

## Biotic Changes in a Eustatic Cyclothem: Domodedovo Formation (Moscovian, Carboniferous) of Peski Quarries, Moscow Region

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**Abstract**—Stacking lithofacies in the Domodedovo Formation of Peski quarries show prominent changes in paleodepth and depositional environment. Distribution in the section of fusulinoids, algae, conodonts, and macrofossils are revealed. Among the latter, brachiopods and bryozoans are discussed in most detail.

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### INTRODUCTION

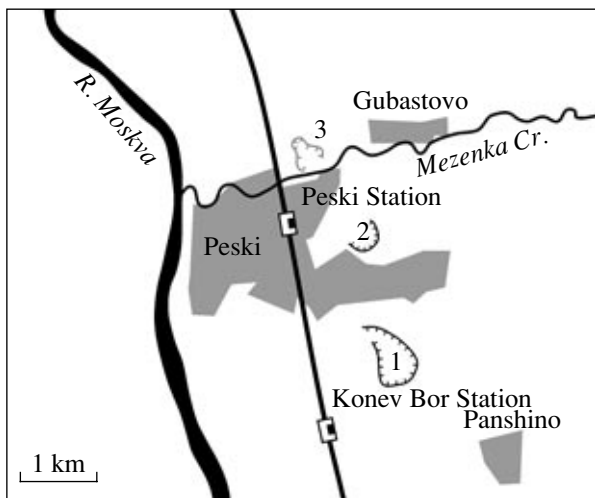
It is clear that sea-level oscillations influence benthic and pelagic organisms. Eustatic fluctuations of the deep past caused by changes in water volume or ocean capacity is an important topic in Earth science. The Middle Carboniferous–Early Permian epicontinental sections provide good subjects for study, since the sea level during the Upper Paleozoic icehouse period could have rapidly fluctuated by at least 60–100 m.

Usually, biotic shifts are assessed qualitatively based on more than one section. This study employs quantification approaches to the fossil distribution in one apparently eustatic cycle. Only few quantitative studies of similar Upper Paleozoic materials are available in the literature. Laporte (1962) has calculated different types of bioclasts in the thin sections from the seven sections of the Cottonwood Limestone of the Lower Permian of the United States. However, this limestone was only part of a cyclothem. Based on qualitative evaluation of fossil distribution in the Red Eagle cyclothem (Lower Permian, United States), McCrone (1963) has drawn inferences about the ancient temperature, salinity, oxygenation, and water energy changes. Many works are devoted to the paleoecology of the Namurian and Westphalian of western Europe. For instance, Böger (1964) has differentiated biofacies in the “marine facies” of the Namurian/Westphalian transitional interval of Germany.

Facies-related changes in the benthic communities of the epeiric sea of the Moscow Syncline have been extensively studied in the mid-20th century (Ivanova, 1947, 1949, 1958; Khvorova, 1953, 1958; Rausertschernoussowa and Reitlinger, 1954; Ivanova and Khvorova, 1955). At that time, however, small-scale transgressive-regressive cyclicality was unknown. The last decade has brought awareness that the succession

under study contains numerous subaerial unconformities (diastems, geosols). The main unconformities can be traced from the southern Moscow Region to the lower reach of the Severnaya Dvina River, that is about 1000 km in a northward direction (Kabanov, 2003; Kabanov, 2005). These unconformities suggest repeated sea withdrawals from vast territories, and are treated as natural boundaries of stacked cyclothem. The thickness of cyclothem ranges from a few meters to a few tens of meters. Transgressive, offshore, and regressive parts are recognized in each cyclothem. However, those parts are always complicated by intermediate levels of shoaling. Those latter may be treated as boundaries of smaller-scale cycles. The offshore (core) parts of most cyclothem feature *Zoophycos* bioturbation and storm rhythmicity, whereas the indicators of euphotic conditions such as phylloid algae, dasyclads, and the products of surface-sediment micritization are scarce or even lacking. The sea-level oscillations capable of moving the seafloor from such an environment up to permanently terrestrial conditions must have approached or even exceeded 100 m (Kabanov, 2003). The same distance of eustatic fluctuations has been inferred for the Pennsylvanian cyclothem of North America (Heckel, 1977, 1986; Soreghan and Giles, 1999).

The term “cyclothem” was first applied to the meter-scale cyclic sedimentary units in the Pennsylvanian Subsystem of North American Midcontinent (Weller, 1930; Wanless and Weller, 1932) and is nowadays widely employed in Upper Paleozoic studies (Heckel, 2001). The origin of cyclothem is commonly linked to the eustatic sea-level changes caused by waxing and waning of the Gondwanan icesheet (Heckel, 1986, 1994). The facies and paleodepth distribution of fossils in Pennsylvanian cyclothem has been studied by Heckel and Baesemann (1975), Boardman et al. (1984),



**Fig. 1.** Location of Peski sections: (1) Konev Bor, (2) Old Peski quarry, and (3) the reclaimed quarry north of the Peski Station.

and Malinky and Heckel (1998), among others. In contrast, paleoecological studies of the Moscovian of the Russian Platform have not been linked to its cyclicity until recently. First inferences about fusulinoid and brachiopod distribution in the late Moscovian cyclothem has been made by Baranova and Kabanov (2003) and Kabanov (2003). The objective of this study is revealing the biofacies indicators that will be sensitive to environmental changes such as paleodepth, salinity, or eutrophication. The algae have been studied by P.B. Kabanov, fusulinoids by D.V. Baranova, bryozoans by R.V. Gorjunova, and conodonts by A.S. Alekseev. Brachiopods were identified by P.B. Kabanov and S.S. Lazarev.

#### MATERIALS AND METHODS

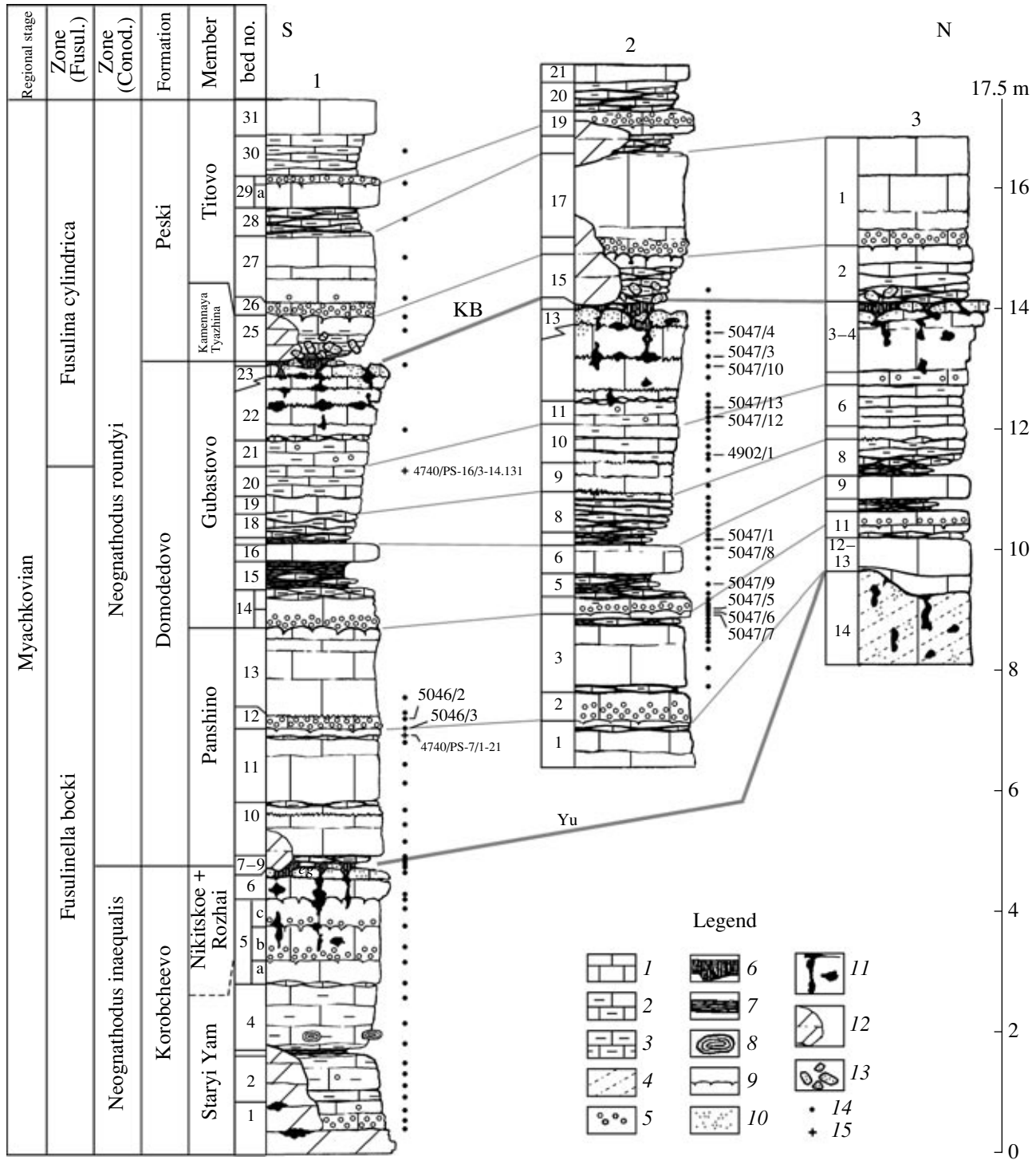
Peski quarries were already known for their Carboniferous fossils in the first half of the 19th century. Starting with Nikitin (1890), most regional geologists discussed in their publications the lithology and stratigraphy of Peski sections. Two quarries are extant nowadays: the operating “Konev Bor” quarry and the abandoned one “Old Peski” (Figs. 1, 2). A third quarry existed to the north of the Peski railroad station (Figs. 1, 2) until the 1980s. Other mines were reclaimed earlier and their detailed columns are unavailable.

