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Tektono-Stratigraphy as a Reflection of Accretion Tectonics Processes (on an Example of the Nadankhada-Bikin Terrane of the Sikhote-Alin Jurassic Accretionary Prism, Russia Far East)

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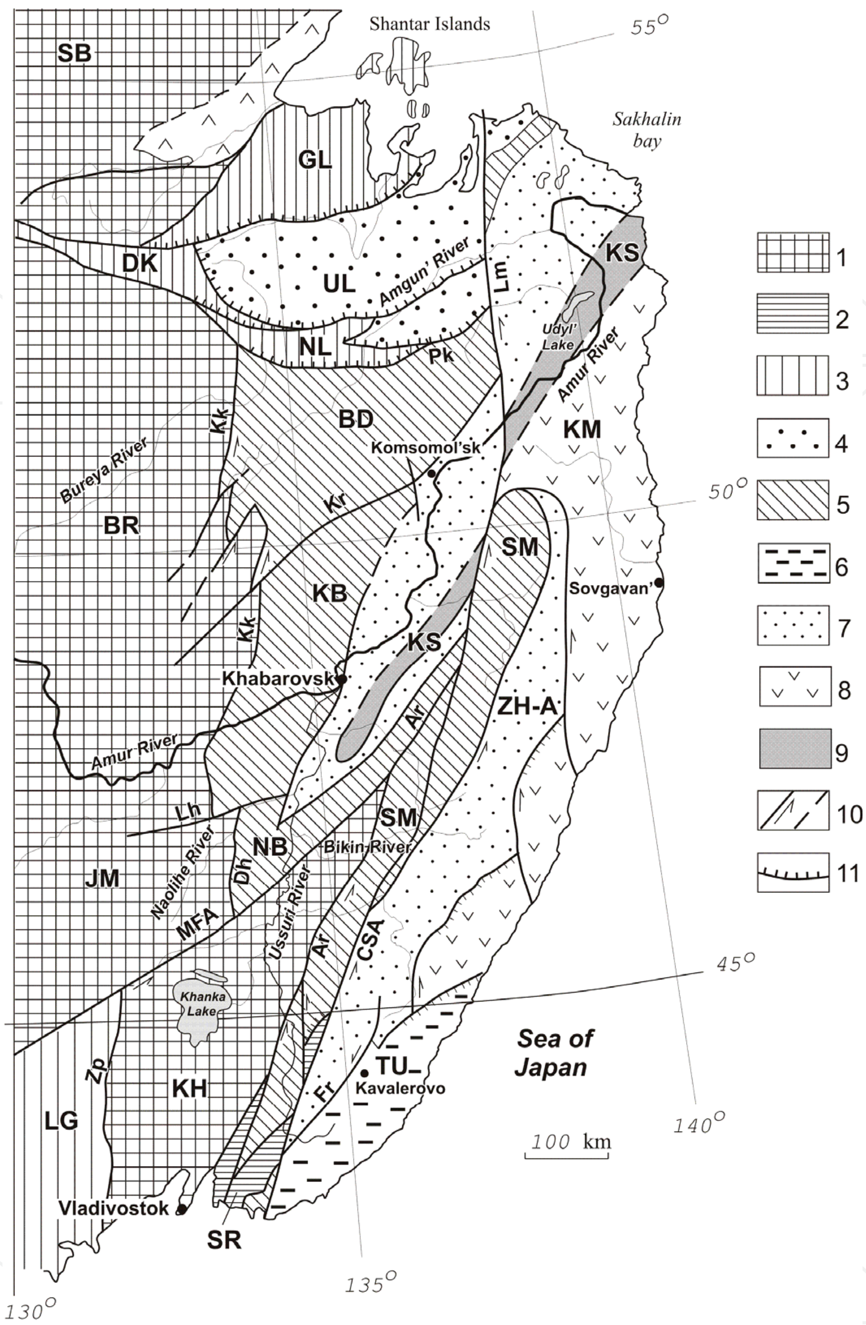
1. Introduction

The Sikhote-Alin folded belt is one of the Asia eastern margin regions, where terranes of ancient accretionary prisms are widely distributed. Within this region there are fragments, as a minimum, of three such different-aged prisms - Jurassic, Early Cretaceous and Middle Cretaceous (fig. 1). Accretionary prisms are complicate-dislocated sedimentary complexes that are formed at the basis of continental or island-arc slopes as a result of accretion of fragments of the sedimentary cover and morphologically positive structures of an oceanic plate during its subduction. The subduction of an oceanic plate under a continent or an island arc is commonly accompanied by intense deformation of the sedimentary cover deposits. At first, in the frontal part of the slope basis the upper part of a sedimentary cover (trench turbidite) under the action of "bulldozer effect" (off-scraping) repeatedly imbricate, forming a series of tectonic slices of terrigenous composition (fig. 2). Secondly, pelagic and hemipeladic sediments located below of an imbrication zone, plunging into a subduction zone rumple under the action of simple shear (effect of drag folding) into the different-amplitude and disharmonious overturned folds, which axial planes are inclined towards a trench. Crumpling of sediments continues until ultimate strength limit of rocks is reached and the ruptures are appearing. Further along these ruptures numerous underplating and doubling of a primary cut-section of an oceanic plate cover occur that results in formation of imbricate-underthrusted structure of the accreated rocks (Hashimoto & Kimura, 1999; Kimura, 1997; Kimura & Mukai, 1991; Moore & Byrne, 1987; Seely et al., 1974; Sokolov, 1992, 1997; Sokolov et al., 2001; etc.). For this reason the accretionary prisms are a tectonic package of repeatedly alternating tectonic slices consisting of marine (pelagic and hemipelagic deposits and also fragments of seamountns), oceanic-margin (turbidites), and chaotic (melange and olistostromes) formations. Structure of ancient accretionary prisms is even more complex because of a numerous post-accretion deformations such as thrusts and strike-slip faults.



1 – Early Paleozoic continental blocks: Bureya (BR)–Jiamusi (JM)–Khanka (KH) superterrane and Siberian craton (SB); 2 – Fragment of an Early Paleozoic continental margin - Sergeevka terrane (SR); 3 – Permian-Triassic accretionary prisms – Dzhagdy-Kerbin (DK), Nilan (NL), Galam (GL), Laoelin-Gradek (LG) terranes; 4 – Jurassic turbidite basin - Ulban and Un'ya-Bom terranes (UL); 5 – Jurassic accretionary prism – Samarka (SM), Nadankhada-Bikin (NB), Khabarovsk (KH) and Badzhal (BD) terranes; 6 – Tithonian-Hauterivian accretionary prism - Taukha terrane (TU); 7 – Early Cretaceous turbidite basin - Zhuravlevka-Amur terrane (ZH-A); 8 – Hauterivian-Albian island arc – Kema (KM) terrane; 9 – Hauterivian-Albian accretionary prism - Kiselevka-Manoma (KS) terrane; 10 – left-lateral strike-slip faults; 15 – thrusts. Faults: Lm- Limourchansky, Pk – Paoukansky, Kk – Koukansky, Kr – Koursky, MFA - Misha-Fushung-Alchan, Lh – Lyaolihe, Dh – Dahezhen, Ar - Arsen'evsky, CSA – Central Sikhote-Alin, Fr – Fourmanovsky, Zp – Zapadno-Primorsky.

Fig. 1. The tectonic scheme of Sikhote-Alin region and adjoining areas (After Khanchuk, 2006 with additions)

It is obvious, that the absence of normal sedimentary contacts between various lithological groups of rocks in such tectono-sedimentary complexes complicates the decision of a number of geological tasks such as study of stratigraphic sequence of deposits, clearing-up structure of an area of accreated formations distribution, its geological evolution, etc. Nevertheless, in some individual tectonic slices, the fragments of primary consecutive section of pelagic to hemipelagic or hemipelagic to oceanic-margin formations are observed. Numerous results of microfaunistic researches of such fragments (Kemkin, 1996; Kemkin & Golozubov, 1996; Kemkin & Kemkina, 1999; Kemkin & Khanchuk, 1992; Kemkin & Khanchuk, 1993; Kemkin & Philippov, 2002; Kemkin & Rudenko, 1998; Kemkin & Taketani, 2008; Kemkin et al., 1999; Kirillova, 2002; Philippov et al., 2000; Philippov et al., 2001; Philippov & Kemkin, 2007; Zyabrev, 1998; Zyabrev & Matsuoka, 1999, etc.) have allowed us to reconstruct primary cut-sections of accreated paleooceanic deposits. Their lowermost part is composed by pelagic cherts which are gradually replaced by hemipelagic cherty-clayey formations, and, further, by terrigenous rocks. Such sequences of deposits named by Oceanic Plate Stratigraphy sequences (Berger & Winterer, 1974; Isozaki et al., 1990; Wakita & Metcalfe, 2005, etc.) reflect the history of sedimentary process on an oceanic plate during its drift from the spreading zone to the subduction zone. Each lithological group of these sequences is very informative. For example, cherts characterize a history and features of pelagic sedimentation. Hemipelagic deposits (siliceous mudstones, mudstones and aleuroargillite) fix the moment of the approach of a foremost site of an oceanic plate to convergent border. The terrigenous rocks, which accumulation occurred in a trench, are the indicator of the time of beginning of immersing of an oceanic plate into subduction zone and, accordingly, of subsequent accretion of fragments of its sedimentary cover.

