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THE MIOSPORES OF THE WESTPHALIAN C / WESTPHALIAN D TRANSITION IN THE CAMPINE BASIN (BELGIUM) IN THE CONTEXT OF THE MACROFLORA ZONATIONS

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(2 figures, 4 tables)

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ABSTRACT. The occurrence of selected miospores and a few macroplants used for the biostratigraphy of the Westphalian C and D, is commented in the context of the lithostratigraphy of the Campine Basin (Belgium). Their morphology and stratigraphic significance are compared with their occurrence in other European and North American basins. The controversial discontinuity in the transitional Westphalian C-D strata of the Campine Basin is not confirmed.

KEYWORDS. *Torispora, Thymospora, Neuropteris ovata, Lobatopteris vestita*, plant macrofossils

1. Introduction

The Westphalian C (Bolsovian) and Westphalian D (? Asturian after Wagner et al., 2002) form traditionally the latest units in the coal measures group of the Campine Basin. With reference to the ICS Geologic Time Scale, they belong to the Middle Pennsylvanian Moscovian Stage (Gradstein et al., 2004).

Stratigraphic terms used in the Belgian Coal Measures Group present a duality between litho- and chronostratigraphy, which is due to the fact that synchronous marine horizons are at the same time lithostratigraphic markers in a rather monotonous sequence with cyclically recurring paleoenvironments. The principal application was for seam to seam correlation within collieries and between the coal districts at the national and western European scales. From the identification of as many marker horizons as possible evolved the global subdivision of the Coal Measures. The initial subdivision of the Coal Measures Group is basically a lithostratigraphic subdivision which parallels the chronostratigraphic scale and subdivision of the Westphalian A, B, C and D. The Campine mining map presents such a correlation between official sections at the colliery level and all exploration boreholes (Delmer, 1963).

The lithostratigraphic strata corresponding to the Westphalian C and lowermost part of Westphalian D are assigned to the Flénu Formation, subdivided in three members (Delmer et al., 2002):

- Meeuwen Member, with Maurage = Aegir Marine Band at its base,
- Wasmes Member,with the coal seam containing tonstein Hagen 1 as its base,
- Neerglabbeek Member, with the weakly marine 'Geisina' band overlying the coal seams with the Nibelung tonsteins as its base.

The maximum thickness of the Flénu Formation in the Campine Coal Basin attains 950 m.
The overlying Neeroeteren Formation, assigned to the Westphalian D, is marked by the onset of coarse fluvial sandstones, building a braided channel complex. Upwards, finer grained sediments tend to become predominant again. The thickness of the Neeroeteren Formation penetrated in borehole KB146 is 300 m but it may attain 500 m, taking into account a recent borehole Opitter 48E294, or maximum 700 m, taking into account seismic prospecting data.

2. The base of the Westphalian D as defined by the plant macrofossils.

The definition of the base of the Westphalian D remains (Laveine, 1977; Cleal, 1984, 1997; Wagner et al., 2002), a subject of discussion and, because this chronostratigraphic subdivision applies only to continental beds at regional, western European scale, it is of low concern for international congresses which are focusing on marine stratotypes.

The traditional limit, based on the first occurrence of *Neuropteris ovata* as originally defined in the limnic basin of Saarland, has been challenged. Cleal (1984), for instance, suggested to use the base of the acme of the "group of species allied to *Neuropteris ovata"*. The use of plant macrofossils to characterise the base of the Westphalian D is subject to caution. The criteria presence/absence is of course poorly reliable when applied to a very small number of data. Furthermore the plant macrofossils are obviously strongly linked to their ecological habitats in the continental environment. The chances of preservation are highly variable and depend on factors such as groundwater level in the floodplain and shifting drainage patterns.

Dicksonites plueckenetii	*Pecopteris miltonii*	*Lobatopteris vestita*	*Mariopteris muricata*	*Neuropteris ovata*
				(cf) 809.80m
840m			839.40m	(aff) 839.40m
			846.45m	(aff) 846.45m
				(aff) 1096-1099m
		1172.70m		
	1178.70m (?)	1178.70m (?)		
1180.85m				
1190.85m				

Table 1: New taxonomic identifications of macroplants of late Westphalian D age found in well KB 146 after van Amerom & van Tongeren (2002) concern a representative but incomplete collection of corehole samples, conserved at the Geological Survey of Belgium and originally described by Erik Houllebergs in Dusar & Houllebergs (1981). With respect to the key taxa and occurrences mentioned in van Amerom & van Tongeren (2002, fig. 3) the following comparison with the original dataset described by Houllebergs can be made:

- agreement on occurrences of *N. aff. ovata* (lowermost occurrence at 1066 m depth and not at 1096-1099 m as noted in van Amerom & van Tongeren, 2002). Note that *N. aff. ovata* presents a slight but consistent morphological modification compared to the specimens from the limnic Saar basin.

