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GEOLOGY

First Finds of Middle Jurassic and Early Cretaceous (Valanginian) Radiolarian Assemblages in the Western Sikhote-Alin: Their Paleogeographic and Tectonic Significance

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The right bank of the lower courses of the Ussuri River in the western Sikhote-Alin comprises tectonic structures of different compositions, ages, and origins. It hosts siliceous–volcanogenic rock complexes associated with oolitic limestones, which is atypical of the continental Russian Far East. In the Snarskii Settlement area, they are attributed to the Kultukha Formation, the age of which was substantiated by finds of Late Jurassic–Early Cretaceous foraminifers in limestones [3]. Subsequently, Tithonian–Berriasian radiolarians were determined in thin sections of siliceous–clayey rocks sampled in the course of large-scale geological mapping. The sediments are considered as inner shelf facies of the basin, which resembled the present-day Sea of Japan and presumably existed during the Jurassic–Cretaceous boundary period near the eastern margin of the Paleoasian continent [4]. This paper presents data on new age assessments of siliceous and siliceous–clayey rocks, which allow new insights into their origin and the tectonic structure of the region.

The siliceous–volcanogenic rocks are exposed in tectonic blocks, which occur in a band (4–8 km wide) that extends in the southwestern direction from the middle courses of the Sed'maya River (east of the town of Vyazemskii) to the Snarskii Settlement (Fig. 1). In the Kamenushka–Omutnaya interfluve area located northeast of the settlement, red cherts, siliceous mudstones, and siliceous–ferruginous tuffites alternate with massive and amygdaloidal basalts and rare volcaniclastic layers. Red cherts and siliceous mudstones contain Tithonian–Berriasian radiolarians, while clayey red cherts developed 900 m south of the town of Glebovo (Sample 28) yielded the following assemblage: *Parahsuum* cf. *officerense* (Pessagno et Whalen), *Parvicingula* cf. *dhimenoensis* Baumgartner, *Stichocapsa* cf. *robusta* Matsuoka, *S. oblongula* Kocher, and *Archaeodictyomitra?* ex gr. *amabilis* Aita. These radiolarians were determined by E.A. Dorukhovsakaya. Other faunal determinations mentioned in the present communication were made by I.V. Kemkin. The occurrence of the first two species in the assemblage indicates the Bajocian–Callovian age of the host rocks [9, 12].

Exposures near the Snarskii Settlement are largely composed of basalts that enclose lenses of oolitic limestones. The northern periphery of the Dobrolyubovo Settlement in the southwestern area shows outcrops of greenish gray tuffaceous silty mudstones with fragments (up to 20 cm across) of limestones, red cherts, and volcaniclastic sandstones. The tuffaceous silty mudstones contain layers (1–5 m thick) of siliceous tuffaceous mudstones and clayey red cherts and basaltic flows up to 2 m thick. The clayey red cherts (samples Dob-1 and Dob-2, Fig. 2) contain radiolarians: *Archaeodictyomitra apiarum* (Rust), *A. excellens* (Tan), *A.* ex gr. *vulgaris* Pessagno, *Cryptamphorella clivosa* (Aliev), *Cr. sphaerica* (White), *Hemicryptocapsa capita* Tan, *Holocryptocanium barbui* Dumitrica, *Pantanellium lanceola* (Parona), *Parvicingula cosmoconica* (Foreman), *P. boesii* gr. (Parona), *Pseudodictyomitra carpatica* (Lozyniak), *Ps.* ex gr. *leptoconica* (Foreman), *Ristola cretacea* (Baumgartner), *Sethocapsa kaminogoensis* Aita, *S. subcrassitestata* Aita, *Stichocapsa* ex gr. *cribata* Hinde, *Stichomitra japonica* (Nakaseko et Nishimura), *St.* ex gr. *mediocris* (Tan), *Thanarla* ex. gr. *brouweri* (Tan), *T. pulchra* (Squinabol), *Wrangellium depressum* (Baumgartner), *W. puga* (Schaaf), *Xitus gifuensis* Misutani, and *X. spicularius* (Aliev). The siliceous mudstones (samples Dob-3, 36/4) yielded *Acaeniotyile umbilicata* (Rust), *Archaeodictyomitra apiarum* (Rust), *A. excellens* (Tan), *A.* cf. *sliteri* Pessagno, *A.* ex gr. *vulgaris* Pessagno, *Cryptamphorella clivosa* (Aliev), *Dictyomitra pseudoscalaris* (Tan), *Godia testa* (Tumanda), *Mirifusus dianae minor* Baumgartner, *Parvicingula cosmoconica* (Foreman), *P. boesii* gr. (Parona), *Pseudodictyomitra carpatica*

