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West Gondwanan aspects of the Middle and Upper Devonian miospore zonation in North Africa and Brazil

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Abstract

The stratigraphical distribution of 11 miospore species found so far only in North Africa and Brazil are compared to the range of taxa which characterize the west European based zonation in order to establish accurate determinations.

The zonate–camerate miospores that are more or less restricted to the Middle Devonian are the most frequent. Other taxa, often camerate with some tabulate ornamentation, first occur near the Givetian–Frasnian boundary. Three of them are restricted to Brazil. These species are more abundant in the early Givetian. During the late Givetian they are probably more numerous in North Africa than in Brazil. Their relative frequencies strongly decrease during the Frasnian.

A greater climatic contrast between the two regions during the late Eifelian (?) and the late Givetian and Frasnian than during the early Givetian is inferred.

1. Introduction

This paper is based on several studies that we have recently published on Middle and Late Devonian miospores from two separated, distinct geographic areas of the western part of the Gondwanan continent: the northern African area (Loboziak and Streel, 1989; Loboziak et al., 1992a) and the Brazilian area (Loboziak et al., 1988a, 1992b).

The studies resulted from detailed palynological analyses of boreholes which allowed the establishment of a well documented stratigraphical record of the most significant species. Everywhere the stratigraphical similarity of these miospore assemblages during the Emsian–Frasnian interval was noted, not only within western Gondwana but also with the Ardenne–Rhenish regions on the southeast border of the Old Red Sandstone Continent. The preliminary conclusions drawn after a comparative study between west European and northeastern Libyan (Streel et al., 1988) material were confirmed. Accurate datations were, therefore, possible across all these regions.

A quantitative approach based on the relative abundance of taxa permitted palaeoclimatic conclusions within western Gondwana (Loboziak et al., 1988b) and between western Gondwana and southern Euramerica (Streel et al., 1990). The almost complete uniformity of the vegetation (as deduced from the miospore record) and therefore of the climate, from palaeotropical to palaeopolar realms during the Givetian and Frasnian, was suggested. However, only a few species were noted to be restricted to western Gondwana giving some sort of provincialism connotation to these regions.

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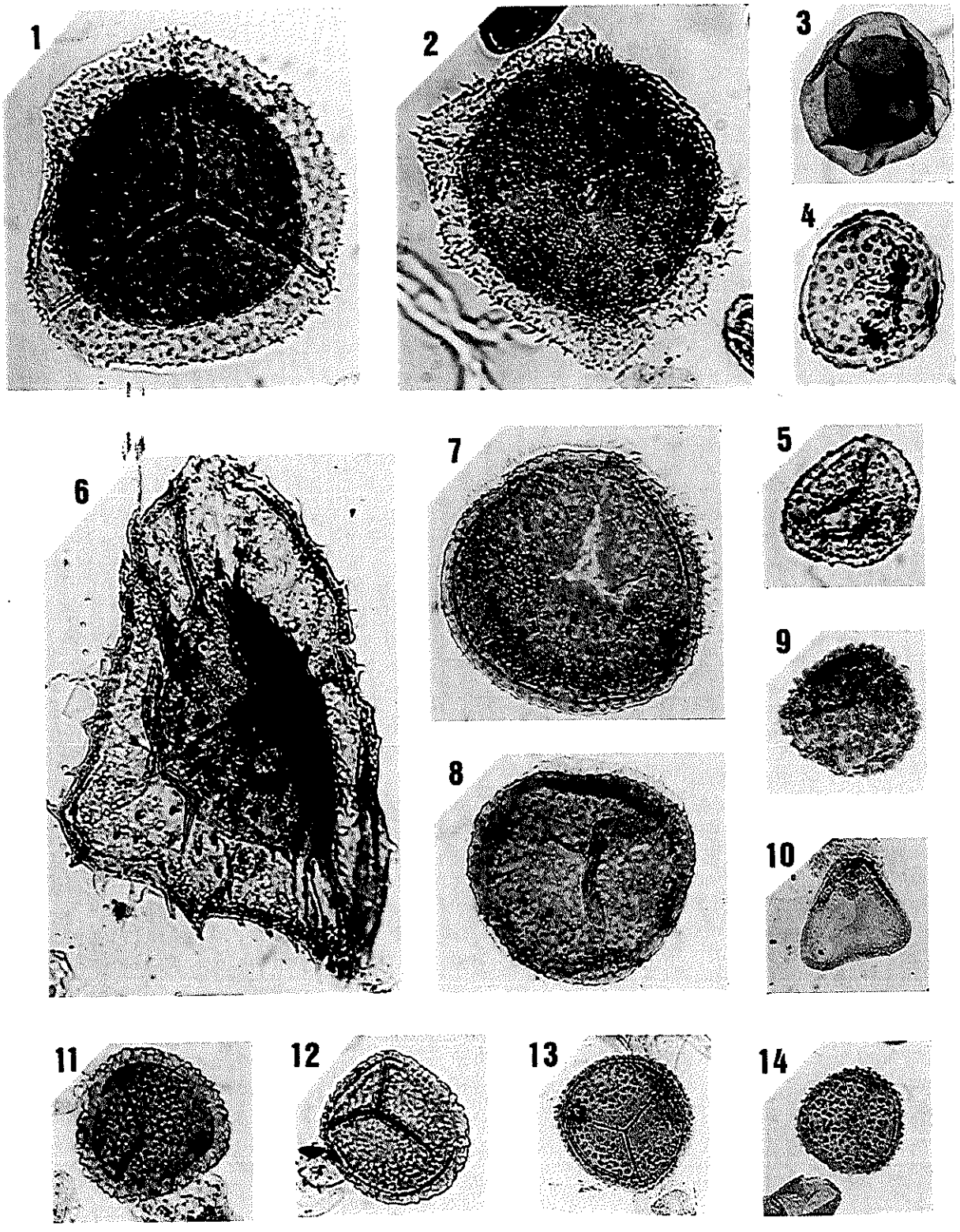
PLATE I



