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The First Find of the Early Jurassic Radiolarians in the Cherty Allochthons of the Samarka Accretionary Prism (Southern Sikhote Alin)

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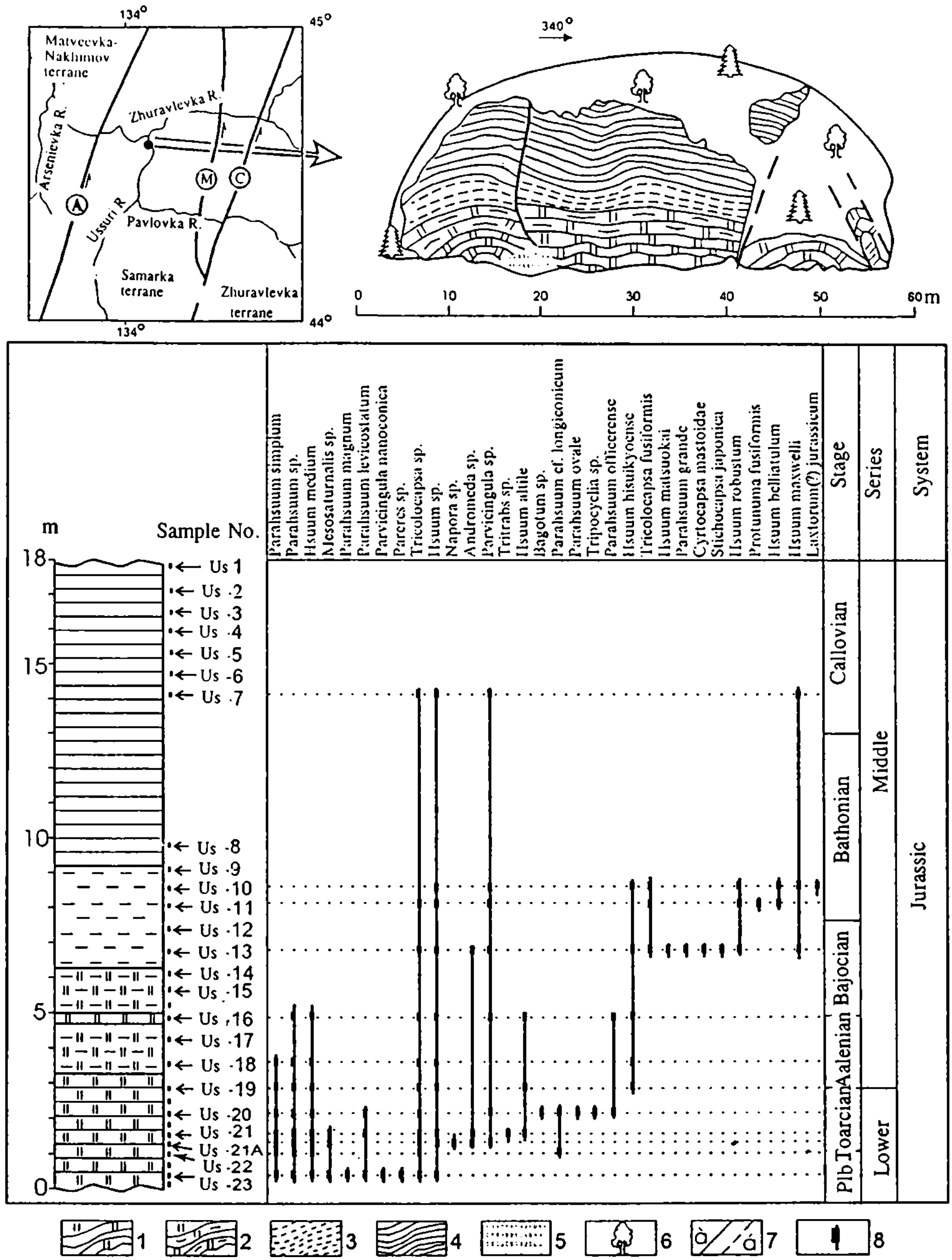
New data on the finds of the Early Jurassic radiolarians in the cherty allochthons of the Samarka accretionary prism and the Middle Jurassic radiolarians (beginning with the Aalenian), in the turbidite matrix are given. The obtained data enable widening the chronostratigraphic range of the cherty allochthons (up to the Lower Jurassic inclusive) and to revise the date of inception of the Samarka accretionary prism. Photographs of the Early and Middle Jurassic radiolarians are supplemented.

