ELSEVIER

Palaeogeography, Palaeoclimatology, Palaeoecology 153 (1999) 139–146

PALAEO

Early Cretaceous changes of vegetation and environment in East Asia

V.V. Golozoubov [a,*], V.S. Markevich [b], E.V. Bugdaeva [b]

[a] *Far East Geological Institute of Far East Branch of Russian Academy of Sciences, 159, Prospect 100-letiya, Vladivostok, 690022, Russia*

[b] *Institute of Biology and Pedology of Far East Branch of Russian Academy of Sciences, 159, Prospect 100-letiya, Vladivostok, 690022, Russia*

Received 12 August 1998; accepted 16 April 1999

Abstract

Early Cretaceous floras of the Razdolnensky (Suifun) and Partizansky (Suchan) basins, currently located close to each other in South Primorye, differ significantly. The pre-Albian flora assemblages of the Razdolnensky basin are similar to those of northeastern China, whereas the pre-Albian assemblages of the Partizansky basin are close to the Rioseki complex of the Outer Japan. Tectonic reconstructions using these data have showed that the Voznesenka terrane, underlying Cretaceous sediments of the Razdolnensky basin, as well as the terranes of Inner Japan were displaced northwards along faults of the Tan-Lu system for more than 5º by latitude. The Sergeevka terrane, forming the basement of Early Cretaceous sediments of the Partizansky basin, as well as the terranes of Outer Japan, were displaced in the same direction for a much larger distance (about 15º by latitude). The major movements occurred in the earliest Albian as is suggested by the same Albian flora assemblages in the two basins.

Keywords: Cretaceous; flora; palynoflora; East Asia; environment; tectonic reconstruction

1. Introduction

Cretaceous epicontinental sediments are abundant in the south of the Khanka superterrane (Primorye region) occurring in the Razdolnensky (Suifun) and Partizansky (Suchan) coal-bearing basins (Fig. 1). In the course of the study it has turned out that the Hauterivian–Albian flora assemblages of these basins are significantly different. Originally, this difference was explained by the presence at that time of a mountain structure separating the basins (Krassilov, 1967). A similar combination of Early Cretaceous floras was also found in Japan: heat-loving flora of the Ryoseki complex (Outer Japan) and cold-resisting flora of the Tetori complex (Inner Japan) (Kimura, 1987). Kimura considers this combination being due to tectonic displacements (Kimura, 1987).

We have analyzed specific compositions of the Early Cretaceous plants within the Partizansky and Razdolnensky basins, and compared these floras to those of northeast China and Japan. This paper represents, in brief terms, the results of our studies. On the basis of the data about the distribution of different types of the Early Cretaceous flora, and geological data, a new version of the pre-Albian reconstruction of the East Asia terrane positioning is offered.

* Corresponding author. Tel.: +4232 317 120; Fax: +4232 317 847; E-mail: fegi@online.marine.su

0031-0182/99/$ – see front matter
PII: S0031-0182(99)00074-7

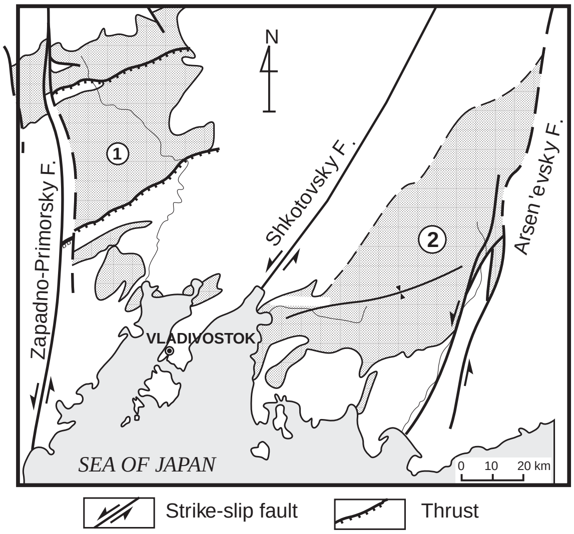

Fig. 1. Early Cretaceous epicontinental basins of South Sikhote-Alin: *1* = Razdolnensky (Suifun) basin; *2* = Partizansky (Suchan) basin.