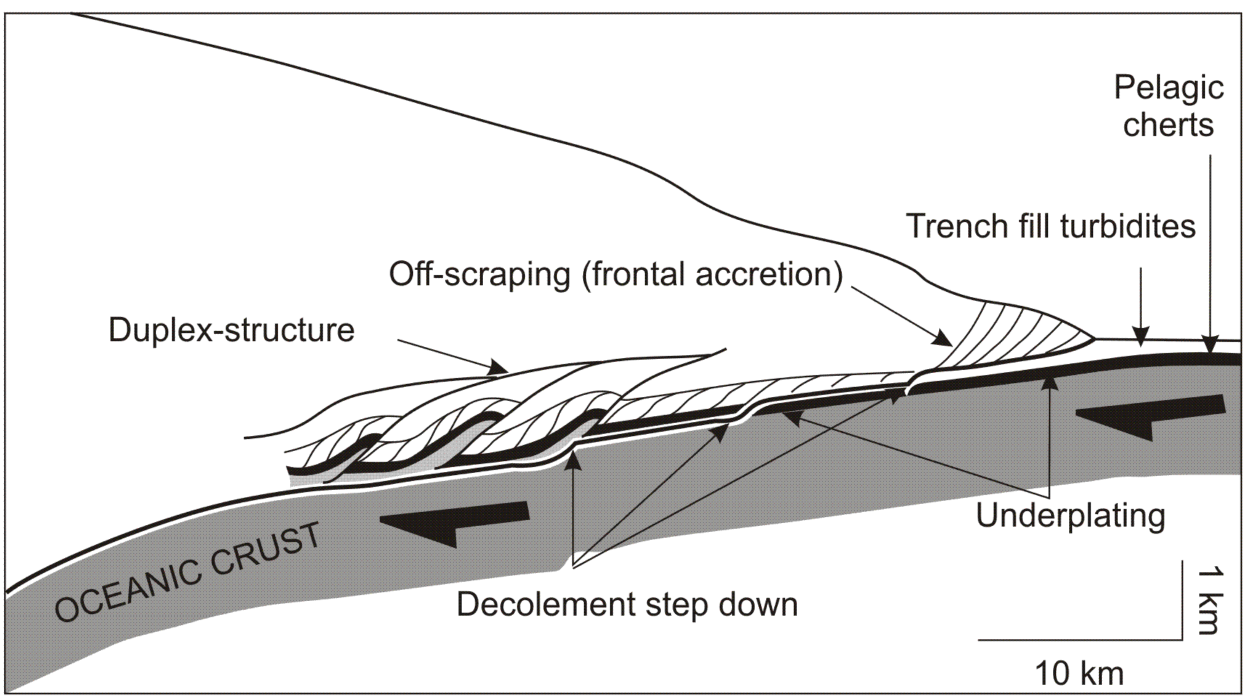


Fig. 2. Model of an accretionary prism structure (After Hashimoto & Kimura, 1999)

Knowing the age of rocks of such Oceanic Plate Stratigraphy sequences in various tectonic slices of the accretionary prism, it is possible to specify the time when individual oceanic fragments were accreted. These date give us the base to subdivide the accretionary prism to several tectono-stratigraphic units responding to certain stages of the prism formation. Subsequent mutual correlation and comparison of the allocated tectono-stratigraphic units allows to reconstruct a succession of the accretion of an oceanic plate fragments and to specify the prism structure as a whole.

Thus, a study of the accretionary prisms is very important as for specification of geological structure and evolution of regions composed of such prisms, as for elucidation of specific features of the accretion process in different areas of a convergent boundary, as well as for correlation of geological events at a junction zone of lithospheric plates, and for reconstruction of a geodynamic evolution of continental margins along which the accretionary prisms were formed.

One of these ancient prisms is a Jurassic accretionary prism, which was being formed during more than 70 m.y. by the consecutive accretion of different-aged and different-facies formations of Paleo-Pacific under the Paleo-Asian continent east margin. In the Sikhote-Alin region, the Jurassic prism is represented by four terranes: Samarka, Nadankhada-Bikin, Khabarovsk and Badzhal.

This article presents results of lithological-biostratigraphic studying of chert-terrigenous formations of the Nadankhada-Bikin terrane of the Sikhote-Alin Jurassic accretionary prism, which allow allocating in terrane structure three different-aged tectono-stratigraphic complexes reflecting successive stages of its formation.

2. Regional tectonic position and the previous researches

The Nadankhada-Bikin terrane is located in the lower reaches of the Ussuri River, in the area between the Black River and the Naolihe River mouths (fig. 3). It extends for about 350 km in a northeast direction along the northwest edge of the Bureya-Jiamusi-Khanka superterrane and is about 60 km in width. The terrane is separated from the Bureya-Jiamusi-Khanka superterrane by Dahezhen fault in the west and by Misha-Fushung-Alchan fault in the south. The Lyaolihe and the Arsen'evsky faults separate it from the Khabarovsk and the Samarka terranes, respectively. The Ussuri River valley divides this terrane into two parts: Nadankhada, located in China, and Bikin, located in Russia.

The Bikin part of the terrane is composed mainly (fig. 4 A) of cherts and terrigenous rocks and much less of volcanogenic formations that had formerly been referred to the Carboniferous-Permian Samurskaya Series (Bersenev, 1969), and later, after the findings of Triassic conodonts in the cherts, to the Triassic-Jurassic chert-terrigenous suite and Early Cretaceous volcanogenic-terrigenous Koultoukha suite (Liht, 1997). A structure of this area of the Sikhote-Alin was considered as a multiple sedimentary alternation of cherts, terrigenous rocks and rare layers of volcanites. However, it was established by the subsequent researches (Phillippov, 1990; Phillippov & Kemkin, 2004) that the cherts compose generally the stratum-like bodies occurring among terrigenous deposits and limited by faults. The results of microfaunistic study have shown that the age of the cherts ranges from Middle Triassic to Early Jurassic (in some cut-sections up to Middle Jurassic), and the age of the terrigenous rocks is Middle-Late Jurassic (up to Early Berriasian in some cut-sections). These data convincingly testify that repeated alternation of Triassic cherts and Jurassic terrigenous rocks can not be sedimentary. It is result of tectonic recurrence. As a whole, the structure of the Bikin part of the terrane represents a package of repeated alternation of tectonic slices of cherts and terrigenous rocks.

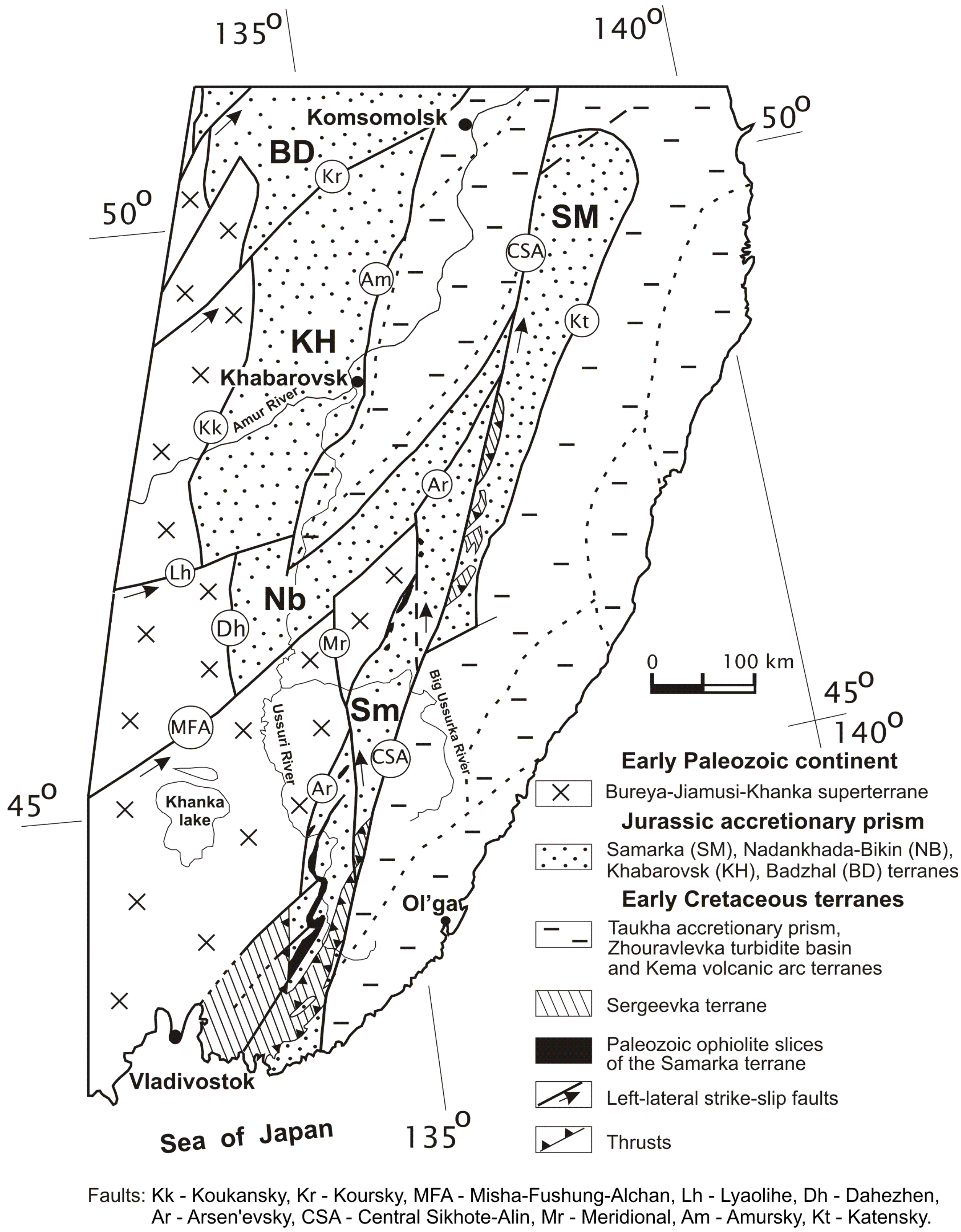
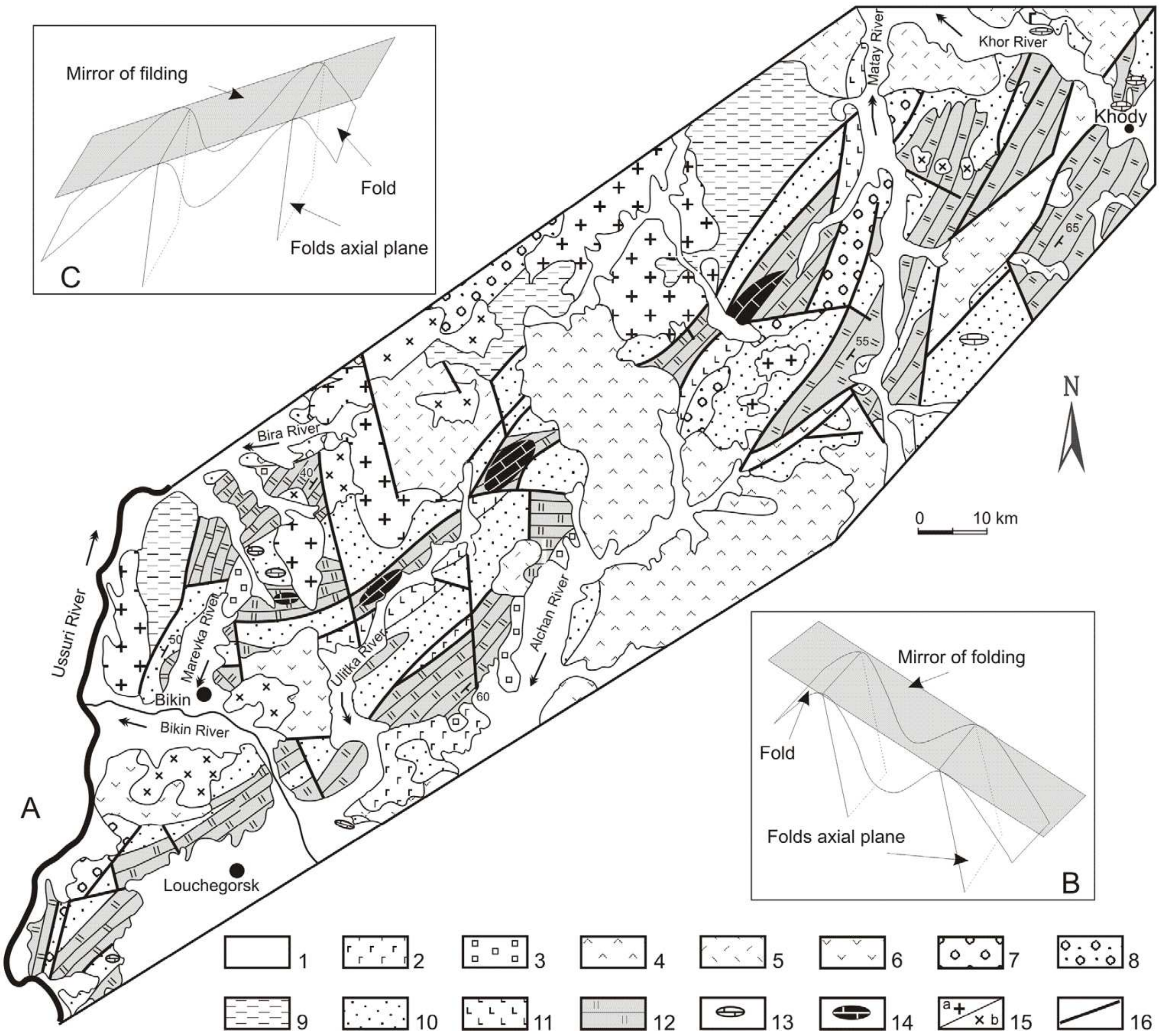


