Journal of Micropalaeontology, **18:** 17–25. 0262-821X/99 $15.00 © 1999 British Micropalaeontological Society.

Revision of the late Famennian miospore zonation scheme in eastern Belgium

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ABSTRACT – New palynological data have been obtained from the Late Famennian Evieux and Comblain au Pont Formations of the Chanxhe section located in the Ourthe Valley in the eastern part of the Dinant Basin. In the light of this new data the stratigraphic ranges of several zonally important miospore taxa are now significantly different to those previously recorded. This has necessitated a re-evaluation and revision of the late Famennian miospore zonation scheme for this region. *Apiculiretusispora verrucosa* and *Vallatisporites hystricosus* are now found to occur below the inception of *Retispora lepidophyta*. Consequently, a new biozone, the *Apiculiretusispora verrucosa–Vallatisporites hystricosus* VH Biozone is described for the late Fa2c interval. The problematical relationship between the *Retispora lepidophyta– Apiculiretusispora verrucosa* LV Biozone and the *Retispora lepidophyta–Knoxisporites literatus* LL Biozone is resolved, and part of the LL Biozone is now considered equivalent to the LV Biozone, which it consequently replaces. The *Retispora lepidophyta–Indotriradites explanatus* LE Biozone is recorded from the upper part of the Comblain au Pont Formation. A continuous succession of miospore zones is now established for the late Famennian Fa2c/Fa2d interval which permits more accurate correlations with other regions in Europe and North America. Correlation with the standard conodont biostratigraphy shows that the base of LL Miospore Biozone is correlated with the middle or late *expansa* Conodont Biozone and the base of LE Miospore Biozone with the early to middle *praesulcata* Conodont Biozone. *J. Micropalaeontol.* **18**(1): 17–25, June 1999.

INTRODUCTION

A classic area for the Upper Devonian (Famennian) succession is located in the Dinant Basin (Synclinorium) in the eastern part of Belgium, and in particular the Ourthe Valley situated a few kilometres south of Liège (Fig. 1). Here the Famennian deposits are assigned to the Psammites du Condroz Group, a thick and predominately siliciclastic sequence characterized by a wide spectrum of depositional environments related to the progradation of a major deltaic system on the south side of the London–Brabant Massif (Thorez & Dressen, 1986; Thorez *et al.*, 1988). The stratigraphic interval covered in this study comprises the two youngest formations of the 'Psammites du Condroz'; these are the Evieux and the Comblain au Pont Formations. The Evieux Formation is subdivided locally into three members but is an essentially distal alluvial sequence with red beds, lagoonal, palaeosols, evaporitic and tidal intercalations. The overlying Comblain au Pont Formation represents a marine transgressive event and includes mainly open marine and subtidal facies with lagoonal to sub-lagoonal intercalations. These two formations have been traditionally assigned to the Famennian Fa2c and Fa2d stratigraphic intervals, respectively.

The Chanxhe section is located on the northern flank of the Dinant Synclinorium and has been referred to in previous publications as the Chanxhe 1 section. This section is well exposed along a road on the east bank of the Ourthe Valley just north of Chanxhe village and displays an almost continuous section from the upper part of the Evieux Formation to the upper part of the overlying Comblain au Pont Formation. A fault interrupts the continuity between the Comblain au Pont Formation and the overlying Hastière Formation (Calcaire de Hastière), however, a transition between these two formations is seen in the Chanxhe 2 section, just to the south of Chanxhe village.

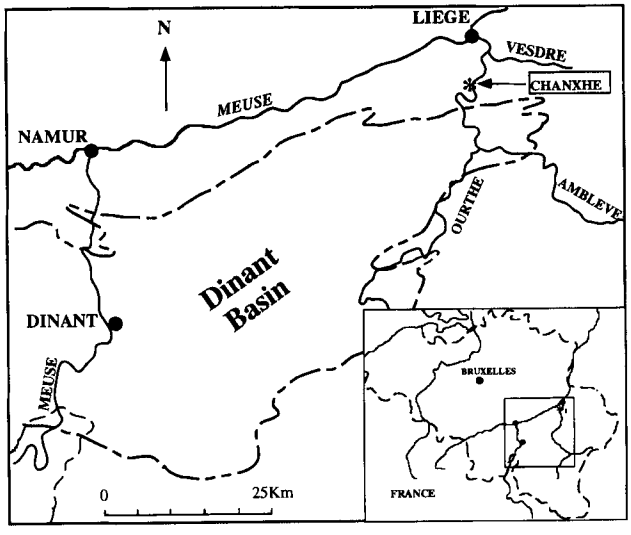


Fig. 1. Location of the section studied.

The micropalaeontology of the Chanxhe sequence has been studied in great detail by the late Prof. R. Conil and by Dr R. Dreesen. Two important biostratigraphic limits have been recognized in the lower part of the Comblain au Pont Formation. Firstly, the base of the *Quasiendothyra kobeitusana* Foraminifer Zone occurs in Bed 115 (Conil *et al.*, 1964) at the base of the second stromatoporoid biostrome (Conil *et al.*, 1964). Secondly, the Late *expansa* Conodont Zone has been identified in the three carbonate beds (Beds 97, 101, and 111) below the first stromatoporoid biostrome (Dreesen *et al.*, 1993).

