Geol. Mag. **143** (*6*), *2006, pp. 829–857. © 2006 Cambridge University Press*
doi:10.1017/S0016756806002457 *Printed in the United Kingdom*

Upper Devonian and Mississippian foraminiferal and rugose coral zonations of Belgium and northern France: a tool for Eurasian correlations

EDOUARD POTY*, FRANCOIS-XAVIER DEVUYST† & LUC HANCE‡

*Service de Paléontologie animale, Département de géologie, Université de Liège, Bâtiment B18, Allée du 6 août,
Sart Tilman, B-4000 Liège, Belgium
†Department of Geology, Trinity College, Dublin 2, Ireland
‡Carmeuse Coordination Center, bd. de Lauzelles, 65, B-1348 Louvain-la-Neuve, Belgium

(*Received* 24 March 2005; *accepted* 31 January 2006)

Abstract – The radiation of early Carboniferous foraminifers and rugose corals following the Devonian–Carboniferous crisis offers the best tool for high-resolution correlations in the Mississippian, together with the conodonts in the Tournaisian, notably in the Namur–Dinant Basin. However, some of the guides are facies-controlled and an integrated approach combining biostratigraphy, sedimentology and sequence stratigraphy is critical to identify delayed entries, potential stratigraphic gaps and to avoid diachronous correlations. The main difficulty is in correlating shallow and deeper water facies at any given time. In existing zonations, the Viséan part of the scheme is always more detailed, reflecting the widespread development of shallow-water platforms in the early Viséan which created conditions more suitable for foraminifers and rugose corals over large areas. In contrast, the Tournaisian zones, less well documented, reflect unfavourable environmental conditions in the lower ramp (Dinant Sedimentation Area) and pervasive dolomitization of the inner ramp (Condroz and Namur Sedimentation Areas). Recent progress in understanding the Belgian early Carboniferous sequence stratigraphy and lithostratigraphy, and revision of the biostratigraphy of the key sections, strongly modify former biostratigraphic interpretations. Improvements mainly concern the latest Devonian, the late Tournaisian and the early Viséan. The late Devonian and the Tournaisian are equated with foraminifer zones DFZ1 to DFZ8 and MFZ1 to MFZ8 respectively. The Viséan correlates with zones MFZ9 to MFZ14. Zone MFZ15 straddles the Viséan–Namurian boundary and Zone MFZ16 is the youngest Mississippian zone. The rugose corals allow the recognition of ten zones, RC0 to RC9, covering the Strunian (late Famennian) to Serpukhovian interval. Discrepancies with former zonations are discussed. The Moliniacian Stage is emended to restore the coincidence between its base and that of the Viséan.

Keywords: Upper Devonian, Mississippian, Foraminifera, rugose corals, biostratigraphy.

1. Introduction

The Carboniferous Namur–Dinant Basin has been studied extensively since the late 18th century and is one of the best documented in the world. It is the type area for the Tournaisian and Viséan stages. The existing stratotype for the base of the Viséan is located in the Bastion section near Dinant (Figs 1, 2). Consequently, outcrops in southern Belgium and northern France have been used as worldwide references for the Mississippian Subsystem (Lower Carboniferous). The biostratigraphic framework is based mainly on foraminifer, conodont and rugose coral associations intensively studied respectively by Raphaël Conil, Maurice Lys and collaborators (Conil, Groessens & Pirlet, 1977; Conil *et al.* 1991; see Delmer & Hance, 1992 for a summary), Eric Groessens (Groessens, 1975; Webster & Groessens, 1991) and Edouard Poty (Poty, 1981, 1985). The last synthesis of the Franco-Belgian Basin biostratigraphy and biozones (foraminifers, conodonts, rugose and tabulate corals) was published in 1991 by Conil *et al.*

After a late Devonian regression which exposed the Brabant Old Land (Figs 1, 2), a south-facing homoclinal ramp developed on its margin during the early Tournaisian. As a result, similar facies are observed across the Namur–Dinant Basin, but formations are thinner with increasing depositional gaps northward. During the late Tournaisian and early Viséan, the ramp evolved progressively to a rimmed shelf, and to a flat-topped broad shelf of regional extension during the middle and late Viséan (Livian–Warnantian). By that time the shelf margin had migrated further southward and eastward and it is not preserved in southern

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* Author for correspondence: e.poty@ulg.ac.be

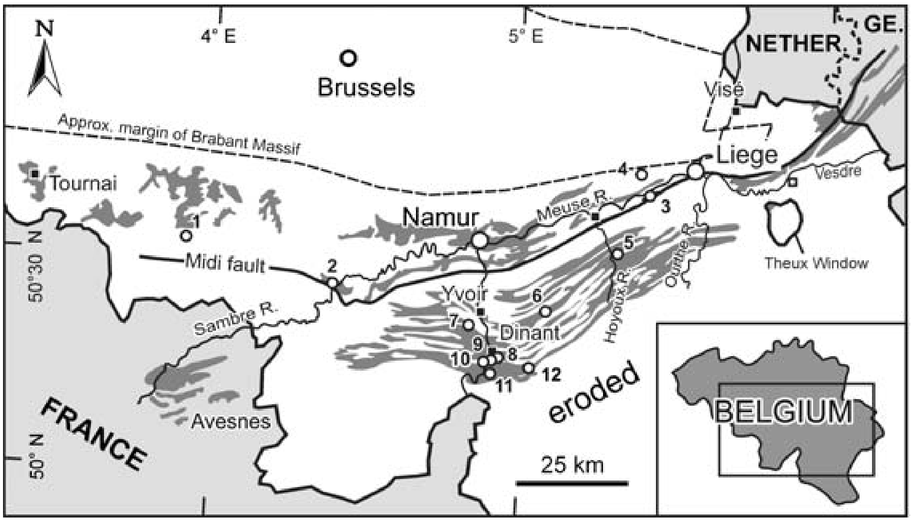

Figure 1. Distribution of Tournaisian–Viséan deposits (shaded areas) in Southern Belgium and neighbouring countries and localities mentioned in text. 1 – Saint-Ghislain drillhole; 2 – Landelies, Sambre river section; 3 – Engihoul quarry; 4 – Horion-Hozémont; 5 – Modave; 6 – Sovet; 7 – Salet; 8 – Bastion; 9 – Anseremme; 10 – Moniat; 11 – Freyr; 12 – Gendron-Celles station; R. – river; Nether – Netherlands; Ge. – Germany.

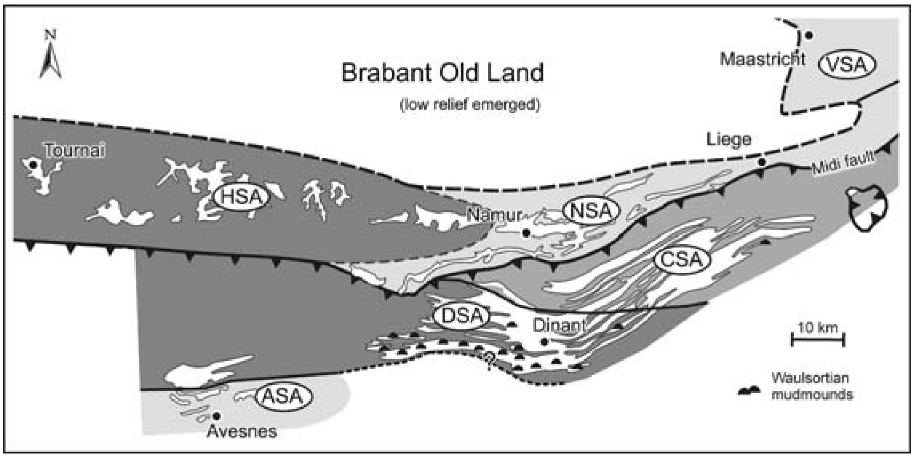

Figure 2. Sedimentation areas of southern Belgium in late Tournaisian time. ASA – southern Avesnois sedimentation area; CSA – Condroz sedimentation area; DSA – Dinant sedimentation area; HAS – Hainaut sedimentation area; NSA – Namur sedimentation area; VSA – Visé-Maastricht sedimentation area.

Belgium and northern France (Hance, Poty & Devuyst, 2001, 2002). Figure 3 gives the lithostratigraphic framework for the Mississippian of southern Belgium and northern France (see Poty *et al.* 2002 for more details).

Viséan foraminifers and rugose coral faunas are therefore prolific in the Namur–Dinant Basin because of the suitable conditions for shallow-water benthic organisms over large areas. In contrast, the Franco-Belgian Tournaisian contains a rather discontinuous foraminiferal record and less diversified coral associations related to unfavourable deeper-water environments in the lower ramp/shelf setting (Dinant sedimentation area) and to pervasive dolomitization of the inner ramp/shelf (Condroz and Namur sedimentation areas) (Fig. 2). This is in addition to a more fundamental evolution, because even in shallow-water facies the diversity in Tournaisian coral and foraminifer associations is lower than in the Viséan. This situation is reflected in the sparse and geographically limited Tournaisian foraminifer occurrences reported in the zonation of Conil *et al.* (1991) and in the fact that Tournaisian foraminifers and corals are not as well documented in the Belgian literature as their Viséan counterparts. Conversely, conodonts offer a powerful tool for biostratigraphy in the Tournaisian and become

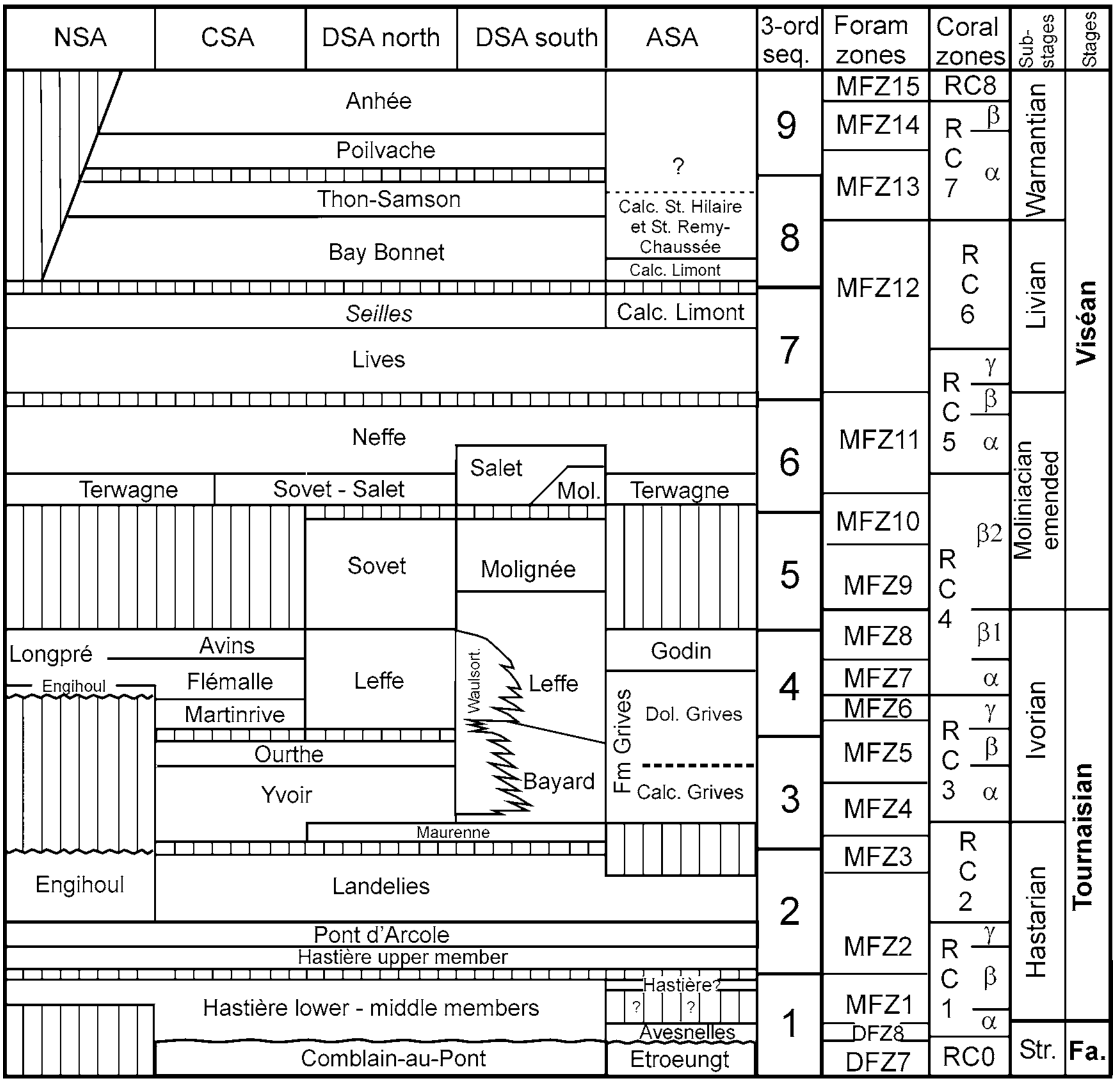

Figure 3. Lithostratigraphic and biostratigraphic framework for the upper Famennian (Fa), Tournaisian and Viséan of Belgium and northern France (see Poty *et al.* 2002 for more details). Gaps are indicated by a striped pattern. Third-order sequences (Seq.) according to Hance, Poty & Devuyst, 2001. Foraminifer zones are from this paper. ASA – southern Avesnois sedimentation area; CSA – Condroz sedimentation area; DSA – Dinant sedimentation area; NSA – Namur sedimentation area; Fa. – Famennian; Str. – Strunian.

rarer and longer-ranging in the Viséan. Reinterpretation of the Belgian stratigraphic sequence (Hance, Poty & Devuyst, 2001, 2002) and revision of key sections and faunas allow us to revise and significantly improve the foraminifer and rugose coral zonations. Data from other basins, sometimes distant, either published in the literature or collected by two of the authors (F. X. Devuyst and L. Hance) are used when they shed light on local problems in the Namur–Dinant Basin. Two difficult intervals in particular are now much better understood, the Devonian–Carboniferous and Tournaisian–Viséan boundaries. The upper Tournaisian foraminiferal succession, well constrained by conodont data, is much better represented than previously thought and offers potential for long distance correlation. In this paper we use the last conodont zonation published for the Namur–Dinant Basin by Conil *et al.* (1991) and Webster & Groessens (1991).

2. **Foraminiferal zonation** (F.-X. Devuyst & L. Hance)

Significant changes cannot be made to the previous schemes (Conil, Groessens & Pirlet, 1977; Conil *et al.* 1989, 1991; Mamet, 1974; Mamet & Skipp, 1970, 1971) without leading to confusion. The present paper therefore proposes a new foraminiferal zonation for the Upper Devonian and Mississippian of Belgium and northern France. The Upper Devonian comprises eight interval zones, DFZ1 to DFZ8 (for Devonian Foraminifer Zone). Sixteen Mississippian Foraminifer Zones (MFZ) are identified, MFZ1 to MFZ16. MFZ1 Zone is an interzone and MFZ16 an assemblage zone;

Conil, Groessens & Pirlet, 1997	This paper	Key elements	Stratigraphic level	References
	DFZ8	*Tournayellina pseudobeata Reitlinger* & Kulagina, *Chemyshinella* spp., C. *gutta* Conil & Lys, *Laxoendothyra parakosvensis nigra* (Conil & Lys), *Septabrusiina* spp., *S. kingirica, Septaglomospiranella* spp., *Earlandia moderata* (Malakhova)	Upper Famennian Avesnelles Fm.	This paper; Conil & Lys, 1970, 1980
Df3ε	DFZ7	*Quasiendothyra kobeitusana* (rauzer), Q. *konensis* Lebedeva, *Klubovella konensis* Lebedeva, L. *parakosvensis* with radial inner layer, *Septatournayella rauserae,* Lipina, *Septabrunsiina kingira* (Reitlinger), *S. krainica* (Lipina), *Glomospiranella* sp., *abundant Paracaligelloides* sp.	Upper Famennian Epinette (N-O-P units) and Etroeungt Fms (ASA). Etroeungt Fm. (= Comblain-au-Pont) (DSA-CSA)	Conil & Lys, 1970,1980; Bouckaert et al., 1978
Df3δ	DFZ6	*Eoendothyra* with radial inner layer, *Septaglomospiranella bouckaerti* Conil & Lys + DFZ5 association	Upper Famennian Epinette Fm. (K-M units) (ASA)	Conil & Lys, 1970, 1980
Df3γ	DFZ5	*Eoendothyra regularis* (Lipina), *Avesnella streeli* Conil & Lys, *Rectoavesnella mourloni* (Conil & Lys), *rectoseptaglomospiranella* sp., *Laxoendothyra parakosvensis* (Lipina)	Upper Famennian Sains and Epinette Fms (G-I-J units) (ASA)	Conil & Lys, 1970, 1980
Df3β	DFZ4	*Eoendothyra communis*	Upper Famennian (DSA)	Conil & Lys, 1968 (fig. 126) Conil & Lys, 1970
Df3α	DFZ3	*Eoquasiendothyra bella* (Chemysheva), *Septaglomospiranella* sp., *Disonella lucens* Conil & Lys, *Baelenia gosseleti* (Conil)	Upper Famennian Souverain-Pré Fm. (CSA)	Bouckaert, Conil & Thorez, 1967
Df2	DFZ2	*Septatournayella* sp. and primitive Tournayellidae	Upper Frasnian? Lower Famennian (unsuitable facies in Western Europe)	Conil, Longerstaey & Ramsbottom, 1980
Df1	DFZ1	*Nanicella* sp. and Semitextulariidae	Eifelian - Frasnian	

Figure 4. Key elements of late Devonian Foraminiferal Zones DFZ1 to DFZ8 and equivalence with the zones of Conil, Groessens & Pirlet (1977). ASA – southern Avesnois sedimentation area; CSA – Condroz sedimentation area; DSA – Dinant sedimentation area; NSA – Namur sedimentation area.

all the others are interval zones. Zone MFZ9 is characterized by the entry of *Eoparastaffella simplex*, which marks the base of the Viséan (Devuyst *et al.* 2003). The index taxon for the base of each zone is given in the heading next to the zone name. Each interval zone iset al the interval between the first appearance datum of the index taxon of the zone and the first appearance datum of the index taxon of the next zone. Correspondence of the new scheme with the Devonian (Df) and Carboniferous (Cf) zones of Conil, Groessens & Pirlet (1977), emended by Conil *et al.* (1991) is discussed.

