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SELECTED SPORES AND POLLEN FROM THE PERMIAN UMM IRNA FORMATION, JORDAN, AND THEIR STRATIGRAPHIC UTILITY IN THE MIDDLE EAST AND NORTH AFRICA

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Abstract. The Umm Irna Formation, exposed along the eastern shore of the Dead Sea, has been the focus of intense palaeobotanical study, but more recently, it has been revealed that well-preserved palynological assemblages are also present. The age of the Umm Irna Formation is such that it provides a showcase for taxa from the Guadalupian (mid Permian) to Lopingian (late Permian) which are hard to find in the carbonate-dominated successions to the southeast in the Arabian Peninsula and elsewhere in the Middle East. In this paper distinctive taxa present in the Umm Irna Formation are described and illustrated, and surveyed for their stratigraphic occurrences, to consider their suitability for biozonal indices within the Guadalupian to early Lopingian. Two appear to be promising: *Protohaploxypinus uttingii* Stephenson and Filatoff, 2000 and *Pretricolpipollenites bharadwajii* Balme, 1970. The first is distinctive in that it is relatively small, has numerous, very narrow taenaie, and a shrunken intexinal corpus; the second has three narrow distal sulci. Both taxa may have first appearance levels within the Permian above the base of the OSPZ6 palynological Biozone, and thus may be useful in the future for further biozonation.

Introduction

The Umm Irna Formation, exposed along the eastern shore of the Dead Sea (Fig. 1), consists of a mixed arenaceous – argillaceous clastic succession. Makhlouf et al. (1991) recognised an informal Lower Member, about 10 m thick, consisting of sandstones and silty shales in upward-fining sequences, which they attributed to a distal braidplain setting. Their Upper Member comprises five fining-upward cycles with elements of both braided and meandering stream deposits, with silty beds deposited in abandoned channels. Palaeosols with ferruginous glaebules are developed in the middle and upper part of the formation (Makhlouf et al. 1991; Powell & Moh'd 1993; Stephenson & Powell 2013).

Palaeontological work in the Umm Irna Formation has mainly focussed on the well-preserved plant fossils and their depositional environments (Kerp et al. 2006; Uhl et al. 2007; Abu Hamad et al. 2008). More recently, Stephenson & Powell (2013) synthesised palynology and sedimentology into a comprehensive depositional model and correlated the Umm Irna Formation with successions elsewhere in the Arabian Peninsula and Israel. Stephenson & Powell (2013) indicated that the complex of lithologies in the Umm Irna Formation is similar to that of the informal 'basal Khuff clastics' unit of the Arabian Peninsula, a unit underlying the carbonate Khuff Formation which in turn represents a major transgressive-regressive cycle deposited along the northern Gondwanan margin in the Arabian Peninsula, Iran, Iraq and Pakistan.

The 'basal Khuff clastics' in Oman are difficult to date directly but the Khuff Formation directly overlying is dated with macro- and microfauna as Wordian (Angiolini et al. 1998). A tentative Roadian or earliest Wordian age has therefore been suggested (e.g. Stephenson et al. 2003). The basal Khuff clastics in central Saudi Arabia known as the Ash Shiqqah Member (see Vaslet et al. 2005) are tentatively dated as ?Capitanian (?Midian) based on the presence of the fusulinids *Monodiexodina kattaensis* and *Reichelina* sp. by Vaslet et al. (2005), and as late Midian by Vachard et al. (2005). The dates for the basal Khuff clastics in Oman and central Saudi Arabia supports the suggestion (e.g. Hughes 2005) that the basal Khuff clastics, and therefore the base of the Khuff Formation, are diachronous, younging to the north

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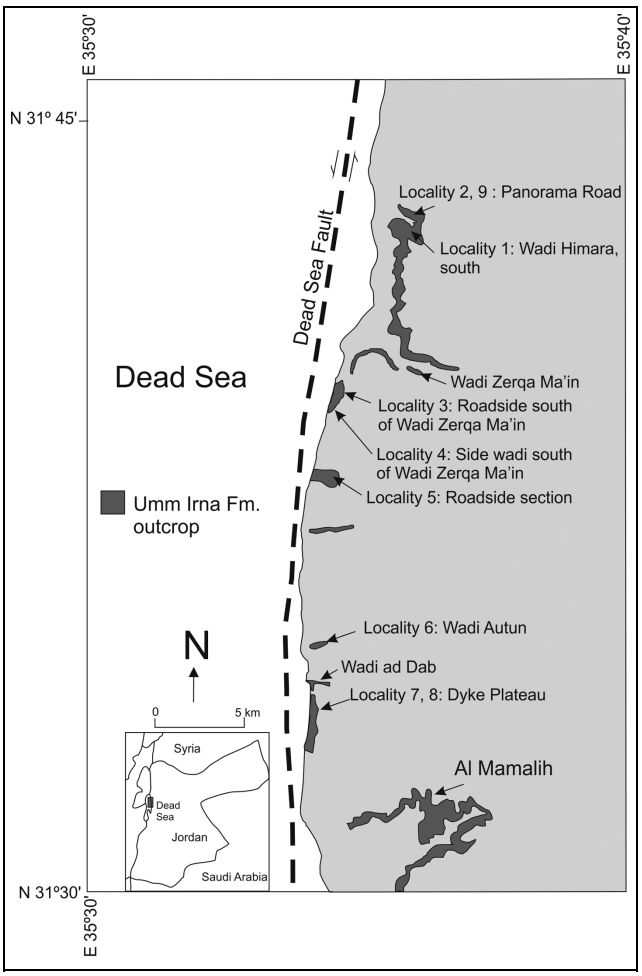

Fig. 1 - Location of the Umm Irna Formation outcrops, based on Stephenson & Powell (2013).

through the Arabian Plate (Fig. 2; see Stephenson & Powell 2013, their fig. 12; Stephenson & Jan 2013).

The similarity in palynology and lithology also strongly suggest that the Umm Irna Formation in Jordan is an equivalent of the basal Khuff clastics. Its total age range suggested by palynology (Wordian-Capitanian to early Wuchiapingian; Stephenson & Powell 2013) may indicate that the diachronous trend continues to the northeast.