2. Floral characteristics in basins of South Primorye

2.1. Partizansky (Suchan) basin

In the Partizansky (Suchan) basin, the Cretaceous section has at its base Berriasian volcanogenic and terrigenous sediments of the Monakinskaya Formation. The enclosed flora includes ferns, Cycadales, Bennettitales and Caytoniales. At the end of the Berriasian–Valanginian period (the Kapreevskaya and Klyuchevskaya Formations), the major wood-forming plants were various conifers associated with ferns and Cycadales. The fauna includes *Buchia*, *Ostrea* and *Corbicula*, as well as micro- and macroflora in the marine deposits of the Klyuchevskaya Formation (Tables 1 and 2).

During the Hauterivian and Barremian, forests were also dominated by conifers, but these were chiefly Taxodiaceae with an undergrowth consisting of ferns (including rare Schizaeaceae). The earliest of the Russian Far East flowering plants with the biporate pollen first appeared at the end of the Hauterivian (Table 1). It was likely connected with a transgression and related destabilization of the paleoenvironment.

Taxodiaceae remained dominant in the Aptian, but the role and diversity of the warmth- and water-requiring Gleicheniaceae increased among ferns. The angiosperms were represented by *Clavatipollennites*. This time was marked by active coal formation.

Terrigenous coal-bearing continental deposits formed in the basin from the Hauterivian to the middle Albian. During the Albian, the vegetation did not change markedly. However, among the conifers the typical Early Cretaceous species became extinct, while the diversity of angiosperms began to increase. A short-term transgression occurred in the middle Albian. At this time, the *Trigonia* layers were deposited. After that, the former continental sedimentation conditions reappeared.

The late Albian manifested a sharp change of vegetation in the basin. Diversity markedly decreased: numerous warmth-requiring species (*Gleicheniidites*, *Ginkgocycadophytus* and others) became extinct (Fig. 2). The niches released were occupied by pioneering plants, including angiosperms, mainly triporate pollen (Table 1).

Table 2 shows the distribution of plant megafossils of Tetori- and Ryoseki-types in the Early Cretaceous deposits of the Suchan and Suifun basins. It is apparent that these floras have mixed features.

2.2. Razdolnensky (Suifun) basin

In the Razdolnensky (Suifun) basin, the base of the Cretaceous section contains Barremian deposits of the Ussuriyskaya Formation. In contrast to the Partizansky basin, the major wood-forming plants in the Barremian were various conifers (Podocarpaceae, Araucariaceae, Caytoniaceae with abundant *Ginkgocycadophytus*, Cyatheaceae and Schizaeaceae).

In the Aptian (the Lipovetskaya Formation), forests were dominated by the warmth- and water- requiring Gleicheniaceae, Matoniaceae and others. In the Albian, the diversity sharply decreased. Many of cycadophytes, conifers and ferns became extinct. The less

Fig. 2. The distribution of the fossil spores (A) and gymnosperm pollen (B) throughout the Lower Cretaceous in the South Sikhote-Alin region.

