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LATE FAMENNIAN MIOSPORE ASSEMBLAGES FROM THE BERGISCH GLADBACH - PAFFRATH SYNCLINE, RHENISH SLATE MOUNTAINS, GERMANY[1]

Christoph HARTKOPF-FRÖDER[2] & Maurice STREEL[3]

(2 figures & 7 plates)

ABSTRACT. During routine palynological analysis of Devonian sediments of the Bergisch Gladbach-Paffrath Syncline, Rhenish Slate Mountains, late Famennian marine strata hitherto unknown in this region have been recognized. The thermal alteration index (TAI of 2 to 2+) is remarkably low compared to other Upper Devonian sediments in the Ardenne-Rhenish area, indicating that the settings were never deeply buried. Due to the low thermal maturity the miospore preservation is very good to excellent. The miospore assemblages are rich and diverse in composition. Species of the *Diducites* complex are particularly abundant. Other stratigraphically significant species are *Cyrtospora cristifera, Grandispora cornuta, Raistrickia variabilis,* and *Retispora lepidophyta*. The latter species is a near world-wide marker for the late Famennian. The occurrence of *Grandispora echinata* and *Knoxisporites literatus* is still doubtful and hence, the assemblages have been assigned to the Oppel Zone LV. The rather large diameter of the exoexine of *Retispora lepidophyta* signifies a position close to the base of the Oppel Zone LV. The next older sediments known in the syncline are of lower Nehdenian age. It is still doubtful whether upper Nehdenian, Hembergian and Dasbergian sediments are present in this area.

KEYWORDS: miospores, palynostratigraphy, Upper Famennian, Strunian, Rhenish Slate Mountains, Bergisch Gladbach-Paffrath Syncline, regional geology.

RESUME. **Assemblages de miospores du Famennien tardif du Synclinal de Paffrath-Bergisch Gladbach, Massif Schisteux Rhénan, Allemagne.** A l'occasion d'une analyse palynologique de routine de sédiments dévoniens du Synclinal de Paffrath-Bergisch Gladbach, Massif Schisteux Rhénan, des couches marines du Famennien tardif, inconnues jusqu'ici dans cette région, ont été identifiées. L'indice d'altération thermale (TAI de 2 à 2+) est remarquablement faible comparé à d'autres sédiments des régions ardenno-rhénanes, suggérant que l'ensemble n'a jamais été enfoui profondément. Grâce à cette maturité thermale faible, la conservation des miospores est très bonne à excellente. Les assemblages de miospores sont riches et diversifiés. Les espèces du complexe *Diducites* sont particulièrement abondantes. D'autres espèces stratigraphiquement significatives sont *Cyrtospora cristifera, Grandispora comuta, Raistrickia variabilis,* et *Retispora lepidophyta*. La dernière espèce est un marqueur pratiquement mondial pour le Famennien tardif. La présence de *Grandispora echinata* et *Knoxisporites literatus* est encore douteuse et, en conséquence, les assemblages ont été attribués à la Zone d'Oppel LV. Les diamètres relativement grands de l'exoexine de *Retispora lepidophyta* indiquent une position proche de la base de la Zone d'Oppel LV. Les sédiments immédiatement plus anciens connus dans le synclinal sont d'âge Néhdénien inférieur. On ne sait pas encore si des sédiments Néhdénien supérieur, Hembergien et Dasbergien sont présents dans cette région.

MOTS-CLES: miospores, palynostratigraphie, Famennien supérieur, Strunien, Massif Schisteux Rhénan, Synclinal de Paffrath-Bergisch Gladbach, géologie régionale.

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[1] *Manuscript received August 1994; accepted September 1994.*

[2] *Geologisches Landesamt Nordrhein-Westphalen, De-Greiff-Str. 195, Postfach 1080, D-47710 Krefeld, F.R. Germany.*

[3] *Services Associés de Paléontologie, Université de Liège, Place du Vingt Août 7, B-4000 Liège, Belgium.*

1. INTRODUCTION

Famennian miospore assemblages have been extensively studied in the Ardenne-Rhenish area (e.g. Higgs & Streel, 1984; Streel, 1986b; Streel *et al.*, 1987; Higgs & Streel, 1994). The miospore zones ranging from the Oppel Zone GF to LV (middle to late Famennian) have been defined in the Dinant Synclinorium where in sediments of the Condroz sandstone facies diverse and rather well preserved palynomorph assemblages are abundant (Streel, 1986b; Streel *et al.*, 1987). However, due to adverse facies conditions latest Devonian miospore-bearing sediments younger than the Oppel Zone LV are rarely recorded in eastern Belgium (Streel, 1986a, b). Instead, a comprehensive miospore zonation has been established in the Irish Famennian - Tournaisian succession comprising LL to CM spore Biozones (Higgs *et al.*, 1988). This zonation has been applied to Devonian/Carboniferous basinal sequences in the Sauerland where detailed studies on macro- and microfaunal index fossils and key sections offer independant biostratigraphic control (Higgs & Streel, 1984; 1994; Streel *et al.*, 1987).

The lowermost miospore zone recognized in these sections is the Interval Zone LL. Although in the Dinant and Namur Synclinoria the late Famennian miospore Zones LL, LE and LN have been recorded from separate sections (Paproth *et al.*, 1983; Loboziak *et al.*, 1994; Streel *in* Dreesen *et al.*, 1993) no single section is yet known in which the transition of the LV/LL Zones has been found.

In connection with a geological and engineering geological mapping program of an area east of Cologne (sheet 5008 Köln-Mülheim of the topographic map 1:25000) numerous samples from shallow boreholes have been dated palynologically. Surprisingly enough, one sample collected from a borehole drilled in the Bergisch Gladbach-Paffrath Syncline yielded a miospore assemblage of late Famennian age. Because the presence of late Famennian strata was hitherto unknown in this region several sections exposing Upper Devonian sediments were sampled. Furthermore, cuttings from two boreholes drilled respectively in 1984 and 1985 were available. It is from these two boreholes that additional late Famennian miospore assemblages were recovered.

The miospores are well to excellently preserved at least compared with assemblages previously described from late Devonian strata of the Ardenne-Rhenish region. The aim of this paper is to document the miospore assemblage and to comment upon its palynostratigraphic significance.

2. GEOLOGICAL FRAMEWORK AND STRATIGRAPHY

The regional geology of the Bergisch Gladbach-Paffrath Syncline or for short Paffrath Syncline is very well known, thanks to the rich fauna of outstanding preservation. Over the years many fossil groups recovered from Devonian sediments of the syncline have been extensively studied making this area a classical source of Devonian palaeontology in the Ardenne-Rhenish regions (for references see Jux, 1991). In fact, research on fossils from the Paffrath Syncline started already in the eighteenth century (Schröter, 1777).

The Paffrath Syncline lies near the northern rim of the Rhenish Slate Mountains, approximately 20 km northeast of Cologne (Fig. 1). Geologically, the syncline is located between the Bechen Anticline which is the southwestern extension of the Ebbe Anticlinorium and the Bensberg Anticline. On the southern flank Middle and Upper Devonian sediments of the syncline are bordered by a very important overthrust fault (Gladbacher Randverwerfung). South of this fault Lower Devonian sediments are widespread. Due to longitudinal and strike-slip faults a complicated tectonic pattern of small-scale thrusted antiforms, synforms and fault blocks is produced (Jux, 1982).

Frasnian and lower Famennian sediments varying from 330 to 410 m in thickness crop out in a narrow sector stretching southwest-northeast (Jux, 1991). The Upper Devonian succession starts with lagoonal limestones (Fig. 2) which have yielded a very famous fish fauna (e.g. Ørvig, 1960/1961; Jessen, 1973). After deposition of the Refrath Formation reefal limestone production ceased and the overlying strata are dominated by grey fine-grained sediments. At the top of the Sand Formation a distinctive unit (correlated with the upper Kellwasser horizon) marks the base of the Knoppenbießen Formation. The formation is characterized by dark grey marlstones and mudstones very rich in well preserved invertebrate fossils (Jux & Groos, 1967; Jux & Krath, 1974) which date the sediments as lower Nehdenian precisely. Until recently it was believed that the Knoppenbießen Formation terminated the Upper Devonian succession in the Paffrath Syncline. The late Famennian sediments encountered in the three boreholes have not yet been named and it is unknown if Upper Nehdenian, Hembergian and Dasbergian sediments are present. The late Famennian sediments are not exposed and no borehole exists which intersects the complete succession. Therefore our knowledge concerning thickness and facies of the late Famennian in the Paffrath Syncline is extremely limited.

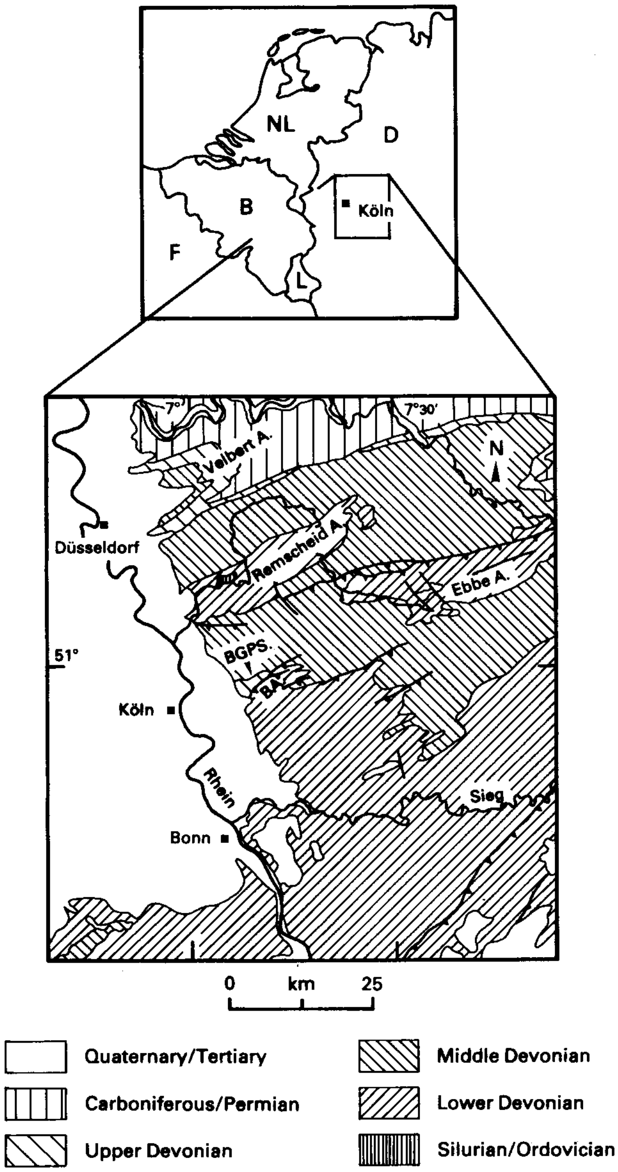


Figure 1. Study area and geological map. Abbreviations: BGPS = Bergisch Gladbach-Paffrath Syncline; BA = Bensberg Anticline; Velbert A. = Velbert Anticline; Remscheid A. = Remscheid Anticlinorium; Ebbe A. = Ebbe Anticlinorium.

