High resolution miospore stratigraphy of the Upper Famennian of eastern Belgium, and correlation with the conodont zonation.

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ABSTRACT. The Ourthe valley in eastern Belgium provides the most complete exposures of the upper Famennian Condroz Group. A detailed miospore stratigraphy has been established for this succession. The lower three miospore biozones of the Upper Famennian (GF, VC and VH Oppel Zones) are re-defined and subdivided into five new interval zones. The GF Oppel Zone which spans the Middle and Upper Famennian boundary was previously subdivided into three interval zones is now reduced to two. The highest Retispora macroreticulata (Mac) Interval Zone is now removed (due to its very sporadic occurrence) which results in the Grandispora microseta (Mic) Interval Zone of the GF Oppel Zone now being the lowest miospore interval zone of the Upper Famennian. The overlying VC Oppel zone is subdivided into two new interval zones, the Rugospora radiata (Rad) and overlying Grandispora cornuta (Cor) interval zones. A detailed study based on new and published material of the two nominal zonal taxa of the VC Oppel Zone has clarified their morphology and resolved identification problems with other closely related Upper Devonian taxa. Furthermore, a biometric comparison of Grandispora cornuta with Grandispora tamarae has resulted in the specific diagnosis of G. cornuta being emended to increase its minimal spine length to 8 μm. The biostatigraphic implications for intercontinental correlations with the Upper Famennian of North America are discussed. The overlying VH Oppel Zone is subdivided into two new interval zones, the Apiculiretispora verrucosa (Var) Interval Zone and the overlying Vallatisporites hystricosus (Hyss) Interval Zone. All of the new miospore interval zones are closely correlated with the well established conodont zones occurring in five sections of the Ourthe Valley. The new integrated data sets provide a high resolution biostratigraphy for the Upper Famennian stratigraphic interval in eastern Belgium.

KEYWORDS: lithostratigraphy, biostratigraphy, guide fossils, Upper Devonian

1. Introduction.

In Belgium, Famennian deposits comprise a 600 m thick predominantly siliciclastic sedimentary sequence which has been subdivided into two biostratigraphic groups (Thorez et al., 2006). The lower Famennian is represented by the predominately pelitic Famennian Group and this is succeeded by the more arenaceous Upper Famennian Condroz Group.

The Condroz Group is best developed in the eastern part of the Dinant Synclinorium, where it shows the most complete suite of constituent formations (Fig. 1). In the classic Ourthe Valley section, Mourlon (1875 - 1886) made the first detailed biostratigraphical division of the Condroz sandstones and described a succession of units that comprised the Esneux, Souvenir-Pré, Montfort and Evieux ‘assises’, which later were formalised to formation status. More recently, new coeval formations have been introduced that include the Bevererie and Comb lain-la-Tour Formations (Bouckaert et al., 1968). The sediments of the Condroz Group originated during an important progradation of deltaic complexes into a shallow epicontinental sea. As a result, a whole spectrum of alluvial, estuarine, restricted marine (lagoonal) and shallow marine siliciclastic depositional settings were developed (Thorez et al., 2006, fig. 6). The mainly regressive Upper Famennian is interrupted by two short transgressive events. The first is represented by the Bon Mariage Shale which occurs at the boundary between the sandstone dominated Montfort Formation and the sandstone/siltstone dominated Evieux Formation in the Comb lain-la-Tour section. This thin (meter scale) black shale horizon has been correlated with the annulata event (Thorez et al., 2006). The second transgressive pulse, occurs within the Evieux Formation and is represented by a restricted marine or peritidal carbonates (the Fontin Event, Drecsen & Jux 1995). These deposits together with conspicuous ball-and-pillow levels and pedogenic red beds, serve as important biostratigraphic tools in the Condroz Group, where block faulting and regional irregularities of the sea floor were responsible for a strong lateral variability (Thorez et al., 2006, fig. 7).

