Structure and genesis of the lower structural unit of the Samarka Jurassic accretionary prism (Sikhote-Alin, Russia)

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ABSTRACT
Based on a study of several cherty-terrigenous sequences of the Samarka terrane in Sikhote-Alin, comprising lithologic and paleontological analysis, the different age of the transitional layers from marine formations to paleo-continental-margin deposits was established and the succession of marine fragments accretion was restored. The obtained data shows that low structural level of the Samarka accretionary prism is composed of a minimum of four successive tectonostratigraphic units that differ both in age of accreted marine fragments and time of their accretion. Each unit consists of deposits of a paleo-oceanic plates gradually changing above on a section by terrigenous rocks, which further are replaced by an olistostrome. The relatively young pelagic rocks and overlapping terrigenous deposits occur structurally below older deposits. Such structure of the Samarka prism results from a consecutive accretion of the fragments of a different-age sites of a paleo-ocean plate. Radiolarian age data for the accretionary prism indicates that fragments of a Late Permian-Triassic, Early Triassic-Early Jurassic and Early Triassic-Middle Jurassic paleo-oceanic plate were consecutively accreted into the prism.

KEY WORDS
Sikhote-Alin, Russia, terrane, accretionary prism, accretion, tectonostratigraphy, radiolaria, olistostrome.

RÉSUMÉ

Structure et genèse de l'unité structurale inférieure du prisme d'accrétion du Samarka d'âge Jurassique (Sikhote-Alin, Russie).

Basée sur l'étude de séries siliceuses et pélitiques des terranes de Samarka dans la région de Sikhote-Alin, les couches de transition entre les formations marines et les formations continentales ont été datées et l'histoire des accrétions successives a été établie (analyse lithologique et paléontologique). Les résultats montrent que le prisme est composé d'au moins quatre unités tectonostratigraphiques qui diffèrent par leur âge et l'âge de leur accrétion. Chaque unité consiste en une série océanique surmontée par des dépôts graduellement plus terrigènes pour finir par un olistostrome. De telles structures sont le résultat d'accrétions successives de fragments de planchers océaniques. Les âges fournis par les radiolaires montrent que ces fragments sont d'âge fin Permien-Trias, Trias inférieur-Jurassic inférieur et Trias inférieur-Jurassique moyen.

MOTS CLÉS
Sikhote-Alin, Russie, terrane, prisme d'accrétion, accrétion, tectonostratigraphie, radiolaires, olistostrome.

INTRODUCTION

Modern geological structure of the northeastern part of the Asia-Pacific margin is a collage of terranes that have various age and genesis. Final accretion of the terranes was finished at the end of the Cretaceous (Natal'in & Faure 1991; Faure & Natal'in 1992; Faure *et al.* 1995; Sokolov *et al.* 1997; Parfenov *et al.* 1998; Nokleberg *et al.* 1998). According to Nokleberg *et al.* (1998), a terrane is a fault-bounded geologic entity or fragment that is characterized by a distinctive geologic history that differs markedly from that of adjacent terranes. Among the terranes there are fragments of ancient passive continental margins, volcanic island and continental-margin arcs, accretionary prisms, backarc and turbidite basins. Accretionary prisms are important for reconstrution of geodynamic evolution, as well as correlation of geological events in a continent-ocean transition zone. Accretionary prisms form along internal slopes of modern convergent margins (Seely *et al.* 1974; Karig & Sharman 1975; Huene *et al.* 1982; Ogawa 1985; Fujioka *et al.* 1988; Matsuda & Isozaki 1991) during subduction of an oceanic plate under continent or island arc by means of consecutive accretion of a fragments of oceanic plate sedimentary cover and seamounts. Older units are accreted first and are underplated by accreted younger units. This results in the formation of a package of tectonic slices. Each structural slice composed of pelagic deposits from central areas of ocean floor, hemipelagic deposits of marginal parts of ocean, and of bottom and slope facieses of trench deposits. These repeating stratigraphic sequences reveal a history of sedimentation of an oceanic plate, from a spreading zone to a subduction zone (Piper *et al.* 1973; Berger & Winterer 1974; Matsuda & Isozaki 1991; Nakae 1992). The transitional layers from marine to continental-margin deposits of these stratigraphic sequences testify to gradual change of geodynamic conditions of sedimentation, and fix an approach of an oceanic plate to convergent boundary. Thus, the age of transitional layers provides a timing of approach of any site of an oceanic plate to a subduction zone and, correspondingly, the beginning of its subsequent accretion. Knowing the age of a transitional layers of these stratigraphic sequences in a various tectonic slices of an ancient accretionary prism makes possible to specify the time of subduction of separate paleo-oceanic fragments. Based on this data, it is easy to restore a

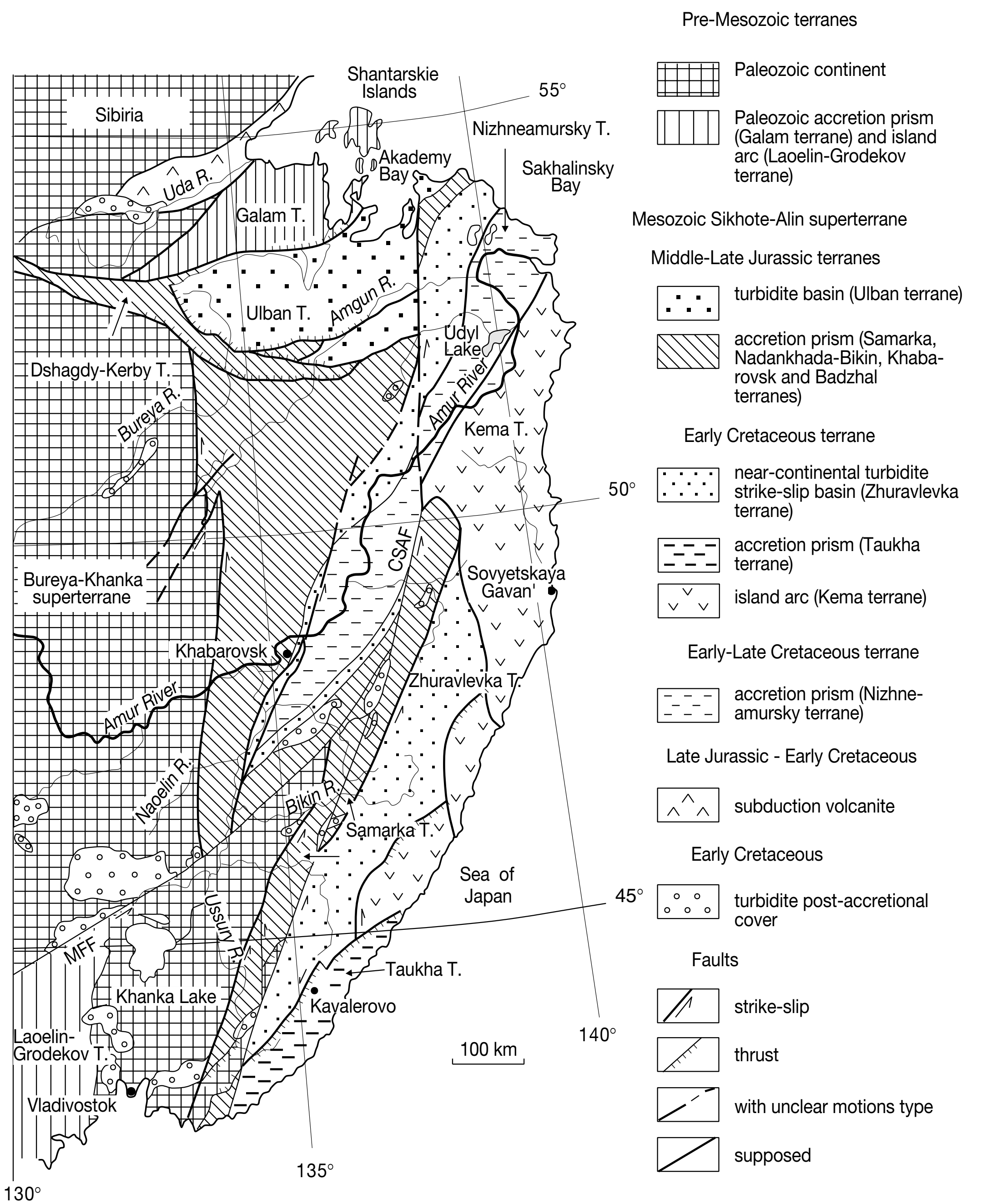

FIG. 1. — Tectonostratigraphic terranes of the Sikhote-Alin and adjacent areas. After Khanchuk (1994). Abbreviations: **CSAF**, Central Sikhote-Alin fault; **MFF**, Mishan-Fushung faults.

