

# Kimmeridgian–Volgian Palynological Assemblages of the Eganovo Section (Moscow Region) and Their Possible Application for Biostratigraphy, Correlation, and Facies Analysis

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**Abstract**—The results of study of marine and terrestrial palynomorphs in the Lower Kimmeridgian and Middle-Upper Volgian in the Eganovo section (Moscow region) are presented. The section is well characterized by ammonites providing a biostratigraphic control of the palynostratons. Beds with spores and pollen are identified for the Volgian interval and beds with dinocysts are distinguished for the entire section. Certain taxa allow comparison of synchronous successions of dinocysts of the European part of Russia, Siberia, and Western Europe. By spores and pollen, a correlation is possible with coeval rocks of the northern Urals, Western Europe, and Australia. The facies analysis of two palynological groups allowed reconstruction of features of marine algaeflora and their interrelation with transgressive–regressive dynamics of the paleobasin, climatic fluctuations, and change in coastal landscapes. The comparative analysis of the lateral distribution of coeval dinocyst assemblages from the Eganovo section and other Boreal regions showed a significant similarity of algaeflora of European Russia, the North Sea region, and Bulgaria in the Kimmeridgian, but the lateral differentiation of algaeflora increased to the end of the Volgian. At the same time, the diversity of the dinocyst assemblages in the European part of Russia remained high. It is suggested that this was caused by favorable temperature and trophic conditions, which are interpreted using the results of facies analysis of terrestrial palynomorphs. The features of their taxonomic composition are typical of the Euro-Sinian paleogeographic area with a subtropical climate. Gradual cooling in the second half of the Volgian was accompanied by recovery of small climatic maxima, which are also traced in Western Europe, Siberia and the northern Urals. No period of aridization typical of the terminal Jurassic of Western Europe was revealed. Wet conditions led to the formation of specific palynoflora with abundant gleicheniaceus ferns in the European part of Russia and adjacent territories of the Urals and margins of Western Siberia.

**Keywords:** Russian Plate, Upper Jurassic, palynomorphs, biostratigraphy, correlation, biofacies

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## INTRODUCTION

The palynological studies of the Upper Jurassic on the territory of the European part of Russia have successfully been conducted since the middle of the last century. The vast available material was partly published and actively used in compilation of several generations of regional stratigraphic charts of the Jurassic rocks of the East European Plate (Mitta et al., 2012). The Volgian interval on the territory of Moscow and Kostroma regions, the Middle Volga River region, and other areas is well characterized by spores and pollen. At the same time, the data on the Kimmeridgian are very limited because of the prevalence of microphytoplankton in palynological spectra and single findings of terrestrial palynomorphs (Shramkova, 1970; Orlova and Tsybin, 1972; Dobrutskaya, 1973; Bolkhovitina, 1973; Selkova et al., 2011). These works characterize the qual-

itative and quantitative composition of the palynological assemblages of several stages and their parts or ammonite zones and compare them with palynological assemblages of adjacent territories. In most cases, however, there are no detailed connections to subdivisions which are established on the basis of other biofossil groups. No biostratigraphic subdivisions were identified from the palynological data. Thus, no clear biostratigraphic boundaries which reflect the most important changes in the composition of the terrestrial palynomorphs were distinguished, or their position relative to a standard regional chart and palynological criteria, which would allow independent division of section by spores and pollen and correlation with palynostratons of other territories.

At the same time, the biostratigraphic potential of dinocysts were fully used: a continuous succession of

the dinocyst zones for the European part of Russia was identified for the Bathonian–Ryazanian on the basis of materials from the Middle and Upper Volga River Region and Pechora Syncline, and the biostratigraphic markers and correlative taxa for some levels were distinguished (Riding et al., 1999). Certain refinements and additions were introduced into a Kimmeridgian–Volgian part of the dinocyst scale on the basis of materials from the Gorodishchi and Kashpir sections (Harding et al., 2011; Pestchevitskaya, 2021).

This work is based on a combined study of the Kimmeridgian–Volgian marine and terrestrial palynomorph successions from the Eganovo section (Moscow region), which is well dated by ammonites, in order to refine and/or supplement the dinocyst scale, to recognize the individual palynostrata by spores and pollen, and to estimate the correlation potential of palynostratigraphic boundaries for the comparison of both local and remote sections. The palynology of the section was studied for the first time. It is also expected that the joint biofacies analysis of two palynological groups will enable simultaneous interpretation of marine paleobasin conditions and adjacent land environments, as well as tracing their joined dynamics in time and interrelations.

## MATERIALS AND METHODS

The studied section is located in the Ramensky district of Moscow region close to the village of Eganovo (Fig. 1). It is exposed by drainage trenches of a quarry of OAO Ramensky GOK for mining of glassy sands (Shirshov, 2005). The section is built of the Kimmeridgian and Volgian clays, silts, and sands. The detailed description and ammonite stratigraphy of the section was provided by Rogov (2017). The section contains the ammonite zone (a-zone) *bauhini*–*catenulatum* zones in the Volgian part, as well as biohorizons. Thus, the palynological material has precise calibration with ammonite zone and the levels of its sampling are verified in detail by an orthostratigraphic group.

Samples for palynological analysis were collected in 2017–2018 during a field trip dedicated to the VII All-Russian Meeting “Jurassic System of Russia: Problems of Stratigraphy and Paleogeography” and during field works under a leadership of M.A. Rogov (Geological Institute, Russian Academy of Sciences (GIN RAS), Moscow). The laboratory preparation of samples included, first, treatment with a hot 10% solution of sodium pyrophosphate, washing from a clay fraction, and centrifugation in a heavy liquid (CdI + KI, specific weight of 2.25) for the extraction of an organic fraction. Some samples were treated with HF and HCl and also underwent acetolysis. The amount of palynomorphs in sample was calculated at least up to 200 specimens: first, together for marine and terrestrial forms (to identify their ratio) and then individually in both groups. The biostratigraphic anal-

ysis and identification of palynological zones as biostratons of complex substantiation were based, first of all, on the first occurrences/last occurrences of stratigraphically important taxa, which are traced on vast territories and their stratigraphic extends are supported by faunistic datings. The dynamics of the amount and diversity were used as additional criteria. The published data and current conceptions on these problems were used for biofacies and paleogeographic analysis of microphytoplankton and terrestrial palynomorphs (Vakhrameev, 1988; Leereveld, 1995; Jansonius and McGregor, 1996; Abbink, 1998; Van Konijnenburg-Van Cittert, 2002). The degree of similarity of dinocyst assemblages in the north of Eurasia was estimated using the Jaccard index (Jaccard, 1901).

## DINOFLAGELLATE CYST STRATIGRAPHY

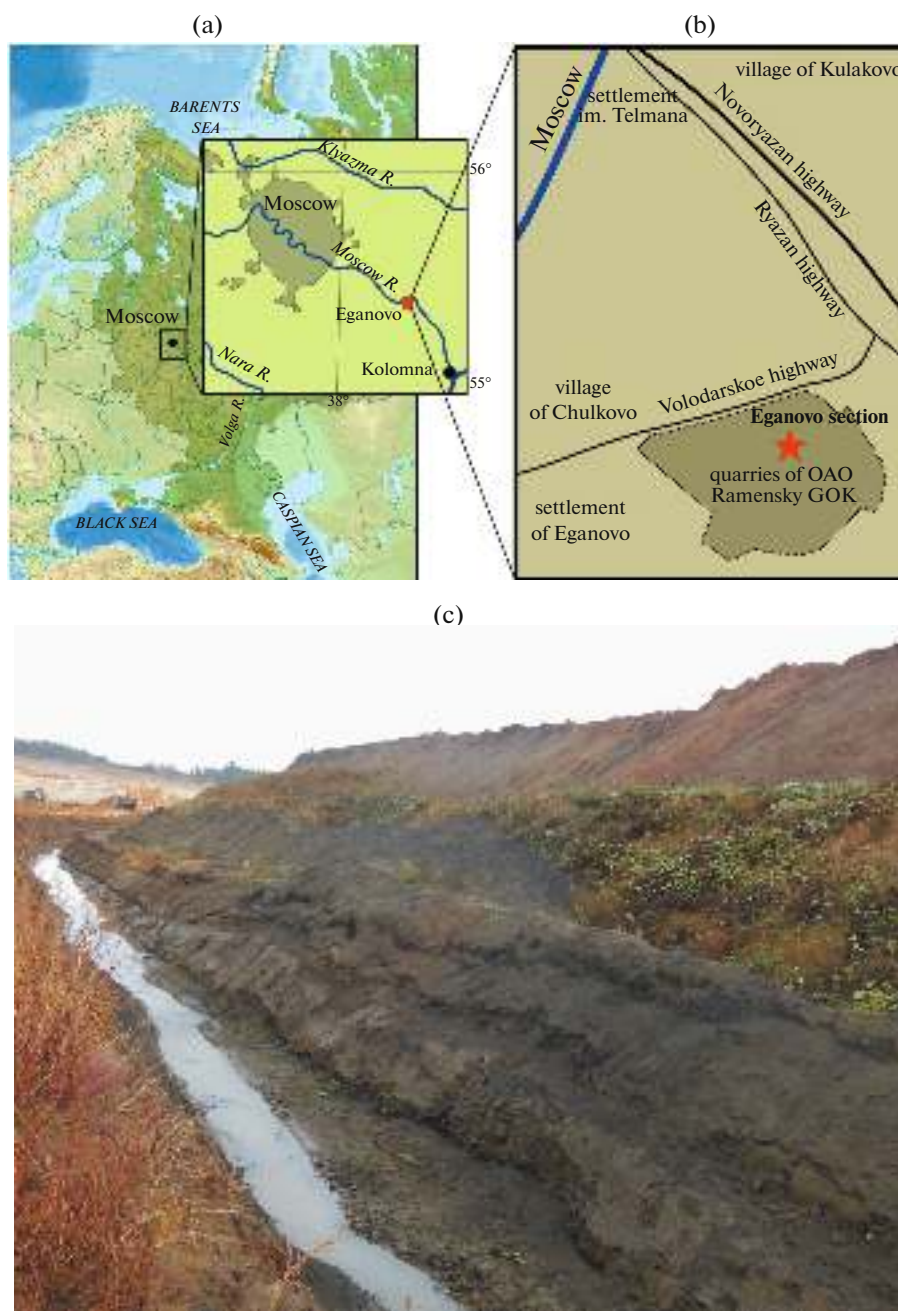
The marine palynomorphs include diverse dinocysts, acritarchs, prasinophytes, and microforamiferal linings with local presence of lacustrine green algae (*Botryococcus*). The section contains two biostratons in a rank of beds with dinocysts. The distribution of dinocysts in the section is shown in Fig. 2.

### Beds with *Cribroperidinium? longicorne*, *Systematophora? daveyi*

**Typical assemblage:** dominated by poorly preserved proximate (16%) and chorate (14%) dinocysts, *Systematophora* spp. (14%), and *Impletosphaeridium varispinosum* (Sarjeant) Islam (16%); numerous (7%) dinocysts of the genus *Cribroperidinium* (including *C.? longicorne* (Downie) Lentin et Williams, *C.? ehrenbergii* (Gitmez) Helenes, *C. angulosum* (Gitmez) Poulsen); low percentages (4%) of the group *Pilosidinium* (genera *Pilosidinium*, *Sentusidinium*, *Barbatacysta*). There are dinocysts of the genera *Dingodinium*, *Evansia*, *Gonyaulacysta*, *Rhynchodiniopsis*, *Leptodinium*, *Scriniodinium*, etc.; acritarchs *Solisphaeridium stimuluferum* (Deflandre) Pocock (1%); and prasinophytes of the genera *Leiosphaeridia* (2.5%) and *Pterospermella* (1.5%). Stratigraphically important species are listed below.

**Stratigraphically important features.** There are dinocysts which appear in the north of Western Europe from the Upper Oxfordian (*Occiscysta balios* Gitmez of a-zone rosenkranzi and *Egmontodinium polyplacophorum* Gitmez et Sarjeant of A. serratum Zone), as well as the taxa the first occurrence of which in the north of Western Europe is registered in the Lower Kimmeridgian: *C. angulosum*, *C.?* (a-zone baylei) and *C.? longicorne*, *Systematophora? daveyi* Riding et Thomas (A. cymodoce Zone) (Sarjeant, 1979; Thomas and Cox, 1988; Powell, 1992; Poulsen and Riding, 2003).

**Boundaries.** The lower boundary is not identified and conditionally follows the lower level of sam-



**Fig. 1.** Eganovo section: (a) general position of the section; (b) location of quarries of OAO Ramensky GOK; (c) image of the Eganovo section.

pling and the upper boundary is combined with a lithological boundary between beds E1 and E2.