Fig. 3. Terranes of Jurassic accretionary prism (After Kemkin & Philippov, 2001 with additions)

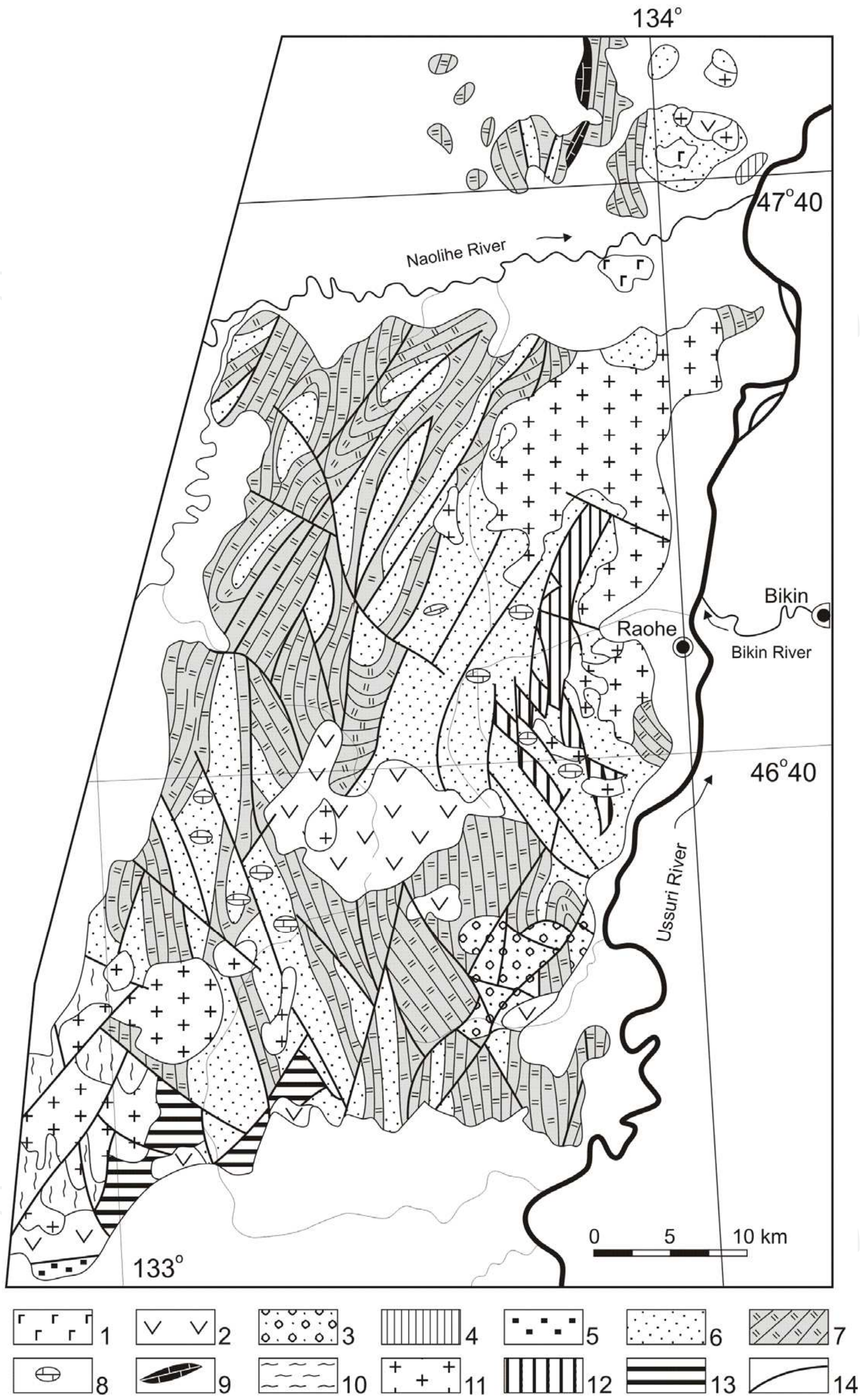


1 - Quaternary sediments; 2 - Neogene basalt; 3 - Cenozoic continental terrigenous rocks; 4 - Paleogene andesite, 5 - Late Cretaceous rhyolite and rhyolitic tuff, 6 - Albian-Cenomanian basalt and andesite; 7 - 9 - shallow-water terrigenous sediments of different ages: Albian (7), Aptian-Albian (8), Berriasian (?)-Valanginian (9); 10 - 12 - volcanic-sedimentary rocks of Jurassic accretionary prism, dominated by clastic (10), volcanic (11), and siliceous (12) rocks; 13 - Late Paleozoic limestone blocks; 14 - Late Triassic limestone interbeds in chert; 15 - Early Cretaceous granite (a) and granodiorite (b); 16 - faults.

Fig. 4. The scheme of geological structure of the terrane Bikin part (After Philippov, 1990 and Pfilippov & Kemkin, 2004 with additions)

The rocks composing this stack of slices are crumpled in the compressed different-amplitude and asymmetric folds of northeast (on some sites submeridional) strike. In the central and eastern parts of the Bikin area the axial planes of folds have northwest vergence with a mirror of folding inclined on the southeast (fig. 4 B). In the western part, on the contrary, the folds axial planes are inclined on the southeast and the mirror of folding is gently immersing to the northwest (fig. 4 C).

The inversion of the folds axial planes in the central and eastern parts is caused by the flexure-like bending of the Jurassic prism deposits during the left-lateral motion of the Bureya-Jiamusi-Khanka superterrane block along the Misha-Fushung-Alchan fault (Khanchuk, 1994).



1 - Neogene basalt; 2 - Late Cretaceous rhyolite and rhyolitic tuff, 3 - 5 - shallow-water terrigenous sediments of different ages: Aptian-Albian (3), Tithonian-Berriassian (4), Late Triassic (5); 6 - 7 - sedimentary rocks of Jurassic accretionary prism, dominated by clastic (6) and siliceous (7) rocks; 8 - Late Paleozoic limestone blocks; 9 - Late Triassic limestone interbeds in chert; 10 - metamorphic rocks;11 - Early Cretaceous granite; 12 - Early Mesozoic (?) ophiolite (Zhaohe complex); 13 - Middle Paleozoic ophiolite (Dahezhen complex); 14 - faults.

