CYCLIC DISTRIBUTIONAL MODEL OF THE LATE MOSCOVIAN FUSULINIDS IN THE DONETS BASIN (UKRAINE) IN RESPONSE TO EUSTATIC SEA LEVEL FLUCTUATIONS AND ITS APPLICATION IN BIOSTRATIGRAPHY AND CORRELATION

by

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The following individuals read and discussed the dissertation submitted by student Rimma Khodjanyazova, and they evaluated her presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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ABSTRACT

The continuous Pennsylvanian shallow-marine, paralic, siliciclastic succession in the Donets Basin is pivotal for correlation of marine and continental strata in northern Pangaea with coeval shallow-marine mainly carbonate strata in the Moscow Basin, a historical type area of Moscovian Horizons. The details of the history of establishment, lithostratigraphy and current biostratigraphy of Podolskian and Myachkovian Horizons in the Moscow Basin that are not readily available in Western literature are reviewed.

A model of cyclic recurrence (~0.6 —1myr) of three main fusulinid assemblages in the Pennsylvanian siliciclastic-carbonate succession in the Donets Basin is proposed. A *Hemifusulina*-association (A) indicates the onset of transgression (ETST: early transgressive system tract); maximum transgression (LTST-EHST: late transgressive – early high-stand system tract) is characterized by the *Beedeina–Neostaffella–Ozawainella–Taitzehoella* (or *Beedeina*-dominated) assemblage (B), which is successively replaced by the most diverse *Fusulinella*-dominated association (C) in a progressively shallowing sea (LHST-ELST: late high stand – early low stand system tracts).

Our proposed model offers refinement of the regional biostratigraphy and permits robust interbasinal correlation of Pennsylvanian-age Tethyan successions based on the *Beedeina*-dominated association, which marks maximum transgressions during the Pennsylvanian. Fusulinids, occurring in the regressive part of each cycle, are the most

provincial and are therefore the most useful for making paleogeographic reconstructions. Specifically, they can be used for recognition of originally contiguous regions that later may have been dispersed hundreds or thousands of kilometers. The model also provides a better understanding of an extinction event at the Moscovian – Kasimovian transition that involved many fusulinid genera inhabiting predominately deeper and colder water environments of transgressive seas. Various combinations of the proposed assemblages record ‘symmetrical’ and ‘asymmetrical’ distributional patterns and are capable of delineating the evolution of basins in different tectonic settings.

Application of a proposed model in the Podolskian and Myachkovian biostratigraphy and correlation is tested. A new integrated biostratigraphic and sequence stratigraphic approach for a biozone definition in the Donets Basin is proposed. Fusulinid biozones are acme or assemblage zones in which an abundant occurrence of the index and associated species is related to relative sea-level change and therefore the bases and tops of proposed zones are bound with unconformities, erosional surfaces or soil formations.

Three fusulinid cycles are recognized in the “M” Formation of the Donets Basin, Ukraine. One of the cycles includes limestone M_7–M_{10}^1. Fusulinids distribution reveals transgressive beds (limestones M_7 – M_8) and high stand – regressive beds (limestone M_9 – M_{10}^1). A *Hemifusulina subrhomboides – H. vozhgalica – Beedeina elshanica vaskensis* Zone is proposed for the transgressive limestones. Within transgressive limestones two subzones are defined. The lower *Hemifusulina vozhgalica – Hemifusulina subrhomboides* Subzone (limestones M_7 and M_7^{up}) is coeval with the middle part of the Smedva Formation in the Moscow Basin, which currently belongs to the Upper Kashirian. The

Beedeina elshanica vaskensis Subzone (limestones M_7^2 and M_8) is correlated with the upper part of the Smedva Formation. High stand – regressive beds are subdivided into two zones. The *Putrella donetziana – Fusulinella colanii* Zone (limestone M_9) is coeval with the Vaskino Formation (lower Podolskian). The *Kamaina rossoshanica – Fusulinella tokmovensis longa* Zone (limestone M_{10}) is provisionally correlated with the Ulitino Formation (middle Podolskian). The analysis of cyclic distributional patterns of fusulinids suggests that the Kashirian-Podolskian boundary should be placed according to its historical position, at the base of the local Smedva Formation. The boundary between Podolskian and Myachkovian in the Donets Basin is unclear, additional material is needed to define the boundary in this region.

A fusulinid taxonomic study of the Gurkovo and Kalinovo sections allows us to refine the biostratigraphy of the poorly studied Myachkovian (Upper Moscovian) strata of the "N" Formation in the Donets Basin. Three fusulinid biozones, *Hemifusulina graciosa – Fusiella spatiosa*, *Fusulina cylindrica – Fusulinella pseudobocki*, and *Fusulinella* (?) *kumpani*, are proposed in the interval from the top of Limestone M_{10} to the base of N_3, and they are correlated with coeval strata in the historical type area of the Moscow Basin. A total of 33 fusulinid species and subspecies belonging to 8 genera are described, including three new species: *Hemifusulina gurkovensis* n. sp., *Beedeina innaeformis* n. sp., and *Fusulina sosninae* n. sp. The main evolutionary trend in fusulinid morphology in the late Moscovian is the appearance of massive secondary deposits in the limestone of the "N" Formation.

The similarity of fusulinid assemblages in the Moscow and Donets Basins and their cognate evolution trends reveal a connection between both regions at least during Podolskian – Myachkovian time.

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Introduction: the Late Paleozoic Ice Age

The Late Paleozoic was a dynamic time of Pangaea supercontinent assembly and pronounced continental glaciation of the Gondwanan continent in the Southern Hemisphere (Veevers and Powell, 1987; Stanley and Powell, 2003). In the far-field of the Northern Hemisphere this time is marked by an expansion of tropical moisture-like forests on the northern front of the Variscan-Hercinian mountain belt extending along the Late Paleozoic paleoequator and resulting in deposition of economically productive coal seams (Donets Basin, Western Europe, North America and Northern China). In shallow epicontinental seas surrounding Laurussia this event is documented in the accumulation of diverse cyclothems separated from each other by unconformities, erosional surfaces and soil formation (Heckel, 2008).

Recent research (Isbell et al., 2003; Montanez et al., 2007; Fielding et al., 2008) reveals that the LPIA (Late Paleozoic Ice Age) was not a single event of Gondwanan glaciation, but that strongly glacial periods alternated with “interglacial” intervals of diminished ice volume and possibly ice free conditions (Montanez et al., 2007; Fielding et al., 2008; Montanez and Poulsen, in press). These discrete glacial episodes and their intervening warmer intervals of contracted ice volume are likely recorded by the cyclicity and stacking patterns of lithofacies in paleotropical successions through the linkage between changes in ice volume and sea-level response (Heckel, 2008; Bishop et al., 2010; Martin et al., 2012; Eros et al., 2012; Montanez and Poulsen, in press). If this hypothesis of a dynamic ice age is correct, then these discrete glacial episodes and their intervening warmer intervals likely impacted marine benthic communities that flourished in shallow tropical epicontinental seas. Although the impact of sea-level fluctuations on biodiversity and extinction events on many groups of fossil organisms have been documented (Bretsky and Bretsky, 1975; Heckel and Baesemann, 1975; Hallam, 1981; Baird and Brett, 1983; McGhee, 1991; Magniez-Jannin, 1992; Brett et al., 1990, 2007), relatively little is known about the effects of sea level fluctuations on the distribution of fusulinids, the most diverse benthic microfauna in shallow epicontinental seas of the Late Paleozoic (Ross and Ross, 1988).

One of the most remarkable Late Carboniferous events affecting both flora and fauna on a global scale, at least in the Northern Hemisphere, is at the Westphalian – Stephanian boundary. As the major floristic change happened simultaneously in the Donets Basin (Eastern Europe), Western Europe and Northern America, Meyen (1987) suggested the connection of this event with a short dry episode resulting from the Gondwanan glaciation. In marine successions this event is marked by a sudden simultaneous extinction of the fusulinid genus *Beedeina* both in North America and in the Eastern Europe at the Desmoinsenian – Missourian boundary. Besides *Beedeina*, several important genera, such as *Hemifusulina*, *Neostaffella, Pseudostaffella, Taitzehoella,* and *Ozawainella* became extinct or notably suffered at the Late Moscovian – Kasimovian transition in the Eastern European shallow marine seas.

I studied a stratigraphic distribution of Moscovian fusulinids in tandem with composite sequences previously defined by Eros et al. (2012) in the Donets Basin (Ukraine). This basin during Late Paleozoic time was an epeiric platform (Eros et al., 2012) with a relative high subsidence rate (Izart et al., 2003; Eros et al., 2012) and where deposition was essentially continuous during the Carboniferous (Aisenverg et al., 1975). Therefore, the Donets Basin is a suitable site for recording all episodes of 'global' sea level fluctuations during the Late Paleozoic. High-precision radiometric ages (Davydov et al., 2010) also provide a sound chronostratigraphic framework for detailed lithostratigraphic, biostratigraphic, and cyclostratigraphic research.

As the waxing and waning of Gondwanaland's glaciers were global events, the common trends in fossil distribution might be developed in different globally distributed basins. The second part of our study tests the distribution of the Paleotethyan fusulinids as possible indicators of sea level fluctuations in Late Paleozoic successions in different basins of the world. We argue that such analysis is helpful for global correlation and recognition of the timing and duration of glacial episodes during the LPIA.

Fusulinid paleoecology

The rapid evolutionary rate among the fusulinids was noted in the last century by stratigraphers who successfully employed these fossils for detailed regional correlations. Groves and Lee (2008) pointed out that taxonomic expansion of fusulinids "coincides almost precisely with the beginning of LPIA". Although most Late Paleozoic benthic foraminifera, including all larger foraminifera, such as fusulinids, went extinct by the end of the Permian, the fusulinid paleobiology and their environmental constraints are relatively well understood, being inferred from studies of recent benthic foraminifers (Leppig et al., 2005; Ross 1982, 1995; Stevens, 1966, 1969, 1971; Vachard et al., 2004).

The fusulinids were confined to the tropical-subtropical belts from 30 - 40° south and north of the equator, and occupied shallow water basins with carbonate to mixed carbonate-siliciclastic sedimentation (Ross, 1995; Kobayashi and Ishii 2003). The paleogeographic distribution of fusulinids, their sensitivity to paleoenvironments, and their high-resolution temporal framework provide the basis for the study presented here. Temperature is generally considered to be the major physical factor influencing the distribution of species or assemblages (BouDagher-Fadel, 2008; Hohenegger, 2004). As the benthic foraminifers are poikilothermic organisms, i.e. their body temperature is very close to the temperature of the surrounding water, they probably responded very quickly to even small changes in the ambient water temperature (Beavington-Penney and Racey 2004).

Here we emphasize the most important observations of fusulinid spatial and temporal distribution, which have been made during the last century. The first paleoecological studies of Pennsylvanian fusulinids revealed a differentiation of fusulinid assemblages with respect to the type of substrate, hydrodynamic activity, water depth, and association with other benthic organisms (Rauser-Chernousova and Kulik, 1949; Ross, 1961, 1967, 1969, 1971, 1972, 1982; Ginkel, 1973; Bensh, 1982). Ross (1969) first recognized that fusulinids occur in two different associations. One is represented by a monospecific population and associated with mixed carbonate-siliciclastic rocks. He suggested that this assemblage was deposited *in situ* and was associated either with muddy, clayed-limestones or with fine calcareous sandstones (calcarenites). The second assemblage is represented by a diverse population of fusulinids, which together with other groups of fossils, such as calcareous algae, corals, gastropods, brachiopods, crinoids and bryozoans, accumulated as carbonate rocks, primarily biogenic packstones.

Monospecific fusulinid occurrences have been noted in many studies (Bogush, 1963, Ginkel, 1973, Bensh, 1982, Villa and Bahamonde, 2001, Baranova and Kabanov, 2003).

In Middle and Late Carboniferous strata two genera, the Moscovian *Hemifusulina* and the Gzhelian *Ferganites,* commonly occur as monospecific assemblages. In the orogenic belts of the Cantabrian Mountains and Central Asia the *Hemifusulina*- and *Ferganites*-assemblages are associated with calcareous sandstones and siltstones intercalated with conglomerates (Bogush, 1963, Villa and Bahamonde, 2001). In cratonic regions, such as the Moscow and Donets Basins, monospecific populations of *Hemifusulina* are associated with muddy limestones (Baranova and Kabanov, 2003, Khodjanyazova et al., 2011). Besides their similar associations, these genera (*Hemifusulina* and *Ferganites*) have a similar morphology: small proloculi, subcylindrical shape rounded at axial ends, symmetrically regularly developed septal folding, and a porous wall structure.

Ross (1969), investigating the spatial distribution of the genus *Triticites* in the Late Pennsylvanian marine strata of Texas, proposed a relationship between test morphology and bathymetry. According to Ross, "some elongate species of *Triticites* are closely associated with sediment of impure silty limestone and fine to medium sandstone that may indicate shallow interdistributary bays and lagoons... Many large fusiform specimens of *Triticites* are associated with shallow water algal meadows and banks of crinoidal fragments... Small fusiform representatives of *Triticites* are most common in poorly sorted limestones that were probably deposited in slightly deeper water on the shelves that extended down to effective wave base".

Stevens (1969, 1971) studied diversity and distribution patterns of Middle Pennsylvanian fusulinids from McCoy, Colorado with respect to water depth and distance from the shore. He proposed a model in which the shallowest assemblage is represented by juvenile forms which "are found in small numbers in rocks deposited in water depth of

4 meters”. Farther from shore large, abundant mature fusulinids are found in “rocks deposited more than 3 km offshore in water with a minimum depth of 13 m”. He suggested the maximum depth for fusulinids is greater than 22 meters. The non-fusulinid, smaller foraminifers, (*Bradyina* and *Palaeotextularia*) occurred abundantly in rocks “deposited in water 15 meters deep, 3.5 km off-shore”.

Dzhenchuraeva (1975) recognized three bathymetric associations among the late Bashkirian – early Moscovian fusulinids in Central Asia. She used algae as the main direct indicator for bathymetric reconstruction. The most shallow-water *Schubertella–Pseudostaffella*-association occurs together with the green alga *Beresella*. The deeper predominatedly *Profusulinella*-assemblage is associated with a mixture of *Beresella* and red alga, *Ungdarella*. Finally, the deepest is the *Neostaffella – Ozawainella* assemblage, in which only the red alga *Ungdarella* occurs. Within the deepest assemblage besides the large spherical *Neostaffella* and large discoid and lenticular *Ozawainella*, the younger Kashirian limestones include subrhomboidal species of *Beedeina* and *Taitzehoella* (Dzhenchuraeva, 1975).

The first mention of a cyclic distribution of different fusulinid assemblages was in the last century by Russian micropaleontologists (Rauser-Chernousova and Kulik, 1949, Rauser-Chernousova, 1953, Rauser-Chernousova and Reitlinger, 1962, Putrja, 1956). They, working on fusulinid biostratigraphy and regional correlation of carbonate successions in the epicontinental shallow-water seas occupying the Eastern-European Platform during Pennsylvanian time, recognized a repetition of fusulinid assemblages that they hypothesized were linked with depositional cycles (“cyclothems”). Rauser-Chernousova and Reitlinger (1962) also noted that the cyclic occurrences of fusulinids were not a simple repetition of facies-dependent faunal associations, but also demonstrated evolutionary trends through time, from cycle to cycle. They concluded that a cyclic alternation of fusulinid assemblages was the result of adaptation of different genera to specific environments corresponding to cyclic sedimentation within a basin (Rauser-Chernousova and Reitlinger, 1962). However, no specific examples were provided in their study.

These previous, if scattered studies of the paleoecology of fusulinids, their facies-dependent distribution, evolutionary rates, and differences in test shape depending on the bathymetry give us some hints as to the sensitivity of fusulinids to eustatic sea level fluctuations.

Geologic, tectonic, and lithostratigraphic settings of the Donets Basin

The Donets Basin is the southeastern segment of the Pripyat-Dniepr–Donets intracratonic rift structure. Approximately 200 km wide and 700 km long (Fig. 1), it is located on the southern rampart of the eastern European craton between the Voronezh crystalline massif to the northeast and the Ukrainian crystalline massif to the southwest, and extends from the Baltic Sea to the Caspian Sea across Belarus, Ukraine, and Russia (Aisenverg et al., 1975; Khain, 1985, 1994; Stovba et al., 1996, Stovba and Stephenson, 1999). The thickness of a prerift and synrift volcano-siliciclastic succession of Silurian-Devonian age and Carboniferous–Lower Permian postrift sedimentary strata increases from about 7 km in the central and westernmost Dniepr–Donets Depression to about 16 km in the Donets Basin (Chekunov, 1994; Stovba et al., 1996, Ulmishek, 2001). The Donets Basin is generally considered to have been uplifted during the Early Permian in response to the buildup of stresses emanating from the Hercinian-Caucasus-Uralian orogenies (Milanovsky, 1992) or to the activity of an asthenospheric mantle diapir (Chekunov, 1994; Gavrish, 1989).

The Carboniferous–Lower Permian succession is represented by cyclic fluvio-deltaic and nearshore-marine mixed carbonate-siliciclastic sediments deposited on the Donets ramp, which steepened distally over several hundred kilometers into the Uralian seaway and Peri-Caspian Basin of the northern Tethys Ocean (Alekseev et al., 1996, Eros et al., 2012). Essentially isochronous biostratigraphically dated limestones provide laterally extensive marker beds that underpinned a detailed chronostratigraphic framework specific to the Donets Basin by the end of the nineteenth century (Aisenverg et al., 1963). The Carboniferous cyclic sequences are divided into major cycles or suites designated by Latin letters (e.g., Aisenverg et al., 1975). Major marine limestones are designated by capital letters and numerals, which indicate the stratigraphic order (e.g., M_1 indicates the first limestone of the “M” Formation). Lower case letters indicate the coal seams of formations, also with numbers for the stratigraphic order (e.g., m_3 is the third coal seam of the “M” Formation). The Moscovian Stage in the Donets Basin comprises the upper part of the “K” Formation, “L”, “M” Formations, and the lower part of the “N” Formation (Einor, 1996).

Widespread distribution of deltaic-marine strata in the Donets Basin includes coals and marine limestones characterized by specific biotic communities. These beds, which can be traced across much of the Donets Basin, indicate the low depositional slope (<< 1°) of the depositional ramp (Eros et al., 2012). Along with the Eastern European craton, this platform extended for thousands of kilometers along the western and northern edges of the warm tropical Tethyan Ocean. During transgression the Donets sea was connected with the Eastern European sea and the Tethys. Therefore the marine fossils are uniform over a vast area. During regression more provincial fauna evolved in marine straits and seaways isolated by exposed uplands. The Donets Basin underwent relatively high and regionally uniform subsidence (Stovba et al., 1996; Izart et al., 2003; Eros et al., 2012) resulting in accumulation of the most complete Carboniferous succession in the world. The Donets Basin is therefore a unique site for studying sea level fluctuations using a paleoecological distributional model of fusulinids.

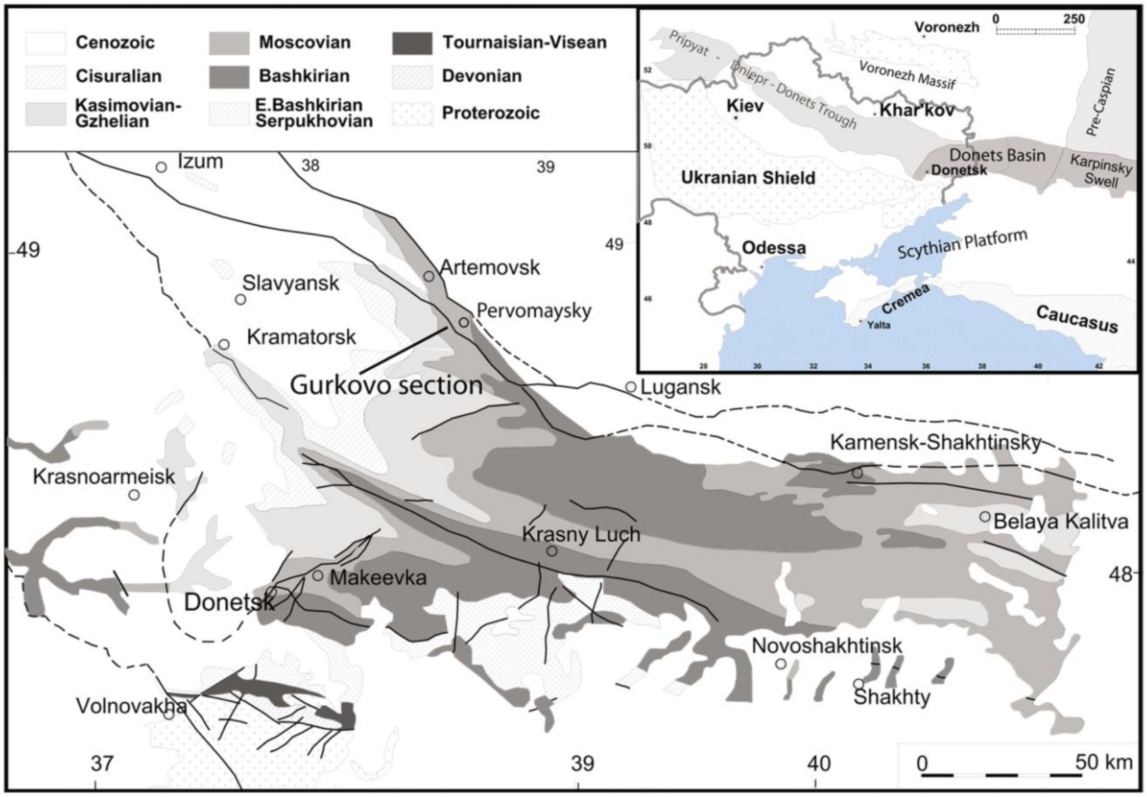


Figure 1. Location map of the Donets Basin modified from Aisenverg *et al.* (1975) with the position of the Gurkovo section.

Cyclic distributional patterns of fusulinid assemblages in response to eustatic sea level fluctuation: hypothesis

Fusulinid biostratigraphy in the Donets Basin

The fusulinids of the Donets Basin have been known since the nineteenth century because of their exceptional preservation and abundance in many limestones throughout Carboniferous strata. During the first half of the twentieth century fusulinids became important chronostratigraphic tools that were widely utilized in the Donets Basin. Putrja (1939, 1940, 1948, and 1956) and Kireeva (1951) developed the fusulinid taxonomy and biostratigraphy within the Moscovian – Kasimovian transition in the Donets Basin. They correlated the "L", "M" Formations as Kashirian and Podolskian, respectively. The lower part of the "N" Formation from limestone N_1 to the N_4 or N_5 limestone were correlated with Myachkovian strata in the Moscow Basin (Kireeva, 1951). Recently we have recognized inconsistency in the generally accepted biostratigraphy of the Donets Basin. The revised Upper Moscovian fusulinid biostratigraphy will be discussed in separate papers. A status of recent biostratigraphy is summarized in Figure 3.

Cyclic distributional patterns of fusulinid assemblages in the Donets Basin

In our initial studies of Moscovian fusulinid biostratigraphy in the Donets Basin we noticed repetition of similar fusulinid generic assemblages every ~ 0.6–1 my. Ross and Ross (1988, 1995) also suggested that the typical late Paleozoic third-order depositional sequences for the North American Midcontinent characterized by fusulinid zonation have duration of about 1 my. Eros et al. (2012) also identified 0.8 to 1.2 my long cycles that are interpreted as possibly being the long-eccentricity modulation of obliquity.

The paleobiological signal that stratigraphically stacks systematically into packages or ‘biocycles’ we call “fusulinid cycles”. These fusulinid cycles are recognized in the Upper Moscovian - Lower Kasimovian succession, the “L”, “M”, and “N” Formations. Each cycle includes an interval of four to six successive fusulinid-bearing limestones. Each fusulinid cycle reveals a continuous increase in diversity from a monospecific and abundant population of *Hemifusulina* in the beginning of the cycle to a highly diverse *Fusulinella* association at the end of cycle, accompanied by a gradual appearance and disappearance of certain genera of fusulinids (Fig. 2). The following assemblages are recognized within a fusulinid cycle:

1) A_1 is a monospecific population of abundant *Hemifusulina* (M_3^{up}, M_7).

2) A_2 is a mixture of abundant *Hemifusulina* and low-diverse *Taitzehoella*, *Beedeina*, *Ozawainella*, *Neostaffella* (L_7^1, M_7^{up}, and N_1).

3) B is a low-diverse community of mature subrhomboidal *Beedeina* and *Taitzehoella*, large discoid *Ozawainella* with highly compressed polar ends, and large spherical *Neostaffella*. At this level *Hemifusulina* disappears (L_7, M_1, M_5, M_8, and N_1^6).

4) C_1 is a diverse population of abundant *Fusulinella* and *Schubertella.* Species of *Taitzehoella* and *Beedeina* are replaced by elongated fusiform species; *Ozawainella* is replaced by smaller subrhomboid species; *Neostaffella* evolves into new species (M_2, M_6, and M_9).

5) Each cycle is completed by diverse species of *Fusulinella* and *Schubertella* of C_2 association. *Beedeina* is replaced by elongated subcylindrical *Fusulina*, large *Neostaffella* is replaced by small species of *Pseudostaffella*, and *Taitzehoella* is replaced by elongated-fusiform *Fusiella* (M_6^{up}, M_{10}).

For simplicity we consider three assemblages A, B, and C. The first two associations we combine into the (A) *Hemifusulina*-dominated assemblage; the third is the *Beedeina*-dominated assemblage (B); the fourth and fifth are combined into the *Fusulinella*-*Fusulina*-dominated assemblage (C). From one biocycle to another all fusulinid genera reveal evolutionary changes at the species level that are very helpful for biozone definition and correlation with coeval strata from the Moscow Basin (Khodjanyazova and Davydov, in press; Khodjanyazova et al., submitted) and other basins of the Paleotethys.

What was the reason for the cyclic occurrences of different fusulinid assemblages? Why do these generic groups also exhibit clear species replacement between cycles? Can this repetition be observed in other regions of Paleotethys, besides the Donets Basin? Why does *Hemifusulina* occur in some beds in abundance, but is represented by a monospecific populations? Why does *Hemifusulina* occur in abundance in the Donets and Moscow basins, while its abundance progressively decreases in the eastern direction toward the Uralian seaway? Why in some sections in Central Asia and in the Cantabrian Mountains *Hemifusulina* species occur in great abundance, whereas other successions are characterized by either *Fusulinella* and *Beedeina* or only *Fusulinella*-assemblages without *Hemifusulina*? Why are other fusulinids, such as *Fusulinella*, or *Fusulina*, rarely associated with *Hemifusulina*, at least in the Donets Basin? What was the reason for the repetitive reoccurrences of fusulinid assemblages? Why finally, did *Hemifusulina*, *Beedeina*, *Neostaffella* and *Taitzehoella* become extinct across the Moscovian – Kasimovian boundary?

We try to answer these numerous questions using the cyclic fusulinid distributional model proposed and discussed in this paper. In order to test a hypothesis that short-term fusulinid biocycles were driven by paleoenvironmental changes in the shallow tropical epicontinental seas due to glacioeustatic sea-level fluctuations, we integrate study of fusulinid taxonomy, biostratigraphy, paleoecology, and biofacies, and analysis of lithofacies with sedimentological and sequence stratigraphic analysis of the Moscovian succession in the Donets Basin.

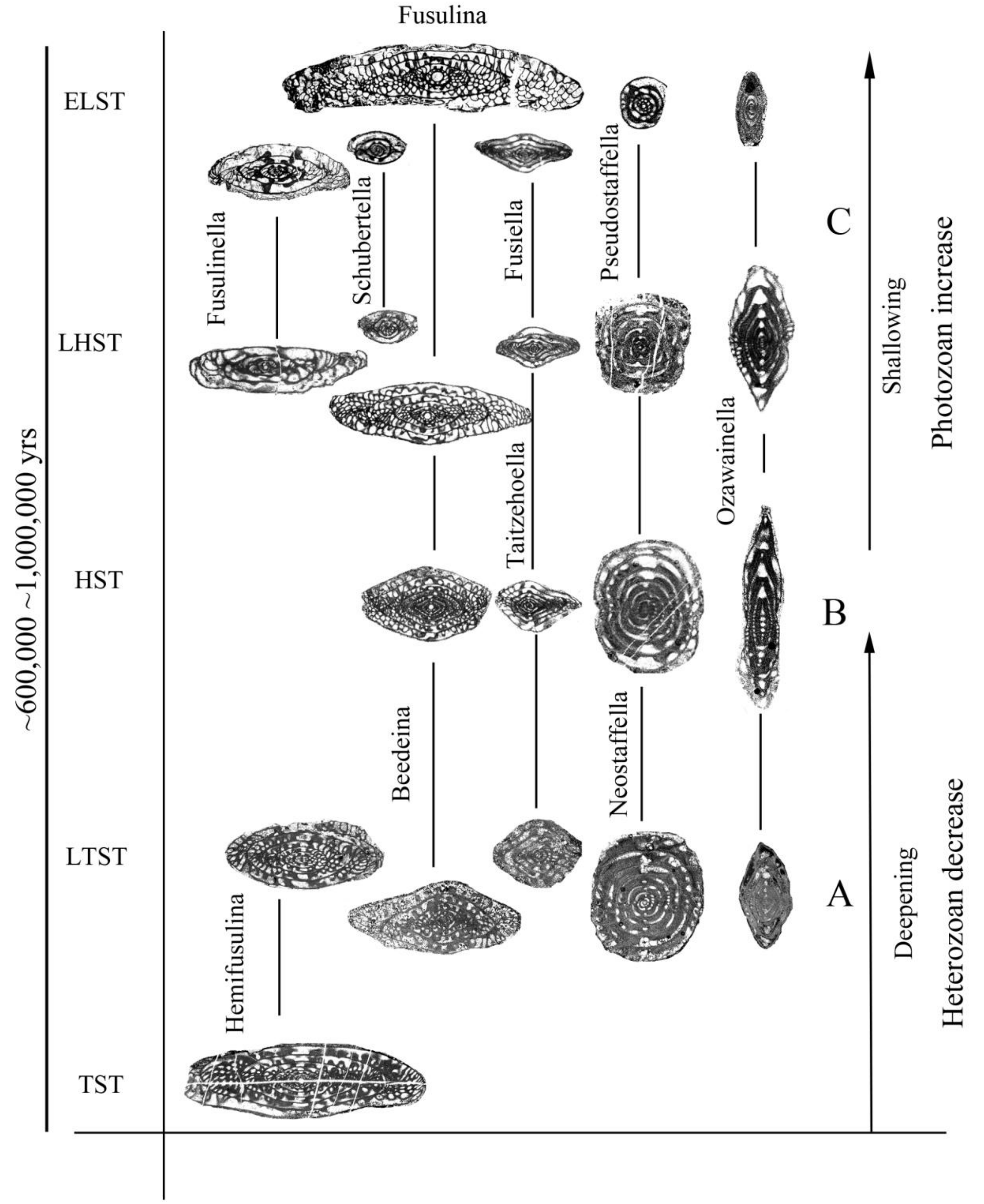


Figure 2. Gradual replacement of fusulinids within a cycle. Morphological changes of main genera with respect to depth/or temperature.

Data and observations

Our research focuses on fusulinid distribution within the Kashirian, Podolskian, Myachkovian and Krevyakian Horizons in the Donets Basin, in which hiatuses are essentially lacking (Aisenverg et al., 1963, Davydov et al., 2010). Fusulinid assemblages from each cycle proposed in this paper for the Donets Basin have been correlated with coeval strata in the Moscow Basin and surrounding areas in the Eastern European platform, as well as Northern China, and the successions documented in the Variscan and Hercinian orogenic belts in the Cantabrian Mountains, Central Asia and Southern Urals. We consider fusulinid distribution in a paleoecological context, intending to define what kinds of fusulinids and other environmentally sensitive fossils are associated with different episodes of sea level fluctuation: transgression, high stand, or regression.

Materials for study of fusulinid, smaller foraminifers and other fossil distribution in the Donets Basin were collected from 28 limestones of the “L”, “M” and “N” Formations. We also integrated data on fusulinid distributions published in previous studies (Brazhnikova, 1939a, 1939b, 1951; Putrja, 1940, 1956; Manukalova, 1950a, 1950b; Pogrebnyak, 1975; Ueno in Fohrer et al., 2007; Davydov and Khodjanyazova, 2009). We employed lithofacies analyses presented by previous authors (Aisenverg et al., 1975, Izart et. al., 1996) and particularly more recent data (Davydov et al., 2010; Eros et al., 2012). Within the Carboniferous succession in the Donets Basin, Eros et al. (2012) proposed a sequence stratigraphic model for the Donets Basin and recognized predictable shorter-term, individual sequences (100 ky duration) which bundle into composite (~400 ky duration) and longer-term ‘composite sequences’ – (0.8 to 1.2 my duration). The internal architecture of composite sequences preserves a genetically related set of strata that collectively record a hierarchy of relative sea level changes. They defined seventy-five ‘composite sequences’ in the Donets Carboniferous–Permian succession. ‘Composite sequence’ boundaries commonly coincide with widespread unconformities that extend to the seaward margin of the study area. In the upper part of the ”L” Formation and the “M” Formation they recognized six composite sequences (Fig. 3): 1) Mo VIII that includes the L_7^1, L_7^2, and L_7^3; 2) Mo IX that includes M_1, M_1^1, M_1^2, and M_2; 3) Mo X that includes M_3, M_4, and M_4^1; 4) Mo XI that includes M_5, M_6, and M_6^1; 5) Mo XII that includes M_7, M_7^1, M_7^2, M_8 and M_8^1; 6) Mo XIII that includes limestones M_9, M_{10}, M_{10}^1 and M_{10}^2 (Eros et al., 2012). In this interval we recognized three biocycles 1) L_7^1 – M_2; 2) M_3 –M_6^{up}; 3) M_7 – M_{10}^1 that each comprises two of the composite sequences defined by Eros et al. (2012).

More than 500 thin sections were studied to provide a more detailed view of representative micro- and biofacies. The detailed illustrations of micro- and biofacies from the “L” and “M” Formation can be found in Supplementary Data (Suppl.), which includes two tables and five figures. Figures illustrate the microfacies of the limestones and associated with them different fusulinid assemblages. Table 1 documents the distribution of fossils within each cycle from the limestone L_7^1 to M_{10}. In table 2 we document all fusulinid species and smaller foraminifer genera in these limestones.

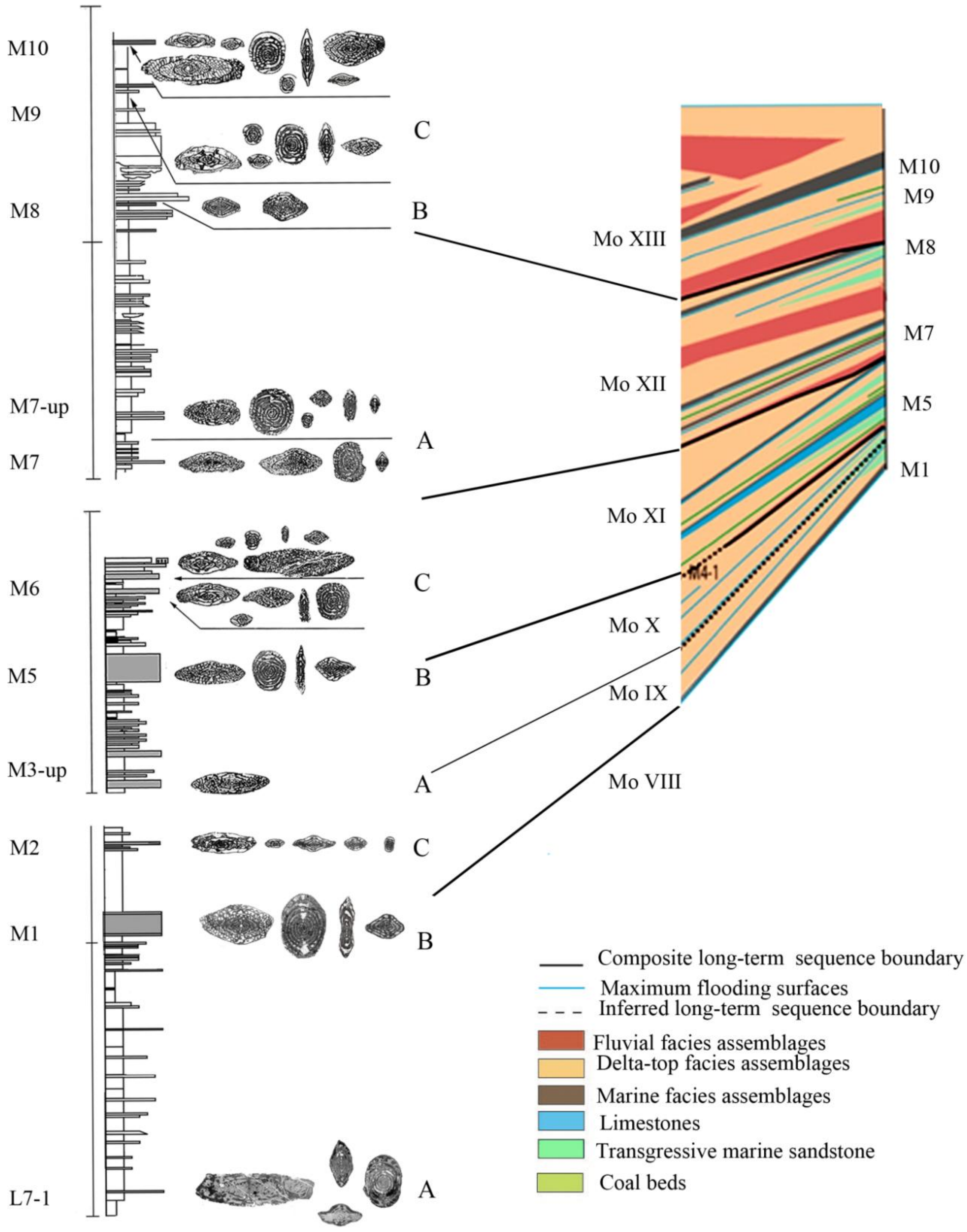

M10
M9
M8
M7-up
M7
M6
M5
M3-up
M2
M1
L7-1
C
B
A
C
B
A
C
B
A
Mo XIII
Mo XII
Mo XI
M4-1
Mo X
Mo IX
Mo VIII
M10
M9
M8
M7
M5
M1
Composite long-term sequence boundary
Maximum flooding surfaces
Inferred long-term sequence boundary
Fluvial facies assemblages
Delta-top facies assemblages
Marine facies assemblages
Limestones
Transgressive marine sandstone
Coal beds

Figure 3. Three fusulinid cycles and their relation to the 'composite cycles' derived by Eros et al. (2012) within the upper "L" and "M" Formations, Donets Basin.

There are repetitive occurrences of three fusulinid assemblages within each fusulinid cycle: (A, *Hemifusulina*-dominated, B, *Beedeina*-dominated, C, and *Fusulinella*-dominated). Mo IX, Mo XI sequence boundaries coincide with the beginning of fusulinid cycles; Mo VIII, Mo X, Mo XII sequence boundaries separate strata with C assemblages from underlying beds characterized by B assemblage.

Micro- and biofacies description of the limestones from the “L” and “M” Formation

Cycle 1

Cycle 1 includes the interval between limestones L_7^1 and M_3 (Fig. 3) and is represented predominatedly by siliciclastic strata (Aisenverg et al., 1975, Fohrer et al., 2007, Eros et al., 2012). This cycle consists of two ‘composite sequences’ Mo VIII and Mo IX proposed for the Donets Basin by Eros (2010). The thickness of this interval is about 150 m. Limestones L_7^1, L_7^2, L_7^3, and M_1 crop out near Izvarino railroad station, ~50 km southwest of Lugansk. M_1 and M_2 limestones are studied in the Gurkovo section, 5 km to the south of Pervomaysk, Donets oblast, Ukraine.

Limestone L_7^1

Limestone L_7^1 is a biogenic, poorly sorted mudstone 20 cm thick (Fig. 4A). The main biogenic components of this limestone are echinoids (E), echinoid spines (Es), crinoids (not shown in the illustrated thin-section), and shells of different invertebrate (Table 1). Among invertebrates a great number of brachiopods (B) and brachiopod spines (Bs) are found, while other invertebrates – bivalves (not shown in the illustrated thin-section), gastropods (G) and ostracods (Os) are less abundant. Small individuals of bivalves and ostracods are often represented by disarticulated valves. Bryozoans (not shown in the illustrated thin-section) are scarce and represented by fenestrate species. Algae are represented by abundant phylloid red alga *Archaeolithophyllum* sp. (AlA), less abundant crustaceous red alga *Cuneiphycus* sp. (not shown in this thin-section), and scarce cyanobacterian oncoids (Cb) (Table 1). Small foraminifers (not shown in the illustrated thin-section) are represented by common *Ammodiscus* and scarce Endothyridae, attached *Tuberitina* and *Ammovertella* (Table 2). Fusulinid assemblage is low diverse (Fig. 5.14–5.18, Table 2) and represented by mature specimens of large subrhomboidal in shape *Ozawainella paratingi* Manukalova, large and compressed at their polar ends *Neostaffella ozawai* (Lee and Chen), large subcylindrical *Hemifusulina pseudobocki* (Putrja) (illustrated in the left side of the Fig.4A), small *Hemifusulina moelleri* Rauser with very thin porous walls, and *Taitzehoella* sp. cf. *T. globulus* (Manukalova).

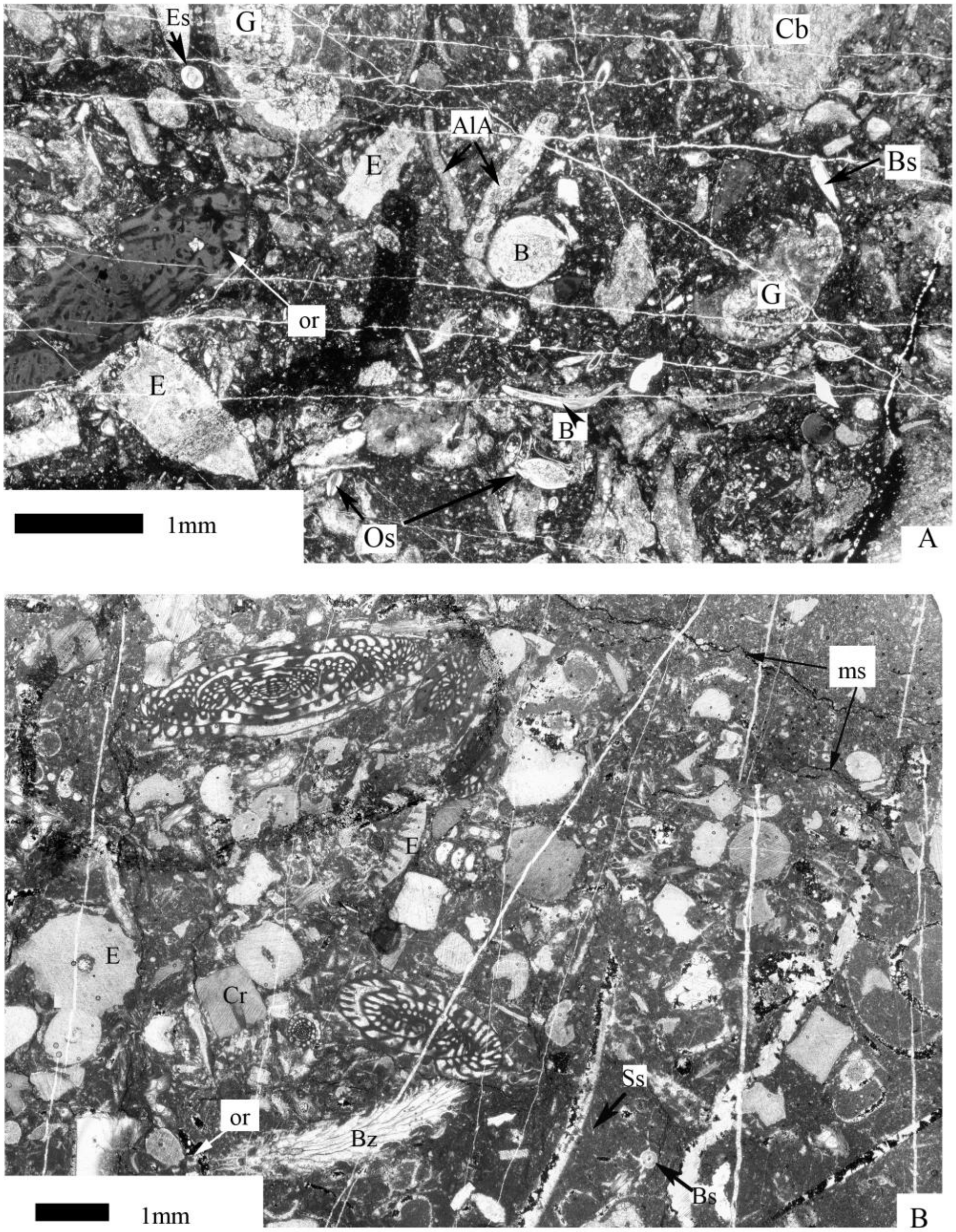


Figure 4 A, B. Microphotographs of limestones of the "M" Formation.

A - limestone L_7^1; B - limestone M_3^{up}. E – echinoids, Es – echinoid spines, Cr – crinoids, B – brachiopods, Bs – brachiopod spines, Os – ostracods, G – gastropods, Bz – bryozoans, Ss – sponge spicules. **Algae:** AlA – phylloid red alga *Archaelithophyllum* sp., Cb – cyanobacterian oncoids; ms – microstylolites, or –organic matter.

Limestone L_7^2

Limestone L_7^2 is a 60-cm thick bedded wackestone with brachiopods and bivalves, and **L_7^3** is a 40-cm thick brachiopod-crinoid packstone with bryozoans (Fohrer et al., 2007). No fusulinid fauna are found in these limestones.

Limestone M_1

Limestone M_1 is 12 m thick. Samples for fusulinid, bio- and microfacies study were collected in the lower bioclastic-rich bedded part. Microscopically it is a foraminiferal wackestone (Fig. 4E). Bioclasts are represented by abundant red algae *Ungdarella* (AlU), and re-crystallized red phylloid *Archaelithophyllum* sp. (AlA), disarticulated echinoid fragments (E), and brachiopod (B), bivalve, ostracod, bryozoan, and trilobite detritus (not shown in the illustrated thin-section) sized up to 1mm. This limestone contains diverse small foraminifers, the most abundant among which is large benthic *Bradyina* (FB) with a fragile porous “keriothecal” walls. Less abundantly occur benthic *Palaeotextularia* (FP) with agglutinated walls, *Ammodiscus* (not shown in the illustrated thin-section), *Endothyra* (FE), some problematic calcisphaeric forms (FC), attached foraminifers (not shown in the illustrated thin-section) *Tuberitina* and *Ammovertella* (Table 2). Large fusulinids are scarce but relatively diverse in this assemblage (Fig. 6.9 – 6.18). They are represented by mature forms of small subrhomboidal *Beedeina schellwieni* (Staff), *B. elschanica* (Putrja and Leontovitch) (this species is illustrated in the lower part of the thin-section in the Fig. 4E), *B. pseudoelegans* (Chernova), *B. apokensis* (Rauser), *B. bona* (Chernova and Rauser) large compressed at polar ends *Neostaffella ozawai* (Lee and Chen), *N. compacta* (Manukalova), large discoid highly compressed at polar regions *Ozawainella stellae* Manukalova, *O*. sp. O. cf. *digitalis* Manukalova, *O. crassiformis* Putrja, subrhomboidal in shape *Taitzehoella* *kashirica* (Rauser), rare fusiform *Putrella* (?) *primitiva* Manukalova sp. and elongated fusiform *Eofusulina* sp. (Table 2).

Organic matter is absent in the matrix, although some traces are observed in rare microstylolites (Fig. 4E, ms).

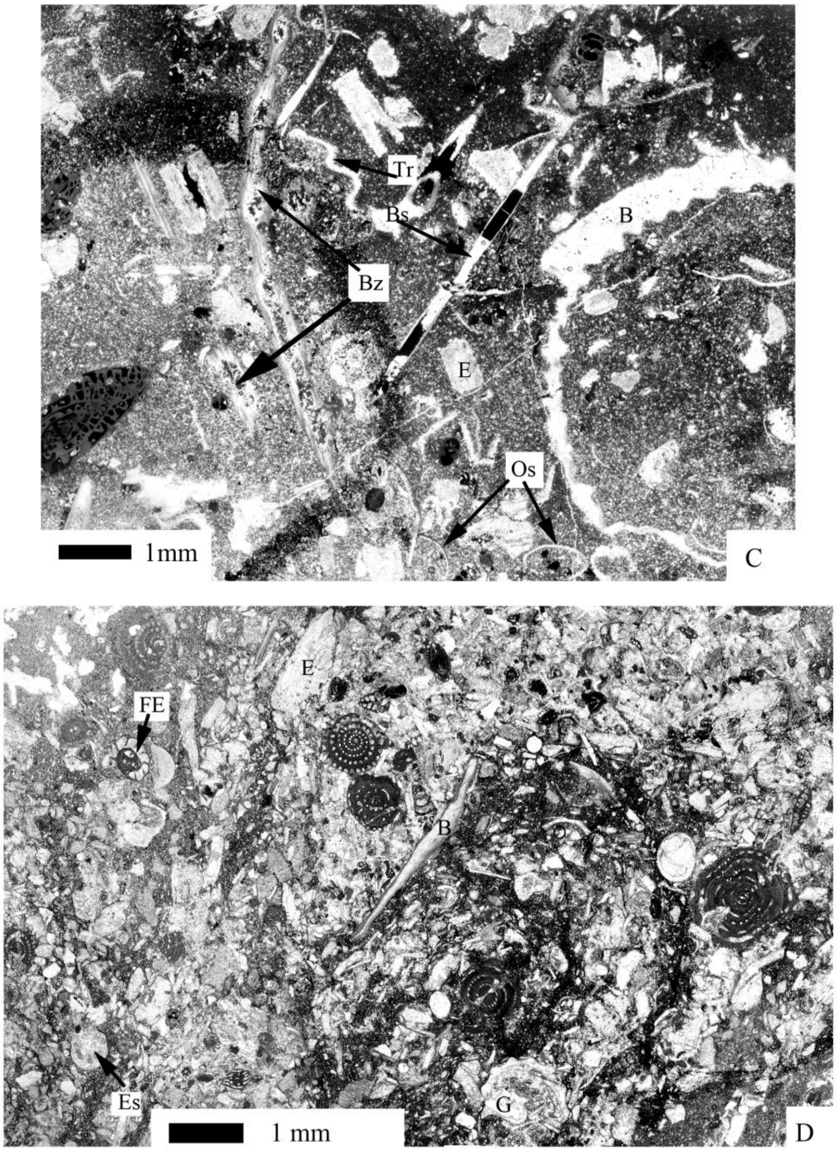


Figure 4 C, D. Microphotographs of limestones of the “M” Formation.

C – limestone M_7; D – limestone M_7^{up}. E – echinoids, Es – echinoid spines, Cr – crinoids, B – brachiopods, Bs – brachiopod spines, Os – ostracods, G – gastropods, Bz – bryozoans, Tr – trilobites, Sr - serpulinids. **Small foraminifers:** FE – *Endothyra* sp.

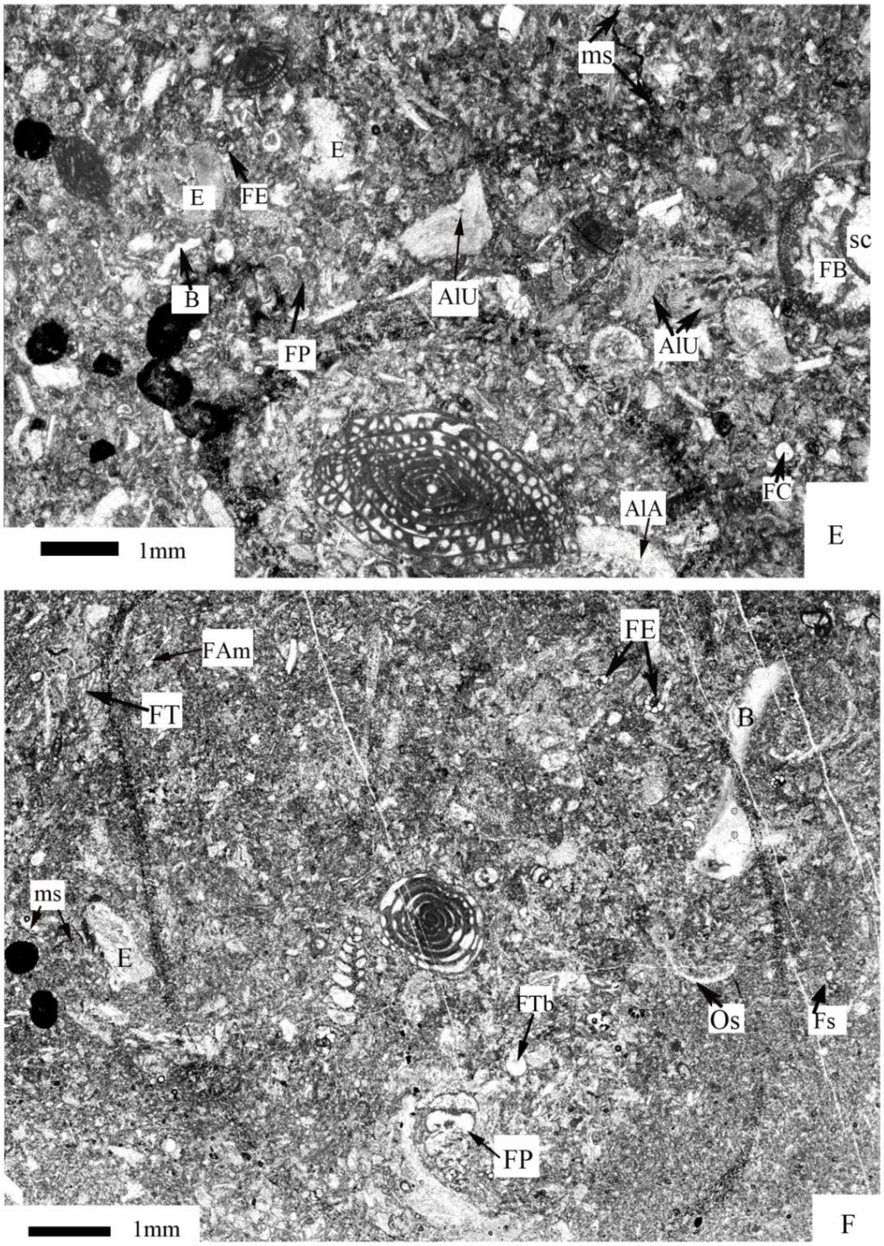


Figure 4 E, F. Microphotographs of limestones of the “M” Formation.

E – limestone M_1; F – limestone M_5. E – echinoids, B – brachiopods, Os – ostracods. **Algae:** AlA – phylloid red alga *Archaelithophyllum* sp., AlU – red alga *Ungdarella* sp. **Small foraminifers:** FB – *Bradyina* sp., FE – *Endothyra* sp., FP – *Palaeotextularia* sp., FT – *Tetrataxis* sp., FTb – *Tuberitina* sp., FC – problematic *Calcisphaera* sp., Fs – attached *Ammovertella*; ms – microstylolites, sc – synsedimentary calcite.

Limestone M_2

Limestone M_2 is 2.5 m thick. Samples for fusulinid, bio- and microfacies study were collected at the base of the bed. This limestone is a poorly sorted foraminiferal packstone (Fig. 4G).

The main bioclastic components of this limestone are abundant smaller foraminifers: Palaeotextulariids (FP) with agglutinated walls, and *Bradyina* (FB) with porous walls, less abundant *Tetrataxis* (not shown in the illustrated thin-section), *Tuberitina* (FTu), *Endothyra* (FE) and attached *Ammovertella* (Fs) (Table 2). Large fusulinids (Fig. 7.17 – 7.24, Table 2) are represented by numerous elongated subcylindrical *Fusulinella (Moellerites) schubertellinodes* Putrja, *F. (M.) plicata* Manukalova, *F. (M.) cylindricus* Solovieva, *F. (M.) lopasaniensis* Solovieva, numerous schubertellids, short fusiform *Taitzehoella librovitchi* (Dutkevitch), T. *pseudolibrovitchi* (Rauser), small forms of globular *Pseudostaffella*: *P. compressa donbassica* Putrja, *P. khotunensis* Rauser, rare large fusiform *Beedeina*: *B. pseudokonnoi* (Sheng), and very small immature individuals of *Beedeina, Fusulinella* and *Taitzehoella* genera with two-three volutions. Larger invertebrate (Table 1) are scarce and represented by scarce brachiopods (B), bivalves (not shown in the illustrated thin-section), ostracods (Os), often with disarticulated valves. Many serpulinid bended tubes (Sr) and a few bryozoan (not shown in the illustrated thin-section) fragments occur. Algae are represented by a mixture of red *Ungdarella* (AlU) and green *Beresella* (AlB).

