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# SUBCOMMISSION ON DEVONIAN STRATIGRAPHY

## NEWSLETTER No. 40

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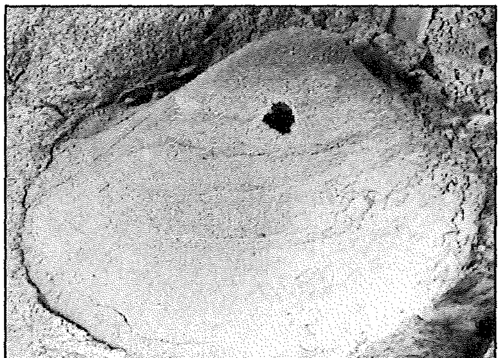

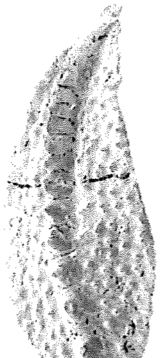

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# SDS DOCUMENTS

## Why not use palynology to reconsider the base of the Carboniferous System in the type region of the Tournaisian?

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**Dedicated to the memory of Raphael CONIL and Charlie SANDBERG, protist and conodont micropaleontologists, who have encouraged palynological research in the Devonian–Carboniferous range.**

**Abstract.** The miospore zonation of the Belgian Tournaisian Tn1a and Tn1b is reviewed and described in nearshore marine facies. The presently used Tournaisian spore zones being inappropriate to define the DCB, the LN and VI zones being poorly understood, the late Famennian limit LL/LE is easier to use and would have advantage of corresponding to the first Carboniferous type glacial episode interpreted from strata in basins of Brazil, Bolivia, and Peru where ice sheets and alpine glaciers reached coastal and marine settings. The cooccurrence of a new wall structure (the *Indotriradites* concept), better known during the Mississippian but present with *Siphonodella praesulcata* in the LE Zone of the Uppermost Famennian studied by Sandberg in the Sappington Member of the Three Forks Formation in Montana (USA), should give more reason to revise the Hangenberg Event and the delineation of the DCB.

### 1. Introduction

Spores (miospores), often with diameters around 50 µm, have the advantage, compared to other microfossils, of being produced by each individual terrestrial plant in thousands of specimens, which are transported into the sediments by wind and fluvial or marine currents. In this context, *Retispora lepidophyta* has the most widespread occurrence in the DCB range.

### 2. The Upper Tournaisian (Tn1b sensu CONIL 1964) microfossil zonations

Recent studies show that the microfossils conodonts and miospores do not provide so far unambiguous data to delimit a D/C boundary in the type area of the Hangenberg Crisis: different concepts of *Siphonodella* or *Protognathodus,* for instance (KAISER et al. 2019; KAISER & HUBMANN 2024); poor definition of the miospore zonation at the same level (DI PASQUO & STREEL 2022). Indeed, the successive zones LN/VI definition is ambiguous (STREEL & STEEEMANS 2020). CLAYTON et al. (1974), working in the South Munster Basin (the Cork beds) in Southern Ireland, subdivided the NV Zone of NEVES et al. (1972) into two subzones, the LN Subzone and the VI Subzone. They were proposed as a Concurrent Range Zone by HIGGS et al. (1988).

The **LN** *(Retispora lepidophyta-Verrucosisporites nitidus)* **Biozone** has most of the taxa of the preceding *R. lepidophyta-I. explanatus* (LE) Biozone. *Lophozonotriletes malevkensis*, *Vallatisporites verrucosus,* and *Densosporites spitsbergensis* appear close to the base of the LN Biozone. *Verrucosisporites nitidus* is rather sparse in the basal LN Zone, usually represented by the smaller verrucate forms (HIGGS et al. 1988).

In the Stockum trench II (HIGGS et al. 1993), the sandy part (Hangenberg Sandstone = HSst) contains an atypical LN assemblage of spores (**LN***), very rich in *Retusotriletes* spp., and where *R. lepidophyta* is rare (about 1 % - but a consistent element). The following taxa start in this LN* informal zone: *Cyrtospora cristifera* (HIGGS et al. 1993), *Bascaudaspora mischkinensis* (= ?*B. submarginata* PLAYFORD after HIGGS et al. 1988).

**The LN-VI transition** corresponds to the Middle and Upper Hangenberg Crisis intervals, ranging from the *Bi. costatus-Pr. kockeli* Interregnum (*cki*) to the *Pr. kockeli* Zone, followed by the *Pr. kuehni-Si. (Eosi.) sulcata* Zone (CLAUSEN et al. 1994; ARETZ et al. 2021). No spore species starts at the base of the so-called **VI Zone**. *Vallatisporites. verrucosus, V. vallatus,* and *Retusotriletes incohatus* are known since the LN Zone in the Stockum trench II.

