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FORAMINIFERAL ZONAL STANDARD FOR THE LOWER CARBONIFEROUS OF RUSSIA AND ITS CORRELATION WITH THE CONODONT ZONATION

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Abstract. This paper describes the zonal subdivisions of the revised Foraminiferal Scale of Russia and their correlation to conodont zones and age-equivalent beds in Western Europe and North America. The foraminiferal zonal sequence is documented in key sections and wells that cover the entire Lower Carboniferous. Boundary reference sections are proposed for most Tournaisian and Serpukhovian zones. Major evolutionary trends within the foraminifers are used to define individual zones.

Riassunto. Sono descritte le suddivisioni zonali della scala a Foraminiferi riveduta per la Russia e la loro correlazione con le zone a conodonti e le successioni coeve dell'Europa Occidentale e del Nord America. La successione zonale a foraminiferi è ancorata a sezioni di riferimento e pozzi, e copre l'intero Carbonifero Inferiore. Sono pure proposte le sezioni di riferimento per la maggior parte delle zone del Tournesiano e del Serpukoviano. Le più significative tendenze evolutive nell'ambito dei foraminiferi sono utilizzate per definire le singole zone.

Introduction

The foraminiferal sequence from upper Famennian to Serpukhovian (Steshevian) was documented by Rauzer-Chernousova (1934) in the Syzran 401 well, where 130 species were identified. The succession was correlated precisely across vast areas of the East European Platform and Ural region and many stratigraphically important species were described as well, using detailed stratigraphic sections and foraminiferal analysis (Rauzer-Chernousova et al. 1940, 1948; Lipina 1960).

This sequence formed the basis for the standard zonation of Lower Carboniferous foraminifers in the Soviet Union (Lipina & Reitlinger 1970; see Fig.1). The zones are characterized by the following features: in most cases the zonal index species occur in the preceding foraminiferal zone and the lower boundary of the zone is defined by the relative frequency of an index species, i.e. the acme of that representative species. The Interdepartmental Stratigraphic Committee of the USSR developed the General Stratigraphic Scale for the Carboniferous twenty years ago (Stepanov & Donakova 1982; Fig. 1). Later improvements and additions were made as the stratigraphic schemes of the Russian Platform and Urals were developed (Kagarmanov & Donakova 1990; Vdovenko et al. 1990; Shcherbakov 1997).

In recent years, with the ongoing development of the Global Stratigraphic Scale for the Carboniferous, some problems have arisen because of the need to correlate stratigraphic units of different ranks in basins with different geologic histories and sedimentary environments.

According to the Carboniferous Scale of the Russian Platform and West Ural region, the Tournaisian/Visean boundary corresponds to the base of the Kosvian which is Visean in age, whereas in the West European Scale (Dinant Basin), beds equivalent to the Kosvian are assigned to the upper Tournaisian. The definitions of the Tournaisian/Visean and Visean/Serpukhovian boundaries are problematic.

The present paper deals with (1) reconstruction of a complete composite foraminiferal sequence derived from closely sampled sections of latest Famennian - Early Carboniferous age; (2) subdivision of the succession into zones based on the first appearance of species in a single phylogenetic line or by short-lived species; (3) establishment of reference sections for the lower boundaries of the majority of zonal units; (4) correlation between foraminiferal and conodont zones based on data from the South Ural sections and revision of foraminiferal correlations to Western Europe and North America.

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Series, Stage	Lipina & Reitlinger, 1970		Foraminiferal Zones of General Stratigraphic Scale of Russia (Stepanov & Donakova, 1982)	Proposed Foraminiferal Zones (Kulagina & Gibshman)		Conodont Zones of the Urals (Pazukhin)		Horizon of the West Urals
Bash-kir			*Plectostaffella bogdanovkensis*	*Pl.varvariensis - Pl. bogdanovkensis*		Early *Declinognathodus noduliferus*		Bogdanovian (part)
Serpukhovian	?	?	*Eostaffellina protvae - Eosigmoilina explicata - Monotaxinoides subplanus*	*Monotaxinoides transitorius - Brenckleina rugosa*		*Gnathodus bilineatus bollandensis*		Yuldybaevian (Zapaltyubinian)
	Protvian	*Eostaffella protvae*		*Eostaffellina paraprotvae*				"Protvian"
	Steshevian	*Eostaffella decurta*	*Pseudoendothyra globosa - Neoarchaediscus parvus*	*Neoarchaediscus postrugosus*		*Lochriea cruciformis*		Kosogorian
	Tarusian	*Pseudoendothyra illustria* and *Ps. globosa*						
Visean	Venevian	*Eostaffella tenebrosa*	*Endothyranopsis crassa - Archaediscus gigas*	*End. crassa - A. gigas*	*E. tenebrosa* subzone	*Lochriea nodosa*		Venevian
	Mikhailovian	*Eostaffella ikensis*			*E. ikensis* subzone	*Lochriea mononodosa*		Mikhailovian
	Aleksinian	*Eostaffella proikensis* and *Archaediscus gigas*			*E. proikensis* subzone	*Gnathodus bilineatus bilineatus*		Aleksinian
	Tulian	*Endothyranopsis compressa*	*Endothyranopsis compressa - Archaediscus krestovnikovi*	*End. compressa*		*Gnathodus austini*		Tulian
	Bobrikian	*Planodiscus primaevus* and *Permodiscus rotundus*	*Uralodiscus rotundus - Ammarchaediscus primaevus*	*Uralodiscus rotundus*		*Gnathodus texanus - Mestognathus beckmani*		Bobrikian
	Radaevkian (lower part of Horizon of Urals)	*Dainella chomatica* and *Eoendothyranopsis transita*	*Eoparastaffella simplex - Eoendothyranopsis*	*Eoparastaffella simplex*				Radaevkian (Pesterkovian)
Tournaisian				*Eoparastaffellina rotunda*		?	Beds with *Embsaygnathus asymmetricus*	?
	Kosvian	*Endothyra elegia*	*Endothyra elegia - Palaeospiroplectammina diversa Tetrataxis*	*Eotextularia diversa*		*Scaliognathus anchoralis*		Kosvian
						Dollymae bouckaerti		
	Kosvian Lower / Kizelian Upper	*Spinoendothyra*	*Spinoendothyra costifera - Tuberendothyra tuberculata*	*Spinoendothyra costifera*		*Gnathodus typicus*	*Bactrognathus hamatus*	Kizelian
							Dollymae hassi	
	Kizelian Lower	*Latiendothyra tuberculata*		*Palaeospiroplectammina tchernyshinensis*		*Gn.punctatus*	*Siphonodella isosticha*	
	Cherepetian (and Upian ?)	*Chernyshinella* and *Septabrunsiina krainica*	*Prochernyshinella disputabilis- Chernyshinella glomiformis*			*Siphonodella quadruplicata*		Kosorechian
				Prochernyshinella disputabilis		*Siphonodella belkai*		Upian
	Malevian ? and *Quasiendothyra kobeitusana* Zone	*Quasiendothyra kobeitusana*	*Bisphaera malevkensis - Earlandia minima*	*Earlandia minima*		*Siphonodella duplicata*		Malevian
			Chernyshinella - Tournavellina pseudobeata	*Tournavellina pseudobeata*		*Siphonodella sulcata*		Gumerovian
Famen			Rare *Eoendothyra*	*Q. kobeitusana* s.l.		*Siphonodella praesulcata*		Lytvian
						P. gracilis expansa (part)		

Fig. 1 - Foraminiferal zonal scheme for the Lower Carboniferous of Russia.

Reference Stratigraphic Sections

To reconstruct an "ideal" stratigraphic column, the following stratigraphic sections were combined (Fig. 2):

- The **Syzran 401 well,** with strata from the upper Famennian to the Serpukhovian (Steshevian) (Rauzer-Chernousova et al. 1940, 1948; Fig. 3) with three disconformities, including one minor stratigraphic hiatus at the Devonian/Carboniferous boundary, and two major stratigraphic breaks from the upper Tournaisian through the upper Visean and at the Lower/Middle Carboniferous boundary.

- **Sikaza, South Urals** (Sinitsyna et al. 1984; Kochetkova et al. 1988; Kulagina & Sinitsyna 2000). The section includes strata from the upper Famennian to the Serpukhovian with a regional unconformity at the Tournaisian/Visean boundary. The gap spans the upper Kosvian and lower Visean. The Tournaisian and Visean strata are shallow-shelf deposits.

- **Burlya, South Urals.** The section provides a sedimentary record for the gap at the Tournaisian/Visean boundary in the Sikaza section and is represented by shallow-shelf facies (Kochetkova & Lutfullin 1982, and authors' new data).

