northwestern Argentina. Micropaleontology. 58:335–350.

Perez Loinaze VS, Limarino CO, Césari SN. 2010. Glacial events in Carboniferous sequences from Paganzo and Río Blanco basins (northwest Argentina): palynology and depositional setting. Acta Geologica. 8:399–418.

Perez Loinaze VS, Limarino CO, Césari SN. 2011. Palynological study of the Carboniferous sequence at Río Francia Creek, Paganzo Basin, Argentina. Ameghiniana. 48(4):589–604.

Phillips G, Robinson J, Glen R, Roberts J. 2016. Structural inversion of the Tamworth Belt: insights into the development of orogenic curvature in the southern New England Orogen, Australia. Journal of Structural Geology. 86:224–240.

Pickett J, Glen D, Dunlop A. 2018. John Roberts, 6 April 1938 – 6 May 2018. The Australian Geologist Newsletter. 189:39–41.

Playford G. 1962. Lower Carboniferous microfloras of Spitsbergen. Part 1. Palaeontology. 5:550–618.

Playford G. 1963. Lower Carboniferous microfloras of Spitsbergen. Part 2. Palaeontology. 5:619–678.

Playford G. 1971. Lower Carboniferous spores from the Bonaparte Gulf Basin, Western Australia and Northern Territory. Bureau of Mineral Resources, Geology and Geophysics, Bulletin. 115:1–105.

Playford G. 1976. Plant microfossils from the Upper Devonian and Lower Carboniferous of the Canning Basin, Western Australia. Palaeontographica, Abteilung B. 158:1–71.

Playford G. 1978. Lower Carboniferous spores from the Ducabrook Formation, Drummond Basin, Queensland. Palaeontographica, Abteilung B. 167:105–160.

Playford G. 1983. Two new genera of trilete *sporae dispersae* from the Lower Carboniferous of Queensland. Pollen et Spores. XXV:265–278.

Playford G. 1986. Morphological and preservational variation of *Rattiganispora apiculata* Playford and Helby, 1968, from the Australian Carboniferous. Pollen et Spores. XXVIII:83–96.

Playford G. 1991. Australian Lower Carboniferous miospores relevant to extra-Gondwanic correlations: an evaluation. In: Brenckle PL, Manger WL, editors, Intercontinental correlation and division of the Carboniferous system. Courier Forschungsinstitut Senckenberg 130; p. 85–125. Frankfurt am Main [imprinted 1990]

Playford G. 2015. Mississippian palynoflora from the northern Perth Basin, Western Australia: systematics and stratigraphical and palaeogeographical significance. Journal of Systematic Palaeontology. 14(9):731–770. online (30 October 2015); printed subsequently (September 2016).

Playford G. 2017. Intraspecific variation and palaeogeographic dispersal of the Mississippian miospore *Reticulatisporites magnidictyus* Playford & Helby, 1968. Palynology. 42(2):210–219. online (01 July 2017); printed subsequently (03 April 2018).

Playford G, Dettmann ME. 1996. Spores. In: Jansonius J, McGregor DC, editors, Palynology: principles and applications Vol. 1. Dallas (TX): American Association of Stratigraphic Palynologists Foundation; p. 227–260.

Playford G, Helby R. 1968. Spores from a Carboniferous section in the Hunter Valley, New South Wales. Journal of the Geological Society of Australia. 15(1):103–119.

Playford G, McGregor DC. 1993. Miospores and organic-walled microphytoplankton of Devonian-Carboniferous boundary beds (Bakken Formation), southern Saskatchewan: a systematic and stratigraphic appraisal. Geological Survey of Canada Bulletin. 445:1–107.

Playford G, Melo JHG. 2012. Miospore palynology and biostratigraphy of Mississippian strata of the Amazonas Basin, northern Brazil. Part one. American Association of Stratigraphic Palynologists Foundation. Contributions Series. 47:1–89.

Playford G, Mory AJ. 2017. 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. Rivista Italiana di Paleontologia e Stratigrafia. 123:275–318.

Playford G, Powis GD. 1979. Taxonomy and distribution of some trilete spores in Carboniferous strata of the Canning Basin, Western Australia. Pollen et Spores. XXI:371–394.

Playford G, Satterthwait DF. 1985. Lower Carboniferous (Viséan) spores of the Bonaparte Gulf Basin, northwestern Australia: Part one. Palaeontographica, Abteilung B. 195:125–152.

