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Precambrian microfossil-characterized biotopes from the southern margin of the Siberian craton

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[1] The microfossils examined in acritarchs from the Neoproterozoic rocks in the southern margin of the Siberian craton have been ecobiologically interpreted. The studied sequences are of particular interest as they represent different sedimentation stages of an evolving marine basin. The conditions of sedimentation were reconstructed and the microfossil assemblages were recognized in three areas of the Sayany–Baikal fold system (SBFS). The ecological and biological affiliation of a part of the organic-walled microfossil morphotypes was revealed owing to the reconstructions and actuopaleontological comparison. Members of green and brown algae, dinoflagellates, and bacteria assemblages from different depths of the paleobasin have been differentiated. Most of organic-walled forms from the SBFS have the property of retaining volume and characters in fossil remains. A modified variant of the acritarch classification is proposed considering this capacity and in an effort to develop in the future a natural classification scheme. *INDEX TERMS:* 1023 Geochemistry: Composition of the biosphere; 1055 Geochemistry: Organic and biogenic geochemistry; 1615 Global Change: Biogeochemical cycles, processes, and modeling; 1637 Global Change: Regional climate change; *KEYWORDS:* Neoproterozoic, Siberian craton, sedimentation conditions, microfossils, acritarchs, algae, bacteria, classification.

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Introduction

[2] The discovery of hundreds of microfossil localities in the Precambrian sediments demonstrated a complicated differentiation of life that included bacteria forms and groups of algae, fungi, and animal organisms [*Martin,* 1993; *Semikhatov et al.,* 1999; *Jankauskas et al.,* 1989]. At the same time the major problem of Precambrian microfossil studies is the elucidation of biological affinity of forms from certain localities. The establishment of natural taxonomic affiliation of microfossils is the most topical issue for Neoproterozoic biotas characterized by the greatest diversity of organic remains. Most of forms derived from syngenetic flints of shallow-water biochemogenic carbonates, according to their morphology and environmental conditions, are correlated with confidence with modern cyanobacteria [*Sergejev,* 1992, 2003; see reference to *Knoll et al.,* 1991]. Organic-walled microfossils extracted using acid from terrigenous rocks are commonly referred to acritarchs (Acritarcha Evitt, 1963), a group of uncertain taxonomic position [*Jankauskas et al.,* 1989]. However, both silicified and most of organic-walled microfossils were mainly studied from shallow-water beds of paleoshelves' littoral and upper sublittoral zones. Microbiotas from deep-water sediments, let alone bathyal zones, are incomparably less known [*Akhmedov et al.,* 2000; *Horodyski,* 1993; *Moorman,* 1974]. But even the available scarce records indicate that forms of deep-water biotas differ greatly in morphology and lesser dimensions from well-known shallow-water microfossils. The knowledge of microfossil assemblages in geodynamic aspect is closely similar. Most of the Proterozoic microbiotas were found in the sediments of paleoshelves that represent relics of passive continental margins. Microfossil findings from sedimentary volcanogenic rocks of Proterozoic island-arc environments are scarce. The major reason for poor knowledge of these forms is a scarce preservation of corresponding sediments. Deep-water sediments and geologic bodies of active continental margins experience more or less intense transformation in collision zones and have a low probability to be preserved

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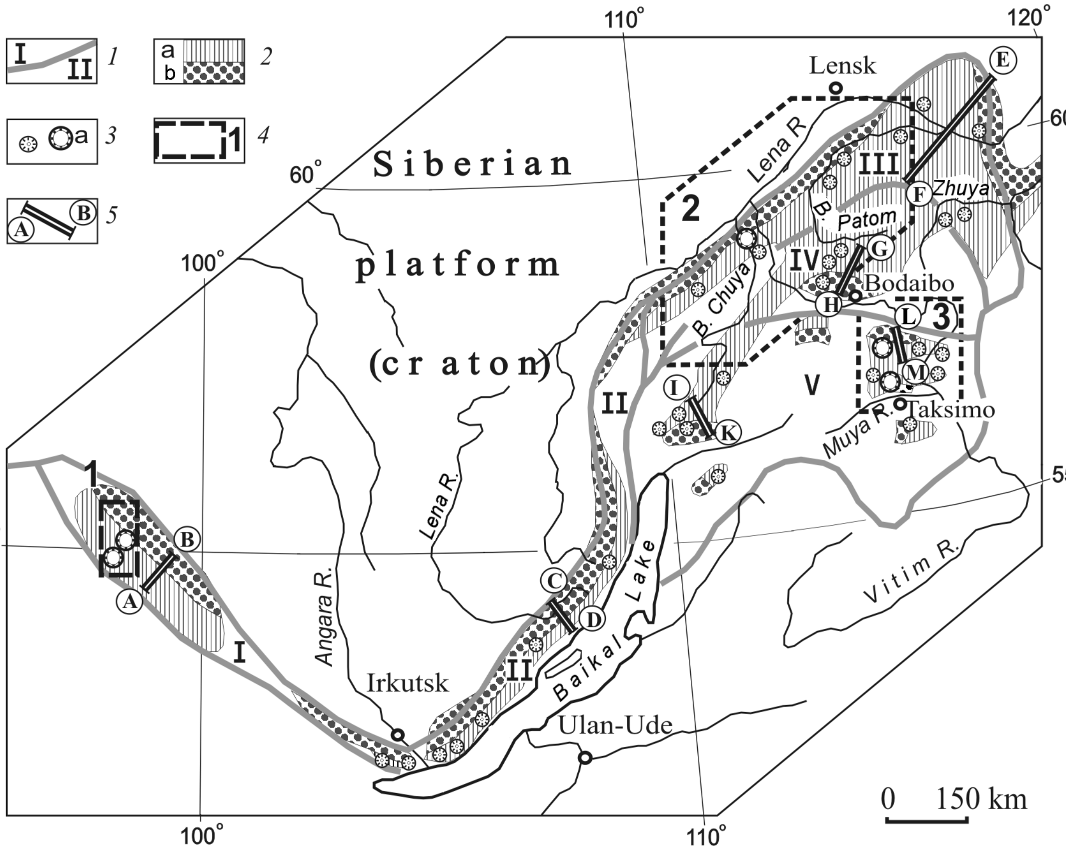

Figure 1. Sayany–Baikal fold system (SBFS): (1) outlines of SBFS, boundaries and numbers of structural formation zones and belts: zones: I – Sayany, II – Baikal, III – Patomskoe, IV – Bodaibo, V – Baikal–Muya; belts: outer, near-platform (Zones I, II, III), inner (Zones IV, V); (2) sedimentary and sedimentary volcanogenic rocks: a – Middle and Late Riphean, b – Vendian; (3) areas with microfossil localities, a – areas of detailed ecobiological interpretation of microfossils; (4) outlines and numbers of schemes illustrated in Figures 3, 4, 6; (5) lines of generalized stratigraphic profiles shown in Figure 2.

[*Reding,* 1990]. These sediments are commonly represented by tectonic fragments of intensely deformed and more or less metamorphized rocks.

[3] Among major lines of microfossil studies the microphytologic correlation is of particular interest. However, on numerous occasions, especially in the initial period of Precambrian microphytology, the chronological inferences from microfossils, lacking a paleontological base, followed the adopted stratigraphic schemes. As new records became available, the microfossils with a sufficiently complicated morphology were recorded and were used for correlation of large stratigraphic units. However, eventually the application of these microscopic and relatively poorly studied remains for correlation implies a comprehensive research permitting the separation of original groups of microorganisms. Having regard to convergent features typical of protozoans and possible affiliation of acritarch forms to different biological groups (up to kingdoms) inhabiting various environments, the use of microfossils for correlation should include records of ecologic and natural taxonomic investigations. The latter results are eventually the components of actuopaleontological correlations that are basic to evolutionary conclusions and therefore to biostratigraphic inferences. This methodical model of classic paleontology is still by far little applicable for heterogeneous assemblages of the Precambrian microremains. However, the available records already permit the attempts to separate microfossil morphotypes in hypothetically related groups.

[4] Microfossils from the late Precambrian sediments of the Sayany-Baikal fold system (SBFS) (Figure 1) have been studied for over 40 years [*Faizullin,* 1998; *Golovenok and Belova,* 1983 *Pyatiletov,* 1983; *Stanevich and Faizulina,* 1992; *Timofejev,* 1966; *Treshchetenkova et al.,* 1982; *Jankauskas et al.,* 1989]. The greater attention was focused on the elucidation of their vertical and lateral distribution in order to use them for correlation. Now it is evident that among all biostratigraphic inferences based on microfossils, the conclusions on interregional distribution of microbiota of the Urin Formation in the Late Riphean [*Faizullin,* 1998] and on a comparatively pronounced first occurrence level of the forms previously included in Subcomplex IIIa from the Siberian platform (Methodical Recommendations for Processing of

Sedimentary Rocks on Spore-Pollen Analysis, VSEGEI, unpublished report, 1986) or in Complex 4 of its southern folded surroundings [*Stanevich and Faizulina,* 1992], are worthy of notice. The first occurrence of this assemblage in the uppermost Late Riphean was recorded in tens of sections with different sedimentary facies in the SBFS area [*Stanevich and Faizulina,* 1992].

[5] The morphology and inhabited environments are still the actual criteria for comparison of modern microorganisms and Proterozoic microfossils. From this standpoint we began the ecobiological interpretation of microfossil assemblages from the SBFS sediments. The revealed relationships between geologic bodies from different areas of the outer and inner belts of the SBFS resulted in the reconstruction of Neoproterozoic geodynamic environments in the region [*Nemerov and Stanevich,* 2001; *Stanevich and Perelyaev,* 1997]. It was found out that when moving from the north to the south of the SBFS one can observe fragments of shelf, slopes, and depression of the backarc basin and remains of contrast-facies sediments of the island-arc depressions. Results of the studies of organic remains from these sediments are commonly not associated with the reconstruction of sedimentogenesis. However, as the analysis of numerous records showed, both lateral and temporal distribution of organic remains most likely resulted from the alteration of depositional conditions and their evolution in time. The available notion of microorganism habitats and burial conditions, along with the actuomorphological analysis, permitted the inference of different biological affiliation of the previously studied forms from the SBFS assemblages (Figure 2) [*Nemerov and Stanevich,* 2001]. The morphological features of microfossils allow the comparison with possible modern types of algae and bacteria, which metabolic characters better correspond to the reconstructed biotopes. The SBFS sequences have the advantage over sections from other regions that they represent environments of shelf, slope, and depression of a near-continental basin at different stages of its Late Proterozoic evolution. This paper suggests the reconstruction of sedimentogenesis environments in three SBFS areas with Neoproterozoic sediments and the ecobiological interpretation of the derived microfossil assemblages.

Age of the Sediments and the Late Proterozoic Marine Sedimentation in the Sayany–Baikal Fold System

[6] According to tectonic structure, the SBFS territory is divided into outer and inner belts (Figure 1). The structural zones within both belts differ in rock composition and degree of tectonic deformations. The geologic structures of the outer and inner belts are separated by a system of sutures and uplifts. The Early Proterozoic granitoids and sedimentary volcanogenic rocks are recovered on the uplifts. The outer belt is characterized by the most complete and well-studied sections of the Late Proterozoic and Lower Paleozoic sedimentary sequences with the established superposition. They include the Medvezhevka, Ballaganakh, Dal'netaiga, Zhuya, and Judoma regional horizons (Resolutions of the All-Union Stratigraphic Conference on the Precambrian, Paleozoic, and Quaternary of Central Siberia, SNIIGGiMS, unpublished material, 1983) that represent greater sedimentation cycles (Figure 2).

[7] The inner belt is characterized by a complicated set of fault blocks and thrust sheets of heterogeneous composition. The rocks of different age from Precambrian to Lower Paleozoic are recovered there. The Late Proterozoic is represented by igneous and sedimentary volcanogenic sequences. Among them the riftogenic, subduction, and subplatform lithocomplexes are recorded. The age of metasediments in the inner zones has long been a matter of discussion and was estimated in the range from Early to Late Proterozoic [*Fedorovskii,* 1985; *Perevalov et al.,* 1983; *Salop,* 1964; *Stanevich and Faizulina,* 1992]. The complex results of geological prospecting, radioisotopic and biostratigraphic research, and formational correlation allowed the recognition of Riphean and Vendian regional horizons in the sections of the Baikal–Muya zone (Figure 2) [*Buldygerov et al.,* 1988; *Dol'nik et al.,* 1980; *Konnikov et al.,* 1994; *Nemerov and Stanevich,* 2001; *Rytsk et al.,* 1999, 2000, 2001; *Stanevich and Faizulina,* 1992]. The sediments assigned to the Vendian (Yudomian) in the sections of both outer and inner zones are overlain by formationally similar carbonate sequences bearing the Lower Cambrian algae and fauna [*Salop,* 1964].

[8] The absence of radiochronologic records and ambiguity of correlative importance of the phytolith and microfossil interregional forms leave the question on the range of the Upper Riphean in reference sections of the outer zones open to discussion [*Stanevich and Faizulina,* 1992]. The extreme age estimates of basal layers of the Dal'netaiga Horizon [*Dol'nik,* 2000; *Khomentovsky et al.,* 1985, 1998] differ by over 300 million years. Most of microfossils known from the SBFS are rare in the Proterozoic sediments of other regions [*Stanevich et al.,* 1999], however, the findings of specimens with a complicated morphology [*Faizullin,* 1998; *Pyatiletov,* 1983] most likely indicate the Late Riphean age of the Dal'netaiga Horizon. The first occurrence of major taxa of this "microbiota" was recorded in the Neoproterozoic sediments in Australia, China, Spitsbergen, and Uchur-Maiskii region of Siberia [*Khomentovsky et al.,* 1998].

[9] As regards the Middle–Late Riphean boundary in the SBFS sections, there are two approaches to the problem. According to a traditional one, the boundary is defined by means of interregional correlation based on phytoliths and microfossils or using the evidence of great tectonic transformations. Despite a great amount of records used for these correlations, the final results are ambiguous. A comprehensive interregional correlation can be supplemented with the data of intraregional correlations and with the recently obtained reliable isotopic datings of igneous rocks from the Baikal–Muya zone.

[10] The Dal'netaiga and Zhuya regional horizons are recorded in both outer and inner [*Nemerov and Stanevich,* 2001; *Stanevich and Faizulina,* 1992] belts of the SBFS (Figure 2). The reliable isotopic datings from sedimentary volcanogenic sequences referred to these horizons fall in the interval from 650 to 850 Ma [*Buldygerov et al.,* 1988; *Rytsk et al.,* 1999, 2000, 2001; *Sklyarov et al.,* 2003]. Thus


I
Sayany zone
II
Baikal zone
III
Patom zone
IV
Bodaibo zone
V
B a i k a l - M u y a z o n e
Olokit-Kholodnaya region
Delyun-Uranskii Range
A
B
C
D
E
F
G
H
I
J
K
L
a
b
Є1
V
Jd
Zn
Dl
R3
Bl
R2-3
Md
PR1
pr
us
ust
ais
mrn+ud
ip
tg
shn
743
ain
kr
ush
kc
ul
gl
ng
ht
rs
cs
nh
tn
zr
cn
nk
kl
ur
vl
br
dz
mr
bg
hv
hr
md
il
dg
an
vc
au
im
hm
ug
bz
bd
kk
tk
old
hl
avg
sn
as
on
pm
pdv
it
st
okt
ts
670
711
727
825
jng
sd
pdr
sm
dl
jk
jkr
dlg
kln
vd
uur
urh
dn
663
704
812
823
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
812
Vertical scale
1 km

among all variants of interregional correlation the above-mentioned records to a greater extent than others [*Dol'nik,* 2000; *Stanevich and Faizulina,* 1992] confirm the assignment of the Dal'netaiga and Zhuya sediments to the upper half of the Late Riphean [*Khomentovsky et al.,* 1985, 1998; *Shenfil',* 1991]. The biostratigraphic data substantiating the age of the SBFS regional horizons in the unified scheme do not contradict with the Late Riphean position of the Dal'netaiga Horizon.

[11] The continental rift, volcanic arc, backarc basin, and orogenic belt geodynamic environments were reconstructed for different periods of the Late Precambrian history of the SBFS [*Dobretsov and Bulgatov,* 1991; *Konnikov et al.,* 1994; *Nemerov and Stanevich,* 2001; *Stanevich and Perelyaev,* 1997]. The Riphean–Vendian sediments represent three major stages of the region evolution, namely, the Medvezhevka–Ballaganakh, Dal'netaiga–Zhuya, and Judoma (Figure 2).