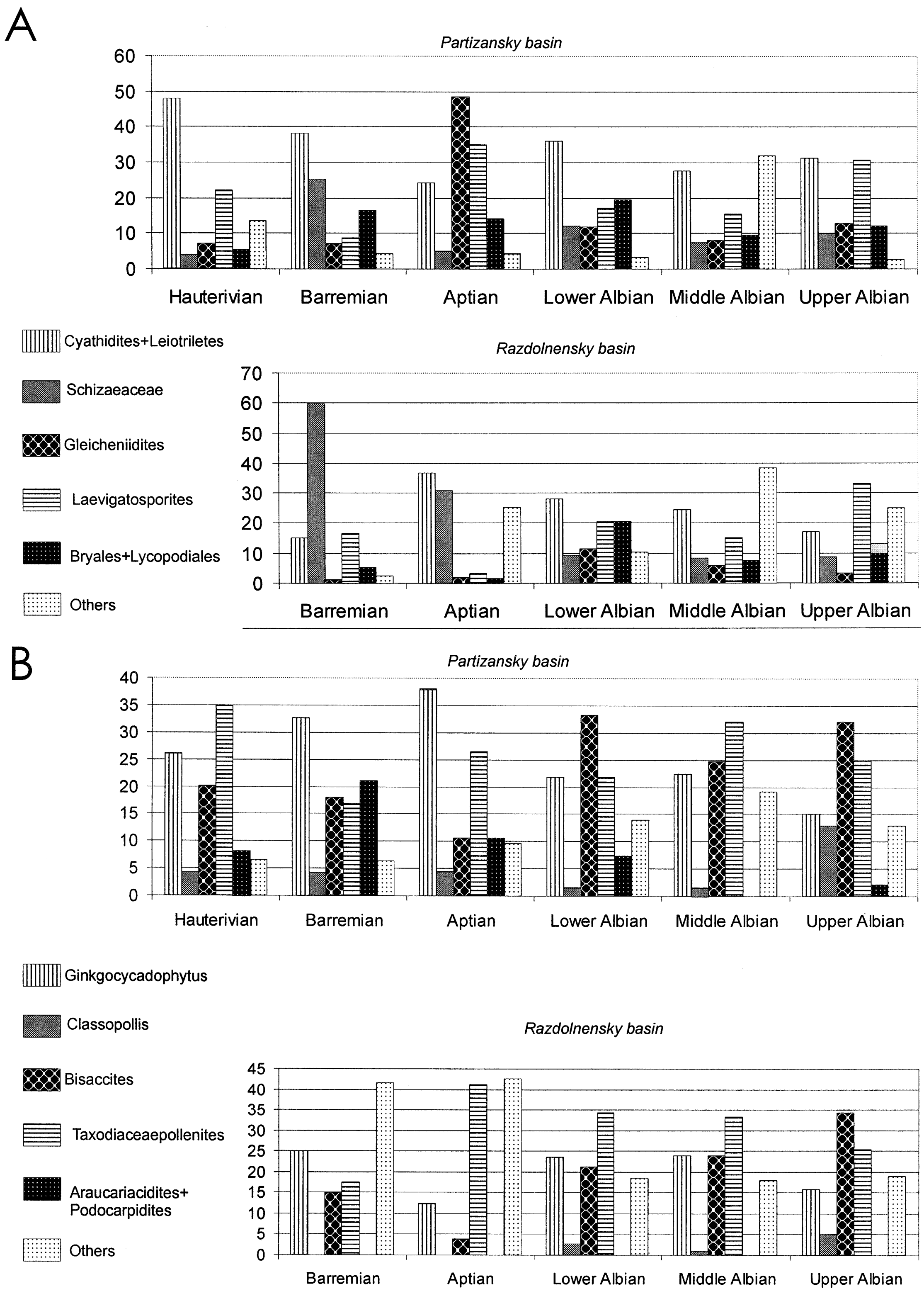
A
Partizansky basin
60
50
40
30
20
10
0
Hauterivian
Barremian
Aptian
Lower Albian
Middle Albian
Upper Albian
Cyathidites+Leiotriletes
Schizaeaceae
Gleicheniidites
Laevigatosporites
Bryales+Lycopodiales
Others
Razdolnensky basin
70
60
50
40
30
20
10
0
Barremian
Aptian
Lower Albian
Middle Albian
Upper Albian
B
Partizansky basin
40
35
30
25
20
15
10
5
0
Hauterivian
Barremian
Aptian
Lower Albian
Middle Albian
Upper Albian
Ginkgocycadophytus
Classopollis
Bisaccites
Taxodiaceaepollenites
Araucariacidites+
Podocarpidites
Others
Razdolnensky basin
45
40
35
30
25
20
15
10
5
0
Barremian
Aptian
Lower Albian
Middle Albian
Upper Albian

Table 1
Distribution of the fossil palynological taxa in the Early Cretaceous of northern China, Russia and Japan

Age	Taxa	North China	Russia		Japan	
			Suifun Basin	Suchan Basin	Hokkaido	Sea of Japan
Alb.	*Cyathidites (Leiotriletes)*	R	R	A		
	Schizaeceae	C	C	C		R
	Aequitriradites	C	R			
	Kuylisporites	C	R			
	Foraminisporites	R	R			
	Laevigatosporites		A	A		C
	Rouseisporites	C				
	Gleicheniidites		R	C		R
	Taxodiaceaepollenites			A		R
	Ginkgocycadophytus			C		
	Classopollis			C		A
	Bisaccate pollen			A		A
	Angiospermae	C	C	R		R
Apt.	*Cyathidites (Leiotriletes)*	R	A	A	A	C
	Schizaeaceae	A	C	R	C	C
	Gleicheniidites	R	A	A	C	
	Osmundacidites			C		
	Rouseisporites	R	R			
	Kuylisporites	R	R			R
	Foraminisporites					R
	Classopollis	R	R	C	A	A
	Inaperturopollenites	C	C	A	C	
	Bisaccate pollen	A	A	C		
	Angiospermae	C			R	
Brm.	*Cyathidites (Leiotriletes)*	C	C	A		
	Schizaeaceae	A	A	S		
Hau.	*Gleicheniidites*	C	C	C		
	Aequitriradites	R	R	R		
	Neoraistrickia	A	S	S		
	Classopollis	R	R	R		
	Bisaccate pollen	A	A	C		
	Inaperturopollenites	R	R	A		
	Angiospermae			R		
Vlg.	*Cyathidites (Leiotriletes)*	A		A		
	Schizaeaceae	R		R		
Ber.	Ginkgocycadophytus	R		C		
	Araucariacidites	R		C		
	Classopollis	R		A		
	Bisaccate pollen	A		A		