A palynological biozonation (the Oman and Saudi Arabia Palynological Zonation, OSPZ, scheme) of the Cisuralian and Guadalupian of the Arabian Peninsula was established by Stephenson et al. (2003) and refined subsequently (e.g. Stephenson 2006, 2008). It has been shown to be applicable at least in part outside the Arabian Peninsula in for example Pakistan, Kuwait and Turkey (see Jan et al. 2009; Tanoli et al. 2008; Stolle et al. 2010). However the scheme terminates within the Guadalupian largely because in Arabia the succession above (through to the Lower Triassic) is dominated by the carbonates of the Khuff Formation that are inimical to the preservation of palynomorphs. In practice, this means that the highest of the OSPZ biozones (OSPZ6) does not have an upper boundary, due to the lack of suitable marker taxa. The base of the OSPZ6 biozone is defined at the first appearance of the small monosaccate pollen *Florinites? balmei* and is best seen in cores of the Gharif and Khuff formations in Oman and is dated as Wordian (Stephenson 2006).

Thus, the well-preserved assemblages of the Umm Irna Formation present an opportunity to identify taxa that may have value in subdividing the higher Permian sequence of the Middle East and North Africa (above the base of OSPZ6, or above the Wordian). The purpose of this paper is therefore to document distinctive taxa from the Umm Irna Formation and survey their ranges in the Middle East and North Africa.

Materials and methods

A total of 25 samples were taken at nine localities in the Umm Irna Formation adjacent to the Dead Sea (Figs 1, 2). Palynological samples were extracted by deep excavation of the claystone, siltstone and coaly beds using a pick-axe to avoid near-surface contamination or the present-day oxidation of palynomorphs. In addition, samples were taken, where possible, from shaded north-facing exposures to avoid, as far as possible, oxidized areas. The preparation of strew mounts for palynological analysis comprised crushing, followed by hydrochloric and hydrofluoric acid treatments (Wood et al. 1996). The post-hydrofluoric acid organic residues were oxidized using Schulze's solution. The palynological slides bear the British Geological Survey code prefix 'MPA' and are curated in the BGS collections in Keyworth, Nottingham.

Twenty five samples were processed and of these only one was barren of palynomorphs. A few samples yielded less than ten palynomorphs, but generally samples yielded large populations of palynomorphs which were moderately- to well-preserved. The assemblages are very variable but in general contain common non-taeniate bisaccate pollen (often fragmentary or too poorly preserved to be identified); those that are determinable include *Falcisporites stabilis*, *Alisporites nuthallensis*, *A. indarraensis*, and *Cedripites priscus*. The most common taeniate bisaccate pollen is *Protohaploxypinus uttingii* and *P. limpidus*. Monosaccate pollen is rare, as are spores. Details of the quantitative character of the assemblages and the stratigraphic ranges of taxa are given in Stephenson & Powell (2013). Schematic ranges of the palynomorphs considered here are shown on Fig. 3. The bisaccate pollen is described according to the scheme shown in Fig. 4.

In this paper previous records for taxa refer to their occurrences in the Middle East and North Africa. The geographically closest sequences to those of the Umm Irna Formation studied in detail for palynology are from boreholes in eastern and southern Israel, west of the Dead Sea. Eshet & Cousminer (1986) and Eshet (1990) studied assemblages from eleven boreholes including the Makhtesh Qatan-1 well, from which the only Permian core material came (Eshet & Cousminer 1986), the rest being from drill cuttings. Previous records from Israel in the present paper thus concentrate on this borehole since the object of the study is to gather information about distinctive taxa whose stratigraphic range is fixed in core and outcrop study.

Discussion and conclusions

Camptotriletes warchianus and *Cedripites priscus* are distinctive components of Wordian to Changsingian Middle Eastern assemblages, but do not allow biostrati-

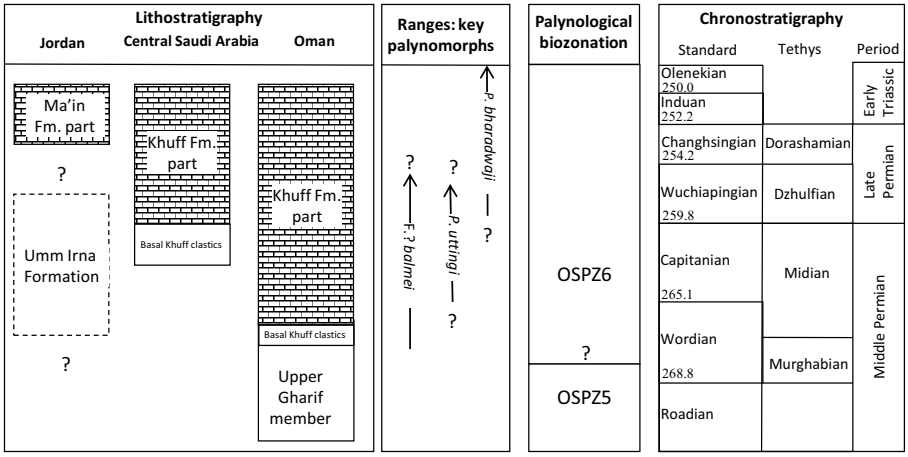

Fig. 2 - Sketch of possible ranges of *F.? balmei*, *P. bharadwajii* and *P. uttingii* against the main features of Arabian plate Permian stratigraphy. Tethyan chronostratigraphic subdivisions from Vachard et al. (2005). The dashed rectangle indicates the total possible age range of the Umm Irna Formation.

graphic subdivision within that period (see Systematic palaeontology section). *Falcisporites stabilis* is common in the Umm Irna Formation assemblages and elsewhere in the Middle East. It is perhaps significant in that it was produced by the corystosperm plant *Dicroidium*, and its occurrence in the Umm Irna Formation is the earliest appearance of that plant genus, long thought to be confined to the Triassic (see Kerp et al. 2006). However, *F. stabilis* is often difficult to distinguish from *Alisporites nuthallansis,* a taxon known to extend below the Guadalupian (Stephenson et al. 2003; Stephenson 2008). Its utility as an easily recognisable marker for Guadalupian or Lopingian sequences may therefore be in doubt.

Pretricolpipollenites bharadwajii may offer more utilty because it is very distinctive in being trisulcate and because its first appearance probably occurs well above the base of OSPZ6 Biozone. Its first occurrence in the Salt Range is in the Changhsingian Chhidru Formation but its presence in the Umm Irna Formation may indicate a lower regional first occurrence (Fig. 2). *Pretricolpipollenites bharadwajii* does not occur in lowest OSPZ6 Biozonal assemblages in Oman. *Protohaploxypinus uttingii* similarly does not occur in the lowest OSPZ6 Biozonal assemblages in the basal Khuff clastics of Oman but is often common in the same unit in central Saudi Arabia. Further studies may allow the establishment of the first appearance of *Protohaploxypinus uttingii* and *Pretricolpipollenites bharadwajii* as subdivisions of the OSPZ6 Biozone or the basis of higher biozones (see Fig. 2).

