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Tournaisian–Lower Visean Calcareous Foraminifera: Biostratigraphy and Palaeogeography

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Carboniferous
Tournaisian
Lower Visean
Calcareous foraminifers
Biostratigraphy
Palaeogeography

Contents

Kalkige Foraminiferen aus dem Zeitraum Tournai–Untervisé: Biostratigraphie und Paläogeographie

Zusammenfassung

Eine kombinierte Untersuchung an Conodonten und Foraminiferen vom mittleren Tournaisium bis unterem Viséum in Mähren sowie eine Auflistung von Conodonten- und Foraminiferendaten aus den Provinzen Paläotethys, Siberia und Nord-Amerika ermöglichen eine weltweite Korrelation von Foraminiferenzonen im Unterkarbon. Hieraus erfolgt eine Diskussion über das die Tournai/Visé-Grenze enthaltene Interval sowie eine Beurteilung der Biogeographie von kalkigen Foraminiferen. Aus- und Einwanderungsereignisse von Foraminiferenfaunen höherer Breiten sind mit eustatischen und isotopischen Events zu korrelieren. Diese stehen in Beziehung zu klimatischen Zwängen im Zusammenhang mit der Vereisung in Gondwana. Das Bild paläobiogeographischer Verbreitung von Foraminiferenfaunen am Kontakt zwischen Gondwana und Laurussia scheint Ost-Avalonia auf dem Süd-Laurussia-Schelf von peri-Gondwana-Einheiten weiter im Süden zu differenzieren.

Abstract

Combined study of conodonts and foraminifers through the middle Tournaisian–lower Visean in Moravia and a compilation of conodont and foraminiferal data from Palaeotethyan, Siberian and North American Realms enables worldwide correlation of Lower Carboniferous foraminiferal zonations, discussion of the interval about the Tournaisian-Visean boundary, and evaluation of the biogeography of calcareous foraminifers. Emigration-immigration events affecting foraminiferal faunas in higher latitudes correlate with eustatic and isotopic events. These are consistent with climatic forcing connected with glaciation in Gondwana. The palaeobiogeographic pattern of foraminiferal faunas at the Gondwana-Laurussia interface seems to distinguish Eastern Avalonia on the southern Laurussian shelf from Perigondwanan terranes to the south.

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1. Introduction

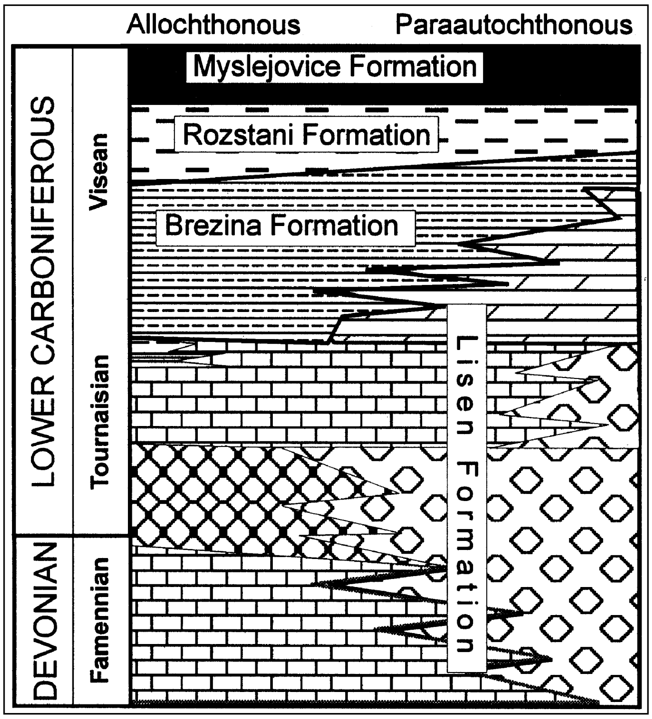
Lower Carboniferous calcareous foraminifers, a benthic group, provide a sensitive tool for biostratigraphic, palaeobiogeographic and palaeoclimatic studies. Data on distribution of foraminiferal faunas and subdivision of the Lower Carboniferous are summarised. The climatically influenced migration patterns of foraminiferal faunas (KALVODA, 1986, 1990a) are suggested to be closely connected with the Gondwana glaciation recently reported in the Lower Carboniferous (STREEL, 1986; STREEL et al., 1993; LANG et al., 1991; ISAACSON et al., 1999).