- **Tengiz 22 well.** Uppermost Famennian-Bashkirian carbonates occur at a depth of 5250 to 4211 m within this well that is located on the southern margin of the Precaspian Depression (Gibshman 1997).

- **Zaborie Quarry,** the Serpukhovian Stage stratotype in the Moscow Basin. This quarry contains nearly complete exposures of limestone, marly shale and dolomite strata that range in age from the Venevian (uppermost Visean) at the base to the Tarusian, Steshevian and Protvian of the Serpukhovian Stage at the top (Gibshman 2001, 2003).

- **Verkhnyaya Kardailovka, South Urals** (Kulagina et al. 1992; Nikolaeva et al. 2001). This section exposes upper Visean terrigenous and carbonate deposits and a carbonate facies rich in goniatites, of Serpukhovian age.

Besides the sections listed above, we used foraminif-

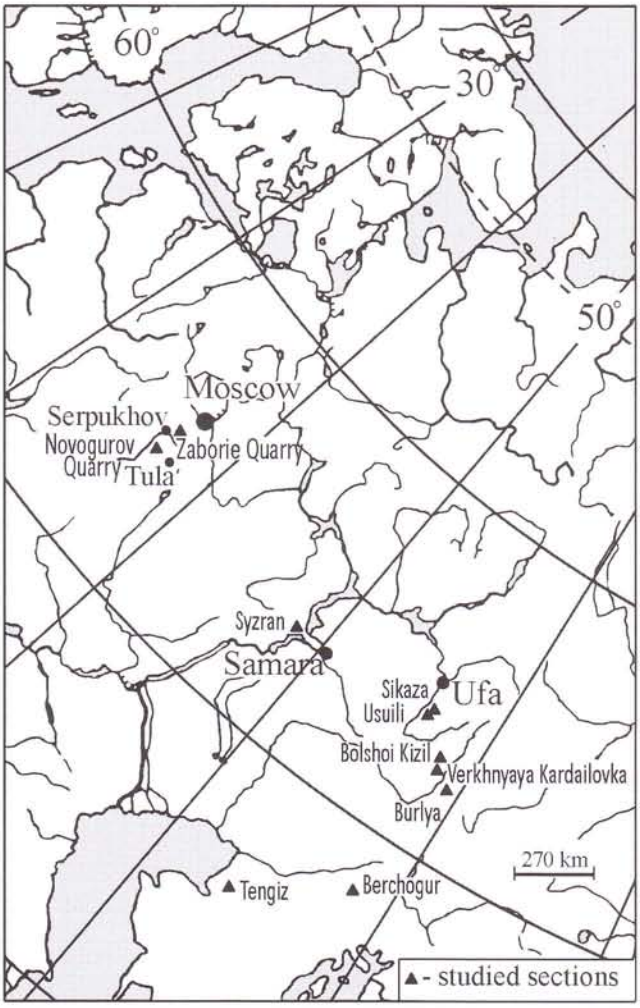


Fig. 2 - Location of the sections studied.

eral data from the Devonian/Carboniferous boundary interval of Berchogur (Reitlinger & Kulagina 1987), Tournaisian strata along the Usuili River (South Urals; Kulagina & Sinitsyna 2000), and Visean and Serpukhovian strata in the Novogurovsky Quarry (near Moscow) and along the Bolshoi Kizil River (South Urals, Kulagina & Gibshman 2002).

Foraminiferal Sequence

The succession of foraminiferal zones described below is shown in the middle column of Fig. 1. Most zones are interval zones (for part of Tournaisian, lowermost Visean and Serpukhovian). The assemblage zones are *Earlandia minima* Zone and most of the Visean zones (from *Uralodiscus rotundus* to *Endothyranopsis crassa - Arhaedisus gigas*).

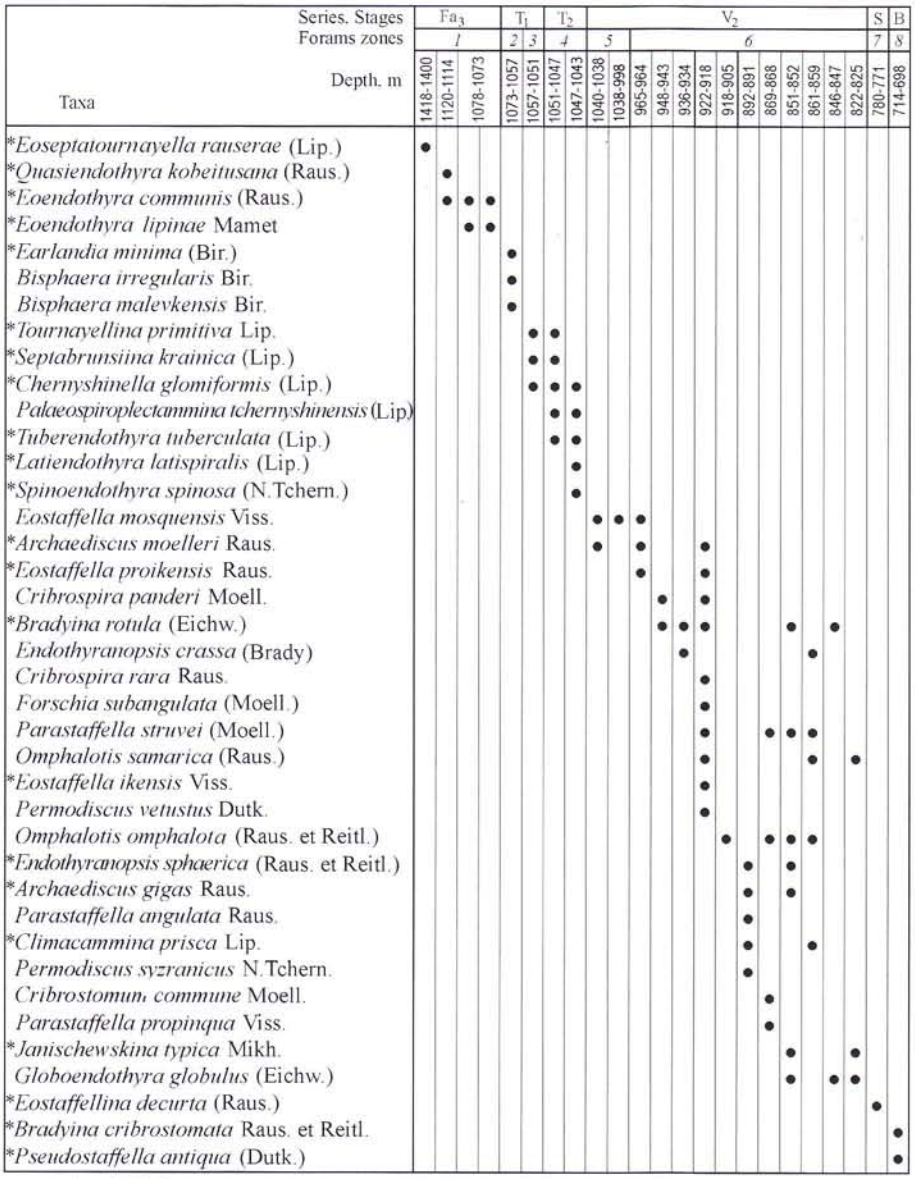
The Tournaisian Series. The *Tournayellina pseudobeata* Zone was first recognized in the Berchogur area (Reitlinger & Kulagina 1987, Burtybai section, member IX), where *Paracaligelloides florennensis* (Conil & Lys) and *Garwoodia* algae occur with *T. pseudobeata* Reitlinger & Kulagina. In the Sikaza section these beds correlate to strata with late occurrences of *Eoendothyra communis* (Rauzer-Chernousova) (Kochetkova et al. 1988). The zone correlates also with the upper *Siphonodella praesulcata* and lower *Siphonodella sulcata* conodont zones. In the Tengiz 22 well this zone probably correlates with the uppermost *Quasiendothyra kobeitusana* Zone that contains *Tournayellina primitiva* Lipina.

The *Earlandia minima* Zone in the Sikaza section (Fig. 4, beds 7-8) contains *Earlandia minima* (Birina), *Bisphaera malevkensis* Birina, *B. irregularis* Birina and Parathuramminidae, taxa that are characteristic of the Malevkian (Sinitsyna et al. 1984; Kochetkova et al. 1988). This zone correlates with the upper part of the *Siphonodella sulcata* and *S. duplicata* conodont zones.

Prochernyshinella disputabilis Zone. The key section of this zone is at Sikaza (bed 9). *Pr. disputabilis* (Dain) and *Eochernyshinella crassitheca* (Lipina) appear at the base of this zone. The zone correlates with the *Siphonodella belkai* conodont zone. In the Tengiz 22 well (Fig. 5) the zone can be defined by abundant *Tournayellina* spp. with common *Septaglomospiranella* spp. and *Septabrunsiina* spp. The zone correlates with the lowermost *Chernyshinella – Septabrunsiina krainica* Zone (Lipina & Reitlinger 1970) of the Upian and also with the Cf1α subzone (Conil et al. 1991) in Belgium.