Microfacies, algae, fusulinoids, and bryozoans have been studied in the vertically oriented thin sections with areas 9–36 cm<sup>2</sup> (Fig. 3; Kabanov, 2003). The collections are housed in the Paleontological Institute, Russian Academy of Sciences, collection nos. 4902, 5046, and 5047. T.N. Isakova (Geological Institute, Russian Academy of Sciences) has kindly lent additional thin sections from the GIN RAN collection no. 4740. The thin section coverage is shown in Fig. 2. The microfacies level of examination employs those sedimentolog-

ical, paleontological, and paleoecological features that are usually revealed in thin sections (Flügel, 1982). The lithofacies is a combination of macroscopic and microfacies features. The lithofacies system employed here (Fig. 3) was proposed by Kabanov (2003). The sections of fusulinoids and algae were counted using a transparent grid with numbered cells mounted on the thin section (Baranova and Kabanov, 2003). The fusulinoids were counted at the genus level, since the majority of test sections cannot be identified to species level. Bryozoans were identified in the same thin sections (Fig. 6). For conodonts, 26 samples about 1 kg each were dissolved in buffered 7% acetic acid solution. The conodont samples were collected in 1994 (Fig. 7). The stratigraphic results and some images were published earlier (Goreva and Alekseev, 2001). The conodonts were picked out under a binocular microscope without fractionation of the insoluble residue. The distribution of macrofossils was studied at Konev Bor in August and September 2004. Sixteen samples were collected (Figs. 8, 9). Each sample includes 10–20 hand samples 25 kg in total weight. Each set of hand samples was collected at every accessible point from one bed or part of a bed (Figs. 8, 9) along a 100-m-wide sector of the western quarry face. The rock was then crushed into 1–2 cm pieces, in which all macrofossil remains larger than 5 mm have been identified and counted. However, if the smallest representatives of some groups were below the 5 mm threshold, they have also been counted in as well. After subsequent density measurements in the lab, the data have been recalculated by volume. Microfossils were identified to genus level or higher, because random sections mostly prevent species identification. It should be noted that the resultant plots (Figs. 8, 9) bias the quantity of buried individuals. Different groups produced different numbers of unbroken skeletal particles. For example, brachiopods and bivalves left two valves, both gastropods and corals one shell, and one pelmatozoan echinoderm could produce hundreds of sclerites.

#### LITHOFACIES AND RELATIVE SEA LEVEL CURVE

The Peski sections crop out the Myachkovian Regional Stage without its top and base (Fig. 2). The origin of unusual, up to 8 m tall, calcarenite paleodunes formerly exposed north of the Peski railroad station were actively debated early in the 20th century (Ivanov, 1926; Ivanova, 1947). Khvorova (1949) have argued for eolian nature of these dunes. The stratigraphic position of the eolian dunes have recently been highlighted by Kabanov (Fig. 2; Kabanov, 2003) who has found small lenses of calcretized eolian grainstone in the top of Korobcheevo Formation at Konev Bor. The Domodedovo Formation represents a complete cyclothem bounded at the base and top by paleosols (Figs. 2, 3). It consists of the Panshino and Gubastovo members. The Panshino is dominated by white massive thick-

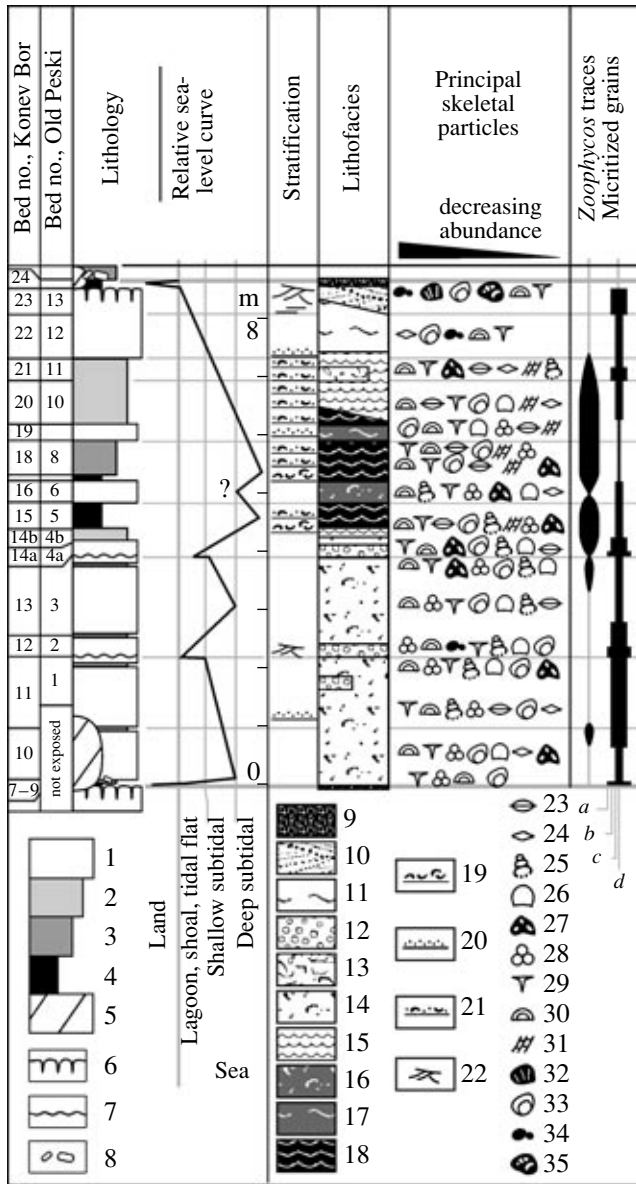


**Fig. 2.** Correlation of Peski sections: (1) Konev Bor, (2) Old Peski quarry, (3) the reclaimed quarry north of the Peski Station interpreted from the unpublished report of M.Kh. Makhlina et al. (1972), (KB) Konev Bor Paleosol, (Yu) Yusupovo Paleosol. Legend: (1) limestone, (2) weakly argillaceous limestone, (3) argillaceous limestone, (4) eolian cross-stratified grainstone, (5) coarse peloidal-bioclastic grainstone "gorokh," (6) clayey paleosol horizons, (7) marine shales, (8) cherts, (9) surfaces of prolonged erosion, (10) calcrete structures, (11) macroscopic solution cavities, (12) stratiform diagenetic dolostones, (13) peddles of calcretized limestone, (14) sampling sites for thin sections (PIN collection nos. 4902, 5046, and 5047), (15) samples GIN RAN employed in fusulinoid identification, collection GIN 4740.

bedded packstones and wackestones with subsequent grainstones (Fig. 3). At places the lower part or even the whole volume of the Panshino limestone is replaced by yellow dolomite. The top of the Panshino Member was chosen at the shoal peloidal-skeletal grainstone KB-14 (SP-4) and/or the erosional surface in the base of this

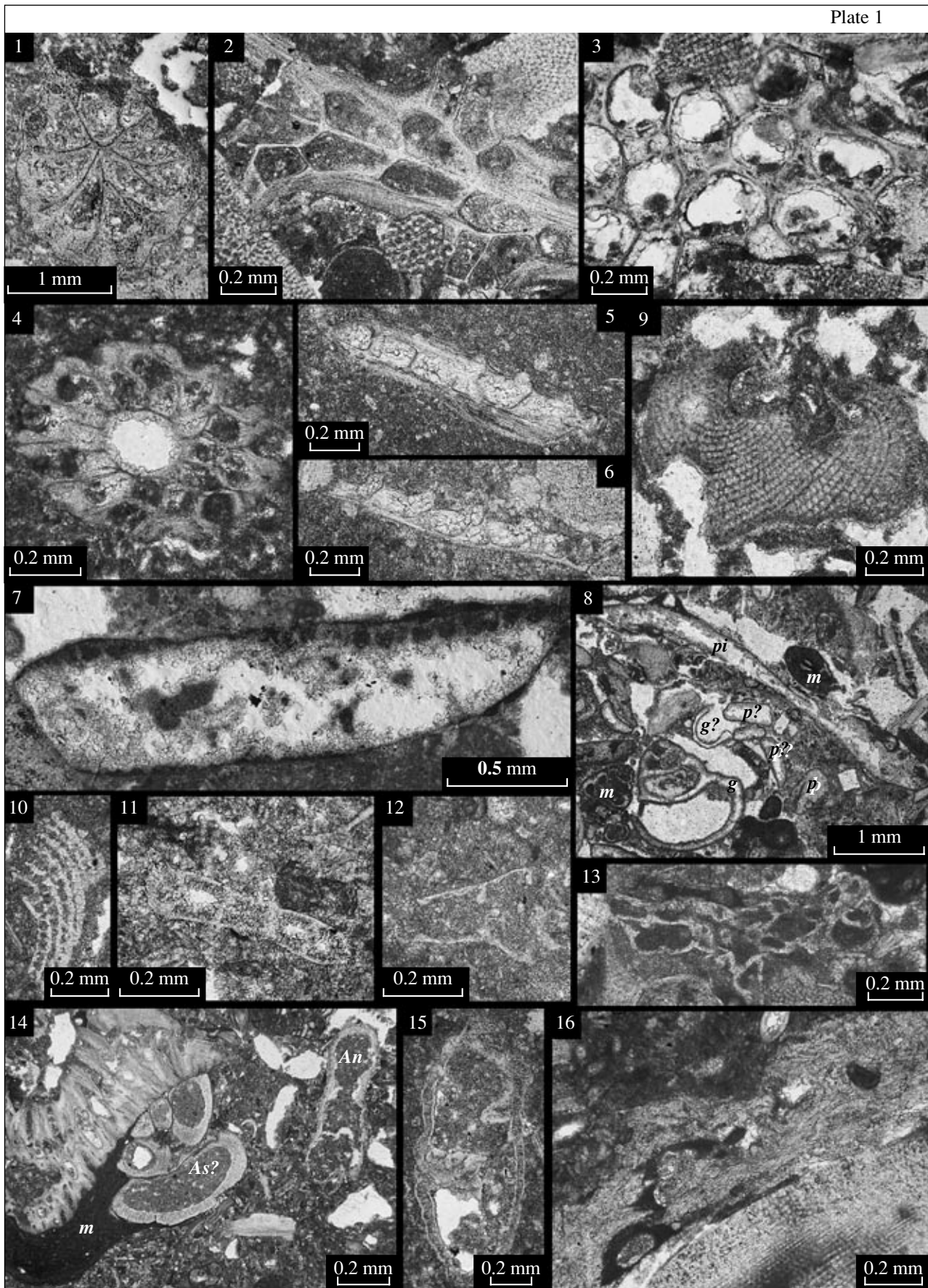
grainstone. Hereafter the beds of Konev Bor are referred to as KB and those of Old Peski as SP. Another erosional surface overlain by the shoal grainstone KB-12 (SP-2) divides the Panshino into two smaller cycles. The insoluble residue from the conodont sample KB-12 has yielded faceted biotite crystals 1–2 mm in diameter. This biotite probably represents long-transported pyroclastic dust. The ancient eolian dunes towered north of the present quarries considerably influence the Panshino limestone. On dune slopes, this interval thins to pinching (Fig. 2), with the correspondent facies shift to crude bioclastic grainstones, rudstones, and probably some varieties of boundstones with numerous chaetetids, colonial corals, and rich mollusk assemblage (Ivanov, 1926; Rauser-Tschernoussowa and Reitlinger, 1954).