We will now evaluate the stratigraphical and geographical significance of those last few species.

2. Descriptions

These species show distinctive morphological characteristics and have been fully described in previous papers (Moreau-Benoit, 1980; Loboziak et al., 1988a; Loboziak and Streel, 1989). There is no need to duplicate these descriptions herein. Only the main characteristics and a few remarks are given below.

These species belong to two groups: the species occurring both in northern Africa and Brazil and those restricted to Brazil.

2.1 Species occurring both in northern Africa and Brazil

Six species range from the Eifelian to the Frasnian, two are restricted to the Frasnian.

Camarozonotriletes? concavus Loboziak and Streel, 1989 (Plate I, 10)

Cingulate miospore with subtriangular amb, rounded angles and slightly concave interradial margins. The width of the cingulum is only slightly smaller at the angle than at the interradial margins; thus the attribution of this species to the genus *Camarozonotriletes* is questionable.

This species is never abundant but is a frequent component within its stratigraphic range from the Eifelian to the early Frasnian.

Craspedispora ghadamisensis Loboziak and Streel, 1989 (Plate I, 8)

Zonate miospore. The zona is thin, narrow and ornamented with biform elements, composed of a bulbous lower part (up to 4 μm wide) and a thin spiny upper part (up to 1 μm wide and 4 μm high). The zona is reduced in width opposite the ends of the trilete mark. Most often the zona is deflected onto the proximal surface.

PLATE I

All ×500. The miospore locations in the slides are based on England Finder graticule coordinates.
All palynological material is housed in the collections of the Laboratory of Palaeobotany of the University of Lille.