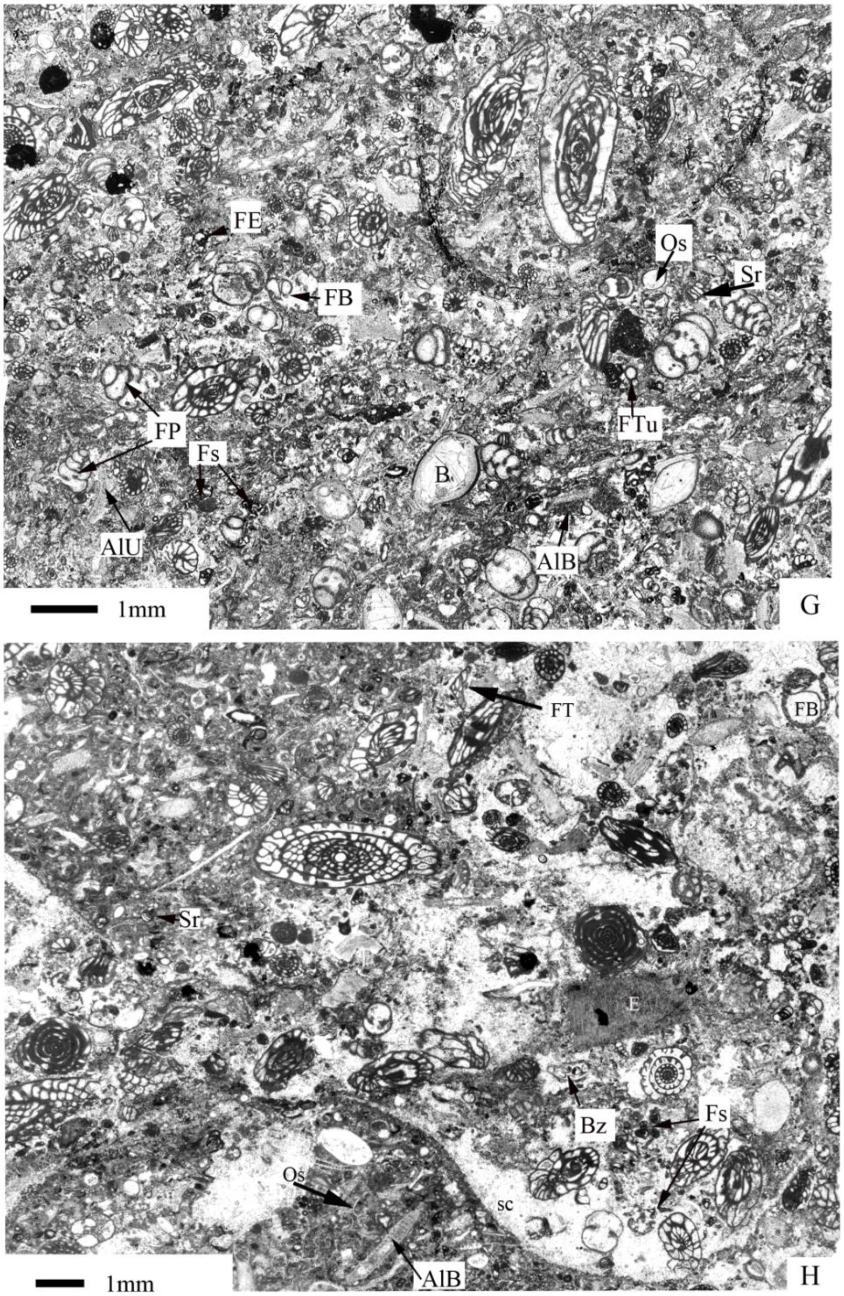


Figure 4 G, H. Microphotographs of limestones of the “M” Formation.

G – limestone M_2; H – limestone M_{10}. E – echinoids, B – brachiopods, G – gastropods, Bz – bryozoans, Os – ostracods, Sr - serpulinids. **Algae:** AlB – green alga *Beresella* sp. **Small foraminifers:** FB – *Bradyina* sp., FE – *Endothyra* sp., FP – *Palaeotextilaria* sp., FT – *Tetrataxis* sp., FTu – *Tuberitina* sp., FC – problematic *Calcisphaera* sp., Fs – attached *Ammovertella*; sc – synsedimentary calcite.

Limestone M_3

Limestone M_3 3 m thick and samples for fusulinid and microfacies study were collected at the base of the bed. This limestone is a poorly sorted crinoid-brachiopod packstone (Fig. 4I) with rare bryozoans and foraminifers. Low diverse smaller foraminifers are represented by large broken tests of *Bradyina* (not shown in the illustrated thin-section) and *Palaeotextularia* (FP), abundant *Tuberitina*, rare *Ammodiscus* (not shown in the illustrated thin-section), *Tetrataxis*, endothyrids and attached *Ammovertella* (not shown in the illustrated thin-section) (Table 2). Solitary corals (not shown in the illustrated thin-section) and sponges (Sp) (Table 1) occur. Algae are represented by a mixture of red and green genera: *Ungdarella* and *Beresella* (not shown in the illustrated thin-section). Fusulinids (Fig. 7.8 – 7.16) are abundant and diverse *Fusulinella (Moellerites) schubertellinoides* Putrja, *F. (M.) plicata* Manukalova, *F. (M.) cylindricus* Solovieva, *F. (M.) lopasaniensis* Solovieva, *F. (M.) paracolaniae* Safonova, *F. pseudocolaniae* Putrja, Schubertelledae, elongated fusiform *Beedeina*: *B. ozawai* (Rauser et Belyaev), *B. pronensis* (Rauser), *B. rauserae* (Chernova), *B. juncta* (Chernova), *B. pseudoelegans* (Chernova), *B. apokensis* (Rauser), *B. bona* (Chernova et Rauser), large *Neostaffella* sp. cf. *N. sphaeroidea cuboides* Rauser, *N. larionovae* Rauser, small *Pseudostaffella khotunensis* Rauser, *P. confusa* (Lee et Chen) (Table 1).

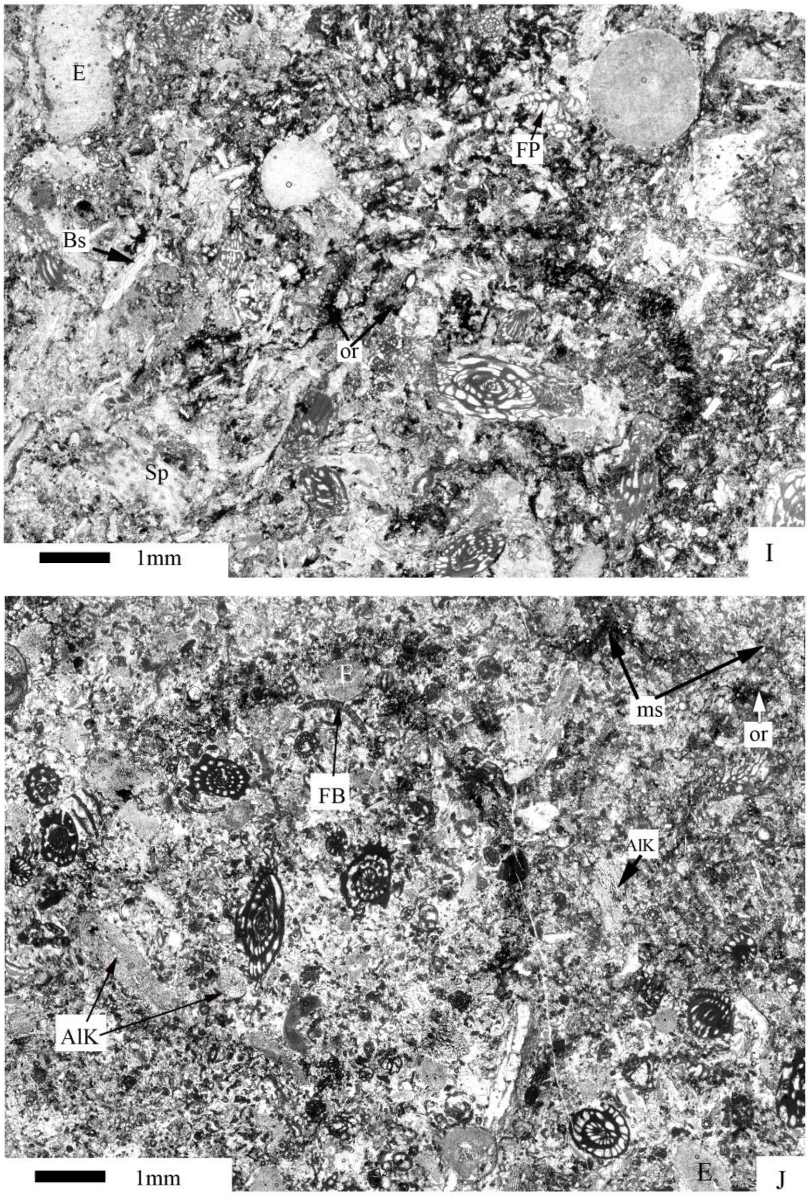


Figure 4 I, J. Microphotographs of limestones of the "M" Formation.

I – limestone M_3; J – limestone M_9. E – echinoids, Bs – brachiopod spines, G – gastropods, Sp – sponges. **Algae:** AlK – red alga *Pseudokomia* sp. **Small foraminifers:** FB – *Bradyina* sp., FE – *Endothyra* sp., FP – *Palaeotextilaria* sp., ms – microstylolites, or –organic matter.

Cycle 2

This cycle, beginning from the M_3^{up} and completed by the M_6^{up} Limestone (Fig. 3), includes M_3^{up}, M_4, M_5, M_6, M_6^{up} limestones in a predominantly by siliciclastic succession (Aisenverg et al., 1975). This cycle consists of two 'composite sequences' Mo X and Mo XI proposed for the Donets Basin by Eros (2010). The thickness of this interval is about 100 m. Limestones were studied from the Gurkovo section, 5 km to the south from the town of Pervomaisk, Donets oblast, Ukraine.

Limestone M_3^{up}

Limestone M_3^{up} is a bioclastic crinoid-bryozoan wackstone, 2.9 m thick (Fig. 4B). Some highly degraded small tube-like remains, probably sponge spicules (Ss), occur sporadically in cement. Fossils remains (Table 1) are abundant echinoids (E), echinoid spines, bryozoans (Bz), scarce brachiopods, brachiopod spines (Bs), and ostracods (not shown in the illustrated thin-section), the valves of which are often undifferentiated. Foraminifers are scarce and comprise a low diversity population of large subcylindrical *Hemifusulina kashirica* Rauser (Fig. 5.13) and very rare *Eostaffella* and immature *Taitzehoella.* Algae are absent. Numerous microstylolites (ms) filled by brownish-colored organic matter (or) are recognized.

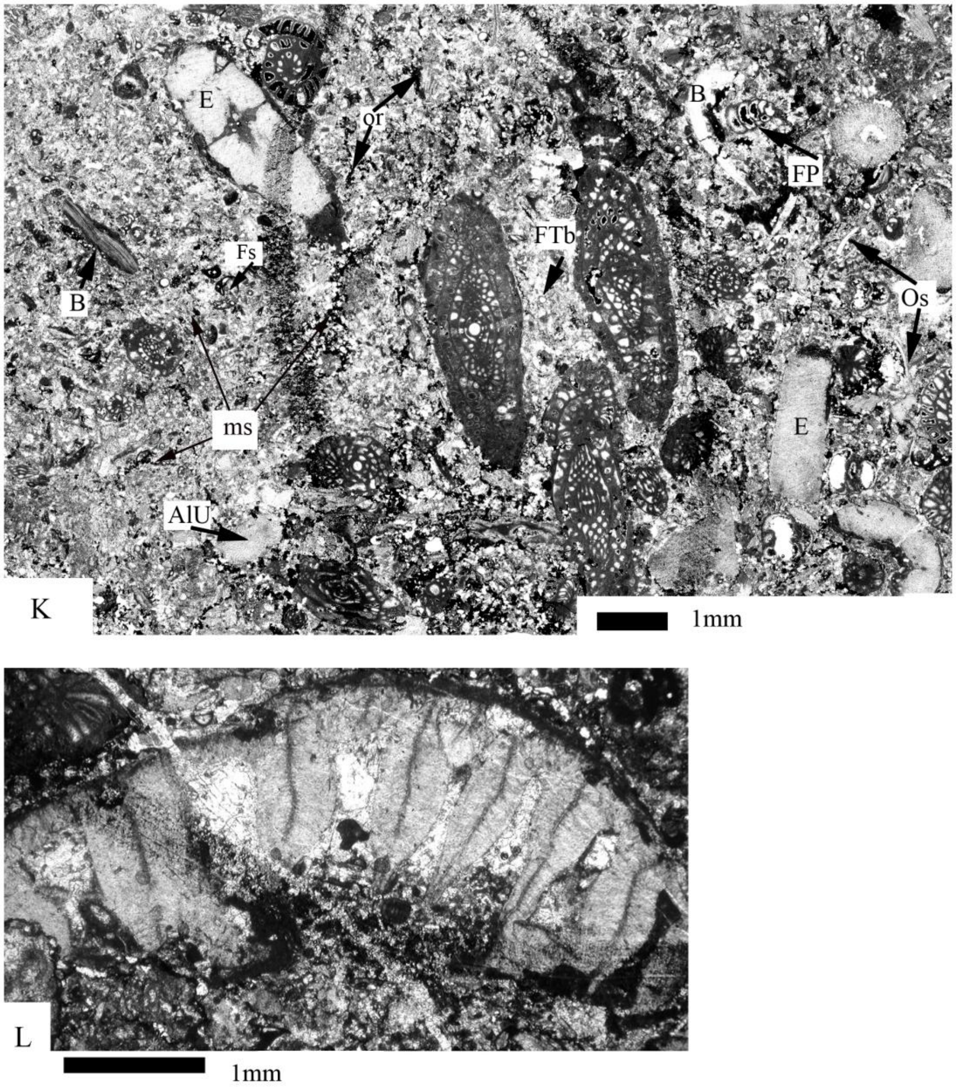


Figure 4 K, L. Microphotographs of limestones of the "M" Formation.

K – limestone M_6; L – solitary coral fragment in the limestone M_6^{up}. E – echinoids, Es – echinoid spines, B – brachiopods, Os – ostracods. **Algae:** AlU – red alga *Ungdarella* sp. **Small foraminifers:** FP – *Paleotextilaria* sp., Fs – attached *Ammovertella*; Ftu – *Tuberitina*; ms – microstylolites, or – organic matter sc.

Limestone M_5

Limestone M_5 is 12 m thick. Fusulinids were sampled from the lower part of this limestone, 1 m above the base. It is a foraminiferal wackestone (Fig. 4F). Bioclasts are represented by scarce invertebrates (Table 1): echinoids (E), brachiopod shells (B) and spines, bivalves, gastropods, trilobites and bryozoans (not shown in the illustrated thin-section). Ostracod shells (Os) are abundant in matrix. Algae are red species of *Ungdarella*. Diverse foraminifers are: abundant large *Bradyina*, small endothyrids (FE), attached tuberitinids (FTu) and *Ammovertella* (Fs), and less abundant *Ammodiscus*, *Palaeotextularia* (FP) and *Tetrataxis* (FT) (Table 2). Fusulinids (Fig. 6.1 – 6.8) are scarce but relatively diverse. They are represented by represented predominately by mature short to elongate fusiform *Beedeina* species, which are quite diverse: *B.rauserae* (Chernova), *B. juncta* (Chernova), *B. cotakarae* (Ginkel), *B. dunbari* (Sosnina), *B. bona* (Rauser), *B. pseudokonnoi* (Sheng), *B. absidata* (Sheng), *B. elegans longa* (Rauser), elongate subcylindrical *Kamaina* (?) sp. cf. *rossoshanica* Putrja, large *Neostaffella compacta* (Manukalova), *N. umbilicata* (Putrja et Leontovitch), small *Pseudostaffella khotunensis* Rauser, *P. confusa* Lee et Chen, large, highly compressed at polar regions *Ozawainella adducta* Manukalova, large subrhomboidal *O. leei* (Putrja), small subrhomboidal *O. umbonata* (Brazhnikova et Potievska) and rhomboidal *Taitzehoella librovitchi* (Dutkevitch) (Table 2).

Microstylolite surfaces are less prominent (ms) in contrast to the underlying limestone M_3, M_3^{up}.

																	Algae								
																	Green		Green phylloid	Red		Red phylloid	Red crustous		Cyanobacteria
Limestones	Bryozoans	Bryozoans fragments	Echinoids	Echinoid spines	Crinoids	Brachiopods	Brachiopod fragments	Brachiopod spines	Bivalves	Gastropods	Octracodes	Sponges	Sponge spicules	Trilobites	Solitary corals	Serpulinids	*Beresella* sp.	*Dvinella* sp.	*Anchicodium* sp.	*Ungdarella* sp.	*Pseudokomia* sp.	*Archaelithophyllum* sp.	*Cuneiphycus* sp.	*Eflugelia* sp.	
M10	r		r				r	r	r		r				r	r	x	x	r						x
M9	r		r			r				r	r			r			a				a				x
M8																									
M7up	x		x	x	x	x				x	x	r		r		r									
M7	x				x	x		x		r				r											
M6up	x		a	a		a			a	x	x				r	x	r		r	r	r			x	r
M6	x		a	a		a			a	x	x					x	x			x	x			x	
M5		r	r				r	r	r	r	a			r						a					
M3up	a		a	a	a		r				r		x												
M3	r				a		a	a				r			r		r			r					
M2		r					r		r		r					x	x			x					
M1		x	x			x			x		x			r						a		r			
L7-3	a				a	a																			
L7-2						a			a																
L7-1	r		a	a	x	a	x	x	x	x	x											x	r		r

Table 1. Distribution of fossils within low frequency cycles. r- rare, x- common, a- abundant.

Blue – early transgressive limestones; grey – late transgressive limestones; yellow – regressive limestones.

	Kashirian								Podolskian					
									Hemifusulina subrhomboides - H. vozhgalica- Beedeina vaskensis				Putrella donetziana	Kamaina kamensis - K. rossoshanica
Fusulinids	L_7^1	M_1	M_2	M_3	M_3^{up}	M_5	M_6	M_6^{up}	M_7	M_7^{up}	M_7^2	M_8	M_9	M_{10}
Hemifusulina moelleri	x													
H. pseudobocki	x													
H. subrhomboidalis									x					
H.cf.subrhomboidalis										x				
H. vozhgalica									x					
H. mucronata									x					
H. pulchella									x	x				
H. elegantula									x					
H. communis acuta										x				
H. bocki													x	
H. sp. cf. H. splendida										x				
H. kashirica					x									
Beedeina schellwieni		x												
B. elshanica		x												
B. pseudoelegans		x		x										
B. keltmensis							x	x						
B. apokensis		x		x										
B. bona		x		x		x	x							
B. sp. cf. B. vaskensis									x	x	x	x	x	
B. elegans elegans														x
B. elegans longa						x		x						
B. pseudokonnoi			x			x	x	x						
B. ozawai				x										
B. pronensis				x										
B. rauserae				x		x								
B. sp. cf. B. rauserae								x						
B. juncta				x		x								
B. cotakarae						x								
B. dunbari						x	x	x						
B. absidata						x	x							
immature Beedeina			x											
Neostaffella ozawai	x	x												
N. compacta		x				x								
N. sp. cf. N. compacta								x						
N. umbilicata						x								

N. larionovae				x				x		x			x	x
N. polasnensis										x				
N. sphaeroidea														x
N. sp. cf. N. sphaeroidea							x							
N. sphaeroidea cuboides													x	
N.cf.sphaeroidea cuboides				x						x			x	
N. syzranica													x	
N. sp. cf. N. rostovzevi													x	
N. sp.				x					x					
Pseudostaffella confusa										x				
Ps. variabilis										x				x
Ps. khotunensis			x	x		x		x					x	x
Ps.compressa donbassica			x										x	x
Ps. primaeva													x	
Ps. confusa				x		x		x						
Ozawainella paratingi	x													
O. stellae		x												
O. sp. O. cf. digitalis		x												
O. crassiformis		x												
O. minima									x					
O. krasnodonica										x				x
O. adducta						x	x	x						x
O. leei						x								
O. angulata										x				
O. rhomboidalis										x				
O. donbassensis										x				
O.umbonata						x								
O. mosquensis													x	
O. vozhgalica													x	
O. sp. cf. O. vozhgalica														x
O. sp. cf. O. lorentheyi										x				
O. sp.								x	x				x	x
O. sp.1										x				
O. sp.2										x				
T. kashirica		x		x										
T. sp. cf. T. globulus	x						x			x				
T. librovitchi			x			x		x						
T. pseudolibrovitchi			x											
immature Taitzehoella			a		x									
Fusiella pulchella													x	x
Fus. typica extensa														x
Fus. praetypica														x
Fus. praecursor														x

Fus. paraventricosa														x
Fus. sp. 1														x
Fus. sp. 2														x
Schubertella lata													x	x
Sch. obscura procera													x	x
Sch. elliptica														x
Sch. subkingi														x
Sch.cf. myachkovensis													x	
Sch. sp.cf. Sch. galinae													x	
Sch. sp.cf. Sch. inflata													x	
Schubertellidae			a	a			a	a						
Eostaffella sp.					r				r					
Putrella brazhnikovae													x	
P. sp. cf. P. fusiformis													x	
P. donetziana													x	
P.(?) primitiva		x												
Fusulinella colanii							x	x					x	x
F.(Moellerites)cylindricus			x	x										
F. (M.) lopasniensis			x	x										
F. (M.)schubertellinoides			x	x										
F. (M.) plicata			x	x										
F. (M.) paracolaniae				x			x	x						
F. (M.) subconaliae														x
F. (M.) plana														x
F. (M.) decurta														x
F. meridionalis							x	x						x
F. borealis													x	
F. pseudocolaniae				x			x	x					x	x
F. devexa														x
F. sp. F. cf. devexa													x	
F. tokmensis longa														x
F. formosa tumida														x
immature Fusulinella			a										a	
Profusulinella rotundata														x
Pr. sp.1														x
Pr. sp.2														x

Eofusulina sp.		x												
Kamaina kamensis														x
K. chernovi														x
K. sp. cf. K. chernovi													x	
K. rossoshanica														x
K.(?) sp. cf. K. rossoshanica						x		x						
K. sp. cf. K. kamerlingi														x
Smaller foraminifers														
Tuberitina sp.	r	x	x			a	a						a	x
Ammodiscus sp.	x	x				x	a							
Ammovertella sp.	r	x	x			x	a			x				x
Bradyina sp.		a	a			a	a						a	a
Palaeotextularia sp.		a	a			x	a		r	x			a	a
Calcisphaera sp.		x												
Tetrataxis sp.			x			x								x
Endothyra sp.		x	x											x
Endothyridae	r					a			r	x			x	

Table 2. Fusulinid and smaller foraminifers distribution in the "M" Formation in the Donets Basin

Limestone M_6

Limestone M_6 is a poorly sorted foraminiferal packstone, 0.3 m thick (Fig. 4K). A sample for fusulinid, bio- and microfacies studies was collected at 0.2 m above the base. Abundant microstylolites (ms) and pores are filled by brown organic matter (or). Quartz grains are common in the cement (Fig. 4M). Bioclasts include abundant and diverse invertebrates (Table 1): echinoids (E) and their spines, brachiopod (B) and bivalve shells, often with large and thick valves, less abundant gastropods (not shown in the illustrated thin-section). Small articulated valves of ostracods (Os) occur in this limestone. This limestone is also characterized by the presence of small curve tubes formed by worms – serpulinids (not shown in the illustrated thin-section). Bioclasts are in high degree crushed, biodegraded and covered by a “micritic envelope” and encrusted by attached foraminifers (Fs). Bryozoans (not shown in the illustrated thin-section) often are crushed into small fragments. Algae are represented by red genera *Ungdarella* (AlU), *Pseudokomia*, encrusted *Euflugelia* and green genus *Beresella* (not shown in the illustrated thin-section). Smaller foraminifers are abundant and diverse *Tuberitina*, *Ammodiscus*, *Bradyina* (not shown in the illustrated thin-section), *and Palaeotextularia* (FP) and attached *Ammovertella* (Fs) (Table 1). Fusulinids (Fig. 7.1 – 7.7) are abundant and diverse: fusiform to elongate-fusiform *Beedeina*, such as: *B. dunbari* (Sosnina), *B. bona* (Rauser), *B. pseudokonnoi* (Sheng), *B. absidata* (Sheng), *B. keltmensis* (Rauser), ovoid to fusiform *Fusulinella*: *F. pseudocolaniae* Putrja, *F. colanii* (Lee et Chen), *F. meridionalis* Rauser, *F.(M.) paracolaniae* Safonova, numerous Schubertellinidae, large compressed at polar ends *Ozawainella*, *O. adducta* Manukalova, large *Neostaffella* sp. cf. N. *sphaeroidea* (Ehrenberg) and *Taitzehoella* sp. cf. *T. globulus* (Manukalova) (Table 2).

Limestone M_6^{up}

Limestone M_6^{up} is 2.5 m thick. Samples for fusulinid, bio- microfacies research were collected at 0.2 and 0.8 m above the base. The main fossil components are similar to those in the M_6. This limestone is also characterized by the presence of quartz grains. In this limestone, besides invertebrates recognized in the limestone M_6, rare rugose corals occur (Fig. 4L). Among algae red crustal *Eflugelia* become more abundant, while red alga *Pseudokomia* and *Ungdarella* become less abundant. Some green phylloid algae *Anchicodium* sp. also appeared in the M_6^{up} limestone, as well as oncoids of Cyanobacteria. The number of attached foraminifers and endothyrids increases in the limestone M_6^{up} compare with the limestone M_6. Fusulinids (Fig. 8.20 – 8.28) are represented by very large elongate-fusiform *Beedeina* species: *B. dunbari* (Sosnina), *B. pseudokonnoi* (Sheng), *B. keltmensis* (Rauser), *B.* sp. cf. *B. rauserae* (Chernova), *B. elegans longa* (Rauser), ovoid and fusiform *Fusulinella*, *F. pseudocolaniae* Putrja, *F. colanii* (Lee et Chen), *F. meridionalis* Rauser, *F. (M.) paracolaniae* Safonova, abundant immature specimens of *Beedeina* and *Fusulinella* with one-two volutions, numerous Schubertellidae, rare, large compressed at polar ends *Ozawainella adducta* Manukalova, small species of *Ozawainella*, large *Neostaffella larionovae* (Rauser and Safonova), *N.* sp. cf. *N. compacta* (Manukalova), small *Pseudostaffella khotunensis* Rauser, *Ps. confusa* (Lee et Chen), and *Taitzehoella librovitchi* (Dutkevitch).

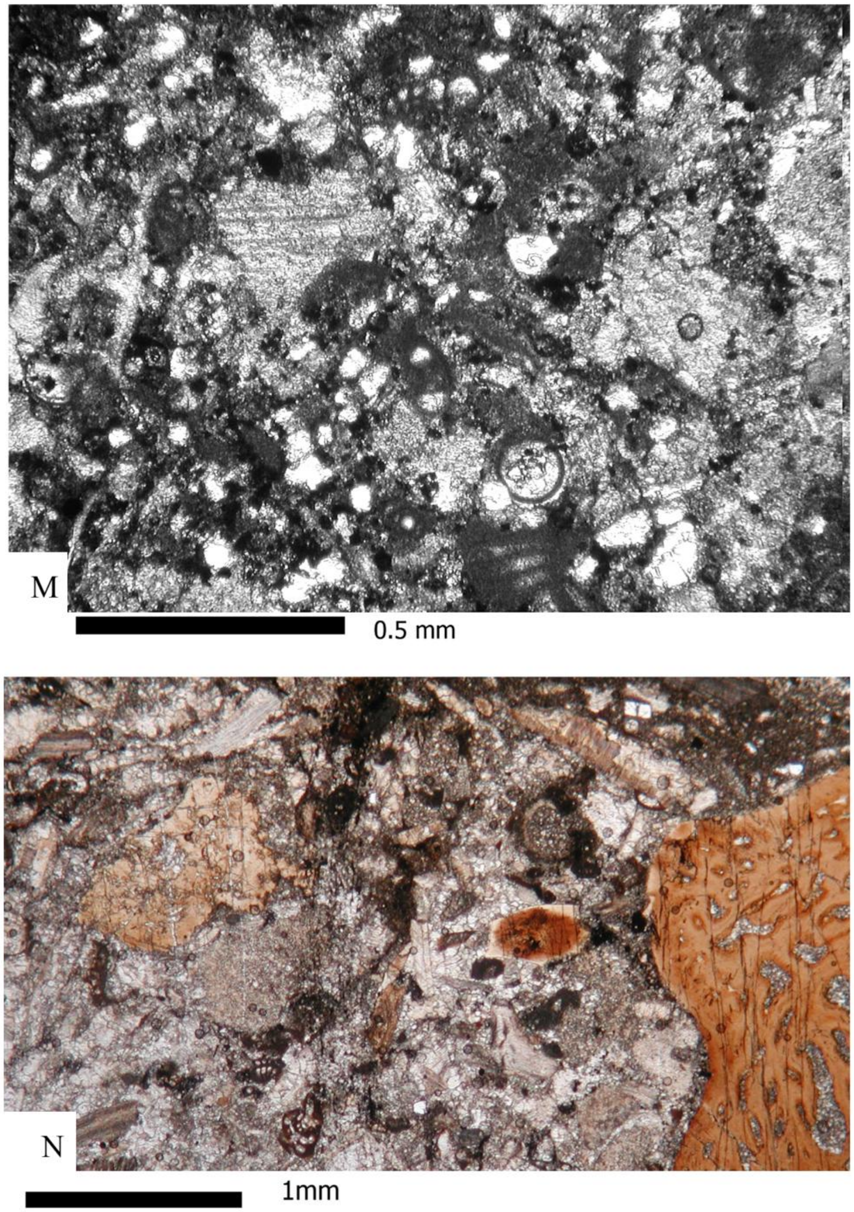


Figure 4 M, N. Microphotographs of limestones of the “M” Formation.

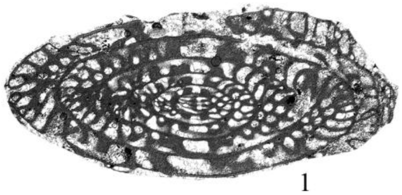
M – quartz grains in the limestone M_9; N – phosphoritization of bioclasts, large sponge fragment in the right corner.

Cycle 3

This cycle (Fig. 3) is represented by siliciclastics and includes the limestones M_7, M_7^{up}, M_7^2, M_8, M_9, and M_{10} (Aisenverg et al., 1975). This cycle comprises of three fusulinid zones: *Hemifusulina subrhomboides – H.vozhgalica – Beedeina vaskensis, Putrella donetziana – Fusulinella colanii,* and *Kamaina rossoshanica – Fusulinella tokmovensis longa* Zones (Khodjanyazova et al., submitted). The thickness of this cycle is about 180 m. This cycle consists of two ‘composite sequences’ Mo XII and Mo XIII proposed for the Donets Basin by Eros (2010).The limestones of this interval studied from the Gurkovo section, 5 km to the south from the town Pervomaisk, Donets oblast, Ukraine.

Limestone M_7

Limestone M_7 is a crinoids-brachiopod wackstone (Fig. 4C), 0.5 m thick. Invertebrates are brachiopods (B) and their spines (Bs), crinoid ossicles, gastropods, trilobites (Tr), and large fenestrate bryozoans (Bz). Small foraminifers (Table 2) are scarce and represented by endothyrids, *Palaeotextularia*. Fusulinids (Fig. 5.10 – 5.12) are scarce: *Eostaffella* sp., *Hemifusulina subrhomboidalis* Rauser, *H. vozhgalica* Safonova, *H. mucronata* Rumjantzeva, *H. pulchella* Rauser, and *H. elegantula* Rauser. Rarely *Beedeina* sp. cf. *B. vaskensis* (Rauser), *Ozawainella minima* Putrja, *O.* sp.1, *Neostaffella* sp. occur (Table 2).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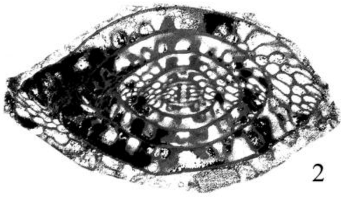
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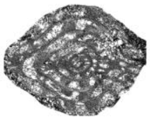
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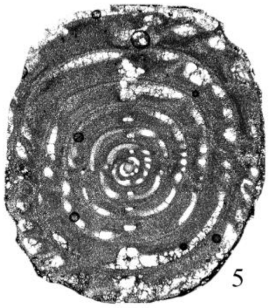
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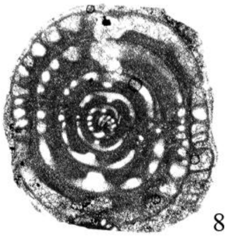
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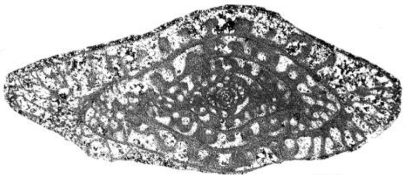
M_7^{up}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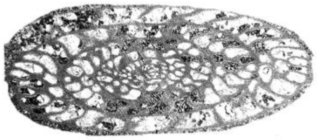
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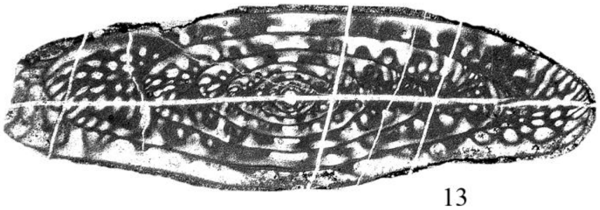
M_7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M_3^{up}


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16


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L_7^1

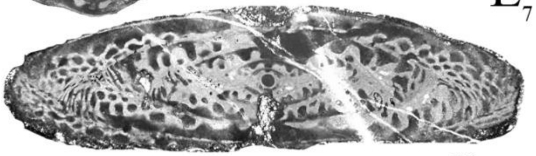
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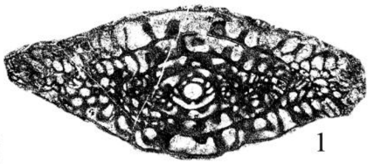
Figure 5. Fusulinids in the *Hemifusulina*-dominated assemblage: 1 – 9 (limestone M_7^{up}), 10 – 12 (M_7), 13 (M_3^{up}), 14 – 18 (L_7^1).

1 – *Hemifusulina communis acuta* Rauser; x 20; 2 – *Hemifusulina* sp. cf. *H. splendida* Safonova, x 20; 3 – *Ozawainella krasnodonica* Manukalova, x 40; 4, 16 – *Taitzehoella* sp. cf. *T. globulus* (Manukalova), x 35; 5, 8 – *Neostaffella larionovae* Rauser and Safonova, x 35; 6 – *Ozawainella* sp. 2, x 45; 7 – *Pseudostaffella variabilis* Reitlinger, x 45; 9 – *Ozawainella angulata* (Colani), x 40; 10 – *Beedeina* sp. cf. *B. vaskensis* (Rauser), x 20; 11 – *N.* sp., x 35; 12 – *Hemifusulina pulchella* Rauser, x 20; 13 – *Hemifusulina kashirica* Rauser, x 20; 14 – *Ozawainella paratingi* Manukalova, x 40; 15 – *Neostaffella ozawai* (Lee et Chen), x 35; 17 – *Hemifuuslina moelleri* Rauser, x 20; 18 - *Hemifusulina pseudobocki* Putrja, x 20.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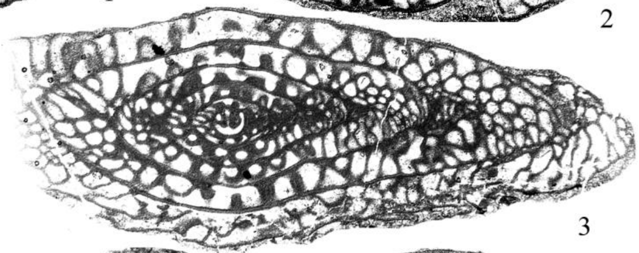
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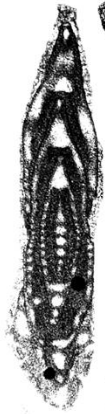
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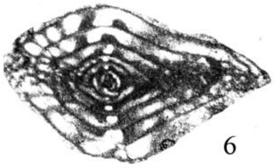
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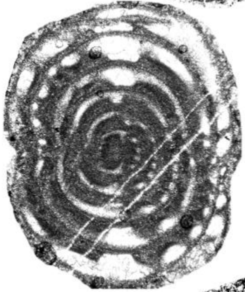
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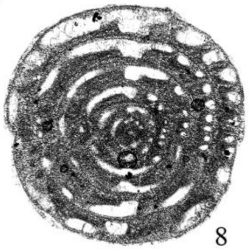
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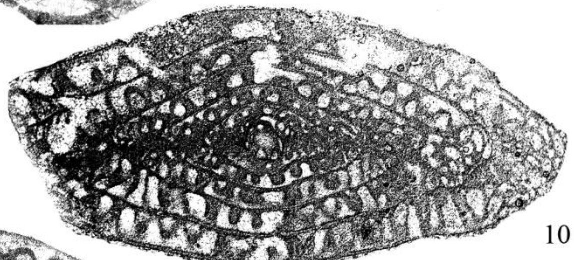
M_5


9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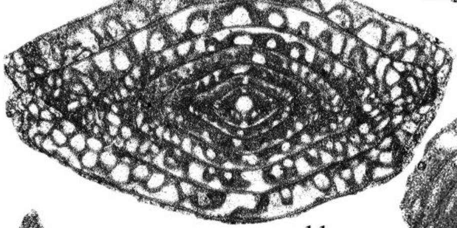
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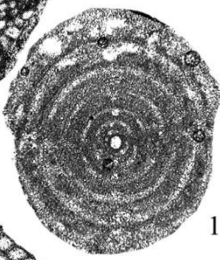
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M_1

Figure 6. Fusulinids in the *Beedeina*-dominated assemblage: 1 – 8 (limestone M_5), 9 – 18 (M_1).

1 – *Beedeina bona* (Rauser-Chernousova), x 20; 2 – *B. dunbari* (Sosnina), x 20; 3 – *B. pseudokonnoi* (Sheng), x 20; 4, 5 – *Ozawainella adducta* Manukalova, x 40; 6 – *Taitzehoella librovitchi* (Dutkevitch), x 35; 7 – *Neostaffella umbilicata* (Putrja et Leontovitch), x 35; 8, 12 – *N. compacta* (Manukalova), x 35; 9 – *B. schellwieni* (Staff), x 20; 10 - *B. pseudoelegans* (Chernova), x 20; 11 – *B. elshanica* (Putrja and Leontovich), x 20; 13 – *N. ozawai* (Lee et Chen), x 35; 14 – *O.* sp. cf. *O. digitalis* Manukalova, x 40; 15 – *O. stellae* Manukalova, x 40; 16 – *O. crassiformis* Putrja, x 40; 17 – *T. kashirica* (Rauser-Chernousova), x 35; 18 – *Eofusulina* sp. x 15.

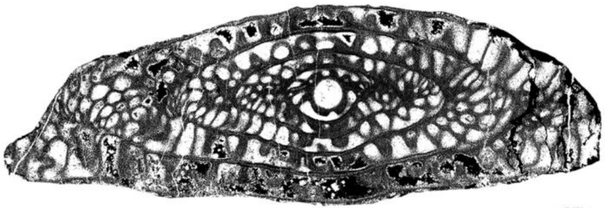
Limestone M_7^{up}

Limestone M_7^{up} is a biogenic packstone to wackestone (Fig. 4D), 0.1 m thick. Some large intraclasts consisted of large detritus. Few traces of phosphoritization are observed in bioclasts (Fig. 4N). Microstylolites rarely occur. Bioclasts unevenly distributed in this limestone and are represented by diverse invertebrates (Table 1): thick-shelled brachiopods (B), echinoids (E), echinoid spines (Es), gastropods (G), crinoid occicles, bryozoans, ostracods, trilobites, sponges and serpulinids (not shown in the illustrated thin-section). Smaller foraminifers (Table 2): endothyrids (FE), paleotextulariids, attached *Ammovertella* (not shown in the illustrated thin-section). Fusulinids (Fig. 5.1 – 5.9) are scarce and low diverse: *Hemifusulina* sp. cf. *H. subrhomboidalis* Rauser, *H. communis acuta* Rauser, *H. pulchella* Rauser, *H.* sp. cf. *H. splendida* Safonova, *Neostaffella larionovae* (Rauser and Safonova), *N. polasnensis* (Rauser and Safonova), *N.* sp. cf. *N. sphaeroidea cuboides* (Rauser), *Pseudostaffella confusa* (Lee et Chen), *Ps. variabilis* Reitlinger, *Beedeina* sp. cf. *B. vaskensis* (Rauser), *Ozawainella krasnodonica* Manukalova, *O. angulata* (Colani), *O. rhomboidalis* Putrja, *O. donbassensis* Sosnina, *O.* sp. cf. *O. lorentheyi* Sosnina, *O.* sp. 1, *O.* sp. 2, *Taitzehoella* sp. cf. *T. globulus* (Manukalova) (Table 2).

Limestone M_8

Limestone M_8 is 1.8 m thick, and contains no fusulinids in the Gurkovo section. Putrja (1956) studied fusulinids from the Eastern part of the Donets Basin and recognized

Fusulina "distenta" Roth and Skinner that is the most similar to *Beedeina* sp. cf. *B. vaskensis* (Rauser) in the limestone M_8.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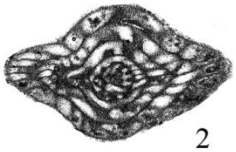
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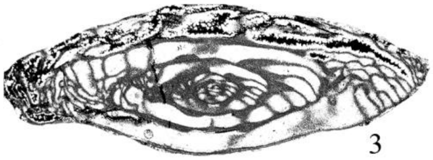
M$_6$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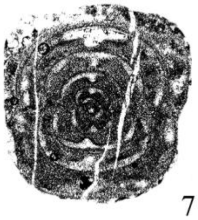
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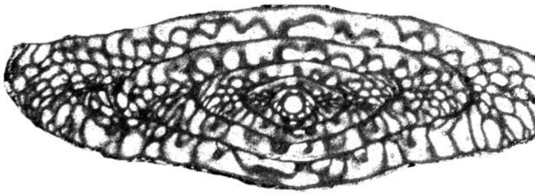
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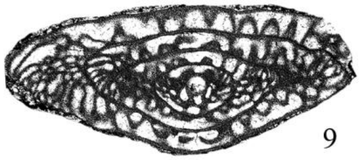
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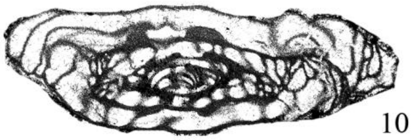
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M$_3$


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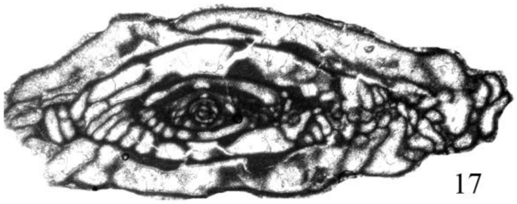
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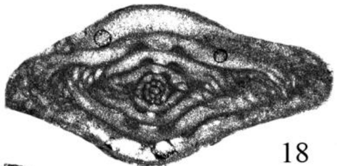
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M$_2$


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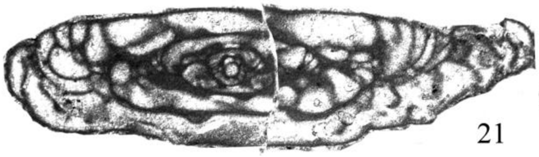
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Figure 7. Fusulinids of the *Fusulinella*-dominated assemblage: 1 – 7 (limestone M_6), 8–16 (limestone M_3), 17 – 24 (limestone M_2).

1 – *Beedeina keltmensis* (Rauser-Chernousova), x 20; 2 *Taitzehoella* sp. cf. *T. globulus* (Manukalova), x 35; 3 – *Fusulinella colanii* (Lee et Chen), x 20; 4, 5, 16, 22, 24 – Schubertellidae x 40; 6 – *Ozawainella adducta* Manukalova, x 40; 7 – *Neostaffella* sp. cf. *N. sphaeroidea* (Ehrenberg), x 30; 8 – *Beedeina pronensis* (Rauser-Chernousova), x 20; 9 – *Beedeina bona* (Chernova and Rauser-Chernousova), x 20; 10, 21 – *Fusulinella (Moellerites) cylindricus* Solovieva, x 20; 11 – *Taitzehoella kashirica* (Rauser), x 35; 12 – *N.* sp., x 30; 13 – *Fusulinella (Moellerites) paracolaniae* Safonova, x 20; 14, 23 – *Pseudostaffella confusa* (Lee and Chen), x 40; 16, 17 – *Fusulinella (Moellerites) schubertellinoides* Putrja, x 20; 18 – *Taitzehoella pseudolibrovitchi* Rauser-Chernousova, x 35; 19 – *Pseudostaffella khotunensis* Rauser-Chernousova, x 40; 20 - *Beedeina* sp., immature specimen, x 20.

Limestone M_9

Limestone M_9 is a foraminiferal wackestone to packstone (Fig. 4J), 2 m thick. Sample was collected at the base. Microstylolite cracks occur within the matrix, filled by brown organic matter. Quartz grains are common in the cement (Fig. 4M). Invertebrates are scarce (Table 1): echinoids (E), bryozoans, brachiopods, gastropods, ostracods and trilobites (not shown in the illustrated thin-section). Algae include abundant red *Pseudokomia* (AlK) and green *Beresella*; encrusting Cyanobacteria (not shown in the illustrated thin-section) also occurs. Smaller foraminifers (Table 2) are abundant: *Bradyina* (FB), *Palaeotextularia*, *Tuberitina*, several genera of endothyrids (not shown in the illustrated thin-section). Fusulinids (Fig. 8.11 – 8.19) are numerous and diverse: *Putrella brazhnikovae* (Putrja*), P.* sp. cf. *P. fusiformis* (Putrja), *P. donetziana* (Lee), *Neostaffella* sp. cf. *N. rostovzevi* (Rauser), *N. sphaeroidea cuboides* (Rauser), *N.* sp. cf. *N. sphaeroidea cuboides* (Rauser), *N. syzranica* (Rauser and Safonova), *N. larionovae* (Rauser and Safonova), *Fusulinella colanii* Lee et Chen, *F. borealis* Rauser, *F. pseudocolaniae* Putrja, *F.* sp. *F.* cf. *devexa* Rauser, many immature specimens of *Fusulinella*. *Schubertella* species are abundant and very diverse: *Sch.* sp. cf. *Sch. myachkovensis* Rauser, *Sch.* sp. cf. *Sch. galinae* Safonova, *Sch.* sp. cf. *Sch. inflata* Rauser, *Sch. lata* Lee and Chen, and *Sch. obscura procera* Rauser. *Ozawainella* species are less abundant; they are represented by large and slightly compressed at axial ends *O. mosquensis* Rauser*, O. vozhgalica* Safonova, and *O.* sp. Small *Pseudostaffella* also occur: *Ps. khotunensis* (Rauser), *Ps. compressa donbassica* (Putrja), and *Ps. primaeva* Putrja. The following species are scarce: *Fusiella pulchella* Safonova, *Hemifusulina bocki* Moeller, *Kamaina* sp. cf. *K. chernovi* (Rauser), and *Beedeina* sp. cf. *B. vaskensis* (Putrja)

(Table 2). Numerous immature specimens with one-two volutions are typical for this microfacies.

Limestone M_{10}

Limestone M_{10} is a foraminiferal packstone (Fig. 4H), 2 m thick. Smaller foraminifers are abundant *Palaeotextularia* (not shown in the illustrated thin-section), less abundant *Bradyina* (FB), *Tetrataxis* (FT), *Endothyra*, and attached forms *Tuberitina* (not shown in the illustrated thin-section) and *Ammovertella* (Fs) (Table 2). Fusulinids (Fig. 8.1 – 8.10) are *Fusulinella colanii* Lee et Chen, *F. meridionalis Rauser, F. devexa* Rauser, and *F. pseudocolaniae* Putrja. Several inflated species appear *F. tokmovensis longa* Reitlinger and *F. formosa tumida* Reitlinger. Among *Fusulinella* some older species are recognized *F. (Moellerites) subcolaniae* Reitlinger, *F. (M.) plana* Reitlinger, and *F. (M.) decurta* Reitlinger with weakly developed diaphanotheca. An older *Profusulinella* without diaphanotheca *P.* sp. 1, *P.* sp. 2, and *P. rotundata* Putrja also occur. *Schubertella* species are numerous and include *Shubertella lata* Lee et Chen, *Sch. procera* Rauser, *Sch. elliptica* Putrja, and *Sch. subkingi* Putrja. Large *Neostaffella* are common and include *N. sphaeroidea* (Ehrenberg) and *N. larionovae* (Rauser and Safonova). Small *Pseudostaffella* include *Ps. khotunensis* Rauser, *Ps. compressa donbassica* Putrja, and *Ps. variabilis* Reitlinger. *Ozawainella* species are similar to those in the limestone M_9 and include *Ozawainella* sp., *O. adducta* Manukalova, *O. krasnodonica* Manukalova, and *O.* sp. cf. *O. vozhgalica* Safonova. In contrast to the limestone M_9, abundant and diverse *Fusiella* occur in M_{10} including *F. typica extensa* Rauser, *F. praetypica* Safonova, *F. praecursor* Rauser, *F. paraventricosa* Rauser, *F. pulchella* Safonova, *F.* sp. 1, and *F.* sp. 2. *Kamaina*, which is scarce in M_9, is abundant and diverse in M_{10} limestone: *Kamaina kamensis* (Safonova), *K. chernovi* (Rauser), *K. rossoshanica* (Putrja), *K*. sp. cf. *K. kamerlingi* (Ginkel), and *K*. sp. *Beedeina* is scarce and include *B. elegans* (Rauser et Belyaev) (Table 2).

Invertebrate (Table 1) are scarce echinoids (E), bryozoans (Bz), brachiopods and spines, bivalves (not shown in the illustrated thin-section), ostracods (Os) with unseparated valves. Rugose corals (not shown in the illustrated thin-section), and serpulinid tubes (Sr) also occur. Algae are represented by green phylloid forms *Anchicodium* (not shown in the illustrated thin-section), well preserved *Beresella* and *Dvinella* with long thallia (AlB), and Cyanobacteria. This limestone is characterized by an absence of microstylolites and remains of organic matter, excellent preservation of bioclasts and presence of numerous encrusting organisms.


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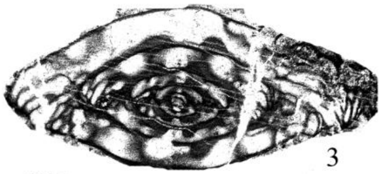
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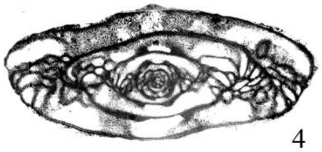
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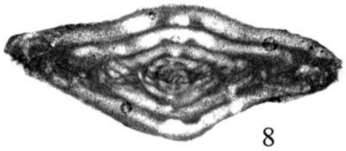
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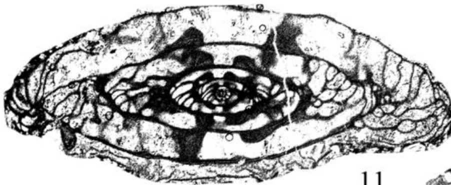
M_{10}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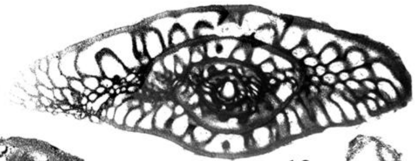
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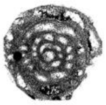
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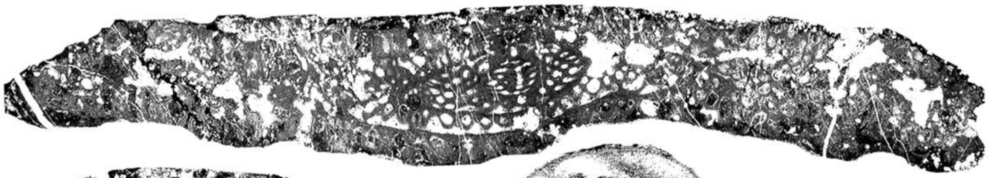
M_9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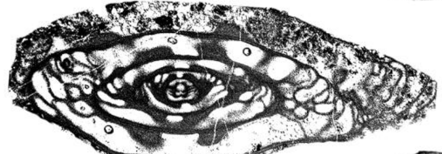
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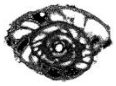
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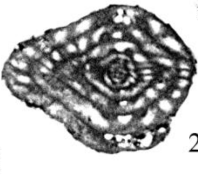
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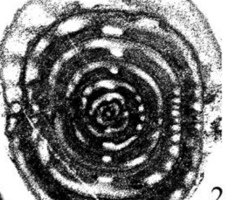
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M_6^{up}

Figure 8. Fusulinids of the *Fusulinella*-dominated assemblage: 1 – 10 (limestone M_{10}), 11– 19 (limestone M_9), 20 – 28 (limestone M_6^{up}).

1, 16 – *Neostaffella sphaeroidea* (Ehrenberg), x 30; 2 - *Schubertella lata* Lee and Chen, x 40; 3 – *Fusulinella tokmovensis longa* Reitlinger, x 20; 4 – *F. (M.) plana* Reitlinger, x 20; 5, 17, 26 - *Pseudostaffella khotunensis* Rauser, x 40; 6 – *Pseudostaffella variabilis* Reitlinger x 40; 7 – *Schubertella subkingi* Putrja, x 40; 8 – *Fusiella praetypica* Safonova, 9 – *Kamaina rossoshanica* (Putrja), x 15; 10, 19 - *Ozawainella* sp. cf. *O. vozhgalica* Safonova, x 35; 11 - *Fusulinella* sp. cf. *vozhgalensis devexa* Rauser, x 20; 12 – *Putrella donetziana* (Lee), x 20; 13, 14 - *Schubertella* sp. cf. *galinae* Safonova, x 40; 15 – *Kamaina chernovi* (Rauser-Chernousova), x 20; 18 - *Pseudostaffella compressa donbassica* Putrja , x 40; 20 – *Kamaina* (?) sp. cf. *K. rossoshanica* (Putrja), x 15; 21 – *Fusulinella colanii* (Lee and Chen), x 20; 22, 23 – Schubertellidae, x 40; 24 – *Taitzehoella librovitchi* (Dutkevitch), x 35; 25- *Neostaffella larionovae* Rauser and Safonova, x 35; 27 - *Ozawainella adducta* Manukalova, x 35; 28 - *Ozawainella* sp. x 40.

A model of cyclic recurrences of the Moscovian fusulinids: Interpretation

In a reconstruction of the bathymetry within each cycle, we use the distribution of algae that can photosynthesize different spectra of sunlight. Abundant green algae usually inhabit waters of very shallow depths, 5–10 m, within the zone of penetration of the red spectrum of sunlight. Deeper and colder water (more than 30 m) is favorable for red algae, which utilize the blue spectrum of sunlight for photosynthesis. Of course such bathymetric reconstructions are not ideal and have many restrictions. For instance, the depth of penetration of sunlight depends on many factors, including geographic position of the sea, temperature of the water, and presence of insoluble organic and inorganic particles and/or ions in the marine water (Vella, 1962; Antoine and Morel, 1996; Conde et al., 2000). In spite of the limitations mentioned above, however, the algae seem to be the only biological markers which provide direct evidence about water depth of habitation, especially when the succession of a single stable basin is considered (Fig. 4).