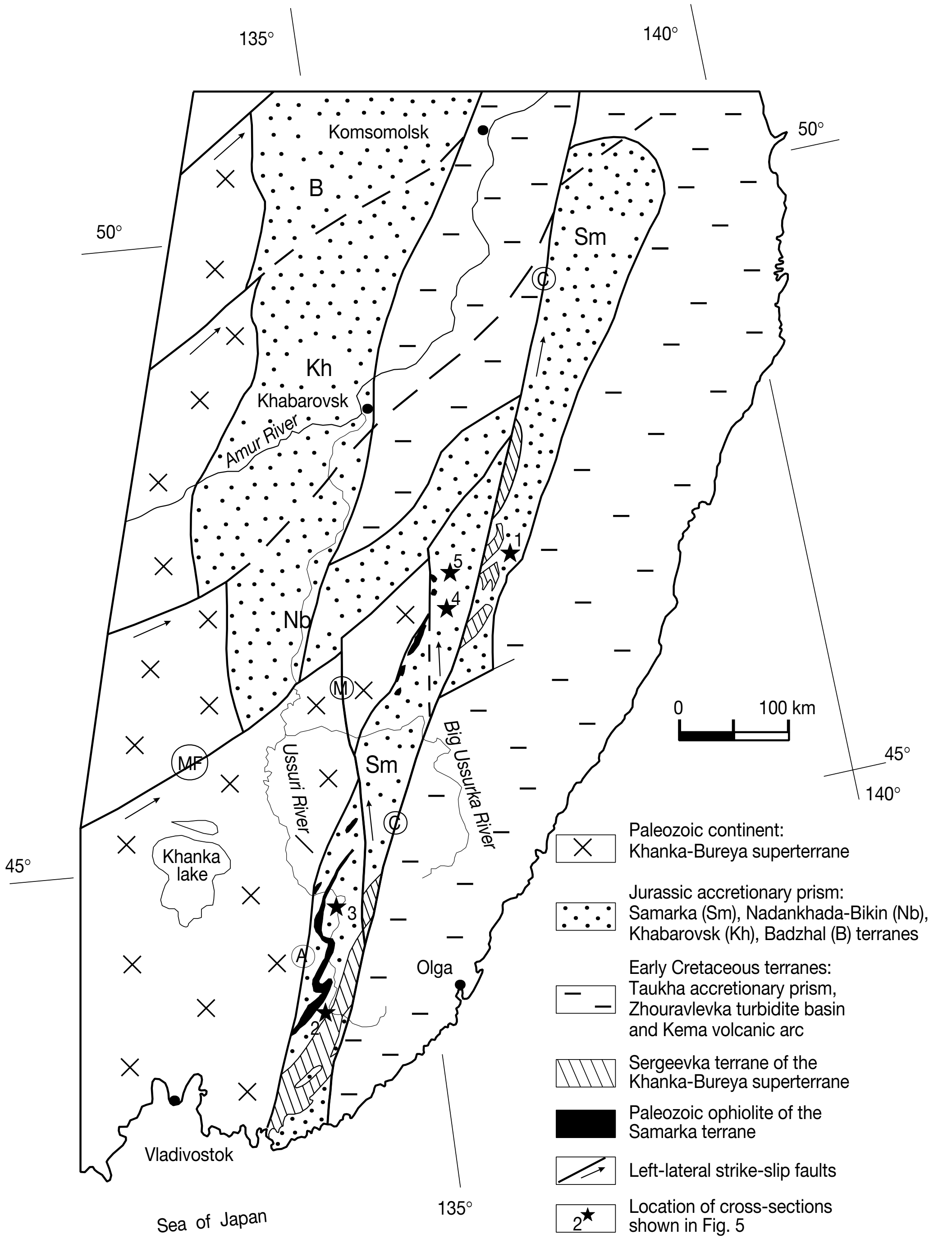

FIG. 2. — Location of studied areas. Abbreviations: **A**, Arsen'evsky; **C**, Central Sikhote-Alin; **M**, Meridional; **MF**, Mishan-Fushung faults.

succession of accretion processes, to divide an accretionary prism into separate tectonostratigraphic units, and to specify a complete prism structure and history of its development.
Samarka terrane is a fragment of ancient (Jurassic) accretionary prism. In modern Sikhote-Alin structure it is bounding the Khanka-Bureya superterrane from East (Figs 1; 2). Nadankhada-Bikin, Khabarovsk and Badzhal terranes are analogous of the Samarka terrane in the Northwest and northern areas (Khanchuk 1994). It was earlier considered that the Samarka terrane deposits represents a section of single Paleozoic-Mesozoic geosyncline stratigraphic sequence that were strongly deformed by a thrusts (Mazarovich 1985; Golozubov & Melnikov 1986). But our researches have shown (Khanchuk *et al.* 1988; Kemkin 1989; Khanchuk *et al.* 1989; Kemkin & Khanchuk 1992, 1993) that the Samarka terrane is a complex package of tectonic alternation of different deposits that were formed in various time, environmental and tectonic conditions. There are two groups of the Samarka terrane rock complexes that precisely differ from each other: 1) Early-Late Jurassic turbidite-olistosrome deposits composing a matrix; and 2) older (from Late Devonian (?) up to Middle Jurassic) oceanic cherts, limestones and ophiolites composing different length and thickness slices at a various stratigraphic levels among matrix deposits. A similar structure was revealed later for the Samarka terrane in northern Sikhote-Alin (Natal'in 1991; Natal'in *et al.* 1994; Faure *et al.* 1995). Nevertheless, there is a number of questions yet not answered. In particular, what are the structural positions of various marine fragments within the terrane section? How many stratigraphic levels are they made of? What was the timing and succession of their accretion to a continental margin? How did the various structural slices form within the terrane? Answers to these questions will allow to carry out the decoding of the internal structure of the Samarka prism and history of its formation.
The results of lithologic-biostratigraphic study of cherty-terrigenous sequences of the Samarka prism are given below, which allow to make clear, at least partly, the designated above questions.

BRIEF GEOLOGY OF THE SAMARKA TERRANE

The Samarka terrane extends along the edge of the Khanka-Bureya superterrane in a Northeast direction from southern coast of Primorye up to the right bank of Amur River by a width up to 100 km (Figs 1; 2). The large left-lateral strike-slip Arsen'evsky and Central Sikhote-Alin faults form its northwestern and southeastern boundaries in southern Sikhote-Alin and, correspondingly, Central Sikhote-Alin and Katen-Choukensky in northern Sikhote-Alin. The terrane is composed of rocks of various lithological composition, age and genesis. Sedimentary deposits, which represent the majority of rocks are mainly represented by continental-margin deposits (turbidite and olistostrome) and pelagic cherts and cherty-clay deposits composed of various panels and slices as well as different-size lumps and block among terrigenous rocks. Besides, there are slices and blocks composed of basalts, limestones and ophiolitic rocks that represents a fragment of seamounts and heights. The accreted marine deposits comprise extensive (up to 20 km long and more) slices, the thickness of which varies from several tens up to several hundreds meters. The separate cherty slices consist of 3-5 times of the tectonic repetition of same-age fragments. Large slices are usually underlied by the olistostrome that contains lumps and blocks of the same lithology.
The strata of the Samarka terrane are crumpled into asymmetric folds of variable amplitude that are often overturned and are trended to the Northeast. The axial plains of the folds exhibit Southeast vergence and the mirror of folding is sloping dip to the Northwest (Figs 3; 4). Regional folding structure has resulted in exposing the lower structural units of the terrane to the Southeast and the upper structural units to the Northwest. The accreted marine formations of upper structural level of the Samarka terrane are as follows: 1) Middle Paleozoic gabbro-ultramafic rocks (Kalinovka Formation); 2) basalts and overlying Late