A = abudant; C = common; R = rare.

warmth-requiring *Laevigatosporites*, Bryales, *Lycopodiumsporites*, *Equisetites* became dominant.

The difference in vegetation between the Partizansky and Razdolnensky basins disappeared in the Albian (Fig. 2). Since this time, plants of these two basins had many common characteristics.

We will discuss causes of the different fossil palynoflora compositions of the basins close to each other in space and time (Table 1) and compare them with the simultaneous floras of Japan (Takahashi, 1974; Markevich, 1981, 1995) and northeastern China (Song, 1988; Wang et al., 1990; Li, 1994).

Table 2
Distribution of fossil plants of Tetori- and Ryoseki-types in the Early Cretaceous of South Sikhote-Alin region (Suchan and Suifun basins)

Age	Fossil plant taxa	Suifun basin	Suchan basin
Alb.	*Coniopteris burejensis* (Zal.) Sew.	R	R
	Neozamites denticulatus (Krysht. et Pryn.)	T	
	Nilssonia ex gr.*brongniartii* (Mant.) Dunk.	R	
	Nilssonia densinervis-type	R	
	Ginkgo pluripartita (Schimp.) Heer	T	T–R
	Sphenobaiera sp.	T	
	Podozamites tenuinervis Heer	T	
	Elatides asiatica (Yok.) Krassil.	T	T
Apt.	*Nathorstia pectinata* (Goepp.) Krassil.	R	
	Matonidium goeppertii (Ett.) Schenk.	R	
	Weichselia reticulata (Stokes et Webb) Ward	R	
	Alsophilites nipponensis (Oishi) Krassil.	R	
	Coniopteris burejensis (Zal.) Sew.	R	R
	Zamites borealis Heer	R	
	Dictyozamites grossinervis Yok.	T	
	D. cordatus (Krysht.) Pryn.	T	
	Ctenis latiloba Krysht. et Pryn.	T	
	C. yokoyamae Krysht.	T	
	C. intermedia (Krysht. et Pryn.) Pryn.	T	
	Nilssonia densinervis-type	R	R
	Nilssonia nicanica Pryn.	R	
	N. ex gr. *brongniartii* (Mant.) Dunk.	R	R
	Ginkgo pluripartita (Schimp.) Heer	T	
	Podozamites ex gr. *lanceolatus* (Lindl. et Hut.)	T	T
	P. tenuinervis Heer	T	
	Araucariaceae	R	
	Elatides asiatica (Yok.) Krassil.	T	T
Bar.	*Osmunda* sp.	T	
	Coniopteris burejensis (Zal.) Sew.	R	R
	Alsophilites nipponensis (Oishi) Krassil.		R
	Neozamites denticulatus (Krysht. et Pryn.)	T	T
	Dictyozamites cordatus (Krysht.) Pryn.	T	
	Ptilophyllum bajulae Krassil.	R	
	Nilssonia densinervis (Font.) Berry	R	
	N. ex gr. *brongniartii* (Mant.) Dunk.	R	R
	Ginkgo pluripartita (Schimp.) Heer		T
	Pseudotorellia sp.	T	
	Podozamites ex gr. *lanceolatus* (Lind. et Hutt.)	T	T
	Araucariaceae	R	R
Hau.	*Alsophilites nipponensis* (Oishi) Krassil.		R
Vlg.	*Coniopteris burejensis* (Zal.) Sew.		R
	Coniopteris arctica (Pryn.) Samyl.		R
	Dictyozamites kawasakii Tateiwa		T
	Podozamites ex gr. *lanceolatus* (Lind. et Hutt.)		T
Ber.	*Alsophilites nipponensis* (Oishi) Krassil.	R	R
	Coniopteris arctica (Pryn.) Samyl.		R
	C. burejensis (Zal.) Sew.	R	R
	C. cf. *vsevolodii* E. Lebed.	R	
	C. setacea Pryn.	R	
	Dictyozamites falcatus (Morris)	T	T

