# ACCRETED MESOZOIC OCEANIC TERRANES OF KORYAK SUPERTERRANE, NORTHEASTERN RUSSIA

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## ABSTRACT

The Koryak superterrane of northeastern Russia contains many Mesozoic accreted oceanic composite terranes. Using conodonts and radiolaria to estimate deposition ages, these composite terranes vary in age between Triassic-Middle Jurassic, Late Jurassic-Early Cretaceous, and Albian-Campanian. Oceanic terranes, moving from in-board to out-board, show the oceanward younging to the south in both deposition and accretion ages. The structure and geometry of these accreted oceanic terranes also vary between: (1) dismembered ophiolite nappes, (2) blocks in serpentinite melanges and olistostromes, and (3) offscraped fragments of the relatively intact oceanic crust in a sheared argillite matrix interpreted to represent an accretionary prism sequence. Our work in the Koryak superterrane of these accreted oceanic terranes may also provide an additional source of information on the composition and structure and motion of Pacific plates.

## INTRODUCTION

The Koryak region, northeastern Russia, of the Eurasian continental margin is interpreted to have formed as a result of Cretaceous-Paleogene accretion (e.g., Sokolov, 1992). This portion of the northwest Bering sea region consists of a complex mixture of rocks interpreted to represent ophiolitic, oceanic, island-arc, and marginal-sea terranes (Fig.1).

Particularly important for paleogeographic or plate tectonic reconstructions are oceanic terranes now exposed in this region. The motions of these Late Jurassic-Early Cretaceous and Albian-Campanian accreted oceanic terranes may be directly related to the motion of contemporaneous Pacific plates, providing additional data for the reconstruction of Izanagi, Farallon, and Kula plates. Older Triassic-Middle Jurassic terranes have been so far virtually the only sources of information on the plate motion in the Northwest Pacific Basin in more ancient times. In this study, we summarize the composition, structure, and tectonic history of a complex accretionary region, which includes terranes of these ages.

## AGE AND TYPES OF OCEANIC TERRANES

Within the Koryak superterrane, there are Mesozoic accreted oceanic terranes of the following ages: Triassic-Middle Jurassic, Late Jurassic-Early Cretaceous, and Late Cretaceous (Albian-Campanian). These terranes occur among high-pressure metamorphic series as dismembered ophilitic nappes, blocks in serpentinite melange or olistostromes, and off-scrapped fragments in accretionary prisms.

### *Triassic-Jurassic Oceanic Terranes*

The Triassic-Middle Jurassic oceanic terranes include the Kuyul and Ekonai composite terranes. In the Kuyul superterrane, oceanic complexes of this age occur as blocks and thrust sheets in serpentinite melange. Triassic-Middle Jurassic units are represented in sequences of two facies types. The first unit consists of basalt (with an apparent thickness of 30-50 m), Carnian-Norian pelagic limestone (10-15 m), and Norian-Bajocian radiolarian jasper. The second unit consists of basalt with rare chert lenses (200-300 m) covered by Late Triassic-Middle Jurassic bedded chert and jasper (a few dozens of meters). In terms of petrology, incompatible elements and rare earth elements (REE's) (Fig.2), both types of basalt are close to weakly fractionated oceanic tholeiite. The ratio of $La/Sm < 1$ suggests that magma generation involved a strongly depleted mantle source common for midoceanic ridge basalt (MORB) (N-type). Thus, both associations appear to be typical of spreading centers, although differently positioned with respect to the carbonate compensation depth (CCD) level.

The Bathonian-Lower Tithonian (Upper Jurassic)-aged association of the Kuyul superterrane is represented by alternating 10-m-thick basalt flows and 2-5-m-thick layers of red radiolarite. Basalt shows various Fe and Ti content, with a distinct tholeiitic fractionation trend on the Miyashiro diagram (FeO* - FeO*/MgO). High abundances of HFSE, MORB-like pattern of REE (Fig.2), and $La/Sm < 1$ indicate that these basalts are close to T-type oceanic tholeiite. Ti, Zr, and Y ratios of these basaltic rocks in Pearce diagrams, like the Triassic basalt, plot into the MORB area and adjoining part of WPB field. This association is interpreted as arising from one terrane formed in the deep sea with MORB/oceanic volcanism associated with deep zones of magma generation. Siliceous rocks in the associations of the two stratigraphic levels are typically pelagic sediment with a low abundance of aluminosilicate clastics.