We recognize an upward stratigraphic succession from a *Beedeina*-dominated (B) community (LTST-EHST) characterized by red algae documented in the limestones L_7, M_1, M_5, M_8 to a *Fusulinella-Fusulina*-dominated (C) assemblage (LHST-ELST) characterized by green algae M_2, M_3, M_6, M_6^{up}, M_9, M_{10} (Fig. 5). This presumably represents a change from deeper to shallower water. The greatest difficulty is in determination of the position of the limestones L_6, L_7^1, M_3^{up}, M_7, M_7^{up}, N_1, which contain the *Hemifusulina*-dominated association. This assemblage rarely contains algae and is associated with heterozoan fauna. In the Donets Basin this assemblage appears immediately above the sequence boundaries proposed by Eros et al. (2012), therefore we suggest that the *Hemifusulina*-assemblage indicates a beginning of transgression.

Recent sedimentological and paleoecological research in the Donets Basin (Fohrer et al., 2007), has focused on detailed microfacies study of the "L" Formation and conodont and ostracod distributional patterns, and revealed that the maximum transgression was in the bottom of limestones L_6 and L_7^1, where *Hemifusulina* species were recognized. In these limestones, Nemyrovska *in* Fohrer et al. (2007) recognized conodonts of genus *Idiognathodus* which reveal their maximal abundance in the off-shore environment in the Pennsylvanian strata of the US Midcontinent (Sweet, 1988). In the same limestones, Fohrer in Fohrer et al. (2007) recognized some ostracod genera, particularly, *Cavellina*, which is considered as an indicator of an unstable near-shore marine environment with high terrigenous input that is associated with a transgressive event.

We suggest that the fusulinid cyclicity marks low-frequency (0.6-1.2 my) sea-level fluctuations (Fig. 4). Each cycle starts with (A) *Hemifusulina*-dominated assemblage indicating beginning of transgression (ETST), followed by (B) *Beedeina*-dominated assemblage indicating late transgression (LTST), and completed by (C) *Fusulinella*-*Fusulina*-dominated assemblage indicating high and early low stand (HST-ELST). This interpretation is also consistent with lithofacies data (Eros et al., 2012).

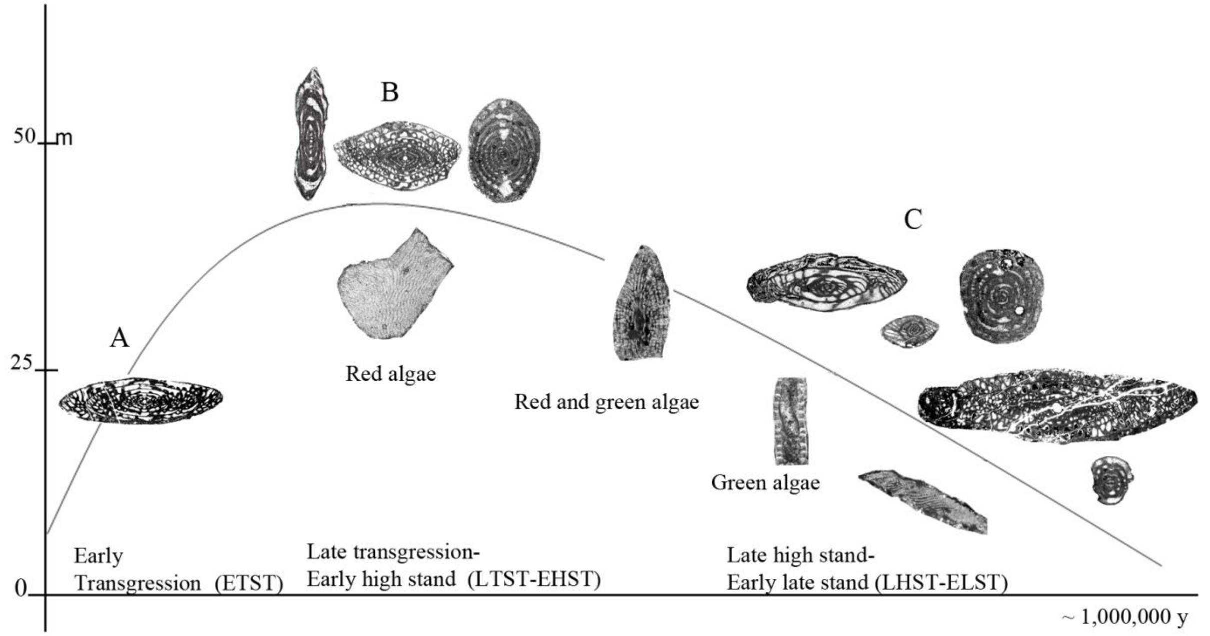


Figure 9. Time – depth relations of fusulinid distributional patterns within a full fusulinid cycle of sea level change from transgression through high stand to low stand (~ 600,000 ~1,000,000 yrs.).

A – *Hemifusulina*-dominated association, B) – *Beedeina*-dominated assemblage, C) – *Fusulinella*-*Fusulina*-dominated assemblage.

Hemifusulina-dominated community: beginning of transgression (ETST)

The *Hemifusulina*-dominated assemblage (A, Figs. 2, 3, 4, and 5) occurs in the limestones L_6, L_7^1, M_3^{up}, M_7, M_7^{up}, and N_1. This assemblage (Suppl., Fig. 2.1–2.18) is represented by either a monospecific *Hemifusulina* population or a low diverse community composed mostly of *Hemifusulina* (1, Fig. 5; Suppl., Fig. 2.1, 2.2, 2.12, 2.13, 2.17, 2.18) with scarce mature species of small subrhomboidal and short fusiform species of *Beedeina* (2, Fig. 5; Suppl., Fig. 2.10) and *Taitzehoella* (3, Fig. 5; Suppl., Fig. 2.4, 2.16), large *Neostaffella* (4, Fig. 5; Suppl., Fig. 2.5, 2.8, 2.11, 2.15), and large *Ozawainella* (5, fig. 5; Suppl., Fig. 2.3, 2.9, 2.14). Species of *Hemifusulina* are variable in shape from elongated subcylindrical (most common) and ovoid with rounded polar ends, to short fusiform with pointed polar ends. *Hemifusulina* differs from many other large fusulinids in having a very small proloculus, regular shape, regularly folded septa, and regular small rounded chomata symmetrically arranged around a regularly widening tunnel. This shape of *Hemifusulina* and its usually monospecific occurrence allowed Villa and Bahamonde (2001) to draw an analogy between *Hemifusulina* and the Gzhelian *Ferganites*. The Permian *Eoparafusulina* described by Skinner and Wilde (1966) from the Pacific Northwest and Alaska also has a similar shape to *Hemifusulina* and *Ferganites* and occurs in similar lithofacies.

Villa and Bahamonde (2001) studied monospecific occurrences of *Ferganites* in the upper Kasimovian and lower Gzelian Lower Member of the Puentelles Formation of the Cantabrian Mountains. This unit comprises “bedded alternations of calcareous breccias and conglomerates, pebbly sandstones, graded and laminated silty and sandy limestones, skeletal grainstones, and bioturbated marly limestones and marls. *Ferganites* occurs at numerous levels.” (Villa and Bahamonde, 2001, p. 174, fig. 2 herein). These strata are cyclic; they recognized three fining upward sequences. Using the facies model proposed by Mutti et al. (1996), Villa and Bahamonde (2001) interpreted the unit “as flood-dominated fan-delta and river-delta systems, which generated alluvial to shelfal lobes of hinterland-derived sediment supplied by episodic river discharges”. Such deposits occur in tectonically-controlled basins characterized by small and medium sized fluvial systems with high-elevation drainage basins and high-gradient transfer zones located close to marine basins (Villa and Bahamonde, 2001 and references therein). Villa and Bahamonde (2001) noted the abundance of *Ferganites* and absence of other contemporaneous genera such as *Rauserites*, *Triticites* and *Quasifusulina*. They linked the monospecific monospecific concentration of *Ferganites* to an adaptation of this genus either to hydrodynamic activity of near-shore environments or to relative low salinity of proximal areas located near the rivers’ mouths due to fresh water discharge.

The *Hemifusulina* assemblage, sometimes represented by a monospecific population, is the only paleocommunity in Moscovian time which occurs predominantly in carbonate rocks with high siliciclastic content. *Hemifusulina*-bearing beds are restricted to only a few regions; it is documented in sandy limestones alternating with coarse-grained conglomerates, sandstones and siltstones in the Cantabrian Mountains (Ginkel, 1973), in Central Asia (Bogush, 1963), and in the silty-micritic mudstones in the Donets and Moscow Basins (Reitlinger and Balashova, 1954; Baranova and Kabanov, 2003). The abundance of *Hemifusulina* populations in the Eastern European Platform decreases gradually in an eastward (seaward) direction (Dalmatskaya, 1961); e.g. the further from the land, the less abundant this genus becomes. *Hemifusulina*, in contrast to

Ferganites, occurs both in high-energy environments (Central Asia and the Cantabrian Mountains) and in low-energy environments (the Moscow and Donets Basins). In the Donets Basin Ih the Donets Basin the limestones with *Hemifusulina* are documented right above composite sequence boundaries, independently inferred by Eros et al. (2012) and which are recorded by trough-cross-bedded sandstone. Limestones with *Hemifusulina* are documented within fine siliciclastics with numerous plant remains intercalated with numerous coal seams. Eros et al. (2012), based on lithology, sedimentary structure, abiotic and biotic components, analyzed lithologic facies and interpreted such facies as deposited in near-shore marine environments: fluvial channel bars, abandoned channels, backbay marsh, tidal mudflats, tidal bars and channels, marine to estuarine. Therefore we suggest that this community was adapted to a near-shore environment with slightly reduced salinity caused by the input of fresh water.

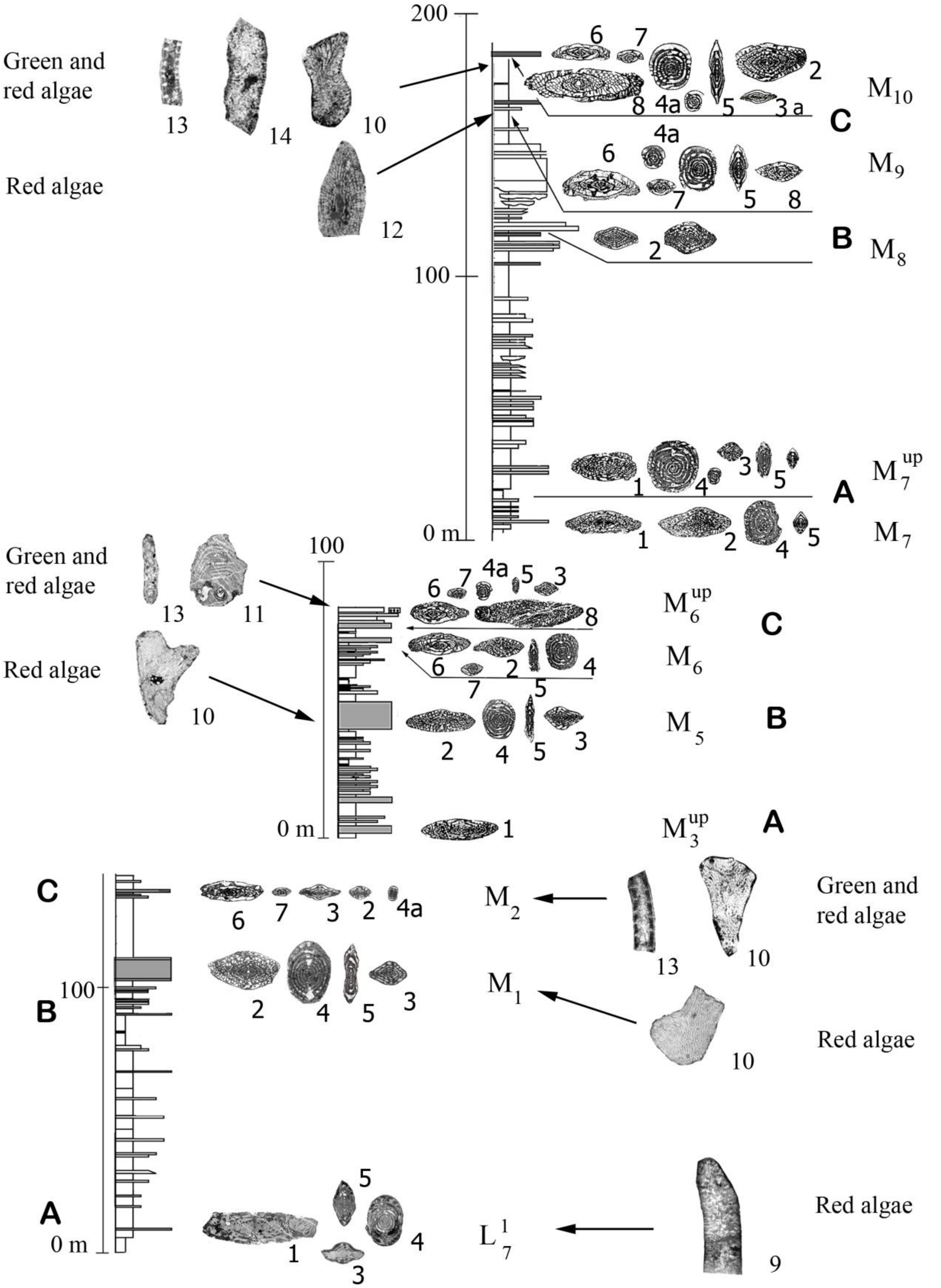
The species of genera in transgressive colder water (e.g. ETST, LTST-EHST) - *Hemifusulina*, *Taitzehoella*, *Neostaffella*, *Beedeina* and *Ozawainella* - possess relatively small proloculi, a greater number of volutions (six – eight), and generally more regularly folded septa. In contrast fusulinids from regressive episodes (e.g. LHST-ELST) – *Fusulinella*, *Fusulina*, *Fusiella*, *Neostaffella*, *Pseudostaffella*, *Ozawainella* - preferred shallower and warmer water, and have relatively larger proloculi, and less volutions (five – six). Advanced fusulinids, such as *Fusulinella* and *Fusulina* have irregularly folded septa. Such differentiation among fusulinids is supported by ecological research on modern foraminifers (Dodd and Stanton, 1981) that reveals an increase of volution number in mature specimens in colder water probably because of higher nutrient input from the upwelling oceanic currents.

Baranova and Kabanov (2003), studying fusulinid paleoecology, suggested that *Hemifusulina* appears during early “forced” regression, associated with an increase of siliciclastic input into the basin. It is generally accepted that during regression, when the area of exposed surfaces is maximal, clastic input increases, while during transgression the input of siliciclastics is considerably reduced. We conversely suggest that this assemblage represents the beginning of a transgression.

The presence of the *Hemifusulina* community, especially its monospecific concentration in mixed carbonate-siliciclastic rocks in the Donets and Moscow Basins, indicates the proximity of exposed land and underlines the western limits of large epicontinental seas. The abundance of *Hemifusulina* gradually decreases in a seaward direction, from the Donets and Moscow Basins toward the Uralian seaway in the east.

We interpret that the beginning of transgression is driven by the decay of large glaciers and consequent rise of sea level. This event was accompanied by a disturbance of the shallow clear water marine environments of the previous coral-algal (photozoan) meadow association which persisted during regression and is associated with the (C) *Fusulinella-Fusulina* assemblage. In the beginning of transgression, this photozoan association was replaced by a cool-water heterozoan assemblage. Although the remains of heterozoans are found in almost all limestones (Fig. 2), their abundance declines considerably from the beginning of transgression (colder water with a *Hemifusulina*-association) to the low sea level stand (shallower and warmer water with a *Fusulinella-Fusulina* association (C). Such biotic change in the benthic fauna, from the (C) to (A) fusulinid assemblages probably could be associated with a decrease of sea bottom temperature due to the continuous deepening of a basin during transgression, and an increasing connection with the open ocean that enhances water circulation and upwelling of colder oceanic water onto the epicontinental basins.

Another explanation for the abrupt change in shallow marine biota is a change in salinity. Normal marine conditions are characterized by salinity in the range of 32 to $38^{o}/_{oo}$, average$35^{o}/_{oo}$ (Flugel, 2004). We hypothesize here that salinity in a shallow sea can be slightly increased during regression probably up to ~$38^{o}/_{oo}$, firstly because fresh water became is sequestered in glaciers, and secondly because the shallower water, the more enhanced the evaporation will be as a response to warming and drying conditions. Transgression brings more water from the continent into epeiric basins, possibly reducing salinity. The beginning of transgression may be accompanied by enhanced runoff from the land, as a result of increasing precipitation or probably accelerated decay of near-field high-mountain glaciers in the adjacent Western Europe (Becq-Giraudon et al., 1996). High input of fresh water into the epicontinental basins would reduce the salinity of near-shore water and increase the input of terrigenous particles and nutrients into seawater resulting in a reduction in transparency of the water, a factor harmful for coral and calcareous algae, but favorable for a heterozoan fauna.


Green and red algae
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Green and red algae
Red algae
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Figure 10. Repetitive reoccurrences of three fusulinid assemblages.

A) *Hemifusulina*-dominated, B) *Beedeina*-dominated, C) *Fusulinella*-dominated in the "M" Formation, Donets Basin. 1 - *Hemifusulina*, 2 – *Beedeina*, 3 – *Taitzehoella* and *Fusiella*, 4 – *Neostaffella* and *Pseudostaffella*, 5 – *Ozawainella*, 6 – *Fusulinella*, 7 – *Schubertella*, 8 – *Fusulina*. Red algae: 9– red phylloid *Archaelithophyllum* (?), 10– *Ungdarella*, 11– *Parachaetetes* (?), 12– *Pseudokomia*. Green algae: 13– *Beresella*, 14– green phylloid, *Anchicodium*.

Beedeina-dominated community: Late transgression – Early high sea level stand (LTST-EHST)

A second fusulinid assemblage (B, Figs. 2, 3, 4, 5), which occurs in the limestones $L_{7,}$ M_1, M_5, $M_{8,}$ N_1^6, N_4, and successively replaces the *Hemifusulina*-association, is the *Beedeina–Neostaffella–Ozawainella–Taitzehoella* community, or as we simplify here, *Beedeina*-dominated assemblage. In our model this community preferred optimal depths of 30-40 m, at which the fusulinids could survive during deposition the LTST–EHST. Smaller foraminifers characterized by a globular shape, *Bradyina*, *Endothyra*, rare textulariid, and attached foraminifers are present (see Suppl., Table 2). This is in agreement with Stevens (1971) who suggested these types of fossils inhabited the deepest part of the sea, deeper than 20 m. Macrofossils are represented by scarce heterozoan. The presence of the red alga *Ungdarella* (Suppl., Fig.1A, AlU) also suggests relatively deeper water, probably more than 30-35 meters.

An important feature for this association is the maturity of the fusulinid specimens. The absence of immature specimens and terrigenous intraclasts also indicates a quiet off-shore environment (see discussion above). The species of *Beedeina* (2, Fig. 5, Suppl., Fig. 3.1–3.3, 3.9–3.11) and *Taitzehoella* (3, Fig. 5, Suppl., Fig. 3.6, 3.17) in the late transgressive – high stand episodes (LTST-EHST) are smaller than their relatives from regression episodes (LHST-ELST), and they are subtriangular in shape, and possess a greater number of volutions (six – eight), than their descendants from lower sea level stand, which have only five, or rarely six volutions. *Beedeina* in this assemblage is distinct in having regularly folding septa and small proloculi. *Neostaffella* is represented by large species, and has seven–eight volutions (4, Fig. 5; Suppl., Fig. 3.7, 3.8, 3.12, 3.13) similar to that of their closest ancestors from the *Hemifusulina*-assemblage and descendants from the *Fusulinella*-association. Large discoid species of *Ozawainella* are highly compressed at their polar ends (5, Fig. 5; Suppl., Fig. 3.4, 3.5, 3.14–3.16) and replaced by smaller subrhomboidal species in the successive *Fusulinella*-association. A very important feature for this association is the absence of genera *Fusulinella* (6, Fig. 5), *Schubertella* (7, Fig. 5) and *Hemifusulina* (1, Fig. 5).

We suppose that the subrhomboidal to shortly fusiform test outline of species of *Beedeina* and *Taitzehoella*, the globular shape of the large *Neostaffella*, and discoid shape of the large *Ozawainella* evidence their adaptation to deeper depth under increased pressure at the bottom substrate where the fusulinids lived.

The limestones containing this community are usually thin-bedded, and formed when the sea level reached maximum stability. Species of *Beedeina* show the same evolutionary trend in the many regions of the Paleotethys and are recognized in the Moscow Basin (Rauser-Chernousova et al., 1951), Central Asia (Bogush, 1963), Northern China (Sheng, 1958), Southern Urals (Ivanova, 2008), and Cantabrian Mountains (Ginkel, 1965) and therefore are important for biostratigraphic correlation. This is because they inhabited seas close to the maximum sea level rise when a connection among basins of the Tethyan realm was considerably increased.

Fusulinella-dominated association: Regressive episode (ELST)

The most diverse association of fusulinids (C, Figs. 2, 3, 4, 5) with abundant Fusulinellids (*Fusulinella*, *Protriticites*, *Obsoletes*) replaces the *Beedeina*-dominated association in the limestones L_5, M_2, M_3, M_6, M_6^{up}, M_9, M_{10}, N_2, N_3, N_5, N_5^1, O_1, which were deposited in progressively shallowing seas from high stand to low stand. This diverse community of fusulinids includes abundant small species of *Schubertella* (7, Fig. 5; Suppl., Fig. 4.4, 4.5, 4.15, 4.16, 4.22–4.24, 5.2, 5.7, 5.13, 5.14, 5.22, 5.23) and *Fusulinella* (6, Fig. 5; Suppl., Fig. 4.3, 4.10, 4.13, 4.17, 4.21, 4.3, 4.4, 4.11, 4.21) and immature individuals of *Fusulinella* and *Beedeina* (Suppl., Fig. 4.20) with two-three volutions.

Beedeina is usually represented by elongated fusiform species, with irregularly folded septa (Suppl., Fig. 4.1, 4.8, 4.9). Large species of *Beedeina* in the *Fusulinella*-association possess fewer volutions (maximum five) and are almost three to four times longer than species from previous assemblages, and often have very large proloculi. Species of *Taitzehoella* (3, Fig. 5; Suppl., Fig. 4.2, 4.18, 5.24) also become elongate fusiform. In the Podolskian, species of Fu*siella* (3a, Fig. 5; Suppl., Fig. 5.8) derived from *Taitzehoella* become an important element of the ELST assemblage. Large species of *Neostaffella* are replaced by small individuals of *Pseudostaffella* (4a, Fig.5; Suppl., Fig.4.14, 4.19, 5.5, 5.6, 5.17, 5.18, 5.26). The *Fusulinella*-dominated assemblage is usually characterized by an absence of the *Hemifusulina*. Single specimens are recognized in the Podolskian, M_9 limestone. Large elongate-subcylindrical *Fusulina* (8, Fig. 5; Suppl., Fig. 5.9, 5.20) appear at the end of each cycle. Within the Moscovian – Kasimovian transition subcylindrical *Fusulina* evolved into *Quasifusulinoides* and *Quasifusulina*.

A distinctive feature of this assemblage is a mixture of mature and immature fusulinid specimens, as well as an increased abundance of photozoan. We suggest that the slow accumulation of ice at polar region led to slow sea level falls during regression and that very shallow depth persisted relatively longer, resulting in the explosion of a diverse and abundant fauna and algal flora. The algal associations reveal shallowing upward successions: the lower limestones in the regression series of three described cycles M_2, M_6, M_9 contain both red and green algae (Figs. 4, 5), that we suppose could have been deposited at a depth ~10–20 m, whereas the upper limestones M_3, M_6^{up}, M_{10} containing mainly green algae, and may indicate a shallower depth up to10 m. The presence of abundant immature fusulinids and large numbers of broken shells of diverse macrofauna indicate active hydrodynamics at shallow depths.

The diverse species of *Fusulinella* and *Fusulina* reveal a higher degree of provinciality during regression episodes, when the marine connection between provinces was reduced by exposed land. The further from the Donets Basin the more difficult it was to correlate the proposed zone using *Fusulinella* and *Fusulina* species.

Summarizing we propose here a model of fusulinid distribution in the shallow epicontinental sea in the Donets Basin with respect to different sea level stands (Fig. 4) which resulted from the waxing and waning of far-field glacial Gondwanan ice caps and probably near-field high mountain glaciers. The beginning of a transgression is characterized by a monospecific population of *Hemifusulina*, or a low-diverse community composed of *Hemifusulina* small subrhomboidal species of *Beedeina* and inflated *Taitzehoella*, large *Neostaffella* and *Ozawainella*. During the maximum sea level stand with depths greater than 35 m was marked by disappearance of *Hemifusulina*, while other genera experience little morphological change: Species of *Taitzehoella* and *Beedeina* became subrhomboidal in outline, while those of *Neostaffella* became larger, *Ozawainella* is represented by large species which have highly compressed in polar ends. Regression episodes are marked by an increase of diversification in the fusulinid populations.

Applications of the fusulinid distributional model

Extinction event at the Moscovian – Kasimovian boundary

In the first half of the last century Carboniferous stratigraphy in the former Soviet Union was developed based upon fusulinid evolution, and divided into three subsystems: Lower (=Mississippian), Middle (=Lower and Middle Pennsylvanian) and Upper (=Upper Pennsylvanian) Carboniferous. The boundary between the Middle and Upper Carboniferous (Moscovian/Kasimovian) was established by extinction of many Middle Carboniferous fusulinid genera. The prolonged extinction event (Fig. 6) starts at the N_1^1 and ends at the N_4 limestones. This event occurred between two transgressions marked by the limestones N_1^6 and N_4. From the fusulinid distributional pattern within a cycle (Fig. 2) two groups can be recognized; the first includes fusulinids that inhabited a deepening colder sea during transgressive episode (TST, LTST); the second is composed of fusulinid which preferred a shallowing warmer sea during regression (HST, ELST). The great extinction event at the Moscovian – Kasimovian boundary mainly affected fusulinid genera associated with transgressive episodes including *Hemifusulina*, *Neostaffella*, *Ozawainella*, *Beedeina,* and *Taitzehoella.* This can be explained by a global regression resulting in a profound ecological disturbance of their habitat, specifically the pronounced expansion of shallow water environments that were ecologically unfavorable for these genera.

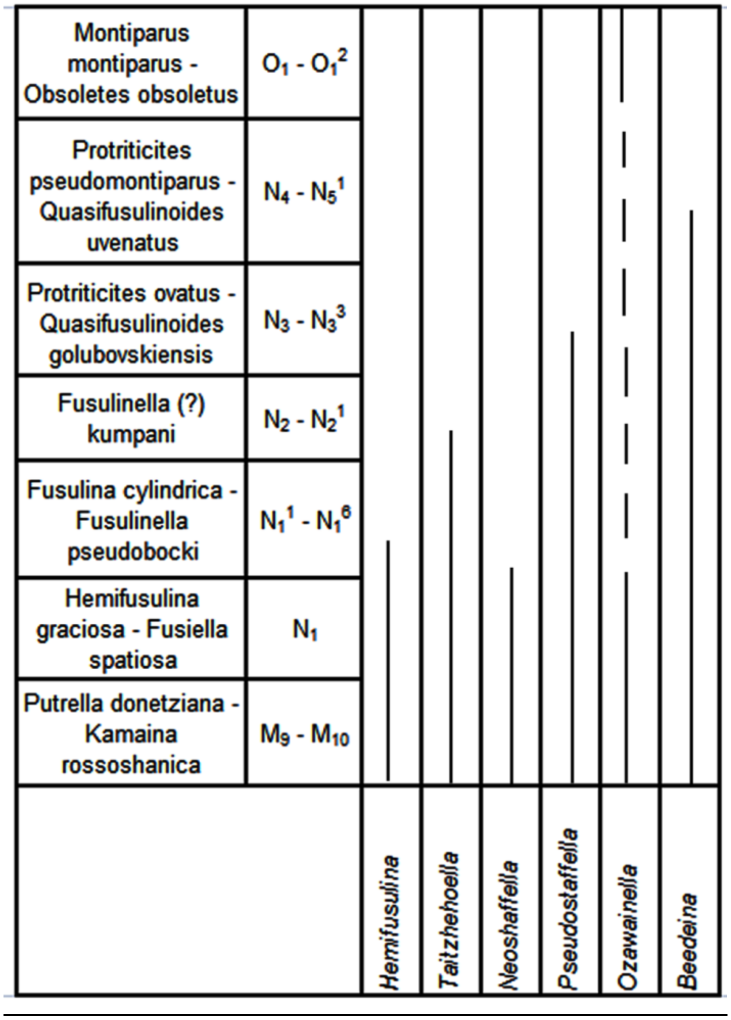

Figure 11. Extinction of fusulinid genera across Moscovian – Kasimovian boundary.

Biostratigraphy and global correlation

Trends in evolution, biogeography and biodiversity that are recognized within the established biocycles possess valuable application in biostratigraphy. The species recognized in all three assemblages distinguished within a cycle have a very narrow temporal range (0.3 – 0.4 my). The deepest 'transgressive' *Beedeina*-dominated assemblage (LTST–EHST), recognized in the limestones L_7, M_1, M_5, M_8, N_1^6, and N_4 from the eastern deeper to the western shallower part of the Donets Basin (Putrja, 1939, 1956), are absent in some limestones, for example M_8 and $N_{4,}$ in the shallower water in the western part in the Gurkrovo and Kalinovo sections. As we consider *Fusulinella*-association as a proxy of shallower depth, its appearance might be expected closer to the shore, however neither *Beedeina*, nor *Fusulinella* occur in the limestones M_8 and N_4. Therefore the 'transgressive 'and 'regressive' fusulinids are not only depth-related forms but occur at particular time intervals, or depth-time-related assemblages. In other words the fusulinid assemblages we have defined for different sea level stands are not only associated with depth, but with some other specific environmental conditions, such as temperature or salinity that existed during short time intervals, either transgression or regression. This differentiation is useful for interbasinal correlation, especially with the historical type region, the Moscow Basin. A usage of this model in correlation of late Kashirian – Podolskian strata of the Donets and Moscow Basins, that allows us almost bed-to-bed correlation of successions with different lithology, we present in a separate paper.

As the 'transgressive' fusulinids from LTST–EHST inhabited seas during periods close to maximum sea level rise, they are the most important and potentially useful for global correlation. Ross and Ross (2009) in the proposed sea level curve documented an evolution in the *Beedeina* that probably reveals similar trends in the Pennsylvanian succession of the North America and the Donets Basin (Ukraine). For example, before the last occurrence of *Beedeina* in North America during the Lost Branch (Nuyaka Creek) transgression, the latest Desmoinesian, there was a long episode when factors were unfavorable for this genus. We also recognize a long interval between N_1^6 and N_4, which is characterized by the absence of *Beedeina*. Some similarities in *Beedeina* distribution also likely link the Kashirian –Podolskian strata in the Donets Basin with the early Desmonsenian of the USA. However more detailed work needs to be conducted in a correlation of *Beedeina* evolutionary trends to the distal regions.

By contrast, fusulinids of the *Hemifusulina*-dominated community which occur in the ETST limestones are provincial and therefore have low biostratigraphic and correlation potential. Only correlations of the closest basins, such as the Donets and Moscow Basins, are reliable. Similarly, the most diverse fusulinids occur in limestones deposited during regression (LHST–ELST). Lowering of sea level in epicontinental seas led to creation of geographical barriers that in turn increased isolation of fusulinid populations and development of endemic and provincial species. The *Hemifusulina*-dominated 'transgressive' assemblage, the *Fusulinella*-dominated 'regressive' populations allow correlation between proximal basins, such as the Donets and Moscow basins.

Paleogeography

When we tried to correlate different groups of fusulinids from the Donets Basin with contemporaneous strata in the other regions of the Tethyan province, we recognized that the fusulinids from the HST reveal higher degrees of similarity than the fusulinids from LST. Among *Fusulinella* we found some species in common with those in the Moscow Basin, but farther from the Donets Basin, fewer species are similar. *Fusulinella* is one of the more diverse genera among the late Paleozoic larger foraminifers and as it is the most provincial, it can be used for recognition of originally contiguous regions which later may have been dispersed hundreds or thousands of kilometers.

Sequence stratigraphy definition of TST, HST, LST

The proposed model is a useful tool for the definition of third-order glacio-eustatic sea level stands in areas of shallow marine sedimentation during the Late Paleozoic. Sequence boundaries can be drawn at the base of the beds with *Hemifusulina* (TST). The maximum flooding is marked by the *Beedeina*-dominated assemblage (LTST–EHST) and regression (LHST–ELST) is defined by an abundant *Fusulinella*-*Schubertella*-community.

The fusulinid cyclic model developed for the Donets Basin represents a stratigraphic ‘symmetrical pattern’ in the terminology proposed by Brett (1998). He noted that “Within a single stratigraphic section, habitat tracking may produce a predictable vertical stacking pattern of biofacies that appear in a nearly symmetrical cycle. Such ‘symmetrical tracking’ patterns represent simple lateral shifting of bathymetrically-zoned biofacies, perpendicular to facies strike (shoreline), in response to relative rise or fall of sea level ” (Brett, 1998, p. 249, see figs. 3–5 herein). Brett also proposed ‘asymmetrical patterns’, which are “observed in some sedimentary cycles and may be attributed to incomplete preservation of intermediate facies” (Brett, 1998, p. 249).

In this paper we consider fusulinid distribution in the Donets Basin to represent a “symmetrical pattern”, where all three assemblages are represented and record all sea level stands from transgression to regression (ETST, LTST–EHST, LHST–ELST). However, in correlating the Donets Basin succession with other regions of the Tethyan realm we found different combinations of the proposed three associations – ‘asymmetrical patterns’- which also reveal cyclic temporal distributional patterns, but with the omission of one or another assemblages.

In intracratonic basins, depending upon subsidence and sedimentation rates and distance from the land, there are three types of succession (Fig. 7). In the Donets Basin, with a subsidence rate of ~0.09 mm/y (Izart et al., 2003, Eros et al., 2012), all three fusulinid assemblages (*Hemifusulina*-dominated (ETST), *Beedeina*-dominated (LTST–EHST), *Fusulinella*-dominated (LHST–ELST) develop in a symmetrical distributional patterns recognized in the mixed siliciclastic-carbonate succession. By contrast, in the predominantly carbonate succession of the Moscow Basin, the recorded asymmetrical pattern, includes early transgression beds (ETST), whereas fusulinids from the late transgression (LTST–EHST) either occur as a mixture together with fusulinids from the regression episodes (LHST–ELST), or are absent depending on the magnitude of the transgression. Because of the low subsidence rate in the Moscow Basin (0.04 mm/y) (Izart et al., 2003) the reduced accommodation space was sometimes too shallow for the *Beedeina*-dominated assemblage. Farther to the east, in the deeper marine Uralian Foredeep, the early transgressive strata (ETST) disappear, whereas the beds with late transgressive (LTST–EHST) and regressive assemblages (LHST–ELST) are well separated rather than mixed. The occurrence of *Beedeina*-dominated assemblages reveals a deepening of the basin in the eastern part of the Eastern European Platform. The presence of both the *Beedeina*-dominated and *Fusulinella*-dominated assemblages in thick beds was mentioned in previous studies (Ivanova, 2008) and can be explained by an increased subsidence rate and associated accommodation space. Subsidence rates in this part of the Eastern European Platform are not known, but the occurrences of the *Beedeina*-dominated and *Fusulinella*-dominated assemblages suggest a subsidence rate in Urals similar to that in the Donets Basin ~0.1mm/y (see discussion below).

A repetition of fusulinid assemblages from (LTST–EHST) and (LHST–ELST) and correspondently low subsidence rates (see discussion below) are recognized in other basins: in Central Asia, within predominantly carbonate strata of the southwestern Darvaz, Pamir (Leven, 1998) (Fig. 8), and within oceanic carbonate mounds of the Akyoshi Limestone, Japan (Sano al., 2004; Sano 2006). The absence of Hemifusulina (ETST) indicates a deposition setting in the distal parts of basins where input of siliciclastic sediments is absent or considerably reduced.

Different modifications to the 'asymmetric fusulinid assemblage pattern' are found in areas of tectonic uplift. Cyclic, predominantly coarse-grained, fining upward siliciclastic successions with intercalated sandy limestones underlain by conglomerates are characterized mainly by the *Hemifusulina*-dominated assemblage (ETST), and illustrate an asymmetric pattern (Fig. 8) in which the deeper (LTST–EHST) and (LHST–ELST) regressive assemblages are absent or rare (Bogush, 1963). Such successions are documented in orogenic belts of the Cantabrian Mountains and Central Asia. The Mesao Limestone Member of the Pando Formation (400 m thick) in northeast Leon, Northern Palencia of the Cantabrian Mountains (Ginkel, 1965), which contains *Hemifusulina*, is unconformably overlain by conglomerates of the Cea Formation. A similar succession is recognized on the eastern and northern slopes of the Alaysky Ridge and in the southern slope of the Dzhungarsky Alatau Ridge in Central Asia. Such different sequences of fusulinids assemblages can be explained by various tectonic settings for the basins and differential paleo-topography of the near-shore areas, which were submerged during transgressive and exposed during regressive episodes.

As Pennsylvanian fusulinids and other shallow-water fauna and algal flora demonstrate a steady repetition approximately every 0.6–1 my in large areas of Paleotethys, we suggest that this cyclicity was governed by global glacial eustasy. Considering the Donets Basin succession, in which subsidence rate is 0.09 mm/y (Izart et al., 2003) and the depth of the basin was varied from 0 to 50 meter, we estimate an approximate eustatic sea level rise and fall for a long-term cycle duration in 0.6–1 my as varying from 0.1 to 0.5 mm/y. Observations in the modern basins documented subsidence rates from 0.1 to 17 mm/y (Schwab, 1976, Dokka, 2006), while uplift in modern mountains, for example calculated for the Coastal Range, Taiwan, is as 0.2-18.5 mm/y (Lundberg and Dorsey, 1990; Ching et al., 2011). Thus, because the values of the large scale glacial eustasy and tectonic rates are commensurate and fusulinid assemblages are indicators of shallow water in different transgressive-regressive episodes, it enables the interpretation of the tectonic evolution of different sedimentary basins.

Relative sea level (RSL) rise during transgression in the intracratonic (Fig.7) and foreland basins (Fig. 8) is a sum of subsidence rate of a basin (red arrow) and global glacial sea level rise (blue arrow). RSL fall during regression is a subtraction between subsidence rate (red arrow) and global sea level fall (blue arrow). Because foreland basins (Fig. 8) and deeper intracratonic basins (Fig. 7) are fusulinid-rich successions, we suggest that the subsidence rate of such basins was not much greater than that in the reference Donets Basin. With greater subsidence rates these basins would be drowned to depth unfavorable for fusulinids.

Nelson (2007) pointed out that Quaternary relative sea level (RSL) change as well as tectonic processes is recorded mainly along shorelines. “One-third to one-half of the Earth’s marine coasts lie along or near tectonically an active plate boundary...Much of our understanding of tectonic processes over hundreds to hundreds of thousands of years has come from study of displacements obtained through mapping and dating sequences of strandlines along tectonically active coasts” (Nelson, 2007, p. 3072). RSL changes in such areas are a composite of eustatic seal level changes, which include vertical movements of the ocean’s surface, and vertical land-level changes along coasts (Nelson, 2007 and references herein).

In orogenic belts (Fig. 8) of the Cantabrian Mountains and Central Asia, RSL during transgression is a subtraction between glacial-eustatic sea level rise and the rate of tectonic uplift. RSL during regression is a sum of glacial-eustatic sea level fall and rate of tectonic uplift. Due to an uplift of strandlines in tectonically active areas, relative sea level changes thus are less than RSL changes in intracratonic basins. At the same time the rate of tectonic uplift must be less than glacial-eustatic sea level rise so that accommodation space is available for accumulation of at least transgressive beds with *Hemifusulina*. If accommodation space for sediment accumulation is formed only during a transgression, as soon as sea level begins falling during regression, the accommodation space is rapidly reduced to zero and no sediment will accumulate, and the area will be exposed and eroded resulting in development of hiatuses.

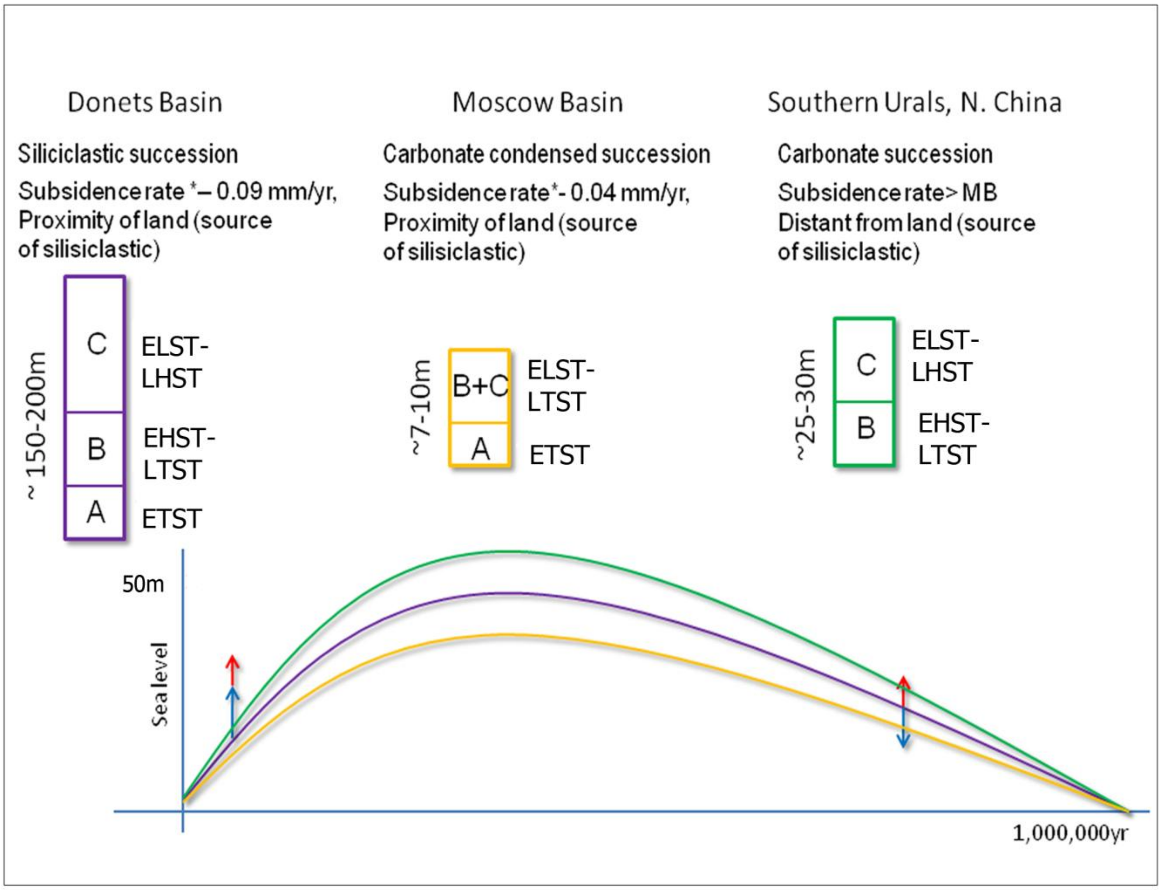

Figure 12. Asymmetrical cycles in intracratonic settings.

A) – *Hemifusulina*-dominated association, B) – *Beedeina*-dominated assemblage, C) – *Fusulinella-Fusulina*-dominated assemblage. Red arrow is tectonic effect to RSL (relative sea level); blue arrow is eustatic effect to RSL. *⁾ Subsidence rates from Izart et al. (2003). The rates of subsidence in the Moscow and Donets Basins reveal discrepancy with thickness of strata. Such inconsistency can be explained by numerous non-depositional events in the Moscow Basin that resulted in deposition of condenced succession.

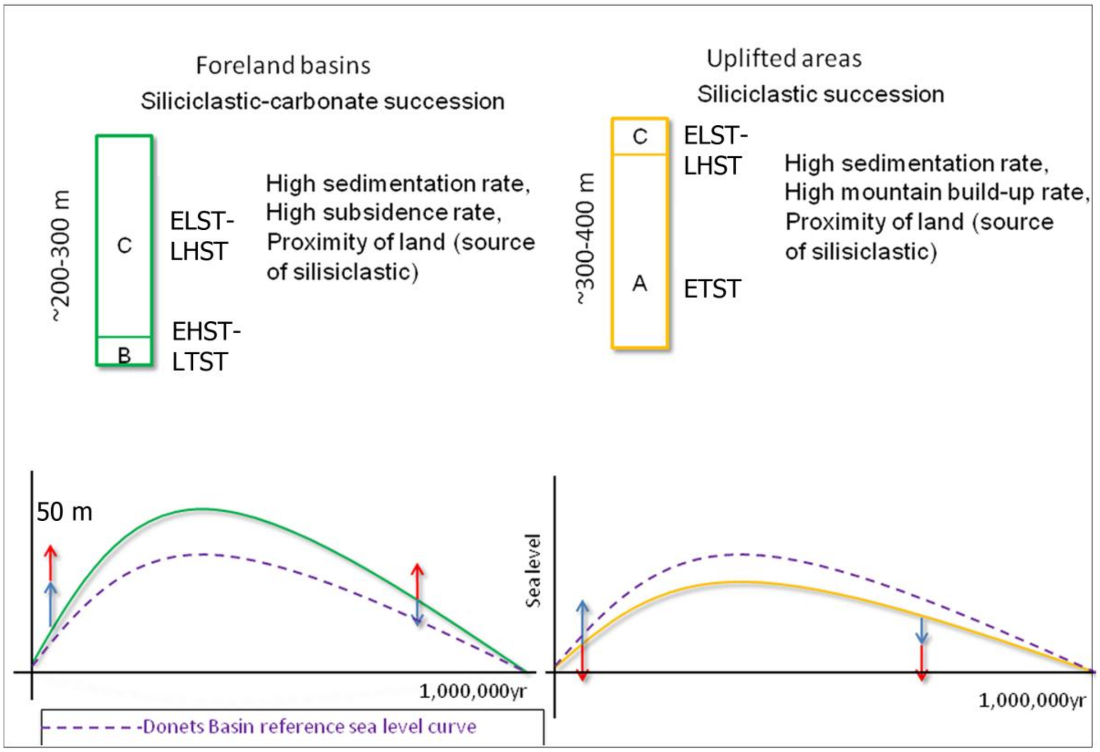

Figure 13. Asymmetric cycles in orogenic belts of Central Asia and Cantabrian Mountains.

A) – *Hemifusulina*-dominated association, B) – *Beedeina*-dominated assemblage, C) – *Fusulinella*-assemblage. Red arrow is tectonic contribution to RSL (relative sea level); blue arrow is eustatic contribution to RSL.

Conclusions

i. A new paleoecological model is proposed for the cyclic reoccurrence of Pennsylvanian fusulinid assemblages in the shallow epicontinental sea of the Donets Basin and linked to glacio-eustatic sea level fluctuations resulting from the waxing and waning of far-field Gondwanan ice caps. New radiometric data obtained from volcanic ashes in the Donets Basin allow estimation of the duration of each fusulinid cycle of ~ 0.6 to 1 my.

ii. Three types of fusulinid assemblages accompanied by specific microfacies and biofacies, and interpreted different sea level stands are recognized. The *Hemifusulina*-dominated assemblage (**A**) indicates the depth of ~10-20 m at the beginning of transgression (TST), the late transgression – high sea level stand is marked by the *Beedeina*-dominated assemblage (**B**) which occupied depths up to 30-50 m (LTST–EHST). This assemblage is successively replaced by the most diverse *Fusulinella*-dominated association (**C**) in a progressively shallowing sea with a depth of 10–30 m (LHST–ELST).

iii. Periodic maximum submergence in the Donets Basin epicontinental sea prior to the Moscovian – Kasimovian transition is recorded by deposition of the limestones M_1, M_5, M_8, N_1^6, N_4, which are characterized by the *Beedeina*-dominated association. This was the time of the decay of the Gondwanan ice caps and the maximum interglacial episodes, events that are recognizable globally and therefore are potentially useful for global correlations.

iv. An extinction event at the Moscovian – Kasimovian boundary, which mainly affected fusulinid genera associated with transgressive episodes

(*Hemifusulina*, *Neostaffella*, *Ozawainella*, *Beedeina*, *Taitzehoella),* can be explained by a global long-lasting glacial event and global regression, resulting in ecological disturbances of their habitat.

v. ‘Symmetrical’ and ‘asymmetrical’ fusulinid distributional patterns are helpful tools in interpretation of basin evolution in different tectonic settings and in reconstruction of the paleo-topography near-shore strandlines during the Pennsylvanian along the eastern margin of “Proto-Pangaea”.

CHAPTER TWO: CYCLIC DISTRIBUTIONAL PATTERNS AND CORRELATION OF THE LATE KASHIRIAN – PODOLSKIAN FUSULINIDS IN THE DONETS BASIN, UKRAINE

Russian Stages (Serpukhovian, Bashkirian, Moscovian, Kasimovian, and Gzhelian) are the international units in the global Carboniferous stratigraphic chart (Heckel, 2004; Gradstein *et al.,* 2004; Goreva *et al.,* 2009). However, GSSPs (Global Boundary Stratotype Sections and Points) for these stages are not yet ratified, because of high provincialism of the fauna in shallow epicontinental seas. Regional chronostratigraphic subunits of the Moscovian Stage in the Moscow Basin include the Vereian, Kashirian, Podolskian and Myachkovian Horizons. Despite the detailed bio- and lithostratigraphic study of this region for more than a century (Makhlina *et al.,* 2001 a, b and references therein), many problems, particularly with Stages and Horizons boundary definitions, remain unresolved. Definition of the boundaries between Horizons, originally based on lithostratigraphic studies, have been repeatedly revised and redefined as new bio- and lithostratigraphic data became available for chronostratigraphic interpretation. This information, however, is not readily available in the western literature and thus the logic behind the definition of the Horizons remains hidden for the international community.

Even the recent comprehensive synthesis of the Moscovian stratigraphy (Makhlina *et al.,* 2001a, b) did not resolve problems with boundary definitions.

Especially problematic is a boundary between the Podolskian and the Myachkovian, first proposed by Ivanov (1926). Makhlina *et al.* (2001a, p.149) pointed out that this boundary is one of the most unclear boundaries in the Moscow Basin because it was defined within a single depositional rhythm. Such a vague and therefore ineffectual position of this boundary is the main cause of discordant correlation of the local upper Podolskian Shchurovo Formation and the lower Myachkovian Korobcheevo Formation even within the Moscow Basin. The fusulinid fauna in both of the Formations is represented by very similar assemblages from the group *Fusulinella bocki.* Further from the type area this boundary becomes more vague resulting in misinterpretation and miscorrelation of the late Moscovian in other regions, for example in the nearest Donets Basin.

The difficulty correlating between the Moscow and Donets basins is further hindered by the fact that fusulinid biostratigraphy in the Donets Basin was not refined or improved for more than 60 years. Many biostratigraphers (Kireeva, 1951; Makhlina *et al.,* 2001a; Ueno and Villa, 1998) therefore believed that difficulties in correlation of the Moscow and Donets basins were linked with high provincialism of the fusulinid assemblages occurring in both regions.

On the contrary, we suppose that many species in the Donets Basin and Moscow Basin are similar and they provide reliable correlation between these important basins. The fusulinid assemblages in both regions have similar cyclic distributional patterns, which are expressed by repetitive occurrence of specific communities in stratigraphic succession. Recent research on Myachkovian fusulinid biostratigraphy in the Donets Basins reveals similar evolutionary trends of the main fusulinid groups in both regions (Khodjanyazova and Davydov, in press).

A refined correlation of these basins is an important step in global correlation because a continuous succession of the Donets Basin is considered pivotal for relating shallow-marine strata of Eastern Europe with terrestrial, coal-bearing deposits of Western Europe and North America. High-precision radiometric ages recently obtained from the Donets Basin (Davydov *et al.,* 2010) provide a numeric calibration of Moscovian Stage and its subunits originally distinguished in the Moscow Basin.

This paper reviews the litho- and biostratigraphy of the Podolskian Horizon in the type area Moscow Basin and presents a fusulinid biostratigraphy from the middle and upper part of suite "M" of the Donets Basin. We recognize the particular cyclic distribution of fusulinid assemblages, which in general is the same in the Moscow Basin at the late Kashirian – Podolskian time. These fusulinid cyclicity patterns significantly refine the regional biostratigraphy and are useful in the interregional correlation in northern Pangaea.

Podolskian Horizon: Historical preview

The Podolskian Horizon in the Moscow Basin was recognized by Ivanov (1926). As conglomerate reveals a new stage in the depositional history of a basin, Ivanov (1926) placed a boundary between the Kashirian and Podolskian at the base of the Rostislav Beds represented by thick (3 m) reddish clays and sandstones with conglomerate at the base (Table 3). Ivanov (1926) did not designate a type section for the Podolskian, but later stratigraphers supposed that it was described in a quarry, near Podolsk, on the north bank of the Pakhra River (Figure 4). The upper boundary of Podolskian was placed at a base of gray bedded marly limestone and clays (2–3 m thick), below the foraminifer-coral limestone (5–7 m in thickness), the latter of which is widely distributed and recognized in the Moscow Basin (Ivanov, 1926). The original thickness of the Podolskian was about 40 m.

Later it was recognized that the Rostislav Beds are discontinuous in their occurrence. Rostislav Beds are overlain by dolomites of the Smedva Formation (Table 3) that was also first distinguished by Ivanov (1926). The characteristics of this formation came from the outcrops in the Valley of the Smedva River, a tributary of the Oka River, to the south of Moscow city (Fig. 14). Due to the lack of these outcrops in present time, Makhlina *et al.* 2001a proposed an interval of 12.4–25.4 m in well 4k, near Kiyasovo village (Fig.14) as a type section of the Smedva Formation.

The most comprehensive strata for interbasinal correlation in terms of fusulinid fauna and lithostratigraphic characteristics, in our opinion, is a succession of the Smedva Formation from Tver Oblast, the Rzhev area, near the town of Staritsa, on the bank of the Kholokholnya River (Fig. 14, 15B; see Reitlinger and Balashova, 1954, section 37, figure 3, 4). In the Kholokholnya section the upper Kashirian strata of the Smedva Formation were subdivided by Makhlina *et al.* (2001a) into three units: the lower Member ($C_2sm_{1,}$ beds 25–30, unit VIII; Fig. 15B; Table 3); the middle Member ($C_2sm_{2,}$ beds 31–32, unit IX; Fig. 15B; Table 3); and the upper Member ($C_2sm_{3,}$ bed 33, unit X and beds 1-5, units XI; Fig. 15B; Table 3). Beds 1-5 originally were considered as lower Podolskian described from the section 37, therefore the bed’s number is changed (Reitlinger and Balashova, 1954, p. 142–146, 151-153).

In the lower Member of the Smedva Formation (C_2sm_1) numerous fossils are documented in a thin-bedded clayed crinoid packstone with echimodermata, ostracods and brachiopods. Small foraminifers are represented by *Endothyra*, *Hyperammina*, *Ammodiscus*, *Ammovertella*, *Tolipammina*, and *Haplophragmina* species. Fusulinids *Fusiella* and *Schubertella* species occur in beds 27 and 30; *Taitzehoella* and *Hemifusulina* occur only in bed 30 (Reitlinger and Balashova, 1954, p. 143, Makhlina *et al.,* 2001a, p. 108). Generic names here and in the entire paper are given in our interpretation that is often different from the original references. Makhlina *et al.* (2001a) believed that beds 25–29 belong to C_2sm_1, while bed 30 was included to the middle Smedva (C_2sm_2). The thickness of the lower Member, beds 27–30 in this section is 3.5 m and varies from 2 to 8 m in the Moscow Basin.