[12] At the **Medvezhevka–Ballaganakh stage** the sediment deposition occurred in the riftogenic marine basin [*Dobretsov and Bulgatov,* 1991; *Korobeinikov,* 1990; *Nemerov and Stanevich,* 2001]. Initially (Figure 2) the riftogenic troughs were filled with coarse detritus. Basalt effusion occurred along the faults that confined troughs. The inherited downwarping resulted in the extension of the basin. The environments favorable for deposition of fine-grained carbonaceous sediments appeared in its distant and deep parts. Finally, as the trough became filled with terrigenous sediments, the carbonate shallow deposits were deposited throughout the basin. Concurrently the deposition of carbonate terrigenous sediments of the Oktolokit, Stoibishchnaya, and other formations occurred in the Baikal–Muya zone. The terminal stage of the riftogenic development is represented by laterally continuous uppermost beds of the Ballaganakh Horizon, which are of regional correlative importance and underlie the sediments referred to the Dal'netaiga Horizon in the sections of the outer and inner zones.

[13] The sediment deposition of the **Dal'netaiga–Zhuya stage** (Figure 2) occurred in the basin characterized by marginal marine environments, mainly by island-arc complexes inferred for the Baikal–Muya zone. The stage began with the sea transgression towards the craton margin. The sedimentation was of cyclic character. During an active downwarping the heterogranular clastic rocks were deposited, then followed by clayey carbonaceous and carbonate sediments. The analysis of facies composition and relationships permits to reconstruct of transverse profiles of that part of the basin where shelf areas (Baikal and Patomskoe zones), back-arc basin depression (Bodaibo zone), and island-arc system have been established (Baikal–Muya zone) (Figure 2). The position of island arcs is confirmed by interpretation of fragments of ophiolitic suites as derivatives of the back-arc basin spreading [*Dobretsov and Bulgatov,* 1991; *Stanevich and Perelyaev,* 1997].

[14] Sediments of the outer, near-platform zones of the Dal'netaiga period (Figure 1) represent different types of shelf sedimentation. In the Baikal area a combination of phytolithic constructions and beds and lenses of finely terrigenous sediments of the Uluntuiskaya Formation is characteristic of littoral and inner sublittoral environments with

Figure 2. Correlation of Late Precambrian geologic bodies in the Sayany–Baikal fold system (SBFS). Microfossil localities and their ecobiological interpretation. a – general chronological scale; b – regional horizons (series) of SBFS: Md – Medvezhevka; Bl – Ballaganakh; Dl – Dal'netaiga; Zn – Zhuya; Jd – Judoma. (1–6) microfossil ecobiological groups (explanations see below); (7) conglomerates and breccia-conglomerates; (8) gravelstones and polymictic, arkose-graywacke sandstones; (9) quartz sandstones; (10) siltstones; (11) argillites, silty argillites; (12) carbon-bearing argillites and silty argillites, sign of carbonaceous sediments; (13) limestones, sandy limestones, interbedded limestones and silty argillites; (14) dolomites, sandy dolomites, interbedded dolomites and silty argillites; (15) dolomitic limestones, calcareous and silty argillitic dolomites; (16) marls; (17) carbonates bearing stromatolites and microphytoliths; (18) granite, plagiogranite; (19) acidic volcanic rocks; (20) intermediate volcanic rocks; (21) basic volcanic rocks; (22) tuffs and tuffites; (23) boundaries of regional horizons; (24) isotopic age: 743±47 (Sm-Nd isochron) [*Sklyarov et al.,* 2003]; 670±65 (Rb-Sr isochron) [*Buldygerov et al.,* 1988]; 663±3, 704±71, 812±19, 823±2, 825±3 (Sm-Nd isochron and U-Pb by zircon) [*Rytsk et al.,* 1999, 2001]; 711±6, 727±18 (U-Pb by zircon) [*Rytsk et al.,* 2000]. Formations and sequences: ai – Aiktin; ain – Ayanka; ais – Aisa; an – Anangra; as – Asektamur; au – Aunakit; avg – Avgol; avk – Avkit; bd – Bodaibokan; bg – Bugarikhta; br – Barakun; bz – Buzhuikhta; cn – Chencha; cs – Chaya; dg – Dogalda; dl – Delyun; dlg – Dzhalagun; dn – Dannaya; dz – Dzhemkukan; gl – Goloustnaya; gr – Gramdakan; hl – Kholodnaya; hm – Khomolkha; hr – Kharlukhtakh; ht – Khoty; hv – Khaiverga; il – Iligir; im – Imnyakh; ip – Ipsit; it – Itykit; jk – Yakor; jkr – Yakrin; jng – Yanguda; kc – Kachergat; kk – Kooktin; kl – Kalancha; kln – Kelyana; kr – Kurtun; md – Medvezhevka; mm – Mamakan; mr – Mariinskii; mrn – Marnin; ng – Nugan; nh – Nokhtuisk; nk – Nikolskoe; okt – Oktolokit; old – Oldakit; on – Ondoko; pdr – Padrokan; prv – Protivodavan; pm – Pravomam; rs – Rassokha; sd – Sidel'tin; shn – Shangulezh; sm – Shumnyi; sn – Synnyr (Inyaptuk volcanic complex); st – Stoibishchnaya; tg – Tagul; tk – Tukolamii; tn – Tinnaya; ts – Tyya; ud – Uda; ug – Ugakhan; ul – Uluntuiskaya; ur – Urin; urh – Uryakh; us – Usol'e; ush – Ushakovo; ust – Ust'tagul; uur – Ust'uryakh; vc – Vacha; vd – Vodorazdel'naya; vl – Valyukhta; zl – Zolotoi; zr – Zherba; pr – Primorskii granite complex. Ecobiological groups (symbols 1–6): (1) anaerobic, sulfate-reducing, and other (?) bacteria, marine benthos from different depths; (2) aerobic sulfur bacteria, shallow marine benthos; (3) dinoflagellates or aerobic prostecobacteria, facultative marine plankton; (4) cyanobacterial, mainly littoral assemblages; (5) acanthomorphic and other eucaryotic algae, mainly plankton; (6) green algae, facultative marine plankton. Microfossil species and genera referred to ecobiological groups are shown in Table 1.

contrasting facies relationships in the bioherm areas. In the northern Patomskoe zone the prodelta of a large stream occurred, which resulted in a heterogeneous facies composition of the Valyukhta, Urin, and other formations composed of quartz sandstones and chemobiogenic carbonates likely formed in the offshore area at a depth down to 50 m. In southeastward direction (the Zhuya River) the carbonates grade into silty pelitic cyclic sediments with finely ribbon banding, formed in the distal part of the shelf at depths over 100 m. Further southwards, in the Bodaibo zone the level corresponding to the Valyukhta Formation is represented by carbonaceous, terrigenous sediments of the Khomolkha Formation. These flyschoid deposits with graded bedding and traces of turbidity currents are characteristic of the continental slope and continental rise environments formed at possible depths of 400 m to 2000 m [*Kennett,* 1987]. The overlying carbonaceous quartz sandstones and silty pelites of the Zhuya Horizon (Aunakit and Vacha formations) were formed in stagnation conditions in the most downwarped part of the paleobasin. In the Baikal–Muya zone the Valyukhta sedimentogenesis is represented by fragments of sedimentary volcanogenic sections (Dzhalagun, Ondoko, and other formations, Figure 2) bearing products of aerial volcanism. The volcanic activity significantly affected the geochemical properties of sediments of the Valyukhta and other formations from the northern areas [*Nemerov,* 1988; *Nemerov and Stanevich,* 2001].

[15] The sediments of the Zhuya Horizon in the Patomskoe zone (Figures 1 and 2) were deposited in conditions of clayey carbonate sedimentation on a prograding shallow shelf platform with following wide distribution of stromatolite biostromes in the late Zhuya period. In the Bodaibo zone (Figure 2) the variegated marls of the Imnyakh Formation were deposited in a distal part of the shelf platform, which sharp downwarping in the upper Zhuya period resulted in deposition of highly carbonaceous, sandy and silty pelitic deposits of the Vacha Formation. Turbiditic textures indicate large depths and stagnation in this part of the paleobasin. The maximum values of carbonaceous component in the Vacha sediments correlated with the biochemogenic carbonates of the Patomskoe zone [*Nemerov,* 1988; *Nemerov and Stanevich,* 2001], indicate a high biological productivity of deposits. In the Baikal–Muya zone (Figure 2) the carbonaceous silty pelites are associated with lavas of contrasting composition and with psammitic tuffs and tuffites of andesite–dacite series (Asektamur, Ust'-Kelyana, and other formations/sequences). In the Baikal zone the late Kachergat sedimentation was characterized by stagnant conditions in deep parts of the middle and distal shelf. Against the background of stagnant depositional conditions the Kachergat Formation is marked by the appearance of polymictic psammitic material. These records define the pre-Judoma conditions of sedimentation in all zones as stagnant and preorogenic, indicating the alteration from a back-arc to foreland basin environment [*Nemerov and Stanevich,* 2001].

[16] The sediments of the **Judoma stage** are represented by two formation types. The platform type, characteristic of proximal and middle shelf areas, is recorded in the sections of the Patomskoe zone and eastwards. It is represented by quartz sandstones, silty pelites, and chemobiogenic carbonates (Zherba Formation, Figure 2). The Siberian platform was the source of the material. Towards the Baikal zone the detrital composition of terrigenous facies grades from quartz through arkosic to polymictic and fragments' dimensions increase up to pebble size. These molassoid sediments of the Judoma Horizon are the most characteristic of the SBFS inner zones. The thickness of the horizon reaches there 7 km and the lower parts of the sections are commonly represented by graywacke, coarsely grained tuffites, and hybrid turbidites (Ushakova, Anangra, Dogalda, Kholodnaya, and other formations, Figure 2). The local uplifts separating troughs of sublatitudinal extension served as a source of detritus.

[17] The second half of the Yudomian in different zones of the SBFS is characterized by a similar type of shallow carbonate terrigenous sediments. Compensation sedimentation occurred in the relict depressions of the basin. Its rapid filling and flattening of topography resulted in the formation of a relatively shallow but extended basin. In the Lower Cambrian its carbonate deposition expanded throughout the Siberian platform and adjacent SBFS areas [*Khomentovsky et al.,* 1972; *Salop,* 1964].

Methods of Microfossil Study

[18] Microfossils from terrigenous sediments were studied under light and electron microscopes in the organogenic residue of dissolved samples and in silty argillite petrographic slides. The thin sections were, wherever possible, approximated to the plane of metasediment layers. The dissolution was carried out according to a standard palynological procedure [*Timofejev,* 1966] using HF and HCl acids. Owing to small size, most of specimens were studied under immersion lenses. To provide a greater sterility of maceration, the processing was supplemented with an additional phase. The samples crushed to 0.5–1-cm fragments were repeatedly (12 to 15 times) washed with water. Thereupon rock fragments were partially dissolved in HF acid during 20 to 40 minutes and again repeatedly washed (12 to 15 times). These operations were followed by a complete dissolution and other standard phases of maceration process. Before the preparation of organic residues for studies under scanning electron microscopes Philips Sem 525M and XL30 ESEM TMP, they were processed in hydrogen peroxide with subsequent heating in nitric acid to boiling temperature, in order to remove a fine clayey carbonaceous fraction. The specimens were photographed digitally using SEM and under light microscope – using a common photomicrocamera with subsequent scanning of images.

Late Riphean Environments of Sedimentation, Microfossil Aassemblages, and Their Ecobiological Interpretation

The Sayany Zone

[19] Until recently microfossils were almost unknown in thoroughly studied Neoproterozoic rocks of the Sayany zone [*Dol'nik,* 2000; *Dubin et al.,* 1969; *Khomentovsky et al.,* 1972] (Figures 1 and 2). Our research showed that the sediments of the region yield acritarchs that were previously found in a lot of Late Precambrian "microbiotas".

[20] The Late Riphean age of the Ipsit Formation and the whole Karagasskii Series (Figure 3) was determined by radiologic records and substantiated by biostratigraphic correlation and historical geological reconstructions [*Dol'nik,* 2000; *Khomentovsky et al.,* 1972]. Radiometric datings of 20 gabbro–diabase whole-rock samples of the Nersin complex intruding the Karagasskii Series sediments, which were obtained in 1970s, indicate the age interval ranging from 783 to 959 million years [*Domyshev,* 1976]. Subsequently a Sm–Nd age determination of 743±47 Ma was derived from basaltoids referred to the Nersin complex [*Sklyarov et al.,* 2003]. The degree of transformation of the Ipsit rocks in all sections is alike and corresponds to boundary conditions between diagenesis and initial metamorphism.

[21] The analysis of sedimentation textures and composition of siltstones and sandstones revealed that three studied sections represent fragments of a lateral succession of the Ipsit shelf environments. In this series two groups of environments are recognized. Sections 1 and 2 (Figure 3) are characteristic of the first group. Section 2 demonstrates the formation of an infra- and supratidal carbonate platform and the following transgression with deposition of laminite siltstones in the proximal inner shelf part. The deeper shelf environment is represented by low-angle cross-bedded sandstones and siltstones of Section 1 that were deposited in the zone between wave bases of calm weather and storms. The immature composition of clastic material, from feldspathic-quartz to arkose, and slightly rounded fragments indicate a prevailing erosion of granitoid massifs lacking a developed waste mantle.

[22] Silty sandstones of Section 3 (Figure 3) represent the second environmental group. In the Mount Krasivaya scar one can observe numerous tempestite layers composed of fine-grained sandstones, mainly 10 cm to 100 cm thick, which form composite beds up to 250 cm thick and sets with the thickness up to 10–15 m. Tempestites are characterized by a typical for storm beds succession of textures and by lumpy cross-lamination [*Dott and Bourgeois,* 1982; *Walker and Plint,* 1992]. As a whole the sedimentologic analysis of the lower subformation of the Ipsit Formation permits the inference about deposition of mainly proximal storm deposits on a gentle slope and rare penetration of inner shelf environments in the zone. The clastic component of silt- and sandstones is represented by feldspar and, scarcely, quartz, which indicates a prevailing erosion of syenite massifs.

[23] Microfossil assemblages derived from siltstones and argillites of Sections 1 and 2 are taxonomically similar and differ from the assemblage of Section 3. Among the first microfossil group (Samples 119/3, 120/3, 4) rounded nontransparent corpuscles of size 0.5 to 12 μm (Plate 1, fig. 20) are the most numerous numbering hundreds of specimens. The rest forms have clear characters of outer and inner morphology, which allow their assignment to certain acritarch taxa [*Stanevich and Faizulina,* 1992; *Jankauskas et al.,* 1989]. The studied preparations include tens of specimens of *Bavlinella* div. sp., composed of small spheroids or cells (Plate 1, figs. 21–24). According to the presence of small spines along the outline, inner radial arrangement of spheroids, and to other features, the forms were attributed to intergeneric taxa (Plate 1, figs. 13, 27) [*Stanevich and Faizulina,* 1992]. Various volumetric envelopes of polyhedral and rhomboidal outline are characteristic of the species of *Octoedryxium* Rud. (Plate 1, figs. 8–12, 14–16, 17, 19). A complicated polyhedral flowery morphology and the presence inside of smaller compactions with analogous outline permit the assignment of other forms to *Floris* Stan. Inner zonal compactions are characteristic of the species of *Centrum* Stan. (Plate 1, figs. 13, 18).

[24] Microfossil depositions associated with the carboniferous-ferruginous layers of Sections 1 and 2, were studied in slides derived from siltstone and argillite beds (Plate 1, figs. 1–3). The most numerous small rounded or rhomboidal forms number first hundreds of specimens. Tens of *Octoedryxium* div. sp. specimens of size 14 μm to 24 μm are observed on a slide; in rare cases certain species can be identified among them (Plate 1, figs. 3–7). Some forms are characterized by a reticulate inner structure and radial morphology. Rounded, thick-walled specimens of *Margominuscula rugosa* Naum. em. Jank or *Retiforma* sp. are also present (Plate 1, fig. 25). Judging from red color of many forms or their inner elements, the polymerous envelopes contain ferric hydroxides. It should be noted that the inner structure of microfossils is more difficult to recognize in thin sections than in macerated preparations, owing to a background superimposition of mineral particles.