Figure 1: Famennian lithostratigraphy and substage divisions of the Famennian after Thorez et al. 2006, fig. 4.
Bev: Bevererie Formation; CBT: Comblain-la-Tour Formation,
L: Lower; M: Middle; U: Upper; U**: Uppermost

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A detailed biostratigraphical framework for the Upper Famenian interval has been established based mainly on conodonts, foraminifera and spores. Initially, it provided biostratigraphical control of the former Famenian Fa2b, Fa2c and Fa2d lithostratigraphical subdivisions (Bouckaert et al., 1969). However, these divisions are now obsolete and have been replaced by a formal subdivision of the Famenian Stage into four substages: the Lower, Middle, Upper and Uppermost Famenian substages (Thorez et al., 2006).

2. Palynology

Streel et al. (1987) described a miospore biozonation scheme for the classic marine Devonian of the Ardèche - Rhenish regions. The biozonation scheme comprised a series of Oppel and Interval zones. An Oppel Zone is characterized by the association or aggregation of selected taxa of restricted and largely concurrent range chosen as indicative of approximate contemporaneity (After Hedberg 1976, p.58, judgement may vary however as to how many and which of the selected diagnostic taxa need to be present to identify the zone). Interval Zone, on the contrary, is an interval between two distinctive biostratigraphical horizons. Accurate correlation with the conodont biostratigraphy needs the definition of reliable interval zones. The Middle, Upper and Uppermost Famenian parts of the miospore zonation scheme is based predominately on well studied sequences of the Condroz Group in the area of eastern Belgium. Four successive miospore Oppel zones (GH, GF, VC0, LV) were established by Streel et al. (1987) for the Upper Famenian interval. Maziane et al. (1999) subsequently revised this zonation scheme by erecting a new Vallatisporites hystricus - Apiculireussispora verrucosa VH Zone (which was equivalent to the upper part of the original VC0 Oppel Zone), replacing the LV Zone by the Retispora lepidophyta - Knoxisporites literatus LL Zone and establishing the Retispora lepidophyta - Indotradidites explanatus (LE) Zone. Streel (2009) redefined the Middle and lowermost Upper Famenian GH (now DV) and GF Oppel Zones.

The principal aims of the present paper are to:

1. Redefine and subdivide the Upper Famenian GF, VC0 and VH Oppel Zones into five successive interval range zones.
2. Clarify the morphological characteristics of some key zonal spore taxa and to morphologically discriminate these taxa from other closely related Upper Devonian forms.
3. Accurately correlate the Upper Famenian spore zones with the established conodont biostratigraphy.

To achieve these objectives, a detailed palynological study has been carried out on some 200 palynological samples from five sections of the Condroz Group exposed in the Ourthe Valley. (Fig. 2). Most of the material studied is from the research slide collections of Kvists (1977) and Maziane (1993 and 1999) stored in the Palaeopalynology Unit, Department of Geology, University of Liege.

2.1. Miospore zonation scheme

Grandispora gracilis – Grandispora famenensis GF Oppel Zone.

This zone is considered to span the Middle and Upper Famenian boundary and was divided into three Interval Zones by Streel (2009), in ascending stratigraphic order. These were the pre-Grandispora microseta (Premic), the Grandispora microseta (Mic) and the Retispora macroreticulata (Mac) subzones. Due to the sporadic first occurrence of Retispora macroreticulata, the highest Mac Interval Zone is here considered obsolete. Consequently, the Grandispora gracilis - Grandispora famenensis GF Oppel zone is now subdivided in only two zones, the younger one being based solely on the first occurrence of Grandispora microseta. The upper Mic interval zone occurs in the lowermost part of the Upper Famenian.

Diducites versabilis – Grandispora cornuta VC0 Oppel Zone

The base of the original Diducites versabilis - Grandispora cornuta (VC0) Oppel zone was originally defined by Streel et al., 1987 (p. 220, fig. 9) by the co-occurrence of the three taxa Grandispora cornuta, Rugospora flexuosa (now R. radiata) and Retusotriletes philippisi. However, Streel and Lobozia (1996, p.580), were reluctant to define formal First Occurrence Biohorizons for these three zonal taxa due to insufficient biostratigraphical control of their respective inceptions. In addition, Retusotriletes philippisi was originally nominated as a zonal species due to the importance given to this species in the Famenian of eastern North America (Clendening et al., 1980; Richardson & McGregor, 1986). However, its occurrence in the late Famenian of the Ourthe valley, was not established; therefore it is proposed that this species should no longer be used as a diagnostic species for the VC0 Zone in western Europe. It is proposed that the VC0 Oppel Zone be redefined by the occurrence of Rugospora radiata and Grandispora cornuta, and that the

Figure 2: Localities studied in the Ourthe Valley, and location in Eastern Belgium (Dinant Synclinorium).
staggered first appearances of these two taxa within the VCo
Oppel Zone now define two new interval zones: the Rugospora
radiata (Rad) interval zone succeeded by the Grandispora cornuta
(Cor) interval zone.

