The Upper Triassic of northern Middle Siberia: stratigraphy and palynology

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Abstract

The Lower Carnian succession in northern Middle Siberia includes continental and marine deposits. Bivalves, nautiloids and ammonites in the marine units provide biostratigraphic control for a palynological study of three important sections. Palynomorph associations from the base of the succession include forms that have previously been reported only from Norian and Rhaetian deposits in the Tethyan and Boreal realms. This suggests that, in comparison with other areas, the palynoflora of Siberia was more uniform throughout the Late Triassic, and that the Carnian and Norian stages have a miospore assemblage that is recognizable in a wide belt through Arctic Canada and northern Eurasia.

Middle Siberia comprises the Eastern Taimyr Mesozoic troughs of the Siberian Platform and the western slope of the Verkhoyansk mega-anticlinorium (Fig. 1). Triassic rocks are distributed throughout the area and are represented by a wide range of facies, from marine to coastal and continental. Rich and diverse assemblages of brachiopods, bivalves, nautiloids, ammonoids and conodonts, as well as plant macrofossils and miospores, occur in these deposits. The abundant marine invertebrate fossils are the basis for a biostratigraphic scheme that is, at present, the most detailed from the Boreal basins (Dagys & Weitschat 1993). The Triassic succession in this area has been reviewed by Dagis & Kazakov (1984), Egorov & Mørk (2000) and Kazakov et al. (2002). The present contribution focuses on the Upper Triassic deposits of the northern part of this region.

All three Upper Triassic stages are developed in northern Middle Siberia. Carnian deposits occur throughout the study area, but those of Norian and Rhaetian age were developed, or are preserved, less extensively. Synsedimentary tectonic control defines several separate facies belts. The detailed stratigraphic chart of the Upper Triassic is based on studies of bivalves, nautiloids and ammonoids (Kazakov et al. 2002). Plant macrofossils also provide important information, and palynological data facilitate the correlation of marine and continental deposits.

Miospores from the Triassic succession in northern Middle Siberia have been studied by Kara-Murza (1951, 1958, 1960), Korotkevič (1966, 1968, 1973), Odincova (1977), Romanovskaja (1989) and Krugovyh & Mogučeva (2000). The results of palynological studies of the Carnian and Norian stages were utilized in the detailed stratigraphic chart of the Triassic of this area compiled by Kazakov et al. (2002). The exact dating of the local lithostratigraphic units has been disputed, but the age of most of the Carnian deposits is adequately controlled by invertebrate fossils. The potential of miospores for correlating the Late Triassic deposits has been investigated at three reference sections. Palynological studies of the sections at Cape Tsvetkov, near the village of Stannakh-Khocho, and at Cape Chekurovsky (Fig. 1) have attempted to integrate the results with the biostratigraphic data from the accurately dated marine units. For the Cape Tsvetkov section, the data of Romanovskaja (1989) and Krugovyh (in Krugovyh & Mogučeva 2000) have been included. These previous studies have resulted in different interpretations of the age of the formations and of the extent of the stratigraphic gaps in the Upper Triassic succession (Fig. 2).

Kazakov et al. (2002) described the Osipa, Nemtsov and Tumul formations at Cape Tsvetkov (Fig. 2). They interpreted the Osipa Formation as being of early Carnian age. The formation erosionally overlies Middle Triassic deposits, with a small stratigraphical gap. Previously, it was suggested that this gap equated approximately with the Stolleyites tenuis Zone (Dagis & Kazakov 1984).

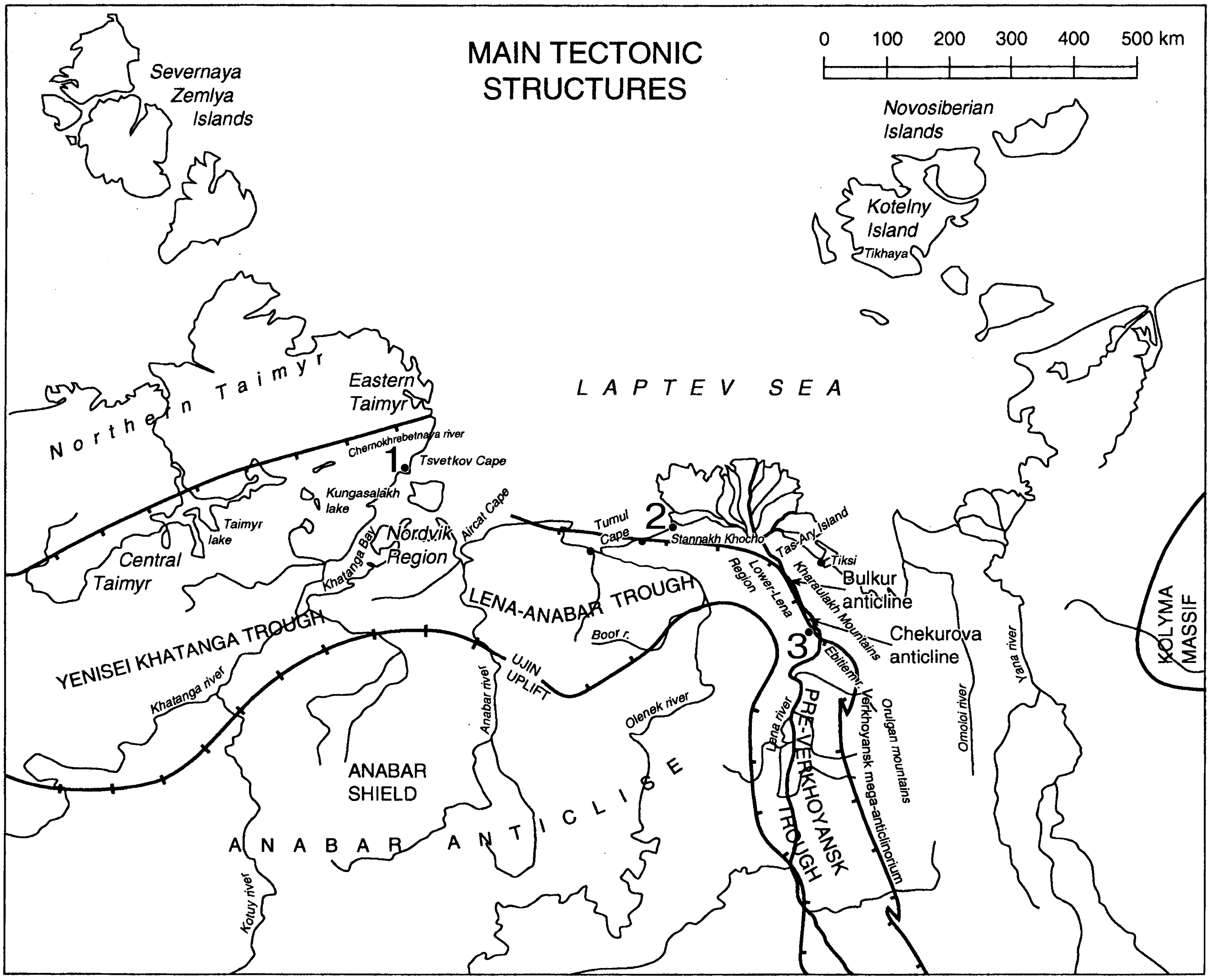


Fig. 1 Tectonic structures in northern Middle Siberia, and location of the sections studied: (1) Cape Tsvetkov section, (2) the section near the village of Stannakh-Khocho and (3) Cape Chekurovsky section. The figure has been modified from Egorov & Mørk (2000).

Later, the presence of deposits of the tenuis Zone in the section at Cape Tsvetkov was established on the basis of finds of the bivalve *Zittelihalobia zitteli* (Kurušin 1991).

The Osipa Formation is composed of marine shales, with siltstones in the upper part: it is characterized throughout by marine invertebrate fossils that are indicative of the tenuis and "Protrachyceras" omkutchanicum zones. The Nemtsov Formation overlies the Osipa Formation conformably: its age was determined as early Carnian–early Norian (Kazakov et al. 1982; Dagis & Kazakov 1984; Kazakov & Kurušin 1992; Kazakov et al. 2002). The formation includes alternating coastal-marine, lagoonal and terrestrial sandstones, with subordinate beds of shaly siltstones and shales, and, in the upper part, coals. Marine fossils are found only in the lower part of the formation. Wood debris and plant macrofossils are common in the upper part of the formation. Foraminifers, bivalves, nautiloids and ammonoids indicate that the base of the formation corresponds with the upper part of the omkutchanicum Zone (Kazakov et al. 2002). The Tumul Formation succeeds the Nemtsov Formation above an erosion surface. It comprises coastal marine sandstones with interbedded argillaceous siltstones in the upper part. At Cape Tsvetkov it lacks marine fossils, but a middle Norian–Rhaetian age is indicated by comparison with the formation stratotype at Cape Tumul. In the stratotype, bivalves indicative of the Middle Norian Otapiria ussuriensis Zone occur at the base of the formation. At 10 m above the base, bivalves indicative of the Rhaetian Tosapecten efimovae Zone and foraminifers are found (Dagis & Kazakov 1984; Kazakov & Kurušin 1992;

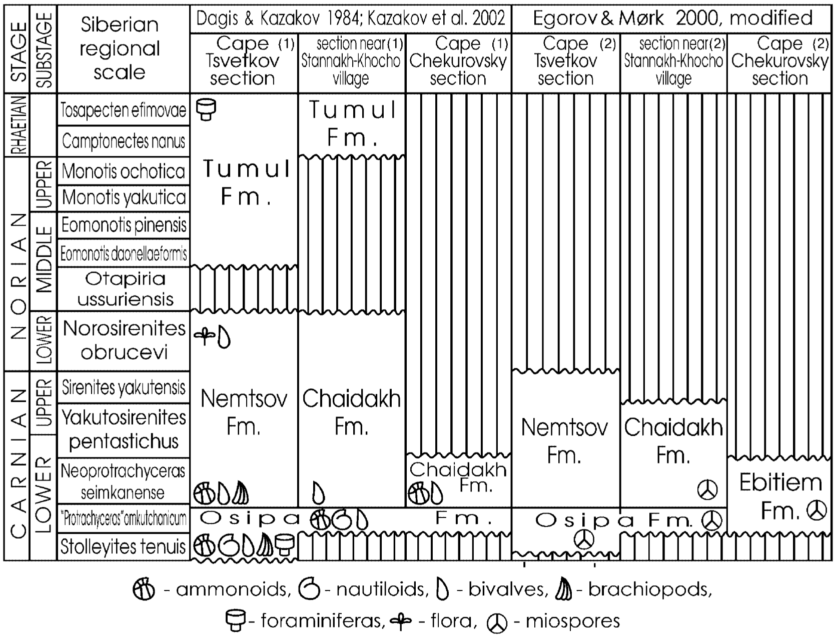


Fig. 2 Upper Triassic stratigraphy of the sections studied, comparing interpretations by Dagis & Kazakov (1984) and Kazakov et al. (2002) (columns marked 1) with interpretions by Egorov & Mørk (2000) and the present study (columns marked 2).

