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PALEOBIOGEOGRAPHIC CRITERIA OF TERRANE GEODYNAMICS OF NORTHEASTERN ASIA IN MESOZOIC

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Analysis of geographical ranges of 200 genera of myrians and more than 170 genera of ammonites over 15 centuries of the Mesozoic (from Late Triassic to Hauterivian) in Northeastern Asia showed that the majority of tethyan taxa of ammonites spread south of latitude 45°, whereas boreal taxa dwelled north of latitude 55°. On the territory between latitudes 45° and 55° boreal and tethyan mollusks co-existed. In this space, a biogeographic ecotone had existed for 15 ages. The border between the tethyan (tropical) and boreal (northern) realm changed its position several times during the Late Triassic, Jurassic and Early Cretaceous, but it rarely left the band between 45° and 55°N. This fact can be explained by the existence of climatic zonation which controlled the fauna spreading in the Mesozoic. Findings of fossilized shells of warm water-loving genera of ammonites and myrians in the Upper Triassic, Jurassic and Cretaceous in the boreal assemblages in the Anyui, Omolon, Okhotsk, Kolyma, and Chukchi sialic massifs in the north reaching 70°–72°N can be explained by migrations connected with the periods of leveling of water temperatures caused by eustatic rises of sea level. Anyui, Omolon, and Okhotsk massifs of Northeastern Asia were located north of the contemporary latitude 55° in the Mesozoic. This is because the Late Triassic invertebrate fauna of these massifs had a boreal character, typical of the coeval Verkhoyansk complex and northeastern margin of the Siberian Craton. Biogeographical data on Alazeya, Novosibirsk, Kolyma and Chukchi sialic blocks are insufficient to make a conclusion about their geographic position for each of the 15 ages. The earliest evidence of high-latitude, i.e. boreal, location of Novosibirsk and Chukchi terranes belongs to the beginning of the Middle Jurassic, whereas Alazeya and Kolyma, to its end. Findings of purely tethyan associations of the marine invertebrates in the Triassic and Jurassic sections of the Koryak and Sikhote-Alin blocks allow us to suppose their horizontal movement for thousands of kilometers to the north of the original location on the tropical latitudes of the Paleopacific. The system of the Koryak blocks in the Mesozoic was located to the south of the contemporary latitude 45°. By the end of the Late Cretaceous, these blocks had accreted to the Siberian Craton. The Sikhote-Alin block system was also located where the tropical climate exerted an effect before the Late Triassic. However, in the Early Jurassic (Pliensbachian), it was located north of latitude 45°, because both boreal and tethyan genera of ammonites and myrians existed in the Early Jurassic assemblages of mollusks.

Terrane, plate tectonics, Mesozoic, paleobiogeography, mollusks, Northeastern Asia

INTRODUCTION

In the 1960s, the revival of mobilism in the light of new ideas of global tectonics awakened interest in paleobiogeography as an instrument for testing new palinspastic constructions. Many tens of papers dealing with continent paleobiogeography have been published, where the researchers either support the conception or subject it to criticism [1–9]. Today the adherents and opponents of this conception have new arguments in connection with the problem of possible horizontal movement of microplates (terranes) during the Mesozoic.

As an argument for the terranes the adherents indicate unusual northern or on the contrary farthest southern occurrence of tethyan (tropical) fossil remains within circum-Pacific continents. Some taxa of marine invertebrates (on occasion, their entire assemblages) unanimously regarded by workers as tethyan (tropical and subtropical) currently occur far north and south of the former tethyan realm. This phenomenon can be explained either by drift of tectonic blocks in the Mesozoic among displaced plates of the old Pacific, or by migration of organisms themselves (including in the larval stage) because of climatic fluctuations or with currents.

Historical study of the distribution of tethyan groups in the Mesozoic may appear to be actually effective on determining the initial position of the microplates, which are now situated within orogenic belts in the north and south of the Pacific. American and English researchers have analyzed the pattern of dispersion of ammonites found in sequences along the Pacific coast of North America during the Jurassic period, and have shown that among a dozen of terranes found along the coast from Mexico to South Alaska today, none occupied the same place where it was 190 Ma ago; they all moved northward for at least 500 to 2500 km [10–14].

