

# Miospore lateral distribution in upper Famennian alluvial lagoonal to tidal facies from eastern United States and Belgium

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## ABSTRACT

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Miospore assemblages from continental rocks of mid late Famennian age of the Hampshire Formation of Virginia and West Virginia, U.S.A., are compared with those from the nearly coeval marine facies of the Ourthe Valley, Belgium. Eighteen spore taxa from the type Famennian 2c section in Belgium are also found in the continental beds of Virginia and West Virginia. Near-shore sediments carry more uniform and richer miospore assemblages than any one continental facies. Offshore currents or barriers, however, can alter the mixture of miospores coming from various land source areas by different drainages. Onshore autochthonous and allochthonous beds generally show correspondence between the recovered megafossils and the miospore assemblages. But the miospore assemblages enable us to distinguish between deposits resulting from short-term flooding episodes, those of autochthonous upland backswamps and deltaic marshes. We can thus distinguish upstream from downstream environments in our continental samples. Near-shore sediments in Belgium show a dominance of upstream over downstream derived miospores that suggests frequent strong floods in their fluvial systems.

## Introduction

As a result of the closing of the Iapetus Ocean, the Acadian orogeny produced events which reached Virginia by the Late Devonian (Oliver, 1980). Continued erosion of the uplands produced broad, flat coastal plains (Bambach et al., 1980). The Hampshire beds of West Virginia and Virginia were mainly deposited under alluvial and fluvial conditions (Meckel, 1970) in mid late Famennian (Fa2c) time (Clendening et al., 1980).

The type Fa2c rocks were deposited 3000 km away on the opposite side of the Acadian Mountains in a shallow epicontinental sea bordering the southern part of the Old Red Continent, in the area which is now the Belgian Ardenne (Paproth et al., 1986).

Very similar assemblages of miospores occur in the continental beds of West Virginia and Virginia and in the marine beds of Belgium. They were

produced by plants growing in a tropical vegetation belt located at that time around 15° or 25° S. Lat. (Scheckler, 1986b; Streel, 1986).

The miospores found in both regions by us and by Clendening et al. (1980) are listed in Table I. *Grandispora cornuta*, *Retispora macroreticulata*, *Retusotriletes phillipsii* and *Rugospora radiata* are all characteristic of the VCo Zone (Streel et al., 1987), the base of which indicates the Fa2b/Fa2c chronozone limit in Belgium (*sensu* Bouckaert et al., 1968). The absence of *Retispora lepidophyta* (Kedo) Playford 1976, the first occurrence of which characterizes the base of the Fa2d chronozone in Belgium, allows us to date our assemblages to an unquestioned Fa2c age. However, there might be a small difference in age between Virginian–West Virginian and Belgian assemblages, as the former contain *Vallatisporites hystricosus* (Winslow) Byvsheva 1985. *V. hystricosus* is known to occur in the uppermost part of the VCo Zone (an upper-

TABLE I

Taxa (and probable synonyms) known from the type Fa2c in Belgium and identified in the continental beds of West Virginia and Virginia.

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*Aneurospora greggsii* (McGregor) Strel in Becker et al., 1974  
*Auroraspora asperella* (Kedo) Van der Zwan, 1980  
 Syn.: *A. asperella* var. B Van der Zwan, 1980  
*A. macra* Sullivan, 1968 in Becker et al. 1974, pro parte  
*Auroraspora hyalina* (Naumova) Strel in Becker et al., 1974  
 Syn.: *Endosporites* gr. *minutus* Hoffmeister et al., 1955 in Bouckaert et al., 1969 (pl. 94, fig.5)  
*A. macra* Sullivan 1968 in Becker et al. 1974, pro parte  
*Auroraspora varia* (Naumova) Ahmed, 1980  
 Syn.: *A. varia* var. *multifuria* Ahmed, 1980  
*Perotrilites* cf. *P. perinatus* Hughes and Playford, 1961 in Bouckaert et al., 1969 (pl. 94, fig.2)  
*Auroraspora* sp. cf. *Perotrilites perinatus* Hughes and Playford, 1961 in Becker et al., 1974, pro parte  
*Incertae sedis* in Becker et al., 1974 (pl. 24, fig.12)  
*Diducites plicabilis* Van Veen, 1981  
 Syn.: *Auroraspora* sp. cf. *Perotrilites perinatus* Hughes and Playford, 1961 in Becker et al., 1974 pro parte (pl. 21, fig.6)  
*Diducites poljessicus* (Kedo) Van Veen, 1981  
*Diducites versabilis* (Kedo) Van Veen, 1981  
*Grandispora cornuta* Higgs, 1975  
*Grandispora gracilis* (Kedo) Strel in Becker et al., 1974  
*Knoxisporites* cf. *pristinus* Sullivan 1968 in Becker et al., 1974  
*Plicatispora quasilabrata* (Higgs) Higgs et al., 1988  
 Syn.: *Pulvinispora* sp. A in Becker et al., 1974 (pl. 16, fig.3)  
*Plicatispora scoleophora* (Neves and Ionnides) Higgs et al., 1988  
 Syn.: *Aneurospora incohata* (Sullivan) Strel (in Becker et al., 1974) in Strel, 1977 (pl. 1, fig.6)  
*Punctatisporites minutus* Kosanke, 1950  
 Syn.: *Punctatisporites glaber* (Naumova) Playford, 1962 in Becker et al., 1974  
*Retispora macroreticulata* (Kedo) Byvsheva, 1985  
 Syn.: *Spelaotriletes* sp. A in Becker et al., 1974  
*Retusotriletes* cf. *coniferus* Kedo 1963 in Higgs et al., 1988  
 Syn.: *Aneurospora incohata* (Sullivan) Strel (in Becker et al., 1974) in Becker et al., 1974, pro parte  
*Retusotriletes incohatus* Sullivan, 1964.  
 Syn.: *Aneurospora incohata* (Sullivan) Strel (in Becker et al., 1974) in Becker et al., 1974, pro parte  
*Retusotriletes phillipsii* Clendening et al., 1980  
 Syn.: *Retusotriletes* sp. A Strel in Becker et al., 1974  
*Rugospora radiata* (Juschko) Byvsheva, 1985  
 Syn.: *Rugospora flexuosa* (Juschko) Strel in Becker et al., 1974.