- agreement on occurrences of *Pecopteris (Asterotheca) miltonii (?)* and *Dicksonites (?) plueckenetii* around 1190 m depth (but not at 840 m depth as drawn by van Amerom in van Amerom & van Tongeren, 2002, fig. 2)

- *Lobatopteris vestita* not observed by Houllebergs (furthermore, no sample exists at depth 1172.70 m, as mentioned and drawn on fig. 2 by van Amerom);

- no *Mariopteris* observed anymore at depth 840 m by Houllebergs.

D. (?) plueckenetii occurs near the top Westphalian C (traditional subdivision) after Laveine (1989), which is lower than the generally admitted time range (from top Westphalian D or base Stephanian into the Permian). Houllebergs (1985, p. 229) mentions similar occurrences in the late Westphalian C of the South Limburg coalfield, based on a personal communication by van Amerom. Therefore the late Westphalian D age of the critical interval below *Neuropteris* aff *ovata* occurrence (and above the presumed hiatus) is based on the macroplants found at 1173m and 1179m where, however, *P. miltonii* identification is questionable.

Plant macrofossils are however the most spectacular fossils observed in the Coal Measures and have long been used in stratigraphical studies, despite serious correlation problems (Stockmans, 1962) and recurrence of macroflora associations (Dusar & Houllebergs, 1981). Paproth et al. (1983; following Stockmans & Willière, 1975) distinguished a megafloral assemblage zone in the Westphalian C, composed of *Linopteris subbrongniarti, Neuropteris rarinervis, N. scheuchzeri, Sphenophyllum emarginatum, Annularia sphenophylloides*. Paproth et al. (1983) characterised the basal strata of the Westphalian D by an assemblage zone, composed of *Neuropteris* aff. *ovata, Annularia sphenophylloides* and *A. pseudostellata*. Megaflora remains were however too rare to allow the description of typical associations in the Neeroeteren Sandstone Formation. Peculiar plant associations, such as the *Eusphenopteris striata* or *Annularia sphenophylloides* bands, observed above the first occurrence of *N.* aff. *ovata*, can be used for local bed-to-bed correlation, in a similar way as faunal bands, coal seam properties or features of facies transition, best derived from geophysical well logs.

The first occurrences of *Neuropteris* aff. *ovata* are found in the Flénu Formation at 60 to 40 m below the base of the Neeroeteren Formation, depending on the borehole (KB117 in Stockmans & Willière, 1975; KB146 in Dusar & Houllebergs, 1981). This first occurrence has been used to set the Westphalian C-D limit, especially since it was supported by miospore and megaspore zonations (Paproth et al., 1983). However, this concept has been questioned by van Amerom & van Tongeren (2002) allowing them not only to lower this boundary considerably but also to suggest that the upper part of the Upper Westphalian C and the Lower Westphalian D were absent in the well KB 146 (see Fig. 2). The indication for Upper Westphalian D in this well and its tectonic implication by van Amerom & van Tongeren (2002) are based on a very small number of macroplant specimens, often widely separated. Only five taxa are considered in that paper: *Dicksonites plueckenetii, Pecopteris miltonii, Lobatopteris vestita, Mariopteris muricata* and *Neuropteris ovata,* often represented by single specimens. But one specimen only of only one species (*L. vestita*) "definitely confirmed" (van Amerom & van Tongeren, 2002 p. 128) the assignment to Upper Westphalian D below the *Neuropteris* aff. *ovata* first occurrence (Table 1). We challenge this identification of *L. vestita* considering that small fragments of pecopteroid fronds can easily be confused (Josten & van Amerom 1999).