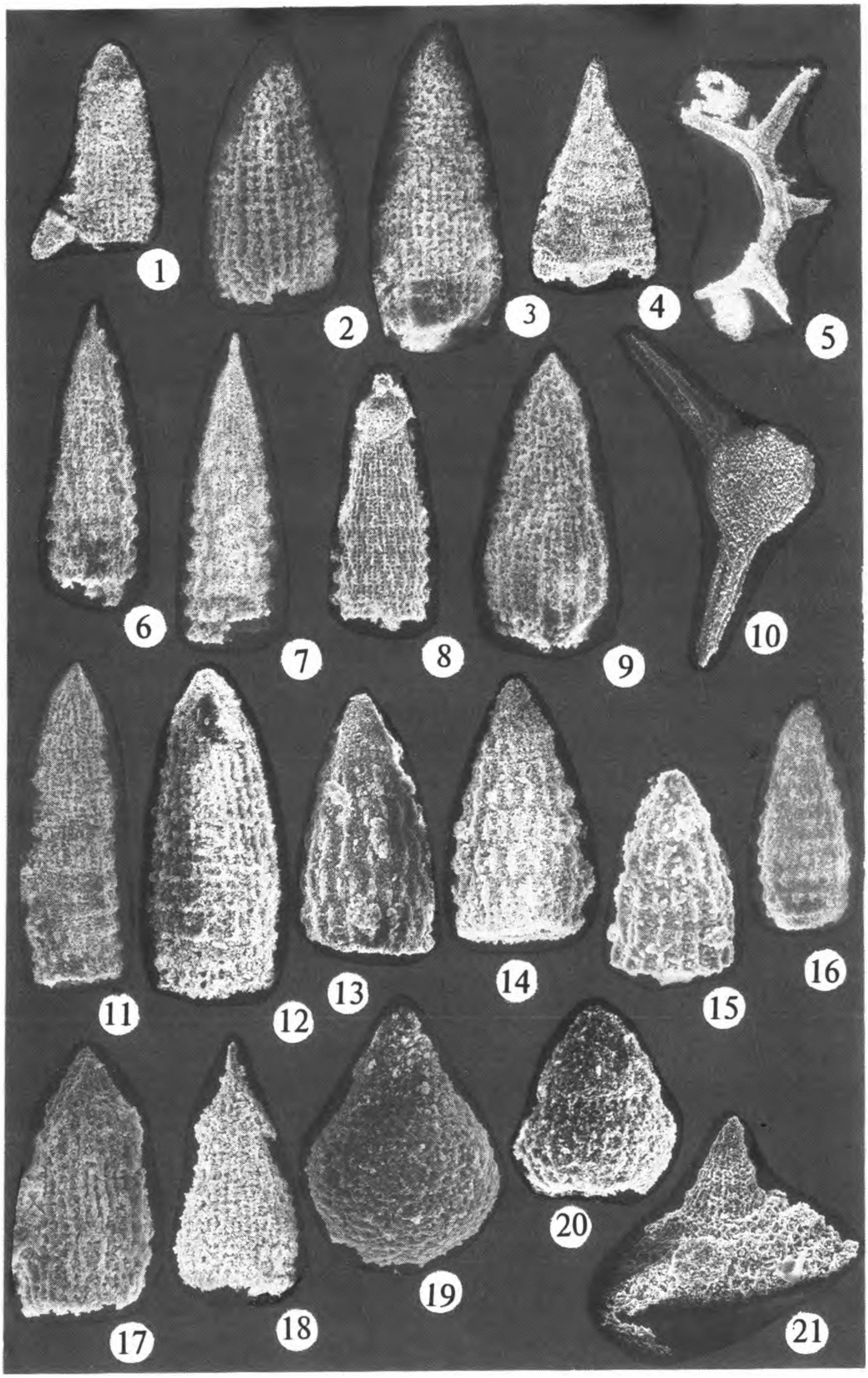
The Samarka terrane of the Sikhote Alin accretionary prism is a complex association of marginal continental and oceanic rocks [4], [6]. The marginal continental rocks are represented predominantly by distal arkosic turbidites and olistostromes; the oceanic, by reefal limestones and basalts that occur as blocks of various size in olistostrome (fragments of subaqueous highs and guyots) and ribbon cherts often associated with tholeiitic basalts that occur both as blocks in the olistostrome and as independent slabs with a length up to several tens of kilometers (fragments of abyssal plains). The previous isotopic datings of the cherts indicated their Late Permian and Triassic age [1], [4], [5]. The clastic rocks contain younger radiolarians of mostly Middle–Late Jurassic age [3], [5], [6]. And the relationships between the cherty and clastic sequences of the Samarka prism, differing in composition, age, and depositional environment, were insufficiently studied. At the same time, the solution to this problem is of great importance, firstly, for the structural interpretation of the accretionary prism and reconstruction of its evolution, and secondly, for the dating of subduction and accretion. In our opinion, the change from silicic to clastic sedimentation indicates that the fragment of an oceanic plate has approached the subduction zone. Therefore, the age of the last cherts and the first clastic rocks may indicate the date when this oceanic plate fragment started to subduct and, accordingly, the accretion process began.


