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MIDDLE-UPPER DEVONIAN MIOSPORES FROM THE GHADAMIS BASIN (TUNISIA-LIBYA): SYSTEMATICS AND STRATIGRAPHY

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Abstract

Loboziak, S. and Streel, M., 1989. Middle–Upper Devonian Miospores from the Ghadamis Basin (Tunisia–Libya): Systematics and stratigraphy. Rev. Palaeobot. Palynol., 58: 173-196.

Fifty-five miospores (including 7 new species and 3 new combinations) that range from Emsian to late Frasnian are identified, and 48 illustrated from 4 boreholes in the Ghadamis Basin. Their stratigraphic distribution is given and correlations made with established chronostratigraphic schemes. The Old Red Sandstone Continent miospore zonation can obviously be applied to this part of the Gondwanaland. The similarity of the miospore assemblages in both continents since at least the Emsian, suggests a close proximity of these continents during the Middle and Upper Devonian.

Introduction

Recent works in northeast Libya (Paris et al., 1985; Streel et al., 1988) have shown that the first occurrence of many of the characteristic species of the miospore zonations recently developed in the Old Red Sandstone Continent (Richardson and McGregor, 1986), particularly in the Ardenne–Rhenish regions (Streel et al., 1987) are observed in the same sequence on the northern border of Gondwanaland. Therefore, unless accurate faunas provide contradictory data, there is no reason not to apply these biostratigraphies to correlations between the two palaeocontinents.

Accepting as a first step the identifications of miospores provided so far in western Libya (Massa and Moreau-Benoit, 1976; 1985; Moreau-Benoit, 1979; 1980; 1984), Streel et al. (1988, table I) have challenged their stratigraphic interpretation, restricting to the Eifelian Stage the palynozones 4–6, previously dated as Eifelian to the Upper Givetian, and to the early Givetian, the palynozones 7 and 8, previously dated as Frasnian by Massa and Moreau-Benoit, 1976.

As these late dates were used in recent North African palynological contributions (Abdesselam-Rouighi, 1986; Schrank 1987, and others), we wanted to study Ghadamis Basin material to compare it with the preliminary works in north-eastern Libya. D. Massa who has worked on the Palaeozoic of western Libya for many years had provided us (M.S.) with core samples of supposed Upper Silurian to Upper Devonian age. He had received permission to mention in his own publications the names of the boreholes and the depths of samples. We want to thank him very much for kindly extending these data to us.

The present paper will concern the systematic results on the more important taxa en-

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countered in this material and the stratigraphic consequences when they are compared with the Old Red Sandstone Continent zonations. Lateral correlations in Gondwanaland will be discussed in a later contribution.

Material studied

The map (Fig.1) locates the boreholes sampled. Borehole A1-69, drilled by SHELL in 1959 ($x = 29°\ 03'\ 50''$, $y = 13°\ 40'13''$) will constitute, by the exceptional amount of cores available, our main reference. It is here studied between 2103 ft (641 m) and 650 ft (198 m), giving 33 productive samples. Three other boreholes where cores are much more rare were also sampled. They are D1-26: 7999 ft (2440 m), C1-49: 1170 m and MG1: 2221 m, 2232.6 m and 2234 m. The electric logs available for borehole A1-69 are too poor to allow any correlations with the corresponding Awaynat Wanin Formations (D. Massa, pers. commun., 1987). Samples from borehole MG1, which is located on the Tunisian side of the Tunisian/Libyan border, and borehole C1-49 are all in Awaynat Wanin Formations II and III, supposed to belong to the Givetian and Frasnian Stages. Accurate faunal data are not yet available.

On the same map (Fig.1) is also located the MOBIL boreholes studied by Moreau-Benoit, 1984 and Massa and Moreau-Benoit, 1985. The material studied by Massa and Moreau-Benoit, 1976 and Moreau-Benoit, 1979 and 1980 were all the samples available from about thirty boreholes aggregated in two composite sections, one for northern Tripolitania, one for southern Tripolitania and Fezzan, both in the Ghadamis Basin. The detailed location of these samples is not yet available (D. Massa, pers. commun., 1987).

Systematics

In most samples, miospores are very abundant, diversified and in a very good state of preservation. We have though that it was not necessary for the purpose of this paper to provide a complete analysis of all observed taxa. On the contrary, we have given some priority to the characteristic species of the Old

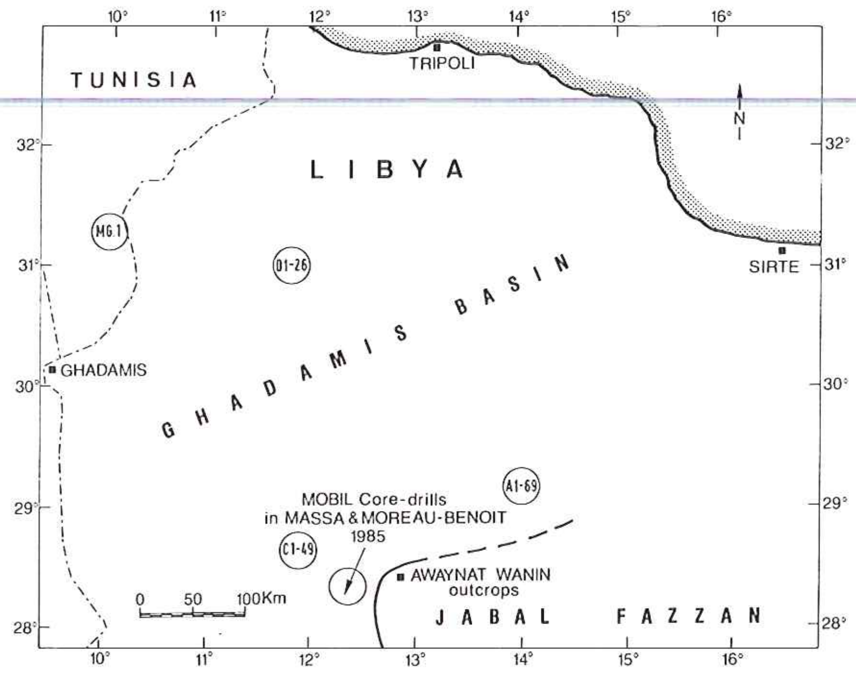


Fig.1. Location map of boreholes investigated in this paper.

Red Sandstone Continent biozonation. However, we have also focused our attention on several frequent taxa restricted to the northern margin of Gondwanaland whose narrow stratigraphic range enhances the local biozonation.

Reference slides are stored in the Paleobotanical laboratory of the Université des Sciences et Techniques de Lille, à Villeneuve d'Ascq, France.

Letters and numbers following the slide numbers are England Finder numbers.

Species are listed below in alphabetic order of genera.

Genus *Acinosporites* Richardson 1965

Acinosporites acanthomammillatus Richardson 1965 (Plate I, 4)

Acinosporites apiculatus (Streel) Streel 1967 (Plate I, 3)

Acinosporites lindlarensis Riegel 1968 (Plate II, 5,6)

Acinosporites macrospinosus Richardson 1965

Genus *Ancyrospora* Richardson 1960 emend. Richardson 1962

Ancyrospora langii (Taugourdeau-Lantz) Allen 1965 (Plate VIII, 2)

Ancyrospora nettersheimensis Riegel 1973 (Plate VIII, 1)

Genus *Archaeozonotriletes* Naumova 1953 emend. Allen 1965

Archaeozonotriletes variabilis (Naumova) Allen 1965 (Plate I, 19)

Genus *Auroraspora* Hoffmeister, Staplin and Malloy 1955 emend. Richardson 1960

Auroraspora hyalina (Naumova) Streel in Becker *et al.*, 1974 (Plate III, 3)

Genus *Camarozonotriletes Naumova 1939 ex Ishchenko 1952*

Camarozonotriletes sextantii McGregor and Camfield 1976 (Plate I, 11, 12)

Camarozonotriletes? concavus sp. nov. (Plate I, 13–15)

Holotype: Plate I, 14, borehole A1-69, slide 1483(1) : D31.

Diagnosis: Trilete cingulate miospores with subtriangular amb, rounded corners and concave to almost straight, interradial margins. Laesura arms simple, straight, reaching the cingulum. Cingulum, 2–6 μm wide, slightly reduced at corners, slightly darker than central area of the spore. Exine proximally laevigate, equatorially and distally microgranulate. Sculptural elements less than 1 μm wide and high, closely spaced.

Diameter: 31–47 μm, mean = 38 μm (28 specimens).

Derivation of name: Related to the concave interradial margins.

Remarks: In most cases, two slightly separated walls can be detected. Reduction of the cingulum width at corners is not often very conspicuous in this species and attribution to *Camarozonotriletes* is therefore questionable.

Comparison: Amongst sculptured species, *C. antiquus* Kedo 1955 has convex interradial margins. *C. parvus* Owens 1971 has a dark proximal area along trilete rays. *C. pusillus* Naumova ex Chibrikova 1959 has ornamentation elements up to 1.5 μm high. *C. sextantii* McGregor and Camfield 1976 has higher and different sculpture.

Occurrence: AD pre Lem Zone = Eifelian.