The Ekonai composite terrane is identified by widespread Middle-Late Triassic oceanic volcanic rock complexes. Spatially, these rocks are associated with ophiolite exposures. There are three sequences within the Ekonai terrane: basalt-chert, siliceous, and exotic.

The siliceous sequence is the most abundant. A 100-m-thick section spans the entire Middle and Upper Triassic and Lower Jurassic. The siliceous sequence is composed of gray-green chert, jasper, and radiolarite. In some sections, there are phthanites and dark-gray phthanoids, siliceous-clay rocks, and tuff. Bedded members with rhythmically intercalated beds of chert (1-5 cm) separated by thin layers (0.5 cm) of clay rocks are typical.

The basalt-chert sequence is composed of horizons of massive and pillow basalt, sometimes with lens-shaped cavities filled with nodular, lutecite ferriferous jasper-quartzite, or spar limestone. Both are nonbiogenic, deposited from thermal springs. Basalt flows are separated by horizons of radiolarian jasper. The age of the jasper is Early Carnian through the Rhaetian (Norian), and it is a few hundred meters thick. The extrusive lava flows are dominated by high-Ti, low-K ferriferous tholeiite.

The exotic sequence (Ladinian-Norian) is distinguished from the siliceous sequence by the occurrence of blocks of shallow-water limestone with Tethyan Carboniferous and Permian fauna and beds of chert-clastic rocks. The source of the "exotic" clastics must have been from the inner oceanic rises (Sokolov, 1985).

In the Late Jurassic-Early Cretaceous Mainits composite terrane described below, Triassic complexes similar to the ones described in the Ekonai terrane occur as blocks in serpentinite melange.

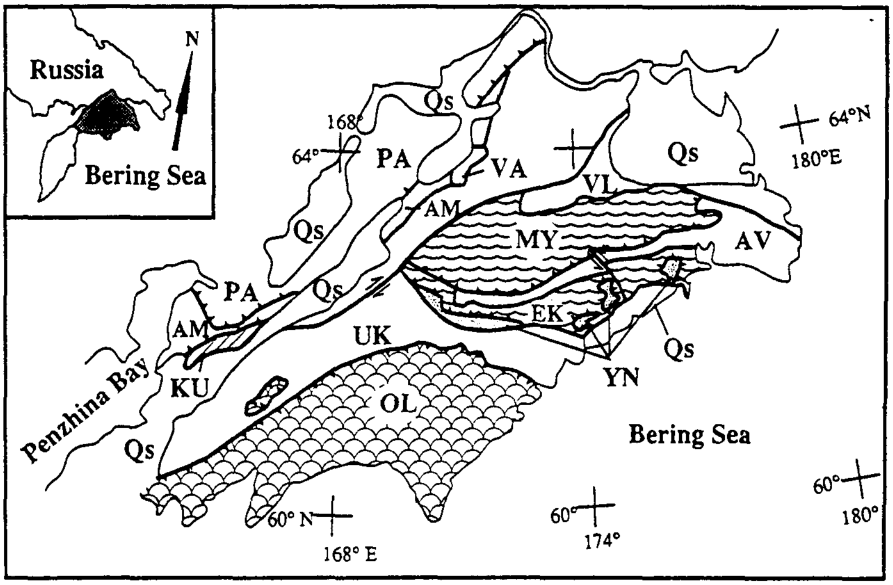


**Fig.1. A scheme showing Koryak superterrane with the arrangement of accreted oceanic terranes. Ticks represent Late Paleozoic-Early Jurassic; left diagonal hatching: Middle Triassic-Late Jurassic; dots: Late Jurassic-Early Cretaceous and Albian-Campanian; circles: Albian-Campanian. Letters indicate the terranes: AL-Algan, AM-Ainyn-Main, AV-Alkatvaam, EK-Ekonai, Ku-Kuyul, MY-Mainits, OL-Olyutor, PA-Penzhina-Anadyr, VA-Vaega, VL-Velikorechensky, UK-Ukelayat.**