Systematic palaeontology

Genus *Camptotriletes* Naumova *ex* Potonié & Kremp, 1954

Camptotriletes warchianus Balme, 1970

Pl. 1, a-f

1964 ?*Camptotriletes* sp. Singh, p. 249; pl. 44, fig. 29.

Description. Spores, radial, trilete; amb rounded triangular with straight to slightly concave interradials. Laesurae distinct, straight, without lips; extend to the margins; often gaping. Exine thick (3-4 µm), rigid; proximal face sparsely and irregularly granulate or cristate; distal face with distinctive cristae and (rarely) discrete ornament. Ornament coarseness and density is variable; most coarsely ornamented specimens have cristae-rugulae and rare discrete coni and bacula; cristae sinuous 2-10 µm in length, 1-2 µm high, 1-2 µm wide. In these coarsely ornamented specimens ornament protrudes at the margin giving a serrated amb. Specimens with finer ornament have cones and rarely bacula (1-2 µm high and wide at the base), with narrow indistinct thickenings in between the elements; these specimens have smoother ambs.

Dimensions. 58(70)87 µm; 8 specimens.

Remarks. Balme (1970) noted that a specimen figured by Singh (1964; pl. 44, fig. 29) and assigned to *Camptotriletes* sp. may be synonymous with the present species; this is also suggested here. Specimens figured by Kaiser (1976; pl. 8, fig. 9) and assigned to *Camptotriletes polymorphus* Kaiser, 1976 display many of the characteristics of the present species including similar variability; however, *C. polymorphus* is smaller (45-55 µm, Kaiser 1976) and has thinner exine (1-1.5 µm, Kaiser 1976).

The large size, thick exine (giving it a rather dark colour) and coarse ornament make *Camptotriletes warchianus* rather distinctive and conspicuous in the often pollen-dominated assemblages characteristic of the Guadalupian and Lopingian in the Arabian Peninsula.

Previous records. *Camptotriletes warchianus* was recorded as common in the Amb Formation, and rare in the Wargal and Chhidru formations of the Pakistan Salt Range, corresponding to a stratigraphic range of Wordian to Changhsingian (Balme 1970). Singh (1964) recorded specimens similar to *C. warchianus* from a single borehole core sample from the Chia Zairi Formation

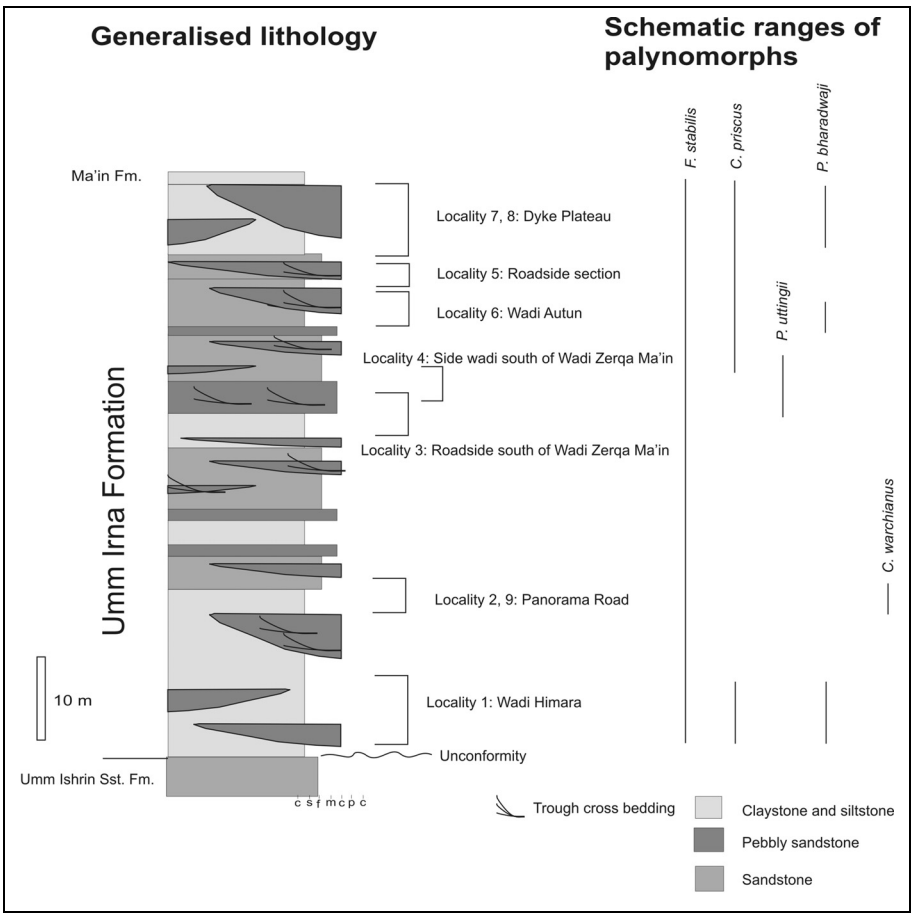

Fig. 3 - Generalised composite Umm Irna Formation section showing a guide to the approximate positions of the sampled sections and schematic ranges of selected palynomorphs.

near Mosul, northern Iraq, assigned to the 'Late Permian' (Singh 1964). Nader et al. (1993) recorded *C. warchianus* from their lower Assemblage Zone A of borehole Mitya-ha-1 (northern Iraq) considered to be 'Tatarian' (broadly Lopingian in age). Stolle (2007) and Stolle et al. (2010) recorded the taxon from the late Wordian to Changhsingian Tanin Group in Turkey. In the Arabian Peninsula, *C. warchianus* is present in the basal Khuff clastics of central Saudi Arabia (Stephenson & Filatoff 2000).

Genus *Cedripites* Wodehouse, 1933

Cedripites priscus Balme, 1970

Pl. 2, a-o

Description. Pollen, bisaccate, bilaterally symmetrical; haploxylonoid. Corpus oval or circular, exoexine of cappa and sacci merge imperceptively. Cappa thick (approx. 3 µm) and densely columellate. Cappula usually indistinct due to indistinct nature of distal saccus onlap; when distinct varies in outline but broadly parallel-sided with width approximately 50% of that of the corpus and length equal to that of corpus. Sacci distally inclined. Sacci outline narrow, crescentic to semi-circular; sacci usually smaller than the corpus. Sacci appear to be continuous around the corpus merging with the columellate cappa. Sacci structure often columellate with a fibrous appearance, columellae <0.5 µm wide, radially arranged. Sacci rigid, robust.