2. Biostratigraphy at the Tournaisian/Visean Boundary

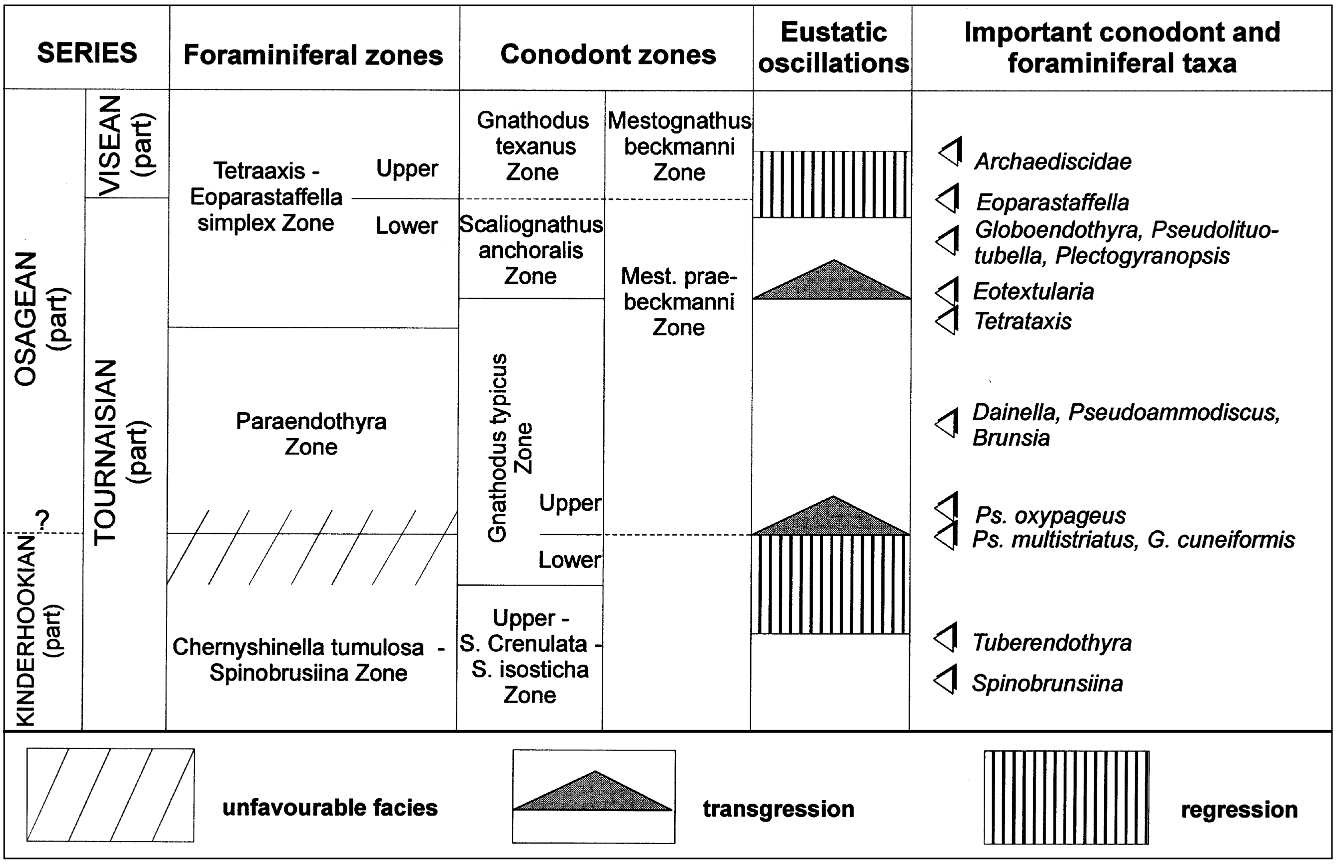
In a quest for possible levels for subdivision of the Lower Carboniferous, new stage definitions have been under discussion (BRENCKLE, 1990, 1992; BELKA, 1992). Problems arise especially because the boundary has been defined at the change from deeper to shallow water facies and because some typical Visean taxa in eastern Avalonian (including Moravia) and eastern European terranes occur at least one or two conodont zones (c. 1–2 million years) sooner than in the stratotype area (KALVODA, 1982).

During the 1987 International Carboniferous Congress in Beijing, the Subcommission on Carboniferous Stratigraphy created three working groups to identify possible stratigraphical levels for subdivision of the Lower Carboniferous (ENGEL, 1992):

1) the interval about the middle/upper Tournaisian (Kinderhookian-Osagean) boundary;
2) the upper Tournaisian–lower Visean interval (Tn3c–V1a);
3) the middle Visean interval.



Text-Fig. 1.
Correlation of Upper Devonian and Lower Carboniferous sediments in the southern part of the Moravian Karst showing transition from Lisen Formation (mainly calciturbidites) to transitional flysh (Brezina Formation) and typical flysh developments (Rozstani Formation and Myslejovice Formation).



Text-Fig. 2.
Occurrence of important middle Tournaisian–lower Visean genera of calcareous foraminifers in Moravia (Czech Republic) relative to conodont zonation.

Stage	Substage	Moravia	Namur and Dinant Synclinorium		Eastern Europe	Tian-Shan	Western Siberia	Omolon and Kolyma Massif		Kuznets Basin	North America	Conodont Zonation
VISEAN	UPPER	Asteroarchaediscus--L.paraammonoides Zone	Neoarchaediscus Zone	δ	E. tenebrosa Zone	H. gibba longa - - N. parvus Zone	E. aff.kazachstanica - - A. karreri- - H. gibba Zone	E.ermakiensis Zone		E. ermakiensis Zone	16	G. bilineatus
		Neoarchaediscus Zone		α–γ	E. ikensis Zone	B. rotula- - F. prisca Zone					15	
					E. proikensis Zone	Pl. spirillinoides Zone	M. excelsaformis- E. diversa- - Eoendothyranopsis Zone					
	MIDDLE	Pojarkovella nibelis - Koskinotextularia Zone	P. nibelis--Koskinotextularia Zone		E. compresus Zone						14 13	Unzoned interval ?
	LOWER	V. eospirillinoides - - G. oblongus Zone	Eoparastaffella Zone	β–δ	Pl. spirillinoides - - U. rotundus Zone	Ps. paraprimaevus- - Viseidiscus Zone	?			M. excelsa- - E. diversa Zone ?	12 11 10	
						T. perfida Z.	E. diversa- - L.cf.grandis - Tetrataxis Zone	E. diversa Zone				
		Tetrataxis- - Eoparastaffella simplex Zone		α	Eoparastaffella - Eoendothyranopsis	O. paraturkestanica Z.				S. evoluta - E. diversa- - Tetrataxis Zone	9	G. texanus
TOURNAISIAN	UPPER		Tetrataxis--P. diversa Zone		E. elegia-P. diversa Z.	D. chomatica - E. michoti Z.						S. anchoralis
		Paraendothyra Zone	Tournayella - Granuliferella - - Paraendothyra Z.		Spinoendothyra Zone	E. turkestanica - P. tchikmanica Zone	E. inflata- - P.tchernyshinensis Zone	Latiendothyr.- -Spinoendoth. Z.	γ	T. tuberculata - Pseudoplanoendothyra Zone	8	G. typicus Upper
					Tuberendothyra - Laxoendothyra Z.				β			
	MIDDLE	Chernyshinella tumulosa - Spinobrunsiina Zone	Spinobrunsiina Zone			B. malevkensis - - E. minima Zone	?		α	T. discoidea - L. parakosvensis Zone	7	Lower
					Chernyshinella - - S.krainica Zone			Chernyshinella Zone	β			Upper S. crenulata - - S. isosticha
		Chernyshinella glomiformis Zone	Ch. glomiformis - P. tchernyshinensis Zone						α		pre 7	S. crenulata
	LOWER	Quasiendothyra kobeitusana - - Quasiendothyra konensis Z.			Q. kobeitusana - Q. konensis Zone	Q. kobeitusana - Q. konensis Z.	Q. kobeitusana Zone	Quasiendothyra Zone	Endothyra - Paracalligelloides Zone			S. sandbergi S. duplicata S. sulcata
FAMENNIAN			Quasiendothyra Zone	ε					α–ε			S. praesculata P. expansa
		Quasiendothyra communis - Quasiendothyra regul. Z.		α–δ	Q. communis Zone	Q. communis - S. lebedevae Zone	?			rare Quasiendothyra		P. postera P. trachytera P. marginifera
		Q. communis-E. evlanensis Interzone	Septatournayella Zone		Q. bella Zone	V	S. nana Z.	?				P. rhomboidea P. crepida P. triangularis
FRASNIAN		Multiseptida corallina - Eonodosaria evlanensis Z.	Nanicella Zone		T. multiformis - E.evlanensis Zone	IV	M. corrallina - E.evlanensis Zone	E. evlanensis - N. porrecta Zone		T. multiformis - E. evlanensis Zone	E. evlanensis - M. corrallina Zone	P. gigas A. triangularis
		Nanicella Zone			N. bella Zone ?	III	S. horrida- - N. polypora Zone					P. asymetricus
Gi.												