The Devonian succession is covered by gravel and sand of Quaternary and Tertiary age which generally speaking decrease in thickness from the west to the east. Hence, stratigraphy and tectonics of the western part of the Paffrath Syncline is less known.

Paleogeographically, the area of the Paffrath Syncline was situated south of the actual Velbert Anticline where during the Famennian a rapidly subsiding trough existed. The sediments which were deposited in this trough are similar to the supposed shelf-type siliciclastics of the Condroz Sandstone facies. East of the Velbert Anticline a very sharp facies boundary separates the well-aerated water area from the basinal (quiet water) areas (Paproth *et al.*, 1986).

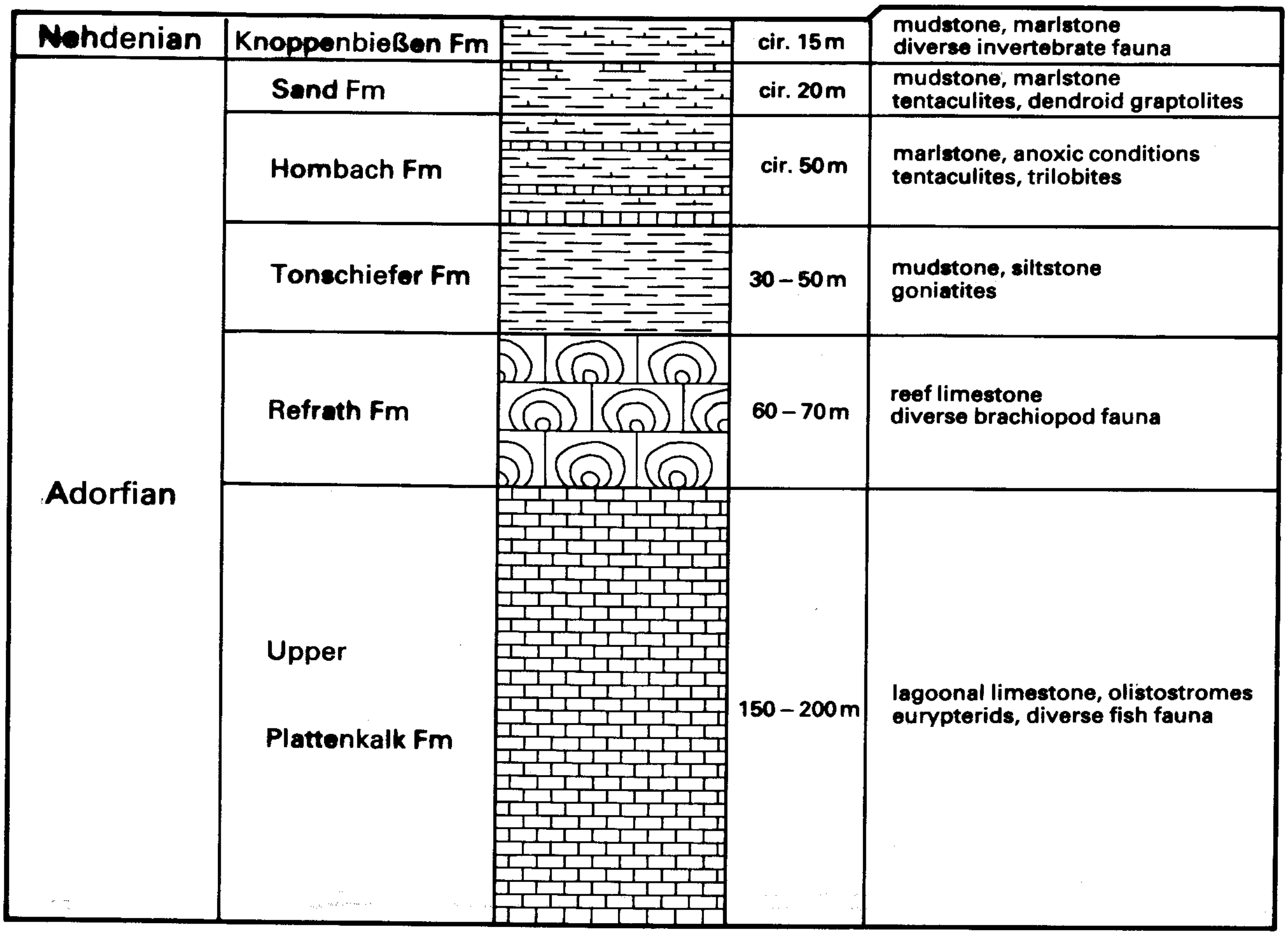
The thermal maturation in the Paffrath Syncline is extraordinarily low compared to the Upper Devonian sediments which crop out at the northern border of the Rhenish Slate Mountains. Paproth & Wolf (1973) report a vitrinite reflectance value of %Ro max = 0.69 for the Knoppenbießen Formation indicating that the Knoppenbießen Formation was never deeply buried. Apparently, the thickness of overlying and in the meantime eroded sediments did not exceed 200 m.

3. PREVIOUS PALYNOLOGICAL WORK

A number of papers which deal with palynomorphs from Devonian rocks of the Paffrath Syncline have been previously published. Amirie (1984; 1989) described Adorfian acritarch and miospore assemblages, respectively. The acritarch communities from the Upper Devonian were considered by Jux (1975; 1984) including TEM investigations. Referring to determinations by G. Schultz, he also provided a very limited account of six miospore taxa from the Knoppenbießen Formation without illustrating or describing the species (Jux, 1975: p. 116). Stratigraphically, the most important one is *Retispora lepidophyta*. The occurrence of this taxon is striking because its inception marks the base of the Oppel Zone LV which in turn coincide with the base of the Fa2d (Streel *et al.*, 1987). However, faunal data clearly indicate a lower Nehdenian age assignement for the Knoppenbießen Formation. Unfortunately, the samples and slides relating to the study of Jux (1975) could not be relocated in the collection of the Department of Geology, University of Cologne (G. Schultz, oral comm.). Therefore 25 samples have been investigated from the Knoppenbießen Formation cropping out in the Lerbach section and from a former excavation (locality Kreishaus) southeast of Bergisch Gladbach. In addition, one sample from Cox quarry nearby where the Knoppenbießen Formation was temporarily exposed was processed. The samples yielded abundant but poorly preserved miospores severely damaged by the growth of pyrite crystals. However, not a single specimen of *Retispora lepidophyta* was recovered. Therefore the previous record of *R. lepidophyta* could not be confirmed and the authors believe it might represent a misidentification of strongly corroded camerate spores.

4. SAMPLE DETAILS

This report is based on five samples collected from three boreholes (topographical map 1:25000, sheet 5008 Köln-Mülheim). All samples are housed in the Geological Survey of North Rhine-Westphalia.



Nehdenian	Knoppenbießen Fm	cir. 15 m	mudstone, marlstone diverse invertebrate fauna
Adorfian	Sand Fm	cir. 20 m	mudstone, marlstone tentaculites, dendroid graptolites
	Hombach Fm	cir. 50 m	marlstone, anoxic conditions tentaculites, trilobites
	Tonschiefer Fm	30 – 50 m	mudstone, siltstone goniatites
	Refrath Fm	60 – 70 m	reef limestone diverse brachiopod fauna
	Upper Plattenkalk Fm	150 – 200 m	lagoonal limestone, olistostromes eurypterids, diverse fish fauna

Figure 2. Lithostratigraphic divisions of Upper Devonian rocks in the Paffrath Syncline.

Borehole Buchenkamp 1985 (coordinates R^{25}76765, H^{56}46930) was drilled for ground-water observation and ended at a depth of 306 m. It penetrated 42 m of Quaternary sediments before it reached late Devonian sediments dominated by dark grey mudstones and marlstones. Marly limestone and medium grey siltstones occasionally occur as thin bands. Due to the deep weathering during Tertiary and Quaternary times at least the upper 60 m of the Devonian sediments are hardly indurated. Only one sample from 60 m (N°. 89509) (all depths as measured from surface; sample number in brackets) was available. It consists of medium grey, slightly calcareous mudstone.

Borehole Brücker-Hardt 1984 (coordinates R^{25}76490, H^{56}45760) was drilled by the Geological Survey NW to a total depth of 60 m during a geological mapping program in the Paffrath Syncline. The Devonian sediments are covered by gravel and sand of Quaternary age. Their thickness is 36,5 m. Like in borehole Buchenkamp *et al.,* 1985 the Devonian mainly consists of medium grey mudstones. In the lowermost part of the borehole micaceous fine-grained sandstone layers are present. Three samples have been examined from 42 m (N° 82348), 45 m (N° 82349), and 48 m (N° 82350).

The third borehole KB-33 1983 (coordinates H^{25}79173, R^{56}49002) is very shallow with a total depth of 9 m. It penetrated 4 m of Quaternary. A palynology sample (N° 91227) consisting of dark grey, slightly calcareous, platy mudstone was obtained at the terminal depth.

The samples studied have been processed following conventional palynological preparation procedures. Due to the low thermal alteration oxidation with Schulze reagents was not required.

5. PALYNOLOGY

All samples studied yielded palynomorphs. The best recovery was from three samples from borehole Brücker-Hardt 1984. They contained a diverse and very well preserved assemblage of miospores and microphytoplankton. The two samples from the other boreholes proved to be less productive in terms of numbers and taxonomic diversity. The following list includes the stratigraphic key taxa which occur in the miospore population encountered in the samples N°. 82348-82350. Species which are of little stratigraphic significance, e.g. smooth trilete spores, are not taxonomically segregated and are not considered in the species list.