As studies of Mesozoic cherty measures on either side of the North Pacific have shown, exotic blocks of reef limestones containing rich tethyan faunas are frequent among them [15–18]. The authors of these publications are inclined to believe that cherty measures are allochthonous by origin, and their heaping in orogenic belts was due to horizontal displacement of the bottom in the deep-water part of the Pacific.

In northeastern Asia tethyan taxa of marine invertebrates have also been found in sequences of the Triassic, Jurassic and Cretaceous age. A number of sites in the Koryak upland (Kenkeren) yielded tethyan invertebrates of Triassic age, such as ammonoids, bivalves, brachiopods, and corals [19, 20]. Also Middle Jurassic (Bathonian-Callovian) tethyan ammonites of the families *Perisphinctidae* and *Oppellidae* were described from here (Kostvarelan basin) [21]. The records of this fauna "exotic" to boreal regions are attributed by the authors to horizontal displacement of the blocks from southern and eastern areas of the Pacific to the north for a distance of many hundreds or even thousands of kilometers.

However, in addition to more popular concepts of migratory terranes, there are also paleogeographic reasons suggested to explain unusual northward distribution of tethyan groups of invertebrates within the Circum-Pacific. The fauna is assumed to spread through unkown marine passages which crossed the continental part of Pangea; either tethyan taxa penetrated to the north of the Pacific owing to warm surface currents or to climatic fluctuations [22–24].

Analysis of mollusk assemblages along the Pacific coast in Northeastern Asia suggests that the distribution of ammonites and bivalves in the Mesozoic has been greatly influenced by climate. On the territory between 45° and 55°N an ecotone zone was established where boreal and tethyan marine invertebrates co-existed. North of the ecotone boreal fauna was dominant, and tethyan fauna dwelled south of it. Based on biogeographic analysis of the mollusks it has been proposed that the Alazeya, Anyui, Omolon and Okhotsk Massifs did not reach low latitudes (were not located south of 55°N) during the Jurassic [25–27].

It is shown for the Cretaceous (Albian) that in the northeast of Asia there existed systems of basins within inner and outer zones of the Paleopacific, which unlike the North-American ones had no barriers in between, thus permitting undisturbed exchange of fauna. This is indicative of territorial proximity of both types of fauna [28]. Biogeographic analysis of fauna from the Cretaceous seas of inner zones (present-day miogeosynclines) reveals its structure-formational zonation of the continent-ocean contact line rather than testifies that it was warm-loving. This explanation is quite valid for the Cretaceous, e.g., in the replacement of buchia-inoceram biotas by radiolarian ones (Early Neocomian) and so on. In all these cases specific inhabitants of the Cretaceous seas in inner zones can in no way be considered tropical (tethyan) for lack of typical tethyan taxa such as rudists, nereids and turritellids [29, 30].

It would be an overestimation to say that the problem of terranes in Northeastern Asia is already solved or brought nearer to the solution. We shall have yet an extended discussion on the geological history of some terranes, the number of which constantly increases with number of publications (see journal of *Tikhookeanskaya Geologiya*, 1995–96). When considering significant horizontal movement of terranes, it is advisable to use a paleontologic or, more precisely, paleobiogeographic method along with physical and geological procedures. The objective of the paper is to show the potential of the method based on the example of several major terranes of Northeastern Asia. Upon analysis of areal ranges and structure of mollusk assemblages we made an attempt to determine a more probable geographic position of a number of major sialic blocks using 15 time intervals over Mesozoic ages (from Carnian to Hauterivian).