The middle Member of the Smedva Formation (C_2sm_2) is characterized by an assemblage of frequent and diverse *Hemifusulina* with subordinate *Fusiella* and *Schubertella* species (Reitlinger and Balashova, 1954, p. 144-145, Makhlina *et al.* 2001a, p. 108-109). The fusulinid assemblage in bed 31 is represented mainly by *Hemifusulina* species: *H. pulchella* Rauser, *H. paraelliptica* Rauser, *H. communis* Rauser, *H. elegantula* Rauser, *H. praelegantula* Rauser, H. aff. *kashirica*, *H.* aff. *subrhomboides* Rauser, *H. natalinae* Rauser, and *H. moelleri* Rauser. Fusulinids in bed 32 are more diverse and include *Hemifusulina*, *Fusiella*, *Taitzehoella* and *Schubertella* species. Makhlina *et al.* (2001a) considered the middle unit (beds 30–32, unit IX) as the middle Member of the Smedva Formation (C_2sm_2). The thickness of the unit IX (beds 30–32) in this section is 1.05 m and varies from 3 to 10 m in the Moscow Basin.

The upper Member of the Smedva Formation (C_2sm_3, in Makhlina *et al.,* 2001a, p. 121) is represented by limestones with chert nodules and includes an interval of the units X (bed 33, 1.20 m thick) and XI (beds 1–5, 3.5 m thick). The thickness of this unit (beds 33–5) in the Kholokholnya section is 4.7 m and varies from 2 to 9 m in the entire Moscow Basin.

Reitlinger and Balashova (1954, p. 159-160) analyzing fusulinids in this interval, which are represented by abundant *Hemifusulina* and large *Neostaffella* species, pointed out that this assemblage is transitional from Kashirian to Podolskian and considered the unit XI as Podolskian. Makhlina *et al.* (2001a) followed by Ivanova and Khvorova (1955) included the unit XI into the Smedva Formation, which is the late Kashirian. They defined a boundary between Kashirian and Podolskian Stages at a base of the unit XII (with *Putrella*, typical *Neostaffella sphaeroidea cuboides*, *Fusulinella* ex gr. *colanii*) because of widely distributed in the Moscow Basin unconformity marked by the limestone conglomerate at the base of bed 6.

Because the Smedva Formation was excluded from the Podolskian (Rauser-Chernousova and Reitlinger, 1954; Reitlinger and Balashova, 1954; Ivanova and Khvorova, 1955), the total thickness of the Podolskian strata is reduced from about 40 m (Ivanov, 1926) to about 20 m (Makhlina *et al.,* 2001a).

Rauser-Chernousova and Reitlinger (1954) stated an ambivalent position to the lower boundary of the Podolskian. On one hand, they accepted litho-biostratigraphic units proposed by Ivanov (1926) and noted the usefulness of his stratigraphic charts for regional correlation. The established fusulinid zone *Hemifusulina subrhomboides* – *Beedeina elegans* included Smedva dolomites and the Vaskino Formation (Table 3). On the other hand, they pointed out that the lower boundary proposed by Ivanov (1926) is difficult to recognized in distant provinces because of restricted occurrence of *Hemifusulina*. Thus, Rauser-Chernousova and Reitlinger (1954) placed the lower boundary of the Podolskian at the top of Smedva dolomite and within the *Hemifusulina subrhomboides – Beedeina elegans* fusulinid zone. This boundary then became commonly accepted (Ivanova and Khvorova, 1955; Makhlina *et al.,* 2001a).

Solovieva (1986) believed that fusulinids occurred in Smedva Formation are Podolskian in age and defined a Kashirian – Podolskian boundary at the base of the Smedva dolomites. She proposed a zone *Fusulinella colanii– Beedeina elegans*, which includes strata of the Smedva and Vaskino Formations (Table 3).

Conodont studies (Gerelzteztег, 1996, Alekseev *in* Makhlina *et al.,* 2001b) reveal similar conodont species in the Smedva and Vaskino Formations. Gerelzteztег (1996) defined a *Streptognathodus consinnus–Idiognathodus robustus* Zone, the base of which coincides with the first occurrence of *Streptognathodus consinnus* at the base of the Smedva dolomites. In the upper part of this formation the first *Idiognathodus podolskensis* and *Idiognathodus delicatus* occur, which became common in the Podolskian (Alekseev in Makhlina *et al.,* 2001b). Thereby Alekseev (Alekseev in Makhlina *et al.,* 2001b) made a suggestion that it would be reasonable to include the Smedva Formation into the Podolskian Stage, and the original definition of this stage first proposed by Ivanov (1926).

Currently, the lower boundary of the Podolskian Horizon is defined above the Smedva Formation, at the base of limestone conglomerates of the Vaskino Formation (Makhlina *et al.,* 2001a). The Podolskian in the Moscow Basin includes the Vaskino, Ulitino and Shchurovo Formations, which were first proposed by Khvorova (1951, 1953) and described in detail by Ivanova and Khvorova (1955). Strata of the Vaskino Formation outcrop near the villages of Obraztsovo and Vaskino on the Lyutorka River, a tributary of the Lopasnya River (Figs. 14, 15C; see Ivanova and Khvorova, 1955, figure 20). In the bed 2 (the Vaskino Formation) abundant fusulinids occurred: *Neostaffella sphaeroidea* (Moeller), *N. sphaeroidea cuboides* Rauser), *N*. cf. *rostovzhevi* Rauser, *N*. cf. *larionovae mosquensis* (Rauser), *Ozawainella angulata* (Colani), *O. mosquensis* Rauser, *O*. ex gr. *stellae* Manukalova, *Hemifusulina bocki* Moeller, *H*. cf. *rjasanensis* Rauser, *H. stabilis* Rauser and Safonova, *H. subrhomboides* Rauser, *Fusulinella* ex gr. *colanii* Lee and Chen, *Beedeina elegans* (Rauser and Belyaev), *B. elegans decurta* Rauser, *B. elegans devexa* Rauser, *B. elshanica vaskensis* Rauser, and *B*. cf . *samarica* (Rauser and Belyaev). Reitlinger and Balashova (1954) recognized a similar assemblage is in Tver Oblast, section 37, near the village of Kholokholnya, beds 6-7, unit XII (Figure 15B, Table 3).

The type section of the Ulitino Formation described by Reitlinger and Balashova (1954) outcrops near the village of Ulitino in Tver Oblast, on the east bank of the Volga River, to the north of the town of Staritsa (Fig. 14, 15B). This formation is characterized by the presence of biostromes with green phylloid algae, *Ivanovia tenuissima* Khvorova and green algae *Dvinella chomata* Khvorova. Reitlinger and Balashova (1954, p. 153–154) recognized units XIV and XV in section 31, near Ulitino and in section 30, near the village of Svistunovo (Fig. 14; Table 3), with abundant fusulinids in biogenic packstones, which are overlying the algal biostromes (Fig. 15B). Fusulinids of this formation are represented by *Neostaffella sphaeroidea cuboides* Rauser, *Ozawainella angulata* (Collani), *O. angulata angusta* Rauser, *Fusulinella praebocki* Rauser, *F. mosquensis* Rauser, *F. vozhgalensis* Safonova, *F. pseudobocki* Lee and Chen, *F*. ex gr. *bocki* Moeller, *F. paracolaniae* Safonova, *F. colanii* Lee and Chen, *Hemifusulina dutkevitchi* (Putrja), *H.*

ex gr. *bocki* Moeller, *Fusiella typica* Lee et Chen, *F. typica ventricosa* Rauser, *Beedeina schellwieni* (Staff), *B. nytvica callosa* (Safonova), *P. elegans devexa* (Rauser), *Fusulina innae* Rosovskaya, and *F. ulitinensis* (Rauser). Solovieva (1986) restudied this interval and defined a local *Fusulinella vozhgalensis – Fusulina ulitinensis* Zone.

The Shchurovo Formation consists of predominantly coral and foraminiferal-crinoid packstones with subordinate beds of dolomites, marls and clay (Khvorova, 1951, 1953). Fossiliferous limestones often include chert nodules. The Shchurovo Formation studied in detail by Ivanova and Khvorova (see Ivanova and Khvorova, 1955, figure 20-29) is near the town of Shchurovo (Figure 14, 15C, Table 3). Makhlina *et al*. (2001a, p. 141) summarizing previous studies, pointed out that fusulinid assemblage of the Shchurovo Formation became less diverse. They recognized considerable reduction of *Neostaffella* and *Hemifusulina* species. The typical fusulinids in this formation are *Beedeina elshanica* (?) (Putrja and Leontovich) and *Kamaina chernovi* (Rauser). Other fusulinids, such as *Ozawainella angulata* (Colani), *O. tingi* (Lee), *Taitzehoella librovitchi* (Dutkevich), *Fusulinella helenae* Rauser, and *Parawedekindellina pechorica* Rauser, occur in this formation. Solovieva (1986) defined *Ozawainella mosquensis* Rauser, *Fusulinella bocki timanica* Rauser, *F. vozhgalensis* Safonova, *Kamaina kamensis* (Safonova), *Beedeina schellwieni* (Staff), *B. elshanica* (Putrja), *B.elegans* (Rauser and Belyaev), and *Putrella brazhnikovae* (Putrja).

The upper boundary of the Podolskian proposed by Ivanov (1926) at a base of the gray bedded marly limestone and clays 2-3 m below the “foraminifer-coral” packstone and grainstone was changed by Ivanova (1947) and placed at the base of the latter unit, as these strata unconformably overlay the older Podolskian beds and are traceable laterally within the Moscow Basin. However, fusulinid assemblages of the upper Podolskian and Lower Myachkovian are similar and precise position of this boundary is difficult to recognize outside of the Moscow Basin. The definition of this boundary is complicated because of continuous regressive sedimentation within the Podolskian – Myachkovian transition and development of highly endemic foraminiferal fauna.

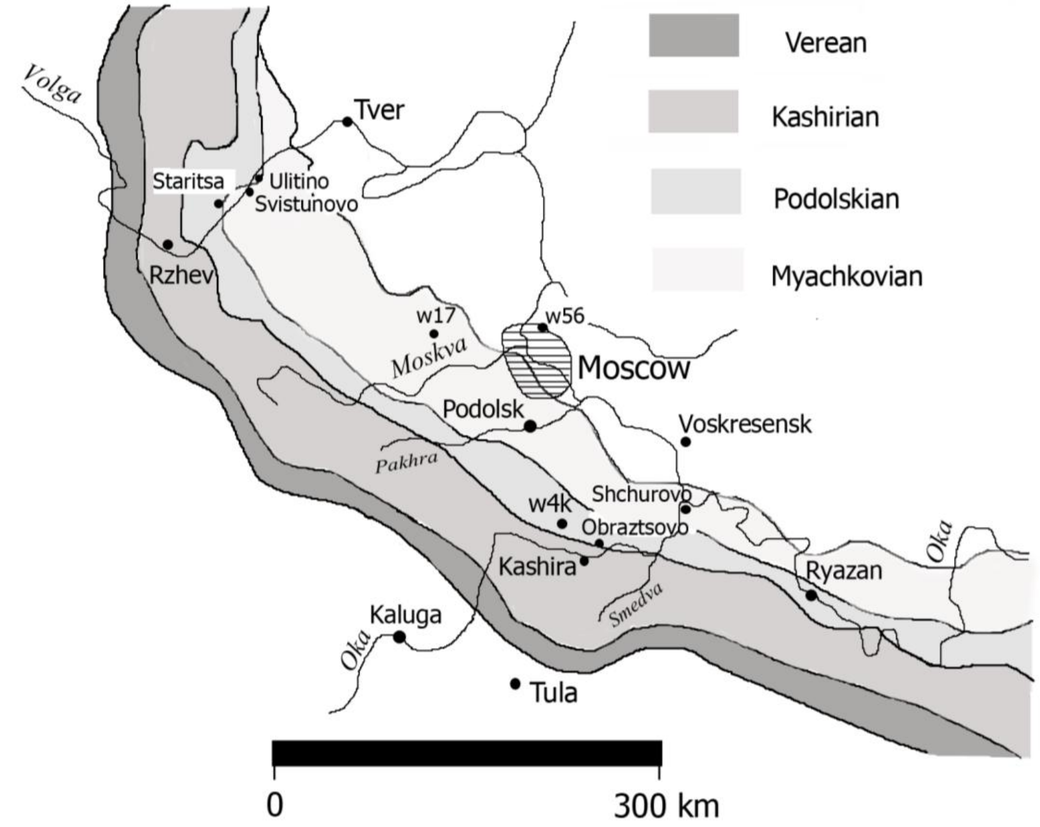

Figure 14. Location map of the Moscow Basin with a position of the main typical sections for the upper Kashirian - Podolskian strata. Modified from Makhlina *et al.* (2001a).

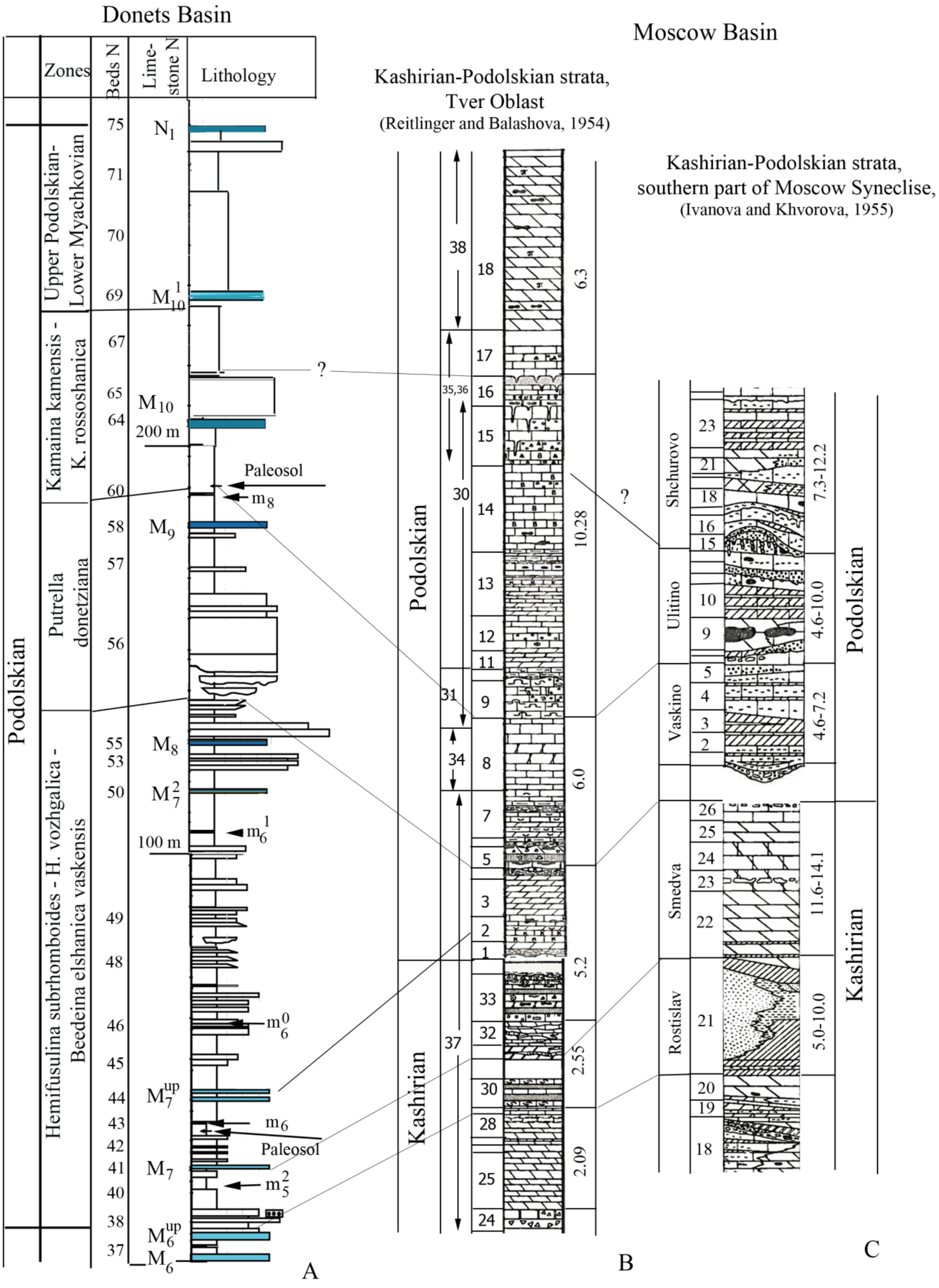
Donets Basin
Zones
Beds N
Lime-stone N
Lithology
Podolskian
Upper Podolskian-Lower Myachkovian
Kamaina kamensis - K. rossoshanica
Putrella donetziana
Hemifusulina subrhomboides - H. vozhgalica - Beedeina elshanica vaskensis
75
71
70
69
67
65
64
60
58
57
56
55
53
50
49
48
46
45
44
43
42
41
40
38
37
N_1
M_{10}^1
M_{10}
200 m
Paleosol
m_8
M_9
M_8
M_7^2
m_6^1
100 m
m_6^0
M_7^{up}
m_6
Paleosol
M_7
m_5^2
M_6^{up}
M_6
A
Moscow Basin
Kashirian-Podolskian strata, Tver Oblast
(Reitlinger and Balashova, 1954)
?
Podolskian
Kashirian
38
35,36
30
31
34
37
18
17
16
15
14
13
12
11
9
8
7
5
3
2
1
33
32
30
28
25
24
6.3
10.28
6.0
5.2
2.55
2.09
B
Kashirian-Podolskian strata, southern part of Moscow Syneclise,
(Ivanova and Khvorova, 1955)
?
Shchurovo
Ulitino
Vaskino
Smedva
Rostislav
23
21
18
16
15
10
9
5
4
3
2
26
25
24
23
22
21
20
19
18
7.3-12.2
4.6-10.0
4.6-7.2
11.6-14.1
5.0-10.0
Podolskian
Kashirian
C

Figure 15. Correlation of the Upper Kashirian – Podolskian strata of the Donets and Moscow Basins.

A) – the Gurkovo section of the upper part of the "M" Formation, redrawn from Eros J. M. (2010), bed numbers from a section described by Makarov (1985). Composite succession of the Upper Kashirian – Podolskian strata in the Moscow Basin: B) – Tver Oblast (Reitlinger and Balashova, 1954). C) – Southern part of the Moscow Syneclise (Ivanova and Khvorova, 1955).

History of Moscovian fusulinid and conodont zonations in the Donets Basin and their correlation with the Moscow Basin

Because of the completeness of the Donets Basin succession and the occurrence of rich marine and continental fossils, this region becomes an important standard in northern Pangaea (Rotai, 1979; Wagner *et al.*, 1996). Many biostratigraphic studies were conducted in the Donets Basin during the 1930s-1960s thanks to extensive exploration of coal deposits. The middle-upper Pennsylvanian fusulinid taxonomy and biostratigraphy were first developed in this region by Putrja (1939, 1940, 1956) and Kireeva (1951) and have been successfully utilized in regional correlation.

Kireeva (1951) first analyzed the biostratigraphic distribution of fusulinids in the Donets Basin and proposed the following correlation of the Moscovian with the coeval strata of the Moscow Basin. Suite K (C_2^5) in the Donets Basin she correlated with the Vereian Stage of the Moscow Basin, and Suite L (C_2^6) and Suite M (C_2^7) with Kashirian and Podolskian respectively. Based on the occurrence of fusulinids *Fusulinella colanii* Lee and Chen, *Ozawainella stellae* Manukalova, *Putrella brazhnikovae* (Putrja and Leontovich) in the lower part of the “M” Formation, Kireeva (1951) assigned the age of this formation as Podolskian (Table 4). Putrja (1956) divided the “M” Formation into two biostratigraphic zones. The first zone included limestones L_7–M_7 and was considered to be Podolskian, whereas the upper part of the “M” and the lower part of the “N” Formations (M_8 – N_1^2), he suggested belong to the Myachkovian (Table 4). Aisenverg *et al.* (1963, 1975) also defined five biozones within the Moscovian (Table 4). Aisenverg *et al.* (1975) first proposed that lower boundary of the Moscovian at the base of the limestone K_3. In the “M” Formation they delineated two subzones: $\mathbf{C_2^mc}$ included the group of limestones (L_7–M_5) and $\mathbf{C_2^{m}d}$ encompassed the limestones M_6–M_{10}. Aisenverg *et al.* (1975) considered the lower zone as Podolskian, whereas the upper $\mathbf{C_2^{m}d}$ zone together with a $\mathbf{C_2^{m}e}$ zone in the lower part of the "N" Formation (M_{10}^1–N_2) as Myachkovian in age (Table 4; *Fusulina cylindrica*, *Fusulinella bocki*, *Fusulinella pseudobocki* Zone). The most recent fusulinid studies (Vachard and Maslo *in* Izart *et al.,* 1996, Ueno *in* Fohrer *et al.,* 2007) also suggested that the lower boundary of the Podolskian in the Donets Basin coincides with the base of M_1 or L_7 limestone, whereas the upper boundary coincides with the base of the N_3 limestone.

The first conodont studies in the Donets Basin (Kosenko, 1975; Kozitskaya *et al.*, 1978) contributed a new alternative correlation and designated a Moscovian age for the strata between the limestone L_3 and N_3^3. On basis of conodont biostratigraphy, Barskov *et al.* (1984) were the first to recognize the inconsistence in correlation between Moscow and Donets Basins. They proposed that an interval of the limestones K_3–K_9 is coeval to the Vereian Horizon, Suite "L" as an analogue of the Tzna Formation (lower Kashirian) of the Moscow Basin. The interval of the limestones M_1–M_8 they correlated with the Kashirian Horizon "sensu stricto = upper Kashirian", whereas the Podolskian Horizon was correlated with the limestones M_9–$M_{10.}$ The Myachkovian Horizon was correlated with the interval of the limestones of M_{10}^1–N_3 (Table 4). Using conodont phylogenies, Gereltzetzeg (1996) attempted to correlate Moscow Basin Horizons with the limestones of the Donets Basin. She suggested that the K_2–K_6 limestones correspond to the Shatska and Aljutovo Formations, and that the K_7–K_8 limestones correspond to the Ordynska Formation of the Vereian Horizon. The Kashirian Horizon (Nara, Lopasnya, and Smedva Formations) included strata between L_1 and M_{10} limestones; the Nara Formation corresponds to the interval between the limestones L_1–M_1, the Lopasnya Formation is characterized by the strata starting from the M_2 limestone, whereas the base of the Smedva Formation is correlated with the base of M_9 limestone in the Donets Basin (Gereltzetzeg, 1996). Nemyrovska *et al.* (1999) described several new species, including index species *Declinognathodus donetzianus* and proposed a *Declinognathodus donetzianus* Zone within the $K_3 – K_6^2$ limestones, which were correlated with the Vereian. The Kashirian was correlated with $K_6^3 – M_1$, the Podolskian with $M_1 – N_1$, and the Myachkovian with $N_2 – N_4$ intervals.

Makhlina *et al.* (2001a, 2001b) revised all previous studies in the Moscow Basin and proposed a new version of the correlation of the Pennsylvanian strata with the Donets Basin. The base of the Moscovian was correlated with the limestone K_2 that coincides with the base of the *Declinognathodus donetzianus* conodont Zone distinguished at the lower part of the Aljutovo Formation of the Vereian Horizon in the Moscow Basin. The Ordynska Formation is correlated with the interval of the limestones K_6–K_8 (Nemyrovska *et al.,* 1999). Makhlina *et al*. (2001a) pointed out that the interval of the Kashirian and Podolskian strata is poorly correlated even by conodonts and placed the Kashirian–Podolskian boundary within the interval of the limestones M_6–M_7. The upper part of Podolskian and lower part of Myachkovian are also poorly correlated. Makhlina *et al.* (2001a) defined a boundary between these Horizons within a poorly exposed interval of several thin-bedded limestones grouped in the N_1. The top of the Moscovian Stage in the Moscow Basin is traditionally placed the base of the Suvorovo Formation that is correlated with the interval between the limestones N_2 and N_3 (Makhlina *et al.,* 2001a, p. 218-220).

Recent conodont research (Nemyrovska, 2011) designated the Kashirian–Podolskian boundary at the base of the limestone M_{10}, where a *Schwadelina* sp.1 Zone is proposed. This zone is correlated with the *Neognathodus medexultimus – Neognathodus podolskensis* Zone distinguished in the Moscow Basin (Makhlina *et al.,* 2001a; Nemyrovska, 2011) and is coeval to the Vaskino and lower Ulitino Formation (Table 4).

Transgressive-regressive cycles	Donets Basin fusulinid assemblages	Ivanov, 1926				Tver Oblast, Rzhev, Reitlinger and Balashova, 1954			Southern part of Moscow Syneclise						Solovieva, 1986			Makhlina et al., 2001a			
									Rauser-Chernousova and Reitlinger, 1954			Ivanova and Khvorova, 1955									
		Stage	Horizon	Formation		Horizon	Local units	Bed units	Horizon	Local units	Fusulinid zo	Horizon	Formation	Members	Horizon	Formation	Fusulinid zones	Horizon	Formation	Fusulinid zones	Conodont zones
		Moscovian	Myachkovian	C_{II}^{4}		Myachkovian	C_2^{2m-b}		Myachkovian	C_2^{2m-b}	6	Myachkovian	Peskovo		Myachkovian	Peskovo	15	Myachkovian	Peskovo	27	36
																				26	
							C_2^{2m-a}												Domodedovo		
										C_2^{2m-a}	5		Novlinsk			Novlinsk	14				
																			Korobcheevo	25	35
ETST-LTST																					
	N_1?		Podolskian	C_{II}^{3}		Podolskian	C_2^{2pd-c}	XVII	Podolskian	C_2^{2pd-c}		Podolskian	Shchurovo		Podolskian	Shchurovo	13	Podolskian	Shchurovo	24	
LHST-ELST							C_2^{2pd-b}	XIV-XVI		C_2^{2pd-b}	4		Ulitino			Ulitino	12		Ulitino	23	
	M_{10}																				34
	M_9							XI-XII		C_2^{2pd-a}	3		Vaskino			Vaskino	11		Vaskino	22	
ETST-LTST					Smedva		C_2^{2pd-a}														
	M_7^{up}											Kashirian	Lopasnya	Smedva		Smedva		Kashirian	Smedva	21	33
	M_7					Kashirian	C_2^{2k-c}	VIII-X	Kashirian	C_2^{2k-c}											
			Kashirian	C_{II}^{2}							2			Rostislav	Kashirian	Rostislav				20	
	M_5							VII								Lopasnya	10		Lopasnya		32
							C_2^{2k-b}			C_2^{2k-b}											
								III					Nara			Khatun				19	31
								II								Nara	9		Nara		
																				18	
							C_2^{2k-a}			C_2^{2k-a}	1										
								I							Tzn in-	Tzna	8		Tzna		
			Verean	C_{II}^{1}		Verean	C_2^{2vr}		Verean	C_2^{2vr}		Verean	Ordynska		Verean	Aljutovo	7	Verean	Ordynska	17	30
																					29
													Aljutovo						Sknigovo	16	28
													Shatska			Cherevsk			Aljutovo		

Table 3. History of establishing and definition of the Kashirian - Podolskian boundary in the Moscow Basin based on litho- and biostratigraphy

Fusulinid Zones: 1-*Ozawainella* ex gr. *digitalis*; 2-*Hemifusulina kashirica - H. moelleri*; 3-*H. subrhomboides - Fusulina elegans*; 4-*F. ulitinensis - F. pancouensis*; 5- *Fusulinella bocki*; 6- *F. cylindrica*; 7-*Profusulinella cavis -Aljutovella aljutovica - A. artificalis*; 8- *A. priscoidea - A. znensis - H. vozhgalica*; 9-*H. kashirica - H.moelleri – Beedeina pseudoelegans*; 10- *Moellerites lopasniensis- B. ozawai, Fus. subpulchra*; 11-*Fus. colaniae – B. elagans*; 12-*Fus. vozhgalensis- F. ulitinensis*; 13- *B. kamensis - Putrella brazhnikovae*; 14-*Fus. bocki- Fus. rara – B. samarica*; 15-*Fus. podolskensis – F. cylindrica*; 16-*A. aljutovica*; 17-*Ovatella arta*; 18-*Priscoidella priscoidea*; 19-*H. moelleri - B. pseudoelegans*; 20- *Moellerites praecolaniae – Fus. subpulchra*; 21-*H. vozhgalica*; 22-*P. brazhnikovae*; 23-*Fus. colaniae - B. ulitinensis*; 24-*F. chernovi;* 25-*Fus. bocki*; 26-*F. cylindrica*; 27-*Protriticites ovatus.*

Conodont Zones: 28 - *Declinognathodus donetzianus*; 29 - *Idiognathodus. ouachitensis*; 30 - *Streptognathodus transivitus*; 31 - *Neognathodus bothrops*; 32 - *N. medadumtimus*; 33 - *S. consinnus - Id. robustus*; 34-*Id. podolskensis - N. medexultimus*; 35-*N. inaequalis*; 36-*N. roundyi*.

Limestones	Kireeva, 1951	Putrja, 1956	Aisenverg et al., 1975		Barskov et al., 1984	Solovieva, 1986	Izart et al., 1996	Makhlina et al., 2001 a	Ueno in Fohrer et al., 2007	Nemyrovska, 2011	This paper
N1-5			Krevyakian	C_3^a					Krevyakian	Krevyakian	Krevyakian
N4						Myachkovian					
N31											
N3					Myachkovian						
N21	Myachkovian						Myachkovian	Myachkovian	Myachkovian	Myachkovian	Myachkovian
N2			Myachkovian	$C_2^m e$							
N1-4											
N1-3										Podolskian	
N1											
M10-2	Podolskian					Podolskian					
M10-1											
M10				$C_2^m d$	Podolskian		Podolskian				Podolskian
M9									Kashirian	Kashirian	
M8					Kashirian						
M7-2		Podolskian									
M7											
M6-up								Kashirian			
M6											
M5			Podolskian	$C_2^m c$							
M1											
L7-3	Kashirian				Tzninskian	Kashirian	Kashirian				
L7-1											
L7				$C_2^m b$							
L6			Kashirian								
L1											
K9	Verean		Verean	$C_2^m a$	Verean	Verean				Verean	
K8								Verean			
K7									Verean		
K6											
K5							Verean				
K3											

Table 4. Correlation of Moscovian Stage in the Donets and Moscow Basins

Integrated biostratigraphic and sequence stratigraphic (cyclic) zonation for the Podolskian in the Donets Basin

Material

Material for this study was collected from the type section of the “M” Formation in the Donets Basin, in Gurkovo ravine, which is incised in the western riverside of the Lugan River and extends in the southern direction from the town of Pervomaisk, Donetsk Oblast, Ukraine (Fig. 1). In this paper we focus on fusulinids of the upper Kashirian – Podolskian in the interval between Limestones M_7 and M_{10} (Fig. 15A). Unfortunately no material from limestone beds (M_{10}^1, M_{10}^2) is available for this study, therefore the biostratigraphy of the Podolskian – Myachkovian boundary is not provided in this paper.

Fusulinid biozonation and its correlation with the Moscow Basin

A new integrated biostratigraphic and sequence stratigraphic approach for a biozone definition in the Donets Basin is proposed. Fusulinid biozones defined in this paper are acme or assemblage zones in which an abundant occurrence of the index and associated species is probably related to relative sea-level change and therefore the bases and tops of proposed zones we bound with unconformities, erosional surfaces or soil formations.

Stratigraphic distribution of Pennsylvanian fusulinids in the Donets Basin reveals predictive repetitive patterns, which seem to be related with sea level transgressive-regressive cycles. A model of a cyclic recurrence of the fusulinid assemblages in the Pennsylvanian siliciclastic-carbonate succession in the Donets Basin (Khodjanyazova *et al.,* 2011) is discussed in detail in CHAPTER ONE.

A *Hemifusulina*-dominant assemblage (A) characterizes the beginning of transgression (ETST) and marks a new step in basin evolution (Figs. 2, 3, 9, 10). This assemblage is mainly associated with muddy thin-bedded limestones (silty packstone and wackstone), interbedded with siltstone, siliciclastic mudstone and coals (L_7^1, M_3^{up}, M_7). As a basin became deeper during transgression, the assemblage of fusulinids is diversified; species of *Beedeina*, *Taitzehoella*, *Neostaffella*, and *Ozawainella* appeared along with the continuous existence of *Hemifusulina* species in the late stages of transgression (L_7^1, M_7^{up}, Fig. 3). This stage can be defined as a *Hemifusulina* zone (or subzone).

I suggest that some species of *Beedeina*, *Taitzehoella*, *Neostaffella*, *Ozawainella* (B) with specific morphology could survive at deeper water during maximal transgression (LTST, Figs. 2, 3, 9, 10); this assemblage excludes *Hemifusulina* species. Thus, I propose to assign acme zones, which mark episodes of maximal transgression, associated with limestone (wackstone) usually greatest in thickness, and are characterized by an abundance of *Beedeina*, *Taitzehoella*, *Neostaffella*, and *Ozawainella* species. This part of the succession is characterized by an absence of coal beds and plant remains in fine siliciclastic strata (M_1, M_5, M_8; Fig. 3, 10). The interval characterized by this assemblage has usually wide geographic expansion. Therefore I suggest defining this episode as a separate zone/subzone with index-species represented by *Beedeina*, *Neostaffella*, or *Ozawainella*.

A *Fusulinella–Fusulina* assemblage (C) occurs in a shoaling upward succession deposited during sea regression (Figs. 2, 3, 9, 10). Limestones deposited during regression are usually fusulinid-rich packstone and grainstone (M_2, M_6, M_6^{up}, M_9, M_{10})

associated with more coarse siliciclastics, although coal seams also occurred in this part of a cycle. As regressive episodes in eustatic sea level fluctuation are slower than transgressive events that confirmed by fusulinid evolution, two or more acme zones can be distinguished in the regressive strata within each transgressive-regressive cycle. The first is associated with late high sea level stand (LHST, Figs 2, 3, 9, 10) and characterized by an abundance of *Fusulinella* species. The second is associated with early low sea level stand (ELST, Figs. 2, 3, 9, 10) and characterized by very elongated subcylindrical *Fusulina* species, which in the proposed model mark the shallowest depth at which fusulinids could survive.

In biozone definition I also use a general evolution trends within cycle (Fig. 2) documented in morphological changes of four genera (*Beedeina, Taitzehoella, Neostaffella* and *Ozawainella*).

The approach proposed in this paper is a useful tool in correlation of different basins. I used these successively replaced patterns to refine regional biostratigraphy and recognize similar trends in the Moscow Basin and other basins of the Tethyan realm. I analyze the correlative potentiality of all three proposed assemblages and recognize that early transgressive *Hemifusulina*-beds (A) have high correlative capability between the Donets and Moscow Basin. Late transgressive beds (B) in the Donets Basin are characterized mainly by four genera: large *Neostaffella*; discoid, highly compressed at the axial ends *Ozawainella*; and relatively small for their genera, subrhomboidal by shape *Beedeina* and *Taitzehoella* species. In the Moscow Basin that we suppose was shallower than the Donets Basin, late transgressive beds do not always contain the *Beedeina* species, whereas the presence of large *Neostaffella* and discoid *Ozawainella* make the recognition of coeval beds in the Moscow Basin possible. At the same time the late transgressive beds, characterized by *Beedeina*, which we suggest is a deeper-water genus, and other accompanying genera, have high correlative capability between the Donets Basin and other regions of Tethyan realm, such as Central Asia, the Cantabrian Mountains, the Southern Urals, and Northern China, which underwent higher subsidence rates. The hypothesis that *Beedeina* and *Neostaffella* preferentially occupied deeper subtidal environments, whereas *Fusulinella*, and *Quasifusulinoides* (*Fusulina*'s descendant) preferred shallower mid- to inner shelf environments, is also confirmed by Forke *et al.* (2010) for the Moscovian–Kasimovian of the Svalbard shallow marine platform, Norway.

The regressive fusulinid assemblage (C) is characterized by diverse *Fusulinella*, *Schubertella*, *Fusulina*, elongated fusiform *Beedeina* and *Taitzehoella*, smaller species of *Neostaffella* (or *Pseudostaffella*) and *Ozawainella*. The regressive associations defined in the Donets Basin are usually represented by two or sometimes three limestones and are also recognized in the Moscow Basin; however their correlative potential is gradually decreased (temporally) to the end of each cycle. At the same time the correlation becomes difficult for the far-field basins, such as Central Asia and the Cantabrian Mountains, because of high endemism developed at the ends of cycles during maximum drop in sea level.

In the "M" Formation of the Donets Basin, Ukraine, we recognize three full transgressive-regressive cycles of low-frequency glacial-eustatic sea level fluctuations (Khodjanyazova *et al.,* 2011). The first cycle includes the interval between limestones L_7^1 and M_3, with maximum transgression in M_1; the second includes limestones M_3^{up}–M_6^{up}, with maximum transgression in the M_5; and finally the interval between the limestones M_7 and M_{10}^1 belongs to the third cycle with maximum transgression in the limestone M_7^2 or M_8 (Figure 2).

The first two cycles are probably coeval with the Kashirian, Nara and Lopasnya Formations. The third transgressive-regressive cycle in the interval between the M_7 and M_{10}^1 limestones corresponds to the upper Kashirian (Smedva Formation) and Podolskian (Vaskino, Ulitino, Shchurovo Formations) Horizons (Makhlina *et al.,* 2001a), or to the most Podolskian stage 'sensu stricto' (Tables 1, 2) proposed by Ivanov (1926). A reduction of volume of Podolskian strata in the Moscow Basin due to the removal of the Smedva dolomites causes a considerable shortening of duration of the Podolskian since its first definition.

Hemifusulina subrhomboides – H. vozhgalensis – Beedeina elshanica vaskensis Zone

This zone includes beds 38–55 in the Gurkovo section (Appendix A, Figure 15A), and is 123.21 m in thickness. This zone comprises of two subzones. The lower *Hemifusulina vozhgalica – Hemifusulina subrhomboides* Subzone marks the beginning of a transgression and is recognized in the proximal part of the large Eastern European Craton, Moscow Basin and in the Donets Basin. The upper *Beedeina elshanica vaskensis* Subzone, as we suggest, indicates the maximal transgression and is traceable in the deeper distal parts of the Tethyan realm. It is impossible to distinguish a *Hemifusulina vozhgalica – Hemifusulina subrhomboides* Subzone in distal parts of the Tethyan realm because of restricted occurrence of *Hemifusulina*. Thus, one zone that combines the two subzones is proposed here. A transgression is a relatively rapid geological event, therefore the time span for the *Hemifusulina vozhgalica – Hemifusulina subrhomboides* subzone can be neglected and the combined zone *Hemifusulina subrhomboides – H. vozhgalica – Beedeina elshanica vaskensis* may be considered as coeval the *Beedeina elshanica vaskensis* Zone of the deeper basins of Tethyan realm.

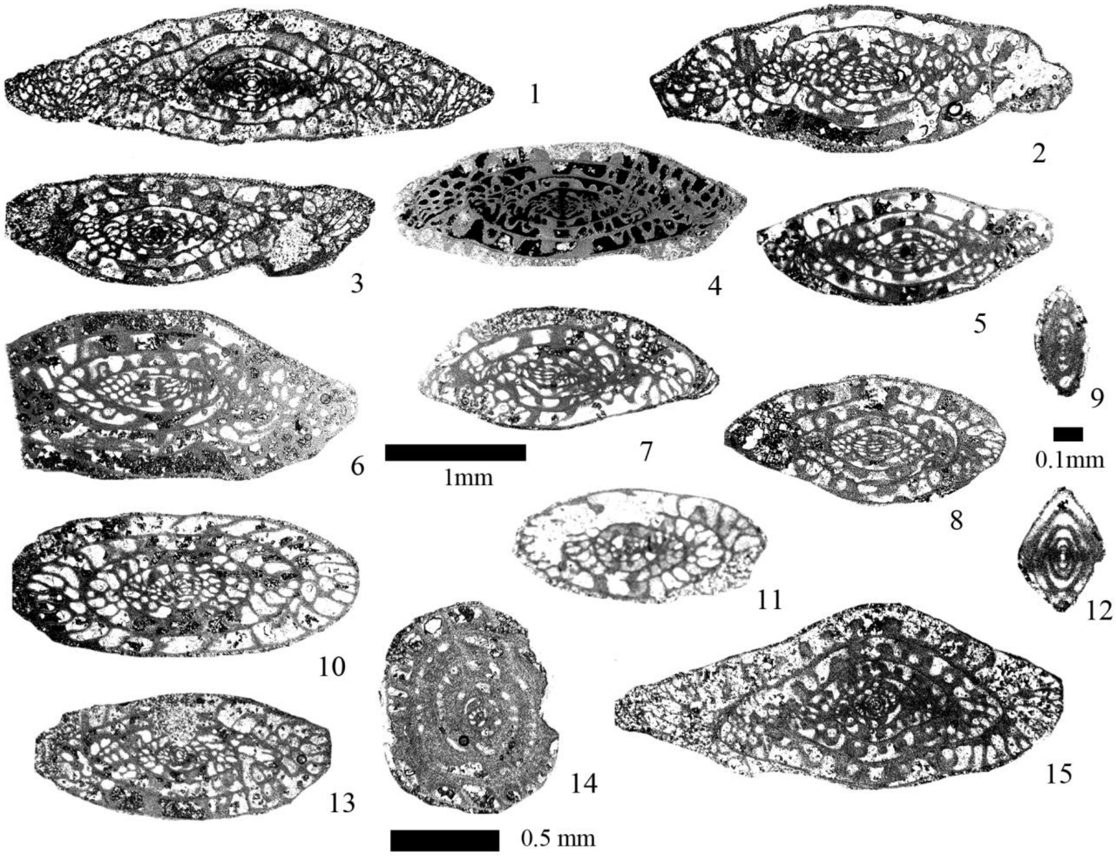

Figure 16. Fusulinids from the M_7 limestone of the upper Kashirian, Donets Basin, Ukraine.

Hemifusulina and *Beedeina* species, x 20; *Neostaffella* species, x 35, *Ozawainella* species, x 45. **1, 3, 5, 7, 8** – *Hemifusulina mucronata* Rumjantzeva: GM7-13/1, GM7-2/1, GM7-5/1, GM7-3/1, GM7-9/1; **2, 6** – *Hemifusulina vozhgalica* Safonova: GM7-14/1, GM7-1/1; **4** –*Hemifusulina subrhomboides* Rauser: GM7-10/1; **9** – *Ozawainella* sp.: GM7-5/2; **10** – *Hemifusulina pulchella* Rauser: GM7-6/1; **11, 13** –*H.elegantula* Rauser: GM7-11/1, GM7-7/1; **12**–*Ozawainella minima* Putrja: GM7-2/2; **14**–*Neostaffella* sp.: GM7-8/1; **15**–*Beedeina* sp. cf. *B. elshanica vaskensis* Rauser: GM7-4/1.

Hemifusulina subrhomboides – H. vozhgalica Subzone

The *Hemifusulina subrhomboides – H. vozhgalica* Subzone includes beds 38–48 in the Gurkovo section (Appendix A, Figure 15A) and consists of siltstone and siliciclastic mudstones with abundant plant remains. Three coal beds and two clayed limestones occur. The lower boundary is proposed at the base of the sandstone (Fig. 3), where a sequence boundary of composite sequence Mo XII is proposed by Eros (2010). The thickness of this subzone is 70.21 m.

Limestone M_7 contains mainly *Hemifusulina* species with abundant *Hemifusulina subrhomboidalis* Rauser, *H. vozhgalica* Safonova, *H. mucronata* Rumjantzeva, *H. pulchella* Rauser, and *H.elegantula* Rauser. Rarely *Beedeina* sp. cf. *elshanica vaskensis* Rauser, *Ozawainella minima* Putrja, *O.* sp., *Neostaffella* sp. occur (Fig. 16, Table 5A).

Limestone M_7^U is characterized by an increase in abundance of *Neostaffella* species; even so *Hemifusulina* is very common in this assemblage as well. The following species occur: *Hemifusulina* sp. aff. *subrhomboidalis* Rauser, *H. communis acuta* Rauser, *H. pulchella* Rauser, *H.* sp. aff. *splendida* Safonova, *Neostaffella larionovae* (Rauser and Safonova), *N. larionovae polasnensis* (Rauser and Safonova), *N.* sp. cf. *N. sphaeroidea cuboides* (Rauser), *Pseudostaffella confusa* (Lee et Chen), *Ps. variabilis* Reitlinger, *Beedeina* sp. cf. *elshanica vaskensis* (Rauser), *Ozawainella krasnodonica* Manukalova, *O. angulata* (Colani), *O. rhomboidalis* Putrja, *O. donbassensis* Sosnina, *O.* aff. *lorentheyi* Sosnina, *O.* sp. 1, *O.* sp. 2, *Taitzehoella* aff. *librovitchi globulus* (Manukalova) (Fig. 17, Table 5A).

The limestones M_7 and M_7^{up} contain *Hemifusulina* species indicating the beginning of transgression and therefore a new episode in sedimentary and evolutionary history of the basin. The M_7 assemblage contains predominantly *Hemifusulina* species, whereas the M_7^{up} comprises of more diverse population that includes large *Neostaffella* species and scarce *Beedeina*, indicating a deeper water condition.

In the Moscow Basin (Smedva Formation) we also recognized two limestones in many sections and wells documented in Makhlina *et al.* (2001a), which are characterized by *Hemifusulina* assemblages. The lower *Hemifusulina*-bearing limestone that can be correlated with the limestone M_7 from the Donets Basin is represented by predominately *Hemifusulina* species; beds 31 and 32 in section 37 (Reitlinger and Balashova, 1954, p. 143-145; Makhlina *et al.,* 2001a, p. 109), beds 13, 14 in the Kiyasovo well, 4k (Makhlina *et al.,* 2001a, p. 99), beds 45, 46a in well 56, north part of Moscow-city (Makhlina *et al.,* 2001a, p. 107), and bed 25 in well 17, near the town of Istra (Makhlina *et al.,* 2001a, p.123). The upper *Hemifusulina*-bearing limestone that can be correlated with the limestone M_7^{up}, besides *Hemifusulina,* contains large *Neostaffella* and subrhomboidal *Beedeina elshanica vaskensis*. This assemblage is documented in bed 12 in Kiyasovo well, 4k (Makhlina *et al.,* 2001a, p. 99), and bed 2 in section 37 (see Reitlinger and Balashova, 1954, p.151, figure 8).

However, Makhlina et.al (2001a), focusing on lithological data, ignored the fusulinid characteristics, which were the main proxies in the boundary definition proposed by Rauser-Chernousova and Reitlinger (1954), Reitlinger and Balashova (1954), and Ivanova and Khvorova (1955). As we recognized recently (Khodjanyazova *et al.,* 2011), the fusulinid characteristics are related to global sea level fluctuation and therefore have concurrent occurrence in a vast area of Northern Pangaea. Such unilateral approach, only based on lithostratigraphy, resulted in intrabasinal miscorrelation and misinterpretation of very important Horizons, which are the main chronostratigraphic units of internationally accepted Stages. As a result the *Hemifusulina*-bearing beds in section 37 near the Kholokholnya River, Tver Oblast, described by Reitlinger and Balashova (1954) are designated as the middle part of Smedva Formation (C_2 sm_2), whereas *Hemifusulina*-*Neostaffella*-bearing beds are designated as C_2 sm_3. The limestones with the *Hemifusulina*-bearing and *Hemifusulina*-*Neostaffella*-bearing fusulinid assemblages are documented in the well near the village of Kiyasovo as the upper part of Lopasnya Formation (C_2lp_3) that is older than the Rostislav Beds. In well 56, at the northwest of Moscow-city *Hemifusulina*-bearing limestones are documented as the lower part of the Smedva Formation (C_2sm_1). *Hemifusulina*-bearing beds in Istra well 17 are correlated with the lower part of Vaskino Formation (C_2vs_1).

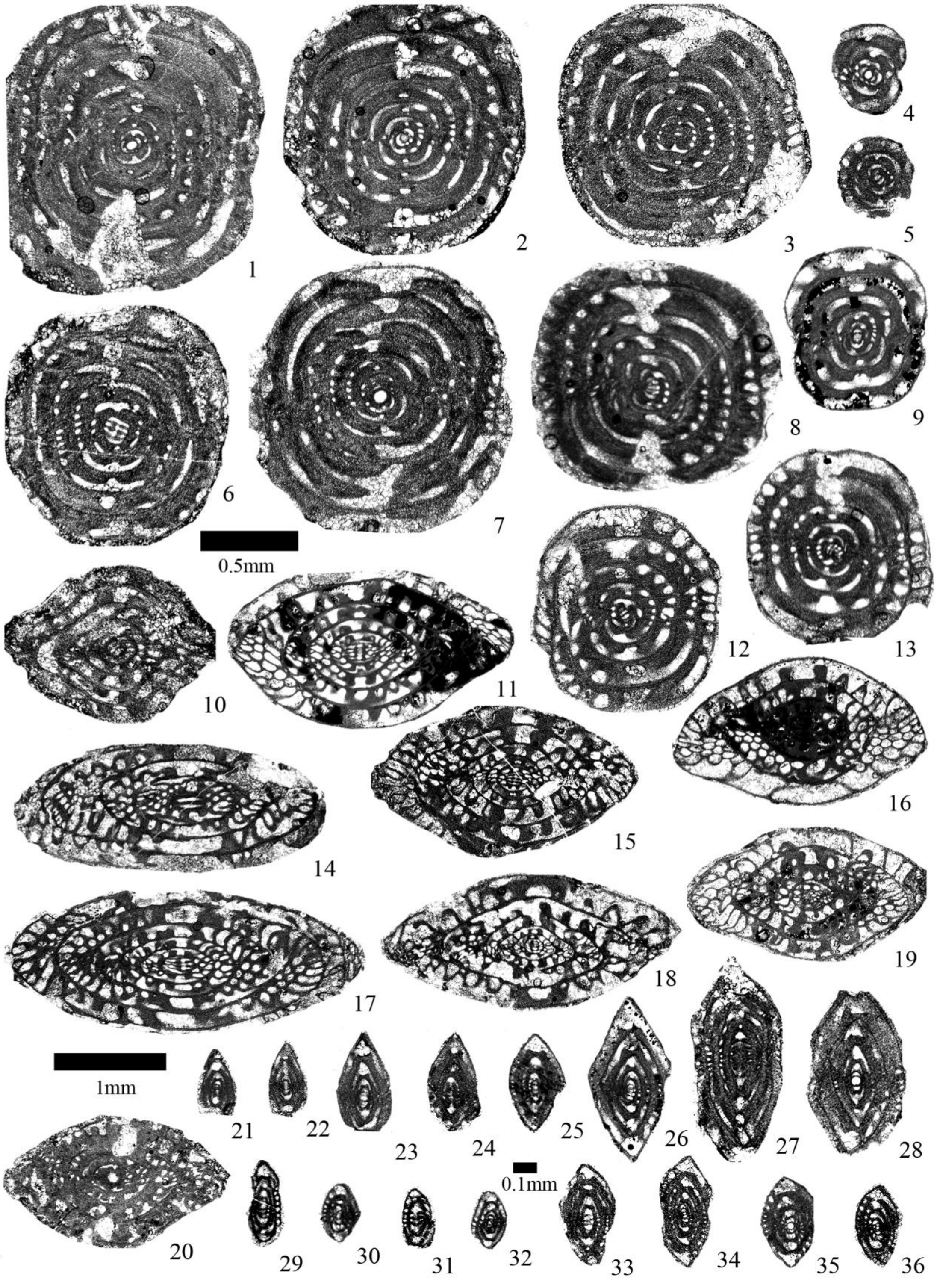
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Figure 17. Fusulinids from the M_7^{up} limestone of the upper Kashirian, Donets Basin, Ukraine.

Hemifusulina and *Beedeina* species, x 20; *Neostaffella* species, x 35; *Ozawainella* and *Pseudostaffella* species, x 45.**1, 2, 7, 12, 13** – *Neostaffella larionovae* Rauser and Safonova: GM7U-7/1, GM7U-5/1, GM7U-8/2, GM7U-8/1, GM7U-14/1; **3, 6, 8** – *Neostaffella* sp. cf. *N. sphaeroidea cuboides* (Rauser): GM7U-2/1, GM7U-3/1, GM7U-11/1; **4** – *Pseudostaffella variabilis* Reitlinger: GM7U-9/4; **5** – *Pseudostaffella confusa* (Lee and Chen): GM7U-9/3; **9** – *Neostaffella larionovae polasnensis* Rauser and Safonova: GM7U-11/2; **10** –*Taitzehoella* aff. *T. librovichi globulus* (Manukalova): GM7U-4/3; **11, 15, 16, 19** –*Hemifusulina* sp. aff. *H. splendida* Safonova: GM7U-10/1, GM7U-9/1, GM7U-12/1, GM7U-3/2; **14** – *H. pulchella* Rauser: GM7U-13/1; **17** – *H. communis acuta* Rauser, GM7U-6/1; **18** – *H.* sp. aff. *H. subrhomboidalis* Rauser: GM7U-1/1; **20** – *Beedeina* cf. *elshanica vaskensis* (Rauser): GM7U-4/1; **21**, **22** – *Ozawainella donbassensis* Sosnina: GM7U-5/3, GM7U-8/5; **23-25** – *Ozawainella rhomboidalis* Putrja: GM7U-12/3, GM7U-7/3, GM7U-14/2; **26** – *Ozawainella angulata* (Colani): GM7U-5/2; **27** – *Ozawainella krasnodonica* Manukalova: GM7U-10/2; **28** – *Ozawainella* aff. *O. lorenteyi* Sosnina: GM7U-14/3; **29-32** – *Ozawainella* sp. N.1: GM7U-11/3, GM7U-8/8, GM7U-1/2, GM7U-5/4; **33-36** – *Ozawainella* sp. N.2: GM7U-9/2, GM7U-2/2, GM7U-12/2, GM7U-7/2.

Beedeina elshanica vaskensis Subzone

The Beedeina *elshanica vaskensis* Subzone includes beds 49–55 in the Gurkovo section (Appendix A, Figure 15A) and is represented by marine sandstone, siltstone and siliciclastic mudstones without plant remains. Two limestones M_7^2 and M_8 belong to this zone. The lower boundary is proposed at the base of a thick unit of marine sandstone (bed 49). The thickness of this subzone is 53.00 m.

No material was collected from the limestones M_7^2 and M_8 in the Gurkovo section, due to a lack of fusulinids. Putrja (Putrja, 1956) described a *Beedeina* species, which is similar to *B. elshanica vaskensis* (Rauser), as *B "distenta*" (Roth and Skinner) in the eastern Donets Basin in the interval, which he questionably considered as M_8 limestone (Fig. 18, Table 5A). In the Moscow Basin *B. elshanica vaskensis* (Rauser) occur in the upper part of Smedva Formation (*Hemifusulina*-assemblage) and in the lower part of Vaskino Formation (*Fusulinella*-assemblage).

We define the interval of the M_7^2 and M_8 limestones as a separate subzone because we suppose that this interval indicate late transgression and potentially will be useful for correlation of the deeper water basins of the Tethyan realm. However the magnitude of this transgression was small, leading to unfavorable environmental conditions for the *Beedeina – Taitzehoella – Neostaffella – Ozawainella* community. Therefore some additional study of the deeper-water sections in the Donets Basin and taxonomy of smaller foraminifers in this interval would be helpful for correlation with the Moscow Basin.

The stratigraphic position of the interval of the M_7^2 and M_8 limestones, which is above the *Hemifusulina*-bearing limestone, M_7 and M_7^{up} and below the fusulinid-diverse limestone M_9 with abundant *Putrella donetziana, Fusulinella collanii, Neostaffella sphaeroidea cuboides,* and many other species (Table 5A, Figs. 19, 20) suggests its correlation with beds between the *Hemifusulina-Neostaffella*-bearing limestones of the Smedva Formation and fusulinid-diverse limestone of the Vaskino Formation. The lower part of this interval, beds 3–5 in the Kholokholnya section, Podolskian strata, *in* Reitlinger and Balashova (1954) is documented as the upper part of Smedva Formation, C_2sm_3 *in* Makhlina *et al.,* (2001a). In the Kiyasovo well this interval is correlated with the entire Smedva Formation (12 m), which is represented by alternation of dolomites and limestones and is poorly characterized by fusulinids.

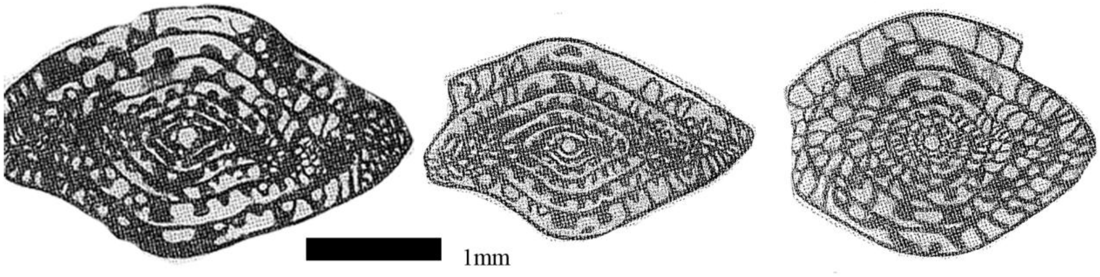

Figure 18. Fusulinids from the M_7^2 or M_8 (?) limestone of the upper Kashirian, Donets Basin, Ukraine.