Potonié R. 1960. Synopsis der Gattungen der Sporae dispersae. III. Teil: Nachträge Sporites, Fortsetzung Pollenites mit Generalregister zu Teil I–II. Beihefte Zum Geologischen Jahrbuch. 39:1–189.

Potonié R. 1966. Synopsis der Gattungen der Sporae dispersae. IV. Teil: Nachträge zu allen Gruppen (Turmae). Beihefte Zum Geologischen Jahrbuch. 72:1–244.

Potonié R, Kremp G. 1954. Die Gattungen der paläozoischen Sporae dispersae und ihre Stratigraphie. Geologisches Jahrbuch. 69:111–194.

Punt W, Hoen PP, Blackmore S, Nilsson S, Le Thomas A. 2007. Glossary of pollen and spore terminology. Review of Palaeobotany and Palynology. 143(1–2):1–81.

Rattigan JH. 1967a. The Balickera section of the Carboniferous Kuttung facies, New South Wales. Journal and Proceedings, Royal Society of New South Wales. 100:75–84.

Rattigan JH. 1967b. Cyclic sedimentation in the Carboniferous continental Kuttung facies, New South Wales. Journal and Proceedings, Royal Society of New South Wales. 100:119–128.

Rattigan JH. 1967c. Depositional, soft sediment and post-consolidation structures in a Palaeozoic aqueoglacial sequence. Journal of the Geological Society of Australia. 14(1):5–18.

Ravn RL. 1991. Miospores of the Kekiktuk Formation (Lower Carboniferous), Endicott Field Area, Alaska North Slope. American Association of Stratigraphic Palynologists, Contributions Series. 27:1–173.

Riding JB, Fensome RA, Head MJ. 2018. Citing the taxonomic literature: what a difference a year makes. Palynology. 43(1):1–3. online (30 December 2018); printed subsequently (01 February 2019).

Roberts J, Engel BA. 1987. Depositional and tectonic history of the southern New England Orogen. Australian Journal of Earth Sciences. 34(1):1–20.

Roberts J, Engel B, Chapman J. 1991. Geology of the Camberwell, Dungog, and Bulahdelah 1:100,000 Sheets 9133, 9233, 9333. New South Wales Geological Survey, Sydney. 1–382.

Roberts J, Offler R, Fanning M. 2006. Carboniferous to Lower Permian stratigraphy of the southern Tamworth Belt, southern New England Orogen, Australia: boundary sequences of the Werrie and Rouchel blocks. Australian Journal of Earth Sciences. 53(2):249–284.

Rosenbaum G. 2012. Oroclines of the southern New England Orogen, eastern Australia. Episodes. 35:187–194.

Shaanan U, Rosenbaum G, Li P, Vasconcelos P. 2014. Structural evolution of the early Permian Nambucca Block (New England Orogen, eastern Australia) and implications for oroclinal bending. Tectonics. 33(7): 1425–1443.

Smith AHV, Butterworth MA. 1967. Miospores in the coal seams of the Carboniferous of Great Britain. Special Papers in Palaeontology. 1: 1–324.

Staplin FL. 1960. Upper Mississippian plant spores from the Golata Formation, Alberta, Canada. Palaeotographica Abteilung B. 107:1–40.

Sullivan HJ, Marshall AE. 1966. Viséan spores from Scotland. Micropaleontology. 12(3):265–285.

Sultan IZ. 1986. Palynostratigraphy of Carboniferous rock sequence in Wadi Araba well n° 1, Gulf of Suez region, Egypt/Palynostratigraphie de la série carbonifère du forage Wadi Araba n° 1, région du golfe de Suez, Egypte. Sciences Géologiques. Bulletin et Mémoires. 39(4): 337–360.

Süssmilch CA, David TWE. 1920. Sequence, glaciation and correlation of the Hunter River district, New South Wales. Journal and Proceedings, Royal Society of New South Wales. 53:310–322.

Traverse A. 2007. Paleopalynology, 2nd ed. Dordrecht: Springer; p. i–xvii + 813.

Turland NJ, Wiersema JH, Barrie FR, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Kusber W-H, Li D-Z, Marhold K., et al., editors. 2018. International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. Regnum Vegetabile 159. Glashütten: Koeltz Botanical Books.

van Geel BV, Grenfell HR. 1996. Green and blue-green algae – spores of Zygnemataceae. In: Jansonius J, McGregor DC, editors, Palynology: principles and applications. Vol. 1. Dallas (TX): American Association of Stratigraphic Palynologists Foundation; p. 173–179.