3. The base of the Westphalian D as characterized by miospores.

Compared to megaflora, miospores offer several advantages to define the base of the Westphalian D. They are present in very large numbers (several hundreds of thousands of specimens in one gram) in coals and shales containing organic matter, i.e. practically in almost every

	RUHR (Grebe 1972)		GREAT BRITAIN (Smith & Butterworth 1967)		CAMPINE (Somers 1971)		NORTH FRANCE (Loboziak 1971)	
Westph. D or C	Dorstener Sch.	VII	Upper Coal Measures	XI	Z. de Neeroeteren	SC4b	Ass. de Bruay	SN5
Westph. C	Dorstener Sch.	VII	Upper Coal Measures	X	Z. de Neeroeteren	SC4a	Ass. de Bruay	SN4
Westph. C	Dorstener Sch.	VI	Middle Coal Measures	IX	Z. de Neeroeteren	SC3d/c	Ass. de Bruay	SN3
Westph. C	Dorstener Sch.	V	Middle Coal Measures	IX	Z. de Meuwen	SC3c	Ass. de Bruay	SN3
	Marine band		**Marine band**		**Marine band**		**Marine band**	
Westph. B	Horst. Sch	IV	Middle Coal Measures	IX	Z. d' Eikenb.	SC3b	Ass. d' Anzin	SN3

Table 2: Comparison of the miospore zonations in several paralic coal basins in Western Europe after Somers (1971), unmodified (SC4a = SF subzone; SC4b = OT zone). Punctate line = *Thymospora* first occurrence / Interrupted line = *Torispora* base of epibole

random sample selected. In coals, they reflect the local site of biomass production but their large number gives a synthetic view of the whole plant assemblage, not just of one or two taxa. In shales, their very small size and their resistance to oxidation allow distribution at much greater distances than the plant macrofossils, and thus there is a mixing of miospores with those coming from other ecosystems. Their dependence on local facies is therefore reduced. However, in continental deposits, in contrast to marine deposits where the mixing of sources is at a maximum, zonation of miospores is often based on assemblage-zones, rather than on interval-zones of single species.

Miospore zonations of the Westphalian C – Westphalian D interval have been intensively studied for more than forty years in several paralic coal basins in Western Europe (Table 2).

Within this context, Somers (1971) established a miospore zonation of the Campine coal beds, emphasizing the quantitative aspect of the assemblages (e.g. base of *Torispora* acme, *Thymospora* first occurrence). No important changes have affected this zonation, which was

KB 169		KB 172		KB 161		KB 168	
Coal seam	*Torispora* %	Coal seam	*Torispora* %	Coal seam	*Torispora* %	Coal seam	*Torispora* %
		1b	*6.6*			2	*5.2*
		3a+3b	*0.4*	10	*X*	5	*2.2*
		5	*7.6*	11	*2.4*	9	*0.4*
		6	*6.4*	12	*6.8*	10	*6.6*
		7	*2.2*	13b	*3.4*	12 et 13	*1.8*
		9	*0.4*	14	*10.6*	14	*16.0*
2b+3	*3.6*	11	*3.8*	15	*3.0*	15	*3.2*
4	*0.8*	12	*0.6*	16	*10.2*	18	*3.6*
5	*1.0*	13	*3.0*	17	*3.6*	23b	*6.8*
6a à f		15 a+b+c	*3.6*	19b	*1.6*	27	*0.6*
7	*0.2*	16	*2.0*	20	*3.2*	32	*4.6*
9	*2.6*	20	*1.0*	22		33	*2.8*
10	*3.2*	23	*4.0*	23	*0.2*	36	*5.4*
11	*8.6*	24	*3.8*	24	*0.4*	37	*2.2*
12	*10.6*	25	*5.6*	25	*15.8*	38	*1.4*
13	*1.2*			26	*1.6*	40a	*3.2*
14	*4.0*			29	*X*	41	*1.2*
15	*1.4*			31	*15.0*	44a	*X*
16	*10.8*			32	*3.8*		
17a à d	*0.3*			33	*X*		
				35	*4.2*		
				36	*3.2*		
				37	*8.8*		
				39	*16.4*		
				40	*6.8*		
				41	*1.0*		
				44	*1.6*		

Table 3: Percentages of miospore *Torispora* in four wells in the Campine Basin, after Somers (unpublished). Punctate line = approximate base of the OT Zone

