SPORES AND POLLEN FROM THE MIDDLE AND UPPER GHARIF MEMBERS, PERMIAN, OMAN

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ABSTRACT

The late Early Permian to Mid Permian palynological biozones Oman and Saudi Arabia Palynological Biozone 5 (OSPZ5) and OSPZ6, defined recently for the Arabian Peninsula, sometimes contain well-preserved and diverse assemblages which are described here for the first time, concentrating on taxa used in recognition of biozones. Some of these were previously assigned to informal taxa. Thus the new spore species *Indotriradites ater, Indotriradites mundus*, *Kendosporites robustus*, and the new pollen species *Kingiacolpites subsaccatus* and *?Tiwariasporis granulatus* are described and illustrated. These distinctive palynomorphs may be useful in further biostratigraphical studies. For example the first uphole occurrences of *Indotriradites mundus* and *?Tiwariasporis granulatus* are close to the base of OSPZ6; while *Indotriradites ater* and *Kingiacolpites subsaccatus* have relatively narrow ranges

within OSPZ5. The previously described taxa *Hamiapollenites karrooensis* and *Hamiapollenites dettmannae* are common in the lower parts of OSPZ5.

Keywords: Permian; spores; pollen; taxonomy; Arabia; Oman.

INTRODUCTION

The standard Permian palynological biozonation for Arabia consists of a framework of eight biozones for the uppermost Carboniferous to Middle Permian rocks in the region (Stephenson et al., 2003; Stephenson 2006). The lower five biozones (OSPZ 1, 2, 3a to 3c) represent the palyniferous uppermost Carboniferous to Lower Permian sequence in Oman, and to some extent these are recognizable in sequences of central and southern Saudi Arabia. OSPZ1 (Oman-Saudi Arabia Palynozone 1), associated with the lower parts of the Al Khlata Formation and the Unayzah C member, is probably Stephanian in age. OSPZ2 is Asselian-Sakmarian in age, and is associated with the upper part of the Al Khlata Formation and the Unayzah B member. OSPZ3, which is subdivided into three sub-biozones, is associated with the Lower Gharif Member and its age is late Sakmarian, based on fusulinid evidence from the subsurface Haushi Limestone, widely present toward the top of the Lower Gharif Member (Angiolini et al., 2006). OSPZ4 was established in the sporadically palyniferous Oman Middle Gharif Member, while OSPZ5 and 6 are based in the Oman Upper Gharif Member and Saudi Arabian Unayzah A member and basal Khuff clastics. OSPZ5 assemblages were first recognised in a large number of Upper Gharif Member sections in the Oman subsurface and in a small number of well sections in

the far southeast of Saudi Arabia (e.g. Rawakib-1), well below the base of the Khuff Formation, and were clearly different from those of the basal Khuff clastics in central Saudi Arabia (e.g. those from Dilam-1, Nuayyim-2, and Haradh-51; see Stephenson and Filatoff, 2000), and from the lower Khuff Formation carbonates in Oman and Saudi Arabia.

The older assemblages were designated by Stephenson et al. (2003) as OSPZ5, and these were characterised by amongst others *Distriatites insolitus*, *Densipollenites indicus, Playfordiaspora cancellosa*, *Pteruchipollenites owensii* and *Thymospora opaque* (see Appendix for author citations of species). None of these taxa occur in OSPZ4, so the assemblages represent a considerable upsection change. The younger assemblages were designated as OSPZ6, and were characterised by *Camptotriletes warchianus*, ?*Florinites balmei, Pyramidosporites cyathodes*, *Protohaploxypinus uttingii* and *Triplexisporites* cf. *playfordii*, though many taxa from OSPZ5 persist.

Originally the exact stratigraphic relationships between OSPZ5 and 6 were not clear because in no section were the biozones in contact with one another. Later work on the densely sampled Upper and Middle Gharif members in Petroleum Development Oman Barik-36 well showed the transition from OSPZ5 to 6 assemblages (Stephenson, 2006). The respective bases of biozones OSPZ5 and 6 were defined by Stephenson (2006) and although the stratigraphic ranges of the main palynomorphs in OSPZ5 and 6 are known, the sometimes well-preserved and diverse assemblages have not been described in detail so far. Thus the purpose of this report is to describe and illustrate key species of the sections, concentrating on those that previously were assigned to informal taxa.

BARIK-36 WELL SECTION

The Barik-36 section is an extensive cored section through the Middle and Upper Gharif members and part of the Khuff Formation in the north Central Oman Barik Field (Text-Figure 1). Palynological analysis was carried out on 196 core samples between 2614.84 m and 2771.67 m (Text-Figure 2). In this and other Barik Field wells, the Middle Gharif Member consists, toward the base, of palyniferous fluvial and lacustrine sandstone and mudstones succeeded by a thick stack of red palaeosols known as the 'Middle Gharif shale', which is palynologically barren. The Upper Gharif Member consists of similar fluvial facies interbedded with stacked palynologically barren palaeosols that have a blocky gamma signature (Text-Figure 2).

Ranges of selected palynomorphs are shown in Text-Figure 2. Between 2771.67 m and 2756.15 m (Middle Gharif Member), the assemblages are typical of those of OSPZ4 with common indeterminate bisaccate, monosaccate and taeniate bisaccate pollen. *Barakarites* spp., *Florinites flaccidus*, *Kingiacolpites subcircularis* and *Vesicaspora* spp. also occur. Between 2698.6 m and 2619.73 m (Upper Gharif Member), are poorly- to moderately-preserved, low diversity assemblages that are dominated by bisaccate pollen including distally taeniate bisaccate pollen (mainly *Distriatites* and *Hamiapollenites*). Spores such as *Indotriradites* spp. and *Playfordiaspora cancellosa* also occur, as well as distinctive monolete spores. Between 2619.73 m and 2614.84 m is a section consisting of heterolithic beds

overlain by the Khuff Formation carbonates. This is termed the 'Khuff transition section' and its palynomorph assemblages are dominated by bisaccate pollen and cingulizonate spores. Most assemblages also contain probable fresh or low salinity aquatic algal spores (e.g. *Botryococcus* spp. and *Tetraporina* spp.) as well as rare marine indicators (scolecodonts, microforaminiferal test linings and spinose acritarchs). ?*Florinites balmei* is common above 2620.3 m, occurring in almost all the samples.

MATERIALS AND METHODS

The preparation of strew mounts for palynological analysis involved well-established procedures of crushing followed by hydrochloric and hydrofluoric acid treatments (Wood et al., 1996). Post-hydrofluoric acid organic residues were oxidized with Schulze's Solution and dilute nitric acid.

SYSTEMATIC PALEONTOLOGY

Terminology

The terminology used is that of Punt et al. (1994) and the turmal organisation is based on that of Neves and Owens (1966). Maximum dimensions are given in microns

(µm), include protruding ornament elements. The measurement and orientation scheme of bisaccate pollen used in the paper is shown in Text-Figure 3. Previous records of taxa given here are not meant to be exhaustive, but to focus on recently reported Gondwanan and Middle Eastern occurrences. Chronostratigraphic ages for these occurrences are those suggested by the respective authors. All specimens, except where otherwise noted, are held in the collection of the British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK.

Anteturma PROXIMEGERMINANTES Potonié 1970

Turma TRILETES Reinsch emend. Dettmann 1963

Suprasubturma CAMERATITRILETES Neves & Owens 1966

Subturma MEMBRANATITRILETES Neves & Owens 1966

Infraturma CINGULICAMERATI Neves & Owens 1966

Genus *Indotriradites* Tiwari emend. Foster 1979

Type species. *Indotriradites korbaensis* Tiwari 1964

Remarks. Foster (1979, p. 55) emended *Indotriradites* to include two-layered spores whose intexinal layer is '... separated (at least distally and equatorially) from (the)

exoexine by a distinct, broad or narrow cavum'. The genus is therefore distinct from *Kraeuselisporites* which is acamerate (Scheuring, 1974).

Indotriradites mundus sp. nov.

Plate 1, figs. 1-15

Indotriradites sp. E Stephenson, 2006; pl. 1, figs. 16, 17 [no description]

?*Kraeuselisporites* sp. A Nader et al., 1993b; pl. 3, figs. 24, 25 [no description]

Holotype. Plate 1, figs. 3, 4, 14.

Paratype. Plate 1, figs. 6, 7.

Type locality. Barik-36 well, Barik field, Oman; slide 2615.60, sample depth 2615.60 m.

Derivation of name. *mundus* (latin), smooth, neat, tidy.

Description. Spores, radial, trilete; amb rounded triangular with smooth margin. Intexinal body distinct; intexine thin, ?laevigate, rarely folded independently of the exoexine. Laesurae distinct, straight; extend to the spore margin with distinct lips less than 1 μm wide. Lips raised by exine folds along the laesurae. Proximal face planar but for raised laesural folds, exoexine finely punctate. Distal face planar to slightly convex; exoexine thick, punctate or spongeous, unornamented. Exoexinal zona width approximately 25 to 35% of spore radius; zona thin, appears flaccid, sometimes

folded. Zona densely punctate; often very light in colour; occasionally with irregular or arch-shaped thickenings. Inner margin of zona slightly raised from the proximal surface, and may appear as a dark coloured ring. Exoexine-intexine separation equatorial; approx. 5 μm when viewed in proximodistal orientation.

Dimensions. 63(78)95 μm; 18 specimens

Comparison. Differs from *Gondisporites variabilis*, *Indotriradites ater* sp. nov., *Indotriradites fibrosus*, *Indotriradites niger* and *Indotriradites splendens* in lacking distal ornament.

Previous records. Oman and Saudi Arabia (Stephenson, 2006; as *Indotriradites* sp. E).

Stratigraphic occurrence. Appears close to the base of OSPZ6 Biozone. Common in lower Khuff Formation palynological assemblages.

Indotriradites ater sp. nov.

Plate 2, figs. 1-12

Indotriradites sp. C Stephenson et al., 2003; pl. 5, figs. 16-17.

Indotriradites sp. C Stephenson, 2006; pl. 1, figs. 19, 20, 27

Holotype. Plate 2, Figures 7, 8, 9.

Paratype. Plate 2, Figures 5, 6, 12

Type locality. Barik-36 well, Barik field, Oman slide 2760.80, sample depth 2760.80 m.

Derivation of name. *ater* (latin), dark, nebulous.

Description. Spores, radial, trilete; amb rounded triangular with smooth margin. Intexinal body distinct; intexine thin, ?laevigate, rarely folded independently of the exoexine. Laesurae distinct, straight; extend to the spore margin with distinct thick lips approximately 2 μm wide. Lips raised by exine folds along the laesurae. Proximal face planar but for raised laesural folds, exoexine finely punctate. Distal face convex; exoexine thick, coarsely punctate (puncta 1 μm in diameter) or spongeous; ornamented with long slender sharp-tipped spines 1-7 μm long, 1-2 μm wide at the base, and 3-10 μm apart (when discrete). Spines discrete or joined into narrow lines arranged concentrically. Exoexinal zona width approximately 15 to 20% of spore radius; thin, sometimes folded, densely punctate, unornamented; often very light in colour in contrast to the dark spore body. Inner margin of zona sometimes slightly darker than the outer part. Exoexine-intexine separation equatorial; approx. 5 μm when viewed in proximodistal orientation.

Dimensions. 65(70)95 μm; 12 specimens

Comparison. Amongst large heavily ornamented spores, *Indotriradites splendens* is most similar to *Indotriradites ater*, however it has a distal ornament of flattened and bulbous verrucae, cones and mamillate spines (see Balme and Hennelly, 1956; Backhouse, 1991)

Remarks. The dark colour of the spore body, presumably related to the thickness of exine and the robust construction of the spore, makes photographic imaging difficult.

However the size of the spore and its habit of being compressed obliquely so that its long distal spines are prominent makes it highly distinctive.