Table 2 (continued)

Age	Fossil plant taxa	Suifun basin	Suchan basin
Ber.	*Nilssonia densinervis*-type		R
	N. pseudomediana Dobrusk.		R
	N. ex gr. *brongniarti* (Mant.) Dunk.		R
	Pseudotorellia sp.		T
	Brachyphyllum aff. *expansum* (Sternb.) Sew.		T

R = representative of Ryoseki-type plants; T = representative of Tetori-type plants.

The Early Cretaceous floras of northern China and the Suifun basin are related. Floras of Outer Japan and the Suchan basin are closely analogous.

3. Tectonic reconstruction

When making a reconstruction, account must be taken of the large-scaled lateral displacements that took place in Cretaceous and Miocene times in this region (Xu et al., 1989; Xu, 1993; Otofuji and Matsuda, 1993; Otofuji et al., 1996).

The map of pre-Miocene tectonic structures of East Asia (Fig. 3) was made using the models of Kropotkin and Shakhvarstova (1965) and Bersenev et al. (1987) and the paleomagnetic data of Otofuji and Matsuda (1993) and Otofuji et al. (1996). The system of continental-margin shear zones is shown after Xu et al. (1989), Utkin (1993) and Xu (1993). The distribution of different-type Early Cretaceous floras and palynological assemblages is given using the data of Krassilov (1967), Kimura (1987), Ohana and Kimura (1995) and Markevich (1995).

Tectonic reconstruction of the eastern margin of Asia for the Late Albian time (Fig. 3) consisted in recovering the original position of the terranes which had been displaced northward along the continental-margin left-lateral faults during the Early Cretaceous (Golozoubov and Khanchuk, 1996). The reconstruction suggests that the Jurassic and Lower Cretaceous terranes were always situated in the vicinity of the continent–ocean border, while they were being formed and transported. This is evidenced by the arcosic composition of most of the Triassic, Jurassic and Lower Cretaceous terrigenous formations in Sikhote-Alin (Markevich, 1985). It is also suggested that the saw-shapes northeastern margins of the terranes resulted from left-lateral replacements along the shear zones. The similarities in structure and history of certain terranes in Sikhote-Alin and Japan — specifically, the Samarka terrane of Sikhote-Alin and the terranes Mino, Tamba, Ashio, Northern Kitakami and others of Outer Japan, the Taukha terrane of Sikhote-Alin and the Southern Chichibu terrane of Outer Japan, the Sergeevka terrane of Sikhote-Alin and the terranes Abakuma and Southern Kitakami of Japan — were taken into account as well. In addition, the reconstruction was based on the distribution of the different-type Early Cretaceous floras on the continental margin.

4. Conclusions

A main conclusion is that the Jurassic and Lower Cretaceous terranes of Outer Japan and southeastern Primorye have been markedly (not less than 15° of latitude) displaced northward from the place of their formation (15–30°N). These terranes chiefly are fragments of the Middle Jurassic–Early Cretaceous subduction-related melange that may be traced as an almost continuous belt along the southeastern margin of Asia.

The terranes of southwestern Primorye and Inner Japan have drifted in the same direction, but not so far (5° of latitude).

Distribution of the different-type Early Cretaceous mega- and palynofloras on the continental margins of Eastern Asia allows a more precise evaluation of the Early Cretaceous left-lateral displacements. The paleomagnetic data (Hirooka, 1990) and data on the distribution of the different-type Early Cretaceous malacofauna (Konovalov, 1988; Matsukawa et al., 1993) are less certain, but do not contradict the reconstruction presented.

