The Uppermost Famennian around the World
(definition, biostratigraphical and sedimentological context)

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A. The need of smaller chronostratigraphic units within the Famennian Stage have led authors around the world to use, for a long time, phrases such as lower, middle, upper or uppermost Famennian but, unfortunately, without any constant definitions. Definitions however are necessary to make progress in fields such as paleodiversity and biogeographic change with time. For that purpose, proposed substage boundaries should have a high degree of synchroneity in different regional entities and facies belts.On the other hand, the great number of Famennian sedimentary sequences and events (among others : *Cheiloceras*, Condroz, Enkeberg, *Annulata*, Dasberg, Epinette, Hangenberg Events), recognized in many regions around the world, offers also many opportunities for Substage boundaries.

B. A fourfold subdivision would be appropriate (see the list of 43 scientists from 15 countries supporting this suggestion, a list inadvertently omitted in SDS Newsletter 17, updated and reproduced here as appendix 1).). If the 5 Ma Frasnian is to be subdivided into 3 substages, the 10 Ma Famennian might well be subdivided into 4 or even 5 substages allowing approximately equal subdivisions of the Stage (see for instance the text-figure in Sandberg, Ziegler & Morrow 2000).

C. In the highest part of the Famennian, one unformal chronostratigraphic unit has been used, for a long time and is still used in many countries, named Etroeungt Zone or Strunian, or simply, uppermost (or latest) Famennian (see the non-exhaustive reference list of papers using this unit, presented by D. Brice). The lower boundary of this unit were considered, in large countries around the world and for a long time, as the official lower boundary of the Carboniferous System, being so considered as a major limit. It has however to be properly defined because having received different interpretations within the Middle and Upper/Late *expansa* Zones interval

D. Several faunal and floral bio-markers are available for characterization and for correlation of convenient stratigraphic levels in the late to latest Famennian time-range. Eighteen bio-markers belonging to acritarchs, ammonoids, conodonts, foraminifers, miospores and ostracods are grouped in 10 biostratigraphic levels in Table 1, with emphasize on the Middle and Upper/Late *expansa* Zones interval. In the type late and latest Famennian (Fa2c /Fa2d/Tn1a) of eastern Ardenne (Belgium) for instance, 9 of these bio-markers are present in succession.

E. Sedimentary sequences and events are now defined in the eastern Ardenne (Thorez & Dreesen, in prep.) and can be correlated with other parts of the world (Figure 1). For instance, the eustatic rise (at level 1) which is the most significant onlap interrupting general Famennian regression in western United States (fourth transgression, Sandberg et al. 1989) is matched by the «Beverire» marine incursion in the eastern Ardenne. The fifth transgression in western United States corresponds to the «Fontin Event» (between levels 2 and 3), and the sixth transgression, to the «Epinette Event» (at level 3). The fifth and sixth transgressions in western USA are minor pulses compared to the fourth one. On the contrary, transgressions in eastern Ardenne (the «Epinette Event») as well as in New York and Ohio (central and eastern USA, in Upper Cleveland and Lower Bedford beds, after House 1985) are more conspicuous upwards.

F. In eastern Ardenne (Chanxhe section), the maximum of flooding is reached soon after the «Epinette Event» and, slowly, the regressive trend starts in a Highstand Systems Tract (HST in Van Steenwinkel, 1993) as demonstrated (Figure 2) by a quantitative study of ecologically significant miospores. A main changeover is at level 6c, (where happens also the abundant occurrence of miospore *Retispora lepidophyta* var. *minor*), also characterized by the first occurrence of the foram. *Quasiendothyra kobeitusana kobeitusana* (6a). Biostratigraphic levels 3 and 5 to 8 (bio-markers 5, 6a, 6c, 7b, 7c, 8) occur in succession at Chanxhe which is a key section for neritic facies.