The Gubastovo Member shows more facies contrast (Fig. 3). Above the basal grainstone KB-14a (OSP-4a), the thick alternation of shales and argillaceous limestones KB-15–KB-21 (SP-5–SP-11) with graded storm layers represent tempestites (Kabanov, 2003). The fragments of phylloid algae and micritized grains that would point to the euphotic depth are present in minor quantities only in the coquinas from the shale SP-5 and in the weakly argillaceous limestone SP-10 and SP-11. Between these levels, no evidence of active phototrophic processes has been detected, and the sediment is bioturbated in the *Zoophycos* ichnofacies. These features suggest a deepest-water character of this interval in the Domodedovo cyclothem (Fig. 3). The packstone KB-16 (SP-6) with less clay and relatively few *Zoophycos* traces may correspond to the shoaling event, which, however, cannot be verified because no increase in the quantity of micritized grains or phylloid algae is observed at this level. The layer KB-21 (SP-11) bears characters transitional between the proximal tempestite and the packstone-rudstone lithofacies (Kabanov, 2003), that is, the abundance of coarse shell debris increases, while the storm layers are largely destroyed by bioturbation. Additional information comes from the “insoluble fraction” after treating the limestone samples for conodonts. This fraction is conventionally insoluble, because the weak acetic acid solution is leaving massive calcite bioclasts along with truly insoluble compounds. Small glauconitized bioclasts have been encountered at the KB-14–KB-20 interval, which may be a consequence of slowing down the net sedimentation rate during the maximum Domodedovo transgres-



**Fig. 3.** Lithofacies characterization of the Domodedovo Formation of Peski sections: (1) limestone, (2) weakly argillaceous limestone, (3) argillaceous limestone, (4) shale, (5) stratiform dolostones, (6) subaerially altered limestones in formation tops, (7) surfaces of prolonged erosion, (8) pebbles; (9–18) lithofacies: (9) clayey paleosol horizon, (10) cross-stratified peloidal grainstone with *Ortonella*, (11) lagoonal mudstone, (12) peloidal-bioclastic shoal grainstone, (13) skeletal packstone-rudstone, (14) shallow-water skeletal packstone-wackestone, (15) proximal tempestite, (16) offshore skeletal packstone-wackestone, (17) offshore wackestone-mudstone, (18) distal tempestite; (19–21) graded storm layers: (19) with basal concentrates framed by whole and broken shells (coquinas), (20) with basal concentrates framed by bioclasts <2 mm in size, and (21) intermediate; (22) herringbone cross-stratification; (23–35) bioclasts (without algae) and peloids: (23) larger fusulinoids, (24) schubertellid fusulinoids, (25) paleotextulariids, (26) *Eotuberitina*, (27) *Palaeonubecularia*, (28) other smaller foraminifers, (29) brachiopods, (30) echinoderms, (31) bryozoans, (32) *Ortonella*, (33) ostracods, (34) peloids, (35) composite micritic lumps; relative abundance of grains affected by micritization, per cent of all bioclasts: (a) over 60%, (b) 25–60%, (c) 5–25%, and (d) less than 5% or absent.





*darella uralica* Maslov, 1956 (SP-1, 3, 18), and one fragment resembling the genus *Archaeolithophyllum* (SP-6, SP-8) have been encountered. The cross-stratified intertidal grainstone in the top of Domodedovo cyclothem (KB-23 and SP-13) contains characteristic cyanobacterial nodules *Ortonella* (Khvorova, 1958; Kabanov, 2003). Bright hyaline crusts, sometimes with indistinct radial structure, characteristically take part in the oncoid-forming encrustations (Pl. 1, figs. 14, 16). These hyaline crusts are identified as *Claracrusta catenoides* (Homann, 1972) (Villa and Mamet, 2004).

The *Claracrusta*-based encrustations often incorporate different algae (Pl. 1, fig. 14), encrusting foraminifers (Pl. 1, fig. 16), rarely bryozoans and other encrusting organisms. The grain-enveloping encrustations correspond morphologically to oncoids, and those blanketing the substrate may be called microstromatolites. The *Claracrusta*-based encrustations partly resemble the archaeolithophyllid-type oncoids (Toomey, 1974). However, the latter are usually larger (not less than 1 cm), and their hyaline layers consist of the lamellar form of the rhodophyte genus *Archaeolithophyllum*. In the material studied, the lamellar *Claracrusta* sometimes grade into the loopy structures tentatively referred to the genus *Asphaltinella* (Pl. 1, fig. 13).

Figure 4 shows good relationship between the abundance of the phylloid algae and sea level changes, which is confirmed on the other studied intervals of the upper Moscovian succession. The fragments of phylloid algae are present in all thin sections of Panshino shallow-subtidal packstones (KB-10–KB-11 and SP-1), sometimes in plenty (up to 2.7 fragments/cm<sup>2</sup>) but lacking in the core wackestone of the upper Panshino cycle

(the lower part of SP-3). In the shoal grainstones KB-12 (SP-2) and KB-14 (SP-4), the abundance of phylloid algae increases abruptly to 16.2 fragments/cm<sup>2</sup>. In the lower part of SP-4, large in situ thalli associated with clotted to dense micritic cement (Pl. 1, fig. 8). Apparently, these codiaceans flourished in the shallowest normal-marine conditions with elevated water energy. The abraded fragments of phylloid algae occur in minor quantities in the transgressive part of the Gubastovo Member, up to the “middle limestone” SP-6. However, here those fragments can be explained by their reworking from the shoal sands of KB-14 and SP-4 rather than survival in the muddy, strongly shadowed, offshore environment during the maximum transgression. In the “upper tempestites” above SP-6, phylloid algae are lacking, and only rare fragments appear again in the shallow-subtidal facies of the upper part of SP-20 and SP-21. This asymmetry in phylloid algal distribution may be explained by suspended siliciclastic fines long resided in the water column and shadowed the seafloor. The phylloid algae probably did not settle in the stress intertidal conditions of the terminal cross-stratified grainstones of KB-23. Another explanation of their absence at this level is profound vadose and pedogenic alteration of the primary lithofacies (Fig. 2; Kabanov, 2005), which could completely obliterate the loose sparitic structure of the thalli.

The remains of Dasycladales may be chosen as another reliable paleodepth indicator (Fig. 4). In the Podolskian and Myachkovian, the dasyclads occur in minor quantities but invariably at shallow normal-marine intervals. Oncoids and *Claracrusta*-based crusts also preferentially occur in shallower normal-marine facies with muddy sand (packstones) or sand

#### Explanation of Plate 1

Bryozoans and algae of the Domodedovo Formation of Peski.

**Figs. 1–6.** Bryozoans.

**Fig. 1.** *Primorella nitida* Gorjunova, 2002, transverse section, thin section PIN 5046/2.

**Fig. 2.** *Filites* sp., tangential section, thin section PIN 5047/1.

**Fig. 3.** *Crustopora* sp., tangential section, thin section PIN 5047/1.

**Fig. 4.** *Pseudorhabdomeson* sp., transverse section, thin section PIN 4902/1.

**Fig. 5.** *Rectifenestella* sp., longitudinal section, thin section PIN 5047/3.

**Fig. 6.** *Spinofenestella* sp., longitudinal section, thin section PIN 5047/4.

**Figs. 7–16.** Benthic calcareous algae.

**Fig. 7.** Fragment of the phylloid alga *Eugonophyllum* sp. with characteristic rounded and cordate “utracles” in the cortex, thin section PIN 5047/5.

**Fig. 8.** In situ thallus of a phylloid alga (*pi*) with foraminiferal encrustations and micritic “buttress,” (*g*) biomold after micritized gastropod shell, (*p*?) supposed recrystallized and abraded fragments of phylloid algae, (*g*?) supposed fragments of gastropod shells, (*m*) strongly micritized foraminifers, shoal grainstone lithofacies, thin section PIN 5047/5.