Illustrations from Putrja (1956), x 20.**1-3** – *Fusulina distenta* Roth and Skinner = *Beedeina* aff. *elshanica vaskensis* (Rauser): Putrja, 1956, pl.12, figure 3, 4, 5.

Putrella donetziana – Fusulinella colanii Zone

The *Putrella donetziana – Fusulinella colanii* Zone includes beds 56–60 in the Gurkovo section (Appendix A, Figure 15A) and is comprised of siltstone and siliciclastic mudstones with plants remains. One limestone M_9 and one coal seam m_8 occur. The lower boundary is provisionally proposed at the base of a thick unit (64 m) of sandstone, which is the sequence boundary of composite sequence Mo XIII (Eros *et al.,* 2012). The thickness of this subzone is 70.04 m.

Limestone M_9 is characterized by abundant and diverse *Putrella* species: *P. brazhnikovae brazhnikovae* (Putrja*), P.* sp. cf. *brazhnikovae fusiformis* (Putrja), and *P. donetziana* (Lee), large abundant and diverse *Neostaffella*: *N.* sp. cf. *N. rostovzevi* (Rauser), *N. sphaeroidea cuboides* (Rauser), *N.* sp. cf. *N. sphaeroidea cuboides* (Rauser), *N. syzranica* (Rauser and Safonova), and *N. larionovae larionovae* (Rauser and Safonova), large fusiform thick-walled *Fusulinella* species with massive chomata: *F. colanii* Lee et Chen, *F. colaniae borealis* Rauser, *F. pseudocolaniae* Putrja, *F.* sp. *F.* cf. *vozhgalensis devexa* Rauser, *F.* sp., and *F.* sp. (immature specimens). *Schubertella* species are abundant and very diverse: *Sch.* sp. cf. *Sch. myachkovensis* Rauser, *Sch.* sp. cf. *galinae* Safonova, *Sch.* sp. cf. *inflata* Rauser, *Sch. lata* Lee and Chen, and *Sch. obscura procera* Rauser. *Ozawainella* species are less abundant; they are represented by large and slightly compressed at axial ends *O. mosquensis* Rauser*, O. vozhgalica* Safonova, and *O.* sp. Small *Pseudostaffella* also occur: *Ps. khotunensis* (Rauser), *Ps. compressa donbassica* (Putrja), and *Ps. primaeva* Putrja. The following species are scarce: *Fusiella pulchella* Safonova, *Hemifusulina bocki* Moeller, *Kamaina* sp. cf. *K.*

chernovi (Rauser), and *Beedeina* sp. cf. *B. elshanica vaskensis* (Putrja) (Figs 19, 20, Table 5A).

This zone we correlate with the Vaskino Formation in the Moscow Basin that is characterized by the occurrences of abundant fusulinids of *Neostaffella*, *Fusulinella*, and *Putrella* genera common with those in the Donets Basin and documented near the village of Obrasztovo, bed 2 (Ivanova and Khvorova, 1955); near the Kholokholnya river, Tver Oblast, section 37, bed 7 (Reitlinger and Balashova, 1954); in quarry Maly Studenets, Tzna river, Ryazan Oblast, beds 15-17 (Makhlina *et al.,* 2001a, p.122).

Abundant large advanced *Neostaffella sphaeroidea sphaeroidea* (Moeller) and N. *sphaeroidea cuboides* (Rauser) first occur in the M_9 limestone in the Donets Basin and in the Vaskino Formation, which differ from their Kashirian ancestors *N.ozawai, N. ozawai compacta, N. umbilicata* and others by a planispiral coiling of volutions and larger test size.

In agreement with our cyclic fusulinid distributional model (Figs. 2, 3, 9, 10) limestone M_9 indicates a high sea level stand and the beginning of gradual regression in epicontinental seas. The assemblage is characterized by an increased diversity of fusulinids, and the appearance of *Fusulinella* species, which are absent both in the underlying Smedva Formation in the Moscow Basin and in the interval of the limestones M_7–M_8 in the Donets Basin. Fusulinids from Subfamily Fusulinellinae in the Kashirian limestone are represented by *Fusulinella* (*Moellerites*) with undeveloped diaphanotheca. In the limestone M_9 *Fusulinella* (*Fusulinella*) with well-developed diaphanotheca in two outer volutions occurs: *F. colanii*, *F. colaniae borealis*, *F. pseudocolaniae,* and *F.* sp. *F. cf. vozhgalensis devexa,* which are also recognized in the Vaskino Formation.

This interval in both regions is marked by an abundant occurrence of *Putrella brazhnikovae* (Putrja). Rauser-Chernousova *et al*., 1996 followed by Isakova *in* Makhlina *et al.,* 2001b, Isakova, 2002 erroneously suggested that *Putrella* is a biostratigraphic marker for the base of Podolskian by its first occurrence in the local Vaskino Formation in the Moscow Basin. This suggestion resulted in miscorrelation with the Donets Basin, where *Putrella* occur in several intervals and its first occurrence is documented in the L_7 and M_1 limestones, consequently the lower boundary of Podolskian in the Donets Basin was proposed by previous fusulinid studies at the base of the limestone L_7 (Putrja, 1956) or M_1 (Kireeva, 1951; Maslo and Vachard in Izart *et al.*, 1996; Ueno in Fohrer, 2007). We compare *Putrella gurovi* Putrja and *P. licharevi* (Putrja) from the L_7 and M_1 limestones and *P. donetziana* (Lee) and *P. brazhnikovae* (Putrja) from the M_9 limestone and recognize that younger species have thicker walls and larger size than those in their ancestors.

The base of Vaskino Formation is associated with the underlying unconformity that is well documented and recognizable in different stratigraphic section in the Moscow Basin. Respectively, the base of *Putrella donetziana – Fusulinella colanii* Zone proposed in the Donets Basin is associated with sequence boundary which coincides with widespread regional unconformity in the Donets Basin (Eros et al., 2012), indicating a new step in the basin evolution.

Although the Vaskino Formation is well documented by fauna, we also recognize some miscorrelation and therefore misinterpretation of the Vaskino Formation summarized in Makhlina *et al*. (2001a). In well 17 near the town of Istra, beds 18 and 19 with *Fusulinella paracollaniae, Neostaffella sphaeroidea cuboides, Beedeina samarica*, which we suppose more typical for Vaskino Formation, are documented as Ulitino Formation (C_2ul_1, Makhlina *et al.,* 2001a, and p.133).

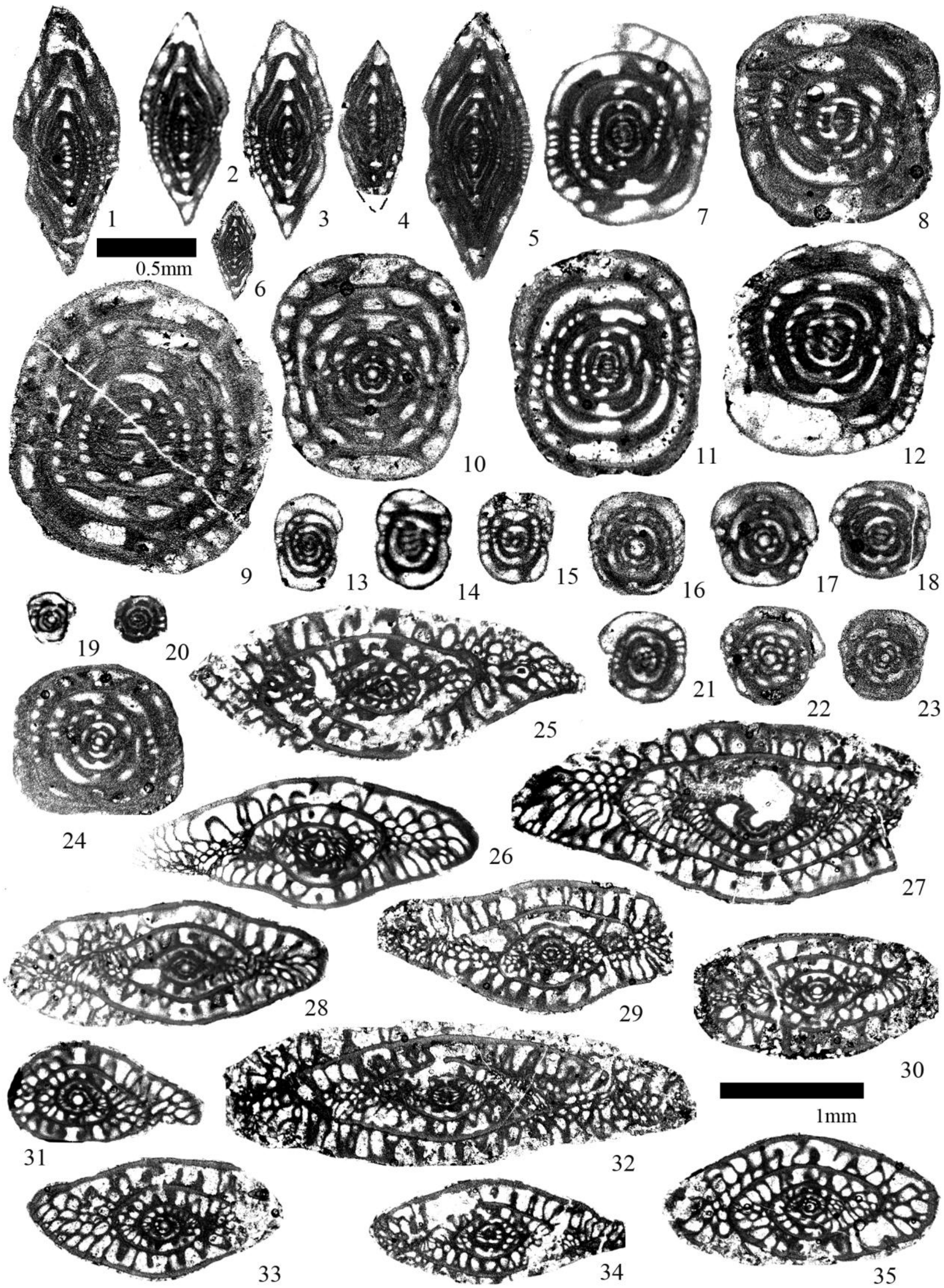
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Figure 19. Fusulinids from the M_9 limestone of the lower Podolskian, Donets Basin, Ukraine.

Putrella species, x 20; *Neostaffella* and *Ozawainella* species, x 35; *Pseudostaffella* species, x 45. **1-3**–*Ozawainella vozhgalica* Safonova: GM9-22/1, GM9-25/1, GM9-10/1; **4, 5**– *Ozawainella mosquensis Rauser*: GM9-16/6, GM9-33/1; **6**–*Ozawainella* sp.: GM9-5/5; **7**–*Neostaffella larionovae* (Rauser and Safonova): GM9-30/4; **8, 12**– *Neostaffella sphaeroidea cuboides* (Rauser): GM9-2/1, GM9-3/1; **9**–*Neostaffella* sp. cf. *N. rostovzevi* (Rauser): GM9-8/1; **10, 11**–*Neostaffella syzranica* (Rauser and Safonova), **13-15**– *Pseudostaffella compressa donbassica* Putrja: GM9-30/5, GM9-10/3, GM9-16/3; **16-18, 21-23**– *Pseudostaffella khotunensis* Rauser: GM9-7/2, GM9-33/3, GM9-30/2, GM9-25/2, GM9-16/4, GM9-8/3; **19, 20**– *Pseudostaffella primaeva* Putrja: GM9-19/4, GM9-31/1; **24**–*Neostaffella* sp. cf. *N. sphaeroidea cuboides* (Rauser): GM9-6/2; **25-27, 29**–*Putrella* sp. cf. *P. brazhnikovae fusiformis* (Putrja): GM9-4/1, GM9-35/1, GM9-20/1, GM9-35/1; **28, 30, 32**– *Putrella brazhnikovae* (Putrja): GM9-18/1, GM9-11/1, GM9-23/1; **31, 33-35**– *Putrella donetziana* (Lee): GM9-31/1, GM9-21/1, GM9-26/1, GM9-16/1.

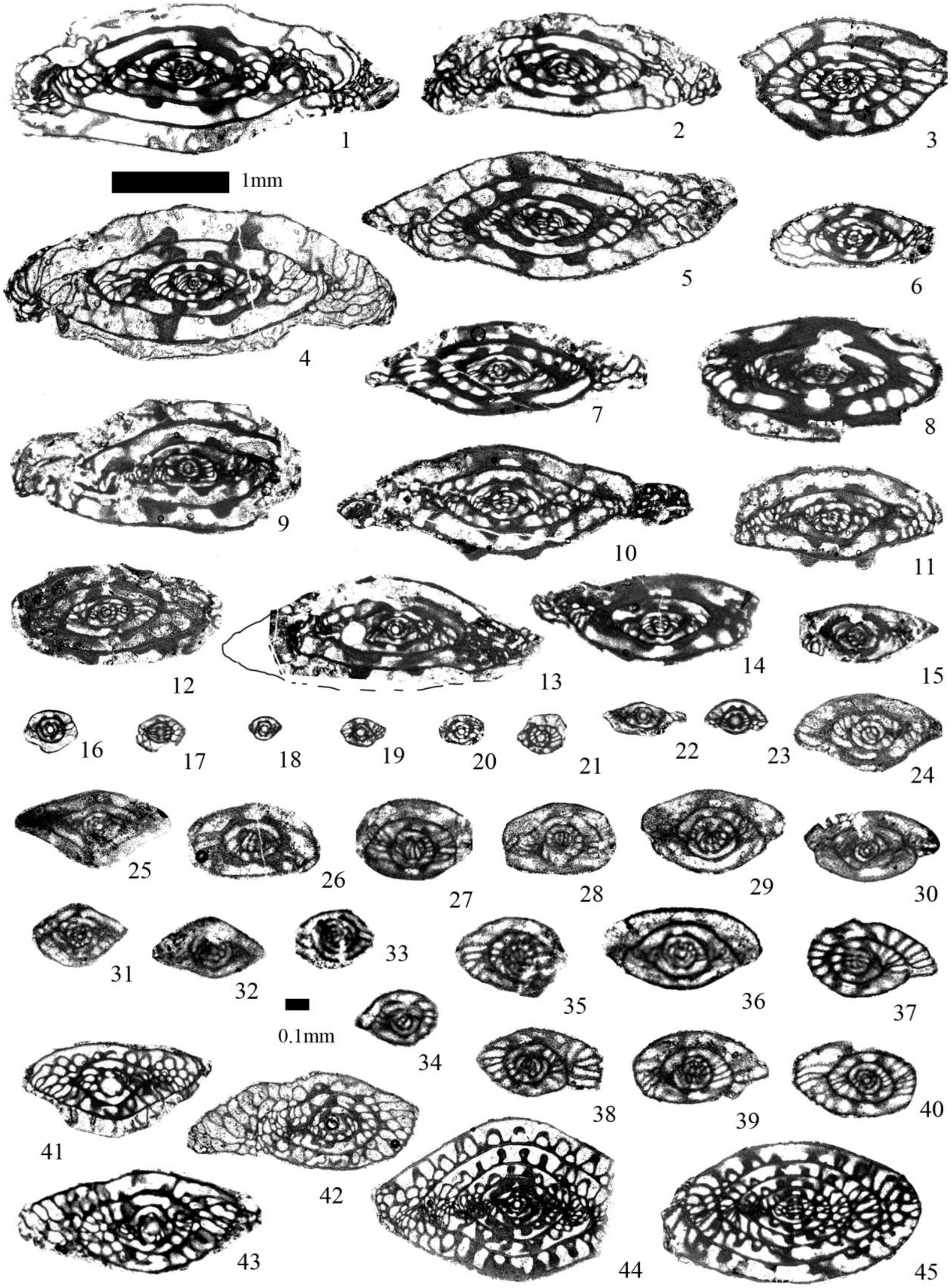
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Figure 20. Fusulinids from the M_9 limestone of the lower Podolskian, Donets Basin, Ukraine.

Fusulinella, Beedeina, Fusulina, Hemifusulina species, x 20; *Fusiella*, *Schubertella* species, x 45. **1**–*Fusulinella colanii* Lee and Chen: GM9-28/1, **2, 6**–*Fusulinella pseudocolaniae* Putrja: GM9-29/1, GM9-6/1(immature specimen); **3, 8,12**–*Fusulinella* sp.: GM9-17/1; GM9-15/1, GM9-16/2; **4**– *Fusulinella* sp. cf. *F. vozhgalensis devexa* Rauser, **5, 7, 10-11, 13, 14**–*Fusulinella colaniae borealis* Rauser: GM9-32/2, GM9-19/1, GM9-5/1, GM9-7/1, GM9-14/1, GM9-31/4; **16-23**– *Fusulinella* sp. (immature specimens): GM9-9/5, GM9-22/2, GM9-6/3, GM9-22/3, GM9-11/6, GM9-2/2, GM9-1/3, GM9-30/6, GM9-20/3, GM9-9/6; **15, 24**– *Schubertella* sp. cf. *Sch. myachkovensis* Rauser: GM9-9/5, GM9-9/6; **25** – *Fusiella pulchella* Safonova: GM9-10/2, **26-28**–*Schubertella lata* Lee and Chen: GM9-1/6, GM9-1/5, GM9-5/4; **29, 30, 36**–*Schubertella* sp. cf. *Sch. galinae* Safonova: GM9-11/5, GM9-27/2, GM9-9/2; **31, 32**–*Sch.obscura procera* Rauser: GM9-12/2, GM9-22/7; **33, 34**– *Schubertella* sp. cf. *Sch. inflata* Rauser: GM9-18/3, GM9-4/3; **35, 37-40**– *Schubertella* sp.: GM9-4/2, GM9-20/2, GM9-14/2, GM9-33/4, GM9-11/8; **41-43**–*Kamaina* sp. cf. *K. chernovi* (Rauser): GM9-27/1, GM9-1/1, GM9-9/1; **44**– *Beedeina* sp. cf. *B. elshanica vaskensis* (Rauser): GM9-32/1; **45**– *Hemifusulina bocki* Moeller: GM9-24/1.

Kamaina rossoshanica – Fusulinella tokmovensis longa Zone

The *Kamaina rossoshanica – Fusulinella tokmovensis longa* Zone includes beds 61–65? (Appendix A, Figure 15A) and is represented by siltstones, siliciclastic mudstones, and sandstones without plant remains. We propose to place a base of this zone at the top of bed 60, coal m_8, where Eros (2010) recognized a paleosol horizon. The thickness of this zone is 28 m. It is characterized by the fusulinids from the limestone M_{10}. We suppose an early low sea level stand resulting in an increase of fusulinid provinciality in the Moscow and Donets Basins.

Limestone M_{10} is characterized by abundant and diverse *Fusulinella* species, mainly fusiform, ovoid, subcylindrical in shape *Fusulinella colanii* Lee et Chen, *F. colaniae meridionalis Rauser, F. vozhgalensis devexa* Rauser, and *F. pseudocolaniae* Putrja. Several inflated species appear *F. tokmovensis longa* Reitlinger and *F. formosa tumida* Reitlinger. Among *Fusulinella* some older species are recognized *F. (Moellerites) subcolaniae subcolaniae* Reitlinger, *F. (M.) subcolaniae plana* Reitlinger, and *F. (M.) subcolaniae decurta* Reitlinger with weakly developed diaphanotheca. An older *Profusulinella* without diaphanotheca *P.* sp. 1, *P.* sp. 2, and *P. rotundata* Putrja also occur. Schubertella species are numerous and include *Shubertella lata* Lee et Chen, *Sch. procera* Rauser, *Sch. elliptica* Putrja, and *Sch. subkingi* Putrja. Large *Neostaffella* are common and include *N. sphaeroidea* (Ehrenberg) and *N. larionovae* (Rauser and Safonova). Small *Pseudostaffella* include *Ps. khotunensis* Rauser, *Ps. compressa donbassica* Putrja, and *Ps. variabilis* Reitlinger. *Ozawainella* species are similar to those in the limestone M_9 and include *Ozawainella* sp., *O. adducta* Manukalova, *O. krasnodonica* Manukalova, and *O.* sp. cf. *O. vozhgalica* Safonova.

In contrast to the limestone M_9, abundant and diverse *Fusiella* occur in M_{10} including *F. typica extensa* Rauser, *F. praetypica* Safonova, *F. praecursor* Rauser, *F. praecursor paraventricosa* Rauser, *F. pulchella* Safonova, *F.* sp. 1, and *F.* sp. 2. *Kamaina*, which is scarce in M_9, is abundant and diverse in M_{10} limestone: *Kamaina kamensis* (Safonova), *K. chernovi* (Rauser), *K. rossoshanica rossoshanica* (Putrja), *K.* sp. *K.* cf. *rossoshanica kamerlingi* (Ginkel), and *K.* sp. *Beedeina* is scarce and include *B. elegans* (Rauser et Belyaev) (Figs. 21, 22, Table 5A).

We correlated this zone with the Ulitino Formation of the Moscow Basin. Although both assemblage from the M_{10} limestone and the fusulinids from the coeval Ulitino Formation in the Moscow Basin are very provincial, there are some common or very similar species that occurred in both basins. The common species are *Neostaffella sphaeroidea cuboides* (Rauser), *Fusiella typica* Lee and Chen, *F. ventricosa* Rauser. Also we believe that "*Fusulina ulitinensis*" Rauser (in Makhlina *et al.,* 2001b, pl. 7, figure 11) from the Moscow Basin is misidentified and in our opinion is identical to the Donets Basin specimen of *Beedeina elegans* (Rauser and Belyaev), (this paper, Figure 11–35). Among diverse *Fusulinella* species the first occurrence of inflated specimens is recorded. *Fusulinella praebocki* Rauser, *F. pseudobocki* Lee and Chen, *F.* ex gr. *bocki* Moeller occur in the Moscow Basin, whereas inflated *F. tokmensis longa* Reitlinger, and *F. formosa tumida* Reitlinger are documented in the M_{10} limestone.

Besides, the Ulitino Formation in the Moscow Basin is marked by an abundance of green algae *Ivanovia tenuissima* Khvorova and *Dvinella chomata* Khvorova. In the Donets Basin abundant algae, particularly *Dvinella chomata*, are documented in the limestone M_{10}.

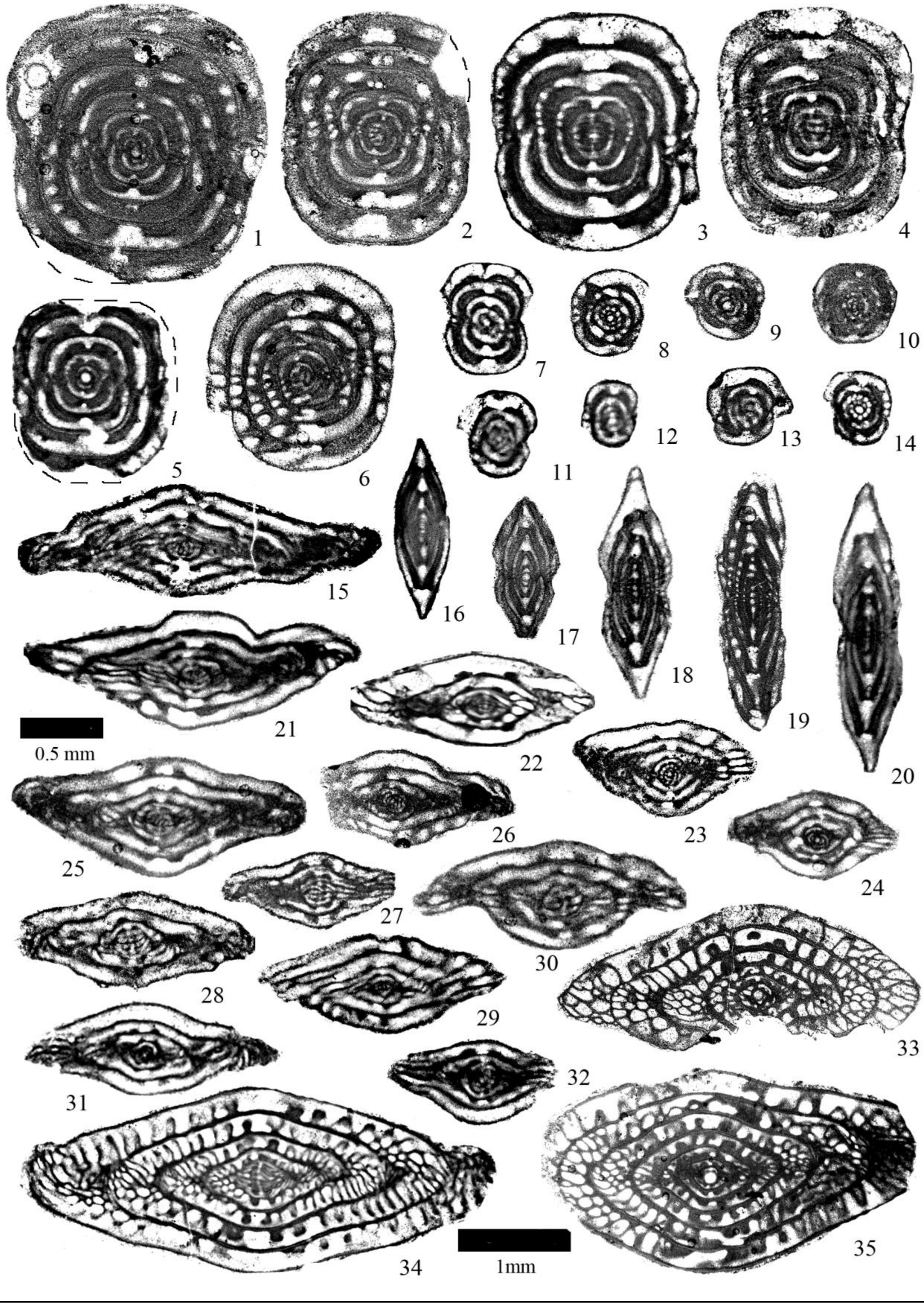
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Figure 21. Fusulinids from the M_{10} limestone of the middle Podolskian, Donets Basin, Ukraine.

Beedeina, species, x 20; *Neostaffella*, *Pseudostaffella*, *Fusiella*, *Ozawainella* species, x 35. **1-5**–*Neostaffella sphaeroidea* (Moeller): GM10-28/1, GM10-18/2, GM10-44/1, GM10-7/3, GM10-31/1; **6**– *Neostaffella larionovae* (Rauser and Safonova): GM10-6/3; **7, 11, 12**– *Pseudostaffella compressa donbassica* Putrja: GM10-37/2, GM10-20/2, GM10-20/6; **8-10**– *Pseudostaffella khotunensis* Rauser: GM10-46/4, GM10-31/3, GM10-35/2; **13-14**–*Pseudostaffella variabilis* Reitlinger: GM10-27/2, GM10-2/3; **15, 21**– *Fusiella typica extensa* Rauser: GM10-8/2, GM10-11/2; **16**– *Ozawainella* sp.: GM10-31/1; **17-18**– *Ozawainella* sp. cf. *O. vozhgalica* Safonova: GM10-22/3, GM10-22/2; **19**– *Ozawainella krasnodonica* Manukalova: GM10-46/5; **20**– *Ozawainella adducta* Manukalova: GM10-29/3; **22, 26, 28, 29, 31**– *Fusiella praecursor* Rauser: GM10-11/3, GM10-42/6, GM10-40/2, GM10-12/4, GM10-2/2; **25–** *Fusiella praetypica* Safonova: GM10-45/1; **23**– *Fusiella* sp.1: GM10-6/1; **24, 32**– *Fusiella pulchella* Safonova: GM10-51/1, GM10-37/3; **27**– *Fusiella praecursor paraventricosa* Rauser: GM10-3/5; **30** – *Fusiella* sp. 2: GM10-23/1; **33-35**– *Beedeina elegans* (Rauser and Belyaev): GM10-35/1, GM10-8/1, GM10-16/1.

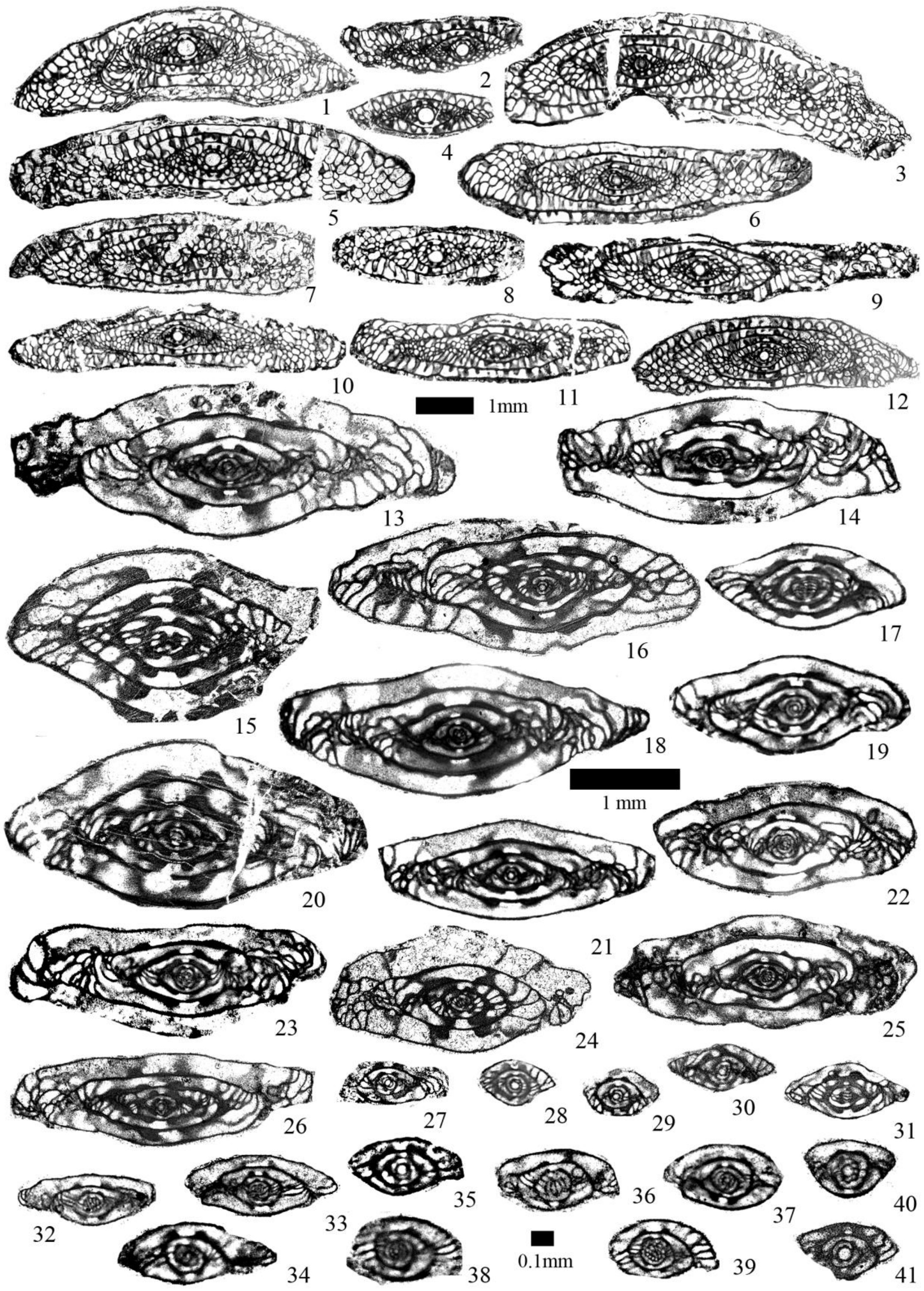
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Figure 22. Fusulinids from the M_{10} limestone of the middle Podolskian, Donets Basin, Ukraine.

Kamaina species, x 10; *Fusulinella* and *Profusulinella* species, x 20; *Schubertella* species, x 40. **1, 3**– *Kamaina rossoshanica* (Putrja): GM10-41/1, GM10-7/2; **4, 8**– *Kamaina chernovi* (Rauser): GM10-3/2, GM10-25/2, GM10-17/1; **5, 7**– *Kamaina kamensis* (Rauser): GM10-7/1, GM10-19/1; **6, 12** –*Kamaina* sp.: GM10-40/1, GM10-15/1; **9-11**–*Kamaina* sp. *K.* cf. *rossoshanica kamerlingi* (Ginkel): GM10-1/1, GM10-34/1, GM10-27/1; **13**– *Fusulinella colanii* Lee and Chen: GM10-37/1; **14, 16**– *Fusulinella pseudocolaniae Putrja*: GM10-32/1, GM10-14/1; **15**–*Fusulinella formosa tumida* Reitlinger: GM10-50/1; **17, 19**– *Fusulinella (Moellerites) subcolaniae decurta* Reitlinger: GM10-14/5, GM10-4/1; **18, 21**– *Fusulinella (M.) subcolaniae* Reitlinger: GM10-29/1, GM10-39/1; **20**– *Fusulinella tokmovensis longa* Reitlinger: GM10-25/1; **22, 25**– *Fusulinella (M.) subcolaniae plana* Reitlinger: GM10-30/1, GM10-22/1; **23, 26**– *Fusulinella colaniae meridionalis* Rauser: GM10-20/1, GM10-18/1; **24**– *Fusulinella vozhgalensis devexa* Rauser: GM10-38/1; **27**– *Profusulinella* sp.1: GM10-9/3; **28, 29**– *Profusulinella rotundata* Putrja: GM10-20/5, GM10-9/2; **30-31**– *Profusulinella* sp. 2: GM10-23/2, GM10-22/4; **32-34**– *Schubertella subkingi* Putrja: **35**– *Schubertella elliptica* Putrja: GM10-11/3; **36-39**– *Schubertella lata* Lee and Chen: GM10-9/9, GM10-42/4; **40, 41**– *Schubertella obscura procera* Rauser: GM10-37/6, GM10-23/2.

Uppermost Podolskian – Lowermost Myachkovian strata

A cyclic distributional model of fusulinids reveals that strata of the Shchurovo Formation were deposited in the shallowest marine conditions accompanied by considerable reduction of *Neostaffella* species (Makhlina *et al.,* 2001a) and the appearance of elongate *Fusulina* and *Fusiella* species. The interval starting from the limestones M_{10} to the N_1 coincides with a regressive episode, a gradual falling of sea level and development of highly endemic fusulinids. Unfortunately, material from the limestone M_{10}^1 and M_{10}^2 were not available for this study. Therefore, more research needs to be conducted at the Podolskian –Myachkovian boundary to define its exact position in the Donets Basin.

Discussion

A refined biostratigraphic zonation of predominantly siliciclastic Podolskian strata in the Donets Basin and its correlation with the coeval, mainly carbonate, succession of the historical type area, Moscow Basin, where the regional Podolskian Stage was distinguished, reveals common trends in fusulinid evolution. Based on previous detailed biostratigraphic studies of fusulinids in the Moscow Basin conducted by Rauser-Chernousova and Reitlinger (1954), Reitlinger and Balashova (1954), Ivanova and Khvorova (1955), and Solovieva (1986), we are able to trace a successive replacement of Moscow Basin assemblages that is similar to the cyclic distribution of fusulinids in the Donets Basin. The distribution of fusulinids in the upper Kashirian (Smedva Formation) – Podolskian strata in the Moscow Basin is roughly as follows 1) *Hemifusulina* assemblage (lower part of Smedva Formation); 2) the interval characterized by small foraminifers because of absence of fusulinids (upper part of Smedva Formation); 3) assemblage with diverse *Fusulinella*, *Neostaffella*, *Putrella, Beedeina* and others (Vaskino Formation); and 4) assemblage with diverse but highly endemic fusulinid species (Ulitino Formation). This successive replacement of fusulinid assemblages mirrors cyclic distributional patterns we recognized in the Donets Basin, and probably represents a response to global sea level fluctuations.

Recent study in the Moscow Basin (Solovieva, 1986; Alekseev in Makhlina *et al.,* 2001b) revealed that the main faunal change in both conodonts and fusulinids proceeded at the base of the Smedva Formation (see discussion above). Our study of fusulinid evolution also confirms this opinion. We suggest that the main change in faunal evolution over a short time scale can happen at the beginning of transgression because of abrupt environmental disruption in shallow seas and is marked by abundant monospecific populations of *Hemifusulina*, which took place at the base of C_2sm_2, bed 30 in Kholokholnya section (Reitlinger and Balashova, 1954) in Rzhev area, near the town of Staritza, on the bank of the Kholokholnya River. Fusulinids described from bed 27 of the lower Member (C_2sm_1) are mainly represented by elongated *Fusiella*, which usually characterize late stages of regressive succession and probably belong to the Lopasnya Formation (Kashirian Stage).

Since the interval in the Donets Basin between the limestone M_7 and M_{10}^2 that is correlated with the upper Kashirian and Podolskian strata in the Moscow Basin contains one full transgressive-regressive cycle, it would make sense to place the lower boundary of the Podolskian at the base of the Smedva Formation, which needs to be revised using fusulinid biostratigraphy.

Fusulinid cyclicity in the Moscow Basin reveals an association of the *Hemifusulina* assemblage with the thick dolomite units represented by an alternation of the dolomites, limestones and clays. The Smedva dolomites contain *Hemifusulina subrhomboides* assemblage; dolomites at the Podolskian – Myachkovian boundary in the Moscow Basin contain *Hemifusulina stabilis, H. bocki* that can be correlated with the intermediate beds of the N_1 limestone in the Donets Basin. A last occurrence of *Hemifusulina,* represented by *H. bocki mosquensis* beds, is documented in the Peski Formation. We suppose that these beds are associated with the Turaevo dolomites and can be correlated with the *Hemifusulina*-bearing beds recognized by Putrja (1940) in the eastern part of the Donets Basin right below the N_3 limestone. Unfortunately the material from the Eastern Donets Basin was not available for our study; therefore we are unable to outline fusulinid cyclicity in the middle part of the “N” Formation.

By analogy to the lower Podolskian, the lower Myachkovian boundary, which could be marked by a new transgression, should be documented by the occurrence of *Hemifusulina* species. Such change in fusulinid assemblages we recognized in the Ordynskaya well (Moscow city) at a depth of 66.54-77.49 m (Rauser-Chernousova and Reitlinger, 1954, p. 69), which these authors defined as the latest Podolskian ($C_2^{2\ pd\text{-}c}$, the Shchurovo Formation?). The base of this lithostratigraphic unit, represented by alternating dolomites and limestones, is marked by an unconformity with limestone conglomerates. Rauser-Chernousova and Reitlinger (1954, p. 70) pointed out that the fusulinid assemblage sharply changes. They documented *Hemifusulina bocki* which sometimes is abundant in different beds of this unit. For this unit *Fusiella typica*, *Neostaffella sphaeroidea*, and *Ozawainella angulata* are common. Rauser-Chernousova and Reitlinger (1954) documented *Fusulinella bocki* and *F. pseudobocki*, which only occur in the upper part of this unit. They also recognized *Beedeina lanceolata* and *Fusulina* ex gr. *cylindrica*. In the Donets Basin (Putrja, 1940; Pogrebnyak, 1975, Khodjanyazova and Davydov, in press) such fusulinids are documented in the lower part of N Formation (N_1, N_1^2, and N_1^6) and considered as the Myachkovian.

Conclusions

1. Three new fusulinid biozones are proposed for the upper Kashirian – Podolskian strata, interval of the M_7–M_{10} limestone in the Donets Basin. These are *Hemifusulina subrhomboides – H. vozhgalica – Beedeina elshanica vaskensis*, *Putrella donetziana – Fusulinella colanii*, and *Kamaina rossoshanica – Fusulinella tokmovensis longa* Zones.
2. *Hemifusulina subrhomboides – H. vozhgalica – Beedeina elshanica vaskensis* Zone embodies an interval of the limestones M_7 – M_8 that we consider as transgressive beds and correlate with the most of Smedva Formation of the Moscow Basin.
3. *Putrella donetziana –Fusulinella colanii* Zone includes an interval with the limestone M_9. This interval characterizes a high sea level stand and the beginning of regression. This Zone is correlated with the Vaskino Formation of the Moscow Basin.
4. We propose to place the base of the *Kamaina rossoshanica – Fusulinella tokmovensis longa* Zone at the paleosol horizon above the top of coal m_9. This zone is characterized by fusulinids from the limestone M_{10}. We suppose this assemblage was associated with an early low sea level stand resulting in an

increase of fusulinid provinciality in the Moscow and Donets Basins. Few common species allow correlating this zone with the Ulitino Formation of the Moscow Basin.

5. A definition of the Podolskian – Myachkovian boundary in the Donets Basin remains unclear because of poor sampling in the interval between the M_{10} and N_1 limestones. Additional sampling could be helpful in resolving the problem of correlating the Podolskian – Myachkovian boundary in the Donets Basin.
6. A cyclic distribution of fusulinids is recognized in the Kashirian–Podolskian strata in the Moscow Basin and is represented by successive replacement of fusulinids: 1) *Hemifusulina*; 2) smaller foraminifers; 3) *Neostaffella sphaeroidea cuboides*, *Putrella brazhnikovae*, *Fusulinella colanii*, *Beedeina elshanica vaskensis*; 4) *Kamaina kamensis*, *Fusulinella* ex gr. *bocki*, *Fusulina ulitinensis*.
7. We suggest reestablishing the original definition of the Podolskian Stage proposed by Ivanov (1926) and include the Smedva Formation in the Podolskian.
8. We propose to define the lower boundaries of the Podolskian and Myachkovian by the occurrence of *Hemifusulina*-bearing beds.

CHAPTER THREE: LATE MOSCOVIAN FUSULINIDS FROM THE “N” FORMATION (DONETS BASIN, UKRAINE)

Introduction

One of the main problems in modern biostratigraphy is global correlation among biotically distinct paleogeographic provinces, such as the Pennsylvanian shallow-marine sedimentary strata of the North American Midcontinent, Eastern European Craton and terrestrial coal-bearing deposits of Western Europe. Three distinct biostratigraphic schemes were developed and applied in these areas (Hills et al., 2002). Until recently it has been difficult to establish relationships among them.

In the last decade biostratigraphers (Menning et al., 2006; Heckel, 2008; Heckel et al., 2007) using conodonts have made great progress in correlating Pennsylvanian (Late Moscovian – Kasimovian) shallow-marine strata of the North American Midcontinent with equivalents in the Eastern European Craton (EEC), particularly the carbonate succession in the Moscow Basin (Russia) and paralic, heterolithic deposits in the Donets Basin (Ukraine). The Donets Basin succession is considered pivotal for relating shallow-marine strata of Eastern Europe with terrestrial, coal-bearing deposits of Western Europe. Wagner (1969) first distinguished the Cantabrian flora between the upper Westphalian and lower Stephanian strata of Spain. Later this floral assemblage was defined as the *Odontopteris cantabrica* Zone (Cleal, 2008). Fisunenko [2000] recognized common species of this zone in the Donets Basin, within the interval of the limestones N_2–N_4, in latest Moscovian time.

Cantabrian flora was extent during a gradual extinction of many fusulinid genera (*Hemifusulina*, *Taitzehoella*, *Neostaffella*, and *Beedeina*) in shallow-marine environments during the latest Moscovian time (N_1–N_4). Establishing precise temporal relationships between terrestrial and marine events requires detailed biostratigraphic correlation of Late Moscovian coal-bearing deposits of Western Europe with shallow-marine successions in the Moscow Basin, the historical type area of the Moscovian Stage. However, predominately carbonate cyclic sedimentation during Moscovian time in the Moscow Basin was discontinuous and these discontinuities are documented in numerous erosional surfaces and paleosols (Kabanov et al., 2006, 2010). Kabanov et al. (2010) conducted research on the late Moscovian paleosols in the EEC that revealed the palygorskitic composition of Podolskian topsols, interpreted ”to reflect hot, well drained semidesert conditions with precipitation less than 300mm/yr.” They also documented the smectitic-illitic composition of Myachkovian paleosols that likely formed in wetter conditions.

The Donets Basin is close to the Moscow Basin and is unique for many reasons. First, continuous tectonic subsidence during Pennsylvanian time (Stephenson et al., 1993, 2001; Stovba and Stephenson, 1999; van Wees et al., 1996; Izart et al., 2003) has resulted in accumulation of a nearly continuous sequence of sedimentary deposits. Second, high frequency glacial-eustatic sea-level fluctuations led to multiple switching between marine and terrestrial sedimentary regimes. Marine beds with diverse, well preserved marine invertebrate alternating with terrigenous beds characterized by rich floral assemblages facilitate the correlation of marine EEC sedimentary strata with continental deposits in Western Europe (Aisenverg et al., 1975; Fisunenko, 2000; Eros et al., 2012). Third, recent ID-TIMS U-Pb zircon tuff ages from twelve stratigraphic levels (Davydov et al., 2010) provide a precise time framework for the Donets Basin. And finally, new research on fusulinid paleoecology in this region reveals cyclic patterns in the distribution of specific assemblages throughout the Pennsylvanian (Khodjanyazova et al., 2011). The cyclically occurring associations can be linked with glacioeustatic sea level fluctuations to reveal paleobathymetries and paleoenvironments characteristic of early transgression, late transgression and long lasting regression episodes.

Repetitive patterns of fusulinid distribution in carbonate successions of the epicontinental seas of the EEC were noted by Russian micropaleontologists (Rauser-Chernousova and Kulik, 1949; Rauser-Chernousova, 1953; Rauser-Chernousova and Reitlinger, 1962). As first recognized by Rauser-Chernousova and Reitlinger (1962), the beginning of every depositional cycle is marked by abundant and diverse foraminiferal populations. The number of species and their abundance are considerably reduced at the end of each rhythm. Rauser-Chernousova and Reitlinger (1962) inferred that the cyclic occurrence of specific fusulinid assemblages was not a simple repetition of facies-dependent faunal associations, but represented specific and generic evolutionary trends throughout time, from cycle to cycle. They concluded that a repetitive alternation of fusulinid assemblages resulting in adaptation of different genera to changing environments corresponded to cyclic sedimentation within a basin. However they did not give any examples of their model. From their research it is difficult to recognize what kind of fusulinids lived during transgressive or regressive episodes.

Although Donets Basin fusulinids are well studied, Moscovian fusulinid biostratigraphy in the Donets Basin is still poorly developed, especially that of the poorly exposed “N” Formation. Further, many collections with stratigraphically important holotypes were lost during World War II. All early papers are in Russian or Ukrainian and thus are not widely read by Western paleontologists.

The main focus of this paper is to document the taxonomy and stratigraphic distribution of fusulinid faunas in the Moscovian – Kasimovian transition in the Donets Basin and correlate the faunas with the equivalents in the Moscow Basin. Our detailed taxonomic and stratigraphic study of Pennsylvanian fusulinids in the Donets Basin should allow improved global correlations among biotically distinct regions, and it forms the basis of a newly proposed model of fusulinid cyclicity, which we intend to discuss in a separate paper.

Biostratigraphy of “N” Formation: Previous study

The “N” Formation is composed of predominant fine-grained marine and lacustrine terrigenous rocks: siltstone and claystone, with rare thin beds of fine-grained sandstone in the lower part of the unit. The upper part is represented mostly by fluvial coarse-grained sandstone (Aisenverg et al., 1975; Eros et al., 2012). Fifteen limestone beds have been recognized in the eastern and northeastern regions of the Donets Basin, and only half of this number in the western and southwestern on the basis of mine logs from the Artemovsk Geological Survey (Makarov, 1985; Izart et al., 1996; Eros et al., 2012).

Fusulinids in the Donets Basin have been known since the nineteenth century thanks to their exceptional preservation and abundance in many limestones throughout the Carboniferous. Since the first half of the twentieth century, fusulinids have become important biostratigraphic tools widely utilized in the Donets Basin. Putrja (1940, 1948, 1956), Kireeva (1950), and Pogrebnyak (1975) developed fusulinid taxonomy and biostratigraphy for the Moscovian – Kasimovian transition in the Donets Basin.

Although foraminifers are well studied in the Donets Basin, the existing record for the Moscovian is controversial, especially for the poorly exposed “N” Formation, which includes the traditional Moscovian – Kasimovian boundary. Indices for the *Protriticites pseudomontiparus – Obsoletes obsoletus* Zone, once used for identifying the Moscovian – Kasimovian boundary definition, were first recognized and described in the Donets Basin (Putrja, 1948; Kireeva, 1950). In 1965 the Interregional Committee on Carboniferous Stratigraphy of the USSR ratified the Moscovian – Kasimovian boundary at the base of the Suvorovo Formation in Moscow Basin. This level has been correlated with Limestone N_3 in the Donets Basin. Nevertheless, Aisenverg et al. (1975) placed the boundary at the base of the N_2 Limestone, and Solovieva (1986) and Kagarmanov and Donakova (1990) placed it significantly higher, at the base of the N_4 Limestone. Recent work (Vachard and Maslo *in* Izart et. al., 1996; Davydov and Khodjanyazova, 2009; Davydov et al., 2010) reveals dramatic changes in fusulinid faunas in limestone N_3. Importantly, the traditional Lower Kasimovian *Streptognathodus subexelsus* conodont zone (Alekseev and Goreva, 2006) has been found in the lower part of the Suvorovo Formation (Moscow Basin) and in Limestone N_3 (Nemyrovska et al., 1999). As *Streptognathodus subexelsus* has restricted occurrence and does not occur globally, a new Moscovian–Kasimovian boundary has been proposed as the first occurrence of conodonts *Idiognathodus sagittalis* or *I. turbatus* (Villa and Task Group, 2008). In the historical type area, Moscow Basin, these conodonts first occur at the base of Middle Neverovo Formation, which is correlated with the limestone O_1 or O_1^1.

The Myachkovian Horizon in the Donets Basin before this study was characterized by a single fusulinid zone *Fusulina cylindrica* (Vachard and Maslo *in* Izart et. al., 1996), which extends from the Limestone M_{10}^{1} to the base of the N_3 Limestone. Davydov and Leven (2003) recognized two zones: *Fusulinella bocki* in the interval M_{10} – N_2, and *Praeobsoletes burkemensis, Quasifusulinoides quasifusulinoides, Protriticites ovatus* in the N_2 – N_5^{1} Limestones.

A comprehensive litho- and biostratigraphic synthesis of Carboniferous stratigraphy in the Moscow Basin was published recently by Makhlina et al. (2001), including a description of numerous sections with detailed lithologies and faunal occurrences for each Formation in the stratotype area. This work allows the recognition of all fusulinid biozones in the Moscow Basin and facilitates correlation with contemporaneous strata in the adjacent Donets Basin, one of the few regions in the world where the entire Pennsylvanian sedimentary succession is documented (Fohrer et al., 2007).

Material

Material for this study was collected from two sections, Gurkovo and Kalinovo, in the interval of the Moscovian – Kasimovian transition (Podolskian, Myachkovian and Krevyakian horizons). In this paper we focus on fusulinid study of the Myachkovian horizon in the interval between Limestones M_{10} and N_3. Samples from the lower portion (N_1 Limestone) were collected in the Gurkovo ravine, and samples from the upper portion of the Myachkovian succession (N_1^{1}, N_1^{2}, N_2, and N_2^{1}) were collected in the Kalinovo ravine, both of which are incised in the western riverside of the Lugan’ River and extend in the southern direction from the town of Pervomaysky, Donetsk Oblast, Ukraine (Fig. 1). Unfortunately here is no material from many limestone beds (M_{10}^{1}, M_{10}^{2}, several intermediate limestone beds between N_1^{2} and N_2, as well as the upper portion below Limestone N_3) because of poor exposures.

Systematic paleontology

Systematic descriptions are given for stratigraphically important taxa. The measurements of all studied specimens are given in the Appendix. All illustrated and measured specimens are housed in the University of Iowa Paleontology Repository, Department of Geosciences (SUI).

Family OZAWAINELLIDAE Thompson and Foster, 1937

Genus OZAWAINELLA Thompson, 1935

Type species.—Fusulinella angulata Colani, 1924.

OZAWAINELLA KRASNOKAMSKI KIROVI Dalmatskaya, 1961

Figures 23.1–23.2

Ozawainella krasnokamski kirovi DALMATSKAYA, 1961, p. 26–27, pl. 1, figs. 3–5.

Material studied.—Axial sections SUI 130697–130699, samples GN1-7/1, KN2-10/3, KA3/4-11/2; tangential section SUI 130700, sample GN1-3/2; one immature specimen SUI 130701, sample GN1-3/4.

Occurrence.—Limestone N_1, Gurkovo section; limestone N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—The studied specimens of *Ozawainella krasnokamski kirovi* occupy a somewhat intermediate position between *O. rhomboidalis* Putrja, 1940 and *O.*

krasnokamski krasnokamski Safonova *in* Rauser-Chernousova et al., 1951. Like both species, the studied specimens possess straight to slightly concave lateral sides, tightly coiled and regularly expanded volutions, as well as low and broad symmetrical chomata. The studied specimens are close to *O. rhomboidalis* Putrja in length but differ from the latter in slightly rounded umbilical regions that make them similar to *O. krasnokamski krasnokamski* Safonova. From both comparable species the studied specimens differ in smaller form ratio; hence they look more compressed in axial view. One more important distinction of *Ozawainella krasnokamski kirovi* Dalmatskaya from *O. rhomboidalis* Putrja and *O. krasnokamski krasnokamski* Safonova is better developed chomata, which are approximately one-half of the chamber's heights. The Donets specimens of *O. krasnokamski kirovi* are slightly smaller than the typical specimens described from Myachkovian strata in the Samara and Saratov regions of the East European Platform. Diameter in the Donets forms with six volutions varies from 0.48 to 0.80 mm, and length varies from 0.22 to 0.34 mm, whereas the typical specimens are 0.71–1.15 mm in diameter and 0.29–0.49 mm in length. The diameter of proloculus is 15 μm in the Donets specimens and 35 μm in the types.

OZAWAINELLA VOZHGALICA Safonova *in* Rauser-Chernousova et al., 1951

Figures 23.3–23.5

Ozawainella vozhgalica SAFONOVA *in* RAUSER-CHERNOUSOVA et.al., 1951, p. 138–139, Pl. 11, figs. 3, 4; RUMJANZEVA, 1974, p. 73, pl. 5, figs. 3, 4; LEVEN, 1998, p.15, pl. 1, fig. 8; LEVEN, DAVYDOV AND GORGIJ, 2006, figs. 10.5, 10.6.

Material studied.—Tangential sections SUI 130702–130705, samples KN2-4/1, KN2-14/1, KN2-15/1, KN2-17/1; immature specimens SUI 130706–130708, samples KN2-3/2, KN2-5/2, KN2-6/2.

Occurrence.—Limestone N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—The studied specimens with pointed periphery, concave lateral sides, distinctly depressed but narrow umbilical regions and massive and broad chomata resemble typical *Ozawainella vozhgalica* Safonova. The test's size of the studied specimens is slightly smaller than the types; the length of the mature specimens with five and a half to six volutions varies from 0.28 to 0.35 mm, the diameter varies from 0.72 to 1.12 mm, whereas the typical specimens from the East European Platform are 0.36–0.58 mm in length and 0.71–1.37 mm in diameter.

Family SCHUBERTELLIDAE Skinner, 1931

Genus FUSIELLA Lee and Chen *in* Lee, Chen, and Chu, 1930

Type species.—*Fusiella typica* Lee and Chen *in* Lee, Chen, and Chu, 1930.

FUSIELLA SPATIOSA Sheng, 1958

Figures 23.13, 23.15, 23.16

Fusiella spatiosa SHENG, 1958, p. 82, pl. 3, fig. 14.

Fusiella lancetiformis Putrja. RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, (part), pl. 5, figs. 2, 3 (only).

Material studied.—Tangential sections SUI 130709–130714, samples GN1-2/1, GN1-6/1, GN1-10/1, GN1-19/1, GN1-22/1, KN2-9/1.

