FUSULINID SUCCESSION FROM THE MIDDLE-UPPER CARBONIFEROUS BOUNDARY BEDS ON SPITSBERGEN, ARCTIC NORWAY

Vladimir I. Davydov and Inger Nilsson

ABSTRACT

New fusulinid data from the Kolosseum locality, central Spitsbergen, show the process of fusulinid evolution in transitional Middle to Upper Carboniferous beds of the Arctic region. This well-preserved fusulinid fauna provides a clear understanding of the nature of Moscovian-Kasimovian fusulinid evolution; particularly in the Arctic region. Fusulinid assemblages in the Moscovian/Kasimovian boundary beds in Spitsbergen show a predominance of representatives of the **Protriticites-Montiparus-Rauserites** lineage. Representatives of the **Praeobsoletes-Obsoletes-Triticites** lineage in Spitsbergen are very rare and occur later than in the stratotype region, the Russian Platform. Four fusulinid zones similar to zones in the stratotype area are defined upwards: **Fusulinella bocki** Zone, **Protriticites** ex. gr. **ovatus-Quasifusulinoides quasifusulinoides** Zone, **Protriticites pseudomontiparus-Obsoletes obsoletus** Zone and **Montiparus montiparus** Zone, respectively. Precise correlation of the Moscovian/Kasimovian transition of Spitsbergen to adjacent areas (Northeast Greenland and Canadian Arctic) as well as with the Moscovian-Kasimovian of the region of the Moscow basin, Spain, and Carnic Alps is suggested. The Moscovian/Kasimovian boundary of Eurasia is approximately correlative with the Middle Desmoinesian (base of DS-3 fusulinid zone of Wilde 1990) of North America. Data from Spitsbergen are of great importance for resolving the problem of Middle/Upper Carboniferous boundary recognition regarding fusulinid phylogenies.

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INTRODUCTION

Fusulinids are widely distributed in Middle Carboniferous to Lower Permian shallow marine deposits of Spitsbergen, the main island of Svalbard Archipelago (Fig. 1). Upper Paleozoic strata exist throughout the archipelago, but the largest outcrops occur in the central Spitsbergen region. In this area the Carboniferous-Permian succession is relatively unaffected by post-Paleozoic tectonic activity. Middle- and Upper Carboniferous fusulinid zones in deposits from Spitsbergen have been reported previously by Forbes (1960), Cutbill and Challinor (1965), Sossipatrova (1967), Nilsson (1988, 1993), Nilsson and Davydov (1992, 1997) and Igo and Okamura (1992). New data presented here focus on the fusulinid fauna from the uppermost Moscovian and lower to middle Kasimovian beds at the Kolosseum locality (Fig. 1). Data from this section are of special interest because a relatively thick unit represents the Moscovian-Kasimovian boundary beds, and well-preserved fusulinids are recorded from many levels within the section. The frequent occurrence and unique preservation of fusulinids in these strata offers an opportunity to study the process of the fusulinid evolution in transitional Middle to Upper Carboniferous beds based on their ontogeny.

Figure 1.

The problem of Moscovian/Kasimovian boundary recognition has been considered for several years by the Moscovian/Kasimovian Working Group (formerly WG 5) of the Subcommission on Carboniferous Stratigraphy (SCCS) (Villa et al. 1994). The efforts of the WG members from different areas have concentrated on working out detailed biozonation in the boundary beds and tracing this zonation as widely as possible. The fusulinid faunas of Spitsbergen have important paleobiogeographic implications as they act as faunal links between the diverse faunas known from Russia (e.g., Russian Platform, Timan-Pechora Basin and Urals) in the east and Northeast Greenland (Wandel Sea Basin) and the Canadian Arctic (Sverdrup Basin) in the west. These basins were included in the Franklinian Shelf in fusulinacean paleobiogeographic reconstruction of Ross (1995). New fusulinid data from Spitsbergen are regarded as being of great importance for resolving the problem of the Middle/Upper Carboniferous boundary recognition.

LITHOSTRATIGRAPHY AND MATERIAL

The present Middle-Upper Carboniferous and Lower Permian lithostratigraphy for central Spitsbergen is based on Cutbill and Challinor (1965) and Dallmann et al. (in press) (Figure 2). This succession is assigned to the Gipsdalen Group and is dominated by carbonate and evaporite sequences with minor clastic input.

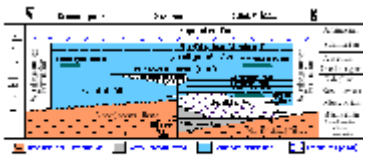

Figure 2.

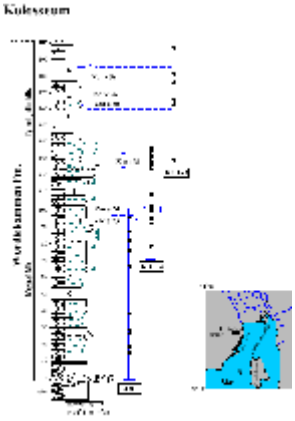

Figure 3.

In the investigated area of central Spitsbergen, the Gipsdalen Group is represented by the Wordiekammen and Gipshuken Formations. This study is based on fusulinid samples from the Kapitol Member of the Wordiekammen Formation.

The Kolosseum section is located in the western part of the Nordfjorden High, central Spitsbergen (Figure 1). At this locality the Middle-Upper Carboniferous Kapitol Member rests unconformably on Devonian strata. Fusulinid-bearing rocks of the Kolosseum section were sampled every 1-3 m in the Moscovian/Kasimovian boundary beds, and every 5-10 m elsewhere (Figure 3).

More than150 thin-sections with oriented fusulinids were prepared for this study. Seventy-two species of 14 genera of fusulinids were identified (Figure 4).

Figure 4.

FUSULINID ZONES IN THE KOLOSSEUM SECTION

Fusulinella bocki Zone (Figure 5)

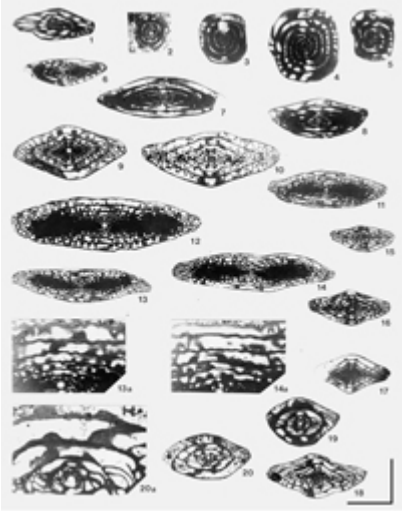

Figure 5.

The body of strata between the first appearance of **Fusiella typica, Fusulinella bocki, Pseudofusulinella pulchra, Quasifusulinoides? kolensis** and first appearance of the representatives of the **Protriticites** and typical **Quasifusulinoides**.

Reference section. Between 28.0 m and 76.0 m in the Kolosseum section, central Spitsbergen (Figures 3-4).

Composition. Fusiella typica Lee and Chen, **Neostaffella sphaeroidea** (Ehrenberg em. Moeller), **Plectofusulina** sp., **Fusulinella bocki** Moeller, **F. helenae** Rauser, **F. mosquensis** Rauser, **Protriticites**? sp., **Pseudofusulinella pulchra** (Rauser and Belyaev), **Beedeina elshanica** (Putrja and Leontovich), **B. paradistenta** (Safonova), **B. samarica** (Rauser and Belyaev), **Quasifusulinoides? kolensis** Nilsson, **Quasifusulinoides? intermedius** (Rauser and Gryzlova), **Quasifusulinoides? firmus** (Rauser), **Wedekindellina dutkevichi** Rauser and Belyaev, **W. subovata** Safonova, **W. uralica** (Dutkevich) (Figure 4).

Chronostratigraphical age. Late Moscovian, early Myachkovian (Novlinskian).

Comments. The recorded assemblage comprises fauna of a mixed nature, where typical Moscovian genera like **Wedekindellina, Beedeina**, and **Fusulinella** occur together with the first **Quasifusulinoides**? Most of the recorded fauna is typically Myachkovian and is dominated by numerous **Wedekindellina, Fusulina, Beedeina, Fusulinella, Pseudofusulinella pulchra**, and rare **Neostaffella**. In the middle part of the zone (38.0 m) transitional forms (Protriticites?) between typical **Fusulinella** and **Protriticites** first occur. These specimens are characterized by thicker walls in the outermost volution and straighter pores in the inner tectorium than are observed in **Fusulinella** (Figure 5.20A). These features are variable, however, and these specimens are still assigned to the genus **Fusulinella**.

Elongate **Quasifusulinoides**? with massive secondary deposits but thin walls, occur in an assemblage of this zone. In the wall of elongate **Quasifusulinoides**? the diaphanotheca becomes more grey and less distinct. The diaphanotheca appears to merge with the inner tectorium, though some specimens posses a well-defined four-layered wall with diaphanotheca in the inner volutions (Figures 5.13A, 5.14A). These specimens are transitional forms between typical **Fusulina** and **Quasifusulinoides**. **Quasifusulinoides**? with transitional features constitute only a small part of the assemblage however. In the stratotype area of the Moscow Basin typical

Quasifusulinoides are first found in upper Myachkovian deposits, i.e. those younger than **Fusulinella bocki** fusulinid Zone (Rauser-Chernousova et al. 1951; Rauser-Chernousova and Reitlinger 1954; Davydov 1997a).

FUSULINID ZONES IN THE KOLOSSEUM SECTION (continued)

Protriticites ex gr. ovatus-Quasifusulinoides quasifusulinoides Zone (Figure 6)

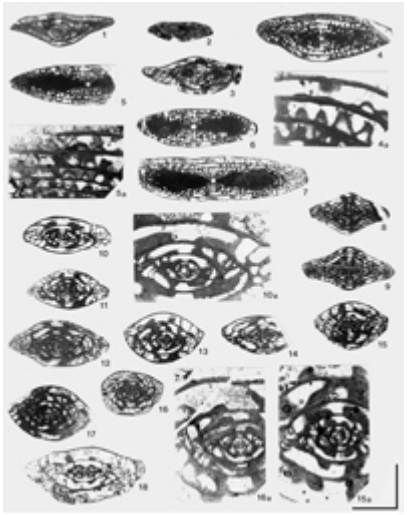

Figure 6.

Definition of biozonal limits. The body of strata between the first appearance of primitive **Protriticites (Protriticites** ex gr. **ovatus**) and typical **Quasifusulinoides (Q. quasifusulinoides** group) and the first appearance of advanced **Protriticites (Pr. pseudomontiparus** group).

Reference section. Between 76.0 and 81.0 m in the Kolosseum section, central Spitsbergen (Figure 4).

Chronostratigraphical age. Latest Moscovian, late Myachkovian (Peskovskian).

Composition. This zone is defined by the occurrence of **Protriticites** ex gr. **ovatus** Putrja and **Quasifusulinoides quasifusulinoides** (Rauser). Other species included in this zone are: **Fusiella praelancetiformis** Safonova, **F. typica** Lee and Chen**, F. praecursor** Rauser, **Plectofusulina** sp., **Oketaella**? sp., **Wedekindellina** sp., **Quasifusulinoides** aff. **fusulinoides** (Putrja), **Q. firmus** (Rauser), **Q. intermedius** (Rauser), **Q. fusiformis** (Rosovskaya), **Q. blear** (Rauser), **Q. shapkiensis** (Konovalova), **Quasifusulinoides? fortissimus** (Rauser), **Fusulinella bocki** Moeller, **F. helenae** Rauser, **F. timanica** Rauser, **Protriticites** aff. **ovatus**, **P**. aff. **sphaericus** Volozhanina (transitional form between **Fusulinella** sp. and **P. sphaericus**), **P**. aff. **inflatus** Bensh, **Pseudofusulinella eopulchra** (Rauser), **Pseudofusulinella? pulchra** (Rauser and Belyaev), and **P. ylychensis** (Rauser) (Figure 4).