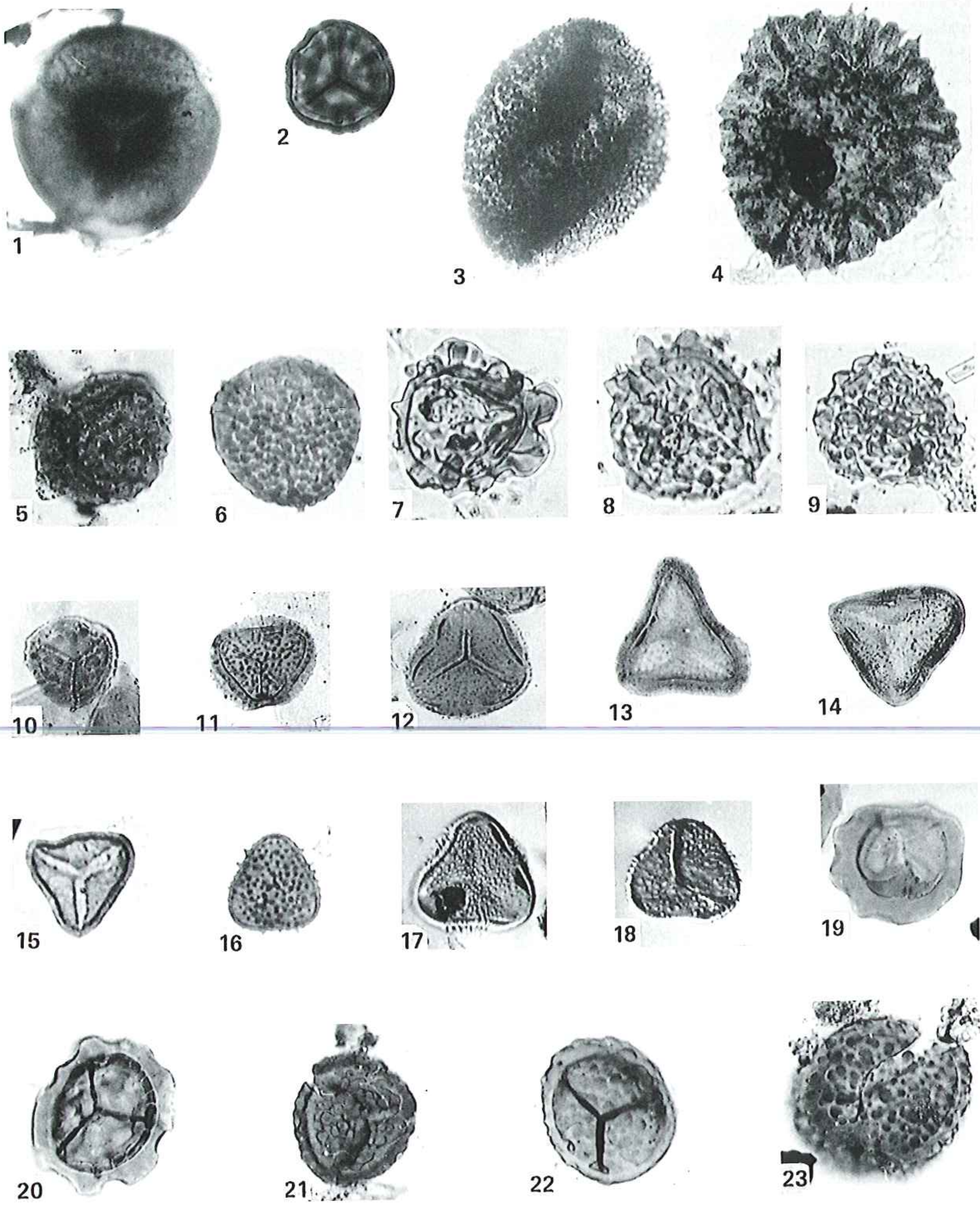
Genus *Chelinospora* Allen 1965

Chelinospora concinna Allen 1965

Chelinospora (Archaeozonotriletes) timanica (Naumova) comb. nov. (Plate II, 8, 9)

Basionym : Archaeozonotriletes timanicus Naumova 1953, Trans. Inst. Geol. Sc. Acad. Sc. USSR, 143: p.81, pl.XII, fig.4.

PLATE I



Remarks: The species of *Archaeozonotriletes* (Naumova) Allen 1965 are smooth. *Ch. timanica* is distally murornate.

Genus *Convolutispora* Hoffmeister, Staplin and Malloy 1955

Convolutispora disparalis Allen 1965 (Plate I, 5)

Genus *Corystisporites* Richardson 1965

Corystisporites multispinosus Richardson 1965 (Plate II, 7)

Genus *Craspedispora* Allen 1965

Craspedispora ghadamisensis sp. nov. (Plate II, 1–4, Plate IX, 4)

Holotype: Plate II, 1 and Plate IX, 4, borehole A1-69, slide 1700(1) : W24[1].

Diagnosis: Trilete zonate miospores with subcircular to roundly triangular amb. Laesura arms slightly sinuous, up to 6 μm high, almost reaching the equator. Proximal exine often microfolded, sometimes slightly thicker in the central area. Zona, including spines, up to 10 μm wide interradially, distinctly narrower or absent radially, if present radially may be deflected onto the proximal face. Proximal surface laevigate. Distal surface and zona bearing biform ornaments: thin (1 μm), elongated (up to 4 μm) spines on broad bases (up to 4 μm diameter).

Diameter: 70–95 μm, mean = 80 μm (30 specimens)

Derivation of name: after the locality of Ghadamis in Libya.

PLATE I

All photographs × 500

1. *Retusotriletes rugulatus* Riegel 1973
   A_1-69, slide 1700(1) : H29[3].
2. *Emphanisporites annulatus* McGregor 1961
   C_1-49, slide 2753(1) : Q27.
3. *Acinosporites apiculatus* (Streel) Streel 1967
   A_1-69, slide 1700(1) : E34[3].
4. *Acinosporites acanthomammillatus* Richardson 1965
   A_1-69, slide 1483(1) : U37.
5. *Convolutispora disparalis* Allen 1965
   A_1-69, slide 1074(1) : F29.
6. *Verrucosisporites bulliferus* Richardson and McGregor 1986
   D_1-26, slide 2764(2) : V34[2].
7. *Verrucosisporites premnus* Richardson 1965
   MG_1, slide 2761(1) : G36.

8, 9. *Verrucosisporites scurrus* McGregor and Camfield 1982
8, MG_1, slide 2761(1) : Q37[3]. 9, MG_1, slide 2761(1) : U39.

10. *Synorisporites libycus* Richardson and Ioannides 1973
A_1-69, slide 2039(2) : L28[4].

11, 12. *Camarozonotriletes sextantii* McGregor and Camfield 1976
11, A_1-69, slide 2039(1) : J32[3]. 12, A_1-69, slide 2039(1) : N39[4].

13–15. *Camarozonotriletes? concavus* nov. sp.
13, A_1-69, slide 1486(1) : X50[1]. 14, Holotype, A_1-69, slide 1483(1) : D31. 15, A_1-69, slide 1483(1) : L53[3].

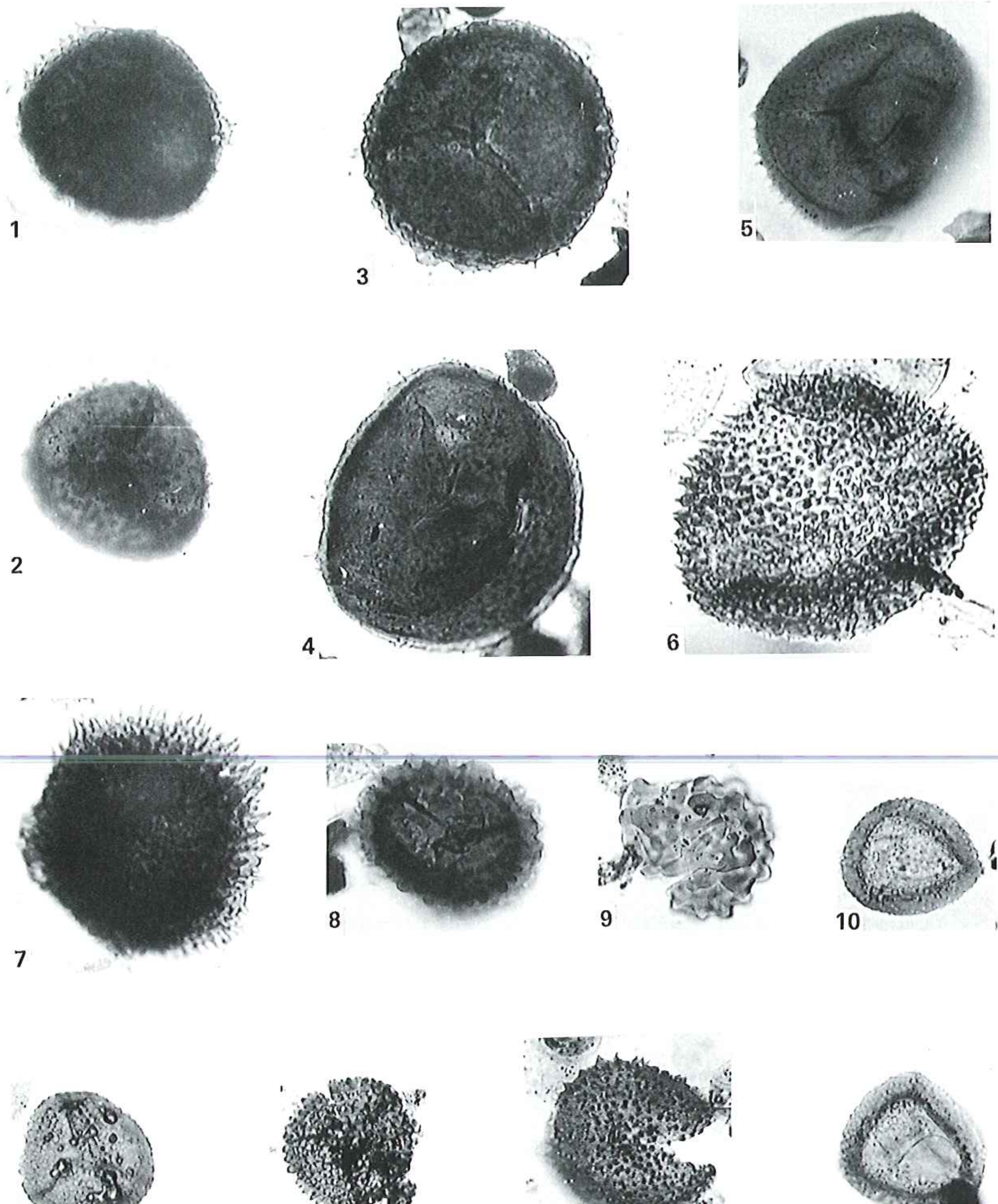
16–18. *Diatomozonotriletes franklinii* McGregor and Camfield 1982
16, C_1-49, slide 2753(1) : W31. 17, MG_1, slide 2760(1) : N25. 18, C_1-49, slide 2753(1) : T27[3].

19. *Archaeozonotriletes variabilis* (Naumova) Allen 1965
MG_1, slide 2760(1) : G39.

20. *Lophozonotriletes media* Taugourdeau-Lantz 1967
A_1-69, slide 976(1) : H38[2].

21–23. *Lophozonotriletes bouckaertii* nov. sp.
21, A_1-69, slide 650(2) : K30[3]. 22, Holotype. A_1-69, slide 650(1) : Q33[3]. 23, A_1-69, slide 650(1) : Q40[1].