**Figs. 9 and 10.** *Fourstonella fusiformis* (Brady, 1876).

**Fig. 9.** Thin section PIN 5046/3.

**Fig. 10.** Thin section PIN 5047/6.

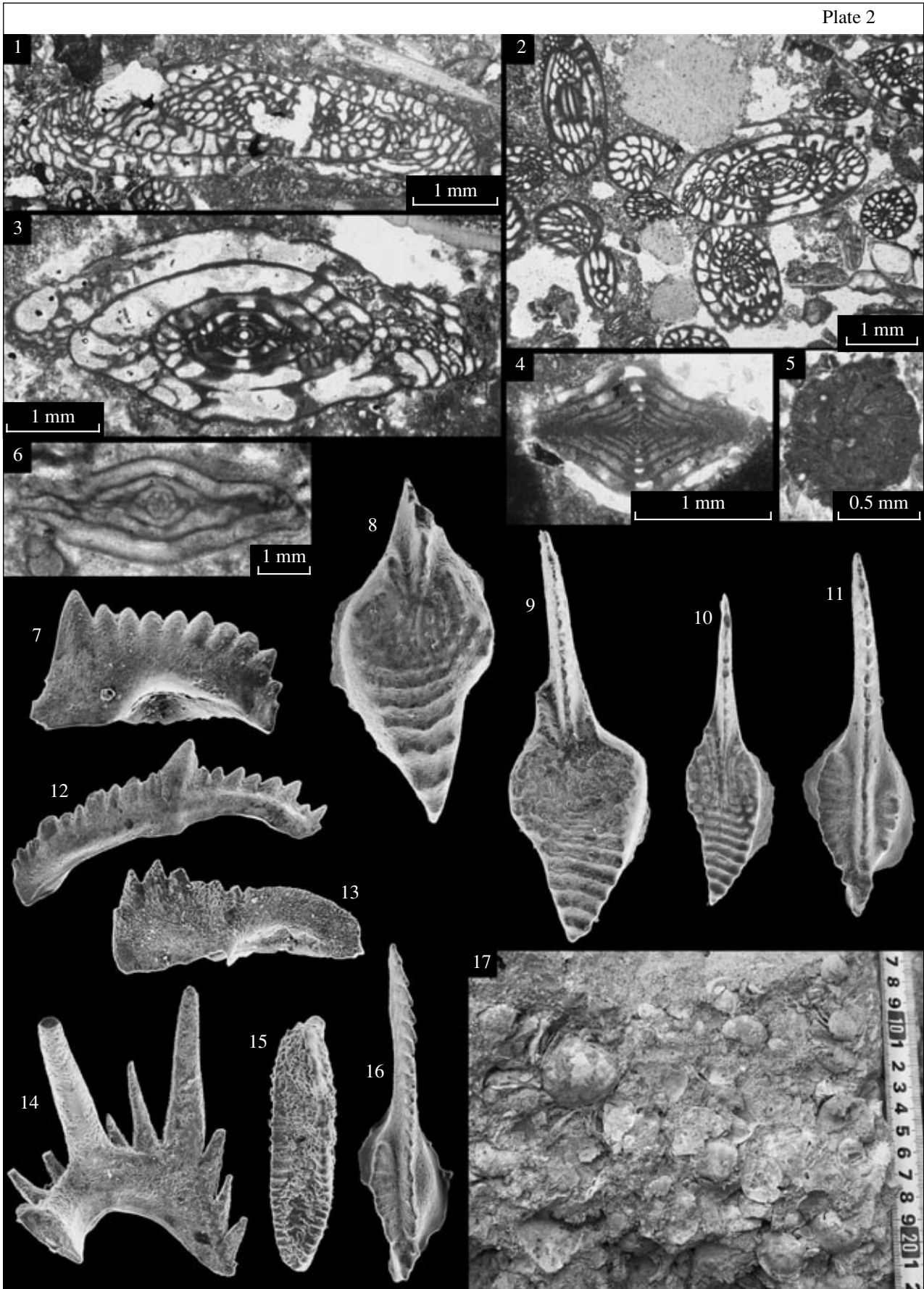
**Figs. 11 and 12.** *Donezella lutugini* Maslov, 1929, thin section PIN 5047/7.

**Fig. 13.** *Asphaltinella* (?) sp., thin section PIN 5047/8.

**Fig. 14.** Thin section PIN 5047/9 showing (*An*) *Anthracoporellopsis machaevii* Maslov, 1956 and the oncoidal envelope around the tetracoral consisting of (*m*) faintly laminar micrite and (*As*?) supposed *Asphaltina* sp.

**Fig. 15.** *Anthracoporellopsis machaevii*, thin section PIN 5047/10.

**Fig. 16.** Fragment of a *Claracrusta*-based oncoid with *Palaeonubecularia* sp., thin section PIN 5047/8.



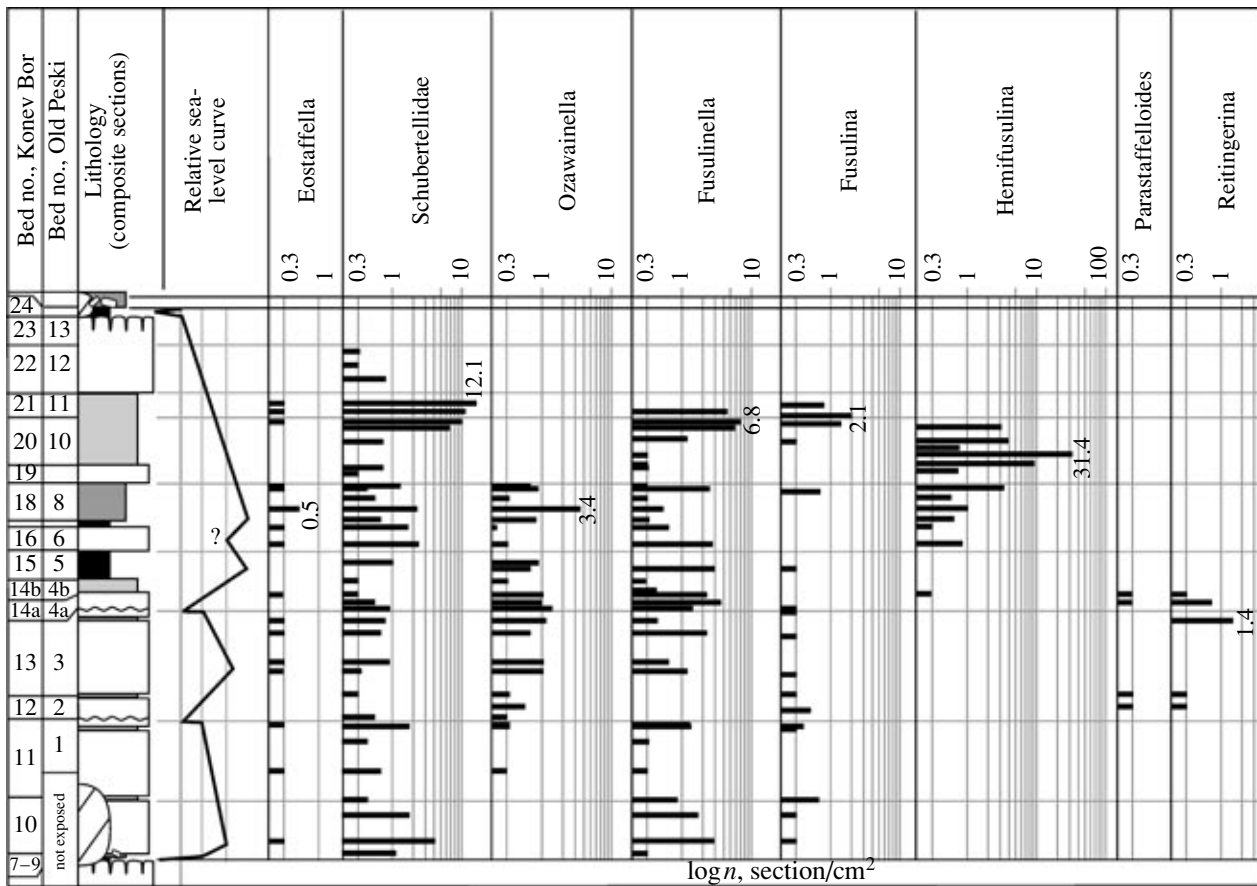


Fig. 5. Distribution of Fusulinoidea in the Domodedovo Formation of Peski sections (logarithmic scale).

(grainstones) substrates (up to 0.9 fragm./cm<sup>2</sup> in the shoal grainstone SP-14). However, oncoids occur too sporadically to draw reliable conclusions about their facies preference. Algae with bright (hyaline) walls such as the genera *Anthracoporellopsis*, *Fourstonella*, *Donezella*, and *Asphaltinella* occur in a broader range of facies but in minor quantities (Fig. 4) and without distinct facies preference. Variability in *Donezella*

abundance seem to be influenced by their preferential preservation in wackestones and packstones, which strongly biases their original distribution.

### Fusulinoidea

Practically all sections of fusulinoid tests, irrespective of their preservation state (Pl. 2, fig. 5), can be iden-

#### Explanation of Plate 2

Fusulinoidea (Figs. 1–6), conodonts (Figs. 7–16), and *Meekella eximia* Eichw. coquinas in the *Ortonella*-peloidal grainstone KB-23 (Fig. 17, view from above).

Fig. 1. *Fusulina kamensis* Safonova, 1951, nearly axial section of adult test, thin section GIN 4740/PS-16/3-14.

Fig. 2. Mass burial of *Hemifusulina bocki* Moeller, 1878 of different ontogenetic stages in a storm bed, thin section PIN 4902/1.

Fig. 3. *Fusulinella schwagerinoides* (Deprat, 1913), nearly axial section of adult test, thin section GIN 4740/PS-16/3-131.

Fig. 4. *Taitzehoella taitzehoensis* Sheng, 1951, axial section of adult test, thin section GIN 4740/PS-7/1-21.

Fig. 5. *Fusulina* sp., tangential section of severely micritized test, thin section PIN 5047/12.

Fig. 6. *Fusiella typical* Lee et Chen, 1930, axial section of adult test, thin section PIN 5047/13.

Fig. 7. *Hindeodus minutus* (Ellison), sample PS1-14/2, ×60.

Figs. 8–10. *Idiognathodus* ex gr. *delicates* Gunnell, ×60: Figs. 8 and 9 from sample PS1-14/2 and Fig. 10 from sample PS1-18/2.

Fig. 11. *Neognathodus roundyi* (Gunnell), ×60.

Fig. 12. Ramiform O-element of *Idiognathodus apparatus*, ×45, sample PS1-14/2.

Fig. 13. *Diplognathodus coloradoensis* (Murray et Chronic), ×100, sample PS1-16/2.

Fig. 14. The element *Aethotaxis* sp., ×100, sample PS-17/1.

Fig. 15. *Adetognathus lautus* (Gunnell), ×100, sample PS1-3.

Fig. 16. *Neognathodus dilatatus* Merrell, ×60, sample PS1-14/3.

