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Stratigraphic Note: Update of the standard Arabian Permian palynological biozonation; definition and description of OSPZ5 and 6

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SUMMARY

A standard Early and Middle Permian palynological biozonation was erected for Arabia in 2003 (Stephenson et al., 2003), following extensive palynological work in sequences in Oman and Saudi Arabia. Oman-Saudi Arabia Palynozone 4 (OSPZ4), and the succeeding two biozones OSPZ5 and 6, were established in the sporadically palyniferous Lower and Middle Permian sequences of Oman and Saudi Arabia. In 2003, the exact stratigraphic relationships between OSPZ4, 5 and 6 were not clear because in no section were the biozones seen to be in contact with one another. To express this uncertainty, the bases of OSPZ5 and 6 were represented by dashed lines in figure 2 of Stephenson et al. (2003).

New work on the upper and middle Gharif members in Barik-36, Oman indicates: (1) the transition from OSPZ4 to 5 assemblages; (2) the transition from OSPZ5 to 6 assemblages; and (3) clearly that OSPZ6 is stratigraphically above OSPZ5 in Oman. The stratigraphic distribution of key taxa in Barik-36 allows the following definitions: the base of OSPZ5 is defined as the horizon of the combined first uphole appearance of *Distriatites* sp. A, *Distriatites insolitus, Indotriradites* sp. C, *Playfordiaspora cancellosa* and *Thymospora opaqua*, and the base of OSPZ6 is defined as the horizon of the first uphole appearance of *?Florinites balmei.* Ages for the OSPZ5 and 6 biozones remain substantially the same as indicated originally in Stephenson et al. (2003), though it is probable that the lower part of OSPZ6 is of Wordian age, extending into the Capitanian.

INTRODUCTION

A standard Permian palynological biozonation was erected for Arabia in 2003 (Stephenson et al., 2003), following extensive palynological work in sequences in Oman and Saudi Arabia (Figure 1). The biozonation consisted of a framework of eight biozones for the uppermost Carboniferous to Middle Permian strata in the region. The lower five biozones (OSPZ 1, 2, 3a to 3c) were established in the palyniferous uppermost Carboniferous to Lower Permian sequence in Oman, and to some extent these are recognisable in sequences of central and southern Saudi Arabia. OSPZ1 (Oman and Saudi Arabia Palynological Zone 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 new fusulinid evidence from the subsurface Haushi Limestone, locally present toward the top of the lower Gharif member (Angiolini et al., 2006).

OSPZ4 and the succeeding two biozones were established in the sporadically palyniferous Middle and Upper Permian sequences of Oman and Saudi Arabia. OSPZ5 assemblages had been 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, Figure 1). These assemblages were from upper Gharif clastic sedimentary rocks 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, Figure 1; see Stephenson and Filatoff, 2000), and from the lower Khuff Formation carbonates in Oman and Saudi Arabia.

The older assemblages were designated as OSPZ5, and these were characterised by *Cedripites* sp. B, *Distriatites* sp. A, *Distriatites insolitus*, *Densipollenites indicus, Playfordiaspora cancellosa*, *Pteruchipollenites owensii* and *Thymospora opaqua* (full author citations in Appendix). 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 persisted.