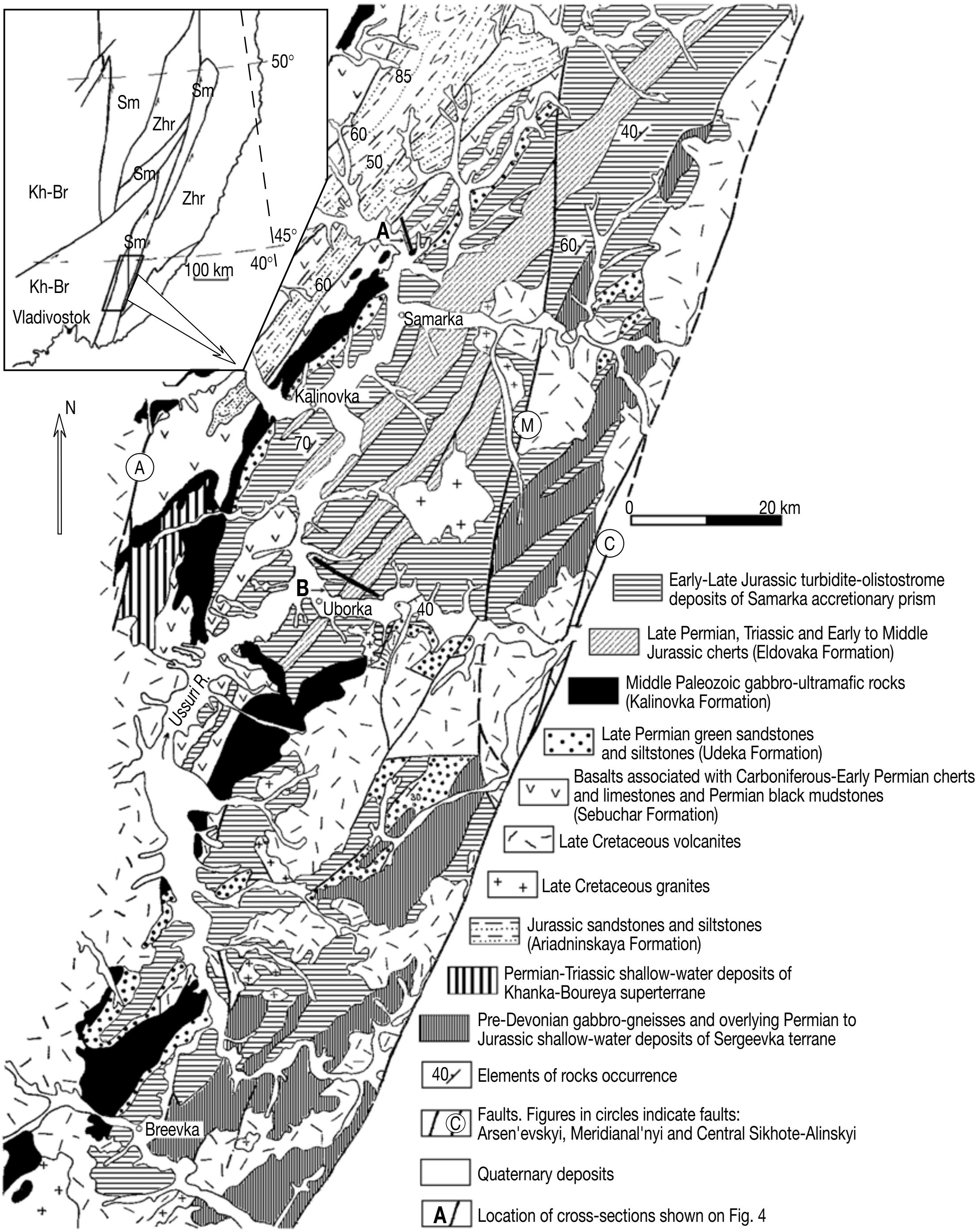

FIG. 3. — Geological map of the southern part of the Samarka terrane.

Devonian(?)-Early Permian cherts, Early Carboniferous-Early Permian limestones and Permian black mudstones (Sebuchar Formation); 3) Late Permian aleuro-psammitic rocks (Udeka Formation). The lower structural level of the Samarka terrane is composed of alternation of turbidite-olistostrome deposits and cherts slices (Eldovaka Formation). The age of cherts changes from Late Permian and Triassic up to Early and Middle Jurassic (Mazarovich 1985; Volokhin *et al.* 1990; Kemkin & Khanchuk 1993; Kemkin & Golozoubov 1996; Kemkin & Rudenko 1998; Philippov *et al.* 2000a). Basalts sometimes underlie the basis of separate chert slices. The age of terrigenous rocks is characterized by Middle-Late Jurassic radiolaria (Khanchuk *et al.* 1988; Kemkin 1989; Smirnova & Lepeshko 1991; Kemkin & Khanchuk 1992, 1993).

Thus, the structure of the Samarka accretionary prism looks like as "multi-layered cake" where relatively young terrigenous deposits alternate with more old marine rocks. The relationship between various formations of the Samarka prism in modern Sikhote-Alin structure are tectonic. The boundaries between them are thrusts.

Stratigraphic successions of the cherty-terrigenous sequences and age of a transitional layers

The fragments of primary section of paleo-oceanic plate sedimentary cover were investigated in various areas of the Samarka terrane. The contacts between chert slices and terrigenous rocks in modern Sikhote-Alin structure are mainly tectonic (it is a result of accretionary and post-accretionary processes). Conformable sedimentary contacts are extremely rare. Five localities with gradual transition from pelagic cherts to continental-margin turbidites were found and studied. The transitional layers of these cherty-terrigenous sequences are represented by cherty mudstones that grade smoothly upward the section into mudstones, muddy siltstones, siltstones and, then, alternation of siltstones and sandstones. The description of investigated prism sections is given below.

Katen River area

On a right bank of the Katen River, areas of Dzhava and Dzho Creek (in the eastmost part of the Samarka terrane near the Central Sikhote-Alin fault, locality 1 on Fig. 2), the Samarka terrane strata shows monoclinal dip to the Northwest. The fragment of prism section reconstructed by four exposures, looks as follows (Fig. 5):

Grey clayish cherts	14 m
Alternation (1-5 cm) light grey clayish cherts and black clayish phthanite	8 m
Greenish grey different-bedded (1-3 - 3-7, less often up to 10 cm) cherts	75 m
Clayish jasper	5 m
Grey cherty mudstones	40 m
Dark grey mudstones and muddy siltstones	20 m
Alternation of siltstones and sandstones	10 m
Fine-medium-grained sandstones	200 m

Late Triassic part of cherty section is represented in some exposures by an alternation of cherts and thin (1-3 to 7-10 cm) layers of grey limestones (Philippov *et al.* 2000a). The age of cherts is characterized by an abundant conodonts and changes from Olenekian stage of Early Triassic up to Bathonian-Callovian of Middle Jurassic (Philippov *et al.* 2000a). The cherty mudstones contains radiolarians: *Tricolocapsa fusiformis*, *Tricolocapsa* ex gr. *plicarum*, *Tricolocapsa plicarum*, *Guexella nudata*, *Eucyrtidiellum unumaensis*, *Dictyomitrella* (?) *kamoensis*, and *Tricolocapsa* sp., that indicate on age of Bathonian-Callovian. Mudstones and siltstones according to radiolarians fauna (Philippov *et al.* 2000a) are Oxfordian-Tithonian in age. Thus, the age of transitional layers from cherts to terrigenous rocks in Katen River area is Bathonian-Callovian.