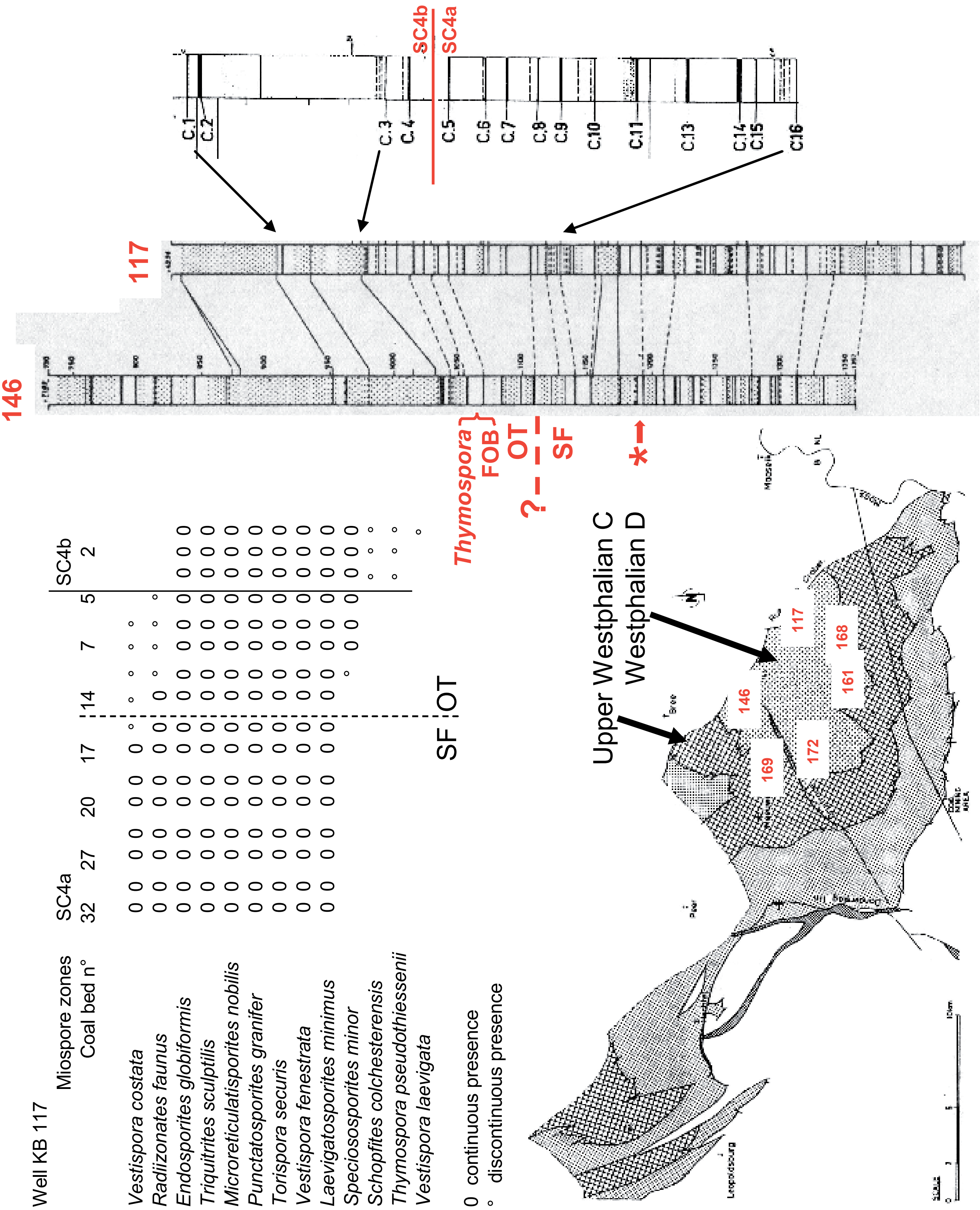

Figure 1: Location of wells studied in the Campine Basin and correlation between wells KB 117 and KB 146. Characteristic miospores of zones SC4a and SC4b in well KB 117 (Somers 1971).
The star in KB 146 log indicates the base of Late Westphalian D after van Ameron & van Tongeren (2002).