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most part of Fa2c that may not be represented by rocks in Belgium; see Strel, 1986, p.77) in Pennsylvania (Strel and Traverse, 1978) and Libya (Paris et al., 1985).

Only the most abundant miospores will be considered in this paper, as we intend to evaluate their approximate lateral distribution from alluvial (in West Virginia-Virginia) to lagoonal-tidal (in Belgium) environments.

#### Miospore distributions

Systematic concepts have evolved since the initial work (in the late nineteen sixties and early

seventies) in the type Fa2c in Belgium. Table I shows a reappraisal of the systematics.

Three groups of miospores are mainly concerned:

(1) The *Retusotriletes* group with "banded" *curvaturae* (Lele and Strel, 1969).

We now separate *R. cf. coniferus* from *R. incohatus*, the former being much more abundant than the latter in the Famennian of Belgium. We refer to *Plicatispora scoleophora* those specimens with a microfolded exine.

(2) The *Auroraspora macra* concept of Strel in Becker et al., 1974.

This is now separated into two entities. The first,

*A. asperella*, has distinct labra and a closely fitted thin bladder on the body; the second, which is more abundant in the Famennian of Belgium, has a thicker bladder at the equator, and is merged with *A. hyalina*.

(3) The *Perotrilites perinatus* concept of Strel in Becker et al., 1974.

This is now separated into two entities: *Diducites plicabilis* with three distinct exine layers and *Auroraspora varia* with two. These two entities are not separated, however, in the quantitative analysis made in the present work.

#### Continental facies

The two localities studied are Elkins, in Randolph County, West Virginia and Rawley Springs, in Rockingham County, Virginia (Scheckler, 1986a).

At the Rawley Springs locality, a coal bed up to 1.5 m thick rests on a bioturbated and partly rooted mudrock at the top of a fluvial fining upward cycle. This type of cycle is interpreted as having been deposited by a river or stream wandering or meandering over a low gradient alluvial plain. The presence of a coal bed indicates that a swamp temporarily existed on this flood plain so that peat accumulated and was preserved. Silty partings in the coal suggest occasional influxes of sediment due to flooding events. One parting (Fig.1) fines laterally and is regarded as a portion of a crevasse splay.

One sample (Hm7) taken at the edge of the crevasse splay carries an assemblage of dark but rather well-preserved miospores, largely dominated by *Retusotriletes* cf. *coniferus* (66%). *Punctatisporites minutus* and *Grandispora gracilis* are also abundant (13% each). *Aneurospora greggsii* and the *Diducites plicabilis*-*Auroraspora varia* Complex are also present (4% each).

Another sample (Hm1) taken in the crevasse splay near its contact with the overlying fluvial cycle contains a poorly preserved assemblage composed, in decreasing proportion, of *Retusotriletes* cf. *coniferus*, *Punctatisporites minutus*, *Grandispora gracilis* and *Aneurospora greggsii*.

At the Elkins locality, the study section includes two 15 cm thick coal beds separated by 17 m of

deltaic sediments and associated strata (Fig.2). The bioturbated and rooted zones beneath the two coal beds suggest that these were autochthonous communities that colonized a delta lobe that was temporarily exposed and abandoned. Above the coals lies a thick sequence of mudrocks and sandstones. The presence of a few hummocky cross-stratified sandstones indicates that the waning stages of stormwave action were responsible for their deposition.

One sample (Hb), a thin, laminated underclay in the bioturbated and rooted zone beneath the lowest coal-bed, contains a very poorly preserved assemblage of miospores dominated by *Auroraspora asperella* and *Aneurospora greggsii*. It also contains acritarchs. Two samples from the lowest coal-bed carry comparable assemblages of rather well preserved miospores but the dominant species occur in slightly different proportions. One (Hc pyr.), coming from a pyritic part of the coal-bed, is dominated by the *Diducites plicabilis*-*Auroraspora varia* Complex (40%). *Auroraspora asperella* is also abundant (26%). *Punctatisporites minutus*, *Aneurospora greggsii* and *Vallatisporites hystricosus* vary from 7 to 3%. Six other species together with nondetermined forms total 18% of the assemblage. The other one (Hc), coming from another part of the same coal-bed, is even richer in species. It has ten other species (and nondetermined forms) totalling 36% of the assemblage. It is dominated by *Aneurospora greggsii* (30%). The *Diducites plicabilis*-*Auroraspora varia* Complex, *Auroraspora asperella*, *Punctatisporites minutus* and *Vallatisporites hystricosus* vary from 12 to 4%.

One sample (Hg), from the highest pyritic coal-bed, contains only a poorly preserved assemblage of miospores dominated by *Vallatisporites hystricosus*, *Auroraspora asperella* and *Punctatisporites minutus*.