Previous records. Oman and Saudi Arabia (Stephenson et al., 2003; Stephenson, 2006; as *Indotriradites* sp. C).

Stratigraphic occurrence. Defines, along with *Distriatites insolitus, Hamiapollenites dettmannae, Playfordiaspora cancellosa* and *Thymospora opaqua*, the base of the OSPZ5 Biozone (see Stephenson, 2006); common until its last occurrence around the middle part of OSPZ5.

Turma MONOLETES Ibrahim 1933

Subturma AZONOMONOLETES Luber 1935

Infraturma LAEVIGATOMONOLETES Dybová and Jachowicz 1957

Genus *Laevigatosporites* Ibrahim 1933

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

Laevigatosporites callosus Balme 1970

Plate 3, figs. 1-3

Description. Spores, bilateral, monolete; amb oblate oval (mean long axis / short axis ratio 1.25). Laesura very distinct, length 25-70% of the spore length; commissure flanked by what appear to be lips but which are the upturned thick walls of the commissure seen in profile. Exine thick (3-4 μm); often a conspicuously bright yellow in colour; slightly resinous in appearance; comprehensively laevigate and/or very finely punctate near the monolete mark. Occasionally a small thickened area of exine occurs near the distal pole (exine ?5 μm thick); area of thickening irregular in outline.

Dimensions. Long axis 57(72)82 μm; short axis 51(58)69 μm; 25 specimens.

Remarks. Balme (1970) satisfactorily distinguished the present species from *Latosporites planorbis* and *Latosporites intragranulosus*. *Laevigatosporites vulgaris* and *Laevigatosporites robustus* lack the form of laesura of the present species and have thinner exine which lacks a distal callous.

Previous records. Pakistan, Late Permian (Balme, 1970); Israel, Permian (Eshet, 1990a, b; Zaslavskaya et al*.,* 1995); Iran, Permian (Chateauneuf and Stampfli, 1979); Iraq, Permian (Nader et al*.,* 1993b); Oman and Saudi Arabia, (Stump and van der Eem, 1995; Stephenson et al., 2003).

Stratigraphic occurrence. Appears in the upper part of OSPZ5 and persists into OSPZ6.

Infraturma SCULPTATOMONOLETI Dybová & Jachowicz 1957

Genus *Thymospora* Wilson & Venkatachala 1963 emend. Alpern & Doubinger 1973

Type species. *Thymospora thiessenii* (Kosanke) Wilson & Venkatachala 1963

Thymospora opaqua Singh 1964

Plate 3, figs 4-12

?Polypodiisporites ipsviciensis (de Jersey) Playford & Dettmann 1965; Nader et al., 1993b; pl. 4, figs. 19-20 [no description].

?Thymospora perverrucosa (Alpern) Wilson & Venkatachala 1963; Akyol 1975; pl. 2, figs. 24-26 [no description].

Description. Spores, bilateral, monolete or rarely trilete; amb oval with undulate margin; amplitude of undulations 1-2 µm. Laesura distinct, extends the length of the spore; with well developed 'lips' which are composed of fused proximal elements adjacent to the commissure. Exine 1-2 µm thick (including ornament); comprehensively verrucate-rugulate; rugulae 1.5-2 µm wide, <1 µm high, 1-0.5 µm apart, round-topped or rarely surmounted by small spines (<1 µm high). Density of elements is such that an imperfect negative reticulum is apparent. Elements denser in the contact area such that lines of thickened exine flank the laesura, simulating lips.

Dimensions. 23(29)45 μm; 25 specimens.

Remarks. The present species is larger than *Thymospora thiessenii* whose maximum dimensions are given as 14-24 μm by Kosanke (1943) and as 18.7 μm by Alpern and Doubinger (1973; mean 100 specimens). The present species also has coarser ornament elements than *Thymospora thiessenii*. *Thymospora pseudothiessenii* has coarser ornament elements than the present species. *Thymospora cicatricosa* differs from the present species in having reduced or absent proximal ornament.

Previous records. Iraq, Late Permian (?Nader et al.,1993b; Singh, 1964); Iran, Permian (Chateauneuf and Stampfli, 1980);?Turkey, Permian (Akyol, 1975); Oman and Saudi Arabia (Stephenson and Filatoff, 2000; Stephenson et al., 2003; Stephenson, 2006).

Stratigraphic occurrence. Defines, along with *Distriatites insolitus, Hamiapollenites dettmannae, Indotriradites ater* and *Playfordiaspora cancellosa*, the base of the OSPZ5 Biozone (see Stephenson, 2006); common into OSPZ6.

Genus *Kendosporites* Surange & Chandra 1974

Type species. *Kendosporites striatus* (Salujah) Surange & Chandra 1974

Remarks. *Striatosporites* Bhardwaj emend. Playford & Dino 2000 accommodates monolete spores with reticulate sculpture in which distinct primary muri running

parallel to the long axis of the spore are intersected by more numerous, less distinct secondary muri. Thus, as discussed by Playford and Dino (2000), it is a senior synonym of *Columinisporites* Peppers 1964. *Schweitzerisporites* Kaiser 1976 accommodates sculptured monolete spores with two wall layers with a coarse reticulum unorientated with respect to the long axis of the spore. Thus *Kendosporites* Surange & Chandra 1974 is distinguished from *Columinisporites* and *Schweitzerisporites* by its single-layered wall and by its longitudinal pattern of muri. Balme (1995) and Playford and Dino (2000) commented that *Kendosporites striatus* does not possess muri and thus renders the genus insecure. However the holotype (Salujah, 1965; plate 1, fig. 19) clearly possesses longitudinal muri.

Kendosporites robustus sp. nov.

Plate 4, figs. 1-9

Weylandites sp. X Stephenson, 2006; pl. 1, figs. 10, 14

?*Laevigatosporites striatus* (Salujah) Anderson 1977 *pars*; pl. 81, figs. 14-19.

Holotype. Plate 4, fig. 5, 6.

Paratype. Plate 4, figs. 7, 8.

Type locality. Barik-36 well, Barik field, Oman slide 2616.10, sample depth 2616.10 m

Derivation of name. *robustus* (latin), robust.

Description. Spores, bilateral, monolete; amb oval with small ridged protrusions

where muri intersect the amb. Laesura indistinct; when visible the monolete mark is 50 % of the length of the spore. Exine appears single layered; 1-2 μm thick (excluding muri). Thick dark coloured, robust, prominent muri cover the spore body; orientated broadly parallel to the long axis of the spore but sometimes orientated at a small angle to that axis. Around 20-30 muri cover the whole exine. Thus some specimens have more or less straight parallel muri on the proximal and distal surfaces while others (specimens that might have been slightly twisted during preservation or compression) have the appearance of two sets of muri at a slight angle to each other. In these specimens, the proximal set of muri are very distinct from the upper set, creating the impression of intersecting muri. Muri <1 μm high at the amb, 1.5-4 μm wide.

Dimensions. Long axis 60(80)100 μm; 20 specimens.

Remarks. The present species differs from *Kendosporites striatus* in having much more robust and numerous longitudinal muri. A few specimens assigned by Anderson (1977) to *Laevigatosporites striatus* are probably assignable to *Kendosporites robustus* sp. nov.

Stratigraphic occurrence. Appears close to the base of OSPZ5 and persists into OSPZ6; often common in the lower parts of OSPZ6.

Anteturma VARIEGERMINANTES Potonié 1970

Turma SACCITES Erdtman 1947

Subturma MONOSACCITES Chitaley emend. Potonié & Kremp 1954

Infraturma ALETESACCITI Leschik 1955

Genus *Densipollenites* Bharadwaj 1962

Type species. *Densipollenites indicus* Bharadwaj 1962.

Remarks. Several species of *Densipollenites* have been described in the Indian subcontinent by Bharadwaj (1962), Bharadwaj and Salujah (1964), Bharadwaj and Srivastava (1969) and Tiwari and Rana (1981). The species are listed and compared by Vijaya and Tiwari (1986). Balme (1970) recognised fewer species of *Densipollenites* because he considered that intexine thickness (the main criterion that distinguishes species) is gradational. Foster (1979) concurred with Balme (1970) and further considered *Densipollenites pullus* to be a junior synonym of *Densipollenites densus*. The most common species in Oman assemblages is *Densipollenites indicus* though a small number of specimens with very indistinct corpi might be assigned to *Densipollenites invisus*.

Densipollenites indicus Bharadwaj 1962

Plate 5, figs. 1-3

Description. Pollen, monosaccate; amb originally circular or oval but often irregular due to folding. Intexinal body distinct, dark; ?alete, circular in outline; intexine thick 1-2 μm. Corpus nearly always eccentrically placed in the saccus; corpus with monopolar saccus detachment. Detachment close to the pole leaving a small exoexine-free area at the pole of the intexinal body; width of area <50% of the corpus width; detachment of saccus occasionally associated with circumpolar intexinal folds . No distal saccus detachment present; distal exoexinal folds pass across the intexinal body without accompanying distal intexinal folds. Saccus either densely and indistinctly infrareticulate, or with a thick, spongeous appearance. The margin of the saccus sometimes has a columellate structure. The density of the exoexine structure is such that at the saccus margin, the close superimposition of the proximal and distal surface of the saccus creates a dark rim similar in appearance to a limbus.

Dimensions. Total width 85, 85, 90, 90 μm.

Remarks. Foster (1979) placed *Densipollenites indicus* in Monopseudosacciti Smith and Butterworth 1967 implying that the species is not strictly saccate, presumably because of the columellate internal structure in parts of the exoexine/saccus. It is suggested here that *Densipollenites indicus*, along with species of *Corisaccites* Venkatachala & Kar 1966, has an exoexinal extension that functioned as a saccus even though the internal structure of the saccus is unlike that of most other saccate taxa. *Densipollenites indicus* is therefore retained in Monosaccites Chitaley emend. Potonié & Kremp 1954, in agreement with Bharadwaj (1962).

Previous records. Israel, Late Permian-Early Triassic (Eshet and Cousminer, 1986, Eshet, 1990b; Horowitz, 1973); Iraq, Permian (Nader et al., 1993b); India, Permian

(Vijaya and Tiwari, 1986; Tripathi, 1993; Bharadwaj and Dwivedi, 1981). For further Gondwana occurrences of this species see Foster (1979, p. 61).

Stratigraphic occurrence. Appears at the base of the OSPZ5 Biozone; common until its last occurrence around the middle part of OSPZ5.

Infraturma MONPOLSACCITI Hart 1965

Genus *Florinites* Schopf et al. 1944

Type species. *Florinites pellucidus* (Wilson & Coe) Wilson 1958.

Remarks. An important feature of *Florinites* is the lack of saccus development at the distal pole of the grain (Schopf et al., 1944; pl. 2, fig. 13; Potonié and Kremp 1954, fig. 84). To give taxonomic recognition to this structural feature the genus is accommodated in Infraturma Monpolsacciti Hart 1965.

?*Florinites balmei* Stephenson & Filatoff 2000

Plate 5, figs. 4-6.

(For description see Stephenson and Filatoff 2000, p. 208).

Stratigraphic occurrence. Its first appearance defines the base of the OSPZ6 Biozone (see Stephenson, 2006); common throughout OSPZ6.

Subturma DISACCITES Cookson 1947

Infraturma DISACCIATRILETI Leschik 1955

Genus *Alisporites* Daugherty 1941 emend. Jansonius 1971

Type Species. *Alisporites opii* Daugherty 1941.