Fig. 5. The scheme of geological structure of the terrane Nadankhada part (After Shao et al., 1992 with additions)

The similar situation takes place in the Nadankhada part of the terrane (so-called Nadankhada ridge), which occupies a territory between the Naolihe, Tsikhulinhe and Ussuri rivers (fig. 5). Up to middle 1980, this territory was considered to be composed of mainly Upper Paleozoic volcanogenic-chert-terrigenous formations (Li et al., 1979). Later, during the joint Chinese-Japanese researches, it has been established that the cherts contain Triassic and the siliceous shales contain Middle Jurassic radiolarians (Kojima & Mizutani, 1987; Mizutani et al., 1986).

According to the subsequent works (Mizutani et al., 1989, 1990; Shao et al., 1990, 1992 etc.), geological structure of the Nadankhada ridge was defined as a complex alternation of tectonic slices of terrigenous rocks and cherts crumpled in the asymmetric and overturned folds of mostly northeast strike. In the southwestern part of the Nadankhada area, the northeast orientation of the folds axes is gradually changing to the submeridional and further to the northwestern and sublatitudinal one (fig. 5).

3. Structure of the Nadankhada-Bikin terrane chert-terrigenous sequences and age of the chert-terrigenous formations

Deformations behavior of the Nadankhada-Bikin terrane deposits and spatial orientations of the major structural elements of rocks occurrence (i.e. a general dipping of layers, a vergence of the folds axial planes, a direction of the folding mirror inclination) are such that the tectonic slices of the lower structural level of the terrane are cropped out in its central and

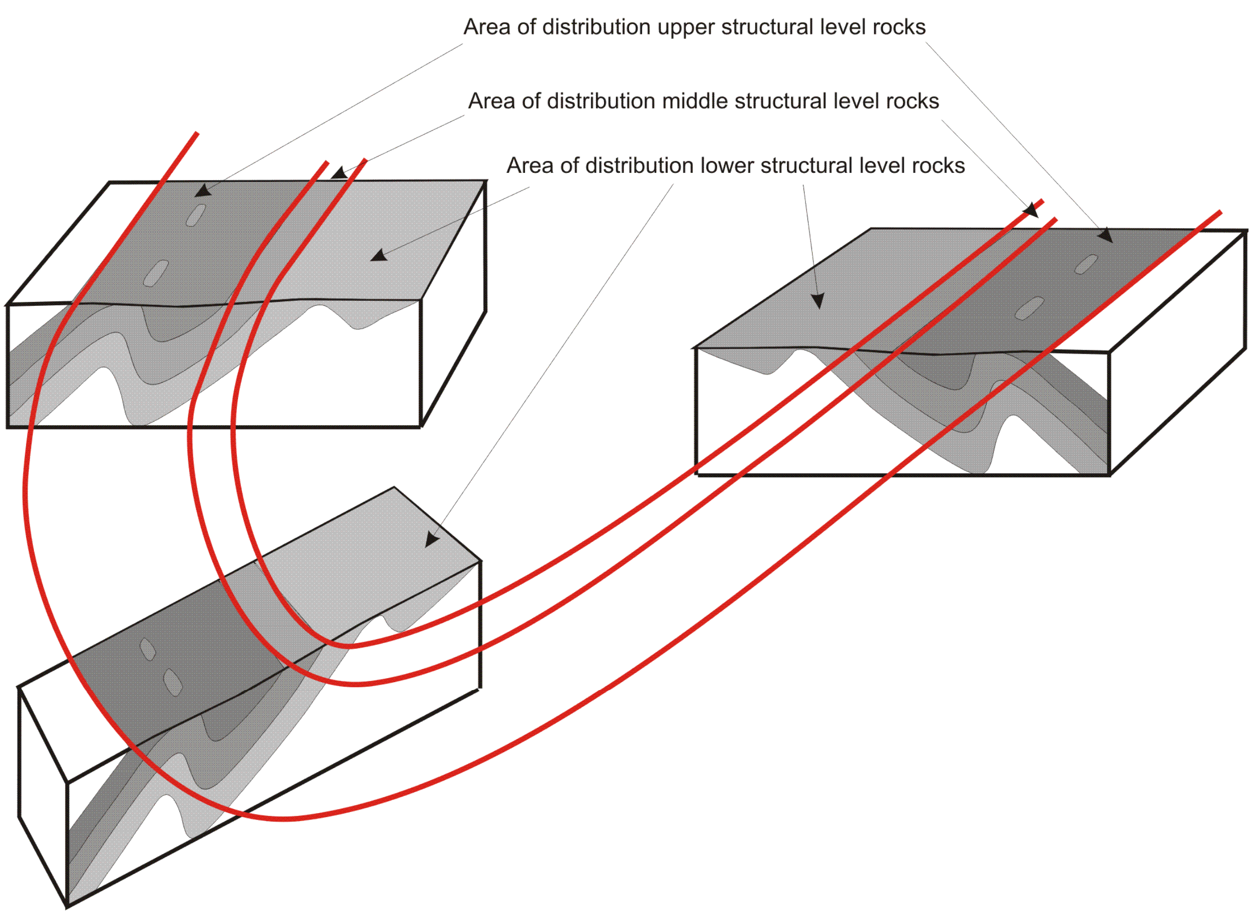


Fig. 6. Block-diagram illustrating distribution of rocks of various structural levels of the Nadankhada-Bikin terrane folded formations on a denuded earth surface

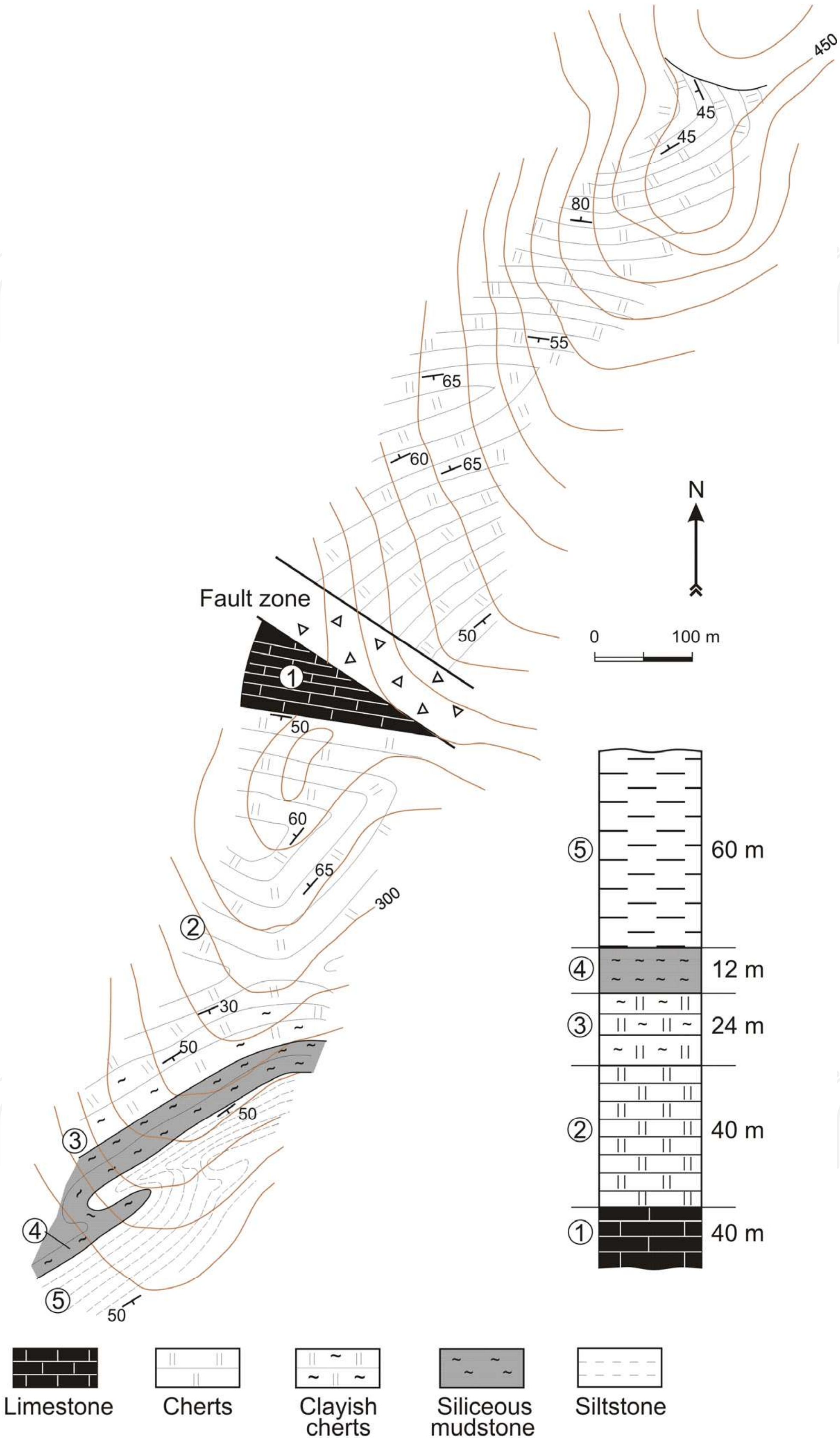


Fig. 7. Example of structure of the chert-terrigenous sequence fragment on the right bank of the Ulitka River (After Philippov & Kemkin, 2004)

northeastern parts, and those of the upper level - in the southeastern, southwestern and western parts of the terrane (fig. 6). In some tectonic slices, fragments of primary cut-section of the paleooceanic plate sedimentary cover are observed, in which cherts are sequentially and gradually replaced by the siliceous mudstones and then by the terrigenous rocks (fig. 7). The results of lithological and biostratigraphic researches of such chert-terrigenous sequences fragments belonging to various structural levels of the terrane show some differences in their composition, structure and age.