PLATE II



Comparison: *Craspedispora craspeda* Allen 1965 is smaller and has a laevigate or sparsely sculptured zona. *C. arctica* McGregor and Camfield 1982 is also smaller and has smaller different ornaments.
Occurrence: AD pre Lem to TA Zones = Eifelian to Givetian.

Genus *Cymbosporites* Allen 1965

Cymbosporites catillus Allen 1965 (Plate II, 10, 11 and Plate IX, 2)

Cymbosporites cyathus Allen 1965 (Plate II, 12–13 and Plate IX, 3)

Cymbosporites sp. (Plate II, 14)

Genus *Densosporites* Berry 1937 emend. Potonié and Kremp 1954

Densosporites devonicus Richardson 1960 (Plate IV, 11, 12)

Genus *Diatomozonotriletes* Naumova 1939 emend. Playford 1963

Diatomozonotriletes franklinii McGregor and Camfield 1982 (Plate I, 16–18)
Remarks: We have observed a large variation in shape and size of ornaments which may vary from coni (1 μm high) to spinae (up to 4 μm high), encompassing the limit between *D. franklinii* and *D. oligodontus* Chibrikova 1962. However, the last species is claimed by Chibrikova to have variably developed curvaturae perfectae, a feature that we have not observed in our material.

Genus *Emphanisporites* McGregor 1961

Emphanisporites annulatus McGregor 1961 (Plate I, 2)

Emphanisporites rotatus McGregor 1961

Genus *Geminospora* Balme 1962 emend. Playford 1983

Geminospora lemurata Balme 1962 emend. Playford 1983 (Plate III, 7, 8, 11-15)

Geminospora punctata Owens 1971 (Plate III, 9, 10, 16–18)

Remarks: The surface of the exoexine possesses fine, densely distributed punctuations (Plate III, 16–18). However, we have only exceptionally noticed the fine radial striations which correspond, according to Owens (1971, p.62) to punctations passing completely through the exoexine.

PLATE II

All photographs × 500

1–4. *Craspedispora ghadamisensis* nov. sp.
1, 2, Holotype, A_1-69, slide 1700(1) : W24[1]. 3, A_1-69, slide 1700(1) : 028. 4, A_1-69, slide 1700(1) : O35[3].

5, 6. *Acinosporites lindlarensis* Riegel 1968
5, A_1-69, slide 2039(2) : R31[4]. 6, A_1-69, slide 2039(1) : E40.

7. *Corystisporites multispinosus* Richardson 1965
A_1-69, slide 1700(1) : F45[3].

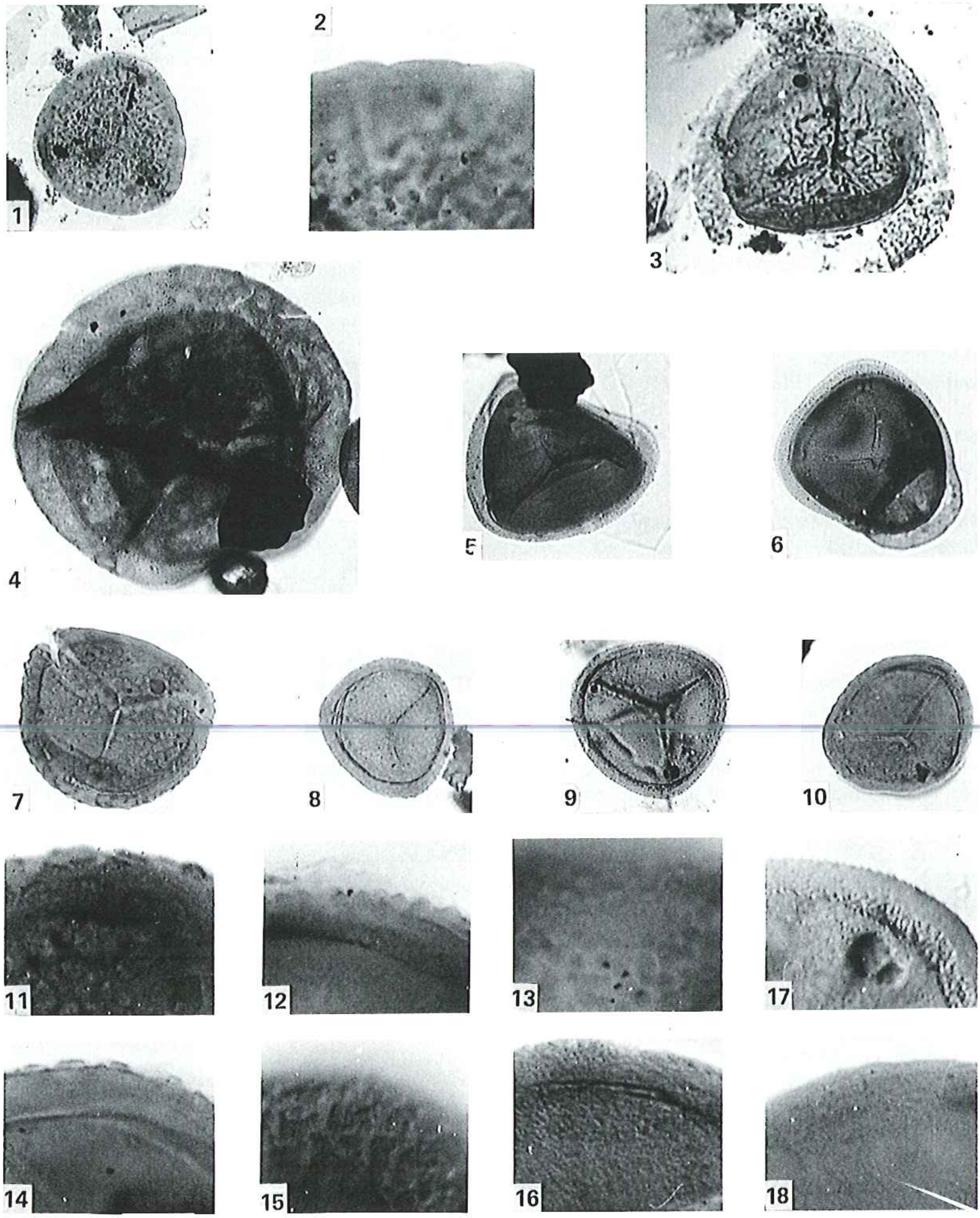
8, 9. *Chelinospora timanica* (Naumova) nov. comb.
8, A_1-69, slide 1416(1) : H36[3]. 9, A_1-69, slide 650(1) : H21.

10, 11. *Cymbosporites catillus* Allen 1965
10, A_1-69, slide 976(1) : H29[3]. 11, A_1-69, slide 976(1) : S41.

12, 13. *Cymbosporites cyathus* Allen 1965
12, A_1-69, slide 650(2) : L33. 13, A_1-69, slide 650(1) : Q38[3].

14. *Cymbosporites* sp.
A_1-69, slide 650(1) : L33[4].

PLATE III



Genus *Grandispora* Hoffmeister, Staplin and Malloy 1955 emend. Neves and Owens 1966, as restated by Playford 1971

Grandispora cassidea (Owens 1971) Moreau-Benoit 1976 (Plate VI, 1 and Plate IX, 26)

Grandispora douglastownense McGregor 1973 (Plate VII, 5 and Plate IX, 27)

Grandispora gabesensis sp. nov. (Plate VI, 2–4 and Plate IX, 17–20)

Holotype: Plate VI, 2 and Plate IX, 18, borehole A1-69, slide 1596(1) : $X30^1$.
Diagnosis: Trilete, camerate miospores with subtriangular to roundly triangular amb. Intexinal body conformable to the exoexinal amb. Laesura arms, straight, up to 4 μm high, usually reaching the equator. Intexine laevigate, sometimes with arcuate folds near the margin. Exoexine thinner than intexine, laevigate in contact areas, sculptured proximo-equatorially and distally with coni, spinae, capilli and biform elements, 3–6 μm high, 0.5–2 μm wide, irregularly spaced.
Diameter: 70–120 μm, mean 97 μm (17 specimens).
Diameter of intexinal body: 62–85% (commonly 77%) of total spore diameter.
Derivation of name: After the Libyan harbour of Gabes.
Comparison: *Grandispora inculta* and *G. riegelii* have smaller different ornaments. Other Devonian and Lower Carboniferous spinose *Grandispora* have more widely spaced ornaments.
Occurrence: AD pre Lem Zone = Eifelian.

Grandispora incognita (Kedo) McGregor and Camfield 1976 (Plate VII, 1 and Plate IX, 24)

Grandispora inculta Allen 1965 (Plate V, 6, 7 and Plate IX, 14, 15)

Remarks: Expanded diagnosis of this species by McGregor and Camfield 1982, p.45 might include some of the specimens here assigned to *Grandispora riegelii* nov. sp. (see diagnosis below). We propose to limit the *G. inculta* concept to specimens where the distances between the ornaments are at least equal to their basal diameter.

Grandispora libyensis Moreau-Benoit 1980 (Plate VII, 3 and Plate IX, 25)

Remarks: The holotype of *G. libyensis* was first described as *Spinozonotriletes echinatus* Moreau-Benoit 1967 in the "Schistes bleus (Siegenien moyen)" from Anjou in France. The presence of this species and of many other large camerate spores in this formation is not compatible with the present knowledge of

PLATE III

All photographs × 500, except where otherwise stated

1, 2. *Rugospora bricei* nov. sp.
1, Holotype, A_1-69, slide 650(1) : $Q38^3$. 2, Detail of the fig.1, × 1800.

3. *Auroraspora hyalina* (Naumova) Streel in Becker et al., 1974
A_1-69, slide 650(2) : $L28^2$.