Another sample (Hd), coming from a more shaley part of a hummocky cross-stratified sandstone overlying the lowest coal-bed, contains a predominance of the *Diducites plicabilis*-*Auroraspora varia* Complex (39%) and of *Vallatisporites hystricosus* (34%). *Punctatisporites minutus*, *Aneurospora greggsii* and *Auroraspora asperella* vary from 7 to 4%. Four other species (and nondetermined forms) total 10% of the assemblage.

RAWLEY SPRINGS, VIRGINIA

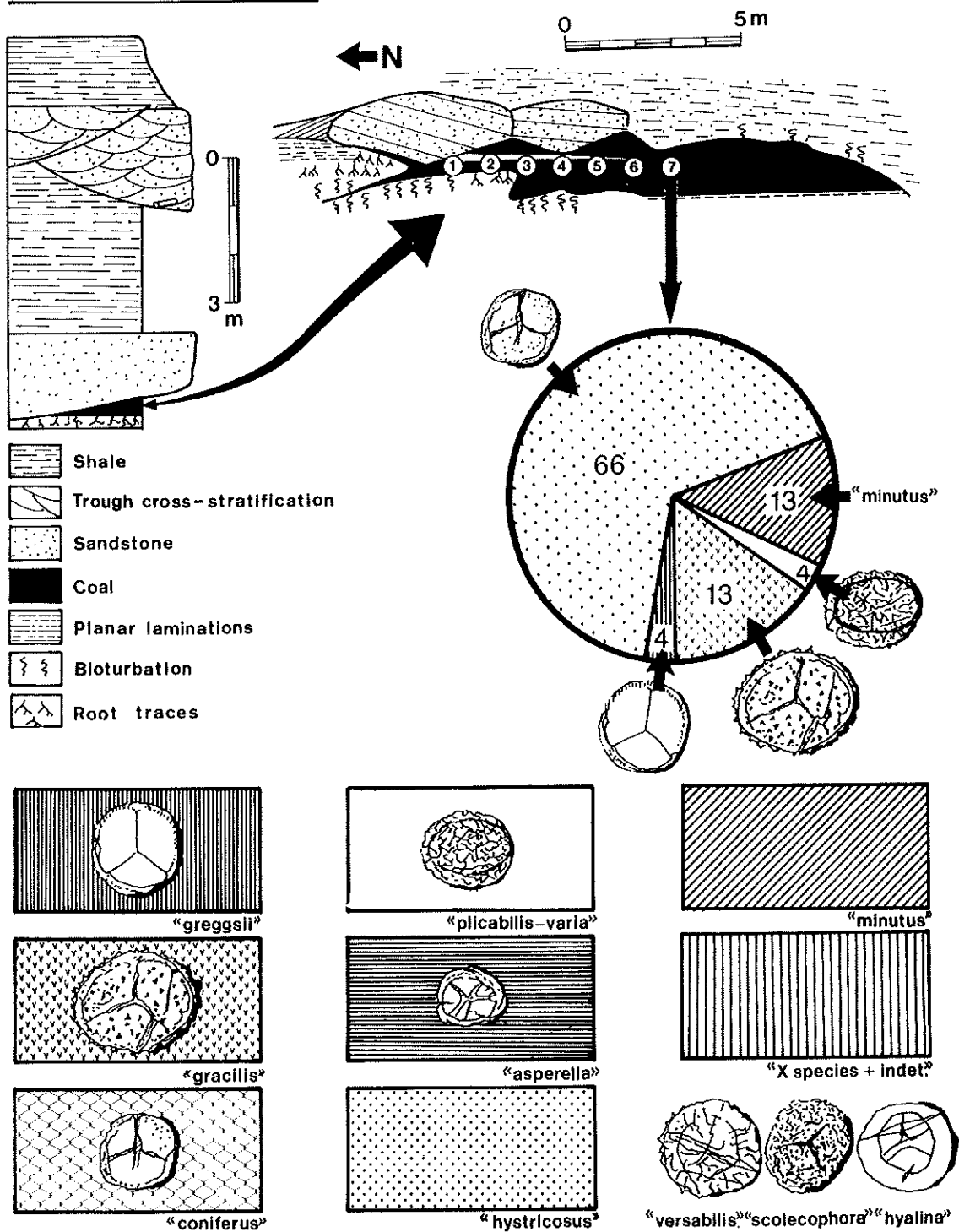


Fig.1. Quantitative analysis of the most abundant miospores in one sample (Hm7) collected at the edge of a crevasse splay, at Rawley Springs, Virginia, U.S.A.