Species list

Aneurospora greggsii (McGregor 1964) Streel 1974 (Not figured)
Archaeozonotriletes micronulatus Kedo 1974 (Plate 1: A, B)
Auroraspora hyalina (Naumova 1953) Streel *in* Becker *et al.* 1974 (Plate 1: C)
Auroraspora solisorta Hoffmeister, Staplin & Malloy 1955 (Plate 1: D)
Auroraspora cf. *solisorta* Hoffmeister, Staplin & Malloy 1955 sensu Higgs, Clayton & Keegan 1988 (Plate 1: F)
Convolutispora sp. (Plate 1: H, I)
Convolutispora cf. *usitata* Playford 1962 sensu van der Zwan 1980 (Plate 1: G)
Corbulispora sp. (not figured)
Cyrtospora cristifera (Luber 1941) emend. van der Zwan 1979 (Plate 1: E)
Diducites mucronatus (Kedo 1974) emend. van Veen 1981 (Plate 2: A, B, H)
Diducites plicabilis van Veen 1981 (Plate 2: C, D, E)
Diducites poljessicus (Kedo 1957) emend. van Veen 1981 (Plate 2: G, I, L)
Diducites versabilis (Kedo 1957) emend. van Veen 1981 (Plate 2: F, K)
Endoculeospora gradzinskii Turnau 1975 (Plate 3: A, B, D, E)
Endoculeospora setacea (Kedo 1971) Avkhimovitch & Higgs *in* Avkhimovitch *et al.* 1988 (Plate 3: C, F, I)
Geminospora lemurata Balme 1962 emend. Playford 1983 (Plate 3: G)
Gorgonispora crassa (Winslow 1962) Higgs, Clayton & Keegan 1988 (Plate 3: K, L)
Grandispora cornuta Higgs 1975 (Plate 3: H; Plate 4: A)
Grandispora aff. *echinata* Hacquebard 1957 (Plate 4: C, E)
Grandispora gracilis (Kedo 1957) Streel *in* Becker *et al.* 1974 (Plate 4: F)
Grandispora cf. *tenuispina* (Hacquebard 1957) Playford 1971 sensu Streel *in* Becker *et al.* 1974 (not figured)
Grandispora cf. *tenuispina* (Hacquebard 1957) Playford 1971 var. *punctata* Streel *in* Becker *et al.* 1974 (Plate 7: H)
Hystricosporites sp. (Plate 4: B, D, G, H)
Knoxisporites hederatus (Ischenko 1956) Playford 1963 (Plate 5: A, B, D)
Knoxisporites aff. *literatus* (Waltz 1938) Playford 1963 (Plate 5: E)
Lophozonotriletes lebedianensis Naumova 1953 (Plate 5: C, K, L)
Lophozonotriletes sp. (Plate 5: F, G, H, I)
Raistrickia minor (Kedo 1963) Neves & Dolby 1967 (Plate 6: E)
Raistrickia variabilis Dolby & Neves 1970 (Plate 6: A, B, C)
Retispora lepidophyta (Kedo 1957) Playford 1976 (Plate 6: F, G, I)
Rhabdosporites langii (Eisenack 1944) Richardson 1960 (Plate 6: D, H)
cf. *Samarisporites* sp. (Plate 7: A, B, C)
Spelaeotriletes cf. *granulatus* (Kedo 1963) Moreau-Benoit 1980 (Plate 7: D, E)
Spelaeotriletes sp. cf. *S. pretiosus* (Playford 1964) emend. Utting 1987 var. *windsorensis* Utting 1987 (Plate 7: G)
Teichertospora torquata (Higgs 1975) emend. McGregor & Playford 1990 (Plate 7: F)

5.1. SELECTED SYSTEMATICS

Information on the abundance of a particular taxon is only given for those species of which less than five specimens have been recovered.

Archaeozonotriletes micronulatus Kedo 1974 (Plate 1: A, B)

Remarks: Currently, late Devonian taxa of the genus *Grandispora* are being revised by a CIMP working group. In order not to anticipate the results or to produce nomenclatural confusion in referring to not yet published new taxa or changed generic assignments we therefore continue to use the old names.

Occurrence: one specimen.

Auroraspora cf. *solisorta* Hoffmeister, Staplin & Malloy 1955 sensu Higgs, Clayton & Keegan 1988 (Plate 1: F)

Comparison: *Auroraspora velata* (Felix & Burbridge) Ravn 1991 is very similar and differs only on the basis of a thinner, flexuous exoexine parts of which are often folded over the intexine.

Convolutispora cf. *usitata* Playford 1962 sensu van der Zwan 1980 (Plate 1: G)

Remarks: The specimen recorded conforms closely to those described by van der Zwan (1980b: p. 221, pl. 7, fig. 3, 4). *Convolutispora caliginosa* Clayton & Keegan *in* Clayton *et al.* 1982 is similar but differs by reduced ornamentation in the contact area.

Occurrence: one specimen.

Endoculeospora gradzinskii Turnau 1975 (Plate 3: A, B, D, E)

Remarks: Most specimens recorded clearly belong to variant B of van der Zwan (1980a). Variant A which is smaller in size is not present in the assemblage.

Endoculeospora setacea (Kedo 1971) Avkhimovitch & Higgs *in* Avkhimovitch *et al.* 1988 (Plate 3: C, F, I)

Remarks and comparison: The exoexine is infragranulate, bearing distally and equatorially discrete pila and bacula with rounded tops and up to 4 µm high. On the proximal surface some rare sculptural elements are present. The species has a similar style of ornament to *E. gradzinskii*, but differs in possessing a thin, folded intexine which is larger in relation to the total spore diameter. The specimens recorded conform closely to those figured by Avkhimovitch *et al.* (1988).

Geminospora lemurata Balme 1962 emend. Playford 1983 (Plate 3: G)

Remarks: The specimen is slightly larger than the size range given by Playford (1983) and the lips are accompanied by laesurae. However, specimens of *G. lemurata* from the type locality (Gneudna Formation, Pelican Hill borehole), which we were able to examine, show a wide range of morphological variation (e. g. depending on the state of preservation, cf. Playford, 1983). Hence we believe that the present specimen is cospecific with that species. At least some taxa of *Geminospora*, figured in Avkhimovitch *et al.* (1993), appear to be synonymous with *G. lemurata* and should be reconsidered.

Occurrence: one specimen.

Gorgonispora crassa (Winslow 1962) Higgs, Clayton & Keegan 1988 (Plate 3: K, L)

Comparison: *Gorgonispora convoluta* (Butterworth & Spinner 1967) Playford 1976 on the distal surface is rugulate, reticulate and subordinately verrucate whereas in *G. crassa* an imperfect reticulum with widely spaced muri is developed. *Gorgonispora multiplicabilis* (Kedo 1963) Turnau 1978 lacks the wide labra.

Occurrence: one specimen.

Grandispora aff. *echinata* Hacquebard 1957 (Plate 4: C, E)

The Paffrath specimens possess spinae and coni which usually are smaller than 2.5 µm in height. However, on any specimen some spinae up to 3 µm and in some rare cases up to 4 µm are present. The holotype of *G. echinata* bears broad based spinae and coni with a maximum height of 2.5 µm (McGregor & McCutcheon, 1988: fig. 4 f.). *G. echinata* from sections located in the Dinant Synclinorium where the Interval Zone *Ech.* has been defined also has smaller sculptural elements than the present specimens. We only tentatively assign our material to *G. echinata* until this species has been reviewed by the CIMP working group (see *Archaeozonotriletes micronulatus*).

Hystricosporites sp. (Plate 4: B, D, G, H)

Description: Amb subcircular, proximal surface flattened, distal surface inflated, hemispherical. Exoexine and intexine separated, exoexine lavigate to infragranulate, total spore diameter 90 µm (excluding projecting ornaments). Overall outline of inner body subcircular, intexine laevigate, partially concentric compression folds developed along periphery of intexine, diameter of inner body 70 µm. Laesurae obscured by high flexuous folds forming an apical prominence at the proximal pole. Contact areas indistinct, delimited by low arcuate ridges and ornamented with 3 or 4 radially oriented thickened ribs in each interradial area. Some ribs vaguely defined. Ribs straight to slightly sinuous, broad and flat, up to 3 µm high, some possessing a median depression, and separated by a furrow. Median depression clearly visible near the proximal pole, disappearing towards the arcuate ridges. Exoexine bears distally, equatorially and on the arcuate ridges slender processes with bifurcate terminations. Each process consists of a broad base, a shaft tapering in its lower part but parallel sided in its middle and upper portion, and a laterally extended and reflexed or a laterally extended termination (terminology according to Owens 1971). Length of the processes 12-17 µm, basal diameter 3-6 µm, length of bifurcate spinae 3-8 µm.

Remarks: In the past, more than thirty species originally assigned to *Hystricosporites* have been erected mainly due to differences in size, distribution of ornaments, process size and profile, nature of terminal bifurcate portion of the processes, development of contact areas and curvaturae or presence of proximal radiating ribs. Because the morphology of the ornaments seems to be fairly variable on one and the same specimen, its taxonomic value may be questionable.

Comparison: The present specimen is characterized by proximal ribbing and sparse, slender processes which are relatively small compared to the spore diameter. *Hystricosporites bulbosus* Chi & Hills 1976, *H. elongatus* Chi & Hills 1976, *H. expandus* Chi & Hills 1976, *H. furcatus* Owens 1971, *H. grandis* Owens 1971, *H. gravis* Owens 1971, *H. harpagonis* Owens 1971, *H. pseudoporatus* Hills *et al.* 1984, *H. reflexus* Owens 1971, *H. spiralis* Chi & Hills 1976, *H. validus* Chi & Hills 1976, and *Hystricosporites* sp. of van der Zwan 1980b, p. 224, pl. 10, figs. 1a-c all have radially orientated ribs on the contact area but bear processes considerably different in size, profile or termination. From the Devonian of Russia some more species with radially disposed costae have been described and originally assigned to *Archaeotriletes.* Several of these taxa subsequently have been transferred to *Hystricosporites* but their description and illustration in most cases is still insufficient in order to definitely confirm or deny identity with the present specimen. Also some of the Russian species are considered to be at least very closely comparable if not identical to one another or may prove to be synonymous with taxa mentioned above (Playford & McGregor, 1993: p. 31). Although no radiating ribs on the contact areas are mentioned in the description of *H. corystus* Richardson 1962 the figured holotype clearly shows this feature. *H. corystus* is distinguished from the present specimen by its triradiate mark with greatly elevated, membraneous ridges and by its longer spines. *H. costatus* Vigran 1964 differs in having seven or more radially aligned ribs and more densely distributed processes which do not have a parallel sided but a gradually tapering shaft and which have triangular terminations. *H. delectabilis* McGregor 1960 is much larger but the processes are very similar besides that in *H. delectabilis* they are longer and more densely distributed. However, Braman & Hills (1992) report *H. delectabilis* from the Upper Devonian of Canada considerably smaller in size than previously noted. If one accepts a concept of broadly defined taxa within *Hystricosporites* as discussed by Playford & McGregor (1993), the Paffrath specimen may be best assigned to *H. delectabilis.*

Occurrence: one specimen.