Vergel MM, Cisterna GA, Sterren AF. 2015. New palynological records from the glaciomarine deposits of the El Paso Formation (late Serpukhovian–Bashkirian) in the Argentine Precordillera: biostratigraphical implications. Ameghiniana. 52(6):613–624.

Wicander R, Monroe JS. 2014. Historical geology: evolution of Earth and life through time, 8th ed. Gengage Learning; p. i–xiv + 434. Boston, MA.

Wicander R, Playford G. 2013. Marine and terrestrial palynofloras from transitional Devonian–Mississippian strata, Illinois Basin, U.S.A. Boletín Geológico y Minero. 124:589–637.

Winslow MR. 1962. Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio. United States Geological Survey, Professional Paper. 364:1–93.

Worobiec E, Worobiec G. 2008. Fossil zygospores of Zygnemataceae algae (Chlorophyta) from the Upper Miocene of the Belchatów Lignite Mine. Przeglad Geologiczny. 56:1000–1004. [In Polish]

Appendix 1

Inventory of specimens illustrated in Plates 1–11. Sample numbers are as cited and positioned in Figure 2. Precise locations of individual specimens on numbered slides are specified by EF coordinates secured via a standard England finder™ gridded slide. Specimen catalogue numbers (MMMC-5382 through MMMC-5549) are those of the permanent repository: Geological Survey of New South Wales, Palaeontological Type Collection, W.B. Clarke Geoscience Centre, 947–953 Londonderry Road, Londonderry, NSW 2753, Australia. In the left-hand column, type categories are parenthesised thus: Ho, holotype; Pa, paratype; To, topotype; Hy, hypotype.