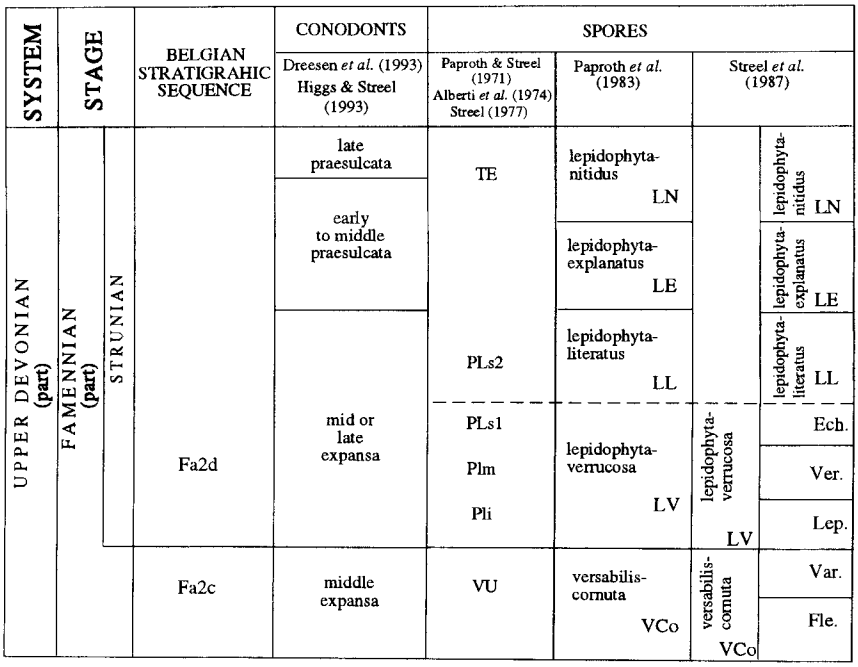


Fig. 2. Comparison of conodont and miospore zones.

HISTORY OF THE MIOSPORE BIOZONATION

Famennian miospore assemblages have been extensively studied in the eastern part of the Dinant Synclinorium (Streel, 1966; Bouckaert *et al.*, 1968; Bouckaert *et al.*, 1969; Paproth & Streel, 1971; Becker *et al.*, 1974). The latter two publications described the *versabilis-uncatus* (VU) Zone and the *pusillites–lepidophytus* (PL) Florizones from the Famennian Fa2c and Fa2d intervals, respectively. The latter florizone was further subdivided into the Pli, PLm, PLs1 and Pls2 Subzones based on the first occurrence of selected species. Parallel to this succession of interval zones, Streel (1966, 1969) recognized a series of biometric zones (C–F) based on progressive changes in the mean size of the *lepidophytus* populations.

In 1983, Paproth *et al.* proposed nomenclatural changes to this zonation scheme. The VU Florizone was replaced with the *versabilis–cornuta* (VCo) Opel Zone, its base being defined on the first appearance of *Grandispora cornuta*, *Rugospora flexuosa* and *Retusotriletes phillipsii*. The Pli, Plm and Pls1 Subzones were replaced by the *lepidophytus–verrucosa* (LV) Subzone in the Dinant Synclinorium. However, the LV Subzone was not recognized in the Namur Synclinorium to the north, here the *lepidophya* Pls2 Subzone was assigned to the *lepidophytus–literatus* (LL) Subzone. This latter subzone was first described by Clayton *et al.*, (1978) from the late Devonian in southern Ireland and southwest Britain and is recognized by the first appearance of *Knoxisporites literatus*. In southern Ireland the LL Zone is succeeded by the *lepidophyta–explanatus* (LE) and *lepidophyta–nitidus* (LN) Zones (these subzones being upgraded to zones by Higgs *et al.*, 1988).

Streel *et al.* (1987) further refined the Belgian zonation scheme when they recognised three successive interval zones (*Lep.*, *Verr.* and *Ech*) within the LV Opel Zone based on the successive first appearances of *Retispora lepidophyta*, *Apiculiretusispora verrucosa* and *Grandispora echinata*. The precise relationship between the Belgian LV and Irish LL Biozones remained uncertain as these two zones had not been recorded together in any one section. However, Streel *et al.* (1987, p. 223) considered the LL Biozone to be either younger than the LV Biozone or partly equivalent to the uppermost part (Ech) of the LV Biozone, see Fig. 2.

In 1993, Streel (in Dreesen *et al.*, 1993) demonstrated for the first time the presence of the *lepidophyta–explanatus* (LE) Biozone in the Chanxhe 2 section of the Dinant Synclinorium.

The present study describes the succession of miospore zones across the late Famennian Fa2c/Fa2d interval and furthermore clarifies the relationship between these zones and proposes a revised miospore zonation scheme.

STRATIGRAPHIC PALYNOLOGY

One hundred and thirty-five new samples were collected from the Chanxhe section and the stratigraphic positions of the productive samples in the section are shown in Fig. 3. All the samples were treated in the laboratory using the method proposed by Streel (1965). Each organic residue was seived at 12 μm and oxidized with Schultze Solution for two hours. All figured specimens are housed in Department of Paleopalynology at the University of Liège. Most of the samples contain abundant miospores and acritarchs and in the majority of cases these are well preserved. Only a few samples proved to be barren.