1. *Grandispora riegelii* Loboziak and Streel, 1989. Slide 315,30(1): K46[1]. Parana Basin (Brazil), RSP-1 borehole, sample at 315.30 m.
2. *Grandispora gabesensis* Loboziak and Streel, 1989. Slide C6(2): V26[3]. Hammadah Basin (Tunisia), MG-1 borehole, sample at 2161.80 m.
3. *Grandispora daemonii* Loboziak, Streel and Burjack, 1988. Slide 11(1): K44[3]. Parana Basin (Brazil), RSP-1 borehole, sample at 11.00 m.
4, 5. *Grandispora tabulata* Loboziak, Streel and Burjack, 1988.
4. Slide 52,80(1): Q25[4]. Parana Basin (Brazil), RSP-1 borehole, sample at 52.80 m.
5. Slide 92,60(1): Q30[2]. Parana Basin (Brazil), RSP-1 borehole, sample at 92.60 m.
6. *Grandispora libyensis* Moreau-Benoit, 1980. Slide C12(2): L57. Hammadah Basin (Tunisia), MG-1 borehole, sample at 2222.70 m.
7. *Craspedispora paranaensis* Loboziak, Streel and Burjack, 1988. Slide 315,30 (1): O31[3]. Parana Basin (Brazil), RSP-1 borehole, sample at sample at 315.30 m.
8. *Craspedispora ghadamisensis* Loboziak and Streel, 1989. Slide 348,60 (1): T40[4]. Parana Basin (Brazil), RSP-1 borehole, sample at 348.60 m.
9. *Acinosporites eumammillatus* Loboziak, Streel and Burjack, 1988. Slide 92,60(1): Q52[4]. Parana Basin (Brazil), RSP-1 borehole, sample at 95.60 m.
10. *Camarozonotriletes? concavus* Loboziak and Streel, 1989. Slide C6(2): F54[4]. Hammadah Basin (Tunisia), MG-1 borehole, sample at 2161.80 m.
11, 12. *Chelinospora paravermiculata* Loboziak, Streel and Burjack, 1988.
11. Slide 259,60(1): N30. Parana Basin (Brazil), RSP-1 borehole, sample at 259.60 m.
12. Slide 259,60(1): O43[2]. Parana Basin (Brazil), RSP-1 borehole, sample at 259.60 m.
13, 14. *Geminospora piliformis* Loboziak, Streel and Burjack, 1988.
13. Slide 2085(1): J35[4]. Hammadah Basin (Tunisia), MG-1 borehole, sample at 2085 m.
14. Slide 2100(1): N27. Parana Basin (Brazil), RSP-1 borehole, sample at 2100 m.

The species is often present and sometimes a common component within its stratigraphic range from the Eifelian to the early Frasnian.

Craspedispora paranaensis Loboziak, Streel and Burjack, 1988 (Plate I, 7)

This species differs from *C. ghadamisensis* by possessing a coarser and somewhat coalescent ornamentation on the zona. Elements are up to 10 μm high and 6–7 μm wide at the base, progressively narrowing towards the top or with parallel sides topped by a coni.

Only few specimens were found from the Eifelian to the early Frasnian.

Geminospora piliformis Loboziak, Streel and Burjack, 1988 (Plate I, 13, 14)

Camerate miospore. The exoexine is ornamented mainly with pila and bacula up to 2 μm high and wide, and also with smaller grana and coni.

This species occurs in the Frasnian. It is often present but rarely abundant.

Grandispora gabesensis Loboziak and Streel, 1989 (Plate I, 2)

Subtriangular to rounded triangular camerate miospore with conformable central body. Exoexine thinner than intexine and ornamented, outside the contact areas, with irregularly but densely distributed slender elements (coni, spinae or capilli) up to 3–6 μm high and 0.5–2 μm wide.

This species is rather rare. It is found occasionally within the Eifelian–early Frasnian range. We consider now as atypical the two badly preserved specimens assigned to *G. gabesensis* in samples 1962 and 1950 m in borehole A1-69 (Loboziak and Streel, 1989, fig. 2).

Grandispora libyensis Moreau-Benoit, 1980 (Plate I, 6)

Large, subtriangular, camerate miospore. Exoexine with an apparent thickened equatorial margin and ornamented with elongate biform coni, up to 12 μm high and up to 8 μm wide.

It occurs from the Eifelian to the early Frasnian. It is rarely frequent.

Grandispora riegelii Loboziak and Streel, 1989 (Plate I, 1)

Camerate miospore with dominant mamillate and biform conical elements, but also with grana, verrucae and coni, 1–3 μm wide and high, irregularly distributed, commonly closely spaced.

This species is the most frequent camerate miospore in the Eifelian–Frasnian deposits of western Gondwana. It is very abundant in the Givetian.

Grandispora tabulata Loboziak, Streel and Burjack, 1988 (Plate I, 4, 5)

Camerate miospore with typical tabulate ornaments.

Rare and only known in the Frasnian.

2.2 Species only occurring in Brazil

Three rare species occur only in Brazil.

Acinosporites eumammillatus Loboziak, Streel and Burjack, 1988 (Plate I, 9)

A camerate miospore with an ornament of very close spaced mammillate elements: verrucae up to 3 μm high and wide with a small coni up to 0.5 μm high and wide on the top.