Comments. The assemblage of this zone is transitional between typical Upper Moscovian and Lower Kasimovian fusulinid faunas. Typical Moscovian genera such as **Wedekindellina, Neostaffella, Fusulina, Beedeina**, and **Fusulinella** occur very rarely. At the base of this zone **Quasifusulinoides** and **Protriticites** first begin to predominate. However, the wall of **Protriticites** is still not quite typical. The diaphanotheca is well-defined, but pores in the inner tectorium are not quite distinct (Figures 6.15A, 6.16A). **Quasifusulinoides** is represented by typical specimens characterized by a thin, three-layered wall consisting of tectum, outer tectorium and an

inner layer which is homologous to an 5 inner tectorium. This inner layer shows a gradual merging of diaphanotheca and inner tectorium, providing an indistinct boundary between these layers (Figure 6.5A). **Fusiella** in this bed are more developed than in the previous assemblage, being of larger size, having a larger number of volutions, and a more elongate shell. In the Moscow Basin these species of **Protriticites, Quasifusulinoides**, and **Fusiella** occur in the Peskovskaya Formation of Upper Myachkovian age.

At 79.0 m the fusulinid fauna is almost the same**. Fusulinella, Pseudofusulinella, Quasifusulinoides, Protriticites** and transitional forms between **Fusulinella** and **Protriticites** occur. **Quasifusulinoides** in this bed have well-defined pores in the inner tectorium, but the diaphanotheca is still discernable. Pores in the diaphanotheca are only weakly developed. In the **Fusulinella**-**Protriticites** lineage there occur forms with a thickened inner tectorium traversed with coarser pores and a distinct diaphanotheca.

The peculiarity of this assemblage is the domination of **Quasifusulinoides** and **Protriticites**, and the absence of **Praeobsoletes**, which dominates at the same level in the stratotype area. The assemblage shows close affinities to fusulinid fauna from the Peskovskaya Formation of the stratotype area, which form the upper part of the Myachkovian Horizon in the Moscow Basin (Rauser-Chernousova et al. 1951; Rauser-Chernousova and Reitlinger 1954; Makhlina et al. 1984; Davydov 1997a). The **Protriticites** ex. gr. **ovatus-Quasifusulinoides quasifusulinoides** Zone is therefore regarded as being of latest Moscovian (late Myachkovian, Peskovskian) age.

FUSULINID ZONES IN THE KOLOSSEUM SECTION (continued)

Protriticites pseudomontiparus, Obsoletes obsoletus Zone (Figures 7, 8)

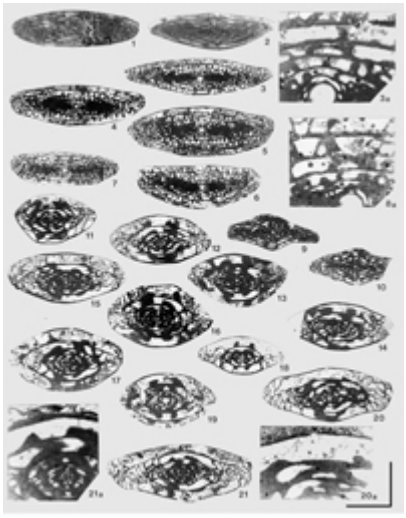

Figure 7.

Definition of biozonal limits: The body of strata between first appearance of **Protriticites pseudomontiparus**, advanced **Protriticites**, and **Praeobsoletes burkemensis**, and the first appearance of **Montiparus**.

Reference section. Between 81.0 and 95.5 m in the Kolosseum section, central Spitsbergen (Figure 4).

Chronostratigraphical age. Early Kasimovian, Krevyakinian.

Composition. Fusiella rawi Lee, **F. lancetiformis** Putrja, **Fusulinella bocki** Moeller, **F.** aff. **bocki** Moeller**, F. helenae** Rauser, **Fusulina pachrensis** Rauser, **Protriticites pseudomontiparus** Putrja, **P. ovatus** Putrja, **P. variabilis** Bensh, **P**. cf. **variabilis** Bensh, **P. ovoides** Putrja, **P. ovatus** Putrja, **P. plicatus** Kireeva, **P. plicatissimus** Kireeva, **P. sphaericus** Volozhanina**, P.** cf. **sphaericus** Volozhanina**, P. subovatus** Bensh, **P**. aff. **subovatus** Bensh, **P. subschwagerinoides** Rosovskaya, transitional form between **Protriticites** and Montiparus, Praeobsoletes sp., **Praeobsoletes burkemensis** (Volozhanina)**, Obsoletes fusiformis** Bensh**, Quasifusulinoides blear** (Rauser), Q. **fusiformis** (Rosovskaya)**, Q. fortissimus** (Rauser)**, Q. quasifusulinoides** (Rauser)**, Pseudofusulinella usvae** (Dutkevich)**, Pseudofusulinella? pulchra** (Rauser and Belyaev), (Figure 4).

Comments. Fusulinella and **Fusulina** occur as single specimens in the lowermost part of this zone while **Protriticites** is abundant. The latter is characterized by a thick wall, thickening of the inner tectorium and more conspicuous almost branching pores. The diaphanotheca is grey and some times even absent (Figure 7.21A) . The wall of **Quasifusulinoides** has well-defined pores in the inner tectorium (Figures 7.3A, 7.8). The wall of **Praeobsoletes** is very thin with only two layers in the outer 1 to 1.5 volutions; it consists of a tectum and gray structureless primatheca (Figure 7.20A).

The fusulinid fauna at 87.5 m resembles the fauna at 81.0 m. The outermost volution of many of the recorded **Protriticites** shells is crushed, however, and the characteristics of the genus are therefore not well distinguished. Nevertheless, there occur a number of specimens with well-defined, thick walls that have a thick inner tectorium with distinct coarse pores. Within this level, very subcylindrical **Fusiella rawi** Lee occur, and this species is common in Kasimovian strata (Villa et al. 1993; Davydov 1997a, 1997b). **Praeobsoletes** and rare **Fusulinella, Pseudofusulinella**, and **Fusulina** are also

present at 87.5 m.

Figure 8.

At 91.5m **Protriticites** is represented by species with coarse pores in an inner tectorium that transforms locally into a keriotheca. In the outermost volution of some specimens, trabeculars similar to those of **Montiparus** are observed in the inner tectorium (Figures 8.9A, 8.12A). These forms have a gray diaphanotheca that nearly merges with the inner tectorium. One specimen with more massive chomata and more intensive septal fluting was found (Figure 8.13). Apparently, this form represents the most developed **Protriticites**, that occupies an intermediate position between **Protriticites** and **Montiparus**.

Earliest **Obsoletes** exhibit a thin two-layered wall with portions of trabeculars in the last volution (Figure 8.3A). Compared with the corresponding assemblage of the stratotype area, **Praeobsoletes** and **Obsoletes** seem to occur later in Spitsbergen. The same pattern is observed in Moscovian/Kasimovian beds of the Cantabrian Mountains of Spain (Villa et al. 1993) and in Carnic Alps (Krainer and Davydov, 1998).

Rare **Pseudofusulinella usvae** are present in this assemblage. Studied specimens of this species appear to be more advanced than in underlying beds as they are larger in size, slightly more elongate, and exhibit tighter coiling.

Based on fusulinid composition of the assemblage and the fusulinid distribution in the section, the zone under discussion fully corresponds to the **Protriticites pseudomontiparus-Obsoletes obsoletus** Zone of the Krevyakinian Horizon of the Moscow region (Davydov 1997a). Similar assemblages are also reported from the Lower Kasimovian of the Urals, Timan-Pechora Basin, Donets Basin, Central Asia, Northern Timan, Cantabrian Mountains and Carnic Alps (Scherbakov et al. 1984; Kireeva 1950, Davydov 1984, 1990a, 1990b, 1992, 1997a, 1997b; Konovalova 1991; Remizova 1997; Bensh 1972; Villa et al. 1994; Davydov and Krainer, in press).

FUSULINID ZONES IN THE KOLOSSEUM SECTION (continued)

Montiparus montiparus Zone (Figure 9)

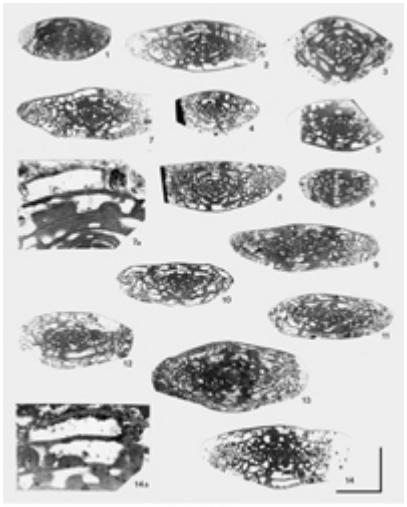

Figure 9.

Definition of biozonal limits. The base of this zone is defined by the first appearance of **Montiparus**. The top of the zone is not defined due to lack of productive samples in this part of the section (Nilsson 1993).

Reference section. At 95.5 m in the Kolosseum section, central Spitsbergen (Figure 4).

Chronostratigraphical age. Middle Kasimovian, Khamovnichenian.

Composition. Montiparus montiparus (Ehrenberg em. Moeller), **Montiparus** ex. gr. **montiparus** (Ehrenberg em. Moeller), **Montiparus calitvicus** (Putrja), **Montiparus likharevi** (Putrja), **Montiparus mesopachus** Rosovskaya, **M. umbonoplicatus** (Rauser and Belyaev), **Montiparus** aff. **umbonoplicatus** (Rauser and Belyaev), **Montiparus** ex. gr. **umbonoplicatus** (Rauser and Belyaev), **Montiparus**? spp., **Protriticites sphaericus** Volozhanina, **Protriticites ovoides** Putrja, **P. lamellosus** Kireeva**, P. manukalovae** Kireeva., **P**. cf. **ovatus** Putrja, **Protriticites**? sp., **Quasifusulina** aff. **eleganta** Shlykova, **Q**. ex. gr. **longissima** (Moeller) sp. nov., **Pseudofusulinella usvae** (Dutkevich) and **Nodosaria** sp.

Comments. In this zone **Quasifusulinoides** is replaced by typical **Quasifusulina** that possess a very thin two-layered wall. **Montiparus** is abundant and exhibit three-layered keriothecal wall consisting of tectum, keriotheca and outer tectorium (Figures 9.7A, 9.14A). Septal fluting of Montiparus is more intensive, and chomata are massive. These **Montiparus** are represented by relatively primitive forms characteristic of the Ratmirovskaya Fm. --the lower Formation of Khamovnichenian Horizon in the Moscow Basin.

However, Protriticites and **Pseudofusulinella usvae** are very rare in this zone. **Nodosaria** sp. are found in this zone, and seem to be one of the earliest representative of this genus. The **Obsoletes-Triticites** lineage appears to be absent at the Kolloseum section.