Kazakov et al. 2002). The formation is overlain by Lower Jurassic deposits.

In the section near the village of Stannakh-Khocho, the Osipa, Chaidakh and Tumul formations are all present. Here, the tenuis Zone is missing at the base of the Osipa Formation, and the Chaidakh Formation is largely a spatial and time equivalent of the Nemtsov Formation; the Tumul Formation consists only of deposits of presumed Rhaetian age, equivalent to its upper part at Cape Tsvetkov (Dagis & Kazakov 1984; Kazakov et al. 2002). At Cape Chekurovsky, only the Osipa and Chaidakh formations are present. The tenuis Zone is missing at the base of the Osipa Formation, and the Chaidakh Formation consists only of deposits of Carnian age (Dagis & Kazakov 1984; Kazakov et al. 2002).

In the present study a different interpretation of the stratigraphy in these sections—that of Egorov & Mørk (2000)—has been adopted (Fig. 2). At Cape Tsvetkov (Fig. 3), marine, coastal marine, lagoonal and continental terrigenous deposits of the Osipa and Nemtsov formations are exposed, but the Tumul Formation has not been found. The Osipa Formation contains brachiopods, bivalves, nautiloids and ammonoids indicative of an Early Carnian age, but there is no evidence of the presence of the complete tenuis Zone. In the section near the village of Stannakh-Khocho, the Osipa and Chaidakh formations are present. At Cape Chekurovsky, the exposed but condensed Ebitiem Formation contains fauna assigned to the early Carnian omkutchanicum Zone, and presumably to the seimkanense Zone (Figs. 3–5).

The Upper Triassic deposits in the three sections studied (Fig. 2) are thought to represent an entire second-order Carnian transgressive–regressive cycle (Egorov & Mørk 2000). The Osipa Formation and the lower part of the Ebitiem Formation represent the basal transgressive part of this sequence. The Nemtsov and Chaidakh formations conformably overlie the Osipa Formation: they are much thicker, and, with the upper part of the Ebitiem Formation, represent the regressive part of the sequence. Lower Jurassic deposits rest on an erosion surface above these formations (Egorov & Mørk 2000).

Palaeobotany

Plant megafossils occur irregularly in the Upper Triassic of northern Middle Siberia, and have only been found in the Osipa and Nemtsov formations at Cape Tsvetkov.

The sandstones in the Osipa Formation contain wood debris, and stem and rhizome remains of equisetalean plants; the calcareous concretions contain the remains of equisetaleans (*Schizoneura grandifolia* Kryshtofovich & Prynada) and ferns (*Danaeopsis* sp.).

A rich and diverse macroflora occurs in the upper part of the Nemtsov Formation; according to Krugovyh & Mogučeva (2000) and Kazakov et al. (2002), this is dominated by the fern *Cladophlebis* (represented by 14 species) and the conifers *Podozamites* and *Yuccites* (represented by three and four species, respectively). The remainder of the flora comprises remains of equisetalean plants (*Annulariopsis inopinata* Zeiller, *Neocalamites carrerei* [Zeiller] Halle), ferns (*Dictyophyllum*

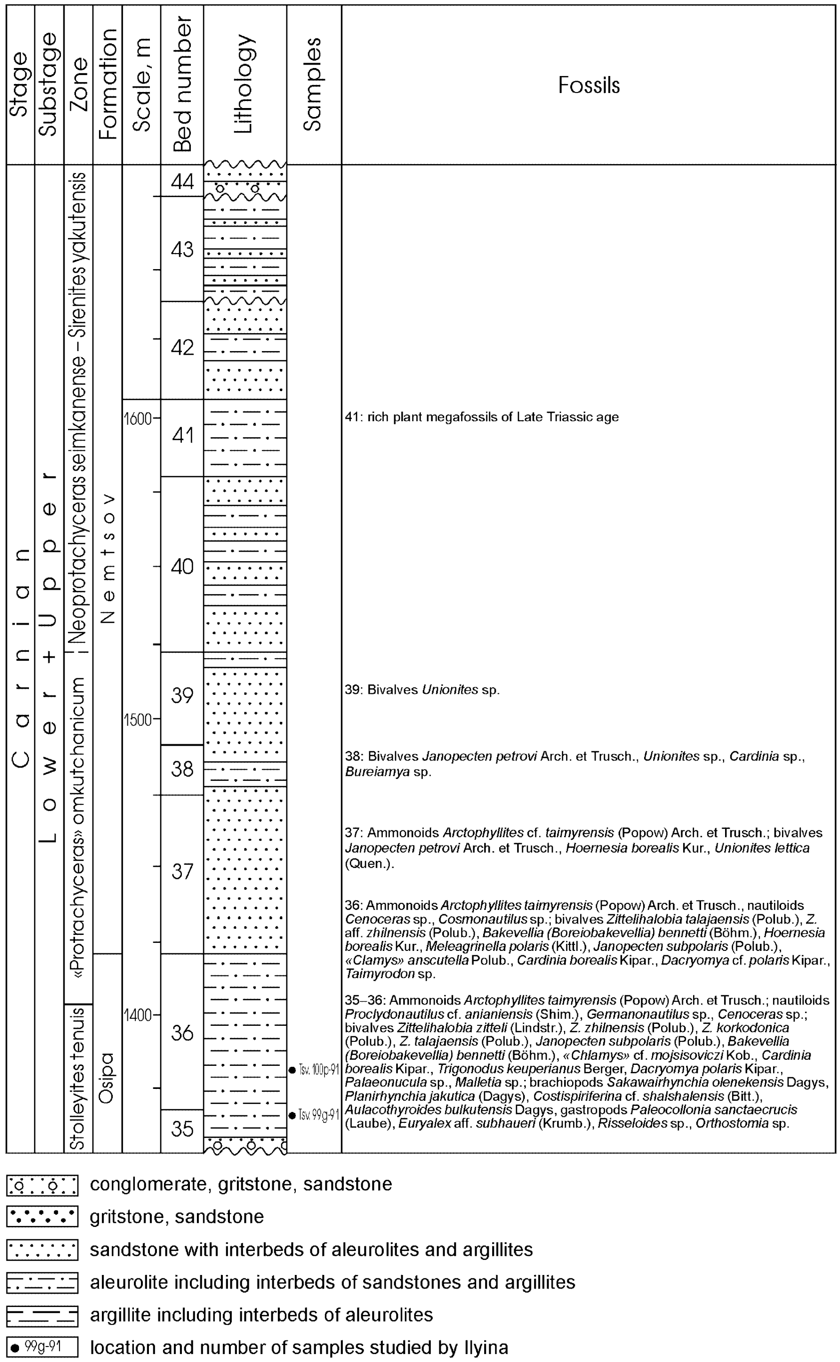


Fig. 3 Litho- and biostratigraphy, lithology and sample levels for the Cape Tsvetkov section.

sp. and *Kugartenia irregularis* Sixtel), peltasperms (*Rhaphidopteris* sp. and *Scytophyllum pinnatum* [Sixtel] Dobruskina), cycadophytes (*Sphenozamites surakaicus* Prynada and *Taeniopteris* sp.) and ginkgophytes (*Czekanowskia mogutchevae* Kiritchkova & Samylina).

The plants in this assemblage are characteristic of the Late Triassic flora of the Siberian palaeofloristic region, and indicate that moderately warm, humid conditions occurred at that time. The macroflora is only indicative of a general Late Triassic age (Dagis & Kazakov 1984; Mogučeva 1991, 1996; Krugovyh & Mogučeva 2000; Kazakov et al. 2002). However, according to the revised stratigraphy of the Cape Tsvetkov section (Egorov & Mørk 2000), the beds of the Nemtsov Formation containing the macroflora are of a later Carnian, post-seimkanense Zone, age (Fig. 2).

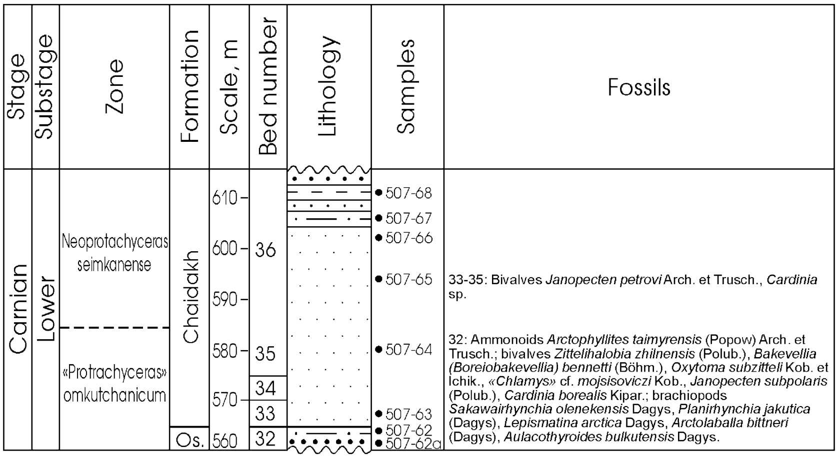


Fig. 4 Litho- and biostratigraphy, lithology and sample levels for the section near the village of Stannakh-Khocho. Legend as in Fig. 3.

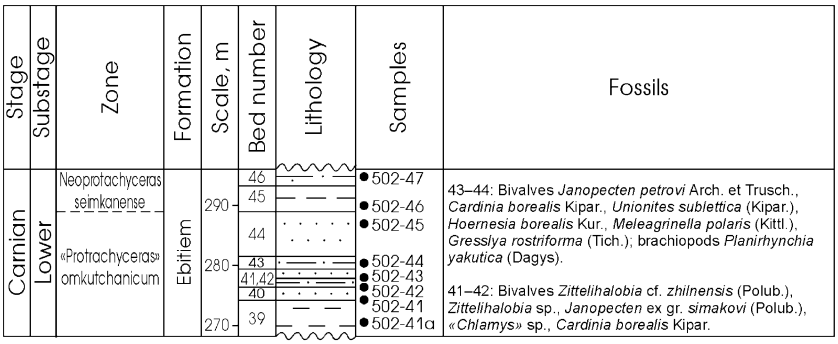


Fig. 5 Litho- and biostratigraphy, lithology and sample levels for the section at Cape Chekurovsky. Legend as in Fig. 3.

Palynology

Miospores occur in samples from all three of the sections studied. Specimens in different states of preservation have been recovered from deposits of the tenuis and omkutchanicum zones, and also from overlying beds that are devoid of marine fossils, but which may be referable to the seimkanense Zone.

