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Mesozoic Radiolarian Biostratigraphy of Northeastern Russia

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The paper demonstrates the stratigraphic potential of radiolarian dating, which enabled the recognition of ten radiolarian assemblages in the previously poorly dated Early-Middle Jurassic deposits: (1) Middle Triassic; (2) Late Triassic; (3) Hettangian-Sinemurian; (4) Pliensbachian-early Bajocian; (5) late Bajocian-early Bathonian; (6) late Bathonian-Callovian; (7) late Callovian (?)-middle Tithonian; (8) late Tithonian-Berriasian; (9) late Berriasian-middle Valanginian; (10) late Valanginian-Hauterivian. Recognition of these radiolarian assemblages of various ages enables not only a detailed stratigraphic subdivision of the Middle Mesozoic deposits, but also the correlation of individual parts of the sequence, tectonically separated or even joined, throughout the Anadyr-Koryak Region.

The completion of large-scale mapping and prospecting work in Russia's Northeast urgently requires the creation of provincial zonal scales or schemes for the subdivision of the Mesozoic volcanic-siliceous strata into generally accepted parastratigraphic groups. During these investigations, not just the dates of individual strata are important, but also their correlation within the region. Without such investigations it is impossible to make reliable paleotectonic and paleogeodynamic reconstructions of the northwestern continental margin of the Pacific Ocean, numerous versions of which have been suggested recently [7], [8], [16], [17].

One of the most widespread and rapidly evolving faunal groups in the Mesozoic volcanic-siliceous deposits of Northeast Russia are siliceous microfossils, namely radiolarians. Mesozoic radiolarians were discovered in Northeast Russia as far back as the 1920s [19]. Since the 1950s they have been attracting the increasing attention of not only paleontologists, but also field geologists and tectonicists carrying out geological surveys in Northeast Russia.

The first attempts to subdivide the Cretaceous deposits of Northeast Russia using the radiolarians, were undertaken by R. Kh. Lipman [14]. Since the late 1950s, A. I. Zhamoida also took part in this work. By 1970s, Zhamoida and Lipman [9] recognized three independent radiolarian assemblages: Koiverelan, Pekulnei, and Lower Cretaceous, and for the first time published their photographs of thin sections.

In the late 1970s, L. I. Kazintsova [11] redescribed the thin sections of the Koiverelan radiolarian assemblage. In the early 1980s, N. Yu. Bragin and V. S. Vishnevskaya [7], [8], and [10] identified Triassic and Upper Jurassic-Lower Cretaceous, or Kimmeridgian-Hauterivian, radiolarians in these regions; and B. B. Nazarov identified the Paleozoic forms. I. E. Pralnikova [15] identified the late Valanginian-Hauterivian and Hauterivian-early Barremian radiolarian assemblages in this region. In the 1980s, Vishnevskaya published photographs of the three-dimensional specimens of the Early-Middle Jurassic [3] and Late Jurassic-Early Cretaceous [3], [5] radiolarians from the river basins of the Main, Koiverelan, Vaega, Khayidin, Elgevayam, and other rivers, taken under a scanning electronic microscope, enabling reliable correlation of the radiolarian assemblages of Northeast Russia with the assemblages of other regions. We have recently suggested [4] a more detailed radiolarian subdivision of the Early-Middle Mesozoic deposits of the Koryak Range (Table 1).

METHOD

Our investigations were based on two main stages. The first included detailed geologic mapping of the numerous junction zones recognized in Northeast Russia (Anadyr-Koryak Region) at a scale of 1:50 000 with layer-by-layer sampling for the radiolarian analysis and the subsequent interpretation of the structural framework of the Mesozoic strata. The second stage included extraction of three-dimensional radiolarian specimens from the rock, using hydrofluoric and other acids, followed by their investigation under binocular microscope and photography of the characteristic and index species under the scanning electronic microscope, where final analysis of the radiolarians was carried out. This approach obtained essentially new age data on the volcanic-siliceous formations.

Investigations revealed that the radiolarians in the sequences could be grouped into assemblages of various ages, differing in their systematic composition and quantity. On this basis, beds containing microfossils encompassing certain age intervals were recognized. During detailed monographic investigations and collation of all available data on the Northeastern region, local microfossil subdivisions were identified for the Jurassic-Cretaceous [4]. Recognition of the chronostratigraphic subdivisions is based on widespread complexes, specific variations of which are caused by the variety of environments and the phylogeny of individual radiolarian forms. The lower limits of the zones are defined mostly by the first appearance of new families, genera, and species; the upper, by extinction of certain taxa. Therefore a chronostratigraphic assemblage is a group of coexisting radiolarian species enclosed in a certain layer. For all intervals of the sequence characterized by identified microfossil assemblages of various ages, the index species, type sections, name and rank, lithologic characteristics, thickness, boundaries, spatial distribution, and correlation with other lithostratigraphic units are indicated, in compliance with the standards of the stratigraphic code. The recognized assemblages are not just correlated with the age equivalents in the same region, but an attempt has also been made to correlate them with assemblages from other regions (Tables 1 and 2).

Table 1 Distribution of Early-Middle Mesozoic radiolarians in the siliceous volcanic sequences of Northeast Russia.

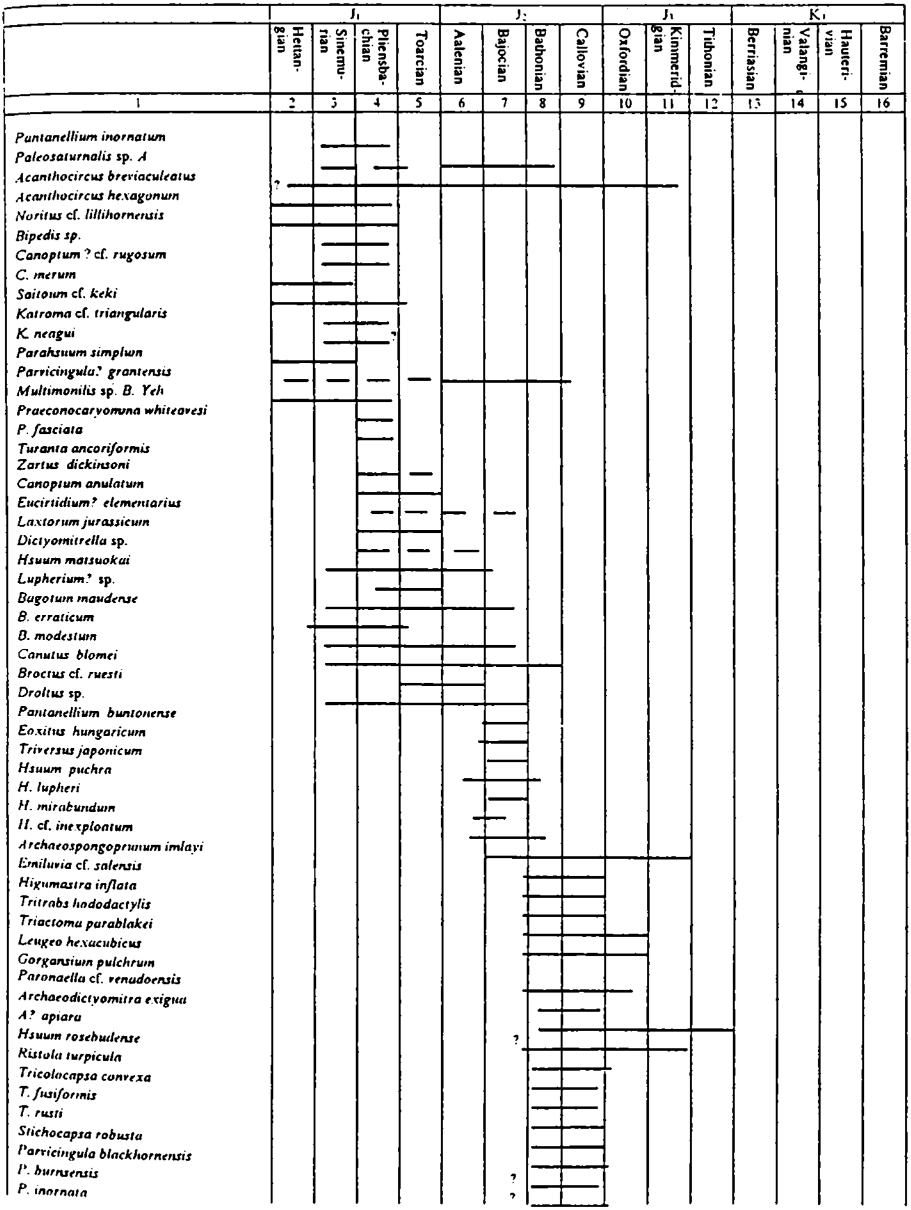
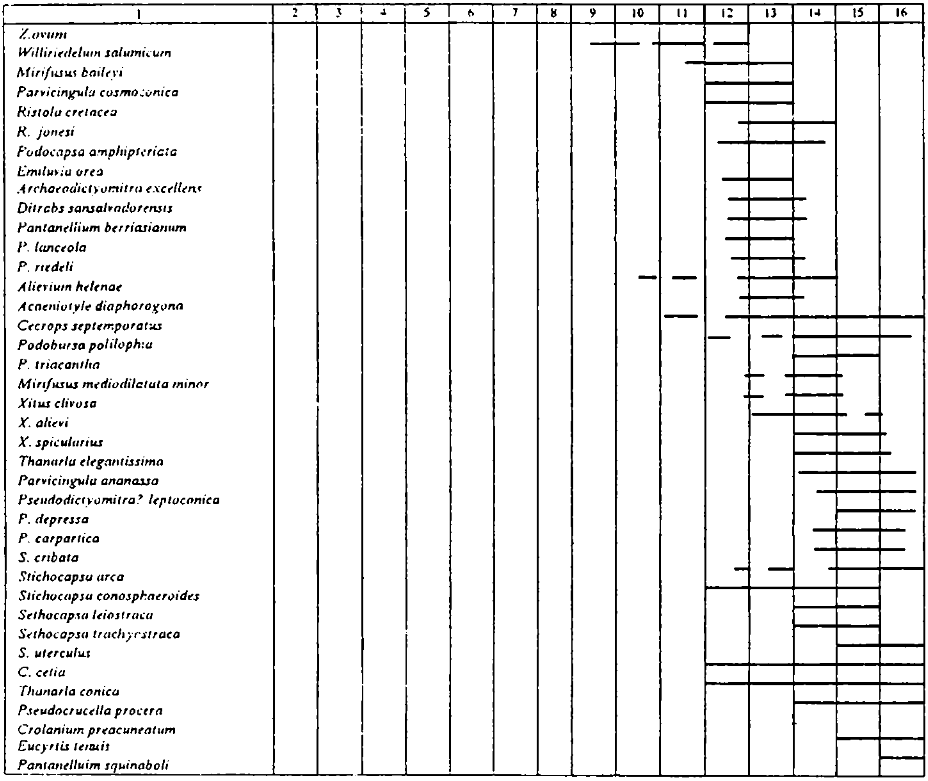


Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P. media							—	—							
P. profunda							—	—							
P. cf. *elegans*							—	—	—	—					
P. ex. gr. *khabakovi*							—	—	—	—	—				
P. schoolhousensis							—	—							
P. sodaensis							—	—	—	—					
P. vera							—	—	—	—					
P. aff. *boesii*							—	—	—	—	—				
Podobursa helvetica							—	—	—	—	—				
Ristola decora							—	—	—	—					
Hsuum maxwelli							—	—	—	—	—				
H. cuestaensis						—	—	—	—	—	—				
H. obispoensis						– –	– –	—	—	—	—				
Napora pyramidalis								—	—	—					
N. deweveri							—	—	—	—					
Ristola altissima										—	—	—	—	—	
R. procera										—	—	—			
Parvicingula blowi										—	—	—	—		
Parvicingula hsui										—	—	—	—		
Eusyringium anglisi							—	—	—	—					
Mirifusus guadalupensis								—	—	—	—				
M. fragilis							—	—	—	—					
M. mediodilatatus								—	—	—	—	—	—	—	
Dibolachras chandrica								—	—	—	—	—			
D. tytthopora											—	—			
Podobursa tricola									—	—	—	—	—		
P. fichli									—	—	—	—	—		
P. spinosa									—	—	—	—	—		
Thanarla broweri								– –	– –		—	—	—	—	—
T. pulchra											—	—	—	—	
Spongocapsula palmerae										—	—	—	—		
S. perampla										– –	—	—	—		
Syringocapsa lucifer											—	—	—		
Acanthocircus dicranacanthos											—	—	—	—	
Pantanellium fisheri										—	—	—			
Bernoullium cristatus										—	—				
Emiluvia premyogii										—	—	—	—		
E. salensis									—	—	—	—			
Milax flexuosus									– –	– –					
M. alienus									– –	– –					
M. inflatus									– –	– –					
Pseudocrucella magna										—	—	—			
P. plana										—	—	—			
Chitonastrum tricuspidatum											– –	– –	– –		
P. venadoensis										—	—	—	—		
Paronaella mulleri										—	—	—	—		
P. pessagnoi										—	—	—	—		
P. venusta										—	—	—	—		
P. worzeli										—	—	—	—		
Triactoma blakei									—	—	—	—	—		
T. echiodes											—	—	—		
T. cornuta									—	—	—	—	—		
T. tithonianum										—	—	—	—		
T. jonesi							– –	—	—	—	—	—	—		
Orbiculiforma multifora									—	—	—				
Spongosaturnalis suboblongus							– –	—	—	—	—				
S. protoformis										—	—				
Mirifusus hunni												—	—		
Parvcingula citae										—	—	—	—		
P.? chimenaensis										—	—	—	—		
Napora lospensis								– –	– –	—	—	—	—		
Zhamoidellum ventricosum								– –	– –	– –	– –				

Table 1 (continued).