Restricted to the Frasnian.

Chelinospora paravermiculata Loboziak, Streel and Burjack, 1988 (Plate I, 11, 12)

Patinate miospore with convoluted and anastomozed rugulae, 0.5 to 1.5 μm wide.

This species is found in the Givetian and early Frasnian.

Grandispora daemonii Loboziak, Streel and Burjack, 1989 (Plate I, 3)

Rounded camerate miospore with conformable central body and an exoexine ornamented with biform elements, verrucae, coni and grana up to 2 μm high and wide.

It occurs only in the Frasnian.

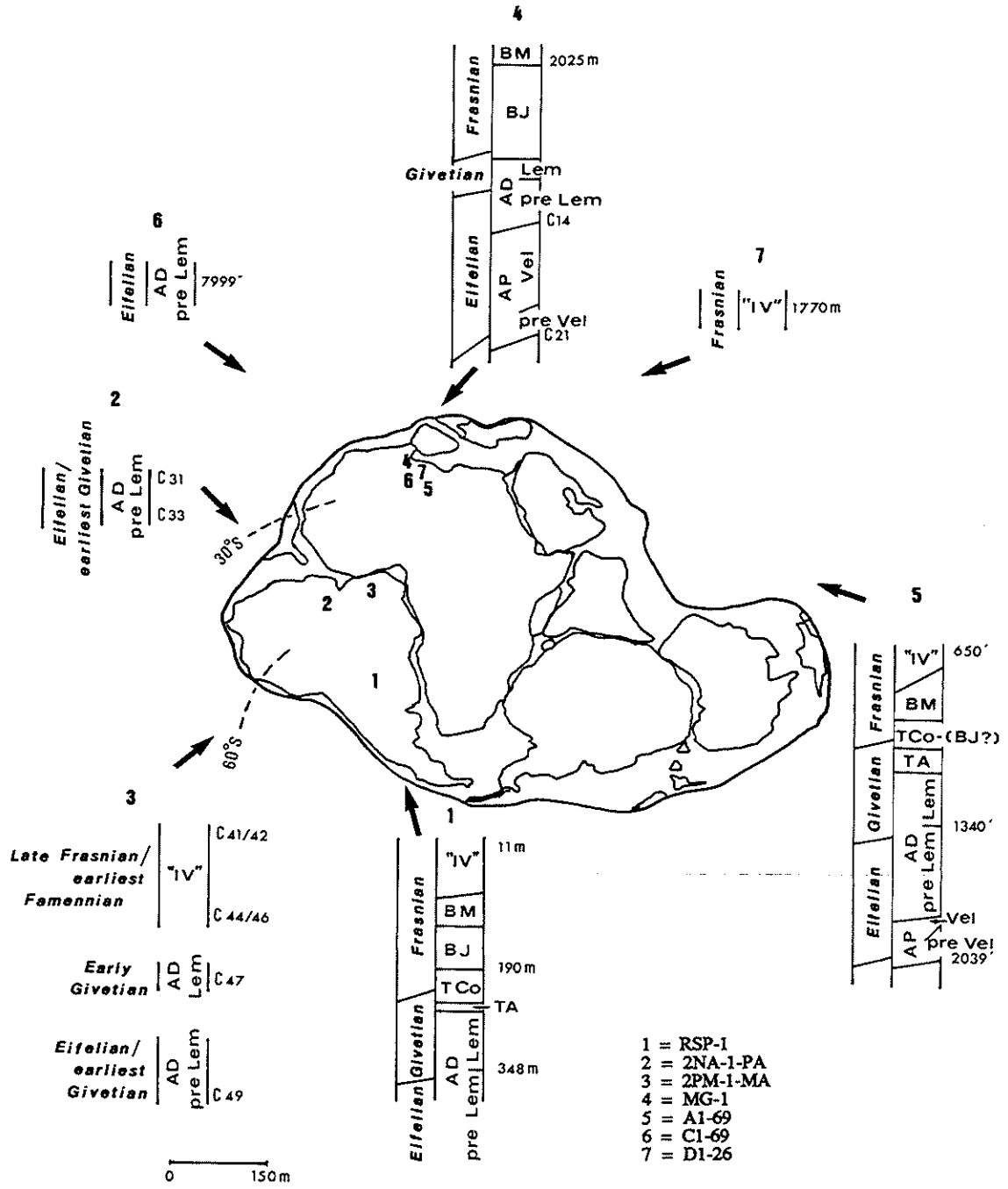