Text-Fig. 3.
Correlation of Upper Devonian–Lower Carboniferous foraminiferal zones in the Palaeotethyan Realm (Namur and Dinant Synclinorium, Eastern Europe, Tien Shan), Siberian Realm (Omolon and Kolyma Massifs, Kuznets Basin) and North American Realm (modified from KALVODA, 1990).

At the general meeting of the Subcommission on Carboniferous Stratigraphy in Krakow on 31 August 1997, a decision was taken to establish a boundary within the Lower Carboniferous close to the existing Tournaisian/Visean boundary. Attention has concentrated mainly on evolutionary changes in *Eoparastaffella*, specifically the change from *Eoparastaffella* Morphotype 1 to Morphotype 2, as a boundary-defining event (HANCE, 1997; HANCE et al., 1997). In the absence of early representatives of *Eoparastaffella* in the Belgium stratotype section for the Tn-V boundary, research has now focused on South China (HANCE et al., 1997) where the two morphotypes necessary for recognition of the boundary are present. No section has been yet discovered that satisfies all requirements for a GSSP; it may therefore be necessary to seek a stratotype elsewhere.

The most suitable profiles for study of foraminifers and conodonts for potential levels for subdivision of the Lower Carboniferous in Moravia occur in the southern part of the Moravian Karst. In the Tournaisian, various types of calciturbidites predominate. In the upper Tournaisian, the transition from preflysch to flysch is represented by proximal and distal calciturbidites alternating with siliciclastic sediments (Text-Fig. 1). The profiles are important as the carbonates contain conodonts and foraminifers; additionally, trilobites (Proetidae and Phillipsidae) have been reported near the Tn/V boundary. Unfortunately the sections are often strongly deformed and the exposures are subject to rapid change because of heavy quarrying.

Many taxa of calcareous foraminifers typical of the Visean in the stratotype area in Belgium occur in the upper Tournaisian in Moravia (Text-Fig. 2). The lineage of the cosmopolitan mesopelagic conodont genus *Scaliognathus*, supplemented by the *Doliognathus* lineage, seems most suitable for revising subdivision of the Lower Carboniferous. Definition of the classical Tournaisian-Visean boundary was based on benthic foraminiferal faunas; these seem to be uncommon elsewhere. Planctic and nectic organisms are generally preferred for interregional correlations.

Although the evolutionary scheme of *Eoparastaffella* morphotypes has been outlined (HANCE, 1997; HANCE et al., 1997), clear definition of this evolutionary lineage at species-level is still required. Other problems arise especially from nearly complete absence of *Eoparastaffella* at the Tn-V boundary in North America, its relatively scarce, facially-influenced occurrence, and poor correlation with biostratigraphies based on conodonts and other pelagic taxa. Conodont biostratigraphy indicates that the classical Tournaisan-Visean boundary correlates neither with the top of the *S. anchoralis* Zone (LANE & ZIEGLER, 1983) nor with the base of the *Mestognathodus beckmanni* Zone (VON BITTER et al., 1986); these occur somewhat above the base of the Visean. Nevertheless an attempt to establish correlation of the *Eoparastaffella* morphotypes of HANCE (1997) with conodont and possibly trilobite biostratigraphy will be the aim of future research in Moravia.

Increased resolution in correlation through the Tournaisian-Visean boundary interval may also come from study of eustatic events. A worldwide regression has been recognized at the Tournaisian-Visean boundary (KALVODA, 1989), an event compatible with climatic cooling and even glaciation in some parts of Gondwana (LANG et al., 1991). In Australia, however, there is a well defined regression and probably a slight cooling of climate, but the faunas are, in general, cosmopolitan and there is a lack of hard evidence for glaciation until early in the Namurian (J. ROBERTS, pers. comm.).

A combined study of conodonts and foraminifers from the middle Tournaisian–lower Visean interval in Moravia, coupled with compilation of conodont and foraminiferal data from the Palaeotethyan, Siberian and North American Realms (KALVODA, 1990, 1990a) have enabled worldwide correlations to be established (Text-Fig. 3) and brought about an improved understanding of calcareous foraminiferal biogeography (see below).