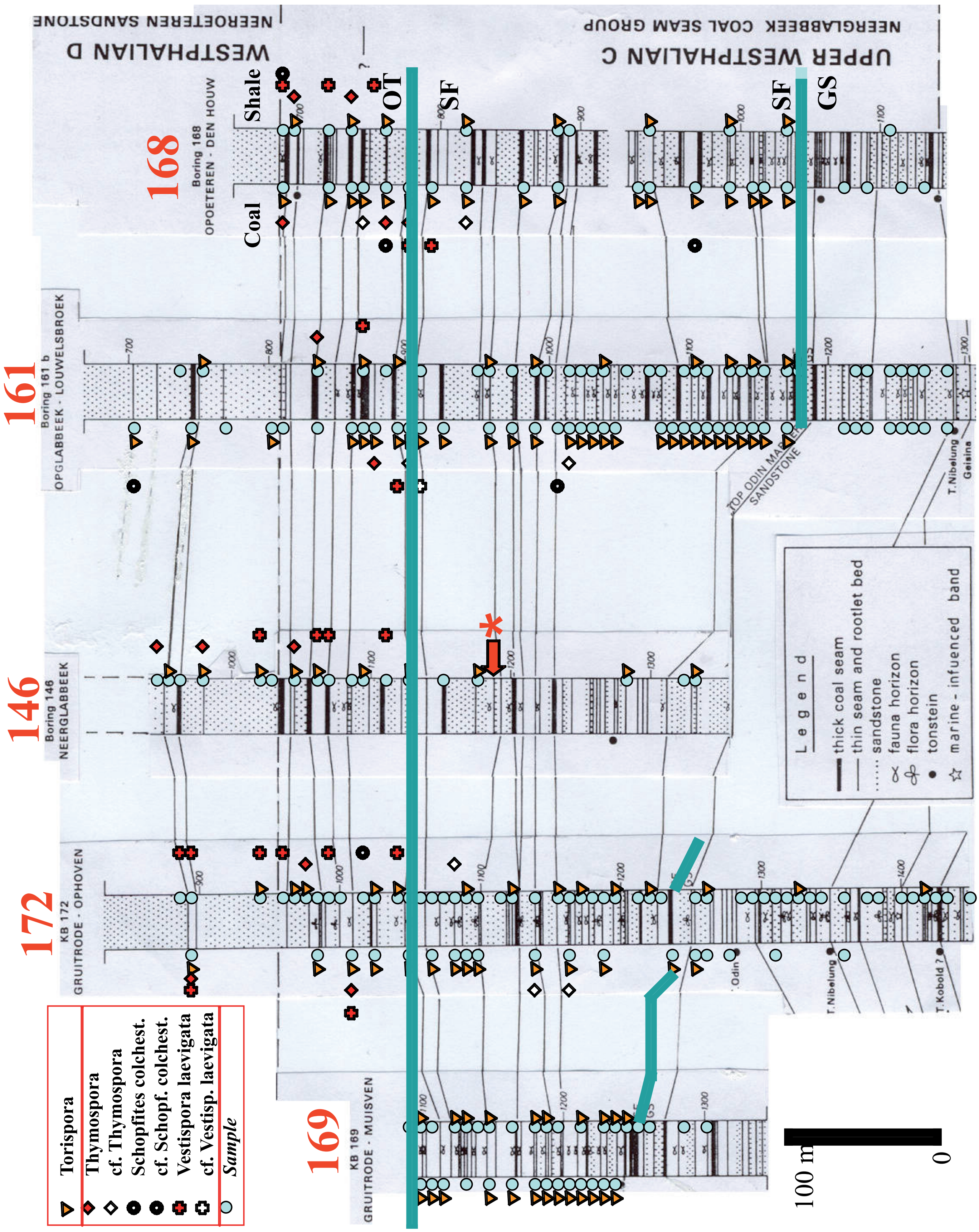

Figure 2: Palynology of SF and OT Zones in wells KB 146, KB 161, KB 168, KB 169, KB 172.
Miospores on the left side of each log were isolated from coals, on the right side, from shales.
GS = *Punctatosporites granifer-Triquitrites sculptilis* Subzone of the SL or *Torispora securis-T.laevigata* Zone,
SF= *Torispora securis-Vestispora fenestrata* Subzone of the SL or *Torispora securis-T.laevigata* Zone,
OT = *Thymospora obscura—T. thiessenii* Zone.
The red star in KB 146 log indicates the base of Late Westphalian D after van Ameron & van Tongeren (2002).

applied subsequently to the exploration boreholes drilled in the period 1979-1988, on coals by Y. Somers and on shales by M. Streel (most in unpublished reports). However, the biostratigraphical nomenclature has been redefined by Streel & Somers in Paproth et al. (1983). The SC4a Subzone of Somers (1971) corresponds now to the SF Subzone (*Torispora securis-Vestispora fenestrata* Subzone of the *Torispora securis-T.laevigata* SL Zone of Clayton et al. (1977), the SC4b Subzone of Somers (1971) to the *Thymospora obscura—T. thiessenii* OT Zone of Clayton et al. (1977).

Discussing the base and the miospore content of the SF Subzone (SC4a of Somers 1971) is beyond the scope of the present paper. Defined by the base of the *Torispora* epibole (Alpern 1971) or acme, this limit is known "worldwide" within the Westphalian C. The *Torispora* producing pecopterid tree ferns (Lesnikowska & Willard, 1997) presumably favoured mineral-poor, ombrogenous, raised mire conditions, similar to those preferred by tree ferns producing the spore *Thymospora* (Mahaffy, 1988). Frequently common to occasionally abundant in upper Westphalian C coal seams, *Torispora* may be rare or virtually absent in shales of the same age (Dusar et al., 2000). This is probably the result of some sedimentary sorting effect on these miospores which, being heavier than others (due to their thick crassitate exine), are not transported by running water far from their production area (see Fig. 2 for comparison of *Torispora* in coal and shales and Table 3 for the quantitative record of *Torispora* in coal seams).