At the Cape Tsvetkov section, samples were collected from the part of the Osipa Formation referred to the tenuis Zone, but only one sample yielded miospores (Fig. 3). Sixteen samples from the sections near the village of Stannakh-Khocho and Cape Chekurovsky represent the omkutchanicum Zone and the above-lying bed, lacking fauna, but referred to the seimkanense Zone (Figs. 4, 5). Five of the samples yielded diverse palynofloras. The palynological associations are of nearly the same composition, and, for practical purposes, have been regarded as one assemblage. Within this assemblage this paper distinguishes four stratigraphic groups of miospores, based on correlation with independently dated Triassic successions (Jarošenko 1978; Fisher 1979; Visscher & Brugman 1981; Van der Eem 1983; Hochuli et al. 1989; Vigran et al. 1998).

The first group (Table 1) comprises taxa that range throughout the Triassic: the quantitative distribution of the main groups of these taxa is shown in Fig. 6.

The reason for assigning some of the taxa to this long-ranging category is as follows: spores of the genus *Polycingulatisporites* are characteristic of the Upper Triassic, and are also widely distributed in Jurassic and Cretaceous sediments. However, in northern Eurasia, in the Finnmark Platform, their first occurrence is in the basal Triassic (Mangerud 1994). They are also a characteristic component of the *Pechorosporites disertus* assemblage, which is of presumed Late Griesbachian–Dienerian age, in the Timan–northern Urals region (Jarošenko et al. 1991). In northern Middle Siberia, species of *Polycingulatisporites* are present up to the top of the Olenekian (Il'ina 2001), and their next main record is in the Upper Triassic. *Camarozonosporites rudis* and *Lycopodiacidites kuepperi* occur almost everywhere in the Upper Triassic. They are placed in the long-ranging group because, in northern Eurasia, their first appearance is in the Upper Olenekian, and they are consistently present in Middle Triassic assemblages (Jarošenko et al. 1991; Mangerud & Rømuld 1991; Vigran et al. 1998; Il'ina 2001); *L. kuepperi* is also recorded from the Spathian in Arctic Canada (Fisher 1979). The smooth triangular spores

Table 1 Distribution chart of miospores with wide stratigraphic ranges recorded from the Carnian in northern Middle Siberia. Compilation of palynological data from (1) Romanovskaja (1989), (2) Krugovyh in Krugovyh & Mogučeva (2000) and (3) this study. Taxa set in bold comprise miospore group 1 of this study.

Stolleyites tenuis Zone		"Protrachyceras" omkutchanicum Zone		Beds referred to the Neoprotrachyceras seimkanense Zone		Nemtsov Formation, upper part with plant megafossils		
1	3	1	3	2	3	1	2	Taxa
					•			***Verrucosisporites applanatus***
			•		•			***Verrucosisporites narmianus***
•			•		•			***Cyclotriletes oligogranifer***
•					•			***Cyclotriletes triassicus***
			•					***Nevesisporites fossulatus***
•	•	•	•	•	•		•	***Nevesisporites limatulus***
					•			***Nevesisporites macrogranulatus***
	•				•			***Nevesisporites pokrovskajae***
		•		•				*Discisporites psilatus*
		•						*Aratrisporites coryliseminis*
			•		•			***Aratrisporites fischeri***
					•			***Aratrisporites flexibilis***
		•	•		•			***Aratrisporites granulatus***
			•		•			***Aratrisporites paenulatus***
					•			***Aratrisporites palettae***
•			•					***Aratrisporites paraspinosus***
			•					***Aratrisporites parvispinosus***
			•		•			***Aratrisporites scabratus***
					•			***Aratrisporites virgatus***
•								*Spinotriletes echinoides*
	•				•			***Apiculatisporis parvispinosus***
			•			•		***Anapiculatisporites spiniger***
			•	•	•		•	***Anapiculatisporites telephorus***
			•		•			***Carnisporites mesozoicus***
					•			***Todisporites major***
			•		•			***Todisporites minor***
					•			***Camptotriletes cerebriformis***
			•					**_Polycingulatisporites_ cf. _circulus_**
			•		•			***Polycingulatisporites crenulatus***
					•			***Polycingulatisporites dejerseyi***
	•		•		•			***Polycingulatisporites densatus***
•			•	•	•		•	***Lycopodiacidites kuepperi***
•			•	•	•		•	***Camarozonosporites rudis***
•				•			•	*Osmundacidites senectus*
	•		•	•	•	•	•	***Dictyophyllidites mortoni***
			•			•		***Dictyophyllum nilssoni***
	•		•		•	•		***Dictyophyllum rugosum***
	•		•	•	•	•	•	***Dictyophyllum vulgaris***
	•		•	•	•		•	***Concavisporites crassexinius***
	•		•		•			***Concavisporites toralis***
	•				•			***Auritulinasporites scanicus***
•					•			***Cyathidites coniopteroides***
•			•					***Cyathidites nigrans***
					•			***Cyathidites triangularis***
	•		•		•	•		***Alisporites australis***
	•		•		•			***Alisporites landianus***
				•			•	*Alisporites grauvogeli*
			•					**_Alisporites_ cf. _grauvogeli_**
				•				*Alisporites magnus*
			•		•			***Alisporites parvus***

Table 1 *Continued*

Stolleyites tenuis Zone		"Protrachyceras" omkutchanicum Zone		Beds referred to the Neoprotrachyceras seimkanense Zone		Nemtsov Formation, upper part with plant megafossils		
1	3	1	3	2	3	1	2	Taxa
			•					***Alisporites* cf. *parvus***
					•			***Alisporites perlucidus***
			•					***Alisporites* cf. *aequalis***
			•					***Alisporites* cf. *cymbatus***
•	•		•		•			***Platysaccus queenslandi***
		•						*Platysaccus niger*
			•	•	•			***Platysaccus leschiki***
			•		•			***Falcisporites stabilis***
			•					***Falcisporites snopkovae***
			•					***Falcisporites* cf. *snopkovae***
			•		•			***Chordasporites singulichorda***
			•					***Chordasporites* cf. *volziaformis***
•		•	•					***Chordasporites australiensis***
					•			***Sulcatisporites institatus***
•		•	•		•			***Sulcatisporites kraeuseli***
				•				*Striatoabieites aytugii*
			•	•				***Striatoabieites balmei***
			•					***Striatoabieites multistriatus***
			•					***Cordaitina gunyalensis***
	•		•		•		•	***Vitreisporites pallidus***
				•	•			***Vitreisporites reductus***
•	•	•	•	•	•			***Ginkgocycadophytus***
		•						*Gnetaceaepollenites steevesi*

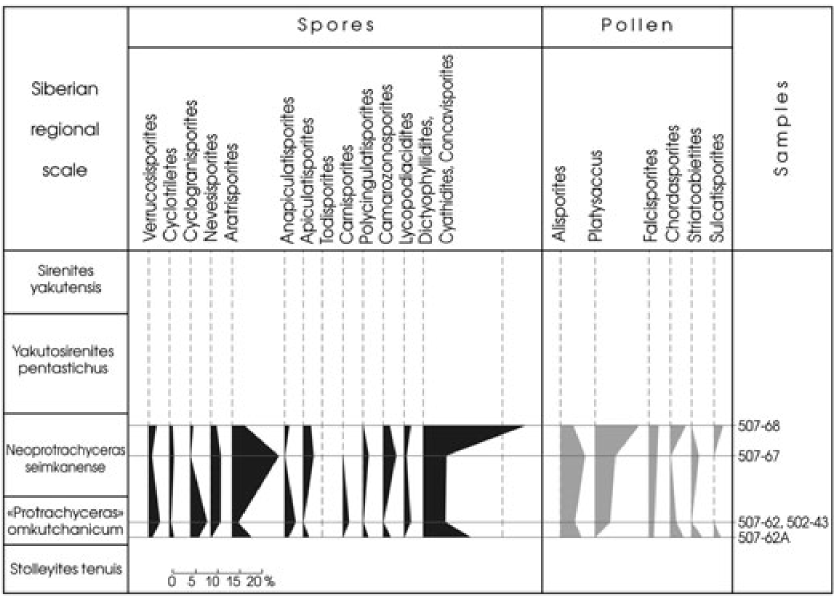


Fig. 6 Quantitative distribution of the miospore genera with wide stratigraphic ranges recorded from the Carnian in northern Middle Siberia.

of *Concavisporites*, *Cyathidites*, *Deltoidospora* and *Dictyophyllidites* may also be included in the long-ranging group (Kručinina & Romanovskaja 1980). In northern Middle Siberia, sparse representatives of these genera occur in the Lower Triassic. In the Middle Triassic their species diversity increases, and in the Ladinian their abundance also increases sharply, up to 27% in some assemblages. In the Upper Triassic they comprise 25–48% of the spores present.

Table 2 Distribution chart of miospores ranging from the Middle Triassic to the Carnian in northern Middle Siberia. Compilation of palynological data from (1) Romanovskaja (1989), (2) Krugovyh in Krugovyh & Mogučeva (2000) and (3) this study. Taxa set in bold comprise miospore group 2 of this study.

Stolleyites tenuis Zone		"Protrachyceras" omkutchanicum Zone		Beds referred to the Neoprotrachyceras seimkanense Zone		Nemtsov Formation, upper part with plant megafossils		
1	3	1	3	2	3	1	2	Taxa
			•	•	•		•	***Duplexisporites gyratus***
•								*Duplexisporites scanicus*
			•		•			***Duplexisporites problematicus***
•								*Duplexisporites toratus*
			•					***Baculatisporites baculatus***
					•			***Baculatisporites comaumensis***
			•		•			***Baculatisporites verus***
	•		•		•			***Converrucosisporites cameroni***
			•					***Converrucosisporites conferteornatus***
			•					***Converrucosisporites luebbenensis***
					•		•	***Concentricisporites nevesi***
	•	•	•		•			***Microcahryidites doubingeri***
•	•		•		•			***Microcahryidites sittleri***
			•		•			***Microcahryidites fastidiosus***
			•		•	•	•	***Minutosaccus potoniei***
	•		•		•			***Minutosaccus schizeatus***
	•		•					***Protodiploxypinus gracilis***
						•	•	*Brachysaccus neomundanus*
			•		•			***Florinites pseudostriatus***
	•		•		•			***Florinites walchius***
•								*Latosaccus latus*
•			•		•			***Podocarpidites keuperianus***
•			•		•	•		***Voltziaceaesporites heteromorpha***
			•		•			***Voltziaceaesporites* cf. *globosus***
							•	*Triadispora aurea*
•		•						*Triadispora crassa*
				•			•	*Triadispora staplini*
		•						*Triadispora falcata*
				•				*Triadispora obscura*
•					•			***Stellapollenites thiergartii***

The second group (Table 2) comprises taxa that are common constituents of Middle Triassic assemblages, and range upwards from that level. Their quantitative distribution is shown in Fig. 7. The pollen *Florinites pseudostriatus* (Fig. 8.4) and *Florinites walchius* (Fig. 9.26) were described from Upper Triassic deposits of western Kazakhstan in 1963 (Kopytova 1963: 65–69, pl. III, figs. 1–6). In Europe, such forms have been recorded as *Illinites chitonoides* Klaus, 1964, which is considered here to be a junior synonym of *F. pseudostriatus*.