[25] The organogenic material of the second group from Section 3 is represented in both preparations and slides by a pellicular detritus and similar acritarch composition (Plate 1, Sample 130/6, 8). Though *Leiosphaeridia* Eis. em. Downie et Sar. forms of size 60 μm to 450 μm (Plate 1, figs. 28–30, 33–37, 40) number in the first hundreds of specimens, they constitute no more than 5% of coalificated detritus that possesses a similar with acritarchs degree of textural degradation. The same ratio is observed in slides, where similarly preserved thallus fragments occur as well (Plate 1, fig. 32). The plant detritus bearing microfossils is associated with dark siltstone and argillite layers of 3 mm to 15 mm thick reflecting the episodes of poststorm calming. This sediment represents a concentrated deposition of plant remains stirred up from more shallow parts of the shelf. The conservation of organogenic material resulted from subsequent poststorm deposition of a fine silt and pelite, almost barren of organic matter.

[26] Under an electron microscope the piercing of the degraded specimen of *Leiosphaeridia* div. sp. by pyrite crystals of likely syngenetic origin is observed (Plate 1, fig. 29).

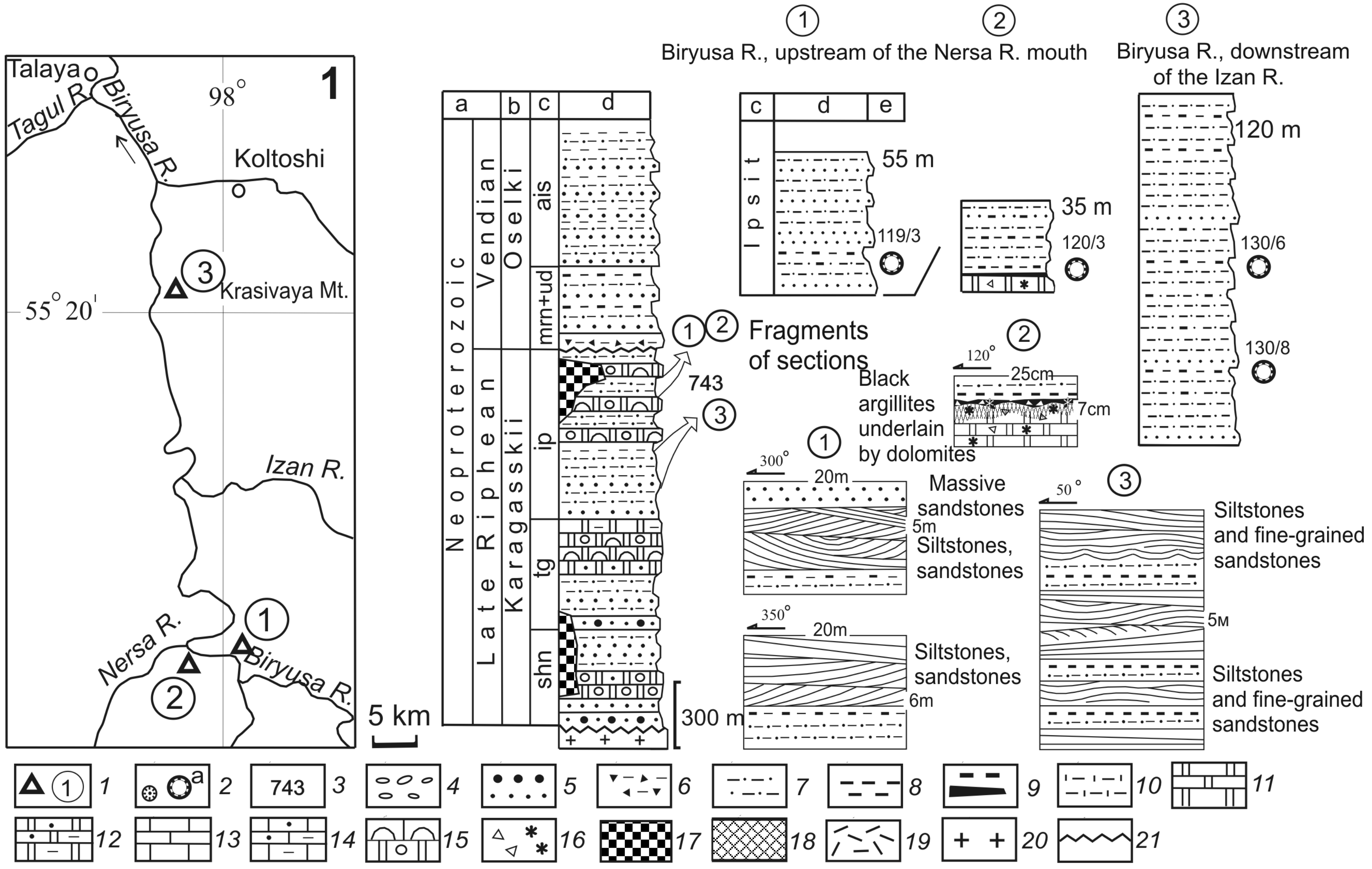

Figure 3. Geographic and stratigraphic position of microfossil localities on the Biryusa River (inset 1 in Figure 1): (1) studied sections bearing microfossils; (2) microfossil localities, a – described in the paper; (3) isotope ages (in more detail see Figure 2); (4) conglomerates; (5) gravelstones and sandstones; (6) diamictites; (7) siltstones; (8) argillites, silty argillites; (9) carbon-bearing argillites and silty argillites; (10) marls; (11) dolomites; (12) sandy and clayey dolomites, interbedded dolomites and silty argillites; (13) limestones; (14) sandy and clayey limestones, interbedded limestones and silty argillites; (15) stromatolite and microphytolitic dolomites and limestones; (16) synsedimentation breccia and silicification; (17) basic volcanic rocks and intrusions; (18) acidic volcanic rocks; (19) tuffs and tuffites; (20) granite, granodiorite; (21) unconformable overlying with a hiatus. Stratigraphic columns: a – general stratigraphic scale, b – series and regional horizons, c – formations, sequences, d – lithology; e – thickness, m, numbers of slides and preparations with microfossils, isotope age records.

In the slides one can see the transfixion of specimens by rock fragments, which explains the presence of holes in some organic-walled forms. For instance, in the form referred to *Leiosphaeridia* aff. *kulgunica* Jank. (Plate 1, fig. 34) the hole produced by pressing in of a 60-μm quartz grain can be taken on examination in preparations for a biologically important character [*Jankauskas et al.,* 1989].

[27] Small microfossil specimens occur in the redeposited detritus (Plate 1, fig. 38). On examination under electron microscope the interesting remains were recorded that differ from known microfossils (Plate 1, fig. 39). They represent an outgrowth composed of tubes with well-pronounced stomas. The outgrowth is connected by another end to desintegrated detrital matrix that includes acritarchs *Leiosphaeridia* div. sp.

[28] As is seen, the two studied groups of environments are associated with different acritarch assemblages. The records mentioned above and previous investigations [*Nemerov and Stanevich,* 2001; *Stanevich and Faizulina,* 1992; *Stanevich et al.,* 1999] permit the inference on the acritarch nature. Among the first group the forms of *Centrum* Stan., *Floris* Stan. and *Octoedryxium* Rud. can be referred to allochthonous taxa, which is confirmed by their random arrangement in relation to other forms and to inner textures of the layers. Orthorhombic outline of *Octoedryxium* Rud. can result from the crystallization of captured sulphur and its subsequent diffusion from cells of aerobic sulfur bacteria in the diagenesis [*Stanevich et al.,* 1999]. This suggestion agrees well with their occurrence in the subaerial carbonate platform zone, where they likely conducted a benthic mode of life. Morphological features of star-shaped *Floris* Stan. and zonal *Centrum* Stan. indicate their more likely planktonic mode of existence. These layers also yield small volumetric forms of *Bavlinella* Shep. and others, which in contrast to the above-mentioned microfossils are clearly associated with lenses and spots of carbonaceous matter. Their attribution to the saprophytic benthic bacteria *in situ* is confirmed by numerous examinations of such forms in slides of carbonaceous silty pelites barren of other taxa from the Valyukhta, Goloustnaya, Dzhalagun, Kachergat, and other SBFS formations [*Nemerov and Stanevich,* 2001; *Stanevich and Faizulina,* 1992].

[29] The allochthonous character of acritarchs of the second group is beyond question. Their specimens are completely flattened, corroded and, like plant detritus, are at final stages of degradation. There is no alternative yet to the evident enough conclusion on correspondence of *Leiosphaeridia* Eis. forms to reproductive organs of brown algae [*Kir'yanov,* 1986]. It is believed that their destructed forms and algae detritus were transported from shallow areas to the deeper zone of tempestite deposition. Further destruction manifested not only in small coccoid forms related to bacteria, but in evolution of more advanced organisms, occurred there. The tubular forms "growing" from the organogenic mass of allochthonous origin likely represent remains of benthic red algae. Compared to other algae, they are mostly characterized by a parasitic mode of life, rapid adaptation to changing environmental conditions, and by distribution at greater depths [*Vasser et al.,* 1989]. There is likely a fragment of overtopped thallome growing on the transferred algae remains and rapidly buried under silty deposit.

[30] The recognized two ecobiological acritarch groups, despite their somewhat debatable biological interpretation, include relics of different superior taxa of natural classifications. However, the morphological and paleoecologic differences of the forms only indirectly manifest their natural taxonomic position. The first group includes microfossils of various morphology, which are unified by such features as volumetric envelopes and the presence of inner characters. Their dimensions range from 5 μm to 20 μm, at times reaching 44 μm. The second group of microfossils is almost monogeneric and contains forms of mean size from 60 μm to 450 μm. In the Ipsit Formation they are mainly characterized by crumpled and flattened specimens and a high degree of destruction of them and associated plant matrix. The latter also contains volumetric forms of bottom bacteria destructors, similar to small microfossils of the first group.

[31] Thus a distinct difference between acritarchs of the two groups, which in this context can be explained only by their biological nature, is manifested in the dissimilar tolerance to the common factors of syngenesis and initial metamorphism. This difference indirectly confirms the suggested attribution of acritarchs to various taxa of algae and bacteria.

The Patomskoe Zone

[32] The sediments in this area, as that in the former, represent various near-continental shelf environments. The Chencha Formation is assigned to the upper part of the Zhuya regional horizon that is overlain by basal beds of the Judoma Horizon correlated with the Vendian [*Khomentovsky,* 1985]. An uninterrupted, 75-m-thick fragment of the upper part of the Chencha Formation, bearing microfossils, is located on the left bank of the Bol'shaya Chuya River (Figure 4). It is composed of clayey–silty sediments characterized by thin rhythmic bedding and bearing thin limestone layers. The rocks of the Chencha Formation are conformably overlain by quartz gravel- and sandstones of the Zherba Formation of the Judoma Horizon. In the northeastward direction the thickness of the Chencha Formation significantly increases and it mainly contains stromatolite and microphytolithic limestones interbedded with siltstones, marls, and fine-grained quartz sandstones. West of the Bol'shaya Chuya River the Chencha Formation slightly increases in thickness and in its upper portion the carbonaceous sediments replacing upwards shallow stromatolite limestones, indicate the stagnation in this part of the basin. It can be inferred that the major part of the formation was deposited on the inner-shelf carbonate platform [*Khabarov,* 1999]. The upper Chencha beds in the section on the Bol'shaya Chuya River represent shallow-water conditions of significantly siliciclastic, passive sedimentation that resulted likely from a transverse ledge of the shelf that separated areas of stromatolite constructions in the early Chencha time. In the later Chencha period this ledge separated stromatolite carbonates of the shelf platform in the east from carbonaceous clayey limestones that were de-

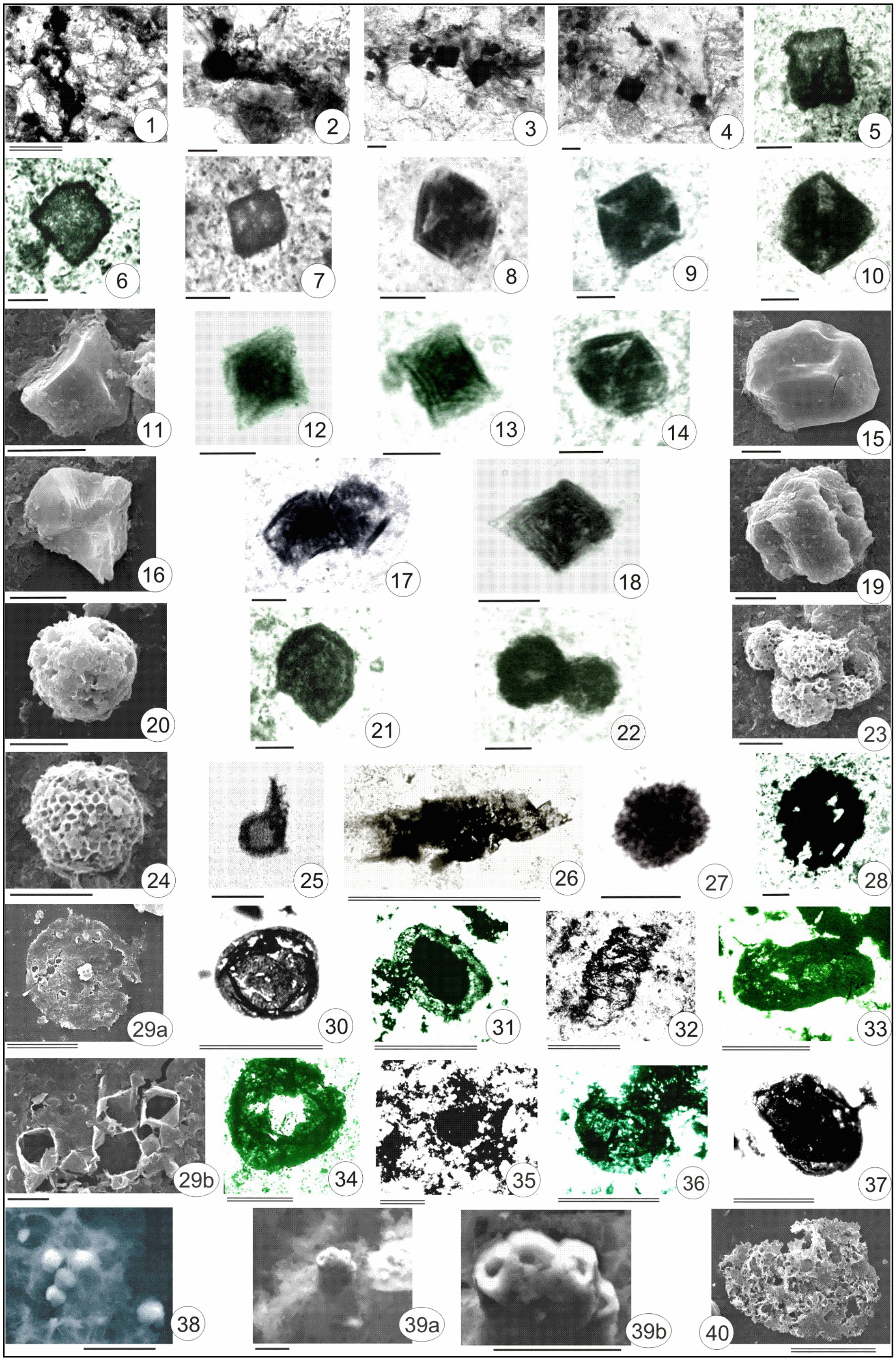
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Plate 1. Fig. 1. General view of silty deposit and microfossil depositions in the carbon-bearing cement. Slide 120/3. Fig. 2. *Bavlinella div. sp.* in the carbon-bearing cement of siltstone. Slide 120/3-1/3. Figs. 3, 4, 5. *Octoedryxium div. sp.* in the carbon-bearing cement of siltstone. 3 – Slide 120/3-1/6; 4 – Slide 120/3-1/1; 5 – Slide 119/3-1/1. Figs. 6–10. *Octoedryxium truncatum* Rudavskaja. 6 – Slide 119/3-6; 7 – Slide 119/3-3/3; 8 – Preparation 119/3-3/39; 9 – Preparation 119/3-3/13; 10 – Preparation 119/3-3/27a. Figs. 11, 12, 16, 17. *Octoedryxium div. sp.* 11 – Macerate 119/3-L15 (SEM); 12 – Preparation 120/3-a8; 16 – Macerate 119/3-L17 (SEM); 17 – Preparation 119/3-3/23. Fig. 13. *Centrum sp. (ad lib. Octoedryxium sp.).* Preparation 120/3-a3. Figs. 14, 15, 19. *Octoedryxium aff. neftelenicum* Rudavskaja. 14 – Preparation 119/3-3/39; 15 – Macerate 119/3-L05 (SEM); 19 – Macerate 119/3-L19 (SEM). Fig. 18. *Centrum aff. quadratum* Stanevich. Preparation 120/3-a4. Figs. 20, 38. *Protosphaeridium (?) div. sp.* 20 – Macerate 119/3-L18 (SEM); 38 – Macerate 130/6-P12, P13 (SEM). Plant detritus with coccoid forms (saprophytic bacteria). Fig. 21. *Bavlinella cf. variabilis* (Moorman) Stanevich. Preparation 119/3-3/5. Figs. 22–24. *Bavlinella div. sp.* 22 – Preparation 119/3-3/22, accretion of forms; 23 – Macerate 119/3-L09 (SEM); 24 – Macerate 119/3-L08 (SEM). Fig. 25. *Margominuscula rugosa* Naumova, emend. Jankauskas. Preparation 120/3-a2. Fig. 26. Fragment of plant tissue. Preparation 119/3-2/13. Fig. 27. *Bavlinella sp. (ad lib. Micrhystridium sp.).* Preparation 119/3-2/19. Fig. 28. *Leiosphaeridia holtedahlii* (Timofejev) emend. Jankauskas. Slide 119/3-1/19. Figs. 29, 36, 37, 40. *Leiosphaeridia div. sp.* 29 – Macerate 130/6-L01, L02 (SEM), a – general view, b – fragment with traces of pyrite (?) crystals' piercing; 36 – Preparation 130/6-2/3; 37 – Preparation 130/6-4/2; 40 – Macerate 130/6-L05 (SEM). Fig. 30. *Leiosphaeridia minutissima* (Naumova) emend. Jankauskas. Preparation 130/6-4/15. Fig. 31. *Pterospermopsimorpha insolita* Timofejev, emend. Mikhailova. Preparation 130/6-2/13. Fig. 32. *Plicatidium cf. latum* Jankauskas. Slide 130/8-2/3. Fig. 33. *Leiosphaeridia laminarita* (Timofejev) emend. Jankauskas. Preparation 130/6-2/5. Fig. 34. *Leiosphaeridia aff. kulgunica* Jankauskas. Slide 130/8-1/1; a transfixing quartz grain (60 μm) in the center. Fig. 35. *Leiosphaeridia jacutica* (Timofejev) Mikhailova et Jankauskas. Slide 130/8-3n, crossed nicols; the form in a carbonaceous quartz–feldspar cement of siltstone. Fig. 39. Tubulose forms (red algae?) in the organogenic disintegrated matrix. Macerate 130/6-P04, P05 (SEM).
The material is deposited in the Institute of the Earth's Crust, Siberian Division, Russian Academy of Sciences, in Irkutsk. Locality: East Siberia, Sayany zone, Biryusa River, Late Riphean, Ipsit Formation. Sources of illustrations: biological preparations, petrographic slides, scanning electron microscopes (SEM). Scale bars: single – 10 μm, twofold – 100 μm.