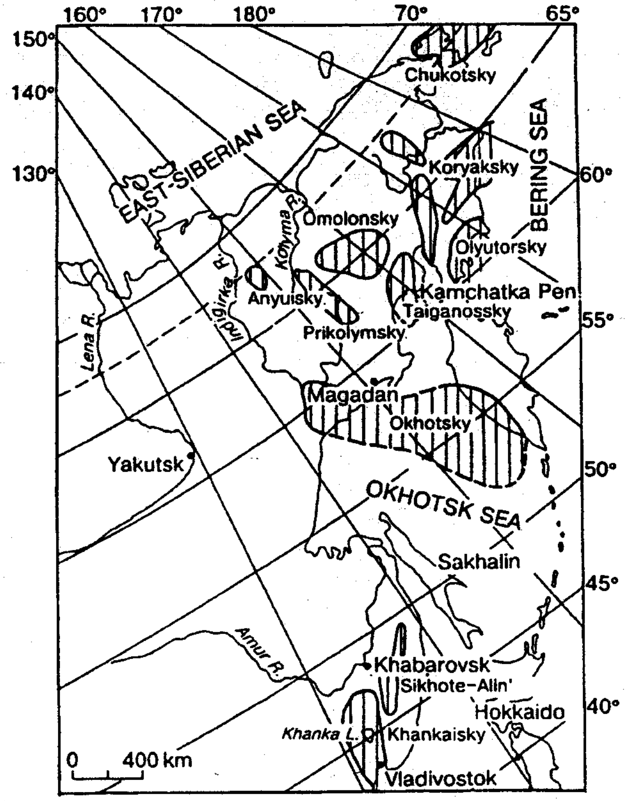


Fig. 1. The scheme of location of sialic massifs and blocks in Northeastern Asia (according to [32, 34, 39, 50]).

CHOICE OF OBJECTS

We have considered some of the terranes known from literature (sialic blocks, median massifs, tectonostratigraphic units, allogenic or exotic blocks, microcontinents, microplates). The choice of specific blocks was dictated by the presence of sedimentary cover or by the occurrence of proven coeval facies equivalents at their margins (Fig. 1).

The number of terranes, nomenclature and judgement of their nature vary from one author to another [31]. Thus, Chikov [32] has recognized two types of median massifs: with pre-Cambrian basement (eight massifs, which include Omolon, Okhotsk and Taygonos), and combined pre-Cambrian-Paleozoic basement (Kolyma, Chukchi-Siuard, and Khanka Massifs). The monograph by Parfenov [33] lists four microcontinents: Bureya-Khanka, Omolon, Okhotsk and Chukchi, and ten small sialic blocks. Subsequently this author has developed more complex genetic classification for terranes, where accreted terranes formed a separate group: of island arcs, accretion wedge, oceanic, carbonate platform, shelf terrigenous, cratonic; post-algamated formations in Kolyma-Omolon superterrane: volcanic arcs, front-arc troughs and back-arc troughs, plate and post-accretionary formations [34]. Churkin and Trexler [35] distinguished 2 types of terranes: with continental crust (in the Lomonosov Ridge, on the Novosibirsk Islands, Kolyma and Chukchi) and oceanic crust (Okhotsk terrane, a number of Koryak terranes). Kojima [36] classifies tectonostratigraphic terranes in Primoriye into two types: the Central Sikhote-Alin' monotype and the continental type, such as Khanka, Dzhamusy, Tetyukhe and Eastern Sikhote-Alin'. Westermann [37, 38] separated the terranes of Northeastern Asia into terranes with continental crust (Omolon, Prikolyma) and oceanic crust (Anadyr, Koryak, Olyutor, Sakhalin and North Japanese). A greater number of massifs and allogenic blocks (totalling to 17) were recognized in Northeastern Asia by Zonenshain et al. [39]. Inasmuch as there is no strict definition for the notion "terrane", we confine ourselves to its more general notion as part of the Earth's crust that differs greatly in its characters from structural framing.

In most listed and many other publications the following sialic blocks are mentioned most often: Omolon, Okhotsk, Alazeya, Anyui, Koryak, Kolyma (found to be heterogeneous by nature), Sikhote-Alin', Chukchi, Taygonos. However, even these major sialic blocks are recognized within different limits by different authors. The Okhotsk block for example is now either considered as part of the Okhotsk median massif [40], or is interpreted as a separate one. The Okhotsk and Omolon Massifs are united into a single microcontinent [39], though the latter is sometimes included into the Kolyma Massif [33, 34].

The adherents of the terrane concept consider all sialic blocks of Northeastern Asia to be to a different extent foreign, i.e., alien to a geologic situation in which they are at present. Some authors such as: Savostina et al. [41], Zonenshain et al. [39, 42], Stavskii et al. [43], Kononov [44], Zonenshain and Kuzmin [45], Natapov and Surmilova [46], Fujita and Newberry [47], Westermann [37, 38], and Kojima [36] believe that sialic blocks (terranes) in Northeastern Asia (Alazeya, Anyui, Koryak, Olyutor, Omolon, Okhotsk, Chukchi, etc.) during the Triassic, Jurassic and, partly, Cretaceous periods have been situated to the southeast, south or even far to the south (as far as Southern Hemisphere) from their present-day position. During the Jurassic, Cretaceous and, partly, Paleogene these accreted to the Siberian craton. The workers arrived at this conclusion, mainly, on the basis of paleomagnetic, petrologic, geomorphologic and structural data. Where paleontologic and stratigraphic material were used, they were interpreted in isolation from the regional paleogeographic situation. We decided to bridge this gap and to make an effort to determine the geographical position of some crustal blocks of Northeastern Asia in the Mesozoic based on paleobiogeographical analysis of microfauna.