G. Correlation with other neritic facies.

   a. Correlation with the Avesnois (the type Etroeungt, in northern France) by bio-markers 3 (*R. lepidophyta* var *typica*) and 6a (*Quasiendothyra kobeitusana kobeitusana*) after Conil et al., 1964, Conil & Lys, 1980 and Sartenaer & Mamet, 1964. Additional interest is the first occurrence of foram. *Quasiendothyra communis radiata* and the related taxon *Quasiendothyra eokobeitusana* (bio-marker 4a), together with the first radiation of Rugosa taxa (Poty 1999)

   b. Correlation by foraminifers (Bio-markers 4a and 6a) with southern China (Hunan) after Hance 1996.

   c. Correlation by conodonts, foraminifers and miospores (Bio-markers 2, 3, 4a, 5, 6a, 6c, 7b, 8) with eastern Europe (Pripyat, Belarus) after Obukhovskaya & Kruchek (in press.) and with easternmost Europe (Timan-Pechora, Russia) after Durkina (in press.). See also **Table 2** by Durkina, Dreesen & Streel.

   d. Correlation by acritarchs, conodonts and miospores (Bio-markers 5, 6c, 7a, 7b, 7c) with the upper Mississippi Valley (USA) after Sandberg, Streel & Scott (1972) and with the Michigan Basin (USA) after Gutschick and Sandberg (1991)

H. Correlation between neritic and pelagic facies

Neritic and pelagic faunas are only known, in a same section, in the Sudetes Mts. (Poland) where, in the ancient quarry of Wapnica Hill near Dzikowice (former Kalkberg near Ebersdorf), forams (4a in the Main Limestone and 6a in the lower part of the «Clymeniid Limestone», after Gorecka & Mamet, 1970) and rare corals and stromatoporoid (Mistiaen & Weyer, 1999) occur with ammonoids, trilobites, conodonts and entomozoid ostracods. (Work in progress on conodonts by J. Haydukiewice and on corals by B. Berkowski). The «Clymeniid Limestone» is well dated (6d) by ammonoids as belonging to the lower/middle Wocklumeria genozone (Kalloclymenia subarmata Zone and lower part of the Parawocklumeria paradoxa Zone).

I. Correlation within pelagic facies

a. Correlation by conodonts (1, 2, 5, 7a, 9), entomozoacean (4c) and Thuringian ecotype (4b and 7d) ostracodes in Germany (after Groos-Uffenorde et al., 2000)

b. Correlation by conodonts (1, 2, 5, 6b, 7a, 9) and ammonoids (6d) with the chrono-stratigraphic German Substages (after Korn & Luppold, 1987, Becker & House, 2000 and Korn, 2000)

c. Correlation by conodonts (1, 2, 5, 6b, 7a, 9) in the Pyrénées Mountains (after Barnolas & Chiron, 1995)

J. Selection of a stratigraphical level and bio-marker to characterize the base of an uppermost Famennian.

Table 3 summarizes the data given from §F to §I. Level 5, the lower boundary of the Upper/Late expansa Zone, have been proposed by Streel et al., 1998, to characterize the base of an uppermost Famennian. However, obviously, level 6 offers more possibilities of correlation in both neritic and pelagic facies than level 5. Biomarker 6b, entry of conodont Palmatolepis gracilis gonioclymeniae, might be selected to define the base of the uppermost Famennian. Level 6b approximately matches an old Strunian definition (level 6a) and a new Wocklumian definition (6c).

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Table 1 : Characterization by 18 bio-markers of 10 biostratigraphic levels, from the base of the conodont Lower/Early *expansa* Zone to the Hangenberg Event, with emphasize on the Middle and Upper/Late *expansa* Zones interval

(the use of the same number for several bio-markers indicates that their respective stratigraphic position is uncertain but close).

*10 Entry of miospore *Verrucosisporites nitidus* (base of *R. lepidophyta-V.nitidus*-LN Zone) (Higgs & Streel 1994). Base of the Hangenberg Event sensu Walliser (1984)

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*9 Extinction of conodont *Palmatolepis gracilis gonioclymeniae*, lower boundary of the Middle *praesulcata* Zone (Ziegler & Sandberg 1984)

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*8 Entry of miospore *Indotriradites explanatus* (base of the *R. lepidophyta-I. explanatus*-LE Zone) (Maziane et al. 1999).