The principal objective of this study has been to identify the miospore taxa occurring in the samples and to determine their stratigraphic distribution throughout the section. A selection of the stratigraphically more important taxa are illustrated in Plates 1 and 2 and their stratigraphic ranges in the section are shown in Fig. 4. The detailed level of sampling has allowed more

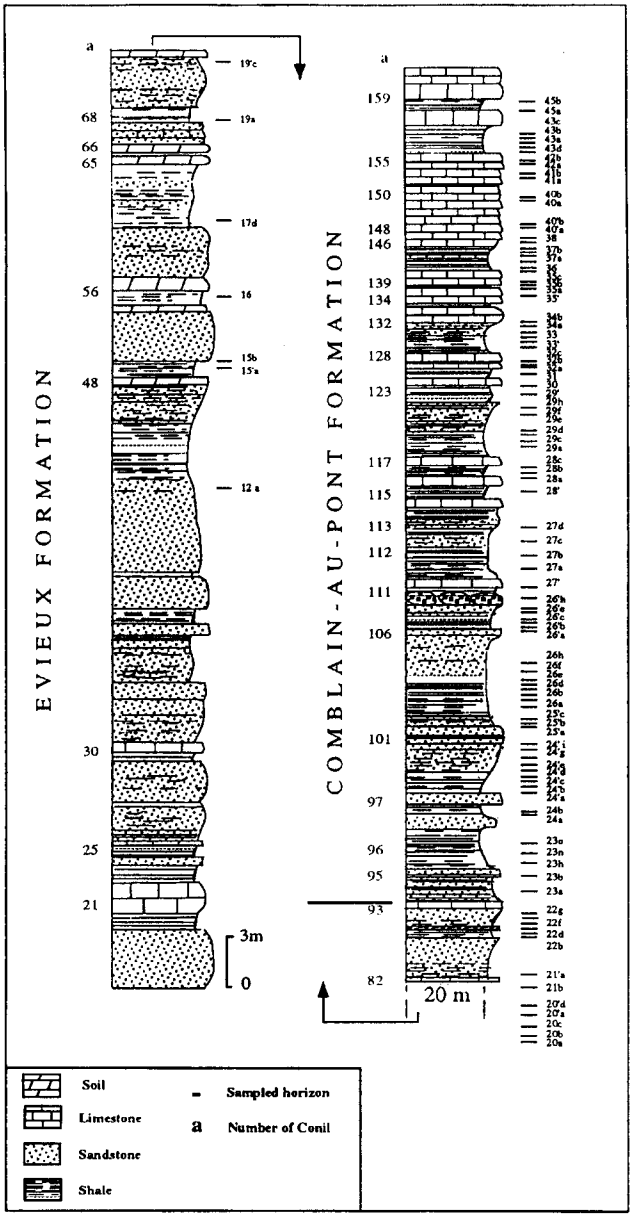


Fig. 3. Stratigraphic position of samples in Chanxhe.

precise determination of the stratigraphic ranges of the miospore taxa in the Chanxhe section. Consequently, the ranges of several of the more zonally important taxa are now different to those previously recorded and this has necessitated a re-evaluation and revision of the miospore zonation scheme.

Revised miospore zonation

Four successive miospore biozones are now recognized in the late Famennian of the Chanxhe section. The miospore zonation scheme is shown in Fig. 5; also shown is the correlation with the conodont, foraminifera and acritarch zones. The miospore zones are described in ascending stratigraphic order.

Diducites versabilis–Grandispora cornuta (VCo) *Biozone.* The VCo Biozone is defined by the first occurrence of *Grandispora cornuta, Retusotriletes phillipsii* and *Rugospora radiata.* It is also characterized by the presence of *Diducites versablis* and *Retispora macroreticulata.*

Assemblages of the VCo Biozone have been obtained from the upper part of the Evieux Formation. Eleven productive samples were obtained between Bed 12'a and Bed 20'a. In this interval the assemblages are rather sparse in numbers but diverse in composition.

The following miospore taxa were recorded in the VCo Biozonal assemblages:

Aneurospora greggsii, Auroraspora asperella, Auroraspora hyalina, Auroraspora solisorta, Auroraspora varia, Diducites plicabilis, Diducites poljessicus, Diducites versabilis, Grandispora cornuta, Grandispora famenensis var. *minuta, Grandispora famenensis* var. *famenensis, Grandispora gracilis, Grandispora microseta, Plicatispora quasilabrata, Plicatispora scolecophora, Punctatisporites irrasus, Punctatisporites minutus, Raistrickia variabilis, Retispora macroreticulata, Retusotriletes incohatus, Retusotriletes phillipsii, Retusotriletes planus* and *Rugospora radiata.*