Apiculiretisporispora verrucosa - Vallatisporites hystricous. VH
Oppel Zone

This zone was first described by Mazziane et al. (1999) from the
Chaxhe section in the Ourthe Valley, and was defined by the
first appearance of Apiculiretisporispora verrucosa and
Vallatisporites hystricous. Other taxa mentioned as appearing in
this zone included, Endoculocospora gradzniskii, Spalaeotritiles
crenulatus and Grandispora echinata. However, revision of the
slides from the Evieux-railway cutting (EVR) shows that these
three species first appear at level well below the base of the zone
and so can no longer be considered as a characteristic species of
the VH Oppel Zone. Furthermore, A. verrucosa, one of the zonal
nominal species has been now recorded below the first occurrence
of V. hystricous in the Ourthe Valley section. Consequently the
staggered first appearances of these two taxa within the VH
Oppel Zone allows the definition of two new interval zones, the
Apiculiretisporispora verrucosa (Ver) interval zone followed by the
Vallatisporites hystricous (Hys) interval zone. The taxonomic
distinction of Vallatisporites hystricous from the Russian
taxon Vallatisporites pusillites was clarified by Avchimovitch et al.
(1988) who showed that V. hystricous is a much more coarsely
ornamented form with spines 3-16 μm in length whereas the
stratigraphically younger V. pusillites normally has small spines
1-2 μm in length. Richardson and Ahmed (1988) recorded the
Apiculiretisporispora verrucosa (as A. fructicosa) and Vallatisporites
hystricous (as V. pusillites) assemblage zone from the lower part
of the Cattaraugus Formation of western New York State. This
assemblage zone broadly correlates with the VH Oppel Zone of
Belgium; however the two zonal taxa appear in a reversed
stratigraphic order to that observed in eastern Belgium.

2.2. Systematics

A taxonomic review has been carried out of Rugospora radiata
and Grandispora cornuta to provide a clear understanding about
the morphological features of these two zonal species and a better
discrimination with other closely related Upper Devonian taxa.

Grandispora cornuta Higgins 1975 emend

Plate 1, Figs. A-F; Plate 3, Figs. K and N

XVI fig. 11._
1966 Spinnoznotritiletes cf. uncatus Hacquebard 1957 in Streel
pl II fig. 27.
1968 Spinnoznotritiletes cf. uncatus Hacquebard 1957 in Streel.
pl I: 7.
1971 Spinnoznotritiletes cf. conspicus Playford 1964 in Combaz
& Streel. pl 3 fig. 8.
1973 Spinnoznotritiletes sp. cf. S. uncatus Hacquebard 1957 sensu
Bouckaert, Streel, Thorez & Mound 1969 in Gayer et al., 8, pt 2,
pl. 14 fig. B.
1976 Spinnoznotritiletes uncatus Hacquebard 1957 in Coquel et
al., pl. IV fig. 23.
1 fig. 25.

Figure 3: Comparison of spine length and shape in a. Grandispora
cornuta and b. G. tamarae

Remarks: The diagnosis of this species is emended in light of the
present biometric study of G. cornuta and G. tamarae from Upper
Devonian material from eastern Belgium and Ireland (described
below). The size range of the spines for G. cornuta is changed from
5-16 μm to 8-16 μm in length (see Fig. 3)

Grandispora tamarae Loboziaik in Higgins et al., 2000
Plate 1, Figs. G-N; Plate 2, Figs. A-F; Plate 3, Figs. I-J