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*7a Entry of conodont *Siphonodella praesulcata*, lower boundary of the Lower/Early *praesulcata* Zone (Ziegler & Sandberg 1984).

*7b Entry of miospore *Tumulispora malevkensis* (Maziane et al. 1999).

*7c Entry of acritarch *Gorgonisphaeridium winslowiae* (Maziane & Vanguestaine 1997)

*7d Base of Thuringian ecotype ostracode zones 8 in Groos-Uffenorde et al. (2000, fig. 5) (see also Blumenstengel 1997)

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*6a Entry of foraminifer *Quasiendothyra kobeitusana kobeitusana* (Df3ε Zone)

*6b Entry of conodont *Palmatolepis gracilis gonioclymeniae* (Ziegler & Sandberg 1984).

*6c Abundant occurrence of miospore *Retispora lepidophyta* var. *minor* (Streel 1966, Maziane et al.,in press)

*6d Entry of ammonoid *Kosmoclymenia sublaevis* replacing (Korn & Becker, in preparation) the rather rare *Sphenoclymenia brevispinosa* to characterise the lower boundary of the Wocklumeria Stufe-VI (Becker & House 2000)

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*5 Entry of conodont *Bispathodus ultimus*, lower boundary of the Upper/Late *expansa* Zone (slightly below the base of

			Forams	Forams	Miospores	Miospores	Conodonts	Conodonts	Regional subdivision	Regional subdivision
			Timan-Pechora	West. Eur.	Timan-Pechora	West. Eur.	Timan-Pechora	Western Europe	Pripjatsky Depression	Russian Platform
Nijmylga-1	Zap.Sopljas'	Yeshajr-835 Yeshajr-825								
412 - ? m	362.3 - 373.5 m	285 - 286 m	8: Q. deunata - Q. kob. gradis Zone		8: LE Zone	LE	8: Middle expansa to Middle praesulcata	Early praesulcata Z.	8: Borovskie beds (upper part)	
432 - 436 m			6α-6c: Q. kobeitusana Zone	Dl'3epsilon	6α-6c: (LMb Zone)	LL	6α-6c: Middle to Late expansa	Late expansa Z.	6α-6c: Borovskie beds (lower part)	Horwaclik beds (lower part)
452 - 464 m		431 - 433 m	4α-5: Q. eokobeitusana (=Q. radiata) Zone	Dl'3delta	4α-5: LL Zone	LL	4α-5: Middle to Late expansa	Middle or Late expansa Z.	4α-5: Strishalik beds	Osnezkie beds (upper part)
518.3 - 521.8 m			Q. regularis Zone	Dl'3gamma	LV Zone	LL			Starobinskie beds (upper part)	Osnezkie beds (middle part)
518.3 - 521.8 m		433 - 437 m	3: Q. regularis Zone	Dl'3gamma	3: LF Zone		3: Middle expansa	Middle expansa Z.	3	Osnezkie beds (lower part)
923 - 933 m		546.7 - 549.7 m	2: Q. regularis Zone	Dl'3gamma	2: R. L. tenera - L. minor		2: Middle expansa, at least	Middle expansa Z.	2: Starobinskie beds	Osnezkie beds
946 - 953.7 m			Q. c. com. - Q. b. crassa Subzone		VF Zone	VCo	(postera to early expansa ?)			
953.7 - 958 m			Q. c. com. - Q. b. crassa Subzone		VF Zone	VCo			Ijbovskie beds	Kudejarovskie beds
958 - 963 m			Q. c. rowachi - Q. b. bella Subzone		VF Zone	VCo	Early postera to early expansa	postera Zone		

the former Middle *costatus* Zone) (Ziegler & Sandberg 1984). Proposed as the lower boundary of an Uppermost Substage of a fourfold Famennian (Streel et al. 1998). *B. ultimus* being unknown in the Great Basin and Rocky Mountain regions of North America, the lower boundary of the Upper/Late *expansa* Zone was defined, there, by the lowest occurrence of *Pseudopolygnathus marburgensis trigonicus, Polygnathus vogesi, or Protognathodus meischneri* (Sandberg 1979, p.97)

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*4a Entry of foraminifer *Eoendothyra communis radiata* (Df3δ Zone) and of the related taxon *Quasiendothyra eokobeitusana*.