*Late Jurassic-Early Cretaceous Oceanic Terranes*

The Late Jurassic-Early Cretaceous terranes include the Mainits and Yanranai composite terranes. In one of the thrust sheets of the Mainits composite terrane, terrigenous Cretaceous strata include a condensed section of radiolarite, chert, calcareous jasper, and siliceous limestone. The overall thickness of the section is 80 m. This section is characterized by Late Callovian-Kimmeridgian, Bajocian-Tithonian, Berriasian-Valanginian, and Valanginian-Hauterivian radiolaria and Valanginian Buchia. Vishnevskaya and Filatova (1992) suggest that the radiolarian assemblage corresponds to the northern Tethyan province and that they accumulated in the oceanic pelagic zone. Apparently, this complex formed at relatively shallow depths above the CCD level.

The Yanranai composite terrane is interpreted to represent an accretionary prism. The upper structural section consists of Late Jurassic-Early Cretaceous strata (the Yakanyveem thrust sheet) (Grigoriev et al., 1987). This sheet includes basalt flows alternating with bedded red jasper and chert. Overlying this sequence are terrigenous sedimentary rocks. Their thickness varies from 100 to 1000 m, generally as a function of the distance to the lower thrust contact.

Typical MORB's are the predominant basalt type in the sequence, particularly in the Jurassic portion. The Miyashiro diagram indicates that they plot along the tholeiitic differentiation trend. In the Pearce diagram of

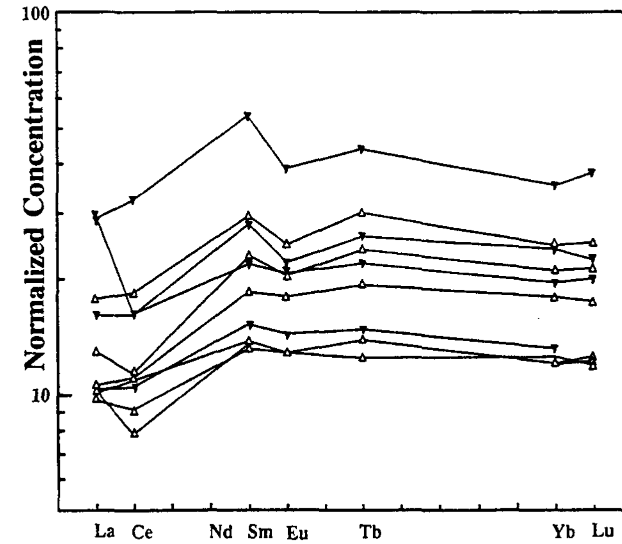


**Fig.2. REE pattern in Kuyul terrane's oceanic basalts normalized by the primitive mantle. Blank triangles are Triassic tholeiites; filled triangles are Bajocian-Early Tithonian tholeiites.**

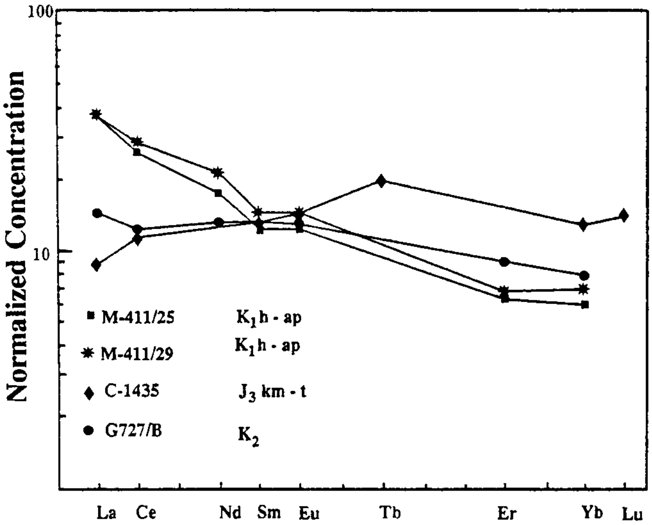


**Fig.3. REE pattern in the Yanranai accretionary prism's basaltoids normalized by the primitive mantle. Yakanyveem sheet, samples: M-411/25-trachyandesite-basalt, M-4111/29-alkaline basalt, C-1435-MORB tholeiite. Vaamychgyn sheet, sample G-727/B, is tholeiite.**

Ti, Zr, and Y ratios, the Jurassic basalt falls into the MORB field and neighboring part of the WPB area. REE distribution patterns (Fig.3) with La/Sm$<1$ also indicate typical oceanic N-type MORB tholeiite, derivatives of the depleted mantle. In the Lower Cretaceous section, tholeiite coexists with alkaline basalt and occasional flows of trachyandesite-basalt. They are rich in HFSE and REE (Fig.3). The La/Sm ratio is greater than one. In terms of their petrologic and geochemical characteristics, the Lower Cretaceous basalt is close to WPB. The geochemical patterns of red radiolarian jasper in this sheet correlate with deep-water pelagic oceanic strata with a pronounced negative Ce anomaly (Fig.4).