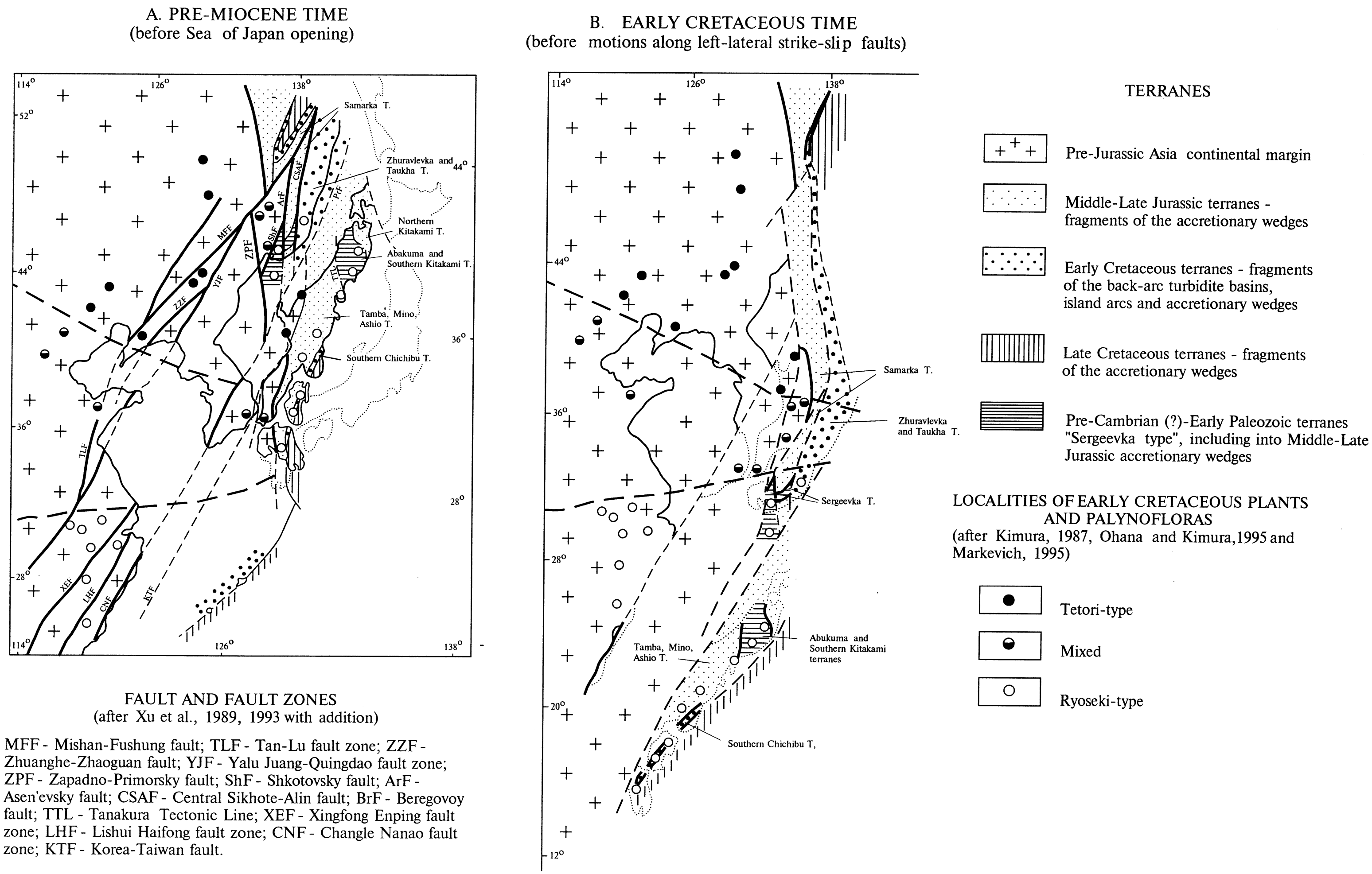

Fig. 3. Tectonic reconstruction of the eastern margin of Asia for the Pre-Miocene (A) and the Early Cretaceous (B).

Acknowledgements

The research was supported by grant No. 98-05-65343 of the Russian Foundation for Basic Researches. The authors thank Professor Hakuyu Okada of Kyushu University for helpful advice improving an earlier version of the manuscript.

References

Bersenev, I.I., Lelikov, E.P., Bezverkhniy, V.P., 1987. Geologiya dna Yaponskogo morya (Geology of the Japan Sea bottom). DVNCs AN SSSR, Vladivostok, 140 pp.

Golozoubov, V.V., Khanchuk, A.I., 1996. Taukha and Zhuravlevka terranes of South Sikhote-Alin — fragments of the Early Cretaceous margin of Asia. Geol. Pac. Ocean 12, 203–220.

Hirooka, K., 1990. Paleomagnetic studies of Pre-Cretaceous rock in Japan. In: Pre-Cretaceous Terranes of Japan. Publ. of IGCP Project 224, Osaka, pp. 401–406.