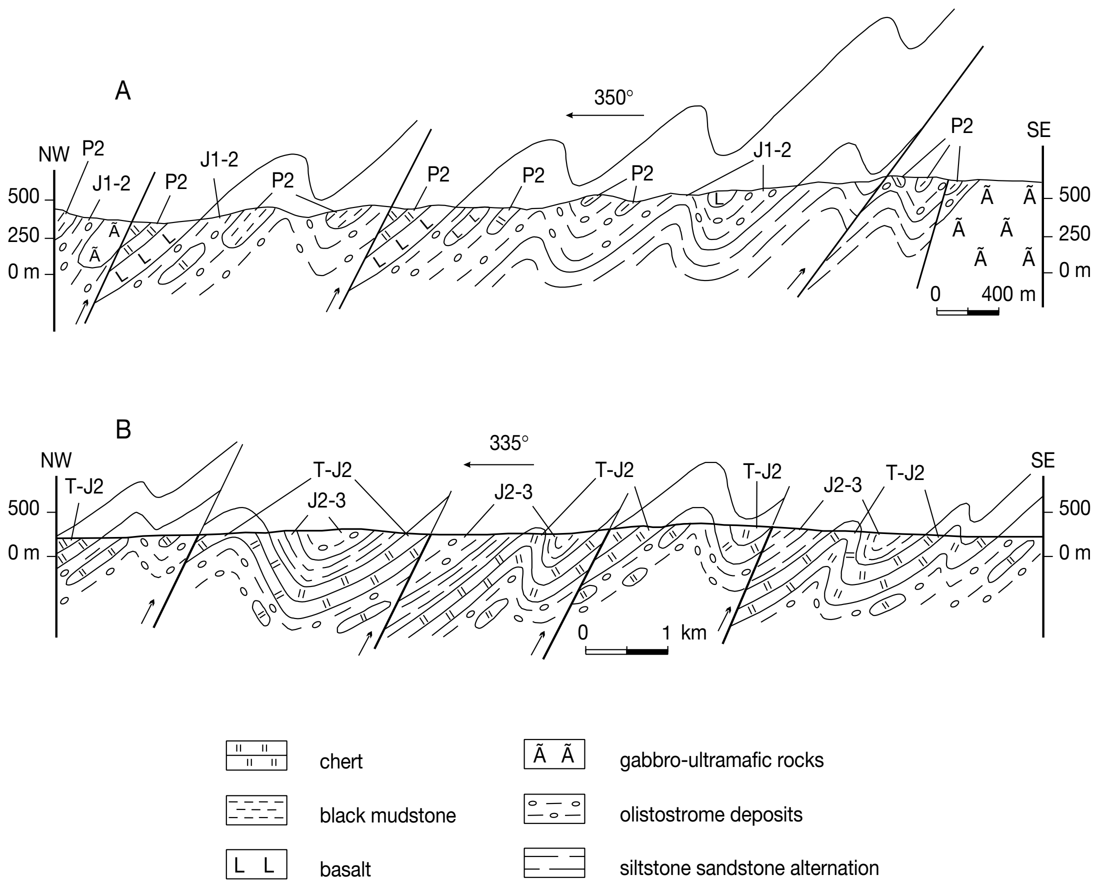

FIG. 4. — Cross-sections across the Samarka terrane in the Samarka village (**A**) and Uborka village (**B**) areas.

Medvedka River area

On a right bank of Medvedka River (a southern margin of Breevka village, locality 2 on Fig. 2), other fragment of the Samarka prism section is detail investigated. The Breevka section occur structurally higher then Katen section. It is represented in ascending order by (Fig. 5):

Grey and yellowish-grey cherts	70 m
Greenish-yellowish-grey cherty mudstones	3 m
Dark grey mudstones and muddy siltstones	5 m
Siltstones changing upward the section into an alternation of siltstones and sandstones	65 m

Olistostrome formations occur above the terrigenous rocks, but the contact between them are not croped out. The majority of the outcrop is represented by grey bedded cherts. The bedding is caused by thin (1-3 mm) clayey interbeds. Thickness of the chert beds varies from 1-2 cm in low and upper parts of the section up to 3-5 - 7-10 cm in middle. Within the exposure, the strata shows monoclinal dip to the Northwest (dip azimuth, 345°, angle 50°-60°). In the lower part of chert section the clastic layer (about 10 cm of thickness) is embedded within the grey bedded cherts. The clastic layer shows graded bedding. Grain size of the lower part is more then 0.5 mm, whereas that of the upper part is about 0.1-0.3 mm. The clastic grains are composed

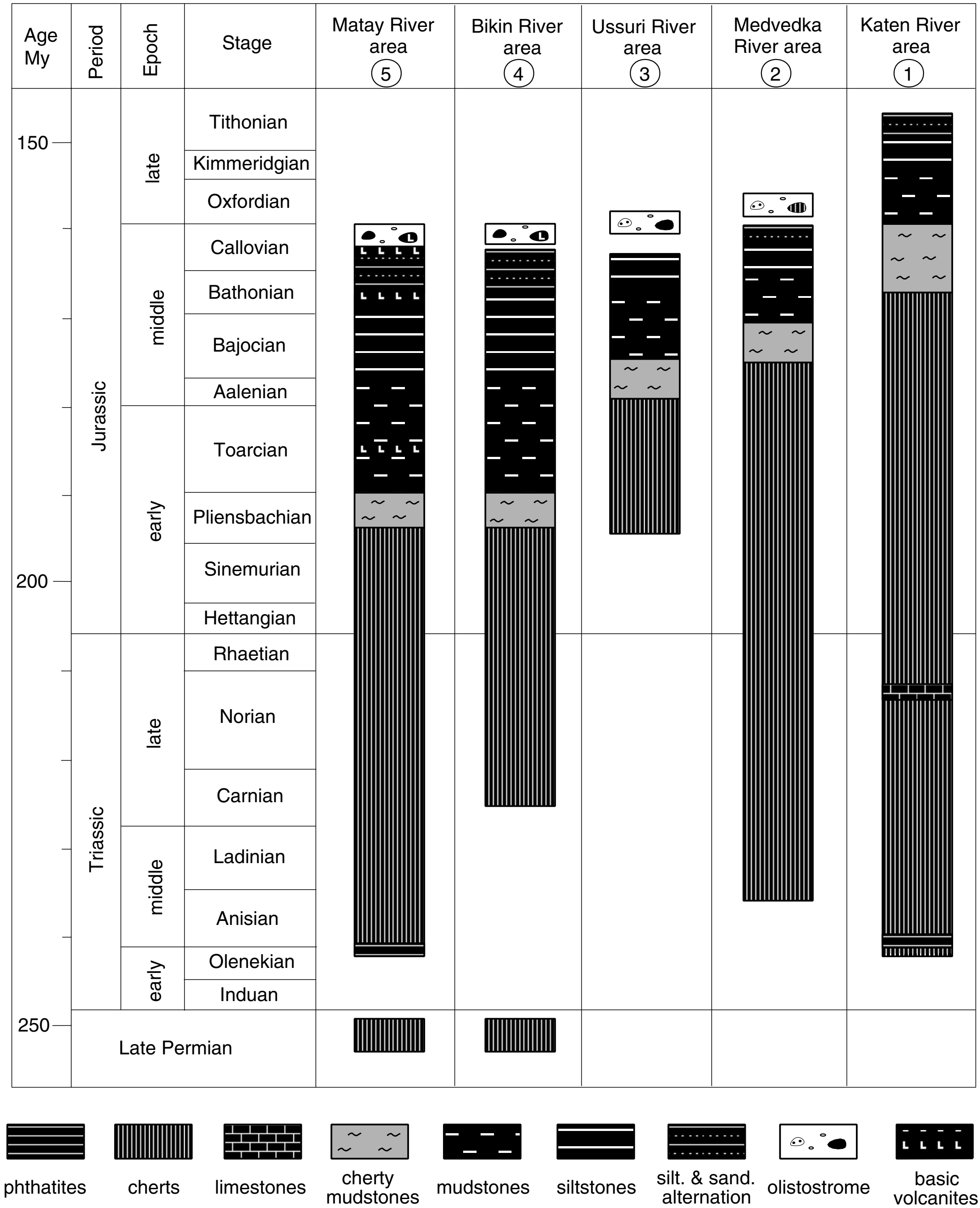

FIG. 5. — Stratigraphic columns of cherty-terrigenous sequences of the Samarka prism. See location on Fig. 2.

mainly of basalt, volcanic glass, chert, cherty mudstone, and plagioclase. Cherts are changes smoothly to terrigenous rock through cherty mudstone. The data of micropaleontological study have shown (Kemkin & Rudenko 1998) that the age of chert part of the Breevka section changes from Anisisan stage of Middle Triassic up to Aalenian-Bajocian of Middle Jurassic. The cherty mudstone contain radiolarians: *Tricolocapsa ruesti* Tan Sin Hok, 1927, *Tricolocapsa* sp., *Hsuum medium* (Takemura, 1986), *Hsuum fukazawaense* Sashida, 1988, *Hsuum* cf. *fukazawaense* Sashida, 1988, *Hsuum* sp., *Stichocapsa convexa* Yao, 1979, and *Milax* sp., that indicates their Bajocian age. The mudstones and siltstones are characterized by Bajocian-Bathonian and Callovian radiolarians correspondingly (Kemkin & Rudenko 1998). Thus, the age of transitional layers from cherts to terrigenous rocks of the Breevka section is Bajocian.