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posited westward in a local shelf trough. This depression most likely represented an apical fragment of the deep part of the pre-Vendian foreland basin characterized by a stagnant carbon-producing biolithogenesis [*Nemerov and Stanevich,* 2001]. Thus the upper Chencha beds in the Bol'shaya Chuya River section were deposited in an upper sublittoral environment with a passive sedimentation regime. The background deposition of silt and organogenic microfossil-bearing layers occurred within a likely isolated by barrier reefs part of the shelf, without a significant influence of storms and intense currents.

[33] New genera and species from the Chencha Formation were described previously [*Stanevich,* 1986; *Jankauskas et al.,* 1989]. Subsequently that and additionally available material was studied more thoroughly. The revision revealed a group of forms that, according to morphology and mean size of 7 μm to 35 μm, are comparable to certain members of modern green algae. Almost all preparations from 18 samples contain hundreds of forms that can be assigned to several acritarch genera and species.

[34] Among the Chencha acritarchs *Dictyotidium minor* Stan. was distinguished (Plate 2, figs. 1–6); in [*Stanevich,* 1986]: Plate 2, figs. 4–7); subsequently, independently of the author, it was published again within the new genus *Dictyotidia* [*Jankauskas et al.,* 1989]. The occurrence of forms of *Dictyotidium* Eis. emend Stapl. in the Precambrian sections was soon confirmed by the description of *D. fullerene* Butt. from organogenic carbonates of Spitsbergen, synchronous with the Chencha Formation [*Butterfield et al.,* 1994]. The investigation of *Dictyotidium minor* Stan. under an electron microscope revealed the features indicating its similarity to modern coenobial green algae *Pediastrum boryanum* (Turp.) Menegh. This species, along with *P. kuwraiskyi* Schmidle, was discovered among fossil remains and is characterized by a coenobial structure of 4 to 128 and over cells. The cells are differentiated into outer and inner ones, commonly closely accreted by all sides [*Tsarenko,* 1990; *Van den Hoek et al.,* 1995; *Vasser et al.,* 1989]. The outer cells are grooved, with two non-branched, slightly narrowed to the top shoots, fitted with long, narrow appendages in the coenobium plane. The illustrated on the photo ribs or nodes of *D. minor* (Plate 2, fig. 3) are most likely the accreted appendages formed by outgrowths of the cell envelope.

[35] The Chencha "microbiota", along with forms of *D. minor*, includes rounded and tetrahedral *Tchuja* and *Centrum* Stan., the forms morphologically transitional between them, their clusters, and other acritarchs (Figure 5; Plate 2). According to their characters, these forms and especially *Centrum* Stan. (Plate 2, figs. 14–17, 22) are similar

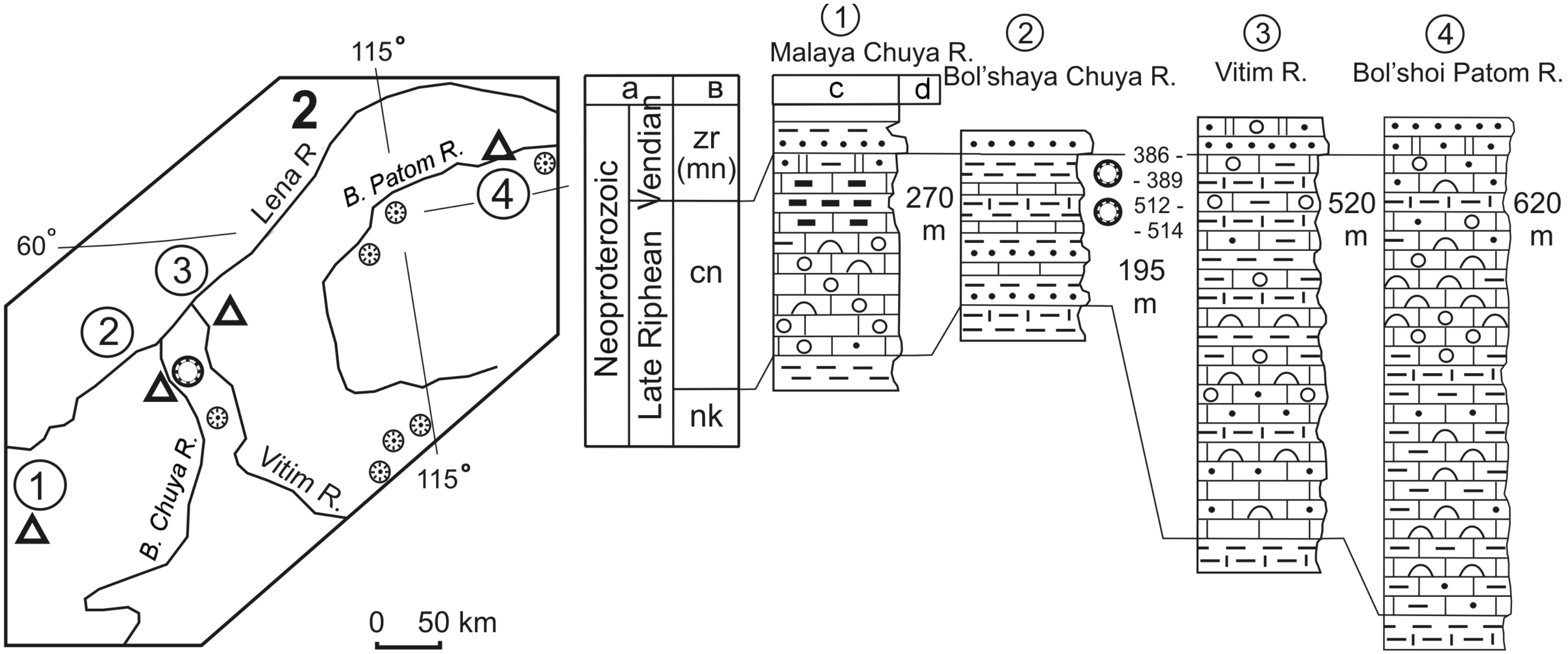

Figure 4. Geographic and stratigraphic position of microfossil localities on the Bol'shaya Chuya River (inset 2 in Figure 1) and correlation of facies environments in the sections of the Chencha Formation. Symbols in Figure 3.

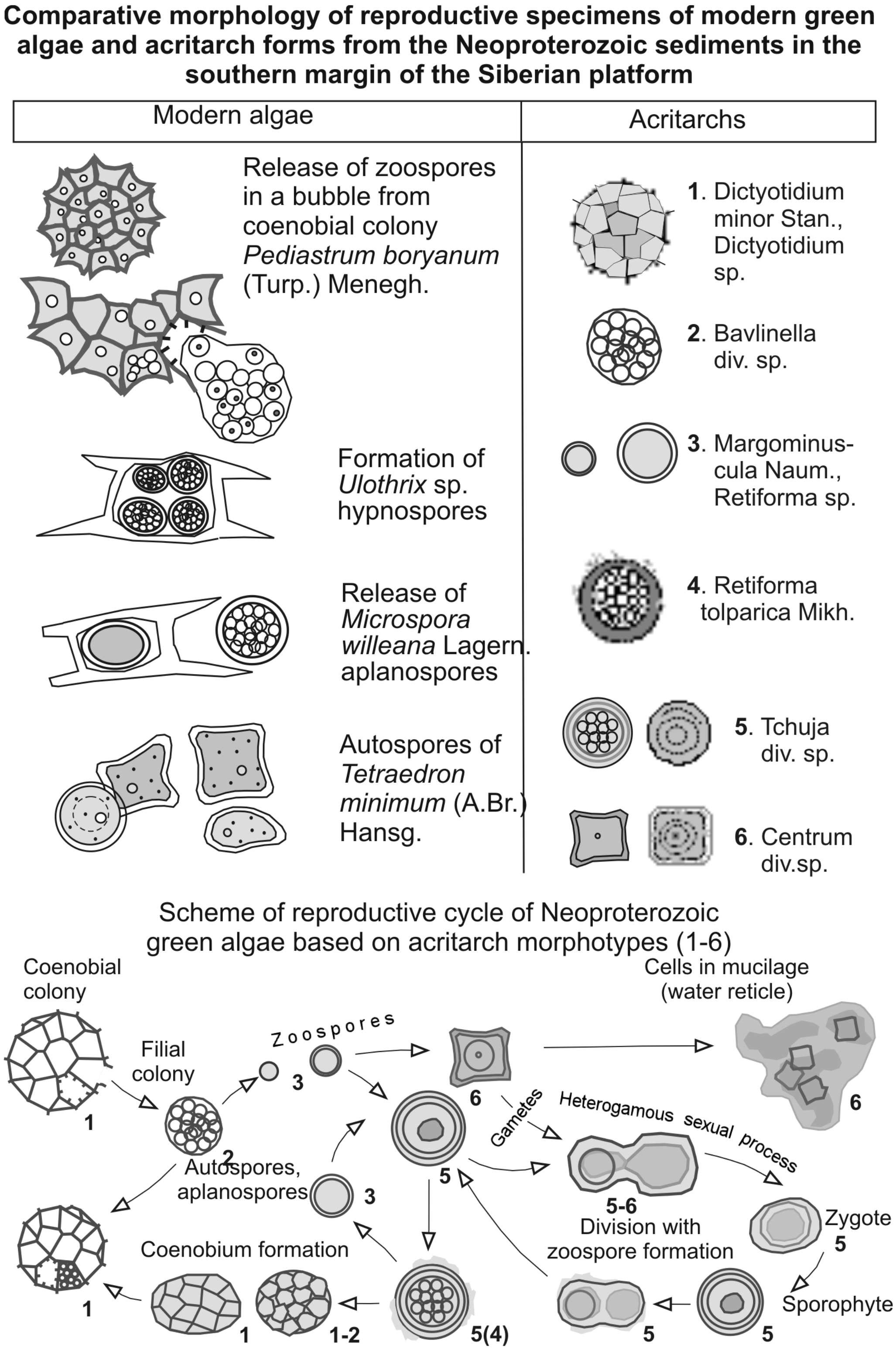

Figure 5. Morphology of reproductive forms of modern green algae and of Late Riphean acritarchs from the SayanyBaikal fold system.