Species (type)	Plate/figure	Sample number	Slide number	EF	Photograph number	Catalogue number
Calamospora sp.	1/3	A710	B365/1B	T39	BA1629	MMMC-5382
Calamospora sp.	1/4	A710	B365/1B	T38/2	BA1630	MMMC-5383
Leiotriletes ornatus (Hy)	1/1	A710	B365/1A	E41/2	BA1609	MMMC-5384
Phyllotriletes golatensis (Hy)	1/2	A720	K40/21	R38/1	BA1500	MMMC-5385
Punctatisporites lucidulus (To)	1/9	A719	B366/x1	L56	BA99	MMMC-5386
Punctatisporites lucidulus (To)	1/10	A720	K40/21	Q55	BA1536	MMMC-5387
Punctatisiporites subtritus (To)	1/11	A720	K40/16	F21/3	BA1090	MMMC-5388
Punctatisiporites subtritus (To)	1/12	A718	B412/1	Q48	BA592	MMMC-5389
Punctatisiporites subtritus (To)	1/13	A718	B412/1A	O19/2	BA1679	MMMC-5390
Punctatisiporites subtritus (To)	1/14	A718	B412/1B	M33	BA1683	MMMC-5391
Retusotriletes separatus (Hy)	1/5	A707	B364/x3	T51/2	BA261	MMMC-5392
Cyclogranisporites firmus (Hy)	1/6	A720	K40/23	P43/1	BA1881	MMMC-5393
Cyclogranisporites firmus (Hy)	1/7	A720	K40/14	W41/4	BA895	MMMC-5394
Cyclogranisporites firmus (Hy)	1/8	A720	K40/1	M25/4	BA513	MMMC-5395
Verrucosisporites adgeratus (Ho)	2/1a, b	A720	K40/33	L30/3	BA2325/2324	MMMC-5396
Verrucosisporites adgeratus (Pa)	2/2a, b	A720	K40/28	E55/2	BA2138/2137	MMMC-5397
Verrucosisporites adgeratus (Pa)	2/3	A720	K40/31	D45/1	BA2716	MMMC-5398
Verrucosisporites adgeratus (Pa)	2/4	A720	K40/26	G22/2	BA2011	MMMC-5399
Verrucosisporites adgeratus (Pa)	2/5a ,b	A720	K40/32	P28	BA2650/2649	MMMC-5400
Verrucosisporites aspratilis (To)	2/6	A720	K40/32	W29	BA2319	MMMC-5401
Verrucosisporites aspratilis (To)	2/7	A720	K40/15	S19	BA959	MMMC-5402
Verrucosisporites aspratilis (To)	2/8	A720	K40/16	K25	BA1110	MMMC-5403
Verrucosisporites basiliscutis (Hy)	2/9a, b	A720	K40/16	H15	BA1071/1070	MMMC-5404
Verrucosisporites gregatus (Hy)	2/10	A720	K40/34	N31/1	BA2372	MMMC-5405
Verrucosisporites gregatus (Hy)	2/11	A720	K40/13	N41/4	BA800	MMMC-5406
Verrucosisporites iannuzzii (Hy)	2/12	A720	K40/15	P43	BA1046	MMMC-5407
Verrucosisporites iannuzzii (Hy)	2/13a, b	A720	K40/13	T32/4	BA782/781	MMMC-5408
Verrucosisporites iannuzzii (Hy)	2/14	A720	B300/20	O34/1	BA15	MMMC-5409
Verrucosisporites iannuzzii (Hy)	2/15	A720	B300/32	N42/3	BA13	MMMC-5410
Verrucosisporites iannuzzii (Hy)	3/1a, b	A720	K40/30	L24/1	BA2756/2757	MMMC-5411
Verrucosisporites iannuzzii (Hy)	3/2	A720	K40/16	G21/2	BA1092	MMMC-5412
Verrucosisporites iannuzzii (Hy)	3/3	A719	B366/1A	F28/3	BA1548	MMMC-5413
Verrucosisporites italiaensis (To)	4/13	A710	B365/x1	C53	BA90	MMMC-5414
Verrucosisporites italiaensis (To)	4/14	A710	B365/x1	K43	BA89	MMMC-5415
Verrucosisporites italiaensis (To)	4/15	A710	B365/x1	H34/4	BA88	MMMC-5416
Verrucosisporites johnstonense (Ho)	3/12	A720	K40/33	M29/1	BA2318	MMMC-5417
Verrucosisporites johnstonense (Pa)	3/13	A720	K40/15	N54/2	BA1065	MMMC-5418
Verrucosisporites johnstonense (Pa)	3/14	A720	K40/17	E43/3	BA1244	MMMC-5419
Verrucosisporites johnstonense (Pa)	3/15	A720	K40/11	J31/4	BA669	MMMC-5420
Verrucosisporites pavimentatus (Ho)	3/8	A720	K40/11	W57/3	BA704	MMMC-5421
Verrucosisporites pavimentatus (Pa)	3/9	A720	K40/14	O26	BA865	MMMC-5422
Verrucosisporites pavimentatus (Pa)	3/10	A720	K40/10	B37/3	BA626	MMMC-5423
Verrucosisporites pavimentatus (Pa)	3/11	A720	K40/15	Q54	BA1064	MMMC-5424
Verrucosisporites quasigobbettii (To)	4/1a, b	A720	K40/21	J38/4	BA1505/1504	MMMC-5425
Verrucosisporites quasigobbettii (To)	4/2	A720	K40/15	H50	BA1063	MMMC-5426
Verrucosisporites quasigobbettii (To)	4/3	A720	K40/16	E45	BA1159	MMMC-5427
Verrucosisporites quasigobbettii (To)	4/4	A720	K40/32	S24/3	BA2643	MMMC-5428
Verrucosisporites quasigobbettii (To)	4/5	A720	K40/18	P46	BA1314	MMMC-5429
Verrucosisporites quasigobbettii (To)	4/6	A720	K40/22	T37/4	BA1802	MMMC-5430
Verrucosisporites quasigobbettii (To)	4/7	A720	K40/25	R63/1	BA1962	MMMC-5431
Verrucosisporites quasigobbettii (To)	4/8a, b	A720	K40/21	H29/2	BA1476/1477	MMMC-5432
Verrucosisporites quasigobbettii (To)	4/9a, b	A720	K40/16	N40/3	BA1149/1150	MMMC-5433
Verrucosisporites quasigobbettii (To)	4/10	A720	K40/21	M28/2	BA1474	MMMC-5434
Verrucosisporites quasigobbettii (To)	4/11	A720	K40/22	P23	BA1789	MMMC-5435
Verrucosisporites quasigobbettii (To)	4/12a, b	A720	K40/21	G49/2	BA1525/1524	MMMC-5436
Verrucosisporites souzai (Hy)	3/4	A720	K40/28	K51	BA2127	MMMC-5437
Verrucosisporites souzai (Hy)	3/5	A720	K40/12	Q29/3	BA721	MMMC-5438
Verrucosisporites souzai (Hy)	3/6	A720	K40/16	S24	BA1102	MMMC-5439
Verrucosisporites souzai (Hy)	3/7	A720	K40/33	T42	BA2338	MMMC-5440
Anapiculatisporites amplus (Hy)	5/14	A707	K30/1	G54/2	BA371	MMMC-5441
Anapiculatisporites amplus (Hy)	5/15	A707	B364/11	Q39/4	BA43	MMMC-5442
Anapiculatisporites amplus (Hy)	5/16	A720	K40/15	P46/2	BA1054	MMMC-5443
Anapiculatisporites concinnus (Hy)	5/10	A720	K40/28	F51	BA2131	MMMC-5444
Anapiculatisporites concinnus (Hy)	5/11	A720	K40/15	W55/4	BA1067	MMMC-5445
Anapiculatisporites concinnus (Hy)	5/12	A720	K40/31	N60/3	BA2740	MMMC-5446
Anapiculatisporites concinnus (Hy)	5/13	A720	K40/20	P27/1	BA1415	MMMC-5447