2.a. Interval zones DFZ1 to DFZ7

No changes are made to the Upper Devonian zones succession of Conil, Groessens & Pirlet (1977). A new notation is adopted for coherence with the Mississippian zonation and because we introduce an additional Devonian zone (see below and Fig. 4).

2.b. Zone DFZ8 – *Tournayellina pseudobeata* interval zone

In northwestern France (southern Avesnois sedimentation area), the Avesnelles Formation, resting on the undoubtedly Devonian Etroeungt Formation, yields a rich microfauna including *Chernyshinella* spp., *C. gutta* Conil & Lys, *Earlandia moderata* (Malakhova), *Laxoendothyra parakosvensis nigra* (Conil & Lys), *Septabrunsiina* spp., *S. kingirica*, *Septaglomospiranella* spp. and *Tournayellina pseudobeata* Reitlinger & Kulagina, as most common taxa, together with conodonts with Devonian affinities (Conil & Lys, 1970; Conil *et al.* 1986). We assign that foraminifer fauna to the DFZ8 Zone and take *T. pseudobeata* as the guide for its base. The specimen identified as *Chernyshinella glomiformis* (Lipina) by Conil & Lys (1970, pl. 13, 123) is closer to *C. gutta*. *Tournayellina beata* was erroneously reported from the latest Devonian Etroeungt Formation (Df3ε Zone) by Conil & Lys (1970, pl. 12, 120). The specimen they figured is indeed *T. beata*, but it was in fact collected in the upper part of the Avesnelles Formation (Conil *et al.* 1986, p. 22). The Avesnelles Formation post-dates the most evolved quasiendothyrids and the last

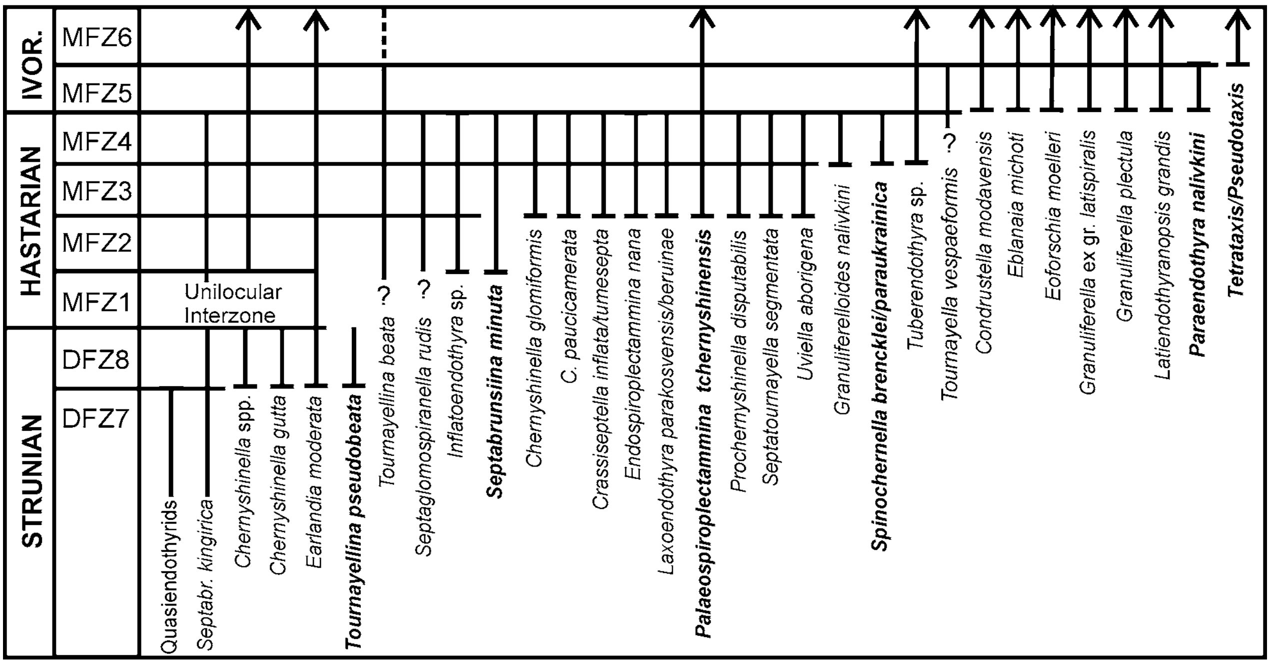

Figure 5. Distribution of the significant foraminifer taxa covering zones MFZ1 to MFZ5. Taxa for the uni/bilocular interzone MFZ1 have not been reported here. Ivor – Ivorian.

stromatoporoids. It has not yielded corals. Significant conodont taxa include *Siphonodella* cf. *praesulcata* Sandberg, *Polygnathus inornatus* Branson, *P. communis* Branson & Mehl, *Pelekysgnathus inclinatus* Thomas, *Protognathodus kockeli* (Bischoff) and *Pseudopolygnathus graulichi* Bouckaert & Groessens. This association assigns the Avesnelles Formation to the Upper *praesulcata* Zone (Ziegler & Sandberg, 1984) and therefore to the latest Famennian, and not the Middle *praesulcata* Zone as indicated by Casier *et al.* (2004, fig. 2).

The DFZ8 Zone is equivalent to the lower part of the *Tournayellina beata* Zone reported by Kalvoda (2002) in Moravia. It correlates with the *T. pseudobeata* Zone recognized by Barskov *et al.* (1984) and Reitlinger & Kulagina (1987) in the Berchogur area (Russia), and by Kulagina, Gibshman & Pazukhin (2003) in the southern Urals where it covers the Gumerovo Horizon (Upper *preasulcata* and Lower *sulcata* zones) in which the last *Eoendothyra communis* (Rauzer) are found. In the Dinant sedimentation area, the lateral equivalent of the Avesnelles Formation should be sought for in the lowermost part of the Hastière Formation (Fig. 3) and is probably, for the most part, equivalent to the basal bed of that formation, which is locally conglomeratic and which contains a similar conodont fauna, recently re-examined by Sandberg in the Anseremme section (Casier *et al.* 2004). The lack of quasiendothyrids in the Avesnelles Formation could be related to the dominance of wackestone facies in that formation, as quasiendothyrids seem to have favoured high-energy environments (Lipina, 1961), but it is more likely linked to the 'Hangenberg event' which also caused the extinction of many other Devonian fossil groups. The base of the Hastière Formation contains a reworked pre-Hangenberg Strunian fauna including quasiendothyrids (Conil *et al.* 1986). This interpretation differs from the model of Conil *et al.* (1986), who considered that the foraminifer fauna of the Avesnelles Formation has Carboniferous affinities and that conditions more suitable for the foraminifers prevailed in the Dinant sedimentation area at the time of deposition of the Hastière Formation.

2.c. Interzone MFZ1 – Unilocular Zone

The most common taxa of this interzone are *Bisphaera irregularis* Birina, *Earlandia minima* (Birina), *E. moderata* and various Parathuramminidae (Fig. 5). Plurilocular foraminifers are very scarce and include mainly small Tournayellidae. In the Namur and Dinant sedimentation areas, the oldest Carboniferous sediments, represented by the lower and middle members of the Hastière Formation (Tn1b$\alpha-\beta$ of the literature), except its basal metre-thick bed (see above), correlate with MFZ1. *Septabrunsiina kingirica* and *Tournayellina beata* have been found in the middle member of the Hastière Formation, at Landelies and Engihoul, respectively (Namur sedimentation area: Conil, unpub. data; Brenckle & Hance, 2005, pl. 1, figs 6, 8; pl. 4, fig. 12). The entry of the first *T. beata* in the Hastière Formation is cryptic and poorly documented, and hence does not constitute a reliable level for correlation.

The Unilocular zone can be identified across Eurasia. It corresponds to the Malevsky Horizon of the Russian Platform (e.g. Vdovenko *et al.* 1990) and to the *Earlandia minima* Zone of Kulagina, Gibshman & Pazukhin (2003) and can also easily be traced in southern China (Hance, 1996). According to Conil, Groessens & Pirlet (1977) and Conil *et al.* (1991), the upper member of the Hastière Formation ('Tn1bγ') equates with the unilocular Cf1α' Subzone (lower MFZ2 here). This interpretation was the result of an erroneous correlation between the Avesnelles and Hastière formations.

The upper member of the Hastière Formation does contain a plurilocular fauna typical of the MFZ2 Zone described below.

The conodont *Siphonodella duplicata* (Branson & Mehl) enters in the lower part of the Hastière Formation (Van Steenwinkel, 1980, 1984; Webster & Groessens, 1991).

2.d. Zone MFZ2 – *Septabrunsiina minuta* interval zone

The MFZ2 Zone corresponds to the Cf1α'–α" subzones of Conil *et al.* (1991). Note that these notations, first introduced by Gilissen (1988), do not coincide with the subzones of Conil, Groessens & Pirlet (1977, fig. 13). The zone is based on a poorly diversified fauna, and foraminifers are not abundant to rare locally (Fig. 5). The fauna comprises *T. beata, Chernyshinella* sp., *Septabrunsiina kingirica, S. minuta* (Lipina), *Septaglomospiranella rudis* (Conil & Lys), *S. bouckaerti* and *Inflatoendothyra* sp. In the Dinant sedimentation area, the base of the zone coincides with the base of the middle member of the Hastière Formation ('Tn1bγ'). Specimens from this level have been reported in the Dinant sedimentation area by Chabot (1976), in the Condroz sedimentation area by Bouckaert *et al.* (1978, pl. I, 8–20; pl. II, 1–38) and in the Visé-Maastricht sedimentation area by Bless *et al.* (1981).

The middle and upper members of the Hastière Formation are included respectively in the upper part of the *Siphonodella cooperi* Subzone and in the lower part of the *S. obsoleta* Subzone (Conil, Groessens & Vandenven, 1981, fig. 4).

2.e. Zone MFZ3 – Palaeospiroplectammina tchernyshinensis interval zone

The MFZ3 Zone is equivalent to the Cf1β Subzone of Conil *et al.* (1991). It marks a diversification in the foraminifer associations (Fig. 5). *Chernyshinella glomiformis* (Lipina) and *C. paucicamerata* Lipina are frequent and coexist with large *Crassiseptella inflata* (Zeller), *C. tumesepta* (Zeller), large *Laxoendothyra* ex gr. *parakosvensis*, *Palaeospiroplectammina tchernyshinensis* (Lipina), *Prochernyshinella disputabilis* (Dain), *Septatournayella segmentata* (Dain) and *Uviella aborigena* Ganelina. The base of the zone is taken at the entry of *P. tchernyshinensis* and coincides with the middle part of the Landelies Formation. It is easily identified in the Dinant, Condroz and Visé-Maastricht sedimentation areas. The following published material comes from Zone MFZ3: Conil & Lys (1964, figs 183, 187, 414–16, 422–4, 428, 500, 511, 523, 664), Conil & Lys (1967, figs 6, 18, 19), Conil & Lys (1968, figs 91–5), Conil *et al.* (1988), Chabot (1976, pl. I, 1–12), Bouckaert *et al.* (1978, pl. I, 1–7) and Kimpe *et al.* (1978, pl. 8, 1–30; pl. 9, 31–8).

The most significant coexisting conodont taxa are *Polygnathus inornatus* Branson, *Siphonodella cooperi* Hass and *S. obsoleta* Hass. This association indicates the *Siphonodella obsoleta* Subzone.

2.f. Zone MFZ4 – *Spinochernella brencklei* interval zone

The zone correlates with the Cf1γ Subzone, but is extended up to the entry of the MFZ5 (Cf2) guides and not restricted to the upper part of the range of *Siphonodella*. The first tuberculate endothyrids enter at this level. *Granuliferelloides nalivkini* (Malakhova), *Spinochernella brencklei* Conil & Lys, *S. paraukrainica* (Lipina) and *Tuberendothyra* sp. are the most significant elements (Fig. 5). *Crassiseptella tumesepta, Laxoendothyra* ex gr. *parakosvensis, Palaeospiroplectammina tchernyshinensis*, *Septatournayella segmentata, Septabrunsiina minuta* and *Uviella aborigena* Ganelina persist at this level. *Endospiroplectammina nana* (Lipina) and *Tournayella vespaeformis* Malakhova complete the association. The first representatives of the zone enter in the lower part of the Yvoir Limestone in the Condroz sedimentation area (Fig. 3). The Zone is best documented from the Royseux section in the Hoyoux valley (E. Gilissen, unpub. Master's thesis, Catholic Univ. Louvain, 1986; Brenckle & Hance, 2005). Zone MFZ4 cannot be identified in the Dinant sedimentation area where the equivalent strata correspond to the unsuitable facies of the Maurenne Formation (calcareous shales).

The key foraminifer taxa of the MFZ4 Zone coexist with the last siphonodellid conodonts (*S. obsoleta*), the last *Polygnathus inornatus* Branson and the first gnathodids (*Gnathodus delicatus* Branson & Mehl and *G. punctatus* Cooper).

2.g. Zone MFZ5 – *Paraendothyra nalivkini* interval zone

The content of this zone is that of the Cf2 Zone of Conil, Groessens & Pirlet (1977) and Conil *et al.* (1991). However, its base is here taken at the entry of the index taxon (Fig. 5), high in the *Polygnathus communis carina* conodont Zone, and not forced to artificially coincide with the base of that zone as is the case for the Cf2 Zone. Main taxa are *Condrustella modavensis* (Conil & Lys), *Eblanaia michoti*, *Eoforschia* sp., numerous *Granuliferella* ex gr. *latispiralis* (Lipina), *G. plectula* Zeller, *Latiendothyranopsis* spp., *Palaeospiroplectammina* aff. *parva* and *Paraendothyra nalivkini* Chernysheva. *Tournayella vespaeformis* and *Palaeospiroplectammina tchernyshinensis* persist at this level while most of the other older taxa have disappeared. The first taxa characteristic of Zone MFZ5 enter in the Condroz sedimentation area in the upper part of the Yvoir Formation (middle part of the *Polygnathus communis carina* Zone, *Eotaphrus* cf. *bultyncki* Subzone; Groessens, 1973; Conil, 1973, pl. I, 1–21; Conil *et al.* 1989, pl. I, 1–26). Hance (1979, pl. I, 1–11; pl. II, 12–17) also reports a MFZ5 association from the *P. c. carina* Zone at Horion-Hozémont (Namur sedimentation area – Brabant Massif transition). In the southern Avesnois sedimentation area, the middle part of the Grives Formation (*P. c. carina* Zone, *E. bultyncki* Subzone) yields *P.* ex gr. *nalivkini*, *Latiendothyranopsis* aff. *grandis, Rectoseptaglomospiranella* sp. and *C. modavensis* (Mansy *et al.* 1989, pl. VI, 2–14) and is attributed to MFZ5. In the Hainaut sedimentation area, rare elements of MFZ5 occur in the upper part of the Ecaussines Formation (*P. c. carina* Zone; Groessens unpub. data, reported by Conil & Lys, 1977) and in the St-Ghislain core, at −3721 m, in the lower part of the *P. c. carina* Zone (Groessens, Conil & Hennebert, 1982). In the Dinant sedimentation area, Hallet (V. Hallet, unpub. Master's thesis, Catholic Univ. Louvain, 1982) mentions granuliferellid representatives in the cherty crinoidal limestones interbedded with the Waulsortian at Gendron-Celles. At this level, they coexist with the conodont *Dollymae bouckaerti* Groessens (Groessens, unpub. data). The upper part of the zone is not documented in southern Belgium, where the dominant crinoidal facies are unsuitable for foraminifers. A more diversified association which probably corresponds to the upper part of the Zone, is found in southern

China and in the Omolon (Siberia: Shilo *et al.* 1984), with more evolved *Paraendothyra* (*P. portentosa* Conil *in* Shilo *et al.* 1984) and evolved *Spinoendothyra*.