In contrast to the preceding LN assemblage, the basal VI Biozone assemblages are very restricted in composition, usually dominated by simple laevigate forms (HIGGS et al. 1988). *Vallatisporites vallatus* was originally considered by CLAYTON et al. (1974) as characterizing a *V. vallatus-R. incohatus* Zone. The VI (*V. verrucosus-Retusotriletes incohatus*) Biozone is marked by the disappearance of *R. lepidophyta, V. pusillites, Rugospora flexuosa,* and species of the genera *Ancyrospora* and *Hystricosporites*, *Diducites versabilis,* and *D. plicabilis.*

### 3. LN-LN*-VI sequence

A relevant contribution to the quantitative approach of the transitional Devonian to Carboniferous palyno-zonation is the descriptive and quantitative analysis at the generic level, with illustrations of miospores, in the Ballycrovane Harbour (VAN VEEN 1981, fig. 2; see also HIGGS et al. 1988) and Bantry Bay (VAN VEEN 1981, fig. 3) sections (County Cork, southern Ireland). It shows that the most distinct DCB palynological change is taking place between the *Retispora lepidophyta-Verrucosisporites nitidus* (LN) and the *Retispora lepidophyta-Cyrtospora cristifera* (LCr) phases in the basal part of a widespread mudstone unit: the Castle Slate Member of the Kinsale Formation (STREEL & STEEMANS 2020).

The reference section of the Ourthe Valley Chanxhe 1 (MAZIANE et al. 2002, 2007) is interrupted by a fault in its upper part. KUMPAN et al. (2014) studied a comparable section at Rivage, using the original log of CONIL (1964) and providing correlations with two positive carbon isotope excursions. In a similar Rivage Pont de Scay section (PRESTIANNI et al. 2016), an unusual LE zone is noted, where, however, the occurrence in their highest sample (Bed 94) of *Bascaudaspora mischkinensis* and a possible *Vallatisporites vallatus* could correspond with the first thick shaly beds of the Hangenberg Black Shale (HBS in LN Zone in Sauerland).

Based on many boreholes of Eastern Europe, an alternative spore zonation near the DCB has been established. The *Vallatisporites pusillites* (P) Zone has been divided into three Subzones (BYVSHEVA & UMNOVA 1993). The lower *Vallatisporites pusillites - Retispora lepidophyta - Hymenozonotriletes explanatus* Subzone (PLE) has abundant *Retispora lepidophyta*. The middle *Vallatisporites pusillites - Tumulispora malevkensis - Retispora lepidophyta* Subzone (PML) may include rare *Retispora lepidophyta.* The upper *Vallatisporites pusillites – Tumulispora malevkensis* Subzone (PM) does not contain *Retispora lepidophyta*. The PM Subzone has been changed subsequently into the *Vallatisporites pusillites - Bascaudaspora mischkinensis* (PMi) Subzone. The sequence PLE-PML-PMi corresponds to the LN-LN*-VI sequence (AVCHIMOVITCH et al. 2021).

### 4. The lower Tournaisian (Tn1a sensu CONIL 1964) microfossil zonations.

The three sections selected (see figs. 8 and 10 in MAZIANE et al. 2002) are from nearshore marine facies. These are: (1) the Chanxhe section (CONIL et al. 1964; STREEL 1966); (2) the Royseux section (STREEL 1966; AUSTIN et al. 1970); and (3) the Tohogne borehole (BOUCKAERT & DUSAR 1976; BOUCKAERT et al. 1978). The Chanxhe section is the most important because it is the reference section used by STREEL (1966) in the original biometric study compared with the Foraminifer stratigraphy of CONIL (1964). It is also the most Famennian complete section and possesses abundant mudrock levels. The Tohogne borehole also displays a complete late Famennian succession with some conodont data, but cores provided less productive material. The Royseux section is the least satisfactory because it allows for the smallest number of productive samples with more limestone beds. Secondly, it does not extend down to the base of the latest Famennian. Two of these eastern Belgian sections display a continuous succession of late to latest Famennian miospore zones ranging from the *Diducites versabilis – Grandispora cornuta* (VCo) and *Apiculiretusispora verrucosa-Vallatisporites hystricosus* (VH) in which *Retispora lepidophyta* is absent, up into the overlying *Retispora lepidophyta-Knoxisporites literatus* (LL) and *Retispora lepidophyta-Indotriradites explanatus* (LE) Zones (MAZIANE et al. 1999). Indeed, CLAYTON et al. (1978) had proposed two new subzones within the *Vallatisporites pusillites-Retispora lepidophyta* (PL) Zone of NEVES et al. (1972). These are the LL and LE Subzones.

Some of these microspore zones in the studied sections were independently searched for conodonts (AUSTIN et al. 1970; BOUCKAERT et al. 1978), but did not record any significant results compared to more recent conodont research near the DCB.