(*continued*)

Appendix 1. Continued.

Species (type)	Plate/figure	Sample number	Slide number	EF	Photograph number	Catalogue number
Anapiculatisporites hispidus (Hy)	5/8	A720	K40/1	D54/2	BA561	MMMC-5448
Anapiculatisporites hispidus (Hy)	5/9	A720	K40/13	P54/4	BA831	MMMC-5449
Anapiculatisporites robertsii (Pa)	5/1a, b	A707	K30/1	R20/4	BA328/327	MMMC-5450
Anapiculatisporites robertsii (Pa)	5/2a, b	A718	B412/1A	G54	BA1674/1673	MMMC-5451
Anapiculatisporites robertsii (Ho)	5/3a, b	A707	K30/1	O33	BA2801/2802	MMMC-5452
Anapiculatisporites robertsii (Pa)	5/4	A707	K30/1	E48	BA357	MMMC-5453
Anapiculatisporites robertsii (Pa)	5/5	A718	B412/1B	X41/3	BA1684	MMMC-5454
Dibolisporites disfacies (Hy)	5/6	A720	K40/25	G45/4	BA1994	MMMC-5455
Dibolisporites disfacies (Hy)	5/7	A720	K40/27	P42	BA2067	MMMC-5456
Raistrickia accincta (To)	7/1	A710	B365/1A	V54/3	BA1617	MMMC-5457
Raistrickia accincta (To)	7/2	A710	B365/1B	K48/2	BA1631	MMMC-5458
Raistrickia accincta (To)	7/3	A710	B365/1B	R25	BA1625	MMMC-5459
Raistrickia accincta (To)	7/4	A710	B365/1A	S54/2	BA1618	MMMC-5460
Raistrickia corymbiata (Hy)	7/5	A720	K40/16	V33/1	BA1130	MMMC-5461
Raistrickia corymbiata (Hy)	7/6	A720	K40/15	R23/3	BA978	MMMC-5462
Raistrickia radiosa (To)	7/7	A707	K30/1	J44	BA350	MMMC-5463
Raistrickia radiosa (To)	7/8	A710	B365/1A	S54/2	BA1618	MMMC-5464
Brochotriletes diversifoveatus (Hy)	6/9a, b	A707	K40/1	H44/2	BA2803/538	MMMC-5465
Convolutispora perplicata (Pa)	7/16	A707	K30/2	R57/1	BA451	MMMC-5466
Convolutispora perplicata (Ho)	7/17	A720	K40/11	D58/1	BA708	MMMC-5467
Convolutispora perplicata (Pa)	7/18	A720	K40/30	K28/3	BA2743	MMMC-5468
Cordylosporites asperidictyus (To)	6/15	146	K52/1B	X50/1	BA1764	MMMC-5469
Cordylosporites asperidictyus (To)	6/16	A719	B366/1A	N30/3	BA1550	MMMC-5470
Cordylosporites asperidictyus (To)	6/17	146	K52/1C	V23/1	BA1766	MMMC-5471
Foveosporites pellucidus (To)	6/10	146	K52/1B	P48	BA1763	MMMC-5472
Foveosporites pellucidus (To)	6/11	146	K52/1B	W26/3	BA1756	MMMC-5473
Foveosporites pellucidus (To)	6/12	A720	K40/22	N22	BA1787	MMMC-5474
Foveosporites pellucidus (To)	6/13	146	K52/1D	R42/2	BA1781	MMMC-5475
Foveosporites pellucidus (To)	6/14a, b	A720	K40/27	K22/4	BA2045/2044	MMMC-5476
Microreticulatisporites sp. A	7/13	A707	K30/3	G45/4	BA488	MMMC-5477
Microreticulatisporites sp. A	7/14	A720	K40/25	E58	BA1952	MMMC-5478
Microreticulatisporites sp. A	7/15	A720	K40/14	F33	BA881	MMMC-5479
Rattiganispora apiculata (To)	7/9a, b	A718	B412/1A	G51/2	BA1672/1671	MMMC-5480
Rattiganispora apiculata (To)	7/10	A718	B412/1A	O19/2	BA1646	MMMC-5481
Rattiganispora apiculata (To)	7/11	A707	K30/1	K57	BA376	MMMC-5482
Rattiganispora apiculata (To)	7/12	A707	K30/1	H52/2	BA368	MMMC-5483