3. Lower Carboniferous Foraminiferal Biogeography

3.1. Introduction

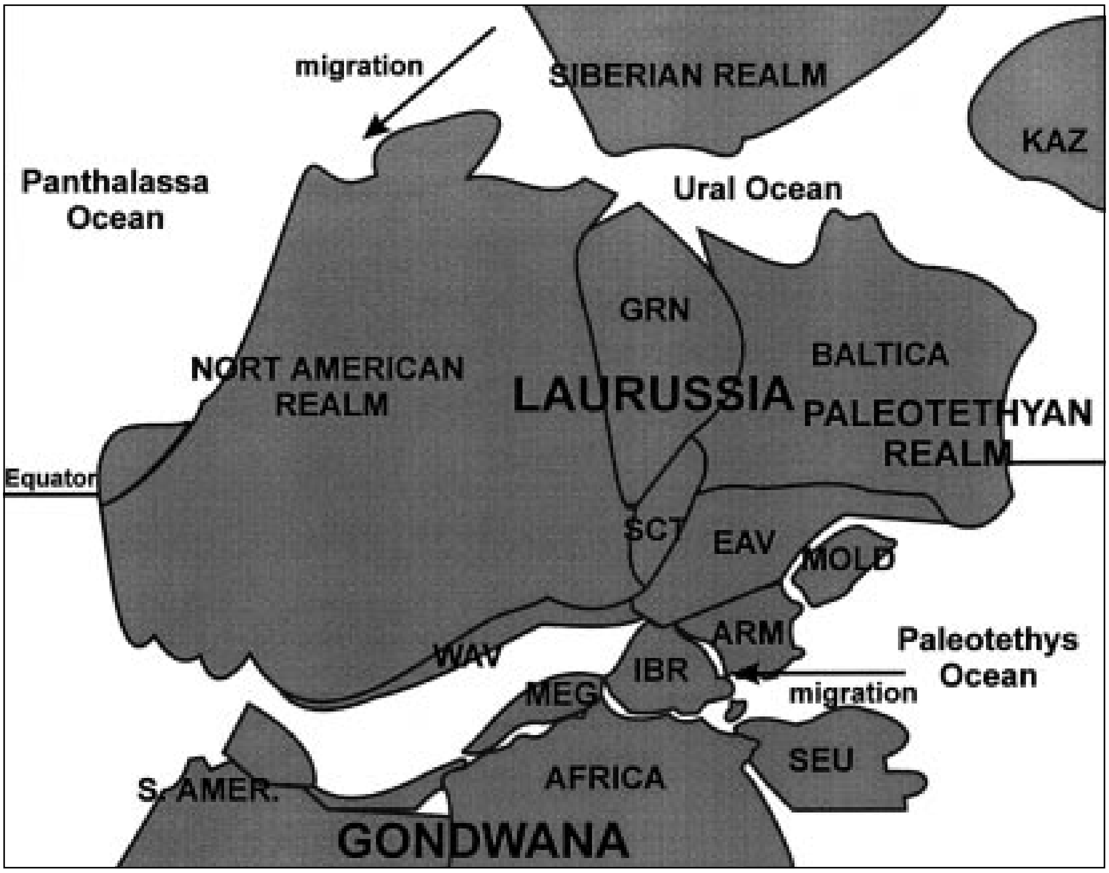
The distribution and dispersal of Recent benthic foraminifers is closely linked with water temperature (SAIDOVA, 1975) and, within latitudinal limits, their dispersal is extremely limited. Migration of climatic zones during the Quaternary has been determined from changes in the distribution of planctic foraminifers; differences in composition of benthic foraminiferal assemblages have been used to discriminate temperate and subtropical environments in Recent and Cainozoic seas (MURRAY, 1987). An attempt is made here to explain changes in Upper Devonian–Lower Carboniferous biogeography from this prospective.

Rich, highly diverse benthic calcareous foraminiferal faunas occur on modern continental shelves of the tropical–subtropical belt in Recent seas; these faunas contrast with the monotonous, poorly diversified benthic faunas of high latitude shelves (SAIDOVA, 1975; YUFEREV, 1978). Foraminiferal faunas on the high latitude shelves contain components from deep water faunas of the tropical–subtropical belt, particularly agglutinated forms (SAIDOVA, 1975; LUKINA, 1975). The biogeography of Palaeozoic benthic foraminifers is not understood as well as that of recent benthic faunas, but two major patterns can be discriminated: a basinal fauna dominated by agglutinated forms (SANDBERG & GUTSCHICK, 1984; CONKIN & CONKIN, 1970, 1977) and a shelf fauna represented by calcareous foraminifers.

The presently understood biogeographic divisions of the Lower Carboniferous foraminiferal faunas are based on data published by LIPINA (1973), MAMET (1977), VDOVENKO (1980) and especially YUFEREV (1978). I agree with YUFEREV, that temperature was the main factor accounting for distribution of foraminiferal faunas, but my divisions diverge to some extent from his. Based on differing composition of the shelf faunas mentioned above, I distinguish the highly diversified faunas of the Palaeotethyan Realm from the less diversified faunas of the North American and Siberian Realms (Text-Fig. 4). The foraminiferal faunas of the Palaeotethyan Realm (MAMET, 1977) are characterized by highly diverse calcareous assemblages on the shelves, with agglutinated forms dominating basinal environments. The North American Realm is characterized by lower diversity calcareous assemblages; agglutinated forms were often important components of shelf faunas of the Midcontinent east of the Transcontinental Arch.

The northern temperate Siberian Realm (YUFEREV, 1978) spans several tectonic plates: Angara, Taimyr, Omolon, and Kolyma. The most boreal environment occurs in the Tungusska – Kuznets region of the Angara Plate. The Kolyma and Omolon Plates and probably also the Verkhoyansk Fold Belt (YUFEREV, 1973), which displayed strong Palaeotethyan influence during the Upper Devonian and

Text-Fig. 4.
Lower Carboniferous palaeogeography showing the main palaeobiogeographic realms. There were two avenues for migration to the North American Realm:
a) from higher latitudes from the Siberian Realm, and
b) from closer proximity of the continental blocks facilitated by the closing of the Palaeotethyan Ocean.
ARM = Armorica, EAV = Eastern Avalonia, GRN = Greenland, IBR = Iberia, KAZ = Kazakhstan, MEG = Meguma, MOLD = Moldanubica, SCT = Scotland, SEU = southern Europe, WAW = western Avalonia.



Tournaisian, became part of the Siberian Realm in the Visean. This accords with the views of FEDOROWSKI (1981) who, based on Tournaisian rugose corals, regarded the eastern part of Siberia (Chukotka and Omolon regions) as part of a discrete Chukotka-Alaskan Province having comparatively good linkage with both the American and Euroasiatic Provinces. During the Visean, Chukotka was part of the Chukotka-Alaskan Province; corals in the remainder of northern Siberia displayed minor connections with the North American Province.

The foraminiferal faunas of the Taimyr Plate are relatively little known but they seem to be in some way linked more with the Palaeotethyan Realm than the Tungusska – Kuznets Region (AKSENOVA et al., 1980) with its typically impoverished Siberian fauna.

According to SANDO et al. (1977), the North American Realm can be subdivided into a Western Interior (Cordilleran) Province extending from northern Canada southwards to Sonora, and a South-eastern Province extending from the mid-continent and south-western USA to the Mississippi Valley and the Appalachian region. The mid-continent continental arch may have served as a barrier restricting migration between the two provinces, with a connection in southern Arizona. A Visean Pacific Coast Province can be discriminated in the accreted terranes along the Pacific coast of North America. The Western Interior Province displays connections with the Siberian Realm. The South-eastern Province, successor to the Devonian New World Realm, is less diverse; this may be a reflection of widespread occurrence of facies unsuitable for calcareous foraminifers. Abundant agglutinated foraminifers are characteristic of the interval in question. Malvinokaffric influences reported in this region for much of the Devonian may reflect an oceanic circulation pattern from part of Gondwana, the South American part of which has been argued to have been glaciated (COPPER, 1986). The Pacific coast faunas found in the accreted terranes are viewed as belonging to the Palaeotethyan Realm.