METHODS OF STUDY

The most representative and numerous group among Triassic, Jurassic and Cretaceous invertebrates are mollusks. This work considers over 200 genera of bivalves and more than 170 genera of ammonites, each genus being confined to an appropriate time and geographic locality. According to biogeographical characters all taxa of genus rank were divided into three groups: boreal, tethyan, and cosmopolitan. Ammonite genera localities and those of most typical bivalves were plotted on paleogeographical charts at a scale of 1 : 20,000,000 developed for the Late Triassic (two charts), for ten ages of the Jurassic period and three ages of the Cretaceous period for the Pacific territory of Northeastern Asia (Figs. 2–12). The geographical range of all mollusk genera are analyzed to reveal regularities in distribution of tethyan and boreal taxa remains along the Asian margin of the North Pacific. The material was analyzed to determine the boundaries of two paleobiochores of first rank (boreal and tethyan areas) and to ascertain a zone of joint occurrence of boreal and tethyan genera, i.e., a biogeographical ecotone for each of 15 ages. To discuss possible reasons of the presence of tethyan fauna in boreal seas and boreal fauna in tethyan seas we have investigated spatial and temporal dynamics of mollusk migration over Jurassic ages.

It is useful to keep in mind that paleobiogeographical analysis like any other method has natural restrictions and resolution. It is hardly probable that based on this method we shall ever manage to locate microplates in system of coordinates; nevertheless it may be helpful in considering their position in a specific biogeographical area and (for Mesozoic and Cenozoic) within a particular climatic zone in a given geologic time.

STRATIGRAPHIC BASIS AND PALEONTOLOGICAL MATERIAL

Mesozoic deposits in the northeast and Far East of the USSR have been thoroughly studied in both structural and paleontological aspects. Complete Jurassic sections were described in detail from the Verkhoyansk depression, Yano-Tarym folded area, In'yali-Debin synclinorium, Ol'dzhoy-Polousninsk and Momo-Zyryanka depression, Bokhapchino-Sugoy folded area, Kolyma, Omolon and Okhotsk Massifs, Alazeya-Oloy and Chukchi geosynclinal system, Koryak-Kamchatka and Sikhote-Alin' geosynclinal areas, Armano-Gizhigin, Uda, Toromsk and Bureya troughs.

In a number of massifs such as Omolon, Okhotsk, Alazeya and sialic blocks including Anyui, Koryak, Chukchi, and Sikhote-Alin' thick marine deposits of Triassic, Jurassic and Early Cretaceous age have been known for a long time. Here all stages, substages and most zones are often recognized in continuous sections, thus indicating that marine basins persistently existed thoughout the Triassic, Jurassic and Early Cretaceous time, i.e., in the range of 65–240 Ma. The rocks are mainly represented by terrigenous clastic sediments with an admixture of tuffaceous material [30, 48–50]. Laterally, foreshore facies are replaced by moderately deep-water and deep-water facies [51, figs. 5, 7, 10, 13, 16, 18, 21, 24, 27, 30]. Merely cherty and carbonate facies occur on some restricted territories. Development of purely clastic terrigenous rocks during the Late Triassic, Jurassic and Early Cretaceous (i.e. over 130 Ma) in the framework of the sialic blocks mentioned is indicative of sedimentation in cool (boreal) waters.

As much as 90–95% of taxa of marine invertebrates form boreal and, occassionally, arctic groups such as inoceramids and buchiids (among bivalves) common in deposits of Central Arctic, North Siberia, Arctic Canada, Greenland and North Scandinavia [51]. Southern (tethyan) representatives are rare, and at certain stratigraphic levels only they are found jointly with boreal groups.