The recorded fauna from the **Montiparus montiparus** Zone of Spitsbergen compares well with that of the lower portion of the Khamovnichenian Horizon of the Kasimovian of the Moscow Basin and to **Montiparus paramontiparus** zone of the Donets Basin, North Timan, Spain and Carnic Alps (Rauser-Chernousova and Scherbovich 1974; Davydov 1990a, 1990b, 1992, 1997a, 1997b; Remizova 1997; Villa et al. 1994; Krainer

and Davydov, 1998).

DISCUSSION AND CORRELATION

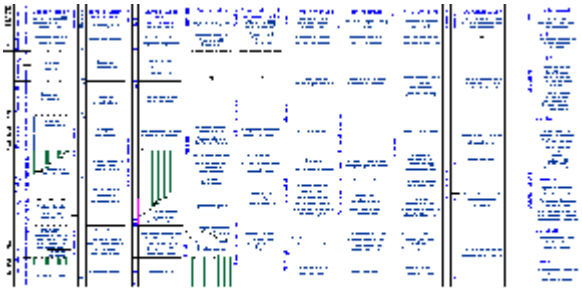

Figure 10.

The Middle/Upper Carboniferous boundary in the stratotype area of the Moscow Basin is placed at the base of the Krevyakinian Horizon (Ivanov 1926, Dan'shin 1947) (Figure 10). This boundary was traditionally defined by fusulinids in the 1950's (Rauser-Chernousova et al. 1951; Rauser-Chernousova and Reitlinger 1954; Rauser-Chernousova and Scherbovich 1974; Ivanova and Khvorova 1955), and the base of the **Protriticites pseudomontiparus-Obsoletes obsoletus** Zone was assigned to correspond to the base of the Kasimovian (i.e. base of Krevyakinian Horizon). This definition is accepted and widely used.

Former Soviet Union

In the Russian Platform, Timan-Pechora Basin, Urals, Donets Basin and Central Asia the Middle/Upper Carboniferous boundary is defined by the first occurrence of **Obsoletes** and accompanying advanced **Protriticites** and **Quasifusulinoides** (Rauser-Chernousova and Scherbovich 1974; Davydov 1986, 1990a, 1990b, 1997a, 1997b; Konovalova 1991; Remizova 1995). However, representatives of the latter two genera first appear in the underlying upper Myachkovian beds (i.e. uppermost Moscovian). **Protriticites**, **Quasifusulinoides**, and **Obsoletes** can be identified only if their tests are well preserved. Even slight recrytallization hampers recognition of these genera. Some specialists deny the independence of these genera for this reason (Villa et al. 1993). Distinct changes in fusulinid wall structure (i.e., well-defined trabecularity of keriotheca) are observed at the base of the **Montiparus montiparus** Zone, and some investigators prefer therefore to place the Moscovian/Kasimovian boundary at the base of this zone (i.e., at the base of the Khamovnichenian Horizon in the stratotype section of the Moscow Basin area; Remizova 1997; Villa et al. 1993).

The problem of the Moscovian/Kasimovian boundary has recently been discussed by Davydov (1997a). Several variations of the Moscovian/Kasimovian boundary position were considered:

1. At the base of **Praeobsoletes burkemensis-Protriticites ovatus** Zone corresponding to the base of the **Protriticites** Genozone and Peskovskyi Fm. of

Myachkovian Horizon in the Moscow Basin.

2. At the base of **Protriticites pseudomontiparus-Obsoletes obsoletus** Zone that places the classical Moscovian/ Kasimovian boundary at the base of Krevyakinskian Horizon.

3. At the base of the **Montiparus montiparus** Zone corresponding to the base of Khamonicheskian Horizon.

Based on the latest fusulinid and conodont studies in the region of the Moscow Basin (Alekeseev et al. 1994; Davydov 1997a) the best correlation potential is shown by the following boundaries:

A) at the base of the Suvurovskaya Fm. (or probably base of "liska" bed of the Peskovskaya Fm. of the Myachkovian Horizon) - the base of the **Protriticites pseudomontiparus, Obsoletes obsoletus** Zone and its equivalent the **Streptognathodus subexcelsus** conodont Zone;

B) at the base of the **Montiparus paramontiparus** Zone and its equivalent the **Streptognathodus oppletus** conodont Zone (Villa et al. 1997; Davydov 1997a).

Based on evidence mentioned above, we can conclude that the Moscovian/Kasimovian boundary problem still is unresolved in the stratotype area and the boundary therefore should be left at an accepted level, i.e. at the base of the Krevyakinian Horizon, that corresponds to the base of the **Protriticites pseudomontiparus-Obsoletes obsoletus** Zone and base of **Streptognathodus subexcellsus** conodont Zone.

Spain

In the Cantabrian Mountains lower Myachkovian assemblage with **Fusulinella bocki** occur in the middle portions of Picos de Europa Formation (Villa et al. 1997). In the upper portion of this formation, primitive **Protriticites** first appear together with conodonts resembling **Streptognathodus subexcellsus**. The base of the Kasimovian is established based on the occurrence of **Protriticites pseudomontiparus** and other advanced **Protriticites**, and by the first appearance of **Praeobsoletes**. First **Obsoletes** occur together with **Montiparus** (i.e., higher in the section than in the stratotype area). The same phenomena is observed in the Kolosseum section at Spitsbergen, where **Praeobsoletes** and **Obsoletes** appear slightly later than in the stratotype area.

Carnic Alps

The lower most portion of the Upper Paleozoic succession in the Carnic Alps has been restudied recently (Krainer and Davydov 1998). The Bombaso Formation and basal Meledis Formation in the central Carnic Alps near Straniger Alm and Zollnersee (Austria/Italy border) consist of shallow marine clastic and carbonate sediments that are arranged to form two fining and deepening upward sequences. Limestones in particular and even breccias of the Bombaso and lower Meledis Formation yield a rich fusulinid

fauna composed of 33 species that are attributed to the following zones: **Quasifusulinoides quasifusulinoides-Protriticites ovatus; Protriticites pseudomontiparus, and Montiparus montiparus.** Breccia of the Bombaso Formation west of Straniger Alm contains the oldest fusulinid fauna of the Carnic Alps, belonging to the **Quasifusulinoides quasifusulinoides - Protriticites ovatus** Zone corresponding to the Peskovskaya Formation of the Myachkovian Horizon in the Moscow basin indicating uppermost Moscovian age. A similar assemblage is found in limestones from depositional sequence 1 at Zollnersee (Krainer and Davydov 1998). Limestones and calcareous sandstones-siltstones of the basal Meledis Formation of depositional sequence 2 near Zollnersee and at Cima Val di Puartis are characterized by fusulinids of the **Protriticites pseudomontiparus** Zone (**Protriticites globulus, Pr. pseudomontiparus, Pr. sphaericus, Pr. rotundatus, Pr. ovoides, Pr. lamellosus**, and **Praeobsoletes burkemensis**) and by **Montiparus paramontiparus** Zone (**Praeobsoletes pauper, P. burkemensis, Obsoletes timanicus, O. obsoletus**, **Montiparus paramontiparus, M. umbonoplicatus, M. montiparus, M. likharevi, M. rhombiformis**, and **M. priscus**) indicating correlation to Krevyakinian (Lower Kasimovian) and Khamovnichenian Horizons (Middle Kasimovian) of the Russian Platform, respectively. In the Carnic Alps, **Praeobsoletes** and **Obsoletes** first occur in the Khamovnichenian Horizon (i.e., later than in the stratotype area).

Northeast Greenland (Wandel Sea Basin)

New fusulinid collections from Amdrup Land have recently been studied by Davydov and Nilsson. Beds with **Beedeina paradistenta, Fusulinella praebocki, Pseudofusulinella eopulchra** and primitive **Protriticites** are correlated with the Peskovskaya Formation of the upper Myachkovian Horizon in the Moscow Basin. These beds are overlain by beds with advanced **Protriticites, Quasifusulinoides**, rare **Praeobsoletes, Obsoletes**, and **Plectofusulina**. This assemblage corresponds to the Krevyakinian Horizon of the Lower Kasimovian in the Moscow Basin. Higher in the section **Quasifusulina, Montiparus**, and rare **Protriticites** occur. This assemblage is correlative with the Khamovnichenian Horizon (Middle Kasimovian) in the Moscow Basin. Beds with assemblages of **Quasifusulina, Montiparus**, and rare **Protriticites** are overlain by beds with numerous **Quasifusulina** and the first **Rauserites**, that correlate with the Dorogomilovian Horizon (Upper Kasimovian) in the Moscow Basin. Moscovian-Kasimovian fusulinid assemblages in Northeast Greenland show strong similarities with those in Spitsbergen and correlate well with the Moscovian-Kasimovian transition in the stratotype sections of the Moscow Basin.

Canadian Arctic

In the Canadian Arctic (Sverdrup Basin) fusulinids from the Middle/Upper Carboniferous boundary beds are reported by Rui Lin et al. (1991), Nilsson (1993) and Rui Lin and Nassichuck (1994). An upper Moscovian **Fusulinella eopulchra** assemblage, a lower to middle Kasimovian **Protriticites-Pseudofusulinella** ex. gr. **usvae** assemblage and an upper Kasimovian **Rauserites** aff. **quasiarcticus** assemblage are recorded from the Canyon Fiord Formation (Nilsson 1993). Rui Lin et al. (1991) defined two upper

Moscovian fusulinid zones in the type section of the Nansen Formation: **Wedekindellina lata-W. uralica longa** Zone (units F-G) and **"Fusulinella" eopulchra** Zone (units H-L). The former zone is correlated by Rui Lin et al. (1991) with the Podolskian Horizon and the latter zone with the Myachkovian Horizon. We kindly were permitted by Dr. Nassichuk and Dr. Rui Lin to study the thin sections from the type section of the Nansen Formation. This study enabled us to propose another correlation of this section. We consider fusulinid assemblages from the units F-G most similar to the Myachkovian of the Moscow Basin. In particular, units F-G comprise species of **Wedekindellina, Neostaffella**, and **Fusulinella**, that are characteristic for the Myachkovian of the Moscow Basin (Rauser-Chernousova and Reitlinger 1954). The fusulinid taxa notably change in the units H-L. Typical Moscovian genera such as **Wedekindellina** and **Neostaffella** completely disappear while **Fusulinella** and **Pseudofusulinella** predominate. In unit L we recognized **Nodosaria** aff. **longissima** Suleimanov and **Raphconilia** sp. Until now these small foraminifera were not known in deposits older than Kasimovian (Davydov 1988; Brenckle and Whalman 1993; Groves and Whalman 1997). Also in Spitsbergen **Nodosaria** has not been reported in beds older than Krevyakinian (Nilsson and Davydov 1992). **"Fusulinella" eopulchra** Zone of Rui Lin et al. (1991) is therefore partly of early Kasimovian and may be middle Kasimovian in age.

Rui Lin and Nassichuk (1994) describe two new fusulinid assemblages above unit L in the type section of the Nansen Formation. Both **"Protriticites"** sp. A Zone (thickness 1.5 m) and **Eowaeringella placitasensis** Zone (thickness 23 m) are correlative with the Lower Missourian of the American Stratigraphic Scale and with the Krevyakinian Horizon of the Lower Kasimovian of the Moscow Basin . In our opinion however, their **"Protriticites"** fauna should belong to the genus **Rauserites** , because those specimens have a true keriothecal wall structure; sometimes slightly recrystallized. **Rauserites** occurs only from the beginning of the upper Kasimovian in the Moscow Basin, Urals, Donets Basin, Central Asia, North Greenland and Spitsbergen (Villa et al. 1994). Rauserites assemblage from type Nansen seems to correlate well to the **Rauserites quasiarcticus** Zone of the stratotype area (i.e., Dorogomilovian Horizon of Moscow Basin). Consequently, the proposed Moscovian/Kasimovian boundary in type Nansen by Rui Lin and Nassichuk (1994) is actually closer to the middle Kasimovian/upper Kasimovian boundary. In our opinion the Moscovian/Kasimovian boundary in the type Nansen should be placed at the base of unit H.