Knoxisporites hederatus (Ischenko 1956) Playford 1963 (Plate 5: A, B, D)

Remarks and comparison: According to Bertelsen (1972) and Playford (1976) *K. hederatus* is distinguished from *Knoxisporites pristinus* Sullivan 1968 in having a stronger exine, no proximal thinning, and simple laesurae whereas *K. pristinus* possesses elevated laesurate lips and a granular exine. In addition, *K. pristinus* is frequently deformed due to the thin exine. However, as Bertelsen (1972), Playford (1976), and Hibbert & Lacey (1969) commented, both species are difficult to distinguish from each other. The differences between *K. hederatus* and *K. pristinus* appear unconvincing to the present authors and hence we consider the two species as synonymous. One specimen recorded in the Paffrath assemblage (pl. 5: D) displays a thin deformed exine but is devoid of any ornaments and lacks lips. Well preserved specimens (pl. 5: A, B) possessing a thick exine are scabrate with micrograna smaller than 0.5 µm giving the exine a rough appearance. A similar ornamentation was described and figured for *K. pristinus* from the Lower Carboniferous of Denmark (Bertelsen 1972, pp. 51-52, pl. 18, fig. 5). A microgranulate exine was not positively mentioned in former descriptions of *K. hederatus*. Some specimens (e.g. pl. 5: A) show folds along the laesurae superficially giving the impression of broad labra. *Knoxisporites dedaleus* (Naumova 1953) Streel 1973 is distinguished from *K. hederatus* by a narrow cingulum and a granulate exine (Avkhimovitch *et al.*, 1988 p. 172).

Knoxisporites aff. *literatus* (Waltz 1938) Playford 1963 (Plate 5: E)

Remarks: The species is characterized by broad, low labra. The figured specimen does have labra but developed only along two laesurae of the trilete mark. Also one labrum tapers toward the cingulum. We therefore hesitate to assign the specimen unequivocally to that species.

Occurrence: one specimen.

Lophozonotriletes lebedianensis Naumova 1953 (Plate 5: C, K, L)

Remarks: Naumova (1953) proposed *Lophozonotriletes* and assigned fifteen newly instituted species and four varieties to the genus. They all are only briefly described and illustrated as stylized line drawings. Mostly, the diagnosis does not mention the identifying characters which separate the taxon from its allies. Hence, many taxa are not clearly circumscribed and appear to be indistinguishable from one another.

Specimens bearing prominent, often irregularly spaced very short bacula and verrucae with rounded tops and sometimes with constricted base are attributed to *L. lebedianensis* in this report. The ornaments are widely spaced to densely distributed as it is figured by Naumova (1953: pl. 19, fig. 32-34) and Avkhimovitch *et al.* (1993). The verrucae are up to 7 µm in height, up to 15 µm in basal diameter and only rarely fused. In the Paffrath specimens the contact area is laevigate except for one (pl. 5: K) which is ornamented on the proximal face with small and flat verrucae up to 3 µm in diameter. This specimen also has labra.

Lophozonotriletes sp. (Plate 5: F, G, H, I)

The specimen resembles *L. lebedianensis* except that the verrucae are irregularly shaped and have flat or irregular tops. Also smaller verrucae are present amongst the larger ones. Frequently, larger verrucae show constrictions giving rise to a knotty impression. *Pustulatisporites multicapitis* Bertelsen 1972 is similar regarding the shape of the ornaments but differs by being sculptured on both the proximal and distal surface. Additional specimens are required before they can be confidently assigned to a species of *Lophozonotriletes*.

Raistrickia minor (Kedo 1963) Neves & Dolby 1967 (Plate 6: E)

Remarks: Combaz & Streel (1971, pp. 231-232, pl. 4, figs. 5 and 9) figured two specimens from the late Famennian of Pas-de-Calais (France) which are very similar to the present material and which they assigned to *Raistrickia variabilis* Dolby & Neves 1970. According to Higgs *et al.* (1988), these specimens are conspecific with *R. minor.*

Occurrence: one specimen.

Raistrickia variabilis Dolby & Neves 1970 (Plate 6: A, B, C)

Remarks: One specimen (pl. 6: C) is ornamented on both surfaces with a mixture of bacula and small (1-3 µm in basal diameter), closely spaced verrucae, subcircular to irregular in plan view, sometimes coalescent, and with flattened tops. However, the specimen is identical in any other respect with *R. variabilis.*

Rhabdosporites langii (Eisenack 1944) Richardson 1960 (Plate 6: D, H)

Remarks: The diameter of the exoexine is 85 µm, that of the intexine 62 µm which falls into the size range of *Rhabdosporites parvulus* Richardson 1965. In the original description this species was differentiated from *R. langii* by its smaller size range and by its relatively larger intexine although the size ranges overlap as is clearly shown in the graphical plot of exoexine and intexine diameters (Richardson, 1965: text-fig. 8). Both species were originally described as uniformly covered by densely packed rods which are parallel sided and have truncated tips. In the present specimen the bladder is densely covered with often fused minute coni and spines. However, the different ornamentation may be the result of preservational alteration as it was previously demonstrated to be the case for *R. langii*, too (Lele & Streel, 1969, McGregor & Camfield, 1982). Specimens appearing identical or at least very similar to the present one have been described and tentatively assigned to *Rhabdosporites langii* by Streel (1965), to ?*Rhabdosporites parvulus* by Lele & Streel (1969) and Higgs & Russell (1981), and to ?*Rhabdosporites* cf. *parvulus* by Streel *in* Becker *et al.* (1974). Possibly, there is a morphographic gradation between the above mentioned taxa, particularly since Marshall & Allen (1982) proved a gradual change in exoexine/intexine diameter and ratio of *R. langii* and *R. parvulus*. Hence, we follow Marshall & Allen (1982) and Balme (1988) and regard these species as synonymous.

Occurrence: one specimen.

cf. *Samarisporites* sp. (Plate 7: A, B, C)

Remarks and Comparison: The specimen superficially resembles *Samarisporites* sp. cf. *Acanthotriletes hirtus* Naumova 1953 sensu Streel *in* Becker *et al.* 1974 and the unidentified spore in Chitaley & McGregor (1988: pl. 13, fig. 3). As only one specimen is available and because of the poor preservation, accurate identification is precluded.

Occurrence: one specimen.

Spelaeotriletes cf. *granulatus* (Kedo 1963) Moreau-Benoit 1980 (Plate 7: D, E)

Description: Trilete camerate miospore, amb convexly subtriangular with rounded apices and convex sides. Intexine distinct, thin, laevigate, eccentrically placed with respect to the exoexine, comprising approximately 60 per cent of the total spore diameter. Suturae obscured by ray folds, folds flexuose, reaching equator where they merge with an equatorial darkening of the exoexine forming curvaturae. Ornaments consisting of coni, microconi, and microspinae, superimposed on infragranulate exoexine, some rare coni 1 µm in height, most microconi 0.5 µm or less in height and less than 1 µm in basal diameter, microspinae less than 0.5 µm in height. Ornaments discrete, hardly discernible on distal surface due to their minute size, readily visible at the equator. Overall diameter of exoexine 100 µm, of intexine 60 µm.

Remarks and comparison: *Spelaeotriletes eccentricus* Butterworth & Mahdi 1982 is similar to the present specimen but differs in possessing an intexine ornamented with minute, closely spaced bacula and in being ornamented with coarse grana and some scattered coni/spinae. *Spelaeotriletes exiguus* Keegan 1977 which Higgs *et al.* (1988) consider to be synonymous with *Spelaeotriletes crustatus* resembles the Paffrath specimen and bears minute ornaments up to 1 µm in height. However, the sculptural elements consist of a mixture of microverrucae, microbaculae, microconi and microspinae. *Spelaeotriletes queenslandensis* Jones & Truswell 1992 possesses coarser, occasionally fused sculptural elements and a less distinct intexine which is also larger in relation to the exoexine. Generally, the Paffrath specimen is considered conformable to *S. granulatus* but the rather undifferentiated diagnosis and line-drawn illustrations do not facilitate detailed comparisons. We tentatively assigne the specimen to *S. granulatus* because according to the original diagnosis, the Russian species is slightly smaller and granulate, not conate/microconate. However, depending on the resolving power of the used objective extremely minute sculptural elements may be misinterpreted. Moreau-Benoit (1980) who encountered the species from the late Famennian of the Rhadames Basin (Western Libya) does not discuss it in detail. She describes it as possessing an exoexine uniformly ornamented with small grana («une fine granulation uniforme») whereas Coquel & Moreau-Benoit (1989: p. 89) state that *S. granulatus* is infragranulate. As mentioned before, the coni on the Paffrath specimen are so small that if any ornaments can be detected over-oxidized or mediocrely preserved specimens will at best display grana rather than coni. Cf. *Hymenozonotriletes granulatus* Kedo 1963 sensu Chitaley & McGregor (1988) from the latest Famennian of Pennsylvania, illustrated but undescribed, appears to be similar.

Outside of Russia *S. granulatus* was rarely found namely in sequences exclusively dated within the Strunian to Tournaisian (Streel in Paris *et al.*, 1985; Moreau-Benoit, 1989). In addition to the records already mentioned the species was also reported to occur in the Strunian of the Illizi basin, eastern Algerian Sahara (Coquel & Latreche, 1989).

The author attributions for *Spelaeotriletes granulatus* are still unclear, especially regarding the first validating author (cf. the differing authorship citation in Moreau-Benoit, 1980: p. 40 but pl. 13, fig. 1; Coquel & Moreau-Benoit, 1986: p. 29; Moreau-Benoit, 1989: p. 13) and the validity of the combination made by Moreau-Benoit (1980). As it is not the intention of this paper to unravel nomenclatural problems we continue to use the most customary citation.

Occurrence: one specimen.

Spelaeotriletes sp. cf. *S. pretiosus* (Playford 1964) emend. Utting 1987 var. *windsorensis* Utting 1987
(Plate 7: G)

Comparison: The Paffrath specimen closely resembles *S. pretiosus* var. *windsorensis*, but has a slightly smaller intexine in relation to the exoexine and possesses an equatorial darkening of the exoexine.

Remarks: Higgs *et al.* (1988) followed the original concept of *Pustulatisporites pretiosus* Playford 1964 when they defined the late Middle/early Upper Tournaisian PC Biozone whose base is marked by the first appearance of this taxon. The Irish species which is used in their zonal concept is identical with *Spelaeotriletes pretiosus* (Playford 1964) emend. Utting 1987 var. *pretiosus* Utting 1987 and does not include forms ornamented with small, discrete sculptural elements. Therefore the stratigraphic range of the Irish species is not extended downward into the latest Devonian by the single, questionably identified specimen of *S. pretiosus* (Playford 1964) emend. Utting 1987 var. *windsorensis* Utting 1987.

Occurrence: one specimen.

6. STRATIGRAPHIC SIGNIFICANCE OF THE MIOSPORES

Without doubt the Paffrath miospore assemblage is of late Famennian age.