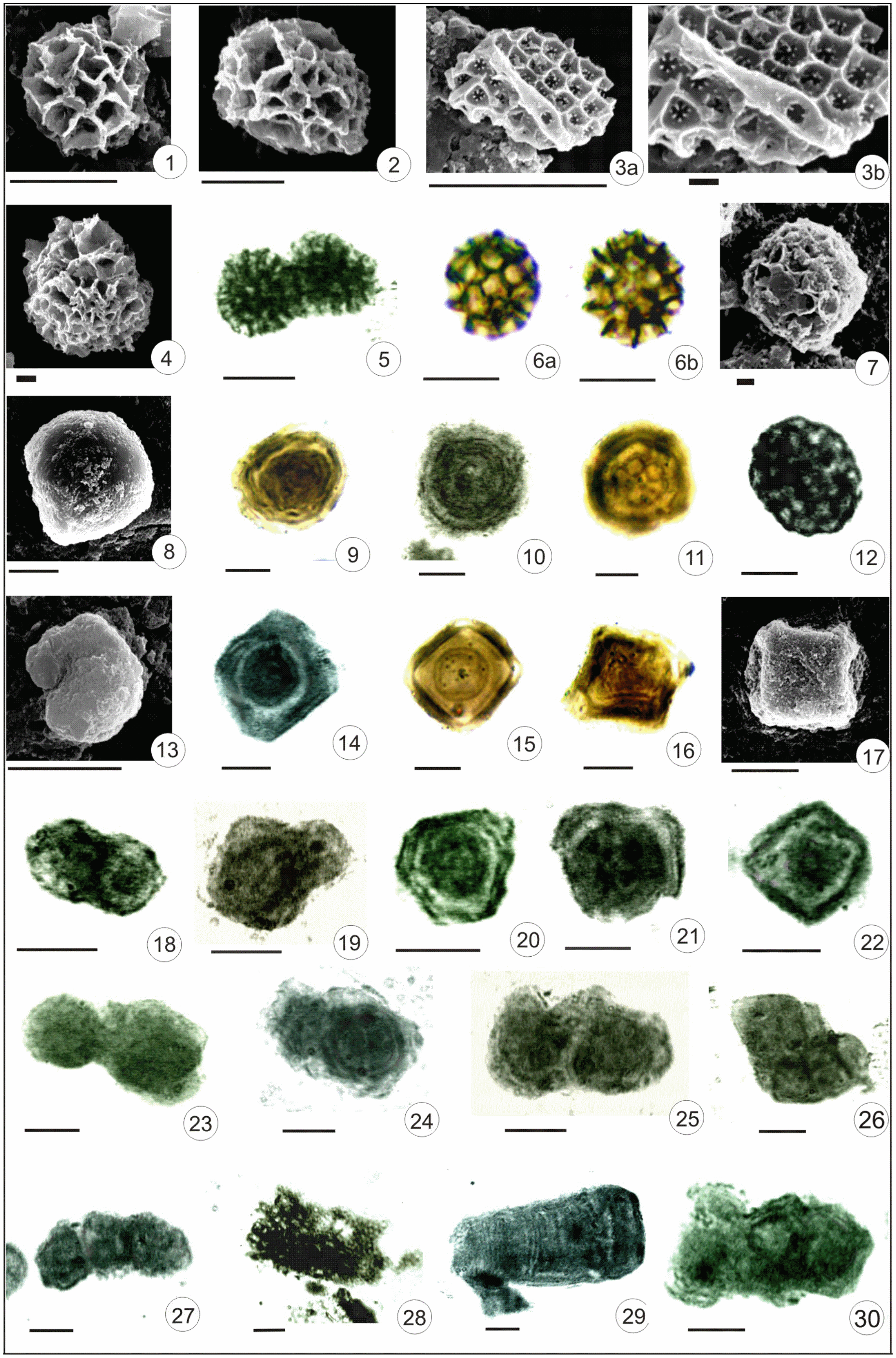
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Plate 2. Figs. 1–6. *Dictyotidium minor* Stan. of different preservation. 1–4 – Macerate 386; 3 – the form with outgrowths of cell envelope (SEM); 5 – Preparation 514-1/7, accretion (?) of two forms (coenobiums); 6 – holotype, different optical sections, 6a – upper focus, 6b – middle focus, Preparation 386-1/7. Figs. 7, 12. *Dictyotidium (?) sp.* Forming coenobiums?; 7 – Macerate 386 (SEM); 12 – Preparation 386-1/7a. Figs. 8, 16, 17, 22. *Centrum sp.* 8, 17 – Macerate 386 (SEM); 16 – Preparation 512-2/1; 22 – Preparation 512-2/8a. Figs. 9, 10. *Tchuja zonalis* Stan. 9 – holotype, Preparation 388-2/11; 10 – Preparation 512-2/10. Fig. 11. *Tchuja granosa* Stan. Holotype, Preparation 388-2/2. Figs. 13, 18, 19, 23–27, 30. *Centrum sp. (ad lib. Tchuja sp.).* Divisible (?) forms or their depositions surrounded by mucilage. 13 – Macerate 386 (SEM); 18 – Preparation 513-a/5k; 19 – Preparation 513-a/5j; 23 – Preparation 514-1/7a; 24 – Preparation 512-2/9c; 25 – Preparation 513-a/5o; 26 – Preparation 513-a/5h; 27 – Preparation 512-2/11; 30 – Preparation 513-a/5b. Figs. 14, 15. *Centrum quadratum* Stan. 14 – Preparation 512-2/8; 15 – holotype, Preparation 389-1/14. Fig. 20. *Centrum ovalis* Stan. Preparation 514-1/10. Fig. 21. *Centrum sp. (ad lib. Tchuja sp.).* Preparation 513-a/8. Fig. 28. Fragment of plant issue. Preparation 386-1/7. Fig. 29. Trichome fragment of Oscillatoriales. Preparation 513-a/5a.
The material is deposited in the Institute of the Earth's Crust, Siberian Division, Russian Academy of Sciences, in Irkutsk. Locality: East Siberia, Patomskoe zone, left bank of the Bol'shaya Chuya River, above the Stupino River, Late Riphean, Chencha Formation. Sources of illustrations: biological preparations, scanning electron microscope (SEM). Scale bars: thickened – 1 μm, thin – 10 μm.

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to the modern widespread cosmopolitan species *Tetraëdron minimum* (A. Br.) Hansg. and *Chlorotetraëdron fitridens* (Berk – Mannag.) Kom. et Kovac. (Chlorococcales) that are characterized by solitary cells with tetrahedral and polyhedral (quadrangular or hexagonal) outline and straight or concave sides. The envelopes can be three-layered. The asexual reproduction is by way of autospores. Considering the fact that cells of modern *T. minimum* are flattened, *Centrum* Stan. is most similar to *C. fitridens.* Cells of the modern Chlorococcales that are related to acritarchs, possess a wide specific polymorphism [*Gorlenko,* 1981; *Van den Hoek et al.,* 1995; *Vasser et al.,* 1989]. The Chencha assemblage yields morphotypes with characters of both *Tchuja* and *Centrum* Stan. (Plate 2, figs. 19–21). In their specimens the different types of zonal layers and morphologically transitional forms are clearly observed. A thick-walled envelope that often occurs in these forms and that is a generic character for acritarchs *Retiforma* Mikh. [*Mikhailova and Podkovyrov,* 1987], is characteristic of aplanospores or akinetes, for instance, of modern *Tetrasporales* [*Gorlenko,* 1981; *Vasser et al.,* 1989]. The inner coccoid morphology of both *Tchuja zonalis* Stan. (Plate 2, fig. 11) and *Retiforma tolparica* Mikh. (Figure 5) can be explained by the presence of primordial autospores, which is characteristic of autosporangiums of green algae. They are similar in morphology (Plate 2, figs. 8–11) to autosporangiums of modern *Chlorella* Beijer. According to certain records [*Kalina and Punčochářová,* 1987], *Chlorella* includes species with a single-layered envelope missing sporopollenin, whereas the members of *Coelastrella* Näg. of the same family possess sporopollenin in their envelopes. The forms of the latter genus can produce up to 16 autospores inside a maternal envelope, grow up, and initiate next generation. Considering a high probability of convergent characters in fossil remains, there is another interpretation; namely, the coccoid forms inside acritarch envelopes can represent bacteria cells that posthumously (or symbiotically) replace the alga protoplast in syngenesis [*Stanevich,* 2003].

[36] The records on chemical composition of modern Chlorococcales are discrepant and incomplete. It is known that apart from cellulose they include other polysaccharides, pectin, and sporopollenin [*Andrejeva,* 1998]. The latter represents a resistant polymeric carotenoid incorporated into the envelopes of spores, pollen grains, and acritarchs [*Bruck and Show,* 1973; *Martin,* 1993]. With the presence of cellulose, a multi-layered envelope can be formed [*Andrejeva,* 1998], which is an additional evidence for comparison of *Tchuja* and *Centrum* Stan. with the Chlorococcales members. Their zonal lamellar structure can be also explained by the occurrence of maternal envelopes around filial cells. In certain modern species the envelopes can become mucous, diffused, and filial cells are found to be enclosed in common mucilage. Similar structures are conceivably represented in some acritarch morphotypes (Plate 2, figs. 24 and 30). One can commonly observe their elongated and two-layered envelopes surrounded by mucilage of various density (Plate 2, figs. 13, 18, 19, 23–27). They are considered as forms in the cytokinesis stage or can represent the analogues of uniform or local bulges of cell envelopes, occasionally forming bladder-like outgrowths, characteristic of aged algae in some Chlorococcales members.

[37] A combination of diversity and at the same time morphological similarity of forms of the Chencha taphocoenosis indicates their affiliation to a single assemblage. Judging from their morphology and by analogy with modern specimens, they likely conducted a planktonic mode of life. Deposition of microfossils in the layers resulted from the absence of intense hydrodynamics during the sediment deposition. Planktonic forms were likely associated with a macrophytic stage of algae life (Plate 2, fig. 28), that does not exclude a facultative benthic existence [*Van den Hoek et al.,* 1995; *Vasser et al.,* 1989]. Modern members of Chlorococcales include unicellular, colonial, and coenobial forms with alternating sexual and asexual reproduction [*Gorlenko,* 1981; *Van den Hoek et al.,* 1995; *Vasser et al.,* 1989]. The morphological varieties of acritarchs represent a

morphotype series reflecting different stages of life cycle of certain modern green algae. Figure 5 shows the alternation of generations. The reproductive process is isogamic. The generated gametes merge together forming a zygote, which after a rest stage produces zoospores that turn into multangular polyhedral cells. Within the polyhedrons, subsequent to their germination, the new coenobiums are formed. Preservation of zoospores in the sediments, especially in the Precambrian, is unlikely owing to the chemical composition of their envelopes that are of glycoprotein nature. Zoospores of certain Chlorococcales species are characterized by the absence of cell envelopes [*Andrejeva,* 1998]. In modern algae, on deterioration of habitat conditions, the more resistant aplanospores are generated instead of zoospores. They were most likely retained in fossil remains along with the coenobial and other reproductive cells.

[38] It should be noted that in modern members of Chlorococcales the sexual reproduction is comparatively rare. However, we presume that in the Chencha microbiota this type of reproduction, namely, its heterogamic variety, was much more common. This inference is confirmed by numerous findings of elongated and isometric forms consisting of two and over cells. The cytokinesis stage presumably represented by them is more preferential for the formation of mucous pellicle that includes numerous cells and makes up the plankton matrix of green algae. The forms or depositions of acritarchs of different outline enclosed in a less dense, veil-like matter, correspond to that stage. The matter most likely represented a mucilage composed of resistant polymers.

[39] Thus the correlation of major acritarch morphotypes from the Chencha Formation with reproductive stages of modern green algae is quite acceptable owing to a distinct morphological similarity and peculiarities of the envelopes' chemical composition. Their biological interpretation conforms with the reconstruction of hydrodynamically passive and photically favorable environment of the "microbiota" locality. The discussed material yields trichome fragments of oscillatorias (Plate 2, fig. 29) that likely represent remains of stromatolite-forming cyanobacteria assemblages inhabiting shallower parts of the shelf carbonate platform.

The Baikal–Muya Zone. Muya Region

[40] In the Muya region (Figure 6) the sedimentary volcanogenic rocks distinguished as the Kelyana Subseries (sequence), were referred to either Lower Proterozoic [*Salop,* 1964] or Lower Riphean [*Bulgatov,* 1983; *Mitrofanov,* 1978]. The first found microfossil assemblage that is partially discussed in the paper, included the forms known in the region only from the Zhuya beds underlying the sediments of the Vendian Judoma Horizon [*Stanevich and Zheleznyakov,* 1990]. Subsequently the Neoproterozoic age of the Kelyana sequence was confirmed by a number of trustworthy radiologic datings [*Rytsk et al.,* 1999, 2000, 2001]. The establishment of relative synchrony of geologic bodies from different zones of the outer and inner belts of SBFS permitted the reconstruction of Neoproterozoic geodynamic environments in the area [*Nemerov and Stanevich,* 2001; *Stanevich and Perelyaev,* 1997]. The sedimentary volcanogenic rocks in the Muya region (Figure 6) contain rich microphytologic remains, only partially reported [*Stanevich and Faizulina,* 1992]. The acritarch assemblages are mainly represented by forms examined solely in the sediments of SBFS. In the paper we discuss most thoroughly the morphology, habitat conditions, and inferred nature of *Floris* Stan., which forms retain their volume and original flowery morphology in fossil remains.

[41] Long-term studies of stratigraphic units in the Baikal–Muya zone mainly revealed their geological [*Bulgatov,* 1983; *Salop,* 1964] and geodynamic [*Bozhko et al.,* 1999; *Gusev et al.,* 1992; *Konnikov et al.,* 1994; *Levitskii and Odintsova,* 1986; *Stanevich and Perelyaev,* 1997] peculiarities. A debated character of such questions as the units' range, their chronological succession, and correlation within the region, results significantly from the folded–faulted nature of sequences and the occurrence of thrust–nappe structures [*Kovalenko et al.,* 1995; *Stanevich and Perelyaev,* 1997]. Typical structures are the fragments of isocline flanks complicated by upthrow strike-slip faults. A consideration of repeated occurrence of section fragments in these structures and tracing of certain lithocomplexes in the studied area allowed the elucidation of the most probable range of the units. Unfortunately, the results of the known [*Bulgatov,* 1983; *Salop,* 1964] and later [*Stanevich and Faizulina,* 1992; *Stanevich and Perelyaev,* 1997] stratigraphic research were mainly not considered in the development of the new legend for geological maps of the Muya region [*Rytsk et al.,* 2001]. For instance, its stratigraphic succession lacks a number of described in the literature units (Chayangro, Dzhalagun, Uryakh, etc.) and it is not improbable that the corresponding rocks are represented under other names. This conclusively complicated the understanding of as it is many-varied framework of the Precambrian stratigraphy in the Muya region. Therefore, we use the stratigraphic units based on the sections with established structure and reconstructed succession of beds and range (Figure 6), which to a greater extent meets certain standard requirements (Stratigraphic Code. 2nd, supplemented edition, 1992). The exception is the Kelyana sequence (subseries); its sedimentary volcanogenic rocks up to now lack a type description.

[42] The most complete sections representing microfossil habitats are recovered on the Bolshoi Yakor River (Figure 6, Section 1) and in the low reaches of the Kelyana River (Section 2). The sedimentary volcanogenic deposits of the Yakor and Ust'-Kelyana sequences are an element of island-arc structural sedimentation complex and were deposited in a marine marginal paleobasin. The Yakor section is characterized by an alternation of thick rhythm-members and beds bearing pyroclastic material of various size. Thin-bedded and massive vitroclastic tuffites, sandstones, and siltstones occur at the base of the 70-m-thick sequence. The heterogranular sandstones and siltstones grade into tuffites. Their clastic material is represented by extrusive fragments, tuffs, crystals of feldspar, pyroxene, quartz, and by volcanic glass splinters. The silty pelitic, pelitic, or ash-clayey, mainly porous, cement includes sericite, secondary quartz secretions, and carbonaceous matter. Carbonate interbeds are represented by chlorite-bearing limestones and calcareous

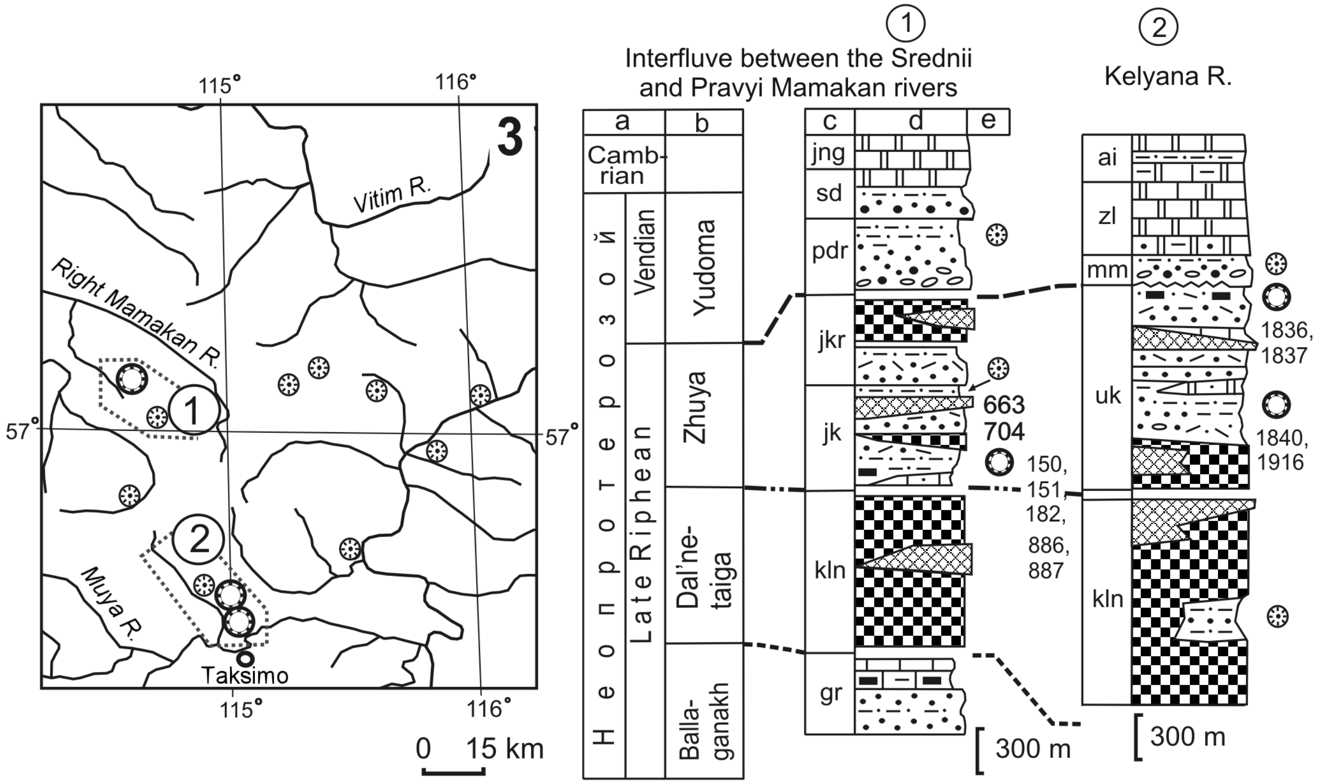

Figure 6. Geographic and stratigraphic position of microfossil localities in the Muya region of the BaikalMuya zone (inset 3 in Figure 1) and correlation of facies environments of the Neoproterozoic rocks. Symbols in Figures 2 and 3. The illustrated succession of geologic bodies is compiled from the fragmentary sections of Areas 1 and 2.

argillites (calcilutites) with a slightly flaser structure owing to a small admixture of carbonaceous matter. Pure dark limestones associated with silty argillites with a carbonaceous content reaching up to several percent and bearing the greatest number of microfossils, are less common.