Climatic zonation in the Jurassic period is a reliably established fact. At the margins of the North Pacific it is reflected in a regular distribution of rock types: in the boreal realm (normally north of latitude 50°N), clastic terrigenous rocks occur dominantly and in the tethyan realm (generally south of latitude 45°N) largely carbonate rocks occur. The same is true of biota: boreal biota (north of latitude 55°N) is essentially more uniform and is characterized by the presence of plant and animal forms which lived only in a cool climate. Thus, the features of differentiation of sediments and organic world taxa may be indicative of the latitudinal position of the Earth's crust blocks at any interval of geologic time provided there are no contradictory datings of fossil-containing rocks.

FEATURES OF DIFFERENTIATION OF MESOZOIC MARINE BIOTA AT THE PACIFIC COAST OF NORTHEASTERN ASIA AND LOCALIZATION OF BIOGEOGRAPHICAL ECOTONE

The biogeography of marine Triassic, Jurassic and Cretaceous invertebrates in Northeastern Asia has been well studied for each age. The main character of the Mesozoic marine boreal fauna from Northeastern Asia is its poor taxonomic diversity as compared with that of Southeastern Asia (tethyan). It was proven that the entire Northeastern and Far East Russian territory (with the exception of Southern Primorie) should be included, based on benthos, into the boreal region, while, according to semipelagic species, especially ammonites, the Amur area and most parts of the Primorie belonged to the northern margin of East Tethys. Between the contemporary 45° and 55°N there is a zone (from 5 to 10°) of mixed boreal and tethyan fauna, i.e. a biogeographical ecotone first noted in the Early Jurassic [22].

In the Early and Middle Jurassic the ecotone was not yet reliably localized, because of poor differentiation of marine biota in the North Pacific. Judging from the marked predominance of tethyan genera in the Early and Middle Triassic mollusk assemblages in Primoriye and in the south of the Khabarovsk Territory, the boundary between tethyan and boreal realms runs near contemporary 50°N [49]. The indications of ecotone appear only in the Late Triassic, when the fauna from the lower and high latitudes becomes more varied in composition.

The Late Triassic invertebrate assemblages from the Anyui, Omolon and Okhotsk terrane seas include typical boreal mollusks, though the portion of cosmopolitan genera among benthos and primarily bivalves as the dominating group constitutes 65–75%. Tethyan genera are extremely rare, and in some localities they are not present at all (Fig. 2). Fossil marine invertebrates found in the Upper Triassic of the Omolon, Okhotsk, and Anyui Massifs are monotypic boreal in character, which is typical of the Verkhoyansk assemblage from Yano-Kolyma, Verkhoyansk-Chukchi and Mongolo-Okhotsk miogeosynclinal areas and sharply differ from that of Koryak and Sikhote-Alin' Massifs. The boundary between boreal and tethyan areas in the Carnian runs in Southern Sakhalin according to ammonites and south of Primorie according to bivalves. The ecotone covered the Primorsky Territory (Fig. 2). In the Norian age the boundary of the above areas based on ammonites is displaced southward and coincides with the bivalve-based boundary.

In the Norian, tethyan mioforids (*Costatoria, Gruenewaldia*) and cassianelids (*Cassianella*) dominate the Koryak area. Trigoniids (*Trigonia, Maoritrigania*) are common, and indicators of warm water such as thick-shelly large megalodontids (*Neomegalodon*), terquemiids (*Terquemia, Enantiostreon*) and cardiids (*Septocardia*) are quite rare. Pectinids (*Eopecten, Neopecten*) and pteriids (*Pteria*) are abundant. Fossil bivalves and other fossils have been found in carbonate sequences. A number of bivalve species from the genera of *Septocardia, Gruenewaldia* and others are similar to those from eastern margins of the Pacific ocean (Nevada) [52]. Among ammonoids found in the Koryak area, yuvatitids and rarer tropitids occur, which also inhabited the low-latitude seas. Brachiopods are chiefly represented by the genus *Spondylospira*, which is found in the assemblages with typical tethyan groups such as hermatypic corals, heteromorphic ammonoids, megalodontids and others in South and North America [53, 54]. In Kenkeren fauna Tethys indicators are also hermatypic scleractinias and some other groups, e.g., stromatoporoids [55] (Fig. 2).