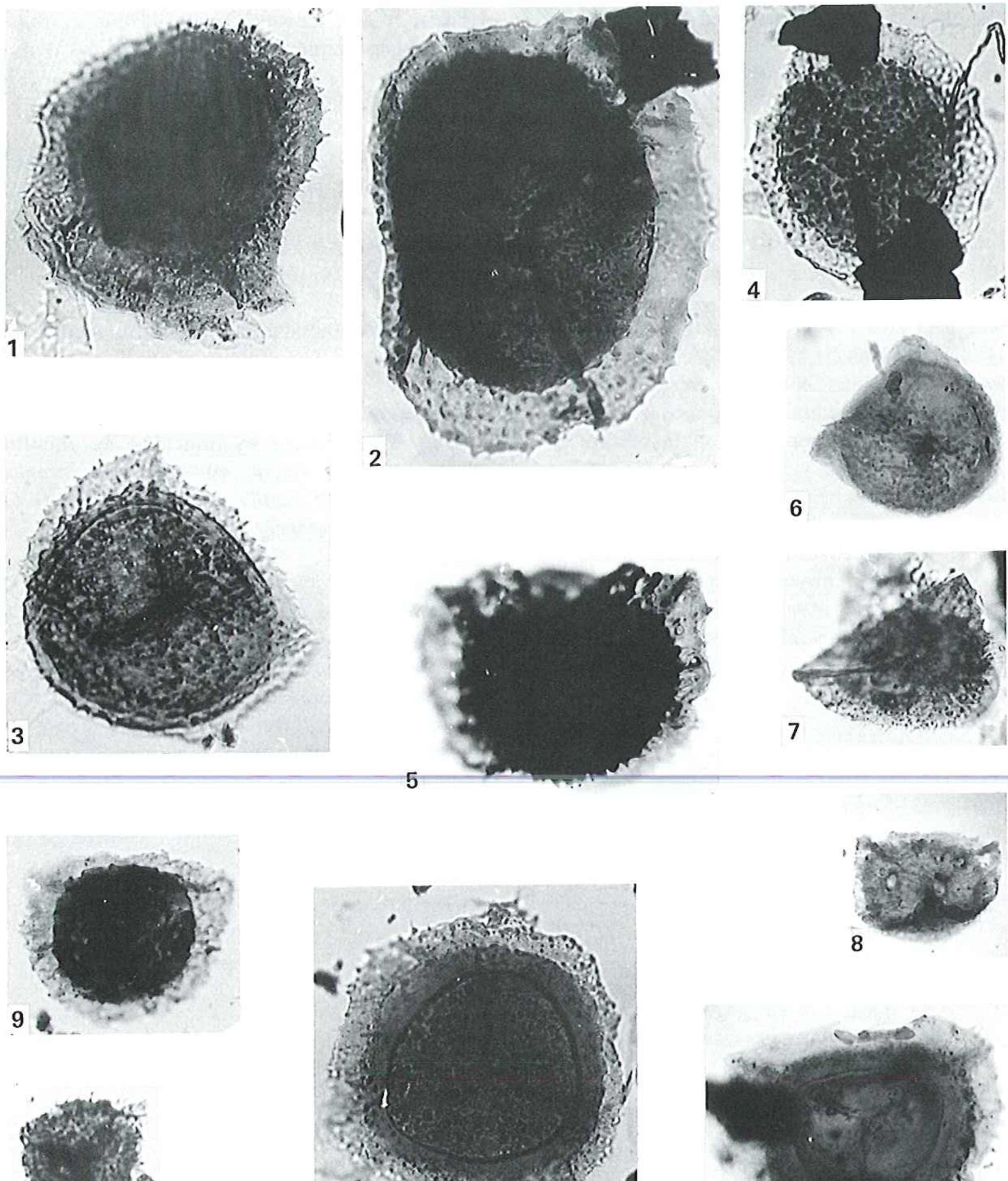
4. *Rhabdosporites langii* (Eisenack) Richardson 1960
A_1-69, slide 1416(1) : $E55^4$.

5, 6. *Rhabdosporites minutus* Tiwari and Schaarschmidt 1975
5, A_1-69, slide 1530(1) : M53. 6, A_1-69, slide 1700(1) : $U43^2$.

7, 8, 11–15. *Geminospora lemurata* (Balme 1962) emend. Playford 1983
7, A_1-69, slide 1322(1) : F40. 8, A_1-69, slide 1322(1) : $W42^4$. 11, Detail of the fig.7 × 1800. 12, 13, A_1-69, slide 1322(1) : $W38^2$, × 1800. 14, 15, A_1-69, slide 1322(1) : $L49^1$, × 1800.

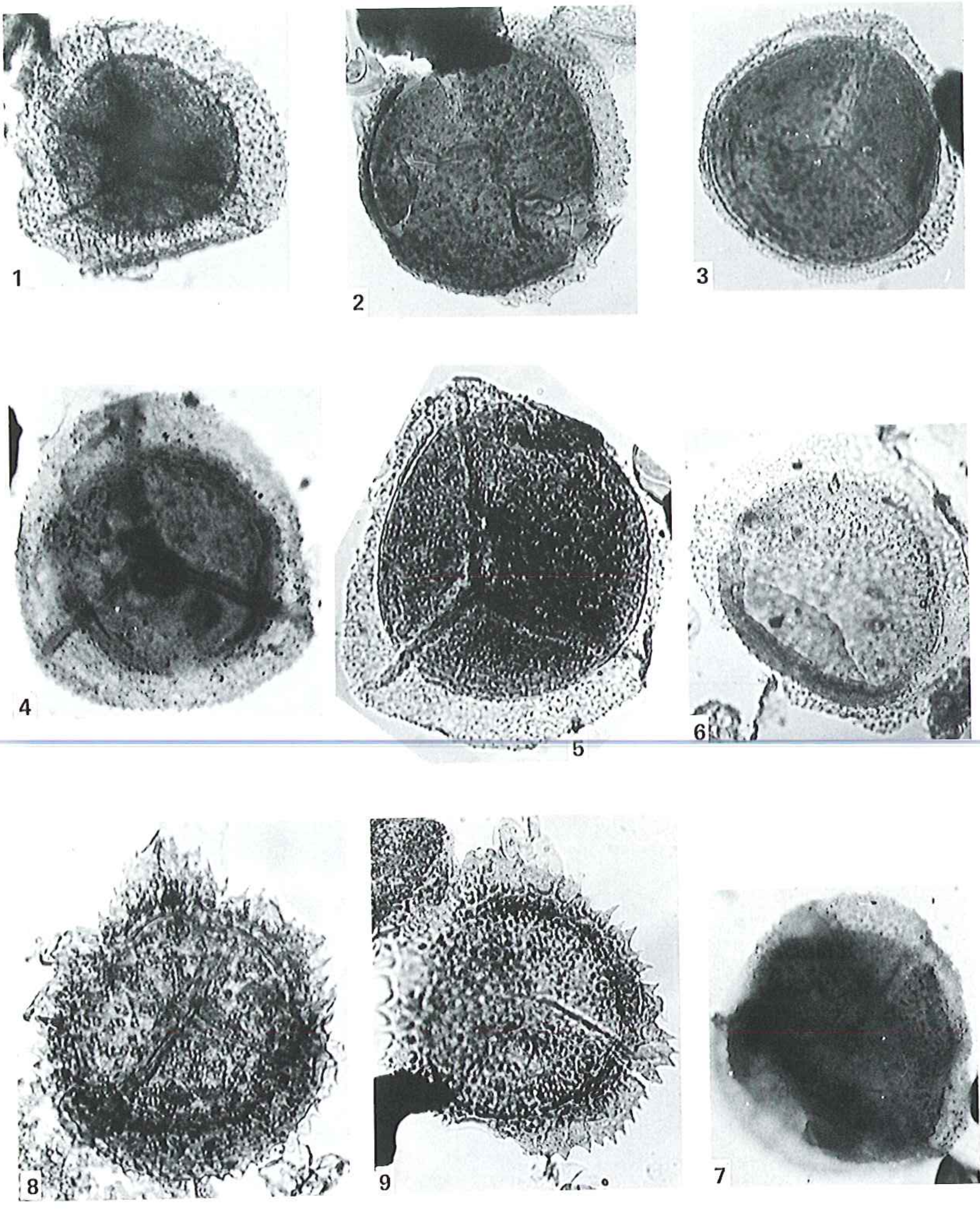
9, 10, 16–18. *Geminospora punctata* Owens 1971
9, A_1-69, slide 650(2) : $H27^1$. 10, A_1-69, slide 1322(1) : N50. 16, A_1-69, slide 1322(1) : $F52^3$, × 1800. 17, Detail of the fig.9, × 1800. 18, Detail of the fig.10, × 1800.

PLATE IV



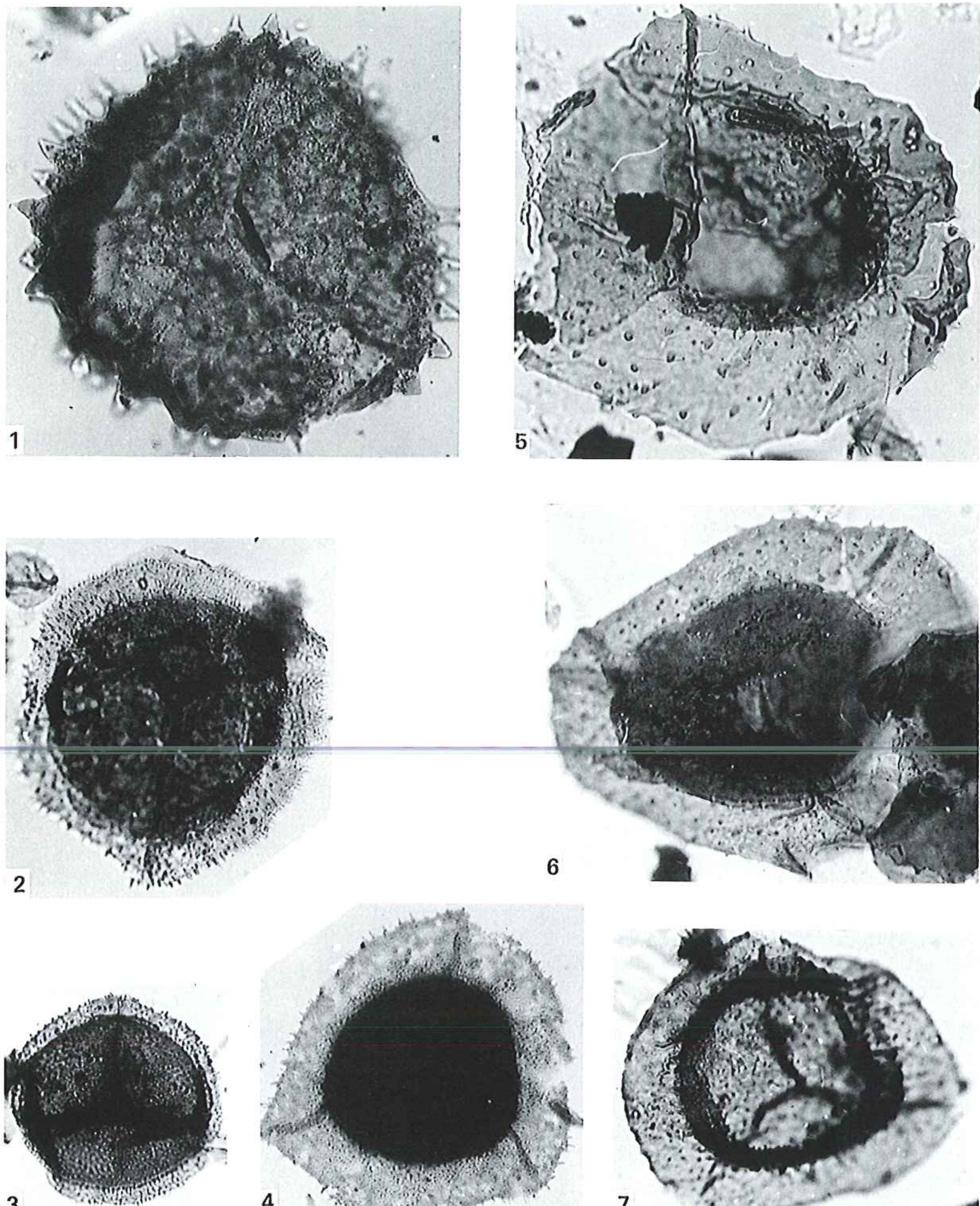
(for explanation see p.187)