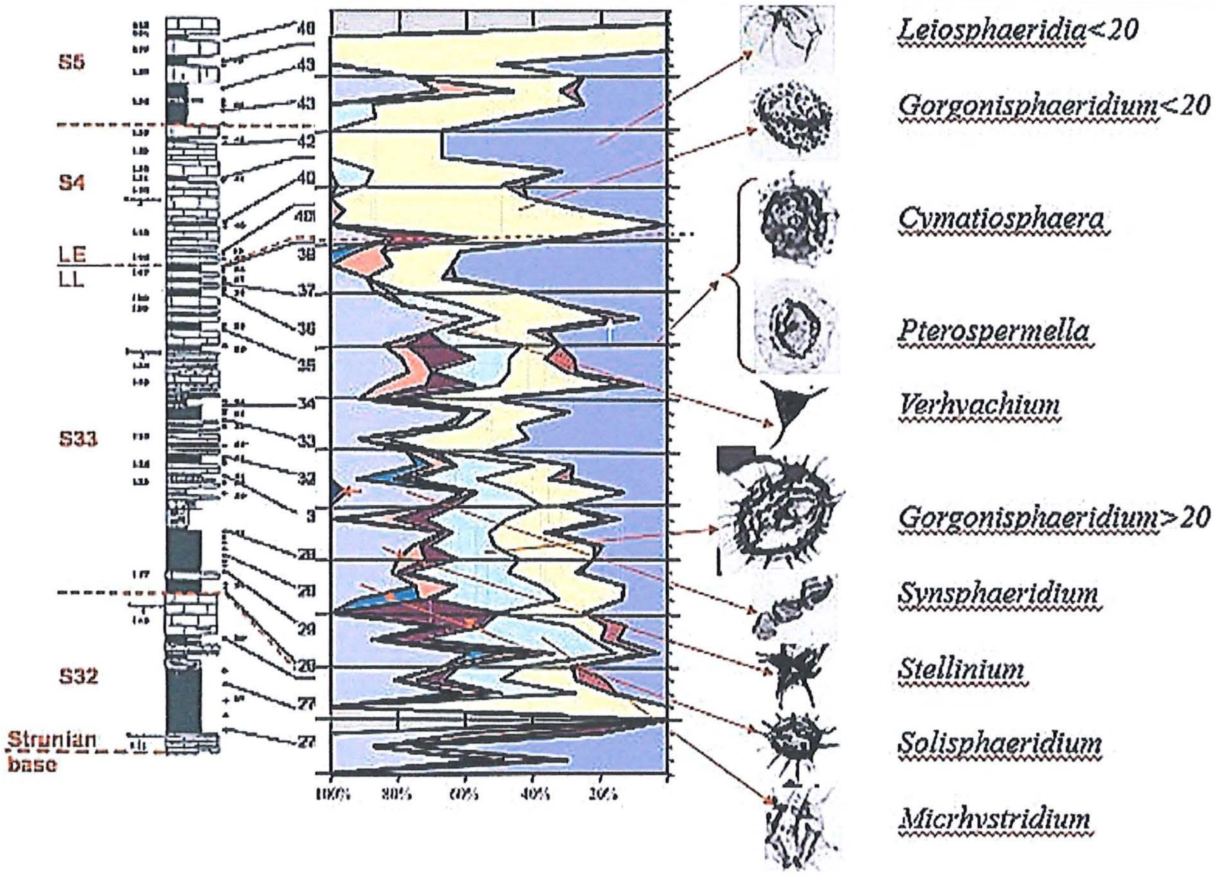

**Fig. 1.** Quantitative analysis of the distribution of miospores and acritarchs and comparison with the new sedimentary sequence in the Chanxhe section (S32, S33, S4, S5 = sedimentary sequence in MAZIANE et al. 2007).

All these sections were also examined by VANGUESTAINE (1978), MAZIANE & VANGUESTAINE (1997), and MAZIANE (1999), who allowed to demonstrate (Fig. 1) the almost coincidence of a noticeable change of the acritarch content (sudden dominance of *Gorgonisphaeridium* and small Leiospheres) and the LL/LE transition. This was interpreted by MAZIANE et al. (2007) as a shallowing sea level corroborated by the occurrence of shallow water ostracods (CASIER et al. 2005). This change occurs in the new biometric zone Z, where one can still observe a large proportion of *Retispora lepidophyta* when compared to all spores. Twenty acritarch species described in the Upper Devonian of Ohio (USA) in the Cleveland

Member of the Ohio Shale are identified in the Upper Famennian of Tohogne.

The late Famennian limit LL/LE is easier to use and would have the advantage of corresponding to the first Carboniferous-type glacial episode interpreted from strata in basins of Brazil, Bolivia, and Peru (CAPUTO & CROWELL 1985), during which ice sheets and alpine glaciers reached coastal and marine settings (Fig. 2).