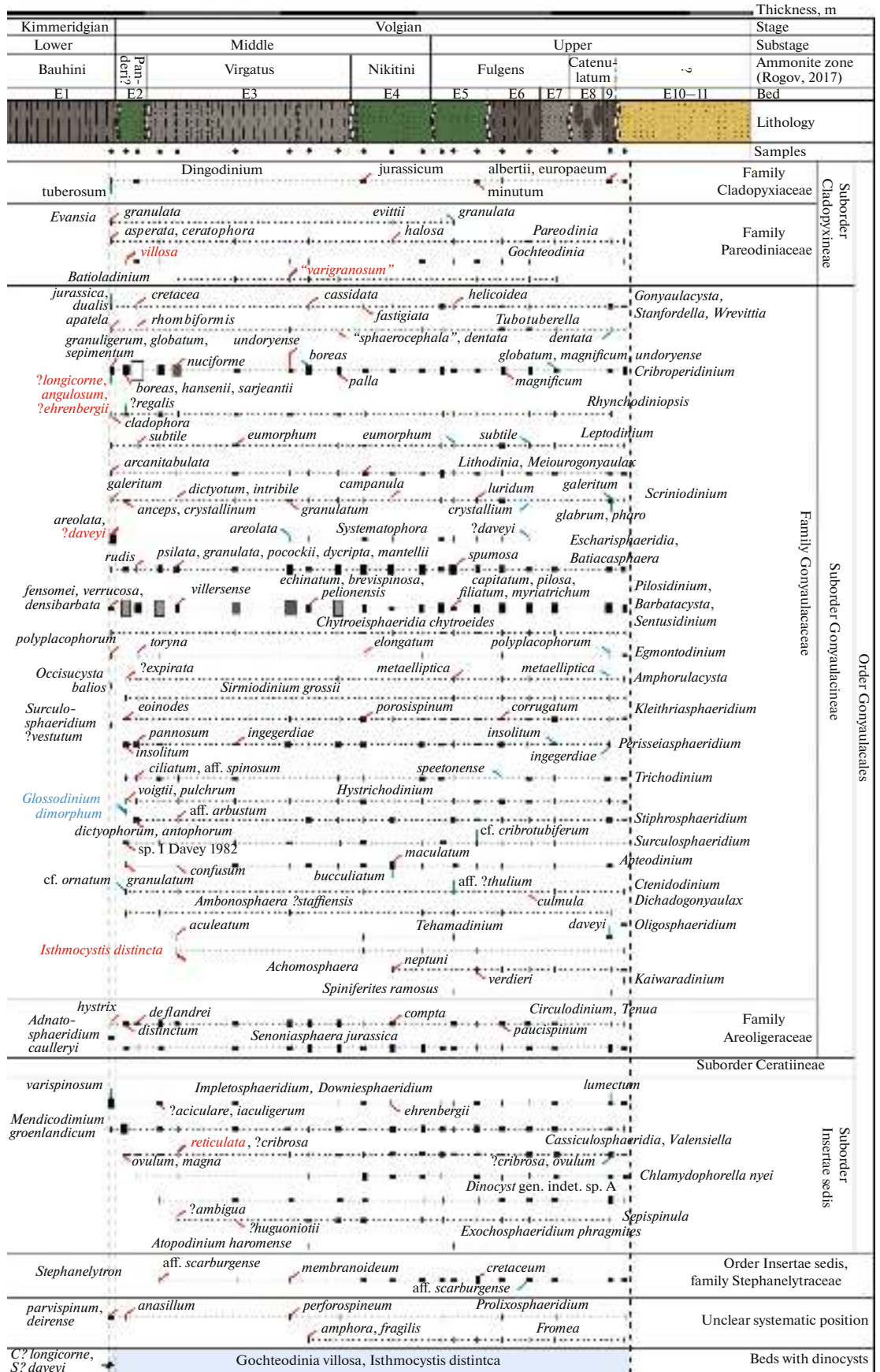
**Stratigraphic position.** The upper part of bed E1, a-zone bauhini, Lower Kimmeridgian.

**Beds with *Gochteodinia villosa*,  
*Isthmocystis distincta***

**Typical assemblage:** dominated by poorly preserved proximate dinocysts (17–29%) and *Cribo-*

*peridinium* (2.5–43%). Locally abundant are representatives of the group Escharisphaeridia (1–5, up to 17%). Fairly numerous are poorly preserved proximochorate dinocysts (2–14%), groups *Pilosidinium* (3.5–11%) and *Circulodinium–Tenua* (1–10%), and locally, *Dingodinium* (up to 5%), *Apteodinium* (up to 7%), *Stiphrosphaeridium* (up to 5.5%), *Perisseiasphaeridium* (up to 5%), *Senoniasphaera jurassica* (Gitmez et Sarjeant) Lentin et Williams (up to 7%), *Impletosphaeridium* (up to 5%), and *Cassiculosphaeridia* (up to 15%);

Fig. 2. Distribution of dinocysts in the Eganovo section. For symbols, see Fig. 3. Here and in Figs. 3 and 6, color of the lithological column corresponds to the color of rocks.





there are consistent occurrences of rare *Pareodinia*, *Tubotuberella*, *Leptodinium*, *Rhynchodiniopsis*, *Meiourogonyaulax*, *Scriniodinium*, etc. Stratigraphically important species are listed below.

**Stratigraphically important features.** The species *Cribroperidinium hansenii* Poulsen is recorded from the lower parts of the Portlandian (a-zone albani) of Denmark (Poulsen, 1996) and the lower part of the Middle Volgian (a-zone panderi) on the Russian Plate (Pestchevitskaya, 2021). The oldest occurrences of the genus *Stiphrosphaeridium* are registered on the Russian Plate in the Gorodishchi section (the upper part of a-zone panderi) (Pestchevitskaya, 2021). The species *Isthmocystis distincta* Duxbury and *Gochteodinia villosa* (Vozzhennikova) Norris first appear in the middle of Portlandian (a-zone kerberus) in the north of Western Europe (Powell, 1992; Poulsen and Riding, 2003). The latter species is also present in the Middle Volgian in the sections of the Russian Plate (a-zone nikitini) (Harding et al., 2011; Pestchevitskaya, 2021) and the north of Siberia (the upper parts of the JF55 foraminiferal zone, which corresponds to the lower part of the a-zone okensis) (Nikitenko et al., 2018). *Achomosphaera neptuni* (Eisenack) Davey et Williams was found in the transitional Middle–Upper Volgian beds of Denmark (Heilmann-Clausen, 1987), although contamination is not excluded, because the dinocysts were studied from cutting samples. This species was previously identified beginning from a-zone virgatus (Harding et al., 2011). *Spiniferites ramosus* (Ehrenberg) Mantell first appears in the transitional Middle–Upper Volgian beds of Denmark (Heilmann-Clausen, 1987) and the upper part of the Middle Volgian (a-zone nikitini on the Russian Plate; Pestchevitskaya, 2021). In the northern Urals, it was found in the Upper Volgian sediments (Lebedeva and Nikitenko, 1998). This species occurs in the Berriasian (a-zone jacobi) in France (Monteil, 1992). The representatives of this genera (species *S. alatus* Duxbury) were also found in the Upper Tithonian of Bulgaria (Dodekova, 1994). The oldest occurrences of *Cassiculosphaeridia reticulata* Davey are recorded in the the uppermost Portlandian (a-zone lamplughi) in the Netherlands (Abbink et al., 2001a) and in the Upper Volgian of Denmark (Heilmann-Clausen, 1987) and Siberia (Nikitenko et al., 2018). *Batioladinium “varigranosum”* (Duxbury) Davey was found in the uppermost Portlandian in the North Sea region (a-zone lamplughi) (Herngreen et al., 2000) and on the island of Newfoundland (Van Helden, 1986), as well as in the Upper Volgian on the Barents Sea shelf (Smelror et al., 1998) and Siberia (Nikitenko et al., 2018). The species *Cribroperidinium undoryense* Smith et Harding and *C. magnificum* Smith et Harding are typical taxa of the Middle and Upper Volgian of the Russian Plate: they first appear in the a-zones virgatus and panderi, respectively (Smith and Harding, 2004; Harding et al., 2011).

**Boundaries.** The lower boundary is combined with the bottom of bed E2; the upper boundary is not identified and conditionally follows the upper sampling level.

**Stratigraphic position.** Beds E2–E9, the base of bed E10, a-zones panderi–catenulatum.

## SPORES AND POLLEN STRATIGRAPHY

In the Eganovo section, the representative spore and pollen assemblages are studied only from the Volgian; the terrestrial palynomorphs in the Lower Kimmeridgian are rare (Fig. 3). The Volgian Stage contains Beds with *Gleicheniidites toriconcavus*, *Plicatella chetaensis* that have previously been identified on the Russian Plate (Gorodishchi section) in the Middle and Upper Volgian (the middle part of a-zone panderi–catenulatum) (Pestchevitskaya, 2021).

### Beds with *Gleicheniidites toriconcavus*, *Plicatella chetaensis*

**Typical assemblage.** Spores of gleicheniaceus ferns of the genera *Gleicheniidites* (15–32%) and *Plicifera* (1–7%) are dominated. There are numerous cyatheaceous ferns of the group Cyathidites–Leiotriletes (1–8.5%) and, locally, schizaeaceous ferns (up to 6%); low percentages of spores of osmundaceous ferns (1–3%) are encountered, as well as diverse sphagnopsoids *Stereisporites* (1–3%). The lycopods include the genera *Lycopodiumsporites*, *Selaginella*, *Uvaesporites*, *Neoraistrickia*, *Densoisporites*, etc. (Fig. 3). The pollen assemblage contains numerous and diverse conifers represented by Pinaceae, Sciadopityaceae, Podocarpaceae, and abundant Cheirolepidiaceae (*Classopollis*, 17–48%). The pollen of Ginkgoaceae/Cycadopsida is always present (0.5–3%). Stratigraphically important species are listed below.

**Stratigraphically important features.** A low amount of striate and verrucate spores of schizaeaceous ferns of the genera *Trilobosporites* and *Cicatricosisporites* are typical of the Portlandian of the north of Western Europe (Jansonius and McGregor, 1996). These morphotypes are also registered in the Volgian in the northern Urals and Siberia, but they occur significantly more rarely (Ilyina, 1985; Dzyuba et al., 2018; Nikitenko et al., 2018). The Eganovo section contains the species *Cicatricosisporites sibiricus* (Kara-Mursa) Chlonova that first appears in the Middle Volgian (the middle of a-zone panderi) on the Russian Plate in the Gorodishchi section (Pestchevitskaya, 2021) and the Upper Volgian in the northern Urals (Dzyuba et al., 2018). *Cicatricosisporites australiensis* (Cookson) Potonie is a key species for the Upper Tithonian of Australia, the first occurrence of which marks an eponymous zone spanning also the Berriasian and the lowermost Valanginian (Sajjadi and Playford, 2002). The base of this zone is also characterized by the first occurrence of *Foraminisporis dailyi*

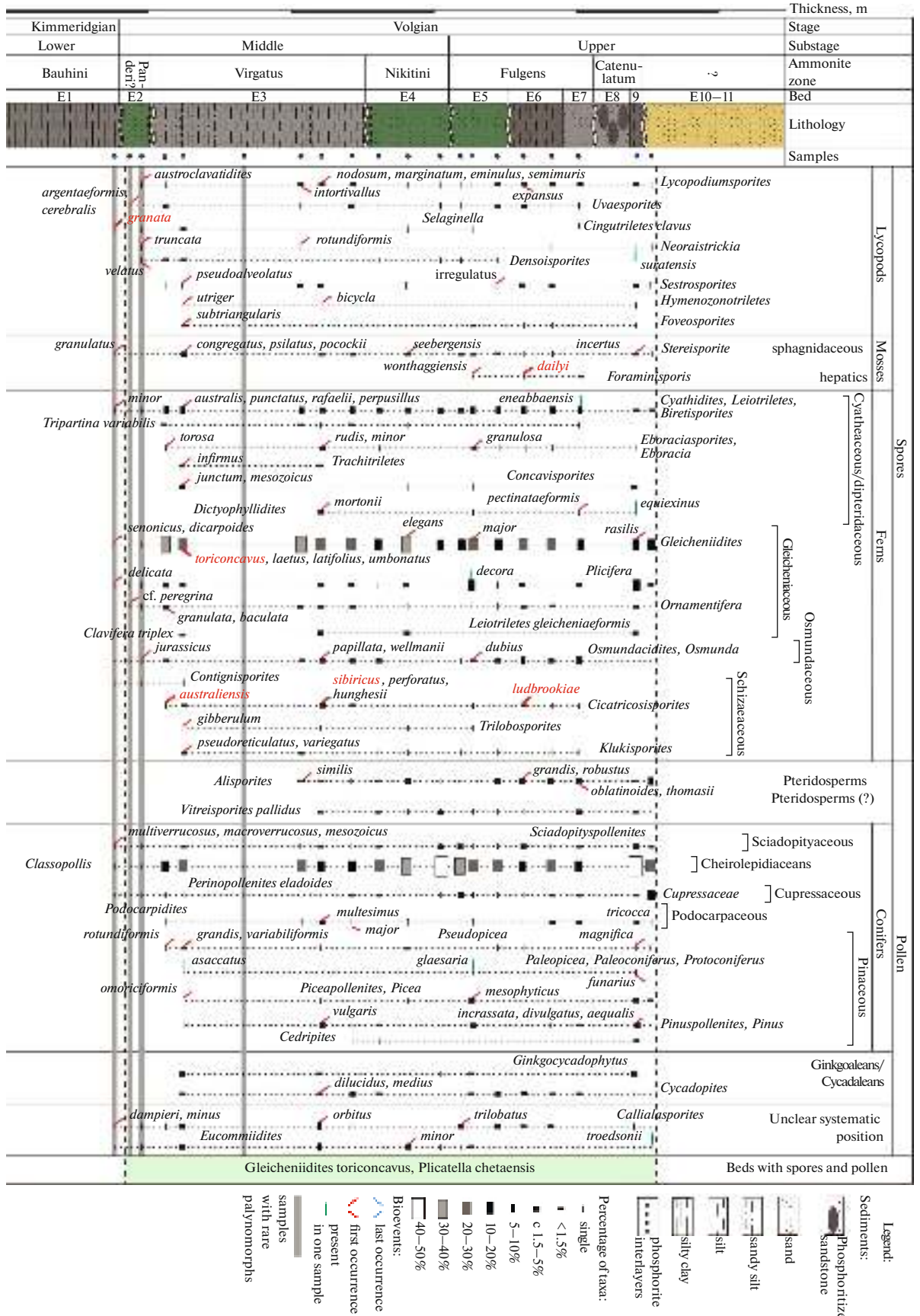


Fig. 3. Distribution of spores and pollen of terrestrial plants in the Eganovo section.