Ussuri River area

On the left bank of Ussuri River, opposite of Saratovka village (locality 3 on Fig. 2), other fragment of the Samarka prism section composing more higher structural level is detail investigated. Within this exposure the 18-meters fragment of the Samarka prism crops out. It is as follows:

Grey bedded cherts	4 m
Greenish-grey cherty mudstones	3 m
Dark grey massive mudstones	3 m
Black bedded muddy siltstones and siltstones	8 m

The strata of Saratovka section shows similar monoclinal dip to the northwest. According to radiolarians fauna data the age of cherts within the exposure is Pliensbachian-Toarcian (Kemkin & Golozoubov 1996). The age range of cherty mudstones, according to the extrated radiolarians, *Parahsuum officerence* (Pessagno & Whalen, 1982), *Parahsuum* sp., *Hsuum medium* (Takemura), *Hsuum hisuikyoense* Isozaki & Matsuda, 1985, *Hsuum altile* Hori & Otsuka, 1989, *Hsuum* sp., *Parvicingula* sp., and *Tricolocapsa* sp., is Aalenian-Early Bajocian. The mudstones and siltstones contain radiolarians that specifies their age as Middle Bajocian-Bathonian and Bathonian-Callovian correspondingly (Kemkin & Golozoubov 1996). Thus, the age of transitional layers from cherts to terrigenous rocks of the Saratovka section is Aalenian-Early Bajocian.

Bikin River area

The next fragment of the Samarka prism section with gradual transition from pelagic deposits to continental-margin formations is investigated on the right bank of Bikin River area, on the Northwest slope of Amba Mountain (locality 4 on Fig. 2). The Amba section is a more high structural level of the Samarka prism then Saratovka section. Geological structure of the Amba Mountain area are similar to described above areas and represented by an alternation of turbidite-olistosrome deposits and cherts slices. These strata are also crumpled into asymmetric folds that are often overturned and are trend to the Northeast. However, the age range of chert slices differs from the Katen River, Medvedka River and Ussuri River areas. Late Permian chert slices are also established here besides Triassic and Jurassic cherts (Philippov *et al.* 2000b). The relationship of Permian and Mesozoic pelagic deposits is unclear. The contacts between them, as well as terrigenous rocks are tectonic. On a contrary, Mesozoic pelagic formations are conformable grade into turbidite (Fig. 5). Here are observed:

Greenish-grey bedded cherts with a lens of calcarenite (up to 30 cm)	6 m
Grey bedded cherts changing into the reddish jaspers	14 m
Clay bedded jaspers	4 m
Brown and greenish-grey cherty mudstones	22 m
Dark grey mudstones and muddy siltstones	8 m
Black bedded siltstones changing into the alternation of siltstones and sandstones	30 m

Late Triassic radiolarians were extracted from chert (Philippov *et al.* 2000b). Clay bedded jaspers and cherty mudstones contains radiolarians: *Bagotum* cf. *modestum* Pessagno & Whalen, 1982, *Bagotum* sp., *Broctus* cf. *ruesti* Yeh, 1987, *Broctus* sp., *Canoptum anulatum* Pessagno & Poisson, 1981, *Canoptum* aff. *dixoni* Pessagno & Whalen, 1982, *Canoptum poissoni* Pessagno, 1979, *Canoptum* cf. *rugosum* Pessagno & Poisson, 1981, *Canoptum* sp., *Drulanta* (?) sp., *Eucyrtidiellum* sp., *Gorgansium* sp., *Ka-troma* sp., *Lantus sixi* Yeh, 1987, *Mesosaturnalis* sp., *Orbiculiforma* sp., *Parahsuum* cf. *kanyoense* Sashida, 1988, *Parahsuum ovale* Hori & Yao, 1988, *Parahsuum simplum* Yao, 1982, *Parahsuum takarazawaense* Sashida, 1988, *Parahsuum* sp., *Praeconocaryomma* sp., *Santonaella* sp., *Staurolonche* sp., *Tetratrabs* sp., *Tricolocapsa* sp., and *Trillus* sp., based on which the age of these rocks is determined as late Pliensbachian-early Toarcian. Same radiolarian species were found in the first layers of mudstones. The age of muddy siltstones and siltstones is not known, because we could not extracted any fossils from them. Thus, the age of transitional layers from cherts to terrigenous rocks of the Amba section is late Pliensbachian-early Toarcian.

Matay River area

One more fragment of the Samarka prism section is described on a right bank of Matay River (locality 5 on Fig. 2). Accreted marine fragments here are also represented by slices of Late Permian and Triassic-Early Jurassic cherts (Philippov *et al.* 2000a). The relationship of Permian and Mesozoic pelagic deposits is also unclear, but taking into account their joint occurrence it is considered that they are fragments of a single sequence of sedimentary cover of a paleo-oceanic plate. The gradual transition from pelagic deposits to continental-margin turbidites is investigated on a right bank of Lyamfana Creek (inflow of Matay River). The fragment of the prism section here looks as follows (Fig. 5):

Phthanites and clayish cherts	12 m
Grey-dark grey thin and medium bedded (1-7 cm) cherts	30 m
Greenish-grey clayish cherts	6 m
Dark grey cherty mudstones with a 6-meter interbed of hyaloclastite	18 m
Dark grey mudstones and muddy siltstones	40 m
Greenish-grey hyaloclastite	50 m
Siltstones changing above the section into alternation of siltstones and sandstones	50 m
Greenish-grey hyaloclastite	20 m
Alternation of siltstones and sandstones	40 m
Basalts and diabases	100 m
Olistostrome formations containing different-size lumps and blocks of siltstones, sandstones, basalts, Early Permian cherts and Carboniferous-Permian limestones	150 m

Age of cherts of the Matay section ranges from Olenekian stage of Early Triassic to Rhaetian stage of Late Triassic according to conodont fossils (Buriy *et al.* 1990; Klets 1995). Clayish cherts (layers 3) contain only two radiolarian species: *Parahsuum simplum* and *Parahsuum ovale* that specify Early Jurassic (Hettangian-Pliensbachian) age of these deposits. Cherty mudstones contain *Parahsuum simplum*, *Parahsuum ovale, Tricolocapsa* sp. and *Canoptum* sp., that indicate an Early Jurassic age. Mudstones and muddy siltstones are characterized by Toarcian-Aalenian radiolarians: *Parahsuum* cf. *cruciferum* Takemura, 1986, *Transhsuum medium* Takemura, 1986, *Hsuum hisuikyoense* Isozaki & Matsuda, 1985, *Hsuum matsuokai* Isozaki & Matsuda, 1985, *Hsuum* sp.*, Tricolocapsa* sp.*, Laxtorum* (?) *jurassicum* Isozaki & Matsuda, 1985, and *Katroma* sp. Bajocian-Bathonian radiolarians *Hsuum* cf. *primum* Takemura, 1986, *Hsuum* cf. *belliatulum* Pessagno & Whalen, 1982, *Transhsuum medium* Takemura, *Stichocapsa convexa* Yao, 1979, *Stichocapsa japonica* Yao, 1979, *Parvicingula* sp., and *Tricolocapsa* sp. were extracted from siltstones. Taking into account the age data of underlying cherts and overlying mudstones, the age of cherty mudstones can be determined as Pliensbachian-Toarcian. Thus, the age of transitional layers from cherts to terrigenous rocks of the Matay section is Pliensbachian-Toarcian, that coincides with that of Amba area.