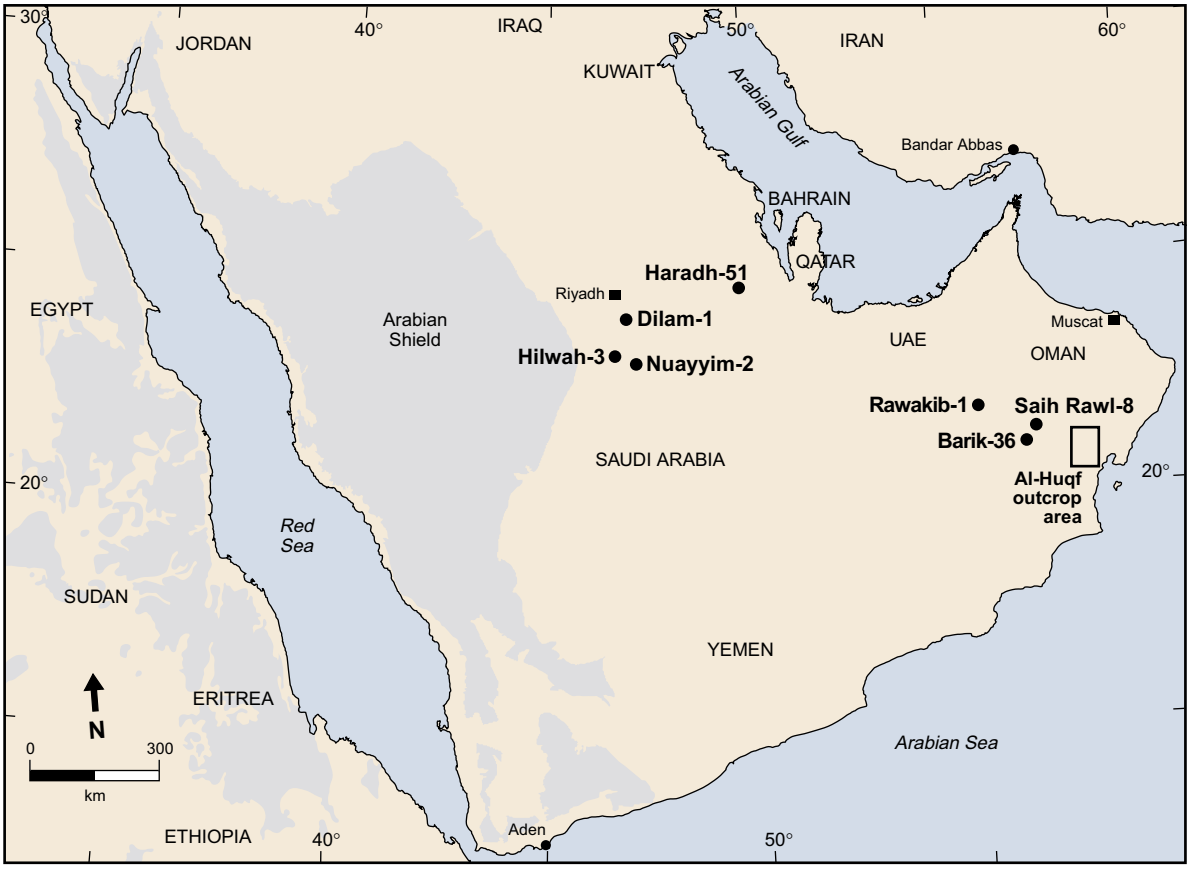


Figure 1: Location of wells and outcrop sections referred to in the text.

In 2003, the exact stratigraphic relationships between OSPZ4, 5 and 6 were not clear because in no section were the biozones seen to be in contact with one another. For example, core samples from the OSPZ5 reference section from 9,029.5–9,062.5 ft (2,752–2,762 m) in Saih Rawl-8 well in northcentral Oman could not be related to OSPZ4 or 6 in the same well because the corresponding intervals were not cored. To express this uncertainty, the bases of OSPZ5 and 6 were represented by dashed lines in figure 2 of Stephenson et al. (2003).

New work on the densely sampled upper and middle Gharif members in Petroleum Development Oman (PDO) Barik-36 well indicates: (1) the transition from OSPZ4 to 5 assemblages; (2) the transition from OSPZ5 to 6 assemblages; and (3) clearly that OSPZ6 is stratigraphically above OSPZ5. Data from many other well sections sampled more sporadically for core, sidewall samples and cuttings, as well as limited surface palynology studies, support the new findings. Ages for the OSPZ5 and 6 biozones remain substantially the same as indicated originally in Stephenson et al. (2003), though it is probable that the lower part of OSPZ6 is of Wordian age, extending into the Capitanian.

Barik-36 Well Section

Barik-36 is an extensively cored section through the middle and upper Gharif members in the northcentral Oman Barik Field (Figure 1). Palynological analysis was carried out on 196 core samples between 2,768.87 and 2,612.04 m (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 rather blocky gamma-ray signature (Figure 2).