North America

Correlation of fusulinids from Russia and Spitsbergen with North America can be performed only conventionally. Traditionally the Moscovian/Kasimovian boundary is correlative with the Desmoinesian/Missourian boundary, with Missourian being the approximate equivalent of the Kasimovian (Ross and Ross 1987).

Rosovskaya (in Ivanova and Rosovskaya 1967) noted, however, that fusulinids from the base of Missourian, according to their evolutionary level, correspond to Upper Kasimovian fusulinids. Rosovskaya assumed a gap between the Desmoinesian and Missourian corresponding to the Krevyakinian and Khamovnicheian Horizons (Ivanova and Rosovskaya 1967). Accepting Rosovskaya's idea of the correspondence of the Lower Missourian and Upper Kasimovian, we propose a correlation between the Desmoinesian with the Lower and Middle Kasimovian and the Lower Missourian with the Upper Kasimovian (Figure 11).

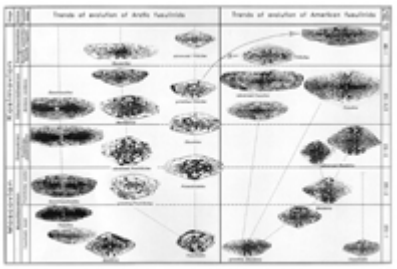

Figure 11.

In Eurasia **Fusulinella** predominates at the end of the Myachkovian. It is simultaneously displaced by **Protriticites** and **Praeobsoletes**, that later are gradually followed by **Montiparus** and **Rauserites** in the first line (Figure 11), and by **Obsoletes** and **Triticites** in the second one respectively (Davydov 1990b). It is also at the end of the Myachkovian that **Fusulina** is displaced by **Quasifusulinoides**, that is followed by **Quasifusulina** in the Khamovnicheian (**Chen-Tzin-Shi 1963**). **Beedeina** disappears completely at the end of the Myachkovian.

The following fusulinid succession in the Upper Moscovian-Kasimovian in Eurasia is shown in Table 1.

In North America **Fusulinella** is scarce in the upper part of the Desmoinesian and disappears relatively quickly. **Beedeina** and **Fusulina** predominate during most of Desmoinesian. The evolution these genera in North America is very different from their evolution in Eurasia. Specialization and gigantism characterize evolution of **Beedeina** in North America. At the beginning of the Missourian in North America, **Triticites** abruptly occurs, perhaps as a result of migration. Triticites instantaneously displaces super-specialized **Fusulina** and **Beedeina**. Recently Wahlman et al. (1997) discovered **Protriticites** and probably **Praeobsoletes** fauna co-occur with **Bartramella bartrami** in the middle Desmoinesian. Table 2 shows recorded fusulinid zones of Desmoinesian (DS) and Missourian (MS) in USA by Wilde (1990).

Comparison of the Myachkovian-Kasimovian fusulinid succession of Eurasia with the Desmoinesian-Missourian fusulinid succession shows the following. Fusulinids from DS-1a,b and DS-2a zones of the Desmoinesian are, according to their evolutionary level, correlative with those from the Myachkovian in the Russian Platform and to **Fusulinella bocki** and **Protriticites** ex. gr. **ovatus-Quasifusulinoides quasifusulinoides** zones in Spitsbergen. Fusulinids in succeeding Desmoinesian fusulinid zones (DS-2b, DS-3, DS-4, and DS-5) differ essentially in a more advanced shell structure.

The first Missourian **Eowaeringella** and **Triticites** Fusulinid Zone replace Desmoinesian successions of **Beedeina** and **Fusulina** in the USA. According to their development these **Triticites** correspond to **Triticites** and **Rauserites** from the Upper Kasimovian (Dorogomilovian) of the Moscow Basin (Ivanova and Rosovskaya 1967).

Position of DS-4, DS-5, DS-6 and DS-7 enables us to assume that the major part of the Desmoinesian corresponds to the Krevyakinian and Khamovnichenian Horizons of the Russian Platform. Desmoinesian Fusulinid Zones DS-4, DS-5, DS-6, DS-7 correspond to **Protriticites pseudomontiparus** and **Montiparus montiparus** fusulinid zones in Spitsbergen respectively. In summary, we propose that the Moscovian/Kasimovian boundary is correlative with the base of DS-3 (Middle**-**Upper zone of **Beedeina** and upper zone of **Wedekindellina**) by Wilde (1990) (Table 3).

Similar conclusions can be drawn based on ammonoids. Ammonoids in the Moscovian/ Kasimovian transition are, however, insufficiently studied because of their scarcity. Rare Moscovian ammonoids occur in the region of the Moscow Basin, Donets Basin and Pai-Khoi (Ruzhenzev 1974). The earliest assemblage of Upper Carboniferous ammonoids (**Dunbarites** and **Prouddenites**) occurs in the lower part of the Kasimovian in Cape Chaika of the Pai-Khoi (Ruzhenzev 1974), where early Kasimovian fusulinids occur (Villa et al. 1994). This ammonoid assemblage is correlative with the Wewoka Formation of the middle Desmoinesian. According to Boardman et al. (1990), **Dunbarites, Prouddenites**, and **Wewokites** occur within the Marmaton Group, and these genera also correspond to the Desmoinesian. This enables correlation of the middle and upper portion of Marmaton Group with the Lower and Middle Kasimovian of the Russian Platform.

The proposed correlation is also supplemented by conodont data. Conodonts in the Moscovian and the Kasimovian are also inadequately studied, especially in North America. **Streptognathodus exelsus** and **St. oppletus**, that occur in the Krevyakinian in the Moscow Basin (Alekseev et al. 1994; Villa et al. 1997), are also known in the Desmoinesian of North America (Merrill 1975). **Idiognathodus saggitalis** Kosenko, that is characteristic of the upper part of the Khamovnicheian and Dorogomilovian in the Moscow Basin (Alekseev et al. 1994), occurs at the base of the Missourian in North America (Barrick et al. 1996). These observations also suggest an approximate correspondence of Upper Desmoinesian and Lower-Middle Kasimovian strata.

To compare the above-mentioned Eurasian zonation and North American fusulinid zonation of Wilde (1990), it is possible to conclude that the **Fusulinella bocki** Zone approximately corresponds to DS-1 of the Desmoinesian. The **Rauserites quasiarcticus** Zone can be correlated with MS-1 of the Missourian. According to their position in the section, the **Protriticites ovatus-Praeobsoletes burkemensis, Obsoletes obsoletus-Protriticites pseudomontiparus** and **Montiparus montiparus** zones correspond to DS-2, DS-3, DS-4, and DS-5 zones of the Desmoinesian, respectively.

Recent data from the Arctic region support this correlation. In the lower and middle Kasimovian of Northern Timan and Kolguev Island **Wedekindellina** occurs (Remizova 1995; Davydov 1997b). This type of **Wedekindellina** in North America is known from the middle Desmoinesian. Also, occurrences of **Plectofusulina** and **Oketaella** in the lower Kasimovian of Kolguev Island were reported recently (Davydov 1997b). Both genera previously were known only in North American sections. **Plectofusulina** first

appears in the middle Desmoinesian and range to Missourian. **Oketaella** ranges from Missourian to the Permian. Therefore Arctic sections are perhaps the key to solving the problem of correlation of Upper Carboniferous between Russian Platform and North America.

CONCLUSIONS

The recorded fusulinid assemblages in Moscovian/Kasimovian boundary beds in the Kolosseum section (Spitsbergen) correspond well to established fusulinid zones in the stratotype region of the Russian Platform.

Fusulinid assemblages in the Moscovian/Kasimovian boundary beds in Spitsbergen show a predominance of representatives of the **Protriticites-Montiparus-Rauserites** lineage. Representatives of the **Praeobsoletes-Obsoletes-Triticites** lineage in Spitsbergen occur later than in the stratotype region of the Russian Platform. The similarity of fusulinids from Moscovian/Kasimovian boundary beds in Spitsbergen, Cantabrian Mountains (Spain) and Carnic Alps (Austria) is compelling.

Moscovian/Kasimovian boundary beds in Spitsbergen and those in the adjacent areas (Northeast Greenland and Canadian Arctic) correlate well. The upper part of the Nansen Formation (units H-L) of the Sverdrup Basin, Canadian Arctic correlates with the Lower-Middle Kasimovian of the region of the Moscow Basin. The Moscovian/ Kasimovian boundary of Eurasia is approximately correlative with the basal DS-3 fusulinid zone of the Desmoinesian of North America.

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Table 1. Upper Moscovian and Kasimovian fusulinid zonal succession in Eurasia.

Zone	Age	Locality
Rauserites quasiarcticus	late Kasimovian	Dorogomilovian, Perkhurovskaya Fm. in the Moscow Basin
Montiparus montiparus	middle Kasimovian	Khamovnicheian, Ratmirovskaya and Neverovskaya Fms. in the Moscow Basin
Protriticites pseudomontiparus-Obsoletes obsoletus	early Kasimovian	Krevyakinian, Suvorovskaya and Voskresenskaya Fms. in the Moscow Basin
Protriticites ovatus-Praeobsoletes burkemensis	late Myachkovian	Peskovskaya Fm. in the Moscow Basin
Fusulinella bocki	early Myachkovian	Novlinskaya Fm. in the Moscow Basin

Table 2. Fusulinid zones of Desmoinesian (DS) and Missourian (MS) in USA by Wilde (1990).

Zone	Characteristic fauna
8. Zone of **Eowaeringella** and **Triticites** of the Missourian (MC1).	**Eowaeringella, Triticites**
7. Upper zone of **Fusulina** (DS5):	**"Fusulina cylindrica"** group.
6. Lower zone of **Fusulina** (DS4):	**Fusulina megista, F. acme, F. exima, Bartramella bartrami, Protriticites** spp., **Praeobsoletes** spp.
5. Upper zone of **Beedeina** (DS3) :	**Beedeina girtyi, B. illinoisensis, B. similis, B. haworthi, Bartramella bartrami, Protriticites** spp. **Plectofusulina** sp.
4. Middle zone of **Beedeina** (DS2b):	**Beedeina novamexicana, B. distenta, B. levicula**
3. Upper zone of **Wedekindellina** (DS2a):	**Wedekindellina euthysepta, W. henbesty, W. excentrica, W. magna, W. ellipsoides**
2. Lower zone of **Beedeina** (DS1b):	**Beedeina eurytensis, B. leei, B. pumila**
1. Lower zone of **Wedekindellina** (DS1a):	**Wedekindellina euthysepta, Fusulinella iowensis, F. matura**

Table 3. Correlation of Middle/Upper Carboniferous fusulinids in Eurasia and North America

Eurasia	North America
Rauserites quasiarcticus (Dorogomilovian)	MS-1 First zone of **Triticites** and **Eowaeringella**
Montiparus montiparus (Khamovnichenian)	DS-5,4 Upper zone of **Fusulina** and lower zone of **Fusulina**
Protriticites pseudomontiparus-Obsoletes obsoletus (Krevyakinian)	DS-2b,3 Middle-Upper zone **Beedeina** and Upper zone of **Wedekindellina**
Protriticites ovatus-Praeobsoletes burkemensis (late Moscovian, late Myachkovian)	DS-1b,2a Lower zone of **Beedeina: Beedeina eurytensis, B. leei, B. pumila**
Fusulinella bocki (late Moscovian, early Myachkovian)	DS-1a Lower zone of **Wedekindellina: Wedekindellina euthysepta, Fusulinella iowensis, F. matura**

Figure 1. Map of Spitsbergen.