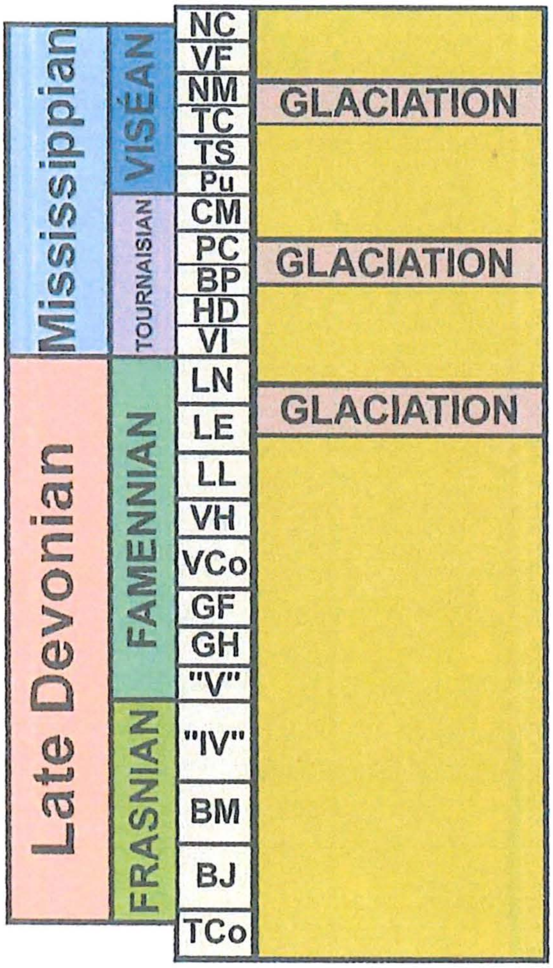

**Fig. 2.** Stratigraphic position of glaciation episodes in South America.

*Retispora lepidophyta* has the most widespread occurrence in the DCB range. Its extinction is observed in two steps. Initially, it is most often dominant, with more than 50 % of all spores counted, usually thousands per gram of sediment. A substantial decline of this species characterizes their **first extinction step,** but it persists in all samples, possibly exceeding 5 % of the total of all spores counted. The **second extinction step** (STREEL & DI PASQUO 2022) led to the complete absence of the species except in possible reworking conditions (STREEL & BLESS 1980; DI PASQUO & STREEL 2022a, 2022b; DI PASQUO et al. 2022).

To control the abundance of *R. lepidophyta*, we have tried to sample the LL/LE transition in the Royseux section and the Tohogne borehole again without success. At Royseux, 16 samples in the shaly contact between limestones contained only modern pollen grains. Also, we could not find shale samples again within the few materials that escaped the numerous former collectors of spores, conodonts, and forams (STREEL & DI PASQUO 2022). Therefore, taking advantage of the percentage of all spores calculated by MAZIANE (1999: appendix 6/4/B for Tohogne, appendix 6/4/C for Royseux), we can see that the first extinction step of *Retispora lepidophyta* starts before the LE Zone (Fig. 3), at least in the biometric zones, i.e., the Rlm subzone marking the base of the uppermost Famennian in AVCHIMOVITCH et al. (2021).

The extinction of *R. lepidophyta* might have at least two explanations: the rarefaction and progressive disposition of the mother plant (an herbaceous lycopod) and/or a reworking process expected from older sediment containing many specimens of this species (DI PASQUO & STREEL 2022a). Consequently, if the extinction of *R. lepidophyta* cannot mark the DCB, at least, its extinction steps may serve to characterize the Uppermost Famennian (DI PASQUO et al. 2021).