Fig. 1. Location of the investigated boreholes and the Middle–Upper Devonian bio- and chronostratigraphy (after Streel et al., 1987; paleogeographical reconstruction after Scotese and Barrett, 1990, fig. 9). "IV" = phase zone not yet named; BM = *bulliferus–media*; BJ = *bulliferus–jekhovskyi*; TCo = *triangulatus–concinna*; TA = *triangulatus–ancyrea*; Lem = *lemurata*; AD = *acanthomammillatus–devonicus*; Vel = *velata*; AP = *apiculatus–proteus*.

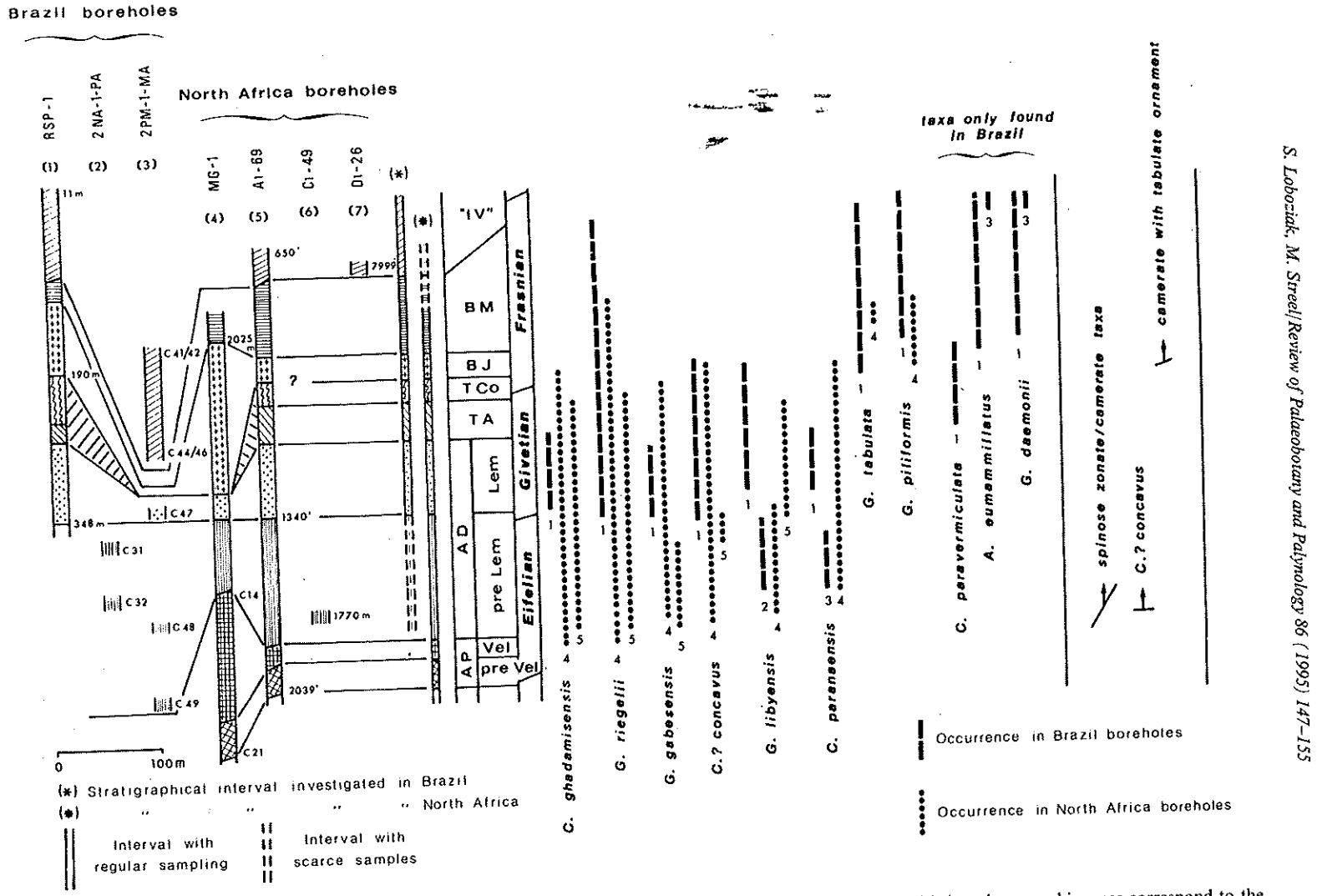


Fig. 2. Stratigraphic distribution of Gondwanan miospores in Brazil and North Africa boreholes (the numbers indicated below the range biozones correspond to the borehole numbers between brackets).