Figure 2. Lithostratigraphy of central Spitsbergen.

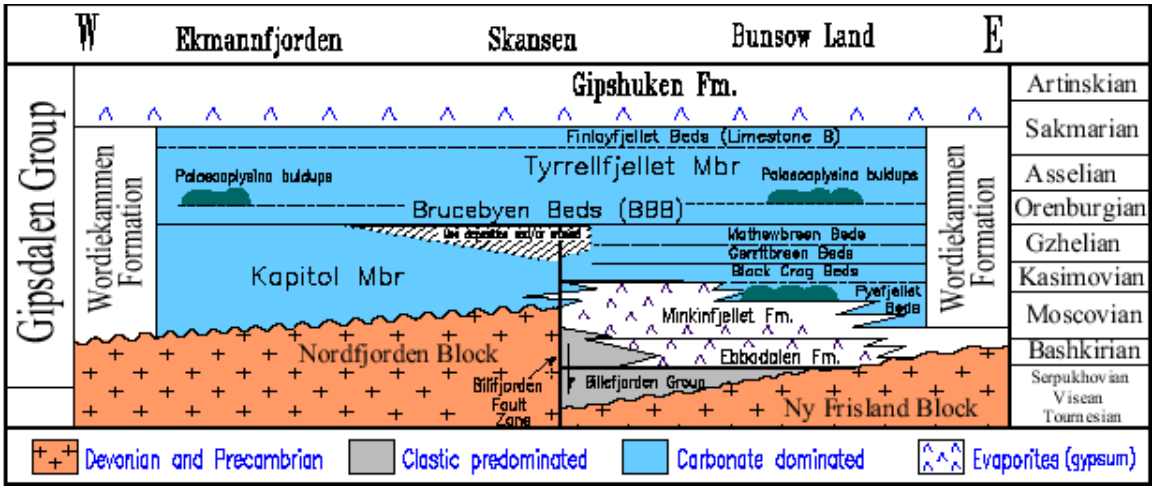

Figure 3. Kolosseum section, with samples marked.

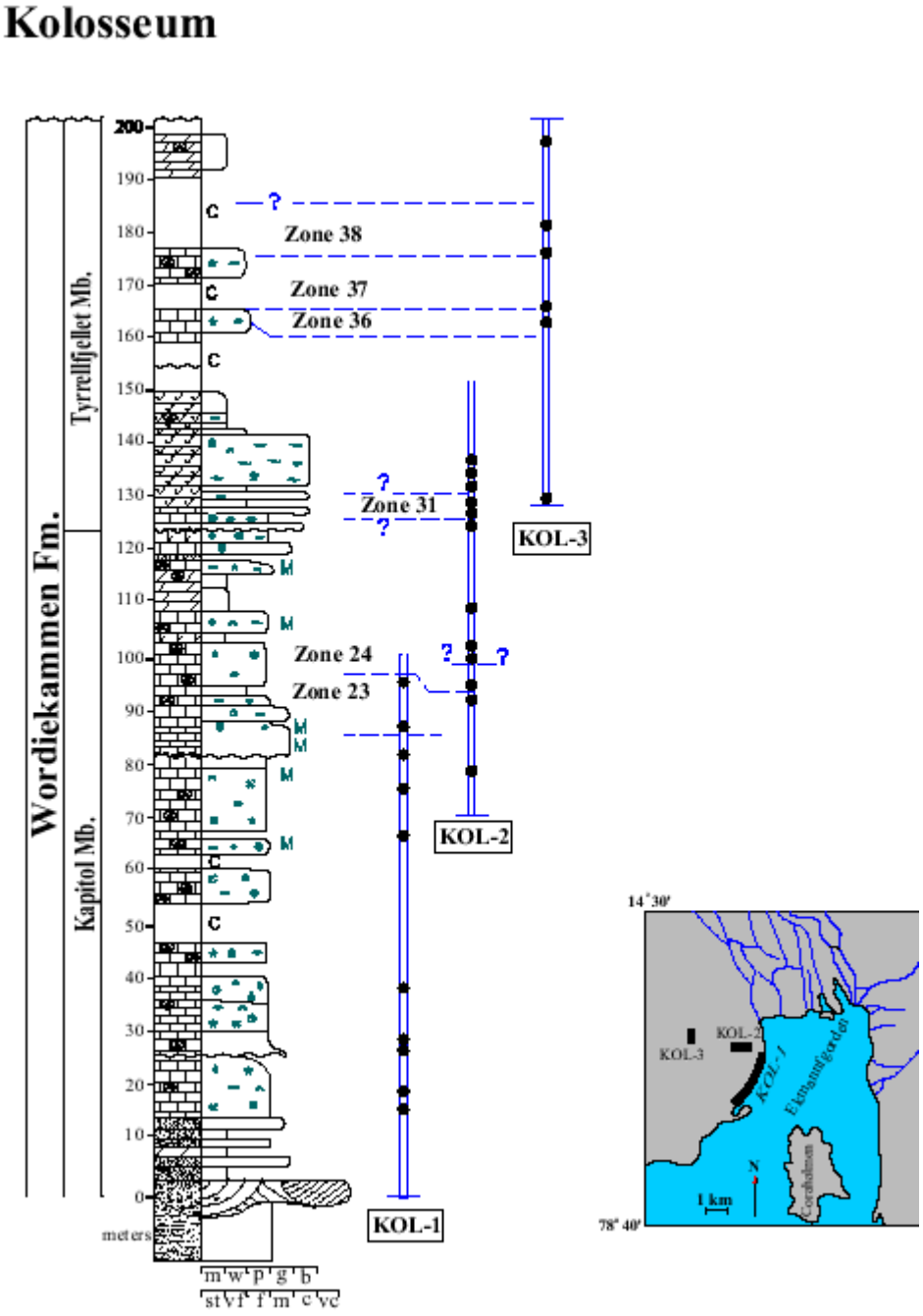

Figure 4. Fusulinid distributions in the Kolosseum section. All specimens from this collection are housed in the Oslo Paleontological Museum (PMO), collection number 43865.

Fusulinid Zonation	**Fusulinella bocki** Zone				**Protriticites ex. gr. ovatus Quasifusulinoides quasifusulinoides** Zone		**Protriticites pseudomontiparus Obsoletes obsoletus** Zone				**Montiparus montiparus** Zone
Taxa \ Sample	KOL-28.3	KOL-29.5	KOL-38.0	KOL-66.0	KOL-76.0	KOL-79.0	KOL-81.0	KOL-82.0	KOL-87.5	KOL-91.5	KOL-95.5
1. **Fusulinella bocki**	x		x			x	x				
2. **Fusulinella helenae**	x					x	x				
3. **Wedekindellina dutkevichi**	x	x	x								
4. **Beedeina elshanica**		x									
5. **Beedeina paradistenta**		x									
6. **Beedeina samarica**		x	x								
7. **Fusulinella** cf. **bocki**		x				x	x				
8. **Fusulinella mosquensis**		x									
9. **Beedeina distenta**			x								
10. **Eowaeringella?** sp.			x								

11. **Fusiella typica**			x		x						
12. **Fusulinella** sp.			x			x					
13. **Neostraffella sphaeroidea**			x								
14. **Protriticites** ex gr. **globulus**			x								
15. **Protriticites?** sp.			x			x					
16. **Pseudofusulinella? eopulchra**			x	x	x	x					x
17. **Quasifusulinoides? eopulchra**			x								
18. **Quasifusulinoides? intermedius**			x								
19. **Quasifusulinoides? kolensis**			x								
20. **Pseudofusulinella? pulchra**			x		x		x		x		
21. **Fusulina mosquensis**				x	x						
22. **Protriticites** aff. **sphaericus**					x				x		x
23. **Protriticites** ex gr. **ovatus**					x						x
24. **Pseudofusulinella? ylychensis**					x						

25. **Quasifusulinoides blear**					x	x	x				
26. **Quasifusulinoides firmus**					x	x					
27.**Quasifusulinoides fusiformis**					x		x		x		
28. **Quasifusulinoides quasifusulinoides**					x						
29. **Quasifusulinoides** sp.					x			x	x		
30. **Quasifusulinoides fusulinoides**						x					
31. **Quasifusulinoides? fortissimum**						x	x				
32. **Fusiella** ex gr. **rawi**						x	x				
33. **Fusulina pachrensis**							x				
34. **Praeobsoletes** sp.							x				
35. **Protriticites** aff. **plicatissimum**							x				
36. **Protriticites ovatus**							x		x	x	
37. **Protriticites plicatus**							x			x	

38. **Protriticites pseudomontiparus**							x			x	
39. **Protriticites sphaericus**							x		x	x	
40. **Protriticites variabilis**							x				
41. **Pseudofusulinella** aff. **usvae**							x				
42. **Fusiella rawi**									x		
43. **Fusulinella** to **Praeobsoletes**									x		
44. **Obsoletes fusiformis**										x	
45. **Praeobsoletes burkemensis**										x	
46. **Praeobsoletes** to **Obsoletes**											x
47. **Protriticites subovatus**											x
48. **Protriticites ovoides**											x
49. **Protriticites** to **Montiparus**											x
50. **Protriticites Subschwagerinoides**											x
51. **Motiparus calitvicus**											x
52. **Montiparus likharevi**											x

53. **Montiparus mesopachus**											x
54. **Montiparus montiparus**											x
55. **Montiparus umbonoplicatus**											x
56. **Montiparus** sp.											x
57. **Protriticites lamellosus**											x
58. **Protriticites manukalovae**											x
59. **Pseudofusulinella usvae**											x
60. **Quasifusulina** aff. **eleganta**											x
61. **Quasifusulina** ex gr. **longissima**											x
62. **Quasifusulina** sp.											x
63. **Quasifusulina** sp. nov.											x

Figure 5.1-20. Fusulinid assemblage of **Fusulinella bocki** Zone, all figures from bed 38.5 m. **1.** **Fusiella** cf. **typica** Lee and Chen 1930, scale bar = 88mm, (PMO-43865/14a), oblique section; **2-4.** **Neostaffella sphaeroidea** (Ehrenberg em. Moeller 1878), **2.** scale bar = 88mm, axial section of young specimen, (PMO-43865/14a); **3.** scale bar = 44mm, oblique axial section, (PMO-43865/22a); **4.** scale bar = 66mm, oblique axial section, (PMO-43865/14a). **5.** **Neostaffella** cf. **paradoxa** (Dutkevich 1934a), scale bar = 88mm, oblique axial section, (PMO-43865/22a). **6-7.** **Wedekindellina uralica** (Dutkevich 1934b), **6.** scale bar = 44mm, axial sections, (PMO-43865/14a); **7.** scale bar = 88mm, axial section, (PMO-43865/9a). **8.** **Wedekindellina subovata** Safonova 1951, scale bar = 88mm, near axial section, (PMO-43865/18a). **9.** **Beedeina samarica** (Rauser and Belyaev in Rauser-Chernousova, Belyaev, and Reitlinger 1937), scale bar = 33mm, oblique axial section, (PMO-43865/10a). **10.** **Beedeina elegans** (Rauser 1951), scale bar = 33mm, near axial section, (PMO-43865/4a). **11-14.** **Quasifusulinoides? kolensis** (Nilsson 1988 msc.), scale bar = 22mm, axial sections **11.** (PMO-43865/21a); **12.** (PMO-43865/12a); **13.** (PMO-43865/1a); 13a. scale bar = 88mm, enlargement of figure 6-13, wall structure with tectum, gray diaphanotheca and dark inner tectorium; **14.** (PMO-43865/18a); 14a, scale bar = 88mm, enlargement of figure 6-14. **15-16.** **Pseudofusulinella? pulchra** (Rauser and Belyaev in Rauser-Chernousova, Belyaev, and Reitlinger 1937), scale bar = 33mm **15.** near axial section, (PMO-43865/8a); **16.** axial section, (PMO-43865/6a). **17-18.** **Pseudofusulinella? eopulchra** (Rauser 1951), scale bar = 33mm, both axial section **17.** (PMO-43865/3a); **18.** (PMO-43865/14a). **19-20.** **Fusulinella bocki** (Moeller 1878) **19.** scale bar = 66mm, axial section, (PMO-43865/10a); **20.** scale bar = 33mm, oblique axial section, (PMO-43865/6a); 20a enlargement of figure 6-20, scale bar = 110mm, typical **Fusulinella** wall structure with tectum, light diaphanotheca and dark inner and outer tectorium.