Palaeospiroplectammina tchernyshinensis Zone. The key section of this zone is at Sikaza (bed 11). In the Tengiz 22 well it occurs at a depth of 5106 to 4970 m. The lower boundary can be defined by the first appearance of *P. tchernyshinensis* (Lipina) with *Chernyshinella glomiformis* (Lipina), *C. paucicamerata* Lipina, *Laxoendothyra parakosvensis* (Lipina) and *Tuberendothyra tuberculata* (Lipina). The *Chernyshinella glomiformis* and *Latiendothyra latispiralis* local subzones can be recognized in this zone in the Sikaza and Usuily sections of the South Urals. However, the two species do not appear at the same level in different sections and their usefulness as stratigraphic markers are therefore only of local significance. The *Chernyshinella glomiformis* subzone correlates with conodonts of the *Siphonodella quadruplicata* Zone that occurs in the stratotype of the Kosorechenian in the Urals (Pazukhin, unpubl. data). In the Sikaza section the zone contains *Siphonodella* aff. *quadruplicata* (Branson & Mehl) and *S. crenulata* (Cooper). The *L. latispiralis* subzone corresponds to the *Siphonodella isosticha* conodont zone. The lower boundary of this subzone is defined by the appearances of *L. latispiralis* (Lipina) and *Inflatoendothyra oldalipinae* (Loeblich & Tappan).

The *P. tschernyshinensis* Zone corresponds to the Cherepetian Horizon on the Russian Platform, to most of the Kosorechian through the lower half of the Kizelian at Gubakha in the Middle Urals (Lipina 1960; Brenckle 1997) and also correlates with the Cf1β subzone (Conil et al. 1991) in Belgium, as well as with the late Kinderhookian



* - stratigraphically important taxa

Fig. 3 - Distribution of the stratigraphically most important foraminifers from the Famennian to Serpukhovian stages in the Syzran 401 well (Samara Bend) (Modified by Gibshman from Rauzer-Chernousova et al. 1940, 1948; Lipina 1960). Zones: 1- *Quasiendothyra kobeitusana*; 2 - *Earlandia minima*; 3 - *Prochernyshinella disputabilis*; 4 - *Palaeospiroplectammina tchernyshinensis*; 5 - *Endothyranopsis compressa*; 6 - *Endothyranopsis crassa - Archaediscus gigas;* 7 - *Eostaffellina decurta*; 8 - *Pseudostaffella antiqua*. Fa - Famennian, T1– Lower Tournaisian, T2 –Upper Tournaisian, V2 – Upper Visean, S – Serpukhovian stage, B – Bashkirian stage.

– early Osagean (Brenckle 1991) in North America.

Spinoendothyra costifera Zone. The key section of this zone is at the Sikaza River (bed 14). In the Tengiz 22 well the zone is recognized at a depth of 4944-4970 m. The lower boundary of the zone is based on the first appearance of *S. costifera* (Lipina) and *Spinoendothyra recta* (Lipina). The assemblage contains most species of the preceding zone, and the new taxa *S. paracostifera* (Lipina) and *Latiendothyranopsis grandis* (Lipina); *Pseudoplanoendothyra rotai* (Brazhnikova), *Urbanella urbana* (Malakhova), *Eoforshia moelleri* (Malakhova) and *Eblanaia michoti* Conil & Lys appear at a higher level (Fig. 4-5; Lipina 1960; Brenckle 1997). The zone corresponds to the lower part of the *Gnathodus typicus* conodont zone (*Dollymae hassi* and *Bactrognathus hamatus* subzones) and also to the upper Kizelian (Lipina 1960) and correlates tentatively with the Cf1δ- Cf2 (Tn2c-Tn3 a-b) zones in Belgium (Conil et al. 1991). In the North American Midcontinent it is recognized in part by the occurrences of *S. costifera* and *S. recta* just above *T. tuberculata* in the lower Osagean Humboldt Oolite (Brenckle & Groves 1987).

Eotextularia diversa Zone. The key section of this zone is at the Sikaza River (bed 23). Its base is defined by the first appearance of *Eotextularia diversa* (N. Tchernicheva) as well as of *Darjella monilis* Malakhova. This zone differs from the previous zone by a decrease in diversity of the foraminifera that began in the Tournaisian. Dainellids and bessiellids dominate the assemblage along with the appearance of *Tetrataxis* sp., *Laxoendothyra laxa* (Conil & Lys), *Endospiroplectammina conili* Lipina, *Loeblichia fragilis* (Lipina) and pre-*Eoparastaffellina* (Pl. 1, fig. 1). It correlates with the *Dollymae bouckaerti* and *Scaliognathus anchoralis* conodont zones and corresponds to most of the Kosvian. It also correlates with most of the Cf3 (T3c) Zone (Conil et al. 1991; Hance et al. 1997) in Belgium, but is unknown in North America (Brenckle 1991), where its

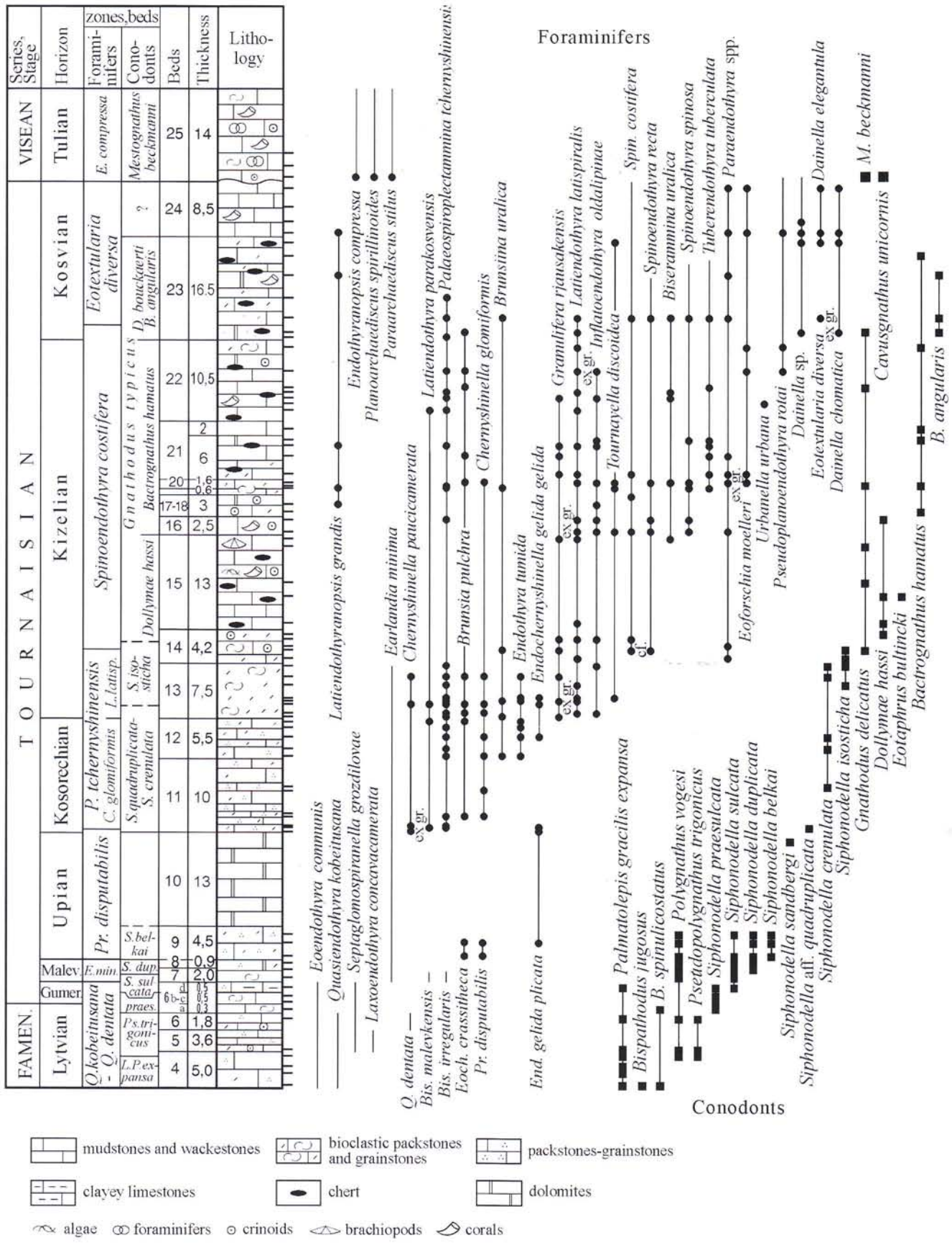


Fig. 4 - Range of representative foraminifers (Sinitsyna et al. 1984; Kulagina & Sinitsyna 2000) and conodonts (Pazukhin, this paper) in the Tournaisian strata of the Sikaza section.