*4b Base of Thuringian ecotype ostracode zones 7 in Groos-Uffenorde et al. (2000, fig. 5) (see also Blumenstengel 1997)

*4c Base of entomozoacean ostracode upper *hemisphaerica-dichotoma* in Groos-Uffenorde et al. (2000, fig. 3)

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*3 Entry of miospore *Retispora lepidophyta* var. *typica*

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*2 Entry of conodont *Bispathodus aculeatus*, lower boundary of the Middle *expansa* Zone (slightly above the base of the former Lower *costatus* Zone) (Ziegler & Sandberg 1984).

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*1. Entry of conodont *Palmatolepis gracilis expansa*, lower boundary of the Lower/Early expansa Zone (base of the old Upper *styriacus* Zone) (Ziegler & Sandberg 1984), proposed as the lower boundary of an Upper Substage of a threefold Famennian (Ziegler & Sandberg 1997, Sandberg & Ziegler 1998)

		F.	Ga	Gb	Gc	Gd	H	Ia	Ib	Ic
V. nitidus	10									
Middle praesulcata	9							X	X	X
I. explanatus	8	X			X					
Early praesulcata	7a					X		X	X	X
T. malevkensis	7b	X			X	X				
G. winslowiae	7c	X				X				
Thur.ecotype 8	7d							X		
Q. kob. kobeitusana	6a	X	X	X	X		X			
P. grac. gonioclymeniae	6b								X	X
R. lepidophyta minor	6c	X			X	X				
K. sublaevis	6d						X		X	
Late expansa	5	X			X	X		X	X	X
E. com. radiata	4a			X	X		X			X
Thur.ecotype 7	4b							X		
Upper hem.dichotoma	4c							X		
R. lepidophyta	3	X	X		X					
Middle expansa	2				X			X	X	X
Early expansa	1							X	X	X