XVI fig. 13._
1969 Spinnoznotritiletes cf. S. uncatus Hacquebard 1957 in
Bouckaert et al., pl. 93 figs. 7 and 8
1969 Spinnoznotritiletes cf. S. tenuispinus Hacquebard 1957 in
Bouckaert et al., pl. 93 fig. 6.
1969 Hymnoznotritiletes microsetus Kedo 1965 in Bouckaert
et al., pl. 93 fig. 9.
1973 Spinnoznotritiletes sp. cf. S. uncatus Hacquebard 1957 sensu
Bouckaert, Streel, Thorez & Mound 1969 in Gayer et al., 8, pt 2,
pl. 14 fig. A.
1977 Grandispora cf. tenuispina (Hacquebard) Playford 1971 in
Clayton et al., pl. 2 fig. 15.
1986 Grandispora cornuta Higgins 1975 in Richardson &
McGregor pl 20 fig. 1.
1 fig. 5.
1992 Grandispora cornuta Higgins 1975 in McGregor & Playford
pl. 15 fig. 9.
1992 Grandispora cornuta Higgins 1975 in Grey pl.16 fig. 6.
1993 Grandispora cf. tenuispina (Hacquebard) Playford 1971 in
Hartkopf- Fröder & Streel pl 7 fig. H.
1997 Grandispora cornuta Higgins 1975 in Loboziaik et al., pl. 2
fig. 11.
2003 Grandispora cornuta Higgins 1975 in Melo & Loboziaik. pl
IV fig. 7.

Figure 4: Ornament length compared to the ratio external body/internal
body in Grandispora cornuta and G. tamarae.
Black dots were all referred to belong to G. cornuta, black triangles to
G. tamarae

Numbered specimens are now transferred to G. tamarae
1: Unpublished specimen previously considered to mark the base of the
VCo Zone, Bon Mariage 12/54.
2: Spinnoznotritiletes cf. S. uncatus, Beverire 55 in Bouckaert et al., 1969
pl.93 fig. 7
3: Grandispora cornuta, Pennsylvania (USA) in Richardson & McGregor
1986 pl 20 fig. 1.
4: Spinnoznotritiletes cf. S. uncatus, Beverire 45 in Bouckaert et al., 1969
pl 93 fig. 8.
5: Unpublished specimen previously considered to mark the base of the
VCo Zone, Bon-Mariage 11/54.
6: Hymnoznotritiletes microsetus, Chera E 9 in Bouckaert et al., 1969
pl. 93 fig. 9.
2.3. Biometric analysis of Grandispora cornuta and G. tamarae

A morphological analysis of Famennian Grandispora species was carried out by Higgs et al. (2000), and thirteen individual species were discriminated on the basis of exosome wall thickness, exosome/intexine ratio, and ornament type, size and distribution. In this study, Grandispora cornuta was defined as having a spine length of 5-16 μm whereas G. tamarae, a form that appears in the Upper Frasnian but is common in the Upper Famennian assemblages, has a spine length of 2-5 μm. This overlap in ornament size has presented some difficulty for the identification of the smaller ornamented forms of the zonal taxon G. cornuta. In the present study a morphological analysis of G. cornuta and G. tamarae specimens was carried out on both published and unpublished material. This included unpublished data from the Upper Famennian of the Namur Syncline in Belgium (Plate 2) and Hook Head, Ireland, the type locality for the two species (Plate 1), as well as data from 38 published records of these two taxa. The principal parameters measured in the analysis of the Grandispora specimens are, ornament length, ornament basal width and the exosome/intexine size ratio. A summary of the results is given below.

Fig. 4 shows the length of ornaments (in μm) plotted against exosome/intexine ratio (given as %). It shows that two populations are clearly distinguished, G. cornuta (dots) and G. tamarae (triangles). This analysis also shows that some specimens previously identified as G. cornuta in the literature plot within the G. tamarae group (see the dots numbered 1-6 in Fig. 4). These include the specimen illustrated in Richardson & McGregor (1986) and Richardson & Ahmed (1988), specimens from the Becquer site (Bouckaert et al., 1969), sample 55 (pl. 93 fig. 7) and 45 (pl. 93 fig. 8) and one specimen from Chera in the Vesdre Valley attributed (Bouckaert et al., 1969, pl. 93 fig. 9) to Hymenozonotrietes microsetus. On the basis of this evidence we suggest all of these specimens to be transferred into G. tamarae. Two additional unpublished specimens, formerly believed to mark the base of the G. cornuta Interval Zone at level 54 of the BM section (see fig. 7), should also be assigned G. tamarae.