*Albian-Campanian Oceanic Terranes*

The Albian-Campanian terranes include the Yanranai and Olyutorsky composite terranes. The upper part of the Yanranai composite terrane consists of two lower sheets: the Yakenmyveem and Vaamychgyn overlain by a sedimentary section. The lower part of the Yakenmyveem sheet is represented by basalt and spilite, often pillow-shaped, and by hyaloclastic rocks. The overall thickness of the effusive portion is about 300 m. It is covered by bedded chert, jasper, and radiolarites (40-60 m thick), containing Albian-Turonian radiolaria. The upper part of the section consists of siltstone alternating with sandstone that exhibits flyschoid stratification in its upper part. Grains within the clastic rocks include quartz, plagioclase, chert, and effusive fragments. The terrigenous part of the section is 700-800 m thick, and its age is determined by radiolaria and Inocerams as Coniacian-Campanian. At the time, this part of the oceanic plate was close to the active margin where the

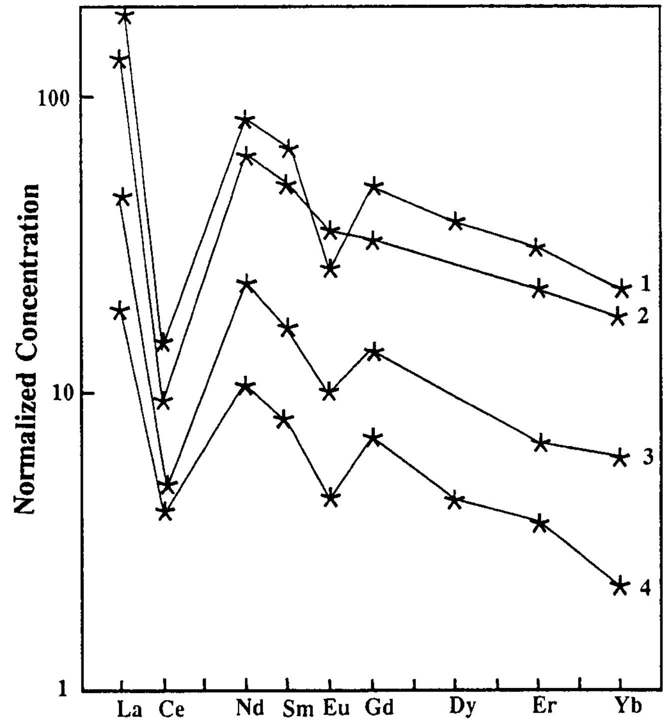


**Fig.4. REE pattern in cherts of the Yanranai accretionary prism normalized by the primitive mantle. Vaamychgyn sheet (Alb-Campanian), metalliferous jaspers ($FeO^*+MnO>20$ w%): 1-G-738/20, 2-M-389/7, 3-M-405/10. Yakanyveem sheet (Tithonian-Necocomian), jasper ($FeO^*+MnO=4,5$ w%): 4-G720/1.**

clastics were brought in by autokinetic currents.

Rocks of the Vaamychgyn sheet include interbedded basalt; hyaloclastic rocks; mafic tuff; and less frequently bedded chert, radiolarite, and metalliferous (Fe-Mn) jasper. Up-section there is organo-clastic limestone and calcarenite with pieces of thick-walled mollusks, including *Inoceramus schmidti*. The indicated age of the Vaamychgyn sheet is Albian through Campanian, and it is 150 m thick.