Alisporites nuthallensis Clarke 1965

Plate 5, figs. 7-9

Description. Pollen bisaccate, bilaterally symmetrical; amb haploxylonoid to very slightly diploxylonoid. Corpus slightly longitudinally elongate (mean total length : corpus width ratio 1.25); intexine thin, indistinct; cappa exoexine thin. Cappula narrow (<25% of corpus width); parallel sided; extends the length of the corpus. Within the cappula a longitudinal medial distal tenuitas and/or sulcus is sometimes

perceptible. The tenuitas is often the first part of the exine to rupture so that a longitudinal slit is sometimes present within the cappula. Saccus detachment asymmetrical; ?equatorial on the proximal side, close to distal pole on the distal side. Sacci strongly distally inclined. Sacci crescentic to semi-circular in outline; rigid; with relatively coarse infrareticulation (brochi 1 μm in diameter or greater). Sacci slightly larger than the corpus. A pair of narrow crescentic, intexinal folds usually present at the distal saccus bases.

Dimensions. Total width 54(67)94 μm; 20 specimens

Remarks. Balme (1980b, p. 30) described forms assigned to *Alisporites* sp. cf. A. *nuthallensis* which had '...a ragged distal rupture in the cappula...(indicating).... the presence of a differentiated distal sulcus rather than a leptoma...'. He stated that the rupture distinguished the forms from *Alisporites nuthallensis*. He conceded, however, that there seem to be no other significant differences between the two forms; and, in this study, specimens with a ruptured tenuitas are accommodated within *Alisporites nuthallensis*.

Alisporites nuthallenis differs from *Falcisporites stabilis* Balme 1970 and *Alisporites australis* de Jersey 1962 in lacking a well defined distal sulcus. Small specimens of the present species are difficult to distinguish from *Alisporites indarraensis* Segroves 1969.

Previous records. Turkey, Early Permian (Akyol, 1975); Australia, Early Permian (Foster, 1975); Germany, Late Permian (Schaarschmidt, 1963); Britain, Late Permian (Clarke, 1965); Libya, Permian-Triassic (Kar et al., 1972; Grignani, 1991); Pakistan, Permian (Balme, 1970); Iraq, Permo-Triassic (Nader et al., 1993b); Israel, Early

Permian (Eshet, 1983, 1990b); Iran, Permian (Ghavidel-syooki, 1997); Oman and Saudi Arabia (Stephenson et al., 2003; Stephenson and Filatoff, 2000)

Stratigraphic occurrence. Appears close to the base of the OSPZ5 Biozone; common throughout OSPZ5 and OSPZ6.

Infraturma STRIATITI Pant 1954

Genus Corisaccites Venkatachala & Kar 1966

Type species. *Corisaccites alutas* Venkatachala & Kar 1966

Corisaccites alutas Venkatachala & Kar 1966

Plate 5, figs. 10-12

Corisaccites stradivarii Utting 1994: p. 51; pl. 5, figs. 25-28; pl. 6, figs. 1-2.

Description. Pollen bilaterally symmetrical, bisaccate, monolete; amb slightly diploxylonoid to haploxylonoid. Corpus distinct, dark in colour; circular, latitudinally oval or longitudinally oval in outline; split into two reniform halves by a latitudinal

medial cleft. Corpus exine thick (1-2 μm), 'leathery' and unstructured in appearance; intexine only discernible in the floor of the medial cleft; intexine thin, light in colour, laevigate. Cappula distinct, narrow, parallel sided; length equal to length of corpus, width <30% that of corpus. Cappula often deep, notch-like. Rarely saccus connections join the sacci on the distal surface of the grain giving a 'monosaccate aspect'. Sacci large (approximately the same size or larger than the corpus), regular and semicircular in shape; strongly distally inclined. Sacci rigid, robust, dark in colour, usually 'leathery' and unstructured in appearance; rarely with fine, radially-arranged 'fibrous' infrareticulation. Offlap variable but usually small (10-20 μm). Monolete mark present in the intexine of the proximal cleft, usually short with slight tendency to geniculate shape.

Dimensions. 58(68)83 μm; 12 specimens

Remarks. *Corisaccites stradivarii* is purportedly distinguished from *Corisaccites alutas* by its larger size and narrower polar cleft (Utting, 1994). The sizes of the two forms are however very similar (Utting, 1994; total width 30(46)52 μm; Venkatachala and Kar, 1966, 46-64 μm x 50-69 μm) and as figured specimens show (e.g. Venkatachala and Kar, 1966; pl. 1, figs. 1-3) the width of the polar cleft may be variable in *Corisaccites alutas. Corisaccites stradivarii* is therefore considered a junior synonym of *Corisaccites alutas.*

Corisaccites Venkatachala & Kar 1966 was regarded by Visscher (1971) and Sinha (1972) as a genus based on overmacerated specimens of *Lueckisporites* whose intexine had been removed. The present author concurs with Balme (1970) in regarding the two genera as separate. However the more haploxylonoid specimens of

Lueckisporites virkkiae Potonié & Klaus emend. Clarke 1965 (referred to as norm B of Visscher (1971) and variant B of Clarke (1965) are more difficult to separate from *Corisaccites alutas* and may be better accommodated in that taxon. This would involve retaining the original concept of *Lueckisporites virkkiae* Potonié & Klaus 1954 as a diploxyloinoid bisaccate pollen grain with wide separation of sacci (see for example Potonié and Klaus, 1954; text-fig. 5, plate 10, fig. 3 holotype), and rejecting the emendation of Clarke (1965).

Previous records. Libya, Early Permian (Brugman et al*.,* 1988); Africa, Permian (Broutin et al., 1990); India, Early Permian (Venkatachala and Kar, 1966); Iran, Permian (Ghavidel-syooki, 1997); Pakistan, Early Permian (Balme, 1970); Oman and Saudi Arabia (Stephenson and Osterloff, 2002; Stephenson and Filatoff, 2000; Stephenson et al., 2003; Stephenson, 2006).

Stratigraphic occurrence. Appears within OSPZ3 Biozone; locally common in OSPZ4 Biozone; persists into OSPZ6.

Genus *Distriatites* Bharadwaj 1962

Type species. *Distriatites bilateralis* Bharadwaj 1962

Remarks. *Distriatites* Bharadwaj 1962 but has proportionately much larger sacci than *Hamiapollenites* Wilson emend. Tshudy & Kosanke 1966.

Distriatites insolitus Bharadwaj & Salujah 1964

Plate 6, figs. 1-3

Description. Pollen bilaterally symmetrical, bisaccate, taeniate; amb slightly diploxylonoid. Corpus circular or slightly latitudinally or longitudinally oval. Cappa with approximately 8-10 latitudinal taeniae; intexine, thin, indistinct. Distal face of corpus with 4-6 longitudinal distal taeniae; central pair of distal taeniae often slightly more inflated than the adjacent taeniae. Cappula width 50-70% of the corpus width; parallel sided, extends the length of the corpus. Sacci slightly distally inclined. Proximal taeniae 5-7 μm wide, parallel or convergent, with narrow striations between (<0.5 μm wide); exine of taeniae appears unexpanded. Distal taeniae 5-9 μm wide, parallel; 'striations' between the distal taeniae broader than on the cappa (width <5 μm); taeniae more expanded than on the cappa though internal structure is not discernible. Sacci detached equatorially on the proximal face with narrow onlap on the distal face. Sacci slightly smaller than the corpus; at the amb an obtuse angle is present at the joint between the saccus and corpus; sacci greater than semicircular in outline. Infrareticulation fine to coarse when discernible (brochi diameter 0.5-2 μm); infrareticulation often not distinct.

Dimensions. 50(70)101 μm; 15 specimens

Remarks. Foster (1979) reports that specimens from the Baralaba Coal Measures are smaller than those reported by Bharadwaj and Salujah (1964). The present specimens are similar in size to those of Foster. *Distriatites bilateralis* has a larger number of

distal taeniae than the present species and as Bharadwaj and Salujah (1964) note, the former is also more haploxylonoid.

Previous records. Iraq, Permian (Nader et al., 1993a, b); France, Permian (Doubinger et al., 1987); Libya, Ghzelian-Early Asselian (Loboziak and Clayton, 1988); Israel, Autunian (Eshet, 1990b; Eshet and Cousminer, 1986); Pakistan, Permian (Balme, 1970); Argentina, Permian (Playford and Dino, 2002; Césari and Gutiérrez, 2000)

Stratigraphic occurrence. Defines, along with *Hamiapollenites dettmannae, Indotriradites ater, Playfordiaspora cancellosa* and *Thymospora opaqua*, the base of the OSPZ5 Biozone (see Stephenson, 2006); common into OSPZ6.

Genus *Hamiapollenites* Wilson emend. Tshudy & Kosanke 1966

Type species. *Hamiapollenites saccatus* Wilson 1962

Hamiapollenites karrooensis (Hart 1963) Hart 1964

Plate 6, figs. 4-13.

Description. Pollen bilaterally symmetrical, bisaccate, taeniate; amb diploxylonoid.

Corpus circular or slightly longitudinally oval. Cappa with approximately 6-8 latitudinal taeniae; intexine, thin, indistinct. Distal face of corpus with 3-5 longitudinal distal taeniae; central pair of distal taeniae often slightly more inflated than the adjacent taeniae. Cappula width 70-90% of the corpus width; extends the length of the corpus. Sacci slightly distally inclined. Proximal taeniae 5-7 μm wide, parallel or convergent, with narrow 'striations' between (<0.5 μm wide); exine of taeniae appears unexpanded. Distal taeniae 4-9 μm wide, parallel or convergent; 'striations' between the taeniae broader than on the cappa (width <5 μm). Sacci detached equatorially on the proximal face with narrow onlap on the distal side. Sacci distinctly smaller than the corpus; sacci width approximately half that of corpus. At the amb an obtuse angle is present at the joint between the saccus and corpus; sacci greater than semicircular to almost circular in outline. Infrareticulation fine to coarse when discernible (brochi diameter 0.5-2 μm); infrareticulation often not distinct.

Dimensions. 50(82)87 μm; 20 specimens

Comparison. *Hamiapollenites bullaeformis* and *Hamiapollenites tractiferinus* have a single strongly defined single distal keel rather than a number of distal taeniae as in the present species. *Hamiapollenites saccatus* is smaller than the present species and has more numerous distal taeniae.

Previous records. See Playford and Dino (2000, p. 107). Recorded also from Iran (Ghavidel-syooki, 1997), and Iraq (Nader et al., 1993a).

Stratigraphic occurrence. Appears in small numbers in sparse assemblages within OSPZ4 but becomes very common at the base of the OSPZ5 Biozone; persists to the middle part of OSPZ5.

Hamiapollenites dettmannae Segroves 1969

Plate 7, figs. 1-14

Hamiapollenites andiraensis Playford & Dino, 2000; pl. 8, figs. 5-9; pl. 11, fig. 6, pl. 12, figs. 1, 2

Distriatites sp. A Stephenson et al., 2003; pl. 5, figs. 1, 11

Distriatites sp. A Stephenson, 2006; pl. 1., figs. 22, 23, 25.

Description. Pollen bilaterally symmetrical, bisaccate, taeniate; amb haploxylonoid to slightly diploxylonoid. Corpus circular or oval. Cappa with approximately 5-8 latitudinal taeniae; intexine, thin, indistinct. Distal face of corpus with one longitudinal distal taenia; often more prominent than the proximal taeniae. Cappula width 40-60% of the corpus width; extends the length of the corpus. Sacci slightly distally inclined. Proximal taeniae 3-10 μm wide, parallel or convergent, with narrow striations between (<0.5 μm wide); exine of taeniae appears unexpanded. Distal taenia 5-8 μm wide. Sacci detached equatorially on the proximal face with narrow onlap on the distal face. Sacci distinctly smaller than the corpus; sacci width approximately half that of corpus. At the amb an obtuse angle is present at the joint between the saccus and corpus; sacci greater than semicircular to almost circular in outline. Infrareticulation fine to coarse when discernible (brochi diameter 0.5-2 μm);

infrareticulation often not distinct.