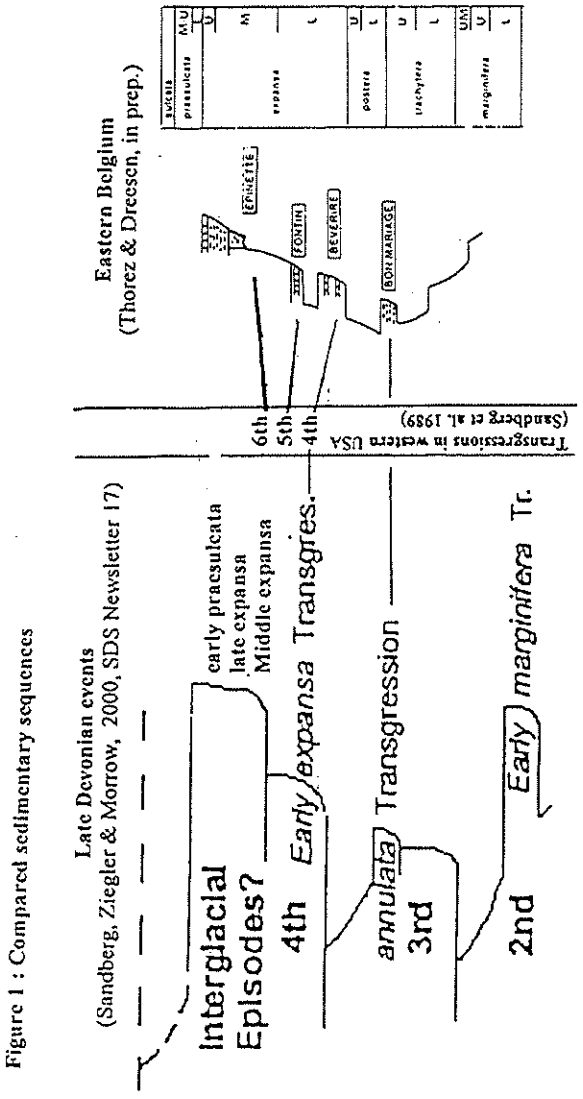
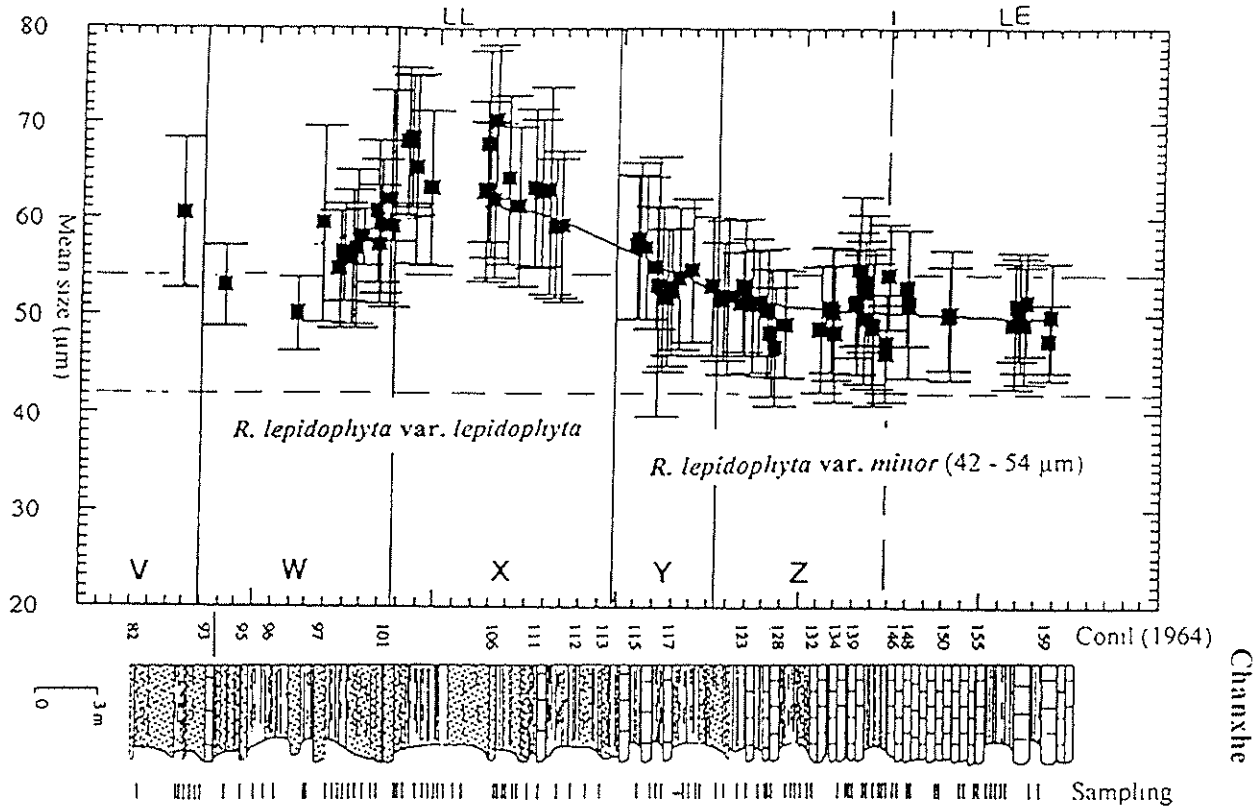