The third group of miospores comprises taxa that have their earliest records at different levels in the Anisian and Ladinian of northern Eurasia, and range into the Upper Triassic (Table 3, Figs. 10, 11).

The fourth group of miospores comprises taxa considered to appear at different stages of the Late Triassic, and requires a revision of views concerning the appearance levels. The miospore associations apparently marking the beginning of the Carnian, Norian and Rhaetian stages (Table 4) are based on data from Europe, Arctic Canada and the Barents Sea (Schulz 1967; Morbey 1975; Bjærke 1977; Bjærke & Manum 1977; Lund 1977; Schuurman 1977, 1979; Fisher 1979; Visscher & Brugman 1981; Van der Eem 1983; Hochuli et al. 1989; Warrington et al. 1995; Warrington 1996, 1997; Hochuli & Frank 2000, 2006; Roghi 2004).

Carnian: *Kraeuselisporites reissingeri*, *Kyrtomisporis gracilis*, *Kyrtomisporis laevigatus* and *Zebrasporites corneolus*, and the pollen *Corollina meyeriana*, *Granuloperculatipollis rudis*, *Lagenella martinii*, *Lunatisporites rhaeticus*, *Paracirculina maljawkinae*, *Paracirculina quadruplicis*, *Ricciisporites tuberculatus* and *Vallasporites ignacii*, and perhaps *Duplicisporites dispertitus*.

Norian: *Cingulizonates rhaeticus*, *Kyrtomisporis speciosus*, *Limbosporites lundbladii*, *Semiretisporis gothae*, *Trianco-*

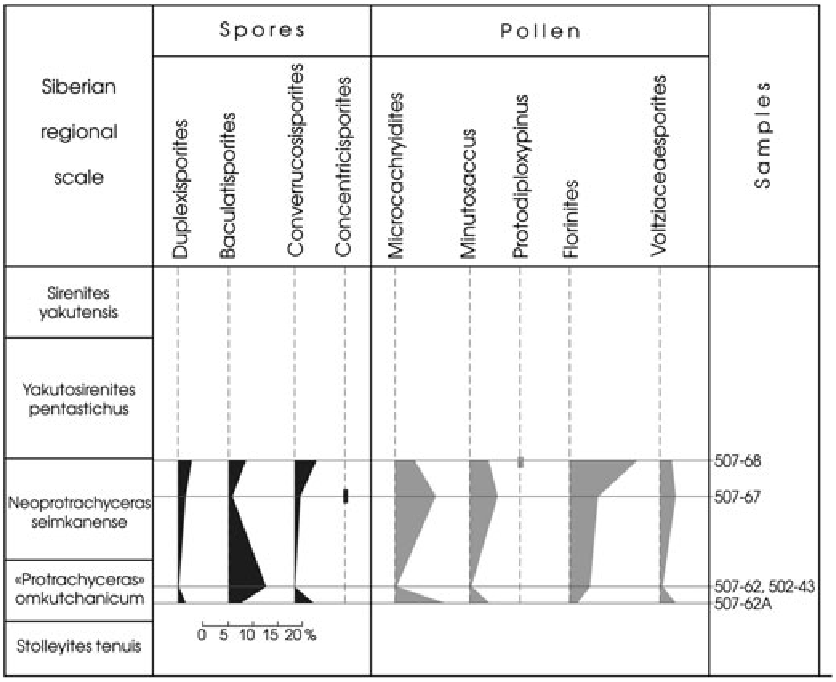


Fig. 7 Quantitative distribution of Middle Triassic genera, which range into the Carnian in northern Middle Siberia.

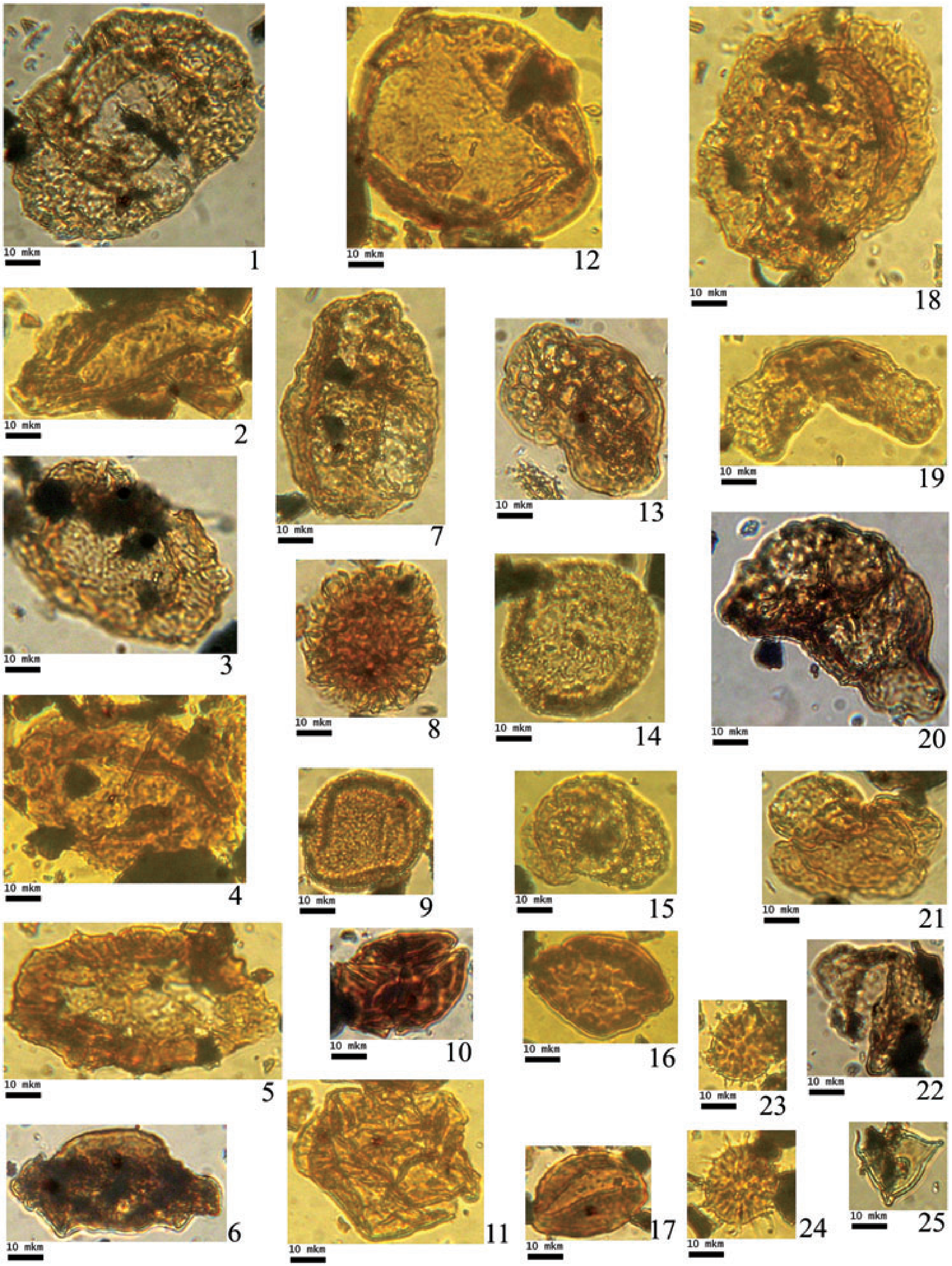
Fig. 8 Sample Tsv. 99g-91 is from the Stolleyites tenuis Zone from the section at Cape Tsvetkov. Samples 507-62 and 507-62a are from the "Protrachyceras" omkutchanicum Zone, and samples 507-67 and 507-68 are from the beds referred to the Neoprotrachyceras seimkanense Zone. All the aforementioned samples are from the section near the village of Stannakh-Khocho. Sample 502-43 is from the "Protrachyceras" omkutchanicum Zone from the section at Cape Chekurovsky. (1) *Lunatisporites rhaeticus*, sample 507-68. (2) *Ovalipollis lunzensis*, sample 507-62a. (3) *Samaropollenites speciosus*, sample Tsv. 99g-91. (4) *Florinites pseudostriatus*, sample 502-43. (5) *Cordaitina gunyalensis*, sample 507-62. (8.6) *Plicatisaccus badius*, sample Tsv. 99g-91. (7) *Chasmatosporites hians*, sample 507-68. (8) *Patinasporites densus*, sample 507-67. (9) *Praecirculina* sp., sample 507-67. (10) *Paracirculina* cf. *quadruplicis*, sample 507-67. (11) Alete folded body, sample 507-62a. (12) *Chasmatosporites apertus*, sample 507-62a. (13) *Microcachryidites sittleri*, sample 507-62. (14) *Vallasporites ignacii*, sample 507-68. (15) *Minutosaccus potoniei*, sample 507-68. (16) *Camerosporites secatus*, sample 507-62a. (17) *Eucommiidites* sp., sample 502-43. (18) *Accinctisporites* cf. *ligatus*, sample 507-68. (19) *Microcachryidites doubingeri*, sample 507-62a. (20) *Minutosaccus* sp., sample 507-67. (21) *Microcachryidites* with four sacci, sample 507-68. (22) *Protodiploxypinus gracilis*, sample 502-43. (23) *Micrhystridium breve*, sample 502-43. (24) *Micrhystridium* cf. *setasessitante*, sample 502-43. (25) *Wilsonastrum colonicum*, sample Tsv. 99g-91.

raesporites ancorae and *Zebrasporites laevigatus*, and the pollen *Rhaetipollis germanicus*.

Rhaetian: *Semiretisporis maljawkinae*, *Triancoraesporites reticulatus* and perhaps *Camarozonosporites golzowensis* and *Retitriletes semimuris* (Table 4).

The view that this sucession of Late Triassic palynomorphs is universal is contradicted by the data from northern Middle Siberia (Table 5). "Norian–Rhaetian" indicators like *Camarozonosporites* cf. *golzowensis*, *K. speciosus* and *S. gothae* are all found in the basal Carnian (i.e., in the tenuis Zone). The following taxa are also present in the omkutchanicum and seimkanense zones: *C.* cf. *golzowensis*, *L. lundbladii*, *R. semimuris*, *R. germanicus*, *S. gothae* and *Z. laevigatus*, together with other spores, including *Camarozonosporites laevigatus*, *K. laevigatus*, *Lycopodiacidites rugulatus*, *Tigrisporites halleinis*, *Zebrasporites interscriptus* and *Zebrasporites kahleri*, and pollen including *D. dispertitus*, *L. rhaeticus*, *Paracirculina* cf. *quadruplicis*, *Patinasporites densus*, *R. tuberculatus* and *V. ignacii* (Table 5).