(Cookson et Dettmann) Dettmann, which is also identified in the Eganovo section. An important feature of this palynological assemblage is the presence of the species *Gleicheniidites toriconcavus* Krutzsch, the oldest occurrences of which are known from the uppermost Upper Jurassic in Germany (Döring, 1965) and the middle part of the Volgian Stage (the middle of a-zone panderi) on the Russian Plate (Dobrukskaya, 1973; Pestchevitskaya, 2021).

**B o u n d a r i e s.** The lower boundary is combined with the base of bed E2 and the upper boundary is not identified and it conditionally follows the upper sampling level.

**S t r a t i g r a p h i c p o s i t i o n.** Beds E2–E9, the base of bed E10, panderi–catenulatum a-zones.

#### CORRELATION POTENTIAL OF DINOCYST BIOSTRATONS

The representative spore–pollen assemblages of terrestrial plants and microphytoplankton allowed the biostratigraphic division based on two palynological groups. Owing to the detailed faunistic datings (Rogov, 2017), the palynostratons are calibrated with ammonite zones. The reliable age by palynological data is based on biostratigraphic analysis of spores and pollen of terrestrial plants and dinocysts conducted as well as published data.

#### *Dinocyst Data*

Stratigraphically important species *Cribroperidinium? ehrenbergii* and *C. angulosum* are defined among dinocysts of the lower part of the section that allow the correlation of their host sediments with the Lower Kimmeridgian of the North Sea region, Arctic Canada, and Siberia (Fig. 4). This is consistent with ammonite datings, which show the presence of the Lower Kimmeridgian a-zone bauhini in the Eganovo section (Rogov, 2017). At the same time, the assemblage contains *C.? longicorne* and *Systematophora? daveyi*, which first appear in the north of Western Europe in the a-zone cymodoce (Powell, 1992; Poulsen and Riding, 2003). This suggests that the upper part of the Kimmeridgian interval in the Eganovo section may correspond to the upper part of the Lower Kimmeridgian.

A dinocyst *Gonyaulacysta jurassica* subsp. *jurassica* Zone was previously identified in the sections of Kostroma region and Middle Volga River Region for the Lower Kimmeridgian and the lower part of the Upper Kimmeridgian (baylei–eudoxus a-zones) (Riding et al., 1999). The Kimmeridgian of the Eganovo section, however, contains no species that mark its lower boundary: *Scriniodinium anceps* (Raynaud) Jan du Chene et al., *Glossodinium dimorphum* Ioannides et al., and *Perisseiasphaeridium pannosum* Davey et Williams. The qualitative and quantitative composition of the dinocyst assemblages also significantly dif-

fers, which complicates the comparison of the dinocyst successions. Thus, the Beds with *Cribroperidinium? longicorne*, *Systematophora? daveyi* are distinguished in the Kimmeridgian of the Eganovo section.

The Volgian part of the section is characterized by different biostratigraphic interpretation of paleontological material by ammonites and dinocysts. According to (Rogov, 2017), the occurrences of ammonites allow to reconstruct a complete zonal succession of the Middle Volgian in the lower part of this interval. At the same time, the features of the taxonomic composition of dinocyst assemblages are more typical of the upper parts of the Middle Volgian and the Upper Volgian. Together with *Cribroperidinium hansenii*, *Stiphrosphaeridium dictyophorum*, and *S. antophorum*, which are the key taxa for the lowermost Portlandian and the middle part of the Middle Volgian, the lower part of the Volgian Stage in the Eganovo section (layers 2 and 3) contains *Isthmocystis distincta* and *Gocht-eodinia villosa*, which were previously unknown below the a-zone nikitini on the Russian Plate (Harding et al., 2011; Pestchevitskaya, 2021), a-zone okensis in the north of Siberia (Nikitenko et al., 2018), and a-zone kerberus in the north of Western Europe (Powell, 1992; Poulsen and Riding, 2003). The presence of the proximochorate dinocysts *Dinophyceae* gen. indet. sp. A is also noteworthy (Plate I). The presence of an apical archeopyle and corona-like septa (locally, two), which occur in the apical area and/or the lower part of a hypocyst, is similar to the genera *Stephanelytron* (Sarjeant, 1961) and *Lagenadinium* (Piel, 1985). The same morphotypes were observed in the Middle and Upper Volgian (nikitini and fulgens a-zones) in the Gorodishchi section (data of E.B. Pestchevitskaya).

The species *G. villosa* is an important biostratigraphic and correlation marker in the north of Western Europe. An eponymous zone (= *Pareodinia dasyforma*, now a junior synonym of *G. villosa*) was determined in the sections of England by the first occurrence and constant presence of the index species and spanned the upper part of the Portlandian (from opressus a-zone) and almost completely the Ryazanian (up to albidum a-zone) (Woollam and Riding, 1983; Powell, 1992). This dinocyst zone is characterized by approximately the same stratigraphic extent (the base of the Upper Volgian—the lower part of the Ryazanian) on the Russian Plate (Riding et al., 1999). Later, single occurrences of *G. villosa* were found in the lower stratigraphic horizons (kerberus a-zone in the north of Western Europe and nikitini a-zone on the Russian Plate), which allowed reconsideration of the position of the base of this dinocyst zone in the latter region (Poulsen and Riding, 2003; Harding et al., 2011; Pestchevitskaya, 2021). In the north of Western Europe, the lower boundary of the zone remained the same; however, in addition to the constant occurrences of the index species, it was substantiated by the last appearance of *Dichadogonyaulax? pannea* (Norris) Sarjeant, *Glossodinium dimorphum* Ioannides et al.,

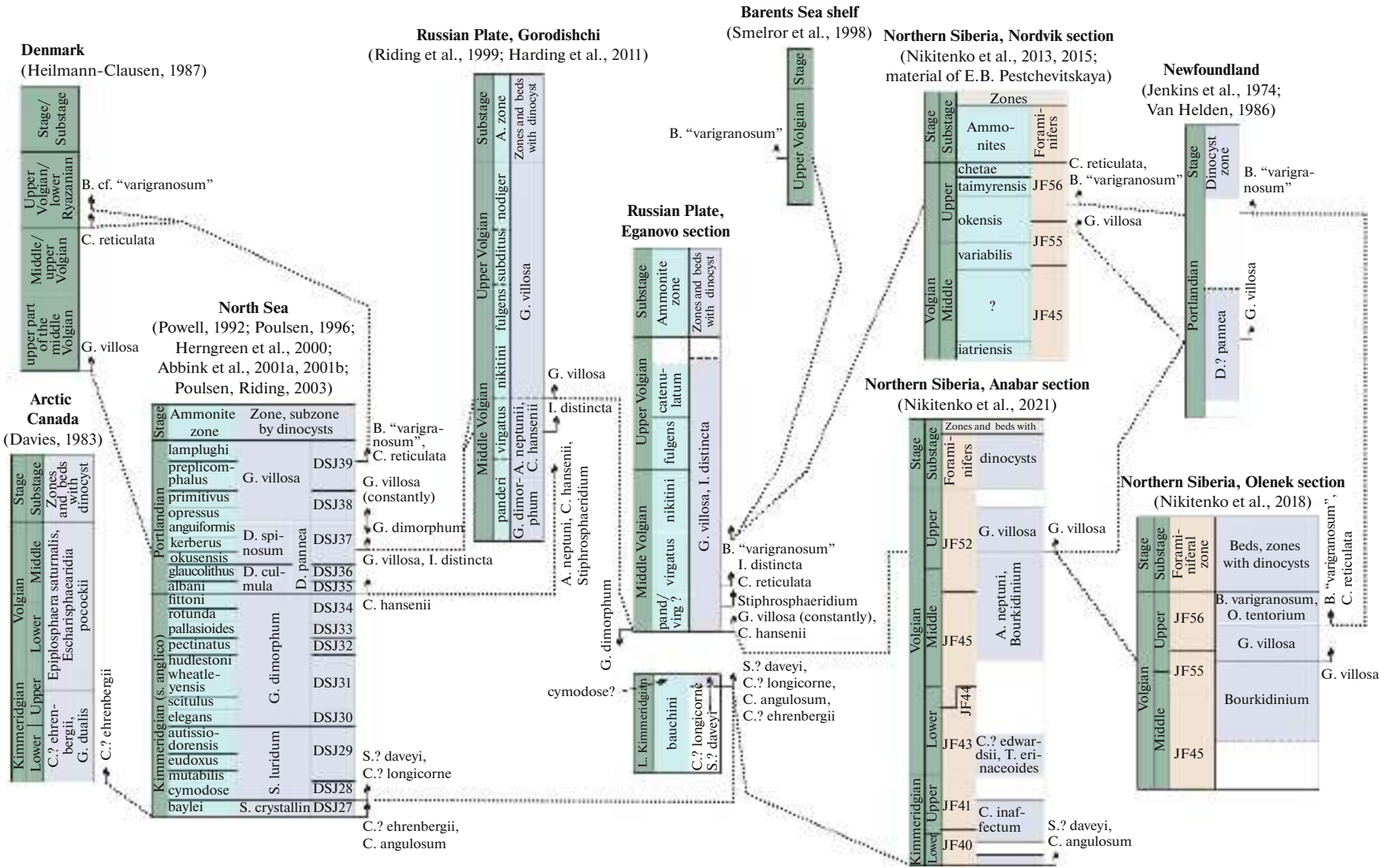


Fig. 4. Correlation of biostratigraphic marking levels by dinocysts.



and *Dingodinium tuberosum* Cookson et Eisenack (Poulsen and Riding, 2003). In the Eganovo section, *Dichadogonyaulax? pannea* is absent, whereas *D. tuberosum* is found only in the Kimmeridgian. *G. dimorphum*, however, was found in bed E2 at the level of the panderi a-zone. The species *G. villosa* first appears in the same level, this species is present in higher intervals of the section and characterized by consistent occurrences with low percentages (1.0–1.5%) (Fig. 2). The upper part of the Volgian interval in the section contains *Cassiculosphaeridia reticulata* and *Batioladinium "varigranosum,"* which are typical of the uppermost Portlandian in the north of Western Europe (Netherlands, Denmark) and Upper Volgian on the Barents Sea shelf and in Siberia (Heilmann-Clausen, 1987; Smelror et al., 1998; Nikitenko et al., 2018). Thus, a certain succession of first occurrences of key dinocyst taxa is observed, which mark the stratigraphic boundaries (Fig. 4).

Our palynological data are largely consistent with ideas of Shirshov (2005) on a stratigraphic range of the Volgian part of the section in the Ramensky district: the glauconite sands with phosphorites in the base of the Volgian part of the section were considered as the Middle Volgian and an overlying clayish–silty bed was accepted as transitional Middle–Upper Volgian. The contradictions with data of Rogov (2017) can be related to different biostratigraphic interpretation of the paleontological ammonite material by various specialists in both the sections of the Russian Plate and other regions. The occurrences of ammonites of the panderi Zone from the Middle Volgian glauconite sands with a denser phosphorite interlayer at the top were previously described from the Moscow Syncline (Gerasimov et al., 1995). According to the opinion of Olfer'ev (2012), however, this is a result of redeposition of the phosphorite nodules with ammonites from older rocks, whereas these nodular-hosting sands could belong to higher horizons (no older than the virgatus Zone). This scenario is possible in the Eganovo section as well. On the other hand, the dinocysts occurrences, typical of the higher stratigraphic horizons in the north of Western Europe and Siberia, in the Eganovo section could be related to the earlier appearance of these species on the territory of the

European part of Russia and their further migration to the adjacent regions.