Compositionally, basalts of the Yakenmyveem and Vaamychgyn sheets correspond to MORB. This is also supported by the REE patterns (Fig.3). In contrast to the Late Jurassic-Early Cretaceous basalt of the Yakanyveem sheet, Late Cretaceous basalt (particularly in the Yakenmyveem sheet) show a greater abundance in fractionated ferriferous tholeiite. Chert and metalliferous jasper of the Vaamychgyn sheet show REE patterns typical of deep-water pelagic sediments, with a pronounced Ce low (Fig.4).

Imbricate structures are characteristic of the Olyutorsky composite terrane and the oceanic complex. The composite terrane and oceanic complex consist of basalt, mafic tuff, hyaloclastic rocks, radiolarite, and bedded chert that form the Vatyn formation (Astrahantzev et al., 1987), which is found in all thrust sheets of the Olyutorsky terrane. In some sheets there are beds of pelagic limestone. The faunal age of the Vatyn formation

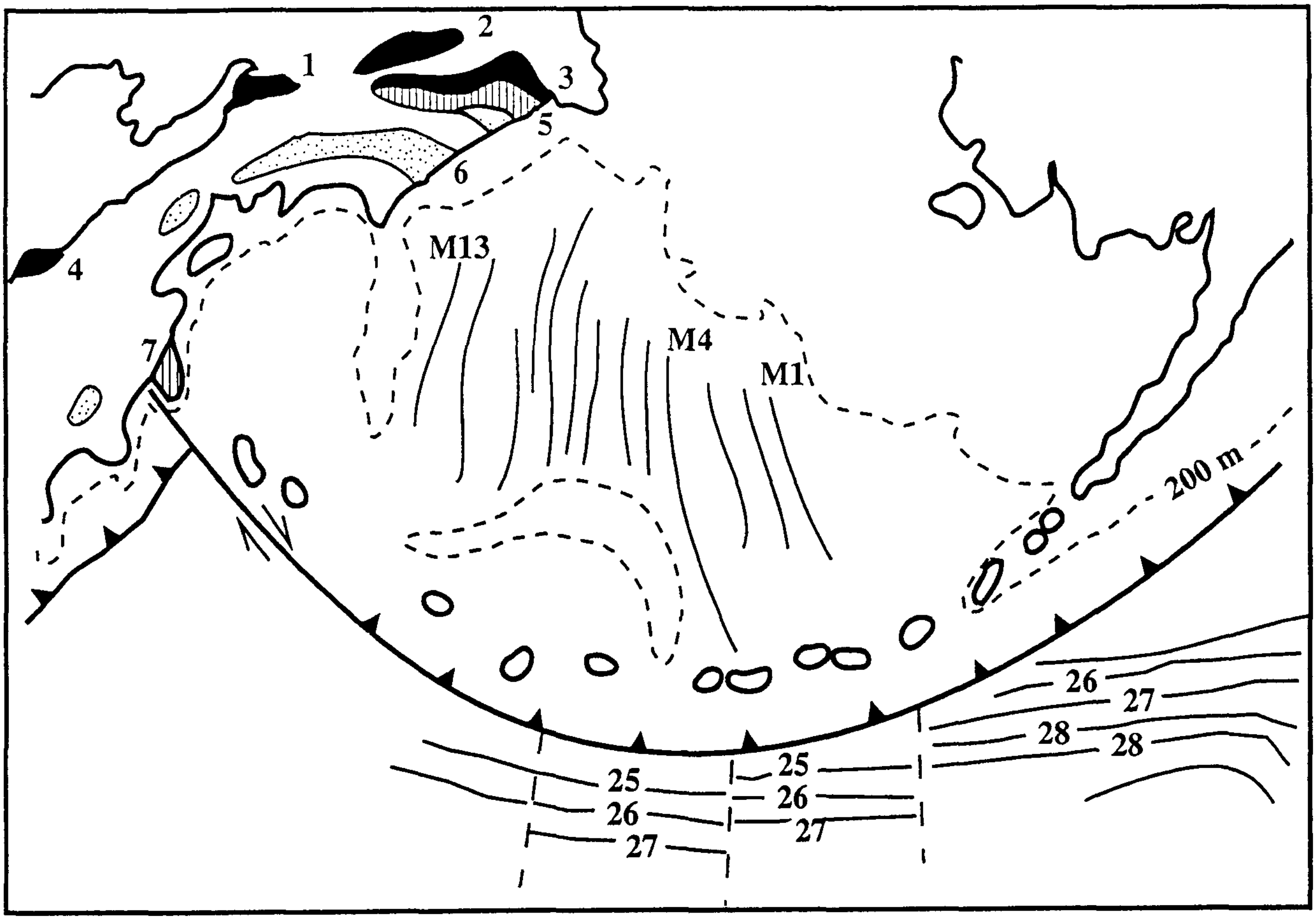


**Fig.5. Index map of the Kamchatka-Koryak-Bering sea region. Data for the Bering Sea from Cooper et al., (1976). Shown with black are oceanic Triassic-Jurassic complexes; hatching: Late Jurassic-Early Cretaceous; dots: Albian-Campanian. Numerals are terranes: 1-Kuyul, 2-Mainits, 3-Ekonai, 4-Omgon, 5-Yanranai, 6-Olyutor, 7-Cape Kamchatka.**

is Albian through Campanian. Analysis of the Vatyn basalts indicates that there are both MORB-like tholeiites and OIB (Fedorov, 1990). The thickness of the Vatyn formation varies from 400 to 1200 m. Upper Cretaceous oceanic complexes also occur in northern Kamchatka (lower part of the Irunei suite) (Grigoriev and Shapiro, 1986), and in the Upper Cretaceous melange and accretionary prisms of eastern Kamchatka (Tsukanov and Fedorchuk, 1989; Fedorchuk et al., 1989).