2.h. Zone MFZ6 – *Tetrataxis* interval zone

The contents of the lower and upper parts of the MFZ6 Zone (Fig. 5) are similar respectively to that of the Cf3 Zone of Conil, Groessens & Pirlet (1977) and Conil *et al.* (1991) and of the lowermost Cf4α1 Subzone of Conil *et al.* (1991). However, the Conil *et al.* (1991) scheme for the Tournaisian–Viséan transition has to be used with caution, as the correlations across the Namur–Dinant Basin were misunderstood (see Section 4.a). The guide for the base of the zone is *Tetrataxis*. In the lower part of the zone, it is rapidly joined by *Eotextularia diversa* (Chernysheva) and *Endothyra* spp. A diversification occurs in the upper part of the zone with the entry of *Brunsia* spp., primitive *Valvulinella* sp., *Endospiroplectammina conili* Lipina, *E. venusta* (Vdovenko) and representatives of the *Bessiella–Dainella* groups. In the Dinant sedimentation area, this association is found in the upper part of the Leffe Formation (in tempestites) and of the Waulsortian (Conil *et al.* 1988, 1991). In the Condroz sedimentation area, the upper part of the Martinrive Formation has yielded *Eblanaia michoti*, *Condrustella modavensis*, *Eoforschia* sp. and *Tournayella* sp. (Hance, 1988; association A of Hance, Poty & Devuyst, 2001), but is lacking *Tetrataxis* and *Eotextularia diversa* and hence could be older than MFZ6 and assigned to the uppermost part of MFZ5. *Protognathodus cordiformis* Lane, Sandberg & Ziegler is present at this level in the Ourthe valley (M. Coen, unpub. data) and indicates that this upper Martinrive association is low in the *Scaliognathus anchoralis* zone (Conil *et al.* 1991). The association of *Tetrataxis*, *Eotextularia diversa* and rare Endothyrids characterizing the lower part of MFZ6 is a depauperate microfauna of environmentally tolerant taxa that colonized the Dinant sedimentation area much earlier than other plurilocular foraminifers. Lees (1997) has demonstrated the diachronous progressive colonization by *Tetrataxis* of the flanks of the Waulsortian mudmounds and the basin floor in response to a progressive relative shallowing of the sea in the late Tournaisian before all other plurilocular foraminifers. This depauperate association persists in the deeper central part of the Dinant sedimentation area, while a rich association (MFZ7; see Section 2.i) developed on the platform and on the Waulsortian mudmounds in the latest Tournaisian (Hance, Poty & Devuyst, 2001, fig. 6). In Belgium, oldest representatives of the zone coexist with the conodont *Scaliognathus anchoralis fairchildi* Lane & Ziegler and *Doliognathus latus* Branson & Mehl and with the last *P. cordiformis* Lane, Sandberg & Ziegler (Conil *et al.* 1988). The conodont *Mestognathus praebeckmanni* Sandberg, Johnston, Orchard & von Bitter enters in the upper part of the zone. It is, however, most likely an ecological entry, as this shallow water taxon is known from the upper *G. typicus* Zone to lower *S. anchoralis* Zone in Moravia and Spain (Van den Boogaard & Vazquez Guzman, 1981; von Bitter, Sandberg & Orchard, 1986; Kalvoda, 1994). In South Wales (Linney Head, Pembroke coast), *Tetrataxis* enters earlier than in the Namur–Dinant Basin, in the *Dollymae bouckaerti* Subzone (Marchant, Sevastopoulo & Clayton, 1984). It is, so far, the oldest record of this taxon.

2.i. Zone MFZ7 – *Darjella monilis* interval zone

Zones MFZ7 and MFZ8 (see Section 2.j), considered globally, have the content of the Cf4α1 Subzone, except for *Brunsia*, *Endospiroplectammina conili*/*venusta*, *Bessiella*/*Dainella* and *Valvulinella* (which were used as the guides for the base of the Cf4α1 Subzone) which enter in the upper part of the MFZ6 Zone. The MFZ7 Zone is equivalent to association B of Hance, Poty & Devuyst (2001) except for *Brunsia*, *Endospiroplectammina* sp. and *Bessiella* sp. The taxa characterizing Zone MFZ6 are still present in MFZ7 (Figs 5, 6), with *Elevenella parvula* (Bozorgnia), *Florennella* spp., *Laxoendothyra laxa* (Conil & Lys), *D. monilis*, *Omphalotis* sp., *Paraendothyra cummingsi* (Conil & Lys), *Pseudolituotuba gravata* and *Pseudolituotubella* spp. in addition. *Spinoendothyra* is also common. *D. monilis* Malakhova is a very distinctive taxon. It has a short time range, its last occurrence being in the lower part of MFZ8 Zone, but a wide distribution in favourable facies. It was probably highly specialized and not able to adapt to the abrupt changes in environmental conditions at the end of the Tournaisian. It has been reported from the Dinant sedimentation area (Waulsortian and proximal peri-Waulsortian facies: Conil *et al.* 1989; Lees, 1997), from the southern Avesnois sedimentation area (Mansy *et al.* 1989), from the Condroz sedimentation area (Flémalle Member, Modave road section: this paper), and from the Namur sedimentation area, where it is, however, rare (Conil & Lys, 1968; A. Lauwers, unpub. data *in* Conil *et al.* 1988, vol. 1). *E. parvula*, which is reported for the first time in Western Europe, also has a short time range similar to that of *D. monilis* in the Franco-Belgian Basin, but it has been reported in the late Viséan of Thailand by Vachard (1994). In the Namur sedimentation area, the zone is identified in the Flémalle Member of the Engihoul Formation (Malpica, 1973). In the Dinant sedimentation area, the ‘Freyr fauna’ (Lees, 1997), assigned by Conil *et al.* (1989, pl. II, 28–32; pl. III, 42–58) to the Cf4α1 subzone, corresponds mostly to MFZ7 (see remark above). Typical elements of the MFZ6 and MFZ7 zones also occur in the upper part of the Moniat Waulsortian buildup (Hance, 1988; revised in Lees, 1997). In these Waulsortian and peri-Waulsortian environments, some typical *Endothyra* species are common in the zone such as *Endothyra obtrita* (Conil & Lys), *E. tenuiseptata* Lipina, *E. freyri* (Conil & Lys), *E. waulsorti* (Conil & Lys) and *E. kaisini* (Conil & Lys) as well as the first *Valvulinella* (primitive forms with a thick wall and irregular chamber division) preceding the entry of *D. monilis.* Associations from the Pont de Lens Formation and from the Lens Formation in the Hainaut sedimentation area, previously regarded as Viséan, are here assigned to the late Tournaisian MFZ7 Zone (Groessens, Conil & Hennebert, 1982, pls XII, XIII). In the southern Avesnois sedimentation area, the base of the zone corresponds to the uppermost part of the Grives Dolostone (Mansy *et al.* 1989).

Conodont associations coexisting with MFZ7 indicate the upper part of the *S. anchoralis* Zone (*S. anchoralis europensis*, *Mestognathus praebeckmanni*). They are documented in Conil *et al.* (1988), Mansy *et al.* (1989) and Lees (1997).

Note that:

(1) Conil, Longerstaey & Ramsbottom (1980) attributed *Darjella monilis* (Malakhova) to the genus *Lugtonia* (Cummings, 1955). We do not follow this interpretation here for the following reasons: (a) the type material of

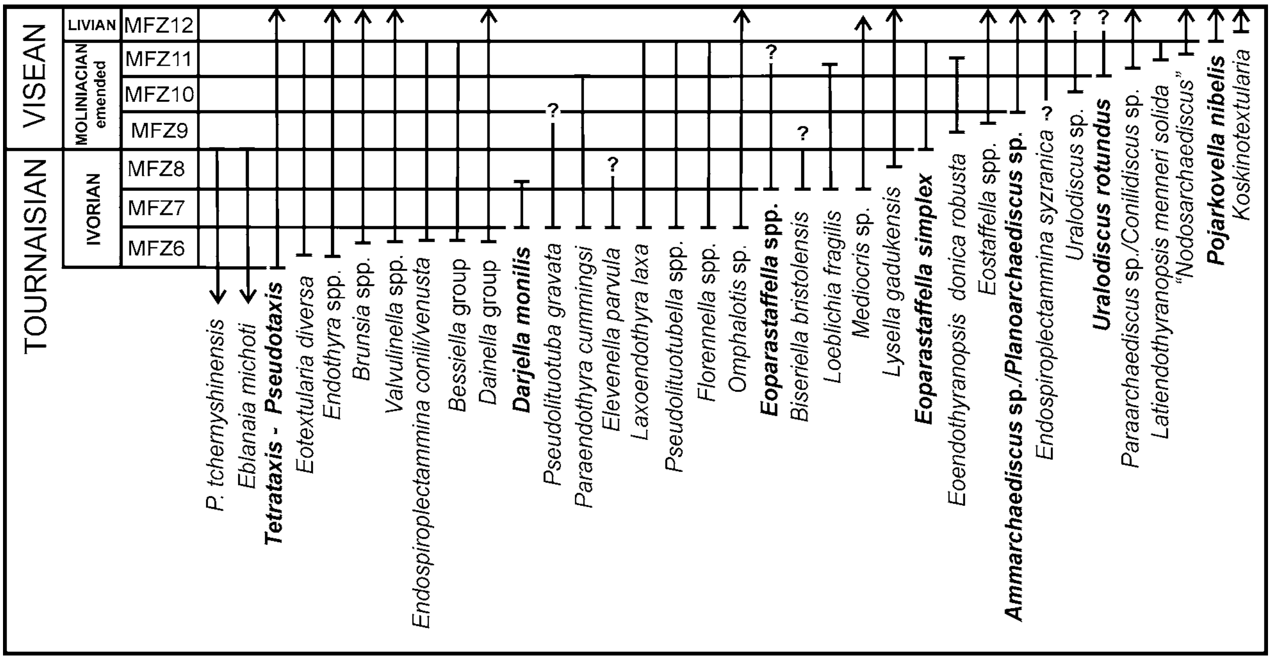

Figure 6. Distribution of the significant foraminifer taxa covering zones MFZ6 to MFZ11. *P.* – *Palaeospiroplectammina*.

D. monilis is well illustrated and there is no doubt about the agglutinated nature of the wall and the distinctive shape of the chambers; (b) the age of the Lunevka Horizon where it is found varies somewhat between authors, from the late Tournaisian to the early Viséan, but is not younger; (c) the nature of the wall of *Lugtonia* is not known, as all specimens known are silicified (secondary) and the shape of the chambers is different from *D. monilis* (distinctively more angular); (d) the reported age of *Lugtonia* (Cummings, 1955) ranges from the middle to late Viséan to the early Namurian. All occurrences of *D. monilis* we have examined suggest that the genus is restricted only to the latest Tournaisian.

(2) *Valvulinella* most likely derived from *Tetrataxis* by resorption of the fibrous calcitic layer and by subdivision of the chambers into chamberlets in the course of the late Tournaisian (upper part of Zone MFZ6). The oldest representatives are large, but rare and restricted to Waulsortian and proximal peri-Waulsortian environments (Conil *et al.* 1989). For this reason, we prefer to use *Darjella monilis* as a guide for the base of MFZ7 as it is more abundant and present both in the Waulsortian and peri-Waulsortian environments and on the platform. *Valvulinella* is, however, a useful taxon, as it displays clear evolutionary characters. Very primitive specimens have a thick undifferentiated wall and an incipient subdivision in chamberlets. The evolutionary trend throughout the Viséan is characterized by the progressive acquisition of a denser and more regular chamberlet division pattern and a thinner wall. Early Viséan specimens have already a much thinner wall and complete but irregular subdivisions (see Hance, 1988, pl. XII, figs 6–10). Late Viséan specimens have dense and delicate subquadratic subdivisions (see, for instance, Conil, Longerstaey & Ramsbottom, 1980, pl. XX, figs 6, 7; pl. XXII, fig. 49).

(3) Cózar & Vachard (2001) have clarified the content of the closely related taxa *Dainella*, *Bessiella* and *Florennella*. We largely follow their emended diagnosis. However, we prefer to keep *Florennella* as a separate genus, even if its type species, being a variety, is not valid (Loeblich & Tappan, 1988, p. 720). Indeed *Florennella sensu* Conil (*in* Groessens, Conil & Hennebert, 1982) differs markedly from *Bessiella* in its more planispiral coiling, with aligned two last volutions (Brenckle, 2005) and denser septation. The type species of *Florennella*, *Plectogyra rotayi* var. *stricta* Conil & Lys (1964, pl. 36, fig. 719), under discussion by Loeblich & Tappan (1988), displays this regular character and is therefore a *Florennella* in our opinion and not a *Bessiella* as interpreted by Cózar & Vachard (2001). There is an abundant *Florennella* material in the Namur–Dinant Basin (see Hance, 1988, pl. XXI) that is not covered by their emended diagnosis.

2.j. Zone MFZ8 – *Eoparastaffella* M1 interval zone

The Zone MFZ8 is equivalent to association C of Hance, Poty & Devuyst (2001). It is included in the Cf4α1 Subzone. The base of the zone (Fig. 6) is defined by the entry of the first primitive *Eoparastaffella* M1 (Morphotype 1 of Hance & Muchez, 1995 and Hance, 1997). These primitive *Eoparastaffella* include '*E. ovalis* type 1' (*E. ovalis sensu* Vdovenko, 1964, 1971 part.; see remark below), *E. rotunda* Vdovenko (this paper) and *E.* ex gr. *interiecta* Vdovenko (Devuyst & Kalvoda, in press). Tournaisian *Eoparastaffella* had not previously been reported from the Namur–Dinant Basin. The evolutionary lineage of *Eoparastaffella* at the transition from the late Tournaisian to early Viséan observed in southern China (Devuyst *et al.* 2003) is also present in Belgium, but recorded discontinuously due to the particular sedimentary history of the Namur–Dinant Basin. *Biseriella bristolensis* (Reichel), *Loeblichia fragilis* (Lipina), *Mediocris* sp. and *Lysella gadukensis* Bozorgnia are other new elements coexisting with most of the taxa present in MFZ7. The MFZ7 Zone also records the last appearance of *E. michoti* and *P. tchernyshinensis*. *Loeblichia fragilis* is a distinctive taxon useful for long distance correlation. However, its use as an index taxon is hampered by its rarity. *Lysella gadukensis* is recognized for the first time in the Franco-Belgian Basin and seems to be a very useful marker in the latest Tournaisian. In the Dinant sedimentation area, the association *L. fragilis*, *B. bristolensis* and *E. parvula* occurs in the upper part of the Leffe Formation, in the first sorted fine-grained tempestite at Sovet (bed 108, Fig. 13) and Salet where they coexist with *Eoparastaffella* M1 (bed 87, Fig. 12). In the Waulsortian context at Moniat, the first *L. fragilis* coexists with the last *Darjella monilis* (= cf. *L. monilis* in Lees, 1997) and with *B. bristolensis* (this paper; not reported in Lees, 1997). Conil *et al.* (1988) report *D. monilis* and cf. *L. fragilis* in bed 54 of the peri-Waulsortian Freyr section. Revision of the thin-sections for this paper also reveals the presence of *E. parvula* and cf. *B. bristolensis* in bed 54 and confirms that of *L. fragilis*.

The coexistence of this association with *Scaliognathus anchoralis europensis* Lane & Ziegler and *Mestognathus praebeckmanni* is documented from the Sovet section (Fig. 14).

Note that:

(1) *Pachysphaerina pachysphaerica* has been used as a reliable indicator for the base of the Cf4α1 Subzone until recently (Conil *et al.* 1991; Hance, 1988; Lees, 1997). This taxon is abundant in the moravamminid packstones which form the thin-bedded units of the Molignée Formation (‘black marble’) and in similar facies from about the same level in Eurasia (D. Vachard, pers. comm.). However, typical forms with a perforated wall are difficult to identify with confidence in the Tournaisian–Viséan transition due to micritization and possible confusion with perpendicular sections of *Earlandia*. Conil & Lys (1964) mention isolated records of the species in the late Tournaisian (their Tn3, thus below the Cf4α1). For these reasons we would advise much care in the use of published ranges.

(2) *Eoparastaffella ovalis* was created by Vdovenko (1954) and later assigned to *Eoparastaffella simplex* form *ovalis* by the same author (Vdovenko, 1964). Varieties and forms published after 1960 are invalid in the International Code of Zoological Nomenclature. Specimens illustrated by M. Vdovenko as *E. ovalis* and *E. simplex ovalis* comprise at least three very distinct morphotypes: two are characterized by a pointed upper last half-volution and one by a rounded periphery in all volutions. The holotype of *E. ovalis* Vdovenko belongs to the first group. The variety of forms published as *E. ovalis* by other authors also demonstrates the poor definition of that species. Pointed specimens of *E. ovalis* do not appear before the latest Tournaisian to earliest Viséan in southern China. In this work we provisionally use ‘*E. ovalis* type 1’ for the rounded morphotype and ‘*E. ovalis* type 2’ for the first pointed forms. These first pointed *E. ovalis* are, however, themselves distinct from the holotype, which is younger (C1vb Zone of the Donbass, Russia). These provisional morphotypes should not be confused with the morphotypes (M1 and M2) proposed by Hance (1997) to describe the shape of the navel in *Eoparastaffella*.

(3) Identification of *Biseriella bristolensis* requires careful examination of the thin-sections because of its very small size. It is also strongly controlled by the facies and is most common in the oolitic limestones of the Avins Member or time-equivalent tempestites in the Basin. It has, however, never been found in the lower and middle Viséan where suitable facies abound. The stratigraphic position of the ‘V1b’ specimen published by Hance, Hennebert & Overlau (1981) from the Orneau valley (Hainaut sedimentary area) was deduced from its co-occurrence with the coral *Dorlodotia briarti densa* whose first stratigraphic occurrence is not precisely determined.

2.k. Zone MFZ9 – *Eoparastaffella simplex* interval zone

The zone is equivalent to the Cf4α2 Subzone and to association D of Hance, Poty & Devuyst (2001). It is the lowest Viséan zone and its base is identified (Fig. 6) by the entry of *Eoparastaffella simplex* Vdovenko. *Eoendothyranopsis donica robusta* Conil enters in the middle part of the zone and *Eostaffella* spp. in its upper part. This latter genus might have derived from evolved *Eoparastaffella* as evidenced by common transitional forms which are difficult to assign to one genus or the other (Conil & Naum, 1977; Conil, Longerstaey & Ramsbottom, 1980; Devuyst *et al.* 2003). The association corresponding to MFZ9 is much richer and more diversified than those of the Tournaisian zones, but most of the taxa are already present below (documented in Hance, 1988). In addition to the index taxa mentioned above, the genera *Pseudolituotubella, Spinobrunsiina, Bessiella, Florennella, Endothyra, Latiendothyranopsis* and *Globoendothyra* have numerous representatives. Zone MFZ9 extends up to the entry of primitive archaediscids (MFZ10). The MFZ9 Zone is known only from the Dinant sedimentary area where it corresponds to sequence 5 of Hance, Poty & Devuyst (2001), except its lowermost part (Sovet Formation). It is not recorded in the more near-shore areas (Condroz and Namur sedimentary areas) due to stratigraphic gaps and/or the presence of restricted peritidal facies devoid of stratigraphically significant foraminifers. The conodont *Gnathodus homopunctatus* Ziegler, a useful guide for the base of the Viséan, enters in the Bastion section less than 1 m above the base of the Viséan (Conil *et al.* 1991).