3. Stratigraphy

The location of the boreholes investigated is indicated in Fig. 1. Three boreholes were investigated in Brazil: RSP-1 in the Parana Basin; 2NA-1-PA in the Amazonas Basin; and 2PM-1-MA in the Parnaiba Basin. The North African boreholes are from the Hammadah Basin: MG-1 in the northern part of this basin, near the Tunisian–Libyan border on the Tunisian side; D1-26 in the northern part of the basin in Libya; and A1-69 and C1-49 in the southern part of the basin in Libya. The biostratigraphical data based on miospores and the age range covered by these boreholes are given in Figs. 1 and 2.

Three boreholes (C1-49 and D1-26 in North Africa and 2NA-1-PA in Brazil) provided only a few core samples. The other boreholes cover a relatively similar stratigraphical range (Eifelian–Frasnian). The lowest part (early Eifelian) is absent or poorly productive in the Brazilian boreholes and the highest part (late Frasnian) is insufficiently sampled in the North African boreholes.

The correlation based on the miospore zonation is shown in Fig. 2 where the data are aligned on the Interval Zones "pre Lem"/Lem limit, corresponding to the first occurrence of *Geminospora lemurata* (Balme) emend. Playford, 1983 [in Lybia, in Borehole A1-69 (Loboziak and Streel, 1989, fig. 2), the first occurrence of *G. lemurata* is based, at level 1480′, on one single specimen which we believe now to be atypical, as far as the ornamentation is concerned, when compared to the description given by Playford, 1983. We now fix the limit at 1340′]. The late Eifelian Interval Zone "pre Lem" which corresponds to the lower part of Oppel Zone AD, below Interval Zone Lem, is represented in Brazil only by a few core samples in which the miospores are not abundant and are poorly diversified. Comparison between Brazil and North Africa therefore remains doubtful at that level. The range of the selected species mentioned in the descriptive part of this paper is given on the right hand side of Fig. 2 for most of the boreholes.

A first group is represented by four species that first occur in the same miospore zone in both regions: *G. libyensis* and *C. paranaensis* in the Eifelian, and *G. tabulata* and *G. piliformis* in the Frasnian. They are informative species for correlation because their stratigraphical ranges are distinct; the first two species are almost entirely restricted to the Middle Devonian.

A second group is represented by four species (*C. ghadamisensis*, *G. riegelii*, *G. gabesensis* and *C.? concavus*) that seem to appear later in Brazil (in the Eifelian–Givetian transition) than in North Africa. This observation needs confirmation when more samples are available in Brazil. However, it is striking to note that *C. ghadamisensis* and *G. riegelii* are already well represented in the lowest productive horizon (i.e. the oldest investigated sample of the RSP-1 borehole). This record probably means that their first occurrence in this area should be expected before the Givetian. On the other hand, if they were already abundant in the Eifelian of Brazil as known from northern Africa, why are they not present amongst the few specimens recovered from the lowest samples of 2NA-1-PA and 2PM-1-MA boreholes?

A third group is represented by three species occurring only in Brazil. *C. paravermiculata* first occurs in the Givetian, whereas *A. eumammillatus* and *G. daemonii* appear in the Frasnian. They might be useful for local stratigraphy despite the fact that they are not abundant species.

Amongst the species of the first and second groups, the Middle Devonian species *G. libyensis* and the Middle Devonian and Frasnian species *G. riegelii* are also known in the uppermost Famennian ("Strunian") and Lower Carboniferous of North Africa (for *G. libyensis*, see Lanzoni and Magloire, 1969; Coquel and Moreau-Benoit, 1986, 1989; for *G. riegelii*, see *Hymenozonotriletes* sp. no. 2972 in Lanzoni and Magloire, 1969, table 1, plate 8, figs. 2 and 3, and *?Grandispora uyenoï* McGregor and Camfield, 1982 in Coquel and Moreau-Benoit, 1989, plate 4, fig. 1). We believe that these species, as well as several other Middle Devonian species, are present as a result of reworking processes.