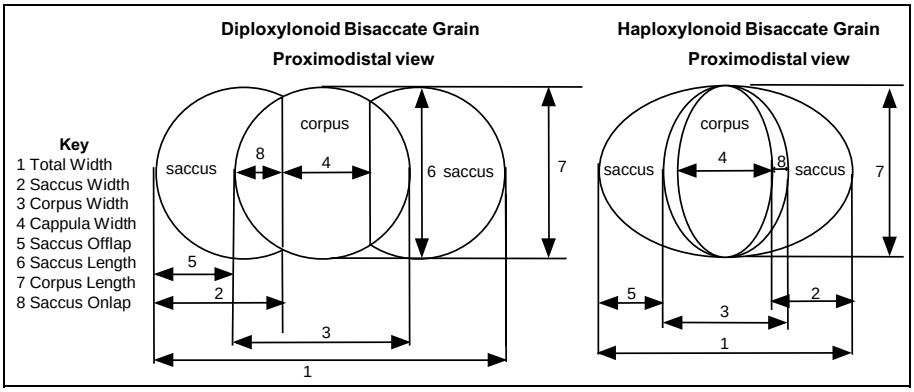

Fig. 4 - The measurement and orientation scheme used for bisaccate pollen in this study.

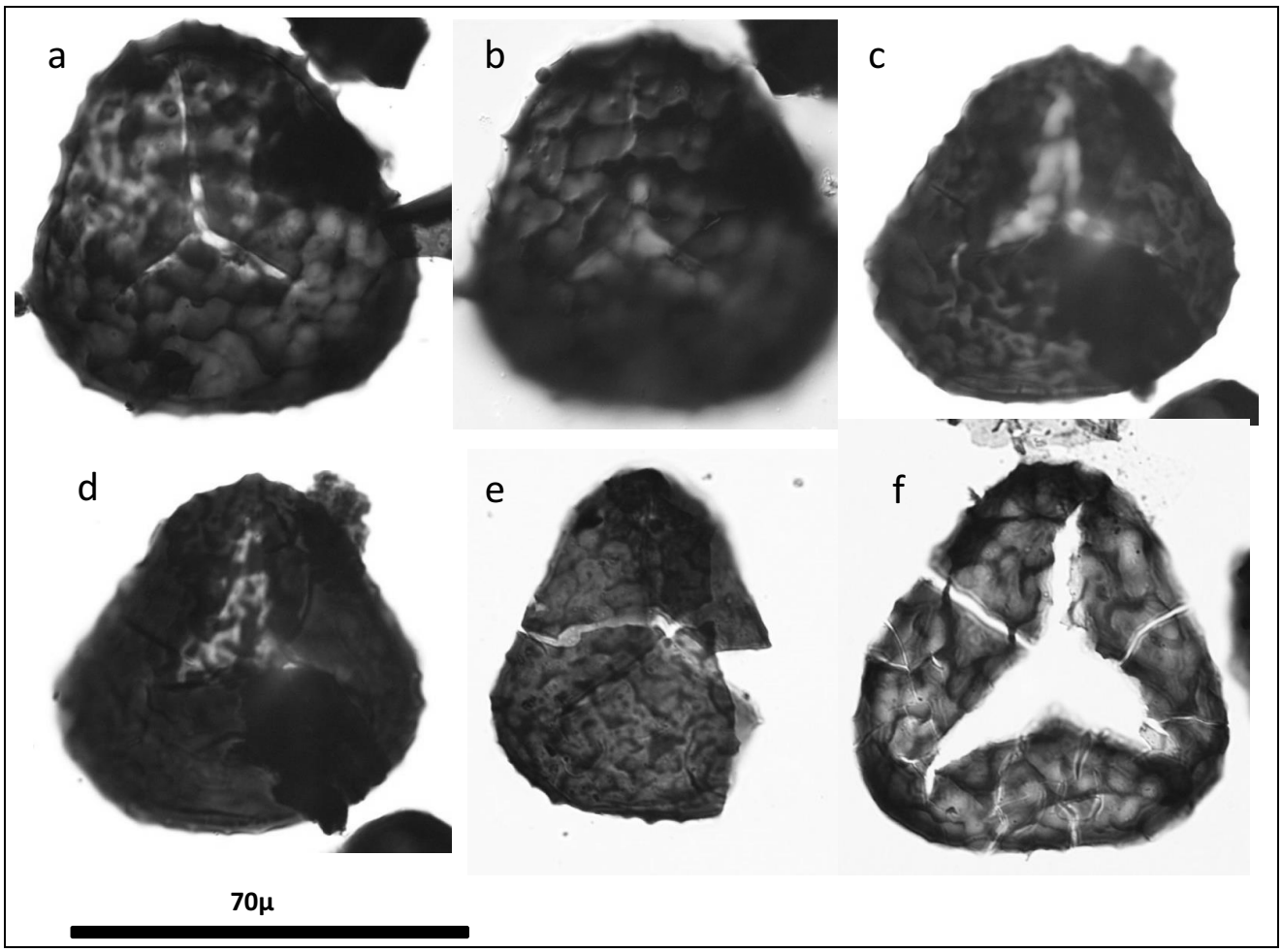

PLATE 1

Camptotriletes warchianus. Slides are held in the collection of the British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK. Specimen locations are given by England Finder code.
a, b - 62242, V56/4; c, d - 62242, R66/1; e - 62242, V56/2; f - 62243, R59/1.

Dimensions. Total width 45(57)88 µm; total length 42(51)66 µm; saccus offlap 5(8)10 µm; saccus onlap 20(22)30 µm; cappula width 10(22)45 µm; 20 specimens.

Remarks. *Cedripites priscus* Balme, 1970 differs from *Rimaesporites aquilonalis* Goubin, 1965 in having a less well defined cappula and associated with this, less distinct distal sacci onlap areas. *Divarisaccus scorteus* Lele and Makada, 1972 differs from the present species in being larger (100-127 µm x 90-102 µm, Lele & Makada 1972) and in having a narrower distal sulcus with more definite distal saccus roots.

Cedripites priscus has a rather compact rigid appearance from its haploxylonoid outline and columellate cappa and sacci, which distinguish it from the more elongate diploxylonoid bisaccate pollen that are common in the Guadalupian and Lopingian in the Arabian Peninsula.