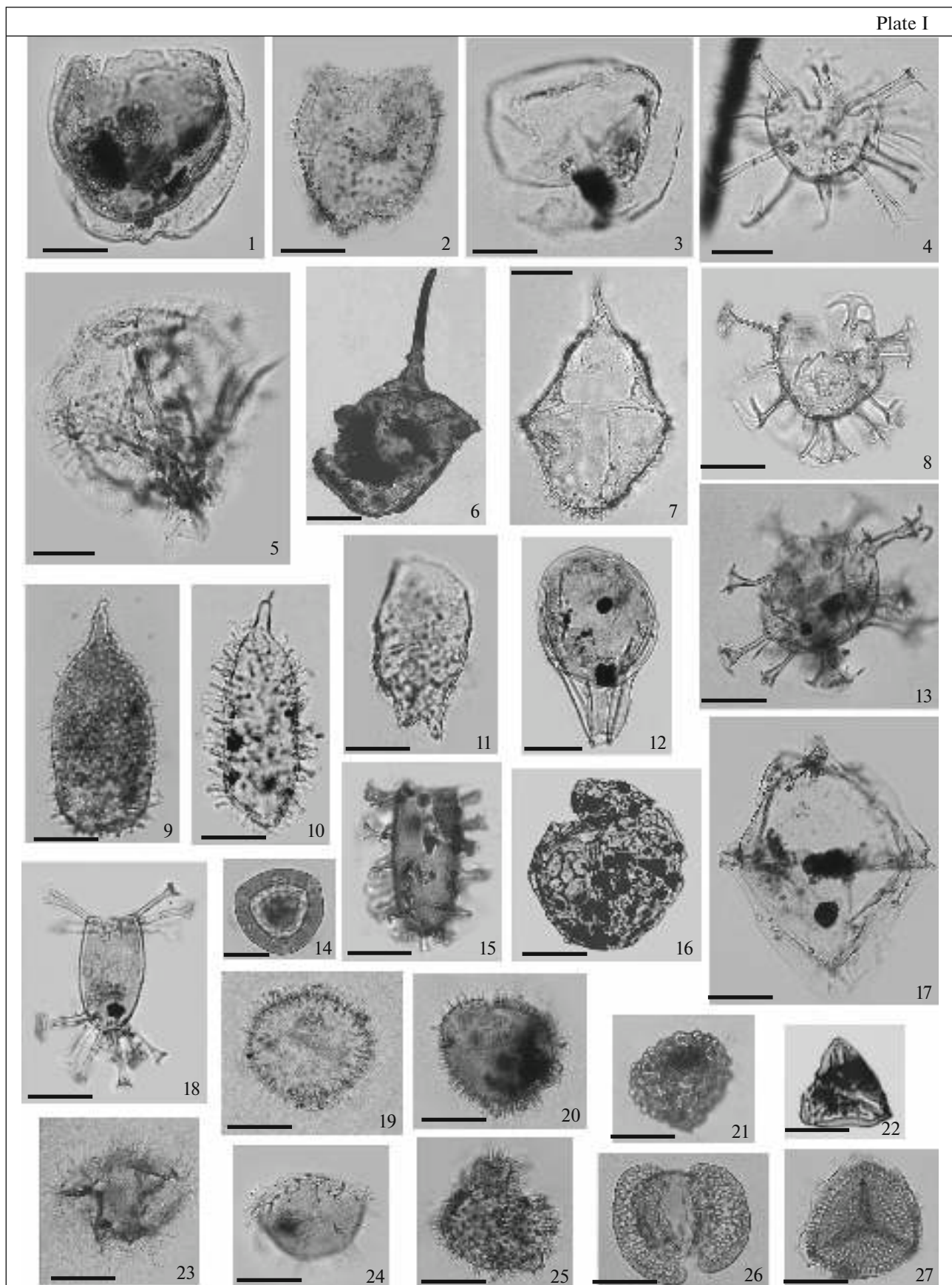
Thus, the Eganovo section exhibits typical features of the Gochteodinia villosa Zone. Taking into account the viewpoint of Rogov (2017), however, it is characterized by atypical earlier appearance of the zonal species at the level of the panderi a-zone. This is significantly lower than in the north of Western Europe (kerberus a-zone; Poulsen and Riding, 2003) and the Middle Volga River Region (nikitini a-zone; Harding et al., 2011; Pestchevitskaya, 2021). As a result, the *Gochteodinia villosa*, *Isthmocystis distincta* Local Zone is identified in the Eganovo section as a working version (Fig. 2).

#### Spores and Pollen Data

The representative assemblages of spores and pollen of terrestrial plants are studied in the Eganovo section only from the Volgian part. The Lower Kimmeridgian contains rare terrestrial palynomorphs (Fig. 3). There are no striate and verrucate spores of schizaeaceous ferns, which are considered as the stratigraphically important features of spore–pollen assemblages of the Upper Oxfordian and Kimmeridgian in the north of Western Europe and Siberia (Jansonius and McGregor, 1996; Nikitenko et al., 2015). This interval on the territory of the European part of Russia was not previously characterized by these morphotypes (Shramkova, 1970; Dobrutskaya, 1973). This could be caused by both an arid climate (Vakhrameev, 1988) unfavorable for growing ferns and the low amount of terrestrial palynomorphs in samples in contrast to dominant microphytoplankton (Dobrutskaya, 1973; Sel'kova et al., 2011; etc.).

The presence of *Selaginella granata* Bolchovitina, however, is noteworthy in the Eganovo section. In the north of Central Siberia, its oldest occurrences are recorded from the middle of the Lower Kimmeridgian (the middle part of kitchini a-zone), which allows correlation with our section. This also supports the possible presence of a level corresponding to the cymodoce a-zone of the north of Western Europe at the top of Bed E1 in the Eganovo section. The species *S. granata* was also registered in the Kimmeridgian–Lower Volgian spore–pollen assemblages of the central and

**Plate I.** Palynomorphs from the Lower Kimmeridgian and the upper part of the Volgian of the Eganovo section. Scale bar is 20 µm. (1) *Senoniasphaera jurassica* (Gitmez et Sarjeant) Lentini et Williams, bed E2; (2) *Circulodinium distinctum* (Deflandre et Cookson) Jansonius, bed E3; (3) *Mendicodinium groenlandicum* (Pocock et Sarjeant) Davey, bed E2; (4) *Perisseiasphaeridium insolutum* Davey, bed E3; (5) *Glossodinium dimorphum* Ioannides et al., bed E2; (6) *Cribroperidinium? longicorne* (Downie) Lentini et Williams, bed E1; (7) *Cribroperidinium hansenii* Poulsen, bed E10; (8) *Surculosphaeridium* sp. 1 Davey 1982, bed E8; (9, 10) *Gochteodinia villosa* (Vozzhennikova) Norris: (9) bed E2; (10) bed E4; (11) *Batioladinium matyjae* Poulsen, bed E5; (12) *Tubotuberella apatela* (Cookson et Eisenack) Ioannides et al., bed E5; (13) *Oligosphaeridium* sp., bed E10; (14) *Cingitriletes clavus* (Balme) Dettmann, bed E7; (15) *Egmontodinium toryna* (Cookson et Eisenack) Davey, bed E4; (16) *Cassiculosphaeridia reticulata* Davey, bed E3; (17) *Scriniodinium crystallinum* (Deflandre) Klement, bed E2; (18) *Kaiwaradinium* sp., bed E10; (19, 20, 25) *Dinophyceae* gen. indet. sp. A: 19, bed E4; (20) bed E3; (25) bed E6; (21) *Uvaesporites cerebralis* Tralau, bed E2; (22) *Gleicheniidites toriconcavus* Krutzsch, bed E3; (23) *Hystrichodinium pulchrum* Deflandre, bed E4; (24) *Dichadogonyaulax culmula* Neale et Sarjeant, bed E6; (26) *Podocarpidites multesimus* (Bolchovitina) Pocock, bed E6; (27) *Sestrosporites pseudoalveolatus* (Couper) Dettmann, bed E3.



northern regions of Western Siberia (Glushkov and Purtova, 1980). On the territory of the Russian Plate, the Beds with *Selaginella granata* have been identified in the uppermost Kimmeridgian and the lower part of the Volgian Stage in the Gorodishchi section (Pestchevitskaya, 2021). Nonetheless, this species was rarely found in the southwest of Ukraine and Central Asia (Yanovskaya, 1973; *Yurskie...*, 1981). It is possible that the earlier appearance of lycopods of the species *S. granata* is related to the paleofloristic zonation: in the Middle Jurassic, the Siberian territories were part of an eponymous paleofloristic area with warm temperate climate, whereas Ukraine and Central Asia belonged to the Euro-Sinian paleofloristic area with a hotter subtropical climate (Vakhrameev, 1988). The northward migration of the species in the Late Jurassic could have been related to a general climate warming (Vakhrameev, 1988) and favorable conditions for its growth, whereas more southerly regions underwent aridization and were unsuitable for growing of lycopods. In the Jurassic, the territory of the Eganovo section was located in the north of the Euro-Sinian paleofloristic area and the species *S. granata* could have originated later than in the southern regions. Its presence in the Middle and Late Jurassic spore–pollen assemblages in both central and southern areas of the Russian Plate, however, has not been identified yet (Shramkova, 1970; Dobrutskaya, 1973; Rostovtseva, 2014). Thus, the importance of this species for the Upper Jurassic palynostratigraphy will possibly be specified taking into account new data.

The spores and pollen of the terrestrial plants in the Volgian part of the Eganovo section allowed the identification of the Beds with *Gleicheniidites toriconcavus*, *Plicatella chetaensis*, which were established on the Russian Plate in the Gorodishchi section in the upper part of the Volgian Stage (the middle part of a-zone panderi–catenulatum a-zone; Pestchevitskaya, 2021). The lower part of beds was palynologically characterized in the Gorodishchi section, whereas the terrestrial palynomorphs were rare in the upper part. The detailed characterization of the upper part of the palynostraton is based on materials from the Eganovo section (Fig. 3).

From the viewpoint of palynostratigraphy, the presence of the species *Gleicheniidites toriconcavus* is important: its oldest occurrences are registered in the upper parts of the Upper Jurassic in Germany (Döring, 1965), as well as in the Middle Volgian in the Kostroma Volga River Region (Dobrutskaya, 1973) and Gorodishchi section (Pestchevitskaya, 2021). The presence of single striate and verrucate spores of schizaeaceous ferns of the genera *Trilobosporites* and *Cicatricosisporites* is typical, which is also characteristic of the Portlandian of Western Europe (Jansonius and McGregor, 1996) and the Upper Tithonian of Crimea (Dorotyak et al., 2009). These morphotypes are observed in the Volgian in the north of the Urals and Siberia, but they are rare (Dzyuba et al., 2018; Nikitenko et al., 2018). The schizaeaceous ferns are

rare on the territory of Central Asia with strongly dominant (95–99%) *Classopollis* pollen in the Tithonian spore–pollen assemblages (*Spory...*, 1971).

The presence of the species *Cicatricosisporites sibiricus*, *C. ludbrookiae*, and *C. australiensis* (Cookson) Potonie in the Eganovo section is important (Fig. 5). The species *Cicatricosisporites sibiricus* first appears in the Middle Volgian (the middle of panderi a-zone) on the Russian Plate in the Gorodishchi section (Pestchevitskaya, 2021) and the Upper Volgian in the northern Urals (Dzyuba et al., 2018). The species *C. ludbrookiae* (together with morphologically similar species *C. abacus* Burger) is a stratigraphic marker of the uppermost Kimmeridgian (*sensu anglico*) and the Portlandian in the north of Western Europe. In the sections of England, the Netherlands, and the North Sea shelf, these species first appear in the the albani a-zone and permanently occur in the Portlandian (Burger, 1966; Hunt, 1985; Abbink, 1998; Herngreen et al., 2000). In Australia, *C. ludbrookiae* first appears in the Upper Tithonian (Sajjadi and Playford, 2002). The oldest occurrences of *C. australiensis* are also revealed in this region. This species is a key for the Upper Tithonian of Australia. Its first occurrence marks an eponymous zone that spans also Berriasian and the lowermost Valanginian (Sajjadi and Playford, 2002). It should be noted that the base of this zone contains *Foraminisporis dailyi*, which was determined in the Eganovo section at a similar stratigraphic level. The spores morphologically similar to *C. australiensis* are also recognized in the Upper Volgian in the northern Urals (Dzyuba et al., 2018). Thus, the above species can be considered as typical of the upper part of the Volgian of the European Russia and Northern Urals and their stratigraphic analogs in the north of Western Europe and Australia. Although their first occurrence in certain sections can be observed at different levels, the lower limits of the stratigraphic occurrence is confined by the panderi/albani a-zones for most species, the virgatus a-zone for *C. australiensis*, and the fulgens a-zone for *Foraminisporis dailyi* (Fig. 5). In the north Siberia, these species appear later in the Boreal Berriasian/Ryazanian Age and/or Early Valanginian (Pestchevitskaya, 2010; etc.), which can be caused by floristic zonation.

The Beds with *Gleicheniidites toriconcavus*, *Plicatella chetaensis* are characterized by a lower amount of the *Classopollis* pollen (from 40–60 to 12–34%) and increasing amount of spores of gleicheniaceous ferns (from 17–38 to 23–50%) in comparison with underlying horizons, which was identified in the Gorodishchi section (Pestchevitskaya, 2021). A similar proportion of these palynomorphs is observed in the Middle Volgian in the Eganovo section: 18–38% for *Classopollis* and 22–35% for Gleicheniaceae. No correlation is observed when compared with more southerly regions. On the territory of the Dnieper–Donets Basin, the amount of *Classopollis* decreases in the virgatus a-zone (to 18% in comparison with 50% and more in the pan-