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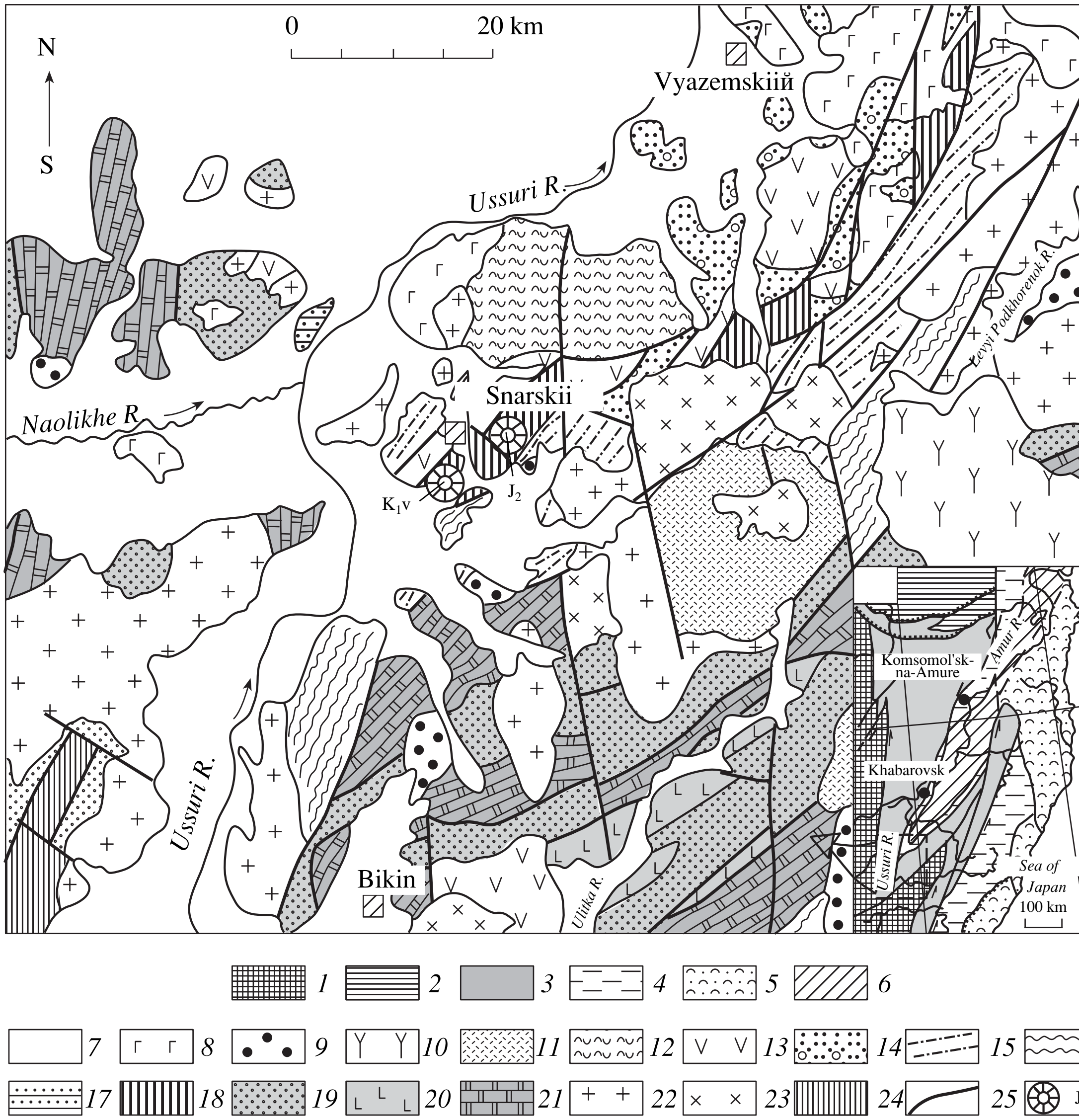