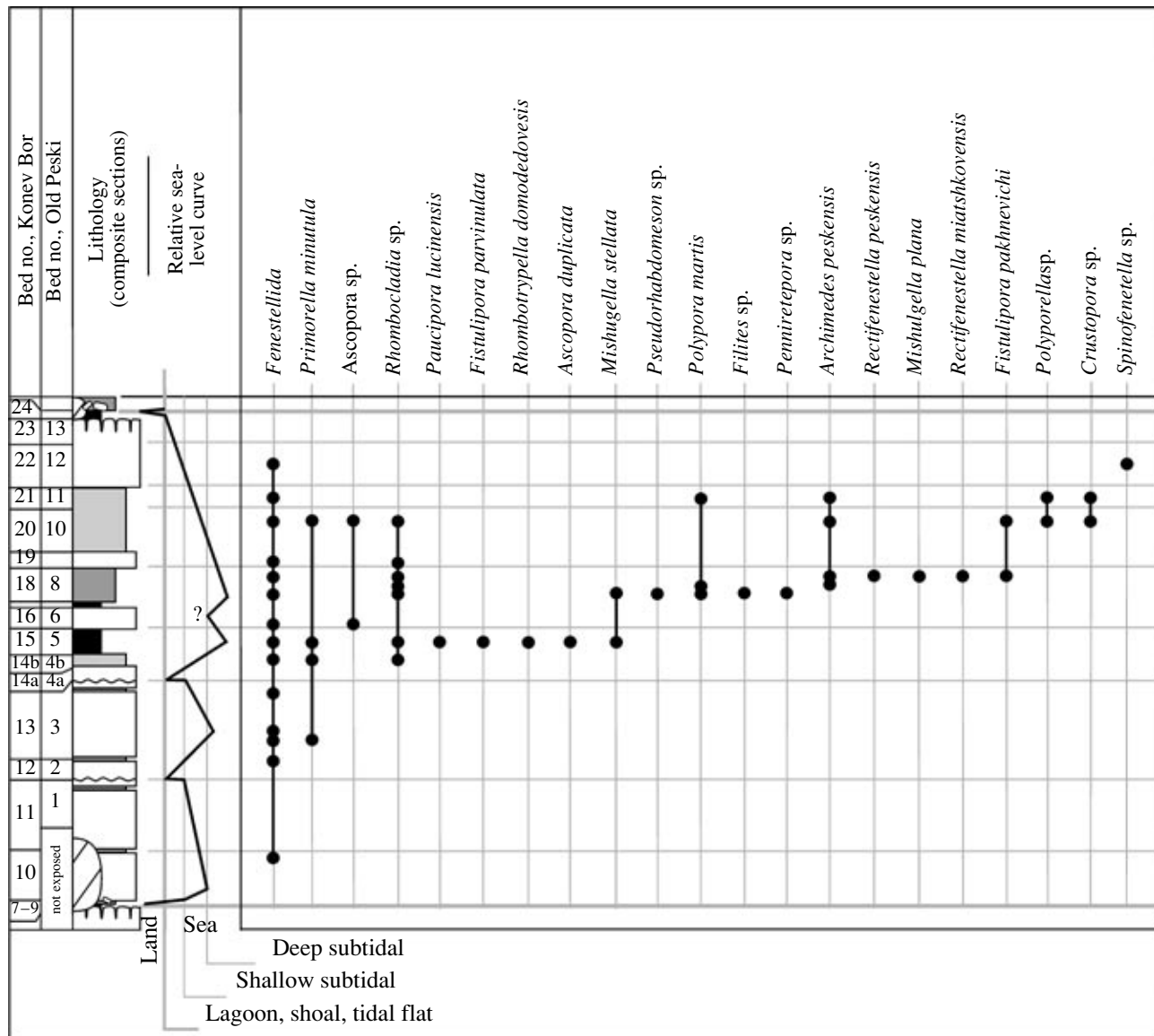


Fig. 6. Distribution of bryozoan genera and species in the Domodedovo Formation of Peski sections.

tified to genus or family level. The tests of the genera *Eostaffella*, *Ozawainella*, *Neostaffella*, *Taitzehoella* (Pl. 2, fig. 4), *Fusulinella* (Pl. 2, fig. 3), *Fusulina* (Pl. 2, fig. 1), *Hemifusulina* (Pl. 2, fig. 2), *Reitlingerina*, and *Parastaffelloides* are identified at the genus level. The schubertellids *Fusiella* (Pl. 2, fig. 6) and *Schubertella* cannot be differentiated in sagittal section, and are therefore counted together as Schubertellidae. The distribution of fusulinoids is shown in Fig. 5, save for a few sections of *Neostaffella* found in SP-5 and KB-10 and *Taitzehoella* encountered in KB-12. Twenty species identified in the Domodedovo Formation of Peski are not discussed here.

In the lower Panshino submember, the highest abundance is attained by *Fusulinella*, which is followed by

Shubertellidae, *Fusulina*, *Ozawainella*, and *Eostaffella*. Noteworthy, the abundance of *Fusulinella* decreases steadily with shoaling from 2.7 tests/cm<sup>2</sup> in the lower part of KB-10 to 0.3 tests/cm<sup>2</sup> in KB-11 and SP-1. The schubertellids exhibit a similar pattern. The upper Panshino submember is characterized, in decreasing abundance, by *Fusulinella*, *Ozawainella*, *Reitlingerina*, schubertellids, *Fusulina*, *Eostaffella*, and *Parastaffelloides*. The staffellid genera *Parastaffelloides* and *Reitlingerina*, known as shoaling indicators in the Myachkovian (Rauser-Tschernoussowa and Kulik, 1949; Baranova and Kabanov, 2003), are only present here and in the basal Gubastovo grainstone SP-4. More remarkable changes are observed in the Gubastovo member. It is featured by *Hemifusulina*, schubertellids,

*Fusulinella*, *Fusulina*, *Ozawainella*, and *Eostaffella*. All these genera attain maximum abundance at the regressive part of the Gubastovo cycle, though the peaks are not coincident. The mass occurrence of *Hemifusulina* in the upper Gubastovo tempestites is a peculiar feature of Peski sections. In SP-10, *Hemifusulina* tests there comprise catastrophically buried thanatocoenoses with all ontogenetic stages present (Pl. 2, fig. 2). The *Ozawainella* is most abundant in the distal tempestites SP-5, SP-7, and SP-8. It is possible that their scarcity in SP-6 may indicate some shoaling. The lagoonal mudstone KB-22 (OP-12) has yielded only scattered schubertellids. No fusulinoids are found in the intertidal grainstone SP-13.

### Bryozoa

The base of the Panshino Member (KB-9) lacks bryozoans (Fig. 6). Upsection, virtually up to the top of the Panshino member, the fragments of branches of unidentifiable fenestellid bryozoans occur in minor quantities (KB-10, KB-11, SP-4). The base of KB-13 is the only level at which the rhabdomeside *Primorella minutula* Gorjunova, 2002 has been detected. There are slim, virtually filamentous, ramified spiral colonies coiling around the central axis (Pl. 1, fig. 1). The apertures for the lophophore in rhabdomesides are arranged in regular longitudinal and diagonal crossed rows that are traced throughout the colony. This suggests that these bryozoans were capable of efficient trapping of nutrient particles from the current, withstanding quite unfavorable environmental conditions, and coexisting with very tolerant fenestellids. In general, the poor assemblage suggests quite unfavorable environmental conditions for bryozoans during the Panshino time. The assemblages of shallow-subtidal packstones and wackestones seems to have been more favorable than the open shoal grainstones (Fig. 3).

The Gubastovo assemblage is much richer in abundance and diversity (Fig. 6). It includes 16 genera distributed among five orders. Twelve fragments are identified to species level. Here the bryozoans are represented by *Fistulopora parvilunata* Sch.-Nest., *F. pakhnevichi* Gorjunova (Cystoporata), *Mishulgella plana* (Sch.-Nest.), *M. stellata* Gorjunova, *Rhombotrypella domodedovens* Gorjunova, *Crustopora* sp. (Trepotomida), *Primorella minutula* Gorjunova, *Ascopora duplicata* Sch.-Nest., *Pseudorhabdomeson* sp., (Rhabdomesida), *Rhombocladia* sp. (Phylloporinida), *Penniretepora* sp., *Filites* sp., *Rectifenesstella miatshkovensis* (Sch.-Nest.), *R. oxovens* (Sch.-Nest.), *Spinofenesstella* sp., *Polyporella* sp., *Polypora martis* (Fischer), *Archimedes peskensis* Sch.-Nest., and *Paucipora lucinensis* (Sch.-Nest.) (Fenestellida). The diversity of bryozoans tends to increase up to the most offshore part of the Gubastovo cycle, and then unevenly decreases in its regressive part. The data from thin sections corresponds well to the field counting of bryozoan remains. Figure 9 shows

scarcity of bryozoans in the Panshino, a diversity peak in the lower Gubastovo, and abundant although non-diverse fenestellids in the lagoonal mudstone KB-22.

### Conodonta

The Domodedovo Formation has a generally low conodont content that seldom exceeds 10 specimen/kg. Only in two samples (14/2, 12/2) does the conodont number exceed 50 specimens/kg. The entire Panshino Formation is poor in conodonts (0–8 specimen/kg) except for its base (Sample 3 from KB-10) where the conodont number rises to 21 specimens/kg. The abundance is rapidly increasing in the lower part of the Gubastovo Member (KB-15, KB-18, KB-20, KB-21) where the maximum deepening is implied. In the Domodedovo top (KB-22), the conodont number decreases to 1–2 specimen/kg. Thus, the trend in conodont abundance is coupled with the general paleodepth trend (Fig. 7). The taxonomic diversity of the assemblage is moderate. Five platform genera have been encountered: *Idiognathodus* (Pl. 2, figs. 8–10), *Neognathodus* (Pl. 2, figs. 11, 16), *Adetognathus* (Pl. 2, fig. 15), *Hindeodus* (Pl. 2, fig. 7), and *Diplognathodus* (Pl. 2, fig. 13). The ramiform elements include, among others, representatives of the genera *Idioproniodus* and *Aethotaxis* (Pl. 2, figs. 12, 14). The majority of samples is dominated by *Idiognathodus* elements that, in total, comprise 66%. Considerably smaller quantities are attained by *Neognathodus* (19%) and *Hindeodus* (about 10%). The only element of *Adetognathus* was encountered at the base of the Domodedovo Formation (Sample 3). Seven species are detected (Fig. 7). The genus *Idiognathodus* is represented by several yet undescribed forms of the *I. delicatus* Gunnell s.l. group. Three *Neognathodus* species are identified: *N. inaequalis* Kozitskaya et Kossenko, *N. roundyi* (Gunnell), and *N. dilatatus* (Stauffer et Plummer). Other genera are represented by one species each: *Adetognathus lautus* (Gunnell), *Diplognathodus coloradoensis* (Murray et Chronic), and *Hindeodus minutus* (Ellison).