[43] The middle, 600-m-thick part of the Yakor sequence is composed of tuffites, tuff gravelstones, and tuffs with a slight admixture of epiclastic material. The tuffites are characterized by a combined composition, presence of angular extrusive fragments and of their phenocrysts. The tuffs are composed of angular, poorly sorted fragments of andesites, andesite-dacites, and dacites with various textures, glass phenocrysts, and matrix; they are homogeneous and lack baking traces. The sediments are characterized by different sedimentary structures, namely, various types of cross- and parallel bedding, normal and reversed graded bedding, and slump folds, that indicate a deposition from turbidity currents and influence of submarine flows. The upper, 200-m-thick part of the discussed section is composed of pelitic, rarely silty psammitic, coarsely platy, black, acidic ashstones, bearing thin terrigenous interbeds. The sequence includes thin metabasalt bodies and rhyodacite sills.

[44] A similar composition and character of deposits is observed in the section of the Kelyana River low reaches (Figure 6, Section 2). Certain peculiarities of this section referred to the Ust'-Kelyana sequence significantly supplement the characteristics of the island-arc sedimentogenesis. The middle part of the section bears an association of lens-like sandy dolomites and quartz sandstones. The upper part of the section represents a transgressive rhythm, when with a decreasing upward grade of clastic material, the tuffaceous admixture declines and the content of carbonaceous matter grows. The upper member of the Ust'-Kelyana sequence is represented by dark to black carbonaceous silty pelitic shale bearing insignificant content of acidic volcanite fragments of silty psammitic size.

[45] Thus the above-reported properties of sediments correspond well to backarc basin environments [*Reding,* 1990; *Stanevich and Perelyaev,* 1997]. They are characterized by asymmetric and irregular distribution of various facies, contrasting differential depths, different content of volcanogenic material, turbidity currents, and slump processes. The backarc-basin sediments, owing to a reworking in subduction zones, are commonly retained only in mantle fragments [*Reding,* 1990]. The analogous tectonic situation occurs in the described areas [*Konnikov et al.,* 1994; *Stanevich and Perelyaev,* 1997].

[46] The deposits were produced by volcanoes of the paleoisland arc and were deposited as a volcanoclastic apron at its foot. The matter of subaerial and/or subaqueous eruptions arrived in the basin in the form of turbidity currents and by the way of deposition through water mass (ash fall),

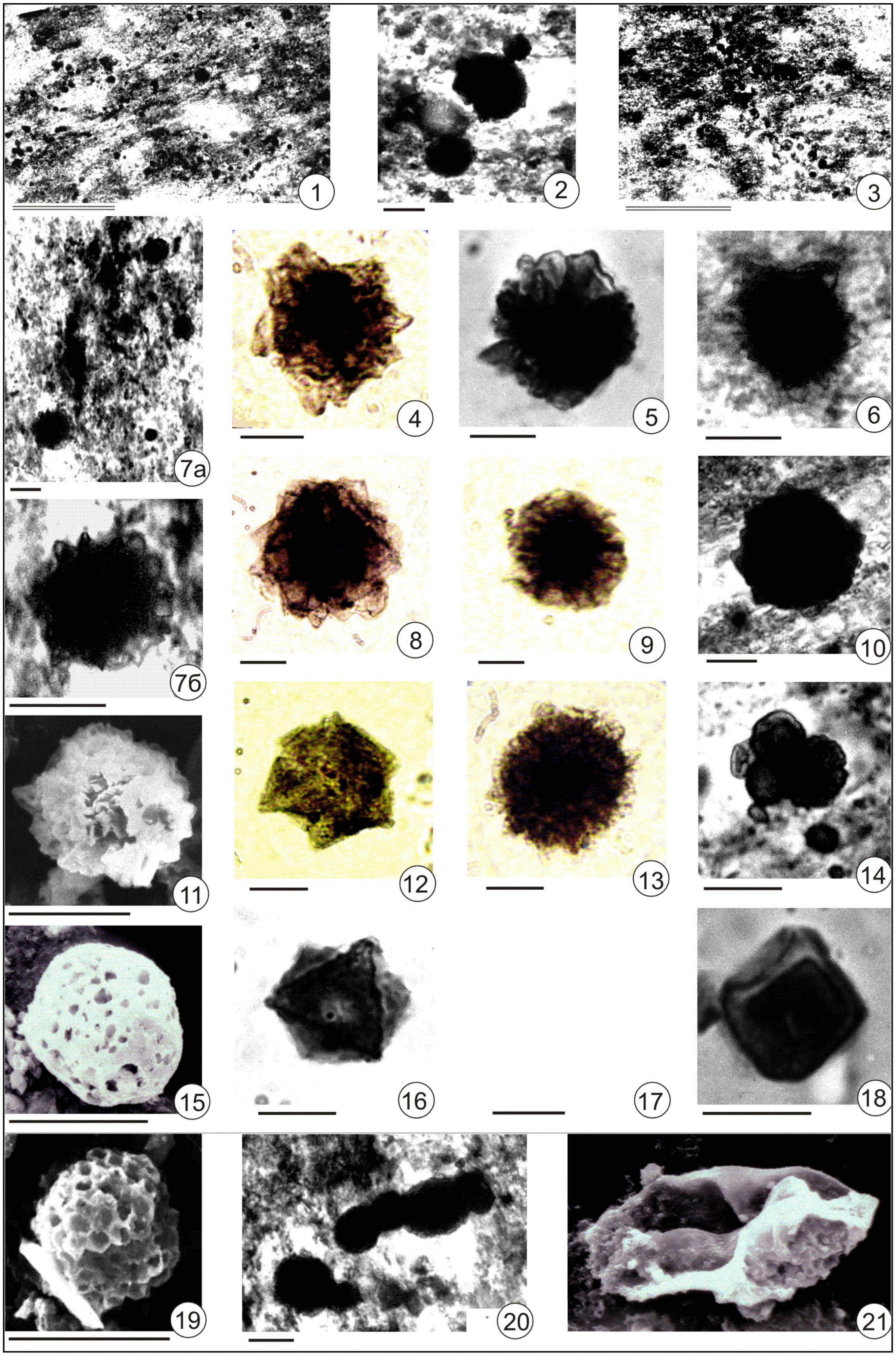
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Plate 3. Figs. 1–3, 7a. Microfossils in petrographic slides. 1 – Slide 151-33; 2 – Slide 151-13; 3 – Slide 151-5; 7a – Slide 182-20-1-12. Fig. 4. *Floris stellatus* Stan. Holotype. Preparation 887-1/20. Figs. 5–8. *Floris vitimus* Stan. et Zhel. 5 – Preparation 887-1/16; 6 – Slide 150-34; 7 – Slide 182-20-1-12, 7a – general view, 7b – *Floris vitimus* Stan. et Zhel. in the mineral matrix; 8 – holotype, Preparation 887-3/18. Figs. 9, 13. *Floris radiatus* Stan. 9 – Preparation 887-2/8; 13 – holotype, Preparation 887-3/17. Fig. 10. *Floris sp.* Slide 151-34. Fig. 11. *Floris aff. vitimus* Stan. et Zhel. Macerate 887-s-1 (SEM). Fig. 12. *Floris primitivus* Stan. Holotype. Preparation 886-1/15. Fig. 14. *Synsphaeridium* Eis. Slide 150-29. Fig. 15. Bacterium (?) corroded form. Macerate 619-4 (SEM). Fig. 16. *Octoedryxium truncatum* Rud. Preparation 887-1/17. Fig. 17. *Paracrassosphaera* Rud. in Trestsh. Preparation 887-1/15. Fig. 18. *Centrum quadratum* Stan. Preparation 887-2/1a. Fig. 19. *Bavlinella faveolata* Schep. (sulfate-reducing bacteria). Macerate 887-s-3 (SEM). Fig. 20. Bottom bacteria forms. Slide 150-36. Fig. 21. *Leiosphaeridia sp.* Macerate 619-3 (SEM).
The material is deposited in the Institute of the Earth's Crust, Siberian Division, Russian Academy of Sciences, in Irkutsk. Locality: East Siberia, BaikalMuya zone, Bol'shoi Yakor River, Late Riphean, Yakor' Formation. Sources of illustrations: biological preparations, petrographic slides, scanning electron microscopes (SEM). Scale bars: single – 10 μm, twofold – 100 μm.

subsequently undergoing repeated redeposition. Clayey and carbonate facies were deposited either below the distal zones of volcanoclastic aprons or during sedimentation pauses between the explosion and clastic material inputs. The latter is most likely for the Kelyana River section. Whereas the carbonaceous microfossil-bearing silty argillites from the Bolshoi Yakor section were formed synchronously with volcanic activity but were deposited at a significant depth almost without a volcanoclastic input, in the Kelyana River section we recorded several different paleoenvironments. It is firstly a sufficiently shallow association of quartz sands and dolomites. Taking into account the findings of stratiform stromatolites in the Kelyana River upper reaches, we most likely deal there with barrier reef fragments of an offshore stripe of the island arc. The underlying thin-bedded silty argillites contain a rich microfossil assemblage. The upper beds of the Ust'-Kelyana sequence also bearing microfossils, represent another environment. It was a comparatively deep zone, where in stagnant conditions the carbonaceous biogenic siltstones bearing an explosion admixture, were formed.

[47] Thus it is seen that the initial filling of the marginal paleobasin with sediments has come about from different sources, at the background of slight volcanic activity, and resulted in deposition of pelagic clayey, to some extent carbonaceous and calcareous sediments bearing a volcanic ash admixture. The deposition of carbonaceous matter likely occurred in relatively deep zones, where terminal grades of turbidity currents were deposited, as well as in shelf troughs in stagnant conditions of terrigenous–biogenic sedimentation. Taking into account a variable microfossil composition in different environments, we infer that in the described microfossil localities we deal with a heterogeneous assemblage bearing both autochthonous and allochthonous forms.

[48] We processed 141 sample from terrigenous sediments of the Muya region, 90 of which contained microfossils referred to over 70 species and intergeneric, mainly acritarch taxa [*Stanevich and Faizulina,* 1992]. All of them, except for *Leiosphaeridia* Eis., em. Downie et Sar., possess volumetric envelopes and therefore most likely retained the primary characters. The most interesting morphology is that of *Floris* Stan. [*Stanevich and Zheleznyakov,* 1990].

[49] Forms of *Floris* Stan. bearing large outgrowths (Plate 3, figs. 4–13) resemble spherical crystal druses, leading to a suggestion [*Golovenok and Belova,* 1995] on their mineral nature (fluorite – CaF_2, sellaite – MgF_2). A questionable character of this inference is evident from the analysis of maceration process. Additionally, these acritarchs were observed in various and obviously noncrystal-like forms (*Floris* sp. (ad lib. *Retiforma* sp., etc.)). For comparison we can offer an example of the long-known acritarchs *Octoedrixium* Rud. (Plate 3, fig. 16) that possess a distinct crystallographic outline and to a greater extent can be assigned to "abiogenic" forms. It should be noted that formation of crystals in the course of colloid particles' interaction during maceration can take place in certain circumstances. However, such processes need a separate study and description. The discussed *Floris* forms represent typical organic-walled microfossils, as confirmed by their occurrence in petrographic slides derived from silty argillites in microphytologic samples that bear numerous other forms (Plate 3, figs. 1–3, 6, 7, 10, 14).

[50] In the Kelyana River section (Figure 6) hundreds of microfossil specimens were studied in Slides 1009/8, 19, 1837/6, 18, 21, derived from carbonaceous siltstone and silty psammitic tuffites with a matrix composed of fine-grained albite–quartz–sericitic aggregate penetrated by carbonaceous matter. The content of the latter reaches 5% to 8% of a slide area. The andesite and andesite–dacite fragments represent an obvious explosion component.

[51] In the Bolshoi Yakor River section (Figure 6) the microfossil-bearing residue was derived from foliated silty argillites. The study of Slides 182/20-1, 2, 3, and 1067/6 revealed that matrix consists of a fine-grained aggregate

of sericite, chlorite, and small (5–40 μm) quartz grains. The relict initial bedding is underlined by lenses and extended spots of carbonaceous matter and by microfossil chains (Plate 3, figs. 1 and 3). Lenses and spots of ferruginous carbonate are common. Single corroded sand-sized fragments of feldspar crystals are recorded. Composition of the shales, considering their lateral grading to indubitable tuffs and tuffites, is determined by explosion (or volcanomictic) admixture of silty–clayey size.

[52] The carbonaceous admixture is scattered throughout the rock. Most of microfossils are associated with its depositions and clots that underline a discontinuous bedding. Their amount is estimated at one to several thousand forms (0.5–1.5%) for every examined slide. The most numerous are rounded nontransparent corpuscles of size 2–20 μm to 30 μm, conventionally identified as *Protosphaeridium* div. sp. (the rejected genus, [*Jankauskas et al.,* 1989]). The forms with distinct features of outer and inner morphology, allowing their assignment to certain acritarch genera and species [*Jankauskas et al.,* 1989; *Stanevich and Faizulina,* 1992] are relatively scarce. Among them are *Bavlinella* sp., *Floris* sp., F. cf. *radiatus* Stan., F. cf. *vitimus* Stan. et Zhel., *Margominuscula rugosa* Naum. em. Jank., *Pterospermopsimorpha* (?) sp., *Retiforma* sp., *Synsphaeridium* Eis., and their various depositions and accretions (Plate 3, figs. 2, 14, 20). The ferruginous background of the deposit is underlined by reddish or orange color of some forms that commonly possess a zonal structure.

[53] In many cases the morphology of *Floris* Stan. is determined by large outgrowths that commence in the central area of the forms. The biological nature of both these and other remains is a rather questionable issue. The sufficiently peculiar primary characters of *Floris* and the reconstruction of their burial and habitat environment permit the actuopaleontological comparison and inference about their natural taxonomic affiliation.

[54] The discussed Neoproterozoic acritarch assemblage of the Muya region, like many others, most likely represents a taphocoenosis composed of remains of different origin. This is witnessed by the occurrence of forms that sharply differ in a set of morphological characters. An additional consideration is the inference about the forms' deposition during sedimentation pauses resulting in the deposition of heterogeneous material and united by a small specific weight. At the same time the biological affinity of acritarchs *Floris* Stan. is inferred from the morphological unity of specimens and a strong difference between their set of features and that of other forms of the assemblage. The systematic character of the outgrowths' set and outlines in over 100 specimens of *Floris* indicates a highly probable presedimentation origin of these features. There is one more, in our opinion important factor resulting in a preservation of microfossil primary characters. It is an ability of certain forms to retain their volume and properties during diagenesis and initial stage of greenschist facies of regional metamorphism [*Nemerov and Stanevich,* 2001; *Stanevich,* 2003].

[55] An extreme resistance to pressure is characteristic of a lot of bacteria groups [*Kuznetsov et al.,* 1962]. Therefore, in the first variant of interpretation the *Floris* forms were compared with bacteria [*Nemerov and Stanevich,* 2001; *Stanevich,* 2003]. A similar "flowery" morphology is recorded in cells of modern aerobic gemmated prostecobacteria [*Hoult et al.,* 1997; *Schlegel,* 1987]. Their occurrence in native basins and chemoorganotrophic nutrition correspond to the conditions characteristic of *Floris* forms. However, the latter are several times larger than modern bacteria. This may be explained by the participation in metabolic process of biophilous elements incoming during volcanic eruptions, which could result in bacteria gigantism.