Dimensions. 45(52)63 μm; 30 specimens

Remarks. The Oman specimens of *Hamiapollenites dettmannae* are very similar to the holotype (Segroves, 1969; pl. 11, fig. F) both in terms of size and distal morphology. However it is curious that Segroves (1969) considered *Hamiapollenites dettmannae* to have '…2-5 (usually 3)…' distal taeniae, since the holotype clearly has one. It is likely that Segroves (1969) mistook the dark areas at the distal sacci bases to be distal taeniae and thus recorded three distal taeniae in the holotype.

The holotype of *Hamiapollenites andiraensis* (Playford and Dino, 2000; pl. 8, fig. 6) is also similar in size and distal morphology to *Hamiapollenites dettmannae* and in other characteristics *Hamiapollenites andiraensis* is encompassed by *Hamiapollenites dettmannae.*

Hamiapollenites dettmannae is smaller, less diploxylonid, and has proportionately larger sacci than *Hamiapollenites karrooensis*. It differs from *Hamiapollenites fusiformis* in having thinner more translucent corpus exine, fewer proximal taeniae and in lacking a monolete mark.

Previous records. Australia, Permian (Segroves, 1969; Foster, 1979); Iraq, Permian (Nader et al., 1993b); Oman and Saudi Arabia (Stephenson et al., 2003; Stephenson, 2006; as *Distriatites* sp. A.)

Stratigraphic occurrence. Defines, along with *Distriatites insolitus, Indotriradites ater, Playfordiaspora cancellosa* and *Thymospora opaqua*, the base of the OSPZ5 Biozone (see Stephenson, 2006); common at the base of OSPZ5; persists into OSPZ6.

Turma PLICATES Naumova emend. Potonié 1960

Subturma COSTATES Potonié 1970

Infraturma COSTATI Jansonius 1963

Genus *Tiwariasporis* Maheshwari & Kar 1967

Type species. *Tiwariasporis flavatus*

?Tiwariasporis granulatus sp. nov.

Plate 8, figs. 1-15

Tiwariasporis sp. Berthelin et al. 2006, pl. 4, fig. 18 [not described].

Holotype. Plate 8, Figure 8, 9.

Paratype. Plate 8, Figure 1.

Type locality. Barik-36 well, Barik field, Oman slide 2617.10, sample depth 2617.10 m

Derivation of name. from its granulate appearance.

Description. Pollen bilaterally symmetrical, alete; amb oval or rarely circular. Proximal face striated; distal face ?laevigate with a single or small group (2 or 3) of medial longitudinal striations (<1 μm wide). Proximal face with 10-16 linear areas (2-5 μ wide) of closely spaced grana (<1 μm wide) that simulate the appearance of taeniae, with linear lighter, unornamented areas in between (<1 μm wide). A narrow saccus-like exine strip extends around the margin but does not encroach on either face to any degree; strip 2-3 μm wide, indistinctly infrareticulate.

Dimensions. Total width 56(71)98 μm; 20 specimens

Remarks. Maheshwari and Kar (1967) indicated that bands of closely-spaced ornament occurs on both faces in *Tiwariasporis*, however in the present specimens, ornament is mainly confined to one face of the grain while the other (?distal) face is mainly unornamented, apart from indistinct longitudinal striations or thickenings in the central part of the distal face. Thus the taxon is tentatively placed in *Tiwariasporis.*

Costapollenites ellipticus differs from the present species in having fewer taeniae not composed of dense granulate ornament (6-8 taeniae; Tshudy and Kosanke, 1966). It also has a more distinct saccate margin. *Vittatina ovalis* Klaus, 1963 also has taeniae in the strict sense (Klaus, 1963). Other species of *Tiwariasporis,* e.g. *Tiwariasporis flavatus*, *Tiwariasporis gondwanensis* and *Tiwariasporis simplex* are distinct from ? *Tiwariasporis granulatus* sp. nov. in being densely ornamented on the distal and proximal faces.

Previous records. Saudi Arabia, Permian (Berthelin et al., 2006).

Stratigraphic occurrence. Appears in the upper part of OSPZ5 and persists into OSPZ6; locally common in OSPZ6.

Subturma MONOCOLPATES Iverson & Troels-Smith 1950

Genus *Kingiacolpites* Tiwari & Moiz 1971

Type species. *Kingiacolpites barakarensis* Tiwari & Moiz 1971

Kingiacolpites subcircularis Tiwari & Moiz 1971

Plate 7, figs. 15, 16

Description. Pollen, bilaterally symmetrical, monosulcate; amb subcircular to oval. Exine 1-2 μm thick; micropunctate with spongeous appearance, puncta just perceptible (approximately 0.5 μm in diameter). Distal surface of the grain invaginated to produce broad or narrow sulcus that extends the length of the grain. Outline of sulcus varies in shape; most commonly biconvex, rarely fusiform. Some

grains are expanded so that the sulcus is less invaginated; these grains have a more broadly oval outline.

Dimensions. Maximum diameter of the long axis 43(49)56 μm; 20 specimens.

Previous records. Oman and Saudi Arabia (Stephenson and Osterloff, 2002; Stephenson et al. 2003, Stephenson et al., 2005; Stephenson, 2006; Stephenson et al., 2008; Love, 1994); ?Iran, Permian (Angiolini and Stephenson, 2008); India, Permian (Tiwari and Moiz, 1971)

Stratigraphic occurrence. Appears within OSPZ2 Biozone; locally common in OSPZ3 and OSPZ4 biozones; persists into OSPZ6.

Kingiacolpites subsaccatus sp. nov.

Plate 9, figs. 1-12

Holotype. Plate 9, Figure 5, 6.

Paratype. Plate 9, Figure 9.

Type locality. Barik-36 well, Barik field, Oman slide 2688.55, sample depth 2688.55 m

Derivation of name. From the poorly developed distal sacci that form the margins of the sulcus.

Description. Pollen, sulcate, bilaterally symmetrical; amb longitudinally or latitudinally oval to approximately diamond-shaped. Proximal surface indistinctly taeniate, 5-8 taeniae present with striations separating the taeniae. Taeniae parallel or distinctively asymptotic (rather like cross-bedding). Taeniae exoexine infrareticulate. Sulcus formed by subsaccate margins at the latitudinal margins of the corpus. Sulcus extends the length of the grain, narrower at the centre or rarely parallel-sided.

Comparison. The species differs from other species of *Kingiacolpites* in having distinctly subsaccate sulcus margins.

Stratigraphic occurrence. Appears to have a very narrow range within the lower part of OSPZ5.

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Figure captions

Text-Figure 1. Location of the Barik-36 well.

Text-Figure 2. Ranges and quantitative character of the described taxa in Barik-36.

Text-Figure 3. Measurement and orientation scheme used for bisaccate pollen.

Plate 1. Specimen locations are given first by the England Finder coordinate, then by BGS collection number (MPA, MPK), then by slide number. Dimensions of each specimen also given. *Indotriradites mundus* sp. nov., 1-15. All specimens from Barik-36 well.

1, C39, 2615.6, MPK 13668, 80 µm, proximal focus.

2, C39, 2615.6, MPK 13668, 80 µm, distal focus.

3, O29, 2615.6, MPK 13669, 75 µm, proximal focus.

4, O29, 2615.6, MPK 13669, 75 µm, distal focus.

5, G40/1, 2615.6, MPK 13670, 85 µm.

6, M24, 2615.6, MPK 13671, 80 µm, proximal focus.

7, M24, 2615.6, MPK 13671, 80 µm, distal focus.

8, V38/2, 2615.6, MPK 13672, 90 µm.

9, U38/1, 2615.6, MPK 13673, 63 µm.

10, P29, 2615.6, MPK 13674, 70 µm, proximal focus.

11, P29, 2615.6, MPK 13674, 70 µm, distal focus.

12, P29, 2615.6, MPK 13674, width of field approx 35 µm, zonal focus.

13, P29, 2615.6, MPK 13674, width of field approx 30 µm, proximal focus.

14, O29, 2615.6, MPK 13669, width of field approx 30 µm, proximal focus.

15, G40/1, 2615.6, MPK 13670, width of field approx 30 µm, zonal focus.

Plate 2. *Indotriradites ater* sp. nov., 1-12.

1, J50, 2785.1, SR-11, Collection of Petroleum Development Oman, 80 µm.

2, J50, 2785.1, SR-11, Collection of Petroleum Development Oman, 80 µm, width of field approx 30 µm, distal focus.

3, K39/2, 2669.64, Barik-36, MPK 13675, 70 µm, proximal focus.

4, K39/2, 2669.64, Barik-36, MPK 13675, 70 µm, distal focus.

5, H37, 2670.65, Barik-36, MPK 13676, 70 µm, proximal focus.

6, H37, 2670.65, Barik-36, MPK 13676, 70 µm, distal focus.

7, E40, 2760.8, Barik-36, MPK 13677, 70 µm, proximal focus.

8, E40, 2760.8, Barik-36, MPK 13677, 70 µm, zonal focus.

9, E40, 2760.8, Barik-36, MPK 13677, 70 µm, distal focus.

10, N46/4, 2670.99, Barik-36, MPK 13678, 60 µm, distal focus.

11, N46/4, 2670.99, Barik-36, MPK 13678, 60 µm, zonal focus.

12, H37, 2670.65, Barik-36, MPK 13676, width of field approx 30 µm, distal focus.

Plate 3. All specimens from Barik-36 well.

Laevigatosporites callosus Balme 1970, 1-3.

1, F43/1, 2615.6, MPK 13679, 65 µm.

2, D53/4, 2615.6, MPK 13680, 70 µm.

3, K32, 2615.6, MPK 13681, 75 µm.

Thymospora opaqua Singh 1964, 4-12.

4, P49, 2615.6, MPK 13682, 28 µm.

5, F51/1, 2615.6, MPK 13683, 28 µm.

6, J30, 2615.6, MPK 13684, 30 µm.

7, K43/1, 2615.6, MPK 13685, 28 µm, distal focus.

8, K43/1, 2615.6, MPK 13685, 28 µm, proximal focus.

9, P49, 2615.6, MPK 13686, 28 µm, distal focus.

10, P49, 2615.6, MPK 13686, 28 µm, proximal focus.

11, P32/3, 2615.6, MPK 13687, 45 µm, proximal focus.

12, P32/3, 2615.6, MPK 13687, 45 µm, distal focus.

Plate 4. All specimens from Barik-36 well. *Kendosporites robustus* sp. nov.1-9.

1, D30/2, 2616.1, MPK 13688, 80 µm.

2, E35/1, 2616.1, MPK 13689, 80 µm.

3, E39/3, 2616.1, MPK 13690, 60 µm; upper half distal focus, lower half proximal focus.

4, F29/2, 2616.1, MPK 13691, 100 µm.

5, N40, 2616.1, high focus, MPK 13692, 80 µm.

6, N40, 2616.1, low focus, MPK 13692, 80 µm.

7, G41, 2616.1, MPK 13693, 75 µm, proximal focus.

8, G41, 2616.1, MPK 13693, 75 µm, distal focus.

9, G43/3, 2616.1, MPK 13694, 85 µm.

Plate 5. All specimens from Barik-36 well.

Densipollenites indicus Bharadwaj 1962, 1-3.

1, B40/4, 2670.65, MPK 13695, 85 µm.

2, H30/2, 2670.65, MPK 13696, 90 µm.

3, K43/4, 2670.65, MPK 13697, 90 µm.

?*Florinites balmei* Stephenson & Filatoff 2000, 4-6.

4, G34, 2612.2, MPK 13698, 40 µm.

5, Q35, 2612.2, MPK 13699, 40 µm.

6, Q47, 2612.2, MPK 13700, 35 µm.

Alisporites nuthallensis Clarke 1965, 7-9.

7, B41, 2668.14, MPK 13701, 60 µm.

8, E30/3, 2668.14, MPK 13702, 60 µm.

9, C32, 2668.14, MPK 13703, 60 µm.

Corisaccites alutas Venkatachala & Kar 1966, 10-12.

10, N29, 2669.64, MPK 13704, 83 µm, distal view.