The conodont assemblages studied belong to the conodont biofacies *Idiognathodus* of the shallow normal-salinity shelf sea (Merrill, 1973; Merrill and von Bitter, 1976). One specimen of *Adetognathus* cannot justify recognition of the co-named biofacies characteristic of stress environments with abnormal salinity. Another shallow-water genus *Diplognathodus* presented in many samples (4–9%) confirms the relative shallowness of the Domodedovo-age sea. It is noteworthy that the representatives of the deep-water biofacies *Gondolella* are completely lacking in the Myachkovian of the Moscow Region and the Oka–Tsna Swell. Representatives of *Gondolella* first appear east of this area in the Volga Region (Sungatullina, 2002). Nevertheless, the Panshino Member with its scarce conodonts and one record of *Adetognathus* appears to be considerably shallower than the Gubastovo Member.

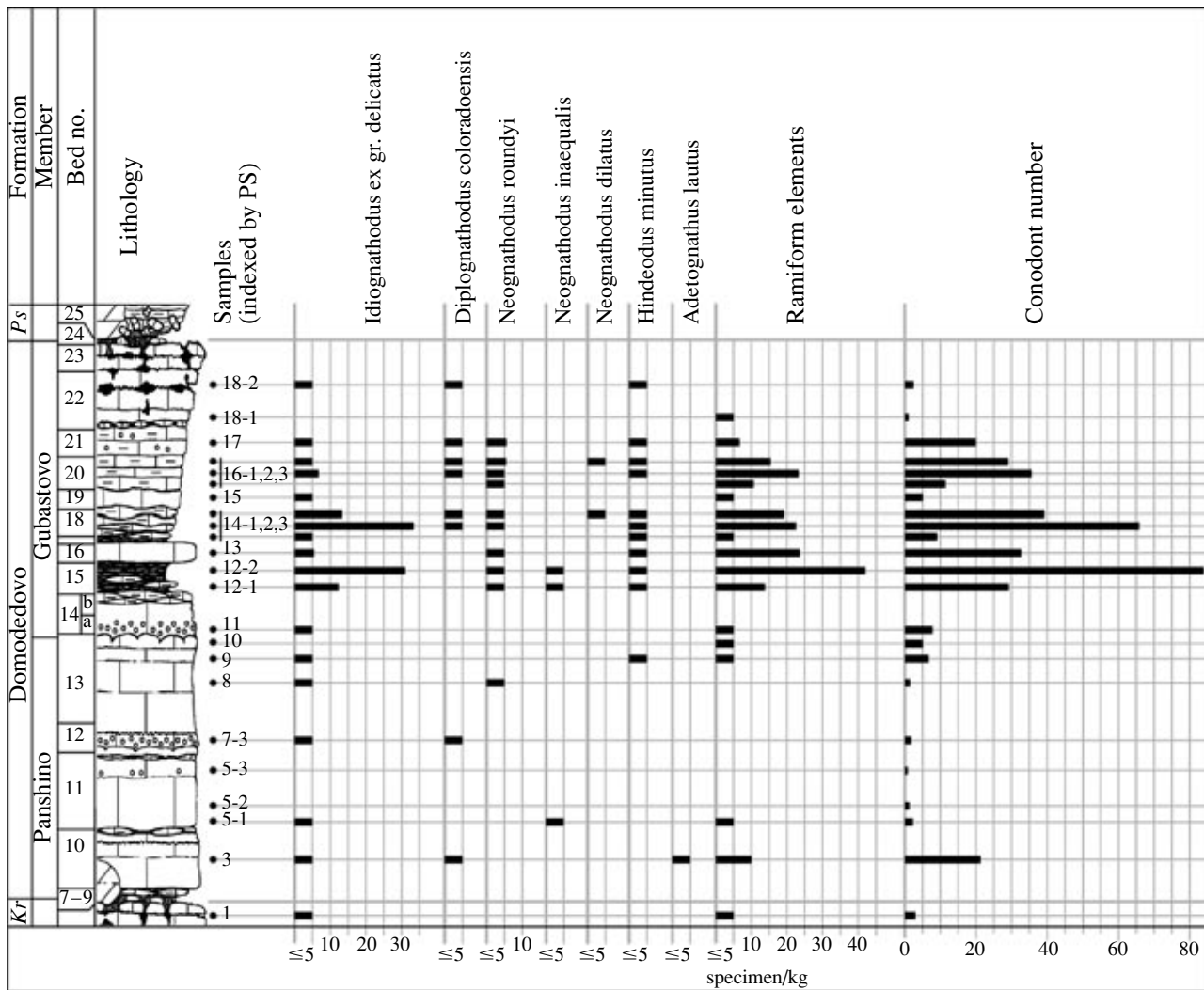


Fig. 7. Distribution of conodonts in the Domodedovo Formation at Konev Bor.

### Brachiopoda

In the materials studied, brachiopods are the most numerous and diverse group of macrofauna. Figure 8 shows the distribution of the relatively common genera *Neochonetes*, *Kozlowskia*, *Choristites*, *Brachythyrina*, *Orthotichia* (?), *Admoskovia*, *Jiguliconcha*, *Meekella*, *Enteletes*, *Composita*, *Orthotetes*, and *Desmoinesia*. Solitary or extremely rare forms include *Chonetinella* (KBf-4), *Krotovia* (KBf-4, KBf-8), *Calliprotonia* (KBf-1), *Neophrycodothyris* (KBf-6, KBf-7), *Isogramma* (KBf-14), *Hustedia* (KBf-15), unidentified terebratulids (KBf-6, KBf-7, KBf-10, KBf-15), and representatives of the family Linoproductidae (KBf-4, KBf-5, KBf-12). The majority of these forms have long been known in the Moscow Syncline (Ivanov, 1935; Sarycheva and Sokolskaya, 1952; Lazarev, 1984, 1990, 2001). Small (less than 5 mm in length) orthids with weak sulcus but lacking frontal plications are tentatively referred to the genus *Orthotichia*. However, these

forms are closely similar to the juvenile shells of *Enteletes lamarckii* (Eichw.). The large productids accommodated before 1975 to the genus *Dictyoclostus* and then to *Reticulatia* have recently been separated into a new genus, *Admoskovia* (Lazarev, 2000).

The distribution of brachiopods in the Domodedovo Formation of Konev Bor (Fig. 8) highlights two groups nearly equal in the number of genera: (1) the group with symmetrical abundance relatively to the cyclothem core and (2) the group with asymmetrical abundance. The first group comprises the genera *Kozlowskia*, *Admoskovia*, *Choristites*, and *Brachythyrina*, i.e., representatives of spiriferids and productids, the two orders dominant in the Late Paleozoic. The second group comprises the genera *Orthotichia*, *Enteletes*, *Orthotetes*, and *Meekella* of the orders Orthida and Strophomenida, which were less diverse but more cosmopolitan (Treatise..., 2000). Our data confirm the objectivity of the two principal brachiopod biofacies *Choristites* and *Meekella* (Kabanov, 2003). The well-