In this interpretation, the North American Realm displays a complex migrational pattern (Text-Fig. 4) reflecting mixing of Siberian and Palaeotethyan influences. Even though the North American Realm was situated partly in the southern hemisphere and in the tropical–subtropical belt, there is evidence for a migration route from high latitudes of the Siberian Realm. In the Lower Carboniferous, the Palaeotethyan seaway seems to have permitted only limited communication, especially in western North America. That most migrations to North America came from the higher latitudes of the Siberian Realm has been stressed by ROSS & ROSS (1985) for Permian foraminifers and by FEDOROWSKI (1981) for Lower Carboniferous rugose corals.

The above data correlate in some respect with the conclusions of BECKER (1993) who discriminated three main avenues of ammonoid migration and exchange: Trans-antarctic, Afro-Appalachian and Prototethyan. The North African-European-Urals Realm was suggested to have been the major evolutionary centre.

3.2. Foraminiferal Dispersal in the Middle Tournaisian–Lower Visean Interval

Study of changes in dispersal of benthic foraminifers has focused on regions with best data, including the Tungusska – Kuznets and Omolon – Kolyma Regions of the Siberian Realm, the North American Realm, the Namur and Dinant Synclinorium, Moravia (Czech Republic), Eastern Europe and the Urals in the Palaeotethyan Realm, and the Tien Shan Region. The last, mostly a part of the Palaeotethyan Realm, is treated separately because it also displays some connections with the Siberian Realm.

Data from the Tungusska – Kuznets region are from papers by YUFEREV (1973), AKSENOVA et al. (1980), BUSHMINA et al. (1984), and BOGUSH (1985), from the Omolon, Kolyma and Verkhoyansk regions by YUFEREV (1973), SIMAKOV et al. (1983), and SHILO et al. (1984), from the Tien Shan region by MICHNO & BALAKIN (1975) and POYARKOV & SKVORTSOV (1977), from North America by MAMET & SKIPP (1970, 1971), MAMET (1977), BRENCKLE & GROVES (1987), and BRENCKLE (1990, 1992). Data sources for the Palaeotethyan Realm were presented by KALVODA (1990).

To minimize subjectivity in correlation, comparisons of foraminiferal faunas and conodont biostratigraphies were made between similar facies in all of the above regions (KALVODA, 1990). As the time-interval is relatively long, change in palaeolatitude needs to be taken into account.

The review of foraminiferal dispersal commences with the middle Tournaisian (Lower *Siphonodella crenulata* Zone, Tn2a) when the first radiation of Tournaisian calcareous foraminifers took place in the Palaeotethyan Realm. The most characteristic feature of the middle Tournaisian is the presence of the Chernyshinella fauna. This fauna has not been demonstrated to occur at this level in the Tien-Shan region. In the Siberian Realm, this fauna has been detected only in the Tungusska region and Verkhoyansk Belt. In the Kuznets and Kolyma-Omolon regions, widely dispersed *Paleospiroplectammina* and holdover Devonian genera such as *Septabrunsiina* and *Laxoendothyra* appear to be characteristic. Calcareous foraminiferal faunas are impoverished in the North American Realm. *Chernyshinella* has been reported sparsely from the Mississippi Valley in the South-eastern Province. *Paleospiroplectammina* seems to be absent at this level (Lower *S. crenulata* Zone). The presence of holdover Devonian genera such as *Septabrunsiina, Laxoendothyra* and *Septatournayella* is characteristic of the succession beneath MAMET's Zone 7. Agglutinated foraminifers are diverse (CONKIN & CONKIN, 1970, 1977).

The second important event in the Tournaisian of the Palaeotethyan Realm is entry of the Lower Kizel fauna, characterized by *Spinobrunsiina*, *Tuberendothyra* and *Latiendothyranopsis*, in the Upper *Siphonodella isosticha–S. crenulata* Conodont Zone (Tn2c). The Lower Kizel fauna also occurs in the Tien-Shan and Omolon-Kolyma regions at a similar level. In the North American Realm, however, this fauna has not been encountered in correlative beds represented by MAMET's zone 7 (SANDBERG et al., 1983), characterized by belated occurrence of Palaeotethyan elements such as *Chernyshinella* and *Paleospiroplectammina* (BRENCKLE, 1990, horizon 2). In the Kuznets – Tungusska region the precise level of occurrence of the Lower Kizel fauna cannot be determined. It may be in the Upper *S. crenulata–S. isosticha* Zone as in the Palaeotethyan Realm, or more probably in the *G. typicus* Zone as in North America.