Occurrence.—Limestone N_1, Gurkovo section; limestone N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—The studied specimens are similar to the type specimens in their subcylindrical tightly coiled tests that are slightly inflated in median area and bluntly pointed in polar ends with slightly developed axial fillings and small chomata. They differ from the typical ones in their smaller diameter and greater form ratio. Form ratio in the Donets specimens varies from 4.0 to 5.3, whereas the holotype possesses a form ratio of 3.48. Rauser-Chernousova (*in* Rauser-Chernousova et al., 1951, pl. 5, fig. 2, 3) erroneously considered late Myachkovian elongated *Fusiella* with weakly developed and discontinuous axial fillings as *F. lancetiformis* Putrja, 1939. The latter, which first appeared in the Donets Basin in the Limestone N_5, is almost as twice larger as Myachkovian specimens and possesses seven or eight volutions, as opposed to specimens with five volutions illustrated by Rauser-Chernousova *in* Rauser-Chernousova et al., 1951, pl. 5, fig. 2, 3. Further, *F. lancetiformis* differs from *F. spatiosa* by having strongly developed, continuous axial fillings.

FUSIELLA PRAELANCETIFORMIS Safonova *in* Rauser-Chernousova et al., 1951

Figures 23.12, 23.14, 23.17

Fusiella praelancetiformis SAFONOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 91–92, pl. 5, fig. 1; RUMJANZEVA, 1974, p. 98–99, pl. 8, figs. 12, 13; VAN GINKEL, 1965, p. 104–105, pl. 28, figs. 21, 22.

Fusiella eolancetiformis GROZDILOVA AND LEBEDEVA *in* BOGUSH, 1963, p. 66–67, pl. 3, fig. 3.

Material studied.—Axial sections SUI 130715–130720, samples GN1-2/3, GN1-7/4, GN1-13/4, KA3/1-13a, KN2-8/1, KN2-12/1; slightly oblique sections SUI 130721–130724, samples GN1-2/1, GN1-14/3, KN2-10/2, KN2-23/11.

Occurrence.—Limestones N_1, Gurkovo section; limestone N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Small tightly coiled fusiform specimens with small chomata and discontinuous axial fillings resemble *Fusiella praelancetiformis* Safonova from the Moscow Basin. Donets specimens are almost identical to the holotype, but differ from the latter in bigger size. Specimens from the Moscow Basin possess four or four and a half volutions, whereas the Donets ones have five volutions. The present specimens with five volutions are 1.00-1.25 mm in length and 0.30-0.40 mm in diameter.

Genus TAITZEHOELLA Sheng, 1951

Type species.—Taitzehoella taitzehoensis Sheng, 1951.

TAITZEHOELLA SIMPLICATA (Lee, 1937)

Figures 23.19–23.21

? *Wedekindellina simplicata* LEE, 1937, p. 78–79, pl. 2, fig. 5.

Fusulinella (Pseudofusulinella) simplicata (Lee). POGREBNYAK, (part), 1975, p. 57–58, pl. 3, fig. 5 (only).

Material studied.—Axial sections SUI 130725–130727, samples KN2-10/1, KA3/4-12, KA3/11-2; slightly oblique sections SUI 130728, sample KA3/4-9; immature specimen SUI 130729, sample KN2-20/2.

Occurrence.—Limestones N_2, N_2^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Mature specimens with six or seven volutions are 1.36–1.58 mm in length and 0.77–0.95 mm in diameter and possess small proloculus, which is 35–45 μm in diameter. The present specimens are identical to the types of *Taitzehoella simplicata*, which were originally described by Lee (1937) from the limestone N_2 in the Donets Basin. Characteristic features includes fusiform test outline, highly inflated medial area, straight lateral slopes and pointed polar ends, tightly coiled inner volutions, well developed rounded chomata that underlie a gradually widening tunnel, and more weakly developed, discontinuous axial fillings.

TAITZEHOELLA EXTENSA Sheng, 1958

Figures 23.18, 23.22, 23.23

Taitzehoella taitzehoensis extensa SHENG, 1958, p. 84, pl. 5, figs. 10, 11.

Fusulinella (Pseudofusulinella) simplicata (Lee). POGREBNYAK, (part), 1975, p. 57–58, pl. 3, figs. 4, 6 (only).

Material studied.—Axial section SUI 130730, sample KA3/11-3; tangential sections SUI 130731–130733, sample KN2-13/1, KA3/4-10, KA3/4-11/1.

Occurrence.—Limestones N_2, N_2^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Large, mature specimens with seven volutions are tightly coiled initially, with well-developed rounded chomata and small proloculus (0.30 μm in diameter). They differ from *T. simplicata* in their elongated test outline, concave lateral slopes, and bluntly pointed polar ends. The studied specimens are 1.9–2.25 mm in length and 0.90–1.16 mm in diameter and closely resemble to the holotype from China.

TAITZEHOELLA PERSEVERATA (Safonova *in* Rauser-Chernousova et al., 1951)

Figures 23.24–23.26

Profusulinella librovitchi (DUTKEVICH) var. *perseverata* SAFONOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 174, pl. 17, figs. 8, 9.

Fusulinella (Pseudofusulinella) simplicata (Lee). POGREBNYAK, (*part*), 1975, p. 57–58, pl. 3, fig. 3.

Material studied.—Axial sections SUI 130734–130736, samples KN2-1/1, KN2-2/2, KN2-18/1; tangential sections SUI 130737–130739, samples KN2-7/1, KN2-16/1, KA3/4-6/1.

Occurrence.—Limestones N_2, N_2^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—The studied specimens with seven or eight volutions are 2.18–2.70 mm in length and 0.98–1.06 mm in diameter and possess a small proloculus (40–50 µm in diameter). The Donets specimens are slightly longer than those from Moscow Basin and have a smaller diameter, and greater form ratio. This species differs from *Taitzehoella simplicata* (Lee, 1937) in its larger size and greater number of volutions, in stronger fluted septa at polar ends, weaker developed chomata and higher tunnel. The studied specimens differ from *Taitzehoella compacta* Leven, 1998 in shape, particularly in strongly concave lateral slopes as opposed to straight and slightly concave ones in *T. compacta*.

Family FUSULINIDAE Moeller, 1878

Subfamily PSEUDOSTAFFELLINAE Putrja, 1956

Genus NEOSTAFFELLA Miklukho-Maklay, 1959

Type species.—*Neostaffella sphaeroidea* Miklukho-Maklay, 1959, designated in Groves (1988).

NEOSTAFFELLA SPHAEROIDEA (Moeller, 1878)

Figures 23.6, 23.7

*Melonia (Boreli*s) *sphaeroidea* EHRENBERG, 1842, p. 274.

Fusulinella sphaeroidea (Ehrenberg). MOELLER, 1878, p. 107–111, pl. 15, fig. 1a.

Staffella sphaeroidea (Moeller). LEE AND CHEN *in* LEE, CHEN AND CHU, 1930, p. 114–115, pl. 6, fig. 26; LEE, 1937, p. 84, p. 2, fig, 13; BRAZHNIKOVA, 1939, p. 256–257, pl. 1, figs. 7–8.

Pseudostaffella sphaeroidea (Moeller). RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 128, pl. 9, figs. 3–5; GROZDILOVA AND LEBEDEVA, 1950, p. 35–36, pl. 5, fig. 4; SHENG, 1958, p. 75, pl. 3, figs. 16–22.

Neostaffella sphaeroidea (Moeller). ISAKOVA *in* MAKHLINA et al., 2001, pl. 7, figs. 2–4.

Material studied.—Axial sections SUI 130740–130744, samples GN1-4/1, GN1-5/1, GN1-13/1, GN1-19/2, KA3-1/14; tangential sections SUI 130745–130749, samples GN1-7/2, GN1-7/3, KA3-1/3, KA3-1/5, KA3-1/6.

Occurrence.—Limestones N_1, Gurkovo section, limestone N_1^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Our material contains an abundant population of tightly coiled *Neostaffella sphaeroidea* specimens with nearly spherical to subquadratic outline, which possess massive, broad and high chomata. The mature specimens of six to eight volutions are 1.00–1.56 mm in length, 1.03–1.59 mm in diameter. These forms closely resemble typical forms from the Moscow Basin (Moeller, 1878). Specimens described by Rauser-Chernousova (*in* Rauser-Chernousova et al., 1951) differ from the Donets forms in slightly larger proloculus (109 µm versus 55–90 µm) and smaller form ratio (0.85 to 0.91 versus 0.89–0.98).

NEOSTAFFELLA KHOTUNENSIS (Rauser-Chernousova, *in* Rauser-Chernousova et al., 1951)

Figure 23.8–23.9, 23.11

Pseudostaffella khotunensis RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 119, pl. 7, figs. 13, 14; SHENG, 1958, p. 76–77, pl. 4, figs. 19–23.

Neostaffella khotunensis (Rauser-Chernousova). UENO *in* FOHRER et al., 2007, p. 39, figs. 20.31–20.47.

Material studied.—Axial sections SUI 130750–130753, samples GN1-2/2, GN1-2/4, GN1-3/3, GN1-9/2.

Occurrence.—Limestone N_1, Gurkovo section; Donets Basin, Ukraine.

Discussion.—Minute sub-globular tests with slightly depressed umbilical regions, well developed massive chomata possess five volutions. The mature specimens are 0.32–0.50 mm in length and 0.38–0.60 mm in diameter. Proloculus diameter ranges from 40 to 55 μm. The studied specimens differ from the types in distinctly depressed umbilical regions.

NEOSTAFFELLA DISTORTA (Pogrebnyak, 1975)

Figure 23.10

Pseudostaffella distorta POGREBNYAK, 1975, p. 52, pl. 2, figs. 2–4.

Material studied.—Axial section SUI 130754, sample KN2-6/4; tangential section SUI 130755, sample KN2-17/1.

Occurrence.—Limestones N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Small asymmetric tests with four or five volutions are 0.42–0.45 mm in length and 0.50–0.60 mm in diameter with slightly depressed umbilical regions and skewed first two initial volutions. They resemble the holotype in shell shape, overall size and asymmetric, well developed chomata. The studied specimens differ from the holotype in slightly smaller width and greater form ratio.

Subfamily HEMIFUSULININAE Putrja, 1956

Genus HEMIFUSULINA Moeller, 1878

Type species.—*Hemifusulina bocki* Moeller, 1878.

HEMIFUSULINA BOCKI Moeller, 1878

Figures 24.1–24.2

Hemifusulina bocki MOELLER, 1878, p. 117–120, pl. 11, figs. 1–3; RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 266, pl. 42, figs. 6–8.

Material studied.—Axial sections SUI 130756–130757, samples GN1-9/1, GN1-15/1; slightly oblique section SUI 130758, sample KA3/1-1.

Occurrence.—Limestone N_1, Gurkovo section; limestone N_1^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Shortly ovoid tests with bluntly rounded polar ends resemble *H. bocki* Moeller in their uniformly expanding volutions, moderately and regularly fluted septa, small proloculus, well developed subsquare chomata and poorly developed axial fillings. The Donets specimens are slightly larger, 3.10–3.20 mm in length, 1.50–1.60 mm in diameter, with seven or eight volutions, whereas Moscow Basin specimens with six or seven volutions are 2.60 mm long and 1.20 mm wide. The diameter of proloculus in our material varies from 60 to 70 μ.

HEMIFUSULINA STABILIS Rauser-Chernousova and Safonova *in* Rauser-Chernousova et al., 1951

Figures 24.3, 24.6, 24.9

Hemifusulina stabilis RAUSER-CHERNOUSOVA AND SAFONOVA *in* RAUSER-CHERNOUSOVA et al., 1951 p. 267, pl. 42, figs.11, 12.

Material studied.—Axial sections SUI 130770–130772, sample GN1-18/1, KA3/1-9, KA3/1-13; tangential section SUI 130773, sample KA3/1-12; slightly oblique section SUI 130774, sample GN1-16/2.

Occurrence.—Limestone N_1, Gurkovo section; limestone N_1^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Small compactly coiled specimens with regular septal folding and small distinct chomata are similar to the types of *H. stabilis* Rauser-Chernousova and Safonova *in* Rauser-Chernousova et al., 1951 described from the Moscow Basin, but differ slightly in test outline. The studied specimens are shortly fusiform with pointed polar ends, while Moscovian forms are more subcylindrical in shape. The mature specimens with six and seven volutions are 1.88–2.25 mm in length, and 0.84–0.95 mm in diameter. The diameter of proloculus varies from 50 to 65 μm.

HEMIFUSULINA GURKOVENSIS, new species

Figures 24.4, 24.5, 24.7

Diagnosis.—Large, elongated, subcylindrical *Hemifusulina* with seven or eight volutions possess bluntly and widely rounded polar ends, regularly folded septa, well developed chomata in inner volutions that are replaced by pseudochomata in outer volutions, and weakly developed axial fillings. Porous, two-layered wall consists of tectum and diaphanotheca.

Description.—Test is shortly subcylindrical with a flat medial area and bluntly and widely rounded polar ends. It consists of seven or eight volutions, and it ranges from 3.25 to 3.50 mm in length and 1.20 to 1.37 mm in diameter. Volutions increase gradually in height and length. The wall consists of two layers, a dark thin tectum and a porous, faint, thick diaphanotheca. Thick septa are regularly and moderately folded throughout the shell, forming low- to medium-height rounded and subsquared arcs. Septa are weakly folded in the medial area of the two outermost volutions. Proloculus is small, 40–70 μm. Chomata are well developed, small and round in inner volutions; in the two outermost volutions they are replaced by pseudochomata. The tunnel is narrow in inner volutions and rapidly widening in two outermost volutions. Axial fillings are weakly developed.

Etymology.—Species named after the Gurkovo ravine, where new species has been found.

Types.— Holotype: axial section SUI 130759, sample GN1-16/1 (Fig. 4.7); paratypes: axial section SUI 130760, sample GN1-21/1; tangential section SUI 130761, sample GN1-14/1 (Fig. 4.4, 4.5); type locality: Gurkovo section, 5 km to the south from town Pervomaysky, Donetsk oblast, Ukraine; type stratum: limestone N_1 of the Gurkovo section, Myachkovian Horizon, Upper Moscovian.

Measurements.—See Appendix.

Occurrence.—Limestone N_1, Gurkovo section; Donets Basin, Ukraine.

Discussion.—This species closely resembles *Hemifusulina mosquensis* Rauser-Chernousova *in* Rauser-Chernousova et. al., 1951 in regular septal folding, the shape of the chomata and tunnel, as well as in the development of weak axial fillings. It differs from *H. mosquensis* in larger size and cylindrical shell outline. The new species differs from *H. truncatula* Rauser-Chernousova *in* Rauser-Chernousova et al., 1951 in more intensive septal folding, larger chomata and tighter coiled volutions.

HEMIFUSULINA GRACIOSA (Lee, 1937)

Figures 24.8, 24.10

Triticites graciosa LEE, 1937, p. 93–95, pl. 2, fig. 22.

Hemifusulina graciosa (Lee), PUTRJA, 1956, p. 466–467, pl. 17, figs. 4–5.

Material studied.—Axial section SUI 130762, sample KA3/1-10; tangential sections SUI 130763–130765, samples GN1-13/2, GN1-17/1, KA3/1-8; slightly oblique sections SUI 130766–130769, samples KA3/1-3, KA3/1-4, KA3/1-7, KA3/1-11.

Occurrence.—Limestone N_1, Gurkovo section; limestone N_1^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—The studied specimens collected from the type area resemble specimens described by Lee (1937) in their elongate fusiform to subcylindrical test outline, rounded pointed polar ends, and the inner structure. The mature specimens are 2.30–3.05 mm in length and 1.02–1.21 mm in diameter and possess a small proloculus that is 50–70 μm in diameter. The studied specimens are slightly bigger than the holotype, because the former possess 6–7 volutions, while the latter consists of 5.5 volutions.

Subfamily FUSULININAE Moeller, 1878

Genus BEEDENA Galloway, 1933

BEEDEINA INNAEFORMIS, new species

Figures 24.11–24.15, 24.20

Diagnosis.—Test is elongated fusiform, slightly inflated in median portion and pointed at the polar ends. The inner volutions are subrhomboidal in shape. The septa are thick and regularly folded, axial fillings are strongly developed. Chomata are developed only on the proloculus and first volution.

Description.—The test of this species with four to five volutions is intermediate in size, elongated fusiform, slightly inflated in medial portion, with pointed polar ends. The length of the studied specimens varies from 3.14 to 5.86 mm; the diameter varies from 0.86 to 1.28 mm. The rate of coil expansion is uniform and moderately rapid in the outer volutions. Inner volutions are subrhomboidal in shape. The wall is thin, three- and four-layered with tectum, faint diaphanotheca, and outer and inner tectoria. The inner tectorium is discontinuous and weakly developed. Continuous outer tectorium is the same color as diaphanotheca (Fig. 8.2a). Thick septa are regularly folded starting from the inner volutions. The folds decrease in amplitude from the poles to the middle part of the shell. Proloculus is spherical and intermediate in size. Its diameter averages 180 µm, varying from 140 to 220 µm. Rounded chomata are developed on the proloculus and the first volution, and then they are replaced by pseudochomata on successive volutions, outlining a narrow tunnel. Secondary axial deposits are strongly developed and fill almost the whole test.

Etymology. —The name is derived from the Myachkovian species (Late Moscovian) *Fusulina innae* Rosovskaya, 1941, which exhibits similarly well-developed secondary deposits in the axial region of the test.

Types.— Holotype: axial section SUI 130775, sample KN2-3/1 (Fig. 4.15); paratypes: axial sections SUI 130776–130782, samples KN2-5/1, KN2-11/1, KN2-19/1, KA3/3-22, KA3/4-4, KA3/4-5, KA3/4-7, type locality: Kalinovo section, 5 km to the south from town Pervomaysky, Donetsk oblast, Ukraine; type stratum: limestone N_2 of the Kalinovo section, Myachkovian Horizon, Upper Moscovian.

Measurements.—See Appendix.

Occurrence.—Limestones N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—This species seems to be morphologically intermediate between the genera *Beedeina* and *Fusulina*. Test outline, shape of inner volutions and chomata resemble those in *Beedeina* species. Septal folding and axial fillings are similar to those in *Fusulina* species. Thick septa, massive axial fillings and large proloculus of studied specimens are similar to those in *Fusulina innae* Rosovskaya, 1941. However, the length of the Donets new species is twice that of *F. innae* from the Moscow Basin. The new species differs from *Fusulina cylindrica* Moeller, 1878 in its fusiform shell outline and tightly coiled inner volutions, which are subrhomboidal with pointed polar ends.

BEEDEINA sp. cf. B. PARADONETZICA (Putrja, 1939)

Figures 24.16–24.18

Material studied.—Axial sections SUI 130783–130784, samples GN1-1/1, GN1-8/1; slightly oblique section SUI 130785, sample GN1-11/1.

Occurrence.—Limestone N_1, Gurkovo section; Donets Basin, Ukraine.

Discussion.—Small mature specimens with five volutions are 2.00–2.20 mm in length and 1.10–1.15 mm in diameter. They resemble *Beedeina paradonetzica* in their shortly fusiform test outline, highly inflated medial area and pointed polar ends, relatively large proloculus, distinct chomata and thin septa. However, the type of septal folding is slightly different. In the studied species the folds are very tight and irregular at the polar ends, become looser and decrease in amplitude along lateral slopes and are absent across the mid plane, whereas Putrja's holotype possesses regular and weakly folded septa throughout the length. In shape, size and septal folding, the studied specimens are very similar to specimens assigned to *Fusulina transcatulina* Thompson, 1936 by Rauser-Chernousova (*in* Rauser-Chernousova et al., 1951, pl. 48, fig. 5, 6) from the Myachkovian limestone at Polazna, Eastern European Platform. The present specimens possess larger proloculi than Rauser-Chernousova's *F. truncatulina* (120–150 μm vs. 85–110 μm).

BEEDEINA sp. cf. B. TRUNCATULINA (Thompson, 1936)

Figure 24.19

Material studied.—Axial section SUI 130787, sample GN1-20/3.

Occurrence.—Limestones N_1, Gurkovo section; Donets Basin, Ukraine.

Discussion.—The shortly fusiform, minute (0.86 mm in length and 0.45 mm in diameter) probably immature specimen possesses four and a half tightly coiled volutions, a very small proloculus (90 μm), distinctly rounded chomata and regularly folded septa. This specimen differs from typical *B. truncatulina* Thompson, 1936 in its smaller size and type of septal folding. In Thompson's specimens, septa are broadly fluted in the polar ends and unfluted near the tunnel, whereas the present specimen exhibits regular septal folding throughout its axial length.

BEEDEINA sp. cf. B. SIVINIENSIS (Rauser-Chernousova *in* Rauser-Chernousova et al., 1951)

Figure 24.21

Material studied.—Slightly oblique section SUI 130786, sample KN2-20/1.

Occurrence.—Limestones N_1, Gurkovo section; Donets Basin, Ukraine.

Discussion.—The present specimen is a slightly oblique section, large (more than 5 mm in length and 1.36 mm in diameter), with tightly coiled subrhomboidal inner volutions and loosely coiled outer ones. It has regularly folded septa, distinct chomata, discontinuous axial fillings in the inner four volutions, and a proloculus diameter of (160 µm). It is similar in all these features to *B. siviniensis*, but its precise shape of a test is unknown, because it is an oblique section.

Genus FUSULINA Fischer de Waldheim, 1829

FUSULINA CYLINDRICA Moeller, 1878

Figures 25.1, 25.3

Fusulina cylindrica FISCHER DE WALDHEIM, 1829, p. 330; MOELLER, 1878, p. 51–54, pl. 7, fig. 1, a–c; SCHELLWIEN (part), 1908, p. 161–163, pl. 13, figs. 1–15, not 3.

Fusulina cylindrica Moeller. PUTRJA, 1939, p. 118–119, pl. 1, figs. 13–15; RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 303–304, pl. 51, figs. 5a, b.

Girtyina cylindrica (Fischer de Waldheim). LEE (part), 1927, p. 32–35, pl. 4, figs. 4, 7, 9, not 1, 2, 5, 6, 8.

Material studied.—Axial sections SUI 130788–130789, samples KA3/3-7, KN2-22/1; slightly oblique section SUI 130790–SUI 130791, samples KA3/3-15, KA3/3-17.

Occurrence.—Limestones N_1^1, N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.— Mature subcylindrical specimens with four or five volutions are 4.00–6.10 mm in length and 1.00–1.42 mm in diameter. The studied specimens closely resemble the types from Moscow Basin in test outline, very large proloculus (220 to 280 μm), rapidly expanding coil with rounded polar ends, thick irregularly folded septa and discontinuous axial fillings.

FUSULINA DOMODEDOVI Rauser-Chernousova *in* Rauser-Chernousova et al., 1951

Figures 25.2, 25.5–25.6

Fusulina cylindrica domodedovi RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 304, pl. 51, figs. 6, 7.

Material studied.—Axial sections SUI 130792–130794, samples KN2-26/1, KA3/11-4, KA3-11/6.

Occurrence.—Limestones N_2, N_2^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Three long subcylindrical specimens with five volutions are 5.58–6.90 mm in length and 1.00 to 1.28 mm in diameter. They closely resemble the types of *F. cylindrica domodedovi* Rauser-Chernousova in their rapidly expanding inner volutions and regularly folded septa that are thickened near the axial plane. The Donets specimens differ from the types in their slightly bent coiling axis.

FUSULINA QUASICYLINDRICA (Lee, 1927)

Figure 25.4

Girtyina cylindrica Fischer de Waldheim. LEE, 1927 (part), pl. 4, figs. 1, 2, 5, 6, 8.

Girtyina quasicylindrica LEE, 1927 (part), p.35–39, pl. 4, figs. 10–19, not. 11.

[not] *Fusulina quasicylindrica* (Lee). RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 305–306, pl. 52, figs. 2–4.

Material studied.—Axial sections SUI 130795–130797, samples KA3/3-9, KA3/3-14, KA3/4-3/2; slightly oblique sections SUI 130798–130799, samples KA3/3-4, KN2-25/1.

Occurrence.—Limestones N_1^1, N_1^2, N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—In the original description Lee (1927) illustrated rather large subcylindrical specimens with lengths varying from 5.46 to and 8.26 mm and diameters varying from 1.33 mm to 1.60 mm (Lee, 1927, pl. 4, figs. 14, 15). Short specimens (Lee, 1927, pl. 4, figs. 11, 12) are obviously immature individuals. Our material from the Donets Basin includes quite variable specimens. The mature specimens with five or five-and-a-half volutions are 4.30–6.00 mm in length and 1.07–1.30 mm in diameter. They closely resemble the types from China in their large size, subcylindrical to slightly inflated test, inner volutions that are tightly coiled, elongated and bluntly pointed, and strong axial fillings. They are similar in shape and type of septal folding to *F. cylindrica*, but differ from the latter in smaller proloculus size, tightly coiled inner volutions with pointed polar ends, and slightly inflated medial portion of the test. Therefore some of specimens with small proloculus and tightly coiled volutions illustrated by Lee (1927) as *F. cylindrica* we consider in this paper as *F. quasicylindrica*.

FUSULINA QUASIFUSULINOIDES Rauser-Chernousova *in* Rauser-Chernousova et al., 1951

Figures 25.7, 25.7a, 25.8

Fusulina quasifusulinoides RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 312, pl. 54, fig. 6, pl. 55, figs. 1, 2.

Material studied.—Axial sections SUI 130802–130803, samples KA3/3-5, KA3/3-20.

Occurrence.—Limestone N_1^2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Large specimens with five volutions are 5.30–7.10 mm in length and 1.57–1.70 mm in diameter. The specimens resemble the types from the Moscow Basin in their slightly bent coiling axis, regularly expanding inner volutions with rounded polar ends, large proloculus (230–320 μm), highly developed axial fillings and irregular septal folding. Wall structure is four-layered in the inner three volutions (thickness 20–40 μm), with a discontinuously developed light gray outer tectorium, dark tectum, thin faint diaphanotheca and poorly developed dark inner tectorium. In the two outermost volutions the spirotheca becomes three-layered because of the disappearance of the outer tectorium. The diaphanotheca and dark inner tectorium became thicker in the outer volutions. The thickness of spirotheca in the outer volutions can reach 50 μm because of the unevenly developed inner tectorium. Starting from the third or fourth volution, the spirotheca is penetrated by thin pores.

FUSULINA SOSNINAE new species

Figures 25.9, 25.9a, 25.10, 25.10a

Fusulina quasicylindrica (Lee). RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 305–306, pl. 52, figs. 2–4.

Diagnosis.—Subcylindrical test outline, small proloculus, irregularly folded septa, small but prominent chomata developed up to the fourth volution, discontinuous axial fillings, thin three-layered wall structure in outer volutions.

Description.—Relatively small specimens with five volutions possess a subcylindrical test outline. Length varies from 3.43 to 3.90 mm and diameter varies from 0.86 to 0.93 mm. Tests of this species are tightly coiled in the inner, elongated subrhomboidal volutions. A small proloculus is ovoid in shape. The diameter of the proloculus varies from 130 to 150 μ. Thick septa are irregularly folded, especially in the inner volutions and along the coiling axis. Small rounded chomata are well developed up to the fourth volution and form a tunnel that irregularly widens in the outer volutions. Axial fillings are well developed. The wall is thin, up to 10 μm, and is weakly differentiated in inner volutions. In the outer volutions it is three-layered, up to 25 μm in thickness, and consists of dark tectum, faint gray diaphanotheca, and outer tectorium that possess the same color as the diaphanotheca. In some small portions of the wall, the diaphanotheca is clear. The wall in the final half-volution is two-layered and consists of tectum and gray diaphanotheca. Pores are very tiny, but visible, especially in the lighter portion of the diaphanotheca.

Etymology.—The species is named for Dr. M. I. Sosnina, a fusulinid micropaleonologist, who contributed greatly to the understanding of the Carboniferous stratigraphy of the Donets Basin.

Types.— Holotype: axial section SUI 130800, sample KA3/11-7 (Fig. 5.9, 5.9a); paratype: axial section SUI 130801, sample KA3/11-5 (Figs. 5.10, 5.10a), type locality: Kalinovo section; type stratum: limestone N_2^1 of the Kalinovo section, Myachkovian Horizon, Upper Moscovian.

Measurements.—See Appendix.

Occurrence.—Limestone N_2^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Rauser-Chernousova *in* Rauser-Chernousova et al., (1951) described medium sized specimens with walls typical for the latest Peskovian representatives of the genus *Fusulina* as *F. quasicylindrica* (Lee). She designated the specimen illustrated on Pl. 4, fig. 10 in Lee (1927) as a lectotype of *F. quasicylindrica*; however the lectotype is remarkably different from specimens from the Russian Platform, indentified by Rauser-Chernousova as *F. quasicylindrica.* The lectotype from China (Lee, 1927) is considerably larger, with more intensively fluted septa, strongly developed axial fillings and less prominent chomata. The new species is erected to accommodate our material from the Donets Basin as well as Russian Platform specimens incorrectly referred to *F. quasicylindrica*.

FUSULINA sp. cf. F. PANCOUENSIS (Lee, 1927)

Figure 25.11

Material studied.—Axial section SUI 130804, sample KA3/3-1.

Occurrence.—Limestones N_1^2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—One tightly coiled, subcylindrical, microsphaerical specimen with eight volutions is 6.43 mm long and 1.58 mm in diameter. The proloculus is very small, and thick septa are irregularly folded. Small chomata are well developed in inner volutions. Axial fillings are strongly developed from the second volution and occupy two-thirds of the test. The wall is thin and poorly preserved in the inner volutions. It is four-layered with a diaphanotheca in the outer volutions. The present specimen resembles to *F. pancouensis* (Lee) in size, well developed secondary deposits and wall structure, but differs in greater volution numbers and smaller proloculi size. *F. pancouensis* (Lee) from China possesses six volutions, whereas the present specimen has eight volutions with skewed first initial one. It has large (0.3 mm in diameter) round to ovoid proloculus, whereas proloculus in the Donets specimen is small (less than 0.1 mm).

Family FUSULINELLINAE Staff and Wedekind, 1910

Genus FUSULINELLA Moeller, 1878

FUSULINELLA PSEUDOBOCKI Lee and Chen *in* Lee, Chen, and Chu, 1930

Figures 26.1, 26.1a

Fusulinella (Neofusulinella) pseudobocki LEE AND CHEN *in* LEE, CHEN AND CHU, 1930, p. 122–123, pl. 9, figs. 10–15 (not 13); pl. 10, figs. 1–6 (not 7).

Fusulinella pseudobocki Lee and Chen. RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 227–228, pl. 32, figs. 8, 9.

Material studied.—Axial section SUI 130805, sample KA3/3-6.

Occurrence.—Limestone N_1^2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—One large, shortly fusiform specimen with six volutions is 3.58 mm in length and 1.47 mm in diameter. It possesses a highly inflated median part and rapidly elongated polar ends in the two outer volutions. This specimen closely resembles a specimen illustrated by Lee and Chen (*in* Lee et. al., 1930, pl. 9, fig. 14), which we are formally designating as a lectotype of *Fusulinella pseudobocki*. This species differs from very similar *Fusulinella bocki* Moeller, 1878 in its test outline and intense septal folding along coiling axis. The two species are similar in their high and massive subsquared chomata. The wall structure in the outer volutions changes from being four-layered with translucent diaphanotheca (typical for the genus), into three-layered with faint diaphanotheca. Some thickening of the wall can be observed in the fourth volution between the chomata because an increase in the thickness of the dark inner tectorium (Figs. 6.1a).

FUSULINELLA sp. cf. F. BOCKI INTERMEDIA Rauser-Chernousova *in* Rauser-Chernousova et al., 1951

Figures 26.2–26.5

Material studied.—Axial section SUI 130806, sample KA3/3-8; slightly oblique sections SUI 130807–130809, samples KA3/3-10, KA3/3-16, KA3/3-19.

Occurrence.—Limestone N_1^2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—The present ovoid tests, with almost globular inner volutions, bluntly polar ends and massive chomata resemble *Fusulinella bocki intermedia* but differ from the latter in their smaller size. The mature specimens with five volutions are 2.32–2.44 mm in length and 0.94–1.21 mm in diameter.

FUSULINELLA RARA Schlykova, 1948

Figures 26.6, 26.8, 26.8a, 26.11

Fusulinella pseudobocki var. *rara* SCHLYKOVA, 1948, p. 134–135, pl. 7, fig. 3–5.

Fusulinella rara Schlykova. RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 231–232, pl. 34, figs. 3, 4.

Material studied.—Axial sections SUI 130810–130812, samples KA3/3-2, KA3/3-12, KA3/3-23.

Occurrence.—Limestone N_1^2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Large fusiform specimens with five volutions are 3.10–3.72 mm in length and 1.05–1.20 mm in diameter. The studied specimens resemble the types described from the Samara region (East European Platform, Russia) in having ovoid tightly coiled inner volutions, small proloculi, massive subsquared chomata and intensively folded thin septa at the polar ends in the outer volutions. The four-layered wall with diaphanotheca thickens gradually from the inner (10–15 µm) to the outer volutions (55–60 µm). Such changes in wall thickness seem to be typical for the *Fusulinella* species that occur in the *Fusulina cylindrica – Fusulinella pseudobocki* Zone.

FUSULINELLA sp. cf. F. PAUCISEPTATA Rauser-Chernousova and Belyaev *in* Rauser-Chernousova, Belyaev, and Reitlinger, 1936

Figures 26.7, 26.9, 26.10, 26.12, 26.13

Material studied.—Axial sections SUI 130813–130817, samples KA3/3-3, KA3/3-5a, KA3/3-11/2, KA3/3-13, KA3/3-21.

Occurrence.—Limestone N_1^2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—The present specimens resemble *Fusulinella pauciseptata*, described from the East European Platform in their fusiform test outline, which is inflated in the medial part, and elongated, bluntly pointed polar ends. However, they differ in their inner structure. The studied specimens possess tightly coiled, ovoid inner volutions and a rapidly expanding outer volution. In *F. pauciseptata* sensu stricto the inner volutions expand gradually and are fusiform with pointed polar ends. Chomata are massive and subsquared in the Donets material and prominent rounded to subtriangular in *F. pauciseptata*. The studied specimens resemble *F. pseudobocki* in their inner structure, but differ from the latter by having fusiform test outline, and smaller size. The studied mature specimens with five volutions are 2.88–3.25 mm in length and 1.06–1.33 mm in diameter and possess small proloculus 80–100 µm. The wall is four-layered with diaphanotheca that gradually transforms from clear into faint gray. The wall is slightly thicker than in Podolskian species of *Fusulinella*.

FUSULINELLA (?) sp. cf. F. KUMPANI Putrja, 1939

Figures 26.18, 26.19, 26.19a

Material studied.—Axial section SUI 130823, sample KA3/11-1.

Occurrence.—Limestone N_2^1, Kalinovo section; Donets Basin, Ukraine.

Discussion.—The elongated subcylindrical specimen is 4.00 mm in length and 1.22 mm in diameter, and possesses two or three globular inner volutions and thin septa that are intensely folded at the polar ends. Chomata in the inner volutions are small and subtriangular. They become massive and subsquared in the outer volutions where they border an irregular tunnel. These features closely resemble those in *Fusulinella kumpani* described by Putrja (1939) from the Donets Basin. This species is characterized by a unique wall structure, different from that in *Fusulinella*, which is four-layered with a thin diaphanotheca, and from that in *Protriticites*, which is four-layered with thick and faintly porous diaphanotheca. In this specimen, the thin diaphanotheca present as a discontinuous layer and only in outer volutions. In inner volutions the wall is three-layered, consisting of a tectum bracketed by inner and outer tectoria.

FUSULINELLA (?) sp.

Figures 26.14, 26.14a, 26.15–26.18

Protriticites ex gr. *P. pseudomontiparus* Putrja. RAUSER-CHERNOUSOVA *in* RAUSER-CHERNOUSOVA et al., 1951, p. 317, pl. 57, fig.1.

Material studied.—Axial section SUI 130818, sample KA3/4-1; paraxial sections SUI 130819–130822, samples KA3/4-2, KN2-21/1, KN2-24/1, KN2-6/3.

Occurrence.—Limestone N_2, Kalinovo section; Donets Basin, Ukraine.

Discussion.—Medium sized specimens with four volutions are 1.68–2.50 mm in length and 0.89–1.12 mm in diameter. The massive chomata and shortly fusiform test outlines in the studied specimens are similar to those in *Fusulinella bocki* Moeller, 1878, a very abundant species in the Korobcheevo Formation in the Moscow Basin. The main and important difference between these comparable species is the wall structure; in the studied species a clear diaphanotheca becomes faint and present, only as discontinuous layer. Specimens of *Fusulinella bocki* from the Latest Podolskian (Limestone M_{10}) possess typical four-layered walls with a continuously developed diaphanotheca in all volutions. Forms from the Early Myachkovian (Limestone N_1^2) possess three- and four-layered walls, with a faint diaphanotheca in the inner volutions that becomes better developed beginning in the fourth volution. In specimens from the limestone N_2, the wall is almost completely transformed into a three-layered structure; however some patches of thin, clear diaphanotheca are still preserved in the polar ends. The studied specimens are similar in wall structure to *Fusulinella* (?) *kumpani* Putrja, 1939, *F.* (?) *podolskensis* Rauser-Chernousova *in* Rauser-Chernousova et al., 1951, although the wall is thinner in the latter. The chomata are also more massive in the studied specimens as opposed to those in *F.* (?) *kumpani* and *F.* (?) *podolskensis*.

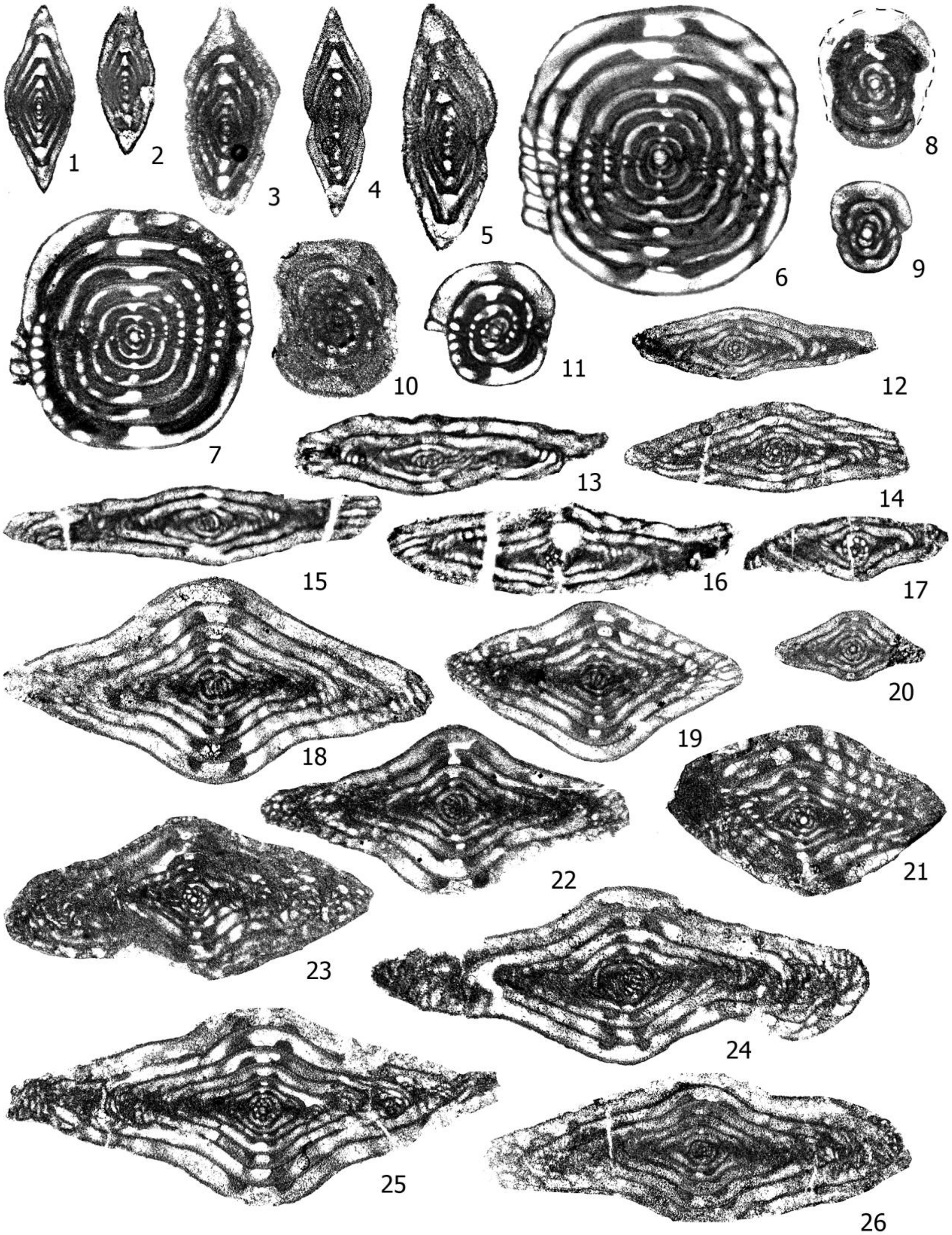
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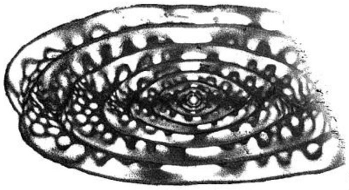
Figure 23. Myachkovian fusulinids. *Taitzehoella, Neostaffella, Pseudostaffella, Fusiella, Ozawainella* species.

Taitzehoella, Neostaffella, *Pseudostaffella*, *Fusiella*, *Ozawainella* species, x 35.**1-2-** *Ozawainella krasnokamski kirovi* Dalmatskaya, 1961, axial sections: **1**– SUI 130697, sample GN1-7/1, limestone N_1, Gurkovo section, **2**– SUI 130698, sample KN2-10/3, limestone N_2, Kalinovo section; **3**–**5 -** *Ozawainella vozhgalica* Safonova, 1951, axial sections: **3**– SUI 130703, sample KN2-14/1, **4**– SUI 130704, sample KN2-15/1, **5**–SUI 130702, sample KN2-4/1, limestone N_2, Kalinovo section; **6**–**7**- *Neostaffella sphaeroidea* (Moeller, 1978), axial sections: **6**– SUI 130743, sample GN1-19/2, **7**– SUI 130741, sample GN1-5/1, limestone N_1, Gurkovo section; **8–9, 11**- *Neostaffella khotunensis* (Rauser-Chernousova, 1951), axial sections: **8**– SUI 130751, sample GN1-2/4, **9**– SUI 130752, sample GN1-3/3, **11**– SUI 130750, sample GN1-2/2, limestone N_1, Gurkovo section; **10** - *Neostaffella distorta* Pogrebnyak, 1975, axial section SUI 130754, sample KN2-6/4, limestone N_2, Kalinovo section; **12, 14, 17** - *Fusiella praelancetiformis* Safonova, 1951, axial sections: **12**–SUI 130716, sample GN1-7/4, limestone N_1, Gurkovo section, **14**–SUI 130720, sample KN2-12/1, limestone N_2, Kalinovo section, **17** –SUI 130718, sample KA3/1-13a, limestone N_1, Kalinovo section; **13, 15**–**16**- *Fusiella spatiosa* Sheng, 1958, axial sections: **13**– SUI 130711, sample GN1-10/1, **15**– SUI 130709, sample GN1-2/1, **16**– SUI 130713, sample GN1-22/1, limestone N_1, Gurkovo section; **18, 22**–**23**- *Taitzehoella extensa* Sheng, 1958, paraxial sections: **18**–SUI 130731, sample KN2-13/1, **22**–SUI 130733, sample KA3/4-11/1, limestone N_2, Kalinovo section, axial section **23**– SUI 130730, sample KA3/11-3, limestone N_2^1, Kalinovo section; **19**–**21**-*Taitzehoella simplicata* (Lee, 1937), axial sections: **19**–SUI 130725, sample KN2-10/1, limestone N_2, **21**–SUI 130727, sample KA3/11-2, limestone N_2^1, immature specimen **20**–SUI 130729, sample KN2-20/2, limestone N_2, Kalinovo section; **24**–**26 -** *Taitzehoella perseverata* Safonova, 1951, axial sections: **24**– SUI 130738, sample KN2-16/1, **25**– SUI 130736, sample KN2-18/1, **26**– SUI 130734, sample KN2-1/1, limestone N_2, Kalinovo section.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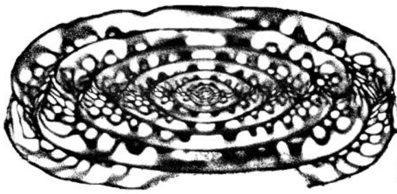
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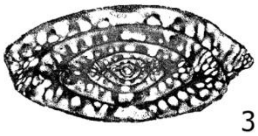
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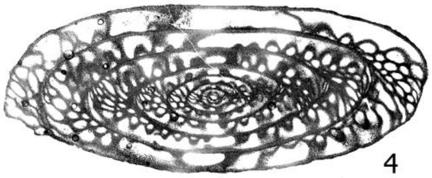
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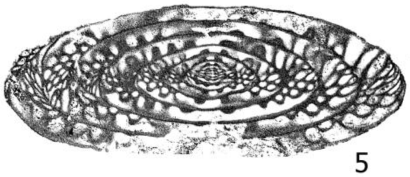
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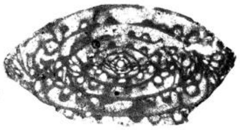
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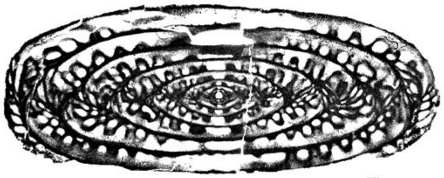
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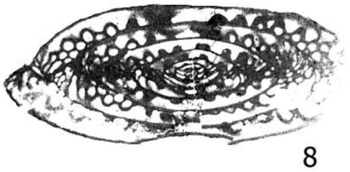
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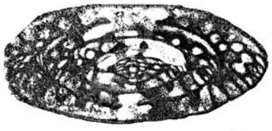
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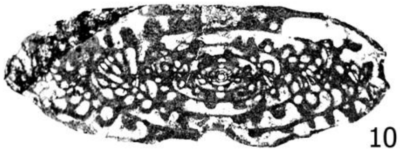
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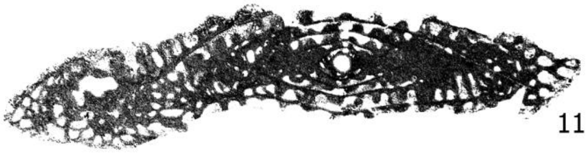
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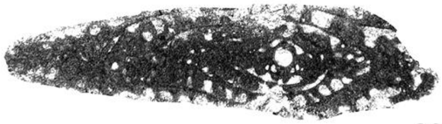
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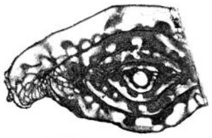
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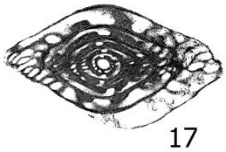
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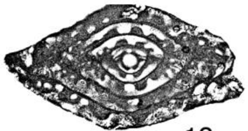
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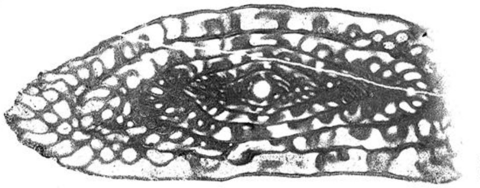
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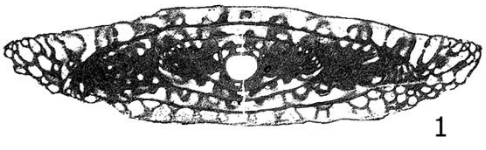
Figure 24. Myachkovian fusulinids. *Beedeina* and *Hemifusulina* species.

Beedeina, Hemifusulina, x 20. **1–2-** *Hemifusulina bocki* Moeller, 1878, axial sections: **1**– SUI 130756, sample GN1-9/1, **2**– SUI 130757, sample GN1-15/1, limestone N_1, Gurkovo section; **3, 6, 9 -** *Hemifusulina stabilis* Rauser-Chernousova and Safonova, 1951, axial sections: **3**– SUI 130770, sample GN1-18/1, limestone N_1, Gurkovo section, **6**–SUI 130771, sample KA3/1-9, **9** –SUI 130772, sample KA3/1-13, limestone N_1, Kalinovo section; **4–5, 7 -** *Hemifusulina gurkovensis* n. sp., axial sections: **4**–SUI 130760, sample GN1-21/1, **5**– SUI 130761, sample GN1-14/1, **7** –SUI 130759, axial section of holotype GN1-16/1, limestone N_1, Gurkovo section; **8, 10 -** *Hemifusulina graciosa* Lee, 1937, axial sections: **8**–SUI 130765, sample KA3/1-8, **10** – SUI 130762, sample KA3/1-10, limestone N_1, Kalinovo section; **11–15, 20**- *Beedeina innaeformis* n. sp., axial section of holotype **15**–SUI 130775, sample KN2-3/1, axial sections: **11**– SUI 130781, sample KA3/4-5, **12**– SUI 130776, sample KN2-5/1, **13**–SUI 130778, sample KN2-19/1, **14**– SUI 130777, sample KN2-11/1, **20**– SUI 130780, sample KA3/4-4, limestone N_2, Kalinovo section; **16–18**-*Beedeina* sp. cf. *B. paradonetzica* (Putrja, 1939), axial sections: **16**– SUI 130783, sample GN1-1/1, **17**– SUI 130785, sample GN1-11/1, **18**–SUI 130784, sample GN1-8/1, limestone N_1, Gurkovo section; **19**– *Beedeina* sp. cf. *B. trunscatulina* (Thompson, 1936), axial section SUI 130787, sample GN1-20/3, limestone N_1, Gurkovo section; **21**– *Beedeina* sp. cf. *B. siviniensis* (Rauser-Chernousova, 1951), slightly oblique section SUI 130786, sample KN2-20/1, limestone N_2, Kalinovo section.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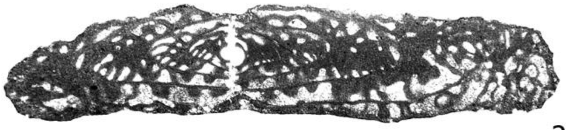
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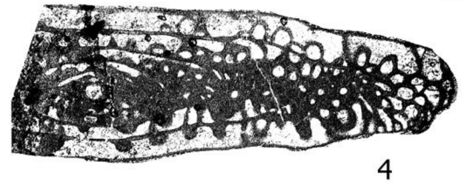
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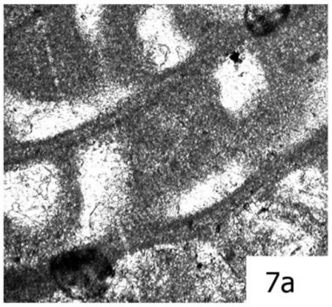
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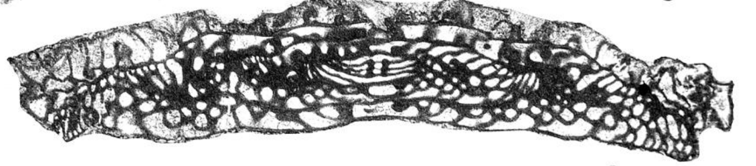
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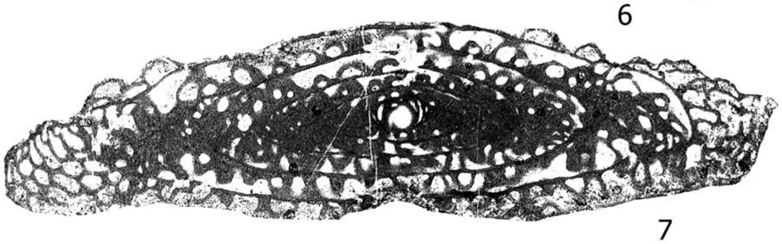
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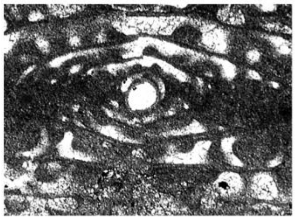
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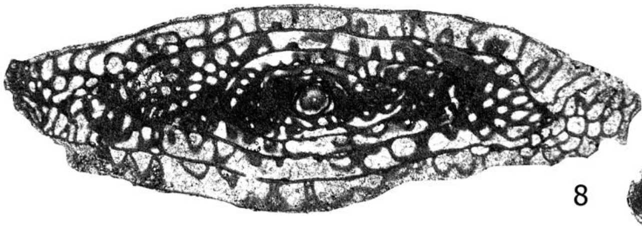
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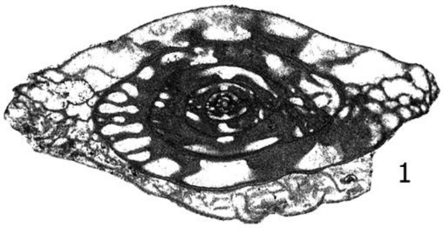
Figure 25. Myachkovian fusulinids. *Fusulina* species.

Fusulina, x20. **1, 3-** *Fusulina cylindrica* Moeller, 1878, axial sections: **1**– SUI 130788, sample KA3/3-7, limestone N_1^1, **3**– SUI 130789, sample KN2-22/1, limestone N_2, Kalinovo section; **2,.5, 6 -** *Fusulina domodedovi* Rauser-Chernousova, 1951, axial sections: **2**– SUI 130793, sample KA3/11-4, limestone N_2^1, **5**–SUI 130792, sample KN2-26/1, limestone N_2, paraxial section**.6**– SUI 130794, sample KA3/11-6, limestone N_2^1, Kalinovo section; **4 -** *Fusulina quasicylindrica* (Lee, 1927), axial section SUI 130795, sample KA3/3-9, limestone N_1^1, Kalinovo section; **7–8 -** *Fusulina quasifusulinoides* Rauser-Chernousova, 1951, axial sections: **7**– SUI 130802, sample KA3/3-5, **8**– SUI 130803, sample KA3/3-20, limestone N_1^1, Kalinovo section, **7a,** wall structure of the specimen SUI 130802, x 100; **9–10 -** *Fusulina sosninae* n. sp., **9**– SUI 130800, sample KA3/11-7, axial section of holotype, limestone N_2^1, Kalinovo section, **9a,** wall structure and coiling expansion in inner volutions of this specimen, x 80, **10** – SUI 130801, sample KA3/11-5, axial section of paratype, limestone N_2^1, Kalinovo section, **10a,** wall structure of this specimen, x 80; **11 -** *Fusulina* sp. cf. *F. pancouensis* (Lee, 1927), axial section of microsphaeric specimen SUI 130804, sample KA3/3-1, limestone N_1^1, Kalinovo section.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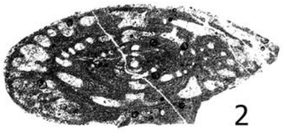
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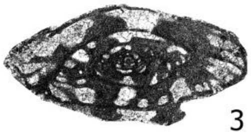
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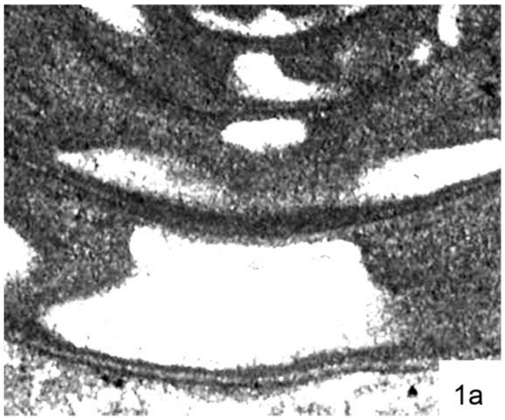
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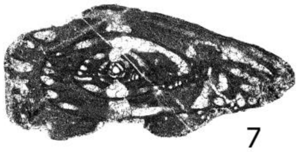
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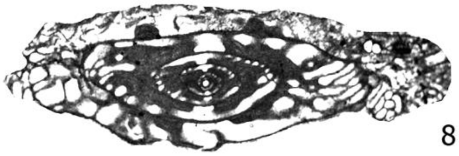
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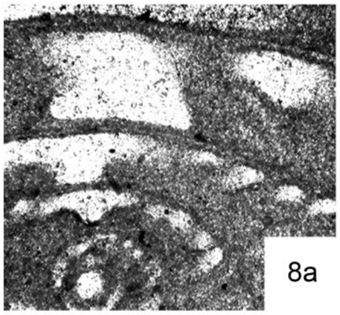
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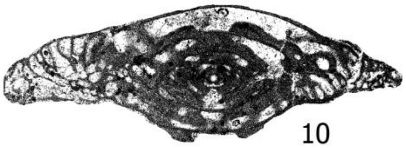
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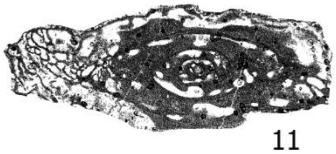
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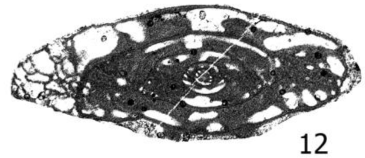
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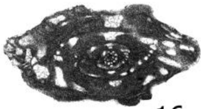
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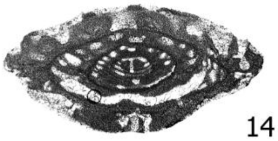
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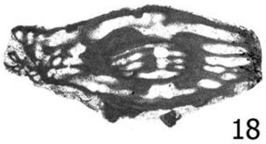
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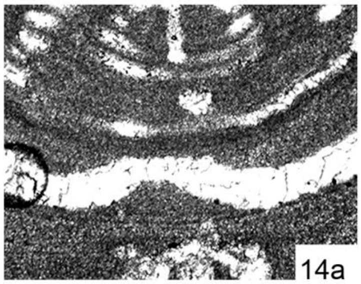
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Figure 26. Myachkovian fusulinids. *Fusulinella* species.