In the Ardenne-Rhenish regions *Grandispora gracilis, Diducites poljessicus,* and *Diducites plicabilis* appear in the upper part of the Frasnian (Streel *et al.*, 1987). In upper Famennian strata of Belgium *Diducites* is particularly abundant (Streel & Scheckler, 1990). McGregor & Playford (1990) compiled the stratigraphic distribution of *Teichertospora torquata* in Upper Devonian rocks of western Europe and North America where the species ranges from very late Frasnian to latest Famennian. However, in Europe this form seems to be confined to the latest Famennian suggesting that its incoming may not have been synchronous in southern Euramerica. *Grandispora cornuta* provides one of the eponyms for the Oppel Zone VCo which marks the base of the chronozone Fa2c and within this Oppel Zone *Raistrickia variabilis* begins, too (Streel *et al.*, 1987). In Ireland and in the Sauerland *Endoculeospora gradzinskii* is first seen in the Interval Zones LE (Higgs *et al.*, 1988) and LL (Higgs & Streel, 1984), respectively but in North America as far as we are aware the oldest recorded occurrence seems to be in the *Rugospora flexuosa* - *Grandispora cornuta* Assemblage Zone (Richardson & Ahmed, 1988) which approximately equates with the late Famennian.

It is generally assumed that in Europe *Cyrtospora cristifera* does not appear before the latest Famennian but that in the northern region of the Old Red Continent the species, among others, characterizes the *Auroraspora torquata* - *Grandispora gracilis* Assemblage Zone which is of latest Frasnian to early late Famennian age (Richardson & McGregor, 1986; Chitaley & McGregor, 1988; McGregor & McCutcheon, 1988). Indeed, the taxon was reported to occur rarely at the very top of the Devonian of the Northern Rhenish Slate Mountains but to be more abundant in the lowermost Carboniferous of Ireland.

In the Sauerland the species makes its first appearance together with an atypical LN assemblage signifying a position near the top of the Interval Zone LN just below the incoming of *Siphonodella sulcata* (Higgs & Streel, 1984; Higgs *et al.*, 1993; Higgs & Streel, 1994). In Ireland the taxon was reported to range from the Biozone VI to PC (Higgs *et al.*, 1988). However, a single specimen of *C. cristifera* was recovered by us from a sample of the Knoppenbießen Formation (lower Nehdenian) collected in the Lerbach section (see 3.) indicating that the taxon, though very rare, is already present in the lower Famennian of Europe. The species was also reported to occur in the lowermost Famennian of the Boulonnais area of northern France (Loboziak & Streel, 1981) and near the Frasnian/Famennian boundary of North-East Libya (Streel *in* Paris *et al.*, 1985).

By far the stratigraphically most important miospore species recorded is *Retispora lepidophyta* which is a near-cosmopolitan miospore marker for the late Famennian. In the Ardenne-Rhenish regions the incoming of *Retispora lepidophyta* defines the base of the Oppel Zone LV which in turn corresponds to the base of the chronozone Fa2d (Streel *et al.*, 1987). The species became extinct at or near the Devonian/Carboniferous boundary. *Grandispora echinata* and *Knoxisporites literatus* could not be positively identified. These species characterize the Interval Zone *Ech.* and the overlying Interval Zone LL, respectively. At this stage in our knowledge of latest Devonian palynostratigraphy the most reasonable age for the Paffrath assemblage is the lower part of the Oppel Zone LV of Streel *et al.* (1987). As pointed out by Streel *et al.* (1987) and Dreesen *et al.* (1993) the base of the Oppel Zone LV occurs near the limit between the conodont Middle and Late *expansa* Zones.

Further information on the age of assemblages containing *Retispora lepidophyta* can be deduced from the size range of this species. Streel (1966) applied biometric methods to define zones which he informally named C - F. Zone B is characterized by small numbers of *R. lepidophyta*, in zone C the taxon is represented by abundant and large forms, in zone D small specimens of *R. lepidophyta* appear, zone E lacks any large forms but some specimens are present displaying an atypical development of the distal lumina, and in zone F atypical representatives of *R. lepidophyta* are dominant. In assemblages which contain *R. lepidophyta* populations typical for the zones B and C, *Grandispora echinata* is absent (Paproth & Streel, 1971). In the Paffrath assemblage *R. lepidophyta* is a common element totaling up to 20 per cent. The diameter of the exoexine of *R. lepidophyta* ranges from 45 µm to 100 µm with a mean of 70 µm and therefore the Paffrath assemblages can be best assigned to the biometrically defined zone C.

The presence of *Geminospora lemurata* and *Rhabdosporites langii* is surprising and represents an unusually young occurrence of these two typically Middle and early Upper Devonian miospores in rocks as young as late Famennian. The exine colour of the last-mentioned species does not differ from other species whereas *G. lemurata* is slightly darker. However, this may be due to its thick exine and is not an argument in favour of reworking. Also the good state of preservation does not point to the fact that the two specimens are derived from older strata.

In the Ardenne-Rhenish region *Geminospora lemurata* characterizes the Interval Zone *Lem.* near the Eifelian/Givetian boundary (Streel *et al.*, 1987). The species is very abundant at the Givetian/Frasnian boundary (Playford, 1983). In northwestern Canada it reaches an acme within the lower Famennian (Braman & Hills, 1992). The youngest occurrence was reported by Chitaley & McGregor (1988) who found *in situ* miospores referable to *G. lemurata* in a heterosporous lycopsid cone collected from the Venango Formation of northwestern Pennsylvania. Dispersed miospores recovered from the matrix around the cone place the rocks into the latest Strunian within the Interval Zone LN. The presence of *G. lemurata* in the Paffrath assemblage supports the findings previously but rarely reported that *G. lemurata* does occur in strata of late Famennian age.

In Euramerica *Rhabdosporites langii* has a widespread distribution from the lower part of the Eifelian to the Givetian/Frasnian boundary. The upper limit of its range is uncertain but may be as high as the middle Frasnian or the Frasnian/Famennian boundary (Richardson & McGregor, 1986; Traverse & Schuyler, 1994). Streel *in* Becker *et al.* (1974) noted the presence of a similar, and probably identical, form in the lower Famennian (Fa1a) from Belgium and Braman & Hills (1992) reported some very rare miospores from the Frasnian and lower Famennian of northwestern Canada which they tentatively assigned to *Rhabdosporites* cf. *R. langii*. Provided that the Paffrath specimen is correctly identified (discussion see 5.1.) and not reworked, its occurrence represents a considerable upward extension of the previously recognized range.

For the time being, it is impossible to unequivocally decide whether the two specimens are rare but genuine constituents of the late Famennian miospore population or whether they are reworked. In the latter case they may derive from outcropping Givetian/Frasnian sediments eroded not far away from the actual Paffrath Syncline during the late Famennian.

7. PALAEOENVIRONMENTAL INTERPRETATION AND THERMAL MATURITY

All samples contain miospores rich in species, acanthomorph acritarchs and prasinophyte green algae. The presence of the last two is an indication of a marine environment. However, as tetrads are common the sediments presumably accumulated not far away from the shore. Also in the upper Famennian of the Ourthe Valley, Belgium, diverse miospore assemblages characterize a marine near-shore environment rather than a terrestrial one (Streel & Scheckler, 1990).

The colour of the spore exines in transmitted light is medium orange to light brown indicating a Thermal Alteration Index (TAI) of 2 to 2+ on a five point scale. These values in turn equate with a vitrinite reflectance of %Ro max = 0.6 to 0.9 approximately and thus are within the oil generation zone, namely in the early to peak generation stage of the oil window (Utting & Wielens, 1992). The vitrinite reflectance of latest Devonian sediments at the northern border of the Rhenish Slate Mountains ranges from %Ro max = 2.9 to 4.6 (Wolf, 1972; Paproth & Wolf, 1973), corresponding to a TAI of 4 - 5. Hence, the thermal maturity is remarkably low and suggests that there was never a significant depth of burial in this area.

8. CONCLUSIONS

It is very surprising that in the Paffrath Syncline, which has been thoroughly studied for a long time in respect to Devonian stratigraphy and palaeontology, a completely unknown late Famennian succession was recognized during palynological routine investigations. The occurrence of *Retispora lepidophyta* dates the assemblage in the Oppel Zone LV and clearly indicates a late Famennian (lower Strunian) age. So far the youngest known Devonian sediments in the syncline were considered to be the Knoppenbießen Formation which on the basis of a rich invertebrate fauna are of lower Nehdenian age. It is not known whether upper Nehdenian, Hembergian and Dasbergian sediments are present in the syncline.

Although informations about the facies of the late Famennian settings in the Paffrath Syncline are still limited, the presence of a diverse population of acanthomorph acritarchs and prasinophyte green algae manifest that the sediments were deposited in a marine environment. As late Famennian sediments were unknown in the Paffrath Syncline until recently, this area was believed to be situated south of the northern boundary of the Ardenne-Rhenish shoal (Paproth *et al.*, 1986).

The Oppel Zone LV has been frequently recognized in late Famennian successions of the Dinant and Namur Synclinoria. Whereas from basinal areas the Oppel Zone LV is virtually unknown except of one section in the Dill Syncline (Somers & Streel, 1978). On the other hand, palynologically defined zones overlying the Oppel Zone LV have been extensively studied in the Sauerland. Therefore the late Famennian settings in the Paffrath Syncline represent an important connecting link between the Condroz sandstone facies in the Belgian Ardenne and the supposed basinal area east of the Velbert Anticline.

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PLATE 1

Photographs were taken on a Zeiss Axioplan using 63x Plan Apochromat or 100x Plan Neofluar oil immersion objectives and a Konica XG 100 film. All specimens were photographed under Nomarski differential interference contrast which greatly enhances resolution of minute sculptural elements. The figures are magnified approximately x750, except as noted otherwise.

In the explanation of the figures, the species name is followed sequentially by remarks where appropriate, the slide identification number and the England Finder reference system co-ordinates provided that the illustrated specimen is from strew mounts. Most of the specimens are preserved in single grain mounts indicated by «SG» as part of the slide identification number.

All material relating to this study is stored in the palynological collection of the Geological Survey North Rhine-Westphalia, Krefeld.

A, B: *Archaeozonotriletes micronulatus* Kedo 1974; 82348SG34;
  A: Median focus
  B: Proximal surface.

C: *Auroraspora hyalina* (Naumova 1953) Streel *in* Becker *et al.* 1974; 82350SG14.

D: *Auroraspora solisorta* Hoffmeister, Staplin & Malloy 1955; 82348SG10.

E: *Cyrtospora cristifera* (Luber 1941) emend. van der Zwan 1979; 82349SG1.

F: *Auroraspora* cf. *solisorta* Hoffmeister, Staplin & Malloy 1955 *sensu* Higgs, Clayton & Keegan 1988; 82348SG7.