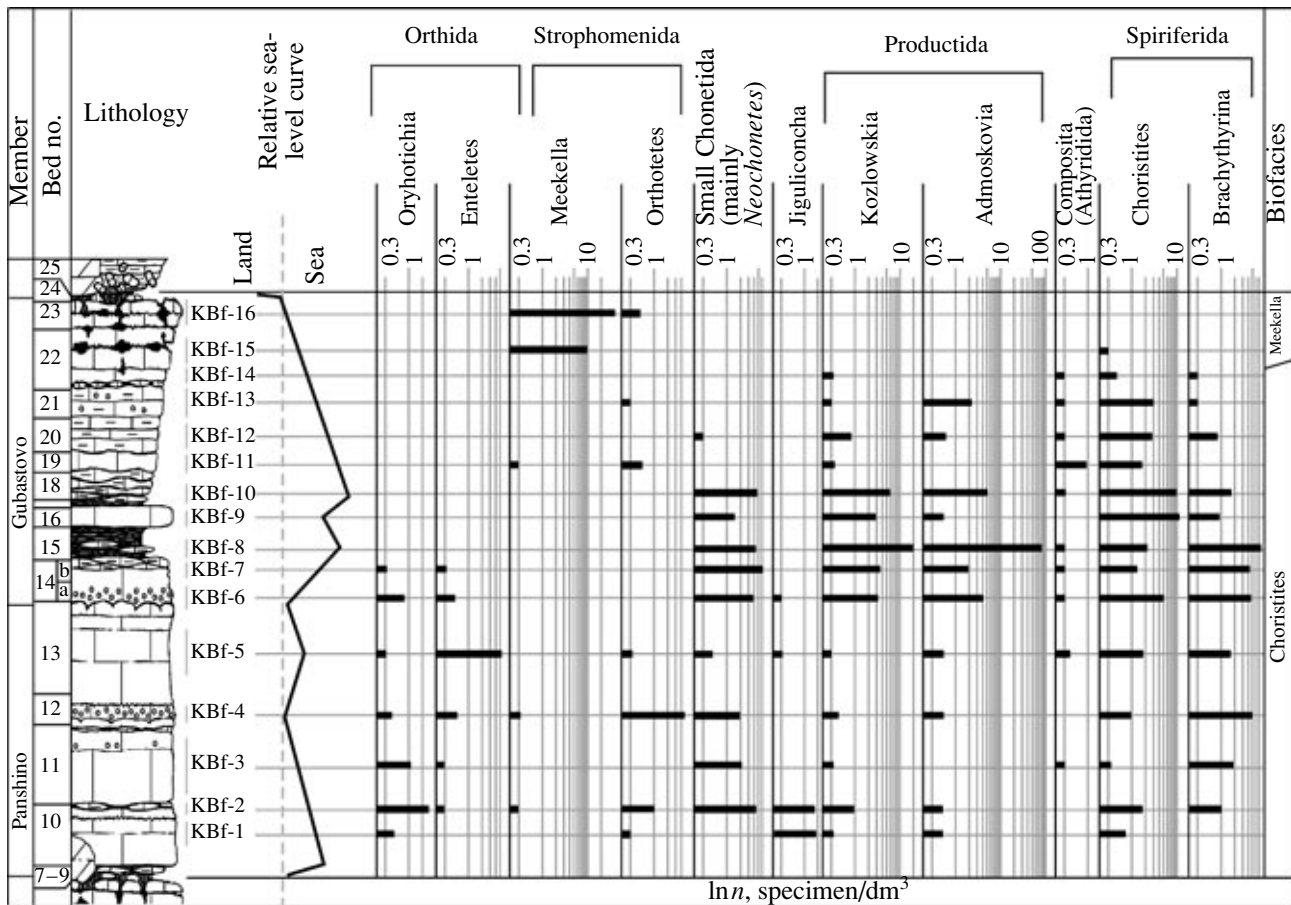


Fig. 8. Distribution of brachiopods in the Domodedovo Formation at Konev Bor (in logarithmic scale).

preserved shells of *Chorisites* are present in all samples but KBf-15 and KBf-16. Sample KBf-15 has yielded two abraded fragments and one juvenile rare and in KBf-16, *Chorisites* has not been found. Unlike *Chorisites*, *Meekella eximia* Eichw. is extremely rare in the main, normal-marine part of the Domodedovo cyclothem (KBf-1–KBf-14) but becomes very abundant in the lagoonal-peritidal facies (KBf-15, KBf-16) where other brachiopods are lacking. In the intertidal cross-stratified grainstone, the shells of *Meekella* comprise coquinas and sometimes occur in situ (Pl. 2, fig. 17). Within the Chorisites interval, the offshore cyclothem core (KBf-7–KBf-10) is distinct by the abundance peaks of *Neochonetes*, *Kozlowskia*, *Admoskovia*, and *Chorisites* (Fig. 8). The shoal grainstone KB-12 (KBf-4) features numerous *Orthotetes* and *Brachythyrina* shells along with relatively few remains of the other genera. However, this character is not repeated in the identical facies of KB-14 (KBf-6), where the relative brachiopod abundance is closely similar to that in the cyclothem core. The shallow-subtidal packstone KB-10 (KBf-1, KBf-2) is remarkably dominating in the thin-shelled brachiopods *Orthotichia* (?) sp., *Neochonetes carboniferus* (Keys.), and *Jiguliconcha pakhrensis* (Laz.). The latter species does not

enter the Gubastovo member. In conclusion, the Chorisites biofacies is obviously heterogeneous and requires further subdivision as far as the data will allow.

### Other macrofossils

The majority of other macrofossils are counted in one of the above-generic groups: Gastropoda, Scaphopoda, Bivalvia, Crinoidea, Echinoidea, solitary tetracorals, tabulatomorph corals (the genera *Syringopora* and *Aulopora*), the spongiomorph *Chaetetes*, fenestellids and encrusting lamellar bryozoans, and Trilobita. Among gastropods, only forms with calcite layers in the shell have been identified to the genus level. Mostly these belong to the genus *Straparollus*. Other gastropods are conventionally grouped into the “smaller gastropods” and Bellerophonaceae. The name “smaller gastropods” is applied because of quantitative domination of the small forms less than 10 mm in height. The distribution of the aforementioned groups is shown in Fig. 9. Rare or solitary findings of colonial tetracorals (KBf-5), rostroconchians *Conocardium* (KBf-7–KBf-9, and KBf-13), scaphopoda (KBf-1–KBf-4, KBf-6, KBf-7, KBf-12, KBf-14), parasitic gastropods *Platyceras* (KBf-6, KBf-8, KBf-9), loxoceratid (KBf-6, KBf-16)

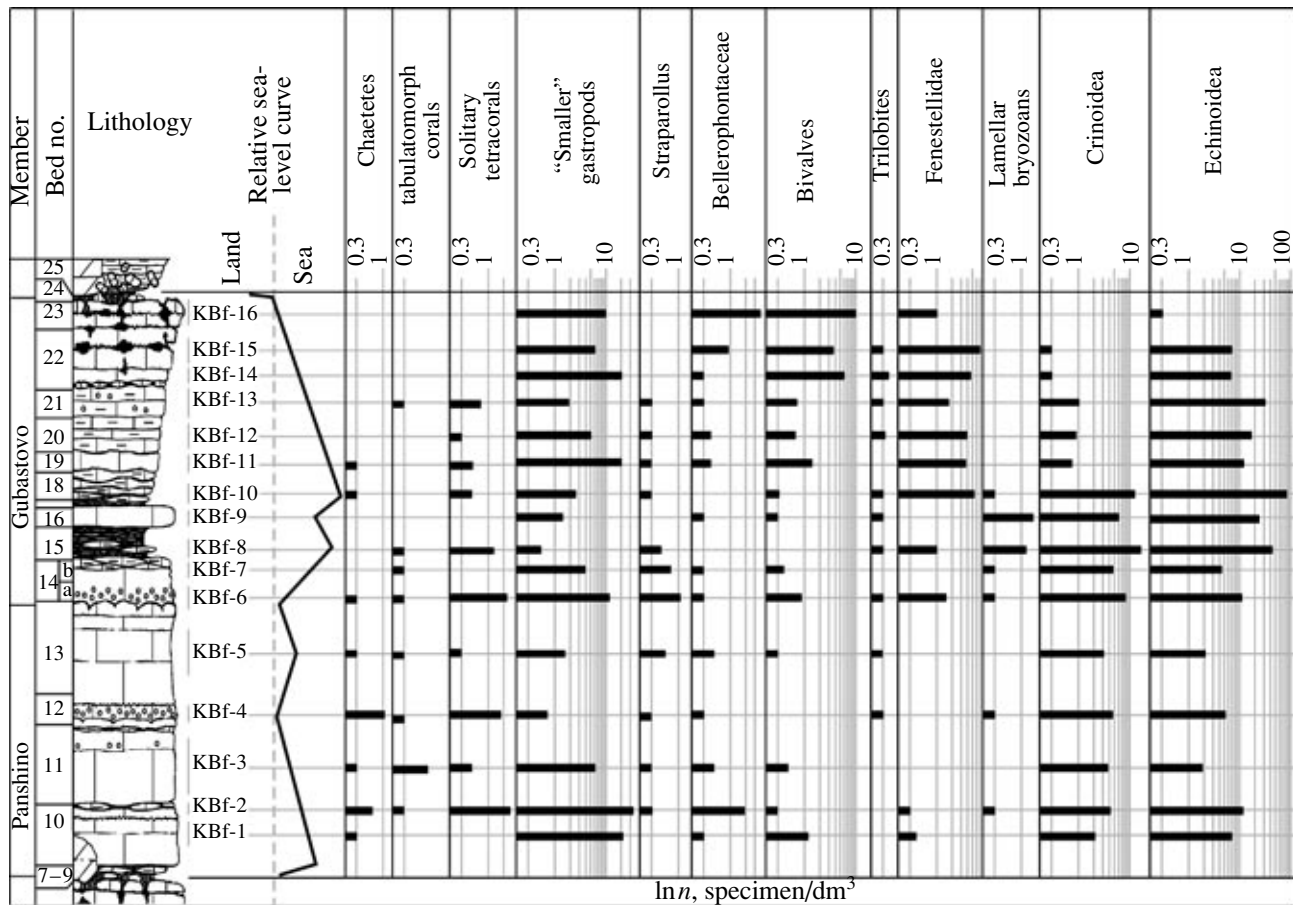
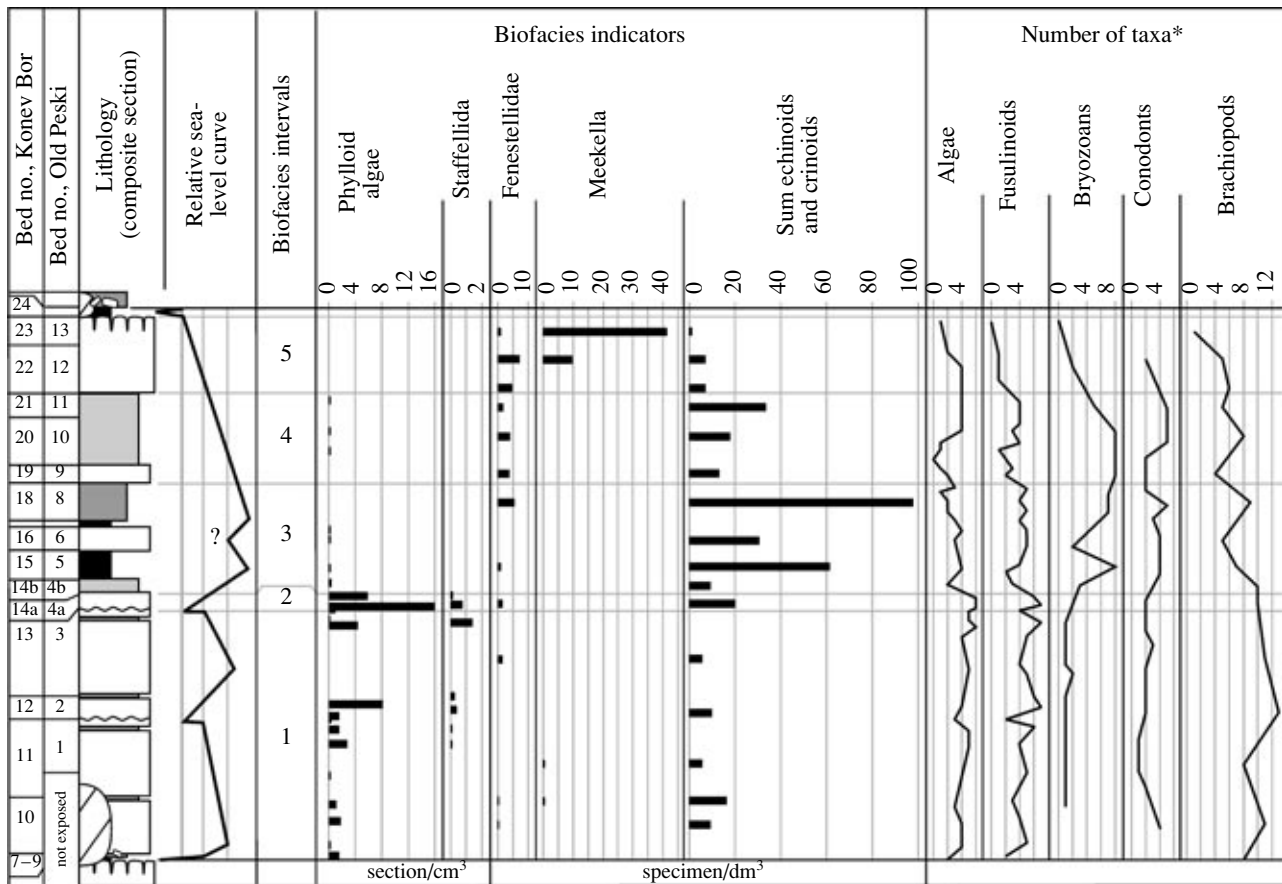