Fusulinella, x 20; wall, x 100. **1** - *Fusulinella pseudobocki* (Lee and Chen, 1930), axial section SUI 130805, sample KA3/3-6, limestone N_1^1, Kalinovo section, **1a,** wall structure of this specimen; **2–5** - *Fusulinella* sp. cf. *F. bocki intermedia*, Rauser-Chernousova, 1951, slightly oblique sections: **2**– SUI 130808, sample KA3/3-16, **3**– SUI 130809, sample KA3/3-19, **4**– SUI 130807, sample KA3/3-10, **5**– SUI 130806, sample KA3/3-8, limestone N_1^1, Kalinovo section; **6, 8, 11** - *Fusulinella rara* Schlykova, 1948, slightly oblique section **6**– SUI 130810, sample KA3/3-2 and axial sections: **8**– SUI 130811, sample A3/3-12, **11** – SUI 130812, sample A3/3-23, limestone N_1^1, Kalinovo section, **8a,** wall structure of the specimen SUI 130811; **7, 9, 10, 12, 13** - *Fusulinella* sp. cf . *F. pauciseptata* Rauser-Chernousova and Beljaev, 1936, axial sections: **9**– SUI 130815, sample KA3/3-11/2, **10**– SUI 130817, sample KA3/3-21, **12**– SUI 130814, sample KA3/3-5a, **13** – SUI 130813, sample KA3/3-3; slightly oblique section **7**– SUI 130816, sample KA3/3-13, limestone N_1^1, Kalinovo section; **14–18** - *Fusulinella* (?) sp., paraxial sections: **14**– SUI 130821, sample KN2-24/1, **15**– SUI 130822, sample KN2-6/3, **18**– SUI 130820, sample KN2-21/1, limestone N_2, Kalinovo section, **14a**, wall structure of the specimen SUI 130821; **16**– SUI 130818, sample KA3/4-1, limestone N_1^2, Kalinovo section, slightly oblique section **17**– SUI 130819, sample KA3/4-2, limestone N_1^2, Kalinovo section; **19 -** *Fusulinella* (?) cf. *F. kumpani* Putrja, 1939, paraxial section *18*– SUI 130823, sample KA3/11-1, limestone N_2^1, Kalinovo section.

Myachkovian fusulinid biostratigraphy

The distribution of 62 species from the upper part of the “M” Formation and the lower part of the “N” Formation is presented in Appendix, Table 6B. Although strata of the “N” Formation are poorly exposed and therefore not well characterized by fusulinid faunas, we propose four fusulinid biozones in the Podolskian – Myachkovian transition, each of which is fairly well correlated with fusulinid assemblages in the Moscow Basin (Isakova *in* Makhlina et al., 2001).

A cyclic distributional model of fusulinids in the Donets Basin reveals two full transgressive-regressive cycles. The first approximately coincides with the duration of Podolskian Horizon, the second with the Myachkovian Horizon. The beginning of each cycle starts with the *Hemifusulina* association interpreted as the beginning of transgression. The M_7 and M_7^{up} limestones contain *Hemifusulina* species that are similar to those of the *Hemifusulina vozhgalica* Zone of the Smedva Formation, the upper part of the Kashirian strata in the Moscow Basin. A detailed discussion of the Kashirian – Podolskian fusulinid biostratiography in the Donets Basin and its correlation with the Moscow Basin using a proposed cyclic distributional model is intended for a separate paper. Late transgressive limestone,M_8 and sea level high stand limestone M_9 contain fusulinids that allow correlation of this interval with the Vaskino Formation of the Moscow Basin. A proposed *Putrella donetziana – Kamaina rossoshanica* Zone corresponds to the interval of $M_9 – M_{10}$ and is correlated with Podolskian strata, the Vaskino (M_9) and probably Ulitino or Shchurovo Formations (M_{10}) in the Moscow Basin.

According to the cyclic model the interval extending from limestone M_{10} to N_1 coincides with a regressive episode, a gradual falling of sea level and development of highly endemic fusulinids. As a result, a correlation of the upper Podolskian and lower Myachkovian strata with coeval strata in the Moscow Basin (Ulitino, Shchurovo and lower part of Korobcheevo Formations) is difficult.

New transgression is marked by the limestone N_1. In the studied sections transgressive beds are represented by a single limestone N_1, whereas in the Eastern Donets Basin (Putrja, 1940) the thickness increases and this bed is represented by several thin clayed limestones intercalated with shales. Fusulinids are represented by mainly *Hemifusulina* species. In the Moscow Basin the coeval strata are documented in the upper part of the Korobcheevo Formation, Myachkovian Horizon (Makhlina et al., 2001). As transgression is a very rapid event, the beds with abundant *Hemifusulina* in both regions can be considered as coeval strata. Therefore a proposed *Hemifusulina graciosa – Fusiella spatiosa* Zone (Fig. 27) is fairly well correlated with the upper part of the Korobcheevo Formation in the Moscow Basin. Maximum transgression is marked by the *Beedeina*-dominant assemblage occurring in the N_1^6 limestone from the northern part of the Donets Basin, Kharkovskaya Oblast, in which Pogrebnyak (1975) described *Beedeina lanceolata* (Lee and Chen *in* Lee, Chen and Chu, 1930) and *B. siviniensis* (Rauser-Chernousova *in* Rauser-Chernousova et al., 1951). The interval of this limestone is poorly exposed in the studied sections. Available material allows definition of two zones: the *Fusulina cylindrica – Fusulinella pseudobocki* Zone corresponds to the interval of the N_1^1 – N_2 limestones (Fig. 27) and is correlated with the *Fusulina cylindrica* Zone of the Domodedovo Formation and probably the lower part of the Peski Formation of the Moscow Basin; the upper *Fusulinella* (?) *kumpani* Zone extending from the base of N_2 to the base of N_3 (Fig. 27) is related to the *Protriticites ovatus* Zone in the upper part of Peski Formation in the Moscow Basin.

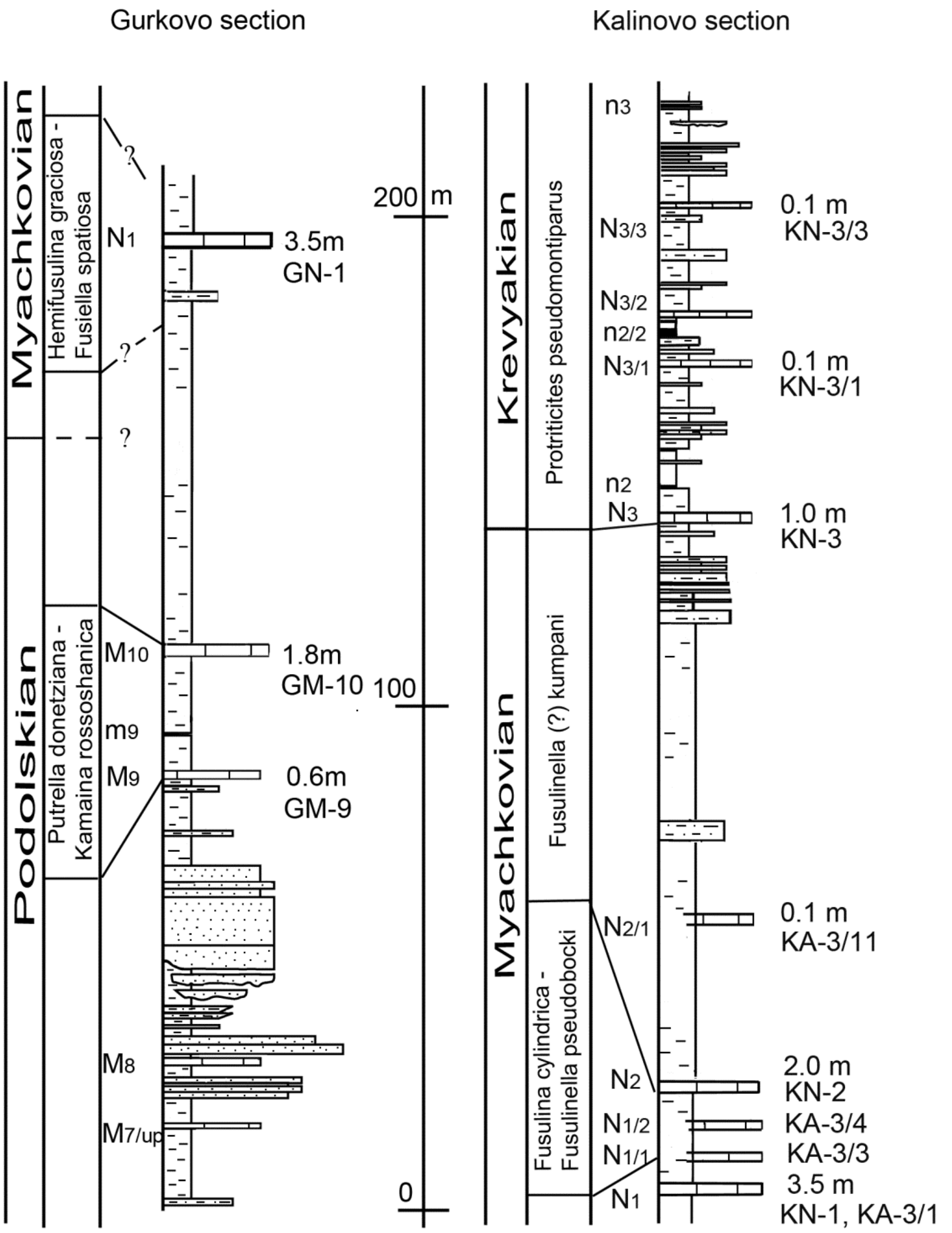


Figure 27. The Gurkovo and Kalinovo sections of the “M” and “N” Formations, redrawn from Eros J. M. et al. 2012.

Hemifusulina graciosa – Fusiella spatiosa Zone

The interval between the M_{10} limestone with Podolskian fusulinids, and the N_1 limestone where first typical Myachkovian forms are recognized, is not characterized by fusulinids. Material from Limestones M_{10}^1 and M_{10}^2 were not available for this study, therefore future work needs to be conducted to clarify the exact position of the Podolskian – Myachkovian boundary.

The main feature of the proposed zone is the disappearance of *Putrella brazhnikovae* (Putrja) and *Fusulina rossoshanica* Putrja, which were abundant in the upper Podolskian Limestones. Predominantly short, fusiform species of *Fusiella* are replaced by large, elongated fusiform *F. spatiosa* Sheng and small sized *F. prealancetiformis* Safonova in the limestone N_1. The latter two are distinguished from their ancestors by their strongly developed axial fillings. An important feature for this zone, in contrast to the upper Podolskian, is the presence of abundant and diverse *Hemifusulina* with a two-layered porous wall structure. The relatively small ovoid *Hemifusulina* aff. *H. bocki* Moeller, which is rare in the M_9 limestone, gave rise to large subcylindrical *H. graciosa* and *H. gurkovensis* n. sp. with prominent axial fillings, which are absent in the late Podolskian form. Besides the large subcylindrical species, the *Hemifusulina* assemblage includes small tightly coiled species similar to *H. stabilis* from the Moscow Basin, which also possesses discontinuous axial fillings. Large *Neostaffella sphaeroidea* are also abundant in this zone and slightly differ from the older late Podolskian specimens in their larger size, more volutions and more massive chomata. Small species of this genus occur in association with the large forms. *Ozawainella* are often in this zone and are represented by small subrhomboidal species *O. krasnokamski* *kirovi* Dalmatskaya. Small *Beedeina* are represented by rare subrhomboidal species, whereas *Fusulinella* species are absent in Limestone N_1.

The Upper Member of the Korobcheevo Formation, Rozhay cyclothem in the Moscow Basin (Kabanov, 2003, Makhlina et al., 2001) contains a similar assemblage of fusulinids, such as *Hemifusulina stabilis* Rauser-Chernousova, *H.* aff. *H. bocki* Moeller and *Neostaffella sphaeroidea* (Moeller), and could be approximately correlative with Limestone N_1 in the Donets Basin.

Fusulina cylindrica – Fusulinella pseudobocki Zone

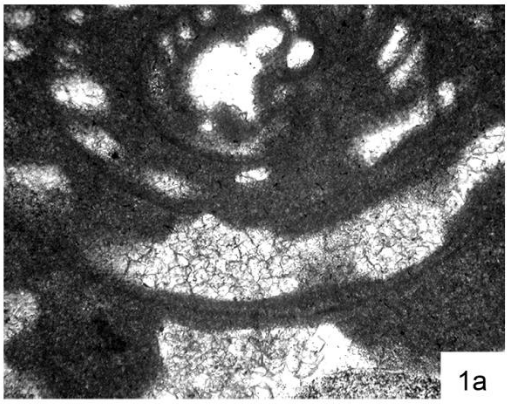
In contrast to the underlying beds, the limestones N_1^1 and N_1^2 contain the index form *Fusulina cylindrica*, as well as diverse and abundant populations of *F. cylindrica domodedovi*, *F. quasifusulinoides*, *F. quasicylindrica*, and *F. pancouensis*, which are distinguished mainly by their large fusiform to subcylindrical shape. The main features of these species and contemporaneous *Beedeina innaeformis* n. sp., are their thick septa and massive axial fillings.

The walls of these genera have evolved from four-layered to three-layered because of the disappearance of the inner tectorium, and the transformation of clear diaphanotheca into a faint thick one. In the limestone N_1^1 these changes are only incipiently developed (*Fusulina quasifusulinoides*, Fig. 25.7a), whereas in the limestone N_1^2 the wall of *Beedeina* species (Fig. 28.2) is mainly three-layered with a tectum, faint diaphanotheca, and continuous outer tectorium, which is the same color as the diaphanotheca with some residual clear portions in the thicker parts of the wall (Fig. 28.2a). The discontinuous inner tectorium is weakly developed as a very thin dark gray line underlining the diaphanotheca. The thickness of the wall in the species of these genera does not significantly change from the M_{10} limestone to the N_1^2 limestone and remains almost constant at approximately 25–35 μm.

A parallel evolution in the wall structure is observed in the *Fusulinella* species, represented by *F. bocki pauciseptata*, *F. pseudobocki*, and *F. rara*, which are distinguished from the Podolskian species by their thicker and intensely fluted septa and more massive chomata. The wall structure is the same as that described for the *Fusulina* and *Beedeina* species. In the limestone N_1^1 the diaphanotheca has advanced into a fainter, gray one which has the same color as the outer tectorium (*Fusulinella pseudobocki*, Fig. 26.1a), but occasionally the residual clear diaphanotheca could be seen in the polar regions of the tests (*Fusulinella rara*, Fig. 26.8a). In contrast to the wall structure of *Fusulina* and *Beedeina*, which possesses weakly developed outer tectorium and rather distinct dark inner tectorium, *Fusulinella* exhibits a well-developed outer tectorium, while the inner tectorium often remains undeveloped (Figs. 26.1a, 28.1a). The wall thickness of *Fusulinella* species progressively increases but does not exceed 50 μm.

Other important characteristics for the association of this zone are the disappearance of large *Neostaffella sphaeroidea*, and the frequent occurrence of large *Taitzehoella* species.

The *Fusulina cylindrica – Fusulinella pseudobocki* Zone proposed here for the interval $N_1^1 – N_1^2$ corresponds to the *Fusulina cylindrica* Zone of the Moscow Basin (Makhlina et al., 2001). The absence of material from the interval between N_1^2 and N_2 complicates the accurate correlation of the Donets fusulinid succession with the typical one in the Moscow Basin.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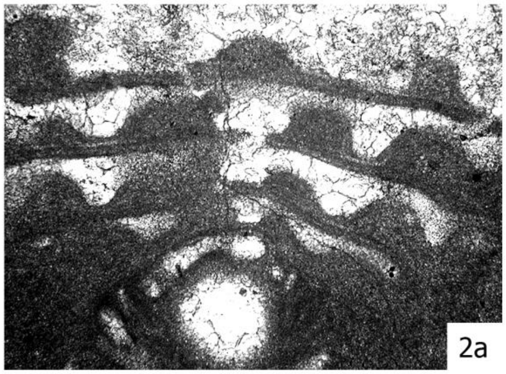
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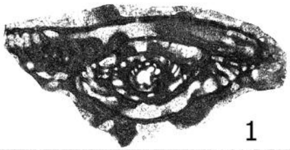
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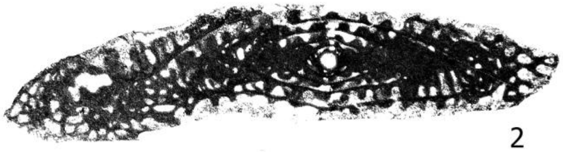
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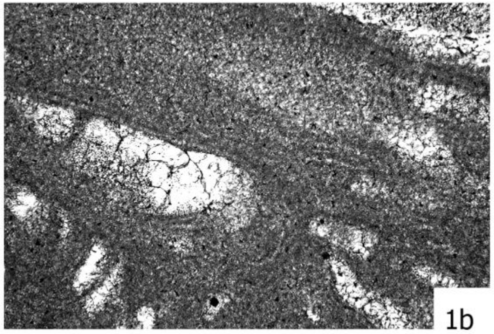
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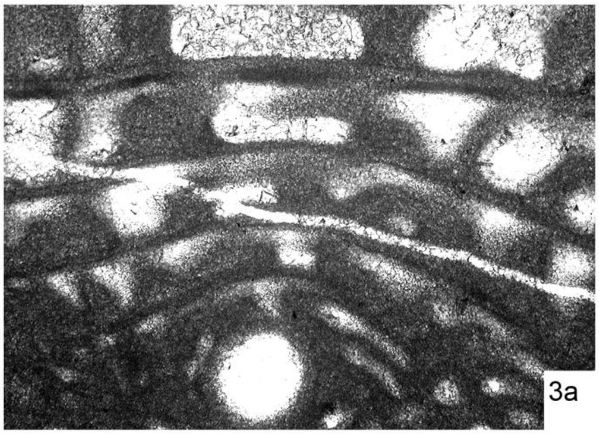
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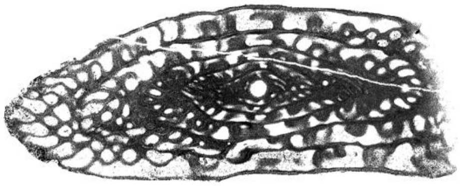
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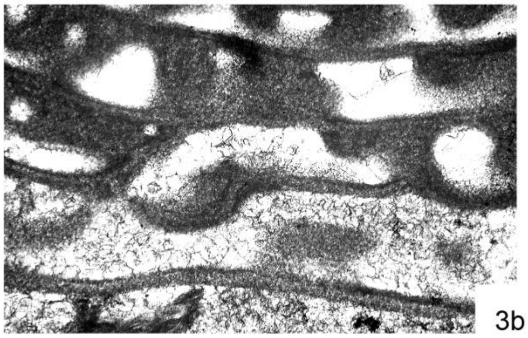
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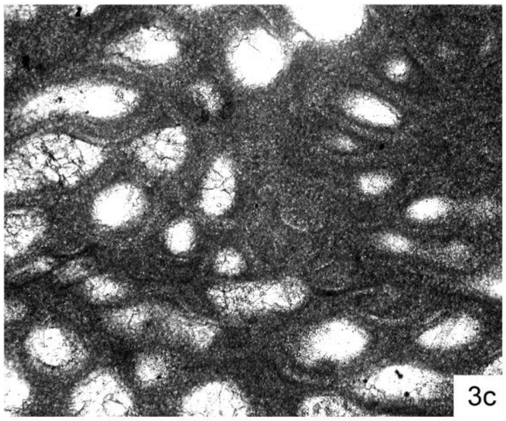
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Figure 28. Evolution of wall structure in *Fusulinella* and *Beedeina***.**

Fusulinella, Beedeina, x 20; wall, x 100. **1**- *Fusulinella* (?) sp., slightly oblique section SUI 130819, sample KA3/4-2, limestone N_1^2, Kalinovo section; **1a,** three-layered wall structure of the outer and inner volutions consists of dark tectum, faint, light gray diaphanotheca, and light gray outer tectorium; **1b,** remnants of light thin diaphanotheca near polar ends of the test; **2** - *Beedeina innaeformis* n. sp., axial section SUI 130781, sample KA3/4-5, limestone N_1^2, Kalinovo section; **2a,** three-layered wall structure of the inner and outer volutions consists of dark tectum, faint, light gray diaphanotheca, and light gray outer tectorium; **3** - *Beedeina* sp. cf. *B. siviniensis* (Rauser-Chernousova), slightly oblique section SUI 130786, sample KN2-20/1, Kalinovo section; **3a,** three-layered wall structure of the inner volutions comprises of dark tectorium, thick faint gray diaphanotheca, and dark gray inner tectorium; **3b**, three- to two-layered wall structure of the outer volutions because of discontinuity of inner tectorium; **3c**, remnants of light diaphanotheca near polar ends of the test.

Fusulinella (?) *kumpani* Zone

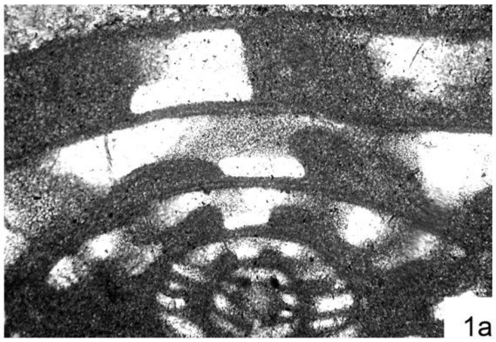
The upper Myachkovian (limestones N_2, N_2^1) in the Donets Basin is characterized by a fusulinid association comprising several species of the genera *Fusulinella* (?), *Fusulina*, *Beedeina* and *Taitzehoella*. The appearance of the elongated species *Fusulina cylindrica domodedovi* Rauser-Chernousova, *Beedeina* sp. cf. *B. siviniensis* (Rauser-Chernousova), and diverse *Taitzehoella*, *T. taitzehoensis extensa* Sheng and *T. perseverata* Safonova, characterizes this zone. This interval contains the last occurrence of the genera *Taitzehoella* and *Hemifusulina*.

In the limestone N_2 a development of a three-layered wall structure in large species of *Fusulina* (Fig. 29.3) and *Beedeina* (Fig. 28.3) has the same trend: diaphanotheca continues its transformation into faint light gray color (Figs. 28.3a, 29.3a). The lightest portion of diaphanotheca is better preserved in the lateral sides of the tests (Figs. 28.3c, 29.3b). A final volution is two-layered and consists of tectum and porous diaphanotheca (Fig. 28.3b, 29.3c). In the limestone N_2^1 the wall structure of *Fusulina* species (Fig. 29.2) is similar to that in *Beedeina innaeformis* n.sp. from the limestones N_1^1 and N_1^2. It is three-layered with dark tectum, and gray outer tectorium and diaphanotheca (Fig. 29.2a).

The wall structure of *Fusulinella* species in this zone continuously transforms from four-layered in the limestone N_1^1 to three-layered in N_2 (Figs. 28.1, 28.1a), but the diaphanotheca is still present in the polar ends of the specimens (Fig. 28.1b). Thickness of the wall increases in the outer volutions (Fig. 26.14a) making them very similar to *Protriticites*. However, remnants of light diaphanotheca (Fig. 28.1b) show their affinity to the genus *Fusulinella*. These species are transitional between these two genera and have been referred to as primitive *Protriticites* (Davydov, 1997).

Representatives of *Fusulinella* (?) *kumpani* (Fig. 29.1) appear in the limestone N_2^1. The main distinctions of this species from its ancestors in the group of *Fusulinella pseudobocki* (fusiform) are less developed secondary deposits (especially in the inner volutions), and a thinner wall. In *F.* (?) *kumpani*, the thickness of the wall is reduced to 25–30 μm in the outer volutions, and 10 μm in the inner volutions. The three-layered wall structure remains unchanged and comprises a faint diaphanotheca and outer tectorium separated by dark thin tectum (Fig. 29.1a, 29.1b).

The proposed *Fusulinella* (?) *kumpani* Zone that embodies the interval between the limestones N_2 and N_3 on the basis of stratigraphic position could be correlated with a zone *Praeobsoletes burkemensis – Protriticites ovatus* of the Peski Formation, the uppermost Myachkovian of the Moscow Basin (Davydov, 1997, Goreva et. al., 2009).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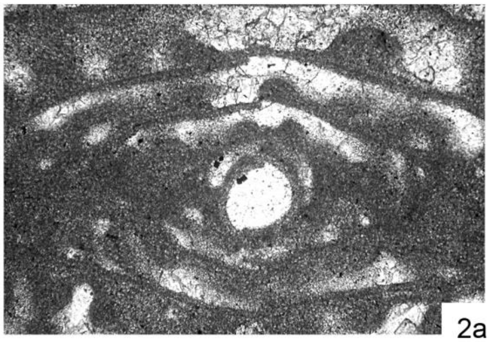
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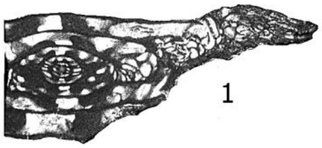
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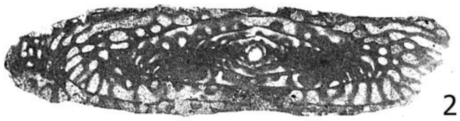
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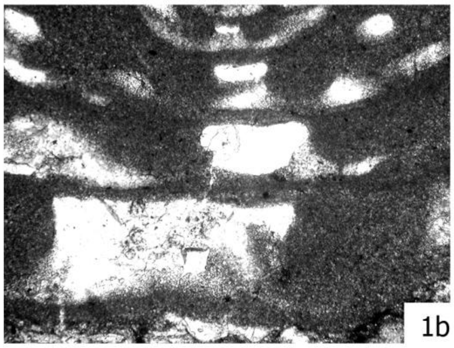
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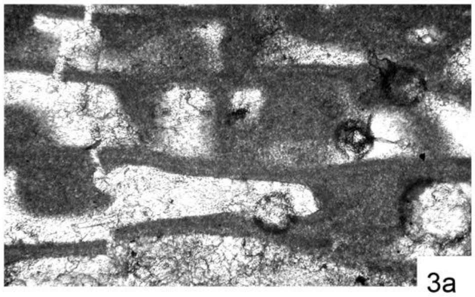
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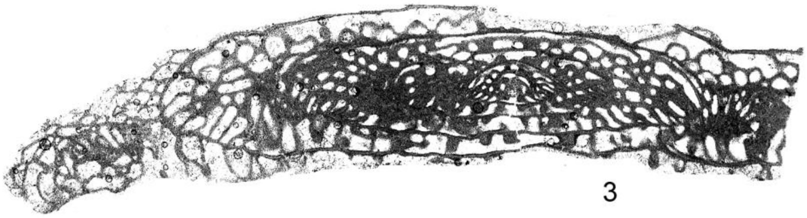
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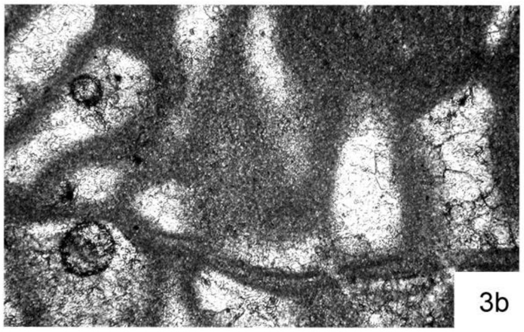
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Figure 29. Evolution of wall structure in *Fusulinella* and *Fusulina.*

Fusulinella, Fusulina, x 20; wall, x100. **1**- *Fusulinella* (?) sp. cf. *F. kumpani* Putrja, paraxial section *18*– SUI 130823, sample KA3/11-1, limestone N_2^1, Kalinovo section, × 20; **1a, 1b,** three-layered wall structure of the outer and inner volutions, comprises of dark gray tectum, gray both diaphanotheca and outer tectorium; **2** - *Fusulina sosninae* n. sp., SUI 130801, sample KA3/11-5, axial section, limestone N_2^1, Kalinovo section; **2a,** three-layered wall structure of the outer and inner volutions, comprises of dark gray tectum, gray both diaphanotheca and outer tectorium; **3-** *Fusulina domodedovi* Rauser-Chernousova, axial section SUI 130792, sample KN2-26/1, limestone N_2, Kalinovo section; **3a, 3b, 3c,** three-layered wall structure of the outer and inner volutions, comprises of dark gray tectum, light gray diaphanotheca and dark gray inner tectorium.

Fusulinid evolution trends in the Late Moscovian

The traditional Moscovian – Kasimovian boundary was first established on the basis of fusulinid evolution. This boundary was critical for many genera, some of them gradually becoming extinct (*Hemifusulina*, *Taitzehoella*, *Neostaffella*, *Beedeina*), while others such as *Protriticites*, *Obsoletes*, and *Quasifusulinoides* progressively evolved from *Fusulinella* and *Fusulina*. Limestone N_2^1 is characterized by the last occurrences of *Taitzehoella* and *Hemifusulina* species. Only a few small and primitive *Neostaffella* species such as *N. distorta, N. khotunensis* persisted into the limestone N_3. Larger species such as *N. sphaeroidea* and *N. larionovae* last occurred at the base of the Myachkovian, in the limestone N_1. *Beedeina* species were the last to go extinct at the latest Moscovian; their last occurrence is marked in the limestone N_5.

By analyzing fusulinids at the Podolskian – Myachkovian boundary, we have recognized that the main change is the appearance of massive secondary deposits in the limestone N_1 that could be correlated with the upper Member of the Korobcheevo Formation, Rozhay cyclothem (Kabanov, 2003). All species in the genera *Fusulina*, *Fusiella*, *Beedeina*, and *Hemifusulina* started to precipitate axial fillings, whereas *Neostaffella* and *Fusulinella* deposited massive chomata. Further in the limestone N_3 secondary fillings appeared in the wall structure in the genera *Fusulina* (*Quasifusulinoides*) and *Fusulinella* (*Protriticites*). Later in the limestone N_5 and O_1 the secondary deposits on the test wall and massiveness of the axial fillings and the chomata were gradually reduced. Such trends in the transformation of fusulinid morphology were also documented in the Moscow Basin, Middle Asia, China, Southern Urals, and the

Cantabrian Mountains (Lee, 1927, Rauser-Chernousova et al., 1951, Sheng, 1958, van Ginkel, 1965, Rumjanzeva, 1974).

Probably the appearance of massive secondary deposits in specimens of all genera accross the Podolskian – Myachkovian boundary, coinciding with a continuous extinction of *Hemifusulina*, *Beedeina*, *Neostaffella*, *Taitzehoella*, was a result of some global or regional events. The floristic zone *Odontopteris cantabrica* which is correlated with the “N” Formation in the Donets Basin [Fisunenko, 2000] also suggests some events happened on the Laurussia continent. These events might be linked either with some paleogeographic and tectonic events on continents resulting in climate change and global glaciation accompanied by reduction and environmental disturbance of epicontinental seas. A global glaciations episode in Myachkovian time is supported by extinction of *Hemifusulina*, *Beedeina*, *Neostaffella*, *Taitzehoella*, which preferentially occur in transgressive deposits, and therefore colder water.

Conclusions

1. Four fusulinid biozones have been proposed in the interval from the base of the Limestone M_9 to the base of limestone N_3: *Putrella donetziana – Kamaina rossoshanica*, *Hemifusulina graciosa – Fusiella spatiosa*, *Fusulina cylindrica – Fusulinella pseudobocki*, and *Fusulinella* (?) *kumpani*. These zones are fairly well correlated with the upper Podolskian – Myachkovian interval (Upper Moscovian strata), in the Moscow Basin. The similarity of fusulinid assemblages in the Moscow and Donets basins and their cognate evolution trends reveal a close connection between those regions at least during Myachkovian time.

2. Similar trends in wall structure evolution have been recognized in *Fusulinella*, *Fusulina* and *Beedeina* genera. Successive stages in the wall transformation are a principal basis for the fusulinid biozonation.

3. The Myachkovian was a critical time for many fusulinids in epicontinental seas. The genera *Hemifusulina*, *Neostaffella*, *Beedeina*, gradually became extinct at the end of Moscovian, while *Fusulinella* and *Fusulina* gave rise to *Protriticites* and *Quasifusulinoides*.

REFERENCES

Aisenverg, D. E., Brazhnikova, N.E., Novik, E.O., Rotai, A.P., and Shulga, P.L. 1963. Carboniferous Stratigraphy of the Donets Basin, Publ. House of Ukrainian Acad.of Sci., Kiev. (In Russian)

Aisenverg, D.E., Babenko, A.M., Belenko, N.G., Belokon, V.G., Bragin, Yu.N., Dedov, V.G., Fissunenko, O.P., Getman, V.G., Konashov, V.G., Lagutina, V.V., Levenstein, M.L., Makarov, I.A., Nagorny, Yu.N., Nesterenko, L.P., Poletaev, V.I., Popov, V.S., Rotai, P.P., Sharmanova, G.V., Shchegolev, A.K., Sokolova G.U. 1975. Field excursion guide book for the Donets Basin. Nauka: Moscow.

Alekseev, A. S., Goreva, N. V. 2006. Kasimovian and Gzhelian (Upper Pennsylvanian) conodont zonation in Russia. *Newsletter on Carboniferous Stratigraphy*, 24:40-43.

Alekseev, A.S., Kononova, L.I., Nikishin, A.M., 1996. The Devonian and Carboniferous of the Moscow Syneclise (Russian Platform): Stratigraphy and sea-level changes. *Tectonophysics*, 268:149-168.

Antoine, D., Morel, A., 1996. Oceanic primary production. 1. Adaptation of a spectral light photosynthesis model in view of application to satellite chlorophyll observation. Global geochemical cycles, 10 (1), 46-55.

Baird, G.C., and Brett, C.E. 1983. Regional variations and paleontology of two coral beds in the Middle Devonian Hamilton Group of western New York. *Journal of Paleontology*, 57:417-446.

Baranova, D. V., Kabanov P. B. 2003. Facies distribution of fusulinid genera in the Myachkovian (Upper Carboniferous, Upper Moscovian) of southern Moscow region. *Rivista Italiana di Paleontologia e Stratigrafia*, 109:225-239.

Barskov, I.S., Alekseev, A.S., Goreva, N.V., Kononova L.I., Migdisova A.V. 1984. Zonal’naya shkala karbona Vostochno-Europeyskoy platform po konodontam. In: Menner, V.V. (Ed). Paleontologicheskaya kharakteristika stratotipicheskihk i opornykh razrezov karbona Moskovskoy sineklizy. Moscow; pp.143-150. (In Russian)

Beavington-Penney, S.J., Racey, A. 2004. Ecology of extant nummulitids and other larger benthic foraminifera: applications in palaeoenvironmental analysis. *Earth-Science Reviews,* 67(3-4):219-265.

Becq-Giraudon, J. F., Montanat, C., Driessche, J. van Den., 1996. Hercynian high-altitude phenomena in the French Massif Central: the tectonic implications. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 122:227-241.

Belskaya, T.N., Ilkhovsky, R.A., Ivanova, E.A., Makhlina, H.Kh., Maslennikov, V.P., Mikhailova, R.V., Osipova, A.I., Reitlinger, E.A., Shik, E.M., Shik, S.M., Yablokov, V.S. 1975. Field excursion guide book for the Moscow Basin. Nauka: Moscow.

Bensh, F. R. 1982. Fusulinidovye zony I yarusnoe raschlenenie verkhnego karbona I nizhney permi Srednei Azii. Izdatelstvo “FAN” Akademii nauk respubliki Uzbekistan.

Bishop, J.W., Montanez, I.P., Osleger, D.A. 2010. Dynamic Carboniferous climate change, Arrow Canyon, Nevada. *Geosphere*, 6(1):1-34.

Bogush, O. I., 1963. Foraminifery i Stratigrafiya Srednego i Verkhnego Karbona Vostochnoy Chasti Alayskogo Khrebta. Akademiya Nauk SSSR, Sibirskoe Otdelenie, Institut Geologii i Geofiziki, Izdatel’stvo Akademii Nauk SSSR, Moscow. (In Russian)

BouDagher-Fadel, M.K. 2008. Evolution and Geological Significance of Larger Benthic Foraminifera, Developments in Palaeontology and Stratigraphy 21, Elsevier, Amsterdam.

Brazhnikova, N., 1939a. Materiali do vivchennya foraminifer Tsentral’nogo rayonu Donbassa. Akademiya Nauk Ukrains’koy SSR, Institut Geologii, Trudy Institutu Geologii po Donbasu, no number: 145–165. (In Ukrainian with Russian and English summary)

Brazhnikova, N., 1939b. Do vivcheniya foraminifer Tsentral’nogo rayonu Donbasa (Sviti C_3^{is}, C_3^{av} i nizi araukaritovoy tovshchi). *Geologichniy Zhurnal*, 6:245–303. (In Ukrainian with Russian and English summary)

Brazhnikova, N., 1951. Materialy k izucheniyu fauny foraminifer zapadnoy okrainy Donbassa. Akademiya Nauk Ukrains’koy SSR, Trudy Instituta Geologicheskikh Nauk, Seriya Stratigrafii i Paleontologii, 5:73–106. (In Russian)

Bretsky, P.W., and Bretsky, S.S., 1975. Succession and repetition of Late Ordovician fossil assemblages from the Nicolet River Valley, Quebec. *Paleobiology*, 1:225–237.

Brett, C.E., 1998. Sequence stratigraphy, paleoecology, and evolution: Biotic clues and responses to sea-level fluctuations. *PALAIOS*, 13:241–262.

Brett, C. E., Hendy, A. J., Bartholomew A. J., Bonelli J. R., McLaughlin, P. I., 2007. Response of shallow marine biotas to sea-level fluctuations: review of faunal replacement and the process of habitat tracking. *PALAIOS*, 22:228-244.

Brett, C.E., Miller, K.B., Baird, G.C., 1990. A temporal hierarchy of paleoecological process in a Middle Devonian epeiric sea, p. 178–209. In: Miller, W. (Ed.) Paleocommunity Temporal Dynamics: The Long-Term Development of Multispecies Assemblages. Paleontological Society Special Publication. 5.

Chekunov, A. V., 1994. The geodynamics of the Dniepr-Donets rift syneclise. *Geophysics*, 16(3):3–13.

Ching, K., Hsieh, M., Johnson, K., M., Chen, K., Rau, R., Yang, M. Modern vertical deformation rates and mountain building in Taiwan from precise leveling and continouos GPS observations, 2000–2008. Journal of Geophysical research, 116, 1-16.

Conde, D., Aubriot, L., Sommaruga, R., 2000. Changes in UV penetration associated with marine intrusions and freshwater discharges in a shallow coastal lagoon of the Southern Atlantic Ocean. Marine ecology progress series, 207, 19-31.

Cleal, C. J. 2008. Palaeofloristics of Middle Pennsylvanian medullosaleans in Variscan Euramerica. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 268:164-180.

Colani, M. 1924. Nouvelle contribution a` l'e´tude des fusulinide´s de l'Extreˆme-Orient. Me´moires du Service Ge´ologique de l'Indochine, 11(1):1–191.

Dalmatskaya, I. I., 1961. Stratigrafiya i foraminifery srednekamennougol'nykh otlozhenyi Gorkovskogo I Uljanovskogo Povolzhya, p. 7–54. In: Shatskiy, N.S. Menner, V.V.(Eds.) Regionalnaya stratigrafiya SSSR, 5, Izdatelstvo Akademii Nauk SSSR, Moscow. (In Russian)

Davydov, V. I., Leven, E. Y. 2003. Correlation of Upper Carboniferous (Pennsylvanian) and Lower Permian (Cisuralian) marine deposits of the Peri-Tethys, Peri-Tethys Program. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 196(1–2):39–57.

Davydov, V. I., Khodjanyazova, R. 2009. Moscovian–Kasimovian transition in Donets Basin: Fusulinid taxonomy, biostratigraphy correlation and paleobiogeography, p.193–196. In: Puchkov,V.N.(Ed.) Type sections of the Carboniferous in Russia and potential stratotypes**:** Proceedings of the International Conference, Institute of Geology, Bashkirian Academy of Sciences, Ufa, Russia.

Davydov, V., I. 1997. Middle/Upper Carboniferous boundary: The problem of definition and correlation, p. 113–122. In: Podemski, M., Dybova-Jachowicz, S., Jaworowski, K., Jureczka, J., Wagner, R. Proceeding of the XIII International Congress on the Carboniferous and Permian, 28th August – 2nd September, 1995 Krakov, Poland. Prace Panstwowego Instytutu Geologicznego, Warszawa.

Davydov, V.I., Crowley, J.L, Schmitz, M.D., Poletaev, V.I. 2010. High-precision U-Pb zircon age calibration of the global Carboniferous time scale and Milankovitch band cyclicity in the Donets Basin, eastern Ukraine. *Geochemistry, Geophysics, Geosystems* (11):1-22.

Dodd, J.R., Stanton, R.J., 1981. Paleoecology, concepts and applications. New York, Wiley.

Dokka, R.K., 2006. Modern-day tectonic subsidence in coastal Louisiana. Geology, 34, 281-284.

Dzhenchuraeva, A. V., 1975. O batimetricheskoy zonalnosti srednekamennougolnikh fusulinid Turkestano-Alaya. *Voprosy mikropaleontologii*, 18:74-96. (In Russian)

Ehrenberg, C. G. 1842. Mikrogeologie. Leopold Voss, Leipzig, 374 p.

Einor, O. L. (Ed.). 1996. The former USSR, p. 13–407. In: Wagner, R. H., Winkler Prins, C. F., Granados, L. F. (Eds.). Carboniferous of the world, Pt. III, The former USSR, Mongolia, Middle Eastern Platform, Afghanistan, and Iran. IUGS Publication no. 33, Instituto Tecnolo´gico Geominero de Espan˜a, Madrid, and Nationaal Natuurhistorisch Museum, Leiden.

Eros, J.M. 2010**.** Permo-Carboniferous Cyclostratigraphy and Relative Sea Level History: Donets Basin, Ukraine. Master Science Thesis. University of California Davis.

Eros, J.M., Montanez, I.P., Osleger, D.A., Davydov, V.I., Nemyrovska, T.I., Poletaev, V.I., Zhykalyak, M.V. 2012. Sequence stratigraphy and onlap history of the Donets Basin, Ukraine: Insight into Carboniferous icehouse dynamics. *Palaeogeography, Palaeoclimatology, Palaeoecology,* (313-314): 1-25.

Eros, J.M., Montañez, I.P., Osleger, D.A., Davydov, V.I., Nemyrovska, T.I., Poletaev, V.I., and Zhykalyak, M.V. 2012. Sequence stratigraphy and onlap history of the Donets Basin, Ukraine: Insight into Carboniferous icehouse dynamics. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 313-314, p. 1-25.

Feldman, H.R., Franseen, E.K., Joeckel, R.M., Heckel, P.H. 2005. Impact of longer-term modest climate shifts on architecture of high-frequency sequences (cyclothems), Pennsylvanian of Mid-continent U.S.A. *Journal of Sedimentary Research*, 75:360-368.

Fielding, C.R., Frank, T.D., and Isbell, J.L., 2008. The late Paleozoic ice age— A review of current understanding and synthesis of global climate patterns, p. 343–443. In: Fielding, C.R., Frank, T.D., and Isbell, J.L. (Eds.) Resolving the late Paleozoic ice age in time and space: Geological Society of America Special Paper 441.

Fischer De Waldheim, G. 1829. Les Ce´phalopodes fossiles de Moscou et de ses environs, en montrant ces objets en nature: Bulletin de la Socie´te´ Impe´riale des Naturalistes de Moscow, 1:300–362.

Fisunenko, O.P. 2000. K probleme moskovskogo yarusa. Izdatelstvo “Alma mater”, Lugansk, 65 p.

Flugel, E., 2004. Macrofacies of carbonate rocks. Analysis, interpretation and application. Springer Berlin Heidelberg New York. 976 p.

Fohrer, B., T. I. Nemirovska, E. Samankassou, Ueno, K. 2007. The Pennsylvanian (Moscovian) Izvarino section, Donets Basin, Ukraine: A multidisciplinary study on microfacies, biostratigraphy (conodonts, foraminifers, and ostracodes), and paleoecology. *Journal of Paleontology*, 81(5):1-85.

Forke, H.C., Scheibner, C., Blomeier, D. 2010. Sequence biostratigraphic correlation and paleoenvironmental reconstruction of Late Carboniferous platform deposits (NE Svalbard, Norway). International Symposium on Foraminifera: Bonn; 86.

Galloway, J. J. 1933. A Manual of Foraminifera. The Principia Press, Bloomington, Indiana, USA, 483 p.

Gavrish, V. K., (Ed.) 1989. Geology and Oil and Gas Potential of the Dniepr-Donets Depression, Depth Structure and Geotectonic Evolution. Nauk. Dumka, Kiev, 208 p. (in Russian)

Gereltzetzeg, L. 1996. Biostratigraphiya nizhnemoskovskogo pod’yarusa (sredniy karbon) tsentral’noy chaste Russkoy platform po conodontam. PhD. Dissertation, Moscovsky Gosudarstvenny Universitet (In Russian).

Ginkel, A.C., van, 1965. Carboniferous fusulinids from the Cantabrian Mountains (Spain). Leidse Geologische Mededelingen, 34, 225p.

Ginkel, A.C., van, 1973. Carboniferous fusulinids of the Sama Formation (Asturias, Spain). (I. Hemifusulina): Leidse Geologische Mededelingen, 49 (1): 85-123.

Goreva, N.V., Alekseev, A.S., Isakova, T.N., Kossovaya, O.L. 2009. "Sub-*Triticites* Beds" of the Donskaya Luka and the Lower Boundary of the Kasimovian Stage. *Stratigraphy and Geological Correlation,* 17:43-61.

Gradstein, F.M., Ogg, O., Smith, A.G. 2004. *Geological Time Scale 2004*. University Press: Cambridge.

Greiner, G.O.G., 1974. Environmental factors controlling the distribution of recent benthonic Foraminifera. *Breviora,* 420:1-35.

Groves, J. R. 1988. Calcareous foraminifers from the Bashkirian stratotype (Middle Carboniferous, South Urals) and their significance for intercontinental correlations and the evolution of the Fusulinidae. *Journal of Paleontology*, 62:368–399.

Groves, J. R., Lee, A., 2008. Accelarated rates of foraminiferal origination and extinction during the late Paleozoic ice age. *Journal of Foraminiferal Research*, 38(1):74-84.

Grozdilova, L.P., Lebedeva, N. S. 1950. Nekotorye vidy shtaffell srednekammenougol'nykh otlozheniy zapadnogo sklona Urala. Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta (VNIGRI), novaya seriya, 50 (Mikrofauna Neftyanykh Mestorozhdeniy SSSR, Sbornik 3:5–45 (In Russian)

Hallam, A., 1981. A revised sea-level curve for the Early Jurassic. *Journal of the Geological Society of London*, 138:735–743.

Heckel, P.H., 1994. Evaluation of evidence for glacio-eustatic control over marine Pennsylvanian cyclothems in North America and consideration of possible tectonic effects, p. 65-87. In: Dennison, J.M., and Ettensohn, F.R.(Eds.) Tectonic and Eustatic controls on Sedimentary cycles: SEPM (Society for Sedimentary Geology), Concepts in Sedimentology and Paleontology, 4.

Heckel, P.H., 2002. Overview of Pennsylvanian cyclothems in North America and brief summary of those elsewhere in the world, p. 79-98. In: Hills, L.V., Henderson, C.M., Bamber, E.W. (Eds.) The Carboniferous and Permian of the World: Canadian Society of Petroleum Geologists Memoir 19.

Heckel, P.H. 2004. “Chairman’s Column”, *Newsletter Carboniferous Stratigraphy* 22, 1-3.

Heckel, P.H., 2008. Pennsylvanian cyclothems in Mid-continent North America as far-field effects of waxing and waning of Gondwana ice sheets, p. 275-290. In: Fielding, C.R., Frank, T.D., and Isbell, J.L. (Eds.) Resolving the Late Paleozoic Ice Age in Time and Space. Geological Society of America Special Paper 441.

Heckel, P. H., A. S. Alekseev, J. E. Barrick, D. R. Boardman, N. V. Goreva, T. I. Nemirovska, K. Ueno, E. Villa, Work, D. M. 2007. Cyclothem [‘‘digital’’] correlation and biostratigraphy across the global Moscovian-Kasimovian-Gzhelian stage boundary interval (Middle-Upper Pennsylvanian) in North America and eastern Europe, *Geology*, 35(7):607–610.

Heckel, P. H., Baesemann, J. F. 1975. Environmental interpretation of conodont distribution in Upper Pennsylvanian (Missourian) megacyclothems in eastern Kansas. *American Association of Petroleum Geologists Bulletin*, 59:486-509.

Hills, L.V., Henderson, C. M., Bamber, E. W. (Eds.) 2002. Carboniferous and Permian of the world: XIV ICCP proceedings. Memoir - Canadian Society of Petroleum Geologists,19:1-947.

Hohenegger, J. 2004. Depth coenoclines and environmental considerations of western Pacific larger Foraminifera. *Journal of Foraminiferal Research*, 34(1):9-33.

Isakova, T.N. 2002. Moscovian foraminiferal biostratigraphy in the type region (Russia), p. 448-460. In: Carboniferous and Permian of the World: XIV ICCP Proceedings, Hills, L.V., Henderson, C.M. Bamber, E.W. (Eds.) Canadian Society of Petroleum Geologists, Memoir 19.

Isbell, J. L., Miller, M. F., Wolfe, K. L., Lenaker, P. A. 2003. Timing of late Paleozoic glaciation in Gondwana; was glaciation responsible for the development of Northern Hemisphere cyclothems?, p. 5-24. In: Chan, M.A., and Archer, A.W., (Eds.) Extreme Depositional Environments: Mega End Members in Geologic Time Geological Society of America Special Paper 370.

Ivanov, A.P.1926. Sredne- i verkhnekamennougol’nye otlozheniya Moskovskoy gubernii. *Bulletin MOIP, otdelenie geologicheskoe* 36:133-180 (In Russian).

Ivanova, E.A. 1947. Biostratigraphiya srednego i verkhnego karbona Podmoskovnoy kotloviny. Trudy Paleontologicheskogo instituta AN SSSR 12(1) (In Russian).

Ivanova, E.A., Khvorova, I.V. 1955. Stratigraphiya srednego i verkhnego karbona zapagnoy chaste Moskovskoy sineklizy. Trudy Paleontologicheskogo instituta AN SSSR, 53 (In Russian)

Ivanova, R. M., 2008. Fusulinidy I vodorosli srednego karbona Urala (zonalnaya stratigrafiya, paleobiogeografiya, paleontologiya). Izdatelstvo Rossiyskoy Akademii nauk, Uralskoe otdelenie, Ekaterinburg. (In Russian)

Izart, A., C. Briand, D. Vaslet, D. Vachard, R. Coquel, Maslo, A. 1996. Stratigraphy and sequence stratigraphy of the Moscovian in the Donets Basin. *Tectonophysics*, 268(1–4):189-209.

Izart, A., Y. L. Nindre, R. Stephenson, D. Vaslet, Stovba, S. 2003. Quantification of the control of sequences by tectonics and eustacy in the Dniepr-Donets Basin and on the Russian Platform during Carboniferous and Permian. Bulletin de la Societe Geologique de France, 174(1):93–100.

Kabanov, P. 2003. The Upper Moscovian and basal Kasimovian (Upper Carboniferous) of central European Russia: facies, subaerial exposures, and depositional model. *Facies*, 49:243–270.

Kabanov, P. B., A. S. Alekseev, D. V. Baranova, R. V. Gorjunova, S. S. Lazarev, Malkov, V. G. 2006. Biotic changes in a eustatic cyclothem: Domodedovo Formation (Moscovian, Carboniferous) of Peski quarries, Moscow region, *Paleontological Journal*, 40(4):351-368.

Kabanov, P. B., T. V. Alekseeva, V. A. Alekseeva, A. O. Alekseev, Gubin, S. V. 2010. Paleosols in Late Moscovian (Carboniferous) marine carbonates of the East European craton revealing ‘‘Great calcimagnesian plain’’ paleolandscapes. *Journal of Sedimentary Research*, 80:195–215.

Kagarmanov, A.K., Donakova, L.M. 1990. Decisions of the Regional Stratigraphic Conference on the Middle and Upper Paleozoic of the Russian Platform. Carboniferous System, Leningrad, p. 3–40. (In Russian).

Khain, V. E., 1985. Geology of the U.S.S.R. Gebru¨der Borntraeger, Berlin- Stuttgart, 272 p.

Khain, V. E., 1994. Geology of Northern Eurasia (Ex-USSR). Gebru¨der Borntraeger, Berlin-Stuttgart, 404 p.

Khodjanyazova, R., Davydov, V., in press. Late Moscovian fusulinids from the “N” Formation (Donets Basin, Ukraine). *Journal of Paleontology.*

Khodjanyazova, R., Davydov, V.I., Schmitz, M.D. 2011. Fusulinid biozonation as a proxy of Milankovitch cyclicity: the record from Moscovian-Kasimovian transition in Donets Basin (Ukraine). In: The XVII International Congress on the Carboniferous and Permian, Hakansson, E., Trotter, J.A. (Eds.) Programme and abstracts, Government of Western Australia and Department of Mines and Petroleum, 80.

Khodjanyazova, R., Davydov, V.I., Schmitz, M.D., submitted. Cyclic distributional patterns and correlation of the Late Kashirian – Podolskian fusulinids in the Donets Basin, Ukraine. Submitted to Journal of Geology.

Khodjanyazova, R., Davydov, V.I., Schmitz, M.D., submitted. Cyclic recurrence of the Pennsylvanian fusulinid assemblages in the Donets Basin (Ukraine) in response to eustatic sea level fluctuations. Submitted to Palaegeography, Palaeoclimatilogy, Palaecology.

Khvorova, I.V. 1951**.** Istoriya razvitiya sredne- i verkhnekamennougol'nogo basseyna zapadnoy chaste Moskovskoy sineklizy. Doctor of Science Dissertation, Paleontologicheskiy Institut AN SSSR (in Russian).

Khvorova, I.V. 1953. Istoriya razvitiya sredne- i verkhnekamennougol'nogo morya zapadnoy chaste Moskovskoy sineklizy. Trudy Paleontologicheskogo instituta AN SSSR 43 (In Russian).

Kireeva, G. D. 1950. Novye vidy fusulinid iz izvestnyakov svit C_3^1 i C_3^2 Donetskogo basseyna. Izdatelstvo Ugletekhizdat:193-218. Moscow-Kharkov. (In Russian)

Kireeva, G.D., 1951. Stratigraphicheskoe polozhenie moskovskogo yarusa v razreze Donetskogo basseyna (na osnove raspredeleniya fusulinid). Bulleten' MOIP, 26 (3):35-51 (In Russian).

Kobayashi, F. and K.-I. Ishii 2003. Permian fusulinacean of the Surmaq Formation in the Abadeh region, central Iran. Rivista Italiano di Paleontologia Stratigrafia, 109(2):307-337.