Defining the base of the OT Zone needs more attention. The progressive change from SF Subzone to the OT Zone is particularly obvious in well KB 117. The progressive disappearance of *Vestispora costata* and *Radiizonates faunus* is matched by the progressive appearance of *Speciososporites minor, Schopfites colchesterensis, Thymospora pseudothiessenii* and *Vestispora laevigata* (Fig 1). Focus (base of SC4b at coalbed 4) was made by Somers (1971) on *T. pseudothiessenii* which first occurrence (FOB) in KB 146, based on lithological correlation, is slightly above the first occurrence of *Neuropteris* aff. *ovata* but the base of the OT Zone in KB 146 can as well be taken at a lower level at the first occurrence of *V. laevigata* (see Fig. 2).

A synthetic view of miospore distribution in five wells (including KB146) is given on Fig. 2. Miospore distribution is coherent with the coal-bed correlation proposed by Dusar (1989), the SF/OT transition being more or less parallel to these correlation lines. The lower part of the OT Zone in these five wells is characterized by the irregular occurrence of rare *Thymospora pseudothiessenii, Schopfites colchesterensis, Vestispora laevigata* or related taxa (see "cf." in Fig. 2 legend). The significance of these irregular and rare occurrences needs to be discussed with more detail.

Comparing the original material of the 8 described species of *Thymospora,* Alpern & Doubinger (1973) retained only 3 distinct species (*T.thiessenii*, the smallest one, *T. obscura*, with the most circular amb and *T. pseudothiessenii*, with the coarser ornamentation). In addition they concluded that all transitions existed between these 3 species often found mixed in the same stratigraphic horizon. Nowadays, one would apply to these three interconnected species the Morphon concept of Van der Zwan (1979): a *T. pseudothiessenii* Morphon. It occurs in northern France (SN5 in Loboziak, 1971) and possibly in the Ruhr (upper Zone 7 in Grebe, 1972). Smith (1987) stated in Great Britain (Oxfordshire) that although the coarse forms are more likely to be found in seams above the epibole of the genus, the species (*T. pseudothiessenii sensu* Alpern & Doubinger 1973) can no longer be regarded as having stratigraphic significance within the Westphalian D. However the *Thymospora (pseudothiessenii* Morphon) epibole base (Table 4) is a widely reported event of biostratigraphic significance occurring in mid Westphalian D times (Peppers, 1985 and Smith, 1987), for instance in the SL1 Zone of the Lorraine Basin (Alpern et al. 1969), but not recorded in the Campine Basin.

Kosanke (1950) describes two species of *Schopfites, S. dimorphus* and *S. colchesterensis,* the latter differing in its slightly smaller size and shorter and less closely spaced distal projections (Smith & Butterworth, 1967). The

MIOSPORE ZONATION		PLANT MACROFOSSIL ZONATION		
CAMPINE (Somers 1971)	LORRAINE (Alpern *et al.* 1969)	SAARLAND (Cleal *et al.* 2003)		Ages
		ZONES	SUBZONES	
	Ass. de La Houve SL1	*L. vestita.*	*D. plueckenetii.*	late Late W.D
	Ass. de La Houve SL1	*L. vestita.*	*L. micromiltoni*	early Late W.D
Z. de Neeroeteren SC4b	Ass. de La Houve SL2	*L. obliqua (bunburii)*		Early W. D.
	Ass. de La Houve SL2			Westph. C
Z. de Neeroeteren SC4a	Ass. de Schulzbach SL2			

Table 4: Comparison between miospore and plant macrofossil zonations, after Cleal et al. 2003.
Wide interrupted line = *Thymospora* base of epibole
Punctate line = *Thymospora* first occurrence
Narrow interrupted line = *Torispora* base of epibole

specimens of *Schopfites* observed (Table 2) in the Campine Basin (SC4b in Somers, 1971), the Ruhr (upper Zone 7 in Grebe, 1972) and northern France (SN5 in Loboziak, 1971) are even smaller than *S. colchesterensis* although they share with *S. dimorphus* or *S. colchesterensis* their other morphological characteristic. They probably all belong to the same taxon (*S. dimorphus* Morphon) which starts around the Westphalian C /Westphalian D transitional beds with the smallest forms, the coarser being more characteristic of the middle Westphalian D (Peppers, 1985).