In the uppermost part of the sections studied, the abundant osmundaceous fern spores may comprise up to 19% of the miospores. Most samples have also yielded acritarchs and algae, including *Baltisphaeridium* sp., *Cymatiosphaera* sp., *Micrhystridium breve*, *Micrhystridium* cf. *inconspicuum*, *Micrhystridium* cf. *setasessitante*, *Micrhystridium triassicum* and *Pterospermopsimorpha* sp. Reworked Early Triassic and older miospores include common *Crustaesporites globosus*, *Klausipollenites* sp., *Kraeuselisporites apiculatus*, *Kraeuselisporites cuspidus*, *Lundbladispora willmottii*, *Pechorosporites coronatus*, *Punctatisporites fungosus*, *Taeniaesporites noviaulensis*, *Taeniaesporites novimundi*, *Taeniaesporites pellucidus* and the algae *Tympanicysta stoschiana* and *Wilsonastrum colonicum*.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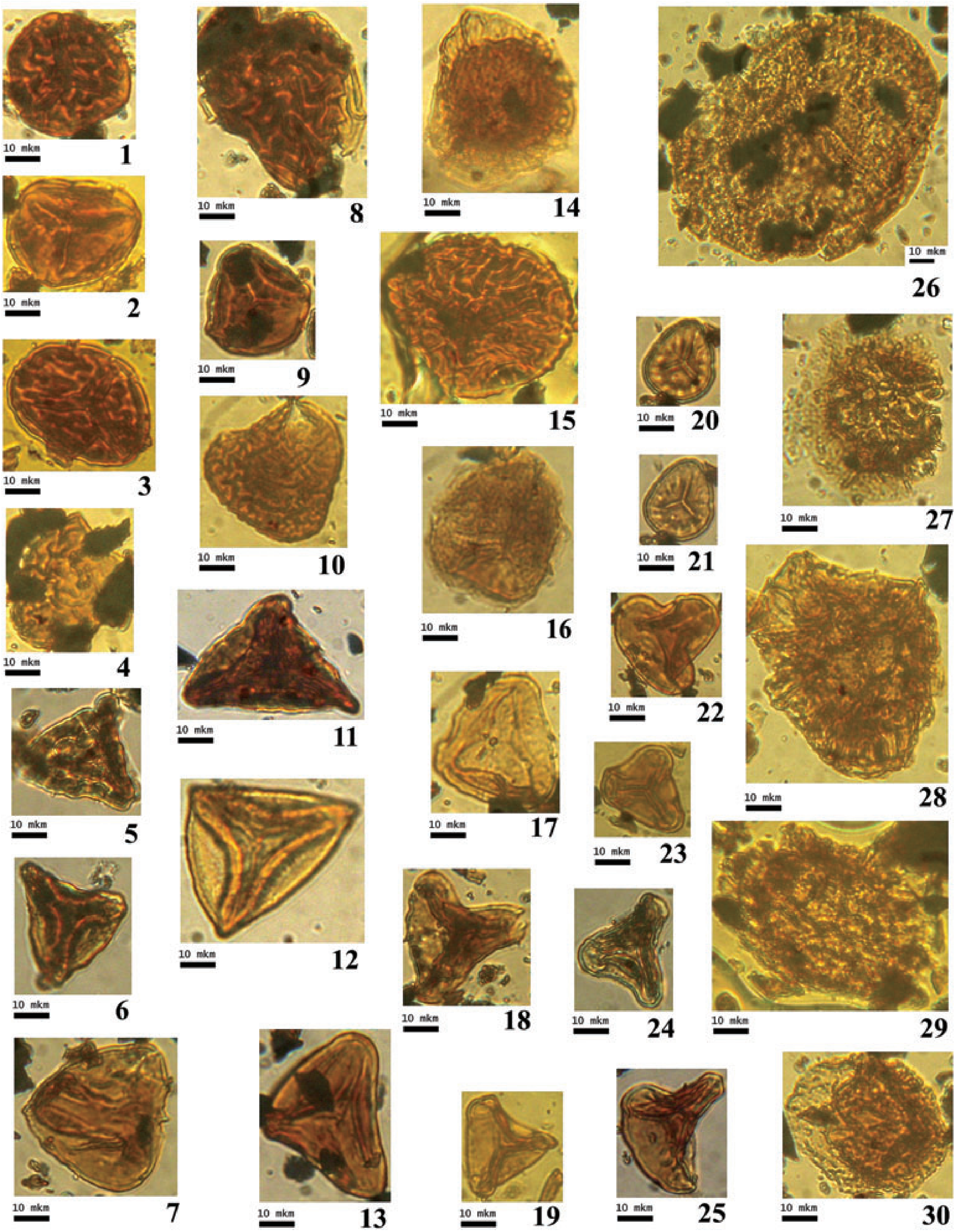
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Fig. 9 Sample Tsv. 99g-91 is from the Stolleyites tenuis Zone from the section at Cape Tsvetkov. Samples 507-62 and 507-62a are from the "Protrachyceras" omkutchanicum Zone, and sample 507-67 is from the beds referred to the Neoprotrachyceras seimkanense Zone. All of the aforementioned samples are from the section near the village of Stannakh-Khocho. Sample 502-43 is from the "Protrachyceras" omkutchanicum Zone from the section at Cape Chekurovsky. (1) *Camarozonosporites rudis*, sample 507-67. (2) *Camarozonosporites laevigatus*, sample 507-67. (3) *Camarozonosporites* cf. *golzowensis*, sample 507-62a. (4) *Retitriletes semimuris*, sample 502-43. (5) *Kyrtomisporis speciosus*, sample Tsv. 99g-91. (6) *Kyrtomisporis laevigatus*, sample Tsv. 99g-91. (7) *Deltoidospora* sp., sample 507-67. (8) *Zebrasporites* sp., sample 507-67. (9) *Zebrasporites laevigatus*, sample 507-67. (10) *Tigrisporites halleinis*, sample 507-62a. (11) *Kyrtomisporis* sp., sample Tsv. 99g-91. (12) *Concavisporites* cf. *kaiseri*, sample Tsv. 99g-91. (13) *Auritulinasporites scanicus*, sample 507-67. (14) *Styxisporites cooksonae*, sample 507-67. (15) *Lycopodiacidites kuepperi*, sample 507-62a. (16) *Lycopodiumsporites* sp., sample 507-67. (17) *Cyathidites coniopteroides*, sample 507-67. (18) *Concavisporites crassexinius*, sample 502-43. (19) *Dictyophyllidites mortoni*, sample 507-62a. (20 and 21) *Annulispora cicatricosa*, sample 507-67. (22) *Dictyophyllum rugosum*, sample 507-67. (23) *Concavisporites juriensis*, sample 507-62a. (24) *Dictyophyllum vulgaris*, sample Tsv. 99g-91. (25) *Phlebopteris* type, sample 507-67. (26) *Florinites walchius*, sample 502-43. (27) *Limbosporites lundbladii*, sample 507-62. (28 and 29) *Semiretisporis gothae*, sample 507-62a. (30) *Lundbladispora denmeadi*, sample 507-67.

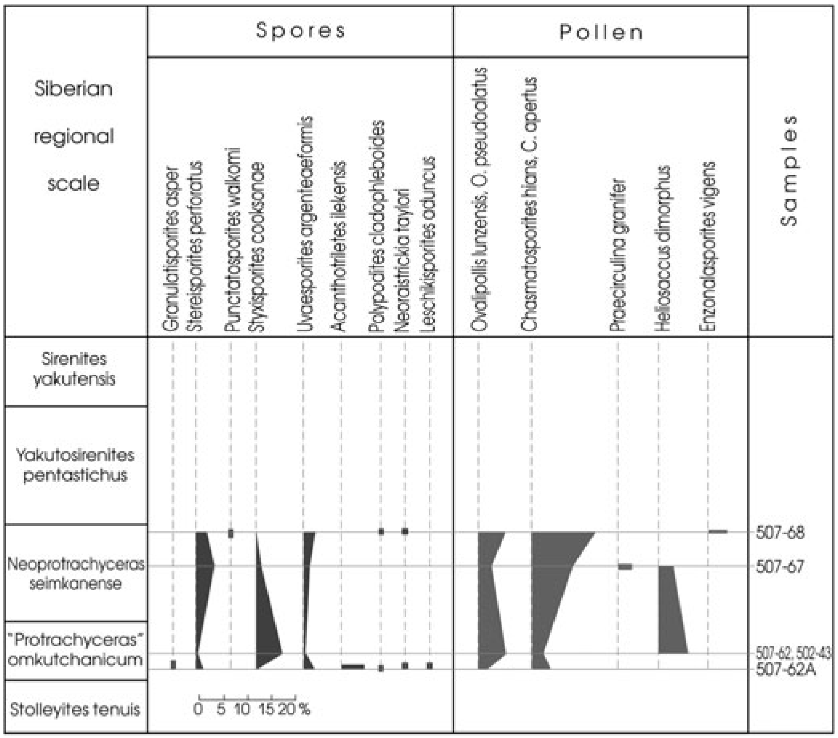

Fig. 10 Quantitative distribution of miospores that appear during the Anisian and Ladinian in northern Eurasia, and that range into the Carnian in northern Middle Siberia.

The presence of "Norian–Rhaetian" miospores in the Upper Triassic, Carnian, deposits at Cape Tsvetkov is consistent with the results of the earlier palynological studies (Romanovskaja 1989; Krugovyh & Mogučeva 2000), when considering that those authors used the stratigraphic scheme proposed by Dagis & Kazakov (1984) (Fig. 2).

Romanovskaja (1989) recorded three assemblages from the Upper Triassic at Cape Tsvetkov—two from the Osipa Formation and one from the Nemtsov Formation—but the number of productive samples studied was not specified. The miospores identified, and their stratigraphic distribution, are illustrated in Tables 1–3 and 5, which show the consistency between the content of the three assemblages documented by Romanovskaja (1989) and the palynofloras recorded in the present study. Romanovskaja's three assemblages include the four groups of miospores recognized in the present study: (1) species with a wide stratigraphic range (Table 1); (2) species that are major constituents of Middle Triassic assemblages, but range into the Upper Triassic (Table 2); (3) species that appear at different levels in the Anisian and Ladinian, and range into the Upper Triassic (Table 3); and (4) species restricted to the Upper Triassic (Table 5).