**ELKINS, WEST VIRGINIA**

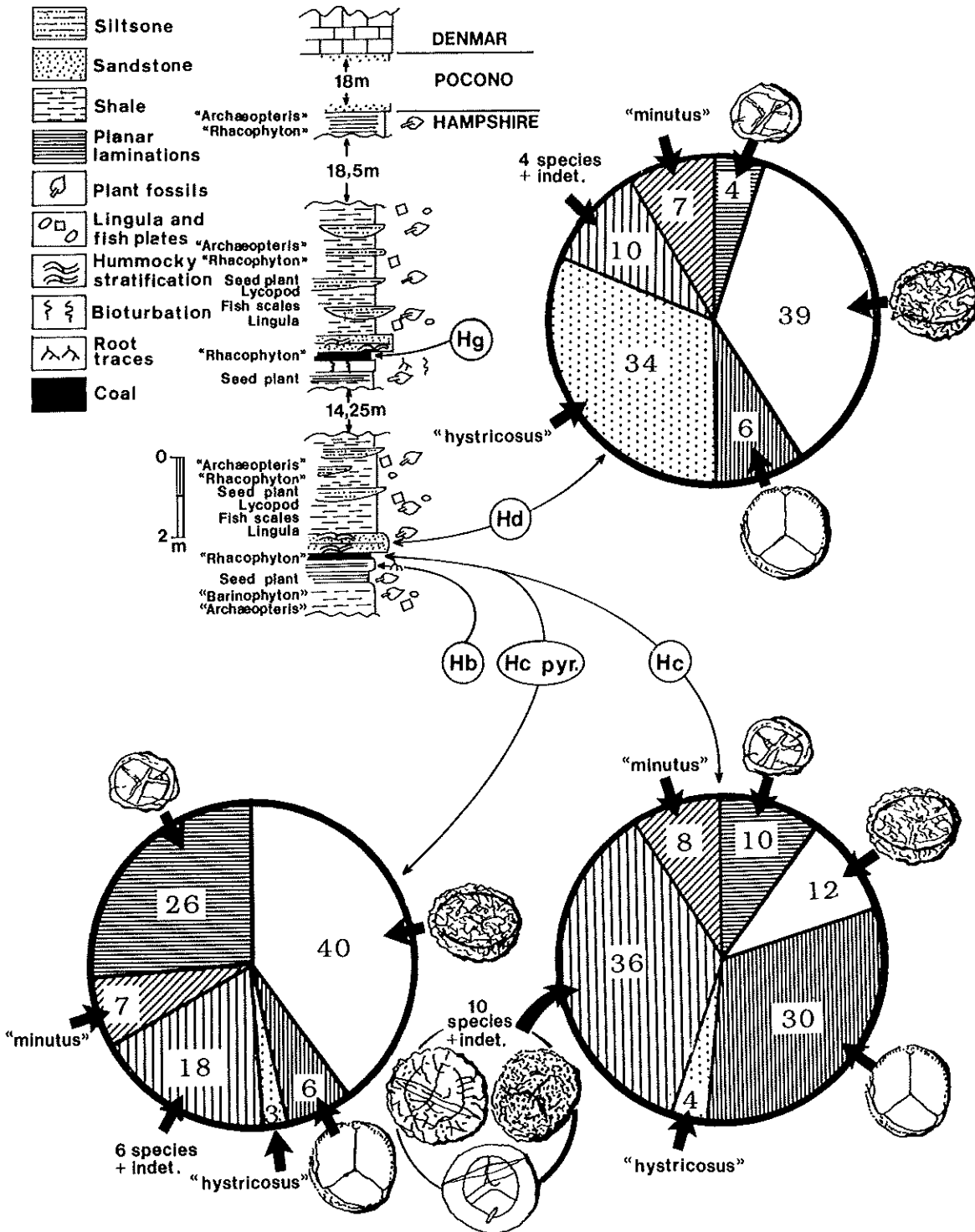


Fig.2. Quantitative analysis of the most abundant miospores in three samples collected at Elkins, West Virginia, U.S.A. See legend on Fig.1.

Samples taken from plane-laminated mudstones at the base of the lower Elkins section, from the alternating mudstones and siltstones in the upper part of this section, and from a bioturbated underclay below the higher coal-bed at Elkins were barren. At Rawley Springs, barren samples were also taken in rooted underclay from beneath and at the edge of the coal-bed, from clastic free coal beneath the crevasse splay, from a thin, laminated, cross-stratified sandstone at the bottom of a channel and from bioturbated levee mudstones/siltstones.

*Marine facies*

The localities studied are in the Ourthe Valley, south of Liège in Belgium and are described in Becker et al. (1974, fig.19). Most of the 18 selected

samples come from lagoonal environments with more or less tidal current influences. Most samples contain acritarchs (see Becker et al., 1974, enclosure II, fig.5).

During the early part of Fa2c, the alluvio-lagoonal environment of Evieux (EV FL) and La Gombe (GO 35 and 38) was separated from the tidal environment of Beverire (BEV 38/2, 42/3, 42/4, 46, 47 and 49) and Comblain (CBT 135 and 142) by a barrier complex. During the late part of Fa2c, the barrier complex vanished, allowing better exchanges throughout the basin between the lagoonal to subtidal environments (Montfort-MT IV/2 and Beverire-57/13, 57/14, 60/5, 62/4, 64/17 and 64/19).

The samples were selected for their well-preserved miospores and their diversity (more than 30 taxa in each sample). They are arranged according