Fig. 9. Distribution of macrofossils excluding brachiopods in the Domodedovo Formation at Konev Bor (logarithmic scale).

and nautiloid cephalopods (KBf-16), ramose bryozoans (KBf-6, KBf-8), and fishes (KBf-11–KBf-13) have not been plotted. The most recent data on the tetracorals from the succession studied are given by Kossovaya (2001), bryozoans by Gorjunova (2002), and fishes by Lebedev (2001). The overview of chaetetids and other sponges, mollusks, trilobites, and echinoderms is given by Alekseev (2001).

Figure 9 shows that the Panshino Member is relatively rich in tetracorals and the potential reef builders such as *Chaetetes* and tabulatormorphs. However, true metazoan buildups are lacking here. Colonial tetracorals are also found at this interval. This character is coupled with virtual lack of clay admixture and normal marine, shallow subtidal to shoal Panshino environment. The potential reef builders colonized in plenty the slopes of the drowned Korobcheevo paleodunes, which towered 2–3 km north of the present Konev Bor (Fig. 2; Ivanov, 1926; Rauser-Tschernoussowa and Reitlinger, 1954). In contrast, the marly Gubastovo tempestites have yielded few *Chaetetes* and tabulatormorphs and much more sclerites of sea urchins and crinoids. Samples KB-15, KB-17, and KB-18 contained the “encrinite” layers, which are storm concen-

trates built of crinoid fragments and the spines and plates of the echinoid *Archaeocidaris rossica* Buch. Fenestellid bryozoans become most numerous at the regressive trend of the Gubastovo cycle. The fenestellid-rich interval spans a rather wide paleodepth range from the distal tempestite KB-18 up to the lagoonal mudstone KB-22. Few common features except for high muddiness is seen in this facies spectrum. Along with lacking early lithification features, the muddiness points to a boggy seafloor. The grainstone KB-23 is also rich in fenestellid fragments. There fenestellids could have been thrown from the muddy intertidal pools which are evidenced by the brecciated mudstone lenses. Large, up to 10 cm tall, funnel-shaped fenestellids have been found in situ in the mudstone SP-12. It is noteworthy that the distribution of the majority of mollusks has been biased in diagenesis, because the moulds left after early dissolved aragonite shells had been selectively eliminated in some beds. For instance, the drop in gastropod abundance in the KBf-4 may be linked to biomold degradation in the loose grainstone, and in the KBf-8 the biomolds must have collapsed under the strong lithostatic compaction typical of shales and marls. Despite this diagenetic bias, the main peaks in the abundance of gastropods (KBf-1, KBf-2,



**Fig. 10.** Biofacies indicators in the Domodedovo Formation of Peski sections; (\*) for algae: number of genera and unidentifiable phylloid and dasyclad algae, without *Claracrusta*-based oncoids; for fusulinoids: number of genera and undifferentiated Schubertellidae; for bryozoans: number of genera; for conodonts: number of genera and undifferentiated ramiform elements; for brachiopods: number of genera and undifferentiated terebratulids and linoproductids.

KBf-16) and bivalves (KBf-14–KBf-16) probably correspond to their abundance in the original benthic community.

## CONCLUSIONS

The distribution of various groups of fossils can be linked to the interpreted relative sea-level curve (Fig. 3). At least five biofacies levels are seen in the Domodedovo cyclothem of Peski: (1) the Panshino shallow subtidal assemblage, (2) the basal Gubastovo shoal to transgressive assemblage, (3) the deeper subtidal (offshore) assemblage of the cyclothem core, (4) the normal-marine “early regressive” assemblage, and (5) the lagoonal-peritidal “late regressive” assemblage. However, erection of standard oryctocoenoses or “biofacies” seems premature unless more sections are studied in a similar way.

**Panshino assemblage** of pure shallow subtidal and shoal limestones (KB-9–KB-13 and SP-1–SP-3) is distinct in having few conodonts (mostly under 5, rarely up to 20 elements/kg; Fig. 7) and bryozoans (Figs. 6, 9), the important potential reef builders (*Chaetetes* and

*Syringopora*; Fig. 9), and high brachiopod diversity (Figs. 8, 10).

**Basal Gubastovo assemblage** in the KB-14a and SP-4a largely retains the Panshino character. The two shoal grainstones KB-12 (SP-2) and KB-14a (SP-4a) are similar in having numerous phylloid algae (Figs. 4, 10) and schubertellids (Figs. 5, 10), which suggests the possibility of joining these grainstones into one “biofacies.” The transition to the offshore assemblage (KB-14b and SP-4b) is accompanied by a rapid increase in the mud fraction and siliciclastic fines, along with introducing *Zoophycos* traces.

**Offshore assemblage of cyclothem core** is recognized in the marly facies featuring storm rhythmicity (KB-15–KB-18 and SP-5–SP-8). The wackestone-packstone KB-16 (SP-6) is tentatively joined to this assemblage, since available data are insufficient to show its difference from the underlying and overlying tempestites. The increased clay content in the cyclothem core suggests long residence of clay suspension in the water column and probably overall eutrophication of the sea during highstands. This is consistent with oryctocoenosis changes. The phylloid algae are present only as rare

and worn fragments (SP-5, SP-6) most probably redeposited from the SP-4 level. The quantity and diversity of other algae-like microfossils is also decreasing (Figs. 4, 10). Chaetetids and tabulatormorhs, which are potential reef builders flourishing in oligotrophic environments, are extremely rare (Fig. 9). In contrast, drastic increase in quantity and diversity is seen for bryozoans (Figs. 6, 9, 10), conodonts (Figs. 7, 10), and pelmatozoan echinoderms. The sclerites of sea urchins and crinoids attain maximum abundance being rock-forming (Figs. 9, 10). The number of brachiopod genera is reducing (Fig. 10) mainly at the expense of smaller, and thin-shelled forms. However, the abundance of *Choristites*, *Brachythyrida*, *Admoskovia*, and *Kozlowskia* reaches its maximum in the cyclothem core (Fig. 8).

**Early regressive assemblage** occurs in the alternating mudstones and mud-dominated tempestites of KB-19–KB-21 and SP-9–SP-11. It is distinct in the virtual absence of algae (Fig. 4) and the low diversity of most fossil groups. However, the bryozoans here are diverse and numerous (Figs. 6, 10). The fusulinoid assemblage is highly dominated in *Hemifusulina bocki* Moell. (Fig. 8). The diversity of algae, fusulinoids, and conodonts is partly restored in the shallow subtidal packstone-rudstone KB-21 (SP-11).

**Late regressive assemblage** is recognized in the stress lagoonal and intertidal facies of KB-22–KB-23 and SP-12–SP-13. This interval shows the most pronounced changes in oryctocoenoses. The number of taxa and abundance of the majority of normal-marine groups is rapidly falling, but fenestellid bryozoans are abundant although of low diversity (Figs. 6, 9, 10). The bivalve and gastropod biomolds are also abundant (Fig. 9). Among fusulinoids, only schubertellids could tolerate these stress environments. Noteworthy, three of seven brachiopod genera (*Isogramma*, *Desmoinesia*, and *Hustedia*) are either extremely rare or unknown elsewhere in the Myachkovian of the Moscow Region. Very abundant *Meekella* are introduced in the upper part of the lagoonal mudstone, along with very few other brachiopods. In the tidal-flat grainstone KB-23, brachiopods are represented only by *Meekella* (Fig. 8; Pl. 2, fig. 17), and algae by *Ortonella* (Fig. 4).

Figure 10 shows some biofacies indicators. Among algae, only phylloid algae and dasyclads distinctly appear to be depth-sensitive within the given paleodepth range (Fig. 4). However, these algae were practically lacking in the siliciclastic-contaminated and muddy shallow-water environments of KB-20–KB-21. Staffellid fusulinoids appear to be another efficient indicator in the Myachkovian (Figs. 5, 10; Baranova and Kabanov, 2003). The abundance of *Archaeocidarid* sea urchins and crinoids along with numerous and diverse bryozoans may indicate an offshore subtidal environment eutrophied by increased influx of terrigenous material. Abundant *Meekella*, *Ortonella*, and low-diversity fenestellids, along with a scarcity or lack of

other brachiopods, algae, and bryozoans, definitely point to stressed shallow lagoon and tidal flat environments.

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