PLATE V



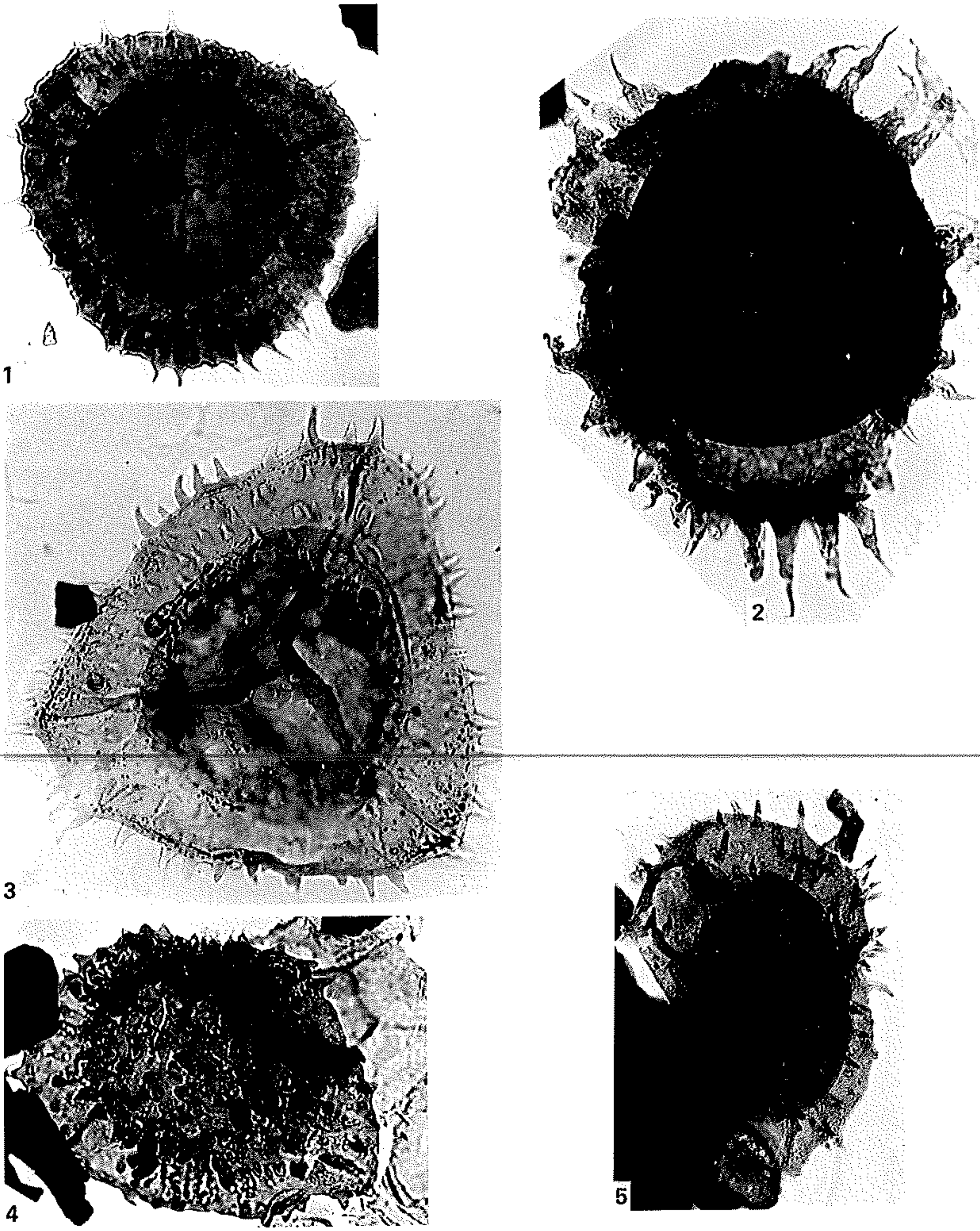
(for explanation see p.187)

PLATE VI



(for explanation see p.187)

PLATE VII



(for explanation see p.187)

PLATE VIII

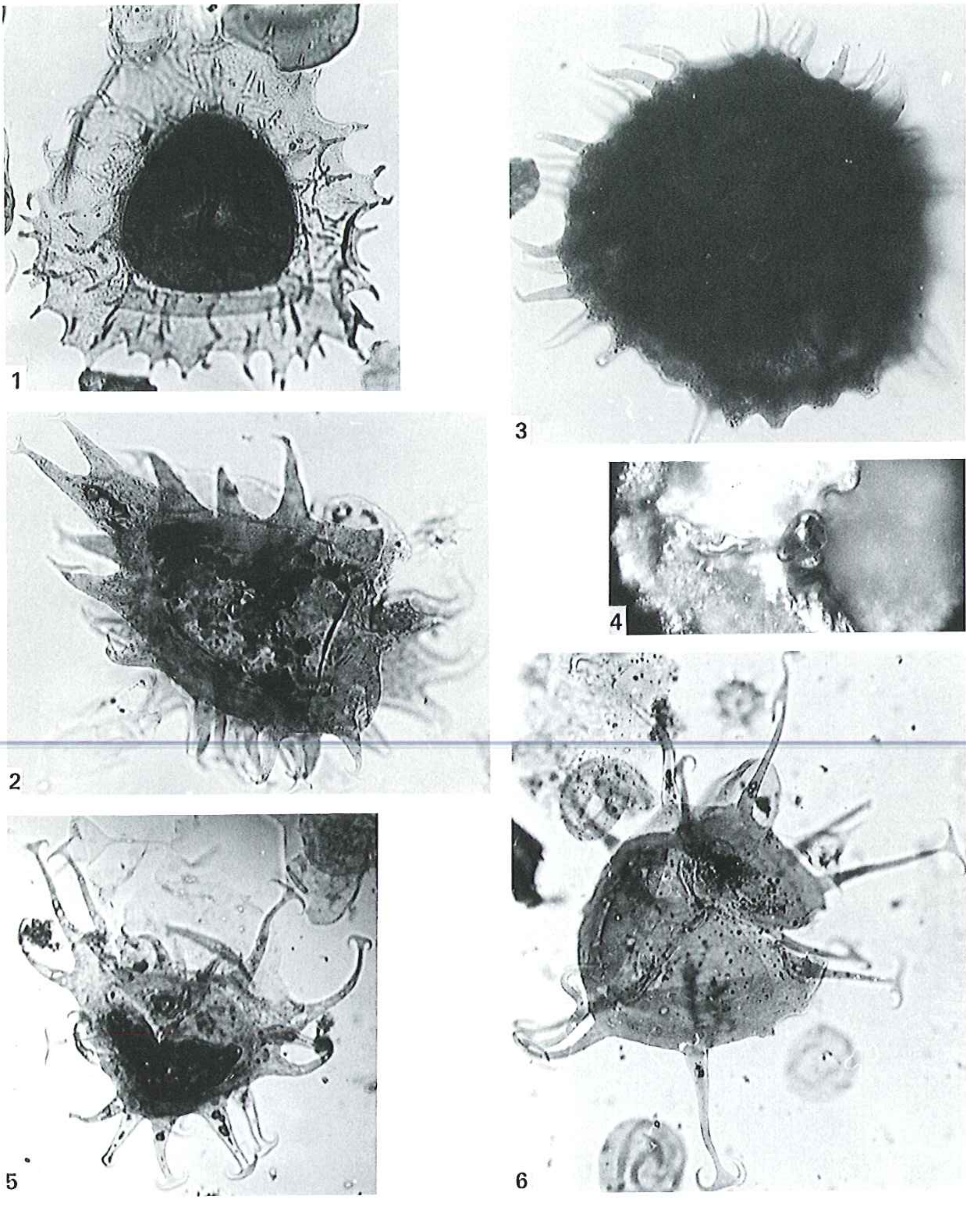


PLATE IV (see p.182)

All photographs × 500

1–4. *Samarisporites eximius* (Allen) nov. comb.
1, A_1-69, slide 1874(1) : $E34^3$. 2, C_1-49, slide 2753(1) : M32. 3, A_1-69, slide 1322(1) : R31. 4, A_1-69, slide 1870(1) : $K47^1$.

5. *Samarisporites praetervisus* (Naumova) Allen 1965
C_1-49, slide 2753(3) : $L33^2$.

6–8. *Samarisporites triangulatus* Allen 1965
6, A_1-69, slide 1277(1) : $G24^4$. 7, A_1-69, slide 976(2) : $R42^3$. 8, D_1-26, slide 2764(1) : $Q37^2$.

9. *Samarisporites* sp. E in Streel and Loboziak 1987
D_1-26, slide 2764(2) : $O40^3$.