## DISCUSSION

Fig.5 shows the position of the Mesozoic oceanic terranes within the Koryak-Kamchatka foldbelts and magnetic anomalies of the oceanic crust in the Aleutian basin (Cooper et al., 1976). The age progression of the accreted oceanic complexes toward the ocean fits well in eastward younging of M1-M13 magnetic anomalies. More significantly, in the western Yanranai composite terrane, oceanic complexes of the Yakenmyveem sheet are Oxfordian in age, while in the east, the sequence begins with Tithonian deposits. These data suggest that Late Jurassic-Early Cretaceous accreted oceanic complexes of the Koryak superterrane and the oceanic crust of the Aleutian basin may be fragments of one and the same plate. In the reconstructions by Engebretson et al. (1984), this could be the Izanagi or the Farallon plate, whereas in the model of Rea and Dixon (1983), it was the Bering plate.

It is far more difficult to invoke generally accepted plate reconstructions to account for the positions of the Late Cretaceous oceanic complexes in the accretionary structure of the Koryak superterrane and Kamchatka. Albian-Campanian oceanic complexes described in this paper have a different origin than the Late Jurassic-Early Cretaceous terranes and may indicate important amendments to the reconstructions of plate motions in the northwestern Pacific Basin. Three possible alternatives are discussed below.

The first explanation holds that the Aleutian plate rotated to a high degree as a result of interaction between the Asian and North American plates. Late Cretaceous oceanic complexes of the Koryak superterrane are considered to be accreted pieces of the Kula plate. However, in this version, the movement path of the plate and the Kula-Farallon spreading ridge must be altered to accommodate accretion of this part of the plate to Asia.