RADIOLARIAN ASSEMBLAGES AND CHRONOSTRATIGRAPHIC SUBDIVISION OF THE HOST ROCKS

This paper gives a more detailed description of the chronostratigraphic subdivision of the Pekulneiveem, Topolevka, and Chirynai "groups", the age of which is presently a matter for continuous discussion [12], [16], [17].

The age of these groups was previously interpreted by most of investigators being Late Jurassic–Early Cretaceous, or Tithonian–Neocomian. No significance was attached to occasional finds of Early–Middle Jurassic radiolarians in the Elgevayam River basin within the range of the above-mentioned groups, in spite of the numerous photographs, satisfactory preservation, and rich taxonomic composition [3]. The lack of attempts to interpret those data was probably due to a consistent underestimate of the radiolarians, which continued to be studied mainly in thin sections by many Soviet specialists. In his description of the Koryak Range nappe system, S. D. Sokolov [7], [8], [16] recognized the Pekulneiveem and Chirynai structural-stratigraphic units of Late Jurassic–Early

Table 2 Correlation of the suggested Middle Mesozoic radiolarian zones with the existing classifications.

Age		Baumgartner, 1987	Aita, 1987	Тихомирова, 1987	Vishnevskaya, 1988, 1994	Aita, 1987	Matsuoka, Yao, 1985	Pessagno, Mizutani, 1990	Pessagno, et al., 1987, 1990		Murchey 1984	Tikhomirova, 1987	Vishnevskaya 1988, 1994	Schaaf, 1986; Matsuoka, 1991, 1992	Sanfilippo, 1974, Foreman, 1977
		Tethys		Carpathians	Caucasus	Japan			North America			Russia's Far East	Russia's Northeast	Pacific Ocean	Atlantic and Pacific
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15
K_1	al			*H.barbui - A.stocki*	*P.pseudomacrocephala - H.barbui*								*P.pseudomacrocephala - H.barbui*	*P.pseudomacrocephala*; *S.zamoraensis*	*A.umbilicata*
	a			*L.elegantissima - E.tenuis*	*A.umbilicata - T.conica*								*C.pythiae*	*A.umbilicata - A.cortinaensis*; *A.similis*	
	b			?	*C.pythiae - X.alievi*									*C.pythiae*	*E.tenuis*
	h			*C.septemporatus - S.trachyostraca*	*C.septemporatus - S.uterculus*								*M.chenodes - S.trachyostraca*	*D.tytthopora*	*S.trachyostraca*
	v	E_2	*S.septemporatus*						5C	5C				*C.septemporatus*	
		E_1	*D.sansalvadorensis*	*D.clivosa - D.cosmoconica*	*P.polyphila - P.cosmoconica*	*D.sansalvadorensis*			5AB	5AB	MII-5	*D.carpatica - P.(?)cosmoconica*			
	bs	D											*M.bailayi - P.khabakovi*	*P.carpatica*	*S.lanceola*

Table 2 (continued).

	tt	D C_2	D.sansalvadorensis S.cetia	T.dicranacanthos - E.khabakovi T.bicornispinosa - T.armenica	T.tithonianum - R.altissima	D.sansalvadorensis S.cetia	P.primitiva	P.primitiva	4	4 3		E.khabakovi - P.altissima		P.primitiva	[illegible]
J_3	km	C_1	P.amphitreptera	N.deweveri - P.helvetica	M.guadalupensis - M.fragilis	Z.mikamense	C.carpatica	C.carpatica S.spiralis + T.conexa	3	2		P.helvetica - M.guadalupensis	M.fragilis - ? M.guadalupensis	C.carpatica	
	ox	B	P.hipposiderius S.(?)spiralis	M.rakhovensis - A.cf. crassa	H.maxwelli - G.carpatica	E.hipposiderica G.sakawaensis S.(?)spiralis						G.sakawaensis - M.guadalupensis		S.(?) spiralis	
	cl	A_2	A.tsunoensis			A.tsunoensis Ar.mirabilis G.nudata T.tetragona	T.conexa		2	IG	MH-4	G.sakawaensis - L.(?) nudata	P.vera - R.turpicula		
J_2	bt				R.turpicula - H.hupheri	O.magniglobosa E.unumaense	T.plicarum	T.plicarum	?	IF		D.conoformis - S.tecta	B.mandense	T.conexa	
	bs	?			T.medium					IE ID IC IB	MH-3	G.oblonga - T.conexa		T.plicarum	
	a				L.officerensis sp. - E. hungaricus		L.jurassicum	L.jurassicum		IA	MH-2	T.(?)fusiformis - T.plicarum U.tupicum			
	t				?							? B.modestum - D.sp.	L.jurassicum		
J_1	pl				P.cruciferum - T.elkhornensis		P.simplum	A.pachyderma + Parahsuum sp. C.		01 02	MH-1	K.(?) cf. bicornis - L.sichotica			
	h-sm									03 04 05		Archecyrtum sp. - Archetypum sp.	P.simplum		

Cretaceous age, composed of volcanic-siliceous-graywacke deposits. Moreover, Sokolov [16] proved the presence in Koryakia of exotic blocks composed of deep oceanic cherts and volcanic-siliceous deposits with enclaves of shallow-marine limestones, volcanics, plagiogranites, and cherts, "accumulated under tropical latitudes in an area that underwent destruction in connection with the opening of the latitudinal Mesotethys Ocean".

On the State Geologic Map, scale 1:200 000 [6], the age of the Pekulneiveem Formation was assigned to late Kimmeridgian-Hauterivian on the basis of a radiolarian assemblage and finds of macrofauna (buchias, inoceramids) [18]. It was divided into two subformations on the basis of late Kimmeridgian-early Tithonian (*Acanthocircus variabilis* Squinabol., *Crusella corallitosensi* Pessagno, *Tripociclia jonesi* Pessagno) and Valanginian-Hauterivian radiolarian assemblages (*Praeconocaryomma* aff. *uhlensis* Pessagno, *Parvicingula khabakovi* (Zhamoida)), identified by N. Yu. Bragin [10] in this formation. Vishnevskaya [3], [4] demonstrated the presence of Pliensbachian-Oxfordian forms in these formations. V. T. Krymsalova [12], who had performed a further investigation of the radiolarians from the Pekulneiveem Formation in the area between the Talyain-Pravyi Talyainyn, revised its composition and age and recognized the following independent members: Talyainyn (Bajocian-Callovian), Euchuvytkin (Kimmeridgian-early Tithonian), and Kepetchakyl (Berriasian-Hauterivian).

Studies of the radiolarians in the Pikasvayam River basin within the extent of the so-called "Tithonian-Neocomian Chirynai Group" also indicated the presence of diverse Jurassic and Cretaceous assemblages [7], [8]. A possible occurrence of older radiolarian assemblages (Early?-Middle Jurassic) in the lower Chirynai complex was reported before [7].

It has also been reported that the composite section of the Chirynai Group, described in the literature [8] is not a stratigraphic succession, but actually a pile of tectonic slabs [16].

Recently a considerable number of finds of Triassic and Early-Middle Jurassic radiolarians were made in the area of the Upper Jurassic-Early Cretaceous volcanic-siliceous strata of Central Koryakia [2], [4].

The Late Triassic chronostratigraphic interval includes two generally coeval sequences composed of different sedimentary facies, recognized in the eastern Koiverelan-Mainitsa zone and in the Pikasvayam zone. Detailed study of the sequences and facies variations of these oldest Early Mesozoic strata was impossible because of intense faulting (exceeding that of the younger Middle Mesozoic units) and due to the paucity of surface outcrops.

In the upper reaches of the Pikasvayam River, the following radiolarians, which unambiguously indicate a Middle-Late Triassic age were identified in a sequence (60-100 m) of gray cherts interbedded with dark to black siliceous mudstones (1-5 cm), and occasional tuffstones (up to 10-15 cm): *Archaeospongoprunum helicatum* Nakaseko et Nishimura, *A. tenue* Nak. et Nish., *A. japonicum* Nak. et Nish., *A. compactum* Nak. et Nish., *Eptingium* Dumitrica, *Pentactinocarpus? tetracanthus* Dumitrica, *Staurodorax dercourti* De Wever, *Pantanellium silberlingi* Pessagno, *Capnodoce sarisa* De Wever, *Triassocampe deweveri* Nak. et Nish., *Yeharaia annulata* Nak. et Nish., and *Xiphotheca* sp.

An age-equivalent assemblage was collected in the Kenkeren Ridge and, in some blocks, from the melange in the Elgevayam River basin.

The Early Jurassic sequence occurs as a wide strip bounded by strike-slip faults, extending northeastward from the Chirynay River basin in the upper reaches of the Malyi Nauchirynai River. Much of its exposure area lies on the right bank of the Elgevayam River. In spite of the numerous strike-slip displacements and thrusting, these strata can be easily distinguished from other units in the studied region and have been mapped with confidence during field surveys. Earlier, much of this unit was recognized as the Elgevayam back-arc petrotectonic assemblage of Late Jurassic–Neocomian age. However, tuffaceous-clastic deposits of Late Jurassic–Neocomian age (according to our data) were also assigned to this unit.

The Early Jurassic sequence has a thrusted contact with the hyperbasites. The thickness of the sequence is no more than a few hundred meters. It is composed of alternating gray and black cherts, black fine sandstones, gray siliceous siltstones, and subordinate red jasper interlayers. The thickness of individual interlayers is a few centimeters, scarcely tens of centimeters. The rocks are strongly cataclased, with numerous fissures infilled with chalcedony. The sandstones and siltstones of this sequence show a subarkosic composition. The clasts (usually angular or subangular) are composed predominantly of plagioclases, quartz, plagiogranites, rhyolites, dacites, dacitic andesites, jasper, chert, scarce pyroxenes, basalts, sandstones, and siltstones. Biotite is practically absent (in this respect they differ from the subarkosic Albian–Upper Cretaceous clastic rocks).

In the cherts and jasper of the above-described sequence (see Fig. 1*a*[a], Table 3), poorly preserved radiolarians of earliest Jurassic age have been identified (Site 27, sample DN 1140/2): *Acanthocircus breviaculiatus* Donofrio et Mostler, *Triactoma* sp. cf. *acythus* De Wever, and *Protopsium* sp., widespread in the Mediterranean province (Armenia, Azerbaijan, and Turkey).

An age-equivalent sequence in small tectonic blocks (where its apparent thickness is just a few tens of meters) is exposed in many areas on the right bank of the Elgevayam River, as well as on the northern and southern slopes of Mt. Srednyaya and on the left bank of the Nauchirynai River. The thickest slabs of this sequence occur on the northern slope of Mt. Srednyaya. At that site a sequence of interbedded alkali titaniferous WPB-type basalts (0.5–2 m thick) and red jasper is exposed within a complex pile of thrust sheets. In places, gray recrystallized limestone members (with thicknesses ranging from less than a meter to a few meters) are present. The sequence appears to be a variegated green–violet in color from the green coloration of the basalts (intense propylitization) and the brownish-red of the jasper, and is therefore easy to distinguish in the field. The rocks of the Mt. Srednyaya sequence are intensely metamorphosed, mylonitized, and strongly deformed by cataclasis. The above-mentioned rock varieties are often transformed into alternating emerald-green and red slates.

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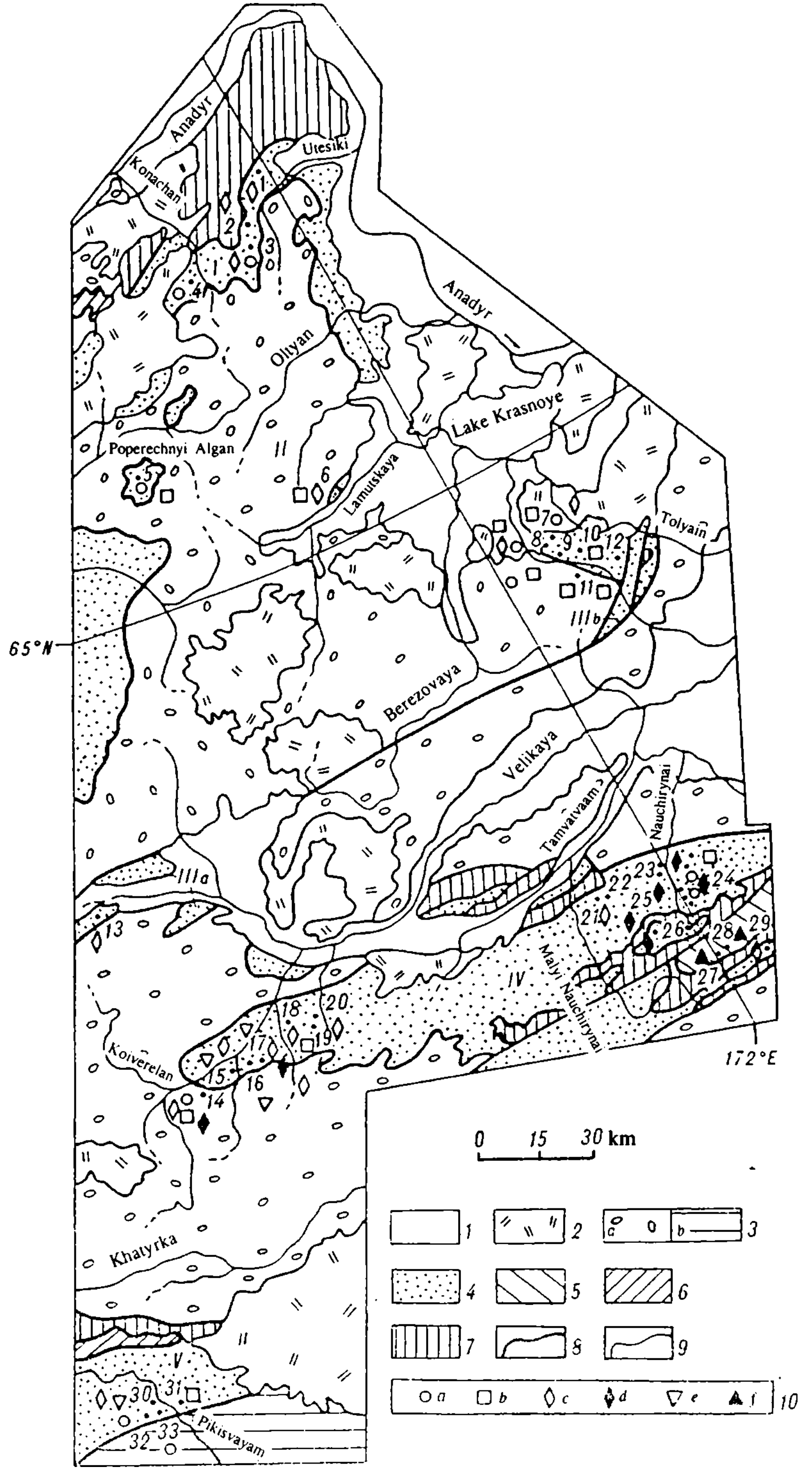
[a] Hereafter numbers in parentheses indicate the sites of radiolarian assemblages in Fig. 1, and some of these assemblages are shown under the same numbers in Fig. 2. The numbers with letters indicate individual samples of rocks carrying the radiolarians.