2.l. Zone MFZ10 – *Planoarchaediscus/Ammarchaediscus* interval zone

This zone corresponds to the lower and middle parts of the Cf4β Zone. Its base is at the entry of the first primitive archaediscids (Fig. 6) and it extends to the entry of *Uralodiscus rotundus* (Chernysheva). The very first representatives of the archaediscids belong to the genus *Planoarchaediscus* (senior synonym for *Brunsiarchaediscus* and *Nudarchaediscus* Conil & Pirlet, *in* Pirlet & Conil, 1974) and *Ammarchaediscus* Conil & Pirlet (*in* Pirlet & Conil, 1974; senior synonym for *Viseidiscus* Mamet, 1975). *Glomodiscus* and *Uralodiscus* enter higher in the zone. Evolved *Eoparastaffella* are still present and coexist with true *Eostaffella* and transitional forms. *Paraendothyra cummingsi* last occurs in this zone. In Belgium, the most primitive archaediscids are found in the Dinant sedimentary area, in allochthonous deposits of the basinal Molignée Formation.

Their first evolutionary stages are well documented in the Salet road section (Hance, 1988; Hance *et al.* 1994).

Conodont data at this level are poor, but *Lochriea cracoviensis* Belka is found at a short distance above the entry of primitive archaediscids (Webster & Groessens, 1991).

Note that Archaediscids constitute one of the most useful groups for subdividing the Viséan. Guides are included in evolutionary lineages and the acquisition of new characters offers a powerful biostratigraphic tool which makes it possible to overcome taxonomic problems. The classification of the archaediscids is still a matter of debate, and controversies and priority problems are not always easy to solve (see Pirlet & Conil, 1974; Brenckle, Ramsbottom & Marchant, 1987; M. Laloux, unpub. Ph.D. thesis, Catholic Univ. Louvain, 1988; Vachard, 1988; Pinard & Mamet, 1998; Somerville & Cózar, 2005). It is not the aim of this paper to address these problems. When using controversial taxa, the synonym used in parallel in the literature is mentioned. The publication date of the important paper of Pirlet & Conil on the evolution of the Archaediscids is controversial. This paper was accepted for publication in the volume 82–1973 of the *Bulletin de la Société belge de Géologie*. However, delay in the printing forced Raphaël Conil to send pre-prints of this paper to the scientific community in 1974. The volume was finally issued in 1977. We follow here the interpretation of Loeblich & Tappan (1988) and Vachard (1988), amongst others, who accept the validity of the 1974 pre-prints which are copies of a camera-ready document. Other authors are taking the International Code of Zoological Nomenclature (ICZN) literally, arguing that these 'pre-prints' are not 'separates' in the sense of the code. Nobody, however, contests the 1974 distribution date of the work and, hence, the intellectual property of its content to the authors.

2.m. Zone MFZ11 – *Uralodiscus rotundus* interval zone

We include in this zone the upper part of the Cf4β Subzone and the Cf4$\gamma-\delta$ subzones. The guide for the base of this zone is *Uralodiscus rotundus*, a widespread taxon (Fig. 6). It is more distinctive than *Paraarchaediscus* which follows together with *Conilidiscus* sp. and which was used as a guide for the base of the Cf4γ Subzone. *Latiendothyranopsis menneri solida* (Conil & Lys) enters in the middle part of the zone. This taxon was used to define the base of the Cf4δ Subzone (Conil & Naum, 1977), but it is restricted to the central part of the Dinant sedimentary area and is therefore unsuitable as a guide. '*Nodosarchaediscus*' sp. first appears in the upper part of the zone.

MFZ11 cannot be identified in the Condroz and Namur sedimentary areas where the restricted shallow water facies of the Terwagne Formation contain a poorly diversified foraminifer association, lacking archaediscids. The uppermost part of the Zone is poorly documented in most places also, due to the presence of unsuitable facies with a depauperate association in the upper part of the Neffe Formation (lagoonal fine-grained limestones with oncoids and stromatolites). More suitable facies are found in the southernmost part of the Dinant sedimentary area, where *L. menneri solida* is recorded at a very short distance below the base of Zone MFZ12. MFZ11 records the last occurrences of typical Moliniacian taxa including *Eotextularia diversa, Pseudolituotubella, Paraendothyra, Granuliferella, L. menneri solida, Spinoendothyra, Endospiroplectammina conili/venusta, Laxoendothyra laxa, Loeblichia fragilis, Eoparastaffella, Florennella, Bessiella, Dainella* and *Uralodiscus*.

Facies are unsuitable for conodonts and they yielded only stratigraphically non-significant gnathodids.

The entry of the algae *Koninckopora* with an inner fibrous layer within the MFZ11 Zone in Belgium, near the base of the Cf4δ Subzone (Paproth *et al.* 1983*a*, p. 194; Conil *et al.* 1991), is cryptic and obviously strongly facies-controlled.

Note that:

(1) *Uralodiscus* is a senior synonym for *Rectodiscus* Conil & Pirlet (see discussion in Brenckle, Ramsbottom & Marchant, 1987 and Vachard, 1988).

(2) Vachard (1988) considers that *Paraarchaediscus* Orlova is a junior synonym of *Archaediscus* Brady. *Paraarchaediscus*, however, still has a distinct dark inner layer as its planispiral equivalent *Conilidiscus* Vachard. We therefore keep this name for designating these bilayered archaediscids which will give rise to single-layered Archaediscids by reduction of the dark inner layer.

(3) Brenckle, Ramsbottom & Marchant (1987) and Brenckle & Grelecki (1993) do not accept the fibrous calcite deposit covering the floor of the tubular chamber of some evolved Archaediscids as a taxonomic feature, but consider it as a diagenetic artefact. Cathodoluminescence analysis carried out on tens of 'Nodosarchaediscus' found in different sedimentary environments revealed, however, the primary nature of these crystallizations (M. Laloux, unpub. Ph.D. thesis, Catholic Univ. Louvain, 1988). Moreover, the first Archaediscids with these supplementary deposits enter at the same stratigraphic level everywhere, that is, in the uppermost part of the Moliniacian MFZ11 Zone. *Nodosarchaediscus* Conil & Pirlet is, however, a controversial taxa due to the unclear nature of the crystallization of the floor of the tubular chamber (Brenckle & Grelecki, 1993; Vachard, 1988).

(4) The holotype of *Kasachstanodiscus* has well-developed nodular deposits; this taxon cannot include evolved *Uralodiscus* which has a reduced dark inner layer and which is devoid of nodular deposits (see Brenckle, Ramsbottom & Marchant, 1987).

2.n. Zone MFZ12 – *Pojarkovella nibelis* interval zone

The MFZ12 Zone is equivalent to the Cf5 Zone. Its base marks a drastic change in foraminifer association (Fig. 7). In addition to the index taxon *Pojarkovella nibelis* (Durkina) and to *Koskinotextularia*, a useful auxiliary guide entering low in the Zone, typical elements include *Palaeotextularia* ex gr. *consobrina*, *Lituotubella* sp., *Rhodesinella* sp., *Omphalotis minima* (Rauzer & Reitlinger), abundant *Eostaffella* spp. and *Endothyra* spp., *Paraarchaediscus* spp., *Nodosarchaediscus* spp. and *Archaediscus* spp. Associations are more diversified in the upper part of the Zone, where large forms are common. The base of the zone coincides approximately with the boundary between the Neffe and Lives formations and marks the base of the Livian Substage. The guide *Pojarkovella nibelis* enters at a very short distance above the base of the Lives Formation in the southernmost part of the Dinant sedimentary area, where facies reflect more open marine conditions. In the other sedimentation areas of the Namur–Dinant Basin, the base of the Lives Formation is almost devoid of plurilocular foraminifers and

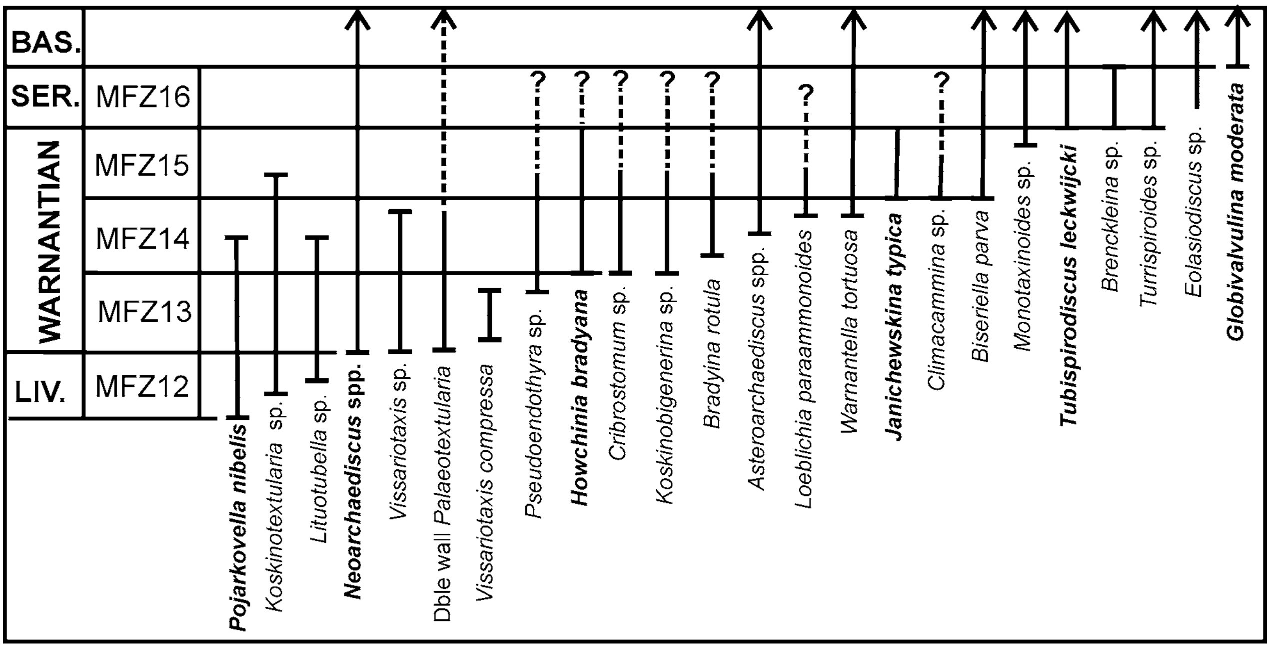

Figure 7. Distribution of the significant foraminifer taxa covering zones MFZ12 to MFZ16. The dotted lines indicate a higher extension in Western Europe, outside the Namur–Dinant Basin (see Conil *et al.* 1991, fig. 4). BAS – Bashkirian; SER – Serpukhovian; LIV – Livian.

P. nibelis enters high in the Haut-le-Wastia Member (Poty *et al.* 2002). The coexistence of *P. nibelis* with typical Moliniacian taxa is reported from the Visé-Maastricht sedimentary area (Conil *in* Kimpe *et al.* 1978, p. 58), the Mendips (SE England: Austin, Conil & Rhodes, 1973), Moravia (Kalvoda, 1990, 2002) and from southern China (Devuyst *et al.* 2003). Strata bearing this association are lacking in southern Belgium.

Facies are unsuitable for conodonts and most common taxa belong to the genera *Cavusgnathus* and *Taphrognathus* (Webster & Groessens, 1991).

2.o. Zone MFZ13 – *Neoarchaediscus* interval zone

This zone is the equivalent of subzones Cf6$\alpha-\beta$, which are well documented by Laloux (1988) and Laloux *et al.* (1988). We do not follow the subdivision into two subzones coinciding respectively with the Thon-Samson and Poilvache members (River Bonne Formation: Poty *et al.* 2002), as no stratigraphically significant taxon enters at the base of the latter member. *Neoarchaediscus*, the index taxon (Fig. 7), first enters in Belgium in the lowermost part of the Thon-Samson Member in its type area (Namur sedimentation area), in sequence 1 of Pirlet (1968; see also Laloux, 1988), at the base of the Warnantian Substage. *Vissariotaxis* sp., *Palaeotextularia* with a bilaminar wall and typical *Endothyra spira* (Conil & Lys) also enter at this level. Conil *et al.* (1991) report the additional occurrences of *Chomatomediocris* sp., *N. incertus* (Grozdilova & Lebedeva), *Vissariotaxis compressa* (Brazhnikova) and primitive *Howchinia* (much closer in fact to *Vissariotaxis* by the development of an incipient fibrous inner layer). *Pseudoendothyra* sp. appears higher in the zone. In the Namur–Dinant Basin, the genera *Chomatomediocris* and *Vissariotaxis* are restricted to MFZ13.

2.p. Zone MFZ14 – *Howchinia bradyana* interval zone

This zone is equivalent to the Cf6γ Subzone and lower part of the Cf6δ Subzone. It is also documented by Laloux (1988) and Laloux *et al.* (1988). The zone covers the uppermost part of the Poilvache Member and most of the Anhée Formation (*sensu* Poty *et al.* 2002). *Howchinia bradyana* (Howchin) enters in the uppermost part of the Poilvache Member (Dinant sedimentary area), together with cribrate Palaeotextulariidae (*Cribrostomum* and *Koskinobigenerina*) (Fig. 7). The successive entries of *Bradyina rotula* (d'Eichwald), *Cribrospira panderi* von Moeller, *Bibradya* sp., stellate Archaediscidae (*Asteroarchaediscus* sp.), *Archaediscus* ex gr. *karreri* Brady, *Endothyranopsis crassa* (Brady), large *Omphalotis*, *Eostaffella* aff. *mosquensis* Vissarionova, *E.* aff. *ikensis* Vissarionova and aff. *proikensis* Rauzer-Chernousova, slightly irregular eostaffellinids (= *Plectostaffella sensu* Conil *et al.* 1991) and *Endostaffella* ex gr. *parva* (von Moeller) complete this rich association. Archaediscids at the 'tenuis stage' (Conil, Longerstaey & Ramsbottom, 1980) appear in the uppermost part of the zone. *Loeblichia paraammonoides* Brazhinova enters in the upper part of the zone in the lower member of the Anhée Formation in the Dinant and Condroz sedimentary areas, at the same level or at a short distance above the entry of *Warnantella* (Laloux, 1988; Laloux *in* Poty *et al.* 1988). Gallagher & Somerville (1997) highlighted the potential of the stellate Asteroarchaediscus for subdividing the Cf6γ zone into $\gamma 1$ and $\gamma 2$. For Cózar & Somerville (2005), however, this criterion is controversial and totally occluded specimens do not enter before the base of the Cf6δ

Subzone. The evolutionary lineage from *Neoarchaediscus* to *Asteroarchaediscus* is indeed progressive, but even evolved representatives of the latter taxon keep the last whorl or half last whorl free of basal nodular deposits (Conil *et al.* 1991).

2.q. Zone MFZ15 – *Janischewskina typica* interval zone

This zone correlates with the Cf6δ Subzone except for its lower part and to the lower part of the Cf7 Zone (see Section 2.r., Zone MFZ16). Its base (Fig. 7) is defined at the entry of *Janischewskina typica* a few metres above *Loeblichia paraammonoides*. This latter taxa, being relatively rare and strongly facies-controlled, is not considered here as a reliable index taxon for a zonal boundary (see also Gallagher & Somerville, 1997). *Climacammina* sp. appears at the same level as *J. typica*. Most of the key taxa typical of Zone MFZ14 are still present. *Asteroarchardiscus* sp. and archaediscids at the '*tenuis* stage' are abundant. The first *Monotaxinoides* sp. are reported by Conil *et al.* (1991) in the upper part of the zone. The strata bearing the MFZ15 association have yielded *Gnathodus girtyi* Hass, *Lochriea commutata* (Branson & Mehl), *L. cruciformis* (Clarke) and *Cavusgnathus naviculus* (Hinde) (Bouckaert & Higgins, 1964; Higgins & Bouckaert, 1968).

2.r. Zone MFZ16 – *Tubispirodiscus leckwijcki* Assemblage Zone

In Belgium (Fig. 7), representatives of Zone MF16 are found only in the ~ 4 m thick Tramaka Member (Chokier Formation, lower part of the Coal Measures Group: Delmer, Dusar & Delcambre, 2002). As a result, appearance levels are not known and the zone is defined as an assemblage zone. The microfauna is largely dominated by small specimens due to environmental conditions and sorting. The absence of larger taxa is not considered significant. New taxa include *Tubispirodiscus leckwijcki* (Conil), *Brenckleina* sp., *Loeblichia minima* Brazhnikova, *Biseriella* ex gr. *parva* Chernysheva and *Turrispiroides* (*sensu* Groves, 1983, including almost planispiral forms). Representatives of *Monotaxinoides* (probably including specimens of the very similar taxon *Eolasiodiscus* which can hardly be differentiated in axial section) and very abundant *Neoarchaediscus*, *Asteroarchaediscus* and *Archaediscus* at the *tenuis* stage complete this association. *Eosigmoilina*, which is not present here, coexists with the first *Brenckleina* in other areas (Paproth *et al.* 1983*b*; Skompski *et al.* 1989).

Coexisting index conodont taxa *Adetognathus unicornis* (Rexroad & Burton) and *Gnathodus bollandensis* (Higgins & Bouckaert) are indicative of the Arnsbergian Stage (Goniatite Zone E2a: Groessens, 1983; Laloux, 1988).

The content of Zone MFZ16 is that of the Cf7 Zone which includes the E1 and E2 Goniatite zones in Conil *et al.* (1991, fig. 4). These authors indicate, however, that no guides of the zone are present in the E1 Zone in Western Europe (see also Paproth *et al.* 1983*b*). In Belgium, moreover, strata corresponding to the E1 Zone are lacking almost everywhere, except perhaps for the Gottignies and Souvré formations, at the Viséan–Serpukhovian transition (unspecified between Warnantian and Arnsbergian-dated: Delmer, Dusar & Delcambre, 2002). Hence, we see no reasons to extend the MFZ16 Zone below the Arnsbergian.

