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New Age Data on the Deposits of the Kiselevka–Manoma Accretionary Complex Based on Radiolarian Fossils

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Abstract—The Kiselevka–Manoma Complex, the youngest accretionary complex in the Russian Far East, is composed of Jurassic–Lower Cretaceous pelagic and hemipelagic oceanic deposits. The radiolarian biostratigraphic study made it possible to refine the stratigraphy of the upper portion of the siliceous sediments from the northeastern fragment of this accretionary complex in the vicinity of the Kiselevka settlement in the Lower Amur region. The transition from pelagic siliceous to hemipelagic siliceous–clayey sedimentation was established within the interval from the Late Barremian to the Middle Aptian in different parts of the complex. The age of the accretion of the oceanic rocks is defined as postmiddle Aptian.

Keywords: biostratigraphy, radiolarians, Jurassic, Cretaceous, oceanic deposits, Kiselevka–Manoma accretionary complex, Russian Far East

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INTRODUCTION

The most part of the Russian Far East is made up of accretionary complexes (Fig. 1) formed owing to the subduction of the Pacific plates in the Jurassic and Early Cretaceous [3, 10, 12, 14, 20]. The subduction-related accretion determined the growth of the Asian continent in the Mesozoic, being a part of the long-lived geological evolution of the region. The complex imbricated-thrust structure of the accretionary complexes is mainly composed of terrigenous clastic rocks formed on convergent plate boundaries and, to lesser extent, of ocean floor rocks. The youngest oceanic deposits are known in the Kiselevka–Manoma accretionary complex [7, 8, 15, 27], which belongs to the Sikhote-Alin accretionary system. This accretionary complex builds up the Amur accretionary complex from the southeast, extending as a discontinuous and narrow (up to 10 km wide) NW-striking band along its frontal part (Fig. 1). Unlike the Amur Complex dominated by terrigenous clastic rocks, the Kiselevka–Manoma Complex is made up mainly of oceanic pelagic cherts containing oceanic within-plate basalts [1, 7] and, to a lesser extent, hemipelagic siliceous mudstone. The biostratigraphic study of fossil radiolarians has proved reliable for dating such deposits and their stratigraphic sequence and often is used for deciphering the history of the oceanic sedimentation and the timing of the accretion events. In this paper, we report new age data on the radiolarians from cherts, siliceous mudstone, and mudstone taken in the vicinity of the Kiselevka settlement from the Kiselevka–Manoma accretionary complex in the Lower Amur region, as well as revised age estimates for previously studied radiolarian assemblages from the youngest cherts.

A REVIEW OF PREVIOUS BIOSTRATIGRAPHIC STUDIES

The biostratigraphy of the deposits of the Kiselevka–Manoma accretionary complex has a long history of study. The volcanogenic–siliceous rocks in the area of the Kiselevka settlement in the Lower Amur region were ascribed to the Kiselevka Formation dated as the Late Triassic–Early Jurassic on the basis of finds of diverse Liassic fauna in the carbonate matrix of volcaniclastic breccia conglomerate lying above organogenic–clastic limestones among mafic volcanics [2, 11]. Zhamoida [5, 6] was the first who divided the Kiselevka Formation into two subformations: (1) the substantially siliceous lower subformation containing radiolarians of the Kiselevka Complex and (2) the upper volcanogenic subformation with Liassic fauna. The Early–Late Jurassic [13] and Early Cretaceous [7] radiolarians found later in the cherts of the Lower Kiselevka subformation raised some doubts regarding the use of Liassic microfauna for dating the volcanogenic subformation. Kaidalov [9] interpreted the Liassic fauna as redeposited and assigned the volcanic rocks with a basalt siliciclastic unit as well as

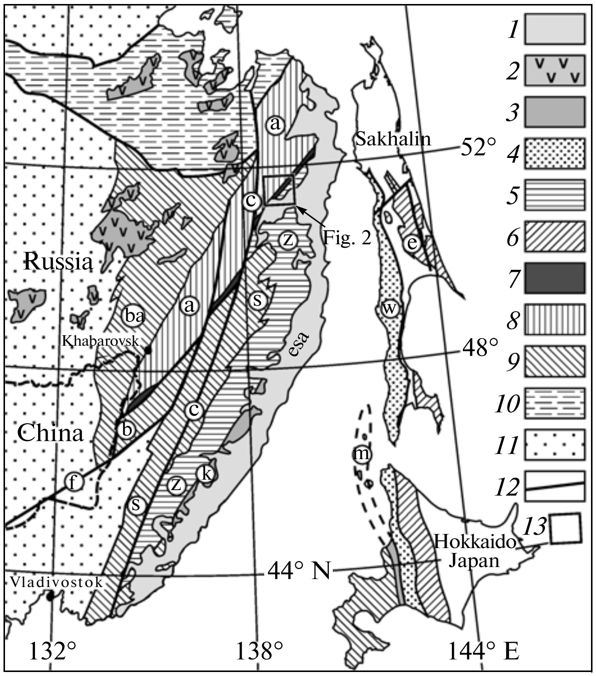


Fig. 1. Tectonic scheme of the Russian Far East and the adjacent areas modified after [12, 17, 18] with the position of the studied area.