The second morphological analysed feature was the relationship of ornament length and overall spore diameter. Fig. 5 shows the plot of spine length against exosome diameter, and again two distinct groups can be differentiated. However, it also shows that in the G. cornuta group there is an obvious trend for the spine length to increase with increased exosome diameter. Based on these analyses, we propose that the minimal size limit for the G. cornuta spine length be increased from 5 μm to 8 μm; this will provide a much clearer morphological distinction between the two species.

The third morphological analysed feature was the shape and width of the ornament bases. In G. cornuta, the base of spines was described as 2-6 μm in width, often swollen or bulbous in shape, tapering uniformly or sharply to pointed and occasionally curved tips. (Higgs et al., 2000). In G. tamarae cones and spines are described as 2.5 μm in basal diameter, typically possessing recurrent sides and sharply pointed tips, often bent over (Fig. 3). Unpublished specimens of both species with homologous specimens taken from the literature are illustrated in Plate 1. In addition, unpublished specimens of g. tamarae from the Upper Famennian of the Namur Syncline are also shown on Plate 2.

The number of spines projecting at the equator in both species was analysed; although the number is slightly more in G. tamarae, it was not considered significant enough to be used to discriminate the two taxa.

Taking into account all these characters, it appears that several specimens previously identified in the literature as G. cornuta are now more appropriately assigned to G. tamarae. For instance, the specimen figured as G. cornuta from the lower Catanaragus Fm. (U.S.A.) named by Richardson & McGregor (1986) and Richardson & Ahmed (1988) now belongs to G. tamarae. This taxonomic re-evaluation has biostratigraphic consequences for international correlations and might partly explain the much debated diachronous correlations between European and American palynozones (e.g. Richardson and McGregor 1986; Steed and Marshall 2007).

2.4. Rugospora radiata (Juschko) Byyscheva 1985

Plate 3, Figs A-B

1960 Campotritetites radiata Juschko, p.128, pl. 2, fig. 26
1974 Trachytretites radiata (Juschko) Kedo p.7, pl. 1, fig.1
1985 Rugospora radiata (Juschko) Byyscheva 1985
1988 Symorisporetes flexuosus (Juschko) Richardson & Ahmed (pl. 2 figs. 1-3)

Rugospora radiata is morphologically similar to Rugospora bricei (Loboziak & Steel 1989) a stratigraphically important species that first appears in the Frasnian. Identification difficulties between these species have resulted in the stratigraphical extension downwards of the VCO Oppel Zone range in some regions, particularly in New York and Pennsylvania (Richardson & McGregor 1986). The main morphological differences are in the size and arrangement of the rugulae. In R. bricei the distal rugulae are small (1-1.5 μm wide) and randomly (rarely radially) arranged. By comparison, R. radiata has thicker and longer rugulae, most commonly radially arranged on and adjacent to the disto-equatorial margin. In addition, the rugulae in R. bricei, rarely reach the equator whereas in R. radiata the rugulae distinctly cross the equatorial border (Fig. 6). Rugospora

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**Figure 5:** Ornament length compared to the external body diameter in Grandispora cornuta and G. tamarae. (the black dots, triangles and numbers are the same as in Fig. 4).

**Figure 6:** Comparison of ornamentation in Rugospora radiata, R. flexuosa (syn.? S. variegatus) and R. bricei.
explicata Gonzalez et al. (2005) from the Upper Famennian (VC0 Zone) Pyrite Belt of southwest Spain, differs from R. radiata and R. bricii in possessing sinuously arranged ornament of rugae that bear very small coni, baculi, and pila (1-2 μm in size).