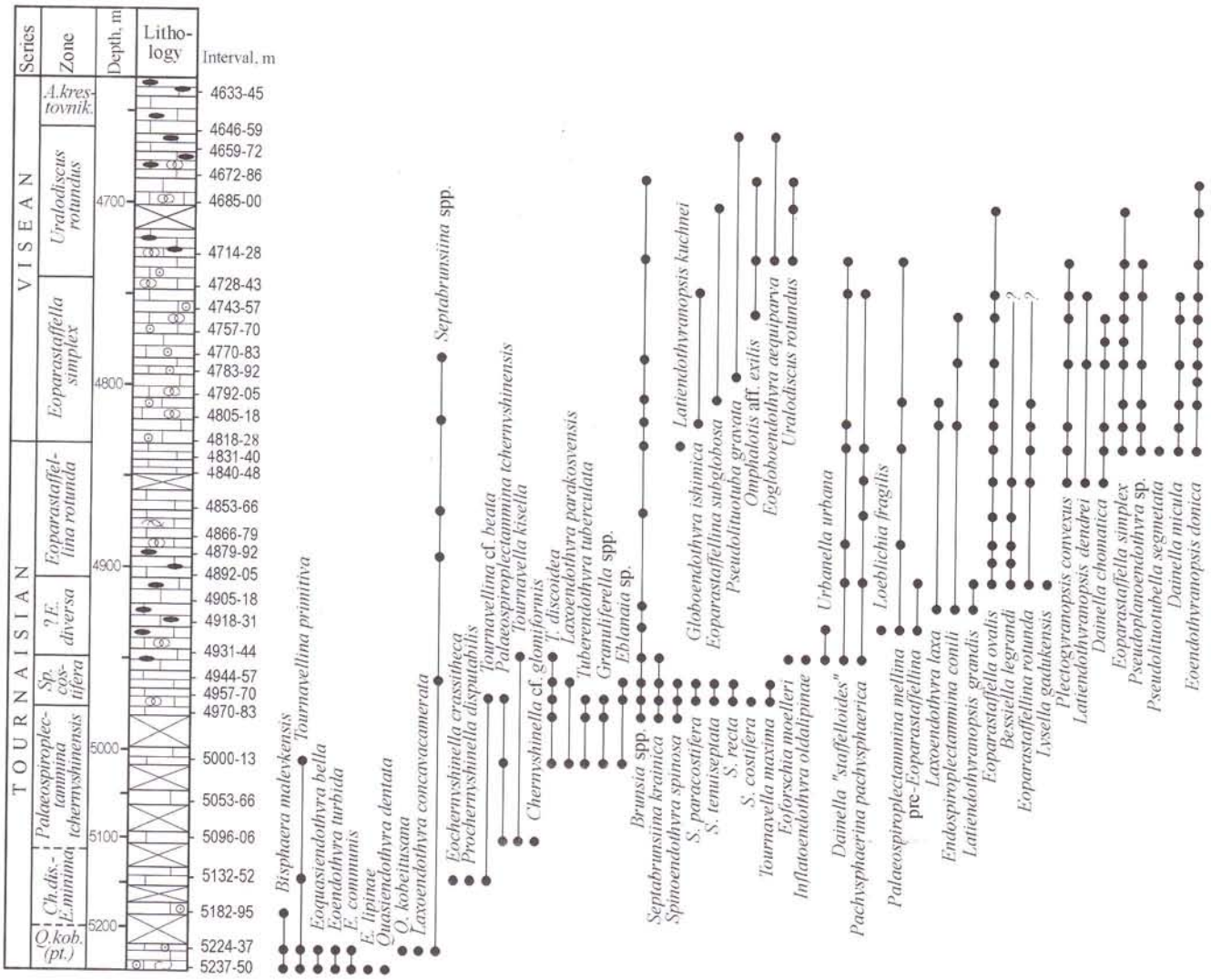


Fig. 5 - Range of representative foraminifers in the Lower Carboniferous of the Tengiz 22 well. Compiled by Gibshman (legend as in Fig. 4).

absence is probably related to provincial differences in foraminiferal distribution.

Eoparastaffellina rotunda Zone. This zone is included in the Russian Scale for the first time. A similar foraminiferal assemblage, recently obtained from South China (Guangxi), was assigned to the late Tournaisian (Hance 1997; Hance et al. 1997; Riley 1994). In the sections studied by the present authors, this interval was tentatively identified in the Burlya section in the South Urals (Fig. 6) and recognized reliably in the Tengiz 22 well (4831-4905 m).

The lower boundary of this zone is based on the first appearance of *E. rotunda* Vdovenko. In the Tengiz 22 well *Eoparastaffella ovalis* Vdovenko, *Bessiella legrandi* Conil & Lys, *Lysella gadukensis* Bozorgnia occur for the first time with the zonal index. A similar assemblage was noted in beds with *Tournayella* and *Eoparastaffella* of late Kosvian age in the Yaburski well (beds 13-16) on the North Urals (Lyadova & Pogorelov 1990). In the Burlya section the *E. rotunda* Zone contains a peculiar conodont assemblage consisting of *Embsaygnathus asymmetricus* Metcalfe, *Clydagnathus burliensis* sp. n., *Clydagnathus* sp., *Cavusgnathus* sp., *Polygnathus bischoffi* Rhodes, Austin et Druce. In the Urals these strata correspond to the Obruchevian. Its correlation to the Radaevkian is debatable. In the Tengiz 22 well the *E. rotunda* Zone was correlated with the lowermost part of the Moliniacian (Cf4α1 subzone) (Conil et al. 1991; Hance 1997) in Belgium.

The Lower Visean. *Eoparastaffella simplex* Zone. The assemblage of this zone was distinguished in many sections of the Urals (Malakhova 1973; Postojalko 1975; Simonova 1975). However, underlying beds are unconformable or are represented by terrigenous or volcanic facies where foraminifera are unknown. In the Tengiz 22 well the zone occurs in the 4818-4728 m interval. Characteristic zonal taxa are *Pseudolituotubella segmentata* (Pronina), *Eoendothyranopsis donica* (Brazhnikova & Rostovseva) and *Globoendothyra ishimica* (Rauzer-Chernousova). This zone corresponds to the lower *Gnathodus texanus* conodont zone and correlates with the up-

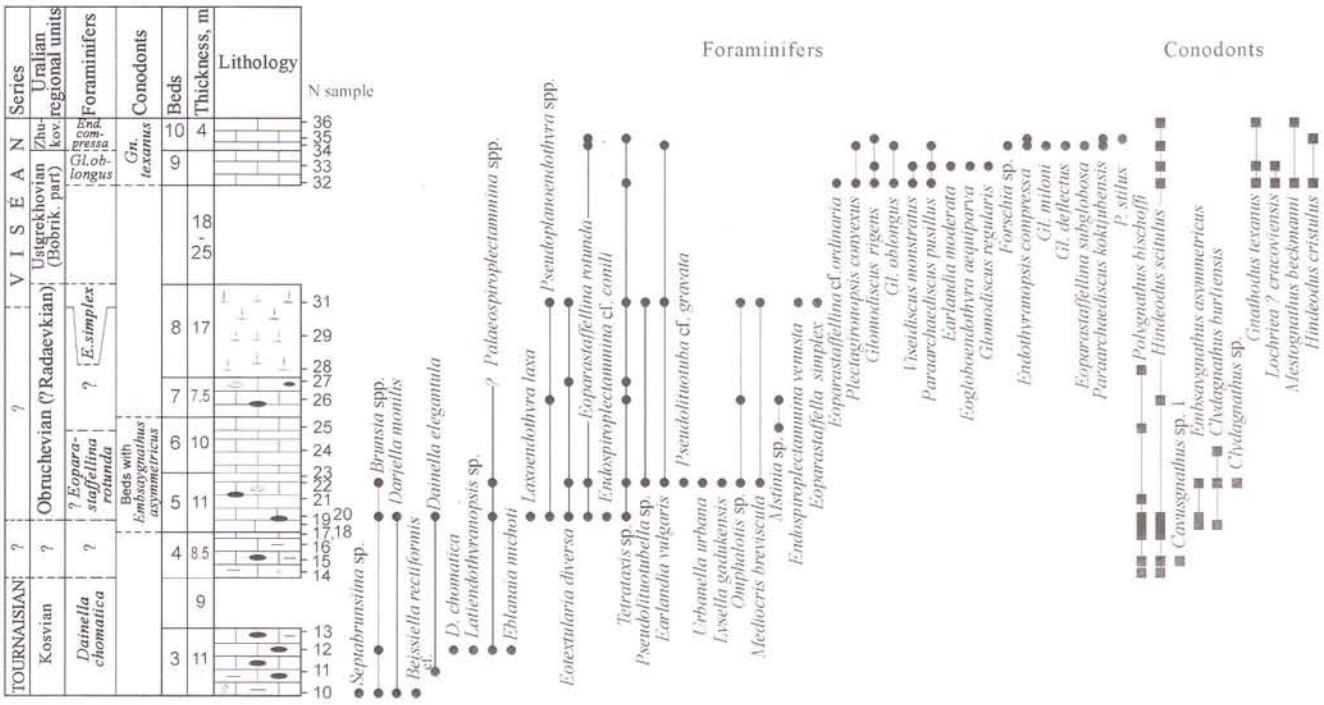


Fig. 6 - Range of representative foraminifers (Kulagina & Gibshman) and conodonts (Pazukhin) in the Burlya section. Stratigraphic columnar section modified from Kochetkova & Lutfullin (1982) (legend as in Fig. 4).