3. Rugose coral zonation (E. Poty)

A zonal scheme of the latest Famennian and the Dinantian based on the distribution of rugose corals in the Namur–Dinant Basin (north France, Belgium) was proposed by Poty (1985) and later extended to other parts of Eurasia (Poty *in* Conil *et al.* 1991). Nine zones, RC0 to RC8 ('RC' for rugose coral), were recognized. Since then, further investigations of the systematics, biostratigraphy and geographic distributions have led to some modifications that are incorporated in the present scheme (Fig. 8). One of the consequences of these modifications is that some boundaries previously regarded as the main levels for correlation are supplanted by others corresponding to former subzonal boundaries, but in order to keep a coherent system, the former coral biozonation will be maintained and those levels that are particularly valuable for widespread correlation will be emphasized.

3.a. Zone RC0 – Clisiophyllid–*Campophyllum* interval Zone

In the Eurasian realm, following the late Frasnian extinctions, there was a very long interval almost totally devoid of corals. The Rugosa reappeared from the DFZ3 Foraminiferal Zone (Df3α Subzone of Conil & Lys, 1980), Upper to uppermost *marginifera* Conodont Subzone, in the Namur–Dinant Basin, and as late as the DFZ4 Zone (Middle *expansa* Conodont Subzone) in Hunan (southern China). The first Rugosa reported are exclusively small, simple, solitary species.

In the Namur–Dinant Basin, the first marked radiation of Rugosa (Poty, 1999) started in the upper part of the DFZ5 Foraminiferal Zone, approximately at the base of the Strunian Substage *sensu* Conil *et al.* (1986). This radiation marks the base of the RC0 Zone. It is characterized by the appearance of Clisiophyllids (corals developing an axial structure of clisiophylloid type, a character usually typical of Carboniferous taxa) and of *Campophyllum* Milne-Edwards & Haime (Fig. 8). Most of these rugose coral species disappeared in the lower part of the DFZ6 Zone, but some gave rise to those reappearing in a second radiation, from the uppermost DFZ6 to the lower part of the DFZ7 Zone. The most common corals of the second radiation are *Campophyllum flexuosum* (Goldfuss), *Campophyllum gosseleti* Weyer, *Clisiophyllum omaliusi* Haime, '*Dibunophyllum*' *praecursor* Frech, and '*Palaeosmilia*' *aquisgranensis* (Frech), the latter two being homeomorphs of Viséan Rugosa. These two distinct coral radiations allow the recognition of the two new subzones RC0α and RC0β.

In the southern Avesnois sedimentation area, the Zone comprises the Epinette Formation (RC0α and base of RC0β) and the Etroeungt Formation (RC0β). Only the RC0β Subzone has been identified in the rest of the Namur–Dinant Basin.

Famennian coral faunas are almost entirely endemic, and corals found in other parts of Eurasia usually belong to other taxa. But, on the basis of the foraminiferal zonation and using the events affecting the distribution of the rugose corals, correlations between endemic assemblages have been achieved (Poty, 1999). The results show that (Fig. 10) (1) the RC0α Subzone corresponds to the *Eocaninophyllum yizhangense* Zone of South China (Poty & Xu, 1996; = *Caninia dorlodoti* Zone of Wu, Zhao & Jiang, 1981) and to the *Siphonophyllia latetabulata* assemblage of Omolon (Siberia), and (2) the RC0β Subzone corresponds to the *Cystophrentis* Zone of South China and with the *Molophyllum* and *Parasiphonophyllia* assemblages of Omolon.

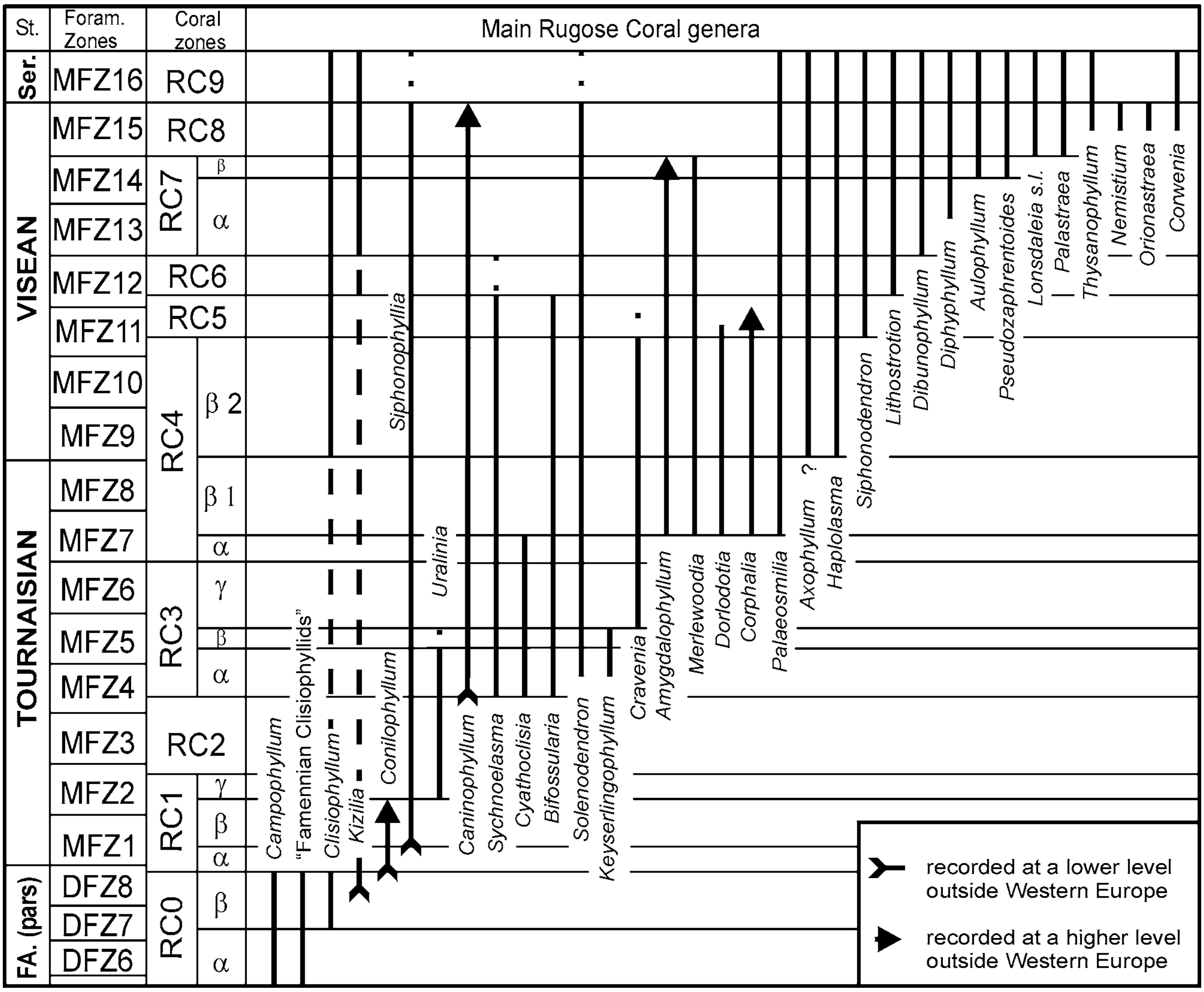

Figure 8. Distribution of the significant genera of the rugose coral biozonation; dashed line – present in the interval but not recorded in Europe; dotted line – possibly present at that level. Fa. – Fammenian; Ser. – Serpukhovian; St. – stages.

3.b. Zone RC1 – *Conilophyllum* interval Zone

Most latest Strunian rugose corals disappeared globally with the Hangenberg event, a little before the Devonian–Carboniferous boundary. The recovery began immediately after the event. The recovering coral faunas were poorly diversified, but relatively widespread in comparison with endemism that characterized the late Famennian. Good connection between distant basins was probably due to a relatively high sea-level corresponding to the end of the transgressive system tract of the third-order sequence 1 of Hance, Poty & Devuyst (2001, 2002). These faunas comprise taxa (Fig. 8) that were previously known in southern Belgium and surrounding areas (*Kizilia* Degtyarev), or in the Omolon (*Conilophyllum* Poty & Boland, *Siphonophyllia* Scouler *in* McCoy), or closely related forms (such as the North American *Vesiculophyllum* Easton which is close to *Kizilia*). In the Namur–Dinant Basin, the base of the zone is marked by the arrival of *Conilophyllum priscum* (Münster) (= *Caninia treg aensis* Poty) and *Kizilia kremersi* (Poty), just above the limestone bed marking the base of the Hastière Formation that yields reworked RC0β (pre-Hangenberg event) corals. In the deep-water facies of Germany, the earliest *C. priscum* are also recorded above the Hangenberg event, in the upper *praesulcata* Conodont Zone (Weyer), and therefore, just below the Devonian–Carboniferous boundary.

In the Namur–Dinant Basin, *K. kremersi* has a very short stratigraphic range, being limited to a few beds at the base of the Zone, whereas *C. priscum* extends into the Pont d'Arcole Formation. The latter taxon gave rise to *C. streeli* (Poty & Boland), which appears more or less at the same level as *Siphonophyllia cylindrica hasteriensis* (Salée), some metres above the base of the Hastière Formation (upper part of the lower member). Interestingly, *Uralinia lobata* (Poty & Boland) first occurs at the base of the Pont d'Arcole Formation. *Uralinia* Stuckenberg (= *Pseudouralinia* Yü) is a widespread Eurasian genus evolving from *Siphonophyllia*, from which it differs mainly in the reduction of the septa in the counter quadrants (Poty & Boland, 1996).

Therefore, three interval subzones can be recognized, their base corresponding respectively to the appearance of *C. priscum* and *K. kremersi* (RC1α Subzone), *S. cylindrica* *hasteriensis* and *C. streeli* (RC1β Subzone), and *Uralinia* and *Saleelasma delepini* (Vaughan) (RC1γ Subzone).

In its type area, the Zone comprises the Hastière Formation (except the basal bed) and the Pont d'Arcole Formation. The base of the Zone can be traced almost everywhere in the Namur–Dinant Basin, and also in the shallow and deep-water facies of Germany (Weyer, 1994, 2001).

On the East European Platform and in the Urals (Fig. 10), the RC1β and RC1γ subzones correspond to the *Siphonophyllia–Conilophyllum* assemblage Zone (Zone I) of Hecker (2001). In southern China (Hunan), the level of appearance of *Uralinia* marks the base of the *U. tangpakouensis* Zone of Tan *et al.* (1987), which was correlated with the base of the Belgian RC1γ Subzone by Poty & Xu (1996). Therefore, the RC1α, β subzones are correlated with the *Cystophrentis–Uralinia tangpakouensis* interval zone of Tan *et al.* (1987), in which *Kizilia* is known.

The RC1 Zone corresponds in the western interior province of North America to the Zone I of Sando & Bamber (1985), in which *Conilophyllum* cf. *priscum* (= *Guerichiphyllum* sp. of Sando & Bamber, 1985) and specimens questionably referred by the authors to *Vesiculophyllum* first appear.

3.c. Zone RC2 – *Siphonophyllia rivagensis* interval zone

The RC2 Zone (Fig. 8) was formerly defined by the first appearance of *Siphonophyllia cylindrica* and/or the genus *Lophophyllum* Milne-Edwards & Haime ('*Siphonophyllia cylindrica* interval zone' of Poty, 1985). Since then, *S. cylindrica hasteriensis* has been recorded from the base of the RC1α Zone (see Section 3.b), at a lower level than previously stated. On the other hand, our revision of *Lophophyllum konincki* Milne-Edwards & Haime, the type species of *Lophophyllum*, based on the lectotype and additional specimens from Tournai, shows that this species is in fact a junior synonym of *Caninia cornucopiae* Michelin *in* Gervais, the type-species of the genus *Caninia*. The so-called *Lophophyllum* sp. from the Zone RC2 (see Poty, 1989, fig. 3, D) is not related to the latter genus, but is a member of the Suborder Aulophyllina, possibly close to *Eostrotion* Vaughan, or to *Amygdalophyllum* Dun & Benson.

The most common species of the RC2 Zone in the Namur–Dinant Basin is *Siphonophyllia rivagensis* Poty & Boland, which appears at the base and extends up to the top of the Landelies Formation. Outside the Namur–Dinant Basin, however, *S. rivagensis* has been recorded only in a borehole on the island of Rügen in the north of Germany (Weyer, 2001), and consequently does not allow widespread correlations. Other species of the Zone are *Uralinia lobata* and *Saleelasma delepini*.

In the Namur–Dinant Basin, the Zone comprises the Landelies Formation and the Maurenne Formation (the latter being present only in the south part of the Condroz sedimentation area and in the Dinant sedimentation area).

On the East European Platform and in the Urals (Fig. 10), the RC2 Zone corresponds to Zone II of Hecker (2001). The RC2 Zone is correlated with the upper part of the *Uralinia tangpakouensis* Zone of Tan *et al.* (1987) in southern China, and with the North American western interior province Zone IIA of Sando & Bamber (1985).

3.d. Zone RC3 – *Caninophyllum patulum* interval zone

The RC3 Zone (Fig. 8) is marked by the development of the first rich coral fauna following the Devonian/Carboniferous crisis. It is characterized by the appearance of *Caninophyllum patulum* (Michelin) and *Sychnoelasma konincki* (Milne-Edwards & Haime) at the base, then *Caninia cornucopiae*, *Cyathoclisia* Dingwall, *Solenodendron* Sando, *Heterostrotion* Poty & Xu, *Bifossularia* Dobrolyubova, *Keyserlingophyllum* Stuckenberg and *Uralinia* cf. *gigantea* (Yü), and much later, *Cravenia* Hudson. Note that the genus *Caninophyllum* is known in southern China from the *Uralinia tangpakouensis* Zone. The Zone can be divided in three subzones: the RC3α Subzone is characterized by the appearance of the first taxa of the Zone, the appearance of *Cravenia* Hudson marks the base of the RC3γ Subzone, and the RC3β Subzone corresponds in Belgium to an interval poor in corals.

In the Condroz and Dinant sedimentation areas, the Zone comprises the Yvoir Formation (RC3α), the Ourthe Formation (RC3β) and the Martinrive Formation (RC3γ). In the southern Avesnois sedimentation area, it corresponds to the Grives Formation.

The RC3 Zone is the first Tournaisian Zone easily recognizable throughout Eurasia (Fig. 10). In Great Britain, it is equivalent to the British *Caninophyllum patulum* Zone of Ramsbottom & Mitchell (1980), which contains, however, a less diversified coral fauna than in the Namur–Dinant Basin. In the Dublin Basin of Ireland, the solitary coral fauna recorded by Somerville (1994) in the Meath Formation and in the corresponding lower part of the Malahide Formation and attributed to the RC2 Zone more likely corresponds to the RC3 Zone, because two taxa of the assemblage, *Fasciculophyllum* (= *Proheterelasma* Cotton) and *Rylstonia* Hudson & Platt, are not known below the RC3 Zone.

RC3α corals are known in Germany, in the Saxothuringian Massif (Weyer, 2001), and in Poland, near Krakow in the Debnik area (Fedorowski, 1981; Poty *et al.* in press). In the former USSR, they are widespread (Fedorowki, 1981) and are known as far as the Omolon region, in northeastern Siberia (Poty & Onoprienko, 1984). The RC3 Zone corresponds to the main part of Zone III of Hecker (2001) defined on the East European Platform and in the Urals (the uppermost part of Zone III corresponds to the RC4α Subzone). The Zone is easily correlated with the *Keyserlingophyllum* Zone of China (Tan *et al.* 1987) with which it shares several taxa, but the base of the latter seems to be somewhat lower than in Belgium (Poty & Xu, 1996). The RC3 Zone is correlated with the lower part of Zone IIB of Sando & Bamber (1985), the latter containing mostly North American endemic corals.

3.e. Zone RC4 – *Sychnoelasma hawbankense* interval zone

In the Namur–Dinant Basin, the base of the RC4 Zone (Figs 8, 9) is marked by the appearance of *Sychnoelasma hawbankense* Mitchell & Somerville (= *S. urbanowitschi sensu* Poty, 1981) and of *Cyathoclisia modavensis* (Salée). The latter is possibly known earlier in England (Mitchell, 1989) and is present only in the lower part of the Zone (RC4α Subzone).