Anadyr
Konachan
Utesiki
Anadyr
Oltyan
Lake Krasnoye
Poperechnyi Algan
Lamutskaya
Tolyain
65°N
Berezovaya
Velikaya
Tamvatvaam
Nauchirynai
Malyi Nauchirynai
Koiverelan
172°E
Khatyrka
Pikisvayam
IIIa
IIIb
IV
V
0 15 30 km
1
2
3
4
5
6
7
8
9
10

The following radiolarians, indicative of the Hettangian-Sinemurian age of the sequence have been identified in the jaspers (Site 27, sample DN 1111/6): *Saitoum keki* De Wever, *Parvicingula? grantensis* Pessagno et Whalen, *Parahsuum simplum* Yao, and *Multimonilis* sp. B. Yeh.

The Early Jurassic radiolarian assemblage of the Elgevayam River basin has a sparse species composition. In terms of its characteristic species it is similar to the North American age-equivalent assemblage from the siliceous rock olistoliths described in Oregon [21], the Japanese assemblage [23], and to a lesser extent to the Mediterranean assemblage [22].

In the jaspers of the underlying tectonic slab (Site 27, sample DN 1079/1), the following forms, also indicative of a Hettangian-Sinemurian age, were identified: *Zartus* sp., *Paleosaturnalis* sp. A., *Pantanellium? inornatum* Pessagno et Poisson, *Canoptum?* cf. *rugosum* Pessagno et Poisson, *Saitoum* cf. *Keki* De Wever, *Bipedis* sp., *Parahsuum simplum* Yao, *Katroma* cf. *triangularis* Kishida et Hisada, and *Katroma neagui* Pessagno et Poisson.

The most complete sequence (Table 4) of the lowest Middle Jurassic is found on the right bank of the Talyakaurkhyn River [5]. There, in a pile of thrust sheets, claret-colored calcareous and tuffaceous jasper and siliceous siltstones are exposed, in which radiolarians of Pliensbachian-Toarcian age, probably extending to the earliest Middle Jurassic (Aalenian-early Bajocian), have been identified (Site 17, sample L 152): *Laxtorium? jurassicum* Isozaki et Matsuda, *Eucirtidium ex. gr. elementarius* Carter, *Parahsuum* sp., and *Foremanina* sp.

Figure 1 Location map of Jurassic-Neocomian radiolarian assemblages (base map after [5]). 1 – Quaternary deposits; 2 – Paleogene-Neogene volcaniclastic deposits; 3 – Albian-Upper Cretaceous deposits: (*a*) clastic, (*b*) jasper-volcanic; 4 – Lower Jurassic-Hauterivian jasper-volcanic, siliciclastic, and volcaniclastic deposits (in places adjacent to fault-bounded Paleozoic, Triassic, and Albian-Upper Cretaceous deposits); 5 – Lower Jurassic siliciclastic and jasper-basalt strata; 6 – undifferentiated Paleozoic and Lower Jurassic sedimentary and volcanic deposits; 7 – essentially serpentinized gabbro-ultrabasite suite (including plagiogranite and migmatite tectonic slabs and melange zones); 8 – faulted contacts (shear and overthrust faults); 10 – radiolarian assemblages: (*a*) Late Tithonian-Hauterivian undifferentiated; (*b*) Middle Callovian-middle Tithonian; (*c*) Late Bathonian-early Callovian; (*d*) Late Bajocian-early Bathonian; (*e*) Pliensbachian-early Bajocian; (*f*) Hettangian-Sinemurian. Circled numbers on the map: I-IV – geographic range of the Jurassic-Neocomian assemblages: I – Talaya-Main; II – Vaezh-Algan; III – Velikaya-Rarytkin: (*a*) Upper Velikaya subzone; (*b*) West Rarytkin subzone; IV – Koiverelan-Mainitsa; V – Pikasvayam-Ekonay. Radiolarian assemblage sites (1-33): *1* – left bank of the Utesiki River (the Perevalnaya River system); *2-3* – left bank of the upper reaches of the Utesiki; *4* – the Pravyi Konachan R.; *5* – left bank of the Poperechnyi Algan R.; *6* – left bank of the Lamutskaya R.; *7-12* – the Rarytkin Range: *7* – the Pravyi Talyainyn-Kepetchakylya river divide; *8* – right bank of the Pravyi Talyainyn R.; *9* – right bank of the Pravyi Talyainyn (near the mouth of the Yasnyi Creek valley; *10* – the Pravyi Talyainyn R.-Yasnyi Creek divide; *11* – left bank of the Pravyi Talyainyn R.; *12* – the Pravyi Talyainyn-Pravyi Talyain river divide; *13* – the upper reaches of the Velikaya R. (right bank); *14-18* – right bank of the Koiverelan R.: *14* – Mt. Semiglavaya; *15-17* – the Talyakaurkhyn R. valley; *18* – the lower reaches of the Koiverelan R.; *19, 20* – the Zavitaya R. valley; *21, 22* – the right bank of the Malyi Nauchirynay R.; *23-26* – the Nauchirynai R. basin: *23* – left bank of the Nauchirynai; *24* – group of sites on the right bank of the Nauchirynai; *25* – the Volchok-Mezhgornyi Creek divide; *26* – left bank of the Virtuoz Creek; *27-29* – right bank of the Elgevayam R., northern slope of Mt. Srednyaya; *30-33* – the Pikasvayam R. drainage.

Table 3 Site 27.

Sample number	Radiolarian species	Age: T_2	T_3 k	T_3 n-k	J_1 g	J_1 sm	J_1 pl	J_1 t	J_2	J_3
DN 1111/6	*Saitoum keki* De Wever									
	Parvicingula grantensis Pessagno et Whalen									
	Parahsuum simplum Yao									
	Multimonilis sp. B Yeh									
DN 1079/1	*Zartus* sp.									
	Paleosaturnalis sp. A									
	Pantanellium inornatum Pessagno et Poisson									
	Canoptum cf. *rugosum* Pessagno et Poisson									
	Saitoum cf. *keki* De Wever									
	Bipedis sp.									
	Parahsuum simplum Yao									
	Katroma cf. *triangularis* Kishida et Hisada									
	Katroma neagui Pessagno et Poisson									
DN 1140/2	*Acanthocircus breviaculeatus* Donofrio et Mostler									
	Acanthocircus sp. C									
	Triactoma sp. cf. *acythus* De Wever									
	Parvicingula ? sp.									
	Protopsium sp.									

Topographically below them, the following sequence is exposed in a northward-tilted (60°) slab overriding the Albian–Upper Cretaceous deposits (upward):

1. Gray limestones with an apparent thickness of 3 m.

2. Gray brecciated cherts (20 m thick), containing Bajocian-Bathonian radiolarians (L 152/3): *Pantanellium* cf. *foveatum* Mizutani et Kido, *Turanta* cf. *ancoriformis* Pessagno, *Parvicingula* cf. *inornata* Blome.

3. Brown calcareous jasper with an admixture of volcanic ash (7 m) with Late Jurassic radiolarians (L 152/2): *Parvicingula* cf. *Khabakovi* (Zhamoida), *P. hsui* Pessagno, *Archaeodictyomitra? apiara* Rust., *Hsuum* cf. *mirabundum* Pessagno et Whalen, *Stichocapsa? cetia* Foreman, *Zhamoidellum mikamense* Aita (see Table 4). Above are bluish-gray jaspers and cherts (15 m) with Early Cretaceous radiolarians (L 152/1, see Table 4, Berriasian-Valanginian).

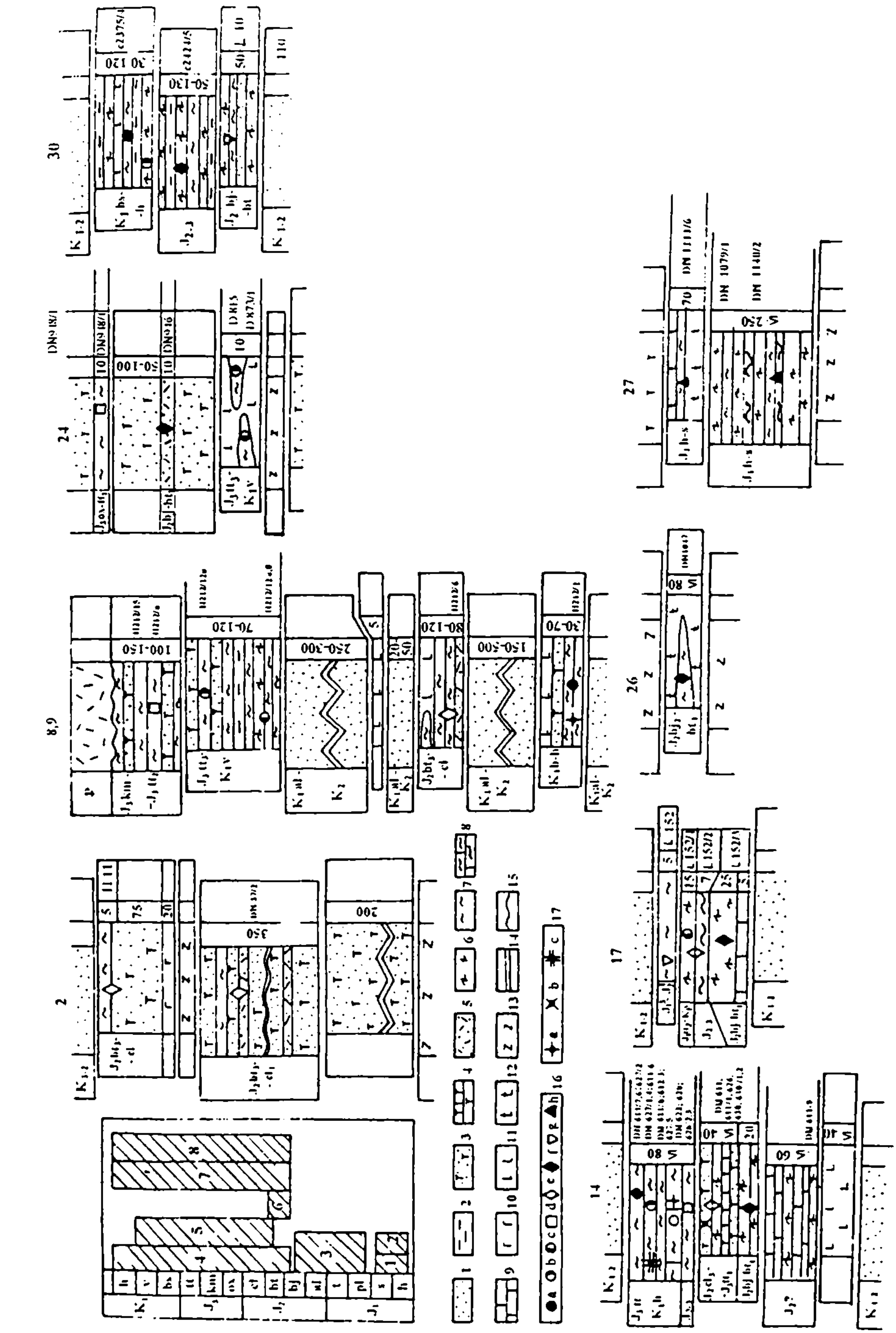
Thin (a few meters thick) lenses of rocks carrying radiolarian assemblages of latest Early and earliest Middle Jurassic age have been discovered in two more areas within the Talyakaurkhyn River basin (Site 16, L 113, L 143): *Zartus* cf. *dickinsoni* Pessagno et Blome, *Hsuum* cf. *lupheri* Pessagno et Whalen, *Parvicingula* sp. C. Carter. The sequence enclosing this radiolarian assemblage is composed of black cherts interbedded with gray,

Table 4 Site 17.