per part of the Radaevkian of the Russian Platform and the Pesterkovian (Postojalko 1975) of the Urals. In the Dinant Basin this foraminiferal assemblage defines the Moliniacian (early Visean) Cf4α2 Subzone of the *Eoparastaffella* (Cf4) Zone (Hance 1997; Riley 1993). In North America (Brenckle 1991) it correlates with the *Eoparastaffella – Eoendothyranopsis* assemblage of Horizon 3.

The *Uralodiscus rotundus* Zone was studied in the South Ural sections along the Burlya River, Verkhnyaya Kardailovka (Nikolayeva et al. 2001) and in the Tengiz 22 well (4728-4659 m). *Uralodiscus rotundus* (N.Tchernicheva), *Glomodiscus oblongus* (Conil & Lys) and *G. rigens* (Conil & Lys) first appear in this zone (Fig. 5, 6). The zone is equivalent to the Bobrikovian of the Russian Platform and Ilychian of the Urals (Postojalko 1975), and corresponds to the middle part of the *Gnathodus texanus* conodont zone. In Western Europe (Hance 1988; Riley 1993) it correlates with the Cf4 β-γ subzones of the Moliniacian, and in North America (Brenckle 1991) to part of Horizon 4 with Planoarchaediscinae.

The Upper Visean. The assemblage zones previously referred to the upper Visean series (Lipina & Reitlinger 1970; Stepanov & Donakova 1982) are not modified in this paper. The selection of a single lineage is complicated because of an intensive radiation of new species.

Endothyranopsis compressa Zone. In the Tengiz 22 well this zone extends from 4633-4672 m and its lower boundary is supposedly defined by the first occurrence of *Lituotubella glomospiroides* (Rauzer-Chernousova), *Paraarchaediscus koktjubensis* (Rauzer-Chernousova), *P. stilus* (Grozdilova & Lebedeva) together with *G. oblongus* (Conil & Lys) and *G. rigens* (Conil & Lys), similar to the Burlya section. In the upper part of the zone in the Tengiz 22 well (core 4633-4646 m). *Glomodiscus* disappears and the assemblage contains *Paraarchaediscus koktjubensis*, *P. stilus*, *P.* spp. Many upper Visean foraminiferal species appear in the upper part of this zone. It characterizes the Tulian and correlates with the upper *Gnathodus texanus*, *G. austini* and lower *Gnathodus bilineatus bilineatus* conodont zones. This assemblage probably correlates with the Cf 5 - Cf 6α zones (Livian - lowermost Warnantian) in the Dinant Basin (Hance 1988; Laloux 1988). However, the data need to be analyzed more carefully.

Endothyranopsis crassa - Archaediscus gigas Zone. Within this zone local subzones can be determined in the Russian Platform and Urals. A large number of new species appear at different levels within this zone, but the occurrence of these species does not coincide consistently with regional stratigraphical units. The lower boundary of the zone (Aleksinian) can be defined by the appearance of *Bradyina rotula* (Eichwald), *Howchinia bradyana* (Howchin), *Archaediscus moelleri* Rauzer-Chernousova and *Archaediscus gigas* Rauzer-Chernousova. The middle part of the zone correlates with the Mikhailovian and its lower boundary is defined by the appearances of *Eostaffella ikensis* (Vissarionova), *Climacammina prisca* Lipina, *Endothyranopsis sphaerica* (Rauzer-Chernousova & Reitlinger). The Aleksinian and Mikhailovian correspond to the Cf6 β-γ subzones in Belgium (Conil et al. 1980; Laloux

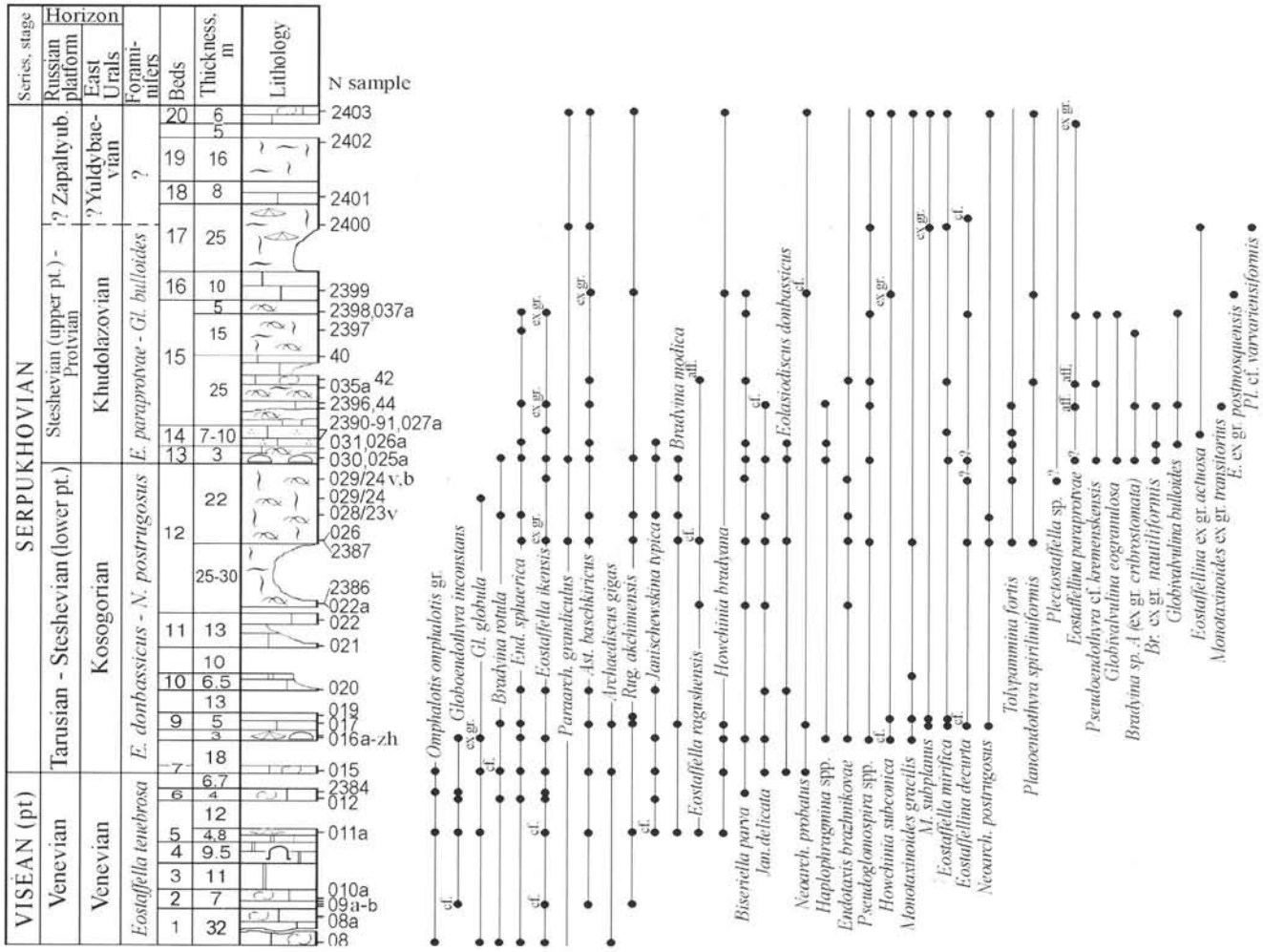


Fig. 7 - Range of representative foraminifers in the Serpukhovian strata of Bolshoi Kizil section (Kulagina & Gibshman 2002) (legend as in Fig. 4)

1987). The lower boundary of the upper part of the zone (equivalents to Venevian) is defined by the appearances of *Climacammina simplex* Rauzer-Chernousova, *Loeblichia paraammonoides* Brazhnikhova, *Janischewskina typica* Mikhailov and probably correlates to the Cf6δ Subzone (Conil et al. 1980; Laloux 1987) of Belgium.