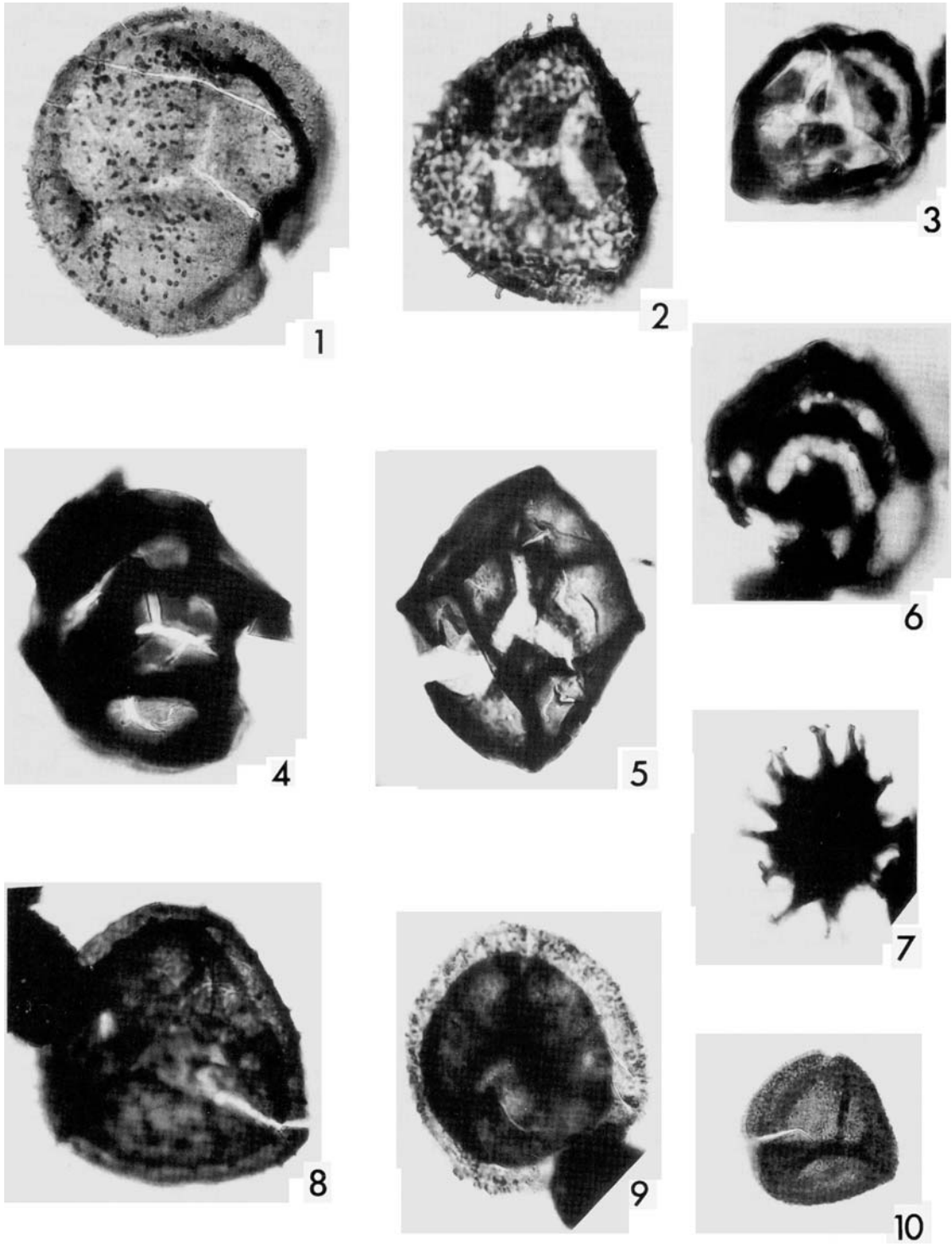
Apiculiretusispora verrucosa–Vallatisporites hystricosus (VH) *Biozone.* This new interval range zone is defined by the first appearance of *Apiculiretusispora verrucosa* and *Vallatisporites hystricosus* . These taxa first appear in Bed 20'd near the top of the Evieux Formation and these first occurrences are significantly lower in the section than had previously been recorded. Earlier records (Streel, 1986; Streel & Scheckler, 1990) have shown *Vallatisporites hystricosus* (as *V. pusillites*) first appearing with *Retispora lepidophyta* at the base of the Comblain au Pont Formation, however the new results show *Vallatisporites hystricosus* now occurring several metres below the first inception of *Retispora lepidophyta* (see Fig. 4).

Other taxa appearing in the VH Biozone include *Endoculeospora gradzinskii, Spelaeotriletes crenulatus* and *Grandispora echinata.* The first specimens of *G. echinata* were found in bed 20'a at Chanxhe which is stratigraphically lower than previous reports, which showed it appearing within the range of *R. lepidophyta.* (The concept of this species was then different.)

Correlation of the VH Biozone. The occurrence of *Apiculiretusispora verrucosa* and *Vallatisporites hystricosus* in the uppermost part of the Fa2c interval in Belgium is highly significant as it allows accurate correlation of the VH Biozone with late Famennian sequences in North America.