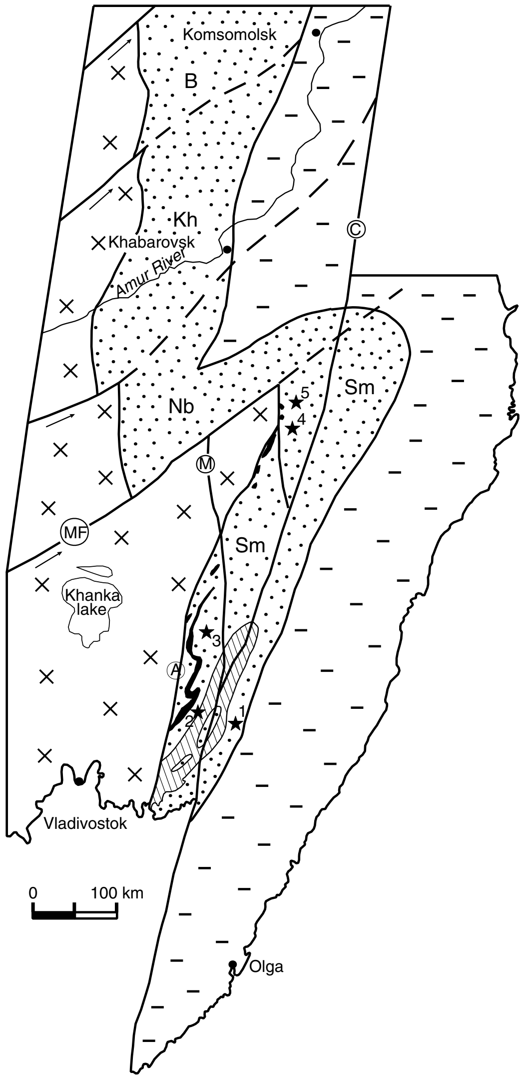

FIG. 6. — Geological reconstruction of the Sikhote-Alin region at the end of Early Cretaceous; **A**, Arsen'evsky; **C**, Central Sikhote-Alin; **M**, Meridional; **MF**, Mishan-Fushung faults.

DISCUSSION

The age of transitional layers from cherts to terrigenous rocks in various marine fragments of the Eldovaka Formation change from Pliensbachian-Toarcian of Early Jurassic up to Bathonian-Callovian of Middle Jurassic. It indicates for them a different timing of approach to a subduction zone and, correspondingly, accretion. Taking into account data of the transitional layers age, it is possible to conclude that the subduction of the paleo-oceanic plate and, correspondingly, accretion of marine fragments of Eldovaka Formation were carried out continuously during approximately 25 my. During this time, a minimum of four different fragments coming from different sites of the oceanic plate were accreted to the Samarka prism. However, actually more numerous entities could be discovered, if new (intermediate) data of age of transitional layers in other chert slices can be established.

Thus, the Eldovaka Formation of the Samarka terrane consists of a minimum of four structural units that differ both in age of accreted marine fragments and timing of subduction. Each units consists of marine deposits that grade smoothly upward into terrigenous rocks of continental-margin origin that are replaced by olistostromes. Figure 6 shows a geological reconstruction at the end of Early Cretaceous. It is time of left-lateral motions along the Central Sikhote-Alin fault. The estranged blocks of the Sergeevka terrane were used as markers of amplitude of motions. It is possible to see, that the age of transitional layers, and, correspondingly, timing of accretion of marine formations are younged (rejuvenate) to the Southeast. The growth (or younging) of the Samarka prism section is also realized to the Southeast. But prevalent (principal) dip of the prism strata is realized to opposite side, i.e. to the Northwest (see Figs 3; 4; 7). In other words, as a whole, the apparent stratigraphy of the Eldovaka Formation of the Samarka terrane is structurally inverted. The relatively younger units compose the lower structural level of the Samarka prism whereas older units compose the higher structural levels of the Samarka prism. But within each structural units the stratigraphic succession is normal (from older to younger). Such structure of the Samarka terrane is consistent to that of the modern accretionary prisms and permits us to identify the Samarka terrane as an ancient accretionary prism.

In spite of identity of both lithological composition and structure of each tectonostratigraphic

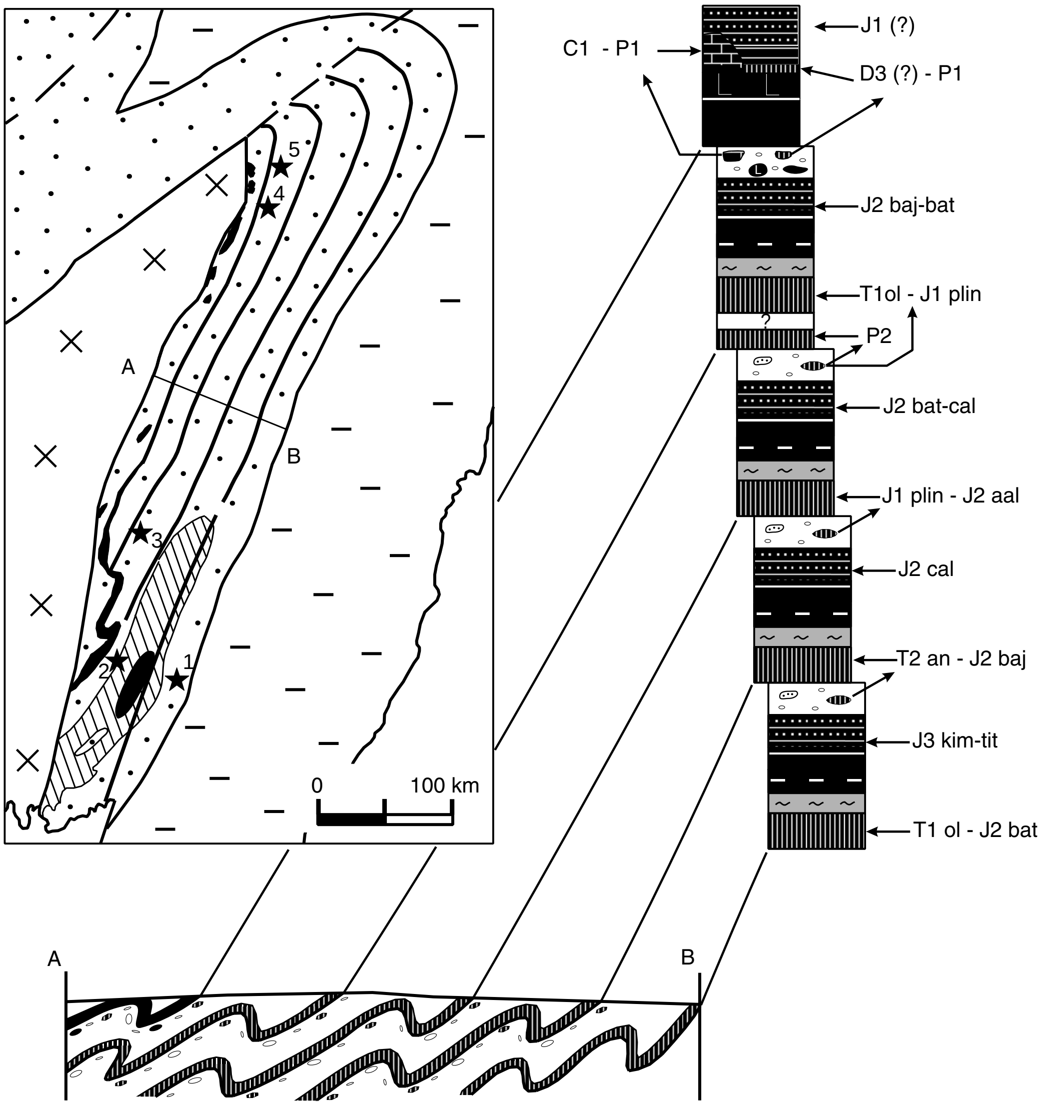

FIG. 7. — Generalized section of the Samarka prism and stratigraphic columns of allocated tectonostratigraphic units. See legend on Figs 2 and 5.

unit, there are small differences reflecting a facies features of different sites of paleo-oceanic plate. For example, Katen section is characterized by presence of limestones interbeds within the chert layers. The Breevka section cherts contain clastic layers consisting of the clasts of basalts, cherts, cherty mudstones, volcanic glass and plagioclases. In Amba and Matay area there are Late Permian cherts slices. It should be noted, that the accumulation of terrigenous part of the Matay section was periodically accompanied by basaltic volcanism (see Fig. 5). The geodynamic nature of it is not clear. Probably modes of paleo-oceanic plate subduction of early and late stages were a little different, in terms of both the morphology of subducted paleo-oceanic plate and the direction of subduction (frontal or oblique).