The RC4β1 Subzone is characterized by the first appearance of the genera *Amygdalophyllum* Dun & Benson, *Merlewoodia* Pickett, *Palaeosmilia* Milne-Edwards & Haime,

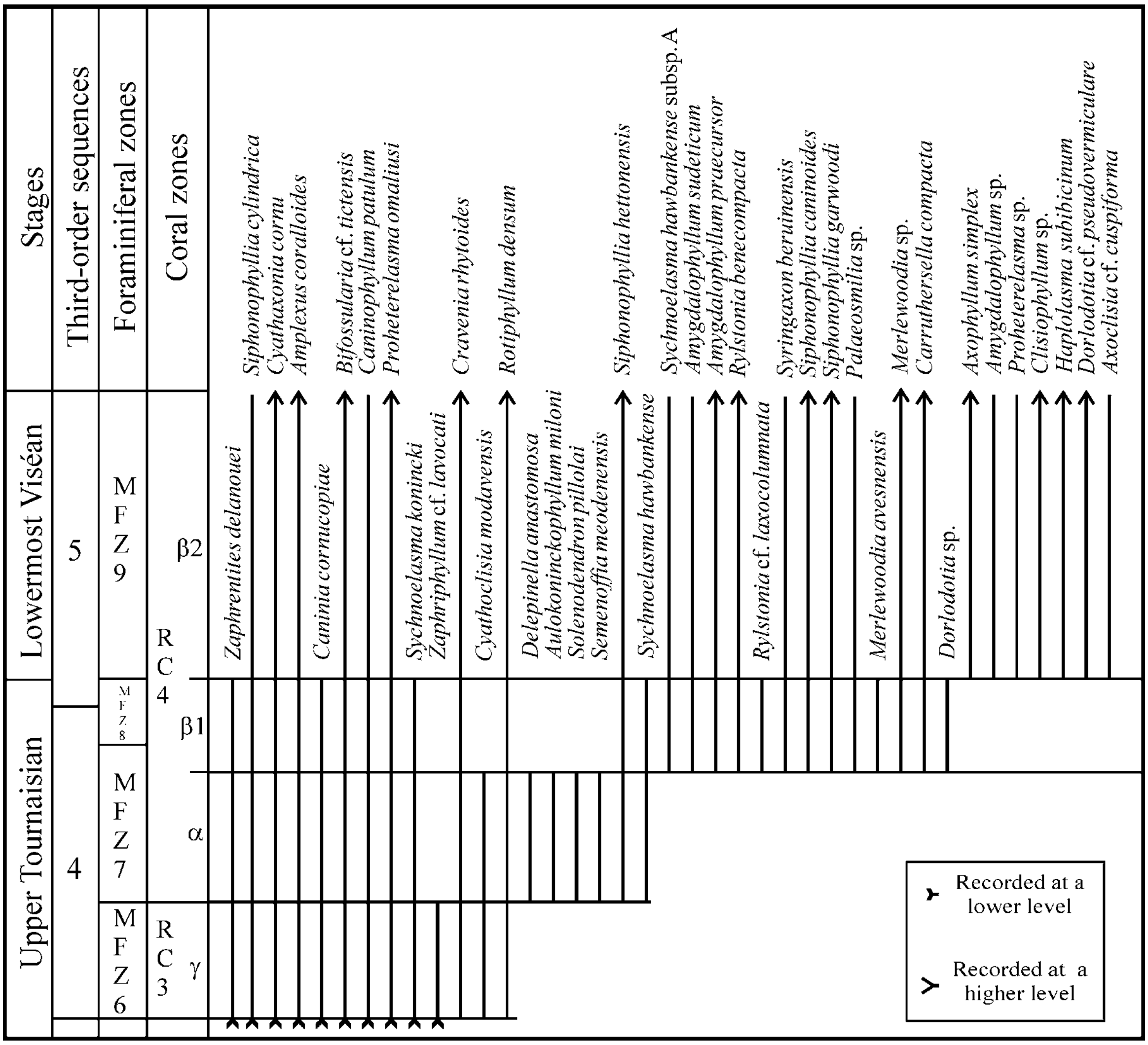

Figure 9. Distribution of the rugose coral taxa around the Tournaisian – Viséan boundary in Western Europe (Great Britain, France, Belgium, Germany).

Dorlodotia Salée and *Corphalia* Poty. The two latter genera are respectively colonial and solitary, but they are closely related, their form resulting from heterochronic modifications during their ontogeny (Poty, 1993). Therefore, they can be misidentified when fragmented.

The RC4β2 Subzone is characterized by the appearance of *Haplolasma* Semenoff-Tian-Chansky, *Axophyllum* Milne-Edwards & Haime, and the reappearance of the genus *Clisiophyllum* Dana, which had been absent since the Hangenberg event. *Axophyllum simplex* (Garwood), the first representative of the genus, is considered to be indicative for the RC4β2 Subzone, but its distribution has to be checked because it could be present earlier, as suggested by its occurrence in the uppermost part of the Eliaszowka Formation of the Czatkowice quarry section (Krakow area, southern Poland) together with foraminifers of the MFZ8 Foraminiferal Zone (Poty *et al.* in press).

The RC4α and the RC4β1 subzones are characteristic of the uppermost Tournaisian (Hance, Poty & Devuyst, 2001), but were previously considered as earliest Viséan (Conil *et al.* 1989, 1991). The base of the RC4β2 Subzone approximately matches the base of the MFZ9 Foraminiferal Zone, which coincides with the base of the Viséan.

The RC4α and the RC4β1 subzones correspond respectively to the Flémalle and Avins members of the Longpré Formation in the Namur and Condroz sedimentation areas of the Namur Dinant-Basin, and to their lateral equivalents in the other sedimentation areas. The RC4β2 Subzone corresponds to levels that developed only in the deeper part of the outer shelf, that is, in the Dinant sedimentation area and locally in the Visé-Maastricht sedimentation area, and were missing on the emergent shallow shelf. Such a distribution exists everywhere and restricts the number of records of the Subzone.

In Britain (Fig. 10), the RC4α Subzone corresponds to the *Siphonophyllia cylindrica* Zone of Ramsbottom & Mitchell (1980), and the RC4β1 and RC4β2 subzones respectively to Faunas A and B of Mitchell (1989).

On the East European Platform and in the Urals, the RC4α, β1 and β2 subzones can be correlated

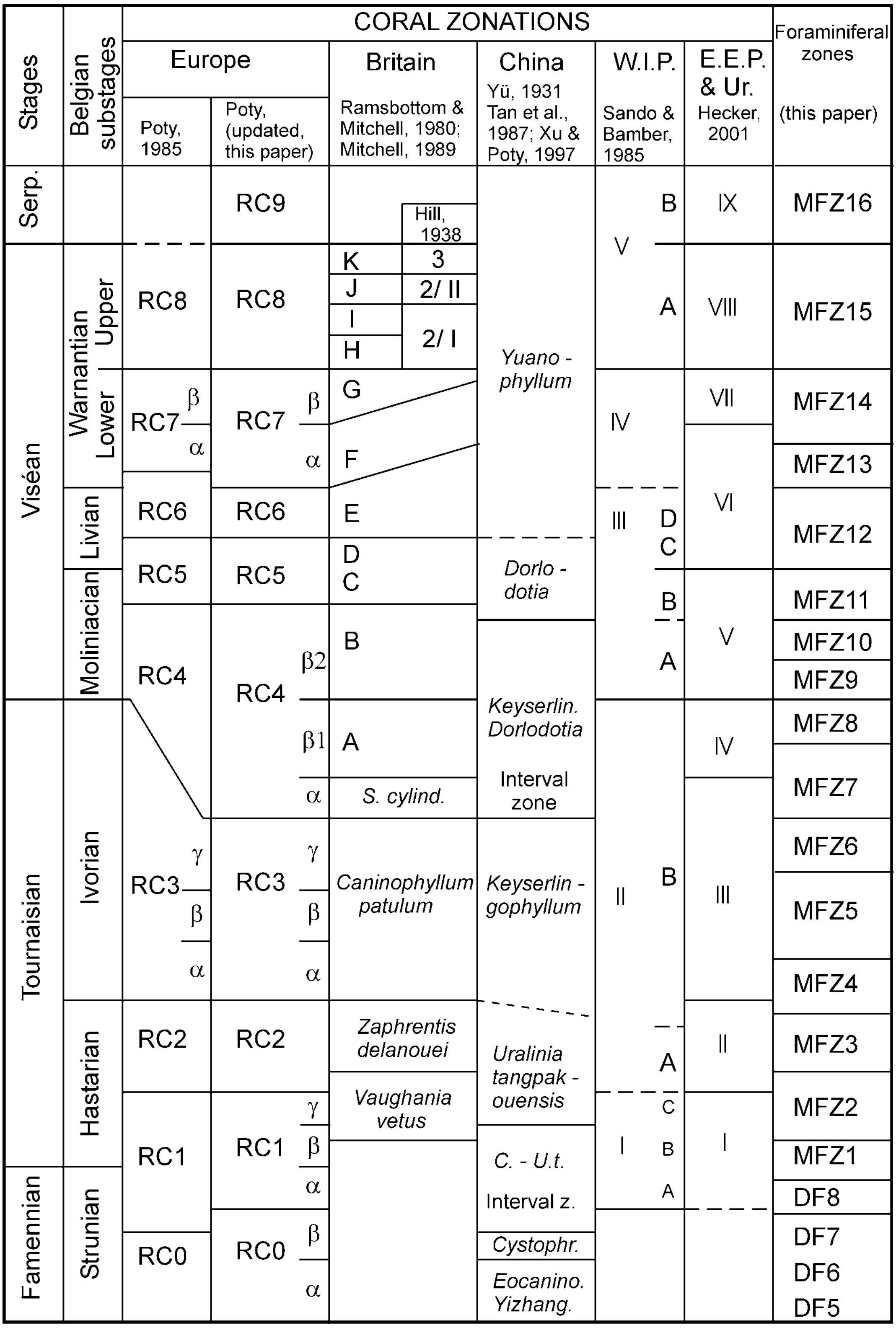

Figure 10. Comparison between the coral biozonations. W.I.P. – Western Interior Province of North America; E.E.P. & Ur. – East European Platform and the Urals; *Cystophr.* – *Cystophrentis*; C.-U.t. – *Cystophrentis-Uralinia tangpakouensis*; *Eocanino. yizhang.* – *Eocaninophyllum yizhangensis*; *Keyserlin.* – *Keyserlingophyllum*; *S. cylind.* – *Siphonophyllia cylindrica*; Serp. – Serpukhovian.

respectively with the uppermost part of Rugose Coral Zone III, Zone IV and the lower part of Zone V of Hecker (2001).

On the basis of the foraminiferal zonation, the interval corresponding to RC4α–lower RC4$\beta 2$ can be correlated in South China with the *Keyserlingophyllum–Dorlodotia* interval zone of Xu & Poty (1997), and the upper part of the RC4β2 Subzone with the lower part of the *Dorlodotia* (*Thysanophyllum*) Zone of Yü (1931).

The RC4β1 Subzone is remarkable because it can be traced not only in Europe, but as far as China, Japan and Australia (Poty, in press). The Subzone is more characteristic and easier to recognize than the RC4α Subzone, the latter being only known in Belgium, France (Boulonnais, Avesnois, Laval basin), Ireland and Great Britain. Note that a taxon of the RC4β1 Subzone is present a few metres below the base of the Viséan in the Pengchong section (Tournaisian–Viséan candidate boundary stratotype: Devuyst *et al.* 2003).

In North America, the RC4α and the RC4β1 subzones can be correlated on the basis of foraminifers approximately with the upper part of Zone IIB, and the RC4β2 with Zone IIIA of Sando & Bamber (1985).

3.f. Zone RC5 – *Siphonodendron* interval zone

In Europe, the base of the RC5 Zone (Fig. 8) corresponds to the arrival of the genus *Siphonodendron* from an older stock of species that may have been situated in the Pacific realm (western North America, Australia). The oldest European species is *S. ondulosum* Poty, which rapidly gave rise to *S. martini* (Milne-Edwards & Haime) (Poty, 1984, 1993). In Belgium and northern France, *S. ondulosum* is known from the base of the Neffe Formation.

Dorlodotia briarti Salée was formerly considered as appearing a little before *S. ondulosum*, that is, at the top of the Terwagne Formation, some metres below the base of the Neffe Formation (Poty, 1985; Conil *et al.* 1991), and therefore was also considered as a guide for the RC5 Zone (Poty, 1985; Conil *et al.* 1991). However, since then, *D. briarti* was found lower, in the RC4 Zone, and therefore it cannot be considered any longer as only characteristic of the RC5 Zone, although it is common in the lower part of this Zone (RC5α Subzone in Belgium and northern France).

Among other species: *Siphonodendron martini* (Milne-Edwards & Haime) and *Axophyllum mendipense* (Sibly) appear in the RC5α Subzone; *Corphalia mosae* Poty is characteristic in Belgium and northern France of the RC5β local Subzone (*Corphalia mosae* range-zone); *Axophyllum vaughani* (Salée), *Siphonodendron irregulare* (Phillips), *Caninophyllum archiaci* (Milne-Edwards & Haime) and *Clisiophyllum garwoodi* (Salée) appear in the RC5γ Subzone. In the Namur–Dinant Basin, the corals of the latter Subzone appear together with foraminifers of the MFZ12 Zone, which marks the base of the Livian substage.

In the Namur–Dinant Basin, the RC5α, β subzones comprise the Neffe Formation and the RC5γ Subzone the Haut-Le-Wastia Member of the Lives Formation.

In the Avon section (S. England), the zone corresponds to the Goblin Combe Oolite, the Upper Clifton Down Mudstone and the lower part of the Clifton Down Limestone (below the '*Lithostrotion basaltiforme* band' of Vaughan, 1906).

The RC5 Zone (Fig. 10) is more or less equivalent to the rugose coral faunal divisions C and D defined in Britain by Mitchell (1989). Note that Mitchell considered that the earliest *Siphonodendron* (*S. martini*) appeared in his rugose coral faunal division B (more or less our RC4β2 Subzone). But, as pointed by the author, this was based on a single record by Rose & Dunham (1977) from South Cumbria, from beds these authors tentatively referred to as the Martin Limestone (Chadian British substage), and that Mitchell referred to as the Red Hill Oolite (early Arundian British substage). No other specimen of *Siphonodendron* having ever been recorded in the latter formation, or from below the Goblin Combe Oolite or its lateral equivalents, this statement is considered as doubtful. On the East European Platform and in the Urals, the RC5 Zone corresponds to the upper part of Zone V and to the lowest part of Zone VI (RC5γ) of Hecker (2001). Note that this latter zone contains *Dorlodotia*, a genus that is not recorded above the RC5α Zone in Western Europe.

The RC5 Zone is correlated with the upper part of the South Chinese *Dorlodotia* Zone of Yü (1931), in which *Siphonodendron* also appears (Xu & Poty, 1997), and with the North American interval IIIB–lower IIID of Sando & Bamber (1985). The latter, however, shares no guide corals in common with the RC5 Zone.

3.g. Zone RC6 – *Lithostrotion araneum* interval zone

The base of this Zone (Fig. 8) is characterized by the appearance of *Lithostrotion araneum* (McCoy), the oldest representative of the genus *Lithostrotion* (Poty, 1984). *L. araneum* is considered to have evolved by a heterochronic process from subcerioid colonies of *S. ondulosum* Poty, such as those known in the RC5β Subzone (Poty, 1993). It extends into the RC7 Zone.

Lithostrotion vorticale (Parkinson), *Siphonodendron sociale* (Phillips) and *Siphonophyllia siblyi* Semenoff-Tian-Chansky, are other species that first appear in the Zone. Note that the most common coral species in the Zone are the long-ranging *Siphonodendron martini* and *S. irregulare*.

In the Namur–Dinant Basin, the Zone comprises the Corphalie and the Awirs members (Lives Formation) and the Grands-Malades Formation. The base of the Corphalie Member is characterized by a horizon with *Lithostrotion araneum* that can be traced as far as the Avon gorge section (Bristol, England), where it is developed at the base of the Lower Clifton Down Limestone (*Lithostrotion basaltiforme* band of Vaughan, 1906).

The RC6 Zone (Fig. 10) is equivalent to the Faunal Division E of Mitchell (1989), but mistakenly the latter includes some species assigned to taxa that in fact appear later (that is, in the RC7 Zone). It is correlated with the middle part of Zone VI defined by Hecker (2001) on the East European Platform and in the Urals, with the upper part of the North American Subzone IIID of Sando & Bamber (1985), and possibly with the base of the South Chinese *Yuanophyllum* Zone of Yü (1931).

3.h. Zone RC7 – *Dibunophyllum* interval zone

This Zone (Fig. 8) is characterized by the appearance of the genus *Dibunophyllum* (*Dibunophyllum* sp.), and the species *Siphonodendron pauciradiale* (McCoy), *S. scaleberense* Nudds & Somerville, *Siphonophyllia samsonensis* (Salée) (= *S. benburbensis* (Lewis)) and *Hexaphyllia marginata* (Fleming) from the base, then by the genus *Diphyphyllum* (*D. furcatum* Hill).

The later appearances of *Lithostrotion maccoyanum* Milne-Edwards & Haime, *Siphonodendron junceum* (Fleming), *Diphyphyllum lateseptatum* McCoy, *D. fasciculatum* (Fleming), and the genera *Aulophyllum* (*A. fungites* (Fleming)) and *Pseudozaphrentoides* (*P. juddi* (Thomson)) characterize the Subzone RC7β.

Other common taxa occurring in the RC7β Subzone are *Lithostrotion decipiens* (McCoy), *Siphonodendron* *intermedium* Poty, *Clisiophyllum keyserlingi* McCoy and *Dibunophyllum bipartitum* (McCoy).

The RC7 Zone was previously defined as the *Diphyphyllum furcatum* interval zone (Poty), and its base was placed higher (at the level of appearance of *D. furcatum* in the Poilvache Member, in the Cf6β Zone of Conil *et al.* 1991). Further investigations showed that some taxa characteristic of the Zone, including *Dibunophyllum* (see above), appeared earlier (at the base of the MFZ13 Foraminiferal Zone), which justifies the new definition of the Zone.

In Belgium, the RC7α Subzone comprises the massive crinoidal limestone of the upper part of the Thon-Samson Member and the Poilvache Member (River Bonne Formation) *sensu* Poty *et al.* (2002). The RC7β Subzone comprises most of the Anhée Fomation (the top belongs to the RC8 Zone). The zone matches the Lower Warnantian Substage (Asbian British Substage).

The RC7 Zone (Fig. 10) corresponds to the D1 Zone of Hill (1938) and to the Faunal Divisions F and G of Mitchell (1989). However, some taxa included in Fauna F appear in fact later, in Faunal Division G. The zone is recognized in Germany (Weyer, 2001), Poland (Fedorowski, 1981) and Spain (see, e.g. Rodriguez & Falces, 1994). On the East European Platform and in the Urals, the RC7α Subzone can be correlated with the upper part of Zone VI of Hecker (2001) and the RC7β Subzone with her Zone VII, the two latter sharing common taxa.

The RC7 Zone is correlated with part of the Chinese *Yuanophyllum* Zone of Yü (1931), and, on the basis of foraminifers, with the North American Zone IV of Sando & Bamber (1985).

3.i. Zone RC8 – *Lonsdaleia* interval zone

The base of the RC8 Zone (Figs 8, 10) is marked by the appearance of the genera *Lonsdaleia* McCoy (including fasciculate, subcerioid and cerioid species, the latter two corresponding to the subgenera *Actinocyathus* d'Orbigny and *Serraphyllum* Poty & Hecker) and *Palastraea* McCoy. Other common genera appearing in the zone are *Nemistium* Smith, *Corwenia* Smith & Ryder, *Thysanophyllum* Nicholson & Thomson, and *Orionastraea* Smith.