G: *Convolutispora* cf. *usitata* Playford 1962 sensu van der Zwan 1980; proximal focus; 82348SG1.

H, I: *Convolutispora* sp.; 82349SG10;
  H: Distal focus
  I: Proximal focus.

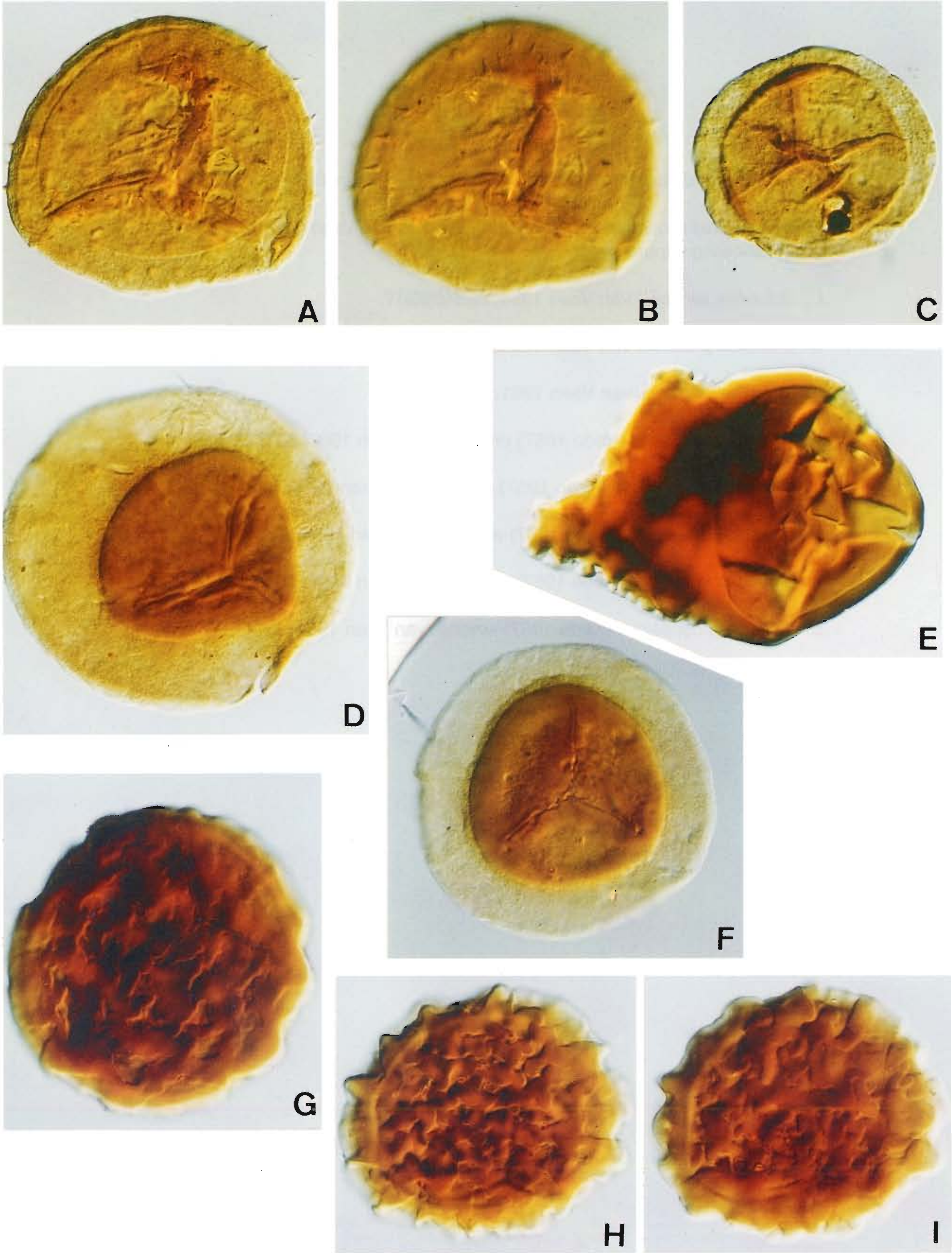
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PLATE 2

A: *Diducites mucronatus* (Kedo 1974) emend. van Veen 1981; 82350SG16.

B, H: *Diducites mucronatus* (Kedo 1974) emend. van Veen 1981; 82348SG8; H: showing separation of outer wall layers.

C: *Diducites plicabilis* van Veen 1981; 82348SG17.

D: *Diducites plicabilis* van Veen 1981; 82350SG21.

E: *Diducites plicabilis* van Veen 1981; 82350SG20.

F: *Diducites versabilis* (Kedo 1957) emend. van Veen 1981; 82350SG19.

G: *Diducites poljessicus* (Kedo 1957) emend. van Veen 1981; 82349SG16.

I: *Diducites poljessicus* (Kedo 1957) emend. van Veen 1981; 82349SG15.

K: *Diducites versabilis* (Kedo 1957) emend. van Veen 1981; 82348SG16.

L: *Diducites poljessicus* (Kedo 1957) emend. van Veen 1981; 82350SG15.

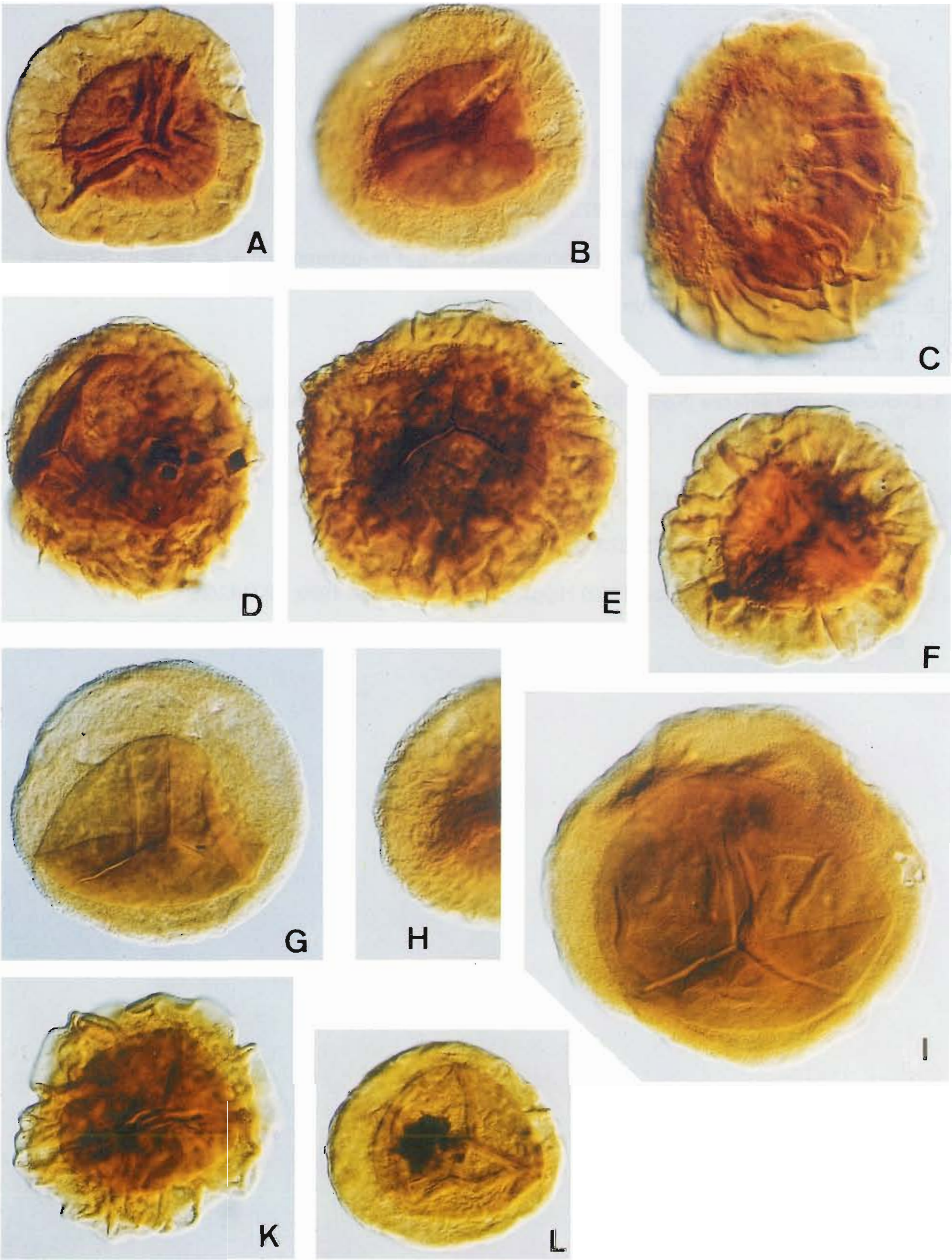
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PLATE 3

A: *Endoculeospora gradzinskii* Turnau 1975; 82350SG26.

B: *Endoculeospora gradzinskii* Turnau 1975; 82350SG27.

C: *Endoculeospora setacea* (Kedo 1971) Avkhimovitch & Higgs *in* Avkhimovitch *et al.* 1988; 82350SG28.

D, E: *Endoculeospora gradzinskii* Turnau 1975; 82349SG18;
D: proximal focus;
E: distal focus.

F, I: *Endoculeospora setacea* (Kedo 1971) Avkhimovitch & Higgs *in* Avkhimovitch *et al.* 1988; 82350SG29;
F: proximal focus;
I: distal focus.

G: *Geminospora lemurata* Balme 1962 emend. Playford 1983; 82348SG22.

H: *Grandispora cornuta* Higgs 1975; 82350SG11.

K, L: *Gorgonispora crassa* (Winslow 1962) Higgs, Clayton & Keegan 1988; 82348SG5;
K: proximal focus
L: distal focus.