Serpukhovian Stage. A great variety of facies and the existence of isolated basins in the Serpukhovian time make it difficult to select global markers. The zonal scale proposed by the authors is based on thorough research of foraminiferal distribution in three facies types. These are shallow epicontinental basins (Zaborie and Novogurovsky quarries); relatively deep, open shelves (Verkhnyaya Kardailovka and Muradymovo sections); bioherms (Bolshoi Kizil section, Fig. 7).

Neoarchaediscus postrugosus Zone. The lower boundary reference section of this zone is in the Zaborie Quarry (bed 3, Gibshman 2001; 2003). In addition to *N. postrugosus* (Reitlinger), it is possible to define this zone using *Pseudoendothyra globosa* Rozovskaya, *"Millerella" tortula* D. Zeller and *Janischewskina delicata* (Malakhova) in shallow-water facies; *Eolasiodiscus donbassicus* (Reitlinger) and *Monotaxinoides* sp. represent equivalent faunas in the bioherm facies. Besides the species mentioned above, characteristic taxa include *Endotaxis brazhnikovae* (Bogush & Juferev) and *Haplophragmina beschevensis* (Brazhnikova). Above the bottom of this zone, *Planoendothyra aljutovica* (Reitlinger), *Eostaffella mirifica* Brazhnikova, *Eostaffellina decurta* (Rauzer-Chernousova), *Rectoendothyra latiformis* Brazhnikhova, *Monotaxinoides subplanus* (Brazhnikova & Jartseva) and *Loeblichia minima* Brazhnikova first occur. Many species that originated in the upper Visean occur within the lower Serpukhovian and under favorable conditions they may constitute the bulk of the assemblage. Of particular significance are *Endothyranopsis sphaerica* (Rauzer-Chernousova & Reitlinger) and *Eostaffella ikensis* Vissarionova. This zonal assemblage is characteristic of the Tarusian and lower Steshevian of the Moscow region and Kosogorian of the Urals, and corresponds to the conodont *Lochriea cruciformis* Zone (excluding its upper part). The presence of *"Millerella" tortula* makes it possible to correlate the base of the Serpukhovian with the mid-Chesterian, Midcontinent USA (Gibshman 2003).

Eostaffellina paraprotvae Zone. The base of this zone is located in bed 28 at the Zaborie Quarry. In addition to *E. paraprotvae* the zone contains *Eostaffellina actuosa* Reitlinger, *Globivalvulina bulloides* (Brady), and *Bradyina* ex gr.*cribrostomata* Rauzer & Reitlinger. The lower boundary is in the middle Steshevian and corresponds to the boundary at the base of the Kosogorian and "Protvian" (or Lower Brazhkian) of the Urals. The zone correlates with the upper *Lochriea cruciformis* conodont zone and lower *Gnathodus bilineatus bollandensis* Zone.

Brenckleina rugosa – Monotaxinoides transitorius Zone. In the Zaborie Quarry stratotype this zonal assemblage contains *Eostaffellina "protvae"* (Rauzer-Chernousova), *Brenckleina rugosa* (Brazhnikova), *Janischewskina* n. sp.. Within the stratotype area in the Moscow Basin, the upper part of the zone is absent but it appears in sections from the Urals and Donetz Basin, where the eosigmoilinids first occur on the East European Platform (Vdovenko et al. 1990). The foraminiferal distribution in the uppermost Serpukhovian may be well illustrated in the Ural sections at Verkhnaya Kardailovka (Nikolaeva et al. 2001) and Muradymovo (Kulagina et al. 1992), where Howchiniidae are widespread. The zone corresponds to the upper Protvian of the Moscow region and Yuldybavian of the South Urals and correlates with the upper Chesterian, in North America (Brenckle 1991).

Conclusions

Several phylogenetic lineages exhibiting evolutionary changes that can be correlated globally may be distinguished in the Lower Carboniferous foraminiferal sequence of Russia. The *Tournayellina – Prochernyshinella – Chernyshinella – Palaeospiroplectammina – Eotextularia* lineage and the *Inflatoendothyra – Spinoendothyra* lineage can be used to zone the Tournaisian. The Tournaisian lineage zones terminate with the development of new short-lived species of Tournayellidae, Loeblichiidae and Paraendothyrinae. The evolution of the *Eoparastaffella – Parastaffella* lineage and the first occurrence of the Loeblichiidae and Archaediscidae can be used to subdivide the lower Visean. In the upper Visean several stratigraphically important evolutionary lineages can be distinguished in the Endothyranopsidae, Janischewskinidae, Bradyinidae and Archaediscidae. The Serpukhovian subdivisions are based on the evolution of the Janischewskinidae, Eostaffellidae, Archaediscidae and Howchiniidae.

Paleontological description

Class Conodonta

Genus *Clydagnathus* Rhodes, Austin and Druce, 1968

Clydagnathus burliensis Pazukhin, sp. nov.

Pl.1, fig. 27

Etymology. From the location at the Burlya River.
Holotype. No. 104/330, Institute of Geology, Ufa Research Centre, RAS. The eastern slope of the South Urals, Burlya section, sample 22, Uppermost Tournaisian or basal Lower Visean, Obruchevian horizon.
Diagnosis. Pa-elements with broad triangular asymmetrical platform, long carina, short anterior trough, and fine transverse ridges in the posterior part. Basal cavity is large and deep and occupies the posterior part of the element.

Description. The platform is broad, triangular and asymmetrical. The inner margin of the platform is raised and convex. The outer margin of the platform is straight. The platform is ornamented with fine marginal ridges that extend to the carina. The carina is low and long and consists of fused nodes. The carina stretches from the posterior end of the platform nearly to the level of the posterior denticle of the blade. The trough between blade and inner margin in the anterior part of the element is shallow and almost indistinct. The blade is high and bears 4 or 5 denticles. The largest posterior denticle hangs over the platform. The broad and asymmetrical basal cavity is situated on the lower side of the platform in its posterior end (two thirds of its length). The deepest part of the basal cavity is on its anterior part.

Comparison. *Clydagnathus burliensis* differs from *C. gilwernensis* Rhodes, Austin et Druce (Rhodes et al. 1969, p. 87-88, pl. 2, fig. 1) and other *Clydagnathus* species by a wide triangular platform with deep basal cavity, longer carina and short medial trough. *C. burliensis* also has on the upper surface of the platform fine transverse ridges, which reach the carina.

Occurrence. Eastern slope of the South Urals, Burlya section (beds 5, 6). Uppermost Tournaisian or basal lower Visean, Obruchevian, Beds with *Embsaygnathus asymmetricus*.

Material. 4 specimens.

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PLATE 1

Fig. 1-24 - Foraminifers from *Eotextularia diversa* and *Eoparastaffellina rotunda* Zones. All magnification x 100, except where noted.

Fig. 1 - Pre-*Eoparastaffellina* sp. Axial section, Tengiz 22 well, 4931- 4918 m, sample 1.

Fig. 2, 6-10, 14, 23 - *Eoparastaffellina rotunda* Vdovenko, 1971 [= *Eoparastaffella fundata* Simonova, 1975 = *Eoparastaffella lenticular* Postojalko, 1975, pl. 7, fig. 29, 30]. 2, 6-8 - axial sections; 9, 10, 14 – oblique section; 23 – x 75, sagittal sections. 2,6, 10, 23 are from Tengiz 22 well: 10, 23 - 4905-4892 m, sample 67/2; 2, 6 - 4866-4879 m, sample 24/2; 7-9,14 – Burlya: 7-8 – sample 20; 9, 14 - sample 22.

Fig. 3-5 - *Eoparastaffellina ordinaria* (Pronina, 1963) [= *Eoparastaffellina rotunda* form *minima* Vdovenko, 1971]. 3, 4 - oblique section; 5 - axial section. All are from Tengiz 22 well, 4905 – 4892 m, sample 67/2.

Fig. 11 – 12 - *Eoparastaffella ovalis* Vdovenko, 1954 [=*Eoparastaffella concinna* Postojalko, 1975, pl. 7, fig. 14-15 = *E. restricta* Postojalko, 1975, pl. 7, fig. 4, 5, pl. 8, fig. 12 = *E. venusta* Postojalko, 1975, pl. 7, fig. 12, 13; non *E. ovalis* in Vdovenko, 1964, pl.1, fig.1-3, 7-9 or in Postojalko, 1975, pl.7, fig. 1-3; pl. 13, fig.18]. Axial section, broken and deformed specimens. All are from the Tengiz 22 well, 4905- 4892m, sample 67/2.