Previous records. *Cedripites priscus* was recorded by Le Nindre et al. (1990) from the upper Unayzah Mbr (= Ash Shiqqah Mbr), Huqayl, Duhaysan and Midhnab members of the Khuff Formation of the SHD-1 borehole, Saudi Arabia, suggesting an age range of Capitanian to Changhsingian (see Vaslet et al. 2005; Angiolini et al. 2006). Broutin et al. (1995) recorded *C. priscus* from the upper Gharif Formation 'Gharif Plant bed' in Oman considered Kubergandian-(?)Murghabian in age by Broutin et al. (1995), and likely Wordian in age on current evidence (see Stephenson 2006, 2011).

Genus *Falcisporites* Leschik emend. Klaus, 1963

Falcisporites stabilis Balme, 1970

Pl. 3, a-j

Description. Pollen bisaccate, bilaterally symmetrical; amb haploxylonoid to very slightly diploxylonoid. Corpus slightly elongate or circular; intexine thin, almost imperceptible, cappa exoexine thick, slightly columellate. Cappula narrow (25% of corpus width); par-

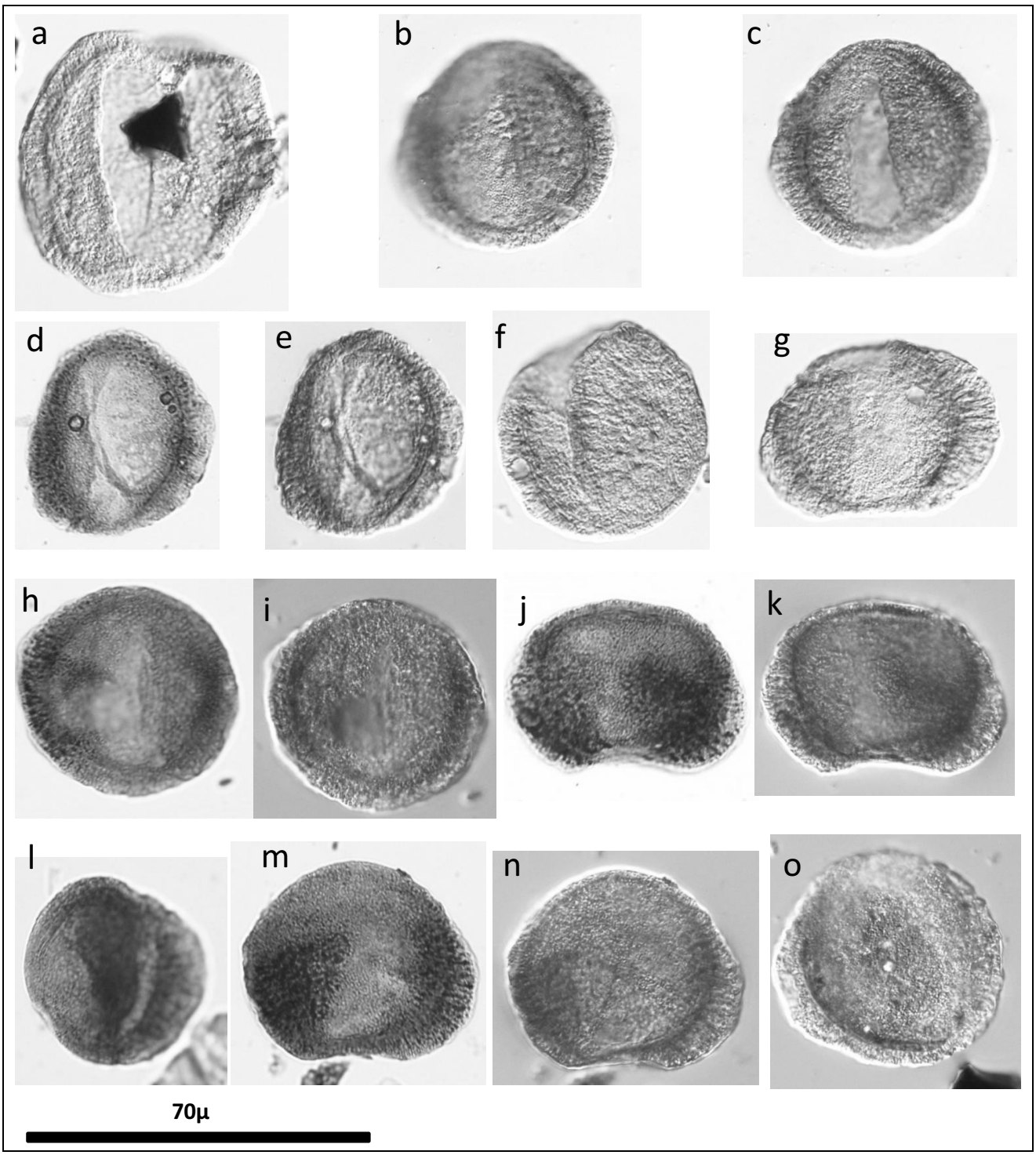

PLATE 2

Cedripites priscus. Slides are held in the collection of the British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK. Specimen locations are given by England Finder code.
a - 62263, H62/3; b, c - 62263, Y62; d, e - 62263, C63; f - 62263, E53; g - 62263, E43; h, i - 62263, M48/1; j, k - 62263, H62; l - 62263, G62; m, n - 62263-1, G58; o - 62263-1, J66/3.

allel sided; extends the length of the corpus. Within the cappula a longitudinal medial distal sulcus is very distinct. Sacci strongly distally inclined; crescentic to semicircular; rigid; with relatively coarse infrareticulation (brochi 1 µm in diameter or greater). Sacci slightly larger or similar in size to the corpus. A pair of narrow crescentic, intexinal folds are often present at the distal saccus bases.

Dimensions. Total width 56(70)105 µm; total length 42(50)55 µm; saccus offlap 20(22)35 µm; saccus onlap 15(22)30 µm; cappula width 5(10)15 µm; 20 specimens.