(*1*) Late Cretaceous–Paleogene East Sikhote Alin volcanic belt (esa); (*2*) Early–Late Cretaceous Khingan–Okhotsk volcanic belt; (*3*) fragments of the Early Cretaceous volcanic arc: Kema–Samarga (k) and Moneron–Rebun–Kabato (m); (*4*) fore-arc trough of West Sakhalin (w) and Hokkaido (Aptian–Cenozoic); (*5*) Early Cretaceous Zhuravlevka turbidite trough (z); (*6–9*) accretionary complexes: (*6*) Cretaceous East Sakhalin (e) and Hokkaido, (*7*) Aptian–Albian Kiselevka–Manoma terrane, (*8*) Early Cretaceous Amur terrane (a); (*9*) the Jurassic Badzhal (ba), Bikin (b), and Samarka (s) terranes; (*10*) Mongol–Okhotsk suture zone; (*11*) cratonic domains: (*12*) major faults, including the Central Sikhote Alin (c) and Fushun-Mishan (f); (*13*) the studied area.

Early Cretaceous cherts to the Late Jurassic–Early Cretaceous Adamin Formation. However this author ignored data on the Late Barremian–Early Aptian age of the proper siliciclastic horizon reported by Khanchuk et al. [15] for the left bank of the Amur River and our determinations of radiolarians from similar rocks in Izvestkovyi Bay. The volcanogenic sequence of this age cannot lie in a single stratigraphic sequence on the Barremian–Aptian siliciclastic horizon. It is tectonically separated from the latter and represents an individual lithostratigraphic unit, which can be considered as the facies analogue of the siliceous Kiselevka Formation. This was noted by Shevelev [13] as early as 1990, and our materials serve as additional arguments in support of this view point. They indicate that the entire chronostratigraphic interval from the Jurassic to the Early Cretaceous, including the Aptian, is mainly occupied by cherts and siliceous mudstone, and there is almost no space for volcanic rocks in this stratigraphic sequence.

The age of the hemipelagic siliceous mudstone in different slices was initially determined [7] as Albian, which made it possible to suggest the post-Albian age of the accretion. The age of the radiolarian assemblages in the cited work was determined using the biostratigraphic scale developed in 1970 to the 1980s [26, 28, 30, etc.].

The more modern scales that appeared in the mid-1990s [16, 18, 21] are based on the refined stratigraphic ranges of many radiolarian species. These scales were applied for dating the sediments from the southwesterly fragments of the Kiselevka–Manoma accretionary complex. Early Jurassic to Early Cretaceous (Aptian–Albian) radiolarian assemblages were found in the Manoma fragment of Central Sikhote Alin [27]. Cherts from the south-western-most fragment on the right bank of the Ussuri River near the boundary with China yielded Late Jurassic–Early Cretaceous (up to Hauterivian) radiolarians, while siliceous mudstone contained Early Cretaceous (Early Barremian–Middle Aptian) assemblages [8]. Obtaining new age data on the Kiselevka–Manoma accretionary complex in the Lower Amur region using the more modern biostratigraphic scale is urgent both for the correlation with the sediments from other fragments of this accretionary complex and for the refinement of the accretion's timing.

GEOLOGICAL POSITION AND STRUCTURE OF THE STUDIED AREA

In the Lower Amur region, an 8-km band of the Kiselevka–Manoma accretionary complex strikes in the NE direction and is intersected by the Amur River in the Kiselevka settlement area (Fig. 2). Further northeast, these sediments are exposed as a low range among a wide field of Quaternary alluvial deposits. This band also contains separate exposures of volcanogenic–siliceous rocks situated on the right bank of the Amur River south of Lake Khavanda. The Kiselevka–Manoma accretionary complex is bounded by faults from the Amur accretionary Complex in the northwest and from the Zhuravlevka turbidite basin in the southeast. The northwestern tectonic contact is not exposed, while its southeastern contact is accessible for observation in the coastal exposures of the Amur River south of Lake Khavanda, being represented by a relatively steep (65°) reverse fault of volcanogenic–siliceous rocks onto terrigenous sediments.

The main varieties of the rocks of the Kiselevka–Manoma accretionary complex are ribbon and, more rarely, coarse-bedded cherts of variable red tints. They host stratal bodies of basalts, which are geochemical analogues of oceanic within-plate basalts [1]. Siliceous mudstone, mudstone, siliciclastic rocks, and stratal and blocked bodies of organogenic–clastic limestones among the basalts are less abundant.

In the vicinity of the Kiselevka settlement, the accretionary complex is best exposed in the high escarpments on the left bank of the Amur River and occurs as separate exposures on the western side of Izvestkovyi Bay (Fig. 3). The structure of the accretionary complex was interpreted as a package of tectonic slices [7, 15]. The SW-vergent slices tens to hundreds meters thick (Fig. 3) and have different internal structures from simple monoclinal to complicated folded ones. In the monoclinal slices, the section is built up in the NW direction [7]. Individual tectonic slices are difficult to correlate and to trace even in closely spaced profiles, since they differ in the composition and proportions of the constituent rocks. In particular, exposures along the Amur River are dominated by cherts and basalts, whereas rock associations developed along the shore of Izvestkovyi Bay are characterized by the lower abundance of basalts but higher contents of olive-gray siliceous mudstones, which upsection are replaced by dark gray mudstone. This is presumably related to the lateral rock variability of the slices, their complex structure and configuration, and to the complex juxtaposition and mixing of the slices during the accretion and postaccretion transformations.