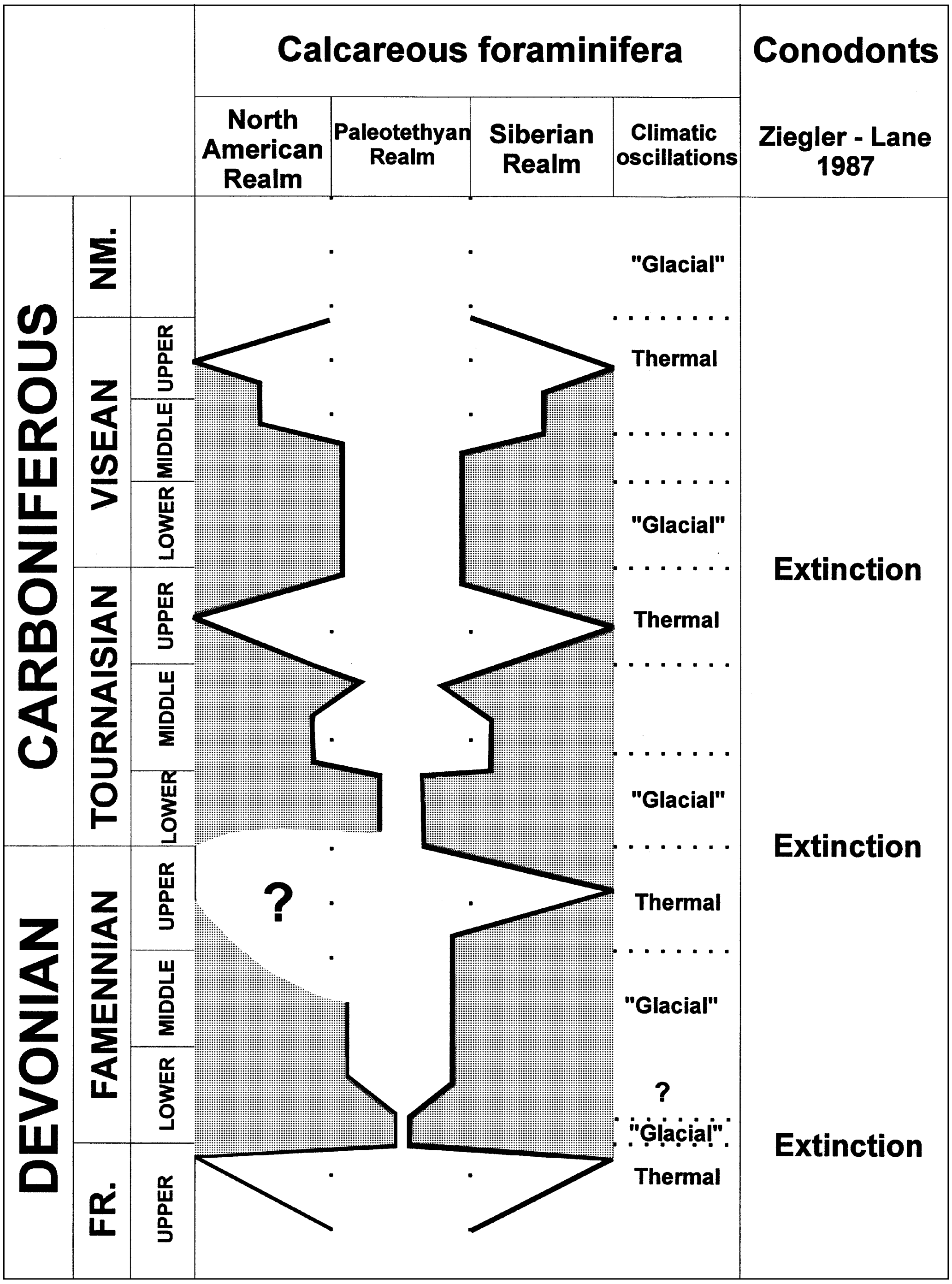
The acme of migration and proliferation of Palaeotethyan calcareous foraminifers seems to coincide with the *G. typicus*–Lower *S. anchoralis* Zone. The lower part of the *G. typicus* Zone in the Palaeotethyan Realm is characterized by occurrence of *Paraendothyra*, *Spinoendothyra*, *Inflatoendothyra* and *Eoforschia*. A similar fauna is present in the Kolyma-Omolon and Tien-Shan regions. In the Kuznets-Tungusska region, *Spinobrunsiina*, *Tuberendothyra* and *Inflatoendothyra* are Palaeotethyan elements, but the Lower and Upper Kizel faunas cannot be distinguished. There are rare *Spinoendothyra*, but only in the Tungusska region. Foraminiferal faunas at this level in the North American Realm contrast markedly with the poor faunas of the preceding interval. *Tuberendothyra*, *Spinotournayella*, *Spinobrunsiina* and scarce *Spinoendothyra* characterize the *G. typicus* Zone in the Cordilleran region, whereas widespread unconformities in the Mississippi Valley (BRENCKLE & GROVES, 1987) appear to prevent recognition of this level.

The first taxa with Visean affinities are present in the Upper *G. typicus* Zone (*E. bultyncki* and *D. bouckaerti* subzones) in the Palaeotethyan Realm (KALVODA, 1983). The interval represented by the Upper *G. typicus–S. anchoralis* Zone is characterized by gradual increase of "Visean" elements such as *Dainella, Eotextularia, Tetrataxis*, *Globoendothyra*, Plectogyranopsis, *Pseudolituotubella*, *Eoendothyranopsis*, *Eoparastaffella* and *Omphalotis*. The Visean-Tournaisian boundary falls somewhere in the upper part of this interval; it can be discerned only with great difficulty.

In the Upper *G. typicus*–lower *S. anchoralis* Zone, the Omolon-Kolyma region retains Paleoethyan affinity, but in the upper part of the *S. anchoralis* Zone the fauna begins to become impoverished with the absence of *Pseudolituotubella*, *Omphalotis*, *Eoparastaffella* and *Dainella* (SIMAKOV et al., 1983; SHILO et al., 1984). The Kuznets-Tungusska fauna is impoverished with some Paleotethyan elements. The presence of *Tetrataxis, Eotextularia, Priscella*, *Globoendothyra*, *Neoseptatournayella* and *Eoendothyranopsis* ex gr. *transitans* seems to be characteristic. In the Cordilleran region of the North American Realm, *Spinoendothyra*, *Eoforschia*, *Inflatoendothyra*, *Spinotournayella, Priscella, Eblanaia and Paradainella* are important constituents of the lower part of the *S. anchoralis* Zone. Some differences exist between the rich faunas of British Columbia (possibly in accreted terranes [HAMMER et al., 1995]) and the impoverished faunas of the south-eastern Cordillera; the latter are transitional to the even more impoverished faunas of the South-eastern Region (Mississippi Valley) where *Tuberendothyra* is the typical taxon. More diversified faunas with *Spinoendothyra*, *Spinobrunsiina*, *Inflatoendothyra* and *Spinotournayella* are encountered only in very shallow lagoonal environments; shelf environments are dominated by agglutinated foraminifers (SANDBERG & GUTSCHICK, 1984).

The lower part of the Visean (V1b–V2a) is characterized in the Palaeotethyan Realm by proliferation of archaediscids, but this group is absent at this level both in the Omolon-Kolyma and Kuznets regions. In the Tungusska region, which had closer ties with the Palaeotethyan Realm, archaediscids occur in the Serebryan Horizon. Impoverished faunas at this same level characterise the Siberian Realm and the Tien-Shan region where primitive *Viseidiscus* is the only representative of archaediscids. In the North American Realm the fauna of the South-eastern Region is impoverished; *Globoendothyra, Priscella*, and *Tetrataxis* are characteristic. Relative faunal impoverishment is evident in the Cordilleran Region in MAMET's zones 10 and 11.