11, N29, 2669.64, MPK 13704, 83 µm, proximal view.

12, R30/2, 2669.64, MPK 13705, 78 µm.

Plate 6. All specimens from Barik-36 well.

Distriatites insolitus Bharadwaj & Salujah 1964, 1-3.

1, V21/2, 2688.0, MPK 13706, 85 µm.

2, C41/4, 2688.0, MPK 13707, 101 µm.

3, K51/4, 2688.0, MPK 13708, 70 µm.

Hamiapollenites karrooensis (Hart) Hart 1964, 4-13.

4, P42/4, 2687.7, MPK 13709, 80 µm.

5, T42, 2687.7, MPK 13710, 50 µm across cappa, compression normal to proximodistal axis.

6, K40, 2687.7, MPK 13711, 60 µm.

7, L40/2, 2687.7, MPK 13712, 66 µm.

8, N27/4, 2687.7, MPK 13713, 81 µm.

9, N24/1, 2687.7, MPK 13714, 82 µm.

10, Q35/4, 2687.7, MPK 13715, 75 µm, distal saccus detachment focus.

11, Q35/4, 2687.7, MPK 13715, 75 µm, proximal focus.

12, Q35/3, 2687.7, MPK 13716, 76 µm, distal saccus detachment focus.

13, Q35/3, 2687.7, MPK 13716, 76 µm, proximal focus.

Plate 7. *Hamiapollenites dettmannae* Segroves 1969, 1-14.

1, N32/4, 2635.28, MPK 13717, 50 µm.

2, O51/3, 2635.28, MPK 13718, 45 µm.

3, T45, 2635.28, MPK 13719, 50 µm.

4, H26, 2635.28, MPK 13720, 48 µm.

5, G34, 2635.28, MPK 13721, 50 µm.

6, N31, 2635.28, MPK 13722, 53 µm.

7, C35/3, 2635.28, MPK 13723, 63 µm.

8, F29/3, 2635.28, MPK 13724, 58 µm.

9, N32/4, 2635.28, MPK 13717, field of view approximately 30 µm.

10, H42, 2635.28, MPK 13725, 53 µm.

11, D30, 2669.64, MPK 13726, 50 µm.

12, F52/3, 2669.64, MPK 13727, 46 µm.

13, Q46, 2669.64, MPK 13728, 46 µm.

14, Q46, 2669.64, MPK 13728, field of view approximately 30 µm.

Kingiacolpites subcircularis Tiwari & Moiz 1971, 15-16.

15, M50/3, 2754.2, MPK 13729, 49 µm, proximal view.

16, M50/3, 2754.2, MPK 13729, 49 µm, distal view.

Plate 8. *?Tiwariasporis granulatus* sp. nov., 1-14.

1, D23/1, 2617.35, MPK 13730, 98 µm.

2, 026, 2617.35, MPK 13731, 70 µm.

3, U33/4, 2617.35, MPK 13732, 86 µm.

4, M33/1, 2617.1, MPK 13733, 54 µm.

5, K44, 2617.35, MPK 13734, 56 µm, proximal focus.

6, K44, 2617.35, MPK 13734, 56 µm, distal focus.

7, S34/2, 2617.35, MPK 13735, 76 µm.

8, E26/3, 2617.35, MPK 13736, 88 µm.

9, V26/3, 2617.35, MPK 13737, 64 µm.

10, S27/4, 2617.1, MPK 13738, 64 µm, distal focus.

11, S27/4, 2617.1, MPK 13738, 64 µm, proximal focus.

12, J23, 2613.49, MPK 13739, 82 µm, distal focus.

13, J23, 2613.49, MPK 13739, 82 µm, proximal focus.

14, O39/3, 2613.32, MPK 13740, 75 µm, distal focus.

Plate 9. *Kingiacolpites subsaccatus* sp. nov., 1-12.

1, H24/4, 2688.55, MPK 13741, 89 µm.

2, F29, 2688.45, MPK 13742, 88 µm.

3, S31, 2688.45, MPK 13743, 77 µm.

4, R34, 2687.9, MPK 13744, 82 µm.

5, J33, 2687.7, MPK 13745, 85 µm, distal focus.

6, J33, 2687.7, MPK 13745, 85 µm, proximal focus.

7, D50/3, 2687.55, MPK 13746, 76 µm.

8, E44/1, 2687.55, MPK 13747, 69 µm.

9, G52/3, 2687.55, MPK 13748, 81 µm.

10, O39/4, 2687.55, MPK 13749, 72 µm, proximal focus.

11, O39/4, 2687.55, MPK 13749, 72 µm, distal focus.

12, J33, 2687.7, MPK 13745, field of view approximately 30 µm.

Appendix: full author citation of species mentioned in text

?*Florinites balmei* Stephenson & Filatoff 2000

Alisporites australis de Jersey 1962

Alisporites indarraensis Segroves 1969

Camptotriletes warchianus Balme 1970

Corisaccites stradivarii Utting 1994

Densipollenites densus Bharadwaj and Srivastava 1969

Densipollenites indicus Bharadwaj 1962

Densipollenites invisus Bharadwaj & Salujah 1964

Densipollenites pullus Segroves 1969

Distriatites bilateralis Bharadwaj 1962

Distriatites insolitus Bharadwaj & Salujah 1964

Falcisporites stabilis Balme 1970

Florinites flaccidus Menéndez & Azcuy 1973

Gondisporites variabilis Anderson 1977

Hamiapollenites bullaeformis (Samoilovich) Jansonius 1962

Hamiapollenites fusiformis Marques-Toigo 1974

Hamiapollenites saccatus Wilson 1962

Hamiapollenites tractiferinus (Samoilovich) Jansonius 1962

Indotriradites fibrosus Stephenson et al. 2008

Indotriradites niger (Segroves) Backhouse 1991

Indotriradites splendens (Balme & Hennelly) Foster 1979

Kendosporites striatus (Salujah) Surange & Chandra 1974

Kingiacolpites subcircularis Tiwari & Moiz 1971

Laevigatosporites robustus Kosanke 1950

Laevigatosporites striatus (Salujah) Anderson 1977

*Laevigatosporites vulgari*s Ibrahim 1933

Latosporites intragranulosus Singh 1964

Latosporites planorbis Imgrund 1960

Playfordiaspora cancellosa (Playford & Dettmann) Maheshwari & Banerji 1975

Protohaploxypinus uttingii Stephenson & Filatoff 2000

Pteruchipollenites owensii Stephenson and Filatoff 2000

Pyramidosporites cyathodes Segroves 1967

Thymospora cicatricosa (Balme & Hennelly) Hart 1965

Thymospora opaqua Singh 1964

Thymospora pseudothiessenii (Kosanke) Wilson & Venkatachala 1963

Thymospora thiessenii (Kosanke) Wilson & Venkatachala 1963

Tiwariasporis flavatus Maheshwari & Kar 1967

Tiwariasporis gondwanensis (Tiwari) Maheshwari & Kar 1967

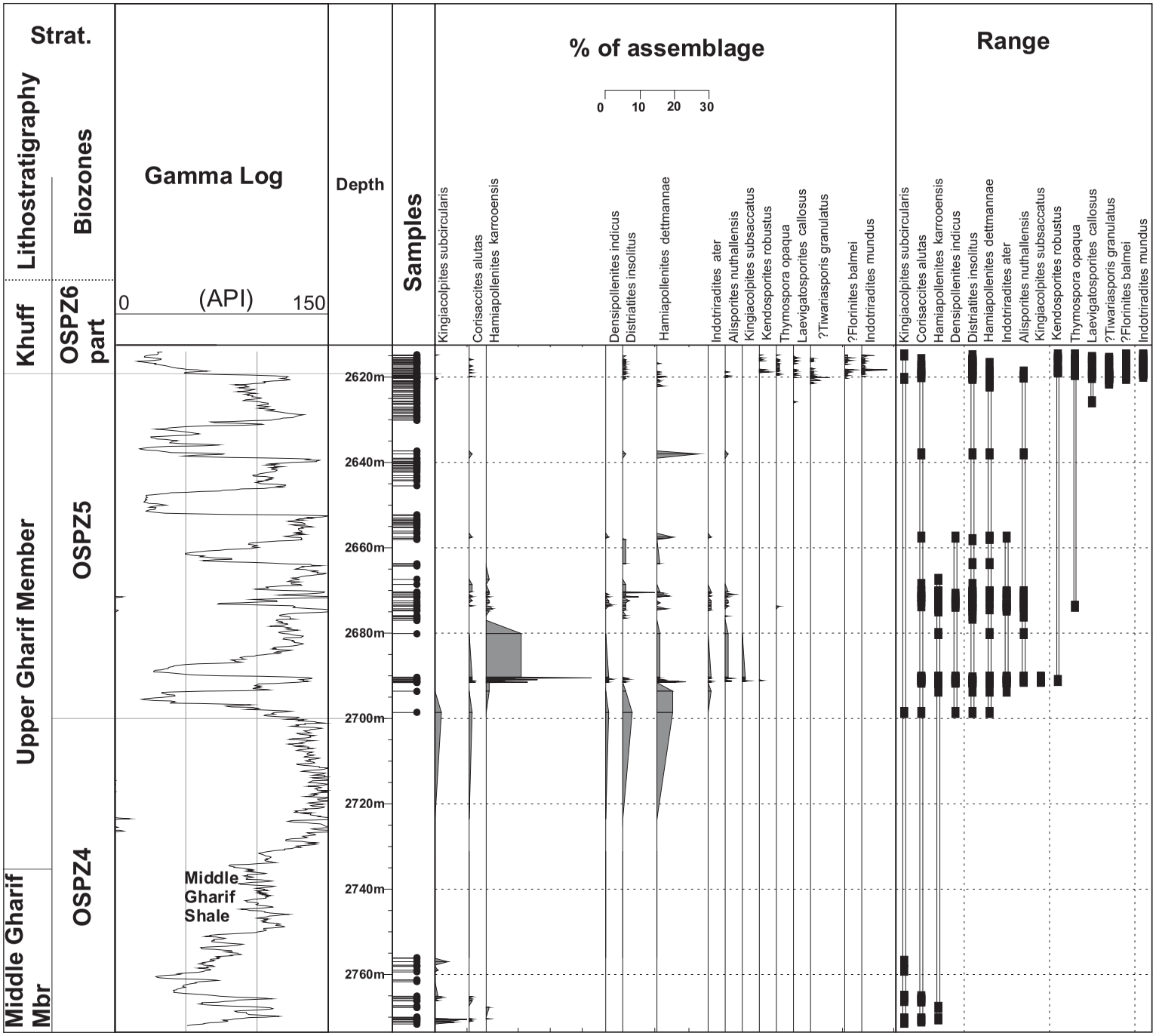
Tiwariasporis simplex (Tiwari) Maheshwari & Kar 1967

Triplexisporites cf. *playfordii* (de Jersey & Hamilton) Foster 1979

Vittatina ovalis Klaus 1963

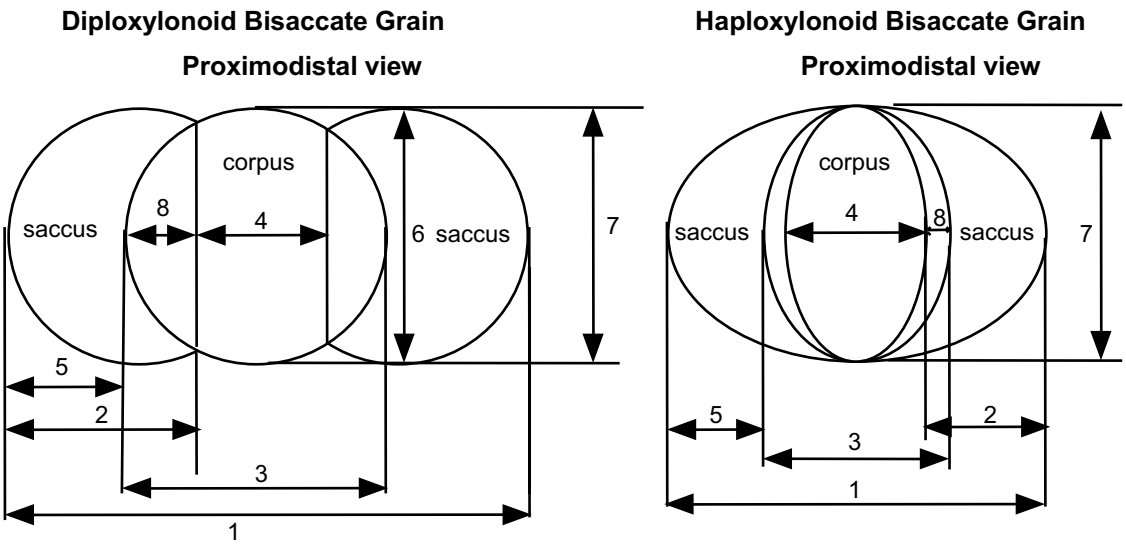

A
58°E
Arabian Gulf
United Arab Emirates
North Oman Mountains
Sultanate of Oman
Kingdom of Saudi Arabia
Ghaba Salt Basin
Huqf Axis
Barik-36
Haushi-Huqf Uplift Area
20°N
South Oman Salt Basin
Republic of Yemen
Arabian Sea
100 km approx.