On the right bank of the Amur River south of Lake Khavanda, strongly deformed sediments of the accretionary complex are discontinuously traceable in the low coastal escarpments and beach over a distance of 4 km. The rocks represented by cherts with variable amounts of basalts compose several tectonic slices. Basalts are the prevailing rocks in the southern part of the complex (Fig. 3b), where their thick stratal bodies contain thinner interbeds of cherts. The basalts also contain a thin tectonic slice of siliceous mudstones.

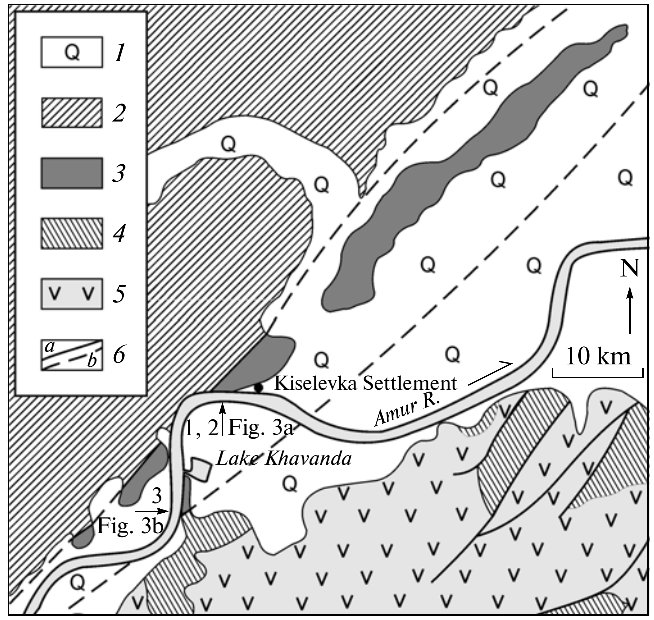


Fig. 2. Geological scheme of the studied area simplified after [4] and the position of the studied sites shown in Fig. 3.

(*1*) Quaternary alluvial deposits; (*2*) Cretaceous deposits of the Amur accretionary complex; (*3*) Jurassic–Lower Cretaceous deposits of the Kiselevka–Manoma accretionary complex; (*4*) Cretaceous deposits of the Zhuravlevka turbidite basin; (*5*) Upper Cretaceous and Paleogene volcanic rocks of the East Sikhote Alin volcanic belt; (*6*) faults: (*a*) observed, (*b*) hidden beneath the Quaternary cover.