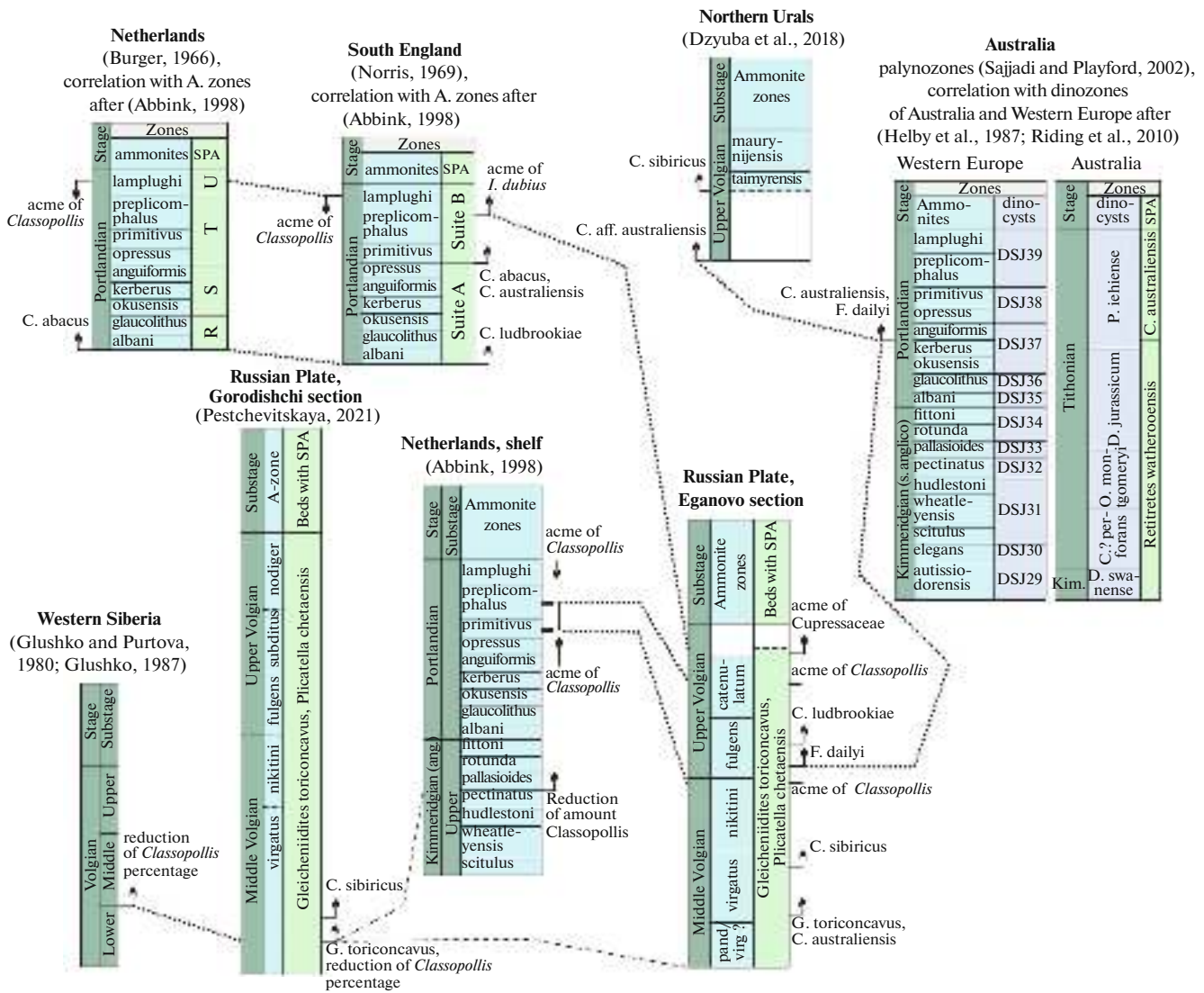


Fig. 5. Correlation of biostratigraphic marking levels by spores and pollen. SPA, spore–pollen assemblage.

deri a-zone) (Voronova and Yanovskaya, 1973). According to Shramkova (1970), however, this pollen is abundant in both zones of the Voronezh Antecline (50–90% for panderi and 83–85% for virgatus).

In the Eganovo section, the amount of *Classopollis* increases to 48% in the upper part of Beds with *Gleicheniidites toriconcavus*, *Plicatella chetaensis*. Similar features are recorded by Dobrutskaya (1969) in the Kostroma Volga River Region in sections characterized by ammonites: the amount of this pollen is 15–30% and 40–70% in the middle part of the Volgian and the Upper Volgian, respectively. A higher amount of *Classopollis* pollen is defined in the Upper Volgian in other sections of Moscow region (Kuntsevo and Milkovo, fulgens and catenulatum a-zones; data of A.V. Lidskaya) and Ryazan region (catenulatum a-zone) (Fedorova and Gryazeva, 1984). The data from the Eganovo section show that the amount of *Classopollis*

pollen increases unevenly with maxima in the uppermost nikitini a-zone–lowermost fulgens a-zone and in the upper parts of the A. catenulatum Zone.

The abundance of the *Classopollis* pollen (50–80%) is also typical of the Portlandian of Western Europe (Burger, 1966; Norris, 1969). According to Abbink (1998), this genus is a main component of a group of thermophilic coastal plants. The quantitative parameters of this group slightly decrease starting with the pallasioides a-zone (from 50–60 to 40%); however, there are maxima in the primitivus a-zone and the middle part of the preplicomphalus a-zone (Abbink, 1998). According to a correlation model of Rogov (2017), this is in agreement with reduced abundance of *Classopollis* in the Gorodishchi section in Beds with *Gleicheniidites toriconcavus*, *Plicatella chetaensis* and quantitative *Classopollis* maxima in its upper part in the Eganovo section (Fig. 5). There is



also a correlation between the amount of Cupressaceae and a morphologically similar type determined by Norris (1969) as *Inaperturopollenites dubius* (Potonie et Venitz) Thomson et Pflug in the uppermost Volgian and Portlandian (Fig. 5).

In Western Siberia, numerous *Classopollis* pollen is typical of the Lower Volgian of the southern and central areas, where it can reach 70–80% (Glushko and Purtova, 1980; Sheiko, 1980). In the Middle Volgian substage, the percentage of *Classopollis* is also lower (Glushko and Purtova, 1980; Glushko, 1987). No regular changes in the amount of the *Classopollis* pollen in the Volgian is identified in the north of Central Siberia, because it is low and rarely exceeds 2% (Pavlov, 1970; Grigor'eva, 1981; Nikitenko et al., 2018). The Volgian sediments of the Vilyui Syncline contain single *Classopollis* pollen (Fradkina, 1967).

Thus, the quantitative dynamics of the *Classopollis* pollen can be a sufficient tool for the detailed correlation of both local and remote sections in the case of available biostratigraphic markers (palynological and other biofossil groups), which enable the confident recognition of the middle and upper parts of the Volgian Stage (Fig. 5).

#### ANALYSIS OF THE PALYNOLOGICAL ASSEMBLAGES DEPENDING ON FACIES, CLIMATIC, AND PALEOGEOGRAPHIC FEATURES

Biofacies analysis of the palynological material confirms normal marine conditions in the Early Kimmeridgian and the second half of the Volgian in Moscow region. This is evident from abundant microphytoplankton with permanently dominant dinocysts (Fig. 6). Many samples contain few freshwater algae *Botryococcus*, which input in marine sediments is probably derived from the land together with other terrestrial palynomorphs.

The deepest facies are typical of the Lower Kimmeridgian, which is characterized by a significant amount of chorate forms (with long radial processes) and representatives of the subfamily Leptodinioideae in the dinocyst assemblage. The abundance of these forms is often considered a depth index (Wilpshaar and Leereveld, 1994; Leereveld, 1995; Nikitenko et al., 2018; etc.). The dinocysts with the processes distally connected by trabeculae are few in number (*Adnatosphaeridium*, 5.5%). These morphotypes are typical of the outer part of the neritic zone and deeper areas (Pross and Brinkhuis, 2005; Sluijs et al., 2005). Nevertheless, the presence of numerous *Systematophora* (14%) and *Impletosphaeridium* (16%) abundant in shallow-water zones (Wilpshaar, Leereveld, 1994; Pestchevitskaya, 2021) does not make it possible to assume the existence of significant depths.

In the Volgian, the amount of dinocysts indicative of shallow-water and coastal environments increases

(Fig. 6), including numerous representatives of the groups Escharisphaeridia and Pilosidinium, which are resistant to unstable conditions (Jarvis et al., 1988; Nikitenko et al., 2015; etc.). Frequently changing conditions were evidently related to both transgressive–regressive processes and variable hydrodynamics, which is also indicated by hiatuses in sedimentation and diverse lithology of the section. In spite of hiatuses in the section, a general regressive trend with small fluctuations is well traced up the section by the increasing amount of spores and pollen of terrestrial plants and reduction of dinocysts among microphytoplankton. The dynamics of the diversity of dinocysts, however, has an opposite trend: the number of genera increases up the section, which, in this case, is probably related to other factors rather than to transgressive–regressive events.

The composition of spore–pollen assemblages indicates a warm subtropical climate and wet conditions. A group of thermophilic taxa with abundant *Classopollis* pollen (reaching 80–100% in areas with a hot and arid climate) becomes numerous (Alvin, 1982; Ilyina, 1985; Vakhrameev, 1988; etc.). Other warm components in the Eganovo section are less numerous (Fig. 6). The end of the Middle Volgian—the beginning of the Late Volgian and the catelanum phase are characterized by periods of insignificant warming. It should be noted, however, that the Russian Plate underwent a gradual cooling in comparison with the Kimmeridgian and the Early Volgian, which is reflected in a strongly reduced amount of *Classopollis* in spore–pollen assemblages (see above).

It is suggested that the conifers of the family Cheirolepidiaceae, which produced *Classopollis* pollen, were adapted to various conditions: they were able to form scarce forests on the slopes and highlands and bushes on the coast or be part of mangrove vegetation (Alvin, 1982; Ilyina, 1985; Vakhrameev, 1988; Pestchevitskaya, 2021; etc.). Many representatives of Cheirolepidiaceae tolerated well dry periods. The materials from the Eganovo section, however, show that dry periods (if they occurred) in the second half of the Volgian Stage on the territory of Moscow region were relatively short, because, in addition to the *Classopollis* pollen, all samples contains numerous spores of gleicheniaceus ferns, which prefer moderately wet conditions. Among ferns, they are most adapted to the reduced moisture and can form monodominant thickets similar to savannas or prairies on open land (Zhizn'..., 1978; Van Konijnenburg-Van Cittert, 2002). It is likely that this type of vegetation was abundant during the virgatus phase, which is evident from a high amount of spores of gleicheniaceus ferns (29–37%). Nonetheless, these ferns were also able to grow in swampy lowlands (Bolkhovitina, 1968; Butdaeva et al., 2006). These habitats, which were also favorable for lycopods and cyatheaceous/dipteridaceous ferns, could have formed close to a marine paleobasin or freshwater reservoirs. The presence of the latter is supported by

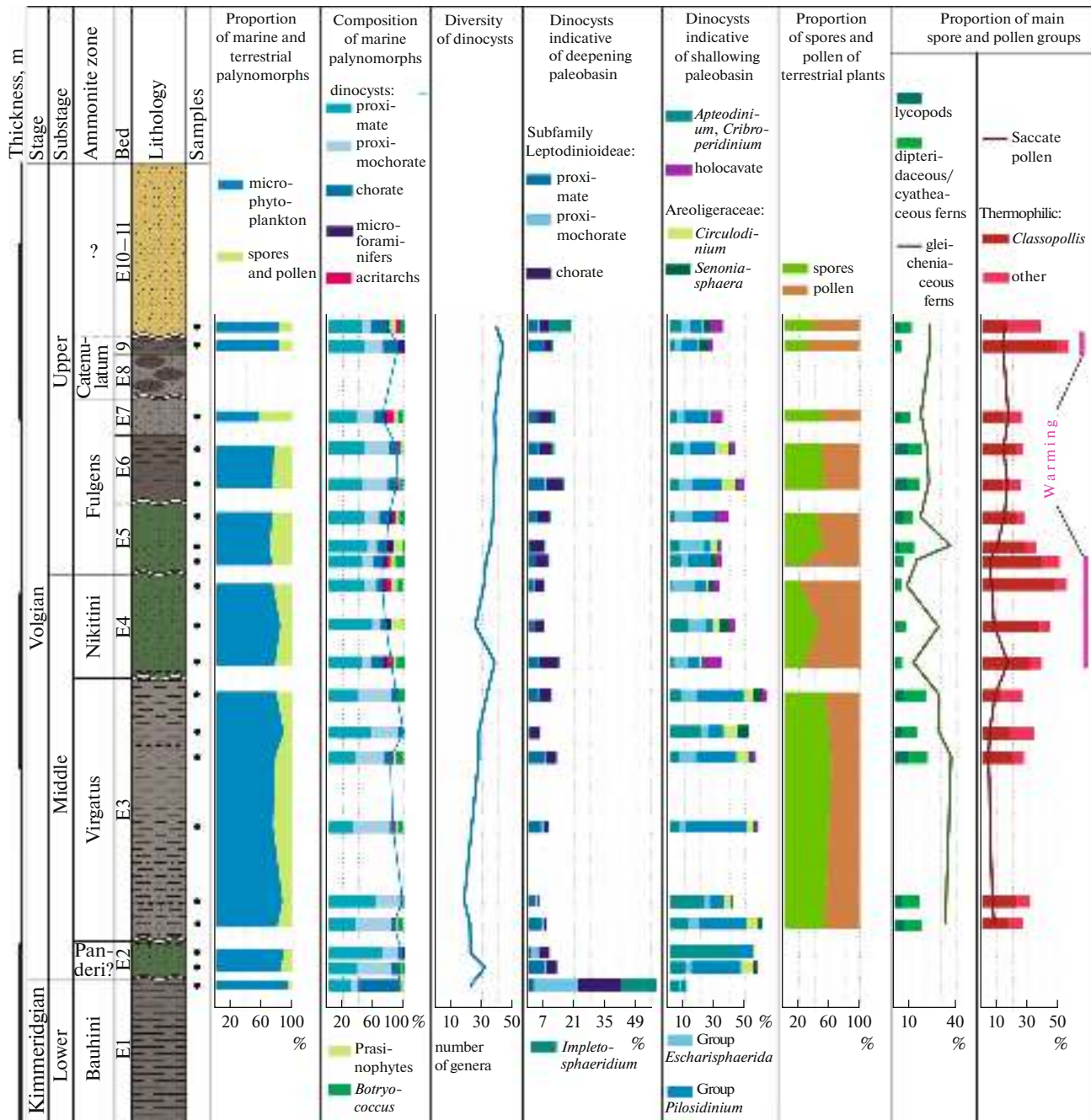


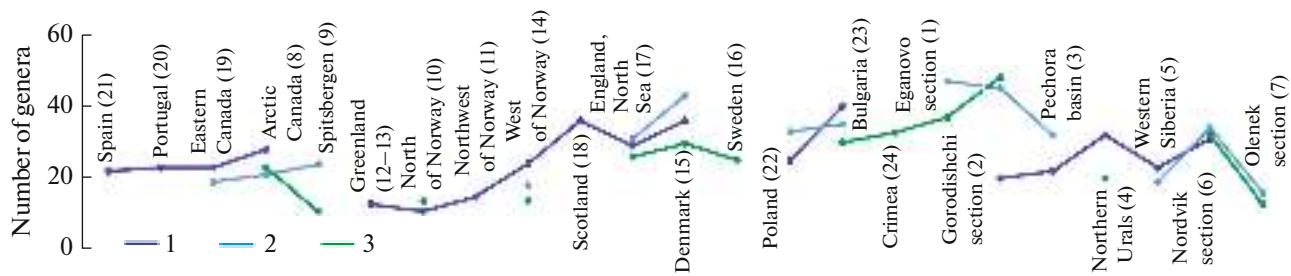
Fig. 6. Quantitative ratio of some ecological groups of marine and terrestrial palynomorphs in the Eganovo section and facies features. Thermophilic components in the group “others” include *Dictyophyllidites*, *Matonisporites*, *Tripartina*, *Plicifera*, *Klukisporites*, and *Cupressaceae*.

the presence of the green algae *Botryococcus* in the microphytoplankton assemblage, which are typical present-day inhabitants of lakes and swamps (*Palynology...*, 1996; etc.).