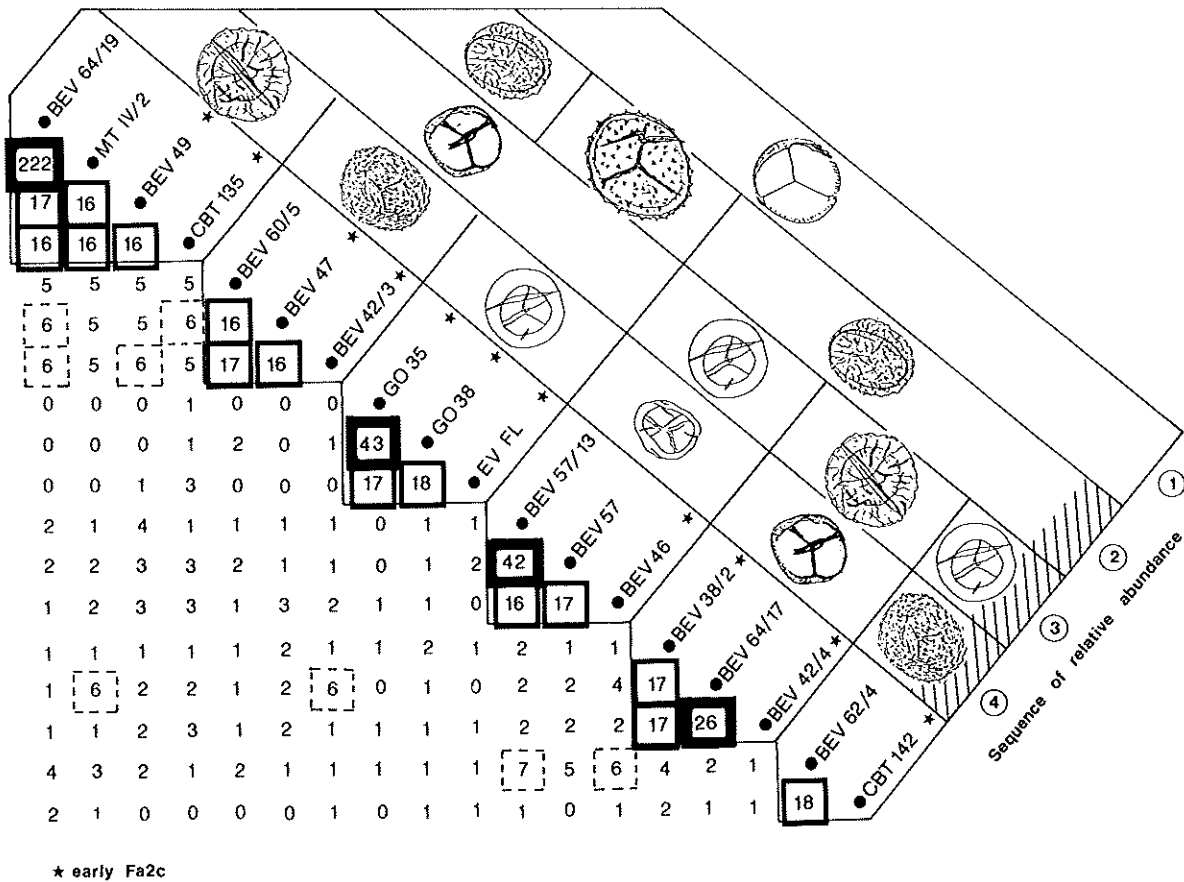


Fig.3. Quantitative analysis of the most abundant miospores in 18 samples collected in the Ourthe valley, south of Liège, Belgium. See legend on Fig.1.

to their similarities in Fig.3 (see legend). The affinity between two assemblages is not based on the percentage values of each species, but only on their rank of relative abundance, the most abundant being classed first. A correlation value was computed between each pair of assemblages: each sequence of  $x$  species presenting the same decreasing order of abundance was given a value calculated with the formula:

$$2^{x-1} - 1$$

The four most abundant species in these assemblages are shown in Fig.3.

All assemblages are dominated by *Aneurospora greggsii*. The second most abundant taxon is the *Diducites plicabilis*-*Auroraspora varia* Complex except in the alluvio-lagoonal environment of La Gombe and Evieux during the early Fa2c where *Grandispora gracilis* is second. The third and fourth most abundant species are always (in 17 of the 18 selected samples) two of the following species: *Auroraspora hyalina*, *Retusotriletes* cf. *coniferus*, *Diducites versabilis*, *Plicatispora scoleophora* or *Auroraspora asperella*.

#### Known miospore mother plants

In the same year, 1968, spores were isolated from the sporangia of *Rhacophyton* both in West Virginia, U.S.A. (Andrews and Phillips, 1968) and in the northeast of the L'vov Trough, U.S.S.R. (Ischenko and Sorokina, 1968). The American *Rhacophyton* corresponds to *R. ceratangium* Andrews and Phillips and was found in the Hampshire Formation at a locality 40 km southwest of Elkins. The Soviet *Rhacophyton* is a possibly synonymous species *R. incertum* (Dawson) Krausel and Weyland found in the Dankov-Lebedyan beds (but see Andrews and Phillips, 1968, p.54).

Although the spores isolated from *R. ceratangium* are compared to *Perotriletes conatus* Richardson 1965 and *Perotriletes perinatus* Hughes and Playford 1961 and those from *R. incertum* to *Hymenozonotriletes varius* var. *minor* Naumova 1953, they look obviously similar. The Russian material contains diads similar to the sporae dispersae figured by Ahmed (1980, pl. 3, figs.3 and 6) under the names *Auroraspora varia* (Naumova)

Ahmed 1980 and *Auroraspora varia* var. *multifaria* Ahmed 1980, from the Famennian of New York State and Pennsylvania. There is little doubt that the miospores described in Virginia, West Virginia and Belgium from the *Diducites plicabilis*-*Auroraspora varia* Complex do belong to the same taxa. They are also found in diads or agglomerates of spores.

Spores have been isolated from several different species of *Archaeopteris*. These are reviewed by McGregor (1979, table 1) for North America and also by Gensel (1980) and Allen (1980). Those in the miospore size range are attributed to *Apiculatasporites*, *Cyclogranisporites*, *Aneurospora* or *Geminospora*. These genera have in common a very similar ornamentation comprising very small conical or grana. They differ mainly in the number of visible exine layers and the presence of haptotypic features which change during development and so vary with the level of maturity of the spores. Presence of an internal layer of exine was not always shown. Sometimes "banded" curvatures as in the miospore genus *Aneurospora* were observed. Therefore, we suggest that *Aneurospora greggsii* which has the same sculpture as the sporae in situ of *Archaeopteris* might belong to this genus.