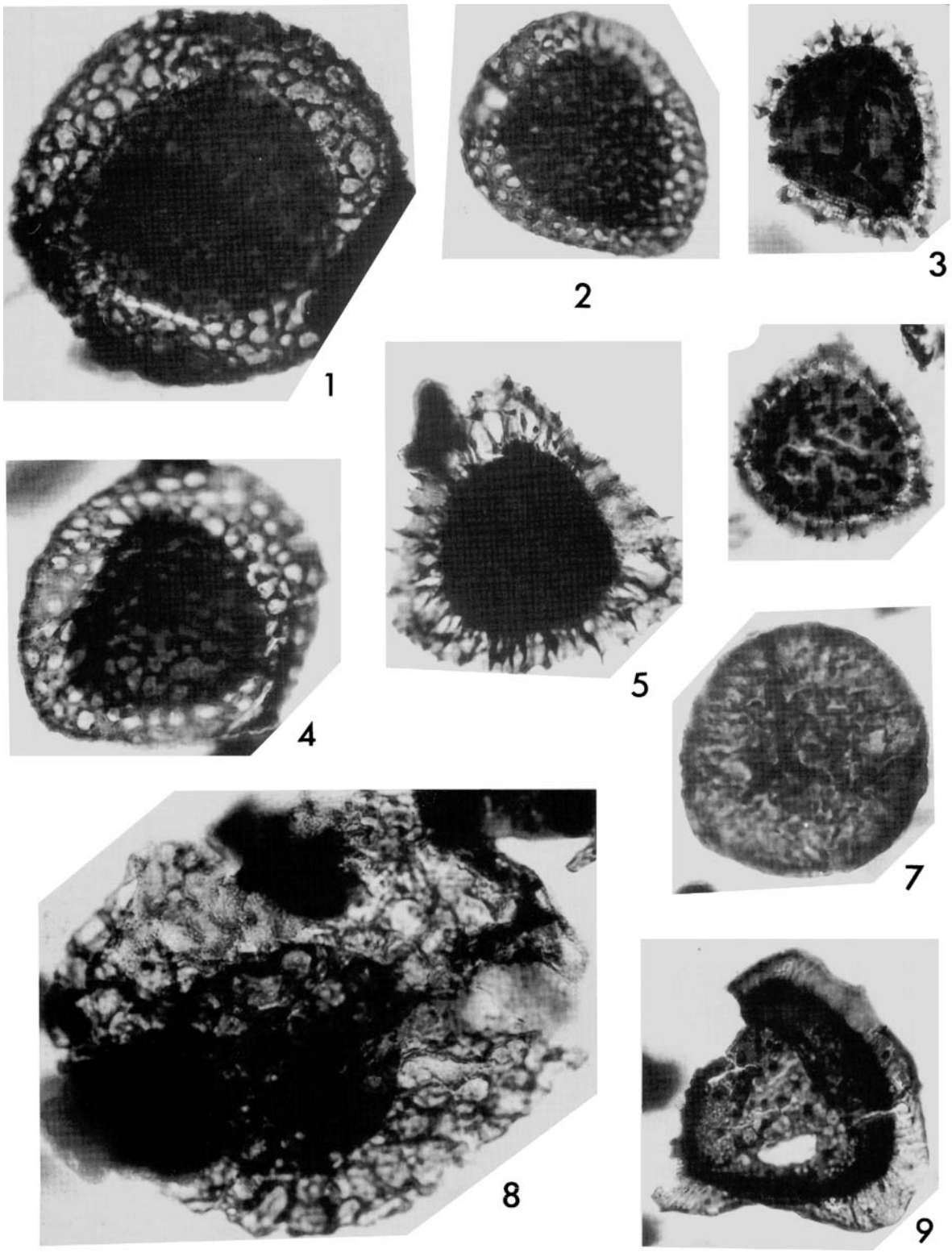
In the Horseshoe Curve section of Pennsylvania Streel & Traverse (1978) have recorded *Vallatisporites hystricosus* (as *Cirratriradites hystricosus*) from the Lower Sandstone Member of the Pocono Formation, a level that is stratigraphically below the first occurrence of *R. lepidophyta.* Their lowest samples (1 and 2) can be assigned to the VH Biozone.

In western New York State and Pennsylvania Richardson & Ahmed (1988) recorded *Vallatisporites hystricosus* (as *V. pusillites*) and *Apiculiretusispora verrucosa* (as *A. fructicosa*) from the lower part of the Cattaraugas Formation, notably from levels below the first occurrence of *R. lepidophyta.* These authors erected two regional interval subzones the *Vallatisporites pusillites* Subzone and the *Apiculiretusispora fructicosa* Subzone



Explanation of Plate 1

Sample numbers are followed by Department of Paleopalynology slide numbers and England Finder Co-ordinates. Magnification. ×750.
fig. 1. *Apiculiretusispora verrucosa* (Caro-Moniez) Streel. Sample36c, 34032, M60/3. **fig. 2.** *Umbonatisporites* sp. *sensu* Turnau. Sample 38b, 34088, G46/2. **fig. 3.** *Tumulispora rarituberculatus* (Luber) Playford var. *malevkensis* Kedo *sensu* Higgs 1996 Sample32c, 33956, U41/3. **figs. 4–5.** *Knoxisporites literatus* (Waltz) Playford. fig. 4, Sample 24a, 34128, L54/3; fig. 5, Sample 37b, 34090, O37/2. **fig. 6.** *Knoxisporites concentricus* (Byvscheva) Playford & McGregor. Sample 26e, 34038, M40/1. **fig. 7.** *Raistrckia minor* (Kedo) Neves & Dolby. Sample 37b, 34090, P38/1. **fig. 8.** *Grandispora echinata* Hacquebard. Sample27a, 34137, M41/1. **fig. 9.** *Endoculeospora gradzinskii* Turnau. Sample 32c, 33956, T47/1 **fig. 10.** *Spelaeotriletes crenulatus* (Playford) Higgs, Clayton & Keegan. Sample 36c, 34032, Z48/3.