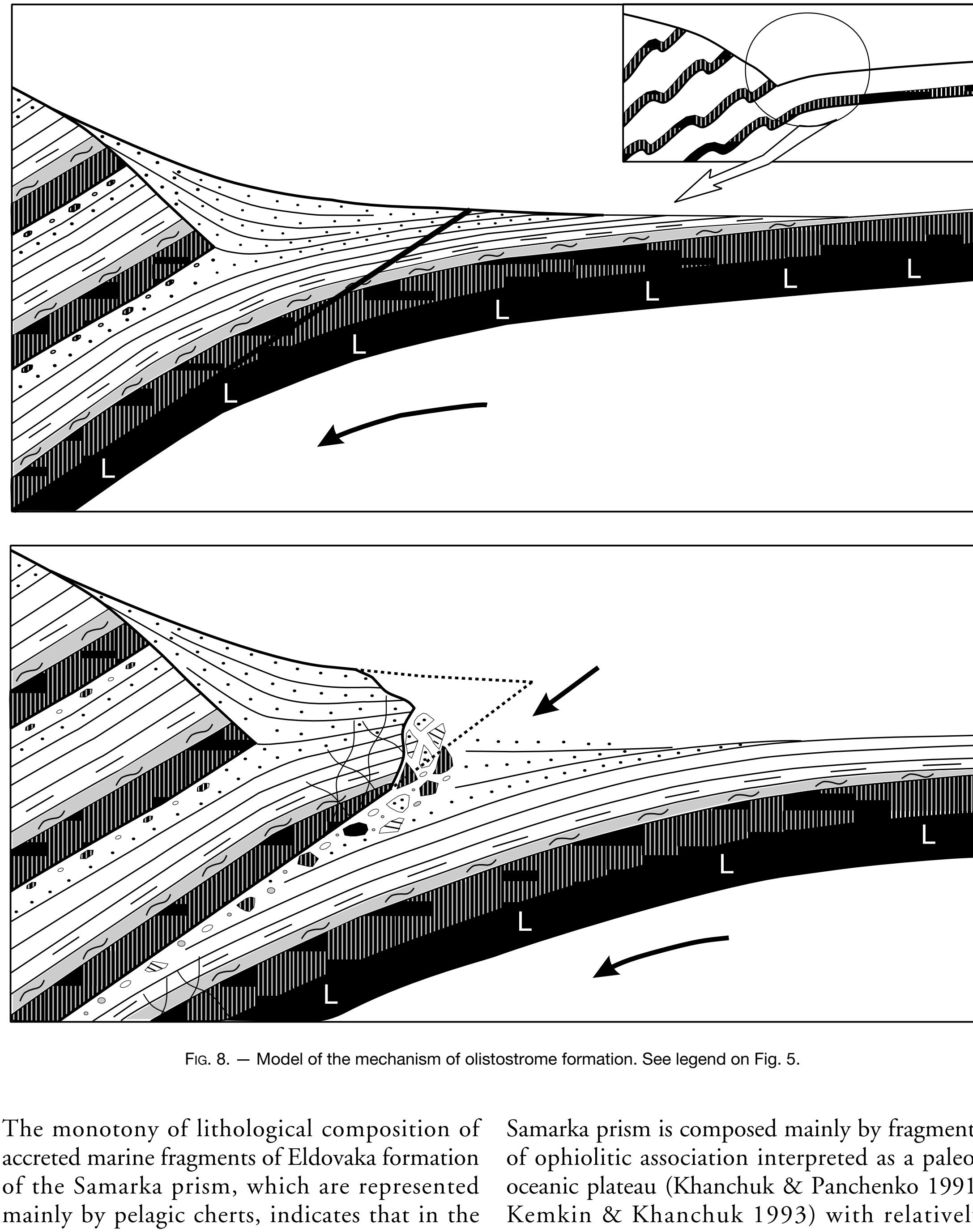

FIG. 8. — Model of the mechanism of olistostrome formation. See legend on Fig. 5.

The monotony of lithological composition of accreted marine fragments of Eldovaka formation of the Samarka prism, which are represented mainly by pelagic cherts, indicates that in the Middle-Late Jurassic the sediment cover of the abyssal plain of a paleo-oceanic plate (without any seamounts and heights) was accreted. On a contrary, the upper structural level of the Samarka prism is composed mainly by fragments of ophiolitic association interpreted as a paleo-oceanic plateau (Khanchuk & Panchenko 1991; Kemkin & Khanchuk 1993) with relatively raised sites (where reef-like knolls were formed) and plain-like sites (where cherts and cherty-clay deposits were formed). The lithological differences of accreted marine fragments reflecting the morphological features of subducted paleo-oceanic plate allow to subdivide the Samarka terrane into the two subterranes called here Sebuchar and Eldovaka, which characterize, correspondingly, upper and lower structural levels. Similar structure is established also for a terranes of the Jurassic accretionary prisms of Japan (Kojima 1989; Mizutani & Kojima 1992; Isozaki 1997). Tamba, Mino and Ashio terranes are also dismembered by the Japanese geologists on a separate tectonostratigraphic units, which are characterized by own oceanic plate stratigraphy (Nakae 1993). The sliding age of transitional layers in various tectonostratigraphic units and younging (rejuvenating) of deposits age to the direction of the lower structural levels are characteristic of them. The set of these data allows to assume a single mechanism of the Samarka and Japanese accretionary prisms formation and to consider them as a fragments of single Jurassic convergent margine (arc-trench system).

CONCLUSION

It is possible to conclude that the lower structural unit of the Samarka terrane consists of units of various ages and facies that represent alternations of paleocontinental-margin and marine rocks. The age of marine fragments ranges from the Late Permian up to the Middle Jurassic, whereas the age of terrigenous rocks is Early to Late Jurassic. The age data for the marine rocks supports the interpretation that the Late Permian-Triassic, Triassic-Early Jurassic and Triassic-Middle Jurassic fragments of marine plates were consecutively accreted into the Eldovaka Formation of the Samarka accretionary prism. The time of beginning of subduction and, correspondingly, subsequent accretion of each marine structural slice are correlated with the age of overlapping terrigenous rocks. The Late Permian-Triassic marine plate fragments were accreted in the Early-Middle Jurassic. The Triassic-Early Jurassic and Triassic-Middle Jurassic marine plate fragments were accreted in Middle-Late Jurassic. Thus, lower structural unit of the Samarka terrane are a package of successive tectonostratigraphic slices consisting of a paleo-oceanic plate formations gradually changing above on a section by terrigenous rocks. In the accretionary prism, the structural units are separated by horizons of olistostrome (accretionary melange), which formed during the underplating of a relatively younger marine slices under an older marine slices (Fig. 8).

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REFERENCES

BERGER W. H. & WINTERER E. L. 1974. — Plate stratigraphy and fluctuating carbonate line, *in* HSU K. J. & JEHKYNS H. (eds), *Pelagic Sediments on Land and under the Sea*. International Association of Sedimentologists, Blackwell, Oxford, special publication (1): 11-48.

BURIY G. I., PHILIPPOV A. N. & RUDENKO V. S. 1990. — Stratigraphy and genesis of cherts of right bank of the Matay River area (Khor-Anuy subzone of the Central Sikhote-Alin), *in* MARKEVICH P. V. (ed.), *Litogenesis and Ore's Formation in Ancient and Morden Sea Basin of the Far East.* Far Eastern Branch, SSSR Academy of Sciences, Vladivostok: 5-16 (in Russian).

FAURE M. & NATAL'IN B. A. 1992. — The geodynamic evolution of the Eastern Eurasian margin in Mesozoic time. *Tectonophysics* 208: 397-411.

FAURE M., NATAL'IN B. A., MONIE P., VRUBLEVSKY A. A., BORUKAEV Ch. B. & PRIHODKO V. S. 1995. — The tectonic evolution of the Anuy metamorphic rocks of Sikhote-Alin (Russia) and their place in the Mesozoic geodynamic frame of Eastern Asia. *Tectonophysics* 241: 279-301.