#### Discussion

Samples from the West Virginian coal-beds at Elkins probably provide the closest approximation to autochthonous (hypautochthonous) assemblages of miospores available. The coal flora consists mostly of *Rhacophyton* foliar axes, but has a small component of lycopod fragments. The latter are mostly megaspores and fragments of megasporangiate strobili, but also include some small xylem strands. The palynofacies of all investigated samples contain large dark organic fragments.

The upper coal is uniformly pure, except for the coal-ball horizon in the middle. Unfortunately, the miospores (Hg) are poorly preserved but seem to favor a dominance of *V. hystricosus* over *A. asperella* and *P. minutus*.

The lower coal is far less pure. In some places it contains so much pyrite as to be a carb-pyrite and in other places it has so much sediment as to be a

carb-shale. It also contains coal-balls. When the coal-balls are examined, the autochthonous swamp community can be seen to consist of almost pure stands of *Rhacophyton*. The lycopod fragments occur almost exclusively in the allochthonous assemblage and were probably brought into the swamp by the same events that led to the pyrite permineralization (Scheckler, 1986a).

*D. plicabilis*-*A. varia* spores dominate the assemblage in the carb-pyrite (Hc pyr) sample. *A. greggsii* spores dominate the assemblage in the carb-shale (Hc) sample. Dominance of species is more exclusive in the carb-pyrite (66%: 40% of *D. plicabilis*-*A. varia* and 26% of *A. asperella*) than in the carb-shale where dominant *A. greggsii* reaches only 30%. The number of taxa is also less in the carb-pyrite (12 taxa) than in the carb-shale (16 taxa) pointing to a less allochthonous content in the former. Dyads and agglomerates of *A. greggsii* and *A. varia* are found in both samples.

The acceptance of *D. plicabilis*-*A. varia* as representing *Rhacophyton* in the miospore content of the lower coal agrees with the large dominance of the megafossil in this coal. In the more allochthonous part of the coal, *A. greggsii* might well represent *Archaeopteris* "which seems to have grown on the flood plains where its litter could be easily picked up and transported during floods" (Scheckler, 1986a, p.218). The low content of miospores in the upper coal (Hg) at Elkins does not allow us to confirm or reject the relationship between the abundance of *D. plicabilis*-*A. varia* and the abundance of *Rhacophyton*. It only indicates that the plants producing *V. hystricosus* spores were probably also living near the swamp.

It should be noted that *A. asperella* spores are the next most abundant spores in each of the coals. This suggests a relationship with the next most abundant plant in these coals: the tree lycopods. "The rare presence of lycopod debris in the allochthonous portion of the coal-balls suggests that a community of tree lycopods existed at the fringes of the marsh and provided the buoyant fragments that were drawn into the swamp as the storm waters retreated from the land" (Scheckler, 1986a, p.217).

The material isolated from the cross-stratified sandstone hummocks at Elkins shows a palynofa-

cies devoid of the large organic fragments which characterize the coals. It corresponds to a more sorted palynofacies. The miospore assemblage with a co-dominance of *D. plicabilis*-*A. varia* and *V. hystricosus* might well represent a mixture of the swamp and near-swamp environments.

At Rawley Springs, the palynofacies of samples Hm1 and Hm7 also has the large organic fragments typical of coals. The relationship between the miospore assemblages and the megafossils present at the edge of the crevasse splay are rather poor. The low proportion (4%) of *D. plicabilis*-*A. varia* suggests that the relatively abundant *Rhacophyton* in this splay resulted from flooding rather than from hypautochthonous growth even though this megafossil comprises from 81-94% of the coal flora. The floods might also have carried into the swamp miospores produced by near-swamp communities represented by high percentages of *R. coniferus* spores and to a lesser extent *G. gracilis* spores, never abundant in Elkins. When comparing Elkins and Rawley Springs palynological data, the difference in the swamp environment suggested by Scheckler (1986a) is not only confirmed but emphasized.

The Elkins locality corresponds to a deltaic marsh characterized by rare introduction of acritarchs (Hb) and different near-swamp communities dominated either by *V. hystricosus* spores or by *A. asperella* spores. *R. coniferus* and *G. gracilis* spores are never abundant. The Rawley Springs locality corresponds to a backswamp on the "upland" floodplain characterized by near-swamp communities dominated by *R. coniferus* and *G. gracilis* spores. *A. asperella* spores are rare and *V. hystricosus* spores are not present.

*D. plicabilis*-*A. varia*, the spores of *Rhacophyton* and *A. greggsii*, the presumed spores of *Archaeopteris*, are present in both types of swamp, but seem more abundant downstream than upstream.

In the 18 samples of the Fa2c of the Ourthe Valley in Belgium, 5 of the 8 most abundant miospores (Fig.3) are also abundant and characterize the different environments in Virginia and West Virginia. *A. hyalina*, *D. versabilis* and *P. scoleophora*, although present in Virginia and West Virginia, are never abundant in the studied samples.



Among the miospores abundant in both regions, the dominant ones, in almost all sequences, are shown in Fig. 3 and are (except one: EV FL, GO 35, GO 38) *A. greggsii* and *D. plicabilis*–*A. varia*. *Archaeopteris* and *Rhacophyton* are therefore thought to represent the dominant source vegetation on the continent for the miospores in the Fa2c marine basin of the Ourthe Valley. This probably means that floodplains and swamps were widespread on the nearby continent.