134°
45°
Matveevka-Nakhimov terrane
Arsenievka R.
Zhuravlevka R.
Ussuri R.
Pavlovka R.
Samarka terrane
Zhuravlevka terrane
134°
44°
340°
0
10
20
30
40
50
60m
m
Sample No.
18
15
10
5
0
Us 1
Us -2
Us -3
Us -4
Us -5
Us -6
Us -7
Us -8
Us -9
Us -10
Us -11
Us -12
Us -13
Us -14
Us -15
Us -16
Us -17
Us -18
Us -19
Us -20
Us -21
Us -21A
Us -22
Us -23
Parahsuum simplum
Parahsuum sp.
Hsuum medium
Mesosaturnalis sp.
Parahsuum magnum
Parahsuum levicostatum
Parvicingula nanoconica
Pareres sp.
Tricolocapsa sp.
Hsuum sp.
Napora sp.
Andromeda sp.
Parvicingula sp.
Tritrabs sp.
Hsuum altile
Bagotum sp.
Parahsuum cf. longiconicum
Parahsuum ovale
Tripocyclia sp.
Parahsuum officerense
Hsuum hisuikyoense
Tricolocapsa fusiformis
Hsuum matsuokai
Parahsuum grande
Cyrtocapsa mastoidae
Stichocapsa japonica
Hsuum robustum
Protunuma fusiformis
Hsuum belliatulum
Hsuum maxwelli
Laxtorum(?) jurassicum
Stage
Series
System
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Plb
Middle
Lower
Jurassic
1
2
3
4
5
6
7
8

The immediate contacts between the cherty and clastic strata are usually strongly deformed: quite common is the multiple repetition of these members resulting from both accretionary and the subsequent collisional tectonics. In some outcrops, however, we were lucky enough to observe gradual transition from the cherts to the overlying clastic rocks. Fig. 1 shows an example of well preserved transition discovered and studied in detail on the left bank of the Ussuri River 3.6 km upstream from the mouth of the Zhuravlevka River. This sequence is a fragment of the lowermost structural level of the Samarka prism formerly recognized as the Tudovak Formation [2]. At this level, stratified cherts are substantially predominant, less abundant are chert slabs, and the olistostrome horizons account for up to 5% of the total rock association volume.

The sequence consists of cherts (Fig. 1), the overlying cherty mudstones, and then silty mudstones and siltstones interbedded with sandstones. It should be noted that the cherts to clastics transition is gradual (by means of decrease in cherty components) within a 3 m-thick cherty mudstone sequence. We have sampled all lithologic rock varieties in search for microfossils. As a result, the following data were obtained: for the first time, the latest Early Jurassic radiolarians were identified in the cherts, and the Middle Jurassic radiolarians, in the clastic sequence (Fig. 1, Plate 1). A relatively rich radiolarian assemblage found in sample Us-23 from the lowermost part of the exposed cherty-clastic is characteristic of a wide chronostratigraphic range (Table 1). However, we determine its age as Pliensbachian, because the first appearance of *Hsuum medium, Parahsuum levicostatum, Mesosaturnalis* sp., *Parvicingula nanoconica*, and *Parares* sp. is reported since the final Early Jurassic, most probably Pliensbachian–Toarcian [7], [11]. The upper age boundary was established on the basis that the radiolarians from the superjacent sample Us-22 are dated as latest Pliensbachian–Toarcian. Sample Us-22 contains a sparse radiolarian assemblage (Table 1) with most of forms characterized by a wide chronostratigraphic range. But the presence of *Parahsuum longiconicum* restricts the age to the interval between the latest Pliensbachian and earliest Toarcian [10]. Therefore, the Pliensbachian/Toarcian boundary lies in the immediate vicinity of sample Us-22. In samples Us-21A, Us-21, and Us-20, fairly rich radiolarian assemblages were identified with most of forms appearing late in the Early Jurassic and most abundant in the Middle Jurassic (Table 1). However, the presence of *Parahsuum longiconicum* restricts the upper age boundary to the final Toarcian. Considering that samples Us-21A, Us-21, and Us-20 were picked from higher stratigraphic levels than sample Us-22, their age can be defined