FUJIOKA K., TAIRA A. *et al.* (eds) 1988. — *6000 Meters Deep: a Trip to the Japanese Trenches.* IFREMER, Brest; CNRS, Paris; University of Tokyo Press, Tokyo, 103 p.

GOLOZUBOV V. V. & MELNIKOV N. G. 1986. — *Tectonics of geosynclinal complexes of the South Sikhote-Alin*. Akademiya Nauk SSSR, Vladivostok, 126 p. (in Russian).

HUENE R., LANGSETH M., NASU N. & OKADA H. 1982. — A summary of Cenozoic tectonic history along IPOD Japan Trench transect. *Geological Society of America Bulletin* 93: 829-846.

ISOZAKI Y. 1997. — Jurassic accretion tectonics of Japan. *The Island Arc* 6 (1): 25-51.

KARIG D. E. & SHARMAN F. G. 1975. — Subduction and accretion in the trenches. *Geological Society of America Bulletin* 86: 377-389.

KEMKIN I. V. & GOLOZOUBOV V. V. 1996. — The first find of the Early Jurassic radiolarians in the cherty allochthons of the Samarka accretionary prism (southern Sikhote-Alin). *Tikhookeanskaya geologiya* 15 (6): 103-109 (in Russian).

KEMKIN I. V. & KHANCHUK A. I. 1992. — New data on age of the paraautochthone of Samarka accretionary complex (South Sikhote-Alin). *Doklady Akademii Nauk SSSR* 324 (4): 847-851 (in Russian).

KEMKIN I. V. & KHANCHUK A. I. 1993. — Jurassic accretionary complex of Sikhote-Alin. *Tikhookeanskaya geologiya* (5): 31-42 (in Russian).

KEMKIN I. V. & RUDENKO V. S. 1998. — New data about chert age of Samarka accretionary prism, southern Sikhote-Alin. *Tikhookeanskaya geologiya* 17 (4): 22-31 (in Russian).

KEMKIN I. V. 1989. — *Olistostromes in the Accretionary Complexes of South Sikhote-Alin*. Author's abstract of thesis prepared by candidate of geological and mineralogical sciences, Far East Branch of Akademiya Nauk SSSR, Vladivostok, 23 p. (in Russian).

KHANCHUK A. I. 1994. — Tectonics of Russian Southeast. *Chishitsu News* (480): 19-22.

KHANCHUK A. I. & PANCHENKO I. V. 1991. — Garnet gabbro from ophiolite of the Southern Sikhote-Alin. *Doklady Akademii Nauk SSSR* 321 (4): 800-803 (in Russian).

KHANCHUK A. I., KEMKIN I. V. & PANCHENKO I. V. 1989. — Geodynamic evolution of the South Far East in Middle Paleozoic-Early Mesozoic, *in* SHOULDINER V. I. (ed.), Pacific Margin of Asia. *Geology* 1: 218-255 (in Russian).

KHANCHUK A. I., PANCHENKO I. V. & KEMKIN I. V. 1988. — *Geodynamic Evolution of Sikhote-Alin and Sakhalin in Late Paleozoic and Mesozoic*. Preprint. Far Eastern Branch, Academy of Sciences SSSR, Vladivostok, 56 p. (in Russian).

KLETS T. V. 1995. — *Biostratigraphy and Triassic conodonts of the Central Sikhote-Alin*. Novosibirsk University, Novosibirsk, 111 p. (in Russian).

KOJIMA S. 1989. — Mesozoic terrane accretion in Northeast China, Sikhote-Alin and Japan regions. *Palaeogeography, Palaeoclimatology, Palaeoecology* 69 (3/4): 213-232.

MATSUDA T. & ISOZAKI Y. 1991. — Well-documented travel history of Mesozoic pelagic chert in Japan: from remote ocean to subduction zone. *Tectonics* 10: 475-499.

MAZAROVICH A. O. 1985. — *Tectonic development of the South primorye in Paleozoic and Early Mesozoic time*. Akademiya Nauk SSSR, Moscow, 103 p. (in Russian).

MIZUTANI S. & KOJIMA S. 1992. — Mesozoic radiolarian biostratigraphy of Japan and collage tectonics along the eastern continental margin of Asia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 96 (1-2): 3-22.

NAKAE S. 1992. — A formative process of the sedimentary complex of the Tamba Terrane in the Wakasa area, Southwest Japan: an example of continuous accretion. *Journal of the Geological Society of Japan* 98 (5): 401-413.

NAKAE S. 1993. — Jurassic accretionary complex of the Tamba Terrane, Southwest Japan and its formative process. *The Journal of Geosciences, Osaka City University* 36: 15-70.

NATAL'IN B. A. & FAURE M. 1991. — Geodynamic of Eastern Asia margin in Mesozoic. *Tikhookeanskaya geologiya* 10 (6): 59-76 (in Russian).

NATAL'IN B. A. 1991. — Mesozoic accretionary and collisional tectonic of Southern Far East SSSR. *Tikhookeanskaya geologiya* 10 (5): 3-23 (in Russian).

NATAL'IN B. A., FAURE M., MONIE P., BORUKAEV Ch. B., PRIHODKO V. S. & VRUBLEVSKY A. A. 1994. — The Anuy metamorphic rocks (Sikhote-Alin) and its significance for Mesozoic geodynamic evolution of Eastern Asia. *Tikhookeanskaya geologiya* 13 (6): 3-25 (in Russian).

NOKLEBERG W. J., PARFENOV L. M., MONGWER J. W. H., KHANCHUK A. I., STONE D. B., SCHOLL D. W. & FUJITA K. 1998. — Phanerozoic tectonic evolution of the Circum-North Pacific. *U. S. Geological Survey*, open-file report 98-754, 215 p.

OGAWA Y. 1985. — Variety of subduction and accretion processes in Cretaceous to Recent plate boundaries around southwest and central Japan. *Tectonophysics* 112: 493-518.

PARFENOV L. M., NOKLEBERG W. J. & KHANCHUK A. I. 1998. — Complication principles and the main units of the legend of the geodynamic map of North and Central Asia, Russia Far East South, Korea and Japan. *Tikhookeanskaya geologiya* 17 (3): 3-13 (in Russian).

PHILIPPOV A. N., BURIY G. I. &. RUDENKO V. S. 2000a. — Stratigraphic sequence of sedimentary deposits Samarka terrane (Central Sikhote-Alin): record of paleooceanic sedimentation. *Tikhookeanskaya geologiya* 20, N 3: 26-46 (in Russian).

PHILIPPOV A. N., KEMKIN I. V. & PANASENKO E. S. 2000b. — Early Jurassic hemipelagic deposits of the Samarka terrane (Central Sikhote-Alin): sequence, composition and sedimentary environments. *Tikhookeanskaya geologiya* 19 (4): 83-96 (in Russian).

PIPER D. I. W., VON HUENE R. & DUNCAN J. R. 1973. — Late Quaternary sedimentation in the active eastern Aleutian trench. *Geology* 1 (1): 19-22.

SEELY D. R., VAIL P. R. & WALTON G. G. 1974. — Trench slope model, *in* BURK C. A. & DRAKE C. L. (eds), *The Geology of Continental Margins.* Springer-Verlag, New York: 249-260.

SMIRNOVA O. L. & LEPESHKO V. V. 1991. — Biostratigraphy and geological structure of volcanogenic-cherty-terigenous deposits of the Central zone of Sikhote-Alin (Primorye, Gornaya River basin), *in* TOCHILINA S. V. (ed.), *Paleontological and Stratigraphical Investigations of Phanerozoic of the Far East*. Far Eastern Branch, SSSR Academy of Sciences, Vladivostok: 30-53 (in Russian).

SOKOLOV S. D., DIDENKO A. N., GRIGOR'EV V. N., ALEKSYUTIN M. V., BONDARENKO G. E. & KRYLOV K. A. 1997. — Paleotectonic reconstruction of the North-East Russia: problems and uncertainties. *Geotectonica* (5): 72-90 (in Russian).

VOLOKHIN Y. G., BURII G. I., RUDENKO V. S. & FILIPPOV A. N. 1990. — Triassic cherty formation of the South Sikhote-Alin. *Izvestiya Akademiya Nauk SSSR, Geology* (4): 45-57 (in Russian).

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