Among the other three miospores abundant in both regions, two (*G. gracilis* and *R. coniferus*) belong to upstream near-swamp environments and one (*A. asperella*) to a downstream near-swamp environment. In almost every type of sequence shown in Fig. 3 (except one: BEV 46, 57/13, 57/14) the most abundant miospores characteristically come from the upstream facies. This is particularly obvious in the 3 samples of the early Fa2c alluvio-lagoonal environment of Evieux and La Gombe where *G. gracilis* (and *R. coniferus*) spores are abundant. In contrast, three samples of the Beverire section, in the tidal environment, show a sequence of miospores, with abundant *A. asperella* in the fourth position, rather similar to the downstream flooding facies of West Virginia (Hc).

The dominance of upstream over downstream derived miospores in marine assemblages has been discussed by Chaloner and Muir (1968). Work done on Jurassic miospores of Yorkshire clearly demonstrated that marine rocks of various lithologies contained miospore assemblages similar to the continental "fluvial" sandstones but quantitatively different from the siltstones, mudstones and coals of the delta plain. The coarse sandstones contain material of more remote source, comprising spores of plants from the hinterland rather than from the delta swamp. A study of recent pollen sedimentation along two small rivers entering the Mediterranean Sea at Calvi in Corsica has also demonstrated (Richelot and Streel, 1985) that most of the pollen deposited within the nearshore marine sediments originated from an upland hinterland through periodical violent floods.

From the latter part of the discussion it might be concluded that the fluvial system draining the hinterland of the Fa2c marine basin in the Ourthe Valley was characterized by strong floods capa-

ble of carrying upstream material directly into the sea.

## Conclusion

The study of the miospore lateral distribution through different environments containing megaplants of mid late Famennian age in Virginia, West Virginia and Belgium allows several conclusions to be drawn.

The relationships between the spores and their mother plants are obvious for the *Diducites plicabilis*–*Auroraspora varia* Complex and the genus *Rhacophyton*. There is a probable relationship between *Aneurospora greggsii* and the genus *Archaeopteris* and a possible relationship between *Auroraspora asperella* and tree lycopods.

Although deltaic marshes and backswamp environments on the "upland" floodplain were both colonized by *Rhacophyton*, their near-swamp communities were distinct. They allow us to characterize separated upstream and downstream vegetation environments. Miospores produced by upstream vegetation environments are abundant in the near-shore marine sediments. They suggest strong flooding in the fluvial system.

Near-shore marine sediments contain miospore assemblages that are more uniform and more diverse than each single continental deposition niche. Barrier complexes can, however, attenuate the mixing of miospores coming from different source areas through different fluvial deliveries.

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## References

- Ahmed, S., 1980. Some forms of the genus *Auroraspora* from the Upper Devonian of New York State and Pennsylvania, U.S.A. *J. Univ. Kuwait (Sciences)*, 7: 227–242.