Reticulatisporites magnidictyus (To)	6/1	A720	K40/27	F26	BA2046	MMMC-5484
Reticulatisporites magnidictyus (To)	6/2	A720	K40/11	F21	BA659	MMMC-5485
Reticulatisporites magnidictyus (To)	6/3	A720	K40/15	K24/1	BA984	MMMC-5486
Reticulatisporites magnidictyus (To)	6/4	A720	K40/28	U54/2	BA2136	MMMC-5487
Reticulatisporites magnidictyus (To)	6/5	A720	K40/30	N42/1	BA2223	MMMC-5488
Reticulatisporites magnidictyus (To)	6/6	A720	K40/20	N24/3	BA1406	MMMC-5489
Reticulatisporites magnidictyus (To)	6/7	A720	K40/28	C27/4	BA2093	MMMC-5490
Reticulatisporites magnidictyus (To)	6/8	A720	K40/21	F42/2	BA1510	MMMC-5491
Diatomozonotriletes sp. A	9/1	A707	B282/101	L48/3	BA23	MMMC-5492
Knoxisporites balickeraensis (Ho)	8/3a, b	A720	K40/16	X54/1	BA1190/1191	MMMC-5493
Knoxisporites balickeraensis (Pa)	8/4a, b	A720	K40/17	Q23/1	BA1208/1209	MMMC-5494
Knoxisporites balickeraensis (Pa)	8/5	A720	K40/26	S36/3	BA2016	MMMC-5495
Knoxisporites balickeraensis (Pa)	8/6	A720	K40/14	L57/2	BA951	MMMC-5496
Knoxisporites balickeraensis (Pa)	8/7	A720	K40/17	K18/3	BA1201	MMMC-5497
Knoxisporites balickeraensis (Pa)	8/8	A720	K40/20	B31/3	BA1422	MMMC-5498
Knoxisporites sp. A	8/1a, b	A720	K40/14	L32/2	BA876/877	MMMC-5499
Knoxisporites sp. B	8/2a, b	A720	K40/27	J56/4	BA2084/2085	MMMC-5500
Densoisporites argutus (Pa)	9/5	A720	K40/15	E22	BA976	MMMC-5501
Densoisporites argutus (Ho)	9/6	A707	K30/1	V51/3	BA364	MMMC-5502
Densosporites infacetus (Hy)	9/7	A720	K40/35	T38	BA2430	MMMC-5503
Densosporites infacetus (Hy)	9/8	A720	K40/25	H63	BA1959	MMMC-5504
Densosporites sp. A	9/9a, b	A707	B364/100	P30/1	BA36/37	MMMC-5505
Densosporites sp. A	9/10	A720	K40/18	W44/4	BA1308	MMMC-5506
Indotriradites kuttungensis (To)	9/2	A720	K40/14	P36	BA882	MMMC-5507
Indotriradites kuttungensis (To)	9/3	A720	K40/14	R38/2	BA888	MMMC-5508
Indotriradites kuttungensis (To)	9/4	A707	K30/1	V23/3	BA316	MMMC-5509
Radiizonates arcuatus (Hy)	9/12a, b	A720	K40/14	X41/3	BA894/2806	MMMC-5510
Vallatisporites sp. cf. *V. hystricosus*	9/13	A720	K40/14	S57/3	BA948	MMMC-5511
Grandispora maculosa (To)	9/14	A707	K30/1	W44	BA352	MMMC-5512
Grandispora maculosa (To)	9/15	A707	B282/101	R15	BA06	MMMC-5513
Diaphanospora sp. A	9/11	A707	K30/1	D59/1	BA379	MMMC-5514
Velamisporites australiensis (To)	9/16	A707	K30/1	X43	BA349	MMMC-5515
Velamisporites australiensis (To)	9/17	A707	B364/x3	B58/4	BA269	MMMC-5516
Velamisporites australiensis (To)	9/18	A720	K40/31	V31	BA2254	MMMC-5517
Velamisporites cortaderensis (Hy)	10/1	A720	K40/15	F38/4	BA1034	MMMC-5518
Velamisporites cortaderensis (Hy)	10/2	A720	K40/22	P58/4	BA1841	MMMC-5519
Velamisporites cortaderensis (Hy)	10/3	A720	K40/23	G52/1	BA1894	MMMC-5520
Velamisporites cortaderensis (Hy)	10/4	A720	K40/12	L22	BA713	MMMC-5521