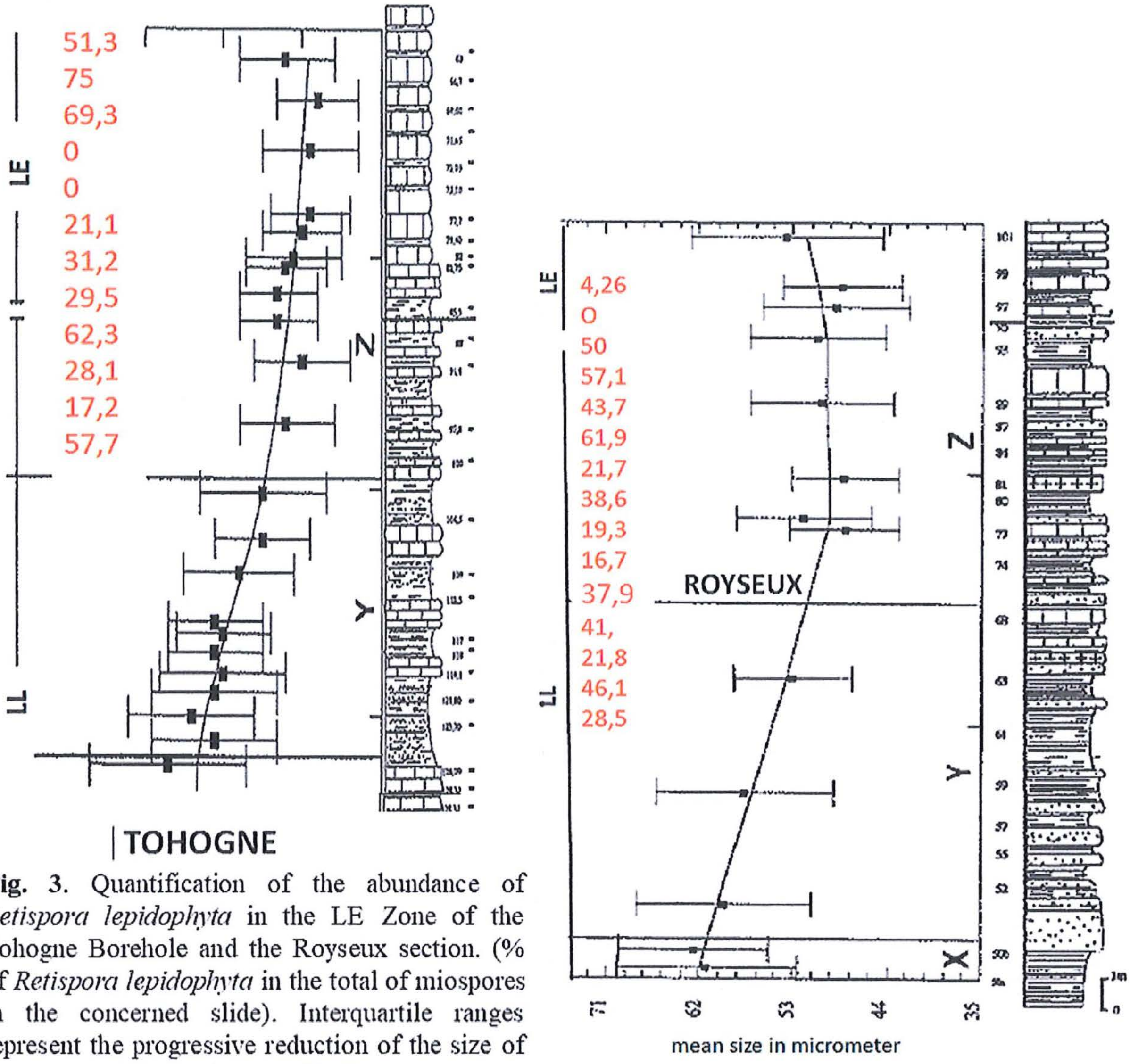

**Fig. 3.** Quantification of the abundance of *Retispora lepidophyta* in the LE Zone of the Tohogne Borehole and the Royseux section. (% of *Retispora lepidophyta* in the total of miospores in the concerned slide). Interquartile ranges represent the progressive reduction of the size of this species (Biometric zones Y, Z).

## 5. The *Indotriradites* Morphon and the *Vallatisporites* Group

*Indotriradites* TIWARI emend. FOSTER 1979 (=*Kraeuselisporites* in AZCUY & DI PASQUO 2005): spores radial, trilete, zonate, cavate. Amb circular to roundly subtriangular. The distal surface is hemispherical (lateral view), and the proximal face is low pyramidal to almost flat (in the same plane as the zona). Laesurae labrate, reaching the outer margin of the zona. Exine two-layered; intexinal layer thin, often folded, apparently unstructured, separated (at least distally and equatorially) from exoexine by a distinct, broad or narrow cavum, exoexine infrastructured, surface pattern appears scabrate or granulate; proximal face laevigate, distal surface (often including that of zona) bearing apiculate sculptured elements. Elements include coni, spinae, broad-based mammoid elements, low bacula, and verrucae; their bases may be partly vacuolate. Zona is distinct and broad; the inner margin is often markedly thicker than the remainder; it has a translucent appearance; the outer edge is continuous or notched.

Late Devonian (late Famennian) miospores have been found in the lowermost 7.3 m of the Horton Group on Harding Brook in the type area, Windsor Subbasin, Nova Scotia, below miospores of the *Indotriradites explanatus* Zone, extending the age of the Horton Group in the type area down into the latest Devonian (MARTEL et al. 1993).

Other *Indotriradites* species described from the Namurian of northern England, *I. ornatus,* also possesses connate sculptural elements more or less regularly distributed over the entire distal surface. But these elements are stouter and not confluent on or around the inner margin of the zona, as is seen in species belonging to the *Indotriradites dolianitii* Morphon (LOBOZIAK et al. 1999), commonly found in the late Visean Faro and Poti Formations of the Amazon and Parnaíba basins, respectively, in northern Brazil. This Morphon also occurs in the uppermost part of the Oriximiná Formation of late middle to early late Tournaisian age.