Fig. 13 - *Besiella rectiformis* (Bogush et Juferev, 1961). Axial section, Burlya, sample 10, Kosvian.

Fig. 15 - *Dainella elegantula* Brazhnikova, 1963. Axial section, Burlya, sample 20, Obruchevian.

Fig. 16 - *Eoparastaffella* sp. Axial section, Burlya, sample 26, Obruchevian.

Fig. 17-18, 22, 24 - *Eoparastaffella simplex* Vdovenko, 1951. 17, 18, 22 - axial and close to axial sections; 24 - x 75, sagittal section. All are from the Tengiz 22 well, 17, 22, 24 - 4805-4792 m, sample 343; 18 - 4770–4757 m, sample 58.

Fig. 19 - *Eoparastaffellina subglobosa* Vdovenko, 1971. Axial section, partly oblique, Tengiz 22 well, 4805-4792 m, sample 625/2.

Fig. 20 - *Lysella* sp. Axial section, Burlya, sample 22, Obruchevian.

Fig. 21 - *Loeblichia fragilis* (Lipina, 1951). Incomplete sagittal section, Tengiz 22 well, 4931– 4918, sample 1.

Fig. 25-30 - Conodonts from beds with *Embsaygnathus asymmetricus*. South Urals, Burlya River section. All magnifications x35. View: a - upper, b - lower, c - side.

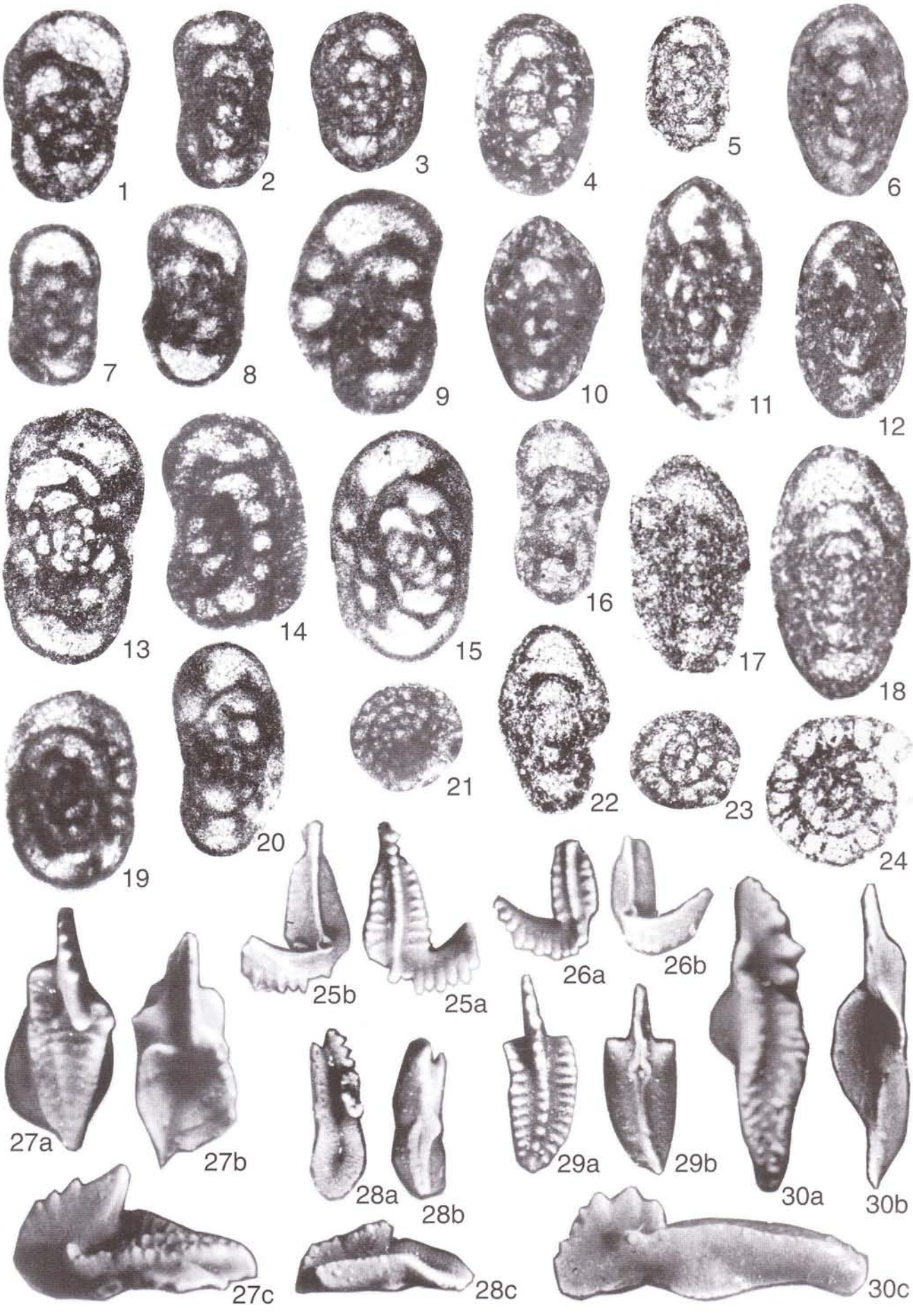
Fig. 25-26 - *Embsaygnathus asymmetricus* Metcalfe, x 35. 25 - IG 104/308; sample 22; 26 - IG 104/307; sample 22.

Fig. 27 - *Clydagnathus burliensis* Pazukhin sp. nov., x 35. Holotype IG 104/330; sample 22.

Fig. 28 - *Cavusgnathus* sp., x 35. IG 104/336; sample 15.

Fig. 29 - *Polygnathus bischoffi* Rhodes, Austin and Druce, x 35. IG 104/120; sample 15.

Fig. 30 - *Clydagnathus* sp., x 35. IG 104/335; sample 22.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REFERENCES

Brenckle P. L. (1991) - Foraminiferal division of the Lower Carboniferous/Mississippian in North America. In: P.L. Brenckle & W. L. Manger (eds.) Intercontinental Correlation and Division of the Carboniferous System. *Cour. Forsch.-Inst. Senkenberg*, 130: 65-78, Frankfurt a. M.

Brenckle P. L. (1997) - Late Tournaisian (Lower Carboniferous) foraminifers from the Middle Urals and their use in Russian Horizon definition. In: C. A Ross, J.R.P. Ross and P. L. Brenckle, (eds.)- Late Paleozoic Foraminifera; their biostratigraphy, evolution, and paleoecology and the Mid-Carboniferous boundary. *Cushman Found. Foram. Res.*, Spec. Publ., 36: 5 – 10, Washington D.C.

Brenckle P. L. & Groves J. R. (1987) - Calcareous foraminifers from the Humbolt Oolite of Iowa: key to early Osagean (Mississippian) correlation between Eastern and Western North America. *Palaios*, 1: 561-581, Tulsa.

Conil R., Groessens E., Laloux M., Poty E. & Tourneur F. (1991) - Carboniferous Guide Foraminifera, corals and conodonts in the Franco-Belgian and Campin basins: their potential for widespread correlation. In: P.L. Brenckle & W. L. Manger (eds.) Intercontinental Correlation and Division of the Carboniferous System. *Cour. Forsch.-Inst. Senkenberg*, 130: 15-30, Frankfurt a. M.

Conil R., Longerstaey P., & Ramsbottom W. (1980) - Materiaux pour l`étude micropaléontologique du Dinantien de Grande-Bretagne. *Mem. Inst. Geol. Univ.* 30: 1-189, Louvain.

Gibshman N. B. (1997) - Foraminiferal zonation and paleogeography of Early Carboniferous, Precaspian depression (West Kazakhstan). In: C. A Ross, J.R.P. Ross and P. L. Brenckle (eds.)- Late Paleozoic Foraminifera; their biostratigraphy, evolution, and paleoecology; and the Mid-Carboniferous boundary. *Cushman Found. Foram. Res.*, Spec. Publ., 36: 47-50., Washington D.C.

Gibshman N. B. (2001) - Foraminiferal biostratigraphy of the stratotype Serpukhovian Stage (Zaborie quarry, Moscow Basin). *Newsletter SCCS*, 19: 31-34, Cincinnati.

Gibshman N. B. (2003) - Foraminifera characteristics of the Serpukhovian stratotype in Zaborie Quarry (Moscow Basin, Russian Platform). *Stratigraphy and Geological Correlation.* 11 (1): 39-63 (in Russian and English).