The abundance of gleicheniaceous ferns could also be related to their ability of easy colonization of new territories formed as a result of sea level oscillations. Because of the fast growth, the present-day gleicheniaceous ferns easily colonize even bare land strongly

heated by the sun in the tropics and subtropics (*Zhizn'...*, 1978).

Some reduction in area of grassy swamps can be suggested in the beginning of the nikitini phase and in the fulgens–catenulatum phase by the increase in the amount of woody plants, which in spore–pollen assemblages is reflected in the increasing amount of saccate pollen of conifers (Fig. 6). It is noteworthy that this period is also characterized by increasing diversity of dinocysts. This is possibly related to the larger amount



**Fig. 7.** Analysis of genus diversity of dinocysts in various regions of the north of Eurasia. (1) Kimmeridgian, (2) Middle Volgian substage, (3) Upper Volgian substage, and their age analogs. Numbers of regions (in brackets) correspond to those in Fig. 8a.

of mineral nutrients contributed from less swampy land. The present-day studies show that waters with their lower content are often formed near the swampy areas owing to active consumption of nutrients by living organisms (*Zhizn'*..., 1978). The greatest diversity of dinocysts is achieved in periods when the increase in the amount of nutrients is accompanied by warming (Fig. 6). Thus, the diversity of dinocysts in this case is mostly controlled by the amount of nutrients and temperature. This explains the mismatch between the dynamics of the diversity of dinocysts in the Eganovo section and transgressive–regressive fluctuations.

Let us note that the increasing diversity of dinocysts during the nikitini and fulgens phases was also observed in shallow-water facies of the Gorodishchi section, where it was also accompanied by diverse chorate forms atypical of similar environments. To explain these facts, it was proposed to consider warmer conditions as a result of better heating of shallow water (Pestchevitskaya, 2021). The data on the Eganovo section show that more favorable temperature conditions during the nikitini and fulgens phases on the Russian Plate could have been related to climate warming. The analysis of O and C isotopes and the composition of clay minerals also confirm that small warming on the Russian Plate begins starting the nikitini phase and becomes more striking in the Late Volgian (Ruffell et al., 2002; Gröcke et al., 2003). This period was also characterized by the quantitative maxima of warm components in spore–pollen assemblages in the north of Western Europe (Burger, 1966; Abbink, 1998; Hergreen et al., 2000; etc.). Small temperature peaks are observed in the Late Volgian on the territory of Eastern Siberia and the northern Urals (Nikitenko et al., 2018; Dzyuba et al., 2018).

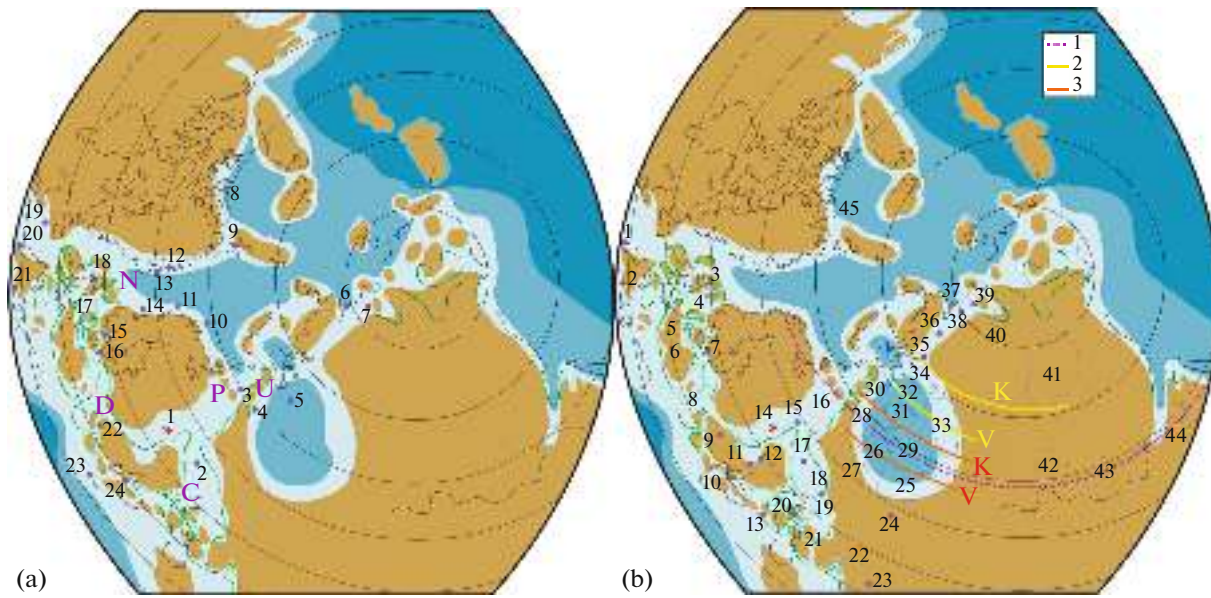
Thus, the analysis of the dynamics of the taxonomic diversity of dinocysts in the Eganovo section shows that it is significantly lower in the Kimmeridgian than in the Volgian. The low generic diversity is also typical of the Kimmeridgian of Greenland and the north of Norway (10–15 genera) (Fig. 7). The reduced generic diversity of the Barents Sea region is registered for the Kimmeridgian communities of foraminifers, which is related to the deeper environments, which are less productive than the middle part of the

shelf (Nikitenko, 2009). The low diversity of dinocysts, however, is also observed in the south of Western Europe, the Pechora basin, and Western Siberia (20–23 genera) in spite of significantly different paleoconditions in these regions (Riding et al., 1999; Ilyina et al., 2005; Borges et al., 2011). In Bulgaria, the North Sea region, the northern Urals, and Eastern Siberia, it is higher (>30 genera) (Fig. 7). In this case, we do not observe an unambiguous correlation between the diversity of dinocysts and the paleogeographic factor and the depth of the paleobasin (Figs. 8, 9). It is possible that, as in the Eganovo region, the diversity of the dinocyst assemblages is affected by various factors and largely controlled by the contribution of nutrients from the continent, which can be limited as a result of climatic conditions (as in the south of Western Europe with arid conditions; Hallam, 1984; Abbink, 1998; etc.) or as a result of lower impact of the river runoff (as in the central areas of the Western Siberia paleobasin; Ilyina et al., 2005). Kimmeridgian dinocyst assemblage from the Eganovo section is similar to coeval assemblages from most Boreal and Subboreal regions (especially, from the North Sea region), as well as from Bulgaria, which can indicate good connections of these basins through the Danish–Poland and Caspian straits (Figs. 8, 9).

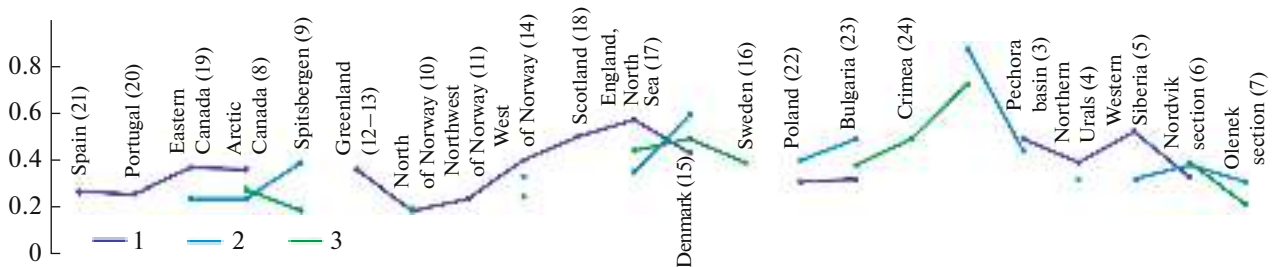
In the Volgian, the diversity of dinocysts on the territory of the Russian Plate significantly increases (Fig. 7). Other regions exhibit less significant changes, mostly, reduction in diversity, which is most expressed in the northern Urals and is possibly related to shallower conditions relative to the Kimmeridgian (Lebedeva and Nikitenko, 1998). The lateral differences in the diversity of the dinocyst assemblages become much more striking. To the end of the Volgian, the similarity of the generic composition of dinocysts from the Eganovo section to that of most regions is gradually reduced except for Denmark, Bulgaria, and, to a lesser extent, the north of Eastern Siberia (Fig. 9).

The taxonomic composition of marine fauna (ammonites, bivalves, belemnites, foraminifers) also shows that the Late Volgian communities are generally less diverse and more regionally differentiated, which is evident from Siberia and the Russian Plate (Zakharov et al., 1994; Nikitenko, 2009; Rogov, 2012;





**Fig. 8.** Occurrences of the Kimmeridgian–Volgian palynomorphs: dinocysts (a) and spores and pollen (b). The paleogeographic interpretations are after (*Atlas...*, 1968; Zakharov, 1981; Abbink et al., 2001b; Nikitenko, 2009; Rogov et al., 2009; Kontorovich et al., 2013; Scotese, 2016). The location of the paleopole is after (Butler, 2004; Nikitenko, 2009, etc.). The position of land is shown for the Kimmeridgian (green dash for the Volgian Stage). **Fig. 8a.** Straits: U, Uralian; P, Pechora; C, Caspian; D, Danish–Polish; N, Norwegian–Greenland; regions: 1, Eganovo; 2, Gorodishchi; 3, Pechora basin; 4, Northern Urals; 5, Western Siberia; 6, Nordvik section; 7, Olenek section; 8, Arctic Canada; 9, Spitsbergen; 10, north of Norway; 11, northwest of Norway; 12, 13, Greenland; 14, west of Norway; 15, Denmark; 16, Sweden; 17, England, North Sea; 18, Scotland; 19, Eastern Canada; 20, Portugal; 21, Spain; 22, Poland; 23, Bulgaria; 24, Crimea. **Fig. 8b.** Legend: 1, Boundary of the Siberian and Euro-Sinian paleogeographic areas by macroflora (Vakhrameev, 1988); 2, boundary of these areas in Siberia by palynological data (K, for Kimmeridgian; V, for Volgian); 3, boundary of distribution of North Siberian palynoflora (K, for Kimmeridgian; V, for Volgian). Regions: 1, Portugal; 2, Spain; 3, Scotland; 4, North Sea; 5, Netherlands; 6, Germany; 7, Sweden; 8, Poland; 9, Prut–Dniester interfluve; 10, Crimea; 11, Dnieper–Donets interfluve; 12, Voronezh region; 13, Caucasus; 14, Eganovo section; 15, Kostroma region; 16, Komi Republic; 17, Gorodishchi section; 18, Orenburg region; 19, south and southeast of the Precaspian Depression; 20, Mangyshlak; 21, Ustyurt; 22, Kyzylkum, Bukhara region; 23, Gissar Range; 24, Pavlodar region; 25, south of Western Siberia; 26, southwest of Western Siberia; 27, Kurgan region; 28, eastern slope of the Urals, west of Western Siberia; 29, middle part of Western Siberia; 30, North Urals, northwest of Western Siberia; 31, Purpe–Surgut region; 32, Nadym–Taz region; 33, Turukhansk region; 34, Ust Yenisei region; 35, Norilsk region; 36, Kheta River; 37, Nordvik section; 38, Anabar section; 39, Olenek section; 40, Zhigan region; 41, Vilyui Syncline; 42, Irkutsk region; 43, Transbaikalia; 44, Bureya Depression; 45, Arctic Canada.



**Fig. 9.** Diagram of similarity of dinocyst assemblages in the Eganovo section and various regions of the north of Eurasia (according to the Jaccard coefficient). Legend: (1) Kimmeridgian, (2) Middle Volgian substage, (3) Upper Volgian substage, and their age analogs. Numbers of regions (in brackets) correspond to those in Fig. 8a. The data are after (Bujak and Williams, 1977; Davies, 1983; Van Erve et al., 1988; Van der Zwan, 1990; Wierzbowski and Aarhus, 1990; Powel, 1992; Dodekova, 1994; Poulsen, 1996; Riding et al., 1999; Wierzbowski et al., 2002; Piasecki et al., 2004; Ilyina et al., 2005; Borges et al., 2011; Lindström and Erlström, 2011; *Berrias...*, 2012; Nikitenko et al., 2015, 2018; Dalsæg et al., 2016; Lebedeva et al., 2019; Pestchevitskaya, 2021).