Ranges of selected palynomorphs are shown in Figure 2. Between 2,771.67 and 2,756.15 m (middle Gharif member) the assemblages are typical of OSPZ4 with common indeterminate bisaccate, monosaccate and taeniate bisaccate pollen. *Florinites flaccidus, Barakarites* spp., *Kingiacolpites subcircularis* and *Vesicaspora* spp. also occur. Between 2,698.6 and 2,619.73 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 insolitus* and *Distriatites* sp. A). Spores such as *Indotriradites* sp. C and *Playfordiaspora cancellosa* also occur, as well as distinctive colpate pollen such as *Weylandites* sp. X. Between 2,619.73 and 2,614.84 m is a section consisting of heterolithic beds followed by the Khuff Formation carbonates. This is termed the "Khuff transition section" and its palynology is dominated by bisaccate pollen and cingulizonate spores. Most assemblages also contain significant numbers of probable fresh or low-salinity aquatic algal spores (e.g. *Tetraporina* spp. and *Botryococcus* spp.) as well as rare marine indicators (scolecodonts, microforaminiferal test linings and spinose acritarchs). *?Florinites balmei* is common above 2,620.3 m, occurring in almost all the samples.

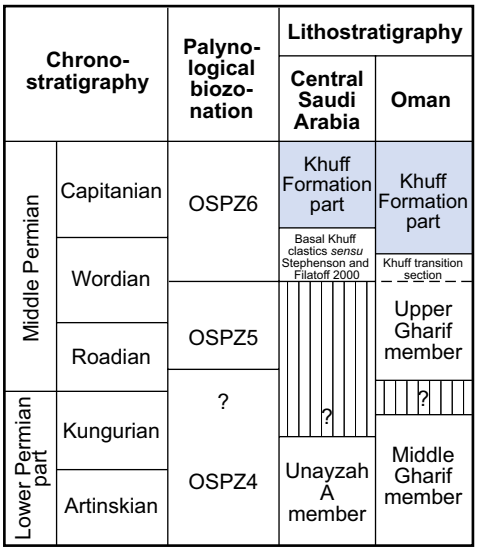


Figure 3: Correlation of OSPZ4 to 6 from Oman (Al-Huqf outcrop and Barik-36) to Saudi Arabia (Dilam-1, Haradh-51, Hilwah-3 and Nuayyim-2). The deposition of the Khuff Formation continued into the Early Triassic.