10. *Samarisporites* sp. A in Loboziak and Streel 1981
D_1-26, slide 2764(2) : $V25^3$.

11, 12. *Densosporites devonicus* Richardson 1960
11, A_1-69, slide 1874(1) : $P36^3$. 12, MG1, slide 2775(1) : H30.

PLATE V (see p.183)

All photographs × 500

1–5. *Grandispora riegelii* nov. sp.
1, A_1-69, slide 1322(1) : V51. 2, A_1-69, slide 1596(1) : M36. 3, A_1-69, slide 1416(1) : $S28^1$. 4, Holotype, MG1, slide 2760(1) : $R33^2$. 5, MG1, slide 2775(1) : H37.

6, 7. *Grandispora inculta* Allen 1965
6, MG1, slide 2760(1) : $V27^1$. 7, A_1-69, slide 1310(1) : $N29^4$.

8, 9. *Samarisporites angulatus* (Tiwari and Schaarschmidt) nov. comb.
8, A_1-69, slide 1867(1) : $P46^1$. 9, A_1-69, slide 1867(1) : $V30^3$.

PLATE VI (see p.184)

All photographs × 500

1. *Grandiflora cassidea* (Owens 1971) Moreau-Benoit 1976
MG1, slide 2775(1) : $Q36^4$.

2–4. *Grandispora gabesensis* nov. sp.
2, Holotype, A_1-69, slide 1596(1) : $X30^1$. 3, A_1-69, slide 1700(1) : O32. 4, A_1-69, slide 1700(2) : $Q34^2$.

5, 6. *Grandispora protea* (Naumova) Moreau-Benoit 1980
5, A_1-69, slide 1874(2) : G21. 6, A_1-69, slide 2039(2) : $R25^2$.

7. *Grandispora velata* (Eisenack) McGregor 1973
C_1-49, slide 2753(3) : $L.34^3$.

PLATE VII (see p.185)

All photographs × 500

1. *Grandispora incognita* (Kedo) McGregor and Camfield 1976
A_1-69, slide 1596(1) : $U28^3$.
2. *Grandispora naumovii* (Kedo) McGregor 1973
A_1-69, slide 1700(1) : $X33^1$.
3. *Grandispora libyensis* Moreau-Benoît 1980
A_1-69, slide 1310(1) : $D39^3$.
4. *Grandispora megaformis* (Richardson) McGregor 1973
A_1-69, slide 1870(1) : $N38^3$.
5. *Grandispora douglastownense* McGregor 1973
A_1-69, slide 1550(2) : $J35^3$.

PLATE VIII

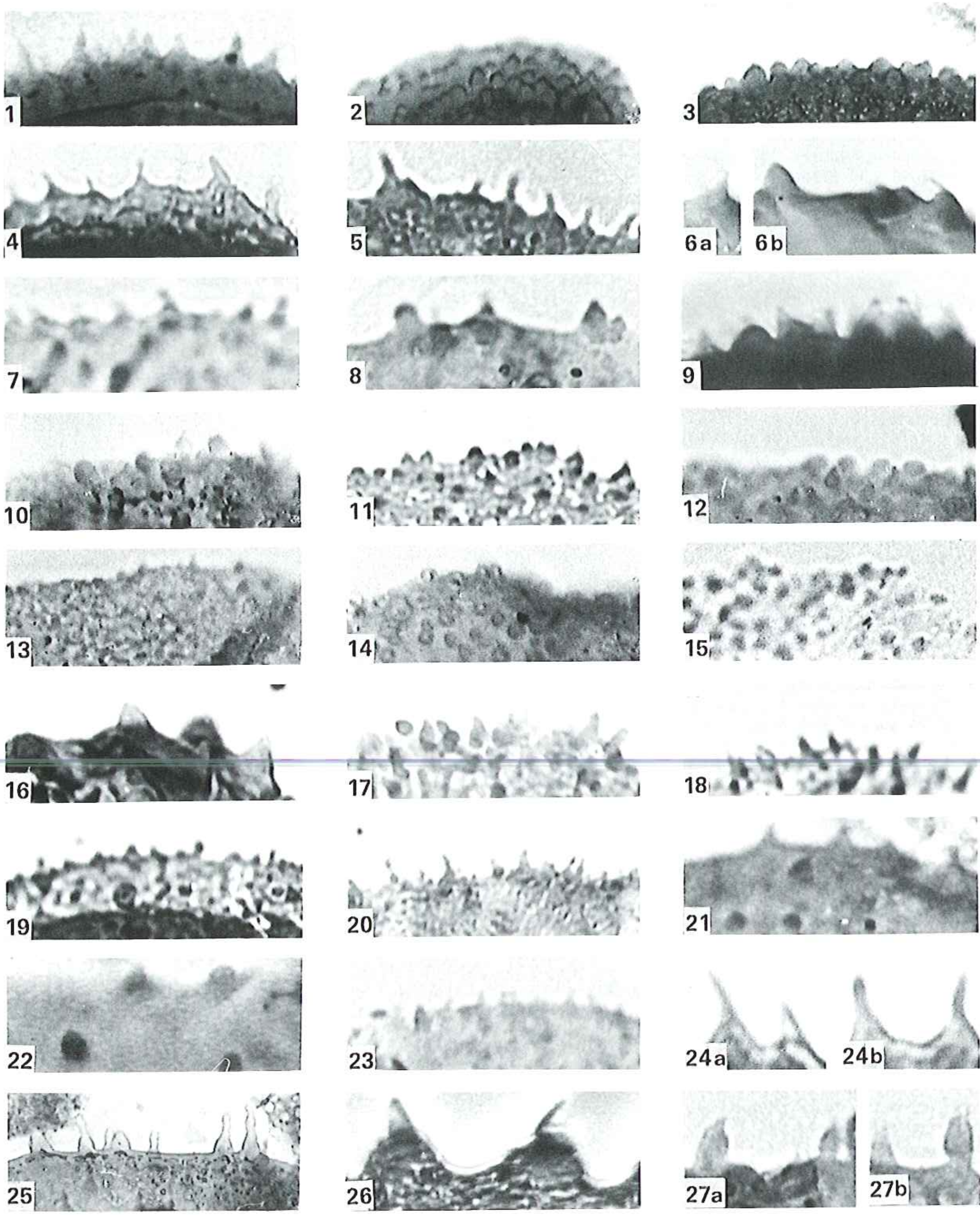
All photographs × 500

1. *Ancyrospora nettersheimensis* Riegel 1973
A_1-69, slide 1700(1) : J34.
2. *Ancyrospora langii* (Taugourdeau-Lantz) Allen 1965
A_1-69, slide 976(1) : $Y24^3$.

3, 4. *Hystricosporites mitratus* Allen 1965
A_1-69, slide 1373(1) : O42.

5, 6. *Hystricosporites blessii* nov. sp.
5, Holotype, A_1-69, slide 650(2) : H22. 6, A_1-69, slide 650(2) : H35.

PLATE IX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24a
24b
25
26
27a
27b

Siegenian spores around the Old Red Sandstone Continent (Richardson and McGregor, 1986; Streel et al., 1987). As the Siegenian age of the "Schistes bleus" cannot be challenged, we have to conclude the possibility of laboratory contamination of this assemblage. However, we have no reason to reject the new name given by Moreau-Benoit, 1980. It should however be emphasized that, with the exception of the Anjou material, all the specimens listed in synonymy by Moreau-Benoit 1980, p.33 are of Gondwanan origin if we reject *Spinozonotriletes multispinosus* Lanninger 1968 which obviously belongs to a different species.

Grandispora megaformis (Richardson) McGregor 1973 (Plate VII, 4 and Plate IX, 16)

Grandispora naumovii (Kedo) McGregor 1973 (Plate VII, 2)

PLATE IX

All photographs × 1800

1. *Acinosporites lindlarensis* Riegel 1968
Detail of the Plate II, 5.
2. *Cymbosporites catillus* Allen 1965
Detail of the Plate II, 11.
3. *Cymbosporites cyathus* Allen 1965
Detail of the Plate II, 12.
4. *Craspedispora ghadamisensis* nov. sp.
Detail of the Plate II, 1, 2.

5–7. *Samarisporites eximius* (Allen) nov. comb.
5, Detail of the Plate IV, 1.
6, Detail of the Plate IV, 2.
7, Detail of the Plate IV, 3.

8, 9. *Samarisporites praetervisus* (Naumova) Allen 1965
Detail of the Plate IV, 5.

10–13. *Grandispora riegelii* nov. sp.
10, Detail of the Plate V, 1.
11, Detail of the Plate V, 2.
12, Detail of the Plate V, 4.
13, Detail of the Plate V, 5.

14, 15. *Grandispora inculta* Allen 1965
14, Detail of the Plate V, 6.
15, Detail of the Plate V, 7.

16. *Grandispora megaformis* (Richardson) McGregor 1973
Detail of the Plate VII, 4.

17–20. *Grandispora gabesensis* nov. sp.
17, A_1-69, slide 1700(1) : X32.
18, Detail of the Plate VI, 2.
19, Detail of the Plate VI, 3.
20, Detail of the Plate VI, 4.

21, 22. *Grandispora protea* (Naumova) Moreau-Benoit 1980
21, Detail of the Plate VI, 6.
22, Detail of the Plate VI, 5.

23. *Grandispora velata* (Eisenack) McGregor 1973
Detail of the Plate VI, 7.
24. *Grandispora incognita* (Kedo) McGregor and Camfield 1976
Detail of the Plate VII, 1.
25. *Grandispora libyensis* Moreau-Benoit 1980
A_1-69, slide 1322(1) : L30[1].
26. *Grandispora cassidea* (Owens) Moreau-Benoit 1976
Detail of the Plate VI, 1.
27. *Grandispora douglastownense* McGregor 1973
A_1-69, slide 2039(2) : R41.