Figure 1 : Compared sedimentary sequences



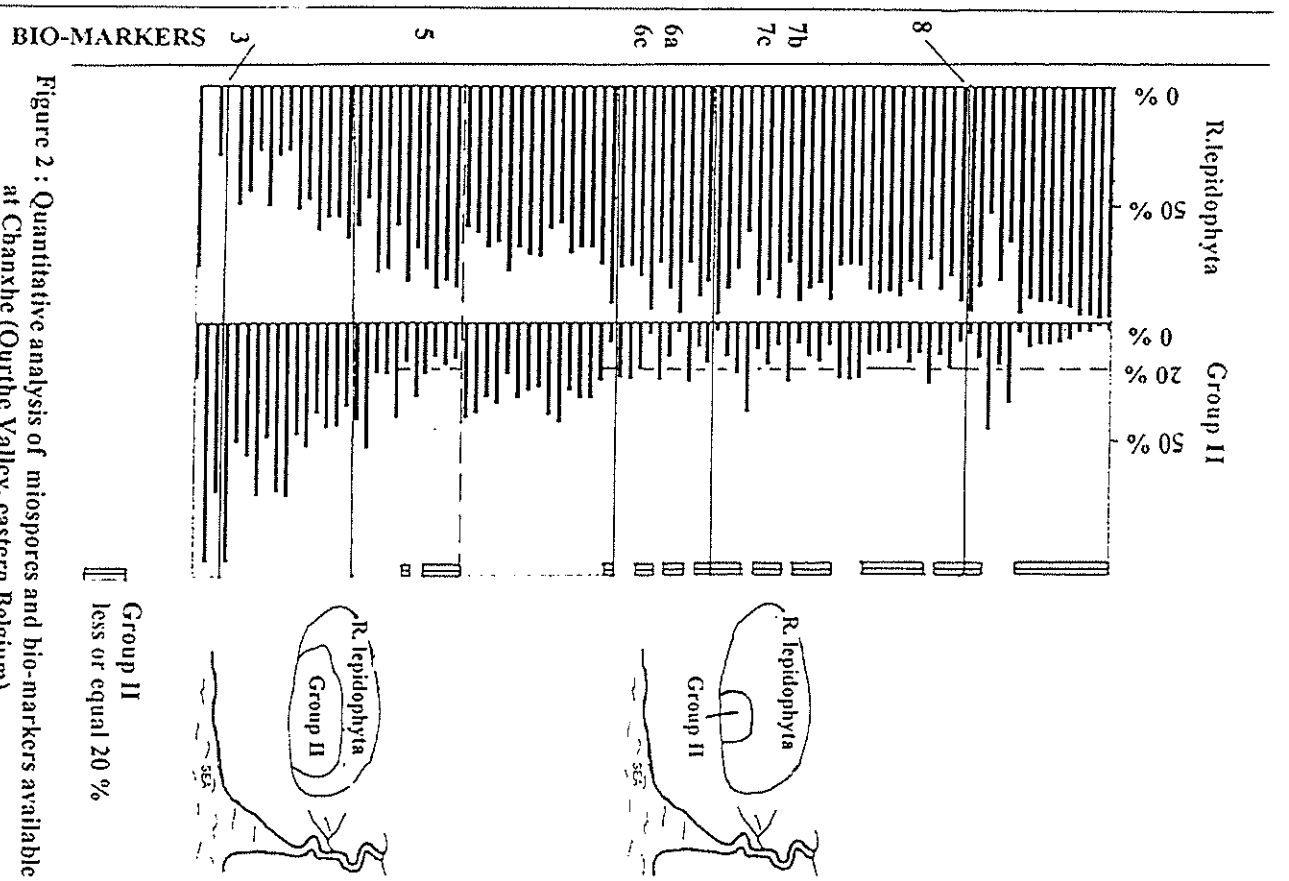


Figure 2 : Quantitative analysis of miospores and bio-markers available at Chanxhe (Ourthe Valley, eastern Belgium)

APPENDIX 1 : LIST OF PARTICIPANTS TO THE UPPERMOST FAMENNIAN WORKING SUBGROUP

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