Four important events (two increases and two decreases in diversity) can be discriminated in the composition and dispersal of Tournaisian calcareous foraminiferal assemblages (Text-Fig. 5). The first increase in diversity, apparent mainly in the Palaeotethyan Realm, occurred in the middle Tournaisian. The second increase in diversity featured the great migration and proliferation of Palaeotethyan fauna in temperate realms in the upper part of the *G. typicus* Zone. Both these events, traceable worldwide, seem to have been coincided with rises in sea level, possibly connected with climatic warming during the Lower *S. crenulata* and *G. typicus* Zones. Decline of the Chernyshin fauna at the middle-upper Tournaisian boundary (LIPINA, 1973), and the absence of Palaeotethyan foraminiferal faunas in the Siberian Realm and part of the North American Realm at the Tournaisian/Visean boundary



Text-Fig. 5.
Migration events affecting Palaeotethyan foraminiferal faunas, and climatic oscillations in the Upper Devonian–Lower Carboniferous.
Modified from KALVODA (1990a).

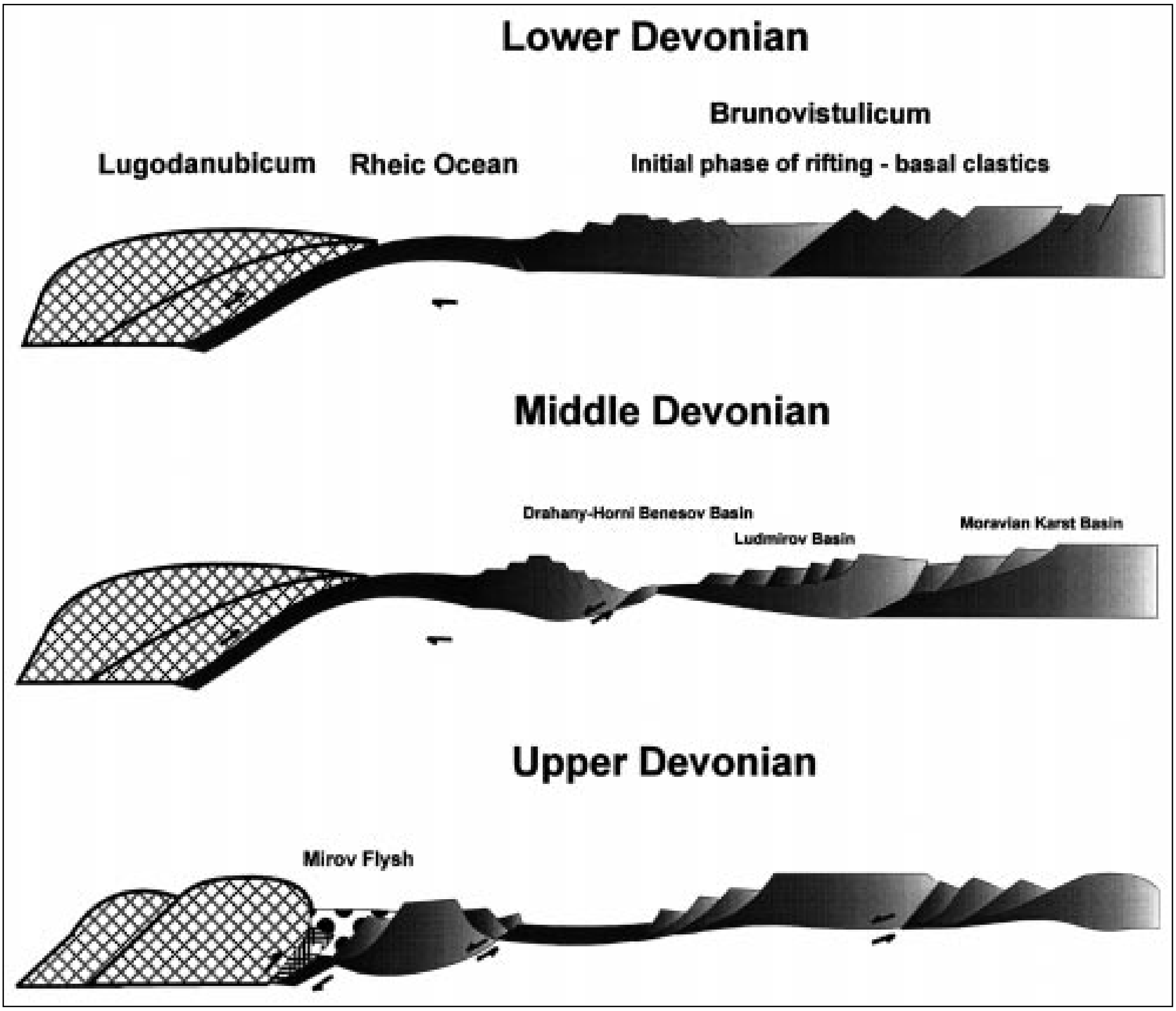
seem to be connected with eustatic fall and, according to my interpretation, possibly connected with climatic cooling (KALVODA, 1986, 1989). A more detailed discussion of climatic oscillations can be found in the paper by ISAACSON et al. (1999, this volume).

The climatic oscillations outlined (Text-Fig. 5) are compatible with the Lower Carboniferous record in Gondwana (STREEL, 1986; STREEL et al., 1993; LANG et al., 1991), and also with isotopic data for oxygen and strontium, both of which show cyclical fourth-order fluctuations superimposed on the third-order trends (BRUCKSCHEN et al., 1994, 1995, 1997). For the Hastarian/Chadian stages they are ~3.1 and 3.7 million years. Since ice-volume fluctuations are the only presently known mechanism that could have produced such sea-level changes, the fourth-order δ^{18} oscillations probably reflect combined icemass and temperature effects (BRUCKSCHEN et al., 1994, 1995, 1997). Other support for the climatic oscillations in the Lower Carboniferous comes from study of migration of brachiopods and land plants (RAYMOND et al., 1989; KELLEY & RAYMOND, 1991) and from glacioeustatic sequence control (MILLER & ERIKSSON, 1996).

3.3. Position of the Eastern Part of Rhenohercynicum and Biogeography at the Baltica-Gondwana Contact

Brunovistulicum is a Cadomian (Panafrican) terrane situated on the eastern flank of the Rhenohercynian Zone (LEICHMANN et al., 1996). It is regarded as being an extension of the Eastern Avalonian group of terranes (KALVODA, 1995) which include the London-Brabant Massif and the Rhenish Massif involved in oblique convergence with the southern Perigondwanan Lugodanubian group of terranes during the Hercynian Orogeny. Tectonically convergent Devonian and Carboniferous carbonate and flysch sequences are remnants of different sub-basins developed on the passive margin of Brunovistulicum.