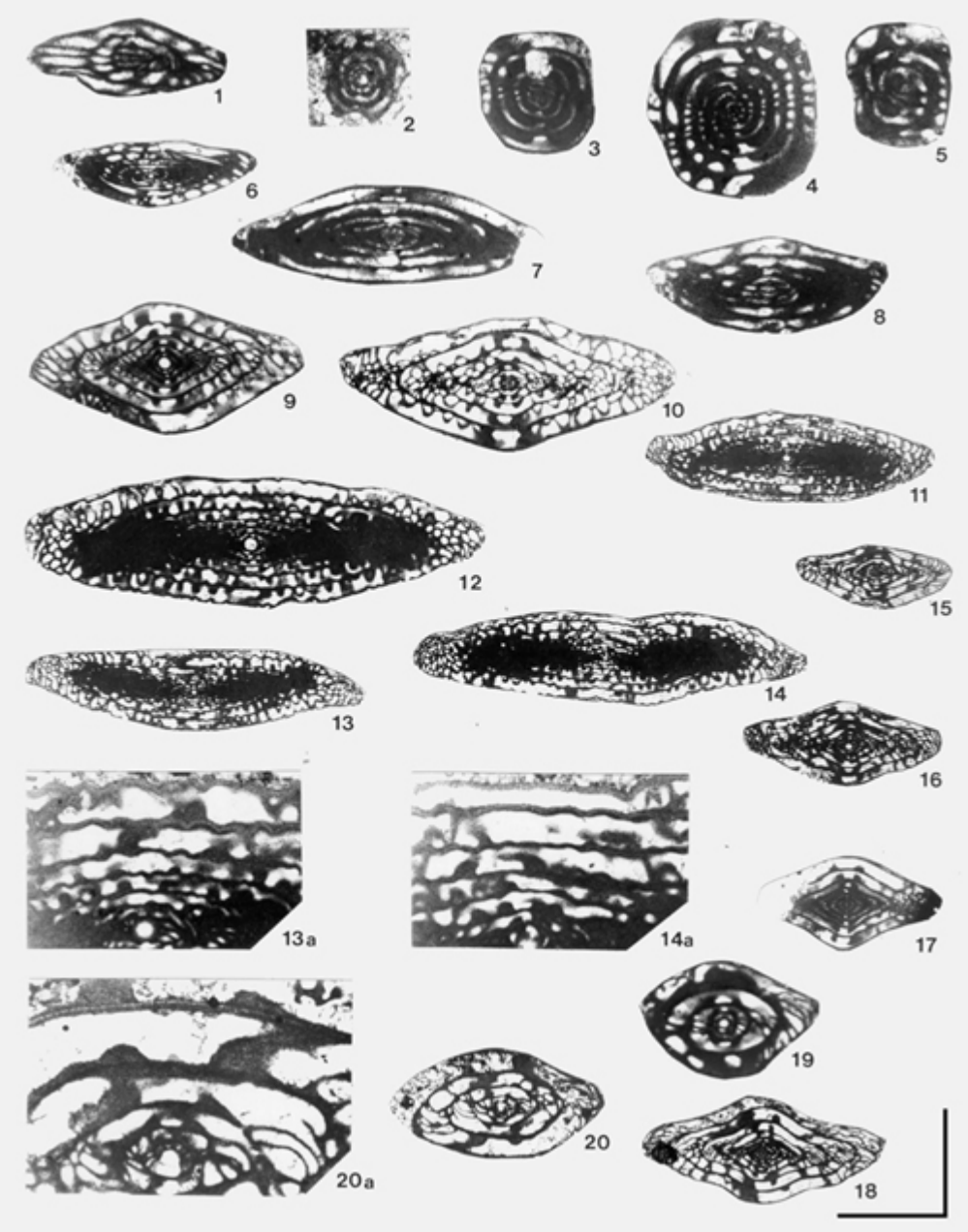
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Figure 6.1-18. Fusulinid assemblage of **Protriticites** ex gr. **ovatus-Quasifusulinoides quasifusulinoides** Zone. **1.** **Fusiella praelancetiformis** Safonova 1951, scale bar = 88mm, axial section, bed 76.0 m, (PMO-43859/A1a). **2.** **Fusiella praecursor** Rauser 1951, scale bar = 88mm, axial section, bed 76.0 m, (PMO-43859/1a). **3.** **Fusiella typica** Lee et Chen 1934, scale bar = 110mm, axial section, bed 76.0 m, (PMO-43859/2a). **4.** **Beedeina mosquensis** (Rauser 1951), scale bar = 22mm, axial section, bed 66.0 m, (PMO-43860/1a); 4a, enlargement of figure 7-4, scale bar = 88mm, typical **Beedeina** wall structure with tectum, light diaphanotheca and dark inner and outer tectorium. **5.** **Quasifusulinoides firmus** (Rauser 1951), scale bar = 22mm, axial section of incomplete specimen, bed 76.0 m, (PMO-43859/B1a); 5a, enlargement of figure 7-5, scale bar = 88mm, wall structure with tectum, indistinct diaphanotheca and dark inner tectorium with well developed pores. **6-7.** **Quasifusulinoides fusiformis** (Rosovskaya,1952), scale bar = 22mm, both axial sections, 6, bed 76.0 m, (PMO-43859/9a); 7, bed 79.0 m, (PMO-43858/12a). **8-9.** **Pseudofusulinella** *?* **eopulchra** (Rauser 1951), scale bar = 22mm, both axial sections, 8, bed 79.0 m, (PMO-43858/1a); 9, bed 76.0 m, (PMO-43858/D1a). **10.** **Fusulinella helenae** Safonova 1951, scale bar = 33mm, near axial section, bed 79.0 m, (PMO-43858/14a); 10a, enlargement of figure 7-10, scale bar = 110mm, wall structure with tectum, diaphanotheca and dark inner and outer tectorium. **11-12.** **Fusulinella bocki** Moeller,1878, scale bar = 33mm, both axial sections, bed 79.0 m, 11, (PMO-43858/25a); 12, (PMO-43858/6a). **13.** **Fusulinella timanica** Rauser 1951, scale bar = 33mm, axial sections, bed 79.0 m, (PMO-43858/8a). **14-17.** Transitional specimens from **Fusulinella** to **Protriticites**, scale bar = 33mm, all axial sections, 14, bed 79.0 m, (PMO-43858/15a); 15, bed 79.0 m, (PMO-43858/3a); 15a, enlargement of figure 7-15, scale bar = 110mm, primitive **Protriticites** wall structure with tectum, indistinct diaphanotheca and inner tectorium; small poor developed pores penetrate throughout the wall; 16, bed 76.0 m, (PMO-43858/14a); 16a, enlargement of figure 7-16, scale bar = 110mm, primitive Protriticites wall structure with tectum, very thin but distinct diaphanotheca and inner tectorium with thin pores throughout the wall; 17, bed 79.0 m, (PMO-43858/22a). **18.** **Protriticites** ex gr. **inflatus** Bensh 1972, scale bar = 33mm, axial section, bed 79.0 m, (PMO-43858/2a).