Fig. 1. Geological map of the lower courses of the Ussuri River (based on materials of the medium- and large-scale geological mapping carried out by A.F. Atrashenko, A.S. Gonokhov, A.T. Kandaurov, F.R. Likht, Yu.I. Maksimenko, and geologists from the Bureau of Geology and Mineral Resources of Heiluntsyang Province (China) in 1990. The inset shows a schematic tectonic structure of Sikhote-Alin and adjacent territories (after [11]). (*1*) Bureya–Khanka-Tszyamusy continental superterrane; (*2*) Early Mesozoic Mongol–Okhotsk orogenic belt; (*3*) terranes of the Jurassic–Early Cretaceous accretionary prism; (*4*) Zhuravlevka–Amur terrane of the Early Cretaceous turbidite basin; (*5*) Early Cretaceous Kem island-arc terrane; (*6*) Kiselevka–Manoma terrane of the Middle Cretaceous accretionary terrane; (*7*) Quaternary sediments; (*8*) Neogene basalts; (*9*) Cenozoic continental sediments; (*10*) Paleogene andesites; (*11*) Late Cretaceous rhyolites and their tuffs; (*12*) Late Cretaceous andesitic tuff; (*13*) Cenomanian basalts and andesites; (*14–17*) terrigenous sediments: (*14*) middle–upper Albian (shallow-water) rudaceous, (*15*) Aptian–Albian (shallow-water) substantially sandy, (*16*) Berriasian(?)–Valanginian substantially aleuropelitic, (*17*) Tithonian–early Valanginian (shelf zone) silty–sandy; (*18*) siliceous–volcanogenic complex of the Kiselevka–Manoma terrane; (*19–21*) volcanosedimentary rocks of the Jurassic–Early Cretaceous accretionary prism with the prevalence of (*19*) clastic, (*20*) volcanogenic, and (*21*) cherts; (*22*) granites; (*23*) diorites; (*24*) Zhaohe ophiolites; (*25*) faults; (*26*) localities of radiolarian assemblages and their age.

(Lozyniak), *Ps. lilyae* (Tan), *Ps.* ex gr. *nuda* Schaaf, *Praecaneta mimetica* Dumitrica, *Sethocapsa kaminogoensis* Aita, *Stichocapsa altiforamina* Tumanda, *St.* ex gr. *cribata* Hinde, *St.* ex gr. *mediocris* (Tan), *Thanarla* ex. gr. *brouweri* (Tan), *Th. elegantissima* (Cita), *T. pulchra* (Squinabol), *Wrangellium depressum* (Baumgartner), *W. puga* (Schaaf), *Xitus* cf. *plenus* Pessagno, and *X. spicularius* (Aliev). Based on the occurrence of *Ristola cretacea, Cryptamorphella clivosa*, and *Hemicryptocapsa capita*, the age of the red cherts is accepted as Valanginian, whereas the age of the siliceous mudstones with *Wrangellium depressum, Pseudodictyomi-*