Hance L. (1988) - Le Moliniacien du Synclinorium de Dinant (Belgique) de la région dinantaise a la vallée de l'Ourthe. *Mém. Inst. Géol. Univ. Louvain*, 33: 1-91, Louvain.

Hance L. (1997) - *Eoparastaffella*, its evolutionary pattern and biostratigraphic potential. In: C. A. Ross, J.R.S. Ross and P. L. Brenckle (eds.) - Late Paleozoic Foraminifera; their biostratigraphy, evolution, and paleoecology; and the Mid-Carboniferous boundary. *Cushman Found. Foram. Res.*, Spec. Publ. 36: 59-62, Washington D.C.

Hance L., Muchez Ph, Hou H.-F. & Wu X. (1997) - Biostratigraphy, sedimentology and sequence stratigraphy of the Tournaisian-Visean transitional strata in South China (Guangxi). *Geol. Jour.*, 32: 337-357, Liverpool.

Kagarmanov A. H. & Donakova L.M. (eds.) (1990) - Resolution of the Interdepartmental Regional Stratigraphic Meeting on the Middle and Upper Paleozoic of the Russian Platform with stratigraphic schemes. Leningrad, 1988. Carboniferous System - *VSEGEI* : 41 pp. and 95 schemes Leningrad (in Russian).

Kochetkova N.M.& Lutfullin J.L. (1982) - New data on Lower Carboniferous stratigraphy along the middle of the Burlya River In: M.A . Garris (ed.) - Upper Precambrian and Paleozoic of the Southern Urals (stratigraphy and lithology). *Akad. Nauk SSSR, Bashkirian Branch, Instit. of Geology*: 100-106, Ufa (in Russian).

Kochetkova N.M., Reitlinger E.A., Pazukhin V.N., Avhimovitch V.I. (1988) - The Devonian / Carboniferous boundary in the Southern Urals. In: The Devonian /Carboniferous boundary in the territory of the USSR. *Izd. Nauka i technica:* 157-166, Minsk (in Russian).

Kulagina E.I. & Gibshman N.B. (2002) - Zonal subdivisions of the Serpukhovian on foraminifera. In: B.I. Chuvashov & E.O. Amon (eds.) - Carboniferous stratigraphy and palaeogeography in Eurasia. *Russian Akad. nauk, Uralian Branch, Inst. Geol. and Geochem*: 183-192, Ekaterinburg (in Russian).

Kulagina E. I., Rumyantzeva Z. S., Pazukhin V.I. & Kochetova N.N. (1992) - Lower/Middle Carboniferous Boundary in the South Urals and Central Tien Shan. *Izd. Nauka.* 112 pp., Moskva (in Russian).

Kulagina E.I. & Sinitsyna Z.A. (2000) - Tournaisian zonal sequence of foraminifers in key sections on the eastern slope of the Southern Urals. *Acad. nauk Bashkirtostan Republic. Izvestiya. otd. nauk o zemle i ekologii.* 5: 88-99, Ufa. (in Russian).

Laloux M. (1988) - Foraminifèrs du Viséan supérieur et du Namurien du bassin franco-belge. *Bull. Soc. belge Géologie,* 96/3: 205-220, Bruxelles.

Lipina O. A. (1960) - The stratigraphy of Tournaisian and Devonian/Carboniferous boundary beds of the eastern part of Russian Platform and west slope of the Urals. *Trudy GIN*, 14: 3-157, Moskva (in Russian).

Lipina O. A. & Reitlinger E. A. (1970) - Stratigraphie zonale et paleozoogeographie du Carbonifere inferieur d'apres les foraminiferes. In: *Compte Rendu VI Congres. Intern. Strat. Geol. Carbonif. Sheffield,* 3: 1101-1112, Sheffield.

Lyadova R.A. & Pogorelov Ju.I. (1990) - Lower Visean deposits of the Yaburcki section of the Vishera basin (North Ural). In: Papulov G.N., Chuvashov B.I. (eds.) – The boundaries of Carboniferous biostratigraphical units of the Urals. Sbornik nauchnyh trudov. *Akad. Nauk SSSR, Uralskii Nauchnyi Tsentr:* 3-34, Sverdlovsk (in Russian).

Malakhova N.P. (1973) - On the age and stratigraphic position of the Gusikhinsky suite of the Southern Urals. In: Carboniferous deposits of the Eastern Slope of the South Urals. *Akad. Nauk SSSR, Uralskii Nauchnyi Tsentr, Trudy Inst. Geol. and Geokhem.,* 82: 127-185, Sverdlovsk (in Russian).

Nikolaeva S.V., Kulagina E.I., Pazukhin V.N. & Kochetova N.N. (2001) - Integrated Serpukhovian biostratigraphy in the South Ural. *Newsletter SCCS*, 19: 38-42, Cincinnati.

Postojalko M.V. (1975) - Early Visean Foraminifers and stratigraphy of the East slope of the Urals. In: Early Visean Foraminifers and stratigraphy of the Urals. *Akad. Nauk SSSR, Uralskii Nauchnyi Tsentr, Trudy Inst. Geol. and Geokhem.,* 112: 110-176, Sverdlovsk (in Russian).

Rauzer-Chernousova D. M. (1934) - On microfauna and stratigraphic division of the Samara Bend Carboniferous. *Neftyanoe khozyaistvo*, 8: 26 - 30, Moskva (in Russian).

Rauzer-Chernousova D. M., Belyaev G.M. & Reitlinger E. A. (1940) - On Carboniferous Foraminifera of the Samara Bend. *Izd. Gostoptehizdat, Trudy Neft. geol.-razved. Inst., nov. ser.*, 7, 87 pp. Leningrad-Moskva (in Russian).

Rauzer-Chernousova D. M., Vissarionova A.J., Glebovskaya E.M., Grozdilova L.P., Lipina O.A., Suleimanov I.S., Tchernysheva N.E. (1948) - The stratigraphy and foraminifers of the Lower Carboniferous of the Russian Platform and Fore-Urals. *Akad. Nauk SSSR. Trudy GIN*, 62, ser., geol. (19): 1-262, Moskva (in Russian).

Reitlinger E.A. & Kulagina E.I. (1987) - Foraminifera. In: Maslov V.A. (ed.) - Fauna and biostratigraphy of the Devonian/Carboniferous boundary of Berchogur (Mugodzhary). *Izd. Nauka*, 48-52, Moskva (in Russian).

Riley N.J. (1993) - Dinantian (Lower Carboniferous) biostratigraphy and chronostratigraphy in the British Isles. *Jour. Geol. Soc.*, 150: 427-446, London.

Riley N.J. (1994) - Foraminiferal Biostratigraphy of the Chadian Stage Stratotype (Dinantian), Chatburn, Northwest England. *Bull. Soc. belge Geol.*, 103: 13-49, Bruxelles.

Rhodes F.H.T., Austin R.L. & Druce E.C. (1969) - British Avonian (Carboniferous) conodont faunas and their value in local and intercontinental correlation. *Bull. Brit. Mus. (Nat. Hist.) Geology*, Suppl. 5, 313 pp., London.

Shcherbakov O.A. (1997) - Biostratigraphy of the Carboniferous system of the Urals. In: C. A Ross, J.R.P. Ross and P. L. Brenckle (eds.)- Late Paleozoic Foraminifera; their biostratigraphy, evolution, and paleoecology; and the Mid-Carboniferous boundary. *Cushman Found. Foramin. Research*, Spec. Publ., 36: 129 – 133, Washington D.C.

Simonova Z.G. (1975) - Gumbeycky and Ust'-Grekhovsky foraminiferal complexes of the Magnitigorsky Synclinorium. In: Early Visean Foraminifers and stratigraphy of the Urals. *Akad. Nauk SSSR, Uralskii Nauchnyi Tsentr, Trudy Inst. Geol. and Geokhem.*, 112: 177-224, Sverdlovsk (in Russian).

Sinitsyna Z.A., Sinitsyn I.I. & Kochetkova N.M. (1984) - Lower Carboniferous section along the Sikaza River. In: Einor O.L. (ed.) - Guidebook for the South Urals. Excursion 047. *27th International Geological Congress USSR*: 25-35, Moskva (in Russian and English).

Stepanov D.L. & Donakova L.M. (1982) - General Stratigraphic Scale of the Carboniferous. In: Sokolov B.S. (ed.) - Resolutions of Interdepartmental Stratigraphic Committee and its permanent commissions. No. 20, pp. 30 - 31, Leningrad (in Russian).

Vdovenko M.V., Aizenverg D.Ye., Nemirovskaya T.I. & Poletaev V. I. (1990) - An overview of Lower Carboniferous biozones of the Russian Platform. *Jour. Foram. Res.*, 20/3: 184-194, Lawrence.