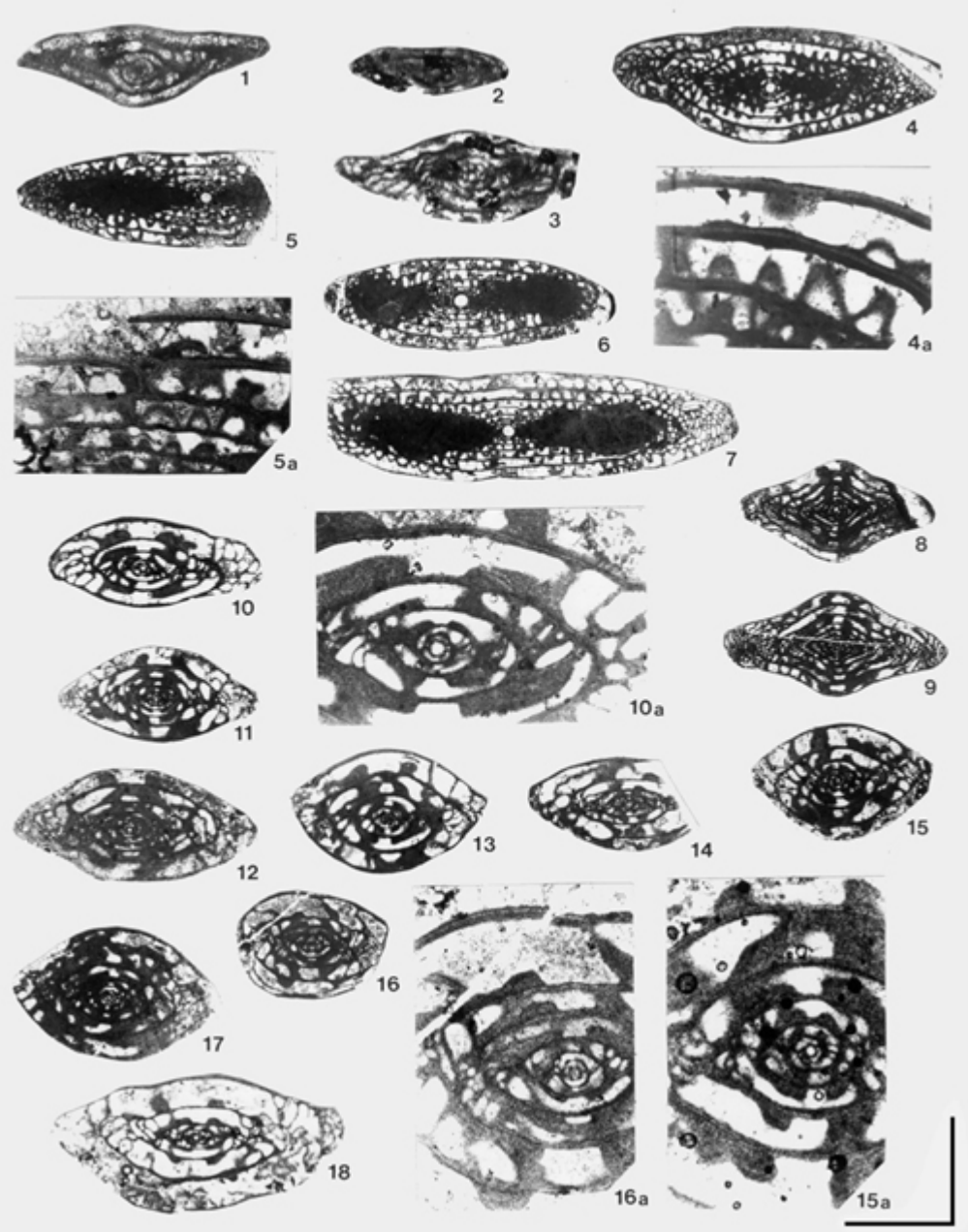
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Figure 7.1-21. Fusulinid assemblage of **Protriticites pseudomontiparus, Obsoletes obsoletus** Zone. **1. Fusiella lancetiformis** Putrya 1939, scale bar = 88mm, axial section, bed 87.5 m, (PMO-43856/16a). **2. Fusiella rawi** Lee 1927, scale bar = 88mm, axial section, bed 87.5 m, (PMO-43856/23a). **3-6. Quasifusulinoides fusiformis** (Rosovskaya 1952), scale bar = 33mm, all axial sections, 3, bed 87.5 m, (PMO-43856/15a); 3a, enlargement of figure 8-3, scale bar = 110mm, **Quasifusulinoides** wall structure with tectum, indistinct diaphanotheca and dark inner tectorium with well developed coarse pores; 4, bed 81.0 m, (PMO-43861/4a); 5, bed 81.0 m, (PMO-43861/14a); 6, bed 81.0 m, (PMO-43861/15a).). **7. Quasifusulinoides fortissimus** (Rauser,1951), scale bar = 22mm, axial section, bed 81.0 m, (PMO-43861/30a). **8. Quasifusulinoides** sp., x50, inner volutions, wall structure with tectum, primatheca and dark inner tectorium with well developed coarse pores, bed 81.0 m, (PMO-43861/5a). **9-10. Pseudofusulinella? pulchra** (Rauser and Belyaev in Rauser-Chernousova, Belyaev, and Reitlinger 1937), scale bar = 22mm, both axial sections; 9. bed 81.0 m, (PMO-43861/24a); 10. bed 87.5 m, (PMO-43856/9a). **11. Fusulinella bocki** Moeller 1878, scale bar = 33mm, axial section, bed 81.0 m, (PMO-43861/1a). **12. Fusulinella pseudobocki** Lee and Chen 1934, scale bar = 33mm, axial section, bed 81.0 m, (PMO-43861/32a). **13. Protriticites pseudomontiparus** Putrja 1948, scale bar = 33mm, axial section, bed 81.0 m, (PMO-43861/16a). **14. Protriticites ovatus** Putrja 1948, scale bar = 33mm, axial section, bed 81.0 m, (PMO-43861/24a). **15. Protriticites variabilis** Bensh 1972, scale bar = 33mm, axial section, bed 81.0 m, (PMO-43861/8a). **16-17. Protriticites sphaericus** Volozhanina 1962, scale bar = 33mm, both axial sections, bed 81.0 m, 16, (PMO-43861/5a); 17, (PMO-43861/26a).). **18.** and **20. Praeobsoletes burkemensis** (Volozhanina 1962), scale bar = 33mm, both axial sections, bed 81.0 m, 18, (PMO-43861/3a); 20. (PMO-43861/12a); 20a, enlargement of figure 8-20, scale bar = 110mm, **Praeobsoletes** wall structure with **Fusulinella** type wall in inner volutions (dark tectum, light diaphanotheca, inner and outer tectoriums) and with tectum and very thin gray primatheca with poor developed pores in outer volution. **19. Protriticites plicatissimus** Kireeva 1950, scale bar = 33mm, axial section, bed 81.0 m, (PMO-43861/25a). **21. Protriticites plicatus** Kireeva 1950, scale bar = 33mm, axial section, bed 81.0 m, (PMO-43861/34a); 21a, enlargement of figure 8-21, scale bar = 110mm, **Protriticites** wall structure composed in outer volution dark tectum, indistinct gray diaphanotheca, which became disappear, thin outer tectorium and relatively thick outer tectorium with well developed pores.

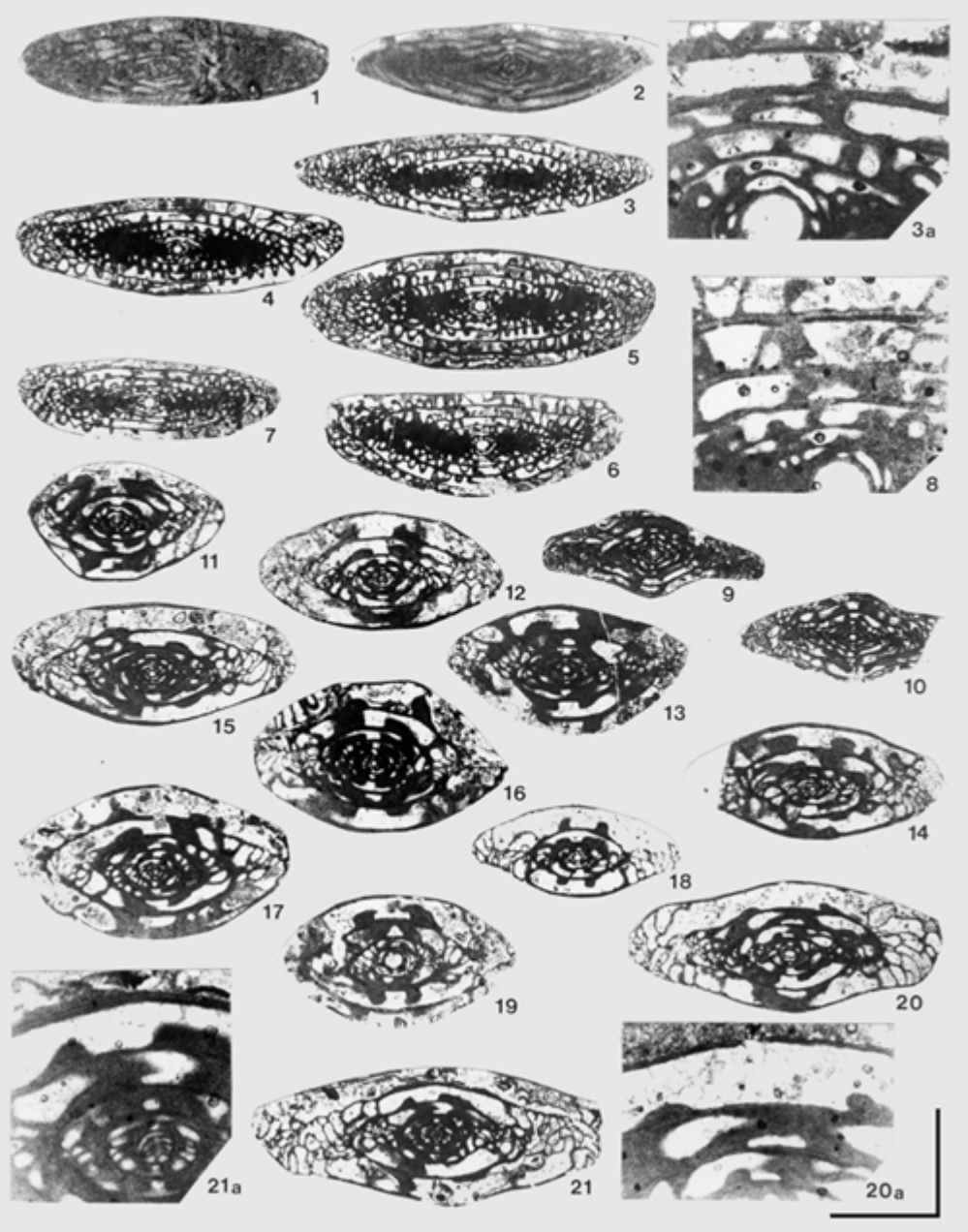
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Figure 8.1-13. Fusulinid assemblage of **Protriticites pseudomontiparus, Obsoletes obsoletus** Zone. **1.** **Pseudofusulinella usvae** (Dutkevich 1934b), scale bar = 22mm, axial section, bed 91.5 m, (PMO-43862/2a). **2.** **Praeobsoletes burkemensis** (Volozhanina 1962), scale bar = 33mm, axial section, bed 91.5 m, (PMO-43862/18a); 2a, enlargement of figure 9-2, scale bar = 110mm, **Praeobsoletes** wall structure with **Fusulinella** type wall in first and second volutions (dark tectum, light diaphanotheca, inner and outer tectoriums) and with tectum and thin primatheca with developed pores in outer two volutions. **3.** **Obsoletes fusiformis** Bensh 1972, scale bar = 33mm, axial section, bed 91.5 m, (PMO-43862/14a); 3a, enlargement of figure 9-3, scale bar = 110mm, thin wall containing dark tectum and gray relatively thin layer with well developed coarse pores. **4.** **Protriticites ovatus** Putrja 1948, scale bar = 33mm, axial section, bed 91.5 m, (PMO-43862/12a). **5-7.** **Protriticites globulus** Putrja 1948, scale bar = 33mm, all axial sections, bed 91.5 m, 5, (PMO-43862/7a); 6, (PMO-43862/6a); 7, (PMO-43862/10a); 7a, enlargement of figure 9-7, scale bar = 110mm, thick wall of advanced **Protriticites** containing dark tectum, gray diaphanotheca, inner and outer tectoriums; diaphanotheca and inner tectorium become joint with each other. Well developed coarse pores pierced the wall. **8.** **Protriticites sphaericus** Volozhanina 1962, scale bar = 33mm, axial section, bed 91.5 m, (PMO-43862/16a). **9.** **Protriticites ovoides** Putrja 1948, scale bar = 33mm, axial section, bed 91.5 m, (PMO-43862/3a); 9a, enlargement of figure 9-9, scale bar = 110mm, thick wall of advanced **Protriticites**, which has similar structure with 9-7a specimen, but pores became branched i.e. develop to the Schwagerinidae type wall structure. **10.** **Protriticites subschwagerinoides** Rosovskaya 1950, scale bar = 33mm, axial section, bed 91.5 m, (PMO-43862/1a). **11.** **Protriticites pseudomontiparus** Putrja 1948, scale bar = 33mm, oblique axial section, bed 91.5 m, (PMO-43862/9a). **12.** **Protriticites globulus turkestanensis** Bensh 1972, scale bar = 33mm, axial section, bed 91.5 m, (PMO-43862/5a); 12a, enlargement of figure 9-12, scale bar = 110mm, thick wall of advanced **Protriticites** similar with wall structure of 9-7a specimen. **13.** Specimen transitional from **Protriticites** to **Montiparus**, scale bar = 33mm, axial section, bed 91.5 m, (PMO-43862/11a).