The oldest of the three assemblages recognized by Romanovskaja (1989) is from the tenuis Zone: although specimens are not abundant, the assemblage is fairly diverse. The most common miospores are *Duplexisporites scanicus*, *Duplexisporites toratus*, *Ginkgocycadophytus* and *L.*

Table 3 Distribution chart of miospores that appear during the Anisian and Ladinian, and that range into the Carnian in northern Middle Siberia. Compilation of palynological data from (1) Romanovskaja (1989), (2) Krugovyh in Krugovyh & Mogučeva (2000) and (3) this study. Taxa set in bold comprise miospore group 3 of this study.

Stolleyites tenuis Zone		"Protrachyceras" omkutchanicum Zone		Beds referred to the Neoprotrachyceras seimkanense Zone		Nemtsov Formation, upper part with plant megafossils		
1	3	1	3	2	3	1	2	Taxa
			•		•			***Styxisporites cooksonae***
					•			***Lundbladispora denmeadi***
				•				*Zebrasporites interscriptus*
			•		•			***Zebrasporites kahleri***
					•			***Punctatisporites leighensis***
		•		•			•	*Annulispora microannulata*
				•			•	*Annulispora folliculosa*
			•		•			***Annulispora cicatricosa***
			•	•	•			***Stereisporites perforatus***
			•		•			***Taurocusporites* sp. A**
					•			***Convolutispora* cf. *microrugulata***
			•					***Convolutispora* sp. A**
			•	•	•			***Uvaesporites* cf. *argenteaeformis***
			•	•	•			***Polypodiisporites ipsviciensis***
			•		•	•	•	***Punctatosporites walkomi***
			•					***Leschikisporites aduncus***
			•					***Apiculatisporis globosus***
			•					***Anaplanisporites echinatus***
•				•				*Porcellispora longdonensis*
•	•	•	•		•		•	***Neoraistrickia taylori***
		•	•		•			***Polypodites cladophleboides***
			•					***Acanthotriletes ilekensis***
			•		•			***Granulatisporites asper***
•								*Asterisporites slewecensis*
•								*Globulisporites primus*
					•			***Lophotriletes bauchiniae***
					•			***Apiculatisporis lentus***
	•				•			***Type Phlebopteris***
•								*Mesostriatites hercynicus*
•								*Schizosaccus keuperi*
	•							***Plicatisaccus badius***
					•			***Protodiploxypinus lacertosus***
					•			***Accinctisporites* cf. *ligatus***
					•			***Heliosaccus dimorphus***
			•	•	•			***Ovalipollis pseudoalatus***
			•					***Ovalipollis lunzensis***
							•	*Ovalipollis cultus*
			•		•			***Chasmatosporites apertus***
			•		•			***Chasmatosporites hians***
				•			•	*Quadraeculina anellaeformis*
			•	•	•			***Camerosporites secatus***
					•		•	***Praecirculina granifer***
			•		•			***Enzonalasporites vigens***
			•					***Enzonalasporites* sp. A**
							•	*Duplicisporites granulatus*
							•	*Classopollis* sp.

Table 4 Miospores, the appearance of which, from published sources, appear to mark the beginning of the Carnian, Norian and Rhaetian stages.

Carnian	Norian	Rhaetian
Corollina meyeriana	*Cingulizonates rhaeticus*	*Camarozonosporites golzowensis*
Duplicisporites dispertitus	*Kyrtomisporis speciosus*	*Retitriletes semimuris*
Granuloperculatipollis rudis	*Limbosporites lundbladii*	*Semiretisporis maljavkinae*
Kraeuselisporites reissingeri	*Rhaetipollis germanicus*	*Triancoraesporites reticulatus*
Kyrtomisporis gracilis	*Semiretisporis gothae*	
Kyrtomisporis laevigatus	*Triancoraesporites ancorae*	
Lagenella martinii	*Zebrasporites laevigatus*	
Lunatisporites rhaeticus		
Paracirculina maljavkinae		
Paracirculina quadruplicis		
Ricciisporites tuberculatus		
Vallasporites ignacii		
Zebrasporites corneolus		

Table 5 Distribution chart of selected miospores in the Upper Triassic in northern Middle Siberia. Compilation of palynological data from (1) Romanovskaja (1989), (2) Krugovyh in Krugovyh & Mogučeva (2000) and (3) this study. Taxa set in bold comprise miospore group 4 of this study.

Stolleyites tenuis Zone		"Protrachyceras" omkutchanicum Zone		Beds referred to the Neoprotrachyceras seimkanense Zone		Nemtsov Formation, upper part with plant megafossils		
1	3	1	3	2	3	1	2	Taxa
•	•		•					***Semiretisporis gothae***
	•	•	•			•		***Kyrtomisporis laevigatus***
•	•					•	•	***Kyrtomisporis speciosus***
•		•		•		•	•	*Cingulizonates rhaeticus*
				•				*Cingulizonates tuberosus*
				•				*Cingulizonates bulbifera*
•			•		•			***Limbosporites lundbladii***
					•			***Zebrasporites laevigatus***
•					•			***Lycopodiacidites rugulatus***
•								*Triancoraesporites reticulatus*
			•					***Retitriletes semimuris***
					•			***Camarozonosporites laevigatus***
	•		•		•			***Camarozonosporites* cf. *golzowensis***
					•			***Convolutispora* cf. *microfoveolata***
					•			***Polypodiisporites polymicroforatus***
			•					***Ischyosporites* cf. *marburgensis***
					•			***Klukisporites* cf. *granosifenestellatus***
			•					***Tigrisporites halleinis***
	•		•		•			***Concavisporites juriensis***
	•				•			***Concavisporites* cf. *kaiseri***
			•	•	•			***Lunatisporites rhaeticus***
			•					***Callialasporites dampieri***
	•		•		•			***Vallasporites ignacii***
					•			***Paracirculina* cf. *quadruplicis***
						•		*Chasmatosporites elegans*
							•	*Chasmatosporites major*
						•		*Chasmatosporites minor*
				•			•	*Corollina meyeriana*
•								*Corollina torosus*
							•	*Ricciisporites tuberculatus*
					•			***Pseudenzonalasporites summus***
			•		•			***Patinasporites densus***
							•	*Patinasporites funiculus*
					•			***Duplicisporites dispertitus***
					•			***Rhaetipollis germanicus***

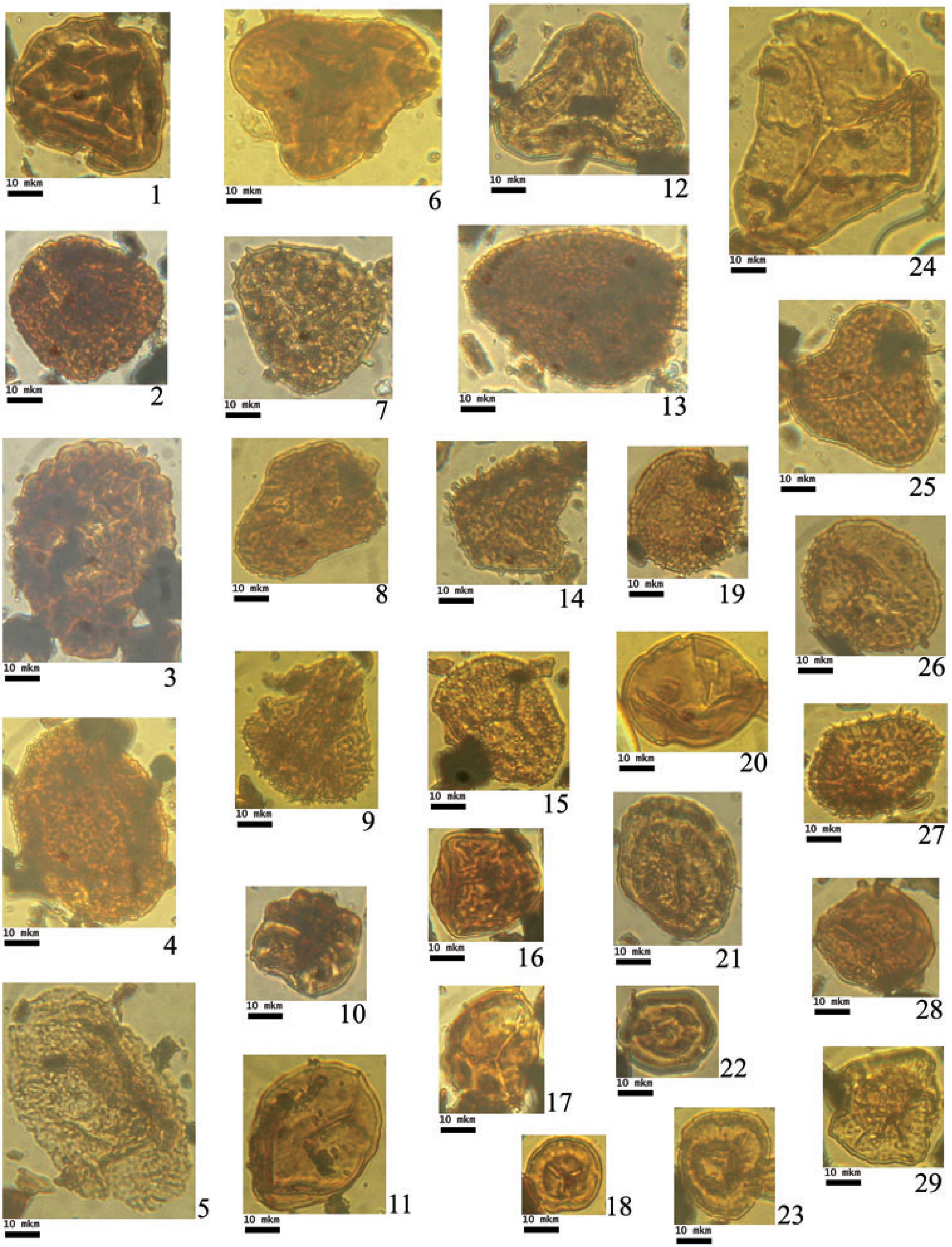
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Fig. 11 Sample 507-62a is from the "Protrachyceras" omkutchanicum Zone, and samples 507-67 and 507-68 are from the beds referred to the Neoprotrachyceras seimkanense Zone. All the aforementioned samples are from the section near the village of Stannakh-Khocho. Sample 502-43 is from the "Protrachyceras" omkutchanicum Zone from the section at Cape Chekurovsky. (1) *Duplexisporites gyratus*, sample 502-43. (2) *Convolutispora* cf. *microrugulata*, sample 507-67. (3) *Uvaesporites* cf. *argenteaeformis*, sample 502-43. (4) *Polypodiisporites* sp., sample 507-67. (5) *Aratrisporites fischeri*, sample 507-62a. (6) *Converrucosisporites* sp. 3 "chagrenate", sample 507-62a. (7) *Converrucosisporites cameroni*, sample 507-68. (8) *Granulatisporites asper*, sample 507-62a. (9) *Acanthotriletes ilekensis*, sample 507-62a. (10) *Concentricisporites nevesi*, sample 507-68. (11) *Todisporites minor*, sample 507-68. (12) *Converrucosisporites* sp. 5 "granulatus", sample 507-67. (13) *Converrucosisporites luebbenensis*, sample 507-62a. (14) *Neoraistrickia taylori*, sample 507-62a. (15) *Baculatisporites comaumensis*, sample 507-67. (16) *Camptotriletes cerebriformis*, sample 507-67. (17) *Carnisporites mesozoicus*, sample 507-67. (18) *Stereisporites perforatus*, sample 507-67. (19) *Anapiculatisporites telephorus*, sample 507-67. (20) *Leschikisporites aduncus*, sample 507-62a. (21) *Nevesisporites pokrovskajae*, sample 507-68. (22) *Polycingulatisporites dejerseyi*, sample 507-67. (23) *Polycingulatisporites densatus*, sample 507-62a. (24) *Converrucosisporites* sp. 2 "smooth", sample 507-62a. (25) *Converrucosisporites conferteornatus*, sample 507-62a. (26) *Apiculatisporis parvispinosus*, sample 507-67. (27) *Anapiculatisporites spiniger*, sample 507-62a. (28) *Nevesisporites macrogranulatus*, sample 507-67. (29) *Nevesisporites limatulus*, sample 507-67.