[56] Another interpretation emerges from a comparison of acritarchs *Floris* Stan. with dinoflagellates, long-known among fossil remains. Their findings were recorded in the sediments from the Silurian up to Cenozoic [*Tappan and Loeblich,* 1973; *Tasch,* 1973]. The investigation of fossil dinoflagellates revealed that they were likely the dominating producers in the Paleozoic biosphere [*Tasch,* 1973]. Their diversity rapidly increased during the Jurassic and Cretaceous, whereupon a number of cystogenous species began to decline [*South and Wittique,* 1990]. Certain dinoflagellates are retained in the sediments in the form of siliceous endoskeleton, thecae, or cysts morphologically similar to members of the genus *Floris* Stan. The tracing of diverse dinoflagellates from the Paleozoic and their yet incomplete studies [*Tappan,* 1980] permit the inference that they likely occurred in the Early Paleozoic [*Evitt,* 1963; *Meien,* 1987] and probably in still older sediments. Their fossil remains are known as hystrichospheres and are assigned, along with other cystogenous fossils, to acritarchs [*Meien,* 1987; *South and Wittique,* 1990]. Modern dinoflagellates represent mobile unicellular, rarer colonial organisms, with dorsoventral morphology. Their cell envelope is armored, composed of few polygonal shields joined by narrow or deep sutures. Dinoflagellates frequently possess hypnospores, cysts or hypnocysts. Cysts are common for dinophytes and are resistant to unfavorable environment. Some cysts are morphologically almost identical to vegetative cells (for instance, those of *Peridinium* Ehr. reminiscent of certain *Floris* members), whereas other are sharply different. The modern members inhabit both fresh-water basins and seas. Fossil dinoflagellates are characteristic of marine sediments [*South,* 1990; *Tasch,* 1973]. The *Floris* forms are derived from marine sediments where they, judging from their morphology, conducted a planktonic mode of life.

[57] There is no evidence that the Early Paleozoic acritarchs compared with dinoflagellates [*Evitt,* 1963; *Meien,* 1987] had a siliceous skeleton. Undoubtedly, the acritarchs are composed of sufficiently resistant cell envelopes that include sporopollenin [*Bruck and Show,* 1973; *Martin,* 1993] and are extracted from rock through a rigid processing by acids. The analogous resistance is characteristic of the *Floris* forms. A periplast, pellicle, and armor (theca), also resistant to acids, refer to cell envelopes of modern dinoflagellates, which have various modifications. A dinophyte theca consists of several layers. Some dinoflagellates possess theca microfibril plates that are located at the cell surface and form peculiar, sometimes fanciful covers with outgrowths. Among modern 10–60-μm-sized dinophytes there are forms lacking a siliceous skeleton. Taking into account a poor notion of ancient algae, diverse morphology and composi-

tion of modern dinoflagellates, and the morphological and dimensional correspondence, we can refer the *Floris* forms to a dinoflagellate group. This inference is confirmed by the fact that the group is known as one of the oldest among algae [*Evitt,* 1963; *Meien,* 1987].

[58] The allochthonous character of the studied microfossil assemblage and distinct morphological difference between its constituent groups indicate their likely different biological nature. The planktonic mode of life of the *Floris* forms that we compare with dinoflagellates, is supported by their scarce occurrence in slides. Contrastingly, the rounded, simple forms and their depositions numbering in thousands of specimens in a single slide (Plate 3, figs. 1–3, 7, 14, 15, 20), most likely represent a saprophytic bacterial benthos that produced the major part of a sediment carbonaceous component. The forms identified as *Bavlinella* Schep. (Plate 3, fig. 19) and correlated with sulfate-reducing bacteria [*Nemerov and Stanevich,* 2001; *Stanevich,* 2003] are referred to the same type. The scarce forms of *Octoedryxium* Rud. (Plate 3, fig. 16), reasoning from their correspondence to shallow-water aerobic sulfur bacteria [*Nemerov and Stanevich,* 2001; *Stanevich,* 2003], are most likely the allochthonous remains. As indicated above, most of the assemblage forms retain the volume and characters in a fossil state. However, we also encountered single corroded and crumpled specimens (Plate 3, fig. 21). These remains can be referred to acritarchs *Leiosphaeridia* Eis., em. Downie et Sar. Diverse members of this genus are well-known from the Late Precambrian and Paleozoic shelf sediments and, according to morphology and size, can be in general defined as eucaryotic algae [*Jankauskas et al.,* 1989].

[59] The stratigraphic importance of the discussed microfossil assemblage is determined by the range of vertical and lateral distribution of its members. Among known acritarchs the *Adara* Fomb. forms from the Cambrian of Spain [*Fombella,* 1977] are the most similar to *Floris* Stan. The *Floris* forms are known from the pre-Vendian sediments in the sections of both outer and inner belts of the SBFS (Figures 1 and 2). The same stratigraphic interval distinguished as the Zhuya regional horizon contains species of the Subassemblage IIIa of the Siberian platform [*Stanevich and Faizulina,* 1992]. In the Muya region the following forms of that subassemblage, noted for the same first occurrence level, were encountered: *Bailikania* (Trestsh.), *Granomarginata* sp., *Micrhystridium insuetum* Trestsh., *Paracrassosphaera* (Rud. in Trestsh.) (Plate 3, fig. 17), *Sibiriella* sp., *Centrum* Stan. (Plate 3, fig. 18), *Dictyotidium* sp., and *Tchuja* Stan. Their findings permitted to infer the Neoproterozoic age of the sedimentary volcanogenic rocks in the Muya region. At the same time, the forms of the discussed assemblage are little known outside the SBFS. This circumstance, despite the occurrence of morphologically complicated microfossils in the uppermost Late Riphean, results in only regional stratigraphic significance of the assemblage at the modern stage of investigation.

[60] The above-reported comparisons based on a vast but heterogeneous complex of records, do not unambiguously define the biological affiliation of the discussed microfossils. However, there is no question that the microfossil assemblage from the Neoproterozoic sediments of the Muya region consists of different groups of microorganisms. Among them the least doubtful is the assignment of simple forms to saprophytic bottom bacteria making up a carbonaceous component of sediments. The rest microfossil specimens that occur in lesser amounts, are characterized by a more complicated morphology, which likely partially reflects their initial structure. This allows their reference to biological objects of different nature and the inference about their allochthonous character. The acritarchs *Floris* Stan. owing to their relatively large size, can be referred to dinoflagellate remains. A different interpretation, considering the lack of unambiguous markers for such comparisons, seems less preferable. The coincident results of independent research are perhaps a single criterion of correct paleobiological interpretations.

Peculiarities of Microfossil Morphological Differences

[61] Microfossils from both the SBFS sediments and localities in other regions [*Horodyski,* 1993; *Mikhailova and Podkovyrov,* 1987; *Moorman,* 1974; *Jankauskas,* 1982] are characterized by a property of retaining the envelope volume and internal characters during the diagenesis and initial stage of greenschist facies of metamorphism. This property and lesser size differentiate them from a lot of acritarchs that become flattened to a plate at the very beginning of the deposit lithification [*Burzin,* 1997] and that are mainly known to most of microphytologists. The peculiarities of volumetric forms and their relationships with other acritarchs and with the deposit were reported previously [*Stanevich,* 1997, 2003]. A suggestion on occurrence of the two types of microfossil forms with the envelopes differently responding to lithostatic pressure appeared from the study of regional materials and their comparison with the Precambrian "microbiotas" of other regions. This resulted in the distinction of a new subgroup Implethomorphitae Jank. et Mikh. published in the generalized summary on microfossils [*Jankauskas et al.,* 1989]. This innovation carried the discussed issue to a formal, classification channel without touching on the prospects of its solution. At the same time the available records indicate that the difference between the two microfossil types mostly results from their original properties. Secondly, this problem has many aspects and is in a realization stage. Thirdly, though indirectly, the indicated difference permits the search and specification of criteria for the biological separation of certain forms referred to acritarchs.

[62] Lack of attention to possible genetic and biochemical differences between the forms united in terms Precambrian "microfossils" or "acritarchs", leads to a notion about similar preservation properties in ancient organisms. There is a widespread opinion that the organic-walled fossils can possess volume only on formation of mineral pseudomorphs. At the same time numerous known localities yield 3–25-μm to 50-μm-sized forms that retain their three-dimensional structure and diverse features, including the finest ones, in conditions of initial stage of the metamorphic greenschist fa-

cies [*Nemerov and Stanevich,* 2001; *Stanevich and Faizulina,* 1992]. The experimental data on determination of original resistance of modern bacteria to pressure [*Kuznetsov et al.,* 1962] are a good illustration for the discussed problem. Certain bacteria in a growth phase died at 500–600 atm and their reproduction was retarded at 300 atm. Some species are well propagated even at 600 atm. Endospores and resting cells of bacteria proved to be the most resistant to pressure. It may be therefore inferred that volume and morphological features of a lot of bacteria can be retained at the pressure values corresponding to conditions of initial metamorphism.

[63] Most of microfossils from the Neoproterozoic sediments of the SBFS including those described above, possess a surprising capacity to withstand lithostatic pressure. Compared to other regions, the microfossil assemblages from the SBFS yield from 70% to 90% of forms retaining volume and features in conditions of regional metamorphism [*Stanevich,* 1997]. Most of rocks bearing like microfossils are quartz–micaceous, rarely chloritic silty pelites (shales). They are marked by the presence of layers, lenses, and clots of carbonaceous matter associated with microfossil findings. The mineral composition of rocks corresponds to the lower–middle stages of greenschist facies or to PT-conditions at 1–1.5 kbar and 150–300°C [*Vinkler,* 1979]. Studies of alteration of sporopollenin and like polymers composing the envelopes of spores and examined microfossils [*Bruck and Show,* 1973; *Ruchnov,* 1981] indicated that the forms are yellowish or light brown in color at up to 120–150°C. Within 150–250°C (as in our case) they become dark brown or grey and at 250–400°C the forms are coalificated and are represented by black bodies with distorted morphology. These petrographic criteria can serve as indicators of in situ position and show the possibilities of microfossil taxonomic identification in metamorphic rocks. Studies of the slides derived from the chlorite–quartz–sericite shales showed that carbonaceous matter limits the growth of minerals and is a conserver for microfossil preservation. Thus the described microfossil forms retain volume and features in a wide range of PT-conditions. This differs them from the more well-known microfossils that become crumpled at the very beginning of diagenesis. The flattened and volumetric forms commonly occur in the same samples. Most of volumetric microfossils are lesser in size and possess characters unknown in the flattened forms. A combination of characters of volumetric forms from the SBFS sediments determines a taxonomic position of the species and genera. The presence in certain forms of features of two genera resulted in the use of the so-called intergeneric taxa proposed previously [*Stanevich and Faizulina,* 1992] and not contradictory to the Code.

[64] Therefore, the Neoproterozoic acritarchs from the SBFS compared in this paper with bacteria, green algae, and dinoflagellates, have a morphologically pronounced property that likely reflects a genetic resistance of the bacteria and algae reproductive organs to unfavorable environment and that can be used as a non-formal character in the acritarch classification. The distribution of acritarch taxa according to the following scheme of modified classification corresponds well to the conducted ecobiological interpretation of microfossils (Table 1).

Classification of Acritarchs. Prospects for Systematics

[65] The distinctive features of the acritarch subgroups and genera [*Downie et al.,* 1963; *Evitt,* 1963; *Volkova,* 1965] are the morphological ones. Only the diagnosis of the subgroup Implethomorphitae Jank. et Mikh., 1989 [*Jankauskas et al.,* 1989] includes the property of physical resistance of cellular organelles to extreme conditions. Inadequate significance of this criterion in comparison with morphological features of the group implies its higher rank in relation to the latters. At the same time, the identity of taxonomic significance of morphological characters for both subgroups and the constituent genera is evident. This likely is the main reason why the supergeneric taxa of Acritarcha Evitt, 1963 [*Downie et al.,* 1963] are unused in classification summaries [*Butterfield et al.,* 1994; *Hofmann and Schopf,* 1983; *Sergejev,* 1992; *Jankauskas et al.,* 1989]. Almost every subgroup is defined by a morphological feature of the constituent genera, part of which possesses characters of another subgroup. This chiefly concerns the forms of Implethomorphitae: most of them, according to morphological characters, can be referred to two or three subgroups.

[66] Therefore, the modern system of acritarch subgroups, considering the diverse and convergent morphological features, does not permit to recognize the "biological sense" of most of the observed characters. In this system the members of different divisions and even kingdoms of organic world can be placed in a single subgroup of acritarchs. We propose a modified acritarch classification that on further transformation can present formal potentials for distinction of natural groups of ancient microorganisms. Within such groups presumably referred to the superior taxa of plant kingdom, one can actually distinguish more detailed taxonomic analogues. It should be noted that the establishment of natural taxonomic position for most of acritarchs is a multivariant, long-term process. A useful part of the process is the development of classification that takes into account the criteria acceptable for a transitional state. The environmental conditions and separation of acritarchs according to a visible evidence of physical and chemical resistance of envelopes, can be referred to such criteria for distinction of related groups. The acritarch classification can include units essentially corresponding to these requirements.

[67] The proposed classification yields a marker of difference in physical and chemical resistance of forms, which is inadequate to usual morphological features differentiating the acritarch genera and subgroups. As is seen from the above-reported records, we state a higher rank of that marker defined by the lack of its combined character and as a reflection of a higher surviving of organisms or their reproductive organs. The hierarchy of the proposed classification includes a possibility of inputing ecological indicators that are an integral part of taxonomic studies. On paleontological research within any system, especially that of acritarchs, the inconclusiveness of results is evident. However, we consider the proposed variant as more promising for taxonomic investigations than the present one.

[68] It is assumed that the construction of the acritarch group is governed by the International Code of Botanical Nomenclature, 1996 (hereinafter – Code). To judge the legitimacy of the proposed changes, the actual relationships of the acritarch system and the Code theses should be emphasized. Almost all the theses touch on the plant taxonomy with more or less established hierarchy of natural taxonomic categories. Among the formal fossil taxa only the generic ones are listed in the Chapter I clauses of the Code. Therefore, the Code theses almost cannot account for the situations with formal categories higher than the genus. As regards the acritarch taxonomic position, we can now state the presence in the group of both members of the plant kingdom (algae) and bacteria. On the other hand, in the absence of a “special code of paleobotanical nomenclature” the Code clauses must be, where possible, considered in the microfossil taxonomy. However, in the light of systematic sense of the Code clauses the latters do not prevent from experimental modifications of the acritarch system. Having regard to that situation we propose a variant of acritarch classification implying the different rank of supergeneric taxa.

[69] The group Acritarcha Evitt, 1963 [*Downie et al.,* 1963; *Jankauskas et al.,* 1989] is subdivided into subgroups that differ in non-morphological criteria including the markers indicating a statistically significant possibility of biological differentiation of groups. Among them there can be vital activity conditions, degree of resistance to metamorphic processes, chemical composition, etc. Subgroups are subdivided into infragroups that differ in types of non-obvious affinity, namely, morphological, ecological, and probably some other. In so doing, a large part of the adopted morphological subgroups gains an infragroup rank. Names of the subgroups and infragroups are not typified and they themselves possess an experimental status permitting to vary or extend their diagnosis and range until elaboration of the regulated summary. Names of the new subgroups are given a little used ending “i”. Type genera of subgroups and infragroups are not defined. Species and genera differ in morphological features. We suggest to divide the group Acritarcha Evitt, 1963 [*Downie et al.,* 1963] into subgroups Implethomorphi (Jankauskas et Mikhailova, 1989) [*Jankauskas et al.,* 1989], Stanevich comb. nov.; Oblidomorphi [*Stanevich,* 1997], Stanevich, nom. mut.; and Incertae sedis.

[70] The subgroup Implethomorphi (Jank. et Mikh.) Stan. includes morphologically diverse acritarchs with the established capacity of retaining the envelope volume and features during diagenesis and metamorphism. It is desirable to include the records of biological and ecological interpretation in the generic diagnoses of both this subgroup and Oblidomorphi Stan.

[71] The subgroup Oblidomorphi Stan. includes acritarchs, which organic-walled specimens occur only in a crumpled, leaflike form, i.e. which are not capable to retain the original volume at the very beginning of diagenesis. The subgroup is subdivided into infragroups differing in morphological features. The names, diagnoses, and description of the infragroups correspond to those previously accepted for subgroups within the group Acritarcha Evitt, 1963 [*Downie et al.,* 1963; *Jankauskas et al.,* 1989]. The range of infragroups (subgroups) decreases at the expense of genera possessing volume and permitting their reference to the subgroup Implethomorphi.