Dzyuba, 2018). This is related to shallowing and reduction of straits which connected both the Arctic territories to the south Paleotlantic and Russian Sea and the Russian Sea to western and southern basins (Fig. 8). On the territory of the Russian Plate, the reduced abilities for migration of marine fauna led to a strong decrease in the taxonomic composition of the ammonite communities (2–3 genera) in the Late Volgian (Mittra and Sha, 2009; Rogov, 2012). The shallowing and periodic closure of the Danish–Polish, Pechora, and Caspian straits yielded a minor impact on the dinocyst assemblage of the Russian Sea. As was mentioned above, their diversity even increased because of the temperature effect and favorable trophic conditions. The coefficient of taxonomic similarity to other regions decreased insignificantly and, locally, even increased (Fig. 9). It is possible that extremely shallow conditions in straits, which were unfavorable for the migration of marine fauna, did not prevent migration of the dinoflagellates. This was possibly related to a life cycle of dinoflagellates including a cyst stage, which helped these organisms to survive during unfavorable periods and to conquer the ecological barriers, which stopped the migration of marine fauna and led to a significant reduction in links between faunistic communities of various regions in the Late Volgian and, finally, to the taxonomic paucity. However, some parameters of local paleoconditions compensated a negative impact of the paleogeographical factor for the fauna. For example, the increasing temperature at the end of the Volgian, which provided the formation of rich dinocyst assemblages in the Russian Sea (Eganovo and Gorodishchi sections), was also favorable for belemnites in the northern Urals, the diverse communities of which here are comparable with Kimmeridgian ones (Dzyuba, 2018).

The composition of the spore–pollen assemblage from the Eganovo section with abundant *Classopollis* pollen shows that this region in the Late Jurassic was located within the Euro-Sinian paleogeographic area with a subtropical arid climate, which was recognized by Vakhrameev (1988) on the basis of paleobotanic data. It is characterized by numerous bennettitaceans, cheirolepidiaceans, pteridosperms, and araucariaceans. This is in agreement with palynological data (Table 1, Fig. 8): the Kimmeridgian spore–pollen assemblages of the southern areas of Western and Eastern Europe, the Caucasus, Crimea, Central Asia, the southern Urals, and Siberia contain abundant pollen of cheirolepidiaceans (*Classopollis*) and saccate pollen (*Disaccites*), which could have been produced by both conifers and pteridosperms. Pollen of *Callialasporites*, which is sometimes attributed to the Araucariaceae, is typical for Western Europe (Abbink, 1998). The wetter coastal and island areas of Scotland, Portugal, and the north of the North Sea region are characterized by abundant cyatheaceous and gleicheniaceus ferns and lycopods (Table 1). In the Late Kimmeridgian (*sensu anglico*) and Portlandian, the *Classopollis* pollen

in many regions of Western Europe becomes especially dominant. It is suggested that this was caused by enhanced aridization, possibly, owing to regression of a marine paleobasin (Abbink, 1998; Herngreen et al., 2000). The hot arid climate was most striking in Central Asia, which is supported by the composition of paleoflora and lithological features (Vakhrameev, 1988). The spore–pollen assemblages are strongly dominated by *Classopollis* pollen (Tables 1, 2).

The abundance of the *Classopollis* pollen and spores of gleicheniaceus ferns is typical of the European part of Russia. Although marine Kimmeridgian sediments here rarely contain representative spore–pollen assemblages (which is also observed in the Eganovo section), the dominant *Classopollis* is defined in the Gorodishchi section. Its amount here is lower (40–60%) than in Western Europe, Ukraine, and southern Russia (55–100%). This is probably related to the northern position of this region within the Euro-Sinian area and wetter conditions, which is confirmed by abundant spores of gleicheniaceus ferns (20–40%) (Table 1). This feature (evident predominance of the *Classopollis* pollen and spores of gleicheniaceus ferns) is well identified in the Volgian by materials from the Eganovo section, as well as by the data from the Middle Volga River Region and Kostroma region (Table 2). The palynological indicators of a wetter climate are well consistent with higher C content in the Volgian sediments in the sections of the Central Volga region, which is typically related to humidification (Ruffell et al., 2002). The amount of *Classopollis* in the Volgian palynological assemblages is highly variable in comparison with the Kimmeridgian, which is related to climatic oscillations and change in temperature conditions. In this paper, this is demonstrated by example of the Eganovo section. The abundance of fern spores, however, indicates no enhanced aridization in contrast to Western Europe.

The abundance of *Classopollis* pollen and spores of gleicheniaceus ferns is also typical of other territories located in the north of Euro-Sinian area (Central and North Urals, northwest of Western Siberia) and considered as ecotone by some researchers (Rovnina, 1972; Vakhrameev, 1988). In the Kimmeridgian, the *Classopollis* pollen is also dominated here, although its amount gradually decreases toward the north. This allowed Rovnina (1972) to distinguish the Uralian province in structure of the Euro-Sinian paleogeographic area. The abundant pollen of *Sciadopityaceae* is a typical feature of these palynofloras (Tables 1, 2). The diversity of macroremains of *Sciadopitys* is recorded for macrofloras of the north of Norway, which are considered ecotone between the Euro-Sinian and Siberian paleogeographic areas and are ascribed to the latter by Vakhrameev (1988). In the east of Eurasia, the ecotone paleofloras are found in Transbaikalia and Primorye (Vakhrameev, 1988). The spore–pollen assemblages of Irkutsk region and Transbaikalia are dominated by saccate pollen of coni-

**Table 1.** Percentage of main components of the Kimmeridgian spore–pollen assemblages in the north of Eurasia

Region	Strongly dominant, >60%	Dominant, >40%	Abundant, 20–40%	Numerous, 10–20%	Significant, 5–10%	Low, 2–5%
Scotland (3)		Cyatheaceae, Gleicheniaceae, <i>Disaccites</i> , <i>Callialasporites</i> , <i>Sciadopityaceae</i> , <i>Classopollis</i>				
North Sea (4)		Lycopodiaceae 30–50%	Cyatheaceae, Osmundaceae: 25–35%	<i>Antulsporites</i> (Bryophytes)	Ginkgoaceae	<i>Disaccites</i>
Netherlands (5)		Cyatheaceae, <i>Classopollis</i> , <i>Disaccites</i> , <i>Callialasporites</i> , locally, <i>Peromonolites</i>		locally, <i>Sciadopityaceae</i> , Cyatheaceae, <i>Callialasporites</i>	locally, Gleicheniaceae	
Portugal (1)		<i>Disaccites</i> , <i>Callialasporites</i>	<i>Classopollis</i> , <i>Perinopollenites</i>			
Spain (2)	<i>Classopollis</i> , <i>Spheripollenites</i>					
Prut–Dniester interfluvium (9)	<i>Classopollis</i> up to 100%					
Dnieper–Donets interfluvium (11)	<i>Classopollis</i> up to 100%					
Gorodishchi section (17)		<i>Classopollis</i> 40–60%	Gleicheniaceae			
Eganovo section (14)	Microphytoplankton 93%					Spores, pollen (rare)
Kostroma region (15), Komi Republic (16)	Microphytoplankton >90%					Spores, pollen (rare)
Mangyshlak (20)	<i>Classopollis</i> 62–95%			Cyatheaceae	<i>Disaccites</i> , Osmundaceae, Gleicheniaceae	
Pavlodar region (24)	<i>Classopollis</i> 54–96%			<i>Disaccites</i> , Cyatheaceae		Osmundaceae
Kurgan region (27), SW of Western Siberia (26)	<i>Classopollis</i>			<i>Disaccites</i>		Cyatheaceae, Osmundaceae, Ginkgoaceae
SW of Western Siberia (26), south of its middle part (29)	<i>Classopollis</i> 70–90%					<i>Disaccites</i> , Cyatheaceae, Osmundaceae, Ginkgoaceae
North of the middle part of Western Siberia (29)		<i>Classopollis</i> 40–50%		<i>Disaccites</i> , Cyatheaceae		Osmundaceae, Ginkgoaceae

Table 1. (Contd.)

Region	Strongly dominant, >60%	Dominant, >40%	Abundant, 20–40%	Numerous, 10–20%	Significant, 5–10%	Low, 2–5%
Eastern slope of the Urals, west of Western Siberia (28)		<i>Classopollis</i> , <i>Disaccites</i>		Cyatheaceae, Sciadopityaceae, Gleicheniaceae	Osmundaceae, Ginkgoaceae, Lycopodiaceae	
Purpe-Surgut region (31)		<i>Classopollis</i> , <i>Disaccites</i>		Cyatheaceae, Ginkgoaceae		Osmundaceae, Lycopodiaceae
Northern Urals, NW of Western Siberia (30)			Cyatheaceae, <i>Disaccites</i> , <i>Classopollis</i> , Gleicheniaceae		Sciadopityaceae	Ginkgoaceae, Lycopodiaceae
Nadym-Taz region (32)		<i>Disaccites</i>	Cyatheaceae 20–35%, <i>Classopollis</i> 11–35%			Ginkgoaceae, Lycopodiaceae
Turukhansk (33) and Ust-Yenisei (34) regions			Cyatheaceae, <i>Disaccites</i>	<i>Classopollis</i>		Ginkgoaceae, Lycopodiaceae, Gleicheniaceae
Norilsk region (35)			Cyatheaceae, <i>Disaccites</i>		Ginkgoaceae	<i>Classopollis</i> , Osmundaceae
Nordvik section (37)			Cyatheaceae 30–40%	<i>Disaccites</i> up to 15%	Osmundaceae	Gleicheniaceae
Anabar section (38)	<i>Disaccites</i> 67–75%				Osmundaceae, Cyatheaceae	Ginkgoaceae, Lycopodiaceae
Zhigan section (40)	<i>Disaccites</i>				Cyatheaceae, Osmundaceae, Ginkgoaceae	Lycopodiaceae, Sphagnaceae
Vilyui Syncline (41)	Cyatheaceae, <i>Disaccites</i>			Osmundaceae		Lycopodiaceae, Sphagnaceae, Ginkgoaceae
Irkutsk region (42), Transbaikalia (43)		<i>Classopollis</i> , <i>Disaccites</i>				Cyatheaceae, Lycopodiaceae, Gleicheniaceae, Sphagnaceae, Ginkgoaceae
Arctic Canada (45)			<i>Disaccites</i> , Cyatheaceae		<i>Classopollis</i>	Lycopodiaceae, Sphagnaceae, Ginkgoaceae

Here and in Table 2, the numbers of regions (in brackets) correspond to those in Fig. 8b. Data are from (Fradkina, 1967; Shramkova, 1970; Kotova, 1971; Ponomarenko et al., 1971; Spory..., 1971; *Stratigrafo-paleontologicheskaya...*, 1972; Voronova and Yanovskaya, 1973; Dobrutskaya, 1973; Sheiko, 1980; Grigor'eva, 1981; Glushko, 1987; Smirnova, 1983; Van Erve et al., 1988; Van Konijnenburg-Van Cittert, Van der Burgh 1996; Herngreen et al., 2000; Skoblo et al., 2001; Borges et al., 2011; Lindström and Erlström, 2011; Galloway et al., 2013; Markevich and Bugdaeva, 2014; McArthur et al., 2016; Dzyuba et al., 2018).

**Table 2.** Percentage of main components of spore–pollen assemblages for the Volgian Stage and its analogs in the north of Eurasia

Region	Strongly dominant, >60%	Dominant, >40%	Abundant, 20–40%	Numerous, 10–20%	Significant, 5–10%	Low, 2–5%
North Sea (4)		Lycopodiaceae 50–60%		Cyatheaceae, <i>Antulsporites</i> (Bryophytes)		<i>Disaccites</i>
Netherlands (5)	<i>Classopollis</i> 50–95%			<i>Disaccites</i> , locally, <i>Peromonolites</i>	<i>Callialasporites</i> , <i>Spheripollenites</i> , locally, Cyatheaceae	<i>Eucommiidites</i> , Cupressaceae
Germany (6)	<i>Classopollis</i> 40–80%			<i>Disaccites</i> , Sciadopityaceae, Cupressaceae, locally, <i>Peromonolites</i> ,		Gleicheniaceae, Schizaeaceae, Cyatheaceae
Poland (8)	<i>Classopollis</i> 50–80%			Cupressaceae 10–25%, <i>Disaccites</i> 10–12%	Gleicheniaceae (rarely 15%), Cyatheaceae	
Sweden (7)	<i>Disaccites</i>		Cyatheaceae, Gleicheniaceae, Sciadopityaceae			<i>Classopollis</i>
Prut–Dniester interfluve (9)	<i>Classopollis</i> 70–80%			Cyatheaceae		Gleicheniaceae, Schizaeaceae, <i>Disaccites</i>
Voronezh region (12)	<i>Classopollis</i> 50–95%			Gleicheniaceae, locally, Cupressaceae	Ginkgoaceae	<i>Disaccites</i> , Cyatheaceae
Dnieper–Donets interfluve (11)		<i>Classopollis</i> >50% (zone panderi)		Gleicheniaceae, <i>Classopollis</i> up to 18% (zone virgatus)		Cyatheaceae, <i>Disaccites</i>
Eganovo section (14)		Rare <i>Classo-pollis</i> 40–48%	Gleicheniaceae 22–35%, <i>Classopollis</i> 18–38%			Cyatheaceae, <i>Disaccites</i> , locally, <i>Eucommiidites</i>
Gorodishchi section (17)		Rare Gleicheniaceae 46–50%	Gleicheniaceae 23–38, <i>Classopollis</i> 20–34%	Locally, <i>Classopollis</i> 12–20%	Cyatheaceae	<i>Disaccites</i>



Table 2. (Contd.)