Explanation of Plate 2

Sample numbers are followed by Department of Paleopalynology slide numbers and England Finder Co-ordinates. Magnification. ×750.
figs 1–2, 4. *Retispora lepidophyta* (Kedo) Playford. fig. 1, Sample 28c, 34136, V42/1; fig. 2, Sample 27b, 34088, K42/2; fig. 4, Sample 36c, 34032, L50/3. **figs. 3, 5–6.** *Vallatisporites hystricosus* (Winslow) Byvscheva. fig. 3, Sample37c, 33947, K45/2; fig. 5, Sample 37c, 33947, W41/4; fig. 6, 37a, 34046, R41/3. **fig. 7.** *Rugospora radiata* (Juschko) Byvscheva Sample 36c, 34032, O52/4. **fig. 8.** *Retispora macroreticulata* (Kedo) Byvscheva Sample 20b, 34162, U52/3. **fig. 9.** *Indotriradites explanatus* (Luber) Playford Sample 43a, 33927, J46/2.

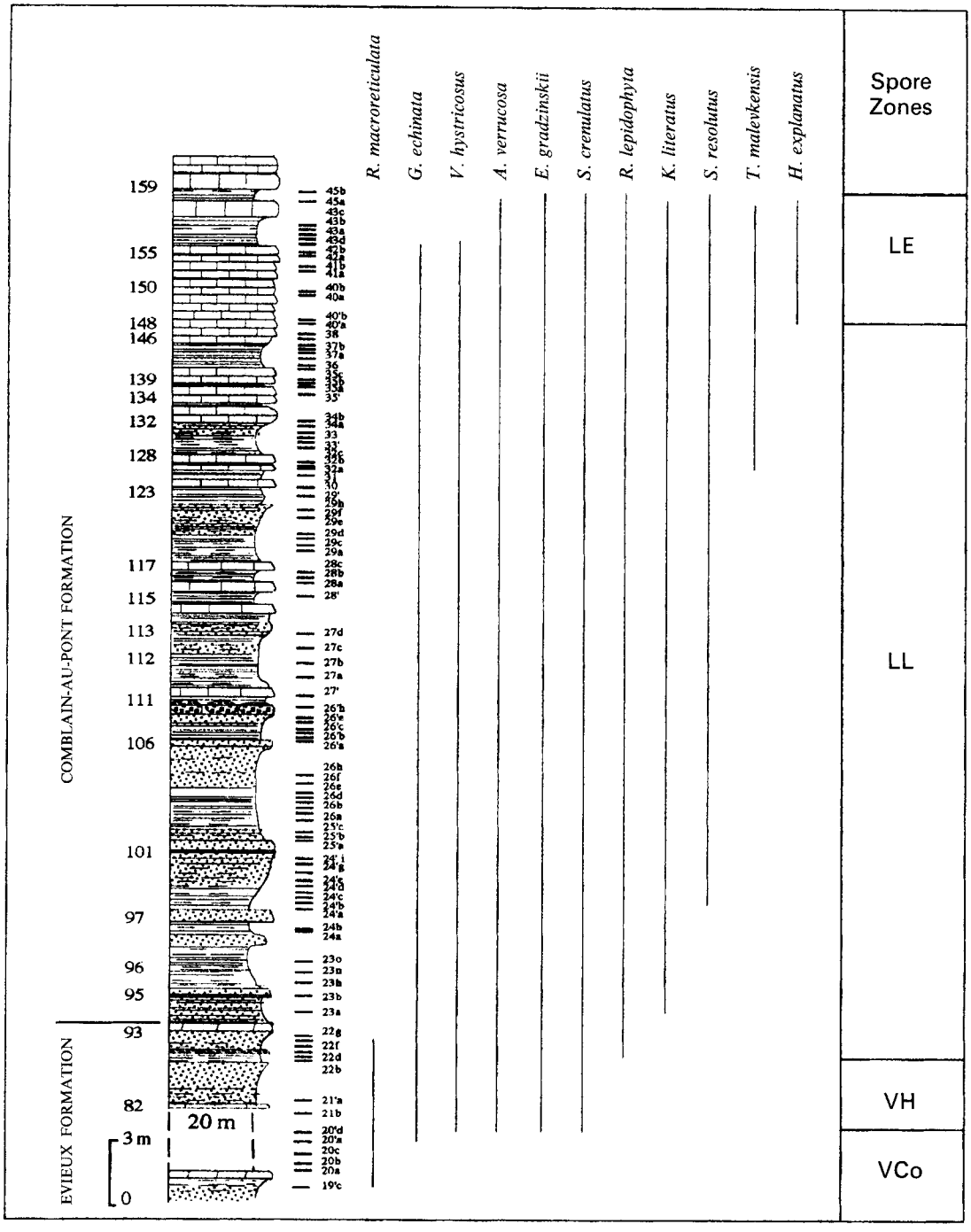


Fig. 4. Selection of the most stratigraphically useful micropores in Chanxhe section referred to in the present paper.

based on the inceptions of these species. These subzones can be correlated with the VH Biozone of Belgium.