This Morphon could also be present in the Visean palynological zones M4 to the lower part of M6 of the Grand Erg occidental, Algerian Sahara (LANZONI & MAGLOIRE 1969).

The genus *Vallatisporites* is characterized by a two-layered exine; intexinal layer thin, separated (at least equatorially) from exoexine by a distinct, narrow cavum; vacuolae are also present around it. Differences in sculpture (anisopolar), variable sizes (ratio inner body-equatorial amb) are the main features used to define species. The nature of their parent plant(s) is still unknown. However, the spore structure resembles lycopods (RICHARDSON et al. in press).

New species of *Vallatisporites*, especially from the Uppermost Famennian or Strunian of New York and Pennsylvania States (USA), Western Europe, and Belarus, some still *nomen nudum,* are listed here in an appendix by AVCHIMOVITCH et al. (2021, described by RICHARDSON et al. in press). Diverse *Vallatisporites* species occur in the LE-LN Zones or those correlatable, with a variation from less abundant in LE to somewhat abundant in LN Zones (Fig. 4; AVCHIMOVITCH et al. 2021, fig. 3).

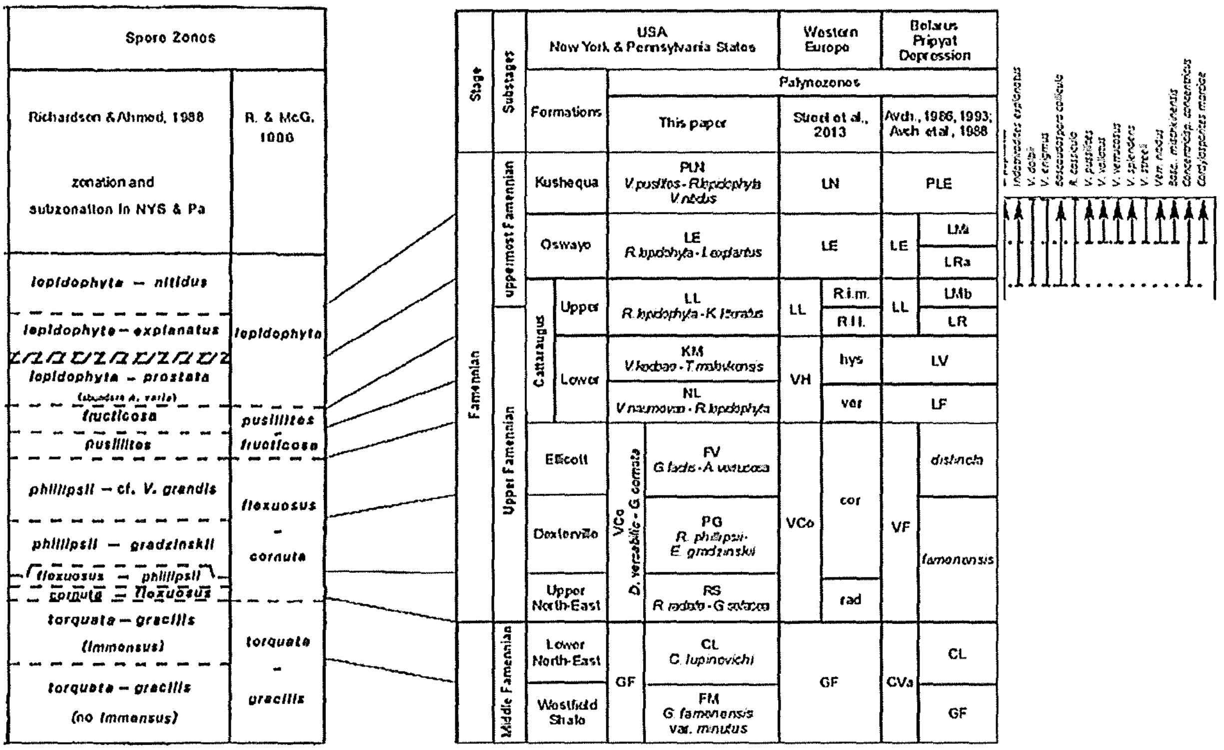

**Fig. 4.** A proposed correlation of the miospores in the middle, upper, and uppermost Famennian of New York State and Pennsylvania (USA), Western Europe, and the Pripyat Depression (Belarus). See AVCHIMOVITCH et al. (2021, fig. 3).