kuepperi, and sometimes *S. gothae*. The second assemblage is from the omkutchanicum Zone, and is poorer than the first in terms of spore diversity and the abundance of pollen. *Annulispora microannulata*, *Ginkgocycadophytus* and *Gnetaceaepollenites steevesi* are quantitatively prominent. Both assemblages include acritarchs, and their ages are constrained as Carnian by the associated marine faunas (Romanovskaja 1989). The third and youngest assemblage is not stratigraphically constrained in the same way: it was recovered from a part of the Nemtsov Formation that lacks age-conclusive faunal evidence, but has been provisionally regarded as Norian (Dagis & Kazakov 1984). Species diversity is even poorer than that from the omkutchanicum Zone: representatives of *Dictyophyllum* and *Kyrtomisporis* dominate.

The fourth group of miospores, comprising taxa restricted to the Late Triassic, is important because of the "Norian–Rhaetian" elements present. In the assemblage from the tenuis Zone, Romanovskaja (1989) recognized five Norian–Rhaetian taxa (*C. rhaeticus*, *K. speciosus*, *L. lundbladii*, *S. gothae* and *T. reticulatus*); *C. rhaeticus* also occurs in the second and third assemblages (from the omkutchanicum Zone and the Nemtsov Formation, respectively), and *K. speciosus* occurs in the third assemblage (Romanovskaja 1989).

Krugovyh studied 19 samples from the Nemtsov Formation of the Cape Tsvetkov section, and recognized two palynological assemblages: VIII and IX (Krugovyh & Mogučeva 2000). Assemblage VIII was recovered from the omkutchanicum Zone and beds correlated with the seimkanense Zone, and, on this basis, is assigned a Carnian age. Assemblage IX characterizes the plant-bearing highest part of the Nemtsov Formation, which lacks conclusive faunal evidence of age. Krugovyh followed the Upper Triassic stratigraphic scheme of Dagis & Kazakov (1984), and adopted a Norian age for this part of the formation.

Assemblages VIII and IX of Krugovyh (in Krugovyh & Mogučeva 2000), although not diverse, include miospores from each of the four groups recognized in this study (Tables 1–3, 5); dominant forms are *Annulispora*, *Duplexisporites* and a group of smooth triangular spores. Most samples also yielded reworked acritarchs (*Veryhachium* sp. and *Micrhystridium* sp.) and Upper Palaeozoic miospores. Krugovyh recorded *C. rhaeticus* in the omkutchanicum and seimkanense zones, and *K. speciosus* in the highest part of the Nemtsov Formation. Krugovyh's assemblage IX accordingly corresponds with the third assemblage of Romanovskaja (1989).

In the first three Upper Triassic miospore groups the records of Romanovskaja and Krugovyh reveal that the species content is consistent throughout the interval studied. We therefore consider it practical to combine the three assemblages of Romanovskaja (1989) and the two of Krugovyh (in Krugovyh & Mogučeva 2000) into one that characterizes the whole Upper Triassic. The appearance of a large number of Norian–Rhaetian taxa as early as the tenuis Zone, and their development in the omkutchanicum Zone and beds correlated with the seimkanense Zone, cast doubt on the correlated Norian age of the assemblage from the upper part of the Nemtsov Formation.

The present study of the sections near the village of Stannakh-Khocho and Cape Chekurovsky recorded a richer miospore assemblage that expands the previous characteristics of the Siberian Late Triassic palynoflora (Romanovskaja 1989; Krugovyh & Mogucheva 2000). The list of "Norian" species present in an independently dated early Carnian assemblage includes *C. rhaeticus*, *K. speciosus*, *L. lundbladii*, *R. germanicus*, *S. gothae* and *Z. laevigatus*, but not *T. ancorae*. Also present are the "Rhaetian" species *C.* cf. *golzowensis*, *R. semimuris* and *T. reticulatus*. These results suggest that the boundary between the Carnian and Norian stages in the Boreal basin cannot be recognized on the basis of palynology (Tables 1–3, 5).

Conclusions

In the present study of sections in northern Middle Siberia, miospores that are considered to be indicative of the Norian or Rhaetian stages have been found to appear in beds dated by marine invertebrates as Carnian. These records alter the stratigraphic range of these miospores, which are now considered as components of a group of taxa that characterizes the whole of the Late Triassic. The Carnian palynoflora from northern Middle Siberia seems more uniform than that in other regions. Therefore, global correlation by miospores may be possible only at the level of the Upper Triassic as a whole, through recognition of a unified palynological assemblage. For more detailed subdivision, the priority should be given to marine biota.

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Appendix

A list of the taxa referred to in this paper, with references to illustrations in this contribution follows.

Spores

Acanthotriletes ilekensis Kopytova, 1963 (Fig. 11.9)
Anapiculatisporites spiniger (Leschik, 1955) Reinhardt, 1962 (Fig. 11.27)
Anapiculatisporites telephorus (Pautsch, 1958) Klaus, 1960 (Fig. 11.19)
Anaplanisporites echinatus Schulz, 1967
Annulispora cicatricosa (Rogalska, 1954) Morbey, 1975 (Fig. 9.20, 9.21)
Annulispora folliculosa (Rogalska, 1954) de Jersey, 1964
Annulispora microannulata (de Jersey, 1962) de Jersey, 1964
Apiculatisporis globosus (Leschik, 1955) Playford & Dettmann, 1965
Apiculatisporis lentus Playford, 1982
Apiculatisporis parvispinosus (Leschik, 1955) Schulz, 1962 (Fig. 11.26)
Aratrisporites coryliseminis Klaus, 1960
Aratrisporites fischeri (Klaus, 1960) Playford & Dettmann, 1965 (Fig. 11.5)
Aratrisporites flexibilis Playford & Dettmann, 1965
Aratrisporites granulatus (Klaus, 1960) Playford & Dettmann, 1965
Aratrisporites paenulatus Playford & Dettmann, 1965
Aratrisporites palettae Klaus, 1960
Aratrisporites paraspinosus Klaus, 1960
Aratrisporites parvispinosus (Leschik, 1955) Playford & Dettmann, 1965
Aratrisporites scabratus Klaus, 1960
Aratrisporites virgatus (Leschik, 1955) Pautsch, 1971
Asterisporites slewecensis Mädler, 1964
Auritulinasporites scanicus Nilsson, 1958 (Fig. 9.13)
Baculatisporites baculatus Orłowska-Zwolińska, 1988
Baculatisporites comaumensis (Cookson, 1953) Potonié, 1956 (Fig. 11.15)
Baculatisporites verus Orłowska-Zwolińska, 1984
Camarozonosporites cf. *golzowensis* Schulz, 1967 (Fig. 9.3)
Camarozonosporites laevigatus Schulz, 1967 (Fig. 9.2)
Camarozonosporites rudis (Leschik, 1955) Klaus, 1960 (Fig. 9.1)
Camptotriletes cerebriformis Naumova, 1958 (Fig. 11.16)
Carnisporites mesozoicus (Klaus, 1960) Mädler, 1964 (Fig. 11.17)
Cingulizonates bulbifera Odintsova, 1977
Cingulizonates rhaeticus (Reinhardt, 1962) Schulz, 1967
Cingulizonates tuberosus Dybová & Jachowicz, 1957
Concavisporites crassexinius Nilsson, 1958 (Fig. 9.18)
Concavisporites juriensis Balme, 1957 (Fig. 9.23)
Concavisporites cf. *kaiseri* Arjang, 1975 (Fig. 9.12)
Concavisporites toralis Nilsson, 1958
Concavisporites sp. 2 Schuurman, 1977
Concentricisporites nevesi Antonescu, 1970 (Fig. 11.10)
Converrucosisporites cameroni (de Jersey, 1962) Playford & Dettmann, 1965 (Fig. 11.7)
Converrucosisporites conferteornatus Pautsch, 1971 (Fig. 11.25)
Converrucosisporites sp. 3 "chagrenate" (Fig. 11.6)
Converrucosisporites sp. 5 "granulatus" (Fig. 11.12)
Converrucosisporites luebbenensis Schulz, 1967 (Fig. 11.13)
Converrucosisporites sp. 2 "smooth" (Fig. 11.24)
Convolutispora sp. A Van der Eem, 1983
Convolutispora cf. *microfoveolata* Schulz, 1967 (Fig. 11.2)
Convolutispora cf. *microrugulata* Schulz, 1967
Cyathidites coniopteroides Romanovskaja, 1980 (Fig. 9.17)
Cyathidites nigrans (Bolchovitina, 1953) Romanovskaja, 1980
Cyathidites triangularis Romanovskaja, 1980
Cyclotriletes oligogranifer Mädler, 1964
Cyclotriletes triassicus Mädler, 1964
Deltoidospora sp. (Fig. 9.7)
Dictyophyllidites mortoni (de Jersey, 1959) Playford & Dettmann, 1965 (Fig. 9.19)
Dictyophyllum nilssoni Brongniart, 1828 (Kruchinina, 1980)
Dictyophyllum rugosum Lindley & Hutton, 1831 (Kruchinina, 1980) (Fig. 9.22)