Region	Strongly dominant, >60%	Dominant, >40%	Abundant, 20–40%	Numerous, 10–20%	Significant, 5–10%	Low, 2–5%
Kostroma region (15)	Rare <i>Classopollis</i> 40–70%		<i>Classopollis</i> 15–30%, Gleicheniaceae 18–20%	Podozamitaceae	Ginkgoaceae	<i>Disaccites</i> , Cyatheaceae
Orenburg region (18)		<i>Classopollis</i> 50–60%		Podozamitaceae	Gleicheniaceae, Cyatheaceae	Schizaeaceae
Crimea (10)	<i>Classopollis</i> 70–98%				<i>Marratisporites</i> , Schizaeaceae, <i>Disaccites</i> , Cyatheaceae, Cupressaceae, Ginkgoaceae, <i>Eucommiidites</i> , <i>Callialasporites</i>	
North Caucasus (13)	<i>Classopollis</i> 52–90%				<i>Disaccites</i> , Ginkgoaceae, <i>Inaperturopollenites</i> , <i>Callialasporites</i>	
SSE of Precaspian Depression (19)		<i>Classopollis</i> 42–60%	<i>Disaccites</i>		Cyatheaceae, Cupressaceae, <i>Disaccites</i> , Ginkgoaceae, <i>Inaperturopollenites</i> , <i>Callialasporites</i>	
Mangyshlak (20)	<i>Classopollis</i> 70–75%				<i>Disaccites</i> , Cupressaceae, Gleicheniaceae, Cyatheaceae	
Ustyurt (21)	<i>Classopollis</i> 94–100%				<i>Disaccites</i> , Gleicheniaceae, Cyatheaceae	
Kyzylkum, Bukhara region (22)	<i>Classopollis</i> 72–76%				<i>Disaccites</i> , Ginkgoaceae, <i>Inaperturopollenites</i> , Gleicheniaceae, Cyatheaceae	
Gissar Range (23)	<i>Classopollis</i> 98–99%					
Pavlodar region (24)	<i>Classopollis</i> 54–96%				<i>Disaccites</i> , Cyatheaceae	
Kurgan region (27), S and SW of Western Siberia (26 and 25)		<i>Classopollis</i>	<i>Disaccites</i>			Cyatheaceae, Ginkgoaceae
Middle part of Western Siberia (29)			<i>Classopollis</i> (rare in the south up to 45%), Cyatheaceae, <i>Disaccites</i>		Gleicheniaceae	Osmundaceae, Ginkgoaceae
Eastern slope of the Urals, west of Western Siberia (28)			<i>Classopollis</i> , <i>Disaccites</i> , Cyatheaceae, Sciadopityaceae		Gleicheniaceae, Lycopodiaceae, Osmundaceae, Ginkgoaceae	
Purpe-Surgut region (31)			<i>Disaccites</i>	Cyatheaceae, Ginkgoaceae, <i>Classopollis</i>		Gleicheniaceae, Osmundaceae

Table 2. (Contd.)

Region	Strongly dominant, >60%	Dominant, >40%	Abundant, 20–40%	Numerous, 10–20%	Significant, 5–10%	Low, 2–5%
North Urals, NW of Western Siberia (30)		Rarely up to 50% <i>Disaccites</i> , Gleicheniaceae	Gleicheniaceae, <i>Disaccites</i> or Cyatheaceae		<i>Classopollis</i> , Lycopodiaceae, Osmundaceae, Ginkgoaceae, Sciadopityaceae	
Nadym-Taz region (32)			<i>Disaccites</i> , Cyatheaceae		<i>Classopollis</i> , Gleicheniaceae (rarely up to 16%)	Lycopodiaceae, Osmundaceae, Ginkgoaceae
Turukhansk (33) and Ust Yenisei (34) regions		<i>Disaccites</i>		Cyatheaceae	Osmundaceae, Ginkgoaceae, <i>Classopollis</i> (in the south up to 20%), Gleicheniaceae (rarely up to 16%)	
Kheta River (36)			<i>Disaccites</i> up to 35%	Cyatheaceae up to 25%	Lycopodiaceae	Osmundaceae
Nordvik section (37)		<i>Disaccites</i> 30–60%		Cyatheaceae	Osmundaceae	Lycopodiaceae, Sphagnaceae
Anabar section (38)	<i>Disaccites</i> 43–74%			Cyatheaceae 13–26%, Osmundaceae 7–16%		Ginkgoaceae, Lycopodiaceae
Olenek section (39)	<i>Disaccites</i> (40–70%)			Cyatheaceae	Osmundaceae, Ginkgoaceae, Sphagnaceae	
Zhigan section (40)		<i>Disaccites</i> , Cyatheaceae			Osmundaceae, Ginkgoaceae	Gleicheniaceae
Vilyui Syncline (41)		<i>Disaccites</i> up to 66%, Cyatheaceae up to 46%		Osmundaceae (locally, less)	Ginkgoaceae, Gleicheniaceae	
Irkutsk region (42), Transbaikalia (43)	<i>Disaccites</i>				Cyatheaceae, Lycopodiaceae, Gleicheniaceae, Sphagnaceae, Ginkgoaceae, <i>Classopollis</i>	
Bureya Depression (44)	<i>Disaccites</i> up to 56%, Cyatheaceae up to 79%			Lycopodiaceae, Osmundaceae, Ginkgoaceae, Sphagnaceae		<i>Classopollis</i>
Arctic Canada (45)			<i>Disaccites</i> , Cyatheaceae		<i>Classopollis</i>	Lycopodiaceae, Sphagnaceae, Ginkgoaceae

Here and in Table 2, the numbers of regions (in brackets) correspond to those in Fig. 8b. Data are from (Fradkina, 1967; Shramkova, 1970; Kotova, 1971; Ponomarenko et al., 1971; Spory..., 1971; *Stratigrafo-paleontologicheskaya...*, 1972; Voronova and Yanovskaya, 1973; Dobrutskaya, 1973; Sheiko, 1980; Grigor'eva, 1981; Glushko, 1987; Smirnova, 1983; Van Erve et al., 1988; Van Konijnenburg-Van Cittert, Van der Burgh 1996; Herngreen et al., 2000; Skoblo et al., 2001; Borges et al., 2011; Lindström and Erlström, 2011; Galloway et al., 2013; Markevich and Bugdaeva, 2014; McArthur et al., 2016; Dzyuba et al., 2018).

fers and *Classopollis* (Skoblo et al., 2001; Bashurova, 2005). In Western Siberia, the boundary of paleofloristic areas in the Kimmeridgian follows approximately a latitudinal course of the Ob River (Sheiko, 1980; Vakhrameev, 1988): with strongly dominant *Classopollis* pollen to the south and cyatheaceous, gleicheniaceous (in the west), and saccate pollen of conifers to the north (Table 1, Fig. 8). The palynomorphs of Arctic Canada are similar to the north Siberian palynomorphs (Plate 1, Fig. 8).

In the Volgian, the boundary of paleofloristic areas was probably shifted to the north. The *Classopollis* pollen is still strongly dominant in the European part of Russia and only in southern regions on the territory of Western Siberia (Table 2, Fig. 8). The Uralian province is considered in the structure of the Siberian paleogeographic area (Rovnina, 1972). This is probably related to the beginning of unstable cooling, which is supported by materials from the Eganovo section: the Volga palynospectra exhibit a significant decrease of *Classopollis* abundance compared to the Kimmeridgian (Gorodishchi section), but it was not continuous, but characterized by quantitative peaks related to the periods of warming (Fig. 6). The quantitative fluctuations of *Classopollis* for this stratigraphic interval are also registered on the territory of Western Europe, the northern Urals, and Western Siberia (Glushko and Purtova, 1980; Abbink, 1998; Dzyuba, 2018) and can serve as additional correlation markers.

According to the palynological data, the Volgian cooling is also revealed in the northern areas of the Siberian paleofloristic area. In the Kimmeridgian, the large amount of the *Classopollis* pollen (up to 22%, rarely more) is defined in the north of Western Siberia including the Ust-Yenisei region (Table 1, Fig. 8). The northeast of Siberia (Lena–Anabar area and Vilyui Syncline) is characterized by dominant saccate pollen of conifers and spores of cyatheaceous ferns, the amount of *Classopollis* spores is low (0–5%), and the amount of spores of osmundaceous ferns increases (5–20%) (Table 1, Fig. 8). In the Volgian Stage, the north Siberian palynoflora occurred in the Ust-Yenisei, Turukhansk, and Nyda regions on the territory of Western Siberia, Transbaikalia, and Pri-morye (Table 2, Fig. 8).

## CONCLUSIONS

The assemblages of spores, pollen, and dinocysts are studied for the first time in the Eganovo section, Moscow region. The biostratigraphic analysis of the palynological material allowed us to subdivide the Kimmeridgian–Volgian interval based on marine and terrestrial palynomorphs. A significant amount of stratigraphically important taxa provides a reliable palynological substantiation of the biostratons and supports confirms the presence of the Lower Kimmeridgian and the upper part of the Volgian Stage in the section, which were previously established based on

ammonites. Both Kimmeridgian and Volgian dinocyst zones are characterized by sufficient correlation potential, allowing the comparison of sections of the European part of Russia, Western Europe, Barents Sea shelf, and Siberia. The low amount of terrestrial palynomorphs in the lower (Kimmeridgian) part of the Eganovo section prevented a proper biostratigraphic analysis by this group. In the upper part of the section, however, abundant and diverse spore–pollen assemblages are determined, and the Beds with *Gleicheniidites toriconcavus*, *Plicatella chetaensis* are defined, which were previously established in the upper part of the Volgian in the Gorodishchi section. The materials from the Eganovo section allowed the detailed characterization of the upper part of this palynostraton, which was insufficiently studied in the Gorodishchi section. Owing to a characteristic palynological assemblage and key taxa, this palynostraton is well recognized on the territory of the European part of Russia. Some species yield the correlation with coeval sediments of the northern Urals, Western Europe, and Australia. It was shown that, in the north of Eurasia, the quantitative dynamics of *Classopollis* pollen reflecting the climatic oscillations can serve an additional feature for the detailed correlation in the upper part of the Volgian Stage.

The results of the biofacies analysis of microphytoplankton indicate normal marine conditions on the territory of Moscow region in the Kimmeridgian and Volgian. The deeper facies are typical of the Early Kimmeridgian. Paleobasin becomes shallower in the Volgian. Upward the Eganovo section, there is a strong regressive trend with constant fluctuations and frequent change of environment parameters. The microphytoplankton assemblages are characterized by numerous dinocysts able to survive in unstable conditions. The dinocysts become more diverse in the catenulatum phase. It is suggested that this is related to favorable trophic conditions and short-period climate warming, which is interpreted on the basis of taxonomic and quantitative dynamics in assemblages of terrestrial palynomorphs. The period of insignificant warming is reconstructed also at the end of the Middle Volgian. The comparative analysis of spore–pollen assemblages from the northern areas of Europe shows that small quasisynchronous climate maxima and minima can be also revealed in Siberia and the north of Western Europe and the Urals.

Generally, the spore–pollen assemblages indicate a warm subtropical climate and wet conditions. By the features of the taxonomic composition, these assemblages are typical of the Euro-Sinian paleogeographic area distinguished by V.A. Vakhrameev by paleobotanical data. The quantitative dynamics of the main components of palynological assemblages at the end of the Jurassic, which was revealed on the territory of North Eurasia by our and published data, indicate hotter conditions in the Kimmeridgian and a gradual cooling in the Volgian Stage. The spore–pollen assemblages with numerous warm components are abundant

in the Kimmeridgian on a vast territory of the south of Eurasia. In the north, the Euro-Sinian paleogeographic area spanned the south of Western and Eastern Siberia. In the Volgian, the boundaries of occurrence of the Euro-Sinian spore–pollen assemblages with abundant *Classopollis* pollen and North Siberian spore–pollen assemblages with dominant saccate pollen of conifers and higher amount of osmundaceous ferns move to the lower latitudes. The territory of the European part of Russia remains within the Euro-Sinian paleogeographic area, but the palynological spectra exhibit a significant reduction in the amount of *Classopollis* pollen and increased amount of gleicheniaceus ferns, which is well demonstrated by materials from the Eganovo section. The period of climate aridization is reconstructed in the north of Western Europe for a time interval synchronous with the Volgian, but this is not manifested in the European part of Russia. This is evident from both palynological materials and published isotopic data. Wet conditions on this territory, in the northern Urals, and in the northwest of Western Siberia were favorable for specific vegetation with abundant gleicheniaceus ferns, which possibly colonized new land areas formed due to regressions, and constituted monodominant thickets, which are similar to present-day thickets in savannas or prairies.

The marine algaefloras of Moscow region from the Eganovo section are similar to algaefloras from most Boreal and Subboreal regions. In the Kimmeridgian, the marine algaeflora was mostly similar to marine algaeflora from the North Sea region and Bulgaria, which can indicate good links between these basins through the Danish–Polish and Caspian straits. By the end of the Volgian Stage, the similarity of the dinocyst assemblages is gradually reduced, which is probably related to the gradual shallowing and reduction of straits connecting the Russian Sea and adjacent paleobasins. The analysis of the dynamics of generic diversity of dinocysts in the Eganovo section, however, shows that it was significantly higher in the Volgian than in the Kimmeridgian. No unambiguous correlation between the dinocyst diversity and paleogeographic factor or the depth of the paleobasin is identified. It is suggested that the diversity of the dinocyst assemblages is a result of a combination of various factors and is largely controlled by the contribution of nutrients from the continent, as well as temperature conditions. In the Eganovo section, this is shown on the basis of a combined analysis of marine and terrestrial palynomorphs. As a result of a favorable combination of various factors, the periodic closure of the Danish–Polish, Pechora, and Caspian straits in the Late Volgian had little effect on the dinocyst assemblages of the Russian Sea in contrast to faunistic communities.

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#### CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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