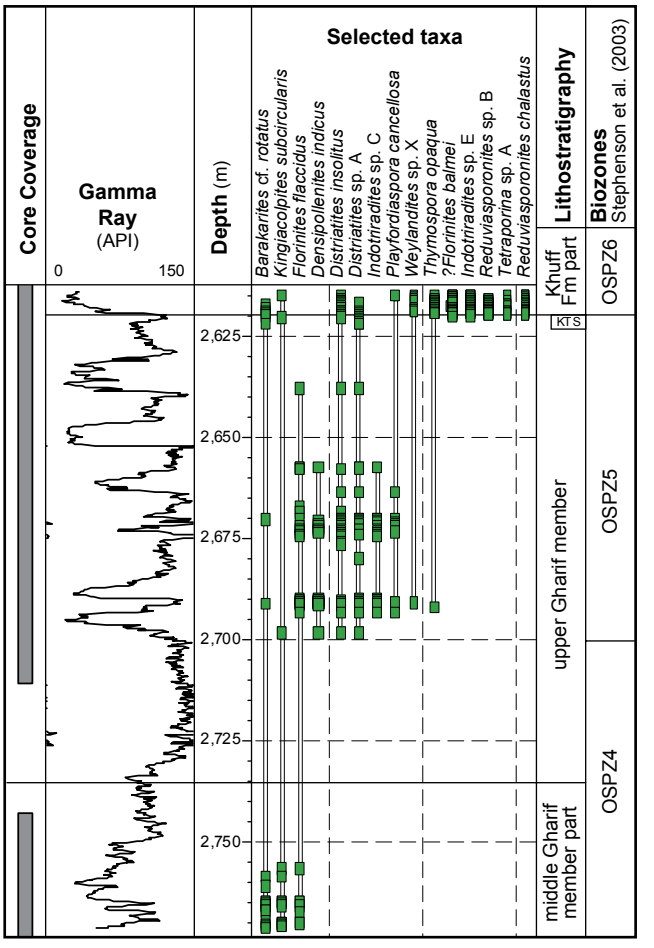


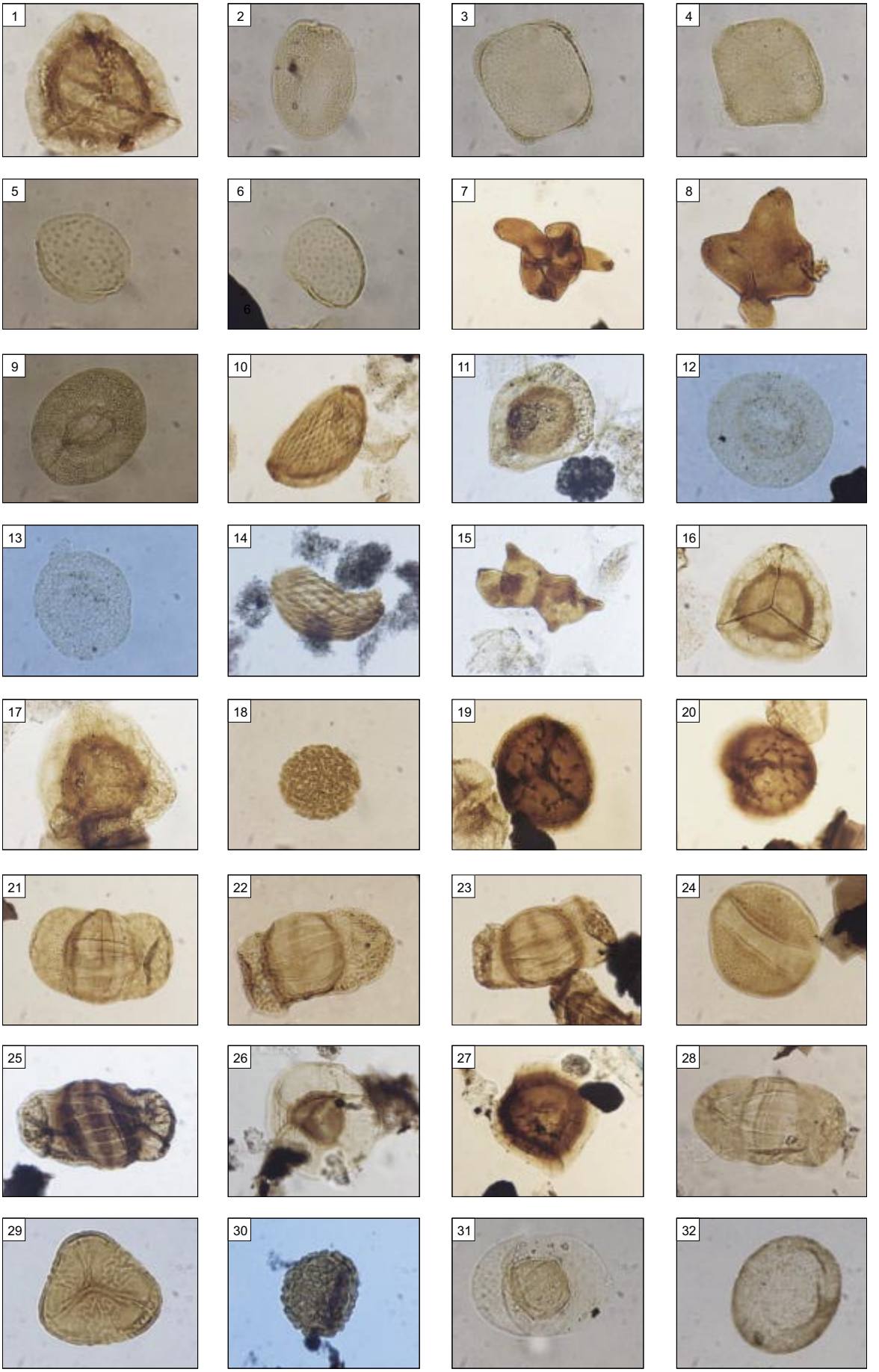
Figure 2: Selected taxa of Barik-36. Note that all sample levels have been shifted downhole by 2.8 m against logs to correct for core shift. KTS = Khuff transition section.