Kimura, T., 1987. Recent knowledge of Jurassic and Early Cretaceous floras in Japan and phytogeography of this time in East Asia. Bull. Tokyo Univ., Sect. IV 39, 87–115.

Konovalov, V.P., 1988. O nevalidnosti manomakhovskoy i kamenskoy svit v melovykh otlozheniyakh Primorskogo kraya (About invalidity of the Monomakhovka and Kamenka Formations in the Cretaceous deposits of the Primorye region). In: Novie dannie po biostratigrafii paleosoya i mesosoya yuga Dalnego Vostoka (New dates on the biostratigraphy of the Paleozoic and Mesozoic of the Southern Far East). DVO AN SSSR, Vladivostok, pp. 171–173.

Krassilov, V.A., 1967. Rannemelovaya flora Yuzhnogo Primorya i eyo znachenie dlya stratigraphii (The Early Cretaceous flora of South Primorye and its stratigraphical significance). Nauka, Moscow, 263 pp.

Kropotkin, P.N., Shakhvarstova, K.A., 1965. Geologicheskoe stroenie Tikhookeanskogo podvizhnogo poyasa (Geological structure of the Circum-Pacific mobile belt). Nauka, Moscow, 366 pp.

Li, W., 1994. The Cretaceous palynofloras and their bearing on stratigraphical correlation in China. Cretaceous Res. 5, 333–365.

Markevich, V.S., 1981. Novy vid *Classopollis* iz melovykh otlozheniy dna Yaponskogo morya (A new species of *Classopollis* from the Cretaceous deposits of the Japan Sea bottom). Palaeontol. J. 1, 129–133.

Markevich, P.V., 1985. Geosinklinal'noye terrigennoye osadkonakoplenie na vostoke Azii v phanerozoye (na primere Sikhote-Alinya i Kamchatki) (Geosynclinal terrigenous sedimentation on the East Asia in the Phanerozoic (on the example of Sikhote-Alin and Kamchatka)). Nauka, Moscow, 118 pp.

Markevich, V.S., 1995. Melovaya palynoflora severa vostochnoy Azii (The Cretaceous palynoflora of the north of East Asia). Dalnauka, Vladivostok, 172 p.

Matsukawa, M., Kalinin, E.A., Futakami, M., 1993. Paleogeography and paleocurrents of the Barremian strata in Japan, NE China and Sikhote-Alin (Russia). Palaeogeogr., Palaeoclimatol., Palaeoecol. 105, 71–81.

Ohana, T., Kimura, T., 1995. Late Mesozoic phytogeography in Eastern Eurasia, with special reference to the origin of angiosperms in time and site. Taegu, Korea, pp. 293–328.

Otofuji, Y., Matsuda, T., 1993. Paleomagnetic evidence for the clockwise rotation of Southwest Japan. Earth Planet. Sci. Lett. 62, 349–359.

Otofuji, Y., Matsuda, T., Nahda, S., 1996. Brief review of Miocene opening of the Japan Sea: paleomagnetic evidence from Japan arc. J. Geomagn. Geoelectr. 38, 287–294.

Song, Z., 1988. The Upper Cretaceous palynological assemblages in North Jangsu, China. Abstr. 7 IPC, Brisbane, p. 154.

Takahashi, K., 1974. Palynology of the Upper Aptian Tanohata Formation of the Miyako Group, North-East Japan. Pollen Spores 16 (4), 535–564.

Utkin, V.P., 1993. Wrench fault of Sikhote-Alin and accretionary and destructive types of fault dislocation in the Asia–Pacific Transition Zone. In: Xu, J. (Ed.), Tancheng–Lujiang Wrench Fault System. Wiley, New York, pp. 225–238.

Wang, D., Sun, X., Zhao, Y., 1990. The Late Cretaceous to Tertiary palynofloras in Xinjiang and Qinghai, China. Rev. Palaeobot. Palynol. 65, 95–104.

Xu, J., 1993. Basic characteristic and tectonic evolution of the Tancheng–Lujiang Wrench Fault System. In: Tancheng–Lujiang Wrench Fault System. Wiley, New York, pp. 17–51.

Xu, J., Tong, W., Zhu, G., Lin, S., Ma, G., 1989. An outline of the Pre-Jurassic tectonic framework in east East Asia. J. South-East Asian Sci. 3 (1-4), 29–45.