Figure1

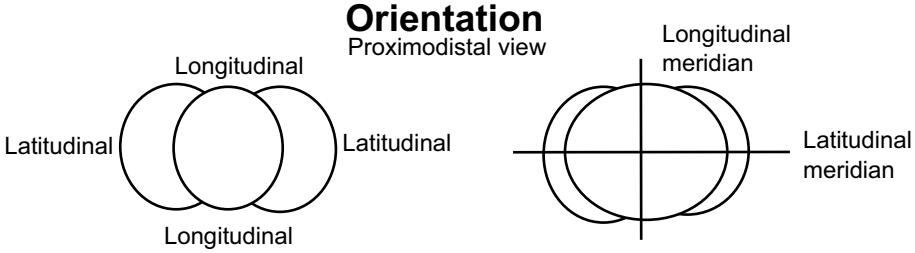

Strat.
Lithostratigraphy
Biozones
Khuff
OSPZ6 part
Upper Gharif Member
OSPZ5
OSPZ4
Middle Gharif Mbr
Middle Gharif Shale
Gamma Log
0
(API)
150
Depth
2620m
2640m
2660m
2680m
2700m
2720m
2740m
2760m
Samples
% of assemblage
0
10
20
30
Kingiacolpites subcircularis
Corisaccites alutas
Hamiapollenites karrooensis
Densipollenites indicus
Distriatites insolitus
Hamiapollenites dettmannae
Indotriradites ater
Alisporites nuthallensis
Kingiacolpites subsaccatus
Kendosporites robustus
Thymospora opaqua
Laevigatosporites callosus
?Tiwariasporis granulatus
?Florinites balmei
Indotriradites mundus
Range
Kingiacolpites subcircularis
Corisaccites alutas
Hamiapollenites karrooensis
Densipollenites indicus
Distriatites insolitus
Hamiapollenites dettmannae
Indotriradites ater
Alisporites nuthallensis
Kingiacolpites subsaccatus
Kendosporites robustus
Thymospora opaqua
Laevigatosporites callosus
?Tiwariasporis granulatus
?Florinites balmei
Indotriradites mundus

Text-Fig 2

Measurement



Orientation

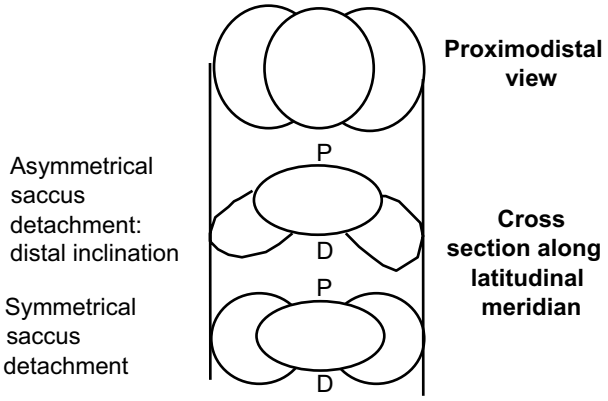


Key

1 Total Width
2 Saccus Width
3 Corpus Width
4 Cappula Width
5 Saccus Offlap
6 Saccus Length
7 Corpus Length
8 Saccus Onlap

Saccus detachment

P= proximal pole, D= distal pole



Text-Fig.3

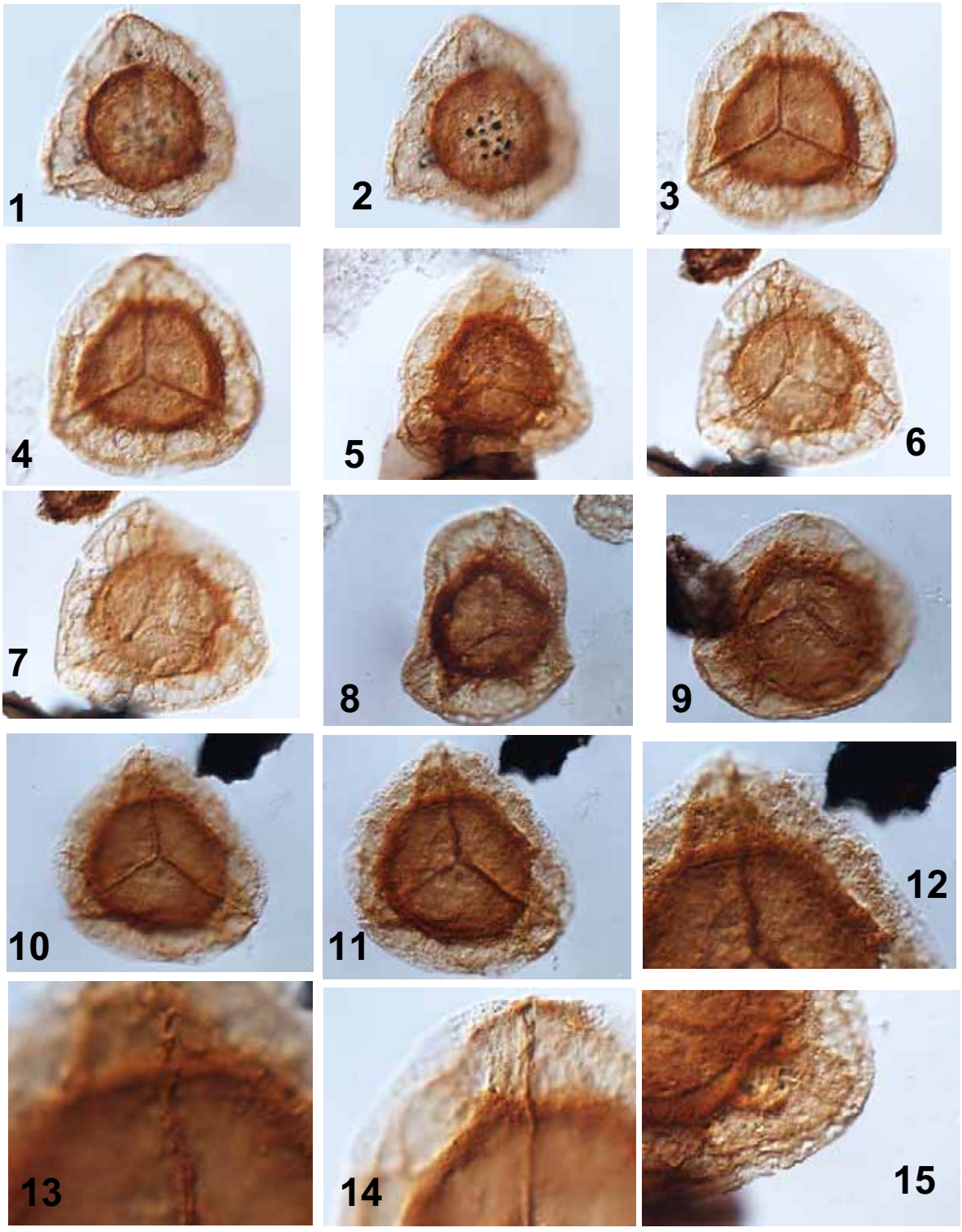
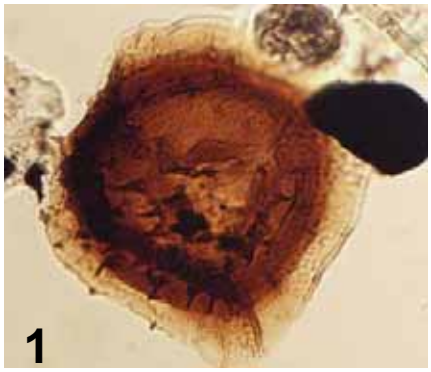
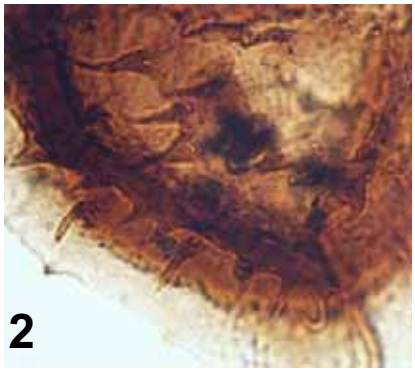
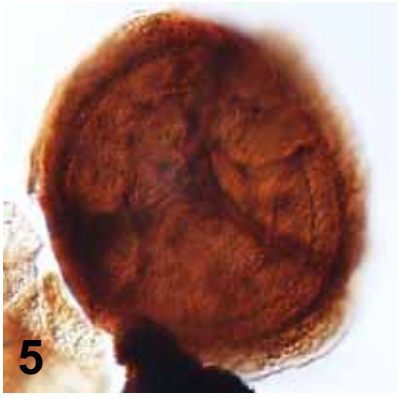
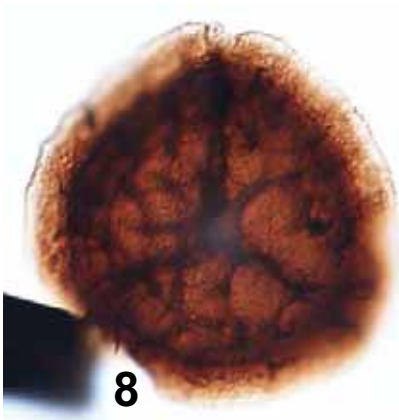