In a different version, supported by the authors, a

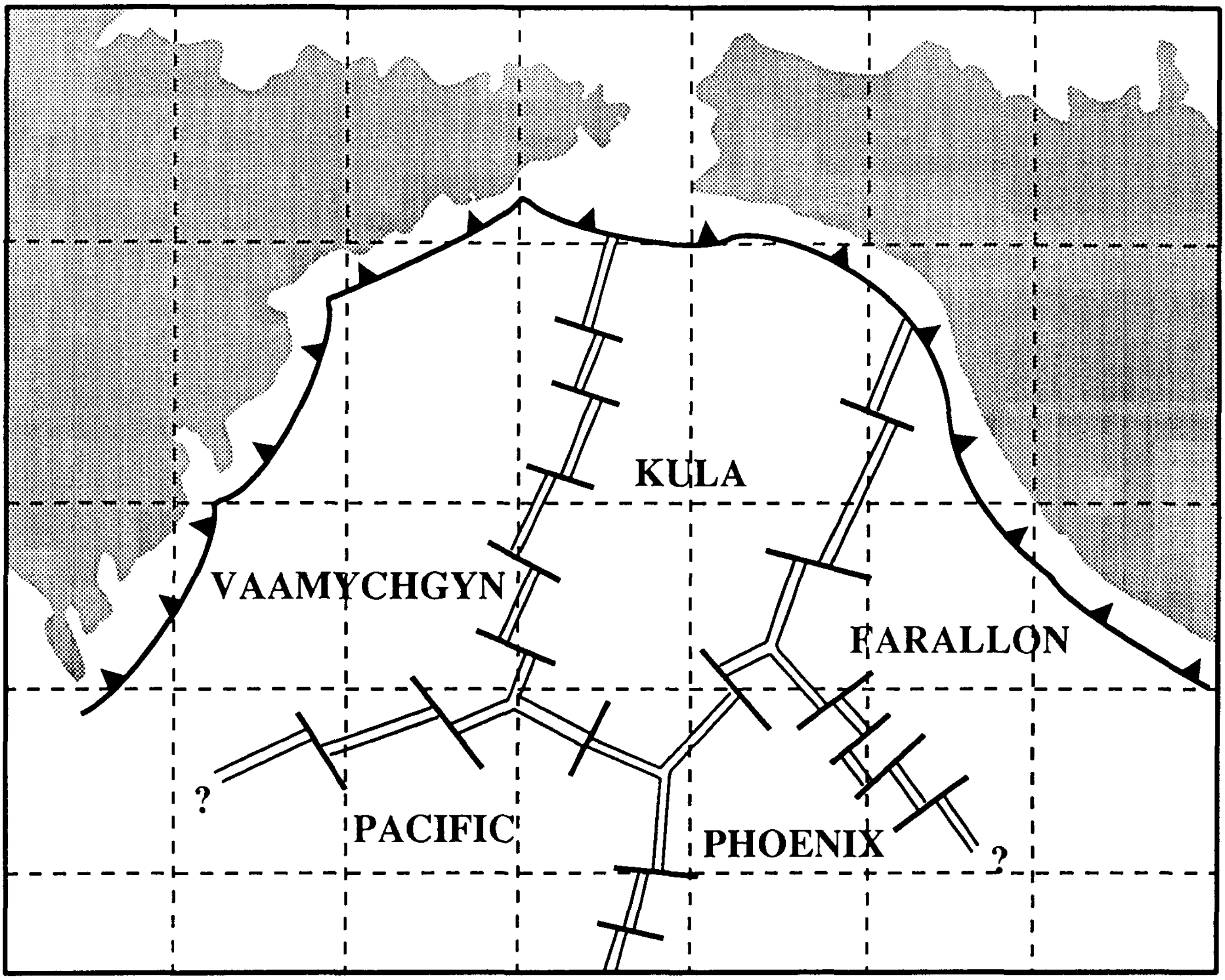


**Fig.6. A reconstruction of Pacific plates for the Late Cretaceous.**

new spreading center (Kula-Vaamychgyn) emerged east of Asia in Albian time (Fig.6). As in the case of traditional reconstructions, the Kula-Farallon plate shifted toward North America, the Kula-Vaamychgyn spreading center shifted northwest, and the Vaamychgyn plate was partly subducted and partly accreted to the Asian continent. Based on paleontological data from Albian-Cenomanian radiolaria (Vishnevskaya, 1990), this new spreading ridge was probably oriented north-south. The difference in fauna between the terranes of the Far East is interpreted as changes in paleolatitude: (1) middle- to high-latitude faunas (40-45° N.) in Koryak, (2) middle-latitude faunas (30-35° N.) in Kamchatka, (3) low-latitude faunas (20-30° N.) in Sakhalin.

The third alternative is that the Aleutian oceanic crust is, in fact, younger than believed. Continental data suggest a Santonian-Early Tertiary age. If this is the case, then the age of magnetic anomalies in the Aleutian basin will have to be significantly revised.

## CONCLUSIONS

The sedimentary strata of the accreted Mesozoic oceanic complexes of the Koryak superterrane are represented primarily by a variety of siliceous rocks: red radiolarite and jasper, gray chert, and phthanoids. In many sections, they cover sequences of basalt comparable to modern oceanic tholeiites. Not infrequently, flows of basalt and siliceous rock alternate. These sequences are similar in type to the Bathonian-Callovian section recovered by DSDP hole 801 in the Eastern Marianas trench (Larson et al., 1992). Certainly, within the central Pacific, these types of deposits were much more extensive. The composition and character of microfauna are indicative of accumulation of siliceous strata at lower latitudes than their present localities (Bragin, 1991; Vishnevskaya, 1990). Paleomagnetic data from the oceanic complexes tend to support their allochthonous position, showing significant post-depositional northward motion (Didenko et al., 1992).