3.1 Lower structural level

The most complete fragment of cut-section of the chert-terrigenous sequence has been investigated in the interstream area between the Ulitka and Zolotoy Klyuch Rivers (Phillippov & Kemkin, 2004). Here are observed (from the bottom to top):

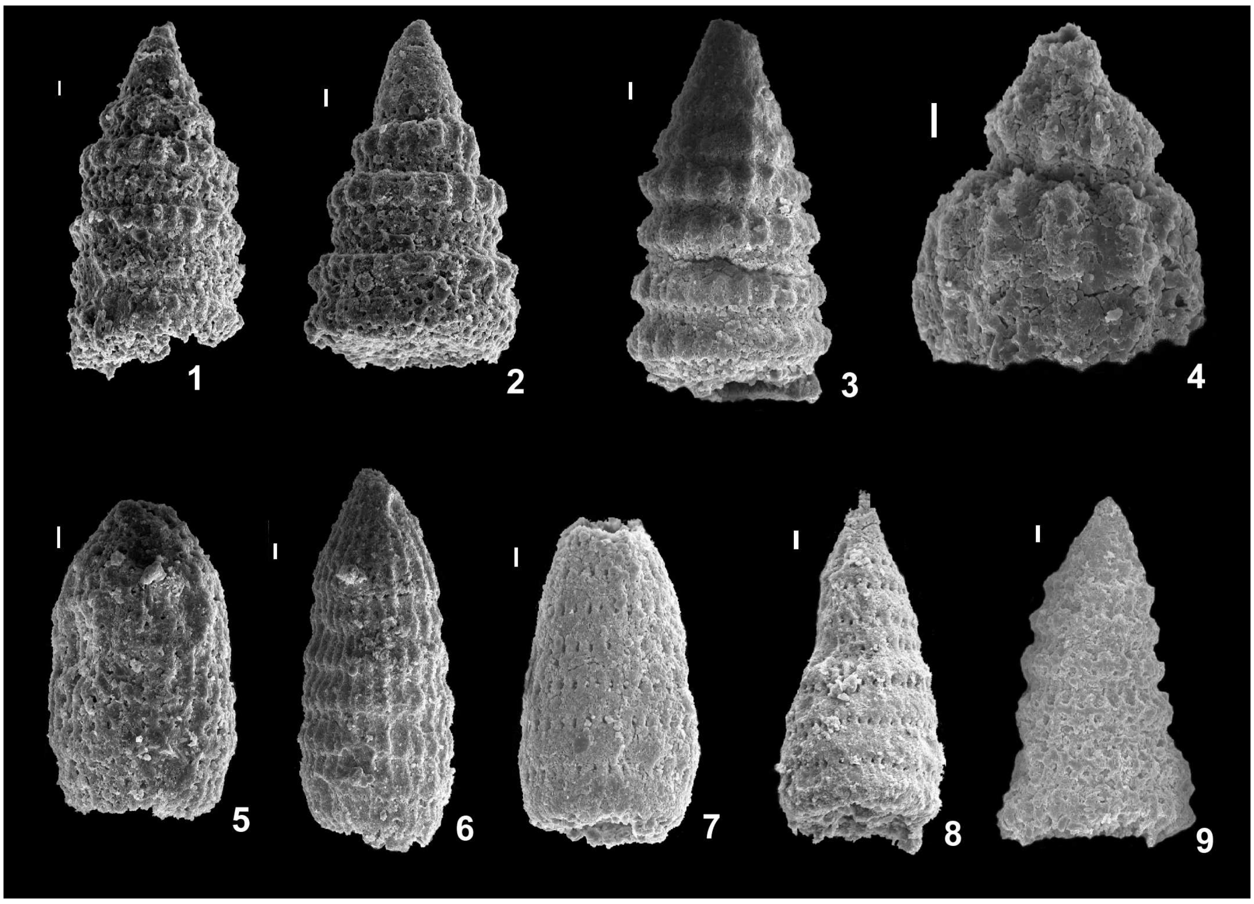
1. Grey, light grey and pink-grey bedded cherts	60 m
2. Grey and light grey limestones and siliceous limestones	40 m
3. Grey and light grey bedded cherts	40 m
4. Grey and greenish-grey massive clayish cherts	24 m
5. Light greenish-grey slightly layered siliceous mudstones	12 m
6. Dark grey layered mudstones and silty mudstones	60 m
7. Dark grey siltstones with rare layers of fine-grained sandstones	20 m
8. Alternation of light grey fine-grained sandstones and dark grey siltstones, (rhythms from 20 to 40 cm). Sandstones contain layers of alkaline basalts and hyaloclastites (10-20 m, rarely up to 100 m). In the upper part of this pack, sandstones are replaced by chaotic formations represented by aleuro-psammites containing different-sized lumps, blocks and fragments of cherts and sandstones.	more than 400 m

According to the radiolarian and conodont fauna (Phillippov, 1990) the age of the cherts ranges from Middle Triassic (Anisian) to Middle Jurassic (Bathonian-Callovian). The limestones embedded in the middle part of the chert cut-section contain Late Carnian-Early Norian conodonts.

Oxfordian-Tithonian radiolarians *Archaeodictyomitra minoensis (*Mizutani), *Archaeodictyomitra* ex gr. *apiarium* (Rust), *Cinguloturris cylindra* Kemkin et Rudenko *Podobursa* sp., *Pseudodictyomitra primitiva* Matsuoka & Yao, *Pseudodictyomitra carpatica* (Lozyniak), *Spongocapsula perampla* (Rust), *Stichocapsa* ex gr. *cribata* Hinde, *Xitus* sp. and others have been extracted from the siliceous mudstones and silty mudstones (fig. 8), and Late Tithonian-Early Berriasian Buchia *Buchia* cf. *unshensis* (Pavl.), *B*. cf. *okensis* (Pavl.) has been found in the siltstones (Phillippov & Kemkin, 2004).

3.2 Middle structural level

Fragments of the chert-terrigenous sequence belonging to the middle structural level are exposed in the numerous outcrops in the interstream areas and banks of the Peshkova, Perepelinaya, Cheremshanka, Kamenushka, and Kedrovka Rivers (all are the right tributaries of the Ussuri River), as well in the road quarries. The reconstructed cut section looks as following:



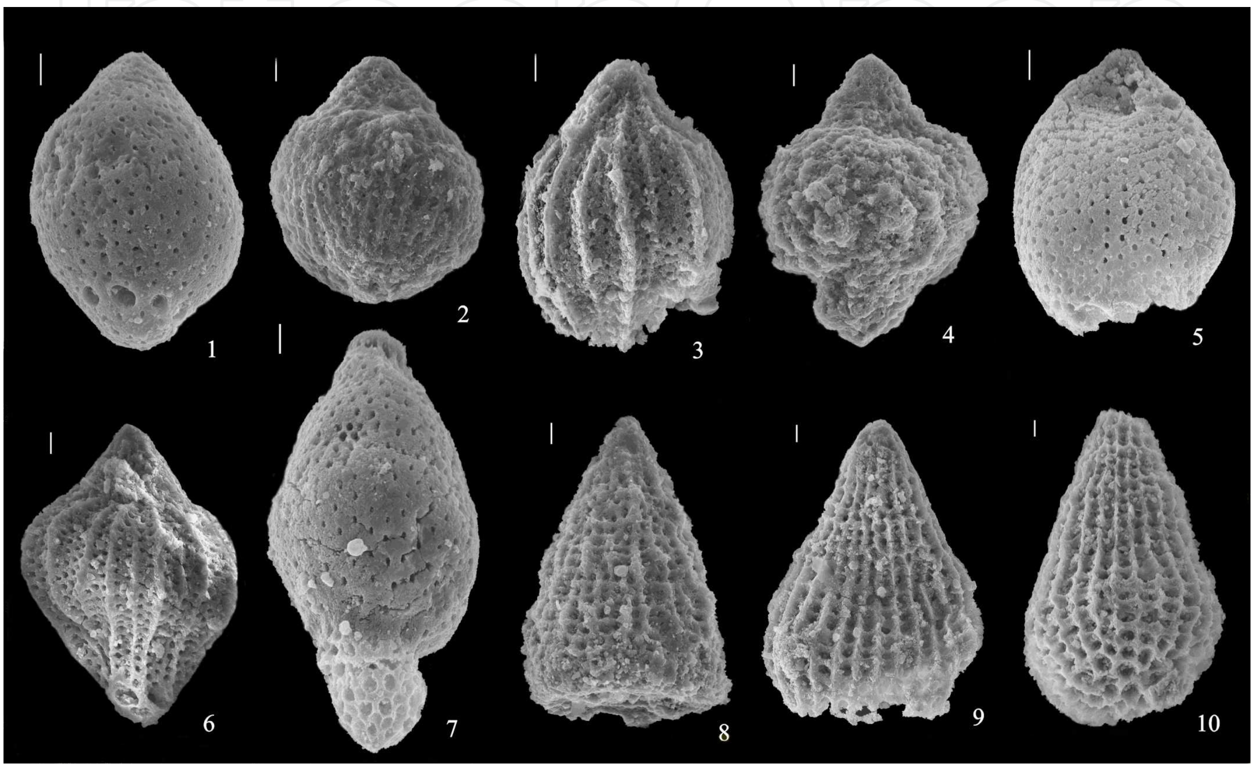
1-2. *Cinguloturris cylindra* Kemkin et Rudenko (sample Sv-3), 3. *Pseudodictyomitra carpatica* (Lozyniak) (sample Sv-3), 4. *Eucyrtidiellum pyramis* (Aita) (sample Sv-3), 5. *Archaeodictyomitra* ex gr. *apiarium* (Rust) (sample Sv-3), 6. *Archaeodictyomitra minoensis* (Mizutani) (sample Sv-3), 7 - 8. *Pseudodictyomitra* ex gr. *nuda* Shaaf (sample Sv-3), 9. *Wrangellium* cf. *puga* (Schaaf) (sample Sv-5). All markers – 10 μκ.