MATYJA et al. (2021) developed a multidisciplinary study based mainly on conodonts, ammonoids, and palynomorphs from the Devonian–Carboniferous boundary interval in pelagic successions of the Holy Cross Mountains and Sudetes and the ramp successions in the Western Pomerania region (Poland). Different published works were re-examined, and geochemical and mineralogical characteristics, as well as magnetic susceptibility measurements across the interval from the Famennian *B. ultimus* conodont Zone to the Tournaisian *S. duplicata* conodont Zone. The sedimentary successions recognized at the Devonian/Carboniferous boundary in Poland display a pattern similar to that observed in many areas in Europe during the Hangenberg Event (black bituminous shale horizon- HBS), with index taxa *Retispora lepidophyta, Vallatisporites verrucosus,* and *Verrucosisporites nitidus*, representing the *R. lepidophyta–explanatus* (LE), *R. lepidophyta–Verrucosisporites nitidus* (LN) miospore Zones (FILIPIAK 2004, 2005). Following MATYJA et al. (2021), the presence of *Vallatisporites vallatus* in this interval is sometimes abundant together with *Vallatisporites verrucosus,* and *V. pusillites* (43.5%), whereas others like *Retusotriletes incohatus* (15.5%) and *Apiculiretusispora verrucosa* (10.6%) are frequent (MARYNOWSKI & FILIPIAK 2007). Other taxa identified are *Apiculiretusispora verrucosa, Bascaudaspora submarginata, Cymbosporites minutus, Diducites versabilis, Grandispora echinata, G. lupata, Indotriradites explanatus, Kraeuselisporites mitratus, Pustulatisporites dolbii, Retusotriletes incohatus, Tumulispora malevkensis* (= *T. rarituberculata*), *Umbonatisporites rarisetosus.*

Conodonts identified by MATYJA et al. (2021) just a few metres below the HBS, in the uppermost part of the nodular limestone unit, indicated the recognition of *Bispathodus ultimus* zone due to the presence of several *Bispathodus* and *Branmehla* species (i.e. *Bispathodus costatus, Bispathodus aculeatus aculeatus, Branmehla suprema*). They provide more precise age determinations for this relatively shallow water part of the DCB succession in relation to the pelagic succession uppermost Famennian *praesulcata* (lower part) Zone (BECKER et al. 2016).

The overlying deposits, above the cephalopod limestone with *Wocklumeria,* were assigned to the *sulcata* Zone and succeeding conodont zones belonging to the Tournaisian. The *V. vallatus-R. incohatus* Palynozone above the HBS is represented by the persistent species *Retusotriletes incohatus, Vallatisporites vallatus*, and *Vallatisporites verrucosus*. Still, it does not possess other typical upper Famennian markers like *R. lepidophyta*. This is relevant for the recognition of the DCB, the same as the documentation of an intense condensation of small acritarchs (*Micrhystridium, Unellium* from the "complex" together with *Veryhachium*), noted by FILIPIAK (2005) just above the DCB. Similarly, it was observed in the Stockum section of the Rhenish Slate Mountains in Europe by STREEL (1999) and in Wales by MCNESTRY (1988). This event could potentially correlate with the base of the lower Tournaisian.

*Retispora lepidophyta* is variably found in the Uppermost Famennian Sappington Formation of Montana, USA, along with some spore species (*I. explanatus, Vallatisporites* spp.) in LE and LN palynozones that are all recorded in the same deposits with *Siphonodella praesulcata* (SANDBERG et al. 1972; DI PASQUO et al. 2017; HU et al. 2024). This is not surprising if we accept that they could belong to their second step of extinction. However, new data from the Sappington in Montana (Fig. 5) show that *Siphonodella praesulcata* and *Siphonodella sulcata* coexist, and further work is needed to determine if they are morphotypes of the same species or a consequence of sedimentary mixtures due to reworking with Early Mississippian conodonts (DI PASQUO et al. 2021, 2022a, 2022b; DI PASQUO & STREEL 2022).

Similarly, the Devonian-Carboniferous boundary in the Eastern Taurides of Turkey at the Northern Gondwana Margin is characterized by *Retispora lepidophyta, I. explanatus,* and species of *Vallatisporites* and *Densosporites variomarginatus*. They are documented in the latest Famennian *Bispathodus aculeatus aculeatus-Bi. costatus* conodont Zone. Overlying, a few Tournaisian spores, along with *Retispora lepidophyta* and with *S. sulcata* in the Lower Tournaisian, can probably be relevant to considering the recycling of latest Famennian taxa as well (ÖZBEK et al. 2024).