Accreted oceanic complexes of the continental margin can provide important insights into the reconstruction of the Pacific Ocean Basin and its margins.

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## REFERENCES

Astrahantzev, O.V., Kazimirov, A.D. and Heiphetz, A.M., 1987, Tectonics of the northern part of the Olyutorsky zone, In: J.M. Pushcharovsky (Editor), Essays on the Geology of the Northwestern Sector of the Pacific Tectonic Belt, Nauka, Moscow, pp. 161-183 (in Russian).

Bragin, N. Yu., 1991. Radiolaria and Lower Mesozoic sequences of the Eastern USSR. Tr. GIN, Nauka, Moscow, n. 469, 123 pp. (in Russian).

Cooper, A.L., Marlow, M.S. and Scholl, D.W., 1976. Mesozoic magnetic lineations in the Bering sea marginal basin, J. Geophys. Res., v. 81, 11: 1916-1934.

Didenko, A., Harbert, W. and Stavsky, A., 1992. Paleomagnetism of Khatyrian and Maynisky terranes, Koryakian Highlands, Northeast CIS (abst). International Conference on Arctic Margins Abstracts, Alaska Geological Society, Anchorage, Alaska, September 2-4, pp. 24.

Engebretson, D.C., Cox, A. and Gordon, R.G., 1984. Relative motions between oceanic plates of the Pacific Basin. Journ. Geophys. Res. 89: 10291-10310.

Fedorchuk, A.V., Vishnevskaya, V.S., Izvekov, I.N. and Rumyantseva, Yu S., 1989. New data on the structure and age of chert-volcanic assemblages of Cape Kamchatka peninsula. Izvestiya vysshikh uchebnykh zavedenii (geologiya i razedka), (11): 27-33 (in Russian).

Fedorov, P.I., 1990. Geochemistry and petrology of Late Cretaceous volcanics of the southern Kamchatka Highlands. Geokhimiya. (11): 1583-1594 (in Russian).

Grigoriev, V.N. and Shapiro, M.N., 1986. Upper Cretaceous volcanics of the Kamchatka neck. Tikhookeanskaya Geologia, (4): 58-65 (in Russian).

Grigoriev, V.N., Krylov, K.A. and Sokolov, S.D., 1987. Jurassic-Cretaceous deposits of the Yanranai accretional complex, Koryak Highlands. In: J.M. Pushcharovsky (Editor). Essays of the Geology of the Northwestern Sector of the Pacific Tectonic Belt. Nauka, Moscow, pp. 110-140 (in Russian).

Larson, R.L., Lancelot, Y., et al., 1992. Proc. ODP, Sci. Results, 129 (Ocean Drilling Program), College Station, TX.

Rea, D. and Dixon, J.M., 1983. Late Cretaceous and Paleogene tectonic evolution of the North Pacific Ocean. Earth and Planet. Sci. Letters, 65: 145-166.

Sokolov, S.D., 1985. Early Mesozoic exotic sequences in the north of the Pacific belt. Dokl. AN SSSR, 283: 690-693 (in Russian).

Sokolov, S.D., 1992. Accretionary tectonics of the Koryak-Chukchi segment of the Pacific Ocean belt. Nauka, Moscow, 182 pp. (in Russian).

Tsukanov, N.V. and Fedorchuk, A.V., 1989. Oceanic complexes in structure of East Kumroch (Kamchatka). Dokl. AN SSSR, 307: 943-947 (in Russian).

Vishnevskaya, V.S., 1990. Albian-Cenomanian radiolaria of the northwestern Pacific as a clue to the paleotectonic reconstructions in the region. Tikhookeanskaya Geologia, (2): 3-15 (in Russian).

Vishnevskaya, V.S. and Filatova, N.I., 1992. Environments of Middle Mesozoic complexes of the Anadyr-Koryak region. Izvestiya vysshikh uchebnykh zavedenii (geologiya i razvedka), 1: 29-49 (in Russian).