Dictyophyllum vulgaris Maljavkina, 1949 (Kruchinina, 1980) (Fig. 9.24)
Discisporites psilatus de Jersey, 1964
Duplexisporites gyratus Playford & Dettmann, 1965 (Fig. 11.1)
Duplexisporites problematicus (Couper, 1958) Playford & Dettmann, 1965
Duplexisporites scanicus (Nilsson, 1958) Playford & Dettmann, 1965
Duplexisporites toratus (Weyland & Greifeld, 1953) Playford & Dettmann, 1965
Globulisporites primus Mädler, 1964
Granulatisporites asper (Nilsson, 1958) Playford & Dettmann, 1965 (Fig. 11.8)
Ischyosporites cf. *marburgensis* de Jersey, 1963
Klukisporites cf. *granosifenestellatus* Fisher & Dunay, 1984
Kraeuselisporites apiculatus Jansonius, 1962
Kraeuselisporites cuspidus Balme, 1963
Kraeuselisporites reissinger (Harris, 1957) Morbey, 1975
Kyrtomisporis gracilis Bjaerke & Manum, 1977
Kyrtomisporis laevigatus Mädler, 1964 (Fig. 9.6)
Kyrtomisporis speciosus Mädler, 1964 (Fig. 9.5)
Kyrtomisporis sp. (Fig. 9.11)
Leschikisporites aduncus (Leschik, 1955) Potonié, 1958 (Fig. 11.20)
Lophotriletes bauchiniae de Jersey & Hamilton, 1967
Limbosporites lundbladii Nilsson, 1958 (Fig. 9.27)
Lundbladispora denmeadi (de Jersey, 1962) Playford & Dettmann, 1965 (Fig. 9.30)
Lundbladispora willmottii Balme, 1963
Lycopodiacidites kuepperi Klaus, 1960 (Fig. 9.15)
Lycopodiacidites rugulatus (Couper, 1955) Schulz, 1967
Lycopodiumsporites sp. (Fig. 9.16)
Neoraistrickia taylori Playford & Dettmann, 1965 (Fig. 11.14)
Nevesisporites fossulatus Balme, 1970
Nevesisporites limatulus Playford, 1965 (Fig. 11.29)
Nevesisporites macrogranulatus Romanovskaja, 1979 (Fig. 11.28)
Nevesisporites pokrovskajae Romanovskaja, 1979 (Fig. 11.21)
Osmundacidites senectus Balme, 1963
Osmundacidites wellmani Couper, 1953
Pechorosporites coronatus Yaroshenko & Golubeva, 1984
Polycingulatisporites cf. *circulus* Simoncsics & Kedves, 1963
Polycingulatisporites crenulatus Playford & Dettmann, 1965
Polycingulatisporites dejerseyi Helby ex. de Jersey, 1979 (Fig. 11.22)
Polycingulatisporites densatus (de Jersey, 1959) Playford & Dettmann, 1965 (Fig. 11.23)
Polypodiisporites ipsviciensis (de Jersey, 1962) Playford & Dettmann, 1965
Polypodiisporites polymicroforatus (Orłowska-Zwolińska, 1966) Lund, 1977
Polypodiisporites sp. (Fig. 11.4)
Polypodites cladophleboides Brick, 1958
Porcellispora longdonensis (Clarke, 1965) Morbey, 1975
Punctatisporites fungosus Balme, 1963
Punctatisporites leighensis Playford & Dettmann, 1965
Punctatosporites walkomi de Jersey, 1962
Retitriletes semimuris (Danzé-Corsin & Laveine, 1963) McKellar, 1974 (Fig. 9.4)
Semiretisporis gothae Reinhardt, 1962 (Fig. 9.28, 9.29)
Semiretisporis maljawkinae Schulz, 1967
Spinotriletes echinoides Mädler, 1964
Stereisporites perforatus Leschik, 1955 (Fig. 11.18)
Styxisporites cooksonae Klaus, 1960 (Fig. 9.14)
Taurocusporites sp. A Morbey, 1975
Tigrisporites halleinis Klaus, 1960 (Fig. 9.10)
Todisporites major Couper, 1958
Todisporites minor Couper, 1958 (Fig. 11.11)
Triancoraesporites ancorae (Reinhardt, 1961) Schulz, 1967
Triancoraesporites reticulatus Schulz, 1962
Uvaesporites cf. *argenteaeformis* (Bolchovitina, 1953) Schulz, 1967 (Fig. 11.3)
Verrucosisporites applanatus Mädler, 1964
Verrucosisporites narmianus Balme, 1970
Zebrasporites corneolus (Leschik, 1955) Klaus, 1960
Zebrasporites interscriptus (Thiergart, 1949) Klaus, 1960 (Fig. 9.8)
Zebrasporites kahleri Klaus, 1960
Zebrasporites laevigatus (Schulz, 1962) Schulz, 1967 (Fig. 9.9)
Zebrasporites sp. (Fig. 9.8)

Pollen
Accinctisporites cf. *ligatus* (Leschik, 1955) Clarke, 1965 (Fig. 8.18)
Alisporites australis de Jersey, 1962
Alisporites cf. *aequalis* Mädler, 1964
Alisporites cf. *cymbatus* Venkatachala, Beju & Kar, 1967–1968
Alisporites grauvogeli Klaus, 1964
Alisporites landianus Balme, 1970
Alisporites magnus Jain, 1968
Alisporites parvus de Jersey, 1962
Alisporites perlucidus (Pautsch, 1971) Pautsch, 1973
Brachysaccus neomundanus (Leschik, 1955) Mädler, 1964
Callialasporites dampieri (Balme, 1957) Dev, 1961
Camerosporites secatus Leschik, 1955 (Fig. 8.16)
Chasmatosporites apertus (Rogalska, 1954) Schulz, 1967 (Fig. 8.12)
Chasmatosporites elegans Nilsson, 1958
Chasmatosporites hians Nilsson, 1958 (Fig. 8.7)
Chasmatosporites major (Nilsson, 1958) Schulz, 1967

Chasmatosporites minor Nilsson, 1958
Chordasporites australiensis de Jersey, 1962
Chordasporites singulichorda Klaus, 1960
Chordasporites cf. *voltziaformis* Visscher, 1966
Cordaitina gunyalensis (Pant & Srivastava, 1964) Balme, 1970 (Fig. 8.5)
Corollina meyeriana (Klaus, 1960) Venkatachala & Góczán, 1964
Corollina torosus (Reissinger, 1958) Klaus, 1960
Crustaesporites globosus Leschik, 1956
Duplicisporites dispertitus (Leschik, 1955) Klaus, 1960
Duplicisporites granulatus (Leschik, 1955) Scheuring, 1970
Enzonalasporites sp. A Van der Eem, 1983
Enzonalasporites vigens (Leschik, 1955) Scheuring, 1970
Eucommiidites sp. (Fig. 8.17)
Falcisporites snopkovae Visscher, 1966
Falcisporites stabilis Balme, 1970
Florinites pseudostriatus Kopytova, 1963 (Fig. 8.4)
Florinites walchius Kopytova, 1963 (Fig. 9.26)
Gnetaceaepollentes steevesi Jansonius, 1962
Granuloperculatipollis rudis Venkatachala & Góczán, 1964
Heliosaccus dimorphus Mädler, 1964
Lagenella martinii (Leschik, 1955) Klaus, 1960
Latosaccus latus Mädler, 1964
Lueckisporites triassicus Clarke, 1965
Lunatisporites rhaeticus (Schulz, 1967) Warrington, 1974 (Fig. 8.1)
Mesostriatites hercynicus Mädler, 1964
Microcachryidites doubingeri Klaus, 1964 (Fig. 8.19)
Microcachryidites fastidiosus (Jansonius, 1962) Klaus, 1964
Microcachryidites sittleri Klaus, 1964 (Fig. 8.13)
Microcachryidites sp. with four sacci (Fig. 8.21)
Minutosaccus potoniei Mädler, 1964 (Fig. 8.15)
Minutosaccus schizeatus Mädler, 1964
Minutosaccus sp. (Fig. 8.20)
Ovalipollis cultus Scheuring, 1970
Ovalipollis lunzensis Klaus, 1960 (Fig. 8.2)
Ovalipollis pseudoalatus (Thiergart, 1949) Schuurman, 1976
Paracirculina maljawkinae Klaus, 1960
Paracirculina cf. *quadruplicis* Scheuring, 1970 (Fig. 8.10)
Patinasporites densus (Leschik, 1955) Scheuring, 1970 (Fig. 8.8)
Patinasporites funiculus Leschik, 1955
Platysaccus leschiki Hart, 1960
Platysaccus niger Mädler, 1964
Platysaccus queenslandi de Jersey, 1962
Plicatisaccus badius Pautsch, 1971 (Fig. 8.6)
Podocarpidites keuperianus (Mädler, 1964) Schuurman, 1977
Praecirculina granifer (Leschik, 1955) Scheuring, 1970
Praecirculina sp. (Fig. 8.9)
Protodiploxypinus gracilis Scheuring, 1970 (Fig. 8.22)
Protodiploxypinus lacertosus Fisher & Dunay, 1984
Pseudenzonalasporites summus Scheuring, 1970
Quadraeculina anellaeformis (Maljavkina, 1949) Iljina, 1985
Rhaetipollis germanicus Schulz, 1967
Ricciisporites tuberculatus Lundblad, 1954
Samaropollenites speciosus (Goubin, 1965) Dolby & Balme, 1976 (Fig. 8.3)
Schizosaccus keuperi Mädler, 1964
Stellapollenites thiergartii (Mädler, 1964) Clement-Westerhof et al., 1974
Striatoabieites aytugii Visscher, 1966
Striatoabieites balmei Klaus, 1964
Striatoabieites multistriatus (Balme & Hennelly, 1955) Hart, 1964
Sulcatisporites institatus Balme, 1970
Sulcatisporites kraeuseli Mädler, 1964
Taeniaesporites noviaulensis Leschik, 1956
Taeniaesporites novimundi Jansonius, 1962
Taeniaesporites pellucidus (Goubin, 1965) Balme, 1970
Triadispora aurea Scheuring, 1970
Triadispora crassa Klaus, 1964
Triadispora falcata Klaus, 1964
Triadispora obscura Scheuring, 1970
Triadispora staplini (Jansonius, 1962) Klaus, 1964
Vallasporites ignacii (Leschik, 1955) Scheuring, 1970 (Fig. 8.14)
Vitreisporites pallidus (Reissinger, 1950) Nilsson, 1958
Vitreisporites reductus (Mädler, 1964) Yaroshenko, 1978
Voltziaceaesporites cf. *globosus* Fisher & Dunay, 1984
Voltziaceaesporites heteromorpha Klaus, 1964

Algae/Acritarchs
Micrhystridium breve Jansonius, 1962 (Fig. 8.23)
Micrhystridium triassicum Jansonius, 1962
Micrhystridium cf. *setasessitante* Jansonius, 1962 (Fig. 8.24)
Micrhystridium cf. *inconspicuum* Deflandre, 1935
Wilsonastrum colonicum Jansonius, 1962 (Fig. 8.25)
Baltisphaeridium sp.
Cymatiosphaera sp.
Pterospermopsimorpha sp.
Tympanicysta stoschiana Balme, 1980