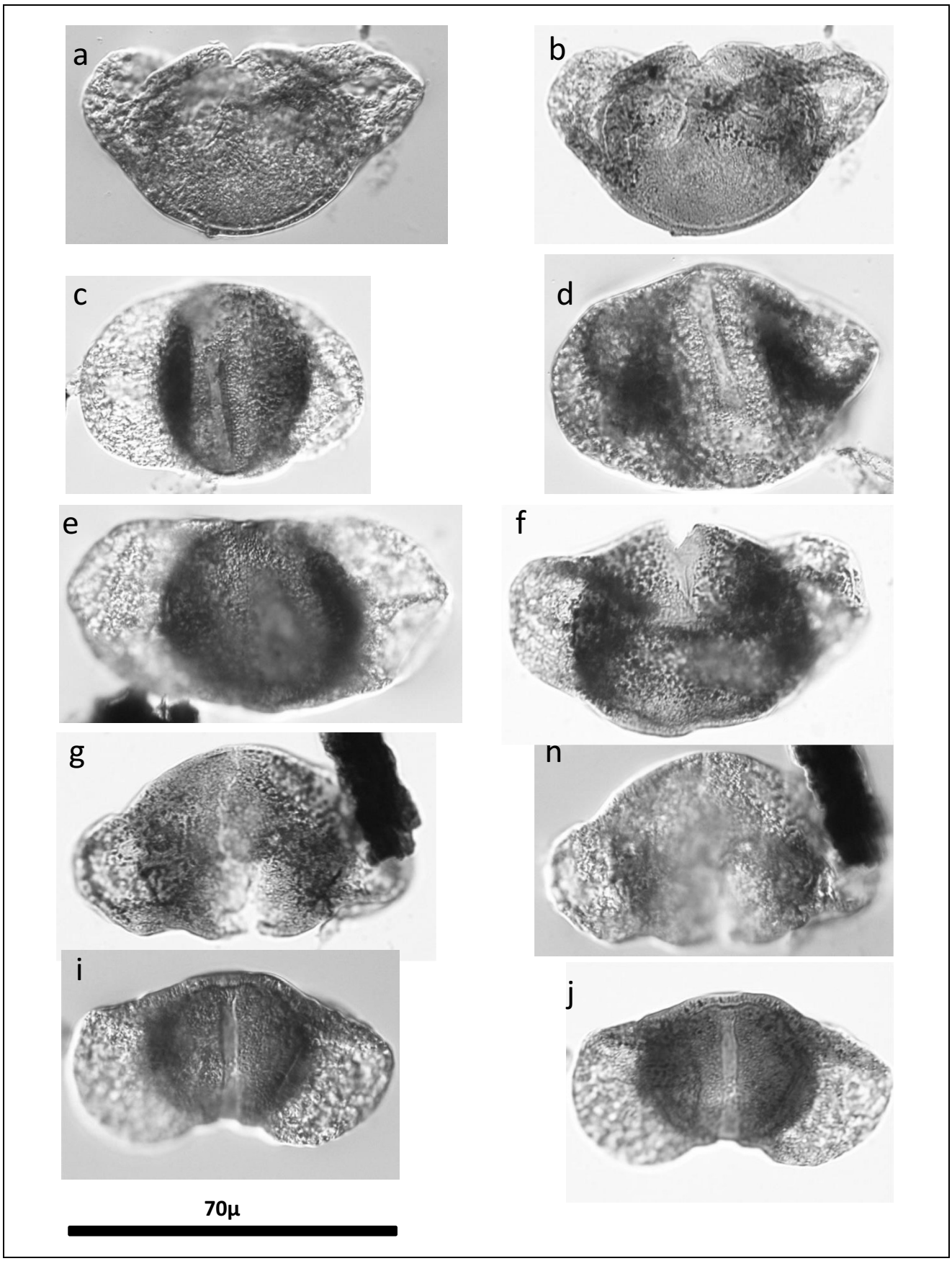

PLATE 3

Falcisporites stabilis. Slides are held in the collection of the British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK. Specimen locations are given by England Finder code.
a, b (lateral view) - 62256, C46/4; c - 62259, G62/3; d - 62259, W44/1; e - 62259, G72/4; f - 62260, P71; g, h - 62256, F56/2; i, j 62256, N63/2.

Comparison and remarks. There is some difficulty in distinguishing *Falcisporites stabilis* and *Alisporites nuthallenis* Clarke, 1965, and even in distinguishing *Falcisporites* Leschik emend. Klaus, 1963 and *Alisporites* Daugherty, 1941 emend. Jansonius, 1971. This is no doubt the reason for frequent generic re-assignments between *Falcisporites* and *Alisporites* in the literature (see de Jersey & McKellar 2013 for discussion). *Falcisporites stabilis* and *Alisporites nuthallenis* Clarke, 1965 are rarely directly compared but Stephenson (2008) considered that *Falcisporites stabilis* differs from *Alisporites nuthallensis* in having a well-defined distal sulcus. This distinction is however difficult to make in poorly preserved material.

Previous records. *Falcisporites stabilis* was recorded by Eshet & Cousminer (1986) from the Arqov, Yamin, Zafir, Ra'af and lower Gevanim formations in Makhtesh Qatan-1 well spanning what those authors considered to represent the Cisuralian to Mid Triassic. It is likely however that the Cisuralian age suggested for the Sa'ad Formation and basal Arqov Formation (see Eshet & Cousminer 1986) is incorrect since these units probably correlate with the Umm Irna and Ma'in formations respectively in Jordan (see discussion in Stephenson & Powell 2013). Bach-Imam & Sigal (1985) recorded *F. stabilis* from the Kurachine and Mulussa formations of the Afandi 1, Habari 1, Jbissa 205, Markada 101 and Wabha 1 boreholes, Syria, suggesting a Mid Triassic age. Le Nindre et al. (1990) recorded *F. stabilis* from the Ash Shiqqah, Huqayl, Duhaysan and Midhnab members of the Khuff Formation of the SHD-1 borehole (Capitanian to Changhsingian; see above).

Genus *Pretricolpipollenites* Danzé-Corsin & Laveine, 1963

Pretricolpipollenites bharadwajii Balme, 1970

Pl. 4, a-u

Description. Pollen, trisulcate; amb oval. Three parallel sulci occur in the distal face of the grain; sulci parallel to the long axis. Large medial sulcus narrow (1-2 µm wide), extends the length of the grain, margins folded inward slightly so that they appear dark; sulcus margins parallel or closer at the centre. Two shorter sulci flank the medial sulcus; flanking sulci narrow, slit-like, slightly shorter than the medial sulcus. Exine thin (<1 µm), laevigate or very finely infragranulate-punctate.

Dimensions. Total length 32(36) 44 µm total width 19 (25) 24 µm; 20 specimens

Comparison and remarks. *Pretricolpipollenites bharadwajii* is very distinctive amongst Permian assemblages because of its trisulcate distal surface.