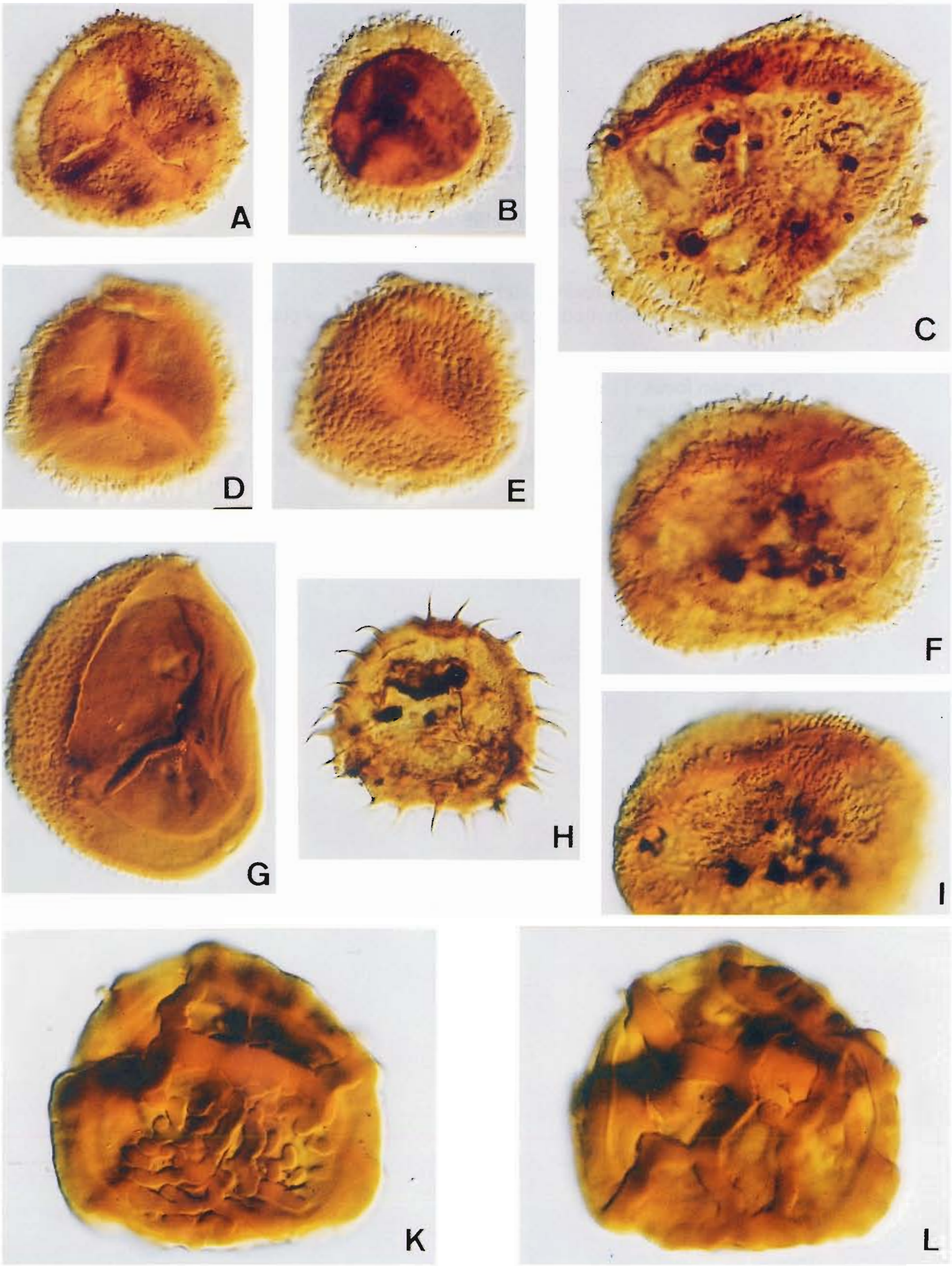
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PLATE 4

A: *Grandispora cornuta* Higgs 1975; tetrad; 82350SG12.

B, D, G, H: *Hystricosporites* sp.; 82349SG9;
  B: proximal focus
  D: median focus
  G: sculptural detail, proximal surface
  H: radiating ribs with median depression near proximal pole.

C, E: *Grandispora* aff. *echinata* Hacquebard 1957; 82348SG31;
  C: median focus
  E: proximal focus.

F: *Grandispora gracilis* (Kedo 1957) Streel *in* Becker *et al.* 1974; 82349SG14.

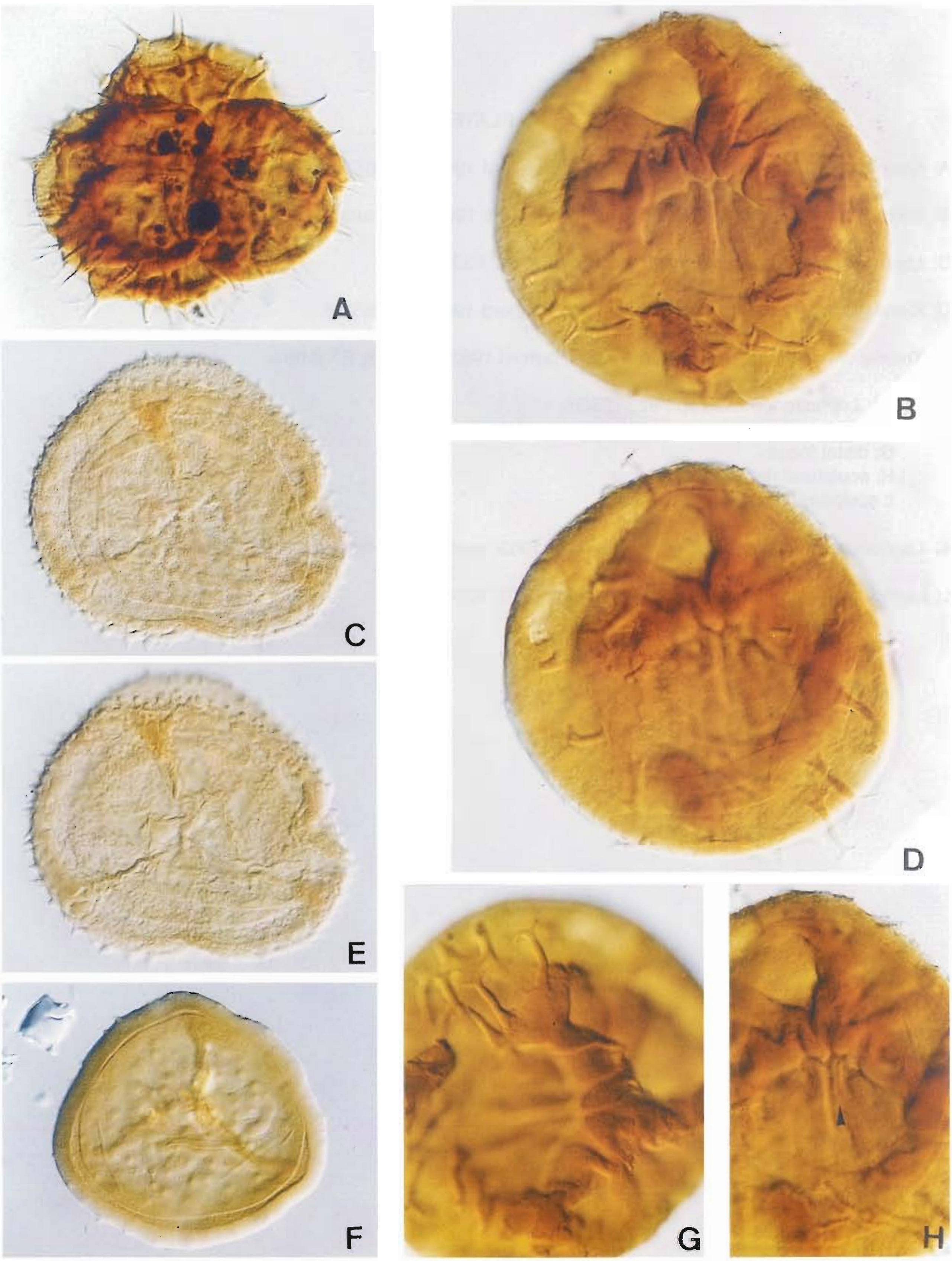
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PLATE 5

A: *Knoxisporites hederatus* (Ischenko 1956) Playford 1963; 82350SG7.

B: *Knoxisporites hederatus* (Ischenko 1956) Playford 1963; sculptural details, distal surface; 82349SG11.

C: *Lophozonotriletes lebedianensis* Naumova 1953; 82349SG6.

D: *Knoxisporites hederatus* (Ischenko 1956) Playford 1963; 82348SG6.

E: *Knoxisporites* aff. *literatus* (Waltz 1938) Playford 1963; 82348/5; EF B46/4.

F, G, H, I: *Lophozonotriletes* sp.; 82349SG5;
F: proximal focus
G: distal focus
H: sculptural details, distal focus
I: sculptural details, median focus.

K: *Lophozonotriletes lebedianensis* Naumova 1953; sculptural details, proximal focus; 82349SG7.

L: *Lophozonotriletes lebedianensis* Naumova 1953; 82349SG4.

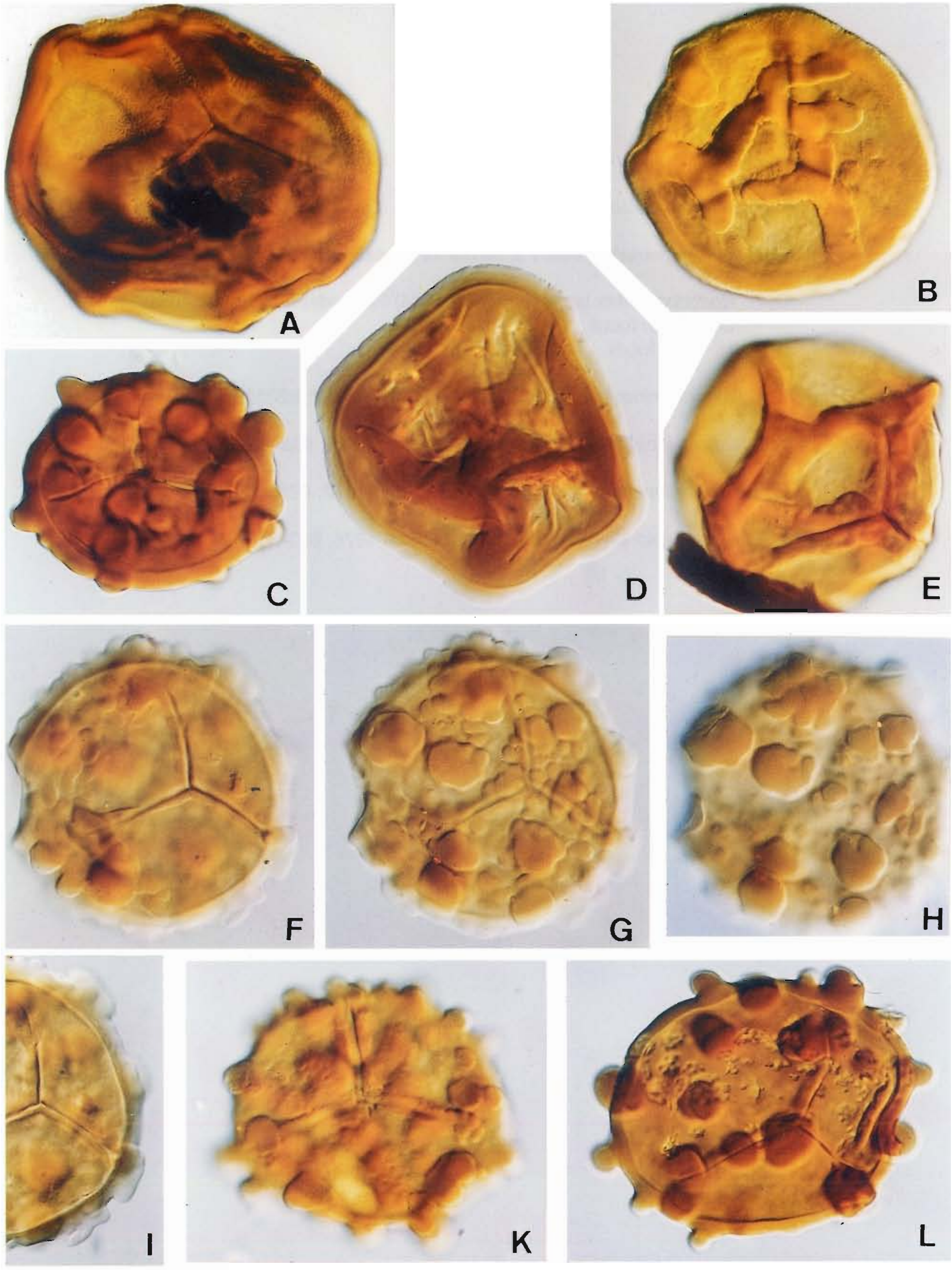
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PLATE 6

A: *Raistrickia variabilis* Dolby & Neves 1970; 82350SG5.