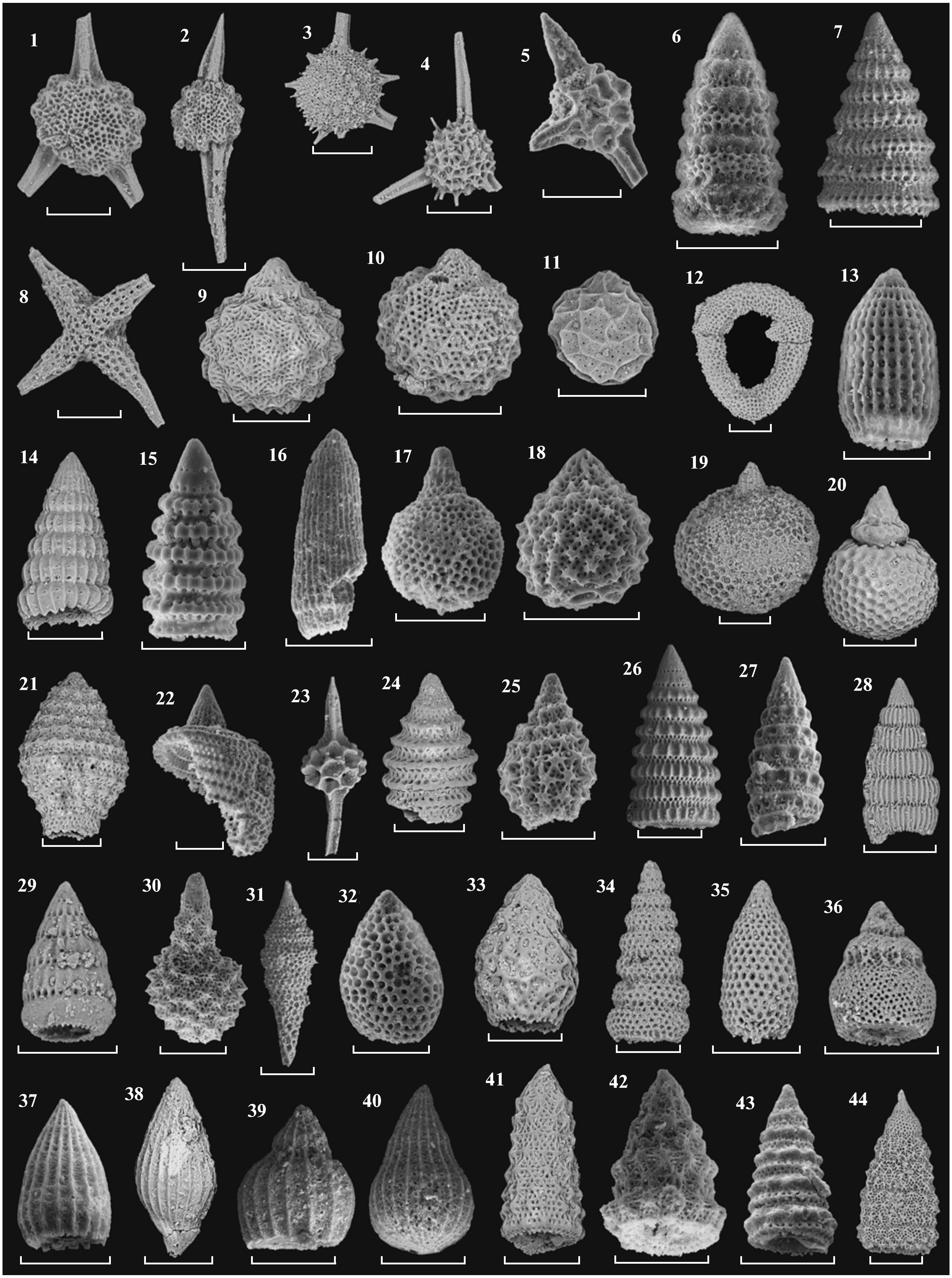
NEW AGE DATA ON THE DEPOSITS

The biostratigraphy and age of the rocks of the accretionary complex were specified using well-preserved radiolarians obtained from different rocks at three sites: (1) in the western wall of Izvestkovyi Bay; (2) in the western margin of the escarpments on the left bank of the Amur River west of the Kiselevka settlement; (3) on the right bank of the Amur River south of Lake Khavanda (Fig. 3).

Radiolarians were extracted from the rocks using the standard technique [25] with a weak (2–4%) solution of hydrofluoric acid. The identified species in the understanding of [16, 21] with some modifications of their taxonomic nomenclature according to [23] are listed in the table. The most part of the identified Cretaceous species were illustrated by electron-microscopic images (plate).

The age of the Cretaceous radiolarian assemblages was determined using a biostratigraphic scale of unitary association zones [22] including scales [18] and [21]. The established radiolarian assemblages were correlated with this scale using the method of unitary associations [17, 29] and BioGraph software [29]. The software algorithm yielded a succession of 56 unitary associations, which includes 3 new (in addition to 53 in the initial scale) associations spanning the Barremian (Fig. 4). A modified succession was correlated with the initial scale [22] and scale [21].

At site 1, the age was obtained for the cherts, olive–gray siliceous mudstones, and dark gray mudstone from different parts of several thin tectonic slices. The oldest age of the Middle Jurassic (late Bathonian–early Callovian) was determined for the cherts from the base of the northwestern slice (sample 2308-22). This age was determined using the Zonal Scale of Unitary Association Zones UAZ95 [16] and corresponds to zone 7 of this scale. The age of the cherts in the structurally lower (southeastern) slices was determined as late Berriasian–early Valanginian (sample 2308), late Hauterivian (sample 2308-13), and late Barremian (samples 2308-8 and 2308-10). The olive-gray siliceous mudstones in several slices were dated as the Barremian–Early Aptian (samples 2308-1, 2308-6, and 2308-21) and early Aptian (sample 2308-18). The age of the dark gray mudstone overlying the olive-gray siliceous mudstone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Radiolarians from cherts and siliceous mudstone of the Kiselevka–Manoma accretionary complex. The numbers after the species names designate the samples. The scale bar is 100 μm.

(**1**) *Acaeniotyle diaphorogona* Foreman, 125D1; (**2**) Acaeniotyle umbilicata (Rüst), KS-35; (**3**) *Becus gemmatus* Wu *sensu* O'Dogherty, 1994, 125D1; (**4**) *Becus helenae* (Schaaf) sensu O'Dogherty, 1994, 125D1; (**5**) *Cecrops septemporatus* (Parona), 125D1; (**6**) *Cinguloturris cylindra* Kemkin & Rudenko, 2308; (**7**) *Svinitzium puga* (Schaaf) sensu O'Dogherty, 1994, KS-35; (**8**) *Crucella euganea* (Squinabol), KKK-2; (**9**) *Cryptamphorella clivosa* (Aliev), 125D1, (**10**) *Cryptamphorella crepida* O'Dogherty, KS-35; (**11**) *Cryptamphorella gilkeyi* (Dumitrica), 125D1; (**12**) *Cyclastrum infundibuliforme* Rüst, 125D1; (**13**) *Archaeodictyomitra apiarium* (Rüst); (**14**) *Dictyomitra communis* (Squinabol), 125D1; (**15**) *Svinitzium depressum* (Baumgartner), 2308; (**16**) *Archaeodictyomitra excellens* (Tan), KS-35; (**17**) *Hiscocapsa asseni* (Tan), KS-35; (**18**) *Hiscocapsa grutterinki* (Tan), KS-35; (**19**) *Hiscocapsa orca* (Foreman), 125D1; (**20**) *Hiscocapsa uterculus* (Parona), 125D1; (**21**) *Mirifusus apenninicus* Jud, 125D1; (**22**) *Mirifusus minor* Baumgartner, 2308-13; (**23**) *Pantanellium lanceola* (Parona) gr., 2308-13; (**24**) *Tethysetta boesii* (Parona), 125D1; (**25**) *Tethysetta usotanensis* Tumanda, KS-8; (**26**) *Pseudodictyomitra carpatica* (Lozyniak), KS-8; (**27**) *Pseudodictyomitra hornatissima* (Squinabol), KS-35; (**28**) *Pseudodictyomitra lodogaensis* Pessagno, KS-8; (**29**) *Loopus nudus* (Schaaf), 2308-21; (**30**) *Pseudoeucyrtis apochrypha* O'Dogherty, KS-35; (**31**) *Pseudoeucyrtis hanni* (Tan), KS-35; (**32**) *Stichocapsa* ? *pulchella* (Rüst), 125D1; (**33**) *Stichomitra* ? *altiforamina* (Tumanda), 125D1; (**34**) *Stichomitra communis* Squinabol, KS-8; (**35**) *Stichomitra mediocris* (Tan), KS-8; (**36**) *Stichomitra simplex* (Smirnova & Aliev) sensu O'Dogherty, 1994, KS-8; (**37**) *Thanarla brouweri* (Tan), KS-35; (**38**) *Thanarla lacrimula* (Foreman), KS-35; (**39**) *Thanarla pacifica* Nakaseko & Nishimura, KS-35; (**40**) *Thanarla pseudodecora* (Tan), KS-8; (**41**) *Praexitus alievi* (Foreman), 125D1; (**42**) *Xitus clava* (Parona), KS-35, (**43**) *Xitus ? elegans* (Squinabol), KS-35; (**44**) *Xitus spicularius* (Aliev), KKK-2.