McGregor & McCutcheon (1988) described miospore assemblages from the Carrow Formation of New Brunswick, Canada which contain *Vallatisporites hystricosus* (as *V. pusillites)* and one specimen of *Retispora lepidophyta*? – a form which appears to be morphologically closer to *R. macroreticulata* than *R. lepidophyta*. McGregor & McCutcheon (1988) discussed whether the assemblage should be assigned to the *Rugospora flexuosa–Grandispora cornuta* Zone or the overlying *V. pusillites–R. lepidophyta* Zone (zonation scheme of Richardson & McGregor, 1986) and concluded that an assignment to the latter

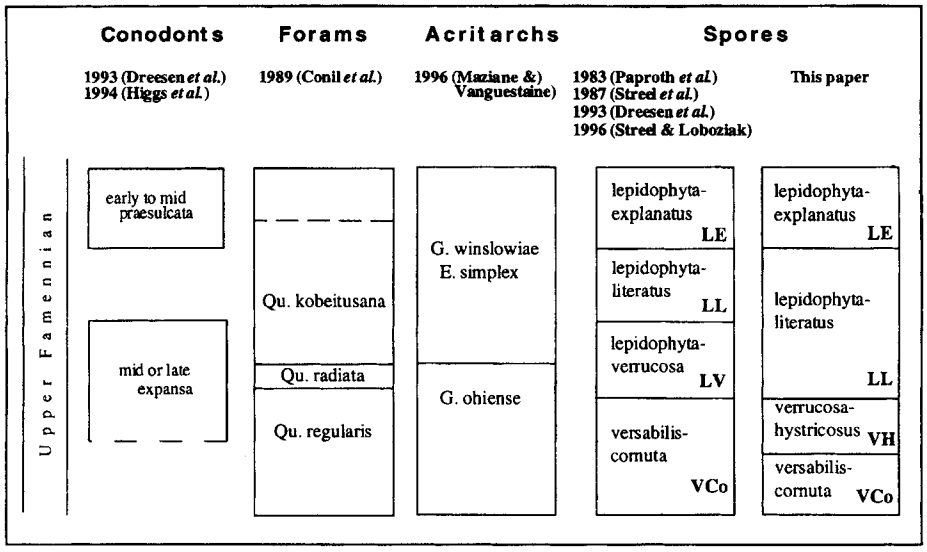


Fig. 5. Correlation between Upper Famennian conodont, foraminifera, acritarch and spore zonations.

zone was more likely. The present authors suggest the Carrow Formation assemblage should probably now be correlated with the VH Biozone of late Famennian Fa2c age.

Other records of *V. hystricosus* occurring below the inception of *Retispora lepidophyta* have been reported from eastern USA (Streel & Scheckler, 1990), in northern Brazil (Loboziak *et al.*, 1997) and in North Africa (Streel, 1986; Streel *et al.*, 1988).

The range of *Endoculeospora gradzinskii* Turnau has been extended down into the VH Biozone in Belgium. Previous records in Europe show *E. gradizinskii* appearing in the LL Biozone in Germany (Higgs & Streel, 1984), in the LE Biozone in southern Ireland (Higgs *et al.*, 1988), and in the LV Biozone in Poland (Avkhimovitch *et al.*, 1993). However, in North America this species has an earlier inception, being recorded in the *Rugospora flexuosa–Grandispora cornuta* Assemblage Zone (Richardson & Ahmed, 1988).

Retispora lepidophyta–Knoxisporites literatus (LL) Biozone. This biozone is defined by the appearance of the two zonal index species. The extremely distinctive and important taxon *Retispora lepidophyta* first appears in Bed 22 (*c.* 2.5 m lower in the section than was previously reported), just below the top of the Evieux Formation. Consequently, the base of the Fa2d stratigraphic interval as biostratigraphically defined by the appearence *Retispora lepidophyta,* no longer coincides with the lithostratigraphic Evieux/Comblain au Pont Formational boundary. The first occurrence of *Knoxisporites literatus* is in Bed 23 just above the base of the Comblain au Pont Formation and is then present in many samples above this level.

The assemblages recorded from the LL Biozone are rich and diverse in composition. However it should be noted that *Retispora lepidophyta* is not abundant at the base of the zone (<4% of the assemblage) but increases significantly to become abundant in the upper part of the zone (53% in Bed 38). The LL Biozonal assemblages contain the majority of the miospore taxa found in the VCo and VH biozones together with some additional species, such as *Tumulispora rarituberculatus* var. *malevkensis, Tumulispora varia, Knoxisporites concentricus, Raistrickia minor, Endoculeospora setacea, Spelaeotriletes resolutus, Diducites mucrornatus, Cristatisporites matthewsii, Convolutispora major, Gorgonispora crassa* and *Umbonatisporites* sp.