Sikhote-Alin' Upper Triassic shallow-water facies (reef limestones of the Tetyukhe Formation) yielded typical tethyan fauna: scleractinias, diverse calcareous algae. Oryctocoenoses usually contain remains of warm water-loving bivalve genera (*Neomegalodon* and *Pteria*), which also have been found in coeval beds in the Koryak area. The Sikhote-Alin' bivalve assemblages include in addition such tethyan genera as *Newaagia, Indopecten, Phacoides, Gervillia?* and others.

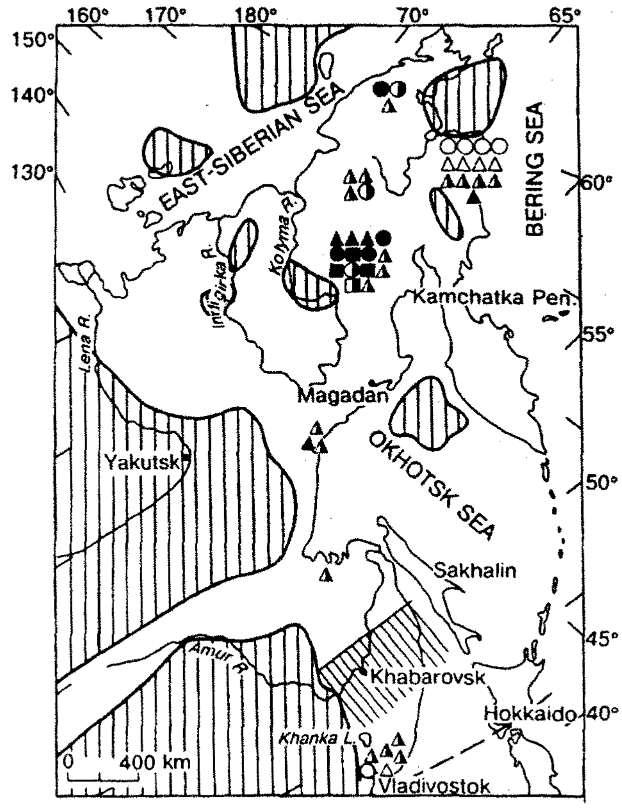


Fig. 2. Biogeographical range of mollusks and brachiopods in the Carnian. Boreal taxa: ***Striatosirenites, Neosirenites, Arctosirenites, Arctophyllites, Janopecten, Ochotochlamys, Dentospiriferina, Pennospiriferina, Aulacothyroides, Viligella.*** **Tethyan taxa:** ***Discotropites, Anatropites, Gonionotites, Yuvavites, Projuvavites, Costatoria, Maoritrigonia, Cassianella, Pteria.*** **Cosmopolitan taxa:** ***Sirenites, Proarcestes, Zittelihalobia, Oxytoma, Cardinia, Chlamys, Neoschizodus, Unionites, Costispiriferina, Zeilleria.*** **Symbols: circles indicate ammonites, triangles indicate bivalves, squares are based on brachiopods, asterisks indicate Koryak pure tethyan assemblage of ammonites. Dark bars indicate boreal taxa, light bars indicate tethyan taxa, combined colors indicate cosmopolitan taxa. Ammonite-based boundary between tethyan and boreal realms is indicated with a solid line, bivalve-based with a broken line. The biogeographical ecotone is hatched.**

The Koryak and Sikhote-Alin' assemblages are characterized by vitually a total absence of boreal faunas widespread in the Upper Triassic of Northeastern Asia, and benthonic communities of Kenkeren and Tetyukhe include no typical boreal tosapecten-oxytoma group of bivalve genera and species [56, 57] and endemic complex of Late Triassic boreal brachiopods [58]. It is worthy to note that from coeval deposits on the Novosibirsk Islands tethyan genera have been recognized in both macro- and microfossils and at the same time boreal taxa dominated. Therefore, following Bragin [59], who recognized from here radiolarian assemblage typical of paleobasins of high latitudes we consider the Novosibirsk Terrane to be boreal in origin.