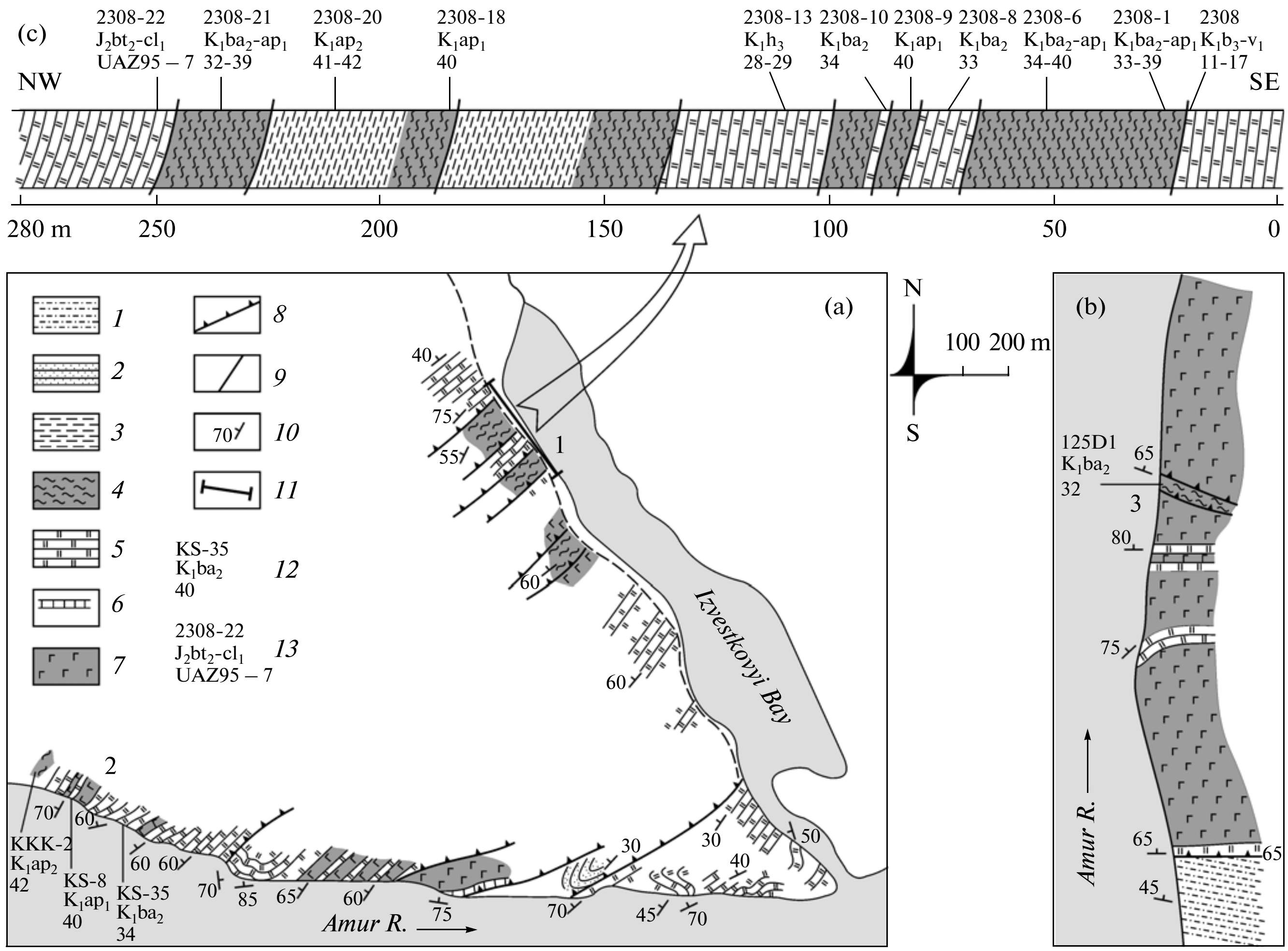

Fig. 3. Structure of the Kiselevka–Manoma accretionary complex in the Kiselevka Settlement area and the position and age of the radiolarian samples: (a) in exposures on the left bank of the Amur River (site 2) and the western side of Izvestkovyi Bay (site 1) in plan view; (b) in exposures on the right bank of the Amur River south of Lake Khavanda (site 3) in plan view; (c) detailed structure of the slice package in the western side of the Izvestkovyi Bay (site 1) section. The numbers show the numbers of the studied areas.