4. Quantitative analysis

Loboziak et al. (1988b, fig. 3) have shown the quantitative distribution of various miospore

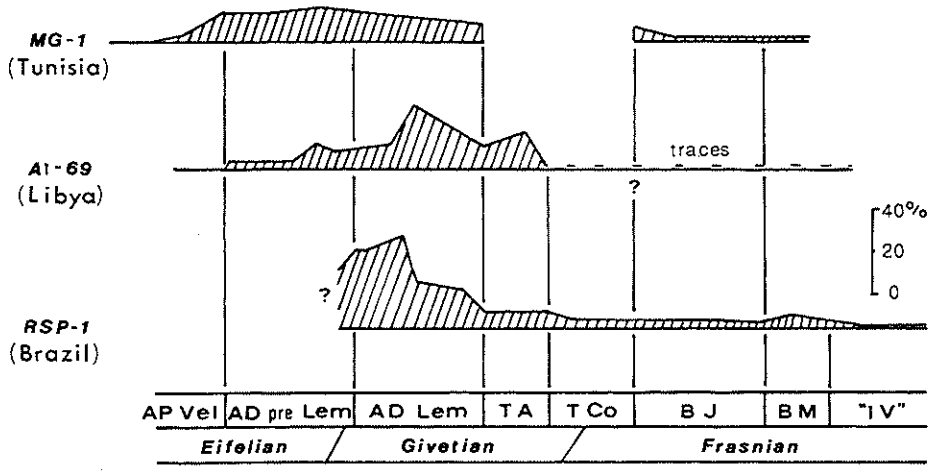


Fig. 3. Quantitative distribution of Gondwanan miospores in Brazil and North Africa boreholes.

groups in the two regions of western Gondwana through counting separately the morphologically simple (smooth or finely ornamented, one-layered) miospores and the morphologically more elaborate miospores. It was a count of specimens rather than a count of species so that the recorded variations do not reflect the changes in the flora (i.e. the number of species) but in the vegetation (i.e. the proportion of specimens of the different species). The relative frequency of the specimens belonging to the characteristic species of western Gondwana described above are reproduced on Fig. 3. These species are the most numerous in the early Givetian and appear to be more abundant during the late Givetian in northern Africa than in Brazil. Their relative frequencies decrease strongly during the Frasnian. *G. riegelii* and *C. ghadamisensis* are largely dominant reaching up to 60% of the specimens belonging to morphologically elaborate miospores.

Obviously, if only a few species are restricted to western Gondwana, their importance in the vegetation is limited. The variation in proportion of these dominant species corresponds to the changes in climate with adverse conditions occurring earlier in the palaeo-polar Brazilian region than in the palaeo-subtropical north African region (Streel et al., 1990).

5. Conclusion

There are a few species which sometimes are even abundant in occurrence which have geographical distributions restricted to western Gondwana. Together with the criteria defined in the Ardenne–Rhine regions, they might represent good stratigraphic markers in these areas.

Two large, coarsely ornamented camerate or zonate miospores, *G. libyensis* and *C. paranaensis*, first occur and are present in the Middle Devonian of North Africa and Brazil. They are succeeded in the Frasnian by smaller species with typical pilate or tabulate ornamentation, *G. tabulata* and *G. piliformis*.

During the Givetian, four additional species, of which *G. riegelii* and *C. ghadamisensis* are the most numerous, are also present in both regions of western Gondwana but might have entered the stratigraphic record later in Brazil than in North Africa. This observation requires confirmation when more productive samples will be available from the Eifelian of Brazil. Three species occur only in Brazil: *C. paravermiculata* in the Givetian–early Frasnian, and *A. eumammillatus* and *G. daemonii* in the Frasnian.

In the late Givetian, all these species might be more abundant in North Africa than in Brazil.

Their qualitative and quantitative distribution might reflect more contrasted climatic regimes between the two regions during the late Eifelian (?) and the late Givetian and Frasnian than during the early Givetian.

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