It is important to note that the Late Triassic invertebrate assemblages from Anyui contain both boreal (*Monotis ochotica, Tosapecten – Oxytoma*, etc.) and tethyan (*Haloritidae, Monotis salinaria*, etc.) elements. On this basis Bychkov and Dagis [20] assign the Anyui Massif to allochthonous blocks. Our reasoning however disagrees with this opinion. Here bivalves are markedly dominated by boreal taxa (the assemblage of *Tosapecten – Oxytoma, Monotis ochotica*, etc.) which constitute 20–30%. The bulk of bivalves is represented by cosmopolitan genera, and among tethyan taxa only the groups of *Monotis salinaria, Cassianella* and *Pteria* (8%) are present. The Anyui ammonoids and nautiloids are dominated by cosmopolitan taxa (megafillitids, hymmitids and others) and in addition there occur typical boreal as well as tethyan ones. Consequently, the dominants in the Anyui biota as regards both quality and quantity are cosmopolitan, and boreal groups and their systematic composition is similar to that of Omolon and Okhotsk areas. Besides, the groups typical of low-latitude waters (megalodontids and others) are absent completely.

Coeval faunas from Kenkere and Tetyukhe belong to the same biochore of first rank. The Koryak Late Triassic fauna has some elements in common with the East Pacific among some species of bivalves, scleractinias and brachiopods [20, 55], and Tetyukhe assemblages are similar to those from northern Tethys. The Omolon, Okhotsk and Anyui Terranes with fauna typical of the boreal realm were located north of 55°N, and the Koryak and Sikhote-Alin' blocks developed in low-latitude waters rather far (some thousands of km) from their present location. Both microplates were most likely located in the Upper Triassic south of the ecotone, that is between 45° and 55°N inasmuch as a taxonomic composition of invertebrates in Koryak and Sikhote-Alin' differs from that of ecotone invertebrate assemblages of the Khabarovsk Territory. Analysis of geographical range of the Late Triassic assemblages and benthic organisms in the first place as dominant group of biota, has cast some doubt on the sialic block drift from southern waters. No tropical hermatypic corals, heteromorphous ammonoids and others are known here, or they are rare (Anyui Massif). The mollusk taxonomic composition these regions have in common is as great as 90–95%.

At the beginning of the Early Jurassic the seas in Northeastern Asia were inhabited by pandemic groups of ammonites and bivalves. In the Hettangian in the northeast of Asia *Psiloceratidae* (*Primapsiloceras*, *Psiloceras*), *Schlotheimiidae* (*Schlotheimia*, *Waehneroceras*, *Alsatites*) are dominant. In Early Sinemurian they are replaced by *Arietitidae* (*Arietites*, *Coroniceras*, *Eparietites*). Benthic communities are dominated by cosmopolitan bivalves *Otapiria* and boreal *Pseudomytiloides* [60]. Many species of ammonites, bivalves and crinoids which inhabited far eastern seas are known from northern Siberia. The Early Lias bivalve assemblage from northeastern Russia numbers 20 genera. Almost all genera are globally widespread. They differ however from bivalves of the Japan sea basin numbering over 40 genera not only in taxonomic poverty but also in sharply distinct composition. Ammonite and bivalve assemblages from Northeastern Asia on the whole are poorer than those on the Pacific coast in North America (West Canada, USA [61]). The lack of Hettangian and Lower Sinemurian fossils in the Russian Far East hampers the placing of boundary between boreal and tethyan realms. It is obvious that the boundary was in low latitudes inasmuch as later a boreal-tethyan ecotone had developed on the territory of Southern Primorie. This boundary probably occurred south of it (Fig. 3).

The Late Sinemurian and Early Pliensbachian ammonite assemblages of Northeastern Asia are extremely poor. Ammonite shells are scarce in the sections. Only one endemic subgenus of Late Sinemurian tethyan genus *Angulaticeras* (*Gydanoceras*) is known among schlotheimiids. This subgenus was recognized from the northeast as well as from the Amur region [62]. The Lower Pliensbachian of Northeastern Russia yielded only a few specimens of boreal *Polymorphites* and in the Russian Far East (at the Amur River) the tethyan genus *Juraphillites* was found. The Late Sinemurian and Early Pliensbachian seas were extremely poor in ammonites, which is indicative of a break in communications with the seas in the south (Japan territory) and east (North-American Pacific coast). In the Early Pliensbachian warm water-loving mollusk communities were transported due to the eustatic rise in sea level to the north up to 50° N. Boreal ammonites of this time (*Polymorphites*) are known from the Northern Okhotsk area at 60° N. Thus, the boundary between boreal and tethyan realms ran approximately between 50 and 55° N. No ecotone zone is known for this time (Fig. 3).