[72] The subgroup Incertae sedis contains morphologically heterogeneous microfossils, which characters do not permit their assignment to the rest two subgroups of acritarchs.

Correlation Potentials of Microphytologic Method in the Precambrian

[73] The world-wide records deposited during 50 years of comprehensive study of phytoliths (stromatolites and microphytoliths) and microfossils showed (1) complexity and diversity of their forms in the Precambrian seas; (2) their promising application to stratigraphy; and, however, (3) certain limitations on correlation by means of phytoliths and microfossils. From our standpoint the major limitation is in consideration of only appearance levels of empirically important taxa [*Stanevich and Faizulina,* 1992]. The conclusion is based on three axioms. Firstly, from a great deal of schemes of microfossil distribution in the Precambrian sections [*Jankauskas,* 1982; *Jankauskaset al.,* 1989; *Pyatiletov,* 1988; *Schopf,* 1983; *Stanevich and Faizulina,* 1992; *Timofejev,* 1979; *Veis,* 1988; *Vidal,* 1976] it is seen that once “appearing”, many forms are encountered in the younger fragments of the sections. Secondly, the microfossil remains that are well preserved on transportation in surface waters can be most likely redeposited in the younger sequences. Importance of this statement is especially great in studies of folded regions where the intense inversion tectonic transformations occurred. The third reason for use of the appearance principle lies in the conservative character of cyanophytes accepted as stromatolite producers, and likely of some other microorganisms, nowadays examined in acritarchs. This inference is not contradictory to the known successive alteration of phytolith forms in type sections, however, it emphasizes the necessary exclusion of upper boundary of their range on correlations. The lack of such limitation for phytoliths and microfossils is one of the causes of contradictory conclusions on the age of sequences estimated by different methods and, for instance, of the discussion on the Middle–Upper Riphean boundary in the Siberian reference sections [*Dol’nik,* 2000; *Khomentovsky et al.,* 1985, 1998; *Stanevich and Faizulina,* 1992].

[74] An important but almost non-touched problem of the Precambrian biostratigraphy are the limits of use of different organic remains for correlation. A preliminary inference follows from answers to two related questions. The first one – whether a certain fossil group is represented by biological morphotypes with established or potentially established temporal transformation of their characters? In this case, if we are oriented to the original state of remains, they should refer to a taxonomically restricted group of flora or fauna. The latter thesis follows from the analysis of the use of paleontological records in stratigraphy [*Stepanov and Mesezhnikov,* 1979]. It indicates that a correlative reflection of the morphotypes’ evolutionary changes is possible

Table 1. Ecobiological and systematic position of Late Riphean and Vendian microfossils from the Sayany–Baikal fold system.

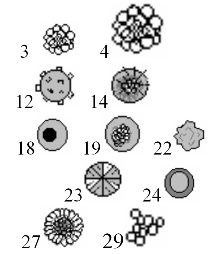
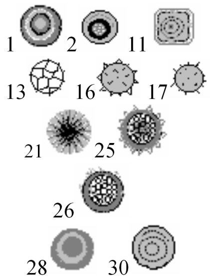
Assumed ecobiological position of microfossils				
Likely original groups		Likely conditions of life activity	Microfossil taxa	
Acritarchs of the Subgroup Implethomorphi (Jank. et Mikh., 1989), comb. nov. (Volumetric forms retaining three-dimensional structure on diagenesis and metamorphism)				
a **(1)**	Assemblage of chemolithotrophic anaerobic bacteria	Benthos from various, down to mesobathyal zones (carbonaceous silty pelites)	**3, 4,** **12, 14,** **18, 19, 22,** **23, 24** **27, 29**	
b **(2)**	Aerobic chemolithotrophic bacteria	Sublittoral benthos and facultative plankton (?) (terrigenouscarbonate facies)	**15**	
c **(3)**	Dinoflagellates or prostecobacteria	Epipelagic plankton	**20**	
d **(6)**	Green algae	Epipelagic plankton, facultative shelf periphyton (finely terrigenous sediments)	**1, 2, 11,** **13, 16, 17,** **21, 25, 26,** **28, 30**	
e **(1, 4?)**	Bacterial substitute forms	Benthos from various zones (carbonaceous silty pelites)	**5, 6, 7,** **9, 10** and others	Intergeneric taxa
Acritarchs of the Subgroup Oblidomorphi (Stan., 1997), subgr. nov. (Flattened, “squashed” forms, crumpled on diagenesis)				
f **(5)**	Eucaryotic forms (brown and other algae)	Benthos of inner shelf and epipelagic plankton (finely terrigenous sediments)	**31, 32, 33, 34, 35,** **36, 37, 38** and others	
Bacteria. Cyanophyta				
g **(4)**	Assemblage of phototrophic lithogenerative cyanophytes and algae (?)	Littoral and inner sublittoral benthos (syngenetic flints of chemobiogenic carbonates)	(order Oscillatoriales and others) **39, 40, 41, 42, 43, 44,** **45, 46, 47, 48, 49, 50, 51** mat-forming, filamentous microfossils **52, 53, 54**	

Table 1. Continued.

Records by *Belova and Golovenok*, [1999], *Golovenok and Belova*, [1983], *Pyatiletov*, [1983], *Stanevich and Faizulina*, [1992], *Stanevich et al.*, [1999], *Faizullin*, [1998], *Schopf et al.*, [1979]. Assemblages of forms (ah) correspond to ecobiological groups (16) in Figure 2. Species, genera, and intergeneric taxa:

Acritarchs of the Subgroup Implethomorphi (Jankauskas et Mikhailova, 1989), comb. nov.: 1. *Aducta sibirica* Fajzulina, 1982; 2. *Bailikania* Trestshetenkova, 1981 (4 species); 3. *Bavlinella faveolata* Schepeleva, 1962; 4. *B. variabilis* (Moorman, 1974), Stanevich, 1992; 5. *Bavlinella* sp. (ad lib. *Bailikania* sp.); 6. *B.* sp.(ad lib. *Dictyotidium* sp.); 7. *B.* sp.(*Floris* sp.); 8. *Bavlinella* sp.(ad lib. *Micrhystridium* sp.); 9. *B.* sp. (*Octoedryxium* sp.); 10. *B.* sp.(*Tchuja* sp.); 11. *Centrum* Stanevich, 1986 (2 species); 12. *Clavata tchuensis* Stanevich, 1987; 13. *Dictyotidium minor* Stanevich, 1986; 14. *Eomarginata* Jankauskas, 1979; 15. *Floris* Stanevich, 1990 (4 species); 16. *Micrhystridium certum* Trestshetenkova, 1981; 17. *M. insuetum* Trestshetenkova, 1981; 18. *Nucellosphaera licis* Stanevich, 1987; 19. *N. tuberculifera* (Fajzulina, 1981); 20. *Octoedryxium* Rudavskaja, 1973, 1989 (3 species); 21. *Paracrassosphaera* Rudavskaja in Trestshetenkova, 1979; 22. *Proteus* Stanevich, 1987; 23. *Radiata costata* Stanevich, 1987; 24. *Retiforma laevis* Stanevich, 1992; 25. *Retiforma fera* Stanevich, 1990; 26. *R. tolparica* Mikhailova, 1987; 27. *Rosella limbata* Stanevich, 1987; 28. *Sibiriella Fajzulina*, 1981; 29. *Synsphaeridium* (?) Eisenack, 1965; 30. *Tchuja* Stanevich, 1986 (2 species).

Acritarchs of the Subgroup Oblisomorphi (Stanevich, 1997), subgr. nov.: 31 . *Cavaspina* Moczydlowska et al., 1993; 32. *Leiosphaeridia* Eisenack, 1958, em. Downie et Sarjeant, 1963 (6 species); 33. *Miroedichia* Hermann, 1989; 34. *Ooidium* Timofeev, 1957, em. Norris et Sarjeant, 1965; 35. *Simia* Mikhailova et Jankauskas, 1989; 36.*Tanarium* Kolosova, 1991, em. Moczydlowska et al., 1993; 37. *Trachyhystrichosphaera* Timofeev et German, 1976, em. Hermann et Jankauskas, 1989; 38. *Veryhachium* Deunff, 1954.

Cyanobacteria. Oscillatoriales: 39. *Brevitrichoides* Jankauskas, 1980; 40. *Botuobia* Pjatiletov, 1979; 41. *Digitus* Pjatiletov, 1980; 42. *Eomycetopsis* Schopf, 1968, em. Knoll et Golubic, 1979; 43. *Leiotrichoides* Hermann (1974) 1979; 44. *Obruchevella* Reitlinger, 1948, em. Yakschin et Luchinina,1981 (4 species); 45. *Omalophyma* Golub, 1979; 46. *Oscillatoriopsis* Schopf, 1968; 47. *Palaeolyngbya* Schopf, 1968; 48. *Plicatidium* Jankauskas, 1980; 49. *Polysphaeroides* Hermann, 1976; 50. *Polytrichoides* Hermann (1974) 1976; 51. *Siphonophycus* Schopf, 1968 (2 species).

Mat-forming, filamentous microfossils Incertae sedis: 52. *Alekania* Golovenok et Belova, 1999 (2 species); 53. *Bifaria* Belova, 1999; 54. *Siphonomorpha* Golovenok et Belova, 1999.

only within such groups. The second question concerns the intercorrection of results of the biostratigraphic and other methods – whether the statistically significant alteration of features, ultimately used for correlation, agrees with geological reconstructions and reliable isotope records?

[75] The Precambrian sediments yield rich assemblages of filamentous and other microfossil forms – stromatolite producers that are assigned to the modern cyanobacteria (blue-green algae) taxa based on their extreme morphological similarity. This indicates the occurrence of an invariant organismal and likely cellular structures of certain cyanophyte taxa from at least Middle Riphean to the Cenozoic. That conclusion does not contradict the empirically established temporal alteration of phytolith forms in the sections, however, it emphasizes the groundlessness of absolutization in biostratigraphy of an upper boundary of taxon distribution. Previously the position of considering only a first occurrence level was accepted by the Resolution of the All-Union Colloquium on Microphytoliths, Stromatolites, and Microfossils, 1975, as one of three methods of the stromatolite use in stratigraphy and was applied by *Shenfil'* [1991] in studies of their distribution in the Riphean of Siberia. The conservatism of cyanophyte forms during the Phanerozoic and Late Proterozoic [*Golubic and Gofmann,* 1976] does not give grounds to assign an evolutionary meaning to morphological changes of phytolith constructions. On the other hand, the association of some types of constructions with certain Late Precambrian intervals is proved. This regularity can hardly be explained only by changes of sedimentation environment and most likely is of biological, though still unclear nature. Thus as regards stromatolites and microphytoliths, we infer that their cyanophytic nature, the same as for microfossils, dictates an application of the appearance principle. This reasonably decreases the stratigraphic potentials of phytolith forms compared to the traditional notion. However, at the same time this approach reduces possible mistakes in controversial cases on correlations.

[76] Most of morphological innovations used for tracing the beds of regional horizons in the SBFS sections [*Nemerov and Stanevich,* 2001] are referred to types that we assign to green algae. Part of them is also known from Vendian sediments of the Late Precambrian reference sections. Most of forms of this assemblage was previously included in the 4th SBFS assemblage or in the Subassemblage IIIa of the Siberian platform [*Stanevich and Faizulina,* 1992]. The occurrence of these forms in both uppermost Late Riphean and Vendian–Lower Cambrian sediments of the SBFS and Siberian platform was among the causes of a discussion on stratigraphic position of the “Moty Series” (Resolutions of the 4th Interdepartmental Regional Stratigraphic Conference on the Refinement of Vendian and Cambrian Stratigraphic Schemes of the Siberian Platform Inner Regions, 1989). It was shown [*Stanevich and Faizulina,* 1992] that a lot of characters of these acritarchs first occurred in the Dal’netaiga Horizon but became taxonomically clear only in the pre-Vendian Zhuya time. This confirms that evolutionary innovations in the Precambrian biotas can be revealed most likely within the biologically related morphotypes. Their tracing upward from the pre-Vendian beds confirms the principle of considering only a first occurrence of typical microfossil forms and infers the general radiation of green algae during the Late and probably Middle Riphean.

[77] Along with the green algae the microfossil assemblage from the Urin Formation is the most significant for correlation of Neoproterozoic sediments [*Faizullin,* 1998; *Pyatiletov,* 1983]. These microfossils owing to a complicated morphology, occurrence in reference sections of distant regions, and appearance in the Neoproterozoic can be considered as index genera for this Precambrian interval. However, it is not improbable that their more simple "ancestors" with similar characters can be encountered in the older Late Riphean beds and still lower. Most of the rest microfossils from SBFS, judging from their simple structure and distribution of the analogues in other regions, are known or likely can be found in the older than the Upper Riphean sequences.

[78] The peculiar *Bavlinella* Schep. forms that on the basis of their wide distribution in the Vendian of the East European platform were dated strictly in this interval [*Jankauskas et al.,* 1989; *Semikhatov et al.,* 1990; *Vidal,* 1976], can serve as an example. However, in the SBFS the *Bavlinella* forms were encountered almost throughout the interval recovered by the reference sections, up to the sediments of the Ballaganakh Horizon. On the other hand, we use the microfossils, which relative chronological significance can acquire an archstratigraphic meaning with further studies, though nowadays they are not formally included in stratigraphic schemes because of the lack of their findings in the reference Proterozoic sections. These are, for instance, the above-reported species of *Dictyotidium* Eis., emend. Stapl. that are known and used for correlation in the Paleozoic sections [*Kir'yanov,* 1978; *Pashkyavichene,* 1980]. In the Baikal zone the oldest forms similar to *Dictyotidium* were encountered in the upper subformation of the Goloustnaya Formation (Figure 2). This fact confirms a common for the Precambrian microphytology tendency of downward extension of the previously accepted range of characteristic microfossil forms. Among prominent examples are the Late Riphean and Vendian acanthomorphytes [*Jankauskas et al.,* 1989; *Moczydlowska et al.,* 1993] many of which were previously considered as especially Paleozoic remains.

Conclusions

[79] 1. The analysis of microfossil distribution in the Late Proterozoic sediments of the SBFS, which were deposited in various environments of the evolving marine basin, shows the actuopaleontological correspondence of the discussed assemblages to certain bathymetrically and facially different zones of the paleobasin.

[80] 2. The reconstruction of sedimentation environments in the Late Precambrian basin of the SBFS confirms as a whole the ecological confinement of the distinguished microfossil groups. Benthic anaerobic bacteria assemblages along with the transported algae remains are characteristic of areas with various depth and stagnant conditions of carbon deposition. The relics of phototrophic cyanophytes and diverse forms of eucaryotic algae are associated with littoral and upper sublittoral sediments. The structures interpreted as bacterial substitute forms occur in almost all environments.

[81] 3. Temporal alterations of microfossil features in the Dal'netaiga and Zhuya horizons are observed almost exclusively in morphotypes referred to the green algae ancestors (*Aducta*, *Bailikania*, *Centrum*, *Dictyotidium*, *Paracrassosphaera*, *Retiforma*, *Sibiriella*, and *Tchuja*). Their initial characters first occurred in the Dal'netaiga Horizon, which basal beds were most likely deposited in the mid-Late Riphean. The ultimate formation of their taxonomic features occurred in the pre-Vendian time, in the uppermost Zhuya Horizon.

[82] 4. Results of the reported investigation support the statement that evolutionary innovations in both Phanerozoic and Precambrian biotas can be revealed only in tracing a temporal succession of biologically related morphotypes and within their inferior taxonomic groups. Taking into account a scantiness of pure morphological method, the improvement of widely used acritarch classification in order to consider the non-formal criteria for distinction of their forms, is desirable.

[83] 5. Considering the studies of Precambrian organic remains as a part of paleontology, we emphasize that its chronological aspect results from notion about nature and evolutionary tendencies of fossil organisms. Thus the ecobiological line of investigation is the decisive for the Precambrian biostratigraphy. The reported records clearly indicate the prospects for use of paleophytological data in conducting the stratigraphic and ecobiological research and geodynamic reconstructions. We suppose that even modest success in this path permits to outline the stratigraphic criteria of previously "mute" microbiotas from ancient basins.

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