Kossenko, Z.A. 1975. Novye vidy conodontov iz otlozhenij moskovskogo yarusa yugo-zapadnoi chasti Donetskogo baseina. *Geol. zhurnal*, 35 (3):126-133. (In Russian).

Kozitskaya, R.I., Kossenko, Z.A., Lipnyagov, O.M., Nemirovskaya, T.I. 1978. Konodonty karbona Donetskogo baseina. Naukova Dumka: Kiev.

Lee, J. S. 1927. Fusulinidae of North China. Paleontologica Sinica, series B, 4(1):1–171.

Lee, J. S. 1937. Foraminifera from the Donets Basin and their stratigraphic significance. Bulletin of the Geological Society of China, 16:57–107.

Lee, J. S., S. Chen, Chu, S. 1930. The Huanglung Limestone and its fauna. Memoirs of the National Research Institute of Geology, 9:85–172.

Leppig, U., H.C. Forke, M. Montenari and B. Fohrer 2005. A three− and two−dimensional documentation of structural elements in schwagerinids (superfamily Fusulinoidea) exemplified by silicified material from the Upper Carboniferous of the Carnic Alps (Austria/Italy): a comparison with verbeekinoideans and alveolinids. *Facies,* 51:559-571.

Leven, E. J., 1998. Stratigraphy and fusulinids of the Moscovian stage (Middle Carboniferous) in the Sothwestern Darvaz (Pamir), *Revista Italiana di Paleontologia e Stratigrafia,* 104(1): 3-42.

Leven, E. J., V. I. Davydov, Gorgij, M. N. 2006. Pennsylvanian stratigraphy and fusulinids of Central and Eastern Iran. *Palaeontologia Electronica*, 9(1):1–33.

Magniez-Jannin, F., 1992. Enregistrement de l'eustatisme par les foraminifer`res dans les sequences de depot du Cretace inferieur du basin vocontien (SE de la France). *Paleogeography, Paleoclimatology, Paleoecology*, 91:247-262.

Makarov, I. A. 1985. Description of the stratigraphic cross-sections of the Upper Carboniferous of the Donets Basin. Ukrainian Geological Ministry, PGO Donbas Geology, Artemovsk GPE. (In Russian)

Makhlina, M. K., A. S. Alekseev, N. V. Goreva, R. V. Goryunova, T. N. Isakova, O. L. Kossovaya, S. S. Lazarev, O. A. Lebedev, Shkolin, A. A. 2001a. Sredniy karbon Moskovskoy sineklizy (yuzhnaya chast'); v 2 tomakh, tom 1, Stratigrafiya. Izdatelstvo Rossiyskoy Akademii Nauk, Moscow 244 p. (In Russian)

Makhlina, M.K., Alekseev, A.S., Goreva, N.V., Goryunova, R.V., Isakova, T.N., Kossovaya, O.L., Lazarev, S.S., Lebedev, O.A., Shkolin, A.A. 2001b. Sredniy karbon Moskovskoy sineklizy (yuzhnaya chast'); v 2 tomakh, tom 2. Paleontologicheskaya kharakteristika. Izdatelstvo Rossiyskoy Akademii Nauk, Moscow (In Russian)

Manukalova, M. F., 1950a. Opisanie nekotorykh novykh vidov fuzulinid iz srednego karbona Donetskogo Basseyna, p. 175–192. In: Materialy po Stratigrafii i Paleontologii Donetskogo Basseyna. Geologo-Issledovatel'skie Raboty, Ministerstvo Ugol'noy Promyshlennosti SSSR, Glavnoe Upravlenie po Razvedkam Uglya, Ugletekhizdat, Moscow. (In Russian)

Manukalova, M. F., 1950b. Novye vidy fuzulinid iz izvestnyakov srednego Karbona Donbassa, p. 219–237. In: Materialy po Stratigrafii i Paleontologii Donetskogo Basseyna. Geologo-Issledovatel'skie Raboty, Ministerstvo Ugol'noy Promyshlennosti SSSR, Glavnoe Upravlenie po Razvedkam Uglya, Ugletekhizdat, Moscow. (In Russian)

Martin L, Montañez IP, Bishop J. 2012. Carboniferous sequence stratigraphy and sea-level history of the Bird Spring platform, Southern Great Basin, USA. Palaeogeography, Palaeoclimatology, Palaeoecology, 329:64-82.

McGhee, G. R., Jr., 1991. Extinction and diversification in the Devonian brachiopoda of New York State: No correlation with rate of change of sea-level? *Historical Boilogy*, 5:215-227.

Menning, M., A. S. Alekseev, B. I. Chuvashov, V. I. Davydov, F.-X. Devuyst, H. C. Forke, T. A. Grunt, L. Hance, P. H. Heckel, N. G. Izokh, Y.-G. Jin, P. J. Jones, G. V. Kotlyar, H. W. Kozur, T. I. Nemyrovska, J. W. Schneider, X.-D. Wang, K. Weddige, D. Weyer, Work, D. M. 2006. Global time scale and regional stratigraphic reference scales of central and west Europe, east Europe, Tethys, south China, and North America as used in the Devonian-Carboniferous-Permian Correlation Chart 2003 (DCP 2003), *Palaeogeography, Palaeoclimatology, Palaeoecology*, 240(1–2):318–372.

Meyen, S.V., 1987. Osnovy paleobotaniki. Nedra, Moscow, 403 p. (in Russian)

Miklukho-Maclay, A. D. 1959. O stratigraficheskom znachenii, sistematike i filogenii shtaffelloobraznykh foraminifer. Doklady Akademii Nauk SSSR, 125:628–631. (In Russian)

Mitchum, R.M.J., Van Wagoner, J.C. 1991. High-frequency sequences and their stacking patterns: sequence stratigraphic evidence of high-frequency eustatic cycles. *Sedimentary Geology*, 70:131-160.

Milanovsky, E. E. 1992. Aulacogens and aulacogeosynclines: Regularities in setting and evolution. *Tectonophysics*, 215(1–2):55–68.

Moeller V. Von. 1878. Spiral-coiled foraminifers from the Carboniferous limestone of Russia. Materialy dlya geologii Rossii, 8, Sankt-Petersburg, 207 p. (in Russian).

Montanez, I.P., Poulsen, C.J. in press. The Late Paleozoic Ice Age: An Evolution Paradigm.

Montañez, I.P., Tabor, N.J., Niemeier, D., DiMichele, W.A., Frank, T.D., Fielding, C.R., Isbell, J.L., Birgenheier, L.P., and Rygel, M.C., 2007, Vegetation instability during late Paleozoic deglaciation. *Science*, 315:87–91.

Nelson, A. R., 2007. Sea-levels, Late Quaternary/Tectonic locations, p. 3072-3087. In: Elias, S. A. (Ed.) Encyclopedia of Quaternary Science.

Nemyrovska, T. I., Perret-Mirouse, M. -F., Alekseev, A. S. 1999. On Moscovian (Late Carboniferous) conodonts of the Donets Basin, Ukraine. Neues Jahrbuch fur Geologie und Palaontologie, Abhandlungen, 214(1–2):169–194.

Nemyrovska, T.I. 2011. Preliminary Moscovian conodont scale of the Donets Basin, Ukraine. Newsletter Carboniferous Stratigraphy**,** 29:56-61.

Pogrebnyak, V.A., 1975. Kharakternyeforaminifery gazonosnyh otlozheniy srednego i nizov verkhnego karbona severnyh okrain Donbassa i ih stratigraficheskoe znachenie, p. 40–69. In: Lapkin, I.Yu. (Ed.), Stratigrafiya verkhnego paleozoya i nizhnego mezozoya Dneprovo-Donetskoy vpadiny. Izdatelstvo Nedra, Moscow. (In Russian)

Putrja, F. S., 1939. Materialy k stratigrafiiverkhnego karbona vostochnoy okrainy Donetskogo basseyna. Azovo-Chernomorskoe Geologicheskoe Upravlenie, Materialy po Geologii i Poleznym Iskopaemym, Sbornik 10:97–156. (In Russian)

Putrja, F. S., 1940. Foraminifery i stratigrafiya verkhnekamennougol’nykh otlozheniy vostochnoy chasti Donetskogo basseyna. Azovo-Chernomorskoe Geologicheskoe Upravlenie, Materialy po Geologii i Poleznym Iskopaemym, Sbornik 11:1–146. (In Russian)

Putrja, F. S., 1948a. *Protriticites* — novyy rod fuzulinid. Trudy L’vovskogo Geologicheskogo Obshchestva pri Gosudarstvennom Universitete im. Ivana Franko, Paleontologicheskaya seriya, 1948, Vypusk 1:90-96. (In Russian)

Putrja, F. S. 1948b. *PSEUDOTRITICITINAE* — novoye podsemeystvo. Trudy L’vovskogo Geologicheskogo Obshchestva pri Gosudarstvennom Universitete im. Ivana Franko, Paleontologicheskaya seriya, 1948, Vypusk 1:97-101. (In Russian)

Putrja, F. S., 1956. Stratigrafiya i foraminifery srednekamennougol’nykh otlozheniy vostochnogo Donbassa. Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatel’skogo Geologo-Razvedochnogo Instituta (VNIGRI), novaya seriya, 98 (Mikrofauna SSSR, Sbornik 8:333–519. (In Russian)

Rauser-Chernousova, D. M., 1953. Periodichnost’ v razvitii foraminifer verkhnego paleozoya i ee znachenie dlya raschleneniya I sopostavleniya razrezov. Materialy paleontologicheskogo soveshchaniya po paleozoyu, 1951. Izdatelstvo Akademiya Nauk SSSR, p. 139–160, Moscow. (In Russian)

Rauser-Chernousova, D. M., G. Belyaev, Reitlinger, E. A. 1936. Upper Paleozoic foraminifera of the Petschoria-lands. Akademiya Nauk SSSR, Trudy Polyarnoy Komissii, 28:159–232. (In Russian with German summary)

Rauser-Chernousova, D. M., Kulik, E. L. 1949. Ob otnoshenii fusulinid k fatsiyam i o periodichnosti ikh razvitiya, Izvestiya Akademii Nauk SSSR, seriya geologicheskaya, 6:131–138. (In Russian)

Rauser-Chernousova, D.M., Kireeva, G.D., Leontovich, G. E., Gryzlova, N.D., Safonova, T.P., Chernova, E.I. 1951. Srednekamennougol’nye Fuzulinidy Russkoy Platformy i Sopredel’nykh Oblastey. Akademiya Nauk SSSR, Institut Geologicheskikh Nauk, Ministerstvo Neftyanoy Promyshlennosti SSSR, Izdatelstvo Akademii Nauk, Moskva, 380 p. (In Russian)

Rauser-Chernousova, D. M., Reitlinger, E.A., 1962. O formoobrazovanii foraminifer, *Voprosy micropaleontologii*, 6:3-30. (In Russian)

Rauser-Chernousova, D.M., Reitlinger, E.A. 1954. Biostratigraficheskoe raspredelenie foraminifer v srednekamennougol’nykh otlozheniyakh yuzhnogo kryla Podmoskovnoy kotloviny. In: Nalivkin, D.V., Menner, V.V. (Eds) Regional’naya stratigrafiya SSSR, tom 2, Izdatel’stvo Akademii Nauk SSSR, Moscow, 7-120. (In Russian)

Rauser-Chernousova, D.M., Bensh, F.S., Vdovenko, M.V., Gibshman, N.B., Leven, E.YA., Lipina, O.A., Reitlinger, E.A., Solovieva, M.N., Chediya, I.O. 1996. Sprabochnik po Sistematike Foraminifer Paleozoya (Endotiroidy, Fuzulinidy). Nauka: Moscow. (In Russian)

Reitlinger, E. A. 1961. Stratigrafiya srednekamennougol’nykh otlozheniy razresa skv. N 1 Krasnoy Polyany v Srednem Zavolzh’e, p. 218–260. In: Shatskiy, N.S. Menner,V.V. (eds.) Regionalnaya stratigrafiya SSSR, 5, Izdatel’stvo Akademii Nauk SSSR, Moscow. (In Russian)

Reitlinger, E. A., and Balashova, N.N., 1954. Stratigrafiya srednekamennougolnyhk otlozheniy Pzhevskogo Povolzhya, p. 121-200. In: Nalivkin D., V. Menner, V.V. (Eds.) Regionalnaya Stratigrafiya SSSR. Tom 2. Izdatelstvo Akademii Nauk SSSR, Moscow. (In Russian)

Ross, C. A., 1961. Fusulinids as paleoecological indicators. *Journal of Paleontology*, 35:398-400.

Ross, C. A., 1967. Development of fusulinids (Foraminiferida) faunal realms. *Journal of Paleontology,* 41:1341-1354.

Ross, C. A., 1969. Paleoecology of Triticites and Dunbarinella in Upper Pennsylvanian strata of Texas. *Journal of Paleontology*, 43:298-311.

Ross, C. A., 1971. Paleoecology of Late Pennsylvanian fusulinids (Foraminiferida), Texas. Compte Rendu - 6e Congres International de Stratigraphie et de Geologie du Carbonifere - International Congress on Carboniferous Stratigraphy and Geology, 4:1429-1440.

Ross, C. A., 1972. Paleoecological analysis of Fusulinacean (Foraminiferida) shell morphology. *Journal of Paleontology*, 46:719-728.

Ross, C.A., 1982. Paleobiology of fusulinaceans. Proceedings - North American Paleontological Convention 3:441-445.

Ross, C.A., and Ross J.R.P., 1988. Late Paleozoic transgressive-regressive deposition, p. 227-247. In: Sea-level changes – An integrated approach, SEPM Special Publication, 42.

Ross, C.A., and Ross J.R.P., 1995. Foraminiferal zonation of late Paleozoic depositional sequences. *Marine Micropaleontology*, 26:469-478.

Ross, C.A., and Ross J.R.P., 2009. Paleontology, a tool to resolve Late Paleozoic structural and depositional histories, p.95-109. In: Geological problem solving with microfossils: A volume in Honor of Garry D. Jones. SEPM Special Publication, 93.

Rotai, A.P. 1979. Carboniferous stratigraphy of the USSR: proposal for an international classification. In: Wagner, R.H., Higgins, A.C., Meyen, S.V. (Eds) The Carboniferous of the U.S.S.R. Yorkshire Geological Society Occasional Publication 4, 225.

Rozovskaya, S. E. 1941. On some Middle Carboniferous species of *FUSULINIDAE* of the Moscow Depression. Doklady Akademii nauk SSSR, 31(2):190–192.

Rumjanzeva, Z. S. 1974. Stratigrafiya i Foraminifery Srednego Karbona Tsentral’nykh Kyzylkumov. Ministerstvo Geologii Uzbekskoy SSR, Sredneaziatskiy Nauchno-

Issledovatel'skiy Institut Geologii i Mineral'nogo Syr'ya (SAIGIMS), Izdatel'stvo FAN, Uzbekskoy SSR, Tashkent, 179 p. (In Russian)

Sano, H., 2006. Impact of long-term climate change and sea-level fluctuation on Mississipian to Permian mid-oceanic atoll sedimentation (Akiyoshi Limestone Group, Japan). *Palaeogeography, palaeoclimatology, palaeoecology*, 236:169-189.

Sano, H., Fujii, S., Matsuura, F., 2004. Response of Carboniferous – Permian mid-oceanic seamount-capping buildup to global cooling and sea-level change: Akiyochi, Japan. *Palaeogeography, palaeoclimatology, palaeoecology*, 213:186-206.

Schellwien, E. 1908. Monographie der Fusulinen. Teil 1: Die Fusulinen des russisch-arktischen Meeresgebietes. *Paleontographica*, 55:145-194.

Schlykova, G. N. 1948. Upper Carboniferous fusulinids of Samara Bend. Trudy Vsesoyuznogo Neftyanogo Nauchno-issledovatelskogo Geologorazvedochnogo Instituta (VNIGRI) novaya seriya, 31(1):109–135, Izdatelstvo Gostoptekhizdat, Moscow and Leningrad. (In Russian)

Schwab, F.L., 1976. Modern and ancient sedimentary basins: Comparative accumulation rates. Geology, 4, 723-727.

Sheng, J. C. 1951. *Taitzehoella*, a new genus of fusulinid. Bulletin of the Geological Society of China, 31:79–85.

Sheng, J. C. 1958. Fusulinids from the Penchi Series of the Taitzeho Valley, Liaoning. Palaeontologia Sinica, new series B, 7 (whole number 143):1–119.

Skinner, J. W. 1931. Primitive fusulinids of the Mid-continent region. *Journal of Paleontology*, 5:253–259.

Skinner, J.W., and Wilde, G.L., 1966. Permian fusulinids from Pacific Northwest and Alaska. The University of Kansas, Paleontological Contributions, Paper 4, 64 p.

Solovieva, M. N. 1986. Zonal'naya fuzulinidovaya shkala moskovskogo yarusa po materialam pereizucheniya stratotipov vnutriyarusnykh podrazdeleniy. Akademiya Nauk SSSR, *Voprosy Mikropaleontologii*, 28:3-23. (In Russian with English abstract)

Staff, H. Von, Wedekind, R. 1910. Der oberkarbone Foraminiferensapropelit Spitzbergens. Bulletin of the Geological Institution of the University of Upsala, 10:81-123.

Stanley, S. M., Powell, M. G., 2003**.** Depressed rates of origination and extinction during the late Paleozoic ice age: A new state for the global marine ecosystem. *Geology*, 31:877–880.

Stephenson, R. A., A. Chekunov, T. Ilchenko, L. Kaluzhna , Ye. Baranova, V. Starostenko, S. Krasovskiy, V. Kozlenko, S. Kuprienko, V. Gordienko, R. Kutas, I. Pashkevich, M. Orlik, M. K. Kivshik, S. M. Stovba, M. T. Turchanenko, V. I. Savchenko, B. S. Krivchenkov, M. Narkiewicz, R. Dadlez, J. Pokorski, Guterch, A. 1993. Continental rift development in Precambrian and Phanerozoic Europe: Europrobe and the Dnieper-Donets rift and Polish trough basins. *Sedimentary Geology*, 86:159–175.

Stephenson, R. A., S. M. Stovba, Starostenko, V. I. 2001. Pripyat-Dniepr-Donets Basin: implications for rift geodynamics and northern Peri-Tethyan tectonic history, p. 369–406. In: Ziegler, P.A., Cavazza, W., Robertson, A. H. F. Crasquin-Soleau S. (Eds.) Peri-Tethyan rift/wrench basins and passive margins, Peri-Tethys Memoir, 6. Memoirs du Museum d' Histoire Naturelle, 186, Paris.

Stevens, C. H., 1966. Paleoecologica implications of Early Permian fossils communities in eastern Nevada and western Utah: Geological Society of America Bulletin, 77: 1121-1130.

Stevens, C. H., 1969. Water depth control of fusulinid distribution. *Lethaia*, 2:121-132.

Stevens, C. H., 1971. Distribution and diversity of Pennsylvanian marine faunas to water depth and distance from shore. *Lethaia*, 4:403-412.

Stovba, S., Stephenson, R. A., 1999. The Donbas Foldbelt: its relationships with the uninverted Donets segment of the Dniepr-Donets Basin, Ukraine. *Tectonophysics*, 313:59-83.

Stovba, S., Stephenson, R. A., Kivshik, M., 1996. Structural features and evolution of the Dniepr-Donets Basin, Ukraine, from regional seismic reflection profiles. *Tectonophysics*, 268:127–147.

Sweet, W.C., 1988. The Conodonta: Morphology, taxonomy, paleoecology, and evolutionary history of a long-extinct animal phylum. Oxford Monographson Geology and Geophysics, 10.

Thompson, M. L. 1935. The fusulinid genus *Staffella* in America. *Journal of Paleontology*, 9:111–120.

Thompson, M. L. 1936. Pennsylvanian Fusulinids from Ohio. *Journal of Paleontology*, 10:673–683.

Thompson, M. L., Foster, C. L. 1937. Middle Permian fusulinids from Szechuan, China. *Journal of Paleontology*, 11:126–144.

Ulmishek, G. F., 2001. Petroleum geology and resources of the Dnieper-Donets Basin, Ukraine and Russia. *U.S. Geological Survey Bulletin*, 2201-E:1-14.

Ueno, K., Villa, E. 1998. Fusulinids from the Donets Basin: primary stratigraphic observations. *Newsletter on Carboniferous stratigraphy*, (16): 6-7.

Vachard, D., Munnecke, A., Servais, T. 2004. New SEM observations of keriothecal walls; implications for the evolution of Fusulinida. *Journal of Foraminiferal Research*, 34(3):232-242.

Van Ginkel, A.C. 1965. Carboniferous fusulinids from the Cantabrian Mountains (Spain). Leidse Geologische Mededelingen, 34:1–225.

Van Wees, J-D., R. A. Stephenson, S. M. Stovba, Shiminovsky, V. A. 1996. Tectonic variation in the Dniepr-Donets Basin from automated modeling of backstripped subsidence curves. *Tectonophysics*, 268:257–280.

Veevers, J.J., and Powell, C. McA., 1987. Late Paleozoic glacial episodes in Gondwanaland reflected in transgressive-regressive depositional sequences in Euromerica: *Geological Society of America Bulletin*, 98:475-487.

Vella, P., 1962. Determining depths of New Zealand Tertiary seas. An introduction to depth paleoecology. Tuatara, 10 (1), 19-40.

Villa, E., and Task Group. 2008. Progress Report of the Task Group to establish the Moscovian-Kasimovian and Kasimovian-Gzhelian boundaries. *Newsletter on Carboniferous Stratigraphy*, 26:12–13.

Villa, E., Bahamonde, J. R., 2001. Accumulation of Ferganites (Fusulinacea) in shallow turbidite deposits from the Carboniferous of Spain. *Journal of foraminiferal research*, 31(3):173 – 190.

Wagner, R. H. 1969. Proposal for the recognition of a new “Cantabrian” stage at the base of the Stephanian Series. C. R., 6e Congre`s Carbonife`re, Sheffield 1967, 1:139–150.

Wagner, R.H, Winkler Prins C.F, Granados L.F. 1996. The Carboniferous of the World. III. The Former USSR, Mongolia, Middle Eastern Platform, Afghanistan & Iran. Instituto Geológico y Minero de España, Madrid.

APPENDIX

Here I attach Supplementary Data for the **CHAPTER TWO**. This Supplementary Data includes description of “M” Formation in the Gurkovo section, outcropped in the southern suburb of the town of Pervomaysky. The “M” formation is represented mainly by siliciclastic deposits: sandstone, siltstone, clays, with subordinate limestone beds and coal seams. A total of 20 limestone beds and 28 coal seams are documented in this formation. This section was described by Makarov (1985). Lithology is adapted to the western terminology.

Appendix A

Gurkovo section

1. Limestone M_1 is comprised of two units. The lower unit is a thin-bedded gray wackstone with abundant sponge spicules and fossil remains: crinoid ossicles, holothurians, bryozoans, ostracods, brachiopods (*Camarophia* sp., *Urustenia dubia*, *Martinia* sp., *Phricodothyris* ex gr. *mosquensis*), and foraminifers. The first occurrence of fusulinids *Ozawainella stellae* Manukalova, and *Fusulinella colanii* (?) Lee and Chen are documented in the lower unit (Aisenverg *et al.,* 1975, p. 85).

   The upper unit is massive, yellow, partly dolomitized silty wackstone with abundant low diverse small brachiopods (*Chonetes* aff. *carboniferous* Keys., *Schizophoria* sp., *Martinia* cf. *minima*, *Avonia* cf. *karpinskiana*, *Carcrinella* cf. *obscuroundatus* Lich., bivalves (*Pecten* sp.) and corals. Thickness is 1.2 m.

2. Siltstone is dark-grey and micaceous with discontinuous ripple laminated cross-bedding. Rare plant remains occur. Thickness is 9.64 m.
3. Sandstone: in the lower and middle parts the sandstone is light-grey, micaceous, from fine- to medium-grained, with ripple cross laminae; in the upper part the sandstone is dark-grey and calcareous. This bed has a sharp boundary with the underlying bed. Thickness 24.82 m.
4. Siliciclastic mudstone is grey, micaceous, and thin-bedded with parallel horizontal laminae. This mudstone contains siderite nodules. This bed has a sharp boundary with the underlying bed. Thickness is 1.68 m.
5. Sandstone is greenish-grey, fine-grained, with flaser bedding. Thickness is 3.75 m.
6. Limestone M_2 is light-grey, crinoid-rich or foraminiferal packstone to grainstone, with abundant ostracods, brachiopods, bryozoans, and corals. Brachiopods are *Choristites* cf. *eudoxiae*, *Martinia* sp.; corals are *Chaetetes* sp., *Petalaxis mohicana* Fom. Fusulinids are *Ozawainella adducta* Manukalova, abundant *Schubertella* and *Fusulinella* "*F. colanii* Lee and Chen" (= *Moellerites lopasniensis* Solovieva)* and. (*test's wall in abundant *Fusulinella* species in this limestone contains poorly developed discontinuous diaphanotheca in the fourth volution, therefore the species defined as *F. colanii* Lee and Chen, belong to older genus "*Moellerites*" Solovieva. Khodjanyazova and Davydov). Thickness is 2.24 m.
7. Siliciclastic mudstone. In the lower part it is patchy, greenish-grey. In the upper part it is dark-grey and massive with siderite nodules. Rare bivalves occur. Thickness is 3.91 m.
8. Sandstone is grey, fine-grained and micaceous with flaser bedding. Plant remains occur. Thickness is 7.83 m.
9. Coal m_2. Thickness is 0.45 m.
10. Siltstone is dark-grey and micaceous with discontinuous ripple laminated cross-bedding. Rare plant remains and siderite nodules occur. This bed has a sharp boundary with the underlying bed. Thickness is 3.86 m.

11. Limestone M_3 in the lower part is gray and in the upper unit is grey-tan. This limestone is crinoid-rich or foraminiferal packstone to grainstone with abundant brachiopods, bryozoans, and corals. In the lower parts coral *Petalaxis mohicana* Fom. occurs. Abundant fusulinids are represented by *Ozawainella stellae* Manukalova, *Neostaffella ozawai* (Lee and Chen), *Beedeina schellwieni* (Staff), *B. pseudoelegans* (Chernova). Brachiopods are *Rhipidomella* cf. *michelini*, *Meekella* sp., *Orthotetes* sp., *Chonetes* sp., *Avonia* cf. *krutojensis*, *Buxtonia* sp., *Dictyoclostus* sp., *Magnifera* sp., *Choristites* sp., *Phricodothyris* cf. *mosquensis*. Thickness is 3.63 m.
12. Siltstone is grey, micaceous and calcareous with discontinuous ripple laminated cross-bedding. Thickness is 3.63 m.
13. Sandstone is grey, micaceous and fine-grained with ripple laminated cross-bedding. Thickness is 1.12 m.
14. Siltstone is grey and micaceous with discontinuous ripple laminated cross-bedding. Rare plant remains occur. Thickness is 2.80 m.
15. Coal m_3^{low}. Thickness is 0.14 m.
16. Sandstone is grey, micaceous and fine-grained with discontinuous ripple laminated cross-bedding. Rare plant detritus occurs. Thickness is 3.69 m.
17. Siltstone is grey and micaceous with discontinuous parallel laminated cross-bedding. Rare plant remains and siderite nodules occur. Thickness is 13.08 m.
18. Coal m_3^{up}. Thickness is 0.23 m.
19. Interbeded grey, fine-grained sandstone and siltstone with parallel laminae. Plant remains in the upper part include abundant *Stigmaria*. Thickness is 4.65 m.
20. Coal m_3^1. Thickness is 0.22 m.
21. Limestone M_4 in the lower part is gray tan and in the upper unit is grey. This limestone is crinoid-rich or foraminiferal packstone with abundant brachiopods, ostracods, and bryozoans. Brachiopods are *Dictyoclostus* sp., *Choristites* sp. Fusulinids are mainly *Neostaffella* and *Beedeina* species. Thickness is 2.50–4.70 m.

22. Siltstone is grey and micaceous with ripple laminated cross-bedding in the upper part of the bed. This siltstone contains calcareous nodules. Thickness is 2.97 m.
23. Coal m_4. Thickness is 0.45 m.
24. Siliciclastic mudstone is dark-grey and massive. Rare plant remains occur. Thickness is 5.05 m.
25. Limestone M_4^1 is dark-gray, organic-rich packstone to grainstone with abundant crinoids, brachiopods, ostracods, bryozoans, and fusulinids. Thickness is 0.74 m.
26. Siliciclastic mudstone is dark-grey and massive. Thickness is 5.20 m.
27. Siltstone is grey and micaceous with ripple laminated cross-bedding and parallel lenticular laminae. Plant imprints occur. This bed has a sharp boundary with the underlying bed. Thickness is 4.98 m.
28. Sandstone is grey to tan, micaceous, and fine-grained with parallel laminae, trough and planar tabular cross bedding. Thickness is 5.79 m.
29. Siliciclastic mudstone is grey and rich in organic matter with abundant *Stigmaria* and calcareous nodules. Thickness is 3.86 m.
30. Coal m_4^1. Thickness is 0.19 m.
31. Interbedded grey, fine- to medium-grained siltstone is micaceous with ripple laminated cross-bedding and parallel lenticular laminae. Plant imprints and siderite nodules occur. Thickness is 7.33 m.
32. Siliciclastic mudstone is grey and massive. Thickness is 3.22 m. In the upper part of this bed coal m_4^2 is documented and is 0.17 m thick.
33. Siltstone is grey, fine-grained and micaceous with ripple laminated cross-bedding and parallel lenticular laminae. In the upper part *Stigmaria* plant imprints occur *in situ*. Thickness is 3.86 m.
34. Limestone M_5 is represented by alternation of grey thick-bedded wackstone and dark-grey and grey tan, organic-rich, muddy packstone to grainstone. In the lower part abundant, irregular shaped chert nodules, 0.2 m in diameter occur. Abundant foraminifers, crinoids, brachiopods, bryozoans, ostracods, gastropods occur. Brachiopods are *Spirifer* (*Choristites*) *priscus*, *Sp.*

(*Choristites*) *trautscholdi*. Fusulinids are represented by *Neostaffella*, *Ozawainella* and *Beedeina* species. Thickness varies from 11 to 17 m.

35. Siltstone is grey-tan and coarse-grained with ripple laminated cross-bedding. Thickness is 11.0 m.
36. Sandstone is grey to tan and fine-grained with trough and planar tabular cross bedding. In the upper part plant imprints, *Stigmaria* occur *in situ*. Thickness is 2.20 m.
37. Limestone M_6: grey wackstone to packstone in lower part and grey to tan clayed packstone and grainstone with abundant fossils: crinoids, brachiopods, ostracods, bryozoans, and foraminifers in the upper part. Brachiopods are abundant *Spirifer* (*Choristites*) *priscus*, bryozoans are *Stenodiscus beralicus*, *Fenestella medvedhensis*, *F. bifurcata*. Fusulinids are represented by *Neostaffella* aff. s*phaeroidea* (Moeller), small *Pseudostaffella gorskyi*, *Ozawainella adducta* Manukalova, *O. stellae* Manukalova, *Beedeina rauserae* (Chernova), *B*. cf. *schellwieni* (Staff). Thickness 4 m.
38. Sandstone is grey-tan arkose with abundant mica, from fine- to medium-grained with ripple cross laminae. Large logs of *Calamites* sp., *Artisia* sp. and scarce large plant remains *Sigilaria* ex gr. *rhytidolepis* occur. Thickness is 21.48 m.
39. Siltstone is grey to green, fine-grained and micaceous, with horizontal parallel laminae. In the upper part *Stigmaria* imprints occur *in situ*. Thickness is 7.20 m.
40. Siliciclastic mudstone is dark-grey with plant remains. Thickness is 1.30 m. In the lower part of this bed coal m_5^2 is documented and is 0.19 m thick.
41. Limestone M_7 is dark-grey, clayed and organic-rich micritic wackstone. Small abundant brachiopods *Chonetes* aff. *carboniferous*, bivalves *Solenomorpha solenoids* and bryozoans Stenodiscus beralicus occur. Fusulinids are represented by abundant *Hemifusulina* species. Thickness 0.6–0.9 m.
42. Siliciclastic mudstone is dark-grey, with horizontal parallel laminae and siderite nodules, up to 4 cm in diameter. Thickness is 19 m.
43. Coal m_6. Thickness is 0.2 m.

44. Limestone M_7^1 is grey, sometimes grey-tan, organic-rich packstone. Bioclasts are represented by crinoids, bryozoans, brachiopods, and foraminifers. Fish remains and scarce trilobites occur. Abundant fusulinids are *Neostaffella*, *Beedeina*, and *Ozawainella* species. Thickness is 0.30–0.65 m.
45. Siliciclastic mudstone is dark-grey, massive, and micaceous with fossil remains. This bed has a sharp boundary with the underlying bed. Thickness is 9.0 m.
46. Siltstone is grey, massive and micaceous, with ripple laminated cross-bedding, sometimes replaced by parallel lenticular laminae. *Stigmaria* Plant imprints occur *in situ*. Thickness is 5.14 m.
47. Coal m_6^0. Thickness is 0.20 m.
48. Siltstone is grey-tan and fine-grained with horizontal and ripple laminated cross-bedding. This bed is poorly outcropped. Thickness is 5.14 m.
49. Sandstone fine-grained, grey tan, with planar tubular and trough cross-stratification. In the middle part sandstone is coarse-grained with herringbone cross stratification. Thickness is 20.0 m.
50. Limestone M_7^2 is a light-grey to tan crinoids-rich wackstone to packstone. Thickness is 1.54 m.
51. Sandstone in the upper part is grey and fine-grained with discontinuous ripple laminated cross-bedding. In the lower and middle parts sandstone is medium-grained with unclear parallel laminae. This sandstone is underlain by siliciclastic mudstone, grey to green, 0.64 m thick. Thickness of sandstone is 20.0 m.
52. Interbedded grey-tan siltstone and fine-grained micaceous sandstone with horizontal and ripple laminated cross-bedding. Thickness is 7 m.
53. Sandstone is fine-grained, and grey-tan with herringbone cross-stratification. Thickness is 1 m.
54. Siltstone is grey-tan and fine-grained with ripple laminated cross-bedding. Thickness is 1.40 m.

55. Limestone M_8 is dark-grey, sometimes dark-brown wackstone, with rare crinoids, ostracods, sponge spicules, brachiopods and bivalves. Bryozoans *Penniretepora inconstans*, *Septora luterkensis*. Thickness is 0.65–2.06 m.
56. Sandstone is thick-bedded, coarse-grained, grey-tan, and is sometimes replaced by conglomerate with planar tubular and trough cross-stratification. Some organic-rich inclusions occur. Within individual beds the size of sand grains fine upward. Large logs of *Lepidodendron* sp., *Calamites* sp., *Artisia* sp. *Sigilaria* sp. and large plant detritus occur. Thickness is 64.0 m.
57. Siliciclastic mudstone is grey to green and massive. Thickness is 3.54 m.
58. Limestone M_9 is tan, biogenic packstone, with abundant crinoids, ostracod, brachiopod, foraminifer and algae remains. Thickness is 0.64 m.
59. Siliciclastic mudstone is grey with organic texture and bioturbation formed by roots of plants. Thickness is 1.67 m.
60. Coal m_8. Thickness is 0.19 m.
61. Siltstone is grey, fine-grained and micaceous with ripple laminated cross-bedding. Plant imprints occur. In the lower part siltstone is replaced by grey to green and micaceous siliciclastic mudstone with siderite nodules. Thickness is 7.72 m.
62. Siliciclastic mudstone is dark-grey and massive. Thickness is 6.43 m.
63. Siltstone is grey, fine-grained, micaceous and massive with unclear flaser bedding. Thickness is 3.22 m.
64. Limestone M_{10} is grey-tan, foraminiferal and crinoid-rich packstone to grainstone with brachiopods, ostracods, bryozoans, sponges, and solitary corals. Brachiopods are *Dictyoclostus* sp., *Magnifera* cf. *pulcher*, *Echinoconchus* cf. *elegans*, and *Choristites sophiae*. Thickness is 2.90 m.
65. Sandstone is grey to greenish-grey, fine-grained and micaceous with unclear ripple laminated cross-bedding. In the lower part underlying siliciclastic mudstone is dark-grey and massive with scarce fossils. Thickness is 7.72 m.
66. Coal m_9. Thickness is 0.28 m.
67. Siliciclastic mudstone is grey to greenish-grey, mottled and massive. Thickness is 26.56 m.

68. Coal m_9^0. Thickness is 0.28 m.
69. Siliciclastic mudstone is grey, uniform and micaceous. Thickness 1.93 m. At this interval, limestone M_{10}^1 is documented in the well. This limestone is a grey tan, micritic crinoid-rich wackstone. Thickness is 0.26 m.
70. Siltstone is grey, fine-grained, micaceous, massive, with horizontal and ripple laminated cross-bedding. Calcareous nodules occur. Thickness is 30.22 m.
71. Siliciclastic mudstone is grey, uniform and massive with siderite nodules. Thickness is 7.07 m.
72. Sandstone grey, fine-grained, calcareous and massive. Thickness is 1.29 m.
73. Siliciclastic mudstone is grey and uniform with trace fossils in the upper part. Thickness 2.57 m.
74. Siltstone is grey and coarse-grained with cross-bedding. Thickness is 0.64 m.
75. Limestone N_1. Thickness is 3.5 m.

	Podolskian					
	Hemifusulina subrhomboides - H. vozhgalica- Beedeina elshanica vaskensis				Putrella donetziana-Fusulinella colanii	K. rossoshanica - F.tokmovensis longa
Fusulinids	M_7	M_7^{up}	M_7^2	M_8	M_9	M_{10}
Hemifusulina subrhomboidalis	x					
H. aff. *subrhomboidalis*		x				
H. vozhgalica	x					
H. mucronata	x					
H. pulchella	x	x				
H. elegantula	x					
H. communis acuta		x				
H. bocki					x	
H. aff. *splendida*		x				
Beedeina elegans						x
B. cf. *elshanica vaskensis*	x	x	x	x	x	
N. sphaeroidea						x
N. larionovae larionovae		x			x	x
N. larionovae polasnensis		x				
N. sphaeroidea cuboides					x	
N. syzranica					x	
N. cf.*sphaeroidea cuboides*		x			x	
N. cf. *rostovzevi*					x	
N. sp.	x					
Pseudostaffella confusa		x				
Ps. variabilis		x				x
Ps. khotunensis					x	x
Ps. compressa donbassica					x	x
Ps. primaeva					x	
Ozawainella minima	x					
O. krasnodonica		x				x
O. adducta						x
O. angulata		x				
O. rhomboidalis		x				
O. donbassensis		x				
O. mosquensis					x	
O. vozhgalica					x	
O. cf. *vozhgalica*						x
O. aff. *lorentheyi*		x				
O. sp.	x				x	x
O. sp.1		x				

Taitzehoella c f. *librovitchi globulus*		x				
Fusiella pulchella					x	x
Fus. typica extensa						x
Fus. praetypica						x
Fus. praecursor						x
Fus. praecursor paraventricosa						x
Fus. sp. 1						x
Fus. sp. 2						x
Schubertella lata					x	x
Sch. obscura procera					x	x
Sch. elliptica						x
Sch. subkingi						x
Sch. cf.*myachkovensis*					x	
Sch. *cf. galinae*					x	
Sch. cf. *inflata*					x	
Putrella brazhnikovae					x	
P. cf. *fusiformis*					x	
P. donetziana					x	
Fusulinella colanii					x	x
Fusulinella colaniae meridionalis						x
F. colaniae borealis					x	
F. pseudocolaniae					x	x
F. vozhgalensis devexa						x
F .cf. *vozhgalensis devexa*					x	
F.(Moellerites)subconaliae						x
F.(M.)subconaliae plana						x
F.(M.)subconaliae decurta						x
F. tokmensis longa						x
F. formosa tumida						x
F. sp.					x	
F. sp. immature species					x	
Profusulinella rotundata						x
Pr. sp.1						x
Pr. sp.2						x
Kamaina kamensis						x
K.chernovi						x
K. cf. *K. chernovi*					x	
K. rossoshanica rossoshanica						x
K. cf. *rossoshanica kamerlingi*						x
Algae						
Dvinella chomata						x

Table 5A. Fusulinid distribution in the upper Kashirian - Podolskian strata in the Donets Basin

Appendix B

Fusulinoideans	*Putrella donetziana - Kamaina rossoshanica*		*Hemifusulina graciosa - Fusiella spatiosa*	*Fusulina cylindrica - Fusulinella pseudobocki*		*Fusulinella* (?) *kumpani*	
	M_9	M_{10}	N_1	N_1^1	N_1^2	N_2	N_2^1
Ozawainella adducta		x					
O. magna	x						
O. krasnokamski kirovi			x	x	x	x	
O. vozhgalica	x	x				x	
Fusiella sp.		x	x				
F. typica		x					
F. pulchella		x					
F. praecursor							
F. mui		x					
F. subtilis		x	x				
F. spatiosa			x				
F. praelancetiformis			x	x		x	
Taitzehoella simplicata					x	x	x
T. extensa					x	x	x
T. perseverata					x	x	
Neostaffella umbilicata	x	x					
N. sphaeroidea	x	x	x				
N. sphaeroidea cuboides	x	x					
N. larionovae mosquensis	x						
N. khotunensis	x	x	x				
N. distorta						x	
Hemifusulina bocki			x				
H. aff. *bocki*	x						
H. stabilis			x				
H. gurkovensis, new species			x				
H. graciosa			x				
Beedeina innaeformis , new species				x	x	x	
B. elegans		x					
B. sp. cf. *B. paradonetzica*			x				
B. sp. cf. *B. truncatulina*			x				
B. sp. cf. *B. siviniensis*						x	
B. aff. *B. elshanica vaskensis*	x						
Fusulina cylindrica				x	x		

F. domodedovi						x	x
F. quasicylindrica				x	x	x	
F. quasifusulinoides				x	x		
F. sosninae, new species							x
F. sp. cf. *pancouensis*					x		
Kamaina rossoshanica		x					
K. rossoshanica grandis		x					
K. rossoshanica kamerlingi		x					
K. chernovi	x	x					
Putrella donetziana	x						
P.brazhnikovae	x						
P. brazhnikovae fusiformis	x						
Fusulinella colanii	x	x					
F. colanii meridionalis	x	x					
F. pseudocolaniae	x	x					
F. subcolaniae		x					
F. subcolaniae plana		x					
F. subcolaniae decurta		x					
F. vozhgalensis vozhgalensis	x	x					
F. vozhgalensis molokovensis	x	x					
F. pseudocolaniae	x	x					
F. paracolaniae	x	x					
F. aff. *F. paracolaniae crassa*		x					
F. pseudobocki				x			
F. sp. cf. *F . bocki intermedia*				x			
F. rara Schlykova				x			
F. sp. cf. *F. pauciseptata*				x			
F. (?) sp.					x	x	
F. (?) sp.cf. *F. kumpani*							x

Table 6B. Stratigraphic distribution of the Late Moscovian fusulinids in the Donets Basin

Collection #	Samples #	No. Vol.	P(μ)	L(mm)	D (mm)	L/D	Sp.(μ)
Genus *Ozawainella* Thompson, 1935							
Ozawainella krasnokamski kirovi Dalmatskaya, 1961							
SUI 130697	GN1-7/1	6	15	0.34	0.80	0.43	5-10
SUI 130698	KN2-10/3	5	15	0.26	0.67	0.39	5-10
SUI 130699	KA3/4-11/2	5	-	0.27	0.77	0.35	5-10
SUI 130700	GN1-3/2	5	-	0.24	0.60	0.40	5-10
SUI 130701	GN1-3/4	4	-	0.22	0.48	0.46	5-10
Ozawainella vozhgalica Safonova *in* Rauser-Chernousova et al., 1951							
SUI 130702	KN2-4/1	6	-	0.34	1.12	0.30	5-10
SUI 130703	KN2-14/1	5.5	30	0.35	0.87	0.40	5-10
SUI 130704	KN2-15/1	5	10	0.25	0.91	0.27	5-10
SUI 130705	KN2-17/1	5.5	-	0.28	0.72	0.39	5-10
SUI 130706	KN2-3/2	3	-	0.12	0.41	0.29	5-10
SUI 130707	KN2-5/2	3	-	0.14	0.40	0.35	5-10
SUI 130708	KN2-6/2	3	-	0.20	0.56	0.36	5-10
Genus *Fusiella* Lee and Chen *in* Lee, Chen, and Chu, 1930							
Fusiella spatiosa Sheng, 1958							
SUI 130709	GN1-2/1	5	-	1.60	0.32	5.00	10-15
SUI 130710	GN1-6/1	5	-	1.54	0.29	5.30	5-10
SUI 130711	GN1-10/1	5	-	1.56	0.32	4.85	10-15
SUI 130712	GN1-19/1	5	-	1.52	0.40	3.80	10-15
SUI 130713	GN1-22/1	5	-	1.84	0.46	4.00	10-15
SUI 130714	KN2-9/1	4	-	1.25	0.38	3.25	5-15
Fusiella praelancetiformis Safonova *in* Rauser-Chernousova et al.,							
SUI 130715	GN1-2/3	4	20	0.91	0.29	3.14	5-10
SUI 130716	GN1-7/4	5	20	1.00	0.30	3.30	10-15
SUI 130717	GN1-13/4	4	20	0.80	0.24	3.30	5-10
SUI 130718	KA3/1-13a	4	20	0.76	0.24	3.17	5-10
SUI 130719	KN2-8/1	5	15	1.14	0.40	2.90	5-10
SUI 130720	KN2-12/1	5	20	1.14	0.36	3.15	5-10
SUI 130721	GN1-2/1	4	-	0.95	0.30	3.16	5-10
SUI 130722	GN1-14/3	4	-	1.05	0.28	3.75	5-10
SUI 130723	KN2-10/2	4	15	0.80	0.31	2.58	5-10
SUI 130724	KN2-23/11	5	-	0.95	0.35	2.71	5-10

Genus *Taitzehoella* Sheng, 1951							
Taitzehoella simplicata (Lee, 1937)							
SUI 130725	KN2-10/1	7	-	1.58	0.76	2.08	10-20
SUI 130726	KA3/4-12	6	-	1.36	0.77	1.76	10-20
SUI 130727	KA3/11-2	7	35	1.42	0.85	1.65	10-15
SUI 130728	KA3/4-9	6	-	1.52	0.95	1.60	10-20
SUI 130729	KN2-20/2	4.5	45	0.78	0.40	1.95	5-10
Taitzehoella extensa Sheng, 1958							
SUI 130730	KA3/11-3	7	30	1.94	0.90	2.16	5-10
SUI 130731	KN2-13/1	7	-	2.25	1.16	1.94	10-15
SUI 130732	KA3/4-10	7	-	1.93	1.15	1.68	10-20
SUI 130733	KA3/4-11/1	7	-	1.94	0.91	2.13	10-20
Taitzehoella perseverata Safonova *in* Rauser-Chernousova et al., 1951							
SUI 130734	KN2-1/1	8	40	2.20	0.95	2.32	10-20
SUI 130735	KN2-2/2	7	40	2.18	1.00	2.18	10-15
SUI 130736	KN2-18/1	8	50	2.60	1.00	2.60	10-25
SUI 130737	KN2-7/1	6	-	1.70	0.65	2.64	10-20
SUI 130738	KN2-16/1	7	-	2.50	0.98	2.55	15-25
SUI 130739	KA3/4-6/1	7	-	2.70	1.06	2.54	10-25
Genus *Neostaffella* Miclukho-Maclay, 1959							
Neostaffella sphaeroidea (Ehrenberg emend. Moeller, 1978)							
SUI 130740	GN1-4/1	6	60	1.17	1.22	0.95	30-45
SUI 130741	GN1-5/1	7	55	1.19	1.25	0.95	10-50
SUI 130742	GN1-13/1	6	75	1.06	1.08	0.98	30-50
SUI 130743	GN1-19/2	8	90	1.56	1.59	0.98	30-40
SUI 130744	KA3-1/14	7	60	1.23	1.33	0.92	30-45
SUI 130745	GN1-7/2	5	-	0.53	0.66	0.80	20-45
SUI 130746	GN1-7/3	7	-	1.18	1.32	0.89	30-45
SUI 130747	KA3-1/3	4.5	-	0.90	0.95	0.94	20-50
SUI 130748	KA3-1/5	6	-	1.00	1.03	0.97	30-50
SUI 130749	KA3-1/6	6	-	1.00	1.15	0.87	20-30
Neostaffella khotunensis (Rauser-Chernousova *in* Rauser-Chernousova et al., 1951)							
SUI 130750	GN1-2/2	5	48	0.50	0.52	0.96	20-30
SUI 130751	GN1-2/4	5	40	0.50	0.60	0.83	20-30
SUI 130752	GN1-3/3	4	50	0.32	0.38	0.84	15-20
SUI 130753	GN1-9/2	5	55	0.43	0.55	0.78	20-30
Neostaffella distorta (Pogrebnyak, 1975)							
SUI 130754	KN2-6/4	5	-	0.42	0.60	0.70	35-40
SUI 130755	KN2-17/1	4	-	0.45	0.50	0.90	10-25

Genus *Hemifusulina* Moeller, 1878							
Hemifusulina bocki Moeller, 1878							
SUI 130756	GN1-9/1	8	70	3.10	1.50	2.07	10-40
SUI 130757	GN1-15/1	8	70	3.14	1.52	2.07	10-40
SUI 130758	KA3-1/1	8	60	3.20	1.60	2.00	20-30
Hemifusulina gurkovensis , new species							
SUI 130759	GN1-16/1(holot	8	60	3.50	1.25	2.80	10-35
SUI 130760	GN1-21/1	8	60	3.42	1.37	2.50	10-40
SUI 130761	GN1-14/1	8	-	3.25	1.20	2.70	10-35
Hemifusulina graciosa (Lee, 1937)							
SUI 130762	KA3/1-10	6	60	3.05	1.16	2.64	10-25
SUI 130763	GN1-13/2	6	-	2.50	1.10	2.27	10-30
SUI 130764	GN1-17/1	6	-	2.74	1.05	2.70	10-25
SUI 130765	KA3/1-8	6	-	2.78	1.21	2.29	10-25
SUI 130766	KA3/1-3	7	50	2.90	1.17	2.47	10-30
SUI 130767	KA3/1-4	6	60	2.60	1.15	2.26	10-35
SUI 130768	KA3/1-7	6	-	2.52	1.05	2.40	10-30
SUI 130769	KA3/1-11	6	70	2.30	1.02	2.27	10-25
Hemifusulina stabilis Rauser-Chernousova and Safonova *in* Rauser-Chernousova et al., 19							
SUI 130770	GN1-18/1	6	60	2.10	0.95	2.20	10-25
SUI 130771	KA3/1-9	5	65	1.89	0.90	2.10	10-35
SUI 130772	KA3/1-13	5	50	2.05	0.90	2.28	10-30
SUI 130773	KA3/1-12	5	-	1.88	0.84	2.23	10-25
SUI 130774	GN1-16/2	7	65	2.25	0.90	2.50	10-30
Genus *Beedeina* Galloway, 1933							
Beedeina innaeformis, new species							
SUI 130775	KN2-3/1(holoty	5	150	4.95	1.26	3.92	15-20
SUI 130776	KN2-5/1	4	200	4.30	0.90	4.77	10-20
SUI 130777	KN2-11/1	5	180	4.32	1.28	3.37	15-25
SUI 130778	KN2-19/1	5	170	3.79	1.05	3.60	15-20
SUI 130779	KA3/3-22	5	150	3.14	1.04	3.02	20-30
SUI 130780	KA3/4-4	4.5	190	4.10	0.86	4.76	10-30
SUI 130781	KA3/4-5	5	200	4.95	1.15	4.30	10-40
SUI 130782	KA3/4-7	5	140	5.86	1.28	4.50	20-40
Beedeina sp. cf. *paradonetzica* (Putrja, 1939)							
SUI 130783	GN1-1/1	5	120	2.20	1.10	2.00	10-20
SUI 130784	GN1-8/1	5	150	2.10	1.10	1.90	15-30
SUI 130785	GN1-11/1	5	120	2.00	1.15	1.75	20-30

Beedeina sp. cf. *siviniensis* (Rauser-Chernousova *in* Rauser-Chernousova et al., 1951)							
SUI 130786	KN/2-20/1	6	160	-	1,36	-	10-30
Beedeina sp.cf. *truncatulina* (Thompson, 1936)							
SUI 130787	GN1-20/3	4.5	90	0.86	0.45	1.91	10-20
Genus *Fusulina* Fischer de Waldheim, 1829							
Fusulina cylindrica Fischer emend. Moeller, 1878							
SUI 130788	KA3/3-7	4	230	4.00	1.00	4.00	20-40
SUI 130789	KN2-22/1	5	220	4.10	1.10	4.00	20-40
SUI 130790	KA3/3-15	4	280	5.28	1.20	4.40	20-30
SUI 130791	KA3/3-17	5	270	6.10	1.42	4.30	20-45
Fusulina domodedovi Rauser-Chernousova *in* Rauser-Chernousova et al., 19							
SUI 130792	KN2-26/1	5	-	6.90	1.05	6.30	20-30
SUI 130793	KA3/11-4	5	220	5.58	1.28	4.02	10-30
SUI 130794	KA3/11-6	5	-	6.08	1.05	5.79	20-30
Fusulina quasicylindrica (Lee, 1927)							
SUI 130795	KA3/3-9	5.5	180	6.00	1.14	5.26	20-45
SUI 130796	KA3/3-14	5.5	230	5.14	1.30	3.95	10-30
SUI 130797	KA3/4-3/2	5	170	4.85	1.14	4.25	10-30
SUI 130798	KA3/3-4	5	220	4.30	1.28	3.36	10-30
SUI 130799	KN2-25/1	5	210	4.60	1.07	4.30	20-40
Fusulina sosninae, new species							
SUI 130800	KA3/11-7(holo	5	130	3.43	0.93	3.68	10-25
SUI 130801	KA3/11-5	5	150	3.90	0.86	4.53	10-25
Fusulina quasifusulinoides Rauser-Chernousova *in* Rauser-Chern							
SUI 130802	KA3/3-5	5	250	7.10	1.70	4.18	20-35
SUI 130803	KA3/3-20	5	320	5.30	1.57	3.38	20-30
Fusulina sp. cf. *pancouensis* (Lee, 1927)							
SUI 130804	KA3/3-1	8	-	6.43	1.58	4.10	10-35
Genus *Fusulinella* Moeller, 1878							
Fusulinella pseudobocki (Lee and Chen, 1930)							
SUI 130805	KA3/3-6	6	70	3.58	1.47	2.44	10-50
Fusulinella sp. cf. *bocki intermedia* Rauser-Chernousova *in* Rauser-Chernou							
SUI 130806	KA3/3-8	5	60	2.32	1.21	1.92	10-45
SUI 130807	KA3/3-10	4	-	1.67	0.64	2.60	20-50
SUI 130808	KA3/3-16	5	70	2.44	0.94	2.60	20-50
SUI 130809	KA3/3-19	4	-	2.11	0.95	2.22	10-40

Fusulinella rara Schlykova, 1948							
SUI 130810	KA3/3-2	4	110	-	1.05	-	20-50
SUI 130811	KA3/3-12	5	85	3.72	1.20	3.10	10-40
SUI 130812	KA3/3-23	5	80	3.10	1.05	2.95	20-60
Fusulinella sp. cf. *pauciseptata* Rauser-Chernousova and Belyaev, 1							
SUI 130813	KA3/3-3	5	95	3.25	1.28	2.53	15-50
SUI 130814	KA3/3-5a	5	-	2.95	1.26	2.34	25-50
SUI 130815	KA3/3-11/2	5	100	2.88	1.06	2.74	20-50
SUI 130816	KA3/3-13	5	80	2.94	1.20	2.45	15-50
SUI 130817	KA3/3-21	5	100	3.22	1.33	2.42	10-40
Fusulinella (?) sp.							
SUI 130818	KA3/4-1	4.5	40	1.68	0.89	1.89	20-50
SUI 130819	KA3/4-2	4	200	2.50	0.95	2.63	20-50
SUI 130820	KN/2-21/1	3	-	2.30	0.95	2.40	20-60
SUI 130821	KN/2-24/1	4	-	2.22	1.12	1.98	20-50
SUI 130822	KN/2-6/3	3	-	1.40	0.80	1.75	20-50
Fusulinella (?) sp. cf. *kumpani* Putrja, 1939							
SUI 130823	KA3/11-1	5	50	4.00	1.22	3.28	10-40

Table 7B. Dimensions of fusulinids from the "N" Formation of the Donets Basin