Fig. 1 Location map, outcrop sketch, and lithostratigraphic column of the transition (cherts to clastics) zone of the Samarka accretionary prism showing the radiolarian species distribution throughout the sequence. 1 - cherts; 2 - cherty mudstones; 3 - silty mudstones; 4 - turbidites; 5 - diluvial cone; 6 - soil and vegetation; 7 - faults: apparent (a) and inferred (b); 8 - localities of the radiolarian species in samples. Circled letters indicate faults: Arsenievka (A), Meridional (M), and Central Sikhote Alin (C).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as Toarcian. The radiolarian assemblage found in sample Us-19 shows a relatively narrow chronostratigraphic range – Toarcian–Bajocian, because it contains *Hsuum altile* [7]. At the same time, the presence of *Parahsuum simplum*, more characteristic of the Early Jurassic, restricts the chronostratigraphic range of this assemblage to the latest Toarcian–earliest Aalenian. Therefore, the Lower/Middle Jurassic boundary lies near sample Us-19 and coincides with the cherts to clastics transition.

Fairly abundant radiolarian assemblages characteristic mostly of the latest Early–latest Middle Jurassic were identified in samples Us-18 and Us-16 (Table 2) collected from the cherty mudstones of the transitional sequence between the cherts and clastics proper. The upper age boundary of these assemblages corresponds to the mid-Bajocian, because the superjacent sample Us-13 contains *Hsuum robustum* with a stratigraphic range between the middle and late Bajocian [9]. Samples Us-11 and Us-10 also carry rich Middle Jurassic radiolarian assemblages. Considering that the subjacent sample is dated middle-late Bajocian, the lower boundary of these assemblages is established as final Bajocian–earliest Bathonian. The upper limit corresponds to the final Bathonian, because the samples carry *Protunuma fusiformis* characteristic of the Bajocian–Bathonian [8]. The age of the last sample Us-7 is tentatively assumed as Callovian, because the subjacent samples are dated as Bathonian, and the sparse radiolarians identified in this sample are characteristic of the Middle to Late Jurassic (*Hsuum maxwelli*).

To summarize, 10 radiolarian assemblages have been identified within a 18 meter-thick continuous cherty-clastic sequence, characteristic of the following chronostratigraphic intervals, respectively: Pliensbachian, final Pliensbachian–earliest Toarcian, Toarcian, final Toarcian–earliest Aalenian, Aalenian, final Aalenian–earliest Bajocian, middle Bajocian–final Bajocian, final Bajocian–earliest Bathonian, Bathonian, and Callovian.

The Lower/Middle Jurassic boundary corresponds to the transition from the cherts to the clastic part of the sequence.

To summarize, the obtained new data enable us to conclude the following:

(1) The age of the cherty allochthons that compose the Samarka prism is established up to the Lower Jurassic inclusive.

Plate 1 Early Jurassic radiolarians from the cherty-clastic sequence of the Samarka accretionary prism. Early Jurassic radiolarians: figs 1, 2 - *Parahsuum simplum* Yao, 1 - Us-21A, 110x, 2 - Us-21, 160x; fig. 3 - *Parahsuum* cf. *simplum* Yao, Us-21, 160x; fig. 4 - *Parahsuum* cf. *magnum* Takemura, Us-23, 80x; fig. 5 - *Mesosaturnalis* sp., Us-21A, 110x; figs 6, 7 - *Hsuum medium* (Takemura), Us-21A, 110x; fig. 8 - *Hsuum medium* (Takemura), Us-23, 110x; fig. 9 - *Parahsuum levicostatum* Takemura, Us-21, 160x; fig. 10 - *Tripocyclia* sp., Us-20, 110x; Middle Jurassic radiolarians: figs 11, 12 - *Hsuum hisuikyoense* Isozaki et Matsuda, Us-13, 11 - 110x, 12 - 160x; figs 13, 14 - *Hsuum robustum* Pessagno et Whalen, Us-13, 160x; fig. 15 - *Hsuum* cf. *belliatulum* Pessagno et Whalen, Us-11, 160x; fig. 16 - *Laxtorum(?) jurassicum* Isozaki et Matsuda, Us-10, 110x; fig. 17 - *Parahsuum* cf. *grande* Hori et Yao, Us-13, 160x; fig. 18 - *Parahsuum officerense* Pessagno et Whalen, Us-16, 160x; fig. 19 - *Tricolocapsa* sp., Us-13, 240x; fig. 20 - *Stichocapsa japonica* Yao, Us-13, 160x; fig. 21 - *Andromeda* sp., Us-13, 90x.

Table 1 Cherts.