"Khuff Transition Section" at the Al-Huqf outcrop area

To support this study of the "Khuff transition section" in Barik-36, palynological analysis of 17 samples from a short vertical section of dark mudstones at "Outcrop 8" of BRGM (BRGM/TOTAL, 1998; GPS E569999 N2324404) at the Al-Huqf outcrop area, approximately 100 km to the east of Barik-36 (Figure 1) was carried out. Outcrop 8 occurs within the "floodplain facies" of subunit B of BRGM/TOTAL (1998; see also Angiolini et al., 2004), a few metres below the base of the Khuff Formation carbonates, and also yielded the "Gharif Palaeoflora" of Broutin et al. (1995).

The samples from Outcrop 8 contain very few allochthonous hinterland spores and pollen; most palynomorphs are autochthonous, probably algal in origin. Assemblages are dominated by *Leiosphaeridia* spp., *Botryococcus* spp., *Tetraporina* sp. A and *Micrhystridium* sp. A. However *?Florinites balmei*, is common at two levels and *Indotriradites* sp. E and *Reduviasporonites* sp. B also occur indicating a close correlation with the "Khuff transition section" in Barik-36.

Plate 1



New Definitions

Thus the stratigraphic distribution of key taxa in Barik-36 and the Al-Huqf outcrop area allow the following definitions: (1) The base of OSPZ5 is defined as the horizon of the combined first uphole appearance of *Distriatites* sp. A, *Distriatites insolitus, Indotriradites* sp. C, *Playfordiaspora cancellosa* and *Thymospora opaqua. (*2) The base of OSPZ6 is defined as the horizon of the first uphole appearance of ?*Florinites balmei.* Figure 3 shows the distribution of the OSPZ4, 5 and 6 biozones in relation to lithostratigraphy in Oman and central Saudi Arabia.

CONCLUSIONS

Barik-36 displays the standard palynological biozones OSPZ4, OSPZ5 and OSPZ6 in an important standard palynological section for the middle and upper Gharif members and the Khuff Formation in Oman. This has allowed definitions for the bases of OSPZ5 and 6, and a clear indication of their relative stratigraphic positions.

ACKNOWLEDGEMENTS

The author is grateful to the Oman Ministry of Oil and Gas, and Petroleum Development Oman for permission to publish this paper. M.H. Stephenson publishes with the permission of the Executive Director, British Geological Survey (NERC). The author acknowledges constructive reviews by Alan Heward, Stewart Molyneux, and James Riding. The final design and drafting of graphics by GeoArabia is appreciated.

Plate 1 (opposite page): Palynomorphs of the OSPZ5 and 6 interval. The locations of specimens are given first by England Finder reference and then by slide code. Slides marked * are held in the Micropalaeontology Collection of the Saudi Arabian Oil Company, PO Box 10781, Dhahran 31311, Saudi Arabia. All other slides are held in the Micropalaeontology Collection of Petroleum Development Oman, PO Box 81, Muscat 113, Sultanate of Oman. Note slide code depths for Barik-36 are uncorrected core depths.
(1) *Indotriradites* sp. E, E43/2, MPA 52576 ('Outcrop 8' of BRGM) (x 300).
(2) ?*Florinites balmei*, E44, MPA 52573 ('Outcrop 8' of BRGM) (x1,230).
(3) *Tetraporina* sp. A, E50, MPA 53572 ('Outcrop 8' of BRGM) (x570).
(4) *Tetraporina* sp. A, E24/4, MPA 52572 ('Outcrop 8' of BRGM) (x570).
(5) *Micrhystridium* sp. A, Q33, MPA 52570 ('Outcrop 8' of BRGM) (x570).
(6) *Micrhystridium* sp. A, M41, MPA 52569 ('Outcrop 8' of BRGM) (x570).
(7) *Reduviasporonites* sp. B, F24/4, MPA 52591 ('Outcrop 8' of BRGM) (x250).
(8) *Reduviasporonites* sp. B, P46/3, MPA 52587 ('Outcrop 8' of BRGM) (x500).
(9) ?*Florinites balmei*, C46, MPA 52591 ('Outcrop 8' of BRGM) (x1,230).
(10) *Weylandites* sp. X, K35/3, Barik-36, 2613.49 m (x235).
(11) *Indotriradites* sp. E, F38/3, Barik-36, 2612.20 m (x300).
(12) ?*Florinites balmei*, H26, Barik-36, 2612.68 m (x1,230).
(13) ?*Florinites balmei*, Q35, Barik-36, 2612.20 m (x1,230).
(14) *Weylandites* sp. X, P34, Barik-36, 2612.78 m (x235).
(15) *Reduviasporonites* sp. B, F42/1, Barik-36, 2613.14 m (x250).
(16) *Indotriradites* sp. E, D29, Barik-36, 2615.60 m (x300).
(17) *Indotriradites* sp. E, G40/1, Barik-36, 2615.60 m (x300).
(18) *Thymospora opaqua*, P49, Barik-36, 2615.60 m (x1,450).
(19) *Indotriradites* sp. C, H37, Barik-36, 2670.65 m (x340).
(20) *Indotriradites* sp. C, N46/4, Barik-36, 2670.99 m (x340).
(21) *Distriatites insolitus*, C41/4, Barik-36, 2688.00 m (x740).
(22) *Distriatites* sp. A, D42/3, Barik-36, 2688.30 m (x1,150).
(23) *Distriatites* sp. A, K30, Barik-36, 2688.65 m (x1,150).
(24) *Kingiacolpites subcircularis*, M50/3, Barik-36, 2754.20 m (x1,000).
(25) *Distriatites* sp. A, H13, RWKB-1, 13890 ft. (x1,150)*.
(26) *Playfordiaspora cancellos*a, Q46/1, SR-8, 9,061.1 ft. (x540).
(27) *Indotriradites* sp. C, J50, SR-11, 2785.1 m (x340).
(28) *Distriatites insolitu*s, P46, SR-8, 9,061.1 ft. (x740).
(29) *Triplexisporites* cf. *playfordii,* L41, 2154 ft., V-619 (x1,115)*.
(30) *Thymospora opaqua*, M30/4, V-619, 2155.6 ft (x1,450)*.
(31) *Protohaploxypinus uttingii*, D34, HWTH-6, 6224.4 ft. (x1,450)*.
(32) ?*Florinites balme*i, G56/1, HRDH-51, 12601.8 ft. (x1,230)*.