(*continued*)

Appendix 1. Continued.

Species (type)	Plate/figure	Sample number	Slide number	EF	Photograph number	Catalogue number
Aratrisporites saharaensis (Hy)	11/12	A720	K40/12	K31	BA728	MMMC-5522
Aratrisporites saharaensis (Hy)	11/13	A720	K40/33	S43	BA2587	MMMC-5523
Laevigatosporites demutabilis (Ho)	10/5	A720	K40/33	Y61/1	BA2614	MMMC-5524
Laevigatosporites demutabilis (Pa)	10/6	A720	K40/34	C54/3	BA2396	MMMC-5525
Laevigatosporites demutabilis (Pa)	10/7	A720	K40/21	C49/1	BA1523	MMMC-5526
Laevigatosporites demutabilis (Pa)	10/8	A720	K40/33	R25	BA2547	MMMC-5527
Laevigatosporites demutabilis (Pa)	10/9	A720	K40/16	U39	BA1148	MMMC-5528
Laevigatosporites demutabilis (Pa)	10/10	A720	K40/14	F38/4	BA890	MMMC-5529
Laevigatosporites demutabilis (Pa)	10/11	A718	B412/1C	F22/3	BA1690	MMMC-5530
Laevigatosporites demutabilis (Pa)	10/12	A720	K40/34	M59/3	BA2407	MMMC-5531
Latosporites durabilis (Ho)	10/13	A720	K40/32	D16	BA2617	MMMC-5532
Latosporites durabilis (Pa)	10/14	A720	K40/30	P58/2	BA2799	MMMC-5533
Latosporites durabilis (Pa)	10/15	A720	K40/15	P43/3	BA1042	MMMC-5534
Latosporites durabilis (Pa)	10/16	A720	K40/35	P55/4	BA2458	MMMC-5535
Latosporites durabilis (Pa)	10/17	A720	K40/33	V31	BA2554	MMMC-5536
Latosporites durabilis (Pa)	10/18	A720	K40/30	J29/4	BA2770	MMMC-5537
Psomospora detecta (To)	11/1a, b	A720	K40/18	D44/1	BA1307/1306	MMMC-5538
Psomospora detecta (To)	11/2	A720	K40/10	M31	BA616	MMMC-5539
Psomospora detecta (To)	11/3	A720	K40/13	G54/1	BA829	MMMC-5540
Psomospora detecta (To)	11/4	A720	K40/21	S20/2	BA1461	MMMC-5541
Psomospora detecta (To)	11/5	A720	K40/29	V26	BA2154	MMMC-5542
Psomospora detecta (To)	11/6	A720	K40/15	N46/3	BA1050	MMMC-5543
Psomospora detecta (To)	11/7	A720	K40/25	V52/4	BA1998	MMMC-5544
Psomospora detecta (To)	11/8	A720	K40/1	L33/3	BA522	MMMC-5545
Psomospora detecta (To)	11/9	A720	K40/30	M19/4	BA2194	MMMC-5546
Psomospora detecta (To)	11/10	A720	K40/14	E54	BA937	MMMC-5547
Psomospora detecta (To)	11/11	A720	K40/21	C46	BA1515	MMMC-5548
Tetraporina horologia (Hy)	11/14	A718	B412/1A	H21/3	BA1649	MMMC-5549