Sample number	Radiolarian species	Age (J_1, J_2^1, J_2^2, J_2^3 cl, J_3 ox, km, tt, K_1 bs, v, h)
L-152	*Laxtorum? jurassicum* Isozaki et Matsuda *Eucyrtidium ex.gr. elementarius* Carter *Parahsuum* sp. *Foremanina* sp.	
L-152/1	*Acanthocircus dicranacanthos*(Squinabol) *Zhamoidellum ovum* Dumitrica *Parvicingula khabakovi* (Zhamoida) *Parvicingula ex. gr. boesli*(Parona) *Parvicingula ? citae* Pessagno *Podobursa polylophia* Foreman	
L-152/2	*Parvicingula hsui* Pessagno *Parvicingula* cf. *khabakovi* (Zhamoida) *Archaeodictyomitra apiara* (Rust) *Hsuum ex. gr. maxwelli* Pessagno *Hsuum* cf. *mirabundum* Pessagno et Whalen *Stichocapsa? cella* Foreman *Zhamoidellum mikamense* Aita	
L-152/3	*Pantanellium* cf. *buntonense* Pessagno et Blome *P.* cf. *foveatum* Mizutani et Kido *Turanta* cf. *ancoriformis* Pessagno *Parvicingula* cf. *inornata* Blome	

stratified limestones, essentially enriched in acidic ash. A younger Middle Jurassic radiolarian assemblage was identified in another thin tectonic slice sandwiched between beds of Lower-Upper Cretaceous flyschoid-sandy strata on the Koiverelan-Talyakaurkhyn river divide (Site 15), where three members are exposed (upward):

1. Red jasper (10–12 m) containing the following radiolarians (L 123/2) (Table 5): *Eoxitus hungaricus* Kozur, *Eucyrtidium? ex gr. elementarius* Carter, *Triversus* cf. *japonicus* Takemura, *Triversus* sp., *Archaeodictyomitra ex gr. rigida* Pessagno, *Droltus* cf. *Droltus* sp. A., *Bagotum* sp., grading downward into gray cherts (L 123/3) with *Pantanellum* cf. *buntonense* Pessagno et Blome, *Parvicingula vera* Pessagno et Whalen, *P.* cf. *media* Pessagno et Whalen, *Ristola* sp., *Podobursa* sp., *Hsuum* cf. *mirabundum* Pessagno et Whalen, and *Laxtorum*.
2. Gray stratified limestones (3 m).
3. Siltstones (10–20 m).


30
24
27
8,9
26
2
17
14

Apparently, this thin member represents a sequence from the Bajocian to Bathonian inclusive; moreover, the presence of the Lower Jurassic (Pliensbachian–Toarcian) at the base of the sequence cannot be ruled out.

A sequence similar to the Talyakaurkhyn member is exposed farther west in the massif of Mt. Semiglavaya, whose geologic structure is the subject of much discussion.

Our investigations revealed that the southern slope of Mt. Semiglavaya is composed of several tectonically joined slabs of Middle Mesozoic deposits (see Fig. 2, Site 14, Table 6), and the Talyakaurkhyn limestone-chert-jasper sequence is exposed in three of them. The lowermost slab, overriding the Albian–Upper Cretaceous deposits, is composed of MORB-type basalts and hyaloclastites (40 m thick), is not characterized by fossil fauna. In the overriding second slab the "Talyakaurkhyn" sequence (up to 60 m) is composed of light-gray bituminous limestones (fine-crystalline bioclastic, algal-crinoid-bryozoan, and micro-olitic) with interbeds (5–10 cm) of spongolite, sometimes with sponge-radiolarian cherts in the lower part. In the limestones, the remains of corals from the family Microssolenidae were identified [18], indicative of a Jurassic, most probably Kimmeridgian–Tithonian age, in the opinion of E. V. Krasnov. The cherts consist of small sponge spicules, asters, and rhabdes. Sometimes they contain single radiolarian forms of the genera *Willeriedellum* and *Zhamoidellum* (samples DN 611/9-10) with a hidden cephalothorax, first appearing below the Middle Jurassic boundary. In the upper part of this sequence, Bajocian–Bathonian radiolarians were identified in the cherts (sample D 630/3): *Eoxitus* sp., *Unuma echinatus* Ichikawa et Yao, *Protunuma fusiformis* Ichikawa et Yao; in the lower part, the Pliensbachian–Aalenian: *Trillus elkhornensis* Pessagno et Blome was identified. The third slab has a bipartite structure, and the "Talyakaurkhyn" member forms just its lower part (up to 20 m), consisting of interbedded, thinly stratified

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Figure 2 Lower Jurassic-Neocomian sequences of the Anadyr–Koryak region. 1 – subarkosic sandstones and siltstones, mudstones; 2 – siltstones and mudstones, including siliceous varieties; 3 – basic tuffs and tuffites, tuffstones, interbedded with acidic ash tuffs; 4 – calcareous tuffs and tuffites; 5 – acid tuffs and tuffites; 6 – green-gray, gray, and black cherts; 7 – brownish-red jasper; 8 – calcareous jasper and siliceous limestones; 9 – limestones; 10–12 – basalts: 10 – island arc tholeiites and boninites; 11 – MORB-type tholeiites; 12 – WPB-type (oceanic-island-type) tholeiites and alkali basalts; 13 – essentially serpentinized gabbro-ultrabasite suite (including plagiogranite and migmatite slabs and melange zones); 14 – faulted boundaries (thrust faults); 15 – stratigraphic boundaries; 16 – radiolarian assemblage sites: (*a*) late Valanginian–Hauterivian; (*b*) late Berriasian–middle Valanginian; (*c*) late Tithonian–early Berriasian; (*d*) middle Callovian–middle Tithonian; (*e*) late Bathonian–early Callovian; (*f*) late Bajocian–early Bathonian; (*g*) Pliensbachian; (*h*) Hettangian–Sinemurian; 17 – macrofauna sites: (*a*) buchias; (*b*) ammonites; (*c*) inoceramids; open symbols indicate possible occurrence. Site numbers correspond with those in Fig. 1. The first column of each section shows the age (for the Middle Mesozoic deposits they are given only in those parts of the sequences that are dated by fossil fauna); the third, thicknesses (apparent) in meters; the fourth, numbers of samples with radiolarian assemblages. The inset shows the fossil age of rock assemblages discussed in the text: (1) siliciclastic, (2) jasper-alkali-basalt (WPB), (3) jasper-siliceous, (4) jasper, (5) jasper-basalt (MORB), (6) Fe-Ti basalts (WPB), (7) tuffite-jasper- basalt (MORB), (8) volcaniclastic (island-arc-type).

Table 5 Site 15.

Sample number	Radiolarian species	Age: T	J_1^1	J_1^2	J_1^3	J_2^1	J_2^2	J_2^3 cl	J_3 ox	J_3 km	J_3 tt
L-123/3	*Pantanellium* cf. *buntonense* Pess. et Blome										
	Parvicingula vera Pessagno et Whalen										
	P. cf. *media* Pessagno et Whalen										
	Hsuum cf. *mirabundum* Pessagno et Whalen										
	Laxtorum? sp.										
L-123/2	*Eoxitus hungaricus* Kozur										
	Eucyrtidium ex. gr. *elementarius* Carter										
	Triversus cf. *japonicus* Takemura										
	Archaeodictyomitra ex. gr. *rigida* Pessagno										
	Droltus cf. *Droltus* sp.A Carter										
	Bagotum sp.										

black cherts and greenish-black siltstones with a thickness of 5-15 cm. The cherts are black, sometimes with an admixture of acidic ash, spongolitic, in places enriched in the radiolarians or even consisting of transitional varieties, sponge-radiolarian or even purely radiolarian. These cherts contain the Bajocian-Bathonian radiolarian assemblage (see sample D 670): *Tritrabs* sp., *Archaeospongoprunum? imlayi* Pessagno, *Podobursa* cf. *helvetica* Rust, *Hsuum matsuokai* Isozaki et Matsuda gr., *Canutus?* sp., *Parvicingula?* sp., *P.? boesii* Parona; (sample D670.3), *Eoxitus hungaricus* Kozur, *Tricolocapsa rusti* Tan., *T. yaoi* Matsuoka, *Eucyrtidium elementarius* Carter.

In the upper part of the sequence of the third slab, the "Talyakaurkhyn" member, without any signs of unconformity, is overlain by a basalt-tuffite member composed of greenish-gray and black tuffaceous sandstones and siltstones (sometimes calcareous), tuffites, and fine- to medium-grained basic tuffs interbedded with black cherts. Plant remains and worm tubes have been reported. In these cherts, the following radiolarians were identified by Bragin [18]: *Hsuum maxwelli* Pessagno, *Mirifusus mediodilatatus* Rust., *Zhamoidellum?* sp., and *Tripocyclia blakei* Pessagno, according to which the age was referred to the late Kimmeridgian-early Tithonian. In the sandstones, numerous ammonites were collected by O. P. Dundo *et al.* [18]: *Perisphinctes* sp., *Putealiceras* cf. *Zieteniceras zieteni* (Tsutovitch), *Lunulocera* cf. *lulula* Reinecke, *Choffatia* cf. *cobra* Waagen, and *C.* cf. *leptonota* Spath, unambiguously indicative of the Jurassic age of the host sandstones (Callovian, according to E. D. Kalacheva). At the same time, some plant remains that were also collected in these sandstones, including leaf imprints of the genus *Gleichenia*, indicate either a Middle Jurassic-Cretaceous age for the sandstones (in the opinion of some authors) or a Late Cretaceous age (in the opinion of the others [18]). On the basis of phytological data, A. D. Chekhov [18] assigns these deposits to the Upper

Table 6 Site 14.

Sample number	Radiolarian species	Age: J_1	J_2	J_2^3 cl	J_3 ox	km	tt	bs	K_1 v	h
DN 628-2	*Triactoma echioides* Foreman									
	T. jonesi (Pessagno)									
	Acanthocircus sp. A Pessagno									
	Paronaella mulleri Pessagno									
	Parvicingula khabakovi (Zham.)									
	Parvicingula boesii (Parona)									
	Hsuum aff. *lupheri* Pessagno et Whalen									
	Hsuum cf. *rosebudense* Pessagno et Whalen									
	Zhamoidellum cf. *ovum* Dumitrica									
DN 628	*Mirifusus mediodilatatus* (Rust)									
	M. baileyi Pessagno									
	Parvicingula boesii (Parona)									
	Ristola altissima (Rust)									
	Williriedellum salumicum Kozlova									
DN 628-3	*Sethocapsa? trachyostraca* Foreman									
	Parvicingula boesii (Parona)									
DN 611/7	*Amphimenium* sp.									
	Podobursa helvetica (Rust)									
	Parvicingula khabakovi (Zham.)									
	P. boesii (Parona)									
	Williriedellum salumicum Kozlova									
DN 611/6	*Stichocapsa Petzoldti* Rust									
	Parvicingula ex gr khabakovi (Zham.)									
DN 611/8	*Paranaella mulleri* Pessagno									
	Mirifusus mediodilatatus (Rust)									
	M. mediodilatatus minor Baumgartner									
	Archaeodictyomitra excellens (Tan)									
	A. aplara (Rust)									
	Podobursa triacantha (Fischli)									
	P. polyacantha (Fischli)									
	Parvicingula boesii (Rust)									

Cretaceous. The poor preservation of the flora, however, along with the scarcity of some forms in the finds suggests that we should give preference to the faunal data. Therefore a synthesis of the radiolarian and ammonite data indicate a Callovian–Tithonian age for the discussed essentially tuffaceous part of the sequence.

The jaspers of the "Talyakaurkhyn" sequence can be traced farther northeast on the right bank of the Velikaya River. The thickest strata have remained in the Zavitaya River valley (Sites 19, 20) in a lens emplaced between beds of the tuff-tuffite complex and the Albian-Upper Cretaceous clastic deposits (similar to those developed on Mt. Semiglavaya). They occur as a thin (up to 60 m) layer of red, stratified jasper, in places calcareous, sometimes grading into a pinkish-gray siliceous limestone. In the lower part of the sequence (sample DN 694), a radiolarian assemblage with a Middle-Late Jurassic aspect was discovered in the jasper. It included forms of the genera *Tritrabs, Dictyomitrella, Tricolocapsa, Parahsuum, Hsuum, Parvicingula,* and *Ristola*, indicative of the latest Middle-earliest Late Jurassic. The following species have been identified; *Parvicingula elegans* Pessagno et Whalen, and *Parahsuum magnum* Takemura *et al.* Higher up in the sequence, a typical late Callovian-early Tithonian assemblage was discovered in the jasper (sample S 2799/2), including the following species: *Triactoma echoides* Foreman, *Ristola altissima* (Rust), *Parvicingula dhimenaensis* Baumgarther, *Parvicingula khabakovi* (Zhamoida), *Parvicingula* aff. *vera* Pessagno et Whalen, *Hsuum* cf. *maxwelli* Pessagno, and *Hsuum* cf. *mirabundum* Pessagno et Whalen.

The Chronostratigraphic equivalents of the "Talyakaurkhyn" sequence, consisting of somewhat different facies were identified farther east (on the right bank of the Malyi Nauchirynai River) and in the south (the Pikasvayam River basin).

In the former area (Sites 21, 22, Table 7) a NE-tilted tectonic slab shielding the watershed is composed of greenish-gray siliceous mudstones and siltstones, sometimes tuffstones, and acidic ash tuffs with cherry-red jasper lenses. In two closely located sites (21, 22) of this slab, radiolarians of latest Middle Jurassic age (sample DN 760: *Conocromyomma* sp., *Mirifusus? guadalupensis* Pessagno, and *Parvicingula? boesii* (Parona), *Hsuum* sp.) and Lower Jurassic (sample DN 760/1: *Praeconocaryomma whiteavesi* Carter, *P.? fasciata* Carter, *Spongostaurus pugiunculus* Carter, *Milax? flecsuosus* Blome, *Canoptum* cf. *annulatum* Pessagno et Poisson, *Parvicingula* cf. *blackhornensis* Pessagno et Whalen, *P. burnensis* Pessagno et Whalen, *Hsuum* cf. *mirabundum* Pessagno et Whalen, *Eucyrtidium?* cf. *elementarius* Carter) were extracted from the siliceous mudstones and jaspers. This slab of Lower-Middle Jurassic rocks rests upon a slab of rocks characterized by the essentially arkosic composition of its clastic components, and the presence of ash tuffs and tuffites. Among these rocks a thin jasper layer (Site 21), with a very rich radiolarian assemblage (sample DN 757/6) of late Callovian-early Tithonian age (see Table 7), has been discovered.