Fig. 8. Some Upper Jurassic radiolarians from silty mudstones of Lower structural level of the Nadankhada-Bikin terrane Bikin part

1. Alternating grey and dark grey cherts (each bed 1-7 cm thick) and yellowish-grey siliceous mudstones (each bed 0.5-5 cm thick)	30 m
2. Grey bedded cherts	66 m
3. Grey and dark grey clayish cherts alternating in the upper part of the layer with thin layers of greenish-grey siliceous mudstones	22 m
4. Greenish-grey siliceous mudstones	8 m
5. Dark grey and black mudstones and silty mudstones	40 m
6. Dark grey siltstones with thin rare layers of fine-grained sandstones in the upper part of the layer	90 m

Based on numerous data of radiolarian analysis, the age of the cherts is established as Middle Triassic (Anisian)-early Middle Jurassic (Aalenian).

The siliceous mudstones contain abundant radiolarians (fig. 9) *Archaeodictyomitra* ex gr. *rigida* Pessagno, *Sethocapsa* cf. *funatoensis* Aita, *Stichocapsa* cf. *robusta* Matsuoka, *Xitus* sp., *Stichocapsa* cf. *convexa* Yao, *Protunuma turbo* Matsuoka, *Stichocapsa decora* Rust, *Dictyomitrella* cf. *kamoensis* Mizutani et Kido, *Parvicingula* cf. *dhimenaensis* s.l. Baumgartner, *Sethocapsa* sp., *Transhsuum* cf. *brevicostatum* gr. (Ozvoldova), *Transhsuum* cf. *maxwelli* gr. (Pessagno), *Archicapsa* cf. *pachyderma* Tan, *Pantanellium* sp., *Tricolocapsa* sp., *Unuma* sp., *Eucyrtidiellum unumaensis* Yao, *Parahsuum officerence* (Pessagno et Whalen), *Cyrtocapsa mastoidea* Yao, *Stichocapsa japonica* Yao, *Unuma latusicostatus* (Aita), *Parvicingula* cf. *nanoconica* Hori et Otsuka, *Tricolocapsa* cf. *fusiformis* Yao, *Tricolocapsa* cf. *plicarum* Yao, *Podobursa* sp., *Mesosaturnalis* sp., *Hsuum* cf. *mirabundum* Pessagno et Whalen, *Unuma typicus* Ichikawa et Yao, *Napora saginata* Takemura, *Napora* sp., that indicate Bajocian age of host rocks.

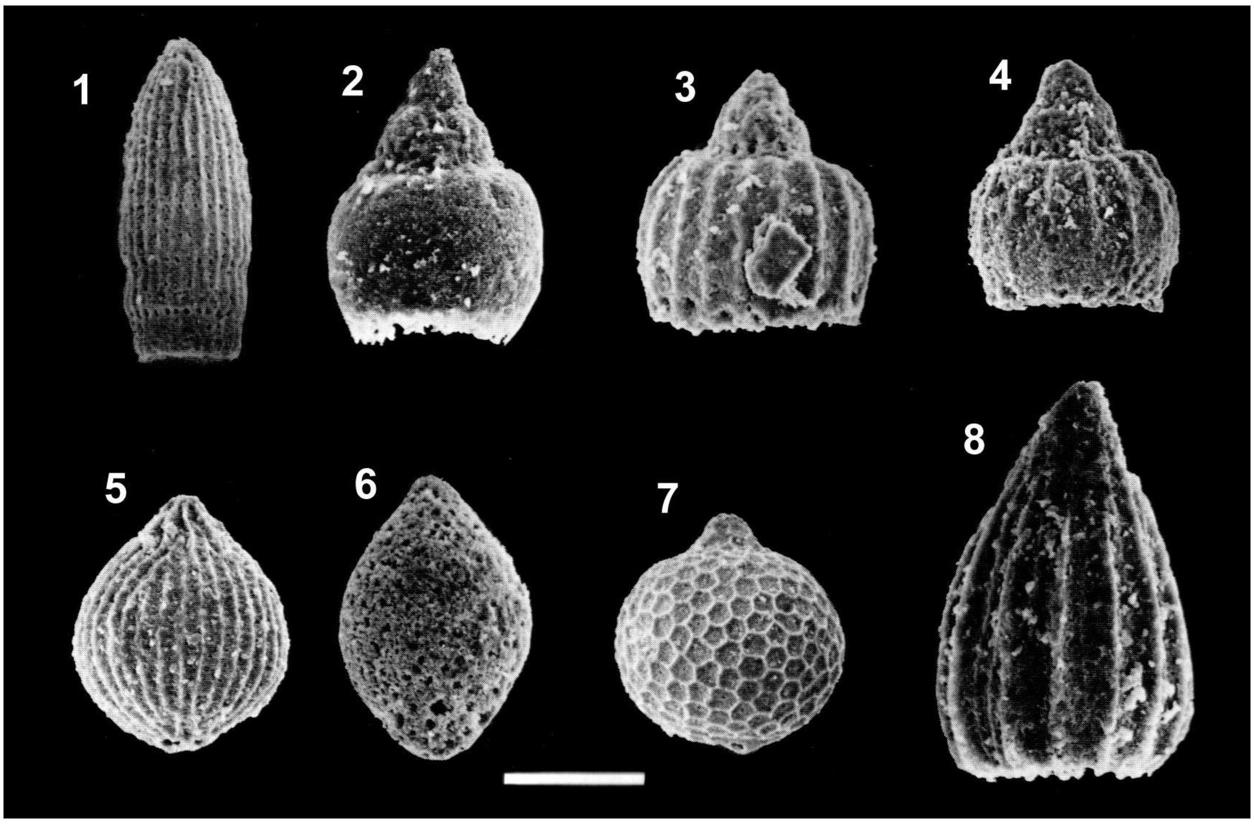


1. *Tricolocapsa fusiformis* Yao (sample Khor-3), 2. *Tricolocapsa* cf. *plicarum* Yao (sample Khor-3), 3. *Protunuma turbo* Matsuoka (sample Khor-2), 4. *Unuma latusicostatus* (Aita) (sample Khor-2), 5. *Stichocapsa* cf. *robusta* Matsuoka (sample Khor-A-436), 6. *Unuma typicus* Ichikawa et Yao (sample Khor A-436), 7. *Cyrtocapsa mastoidea* Yao (sample Khor A-436), 8. *Hsuum* cf. *belliatulum* Pessagno and Whalen (sample Khor A02P-3/5), 9 - 10. *Stichocapsa* cf. *decora* Rust (9 - sample Khor A02P-1/6, 10 - sample Khor Al-9). All markers – 10 μκ.

Fig. 9. Some Middle Jurassic radiolarians from siliceous mudstones, mudstones and siltstones of Middle structural level of the Nadankhada-Bikin terrane Bikin part

Bathonian radiolarians *Stichocapsa decora* Rust, *Archicapsa pachyderma* Tan, *Tricolocapsa fusiformis* Yao, *Hsuum belliatulum* Pessagno et Whalen and others have been extracted from the silty mudstones, and Bathonian–Callovian radiolarians *Stylocapsa lacrimalis* Matsuoka, *Gongylothorax sakawaensis* Matsuoka, *Stichocapsa robusta* Matsuoka, *Stichocapsa naradaniensis* Matsuoka, *Stylocapsa hemicostata* Matsuoka, *Tricolocapsa plicarum* Yao and others has been found in the siltstones.

It should be noted, that the same age radiolarians (Middle Jurassic) have been found (Kojima & Mizutani, 1987) in siliceous mudstones (fig. 10) on a left bank of the Ussuri River, in China (20 km to the west from Shichang village). But originally they were considered as Bathonian–Callovian in age. However, according to the specified data on a time intervals of the Jurassic radiolarian species distribution (Baumgartner et al., 1995), their age is Bajocian. These data indicate that fragments of the middle structural level are also extended in the Nadankhada part of the given terrane.