Sample index	List of radiolarian species	Age								
		J_1				J_2				J_3
		het	sin	plb	toa	aal	baj	bth	clv	
Us-23	*Hsuum medium* (Takemura)									
	Hsuum sp.									
	Parahsuum magnum Takemura									
	Parahsuum simplum Yao									
	Parahsuum sp.									
	Parahsuum levicostatum Takemura									
	Mesosaturnalis sp.									
	Tricolocapsa sp.									
	Parvicingula nanoconica Hori et Otsuka									
	Parares sp.									
Us-22	*Hsuum medium* (Takemura)									
	Parahsuum simplum Yao									
	Tricolocapsa sp.									
	Parahsuum longiconicum Sashida									
	Parahsuum sp.									
Us-21A	*Parahsuum* sp.									
	Tricolocapsa sp.									
	Parahsuum simplum Yao									
	Hsuum medium (Takemura)									
	Mesosaturnalis sp.									
	Parvicingula sp.									
	Napora sp.									
	Andromeda sp.									
	Hsuum sp.									
Us-21	*Parahsuum simplum* Yao									
	Tricolocapsa sp.									
	Parahsuum sp.									
	Hsuum medium (Takemura)									
	Mesosaturnalis sp.									
	Hsuum altile Hori et Otsuka									
	Andromeda sp.									
	Hsuum sp.									
	Parahsuum levicostatum Takemura									
	Tritrabs sp.									
Us-20	*Bagotum* sp.									
	Parahsuum sp.									
	Parahsuum simplum Yao									
	Tricolocapsa sp.									
	Parahsuum longiconicum Sashida									
	Parahsuum levicostatum Takemura									
	Hsuum medium (Takemura)									
	Tripocyclia sp.									
	Parahsuum ovale Hori et Yao									
	Parvicingula sp.									
	Parahsuum officerence (Pessagno et Whalen)									
Us-19	*Parahsuum* sp.									
	Hsuum sp.									
	Hsuum medium (Takemura)									
	Hsuum altile Hori et Otsuka									
	Parahsuum simplum Yao									
	Hsuum hisuikyoense Isozaki et Matsuda									
	Tricolocapsa sp.									

Table 2 Cherty mudstones.

Sample index	List of radiolarian species	Age								
		J_1				J_2				J_3
		het	sin	plb	toa	aal	baj	bth	clv	
Us-18	*Parahsuum simplum* Yao									
	Tricolocapsa sp.									
	Parahsuum sp.									
	Hsuum medium (Takemura)									
	Hsuum sp.									
	Hsuum hisuikyoense Isozaki et Matsuda									
Us-16	*Hsuum medium* (Takemura)									
	Parvicingula sp.									
	Parahsuum sp.									
	Tricolocapsa sp.									
	Hsuum altile Hori et Otsuka									
	Parahsuum officerence (Pessagno et Whalen)									
	Hsuum sp.									
	Hsuum hisuikyoense Isozaki et Matsuda									

Table 3 Silty mudstones and siltstones.

Sample index	List of radiolarian species	Age								
		J_1				J_2				J_3
		het	sin	plb	toa	aal	baj	bth	clv	
Us-13	*Hsuum robustum* Pessagno et Whalen									
	Parvicingula sp.									
	Hsuum sp.									
	Tricolocapsa sp.									
	Tricolocapsa fusiformis Yao									
	Hsuum hisuikyoense Isozaki et Matsuda									
	Hsuum matsuokai Isozaki et Matsuda									
	Parahsuum grande Hori et Yao									
	Hsuum maxwelli Pessagno									
	Andromeda sp.									
	Cyrtocapsa mastoidea Yao									
	Stichocapsa japonica Yao									
Us-11	*Hsuum* sp.									
	Parahsuum sp.									
	Parvicingula sp.									
	Hsuum robustum Pessagno et Whalen									
	Tricolocapsa sp.									
	Tricolocapsa fusiformis Yao									
	Hsuum belliatulum Pessagno et Whalen									
	Protunuma fusiformis Ishikawa et Yao									
Us-10	*Hsuum* sp.									
	Hsuum robustum Pessagno et Whalen									
	Hsuum maxwelli Pessagno									
	Parvicingula sp.									
	Hsuum hisuikyoense Isozaki et Matsuda									
	Laxtorum (?) jurassicum Isozaki et Matsuda									
	Hsuum belliatulum Pessagno et Whalen									
	Tricolocapsa fusiformis Yao									
	Protunuma fusiformis Ishikawa et Yao									
	Ticolocapsa sp.									
Us-7	*Tricolocapsa* sp.									
	Hsuum sp.									
	Parvicingula sp.									
	Hsuum maxwelli Pessagno									

(2) The beginning of subduction and, accordingly, development of the accretionary prism is dated as the earliest Middle Jurassic.

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