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Appendix List of Taxa

?Florinites balmei Stephenson and Filatoff, 2000
Camptotriletes warchianus Balme, 1970
Cedripites sp. B (of consultancy reports)
Densipollenites indicus Bharadwaj, 1962
Distriatites insolitus Bharadwaj and Salujah, 1964
Distriatites sp. A (of consultancy reports)
Florinites flaccidus Menéndez and Azcuy, 1973
Indotriradites sp. C (of consultancy reports)
Kingiacolpites subcircularis Tiwari and Moiz, 1971
Micrhystridium sp. A (of consultancy reports)
Playfordiaspora cancellosa (Playford and Dettmann) Maheshwari and Banerji, 1975
Protohaploxypinus uttingii Stephenson and Filatoff, 2000
Pteruchipollenites owensii Stephenson and Filatoff, 2000
Pyramidosporites cyathodes Segroves, 1967
Reduviasporonites sp. B (of consultancy reports)
Tetraporina sp. A (of consultancy reports)
Thymospora opaqua Singh, 1964
Triplexisporites cf. *playfordii* (de Jersey and Hamilton) Foster, 1979
Weylandites sp. X (of consultancy reports)

ABOUT THE AUTHOR

Michael (Mike) H. Stephenson *is presently a Senior Stratigrapher with the British Geological Survey (BGS) in Nottingham, UK. His education has included a BSc in Geology from Imperial College and an MSc and PhD in Palynology from the University of Sheffield. Mike's scientific work is concerned mainly with the Palaeozoic stratigraphy of Arabia and he has published a number of papers on the region, as well as worked extensively as a consultant to oil companies in the area, mainly in reservoir scale palynostratigraphy, sequence stratigraphy and regional correlation. Mike is also interested in the statistical palynological characterisation of argillaceous baffles to hydrocarbon flow, and use of combined kerogen carbon isotopes and palynology in high-resolution correlation. Outside the Middle East, Mike is involved in computing applications in stratigraphy, and the palynostratigraphy, sedimentology and palaeoecology of Palaeozoic sequences from onshore and offshore northwest Europe, Australia and Africa. He has publications on Palaeozoic sequences in Ireland, Scotland and southern Africa. Mike is a member of the AASP, PESGB and BMS, and is currently Secretary General of the Commission Internationale de Microflore du Paléozoique.*

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