Only the lowest part of the zone is exposed in the Namur–Dinant Basin in Belgium (top of the lower member of the Anhée Formation, Condroz sedimentation area) and the Boulonnais (France, top of the Joinville Formation: Poty, 1994). The corals of the zone are better documented in sections in the British Isles, which allowed Hill (1938) and Mitchell (1989) to recognize several local subzones (Fig. 10). The zone correlates with the upper Warnantian (Brigantian British Substage).

The Zone RC8 can be traced easily in Europe and in Nova Scotia (Canada: Poty, 2002). It corresponds to the zones 2–4 of Hill (1938) and to the Faunal Divisions H–K of Mitchell (1989). On the East European Platform and in the Urals (Fig. 10), the RC8 Subzone corresponds to, and shares coral guide taxa with, Zone VIII of Hecker (2001). It can be correlated with Subzone VA of Sando & Bamber (1985), in which *Actinocyathus* also appears. Corals of the Zone RC8 are known in the *Yuanophyllum* Zone in China, but their systematics and distribution have to be checked.

3.j. Zone RC9

In northwestern Europe, the Viséan–Serpukhovian boundary is usually marked by a strong change in the sedimentary pattern: siliciclastic deposits become dominant over the previously dominant carbonate deposits. Therefore, corals become uncommon and coral faunas developed only in some areas where carbonate sedimentation persisted. These are not as diversified as previously, because of the disappearance of some species. These faunas comprise mainly genera and species known during the late Viséan and only some uncommon new species (Fig. 8). That coral association is not useful to characterize a new zone.

In southwestern Europe, Serpukhovian marine facies with corals are more common, and also comprise mainly taxa known from the Viséan and some new ones. In the Serpukovian of the Cantabrian Mountains (Spain), Rodriguez (1984) recorded the appearance of *Kionophyllum* Chi and *Semenophyllum* Rodriguez. In the Montagne Noire (southern France), Serpukhovian limestones yielded an abundant coral fauna. However, only the advanced stages of evolution shown by several species and some new local species distinguish that fauna from the Viséan fauna recorded in the same area (Poty, Aretz & Barchy, 2002).

On the East European Platform and in the Urals (Fig. 10), Hecker (2001) defined a Serpukhovian coral Zone IX, mainly characterized by the appearance of *Turbinatocaninia* Dobrolyubova and *Paralithostrotion* Gorskiy. *Turbinatocaninia* was recorded in the Serpukhovian of Nova Scotia (Canada: Poty, 2002) and also in the Western Interior Province (zones VB and VI of Sando & Bamber, 1985).

Therefore, the definition of the rugose coral Zone 9 must be improved and its recognition is still commonly based on the disappearances of corals of the previous zone.

4. Discussion

4.a. Evolution of the ideas on the Tournaisian–Viséan transition and implications

The distribution of the foraminifer zones which serve as basis for the correlation model of third-order sequences 4 and 5 between the Condroz and the Dinant sedimentation areas is given in Figure 11 and compared with the previously published interpretation. Late Tournaisian well-diversified foraminifer associations from sequence 4 in the inner shelf areas were previously considered as Viséan in the Belgian literature, based on the abundance of typical taxa with 'Viséan affinities' (*Bessiella, Florennella, Pseudolituotubella, Dainella, Loeblichia fragilis*...). The absence of *Eoparastaffella simplex* was supposed to reflect unsuitable facies conditions affecting mainly inner shelf areas (Conil, 1967; Hance, 1988). The idea of the Viséan transgression, causing the delayed entry of taxa well documented in older sediments in other areas of Eurasia, was also invoked (Conil & Lys, 1977). Several elements suggest, however, a late Tournaisian age for this pre-*Eoparastaffella simplex* fauna, as suspected already by Kalvoda (1983):

(1) its coexistence with *Scaliognathus anchoralis europensis* in South China where it precedes the entry of the primitive *Eoparastaffella* M1 (Hance *et al.* 1997*b*; Devuyst *et al.* 2003);

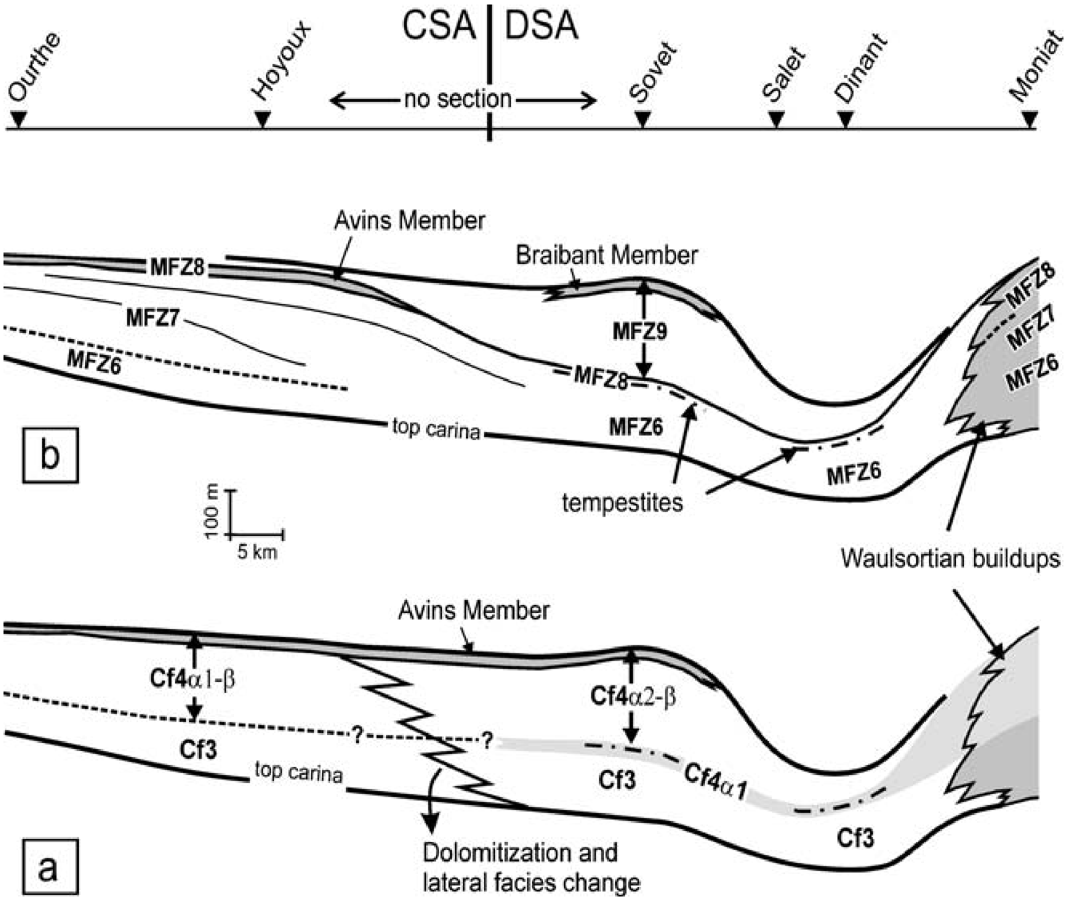

Figure 11. Comparison between the previous correlation model across the Condroz sedimentation area (CSA) and Dinant sedimentation area (DSA) at the time of the Tournaisian–Viséan transition and the interpretation proposed here. Note that the MFZ7 association is not found in the deepest part of the DSA due to unsuitable facies, but well in the Waulsortian buildups where palaeobathymetric conditions were similar to that of the shelf during the late Tournaisian. 'Top carina' corresponds to the last appearance datum of the conodont *Polygnathus communis carina.* Refer to Figure 1 for the localities mentioned. 'Ourthe' and 'Hoyoux' are composite sections in river valleys.

(2) its coexistence with the rugose corals *Sychnoaelasma urbanowitchi* and *Cyathoclisia modavensis* (RC4α Subzone) which are found in the late Tournaisian Black Rock limestone of SW England (Ramsbottom & Mitchell, 1980);
(3) the coexistence of a similar fauna with *S. anchoralis europensis*, well documented from 3653–2950 m in the Saint-Ghislain borehole (Hainaut sedimentation area: Groessens, Conil & Hennebert, 1982);
(4) the succession of zones MFZ7 to MFZ10 consistent with that observed in South China (Hance *et al.* 1997*a*,*b*; Devuyst *et al.* 2003) and with the pattern of the Russian Platform and the Middle Urals (Vdovenko *et al.* 1990; Brenckle 1997; Kulagina, Gibshman & Pazukhin, 2003);
(5) the recognition of major sequence boundaries and the progradational character of the Flémalle Member (HST sequence 4), deduced from the geometry of that body across isopic lines, which suggests that the Flémalle Member pre-dates the Sovet Formation and is not its lateral equivalent as previously supposed (Conil, 1967; Hance, 1988; Hance *et al.* 1994). In this interpretation, the Avins Member, which ends sequence 4, does not correlate with the Braibant Member which caps the Sovet Formation (interpreted as the Avins Member in Conil, 1967; Segura, 1973, and Hance, 1988), but only to the lowermost part of that formation. Recent investigations at this level in the Sovet section (F.-X. D. & L.H., Fig. 13) have clarified foraminifer occurrences at this level and confirmed an age younger than the Flémalle Member and equivalent at least in part to the Avins Member in which *Biseriella bristolensis* is common. The lithostratigraphic correlation is clearer in the Hun-Yvoir area, at the transition between the Condroz and Dinant sedimentation areas, above the Leffe Formation, where a metre-thick oolitic unit is included in the lowermost part of the Sovet Formation (Delcambre & Pingot, pers. comm.).

At least part of the first Viséan third-order sequence (sequence 5) is lacking on the inner shelf areas, which

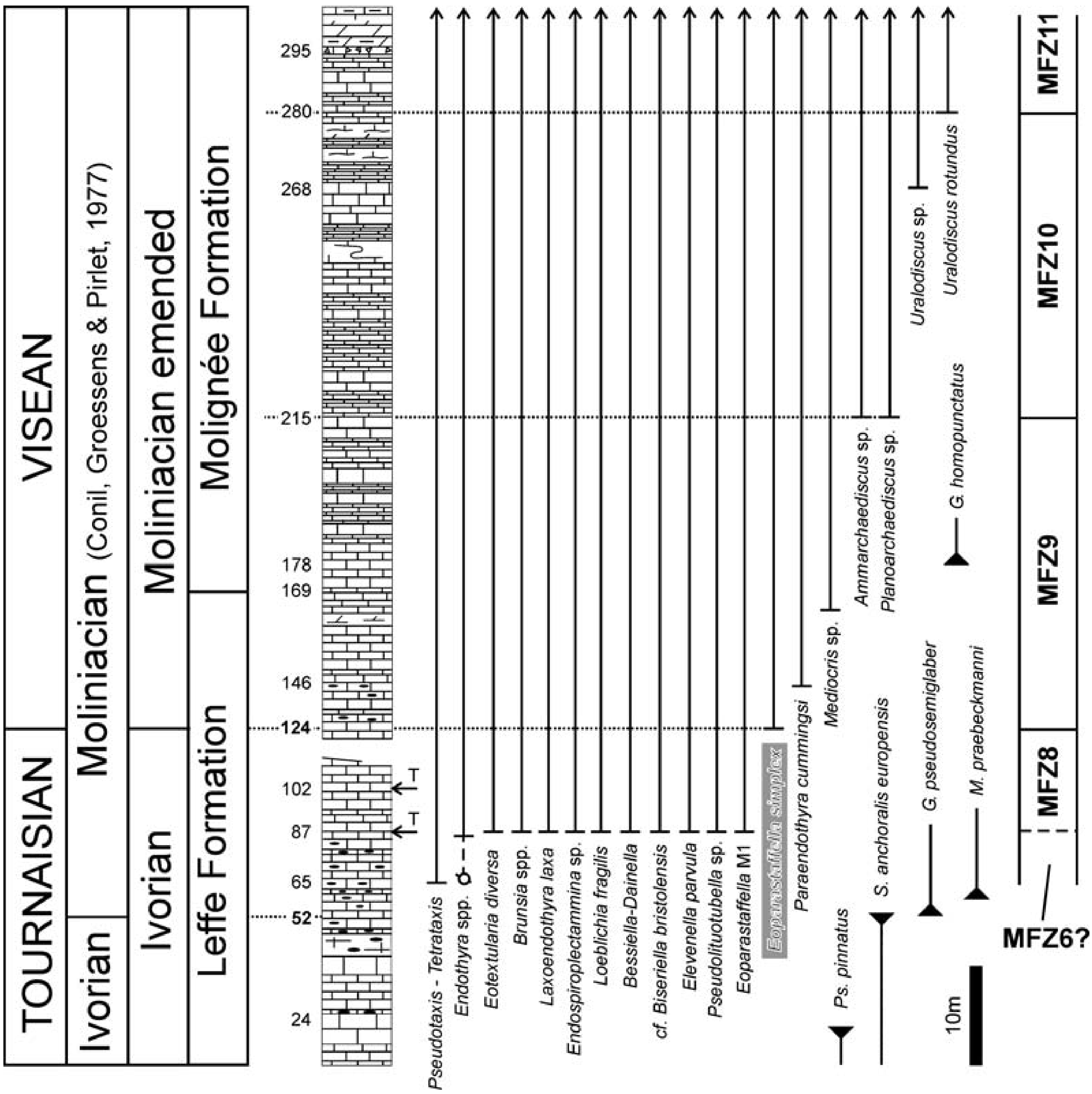

Figure 12. Distribution of the most significant foraminifers at the Tournaisian–Viséan transition in the Salet road section (stratotype) and redefinition of the base of the Moliniacian (bed 124). For more details concerning the distribution of the conodonts, see Belka & Groessens (1986) from which the data are taken. Due to unsuitable facies, the MFZ7 Zone cannot be identified. Bed 87, which contains the first significant and diversified association, is a sorted tempestite derived from shallower areas. *S. – Scaliognathus*; *M. – Mestognathus*; *G. – Gnathodus*; *Ps. – Pseudopolygnathus*; T. – tempestites. See caption of Figure 13 for the legend of the stratigraphic column and ranges.

were emergent during the latest Tournaisian and early Viséan (Hance, Poty & Devuyst, 2001). Overlying the poorly diversified Cf3 Zone, with *Tetrataxis* spp. and *Eotextularia diversa* as the most abundant taxa, the Cf4α1 Subzone was defined by Conil *et al.* (1989) by the rapid entry of taxa supposedly migrating from Eastern Europe, including *Valvulinella*, *Darjella monilis*, *Omphalotis*, 'dainellids' (= *Bessiella* + *Dainella*), *Endospiroplectammina conili*, *Pseudolituotuba gravata*, *Conilites* and *Urbanella* (= *Loeblichia*). Therefore, the Cf4α1 Subzone correlates with the uppermost part of MFZ6, MFZ7 and MFZ8. MFZ8 contains primitive *Eoparastaffella*, but not *E. simplex*, which is used for defining the base of the Cf4α2 Subzone (Conil, Groessens & Pirlet, 1977, tab. II) and that of our MFZ9 Zone. The opinion of Conil about the evolutionary stage of the first *Eoparastaffella* is unclear, however, as Conil *et al.* (1989, p. 181) stated that the base of the Cf4a2 Subzone is recognized by the entry of the most primitive *Eoparastaffella*. The succession MFZ7–MFZ9 can be identified in the upper part of the Waulsortian buildup at Moniat (Lees, 1997).

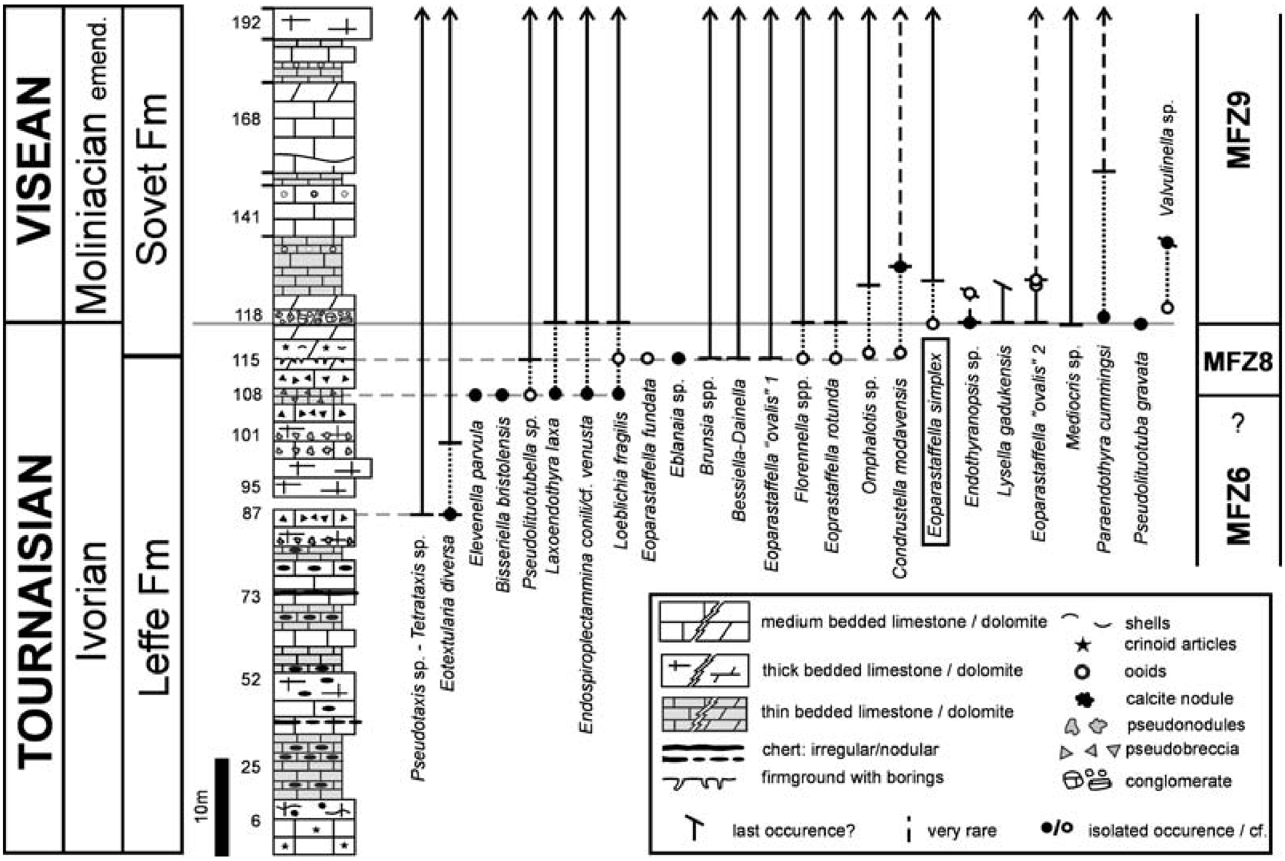

Figure 13. Distribution of the most significant foraminifers at the Tournaisian–Viséan transition in the Sovet railway section (parastratotype of the base of the Moliniacian). Bed 108 is a sorted tempestite. Unsuitable facies hamper recognition of Zone MFZ7 and only the taxa characteristic of MFZ6 are found below MFZ8.