Grandispora protea (Naumova) Moreau-Benoit 1980 (Plate VI, 5, 6 and Plate IX, 21, 22)

Grandispora riegelii sp. nov. (Plate V, 1–5 and Plate IX, 10–13)

1967: *Calyptosporites* sp. A in Daemon et al., p.114, plate 3, 31–34.
1967: *Calyptosporites* sp. B in Daemon et al., p.114, plate 3, 35–36.
1974: *Calyptosporites* sp. B in Bar and Riegel, plate 1, 13.
1980: *Grandispora velata* (Eisenack) McGregor in Moreau-Benoit, plate 12, 3.
1985: *Grandispora macrotuberculata* (Archangelskaya) McGregor in Massa and Moreau-Benoit, plate 1, 6.
1985: *Grandispora* sp. A Riegel in Paris et al., plate 24, 8, 9.
1985: *Grandispora* sp. B Riegel in Paris et al., plate 24, 10.
1987: *Grandispora* sp. A Riegel in Schrank, plate 1, 11.

Holotype: Plate V, 4 and Plate IX, 12, borehole MG1, slide 2760(1) : R33[2].
Diagnosis: Trilete, camerate miospores with subtriangular to roundly triangular amb. Intexinal body conformable to or slightly more circular than the exoexinal amb. Laesura arms straight, up to 6 µm high, generally reaching the equator. Intexine laevigate, sometimes with arcuate folds near the margin. Exoexine thinner than intexine, laevigate in contact areas, sculptured proximo-equatorially and distally with dominant mammillate and biform conical elements, but also grana, verrucae and coni, 1–3 µm wide and high, irregularly distributed, sometimes closely spaced.
Diameter: 80–120 µm, mean = 96 µm (30 specimens)
Diameter of intexinal body: 60–89% (commonly 79%) of total spore diameter.
Derivation of name: After the name of the German palynologist Walter Riegel.
Comparison: *Grandispora inculta* Allen 1965 is smaller and bears only coni. *G. inculta* Allen 1965 in McGregor and Camfield 1982, p.45, text-fig.66, pl.11, 2, has a similar ornament to *G. riegelii* but these elements are more spaced, commonly 1–2 µm apart.
Occurrence: AD pre Lem-TCo Zones = Eifelian to early Frasnian.
Brazil: D3–D5, Parana Basin: Tibagi and Sao Domingos Members, Lower Amazonas Basin: Erere and Curua Formations.
Ghana: shales of Accra.
Cyrenaica: borehole E1-82
Western desert near the Libyan-Egyptian border: Foram-1 well, at 2490 m.

Grandispora tomentosa Taugourdeau-Lantz 1957

Grandispora velata (Eisenack) McGregor 1973 (Plate VI, 7 and Plate IX, 23)

Genus *Hystricosporites* McGregor 1960

Hystricosporites blessii sp. nov. (Plate VIII, 5, 6)
1974: *Hystricosporites* sp. A Streel in Becker et al., p.27, pl.22, 3–5.
1987: *Hystricosporites* sp. A in Streel and Loboziak p.101.

Holotype: Plate VIII, 5, borehole A1-69, slide 650(2) : H22.
Diagnosis: Trilete, camerate miospores with rounded amb. Laesura arms with flexous folds which may form an apical prominence (up to 35 µm high). Intexinal body, laevigate, thin, often folded. Exoexine thicker (4 µm), with laevigate contact areas. Remaining parts of the exoexine bearing very long processes with bifurcate terminations (32–54 µm). The processes may have a bulbous base (6–13 µm), taper markedly in their lower part but are more or less parallel sided in their upper part (2–4 µm). They expand (up to 10 µm) immediately below the bifurcate terminations (up to 20 µm).
Diameter: Maximum equatorial diameter excluding the projecting ornaments: 57–86 µm, mean = 76 µm (10 specimens).
Derivation of name: after the name of the Dutch ostracodologist Martin J.M. Bless.
Comparison: All other *Hystricosporites* with bifurcate processes have smaller ratio:length of processes/diameter of the body.
Occurrence: BM–IV Zones = Frasnian. ?TA–IV = ?Givetian–Frasnian in the Booischot borehole in Belgium.

Hystricosporites mitratus Allen 1965 (Plate VIII, 3, 4)

Genus *Lophozonotriletes* (Naumova) Potonié 1956

Lophozonotriletes media Taugourdeau-Lantz 1967 (Plate I, 20)

Lophozonotriletes bouckaertii sp. nov. (Plate I, 21–23)
Holotype: Plate I, 22, borehole A1-69, slide 650(1) : Q33[3].
Diagnosis: Trilete miospores with rounded amb. Laesura arms straight or slightly sinuous, up to 3 μm high, reaching the inner side of the equatorial structure. Contact areas laevigate. Remainder of the surface bearing closely spaced, sometimes fused, verrucae. Low verrucae of irregular shape and size, up to 5 μm wide, up to 2 μm high, partly confluent at their bases, forming short rugulae. Such rugulae accentuate the thickness of the exine when seen at the equator.
Diameter: 44–64 μm, mean = 53 μm (7 specimens).
Derivation of name: after the name of the Head of the Belgian Geological Survey, Jos Bouckaert.
Remarks: We use the *Lophozonotriletes* concept as emended by Van der Zwan, 1980.
Comparison: This species differs of other species of *Lophozonotriletes* by the high density and the variation in shape and size of its ornamentation.
Occurrence: Zone IV = late Frasnian.

Genus *Retusotriletes* Naumova 1953 emend. Streel 1964

Retusotriletes rugulatus Riegel 1973 (Plate I, 1)

Genus *Rhabdosporites* Richardson 1960

Rhabdosporites langii (Eisenack) Richardson 1960 (Plate III, 4)

Rhabdosporites minutus Tiwari and Schaarschmidt 1975 (Plate III, 5, 6)

Rhabdosporites parvulus Richardson 1965.

Genus *Rugospora* Neves and Owens 1966

Rugospora bricei sp. nov. (Plate III, 1, 2)

1981: *Rugospora* cf. *flexuosa* (Juschko) Streel in Becker et al., 1974, in Loboziak and Streel, p.51, pl.1, 11.
1983: *Rugospora* cf. *flexuosa* (Juschko) Streel in Becker et al., 1974, in Loboziak et al., p. 177.

Holotype: Plate III, 1, 2, borehole A1-69, slide 650(1) : Q38[3].
Diagnosis: Trilete miospores with subtriangular to roundly triangular amb. Laesura arms straight to slightly sinuous, up to 2 μm high, reaching the equator. Wall more or less separated into two layers, at least on the distal side except near the equator, the outer layer partly attached to the inner layer. Surface of outer layer usually smooth, thickness indiscernable, presumably very thin. Folding results in a more or less rugulate condition of the spore. Distal rugulae (1–1.5 μm wide), randomly to rarely radially arranged.
Diameter: 32–54 μm, mean = 45 μm (17 specimens).
Derivation of name: After the name of the French palaeontologist Denise Brice.
Comparison: Rugospora radiata (Kedo) Byvsheva 1985 syn.: *R. flexuosa* (Juschko) Streel in Becker et al., 1974, non *R. flexuosa* (Juschko) Byvsheva 1985, has thicker and longer rugulae, most commonly radially arranged, on the disto-equatorial margin.
R. flexuosa (Juschko) Byvsheva 1985 which has narrow chaotically placed distal rugulae is based on poorly published material.
Occurrence: Zone IV = late Frasnian. Boulonnais: Zones IV and V = late Frasnian–early Famennian.

Genus *Samarisporites* Richardson 1965

Samarisporites (al. *Calyptosporites*) *angulatus* (Tiwari and Schaarschmidt) nov. comb. (Plate V, 8, 9)

Basionym: *Calyptosporites angulatus* Tiwari and Schaarschmidt 1975, Abh. Senckenberg Naturforsch. Ges. 534: 44; pl.27, fig.1.

Remarks: Type material from the Eifel area as well as our material clearly shows a structure with a thick (?acamerate) central area characteristic of *Samarisporites*.

Samarisporites (al. *Perotrilites*) *eximius* (Allen 1965) comb. nov. (Plate IV, 1–4 and Plate IX, 5–7)

Basionym: *Perotrilites eximius* Allen 1965, Palaeontol. 8: 731; pl.102, figs.11–13.

Remarks: Sections made through the type material from Spitsbergen by Allen, 1965, clearly shows the distally thick structure of the central area, characteristic of *Samarisporites*.

Samarisporites praetervisus (Naumova) Allen 1965 (Plate IV, 5 and Plate IX, 8, 9)

Samarisporites triangulatus Allen 1965 (Plate IV, 6–8)

Samarisporites sp. A in Loboziak and Streel 1981 (Plate IV, 10)

Samarisporites sp. E in Streel and Loboziak 1987 (Plate IV, 9)

Genus *Synorisporites* Richardson and Lister 1969

Synorisporites libycus Richardson and Ioannides 1973 (Plate I, 10)

Genus *Verrucosisporites* Ibrahim 1933 emend. Smith 1971

Verrucosisporites bulliferus Richardson and McGregor 1986 (Plate I, 6)

Verrucosisporites premnus Richardson 1965 (Plate I, 7)

Verrucosisporites scurrus McGregor and Camfield 1982 (Plate I, 8, 9)

Verrucosisporites cf. *uncatus* Richardson 1965.

Stratigraphic results on borehole A1-69

The stratigraphic range of the most characteristic miospores in borehole A1-69 is given on the chart, Fig.2. On the right hand part of this figure, we have mentioned the species which were utilised to define the comparable biozonation in the Ardenne–Rhenish regions (Streel et al., 1987) that we use as a reference scale.

The first stratigraphically significant species which occurs at 2039 ft (622 m) is *Grandispora protea*. In the Ardenne–Rhenish zonation, this species marks the base of the Interval Zone AP Pro (*apiculatus–proteus* Oppel Zone, *proteus* Interval Zone).

This species is not present in the lowermost sample at 2103 ft (641 m) but this sample provided only a rather poor assemblage of spores. In the sample from 2039 ft (622 m), the coexistence of *Camarozonotriletes sextantii* and *G. protea* suggests that the basal part of zone AP Pro has been encountered.

In the lowermost sample at 2103 ft (641 m), the presence of *Emphanisporites annulatus* and *C. sextantii* and the absence of large apiculate and spinose zonate-pseudosaccate spores are comparable with the *annulatus–sextantii* Assemblage Zone of Richardson and McGregor 1986.

The entry of *Densosporites devonicus* and *Acinosporites acanthomammillatus* respectively in 1874 ft (572 m) and 1870 ft (570 m) marks the base of the Interval Zone AD Mac (*Acanthomammillatus–devonicus* Oppel Zone, *macrospinosus* Interval Zone). The true first appearance of *Grandispora velata* should probably be searched for in the unsampled interval 1950 ft (595 m)–1874 ft (572 m).