In the Pikasvayam River valley, thin, isolated tectonic scales are clamped between the thrust sheets of Albian-Late Cretaceous clastic deposits (Sites 30-33), the composite section of which (30) is given in Fig. 2 and Table 8. Predominant in them are jaspers, gray cherts, and siliceous siltstones, sometimes containing thin MORB-type basalt flows. The total thickness is not less than 250-300 m. In its lower part, the Pliensbachian-early Bathonian radiolarians (sample L 10, L 10/1: *Parvicingula* cf. *inornata* Blome, *Parvicingula? vera* Pessagno et Whalen, *P.? Khabakovi* (Zhamoida), *Droltus* sp.,

Table 7 Site 21, 22.

Sample number	Radiolarian species	Age: T	J_1^1	J_1^2	J_1^3	J_2^1	J_2^2	J_2^3 cl	J_3^1 ox	J_3^2 km	J_3^2 tt	K_1
DN 760	*Conocromyomma* sp.											
	Eoxitus sp.											
	Hsuum sp.											
	Mirifusus? guadalupensis Pessagno											
	Parvicingula? boesii (Parona)											
DN 760/	*Praeconocaryomma whiteavesi* Carter											
	P. fasciata Carter											
	Spongostaurus puguinculus Carter											
	Milax? flexuosus Blome											
	Canoptum cf. *annulatum* Pess. et Poisson											
	Lupherium sp.											
	Parvicingula burnsensis Pessagno et Whalen											
	P. cf. blackhornensis Pessagno et Whalen											
	Hsuum cf. *mirabundum* Pessagno et Whalen											
	H. cf. belliatulum Pessagno et Whalen											
	Eucyrtidium cf. *elementarius* Carter											

Sample number	Radiolarian species	Age: J_2 cl	J_3 ox	J_3 km	J_3 tt	K_1 bs	K_1 v	K_1 h	K_1 br	K_1 ap
DN 757/6	*Triactoma* ex. gr. *echioides* Foreman									
	T. blakei (Pessagno)									
	T. cf. cornuta Baumgartner									
	Tripocyclia cf. *T.* sp. B Carter									
	Pseudocrucella magna Blome									
	P. plana Blome									
	Paronaella pessagnoi Blome									
	P. cf. *venusta* Blome									
	P. worzeli Pessagno									
	Spongosaturnalis protoformis Yao									
	Orbiculiforma cf. multifora Pessagno									
	Spongocapsula perampla (Rust)									
	Bernoullius ? sp.									
	Podobursa helvetica (Rust)									
	Tetracapsa jucunda Rust									
	Napora lospensis Pessagno									
	Ristola altissima (Rust)									
	Mirifusus baileyi Pessagno									
	Mirifusus sp. nov.									
	Suringocapsa pacifica Vishnevskaya									
	Hsuum cf. mirabundum Pessagno et Whalen									
	Hsuum rosebudense Pessagno et Whalen									
	Parvicingula dhimenaensis Baum.									
	Parvicingula elegans Pess.									
	P. sp. aff. *P. burnsensis* Pess.									
	P. cf. vera Pessagno et Whalen									
	P. praecosmoconica (Foreman)									

Table 8 Site 30.

Sample number	Radiolarian species	Age: T	J₁ g	J₁ sm	J₁ pl	J₁ t	J₂	J₃	K₁ bs-v	K₁ h-b
L-10	*Bagotum* sp.									
	Droltus sp.									
	Katroma sp.									
	Triversus sp.									
	Parvicingula s. l.									
	P. cf. *blackhornensis* Pessagno et Whalen									
S 2424/5	*Eusyringium anglisi* Neviani									
	Podobursa helvetica (Rust)									
L-50/1	*Alievium helenae* Schaaf									
	Thanarla conica (Aliev)									
	T. cf. *pulchra* (Squinabol)									
	Podobursa polylophia Foreman									
S-2375/1	*Acaeniotyle diaphorogona* Foreman									
	Alievium helenae Schaaf									
	Mirifusus mediodilatatus (Rust)									
	M. chenodes (Renz)									
	Sethocapsa trachyostraca Foreman									
	Xitus clivosa (Aliev)									
	Thanarla? conica (Aliev)									
	Parvicingula boesii (Parona)									
	P. ananassa (Rust)									

Katroma sp.) have been collected from the siltstone–chert section on the left bank of the Pikasvayam River (30). In its middle part, the Middle–Late Jurassic radiolarian assemblage (sample S 2424/5: *Eusyringium? anglisi* Neviani, *Kafanella?* sp., *Parvicingula? media* Pessagno et Whalen, *P. vera* Pessagno et Whalen, *Podobursa* sp.) has been extracted from the jaspers interbedded with the basalts on the right bank of the Pikasvayam River (Site 32).

An older Middle Jurassic zone is widely developed farther north, in the upper reaches of the Velikaya River. On both sides of its valley, narrow tectonic wedges occur among the Albian Senonian deposits that include tectonic scales of tuffaceous–clastic Jurassic–Neocomian deposits, with inclusions of strongly altered MORB-type tholeiitic basalts and occasional red jasper lenses. In the latter, radiolarians indicative of the late

Bajocian-Callovian age of the host rocks (*Podobursa* cf. *helvetica* (Rust), *Parvicingula sodaensis* Pessagno et Whalen, and *P. matura* Pessagno et Whalen) were identified on the right bank of the Velikaya (sample S 2817/2, Site 13).

Farther east, a Middle Jurassic (Bathonian-Callovian) radiolarian assemblage was also identified on the right bank of the Koiverelan River (Site 18), among Jurassic-Neocomian island-arc-type volcaniclastic deposits in thin (a few tens of meters) sheets composed of jaspers and MORB-type tholeiites (sample DN 592): *Podobursa helvetica* (Rust), *Parvicingula vera* Pessagno et Whalen, and *P.* cf. *blackhornensis* Pessagno et Whalen. Still farther north, radiolarian species characteristic of the Bathonian-early Callovian (*Parvicingula vera* Pessagno et Whalen and *Parvicingula media* Pessagno et Whalen) were identified in a member of interbedded jaspers (sample S 2548/16) and siltstones, deformed by cataclasis, emplaced among the beds of Jurassic-Neocomian and Lower-Upper Cretaceous deposits on the right bank of the Pravyi Talyainyn River.

The western arms of the Rarytkin Ridge in the Pravaya Talyainyn River basin are made up of E-W striking imbricated thrust sheets tilted in a northerly direction, where allochthonous Middle Jurassic-Hauterivian tuffite-jaspers-basalts alternate with para-autochthonous Albian-Upper Cretaceous clastic deposits (Sites 8 and 9). Radiolarians characteristic of the Bathonian-Callovian (*Praeconocargomma immodica* Pessagno et Whalen, *Conosphaera sphaeroconus* (Rust), *Parvicingula elegans* Pessagno et Whalen, *P.* cf. *schoolhousensis* Pessagno et Whalen, *P. blowi* Pessagno, *P. hsui* Pessagno, *Parvicingula boesii* (Parona), *Parvicingula* cf. *vera* Pessago et Whalen, *Parvicingula khabakovi* (Zhamoida), *Parvicingula profunda* Pessagno et Whalen, *Ristola* aff. *turpicula* Pessagno et Whalen, *Archaeodictyomitra apiara* (Rust), and *Hsuum* sp. were identified in a thin red jasper lens (sample N 212/6) in the lower part of a slab composed of a sequence of tholeiite flows. A similar radiolarian assemblage was discovered farther north on the divide between the lower reaches of the Main and Utesiki rivers.

On the left bank of the Utesiki, a group of slabs tilted in an easterly direction is exposed from west to east. Here (see Fig. 2, Site 3) two slabs override the serpentinized ultrabasic rocks. The sequence of the second slab includes jasper intervals (a few tens of centimeters) with an abundant radiolarian fauna (sample DN 37/2; Table 9) indicative of a host-rock age between late Bathonian and Kimmeridgian: *Gorgansium pulchrum* (Kocher), *Higumastra* cf. *inflata* Baumgartner, *Tritrabs* cf. *rhododactylus* Baumgartner, *Triactoma jonesi* (Pessagno), *Parvicingula? dhimenaensis* Baumgartner, *Podobursa helvetica* (Rust). Above are four slabs comprising as follows (upward): serpentinized hyperbasites, island-arc-type tholeiites, tuffites and tuffstones, and stratified red jaspers. Abundant radiolarians were discovered in the jaspers of the upper, thin lenticular slab (sample N-11). On the basis of the chronostratigraphic distribution of the most typical species, the age of the jaspers was identified as late Bathonian-Callovian: *Orbiculiforma multifora* Pessagno, *Triactoma cornuta* Baumgartner, *Podobursa helvetica* (Rust), *Ristola decora* Pessagno et Whalen, *Ristola prisca* Pessagno, *Parvicingula? khabakovi*

Table 9 Site 2.

Sample number	Radiolarian species	Age: J_2 bt	cf	J_3 ox	km	tt	K_1 bs	v	h	b
N-51	*Pantanellium lanceola* (Parona)									
	Acaeniotyle diaphorogona (Foreman)									
	Parvicingula khabakovi (Zhamoida)	?			?					
	Thanarla cf. *pulchra* (Squinabol)									
	Thanarla? elegantissima (Cita)									
	Thanarla broweri (Tan Sin Hok)									
	Stichocapsa cf. *uterculus* (Parona)									
N-11	*Orbiculiforma multifora* Pessagno									
	Triactoma cornuta Baumgartner									
	Podobursa helvetica (Rust)									
	Ristola decora Pessagno et Whalen									
	Ristola prisca Pessagno									
	Parvicingula? khabakovi (Zhamoida)									
	Parvicingula elegans Pessagno et Whalen									
	Parvicingula vera Pessango et Whalen									
	Parvicingula inornata Blome									
	Parvicingula sodaensis Pessango et Whalen									
	Hsuum cf. *obispaensis* Pessagno									
	Milax cf. *alienus* Blome									
	Milax? inflatus Blome									
	Archaeodictyomitra exigua Pessagno									
	Mirifusus mediodilatatus (Rust)									
	Mirifusus guadalupensis Pessagno									
	Napora pyramidalis Baumgartner									
DN-37/2	*Gorgansium pulchrum* (Kocher)									
	Higumastra? cf. *inflata* Baumgartner									
	Tritrabs cf. *rhododactylus* Baumgartner									
	Triactoma jonesi (Pessagno)									
	Hsuum cf. *obispaensis* Pessagno									
	Parvicingula? dhimenaensis Baumgartner									
	Podobursa helvetica (Rust)									

(Zhamoida), *Parvicingula elegans* Pessagno et Whalen, *Parvicingula vera* Pessagno et Whalen, *Parvicingula inornata*, *Hsuum* cf. *obispaensis* Pessagno, *Mirifusus mediodilatatus* (Rust), *Mirifusus guadalupensis* Pessagno, *Napora pyramidalis* Baumgartner, *Milax* cf. *alienus* Blome, *Milax? inflatus* Blome, and *Archaeodictyomitra exigua* Pessagno. Blocks of island-arc basalts and the associated jaspers were also encountered in an area farther north on the left side of the Utesiki River basin, in the Perevalnaya River valley (Site 1).

Here a late Bathonian–Callovian assemblage was discovered in the jaspers (sample S 2966/5), similar in taxonomic composition to the one described in Site N-II.

The Middle Jurassic radiolarians are equally widespread in the eastern and south-eastern sectors of the studied region. In the Nauchirynai River valley, a tuffaceous–clastic sequence, with occasional thin tectonic inclusions of jasper, has been encountered. Within the latter (see Fig. 2, Site 24), at two different levels (samples D 804, DN 946), the radiolarians (Table 10) indicative of the Bajocian–Bathonian of the Pacific region (*Parvicingula matura* Pessagno et Whalen, *P. elegans* Pessagno et Whalen, *P. vera* Pessagno et Whalen, *Hsuum hisuikyoense* Izotari et Matsuda, *Parvicingula* cf. *inornata* Blome) and the earliest Late Jurassic have been identified (sample DN 948/1). The latter include species known both in the Pacific and the Mediterranean province: *Parvicingula elegans* Pessagno et Whalen, *Pseudodictyomitra primitiva* Matsuoka et Yao, *Archaeodictyomitra apiara* (Rust), *Hsuum directipora* (Rust), *Eucyrtidium ptychtum, Bernoullius diceros, Andromeda* sp. On the left bank of the Nauchirynay River (Site 23) a Bajocian?–Bathonian–early Callovian assemblage (sample L 234/1) was discovered in the same geologic setting, including *Parvicingula elegans* Pessagno et Whalen, *P. khabakovi* (Zhamoida), *P. vera* Pessagno et Whalen, and *Hsuum rosebudense* Pessagno et Whalen.

It should be emphasized that previously [17], the evidence of the tectonic (thrust-faulted) boundaries of the jasper–basalt and jasper members in the Nauchirynai River basin were not taken into account, and that these strata were regarded jointly with the tuffs and tuffites as a single continuous stratigraphic sequence. At the same time, these two types of sediments differ widely even in terms of their depositional environment: the radiolarian assemblages found in the jasper–basalt sequence are characteristic of a deep, open-marine basin, whereas the tuff–tuffite sequence is typical of an island arc and undoubtedly shallow-marine or probably subaqueous, with a high proportion of coarse- and medium-grained pyroclastic material.