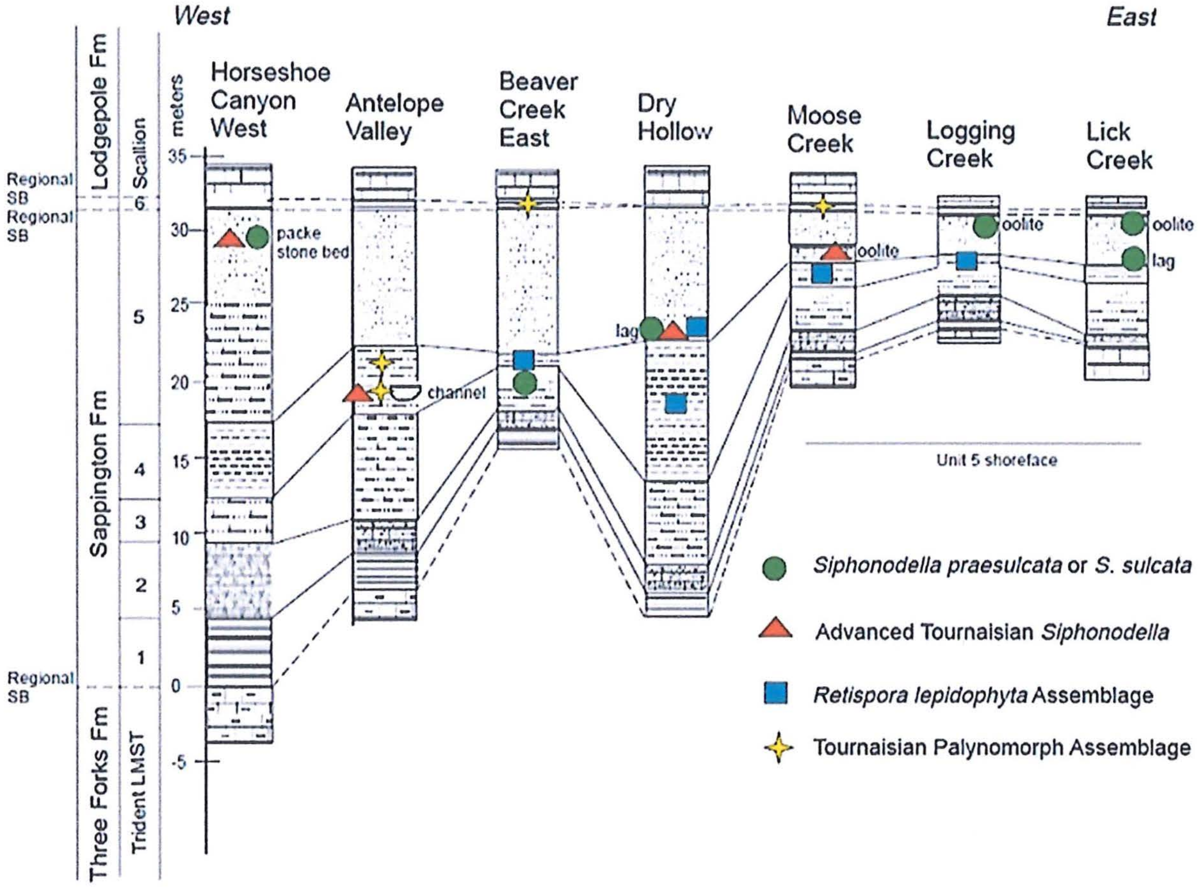

**Fig. 5.** Conodonts versus palynomorphs applied to establish the correlation of the Sappington Formation in Montana, USA (DI PASQUO et al. 2021, 2022; DI PASQUO & STREEL 2022b).

## 6. Conclusions

The present Tournaisian spore zones are inappropriate for defining the DCB, LN, and VI, and possible characteristics are poorly understood or rarely present (like, for instance, *Bascaudaspora mischkinensis*). The latest Famennian limit LL/LE is easier to use and would have the advantage of dating the first Carboniferous glacial episodes.

The first glacial period is of late Famennian age. It is interpreted from the strata of Brazil, Bolivia, and Peru, where ice sheets and alpine glaciers reached coastal and marine settings.

The co-occurrence of the reduction of size (minor subspecies of *Retispora lepidophyta* = biometric zone 7 of MAZIANE 1999), the reduction of percentage of *Retispora lepidophyta,* i.e., their first extinction step at least, and the "*tener* effect" with the first glacial episode suggests some relation of causal effects. The proximity of the first occurrence of the Foraminifer *Quasiendothyra kobeitusana* might be of great help for correlation with Russia and China, as well as the first occurrence of the Acritarch *Gorgonisphaeridium winslowii*, which is also used in North America.

The co-occurrence of a new wall structure (the *Indotriradites* concept), better known during the Mississippian, but present with *Siphonodella praesulcata* in the Uppermost Famennian Sappington Formation in Montana, USA, should give more argument to those who have proposed to define a new DCB within the Hangenberg Event. Further work is needed to determine if conodont morphotypes of the same species/lineages and key spore species, especially *R. lepidophyta*, are a consequence of sedimentary mixtures due to reworking the latest Famennian in Early Mississippian deposits.

## 7. Acknowledgments

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