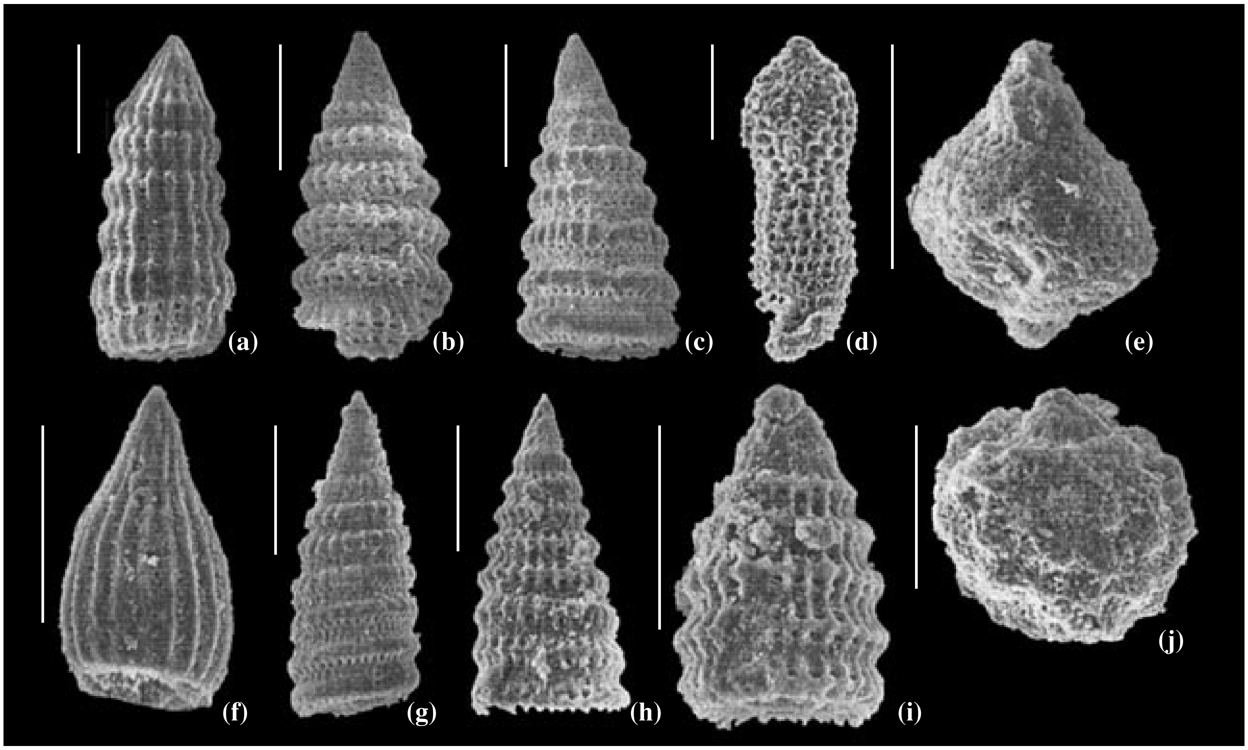

Fig. 2. Some Early Cretaceous radiolarians from red cherts and siliceous mudstones in the Dobrolyubovo Settlement area. (a) *Dictyomitra pseudoscalaris* (Tan), Sample 36/4 (48325); (b) *Wrangellium puga* (Schaaf), Sample 36/4 (48252); (c) *Pseudodictyomitra carpatica* (Lozyniak), Sample 36/4 (48249); (d) *Ristola cretacea* (Baumgartner), Sample Dob-2 (48114); (e) *Hemicryptocapsa capita* Tan, Sample Dob-2 (48134); (f) *Thanarla elegantissima* (Cita), Sample 36/4 (48265); (g) *Pseudodictyomitra lilyae* (Tan), Sample 36/4 (48270); (h) *Praecaneta mimetica* Dumitrica, Sample 36/4 (48303); (i) *Wrangellium depressum* (Baumgartner), Sample Dob-3 (48167); (j) *Cryptamphorella clivosa* (Aliev), Sample Dob-2 (48084). Scale bar 100 μm.

tra lilyae, Dictyomitra pseudoscalaris, Thanarla elegantissima, Praecaneta mimetica, and *Cryptamphorella clivosa* is considered as late Valanginian–initial Hauterivian [9, 10, 13].

Thus, the siliceous–volcanogenic rocks of the Snarskii Settlement area correspond to a wider stratigraphic range (at least, the Middle Jurassic–Valanginian). These age estimates allow the host rocks to be correlated with their counterparts from the Kiselevka–Manoma terrane of the Middle Cretaceous accretionary prism exposed 250 km northeast in the middle courses of the Manoma River and on the left bank of the lower courses of the Amur River. The volcanogenic–siliceous rocks of this terrane are interpreted as fragments of the Jurassic–Lower Cretaceous sedimentary cover of the old oceanic plate [1, 7]. In the Snarskii Settlement area, outcrops are largely composed of basaltic lava flow alternating with Radiolaria-bearing pelagic and hemipelagic sediments with oolitic limestones. Clastic rocks include products of eroded volcanics. In terms of their petro- and geochemical features, these basalts are similar to low-potassic tholeiites of mid-oceanic ridges or spreading centers of marginal seas. The studied rocks most likely characterize an oceanic basin area with many underwater volcanic edifices and islands, near which oolitic limestones accumulated in lagoons.

Recent tectonic maps available for this part of the Sikhote-Alin fold system show a Z-shaped bend of structures (Fig. 1, inset), where rocks of the Jurassic–Early Cretaceous accretionary prism (Nadan'khada–Bikin terrane) and Early Cretaceous turbiditic basin of the Zhuravlevo–Amur terrane surround the Kiselevka–Manoma complex, which previously included only volcanogenic–siliceous rocks developed west of the town of Vyazemskii [11]. It is assumed that this bend is a giant syngenetic strike-slip fold (with a steep hinge) related to the northeastward advancement of the Alchan ledge of the paleocontinent [8]. Our data, coupled with data of the large-scale geological mapping on the right bank of lower courses of the Ussuri River and the adjacent territory of China, allow us to specify the geological structure of the region (Fig. 1). The Kiselevka–Manoma terrane, probably, extends westward up to, at least, the right bank of the Ussuri River, where the rocks of this terrane constitute a narrow tectonic wedge bordered by large faults. On both sides of the fault, one can see outcrops of Valanginian rocks coeval with the youngest sediments of this segment of the Kiselevka–Manoma terrane. However, these rocks are different in terms of genesis and composition. Therefore, they can hardly be attributed to the Zhuravlevo–Amur terrane. In the upper courses of the Levyi Podkhorenok River, the rocks are represented by laminated silty mudstones and siltstones with interlayers of arkosic sandstones (sediments formed by bottom currents and turbidites accumulated at the foot of the continental slope [6]). Near the Naolikhe River mouth in the northwestern area, upper Tithonian–lower Valanginian shelf siltstones and graywacke sandstones are developed [5]. The younger rock complexes of this area are also different and are characterized by the development of specific middle–upper Albian coastal-marine conglomerates with abundant chert pebbles and Albian–Cenomanian basaltic andesites with Radiolaria-bearing siltstone intercalations [2]. These data suggest that the structures of the western Sikhote-Alin region formed under conditions of significant horizontal movements, which resulted in the juxtaposition of genetically different complexes from various areas of the Early Cretaceous continental margin, rather than plicate deformations.

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