(*1*) turbidites of the Zhuravlevka turbidite basin (Fig. 3b); (*2*) siliciclastic turbidites; (*3*) dark gray mudstone; (*4*) olive–gray siliceous mudstone; (*5*) cherts; (*6*) limestones; (*7*) basalts; (*8*) steep thrusts in plan view; (*9*) steep thrusts in a section; (*10*) strike and dip of the bedding; (*11*) position of the section (Fig. 3c); (*12*) locality of the radiolarian samples with indication of the sample numbers and age of the deposits on the basis of radiolarians and according to the scale of the unitary associations (lower row of numerals); (*13*) the position of the radiolarian samples with indications of the sample numbers and the ages of the deposits based on the radiolarians and according to the scale of unitary association zones UAZ95 (the lower row of numerals).

Radiolarians identified in the rocks of the Kiselevka–Manoma accretionary complex

Species / Sample	125D1	KS-35	KS-8	KKK-2	2308	2308-1	2308-6	2308-8	2308-9	2308-10	2308-13	2308-18	2308-20	2308-21	2308-22
Acaeniotyle diaphorogona Foreman	x											x			
Acaeniotyle umbilicata (Rüst)	x	x	x			x						x			
Archaeodictyomitra apiarium (Rüst)	x				x					x	x				
Archaeodictyomitra excellens (Tan)	x	x				x				x				x	
Becus gemmatus Wu sensu O'Dogherty, 1994	x	x							x			x			
Becus helenae (Schaaf) sensu O'Dogherty, 1994	x									x	x	x			
Cecrops septemporatus (Parona)	x														
Cinguloturris cylindra Kemkin & Rudenko					x										
Crucella euganea (Squinabol)				x											
Cryptamphorella clivosa (Aliev)	x	x	x	x		x	x		x			x	x	x	
Cryptamphorella crepida O'Dogherty		x													
Cryptamphorella gilkeyi (Dumitrica)	x	x				x	x		x	x		x	x	x	
Cyclastrum infundibuliforme (Rüst)	x														
Dictyomitra communis (Squinabol)	x	x	x			x	x	x	x		x	x	x	x	
Dictyomitrella ? *kamoensis* Mizutani & Kido															x
Hiscocapsa asseni (Tan)		x	x	x		x	x	x	x	x	x	x	x	x	
Hiscocapsa grutterinki (Tan)		x	x	x		x	x	x	x			x			
Hiscocapsa orca (Foreman)	x										x				
Hiscocapsa uterculus (Parona)	x	x	x				x		x		x	x			
Loopus nudus (Schaaf)							x		x	x		x		x	
Mirifusus apenninicus Jud	x														
Mirifusus minor Baumgartner											x				
Pantanellium lanceola (Parona) gr.	x		x					x		x	x	x			
Parashuum officerense (Pessagno & Whalen)															x
Praexitus alievi (Foreman)	x														
Protunuma japonicus Matsuoka & Yao															x
Pseudodictyomitra carpatica (Lozyniak)	x	x	x			x	x	x	x	x	x	x		x	
Pseudodictyomitra hornatissima (Squinabol)	x	x	x			x	x		x			x			
Pseudodictyomitra lodogaensis Pessagno			x						x			x	x		
Pseudoeucyrtis apochrypha O'Dogherty	x	x	x						x			x			
Pseudoeucyrtis hanni (Tan)		x	x												
Stichocapsa ? *pulchella* (Rüst)	x							x							
Stichocapsa convexa Yao															x
Stichocapsa japonica Yao															x
Stichomitra ? *altiforamina* (Tumanda)	x														
Stichomitra communis Squinabol			x	x								x			
Stichomitra mediocris (Tan)			x	x			x		x	x		x	x		
Stichomitra simplex (Smirnova & Aliev) *sensu* O'Dogherty, 1994			x												
Svinitzium depressum (Baumgartner)					x										
Svinitzium puga (Schaaf) sensu O'Dogherty, 1994	x	x		x		x	x	x	x	x	x	x		x	
Tethysetta ? *dhimenaensis* (Baumgartner)															x
Tethysetta boesii (Parona)	x	x	x		x		x			x	x	x		x	
Tethysetta usotanensis (Tumanda)	x	x	x		x			x				x			
Thanarla brouweri (Tan)		x	x		x	x	x	x	x	x	x	x	x	x	
Thanarla lacrimula (Foreman)	x	x	x												
Thanarla pacifica Nakaseko & Nishimura	x	x	x			x	x		x			x			
Thanarla pseudodecora (Tan)			x												
Transhsuum brevicostatum (Ozvoldova)															x
Transhsuum maxwelli (Pessagno)															x
Transhsuum medium Takemura															x
Wrangellium okamurai (Mizutani)															x
Xitus clava (Parona)	x	x	x		x	x	x	x	x	x		x		x	
Xitus elegans (Squinabol)	x	x							x			x			
Xitus spicularius (Aliev)				x									x		

Note: The position of the samples is shown in Fig. 3. The cherts are samples KS-35, KS-8, 2308, 2308-8, 2308-10, 2308-13, and 2308-22; the siliceous silty pelites are samples 125D1, KKK-2, 2308-1, 2308-6, 2308-9, 2308-18, and 2308-21; and the silty pelites are samples 2308-20.