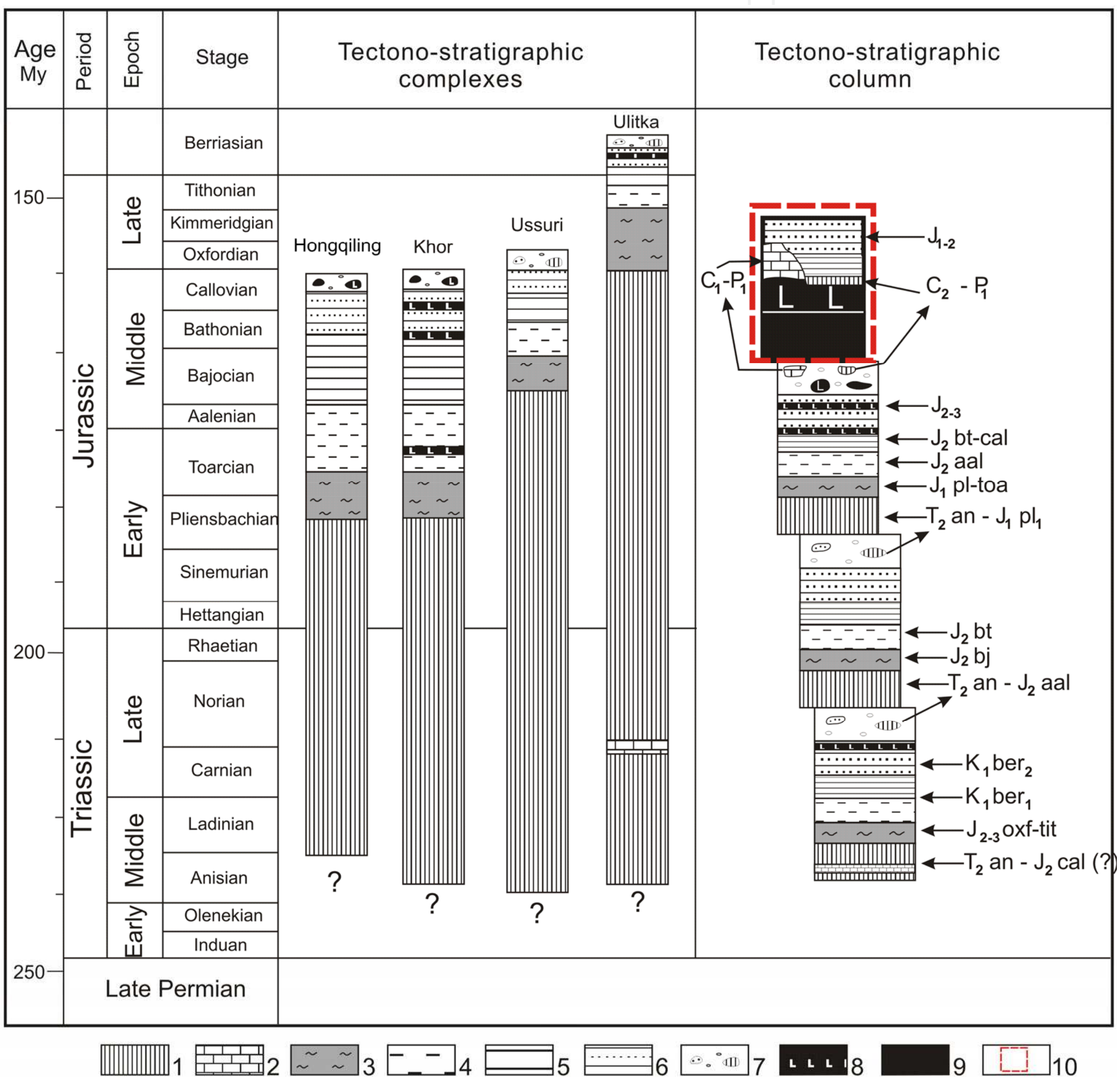
1. *Archaeodictyomitra* sp. (sample 40040/1331) scale bar = 73 μк, 2. *Eucyrtidiellum unumaensis* Yao (sample 42015/1331) scale bar = 54 μк, 3. *Eucyrtidiellum ptyctum* (Riedel et Sanfilippo) (sample 40060/1331) scale bar = 38 μк, 4. *Eucyrtidiellum* sp. (sample 40037/1331) scale bar = 49 μк, 5. *Tricolocapsa plicarum* Yao (sample 42211/1331) scale bar = 80 μк, 6. *Tricolocapsa fusiformis* Yao (sample 39862/1320) scale bar = 54 μк, 7. *Tricolocapsa ruesti* Tan Sin Hok (sample 40054/1331) scale bar = 73 μк, 8. *Thanarla* sp. (sample 42016/1331) scale bar = 54 μк.

Fig. 10. Some Middle Jurassic radiolarians from siliceous mudstones of the Nadankhada-Bikin terrane Nadankhada part (After Kojima & Mizutani, 1987)

3.3 Upper structural level

A fragment of cut-section with gradual cherts-to-terrigenous rocks transition, belonging to the upper structural level, was investigated in detail in the Nadankhada part of the terrane (Yang & Mizutani, 1991; Yang et al., 1993). This cut-section locates about 6 km to the north from the Hongqiling Nongchang village, representing over 40 m exposure of cherts, clayish cherts and siliceous mudstones in which five consecutive radiolarian assemblages have been established (Yang et al., 1993). Four of them, extracted out of the cherts and clayish cherts, characterize their host rocks as being Middle Carnian–Early Pliensbachian in age. The fifth assemblage is related to the siliceous mudstones with Late Pliensbachian radiolarians. The terrigenous rocks associated with these cherty formations are Middle Jurassic in age. The silty mudstones and siltstones contain, correspondingly, Aalenian and Bathonian radiolarians (Yang et al., 1993). In the area of the terrigenous rocks distribution, the chaotic formations representing different-sized lumps, blocks and fragments of Carboniferous-Permian limestones, Triassic cherts, basalts, gabbro and serpentinous ultramafic rocks among the schistose aleuro-psammites are observed. Middle Jurassic radiolarians have been extracted from them too (Yang et al., 1993).

Fragments of the similar chert-terrigenous sequence have been also investigated in the Bikin part of the terrane, in the numerous bank outcrops of the middle reaches of the Khor River and its inflows (Phillippov, 1990). According to the microfaunistic data, the following cut-section was reconstructed: the lower part of this sequence (about 90 m thick) is composed of cherts that are changed by the clayish cherts up the sequence. The age of these rocks,



1 – cherts; 2 – limestones; 3 - cherty mudstones; 4 – mudstones; 5 – siltstones; 6 – siltstones-sandstones alternation; 7 – subduction melange; 8 – basalts; 9 – ultramaphic rocks; 10 - supposed tektono-stratigraphic unit.

Fig. 11. Tektono-stratigraphic complexes and column of the Nadankhada-Bikin terrane

according to the conodont fauna (Klets, 1995), ranges from Anisian to Rhaetian, however, taking into account that they are gradually replaced by the siliceous mudstones containing Pliensbachian radiolarians, their upper age border is likely to be early Pliensbachian. The sequence upper part is composed of terrigenous rocks representing rhythmical alternation of siltstones and sandstones. Middle Jurassic Radiolarians such as *Gongylothorax sakawaensis* Yao, *Eucyrtidiellum* sp., *Diacantocapsa normalis* Yao, *Protunuma turbo* Matsuoka, *Tricolocapsa tetragona* Matsuoka, *Tricolocapsa* sp., *Stichocapsa* sp. and others have been determined in the siltstones layers. Upwards of the terrigenous rocks there is a section of chaotic formations (up to 200 m thick) with rock blocks and fragments represented by Carboniferous-Permian limestones, Triassic cherts, basalts and sandstones. Besides that there are also 10-40 m thick layers of basic volcanites, such as hyaloclastites, tuffs, basalts lavas and picritebasalts among the terrigenous rocks.

4. Discussion and conclusions

Biostratigraphic researches of the above mentioned cut-sections have revealed that the chert-terrigenous deposits of the different structural levels of the Nadankhada-Bikin terrane are slightly differing in their ages (fig. 11).

In particular, the age of the cherts-to-terrigenous rocks transitive siliceous mudstones varies from Pliensbachian to Oxfordian-Tithonian. It means that the chert-terrigenous rocks composing this terrane are fragments of the sedimentary cover of the different-aged sites of the paleooceanic plate (fig. 12) or, in other words, they are the fragments of three different-aged Oceanic Plate Stratigraphy Sequences, which are characterized by the different time of accretion (the accretion starting time is correlated with the age of terrigenous rocks, accumulation of which occur in a trench).

Hence, in the terrane structure, it is possible to allocate as a minimum three successive tectono-stratigraphic complexes (fig. 13) representing the primary cut-sections of the sedimentary cover from the different-aged sites (i.e. areas at different distances from the sea-floor spreding center) of the Paleo-Pacific Ocean and reflecting a process of their consecutive accretion. Let's name them Ulitka (Triassic-Early Cretaceous), Ussuri (Triassic – Late Jurassic) and Khor-Hongqiling (Triassic - Middle Jurassic) Formations.

It should be noted that the age of rocks of the allocated Formations, as well the time of their accretion are gradually rejuvenate from the upper structural level to the lower one. As a whole, the Nadankhada-Bikin terrane structure is characterized by the inverted stratification of formations that make up the terrane. Compared to the upper structural level (the Khor-Hongqiling Formation), the lower level (the Ulitka Formation) is composed of relatively younger rocks, thus the rocks of the middle level (the Ussuri Formation) are of intermediate age. At the same time, a primary stratigraphic succession of deposits within each complex is normal (from older to younger bottoms up). Such structure of the Nadankhada-Bikin terrane completely corresponds to a structure of modern accretionary prisms forming at the basis of internal slopes of the modern convergent margins trenches, and is a result of a successive subduction and partial accretion of the oceanic plate sites of different age and lithology. During the subduction the most remote from the spreading center sites of the oceanic plate, its oldest part, are accreted first, with the following underplating of its younger fragments in future. As a result, a package of tectono-sedimentary complexes is formed.