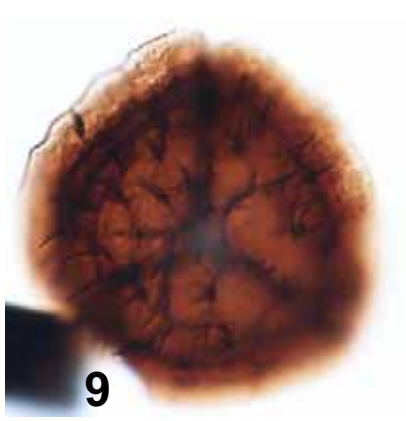
PLATE 1

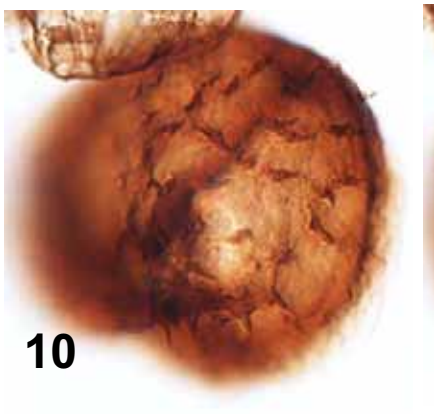


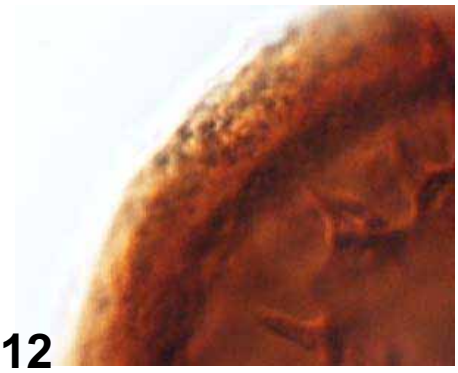












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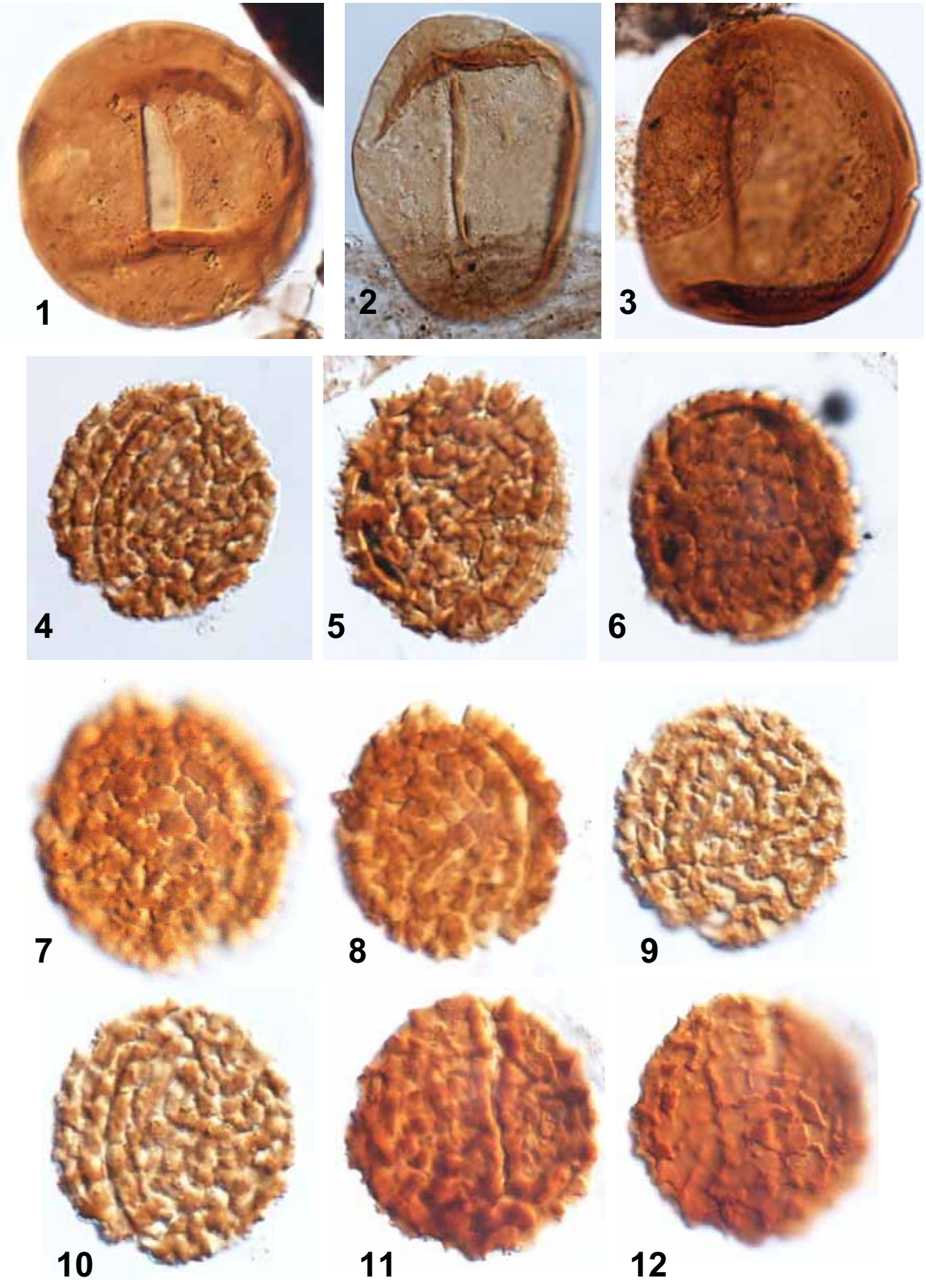
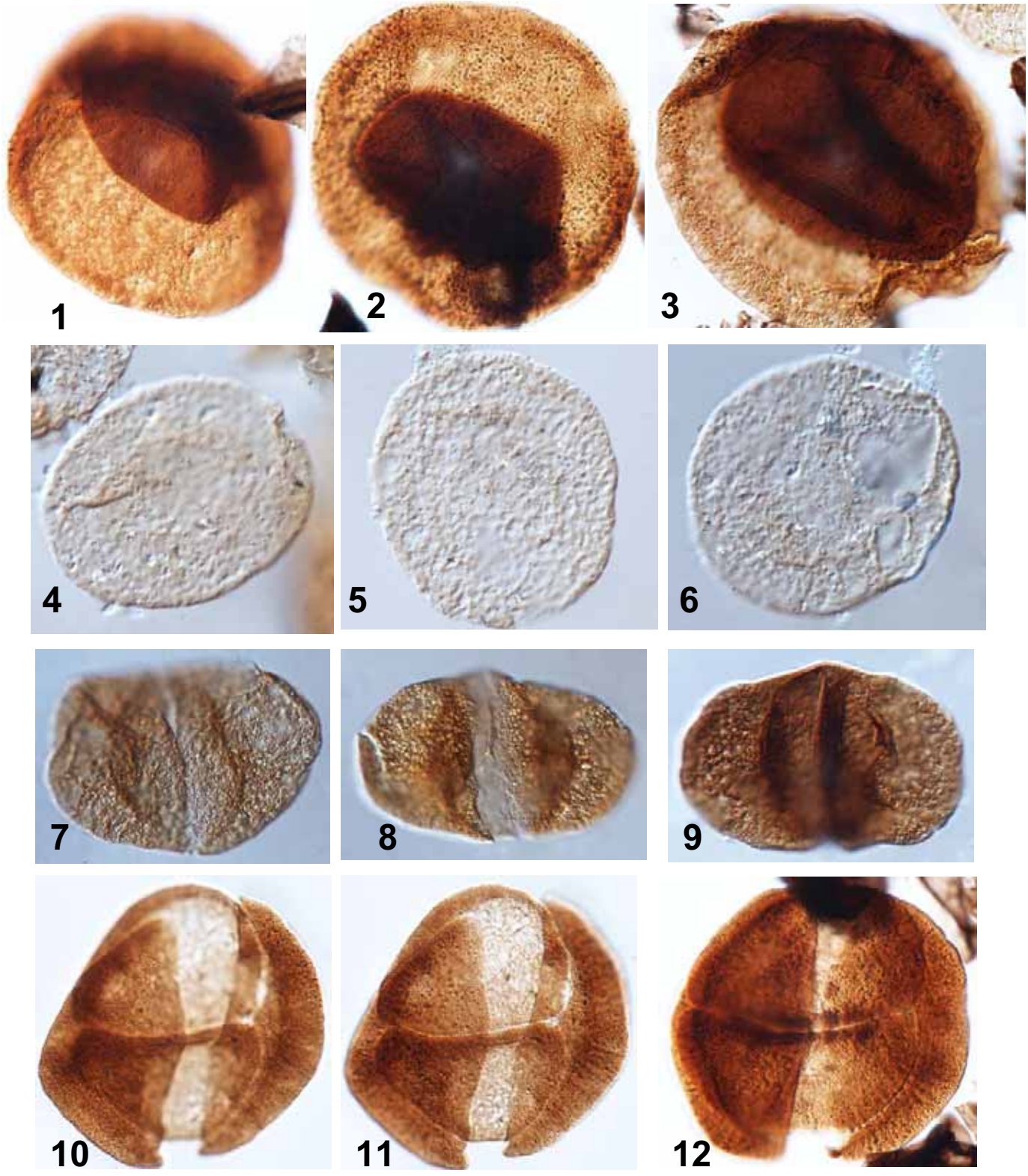


PLATE 3

PLATE 4



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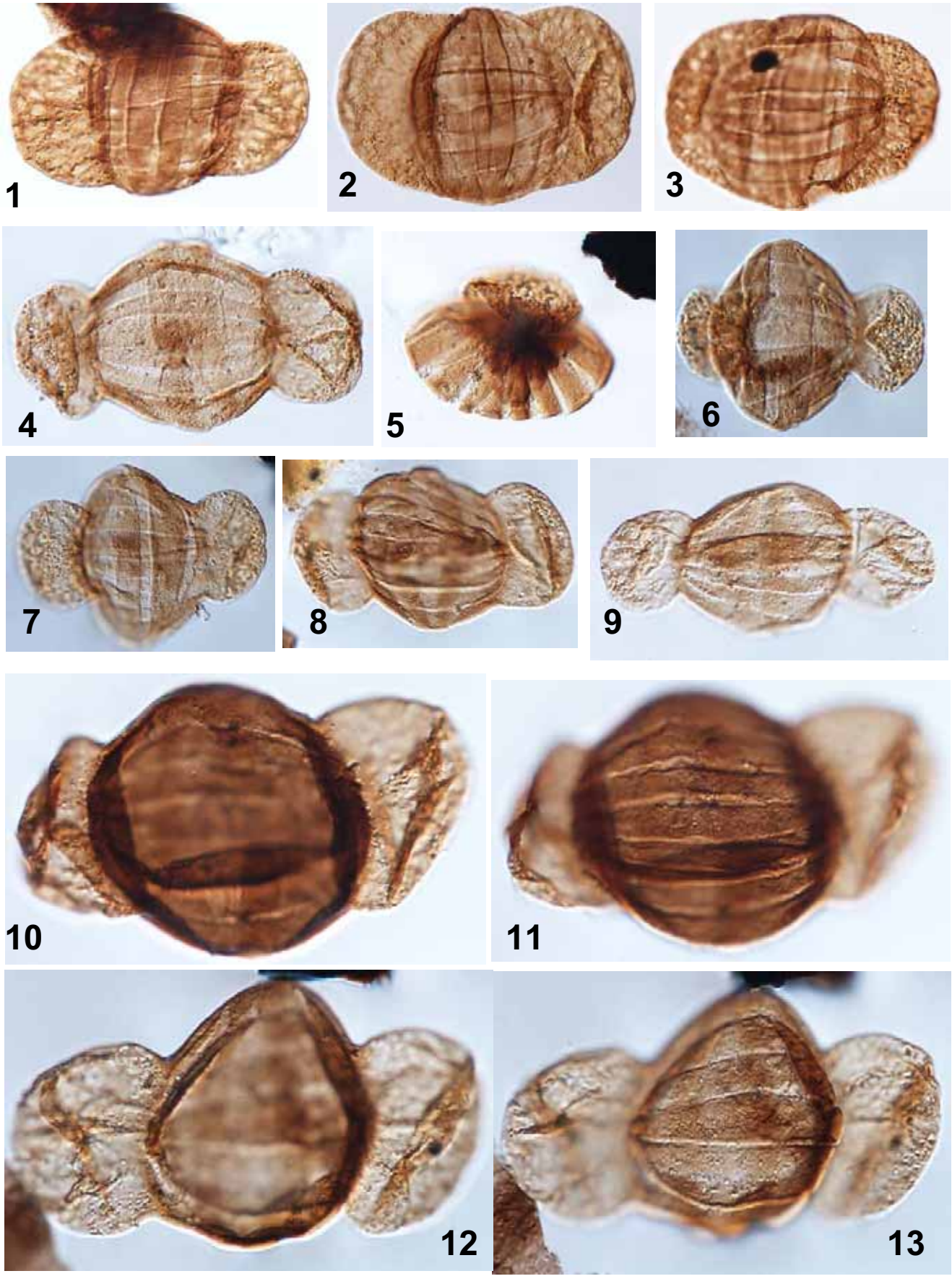