- Allen, K.C., 1980. A review of *in situ* Late Silurian and Devonian spores. *Rev. Palaeobot. Palynol.*, 29: 253-270.
- Andrews, H.N. and Phillips, T.L., 1968. *Rhacophyton* from the Upper Devonian of West Virginia. *J. Linn. Soc. Bot.*, 61, 384: 37-64.
- Bambach, R.K., Scotese, C.R. and Ziegler, A.M., 1980. Before Pangea: the geographies of the Paleozoic world. *Am. Sci.*, 68: 26-38.
- Becker, G., Bless, M.J.M., Streeel, M. and Thorez, J., 1974. Palynology and ostracode distribution in the Upper Devonian and basal Dinantian of Belgium and their dependence on sedimentary facies. *Meded. Rijks Geol. Dienst, Nieuw series*, 25: 9-99 + 2 enclosures.
- Bouckaert, J., Streeel, M. and Thorez, J., 1968. Schéma biostratigraphique et coupes de références du Famennien belge. Note préliminaire. *Ann. Soc. Géol. Belg.*, 91: 317-336.
- Bouckaert, J., Streeel, M., Thorez, J. and Mound, M.C., 1969. Biostratigraphic chart of the Famennian stage (Upper Devonian) in the type localities of Belgium: a preliminary report. *J. Paleontol.*, 43: 727-734.
- Byvsheva, T.V., 1985. Spory iz otlozheny turneiskogo i viseiskogo yarussov Russkoi plity. V kn.: Atlas spor i pyltys neftegazonosnyh tolschh fanerozoyna Russkoi i Turanskoi plit. Tr. VNIGNI, M.: Nedra, 80-158, 253.
- Chaloner, W.G. and Muir, M., 1968. Spores and floras. In: D. Murchison and T. Stanley Westoll (Editors), *Coal and Coal-bearing Strata*. Oliver and Boyd, Edinburgh, pp.127-146.
- Clendenning, J.A., Eames, I.E. and Wood, G.D., 1980. *Retusotrilletes phillipsii* n. sp., a potential Upper Devonian guide palynomorph. *Palynology*, 4: 15-22.
- Gensel, P.G., 1980. Devonian *in situ* spores: a survey and discussion. *Rev. Palaeobot. Palynol.*, 30: 101-132.
- Higgs, K., 1975. Upper Devonian and Lower Carboniferous miospore assemblages from Hook Head Co. Wexford, Ireland. *Micropaleontology*, 21: 393-419.
- Higgs, H., Clayton, G. and Keegan, J.B., 1988. Stratigraphy and systematic palynology of the Tournaisian rocks of Ireland. *Spec. Pap.*, 7, *Geol. Surv. Ireland*: 1-93.
- Hoffmeister, W.S., Staplin, F.L. and Malloy, R.E., 1955. Mississippian plant spores from the Hardinsburg Formation of Illinois and Kentucky. *J. Paleontol.*, 29: 372-399.
- Hughes, N.F. and Playford, G., 1961. Palynological reconnaissance of the Lower Carboniferous of Spitsbergen. *Micropaleontology*, 7: 27-44.
- Ishchenko, T.A. and Sorokina, N.L., 1968. Fructification of the Late Devonian fern: *Rhacophyton incertum*. *Paleontol. Zh.*, 1: 110-114.
- Kosanke, R.M., 1950. Pennsylvanian spores of Illinois and their use in correlation. *Bull. Ill. Geol. Surv.*, 74: 1-128.
- Lele, K.M. and Streeel, M., 1969. Middle Devonian (Givetian) plant microfossils from Goé (Belgium). *Ann. Soc. Géol. Belg.*, 92: 89-121.
- McGregor, D.C., 1979. Devonian Miospores of North America. *Palynology*, 3: 31-52.
- Meckel, L.D., 1970. Paleozoic alluvial deposition in the central Appalachians: a summary. In: G.W. Fisher, F.J. Pettijohn, J.C. Reed and K.N. Weaver (Editors), *Studies of Appalachian geology: central and southern*. Interscience, J. Wiley, New York, pp.49-67.
- Naumova, S.N., 1953. Spore-pollen assemblages of the Upper Devonian of the Russian Platform and their stratigraphic significance. *Trans. Inst. Geol. Sci., Acad. Sci., U.S.S.R.*, 143 (Geol. Ser., 60), 204 pp. (in Russian).
- Oliver, J., 1980. Exploring the basement of the North American continent. *Am. Sci.*, 68: 676-683.
- Paproth, E., Dreesen, R. and Thorez, J., 1986. Famennian paleogeography and event stratigraphy of North-western Europe. *Ann. Soc. Géol. Belg.*, 109: 175-186.
- Paris, F., Richardson, J.B., Riegel, W., Streeel, M. and Vanguetstaine, M., 1985. Devonian (Emsian-Famennian) Palynomorphs. In: B. Thusu and B. Owens (Editors), *Palynostratigraphy of North-East Libya*. *J. Micropaleontology*, 4: 49-82.
- Playford, G., 1962. Lower Carboniferous microfloras of Spitsbergen. Parts 1 and 2. *Palaeontology*, 5: 550-618, 619-678.
- Playford, G., 1976. Plant microfossils from the Upper Devonian and Lower Carboniferous of the Canning Basin, Western Australia. *Paleontographica B*, 158: 1-71.
- Richardson, J.B., 1965. Middle Old Red Sandstone spore assemblages from the Orcadian basin, northeast Scotland. *Palaeontology*, 7: 559-605.
- Richelot, C. and Streeel, M., 1985. Transport et sédimentation du pollen par les courants aériens, fluviaux et marins à Calvi (Corse). *Pollen Spores*, XXVII: 349-364.
- Scheckler, S.E., 1986a. Geology, floristics and paleoecology of Late Devonian coal swamps from Appalachian Laurentia (U.S.A.). In: M.J.M. Bless and M. Streeel (Editors), *Late Devonian events around the Old Red Continent*. *Ann. Soc. Géol. Belg.*, 109: 209-222.
- Scheckler, S.E., 1986b. Old Red Continent facies in the Late Devonian and Early Carboniferous of Appalachian North America. In: M.J.M. Bless and M. Streeel (Editors), *Late Devonian events around the Old Red Continent*. *Ann. Soc. Géol. Belg.*, 109: 223-236.
- Streeel, M., 1977. Corrélations palynologiques dans la Tournaisien du Synclinorium de Namur. *Bull. Soc. Belge Géol.*, 82 (1973): 397-415.
- Streeel, M., 1986. Miospores contribution to the Upper Famennian-Strunian event stratigraphy. In: M.J.M. Bless and M. Streeel (Editors), *Late Devonian events around the Old Red Continent*. *Ann. Soc. Géol. Belg.*, 109: 75-92.
- Streeel, M. and Traverse, A., 1978. Spores from the Devonian/Mississippian transition near the Horseshoe curve section, Altoona, Pennsylvania, U.S.A. *Rev. Palaeobot. Palynol.*, 26: 21-39.
- Streeel, M., Higgs, K., Loboziak, S., Riegel, W. and Steemans, P., 1987. Spore stratigraphy and correlation with faunas and floras in the type marine Devonian of the Ardenne-Rhenish regions. *Rev. Palaeobot. Palynol.*, 50: 211-229.
- Sullivan, H.J., 1968. A Tournaisian spore flora from the Cementstone Group of Ayrshire, Scotland. *Palaeontology*, 11: 116-131.
- Van der Zwan, C.J., 1980. Palynology, phytogeography and climate of the Lower Carboniferous. *Berl. Geowiss. Abh.*, (A) 19: 255-257.
- Van Veen, P.M., 1981. Aspects of Late Devonian and Early Carboniferous palynology of southern Ireland. IV. Morphological variation within *Diducites* a new form-genus to accommodate camerate spores with two-layered outer wall. *Rev. Palaeobot. Palynol.*, 31: 261-287.