Previous records. *Pretricolpipollenites bharadwajii* is mainly recorded from the Triassic in the Middle East. Mazroui-Kilani et al. (1988), Kilani-Mazraoui et al. (1990) and Kamoun et al. (1994) recorded it spanning the Lower to Upper Triassic in Tunisia; similarly Geleta & Wille (1998) recorded the taxon from the Middle Triassic (Ladinian) of west-central Ethiopia. It was first described from the 'upper 12 feet or so of the Chhidru Formation' (Balme 1970, p. 406) of the Salt Range of Pakistan (reportedly Changhsingian, see Wardlaw & Pogue 1995). Hermann et al. (2012) in a recent survey of the Salt Range of Pakistan recorded *P. bharadwajii* and *Pretricolpipollenites* spp. between their units PTr1 and PTr2 (earliest Triassic). Venkatachala & Kar (1968) reported a specimen from the Triassic 'Kathwai Shales' of the Salt Range which they assigned to *Ginkgocycadophytus.* sp. cf. *G. cymbatus* but which is similar to *P. bharadwajii*. Coverage of the palynological succession below the Chhidru Formation in the Salt Range is rather patchy since the study of Hermann et al. (2012) does not extend below that formation and because Balme's (1970) study considered only five samples from the underlying Wargal and Amb formations (Capitanian-Wuchiapingian and Wordian respectively, see Wardlaw & Pogue 1995). It is thus possible that *P. bharadwaji* is present below the Changhsingian, as suggested by its presence in the Umm Irna Formation.

Pretricolpipollenites bharadwajii occurs widely in Israel (e.g. Zuk Tamrur-1 and -2; Zohar-8; Pleshet-1 boreholes) as reported by Eshet (1990), but as discussed above, samples from these boreholes are cuttings rather than core. The key cored well Makhtesh Qatan – 2 does not appear to contain *P. bharadwajii* according to Eshet & Cousminer (1986).

Genus *Protohaploxypinus* Samoilovich emended Morbey, 1975

Protohaploxypinus uttingii Stephenson & Filatoff, 2000

Pl. 5, a-c1

Description. Pollen, bilaterally symmetrical, taeniate, bisaccate, haploxylonoid to weakly diploxylonoid. Corpus oval, exoexine thin; cappa very finely taeniate. Intexinal body usually distinct, shrunken so that it appears as a circular dark-coloured area in the centre of the corpus. Intexinal body has diameter approximately half that of the corpus. Cappula distinct, parallel-sided to barrel-shaped; width 50% of the corpus; extends the length of the corpus. Taeniae on cappa often indistinct; narrow (1-2 µm in width); numerous (approximately 15 present). Sacci distally inclined; semicircular in outline, approximately the same size as the exoexinal corpus. Sacci exoexine delicate, thin; infrare-

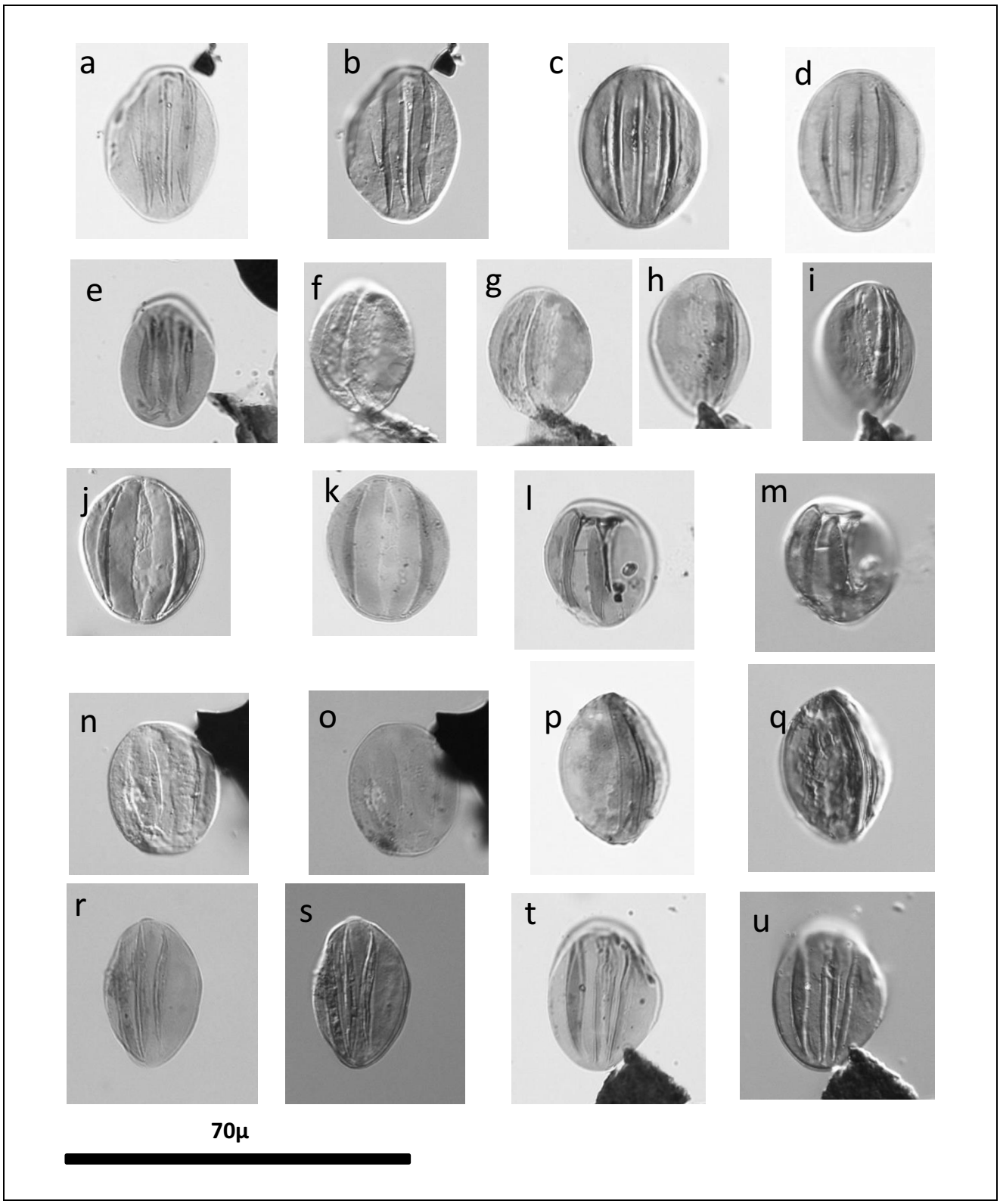

PLATE 4

Pretricolpipollenites bharadwajii. Slides are held in the collection of the British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK. Specimen locations are given by England Finder code.
a, b - 62263, H60/4; c, d - 62263, P68; e - 62263, E51; f, g - 62263, L66; h, i - 62263, K67; j, k - 62263-1, K63; l, m - 62263-1, Q62; n, o - 62263-1, Q64/1; p, q - 62263-1, S63/3; r, s - 62263-1, S66/3; t, u - 62263-1, U48/1.