Correlation of the LL Biozone. The first appearence of *Knoxisporites literatus* immediately above the inception of *Retispora lepidophyta* allows the recognition of the LL Biozone in the Chanxhe section (and indeed in the Dinant Basin) for the first time. The relationship of the LL Biozone with the LV Biozone has been a long standing problem in Late Devonian palynostratigraphy. However, the equivalence of the LL Biozone with the LV Biozone can now be demonstrated. Therefore, in this paper, we propose to replace the LV Biozone with part of the LL Biozone in the miospore zonation scheme.

Retispora lepidophyta - Indotriradites explanatus (LE) Biozone. The LE Biozone is defined by the first appearance of *Indotriradites explanatus* (see Higgs *et al.*, 1988) This species first appears in the upper part of the Comblain au Pont Formation (Bed 40') in Chanxhe 1. The LE Biozonal assemblages are composed of abundant and well-preserved spores, and the composition of these assemblages is very similar to those obtained from LL Biozone. *Retispora lepidophyta* is particularly abundant in this biozone, e.g. in sample 43 it comprises *c.* 75% of the spore population. The LL/LE Miospore Biozone Boundary is placed in the upper part of the Comblain au Pont Formation *c.* 10 m below the fault which interrupts the section.

Streel in Dreesen *et al.* (1993) has also reported the presence of *Indotriradites explanatus* in Beds 42 and 45 from the uppermost

part of Comblain au Pont Formation in the Chanxhe 2 Section. Here the LE Biozone correlates with early to middle *praesulcata* conodont Zone faunas (Dreesen *et al.*, 1993).

The change to a continuous limestone succession in the uppermost part of the Comblain au Pont Formation and in the overlying Hastière Formation precludes the possibility of recognizing the youngest Famennian LN Miospore Biozone in the Chanxhe Sections. However, microfaunal evidence (Paproth *et al.*, 1983, Conil *et al.*, 1986) indicates that the Devonian–Carboniferous boundary should probably be placed in the basal part of the Hastière Formation.

ACKNOWLEDGEMENTS

We thank Ms M. Giraldo for processing the samples and Mr W. Strouvens for photographic work.

APPENDIX: SPECIES LIST

Aneurospora greggsii (McGregor) Streel in Becker *et al.*, 1974
Apiculiretusispora verrucosa (Caro- Moniez) Streel in Becker *et al.*, 1974
Auroraspora asperella (Kedo) Van der Zwan, 1980
Auroraspora hyalina (Naumova) Streel in Becker *et al.*, 1974
Auroraspora solisorta Hoffmeister, Staplin & Malloy, 1955
Auroraspora varia (Naumova) Ahmed, 1980
Convolutispora major (Kedo) Turnau, 1978
Corbulispora cancellata (Waltz) Bharadwaj & Venkatachala, 1961
Cristatisporites matthewsii Higgs, Clayton & Keegan, 1998
Diducites mucrornatus (Kedo) Van Veen, 1980
Diducites plicabilis Van der Zwan, 1980
Diducites poljessicus (Kedo) Van der Zwan, 1980
Diducites versabilis (Kedo) Van der Zwan, 1980
Endoculeospora gradzinskii Turnau, 1975
Endoculeospora setacea (Kedo) Avchimovitch & Higgs in Avchimovitch *et al.*, 1988
Grandispora echinata Hacquebard, 1957
Grandispora cornuta Higgs, 1975
Grandispora famenensis Streel in Becker *et al.*, 1974 var. *minuta* Loboziak *et al.*, 1996
Grandispora famenensis (Naumova) Streel in Becker *et al.*, 1974 var. *famenensis* Loboziak *et al.*, 1996
Grandispora gracilis (Kedo) Streel in Becker *et al.*, 1974
Grandispora microseta (Kedo) Streel in Becker *et al.*, 1974
Gorgonispora crassa (Winslow) Higgs *et al.*, 1988
Indotriradites explanatus (Luber) Playford, 1990
Knoxisporites concentricus (Byvscheva) Playford & McGregor, 1993
Knoxisporites literatus (Waltz) Playford, 1963
Plicatispora quasilabrata (Higgs) Higgs *et al.*, 1988
Plicatispora scolecophora (Neves & Ioannides) Higgs *et al.*, 1988
Punctatisporites irrasus Hacquebard, 1957
Punctatisporites minutus Kosanke, 1950
Raistrickia corynoges Sullivian, 1968
Raistrckia minor (Kedo) Neves & Dolby, 1967
Raistrickia variabilis Dolby, 1970
Retispora lepidophyta (Kedo) Playford, 1976
Retispora macroreticulata (Kedo) Byvscheva, 1985
Retusotriletes incohatus Sullivan, 1964
Retusotriletes phillipsii Clendening *et al.*, 1980
Retusotriletes planus Dolby & Neves, 1969
Retusotriletes triangulatus (Streel) Streel, 1967
Rugospora radiata (Juschko) Byvscheva, 1985
Spelaeotriletes crenulatus (Playford) Higgs *et al.*, 1988
Spelaeotriletes resolutus Higgs, 1975
Tumulispora rarituberculatus (Luber) Playford var. *malevkensis* Kedo *sensu* Higgs, 1996
Tumilispora varia (Kedo) Byvscheva, 1985
Umbonatisporites sp. *sensu* Turnau, 1978.
Vallatisporites hystricosus (Winslow) Byvsheva, 1985

Manuscript received June 1997
Manuscript accepted September 1998

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