Geminospora lemurata first occurs in the sample at 1480 ft (451 m). *Geminospora punctata* occurs below this level. Therefore the 1480 ft (451 m) level should not be far from the base of the Interval Zone AD Lem (*acantho*

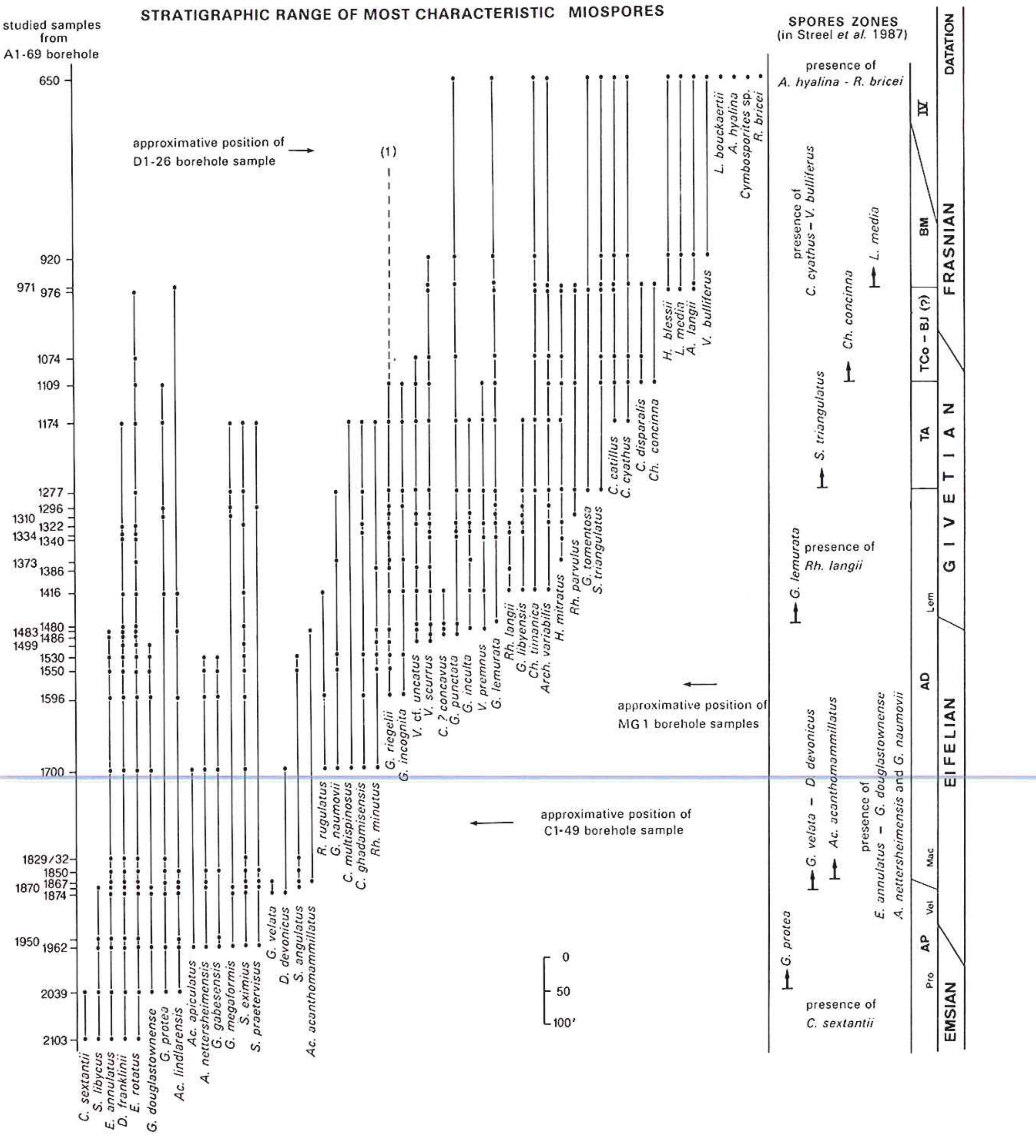

Fig.2. Stratigraphic range of the most characteristic miospores in borehole A1-69 and approximative stratigraphic position of samples studied in boreholes MG1 and C1-49.
(1) = Extension of *G. riegelii* in borehole D1-26 only.

mammillatus–devonicus Oppel Zone, *lemurata* Interval Zone).

The successive first occurrences of *Samarisporites triangulatus, Chelinospora concinna* and *Lophozonotriletes media* correspond respectively to the bases of the Oppel Zones TA (*triangulatus–ancyrea*), TCo (*Triangulatus-concinna*) and BM (*bulliferus–media*). The lack of sample between 1074 ft (328 m) and 976 ft (298 m) does not allow the recognition of the first occurrence of *Verrucosisporites bulliferus* which marks the base of the BJ (*bulliferus–jekhowskyi*) Oppel Zone in the Ardenne–Rhenish regions.

The uppermost sample at 650 ft (198 m) contains, amongst other miospores, *Aurorasspora hyalina* and *Rugospora bricei* (syn.: *R.* cf. *flexuosa* in Loboziak and Streel, 1981). Both species occur within Zone IV in the Boulonnais area in northern France (Loboziak et al., 1983). The lack of sample between 920 ft (281 m) and 650 ft (198 m) prevents us to locate the base of that Zone (IV) in the borehole A1-69.

In this borehole, the first occurences of the characteristic species are distributed in the same stratigraphic sequence as in the Ardenne–Rhenish reference biozonation. As no other biostratigraphic data nor any lithostratigraphic correlation are available in this borehole, we have no reason to challenge the geological ages deduced from this biozonation. The section ranges from the Emsian to the late Frasnian and there is no miospore evidence for the presence of the Famennian Stage in the uppermost part of the borehole.

The base of the Eifelian Stage in the type area of the Eifel occurs between the entry of *Grandispora protea* and the entry of *G. velata*. In this borehole A1-69, the base of the Eifelian Stage is somewhere between 2030 ft (619 m) and 1874 ft (572 m).

There is as yet no internationally accepted position for the base of the Givetian. Most of the proposals however are within the range of the conodont *ensensis* zone. Spores are not known in the classic region of Givet in the Ardenne due to adverse sedimentary conditions. However, in the Eifel, spores are present. *Geminospora lemurata* first occurs, in this region, within the *ensensis* zone which implies not far from the proposed bases of the Givetian stage.

In the borehole A1-69, *G. lemurata* occurs in sample 1480 ft (451 m).

The range of the TCo zone spans the base of the Frasnian stage in the Ardenne (Streel et al., 1987) and the stage boundary cannot therefore be defined accurately using miospores. In this borehole A1-69, the Givetian/Frasnian boundary is taken between 1109 ft (338 m) and 976 ft (298 m).

In conclusion, it appears that the Eifelian and early Givetian stages are represented in this borehole by a much thicker sequence of rocks than the Upper Devonian, a situation also matched in eastern Libya (Streel et al., 1988).

Comparisons with the other boreholes

Borehole C1-49

The sample at 1170 m carries *Synorisporites libycus, Emphanisporites annulatus, Diatomozonotriletes franklinii, Emphanisporites rotatus, Grandispora protea, Acinosporites lindlarensis, Samarisporites eximius, S. praetervisus, Grandispora velata* and *Craspedispora ghadamisensis.*

Borehole MG1

Samples at 2221 m, 2232.6 m and 2234 m carry *Emphanisporites annulatus, Diatomozonotriletes franklinii, Emphanisporites rotatus, Samarisporites eximius, Acinosporites macrospinosus, Densosporites devonicus, Acinosporites acanthomammillatus, Grandispora riegelii, Verrucosisporites* cf. *uncatus, V. scurrus, Geminospora punctata, Grandispora inculta, Verrucosisporites premnus, Grandispora libyensis, Chelinospora timanica, Archaeozonotriletes variabilis* and *Grandispora cassidea*. In the Eifel region, *V.* cf. *uncatus* first occurs about at the same level as *Geminospora lemurata* (Streel et al., 1987).

Borehole D1-26

The sample at 7999 ft (2440 m) contains *Grandispora riegelii, Samarisporites triangulatus, Samarisporites* sp. A. in Loboziak and Streel, 1981 and *Samarisporites* sp. E in Streel and Loboziak, 1987. *Samarisporites* sp. A only occurs in Zone IV in the Boulonnais area (Loboziak et al., 1983, p.176).

These results allow comparisons to be drawn between the borehole A1-69 biostratigraphy and the limited number of samples from the three other boreholes. They are given on the chart (Fig.2). The samples from boreholes C1-49 and MG1 are Eifelian, the sample from borehole D1-26 is Frasnian.

If the samples investigated in the boreholes C1-49 and MG1 do really belong to the Awaynat Wanin Formation II and III (D.Massa, pers. commun., 1987), we have to conclude that these formations are there of Eifelian age.

A similar conclusion was also suggested by Streel et al. (1988, table 1) based only on a stratigraphical interpretation of the then published miospores in western Libya.

Conclusions

The study of 55 species of miospores (including 7 new species) taken from 4 boreholes of the Ghadamis Basin leads to the following conclusions:

(1) In borehole A1-69, the first occurrences of the characteristic miospores are distributed in the same stratigraphic sequence as in the Ardenne–Rhenish reference biozonation. Chronostratigraphic correlations made through this biozonation give an Emsian to late Frasnian age for the 33 samples studied between 2103 ft (641 m) and 650 ft (198 m) in this borehole.

(2) The Eifelian and early Givetian Stages are represented in this borehole by a much thicker sequence of rocks than the Upper Devonian, a situation also noticed in eastern Libya.

(3) The samples belonging to the Awaynat Wanin Formations II and III in the boreholes C1-49 and MG1 are Eifelian.

The 55 species of miospores studied represent most of the species present in these assemblages. We have not taken into account laevigate and apiculate, sometimes retusoid, miospores where the lack of characteristic features does not permit specific determination. We have also neglected a few specimens which probably belong to new species but which were present in too small numbers.

From these 55 species almost 90% are also found in the Old Red Sandstone Continent. This remark is important as it shows that, since the Emsian at least, the respective position of Gondwanaland and Old Red Sandstone Continent have been close enough to allow the general exchange of terrestrial plants (see also Young, 1987).

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