4.b. The Moliniacian Substage emended (F. X. Devuyst)

The Moliniacian Substage was introduced by Conil, Groessens & Pirlet (1977) as the first division of the Viséan above the Ivorian (last Tournaisian substage). The ‘golden spike’ was chosen at the base of bed 52 in the Salet road section in the central Dinant sedimentation area (see also Paproth *et al.* 1983*a*; Belka & Groessens, 1986; Hance, 1988). The passage from the Leffe Formation to the Molignée Formation is transitional (Fig. 12) and bed 52 is the first dark limestone bed (‘black marble’) included in the Leffe Formation. It does not correspond to the entry of any foraminifer guide but occurs just below the appearance of *M. praebeckmanni* and at the end of the range of *S. anchoralis europensis* (Belka & Groessens, 1986). It was correlated with the lithostratigraphically equivalent bed 141 in the Bastion section (Conil *et al.* 1969) which defines the base of the Viséan and which coincides with the local entry of *Eoparastaffella.* The discovery of the Cf4α1 fauna below the base of the Viséan in the Bastion section led Conil *et al.* (1989) to propose a different correlation between the two sections, shifting the base of the Viséan up to bed 124 (not 123 as erroneously reported by Conil *et al.* 1989 and previous papers) in the Salet section, where the first *Eoparastaffella* is found. As a consequence, the 19 lower metres of the Moliniacian, included between the base of bed 52 and the top of bed 123, are late Tournaisian and indeed contain tempestites with a Cf4α1 fauna (*sensu* Conil *et al.* 1991; Lees, 1997). The Moliniacian Substage is therefore emended here to restore the coincidence with the base of the Viséan at bed 124 in the Salet boundary stratotype. Primitive *Eoparastaffella* M1, *B. bristolensis*, *Loeblichia fragilis, Elevenella parvula* and *Mediocris* sp. have now been found in bed 87 which is therefore in Zone MFZ8 (Fig. 12). The Sovet railway section (Dinant sedimentation area: Conil, 1967; Segura, 1973; Hance, 1988) yields the most complete and fossiliferous succession (foraminifers, conodonts) straddling the Tournaisian–Viséan boundary known so far in the Franco-Belgian Basin and is proposed as parastratotype (Figs 13, 14). Bed 108 is a tempestite at the top of the Leffe Formation which yields a foraminifer population characteristic of Zone MFZ8 and resulted probably from the same cause (major storm?) as bed 87 in Salet. The first *Eoparastaffella* (M1) enters in bed 115 at the very base of the Sovet Formation while the first *Eoparastaffella simplex* identifying the base of the Viséan enters in

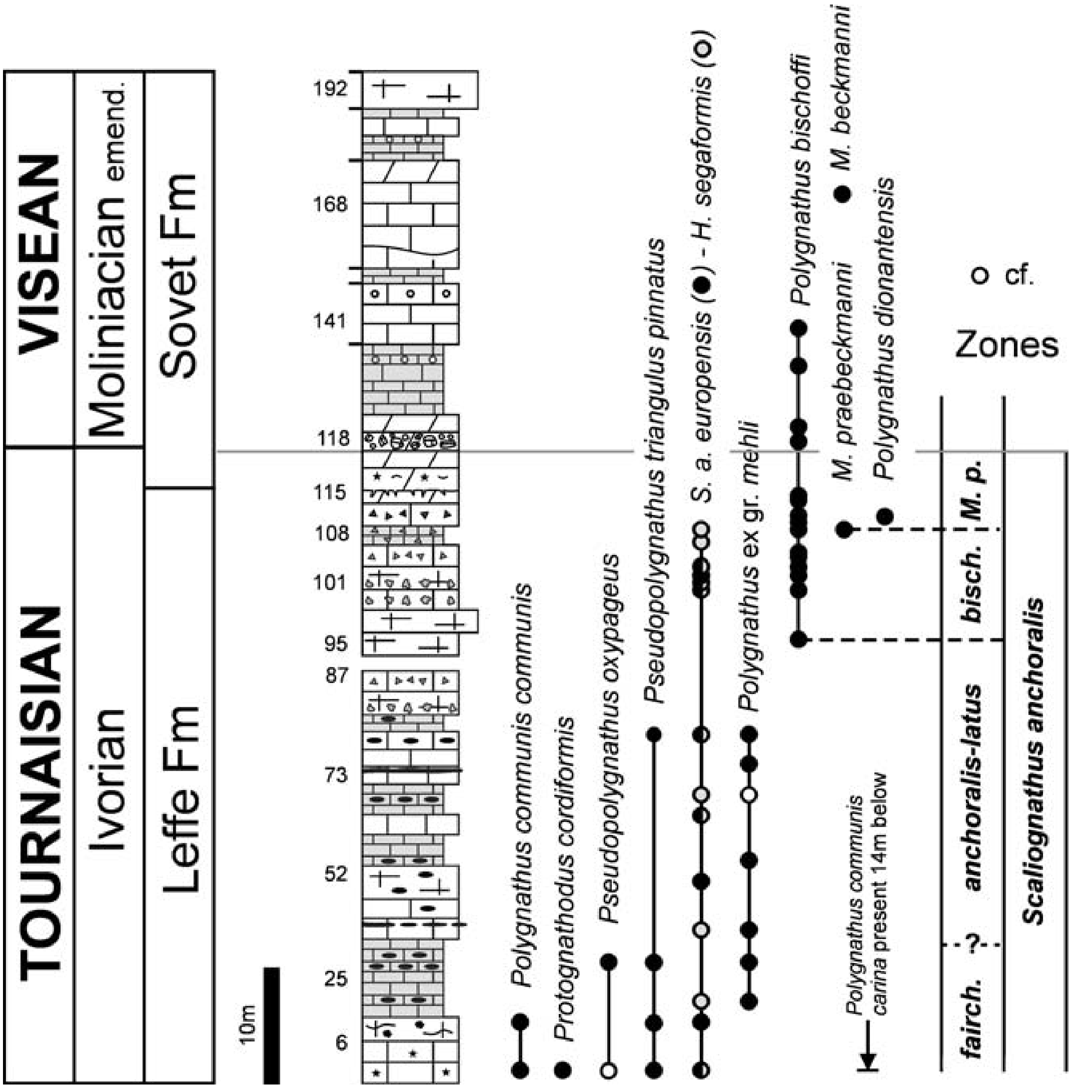

Figure 14. Distribution of the most significant conodonts at the Tournaisian–Viséan transition at Sovet after Groessens (1975) and Conil *et al.* (1988). Zones after Groessens *in* Conil *et al.* (1991). For legend see Figure 13. *H. – Hindeodella*; *M. – Mestognathus*; *S.a. – Scaliognathus anchoralis*; *M. p. – Mestognathus praebeckmanni* Zone; *bisch. – Polygnathus bischoffi* Zone; *anchoralis-latus – S. anchoralis–Doliognathus latus* Zone; *fairch. – S. fairchildi* Zone.

bed 118 (together with pointed *E. ovalis* ‘type 2’ in Fig. 12, ‘evolved *E. ovalis*’ of Devuyst *et al.* 2003), which therefore corresponds to the base of the Moliniacian emended.

4.c. The Freyrian

Lees (1997) discussed the sedimentology and palaeobathymetry of the Waulsortian buildups and proximal peri-Waulsortian rocks during the late Tournaisian in the Dinant sedimentation area. He proposed the informal term Freyrian to cover the interval lying between the base of the Moliniacian (*sensu* Conil, Groessens & Pirlet, 1977) and the base of the Viséan. After compilation of the available biostratigraphic data, the successive entries of the key foraminifer taxa are deduced from the top of the Waulsortian mudmounds (mainly Moniat and Furfooz) and serve to correlate Waulsortian and peri-Waulsortian rocks. The tempestites occurring in the upper part of the Leffe Formation in the peri-Waulsortian sections, which yield all the stratigraphically significant taxa, are interpreted as having been derived from the summit of the Waulsortian mudmounds in the Moniat area. Lees’ foraminifer levels 1, 4, 5 and 6 correspond respectively to zones MFZ6, MFZ7, MFZ8 and MFZ9 of the present paper. Levels 2 and 3 fall in the uppermost part of MFZ6. The entries of *Brunsia* and dainellids in Waulsortian setting are delayed. Indeed these taxa are well known to precede by far the level at which *D. monilis* occurs in Russia and Eastern Europe. In most of the Namur–Dinant Basin, the lower part of the *S. anchoralis europensis* biozone is either dolomitic (platform) or devoid of foraminifers (basin). In the Hainaut sedimentation area (Saint-Ghislain borehole), however, low occurrences of *Brunsia* and *Dainella*

Chronostrat.			Foraminiferal zones				Conodont zones		Coral zones		3rd order seq. strati.
			This paper	Conil et al. 1991		Mamet 1974	Conil et al.,1991 and this paper		This paper		Hance, P. & D., 2001
MISSISSIPPIAN	S.	Arnsb. Pend.	MFZ16	Cf7		17-19	*boll.*	*Adetognathus unicornis* *Gn. bilineatus bollandensis*	RC9		11
	VISEAN	Warnantian	MFZ15	Cf6	δ	16s	*bilineatus*	*Gnathodus bilineatus bilineatus*	RC8		10
			MFZ14		γ	16i			RC7	β	9
			MFZ13		α–β	15				α	
		Liv.	MFZ12	Cf5		14 13	*T. transatlanticus*		RC6		8 7
		Mol. emend.	MFZ11	Cf4	γ–δ	12		*Taphrognathus transatlanticus*	RC5		6
			MFZ10		β	11 10	?	*Gnathodus cracoviensis*	RC4	β2	
			MFZ9		α2		*homo.*	*Gnathodus homopunctatus*			5
	TOURNAISIAN	Ivorian	MFZ8		α1	9	*S. anchoralis*	*Mestognathus praebeckmanni* ? ?		β1	4
			MFZ7							α	
			MFZ6	Cf3			*cordiformis*	*Polygnathus bischoffi* *Doliognathus latus*	RC3	γ	
			MFZ5	Cf2		8	*carina*	*Dollymae bouckaerti*		β α	3
		Hastarian	MFZ4	Cf1	γ	7		*Gnathodus*	RC2		
			MFZ3		β			upper *obsoleta*			2
			MFZ2		α" α'	pre-7		lower *obsoleta* upper *cooperi*	RC1	γ	
			MFZ1		α			*duplicata - cooperi*		β α	
DEVONIAN	FAMENNIAN	"Strunian"	DFZ8					upper *praesulcata*	RC0	β	1
			DFZ7	Df3	ε	6		upper *expansa*			
			DFZ6		δ	5		middle *expansa*		α	
			DFZ5		γ						

Figure 15. Correlation of the new zonations with previous zonal schemes. Note that the base of the Cf4α1 marked by the entry of primitive *Valvulinella* actually falls in the upper part of MFZ6. Chronostrat. – Chronostratigraphy; Arnsb. – Arnsbergian; Liv. – Livian; Mol. emend. – Moliniacian emended; Pend. – Pendleian; S. – Serpukhovian; *S. – Scaliognathus*; 3rd order seq. strati.; Hance, P. & D., 2001 – Third-order sequence stratigraphy of Hance, Poty & Devuyst, 2001.

are well documented (Groessens *et al.* 1982). In the rare sections of the Namur–Dinant Basin where the late Tournaisian platform deposits are not completely dolomitized, *Brunsia* occurs early also. At Landelies (Namur sedimentation area), *Brunsia* appears in bed 198, below the entry of the conodont *Polygnathus bischoffi* (revision of all available thin-sections: this paper; Groessens, Conil & Lys, 1976). In the Modave section (Condroz sedimentation area), dainellids and *Brunsia* occur in the first limestone unit interbedded in the dolomitic Flémalle Member and *D. monilis* in the second, about 25 m higher (revision of all available thin-sections: this paper). Hence the key taxon for level 5 is more probably *Loeblichia fragilis* (= *Urbanella fragilis* in Lees, 1997) rather than *Brunsia*.

As pointed out by Lees, foraminifer level 5 or Zone MFZ8 can be traced across most of the deepest part of the Dinant sedimentation area. The source area for the sorted tempestite bearing a foraminifer association characteristic of MFZ8 (level 5 of Lees, 1997) in the Bastion section is most likely the Moniat mudmound area. In the Salet and Sovet sections, it might well have been the shelf margin. In the model proposed by Lees (1997), foraminifer level 5 approximates the end of a late Tournaisian sea-level fall of about 140 m, starting at a level equivalent to the base of the *S. anchoralis* Zone. It coincides with the deposition of the Avins oolitic limestone, at least its upper part in the more distal areas of the shelf, which contains the MFZ8 fauna. Foraminifer level 4 of Lees (1997) or Zone MFZ7 (entry of *D. monilis*) is identified on the shelf, in the Condroz and Namur sedimentation areas.

Correlating foraminifer level 2 at Moniat (entry of *Valvulinella*) with the peri-Waulsortian sections is much less obvious due to the rarity of that taxon, to facies problems and also to lack of data. We reach here the resolution limit of the biostratigraphy of the Namur–Dinant Basin based on foraminifers. *Valvulinella* enters at Bastion 4.8 m below *L. fragilis* (foraminifer level 5/MFZ8) in the *bischoffi* conodont Subzone. These two taxa are separated by 38 m at Moniat. Primitive *Valvulinella* are not present at Salet, but we suggest correlating foraminifer level 2 with a level within the *bischoffi* Subzone, a few metres below the correlation of the base of the Moliniacian (*sensu* Conil, Groessens & Pirlet, 1977) given by Lees (1997). Foraminifer level 2 cannot be traced outside the Dinant sedimentation area.

5. Conclusions

The last zonation scheme of Conil *et al.* (1991) for the Namur–Dinant Basin is reviewed for foraminifers and rugose corals, with emphasis on the Tournaisian–Viséan transition (Fig. 15). Correlation of the first interval across the basin is better understood. In particular, late Tournaisian foraminifer associations are much more diversified than previously thought. They allow a better biostratigraphic resolution in the Namur–Dinant Basin and improved correlations across Eurasia. Significant change is made also to former models concerning the age of the Avesnelles Limestone fauna (Cf1α of Conil *et al.* 1991) that is now considered as latest Famennian and not early Carboniferous. These changes make necessary the introduction of a new notation to avoid confusion (Fig. 15). The new foraminiferal zonation is based mainly on interval zones. Zones MFZ1 to MFZ8 subdivide the Tournaisian, whereas zones MFZ9 to MFZ15 span the Viséan. Zone MFZ16 is the last Mississippian zone which can be recognized in Belgium. Correlation between the new zonation and the zonation of Conil *et al.* (1991) is quite straightforward as we do not make significant changes to the middle and late Viséan zones. Correlation with the zonation of Mamet (1974) is more problematic due to the mixed nature of the zones used by this author and the lack of information given about the successive entries and coexistences. The correlation proposed in Figure 15 is interpretative and differs from that given in Paproth *et al.* (1983*a*). Zone 9 is particularly long-ranging and spans an interval which could include zones MFZ5 to MFZ10.

Among the coral zonation some zones and subzones defined in northwestern Europe can be recognized across Eurasia and sometimes as far as North America and Australia, and are therefore useful for long-distance correlation (Fig. 10). These are:

(1) the RC1 Zone characterized by the spread of survivors of the Hangenberg event (Eurasia, North America);
(2) the RC1γ Subzone which is characterized by the appearance and dispersal of *Uralinia* (Eurasia);
(3) the RC3α Subzone characterized notably by the appearance and dispersal of *Uralinia* of the *U. gigantea* group, *Cyathoclisia* and *Keyserlingophyllum* (Eurasia); and
(4) the RC4β1 Subzone which comprises taxa (*Amygdalophyllum* and *Merlewoodia*) which are found not only in Eurasia but as far away as Japan and Australia.

More data are needed to apply the RC5, RC7 and RC8 zones confidently outside Europe, in Asia and North Africa, where characteristic corals of these zones are known.

Acknowledgements. This paper is the result of many years of cooperative research, field trips and stimulating discussions involving many colleagues to whom we are most grateful: Paul Brenckle, Nilyufer Gibshman, Eric Groessens, Hongfei Hou, Jiri Kalvoda, Martin Laloux, Alan Lees, Philippe Muchez, George Sevastopoulo, Daniel Vachard and Xianghe Wu. G. Sevastopulo also kindly commented on an early version of the paper. A. Lees provided helpful comments for the Upper Tournaisian. The text was greatly improved by the thorough reviews of Jiri Kalvoda and Daniel Vachard. F. X. Devuyst gratefully acknowledges the award of a doctoral fellowship from the Belgian National Fund for Scientific Research (FNRS), of a post-doctoral fellowship from the Irish Research Council for Science, Engineering and Technology (IRCSET) and the support of grant project MSM 0021622412 of the Ministry of Education, Youth and Sport of the Czech Republic.

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