An extremely complex combination of tectonic lenses, additionally complicated by a system of parallel shears, is located farther south in the valleys of the Volchok and Mezhgornaya Rivers, on the left bank of the Nauchirynai River (Site 25). They exhibit alternating layers of ultrabasites, two types of jasper–basalt sequences (with MORB-type tholeiites and WPB-type basalts), island-arc tholeiites, and boninites. It was found that the jaspers associated with the MORB-type basalts and enriched in the distal ash material also contain abundant high, conical *Parvicingula* (sample DN 915).

The jaspers associated with the WPB-type basalts are scarcer in the study area. They comprise relatively small fragments of tectonic slabs on the right bank of the Yagelnyi Creek, on the left bank of the Virtuoz Creek, and in some other localities in the area between the Malyi Nauchirynai and Nauchirynai rivers, including the Volchok and Mezhgornaya River basins, where the jasper–basalt succession has thrusted contacts with the hyperbasites and gabbro or with the JAT and MORB-type basalts. Predominant among the basalts are ferriferous and titaniferous intra-plate basalts usually typical of oceanic

Table 10 Site 24.

Sample number	Radiolarian species	Age								
		J_2	J_2^3	J_3			K_1			
			cl	ox	km	tt	bs	v	h	b
DN 948/1	*Parvicingula elegans* Pessagno et Whalen									
	Pseudodictyomitra primitiva Matsuoka et Yao									
	Archaeodictyomitra apiara (Rust)									
	Hsuum directipora (Rust)									
	Eucyrtidium ptychium Riedel et Santilippo									
	Bernoullius diceros Baumgartner									
	Andromeda sp.									
DN 946 DN 804	*Histiastrum* cf. *amurense* Zhamoida									
	Parvicingula matura Pessago et Whalen									
	Parvicingula cf. *inornata* Blome									
	Parvicingula vera Pessagno et Whalen									
	Hsuum hisuikyoense Isozaki et Matsuda									
D 837/1 D 815	*Acanthocircus dicranacanthos* (Squinabol)									
	Archaeodictyomitra apiara (Rust)									
	Archaeodictyomitra excellens (Tan)									
	Pseudodictyomitra cosmoconica Foreman									
	Parvicingula ex.gr. *boesii* (Parona)				?					
	Mirifusus mediodilatatus (Rust)									
	Thanarla pulchra (Squinabol)									
	Williriedellum ? *salumicum* Kozlova									

islands, and their thicknesses reach 100–150 m. The jasper lenses inside them are relatively numerous but thin (a few meters to a few tens of meters). On the left bank of the Virtuoz Creek (Site 26) a slab of serpentinized ultrabasites is overridden by a sheet made up of titaniferous and ferriferous basalts with lenses of jasper, also carrying abundant high conical Bathonian parvicingulides (sample DN 1047), concentrations of which are typical of upwelling zones: *Parvicingula inornata* Blome, *P. ex. gr. khabakovi* (Zhamoida), *P.* cf. *burnsensis* Pessagno et Whalen.

To summarize, whereas the age of the jasper-basalt sequence discussed was previously assumed as being generally Late Jurassic-Neocomian, the base of this sequence, according to the radiolarian assemblages from our collection, is dated as Middle Jurassic; and it is not inconceivable that its accumulation began by the end of the Early Jurassic and was completed by Valanginian-Hauterivian times.

The Late Jurassic radiolarians are the most widespread in the Koryak-Anadyr Region. In addition to the above-described Late Jurassic radiolarians from the sites of Mt. Semiglavaya and the basins of the Talyakaurkhyn and Malyi Nauchirynai rivers; their localities are to be found in the river basins of the Main (the tributaries, Algan and Konachan), Lamutskaya, Talyainyn, and Velikaya (the tributaries, Koiverelan, Tamvatnei, and Nauchirynai) and also in the extreme south of the region, in the Pikasvayam River basin.

Late Callovian–middle Tithonian radiolarians (*Mirifusus guadalupensis* Pessagno, *M. mediodilatatus* (Rust), and *M. ovatoidea* (Zhamoida), were discovered in the jaspers (sample DN 435) among tholeiites on the left bank of the Poperechnyi Algan River (Site 5).

Farther southeast, numerous Callovian–early Tithonian radiolarians (*Archaeospongoprunum imlayi* Pessagno, *Tripocyclia trigonum* Rust, *Bernoullius cristatus* Baumgartner, *Podobursa helvetica* (Rust), *Podobursa polyacantha* (Fischli), *Mirifusus mediodilatatus baileyi* Pessagno, and *Hsuum ex gr. maxwelli* Pessagno were discovered in similar jaspers (samples D 512/1,2) on the left bank of the Lamutskaya River (Site 6).

In the northernmost belt of concentrated tectonic lenses of Jurassic–Neocomian deposits located in the area between the Pravyi Talyainyn and the Kepetchaktyl River (Site 7), a sequence of interbedded jasper, red siliceous siltstone, and greenish-gray tuffaceous siltstone and tuffstone members, transformed by boudinage into thin lenses, is exposed beneath slabs of thick MORB-type tholeiites with spheroidal weathering and ropy texture on the banks of the Kepetchaktyl River tributaries. These rocks occur between the thicker beds of the Lower–Upper Cretaceous flyschoid sequence. The following radiolarians, most probably indicating a Kimmeridgian–early Tithonian age, were discovered within the belt in one of the southernmost beds of red jaspoid siliceous siltstones with a thickness of a few tens of meters (sample S 2548/4a): *Parvicingula boesii* (Parona), *Parvicingula* cf. *procera* Pessagno, *Ristola* sp. cf. *altissima* (Rust), and *Hsuum cuestaensis* Pessagno.

In the jaspers of one of the beds in the area between the Pravyi Talyainyn–Yasnyi Creek, a contemporaneous radiolarian assemblage was identified, including the following species: *Archaeospongoprunum imlayi* Pessagno, *Acanthocircus dicranacanthos* (Squinabol), *Parvicingula hsui* Pessagno, *Spongocapsula palmerae* Pessagno, and *Hsuum maxwelli* Pessagno. In the Pravyi Talyainyn River basin (Sites 8 and 9) a series of lenses is overlain by a slab consisting of interbedded red jaspers, black siltstones, and greenish-black tuffstones. The following radiolarians (sample N 212/15) of Kimmeridgian–early Tithonian age were identified in jaspers from the lower part of this slab (see Fig. 4): *Chitonastrum tricuspidatum* Rust, *Pantanellium* cf. *fischeri* Pessagno, *Andromeda* sp., *Mirifusus* cf. *fragilis* Baumgartner, *P. boesii* (Parona), *P. procera* Pessagno, *Podobursa helvetica* (Rust), *Dibolachras* aff. *chandrica* Kocher, *Hsuum? cuestaensis* Pessagno, and *H. obispaensis* Pessagno. This series of tectonic sheets is overlain by horizontally bedded Paleogene ignimbrites of the Krasnenskaya Formation, interpreted as neo-autochthonous.

A Kimmeridgian–Tithonian radiolarian assemblage was also met in a tectonic block of jaspers in the area between the Koiverelan and Malyi Nauchirynai rivers (sample S-2802): *Podobursa* cf. *helvetica* (Rust), *Marifusus?* sp., *Parvicingula* cf. *elegans* Pessagno et Whalen, *P.* cf. *vera* Pessagno et Whalen, *P.* ex gr. *khabakovi* (Zhamoida).

Two richer Oxfordian–early Tithonian radiolarian localities (Sites 18, 19) were discovered immediately to the south of this outcrop (see samples S-2799/1 and S-2799).

In the extreme south of the territory, the following Late Jurassic radiolarians were identified in the upper reaches of the left tributaries of the Pikasvayam River: *Eusyringium anglisi* Neviani and *Parvicingula* cf. *elegans* Pessagno et Whalen.

In the sequence of Mt. Semiglavaya, previously described in [5], the upper fourth slab (overridden by a slab of Albian–Senonian clastic deposits) wholly consists of a single sequence, in this case characterized by a predominantly jasper composition with thin lenses of calcareous jaspers and siliceous limestones; the total thickness of this fragment of the sequence is not more than 60–80 m. The sequence consists of three members. The lower (20 m thick) member is composed of stratified red, brownish-gray, and sometimes green radiolarian jaspers with a late Callovian–Kimmeridgian radolarian assemblage (see Table 6, sample DN-628-2): *Triactoma echoides* Foreman, *T. jonesi* Pessagno, *Acanthocyrcus* sp. A., *Paronaella mulleri* Pessagno, *Parvicingula khabakovi* (Zhamoida), *Parvicingula boesii* (Parona), *Hsuum* aff. *lupheri* Pessagno et Whalen, *Hsuum* cf. *rosebudense* Pessagno et Whalen, *Zhamoidellum* cf. *ovum* Dumitrica. In the middle part of the slab (30 m), ferruginous microstratified jaspers are interbedded with red and pink calcareous jaspers and cherts, sometimes with a considerable carbonate admixture and even with gray and pink-gray siliceous limestones at the top of the member. In the basal jaspers of the middle member (samples DN 622, 628), a Tithonian–Berriasian radiolarian assemblage has been identified: *Triactoma* cf. *blakei* Pessagno, *Spongosaturnalis suboblongus* Yao, *Pantanellium lanceola* (Parona), *Mirifusus* cf. *hanni* (Tan), *Podobursa triacantha* (Fischli), *Parvicingula citae* Pessagno, *P. khabakovi* (Zhamoida), *P.* cf. *inornata* Blome, *P.* cf. *cosmoconica* (Foreman), *P. boesii* (Parona), *Ristola? altissima* (Rust), *Archaeodictyomitra apiara* (Rust), *A. exellens* (Tan), *Zhamoidellum ventricosum* Dumitrica, *Bernullius* sp., *Mirifusus mediodilatatus* (Rust), *M. baileyi* Pessagno, and *Williriedellum? salumicum* Kozlova. An age-equivalent radiolarian assemblage was discovered in the black, microstratified cherts (sample DN 611/8) from the top of the middle member: *Paronaella mulleri* Pessagno, *Mirifusus mediodilatatus* (Rust), *M. mediolatatus minor* Baumgartner, *Archaeodictyomitra excellens* (Tan), *A. apiara* (Rust), *Podobursa triacantha* (Fischli), *P. polyacantha* (Fischli), and *Parvicingula boesii* (Parona). In the upper part of the slab, composed of jaspers with lenses of calcareous jaspers, Valanginian buchias have been collected from the latter: *Buchia* cf. *inflata* (Toula) and *B.* cf. *sibirica* Zakharov [18]. In the siliceous limestones (up to 40 m thick) from this part of the sequence (samples DN 611-7, 611-6), Tithonian–Berriasian–Valanginian radiolarians have been identified: *Amphimenium lanceolatum* (Rust), *Podobursa helvetica* (Rust), *Parvicingula khabakovi* (Zhamoida), *P. boesii* (parona), *Williriedellum salumicum* Kozlova, and *Stichocapsa petzoldti* Rust. At the very top of this slab (sample DN 628-3), the species *Sethocapsa trachyostraca* Foreman and *Parvicingula boesii* (Parona), which flourished during the late Valanginian–Hauterivian, was discovered. To summarize, beds from the late Callovian to the Hauterivian inclusive have been characterized by the radiolarians within a single slab in the Mt. Semiglavaya sequence.

Jaspers in the facies characteristic of the Mt. Semiglavaya sequence (the Koiverelan-Zavitaya River basins) were also encountered in the northeastern Talaya-Main zone. There, a thin (a few meters thick) tectonic sheet made up of red jaspers grading into pink calcareous jaspers, is sandwiched between island-arc tholeiites and MORB-type tholeiites in a rock terrace of the Pravyi Konachan (Site 4). In these rocks, we identified a Berriasian-middle Valanginian radiolarian assemblage (sample S-2646-2V): *Acaeniotyle diaphorogona* Foreman, *Pantanellium lanceola* (Parona), *P. riedeli* Pessagno, *Acanthocircus dicranacanthos* (Squinabol), *A. trizonalis* (Rust), *Mirifusus mediodilatatus* (Rust), *Archaeodictyomitra apiara* (Rust), *Parvicingula ananassa* (Rust), *Parvicingula blowi* Pessagno, *P. khabakovi* (Zhamoida), *Sethocapsa cetia* Foreman, *Williriedelum salumicum* Kozlova, *Podobursa triacantha* (Fischli), *Podobursa polylophia* Foreman, and *Dibolachoras tytthopora* Foreman. In the same sample as the radiolarians, numerous buchias were discovered (first identified by V. A. Zakharov), assigned by K. V. Paraketsov to the early-middle Valanginian.

A tectonic lens of jaspers containing the Neocomian radiolarians (sample N 51, see Table 9: *Pantanellum lanceola* (Parona), *Acaeniotyle diaphorogona* (Foreman), *Parvicingula khabakovi* (Zhamoida), *Thanarla* cf. *pulchra* (Squinabol), *Thanarla? elegantissima* (Cita), *Thanarla broweri* (Tan Sin Hok), *Stichocapsa* cf. *uterculus* Parona), sandwiched between slabs of tuff-tuffite sequences, was also encountered on the left bank of the Utesiki River (3) immediately south of the site of the above-mentioned lens.