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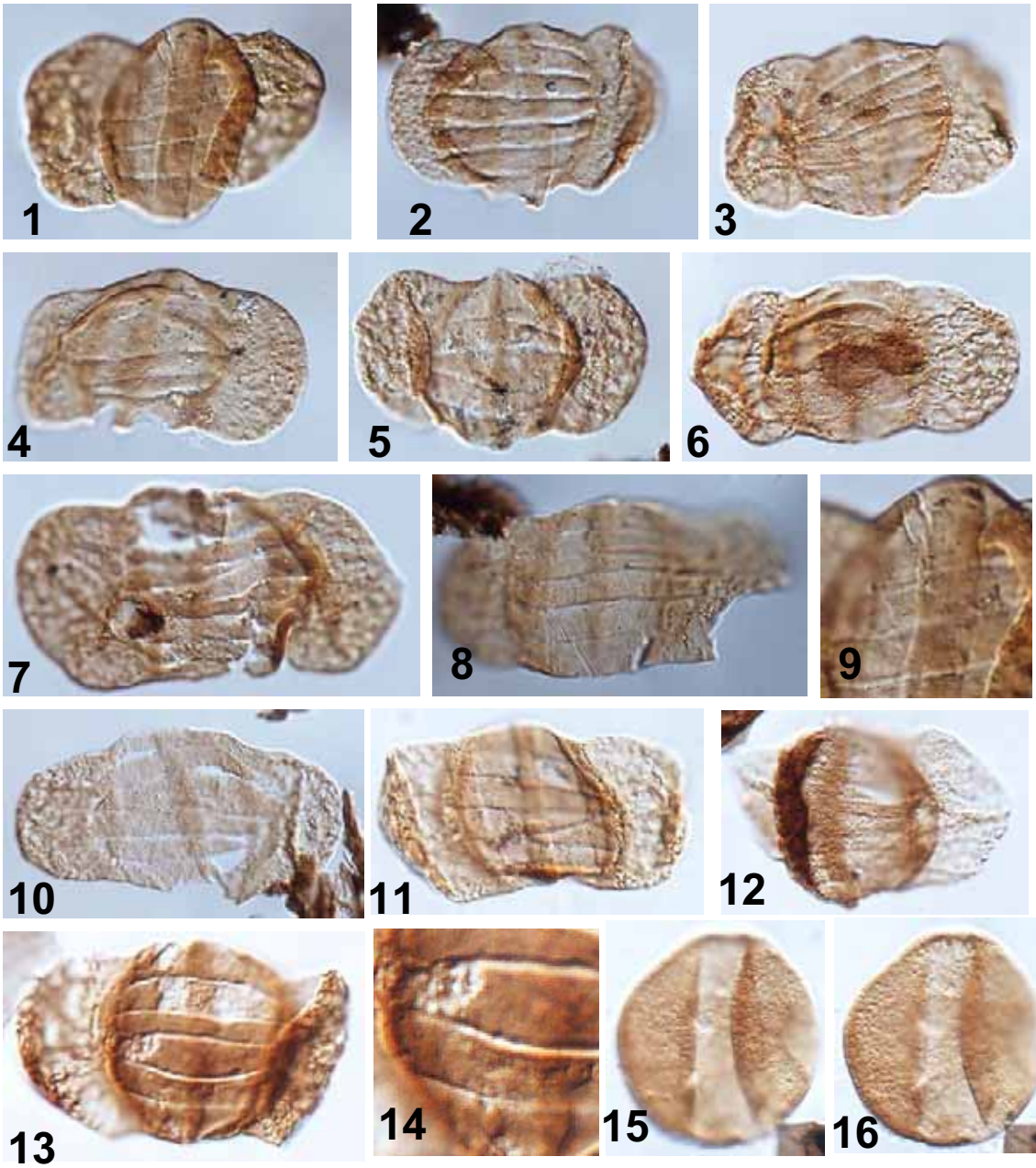

PLATE 7

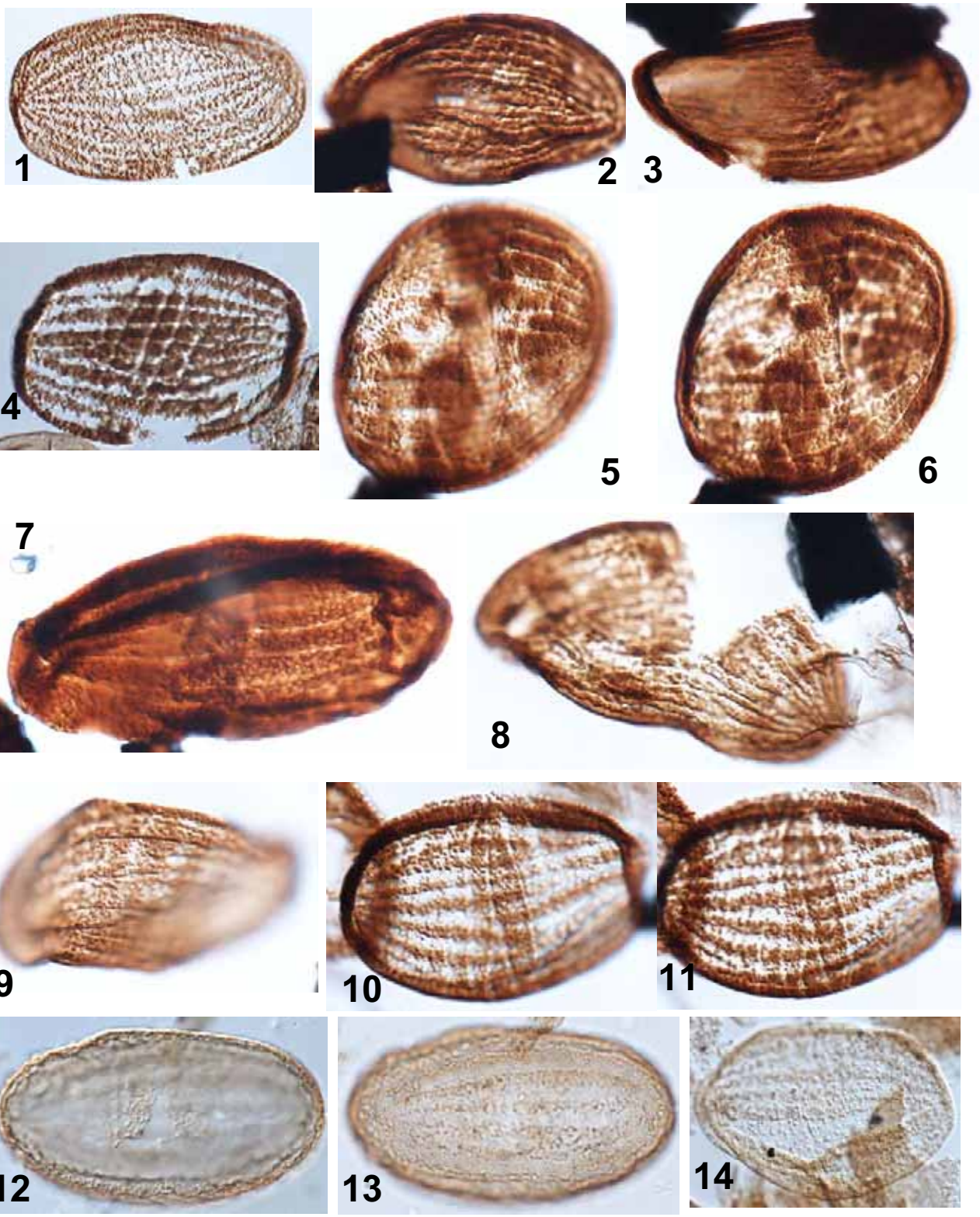

PLATE 8

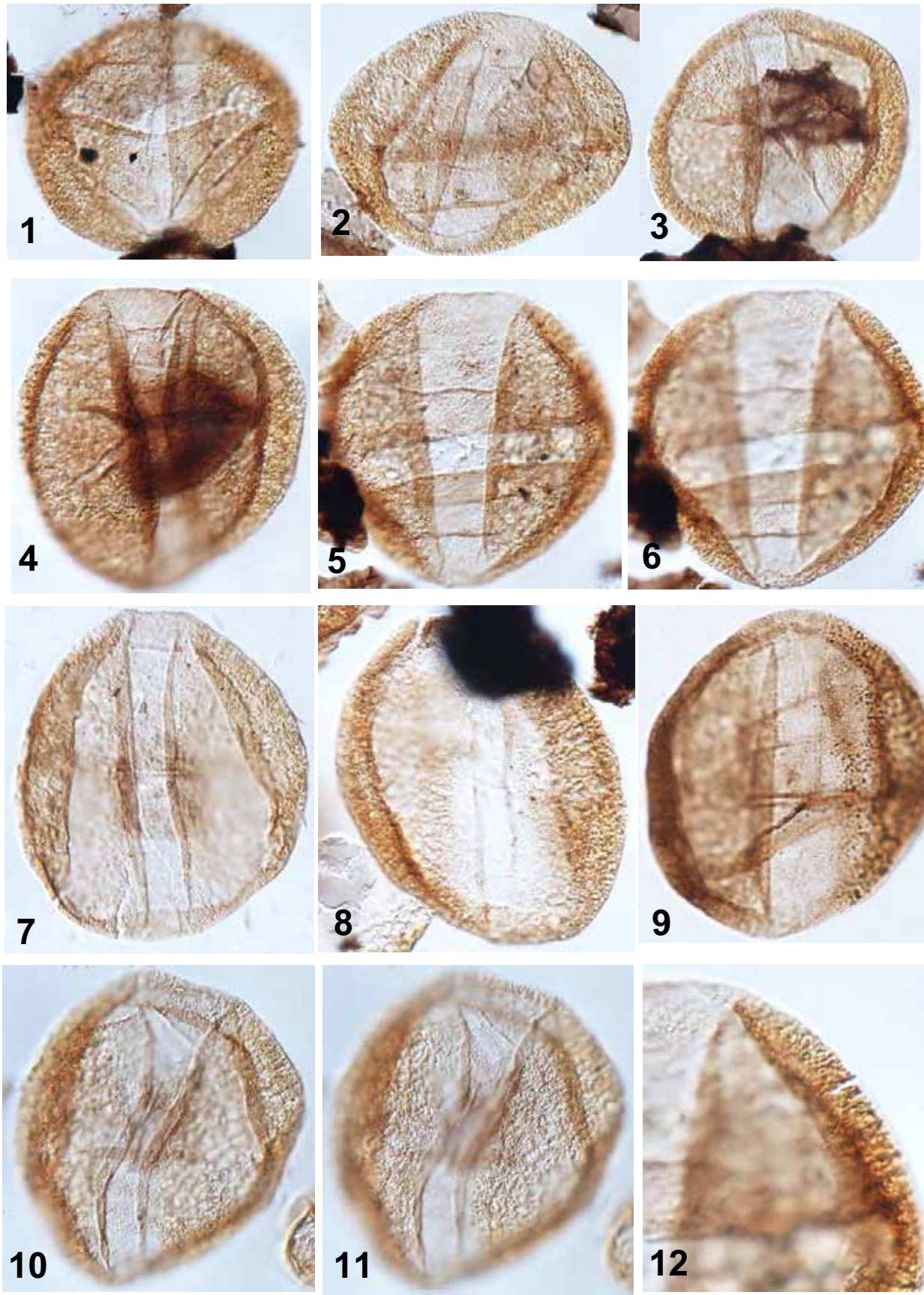

PLATE 9