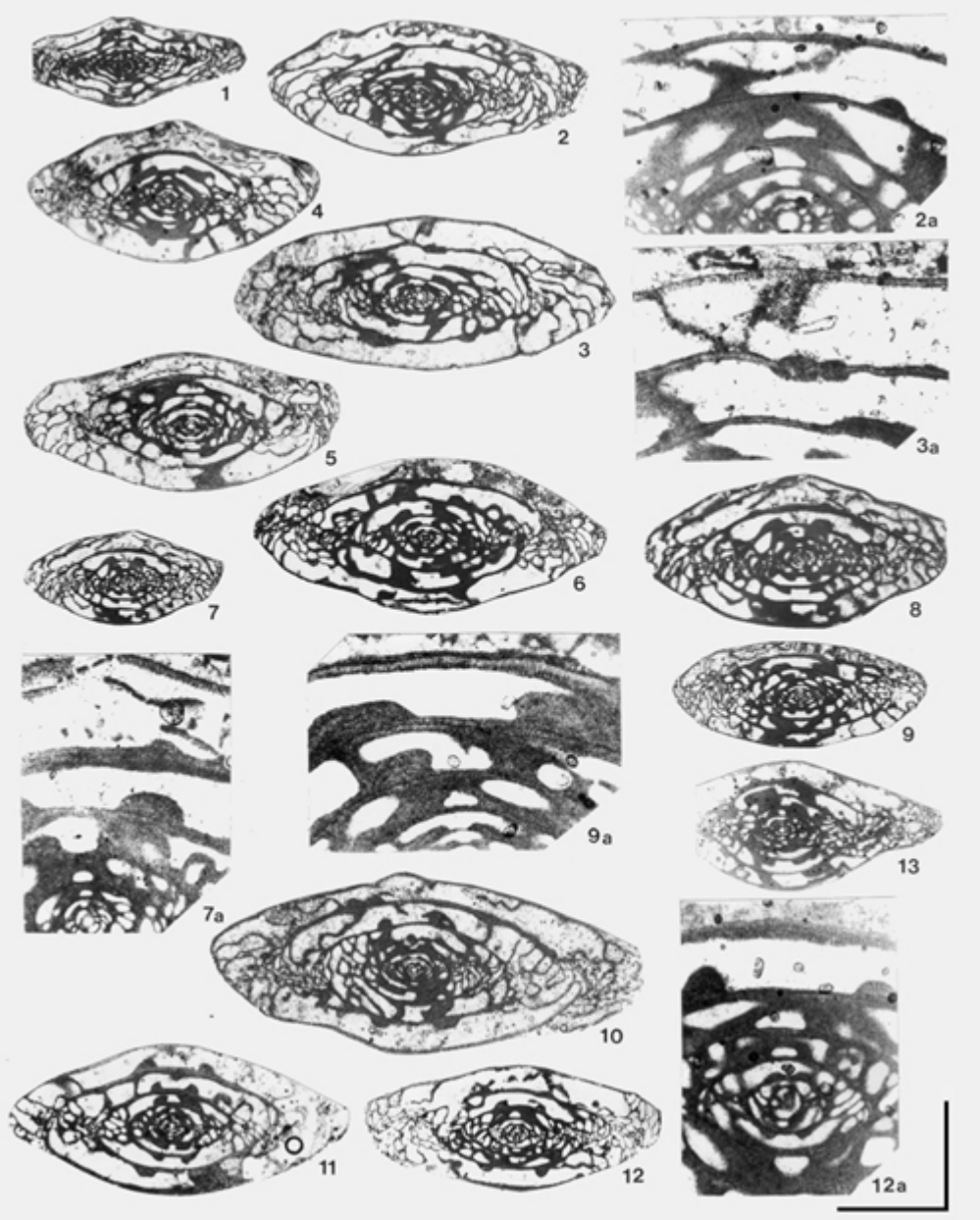
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Figure 9.1-14. Fusulinid assemblage of **Montiparus montiparus** Zone. **1. Protriticites ovoides** Putrja 1948, scale bar = 22mm, axial section, bed 95.5 m, (PMO-43854/Ca). **2.** Elongate specimen transitional from **Protriticites** to **Montiparus**, which probably formed lineage of elongate **Montiparus**, scale bar = 22mm, axial section, bed 95.5 m, (PMO-43854/21a). **3.** Subspherical specimen transitional from **Protriticites** to **Montiparus**, which probably formed lineage of subspherical **Montiparus**, scale bar = 22mm, axial section, bed 95.5 m, (PMO-43854/26a). **4-6. Montiparus montiparus** (Ehrenberg em. Moeller 1878), scale bar = 22mm, all axial sections, bed 95.5 m, 4, (PMO-43854/23a); 5, (PMO-43854/31a). 6, (PMO-43854/24a). **7-11. Montiparus likharevi** (Putrja 1939), scale bar = 22mm, all axial sections, bed 95.5 m, 7, (PMO-43854/27a); 7a, enlargement of figure 10-7, thick wall typical for the Schwagerinidae contains dark tectum, keriotheca and fragmentally developed outer tectorium; 8, (PMO-43854/22a); 9, (PMO-43854/19a); 10, (PMO-43854/32a); 11, (PMO-43854/34a). **12. Montiparus umbonoplicatus** (Rauser and Belyaev in Rauser-Chernousova, Belyaev, and Reitlinger 1936), scale bar = 22mm, axial section, bed 95.5 m, (PMO-43854/24a). **13-14. Montiparus mesopachus** Rosovskaya 1950, scale bar = 22mm, both axial sections, bed 95.5 m, 13. (PMO-43854/30a); 14. (PMO-43854/13a); 14a, enlargement of figure 10-14, keriothecal wall present in all volutions; the wall is slightly recristallized.

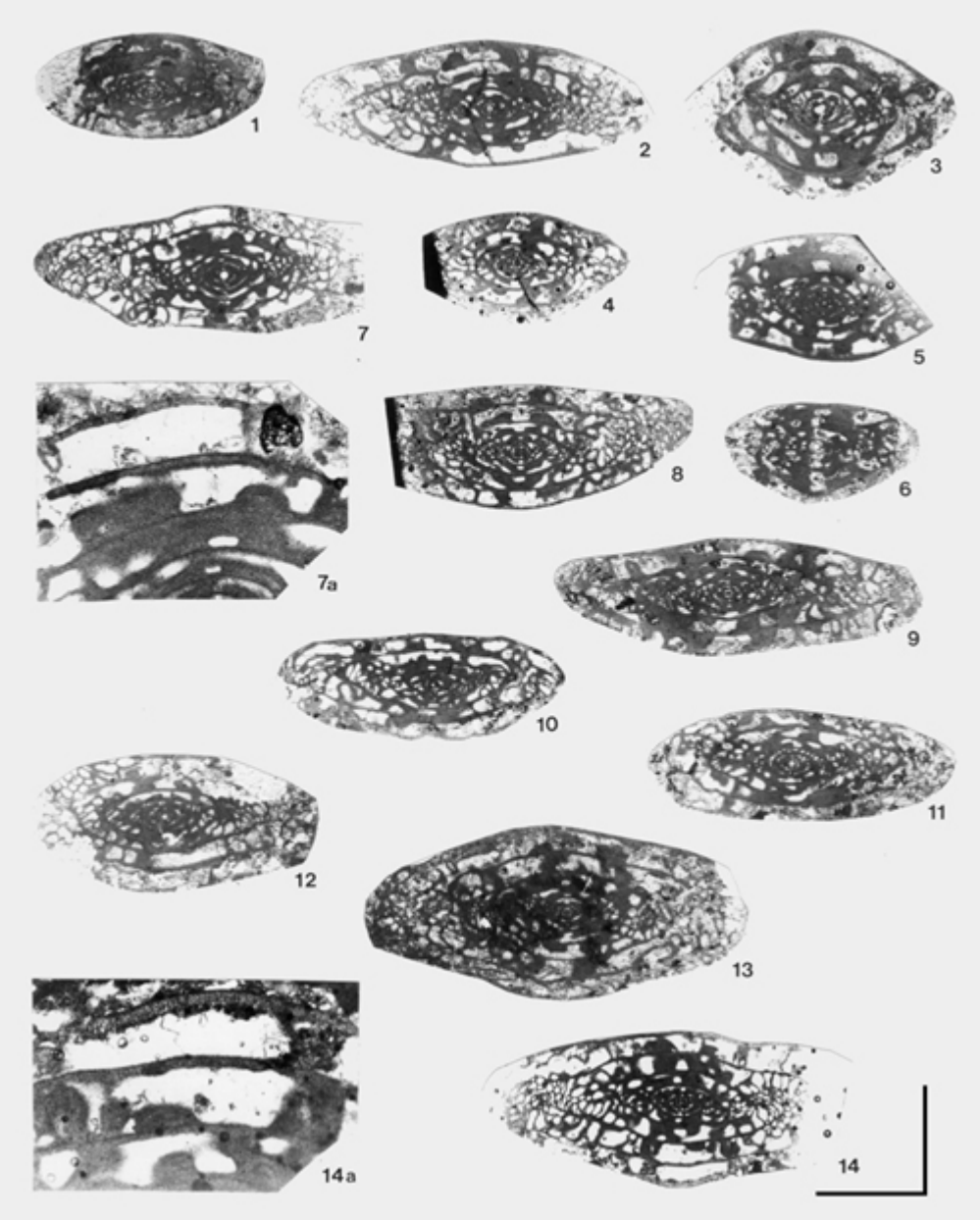
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Figure 10. Correlation of fusulinid zones. Click on section of interest for zoom.

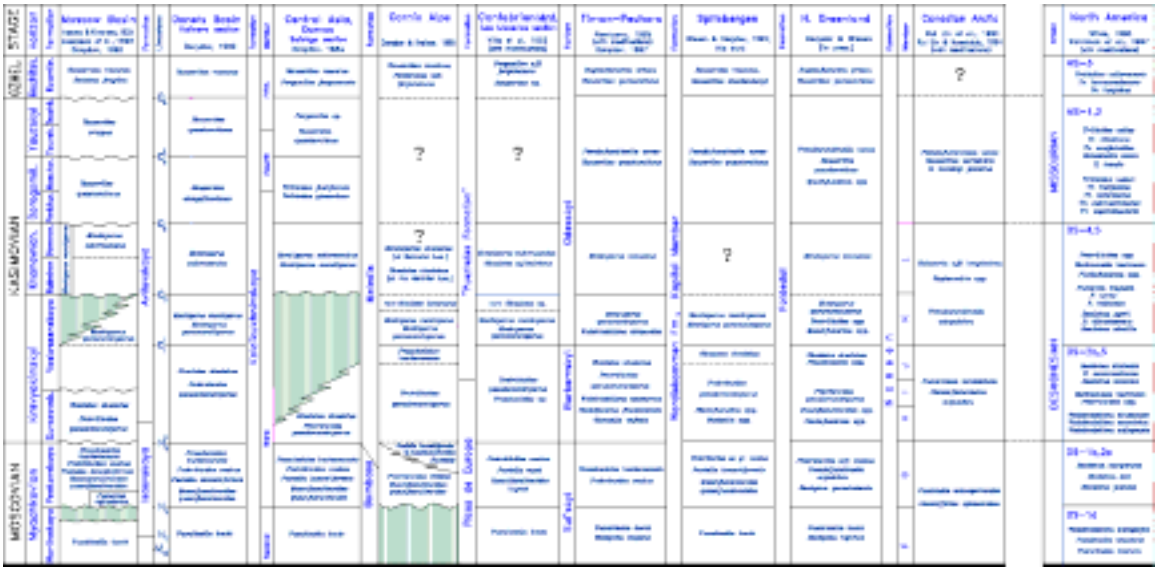

Figure 11. Comparative characteristic of the evolution trends of the Middle/Late Carboniferous of Russian-arctic and American fusulinids. Russian-arctic fusulinids.