Distinguished from other species of *Vestispora* by its thick, unornamented, or faintly ornamented, exoexine, *V. laevigata* is infrequent in the highest seams of Zone X and in Zone XI of Smith & Butterworth, 1967 in Great Britain (Table 2).

4. Conclusions

After having challenged the identification of the macroplant *L. vestita* in the transitional Westphalian C-D strata of the Campine Basin, we also see no reason to correlate the SC4b Subzone of the Campine Basin (Somers 1971) with the SL1 Zone of the Lorraine Basin (Alpern et al. 1969). Such correlation would be, however, the only possibility to correlate further with the macroflora zonation of the late Westphalian D (Cleal et al., 2003) established in the nearby Saarland Basin (Table 4). Therefore we challenge the discontinuity in the transitional Westphalian C-D strata of the Campine Basin suggested by van Amerom & van Tongeren (2002).

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References

ALPERN, B., 1971. Les divisions palynologiques du Westphalien supérieur et la limite Westphalien-Stéphanien. *In* M. Streel. & R. Wagner (eds), *Colloque sur la Stratigraphie du Carbonifère 1969*, Congrès et colloques de l'Université de Liège, 55 : 91-97.

ALPERN, B. & DOUBINGER, J., 1973. Les miospores monolètes du Paléozoïque. *in* B. Alpern & M. Streel (eds), *CIMP, Microfossiles organiques du Paléozoïque 6 : les spores.* Editions du CNRS, Paris.103 p.

ALPERN, B., CHOFFE, M. LACHKAR, G. & LIABEUF, J.-J., 1969. Synthèse des zonations palynologiques des bassins houillers de Lorraine et de Saar. Revue de Micropaléontologie, 11, 4 : 217-221.

CLAYTON, G., COQUEL, R., DOUBINGER, J., GUEINN, K.J., LOBOZIAK, S., OWENS, B. & STREEL, M., 1977. Carboniferous Miospores of Western Europe: illustration and zonation. *Mededelingen Rijks geologisch Dienst,* 29: 71 p.

CLEAL, C.J., 1984. The Westphalian D floral biostratigraphy of Saarland (Fed. Rep. Germany) and a comparison with that of South Wales. *Geological Journal,* 19: 327-351.

CLEAL, C.J., 1997. The palaeobotany of the upper Westphalian and Stephanian of southern Britain and its geological significance. *Review of Palaeobotany and Palynology,* 95: 227-253.

CLEAL, C.J., DIMITROVA, T. Kh. & ZODROW, E.L., 2003. Macrofloral and palynological criteria for recognising the Westphalian-Stephanian boundary. *Newsletter Stratigraphy,* 39, 2/3: 181-208.

DELMER, A., 1963. Carte des mines du Bassin houiller de la Campine. *Annales des Mines de Belgique*, 1963: 739-754.

DELMER, A.; DUSAR, M. & DELCAMBRE, B., 2002 – Upper Carboniferous lithostratigraphic units (Belgium). *In* P. Bultynck & L. Dejonghe, (eds.) Guide to a revised lithostratigraphic scale of Belgium. *Geologica Belgica,* 4/1-2: 95-103.

DUSAR, M., 1989. Non-marine lamellibranchs in the Westphalian C/D of the Campine coalfield. *Bulletin de la Société Belge de Géologie,* 98: 483-493.

DUSAR, M. & HOULLEBERGHS, E., 1981. De steenkoolverkenningsboring van Neerglabbeek (boring 146 van het Kempens bekken). *Annales des Mines de Belgique*, 1981-11: 913-1003.

DUSAR, M., PAPROTH, E., STREEL, M. & BLESS, M.J.M., 2000. Palaeogeographic and palaeoenvironmental characteristics of major marine incursions in Northwestern Europe during the Westphalian C (Bolsovian). *Geologica Belgica*, 3: 331-347.

GRADSTEIN, F.M., OGG, J.G.& SMITH, A.G., eds., 2004. A Geologic Time Scale 2004. Cambridge University Press, 589 pages.

GREBE, H., 1972. Die verbreitung der Mikrosporen in Ruhr Karbon von der Bochumer Schichten bis zu den Dorstener Schichten (Westfal A-C). *Palaeontographica B*, 140: 27-115.

HOULLEBERGHS, E., 1985. Paleobotanische studie van het Westfaliaan van het Kempens Bekken. KU. Leuven, unpublished Ph.D. thesis, 357 p.