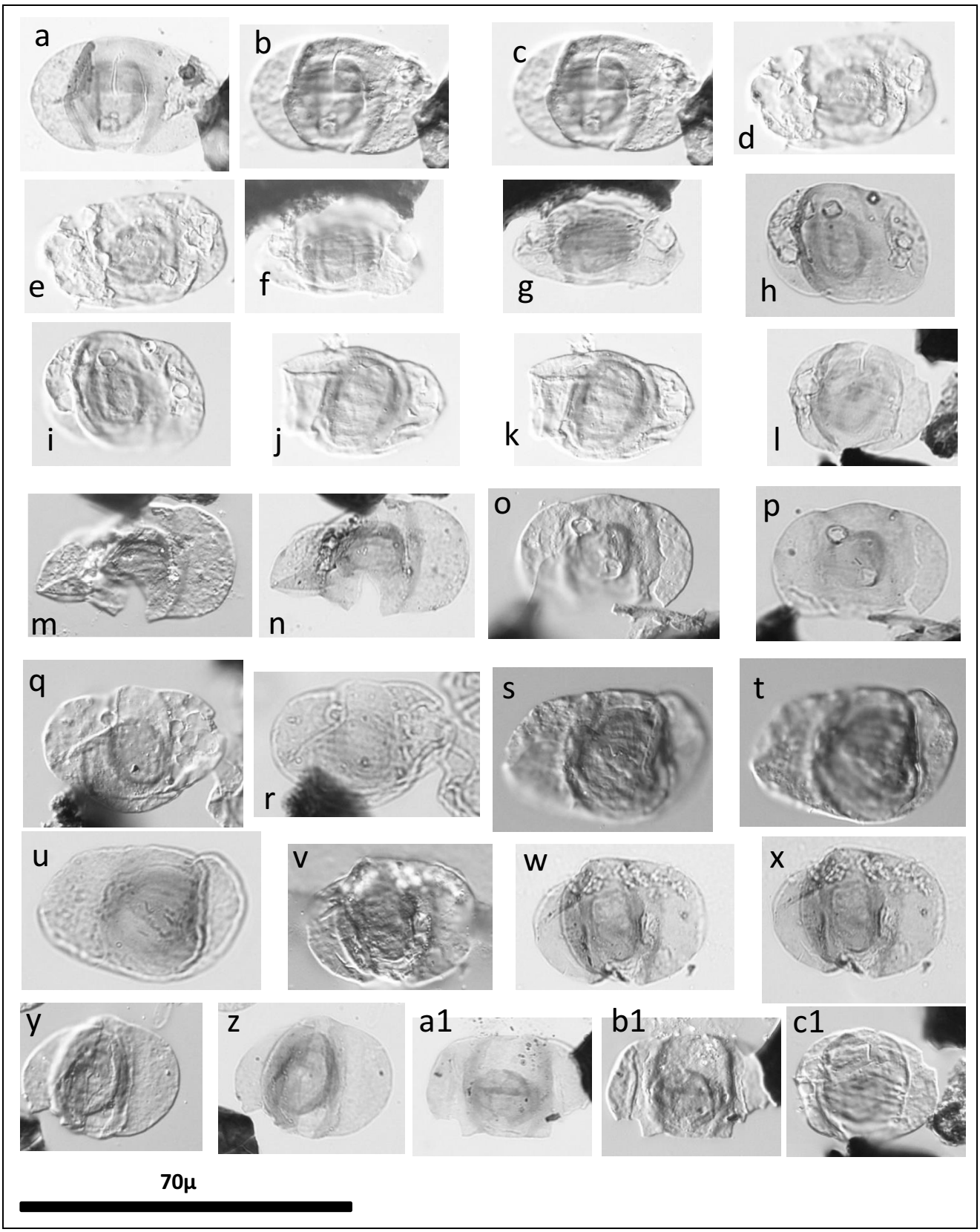

PLATE 5

Protohaploxypinus uttingii. Slides are held in the collection of the British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK. Specimen locations are given by England Finder code.
a-c - 62253, D53/3; d, e - 62253, F51/4; f, g - 62253, F46/4; h, i - 62253, O52; j, k - 62253, N44/3; l - 62253, L46/2; m, n - 62253, L49/2; o, p - 62253, K51/1; q, r - 62253, M53/2; s-u - 62253, M60; v-x - 62253, U69; y, z - 62253, L46/2; a1,b1 - 62253 M64/1; c1 - 62253 /2, L46/2.

ticulation very fine, brochi just perceptible in most specimens.

Dimensions. Total width 32(40)45 µm; total length 25(29)40 µm; saccus offlap 5(7)10 µm; saccus onlap 4(6)10 µm; cappula width 6(9)15 µm; corpus width 30(25)29 µm; 20 specimens.

Comparison. See Stephenson & Filatoff (2000).

Previous records. *Protohaploxypinus uttingii* is common in the Dilam-1, Nuayyim-2 and Haradh-51 wells in the basal Khuff clastics of Saudi Arabia (Wordian -?early Capitanian; Stephenson et al. 2003). The taxon is also known from the overlying Khuff Formation in Oman as it often occurs in the caved components of assemblages derived from cuttings samples from wells that have penetrated the Khuff Formation (confidential Petroleum Development Oman reports). A single possible specimen of *Protohaploxypinus uttingii* was recorded from the ?Guadalupian, Sardhai Formation of Pakistan (Jan et al., 2009), but the taxon is not recorded from horizons above in the Salt Range (see Balme 1970, Hermann et al. 2012).

Remarks. Stephenson & Filatoff (2000) originally considered that the small size and finely, multitaeniate cappa are the main characteristics of this species, but the shrunken intexinal body within the exoexinal corpus (Pl. 5) is perhaps an even more distinctive characteristic – it being extremely rare in other taeniate bisaccate pollen.

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