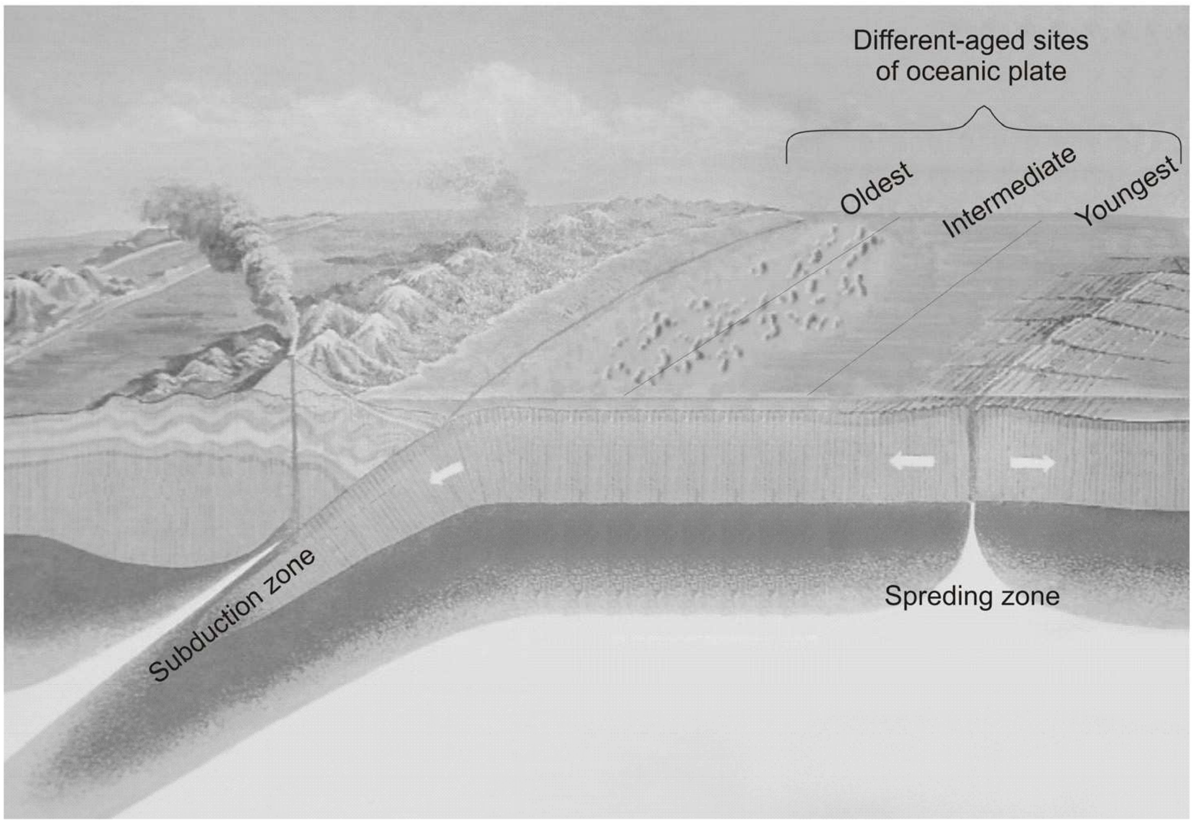
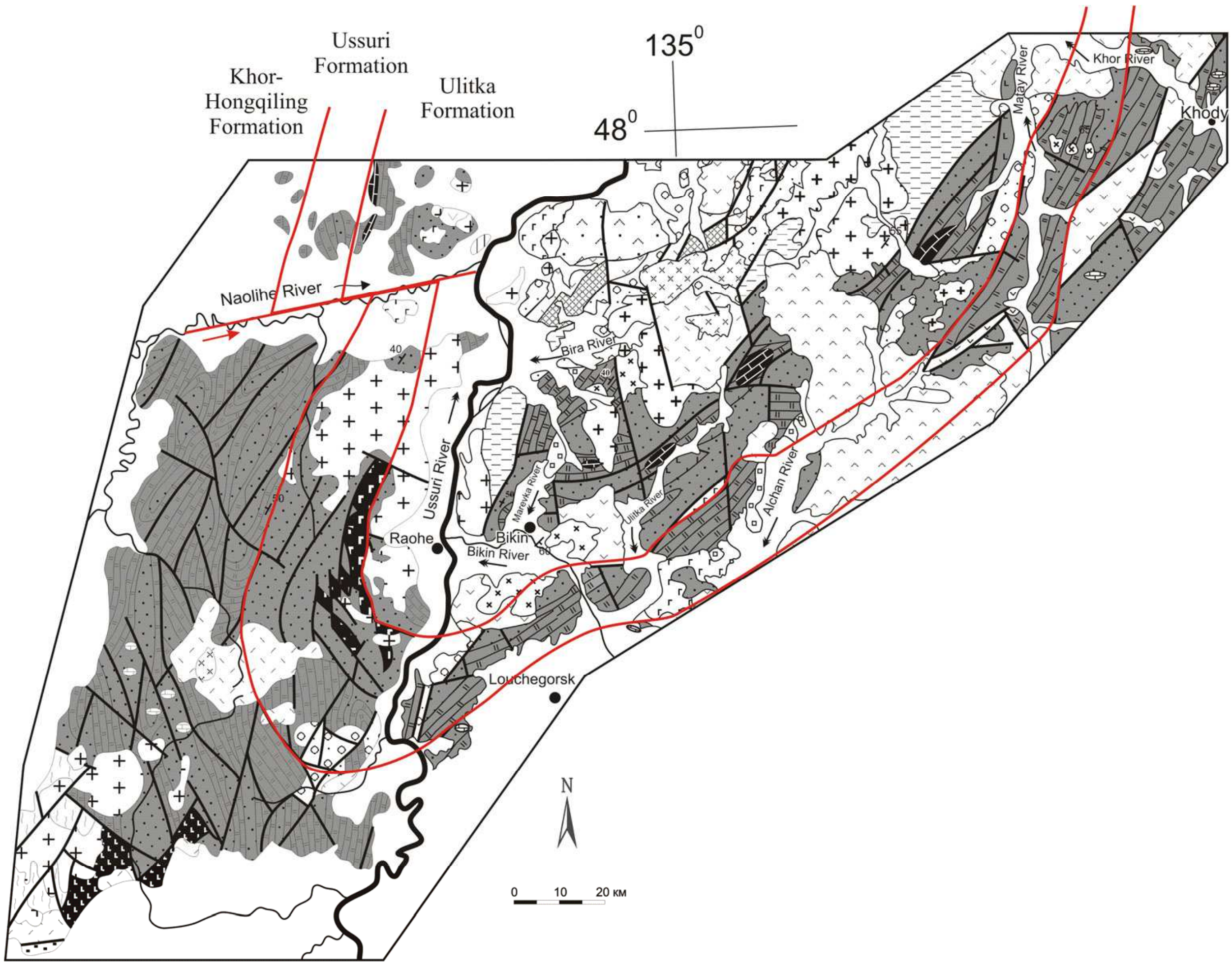


Fig. 12. The scheme illustrating spreding-subduction model of the Plate Tectonics and different-aged sites of drifting oceanic plate

The true structure of the Nadankhada-Bikin terrane thus appears to be a regular recurrence of the strongly deformed fragments of the primary sedimentary cover of the paleooceanic plate sites situating at a different distance from the spreading center, rather than a chaotic repeated alternation of tectonic slices of different age and lithology.

Based on lithological and age characteristics of the rocks, the allocated tectono-stratigraphic complexes of the Nadankhada-Bikin terrane confidently correlate with the corresponding structural complexes of the Samarka terrane which is the most thoroughly investigated unit of the Sikhote-Alin Jurassic prism. For example, the Ulitka Formation that composes the lower structural level of the Nadankhada-Bikin terrane can be compared with the Katen Formation that is also the lowermost tectono-stratigraphic unit of the Samarka terrane. The Ussuri Formation, composing the terrane middle structural level, is correlated with the Breevka Formation, and the Khor-Hongqiling Formation is comparable with the Amba-Matay Formation which also contains chaotic formations with exotic blocks and fragments of Paleozoic limestone, cherts, basalts, and gabbro within.

It should be added that in the southwestern part of the Nadankhada ridge (in China), structurally above the slices of the chert-terrigenous rocks, there are tectonic slices of ophiolite (Dahezhen Formation). These widely distributed ophiolitic slices are made up of basalts in association with Carboniferous - Permian limestones, serpentinites and gabbro (Mizutani et al., 1989; Shao et al., 1992 etc.). Tectonic slices of same composition and age compose the uppermost structural level of the Sebuchar Formation of the Samarka terrane (Kemkin, 2006). These data suggest as a minimum one more tectono-stratigraphic complex in the Nadankhada-Bikin terrane structure (see fig. 10, it is allocated by a dashed line).



See legend on a Fig. 4 and 5.

Fig. 13. Different-aged tectono-stratigraphic complexes of the Nadankhada-Bikin terrane

The comparative analysis of even-aged Formations of the Jurassic accretionary prism different terranes indicates that during the Jurassic the geodynamic mode along the Paleo-Asian continent eastern margin was invariable.

5. Acknowledgments

This work was done with partial financial support from the Grants of the President of Russian Federation (Grant No NSH – 5162.2010.5) and the Far Eastern Branch of Russian Academy of Sciences (Grant No 09-III-A-08-403).

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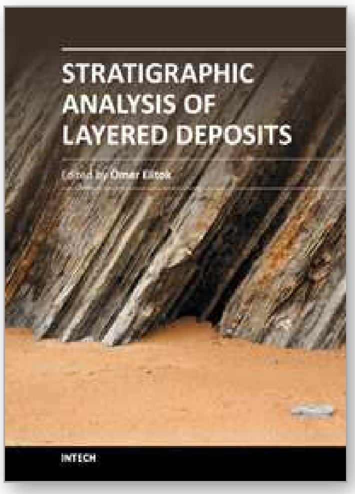

Stratigraphic Analysis of Layered Deposits
Edited by Dr. Ömer Elitok

ISBN 978-953-51-0578-7
Hard cover, 298 pages
Publisher InTech
Published online 27, April, 2012
Published in print edition April, 2012

Stratigraphy, a branch of geology, is the science of describing the vertical and lateral relationships of different rock formations formed through time to understand the earth history. These relationships may be based on lithologic properties (named lithostratigraphy), fossil content (labeled biostratigraphy), magnetic properties (called magnetostratigraphy), chemical features (named chemostratigraphy), reflection seismology (named seismic stratigraphy), age relations (called chronostratigraphy). Also, it refers to archaeological deposits called archaeological stratigraphy. Stratigraphy is built on the concept "the present is the key to the past" which was first outlined by James Hutton in the late 1700s and developed by Charles Lyell in the early 1800s. This book focuses particularly on application of geophysical methods in stratigraphic investigations and stratigraphic analysis of layered basin deposits from different geologic settings and present continental areas extending from Mexico region (north America) through Alpine belt including Italy, Greece, Iraq to Russia (northern Asia).