3. Correlation of the Upper Famennian miospore zones with the conodont biostratigraphy in the Ourthe valley sections.

The Ourthe Valley provided excellent outcrops of the Upper Famennian Condroz Group where a composite stratigraphy has been established based on five sections. These sections are shown on Figure 2; from the south to the north these are: Comblain-la-Tour (upper and lower parts), Comblain-au-Pont composed of a right bank section (Bon-Mariage) and a left bank section (Beverite), Chanxhe and Evieux railway sections. Bed-by-bed sampling for micropaleontological and palynological investigations has resulted in a detailed biostratigraphical framework for the Upper Famennian interval based on conodonts and miospores. (Thorez et al., 2006: 10. Biostratigraphy). The following section provides a correlation of the new miospore zonation with the conodont biostratigraphic data. Fig. 10 shows the Famennian miospore and conodont zonation schemes and the respective zones mentioned in the next section.

The Upper to uppermost Marginifera Conodont Zone (Bode 1991; Dreesen & Thorez 1994) occurs in the lower part of the Comblain-au-Pont section (about 45 m above the top of the Souverain-Pré Formation (Fig. 7). Some 15 m higher in the section, limestone beds 62, 63 and 64 (= beds D, E, F) contain the index species Scaphognathus velifer that indicates the uppermost marginifera or Lower trachytera Conodont Zone. However, conodonts in levels E and O (Dreesen & Thorez 1994) indicate a slightly higher stratigraphic position i.e. the upper trachytera Zone (former Upper Velifer Zone). Level O is just above the shales presumed to correlate with the “annulata” Event (Thorez et al., 2006). Unfortunately, the lower part of the Comblain-la-Tour is very poor in terms of miospore preservation so no direct correlation could be made with the conodont zones.

The lower part of the Comblain-la-Tour section can be lithologically correlated using red beds and ball-and-pillow levels.
with the two sections at Comblain-au-Pont (Bon Mariage BM and Beverie BEV). The Grandispora microsota first occurrence biohorizon (the base of the Mic Subzone of the gracilis-famenensis GF Oppel Zone, see Fig. 7) occurs at level 19 in the BM section; this correlates with one of the marginifera conodont zones. Higher in the same section level 54 is the first occurrence of Rugospora radiata which marks the base of the Rad Interval Zone of the VCo Oppel Zone (Fig. 7), and this correlates with position close to the transition between trachytera and postera conodont zones. At a higher level in the BM section at Bed 62 is the entry of Grandispora cornuta and the base of the Cor Interval Zone of the VCo Oppel Zone (Fig. 8). The Lower expansa Zone is not recorded so far in the Ourthe Valley sections because of unfavourable facies; however it is considered to more or less correspond to the lower part of the Cor Interval Zone.

The Middle expansa Zone is recorded in the Comblain-la-Tour, Beverie (BEV) and Evieux-rail (EVR) sections being coeval with the Fontin Event in the latter section. The Fontin Event is shown in detail in Stroel (1999, fig. 3) after data from Lalfer (1991) and Maziane (1993). This transgressive horizon correlates with the middle expansa conodont zone (Fig.9) and the first appearance of Apiculitesispora verrucosa which marks the base of the Ver Interval Zone of the VH Oppel Zone. The Fontin Event has been correlated by Kaiser et al. (2008) with the Dasberg Event in Germany and indirectly to a late Famenian isotopic excursion (ALFIE) in Western USA by Myrow et al. (2011).

In the Chanteleux(CHX) section Vallatisporites hystrocous appears in bed 21a (Maziane et al., 1999) thus marking the base of the Hys interval zone of the VH Oppel Zone (Fig. 9) followed a short distance by Retispora lepidophyta in bed 22 defining the base of the overlying LL miospore Biozone (Fig. 9). These two miospore zonal bases correlate with the Middle expansa conodont zones. The lower part of the LL biozone was
demonstrated by Strel and Hartkopf-Fröder (2005) to correlate also with the Middle expansa conodont zone. Approximately 18 m above the entry of *R. lepidophyta*, conodonts of the Upper expansa Zone marking the base of the Uppermost Famennian substage are recorded in bed 111 of the Chanxhe (CHX) section (Dreessen et al., 1993). This horizon corresponds to a quantitative change (acme zones) from *Retispora lepidophyta lepidophyta* to *Retispora lepidophyta minor* (Maziane et al., 2002) (Fig. 10).