In the area between the Poperechnyi Algan and Lamutskaya rivers, several small tectonic lenses composed of red and sometimes green stratified jaspers (interbedded with gray siliceous siltstones) and greenish-black MORB-type diabase flows are located. The apparent thickness of these formations reaches 80-120 m. In one of the tectonic lenses jaspers with the late Tithonian-Berriasian radiolarians (*Alievium helenae* (Schaaf), *Syringocapsa lucifer* Baumgartner, *Xitus alievi* (Foreman), *Archaeodictyomitra apiara* (Rust), and *Padocapsa amphitreptera* (Foreman) were identified immediately above the jaspers containing the late Callovian-middle Tithonian radiolarians. In the area between the Pravyi Talyainyn River and the Yasnyi Creek, a series of sheets composed of stratified red jasper members with thick (up to 500 m) groups of basalt flows with jasper lenses sandwiched between them is exposed. The upper lenses are composed of alternating gray cherts, siliceous siltstones, greenish-gray acidic ash tuffs, occasional thin basalt flows, and red jaspers with scarce small (up to 0.5 m long) limestone lenses and nodules. A late Tithonian-Valanginian (sample N 223) radiolarian assemblage was identified in the jaspers from two thrust-bounded scales: *Emiluvia orea* Baumgartner, *Pantanellium lanceola* (Parona), *Parvicingula ananassa* (Rust), *Archaeodictiomitra apiara* (Rust), and *Mirifusus mediodilatatus minor* Baumgartner. In the more easterly outcrops of this locality, late Valanginian buchias were identified by G. P. Terekhova in calcareous jaspers and siliceous limestones. In the upper lens, Terekhova and her colleagues discovered fragments presumed to be the Hauterivian *Inoceramus colonicus* (identified by V. P.

Pokhialainen).

The narrow, fault-bounded N-S-trending outcrops of this sequence extend farther east, on the western slope and the crest of the Rarytkin Range. They also exhibit alternating jaspers, acid and basic tuffs and tuffites, and sometimes cherts and basalts. In the jaspers of one of these outcrops in the area between the Pravyi Talyainyn and Pravyi Talyain (Site 12), a Valanginian radiolarian assemblage has been identified (sample N 302/3): i.e. *Pantanellium lanceola* (Parona), *Acaeniotyle diaphorogona* Foreman *sensu lato, Parvicingula khabakovi* (Zhamoida), and *Parvicingula boesii* (Parona).

Among the Albian-Upper Cretaceous deposits in the Talyainyn River basin, a series of tectonic slabs was discovered. The upper slab is composed of red stratified jaspers (with subordinate gray chert interbeds) alternating with gray siliceous siltstones. In the middle of the slab (Sites 8, 9; sample N 212/12a) the late Tithonian-Berriasian and probably the earliest Valanginian radiolarians have been identified (see Fig. 3): *Alievium helenae* Schaaf, *Emiluvia sedecimporata elegans* (Wishniowski), *Ditrabs? sansalvadorensis* Pessagno, *Pantanellium* cf. *berriasianum* Baumgartner, *Podobursa* cf. *polylophia* Foreman, *Sethocapsa cetia* Foreman, *Stichocapsa conosphaeroides* Rust, *Archaeodictyomitra apiara* (Rust), *Parvicingula cosmoconica* foreman, *X. praespineus* sp. nov., *X. clivosa* (Aliev), *Crolanium praecuniatum* sp. nov., and *Hsuum* sp. In the upper part of the slab (sample N 212/12b), late Berriasian-middle Valanginian radiolarians have been identified: *Stichocapsa conosphaeroides* Rust, *Mirifusus mediodilatatus* (Rust), and *Pseudodictyomitra carpatica* Lozinyak.

On the right bank of the Pravyi Talyainyn River (Sites 8, 9), a steep northward-tilted 30-70 m-thick slab was discovered, which has a fault contact to the south with Albian-Upper Cretaceous deposits. This slab is most extensively exposed at the mouth of the Yasnyi Creek. Its lower part is composed of a member (of apparent thickness, 12-15 m) of red, stratified jaspers, in which G. P. Terekhova, V. B. Shmakin, and their colleagues (1985) collected, and N. Yu. Bragin identified some Berriasian-Hauterivian radiolarians: *Ristola boesii* (Parona), *Archaeodictyomitra apiara* (Rust), *Pseudodictyomitra carpatica* (Lozinyak), and *Parvicingula* sp. These jaspers are overlain by a 20 m-thick member of red jaspers with a Valanginian-Hauterivian (see Fig. 3) radiolarian assemblage (sample 212/1); *Emiluvia? orea* Baumgartner, *Cecrops? septemporatus* (Parona), *Archaeodictyomitra apiara* (Rust), *Xitus alievi* (Foreman), *X. spicularius* (Aliev), *Parvicingula boesii* (Parona), *P. ananassa* (Rust), *P.* aff. *hsui* Pessagno, *P. cosmoconica* (Foreman), *Mirifusus* cf. *chenodes* (Renz), *Thanarla pulchra* (Squinabol), *Sethocapsa uterculus* (Parona), *Podobursa* cf. *polylophia* (Foreman), *P.* cf. *triacantha* (Fischli), and *Pseudodictyomitra depressa* Baumgartner, *P. leptoconica* (Foreman).

South of the study area, radiolarians characteristic of the late Berriasian-early Valanginian of the Tethys were identified in jasper lenses in MORB-type tholeiites that form a tectonic slab in the Nauchirynai River basin (sample DN 873/1): *Triactoma jonesi* Pessagno, *Saturnalis dicranacanthos* (Squinabol), *Podobursa triacantha* (Fischli),

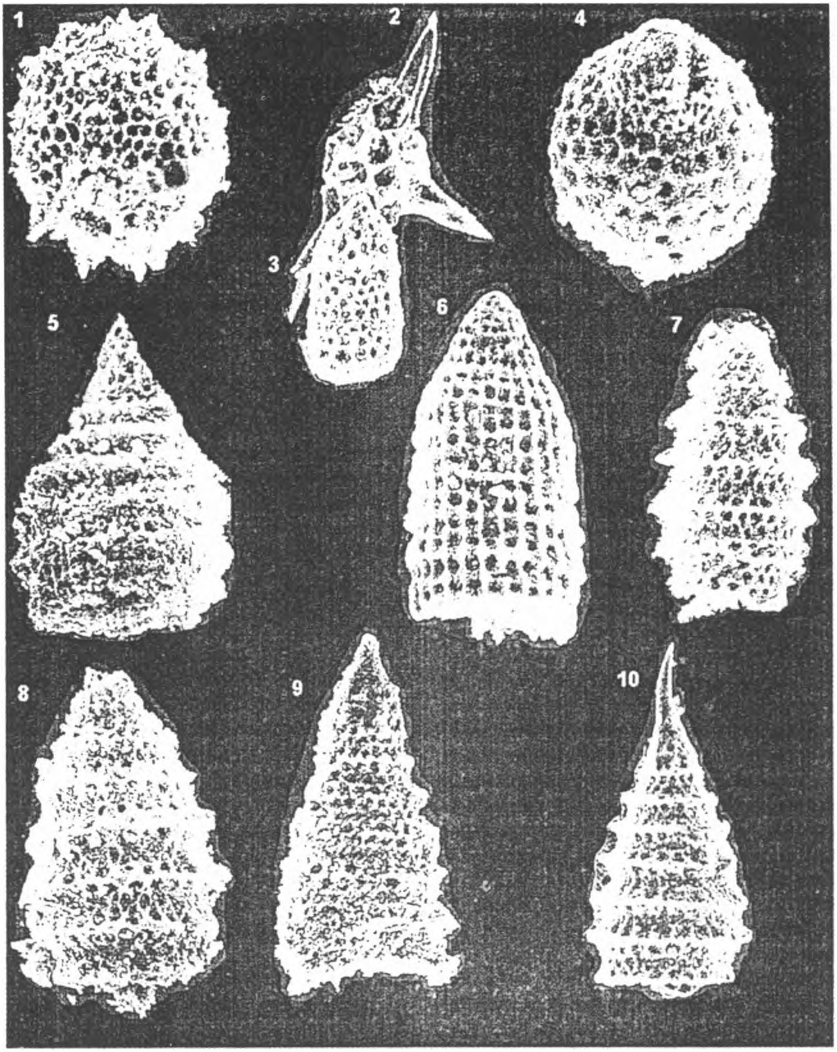

Figure 3 Bathonian-early Callovian and late Valanginian–Hauterivian radiolarians of the Koryak Range (1, 4, 6, 8, and 9 – sample N-212-12a, Hauterivian; 2, 3, and 5 – sample N-212-1a, Valanginian; 10 – sample 212-b, Bathonian, Callovian, the Talyainyn River system): 1 – *Spumellaria gen.* et.*sp.indet*; 2 – *Cecrops septemporatus* (Parona); 3, 6 – *Archaeodictyomitra apiara* (Rust); 4 – *Williriedellum* sp.; 5 – *Parvicingula ? ananassa* (Rust); 7, 8 – *Parvicingula* ex.gr. *boesii* (Parona); 9 – *Parvicingula* cr. *elegans* Pessagno et Whalen; 10 – *Parvicingula khabakovi Zhamoida*.

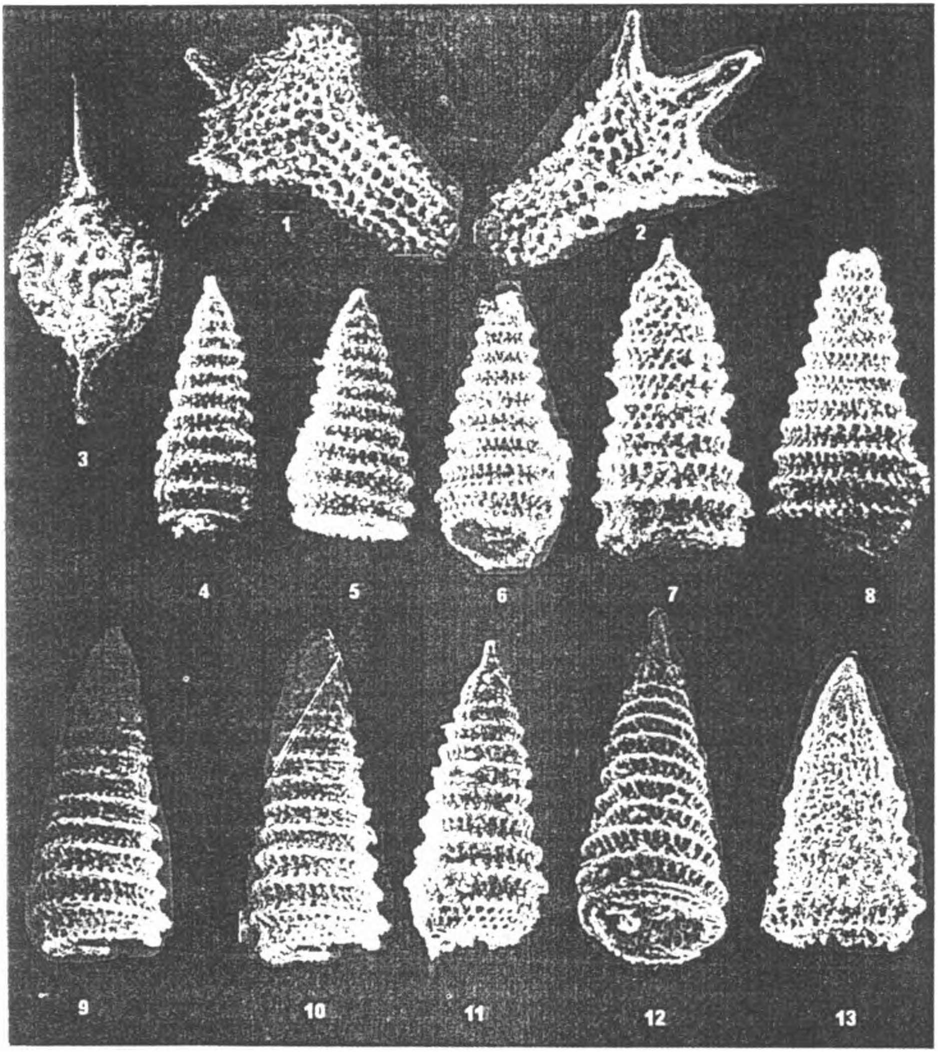

Figure 4 Kimmeridgian?-Tithonian radiolarians of the Koryak Range (the Talyainyn River system, Sample N-212-15a): 1, 2 – *Chitonastrum tricuspidatum* (Rust); 3 – *Pantanellium* sp.; 4–12 – *Parvicingula khabakovi* Zhamoida gr.; 13 – *Parvicingula* sp.

Eucyrtidium ptyctum Riedel et Sanfilippo, *Thanarla pulchra* (Squinabol), *Archaeodictyomitra apiara* (Rust), *A. excellens* (Tan Sin Hok), *Pseudodictyomitra cosmoconica* (Foreman), *Williriedellum? salumicum* Kozlova.

Higher up in the sequence the late Berriasian–Valanginian radiolarian assemblage was discovered in the jaspers (sample L 278): *Acanthocircus dicranacanthos* (Squinabol), *Parvicingula ananassa* (Rust), *Stichocapsa trachyostraca* Foreman, *Podobursa polylophia* Foreman, and *Mirifusus* cf. *baileyi* Pessagno.

It follows that the tectonically deformed jasper–basalt (MORB-type) complex developed in the Nauchirynai River valley is Berriasian–Valanginian in age.

The Tithonian–Neocomian radiolarian assemblages were also discovered in the southernmost sector of the region, in the Pikasvayam River basin [1].

A late Tithonian–early Valanginian radiolarian assemblage was identified on the left bank of the Pikasvayam River outflows (sample S-2415/2). It includes the following species: *Conosphaera sphaeroconus* Rust, *Sethocapsa* cf. *trachyostraca* Foreman, *Parvicingula boesii* (Parona), and *P.* cf. *cosmoconica* (Foreman). The Valanginian–Hauterivian radiolarian assemblage from the left bank of the upper reaches of the Pikasvayam River (sample S-2375/4) is represented by the following species: *Acaeniotyle* cf. *diaphorogona* Foreman, *Alievium ex. gr. helenae* Schaaf., *Mirifusus mediodilatatus* (Rust), *M. chenodes* (Renz), *Sethocapsa trachyostraca* Foreman, *S.? uterculus* (Parona), *Xitus clivosa* (Aliev), *X. alievi* (Foreman), *Thanarla conica* Aliev, *Parvicingula boesii* (Parona), *P. ananassa* Rust, *Podobursa polylophia* Foreman. On the right bank (sample L-50/1), *A. ex.gr. helenae* Schaaf, *Thanarla? conica* Aliev, and *T.* cf. *pulchra* Squinabol were identified.