B: *Raistrickia variabilis* Dolby & Neves 1970; 82350SG3.

C: *Raistrickia variabilis* Dolby & Neves 1970; 82348SG3.

D, H: *Rhabdosporites langii* (Eisenack 1944) Richardson 1960; 82348SG25;
D: median focus
H: distal focus.

E: *Raistrickia minor* (Kedo 1963) Neves & Dolby 1967; 82350SG4.

F: *Retispora lepidophyta* (Kedo 1957) Playford 1976; 82348SG29.

G: *Retispora lepidophyta* (Kedo 1957) Playford 1976; 82350SG40.

I: *Retispora lepidophyta* (Kedo 1957) Playford 1976; 82348SG26.

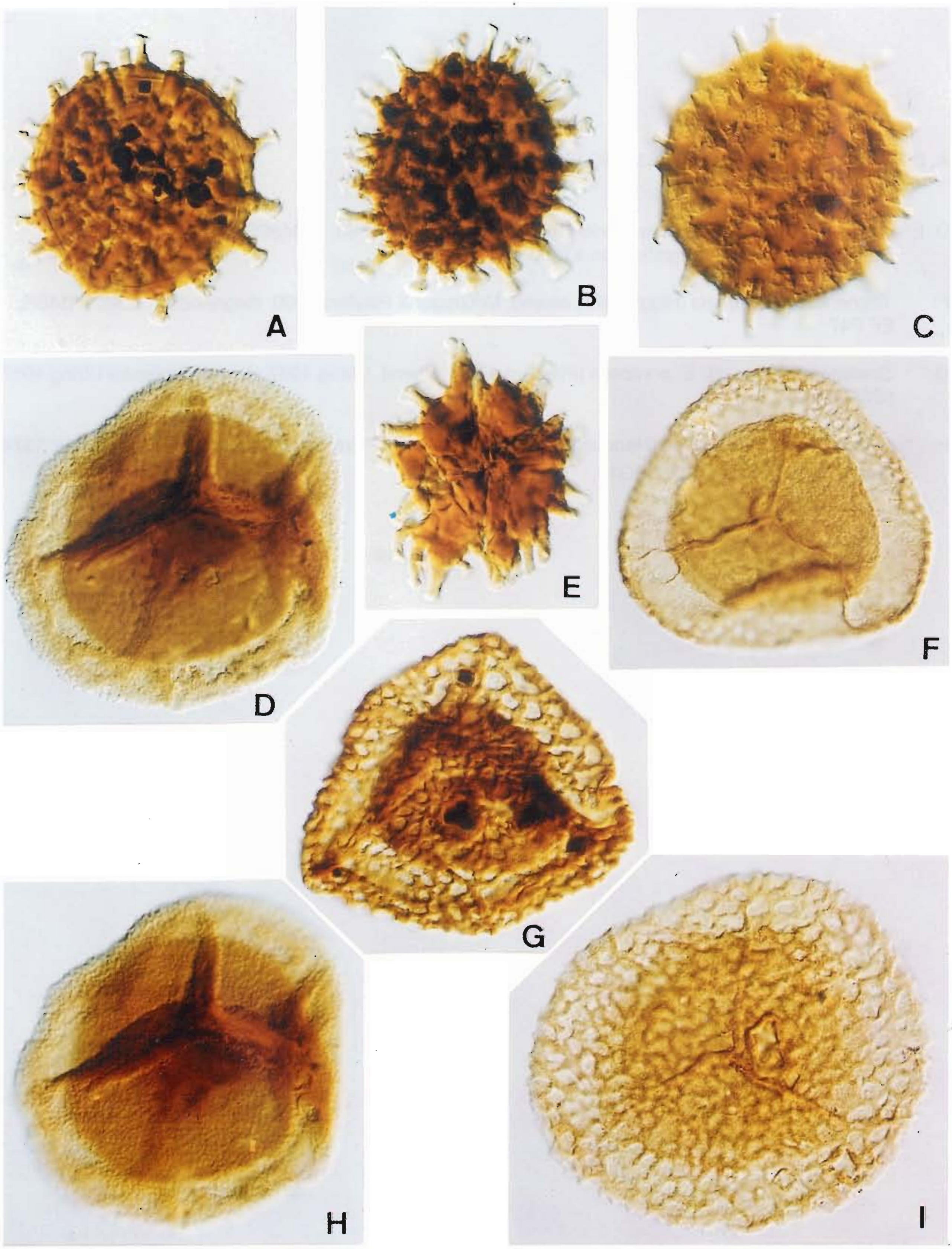
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PLATE 7

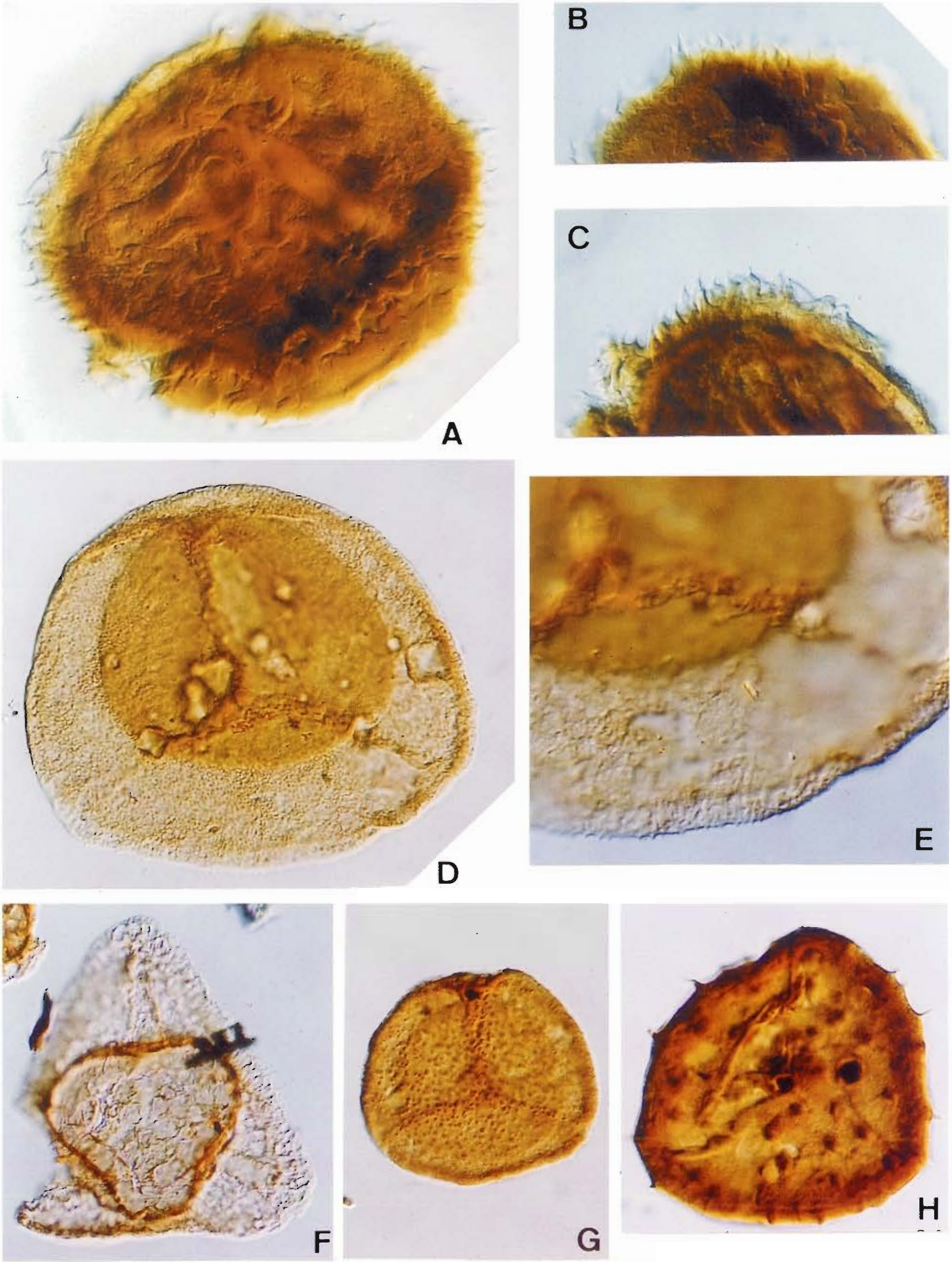
A, B, C: cf. *Samarisporites* sp.; 82349SG13;
B, C: sculptural details.

D, E: *Spelaeotriletes* cf. *granulatus* (Kedo 1963) Moreau-Benoit 1980; 82348SG24;
E: sculptural details; magnification x1200.

F: *Teichertospora torquata* (Higgs 1975) emend. McGregor & Playford 1990; magnification x480; 82348/5; EF P47.

G: *Spelaeotriletes* sp. cf. *S. pretiosus* (Playford 1964) emend. Utting 1987 var. *windsorensis* Utting 1987; 82350SG25.

H: *Grandispora* cf. *tenuispina* (Hacquebard 1957) Playford 1971 var. *punctata* Streel *in* Becker *et al.* 1974; magnification x1200; 82350SG10.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