(sample 2308-20) was determined as Middle Aptian. Thus, the cherts were replaced by siliceous mudstone at the end of the Barremian–Early Aptian, while the hemipelagic siliceous mudstone gave way to terrigenous mudstone at the Early–Middle Aptian boundary.

The olive gray siliceous mudstone (sample KKK-2) recovered by a trench west of the cherts exposed on the left side of the Amur River near the Kiselevka settlement (site 2) yielded the Middle Aptian age. The age of the radiolarian assemblage previously obtained from the youngest cherts [7] was revised and determined as the late Barremian (sample KS-35) and Early Aptian (sample KS-8) according to the scale applied here. The age of the radiolarians in these samples was previously estimated within the Late Hauterivian–Early Barremian [7]. The deposits from this part of the accretionary complex show a transition to hemipelagic sedimentation at the Early–Middle Aptian boundary, i.e., later than the deposits from the side of Izvestkovyi Bay (site 1).

On the right bank of the Amur River south of Lake Khavanda (site 3), the olive-gray siliceous mudstone contain a Late Barremian radiolarian assemblage (sample 125D1). These siliceous mudstone are the oldest among the similar rocks of the considered area, and their age corresponds to the age of the cherts from two other sites. This part of the accretionary complex marks the earliest transition to the hemipelagic sedimentation.

INTERPRETATION

The obtained results specify the stratigraphy of the upper part of the deposits that were accumulated on the subducted oceanic plate and belong to the Kiselevka–Manoma accretionary complex. The systematic change from the Jurassic–Lower Cretaceous pelagic cherts to the Lower Cretaceous (Barremian–Lower-Middle Aptian) hemipelagic siliceous mudstone revealed in the sequence (Fig. 5) indicates that the oceanic plate entered the zone of hemipelagic sedimentation and approached the subduction zone at the end of the Early Cretaceous. It is suggested that the Middle Aptian terrigenous mudstone overlying the Early Aptian hemipelagic siliceous mudstone were accumulated in the immediate vicinity of the convergent plate boundary, possibly, on the near-oceanic slope of a deep-water trench.

It was established that the hemipelagic sedimentation in the deposits of the considered slice packages at the three sites began at different times (Fig. 5). A regularly arranged accretionary complex should demonstrate the systematic rejuvenation of the different-facies deposits and the boundaries between them from the rear to the frontal parts. In the studied area, we observe an opposite and sufficiently controversial age distribution of the deposits. The oldest hemipelagic sediments were found in its frontal part (site 3),