CONCLUSION

When summarizing the above chronostratigraphic subdivision of the Middle Mesozoic deposits it should be emphasized that it is based on the evolutionary changes of the radiolarian assemblages. The chronostratigraphic intervals were recognized with regard to the date of simultaneous appearance or extinction of a specific assemblage or the characteristic index species. This principle of radiolarian dating is the most widely accepted world-wide [2], [13], [20], [24]. The boundaries are defined by the change of radiolarian assemblages or the first or, accordingly, the last frequent occurrence of index species in the assemblage, i.e. according to the abrupt increase or decrease in the abundance of index species forms.

The Middle–Late Triassic (Anisian–early Carnian)

This is recognized on the basis of the characteristic radiolarian assemblage: *Archaeo-*

spongoprunum helicatum, A. tenue, A. japonicum, A. compactum, Eptingium manfredi, Pentactionocarpus? tetracanthus, Staurodorax dercourti, Pantanellium silberlingi, Caphodoce sarisa, Triassocampe deweveri, Yeharaia annulata, Y. japonica, Y. elegans, Xiphoteca sp., unambiguously indicative of a Middle–Late Triassic age.

The lower Middle Triassic (Anisian) boundary is defined by the appearance of *Archaeospongoprunum compactum* along with *A. japonicum, Eptingium manfredi.* The upper Late Triassic (early Carnian) boundary is identified according to the disappearance of *Archaeospongoprunum japonicum* and the appearance of the initial species of the subfamilies Pantanellinae and Capnodocinae. The recognized chronostratigraphic interval is associated with the acme zone of *Triassocampe deweveri, Yeharaia annulata, Y. japonica, Y. elegans.* This interval probably corresponds with the *Triassocampe diordinis, T. dewever, Sarla dispiralis* Ladinian–Carnian zones, suggested by Bragin for the Triassic in Sikhote Alin and Sakhalin [2].

The rocks bearing the radiolarians are gray cherts, sometimes variegated cherts and dark-brown jaspers interbedded with dark to black siliceous mudstones (each 1–5 cm thick), and sometimes gray-green tuffaceous siliciliths (10–15 cm thick, sometimes up to 0.5 m each). Maximum thickness of the outcrops is 60–100 m.

The Koryak Range (the upper reaches of the Pikasvayam and Khatyrka rivers). The characteristic species of this interval are known from the Sikhote Alin, Sakhalin, Japan, North America, Italy, and Romania.

The Late Triassic (late Carnian–middle Norian)

This was recognized by Bragin [17] in a tectonic block on the left bank of the Chirynai River near the mouth of the Elgevayam River, on the basis of the following radiolarians: *Saitoum keki, Paleosaturnalis* sp., *Pantanellium? inornatum, Canoptum* cf. *rugosum, C. merum, Bipedis* sp., *Parvicingula? grantensis, Katroma* cf. *triangularis, K. neagui, Parahsuum simplum, Multimonilis* sp. B. Yeh. The lower (Hettangian) boundary is defined by the appearance of *Parahsuum simplum, Multimonilis* sp. B. Yeh, the complete absence of the genera *Triassocampe* and *Yeharalia.* The upper (Sinemurian–Pliensbachian) boundary is defined according to the first appearance of the family Parvicingulidae and the extinction of the genera *Paleosaturnalis* and *Multimonilis.* This chronostratigraphic interval is associated with the acme of *Parahsuum simplum, Saitom keki,* and the genus *Bipedis.* The chronostratigraphic interval with *P. simplum* is recognized for the first time within the Koryak Range. In Japan it corresponds with the Hettangian–Sinemurian.

The characteristic species of this radiolarian assemblage are known from the Sikhote Alin, South Sakhalin, Japan, China, North America, and the Mediterranean–Alpine province.

Early–Middle Jurassic (Pliensbachian–Aalenian, probably including the earliest Bajocian)

The age of this interval is identified according to the characteristic radiolarian assemblage, including *Praeconocaryomma whiteavesi, P. fasciata, Turanta ancoriformis, Zartus dickinsoni, Spongostaurus puguinculus, Canoptum anulatum, Laxotorum jurassicum, Eucyrtidium* cf. *elementarius, Bagotum* cf. *erraticum, Lupherium* sp., and *Katroma* sp. The lower part (Pliensbachian, possibly including the latest Sinemurian) is defined by the first appearance of the genera *Turanta, Zartus, Laxtorum*; the upper (Aalenian?–early Bajocian), by the extinction of *Canoptum anulatum* and the genera *Katroma, Lupherium.* Considering the presence of the characteristic index species, *Laxtorum jurassicum*, this chronostratigraphic interval correlates with the Japanese *Laxtorum jurassicum* zone (Toarcian–early Bajocian [23]). The chronostratigraphic interval with *Laxtorum jurassicum* is for the first time identified in the Koryak Range. It corresponds with the lower part of the beds with *Pantanellium foveatum–Bagotum maudense* [3].

The characteristic species of this radiolarian assemblage are known from Japan, North America, and the Mediterranean province.

Middle Jurassic (late Bajocian–early Bathonian)

The most characteristic radiolarian species of this interval are as follows: *Pantanellium buntodense, P.* cf. *riedeli, Bagotum* cf. *pseudoerraticum, B. maudense, B.? modestum, Canutus blomei, Eoxitus hungaricum, Triversus japonicum, T. kasinzovae, T. strobilatus, Hsuum lupheri, H. mirabundum, H.* cf. *inexploratum, Parvicingula burnsensis, P.* cf. *blackhornensis, P. media, P. matura, P.* cf. *inornata, Tricolocapsa yaoi, Mita* sp. A. Carter, *Eucyrtidium elementaris, Droltus* sp., *Archicapsa* sp. cf. *A. pachiderma, Stichocapsa* aff. *robusta.* The lower (late Bajocian) boundary is defined by the first appearance of numerous species of the families Amphipyndacidae and Hsuidae and the mass appearance of members of the families Parvicingulidae and Bagotidae; the upper (early Bathonian), by the disappearance of the genera *Bagotum* and *Canutus.* This chronostratigraphic interval corresponds with the top of the beds containing *Pantanellium foveatum–Bagotum naudense*, previously suggested for the siliceous strata of the Pacific region of the USSR [3]. The chronostratigraphic interval with *Bagotum maudense* is recognized for the first time. For the radiolarian assemblage, this interval correlates with the Japanese *Unuma echinatus* Yao Zone [23].

The characteristic species of this interval are known in Japan, New Zealand, North America, Hungary, and the Lesser Caucasus.

Middle Jurassic (late Bathonian-(?early) Callovian)

The age is identified by the following radiolarian assemblage: *Gorgansium pulchrum, Praeconocaryoma hexacubica, Emiluvia* cf. *salensis, Higumastra inflata, Tritrabs rhododactylus, Triactoma* cf. *jonesi, Archaeodictyomitra exigua, Ristola decora, R. prisca, R. turpicula, Parvicingula blackhornensis, P. burnsensis, P.* cf. *vera, P. inornata, Podobursa helvetica, Hsuum mirabundum, H. rosebudense, Milax inflatus, M.* aff. *fluduosus, M.* cf. *abiensis, Napora pyramidalis, N. deweveri, Elodium* sp. The lower (late Bathonian) boundary is defined by the first appearance of the index species *Rustola turpicula*, along with *Podobursa helvetica, Napora pyramidalis, Parvicingula vera*; the upper (Callovian), by disappearance of the genera *Tritrabs, Milax, Elodium* and the mass appearance of the genus *Mirifusus* above this boundary. The interval with *Ristola turpicula* corresponds with the base of the beds containing *Parvicingula vera*, previously recognized from the Northeast of the USSR [3]. The characteristic species are well known in the Pacific region and the Mediterranean-Alpine province.

Late Jurassic (late Callovian?-Oxfordian-middle Tithonian)

This interval is notable for its exceptionally high taxonomic variety, and is recognized on the basis of its characteristic radiolarian assemblage, including the following species: *Archaeospongoprunum imalayi, Pantanellium fischeri, Triactoma jonesi, T. blackei, T. echiodes, T. cornuta, T. tithonianum, T. trigonum, Orbiculiforma multifora, Spongosaturnalis protoformis, S. suboblongus, Garganskium pulchrum, Emiluvia premyogii, E. orea, Pseudocrusella magna, P. plana, Paronaella mulleri, P. pessagnoi, P. venusta, P. worzeli, P. ewingi, P. exotica, Andromeda crassa, Archaeodictyomitra apiara, Bernoullis cristatus, Dibolachras chandrica, Hsuumcuestaensis, H. obispaensis, H. mirabundum, Napora lospensis, Mirifusus hanni, M. baileyi, M. fragilis, M. guadalupensis, Ristola altissima, R. jonesi, R. procera, Parvicingula elegans, P. khabakov, P. vera, P. beisii, P. dhimenaensis, P. blowi, P. hsui, Podobursa helvetica, P. spinosa, Thanarla pulchra, T.* cf. *broweri, Songocapsula palmerae, S. perampla, Syringocapsa lucifer, Sethocapsa? cetia, Zhamoidellum ventricosum, Z. ovum.* The lower boundary (late Callovian?-Oxfordian) is defined by the first appearance of the index species *Ristola altissima* and the acme of the genus *Mirifusus*. The upper boundary (Tithonian) is defined by the extinction of the genera *Hsuum, Gargansium,* and the last appearance of the index species *Ristola altissima*. The interval *Mirifusus fragilis-M. guadalupensis-Ristola altissima* corresponds with the middle-upper part of the previously recognized radiolarian beds containing *Parvicingula vera* [3]. The characteristic species of this interval are well known from North America, Japan, and the Mediterranean-Alpine province.

Late Jurassic–Early Cretaceous (late Tithonian–Berriasian)

The late Tithonian–Berriasian radiolarian assemblage includes as follows: *Acanthocircus dicranacanthos, Chitonastrum tricuspidatum, Ditrabs sansalvadorensis, Emilvia orea, Triactoma tithonianum, Alievium helenae, Pantanellium berriasianum, Archaeodictyomitra apiara, A. excellens, Dibolachras tytthopora, Mirifusus baileyi, M. mediodilatatus, M. hanni, Parvicingula blowi, P. hsui, P. citae, P. cosmoconica, P. khabakov, P.? chimenaensis, Podocaspa amphitreptera, Ristola cretacea, R. jonesi, R. procera, R.* aff. *altissima, Sethocapsa cetia, S. leiostraca, Williriedelum salumiicum.* The lower boundary (late Tithonian) is defined by the first appearance of *Ditrabs sansalvadorensis* and *D. tythophora*, the mass appearance of *Acanthocircus dicranacanthos* and *Parvicingula cosmoconica*. The upper boundary (Berriasian) is defined by the extinction of *Parvicingula khabakovi, Mirifusus baileyi*. This chronostratigraphic interval corresponds with the previously recognized beds containing *P. khabakovi–M. baileyi* [3]. The characteristic species of this assemblage are known in West Kamchatka, Japan, the US, and Italy.

Early Cretaceous (late Berriasian–middle Valanginian)

The most characteristic species of this assemblage are as follows: *Emiluvia orea, Pantanellium berriasianum, P. lanceola, Alievium helenae, Acaeniotyle diaphorogona, Archaeodictyomitra apiara, A. excellens, Mirifusus mediodilatatus, M. hanni, Podobursa polylophia, P. triacantha, Parvicingula ananassa, P. citae, P. cosmoconica, Ristola cretacea, R.? jonesi, Pseudodictyomitra carpatica, P. depressa, P.? leptoconica, Stichocapsa arca, S. cribata, S. conosphaeroides, S. leiostraca, Sethocapsa cetia, S. trachyostraca, Thanarla elegantissima, Xitus alievi, X. clivosa, X. spicularis.* The lower boundary (late Berriasian) is defined by the appearance of numerous new species (*Pantanellium berriasianum, Parvicingula ananassa, Ristola cretacea*) and the genus *Xitus*. The upper boundary (middle Valanginian) is defined by the extinction of the genus *Parvicingula*. The recognized interval corresponds in volume with the lower part of the previously identified beds with *Stichocapsa trachyostraca–Mirifusus chenodes* [3]. The characteristic species are globally widespread (in America, Asia, and Europe).

Early Cretaceous (late Valanginian–Hauterivian)

The following species have been identified: *Cecrops septemporatus, Archaeodictyomitra apiara, Mirifusus mediodilatatus minor, M. chenodes, Xitus alievi, X. spicularius, Parvicingula ananassa, P. boesii, Thanarla? conica, T. elegantissima, Sethocapsa trachyostraca, S. uterculus, Pseudodictyomitra depressa, P. leptoconica, P. carpatica.* The lower boundary of the interval (late Valanginian) is defined by the appearance of abundant species of the genus *Thanarla* (*T. elegantissima* is identified here for the first time) and the index species *Mirifusus mediodilatatus*, and the acme of the subspecies *Mirifusus mediodilatatus minor*. The upper boundary of the interval (Hauterivian) is conventionally defined by the disappearance of *Sethocapsa trachyostraca* and the latest species of the genus *Parvicingula* in the uppermost part. This interval probably corresponds with the top of the radiolarian beds containing *Mirifusus chenodes-Sethocapsa trachyostraca*. The species of this interval are known predominantly from the Tethys.

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