4. Conclusions

- The VCo Oppel Zone is more appropriately defined on the occurrence of *Rugospora radiata* and Grandispora cornuta. Furthermore, the staggered first appearance of these two taxa within the VCo Oppel Zone allows the definition of these two new interval zones: the *Rugospora radiata* (Rad) interval zone, succeeded by the *Grandispora cornuta* (Cor) interval zone.
- A biometric study of coeval populations of *Grandispora cornuta* and *G. tamarae* has shown that the two species can be clearly separated on spine length and shape. The specific diagnosis of *G. cornuta* is emended to a new minimum spine length of 8 µm.
- Close correlation of miospore and conodont zones in the Condroz Group succession in five sections of the Ourthe Valley now provide a close integrated biostratigraphy for the Upper Famennian interval in eastern Belgium. The *Grandispora gracilis-Grandispora famenensis* GF Oppel zone is now subdivided only into two subzones, the higher one being based on the first occurrence of *Grandispora microseta* within the upper part of the marginifera conodont zone. The *Retispora macroreticulata* Mac Subzone characterized by the sporadic first occurrence of *R. macroreticulata* is now considered obsolete.
- The base of the *Diducites versabilis-Grandispora cornuta* VCo Oppel zone, now fixed at the first occurrence of *Rugospora radiata*, most probably correlates with the trachycysta zone.
- The base of the *Grandispora cornuta* interval zone, as understood from this new definition of *G. cornuta*, has to be found in the postera or Lower expansa.
- The transition between the Lower and the Middle expansa corresponds more or less to the Fontin/Dasburg Event and can be correlated with the base of the *Apiculitrespisops verrucosa Interval zone*, a new base for the *Apiculitrespisops verrucosa-Vallatisporites hystricostus* VH Oppel zone.
- The base of the *Upper expansa* zone has been demonstrated by Maziane et al. (2007) to correlate with the change from the acme zones of *Retispora lepidophyta lepidophyta* to *Retispora lepidophyta minor*, and should correspond to the major increase in sea-surface temperature demonstrated at the same level by Kaiser et al. (2011)

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6. References


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Plate 1: Comparison of unpublished material of Grandispora cornuta and G. tamarac with homologous material described in the literature.
A to F: Grandispora cornuta Higgs 1975
A: HK41/S35; B: HK41/P11; C: HK44/U19; D: HK42/U19; E: Tournai borehole 316 m, Belgium, 3010/01. (Syn. Spinozonotrites cf. uncatus Hacquebard 1957 in Strel 1966, plate 1: 7). See also Clayton et al., 1977 plate 3, fig.15; F: HOLOTYPE, Hook Head, Eire, ML1104. See also Clayton et al., 1977 plate 3, fig.16.
G to N: Grandispora tamarac Loboziak in Higgs et al., 2000
Plate 2: unpublished specimens of *Grandispora tamarae* from the Upper Famennian of the Namur Syncline, Evieux Formation, Huy Citadel Mbr. Upper Famennian (Thorez et al., 2006).
Plate 3: Other characteristic taxa

A and B: Rugospora radiata (Jaschke) Byvahova 1985.
   A: Beverite 55-4, slide 2460, J4/2; B: Bon-Mariage 54-5, T24/4
   C and D: Rugospora bricei Loboziak & Streel 1989.
   C: Beverite 55-4, slide 2460, G29; D: Bon-Mariage 54-5A, H21/1
   E: Bon-Mariage 19A, H22/4; F: Bon-Mariage 54-5A, R38/3
   G: Grandispora echinata Hacquebard 1957, Bon-Mariage 35A2, H21/4
   H: Grandispora famenensis (Naumova) Streel 1974 var. minuta Nekriata
   1974, Evieux-rail, slide 33291, G31/2

   I: Beverite 45-6, slide 15638, K46; J: Beverite 71, slide 2490, T25
   K and N: Grandispora cornuta Higgs 1975.
   K: Beverite 62-64-2, slide 15375, S38/2; N: Evieux-rail, slide 33217,
   R25/1
   L: Evieux-rail, slide 31378, Q2442; M: Evieux-rail, slide 33277,
   H21/4
   O, P and Q: Apicaliretusispora verrucosa (Caro-Moniez) Streel in Becker
   O: Evieux-rail, slide 31378, E244; P: Evieux-rail, slide 31388,
   K40; Q: Evieux-rail, slide 31388, M2324-4