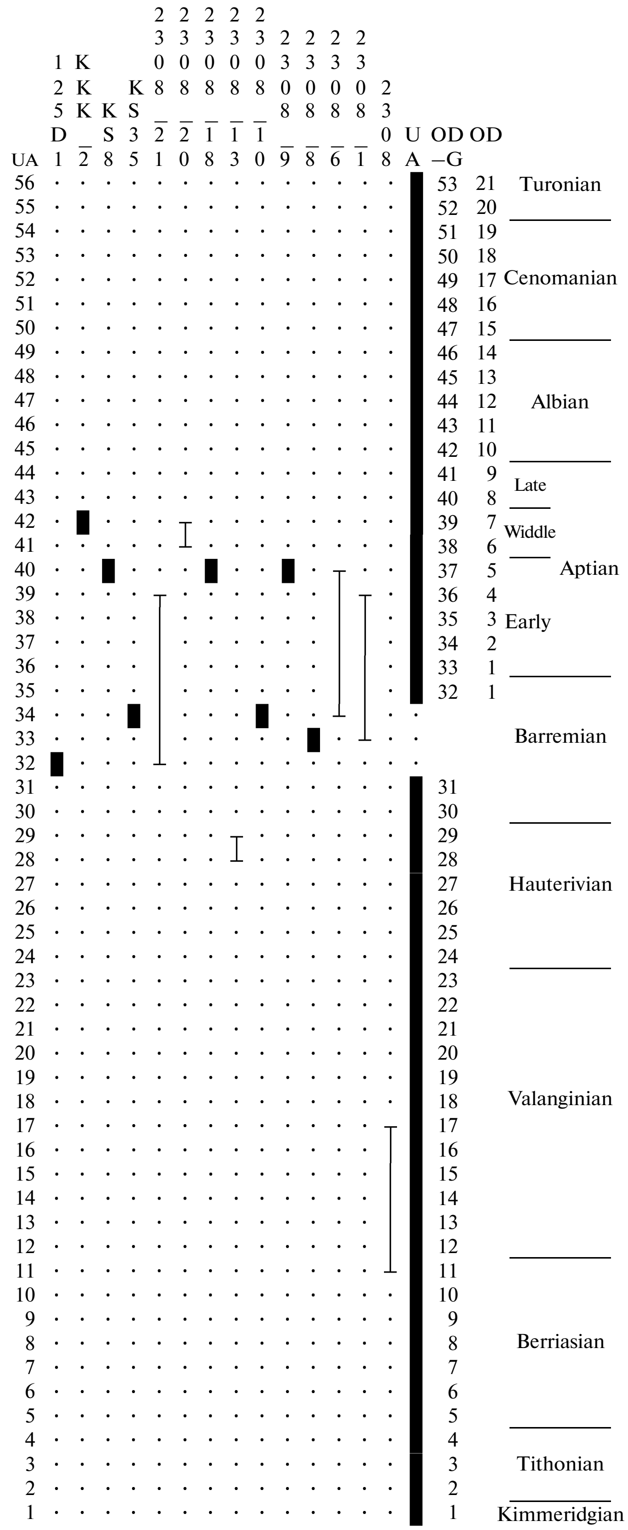

Fig. 4. Age of the radiolarian assemblages from the cherts, siliceous mudstone, and mudstone from the Kiselevka–Manoma accretionary complex according to the scale of the unitary associations.
The result of the correlation as performed by the BioGraph program [27]. The newly obtained unitary associations (the row of numerals on the left side) are correlated with the associations of the initial scale [21], as well as with scale [19] (the columns of numerals on the right side). The position of the samples is shown in Fig. 3.

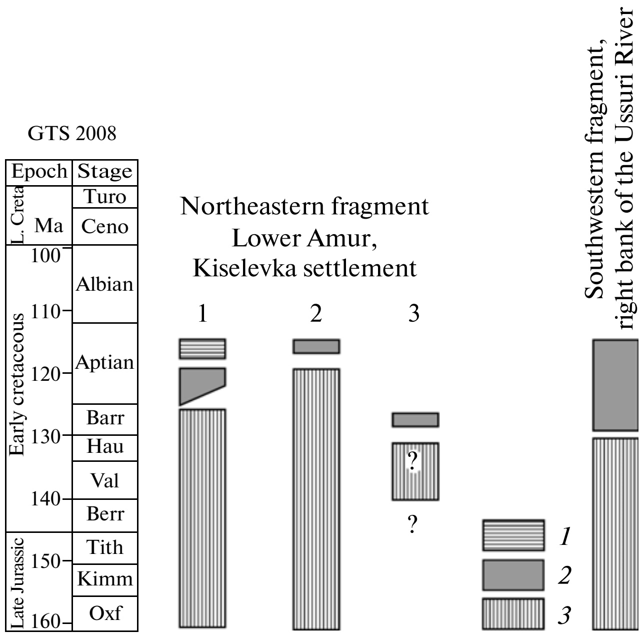

Fig. 5. Correlation of the upper part of the stratigraphic sequences from the northeastern fragment of the Kiselevka–Manoma accretionary complex in different sites in the area of the Kiselevka Settlement and the deposits from the southwestern fragment of the complex (the right bank of the Ussuri River) using the GTS-2008 geological scale [24].

(*1*) Mudstone; (*2*) hemipelagic siliceous mudstone; (*3*) pelagic cherts and within-plate basalts.

whereas the rocks in the rear zone (sites 1 and 2) have somewhat younger ages. Moreover, sites 1 and 2 located along a strike from each other a show notable difference in the age of similar rocks and the boundaries between them. The hemipelagic siliceous mudstone from site 1 are coeval with the youngest pelagic cherts from site 2, whereas the terrigenous mudstone from site 1 were formed simultaneously with the siliceous mudstone from site 2. Such a disturbance of the expected age distribution can be explained by several reasons: (1) the complex and temporally variable configuration of the hemipelagic area; (2) the different amplitude of the underthrusting of the accreted slices supposedly in the zone of tectonic underplating of the accretionary wedge; (3) the significant accretionary transformations, including inferred [8] large-scale sinistral displacements, which could lead to the complex juxtaposition of different fragments of the formed accretionary wedge and the disturbance of its initial tectonic zoning. In general, the age interval of the hemipelagic sediments in the studied area is close to that of similar deposits (Fig. 5) from the southwestern fragment of the Kiselevka–Manoma accretionary complex on the right side of the Ussuri River near the boundary with China [8].

The youngest deposits involved in the accretionary complex are Middle Aptian hemipelagic siliceous mudstone and terrigenous mudstone. The Albian age of these deposits determined using earlier biostratigraphic scales [7] should not be taken into account at present. The accretion age may be established as post-Middle Aptian, which is consistent with estimates (Late Aptian–beginning of the Albian) obtained for the southwestern fragment of the accretionary complex [8].

CONCLUSIONS

The new age data on the deposits of the Kiselevka–Manoma accretionary complex in the Lower Amur region specify the available stratigraphic concepts for the upper part of the siliceous deposits that were accumulated on the subducted oceanic plate. The Jurassic–Early Cretaceous pelagic siliceous sedimentation gave way to the hemipelagic siliceous–clayey one in the middle Early Cretaceous, which marks the approach of the oceanic plate to the subduction zone. The age of the hemipelagic sedimentation at the three studied sites varied from the Late Barremian to Middle Aptian. The oldest hemipelagic sediments were established in the frontal part of the accretionary complex, which suggests the intricate arrangement of the accreted slices and the possible disturbance of the initial tectonic zoning of the complex. The accretionary events are supposedly post-Middle Aptian in age.

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