During the latest Devonian, transtensional basins (Text-Fig. 6) probably with narrow segments of oceanic crust (Drahany-Horni Benešov Basin) and attenuated continental crust (Ludmírov Basin, Moravian Karst Basin) originated on the passive Brunovistulian margin in Moravia. In the Famennian, the Drahany-Horni-Benesov Basin was characterized by pronounced subsidence with the depocentre falling below the carbonate compensation depth (CCD). Shale facies with radiolarites were replaced laterally by distal calciturbidites and volcaniclastics in base-of-slope environments; a similar succession lacking



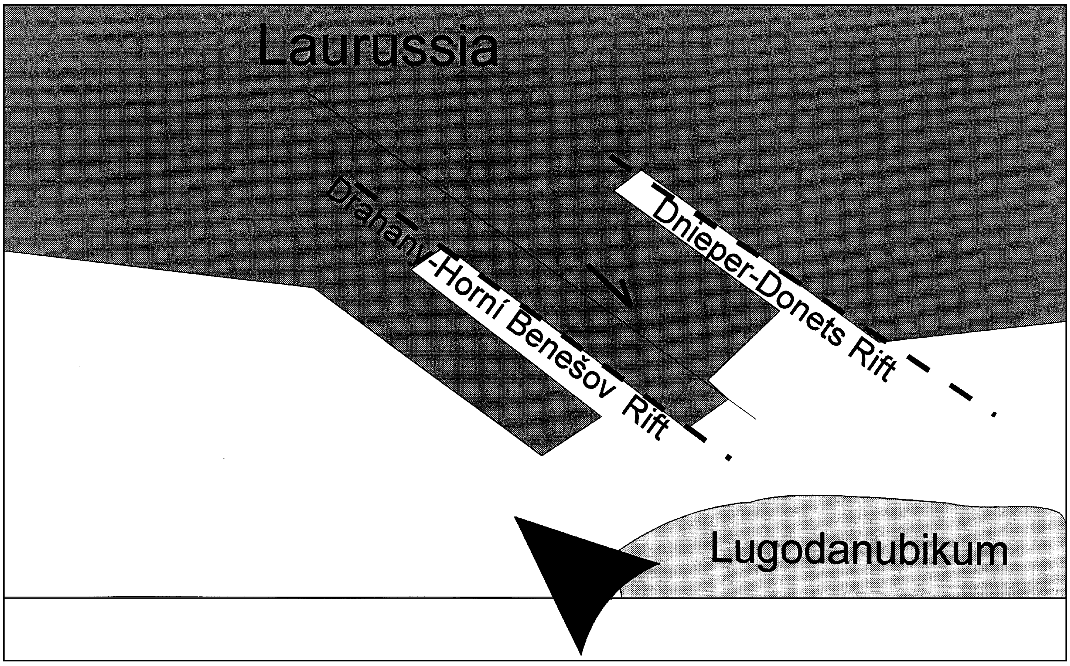
Text-Fig. 6.
During the Devonian, transtension at the passive Brunovistulian margin of Laurussia was connected with subduction of oceanic crust of the Rheic Ocean. The resulting passive rifting influenced the origin and evolution of partial basins with attenuated continental crust. In the Drahany-Horni Benesov region, even narrow segments of oceanic crust falling below the carbonate compensation depth were anticipated by events in the basin during the Famennian.

volcanic rocks accumulated in the Ludmirov Basin. In the Moravian Karst Basin, shallow water carbonate sedimentation predominated during much of the Devonian. Widespread calciturbidites in the Famennian and Tournaisian document development of half-graben structures and differentiation of areas with platform (bioclastic tempestites), upper slope (nodular limestones) and lower slope to basin sedimentation (proximal to distal calciturbidites). Transition to flysch took place at the Tournaisian-Visean boundary. The Famennian transtensional event coincided with the origin and development of the Dnieper – Donetz Rift (Text-Fig. 7).

Foraminiferal faunas of the Late Devonian and Early Carboniferous sedimentary cover of Brunovistulicum are closely related to those of the Eastern European Platform and the Urals; this is consistent with the Brunovistulicum having been part of Laurussia. Based on foraminiferal faunas, two palaeogeographic areas can be discriminated in western and central Europe (KALVODA, 1982). During the Late Devonian and especially during much of the Early Carboniferous, the foraminiferal fauna of the British Central Province, the Campine-Brabant Basin, the Moravo–Silesian cover of the Brunovistulicum (including the Upper Silesian Massif) are characterized by rich and highly diverse Eastern European faunas (the British-Moravian subprovince of KALVODA, 1982). These imply ease of communication. They contrast with faunas from the Montagne Noire, Laval Basin, Pyrenees and Schwarzwald, and also those of the Dinant Basin and the British South-west Province which are less diverse and have incomplete phylogenies due to slackening of influence from East European migrations. The southern Perigondwanan terranes were apparently strongly influenced by upwelling of cold water from glaciated Gondwana; high nutrient levels supported widespread formation of Waulsortian-type mounds having some resemblance to recent high latitude bryozoan cold water associations.

The distinction outlined above seems to coincide with the delineation of the Eastern Avalonian terrane, including the sedimentary cover of the London-Brabant Massif, the Brunovistulicum (including Upper Silesian Massif), the Rhenish Massif from the southern Perigondwanan terranes.

Text-Fig. 7.
Cartoon showing oblique convergence of Lugodanubicum and Laurussia accompanied by passive rifting in the Drahany-Horni Benesov region and the Dnieper-Donets Rift.



4. Conclusions

In both Africa (LANG et al., 1991) and South America (STREEL, 1986; STREEL et al., 1993), glaciation has been identified in the Lower Carboniferous. Immigration-emigration events affecting tropic–subtropic foraminiferal faunas can be discriminated in Lower Carboniferous palaeobiogeographic patterns, and it is therefore tempting to regard Gondwana glaciation as having been one of the underlying factors in Lower Carboniferous foraminiferal palaeobiogeography. Temperature may not have been the sole factor in dispersal of calcareous foraminifers; oceanographic factors and facies distribution may also have been important.

There is still no evidence for the existence of rich assemblages of Palaeotethyan foraminiferal faunas in Northern Africa and the Perigodwanan terranes such as Iberia, Armorica and Moldanubia in the Tournaisian. This absence may reflect not only migrational patterns but also the presence of unfavourable facies and/or lack of information. These data may enable discrimination of terranes along the southern Laurussian shelf from Perigondwanan terranes situated in the south of the Variscan mobile belt.

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