JOSTEN, K.-H. & VAN AMEROM, H.W.J., 1999. Die Pflanzenfossilien im Westfal D, Stefan und Rotliegend Norddeutschlands. *Fortschrift Geologie Rheinland und Westfalia,* 39: 168 p.

KOSANKE, R.M., 1950. Pennsylvanian spores of Illinois and their use in correlation. *Illinois State Geological Survey, Bulletin,* 74: 128 p.

LAVEINE, J.-C., 1977. Report on the Westphalian D. *In*: Symposium on Carboniferous Stratigraphy. Special Publication, Geological Survey, Prague: 71-83.

LAVEINE, J.-C., 1989. Guide paléobotanique dans le terrain houiller Sarro-Lorrain. Houillères Bassin de Lorraine : 154 p.

LESNIKOWSKA, A.D. & WILLARD, D.A. 1997. Two new species of *Scolecopteris* (Marattiales), sources of *Torispora securis* Balme and *Thymospora thiessenii* (Kosanke) Wilson et Venkatachala. *Review of Palaeobotany and Palynology*, 95: 211 – 225.

LOBOZIAK, S. 1971. Les micro- et mégaspores de la partie occidentale du bassin houiller du Nord de la France. *Palaeontographica B*, 132: 127 p.

MAHAFFY, J.F., 1988. Vegetationa1 History of the Springfield Coal (Middle Pennsylvanian of Illinois) and Distribution Patterns of a Tree-Fern Miospore, *Thymospora pseudothiessenii*, based on Miospore Profiles. *International Journal of Coal Geology*, 10: 239-260.

PAPROTH, E., DUSAR, M., BLESS, M.J.M., BOUCKAERT, J., DELMER, A., FAIRON-DEMARET, M., HOULLEBERGHS, E., LALOUX, M., PIERART, P., SOMERS, Y., STREEL, M., THOREZ, J. & TRICOT, J., 1983. Bio- and lithostratigraphic subdivisions of the Silesian in Belgium, a review. *Annales de la Société géologique de Belgique*, 106 : 185-283.

PEPPERS, R.A., 1985. Comparison of Miospore Assemblages in the Pennsylvanian System of the Illinois Basin with those in the Upper Carboniferous of Western Europe. *In* P.K.Sutherland & W.L. Manger (eds), *Compte rendus of IX-ICC, 1979, Washington and Champaign-Urbana, vol. 2: biostratigraphy*. Southern Illinois University Press, Carbondale: 483-502.

SMITH, A.H.V., 1987. Stratigraphic ranges of selected miospores in coal seams of Upper Coal Measures age in Oxfordshire and S.E. Warwickshire. *Journal of Micropalaeontology*, 6, 1: 21-37.

SMITH, A.H.V. & BUTTERWORTH, M.A., 1967. Miospores in the coal seams of the Carboniferous of Great Britain. *Special Paper Palaeontology,* 1: 324 p.

SOMERS, Y. 1971. Etude palynologique du Westphalien du Bassin de Campine et Révision du genre *Lycospora.* Thèse Doctorat en Sciences Botaniques, Université de Liège, 472 p.

STOCKMANS, F., 1962. Paléobotanique et Stratigraphie. Compte rendus of IV-ICC, 1958, Heerlen, 3 : 657-682.

STOCKMANS, F. & WILLIÈRE, Y., 1975. Sondage n°113 (Neerheide) et n°117 (De Hoeven) à Neeroeteren. *Geological Survey of Belgium Professional Paper* 1975/11 N. 124, 54 p.

VAN AMEROM, H.W.J. & VAN TONGEREN, P.C.H., 2002. An important hiatus in the youngest Westphalian C and earliest Westphalian D strata of the Campine Basin (northern Belgium). *Aardkundige Mededelingen*, 12: 127-130.

VAN DER ZWAN, C.J., 1979. Aspects of Late Devonian and Early Carboniferous palynology of southern Ireland. I. The *Cyrtospora cristifer* morphon. *Review of Palaeobotany and Palynology,* 28: 1-20.

WAGNER, R.H., SANCHEZ DE POSADA, L.C., MARTINEZ CHACON, M.L., FERNANDEZ, L.P., VILLA, E. & WINKLER PRINS, C.F. 2002. The Asturian Stage : a preliminary proposal for the definition of a substitute for Westphalian D. *In* Carboniferous and Permian of the World, L.V. Hills, C.M. Henderson & E.W. Bamber (eds), *Canadian Society Petroleum Geology*, Memoir 19: 832-850.

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