In the Late Pliensbachian the situation changed drastically. The expansion of transgression was accompanied by a wide distribution of boreal genus *Amaltheus* in all the seas of East Asia. This genus reached down far to the south into the Japanese seas. At the same time tethyan ammonites penetrated into the north. Southern Primorie was occupied by tethyan arieticeratins (*Arieticeras*, *Fontanelliceras*) and harpoceratins (*Protogrammoceras*, *Paltarpites*). Boreal ammonites were dominant in Northern Primorie and in the Lower Amur region [63]. Consequently, the boundary between boreal and tethyan realms in the Late Pliensbachian was located by ammonites aprroximately at 47–48°N and, based on bivalves, at about 42–43° N, since in Southern Primorie the Late Pliensbachian marine benthic communities were dominated by boreal genera of bivalves (Fig. 4).

The taxonomic composition of the Toarcian ammonites from Northeastern Asia is markedly diverse, but only two genera are attributed to tethyan ones: *Trechiella* which is an Early Toarcian immigrant from the Tethys, and an endemic *Arctomercaticeras* that has tethyan ancestors [64]. Of the fifteen known genera ten are considered cosmopolitan. Because of this fact it is rather difficult to draw the boundary between boreal and tethyan realms. The position of this boundary in the Russian Far East cannot be accurately defined because of no ammonite occurrences in Primorie. Southernmost findings of boreal ammonites (*Porpoceras*) are known from the Bureya trough. Northernmost occurrences of typical tethyan ammonite assemblages are on the island of Honshu. Thus, in the Toarcian the ecotone was located at the latitude of Sakhalin, while the ammonite-based boundary between boreal and tethyan realms ran north of the Japanese Islands (Fig. 5). The features of bivalves distribution are not in conflict with this conclusion, though their boreal assemblages are not specific. Nearly

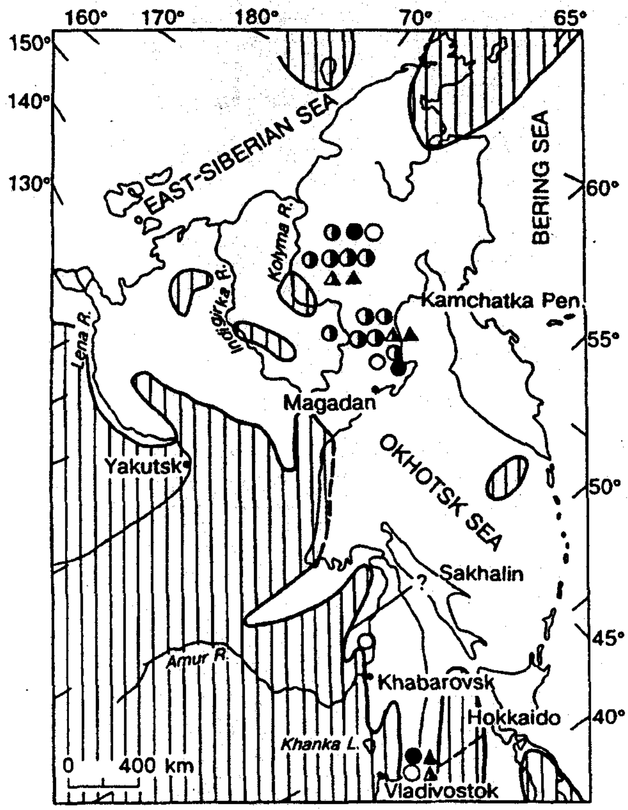


Fig. 3. Biogeographical range of mollusks in the Hettangian, Sinemurian and early Pliensbachian. Boreal taxa: *Angulaticeras (Gydanoceras)* (Upper Sinemurian); *Polymorphytes* (?Lower Pliensbachian), *Pseudomytiloides*. Tethyan genera: *Paradasyceras(?)*, *Vermiceras(?)* (Lower Sinemurian), *Juraphyllites* (Lower Pliensbachian). Cosmopolitan taxa: *Alsatites(?)*, *Psiloceras*, *Schlotheimia*, *Waehneroceras*, *Otapiria* (Hettangian), *Arietites*, *Coroniceras*, *Otapiria* (Sinemurian), *Phylloceras* (Jurassic-Cretaceous). For key to symbols, see Fig. 2.

all bivalve genera known from the Asian part of Russia inhabited east-tethyan seas (on the territory of Japan and Vietnam). However bivalve communities were less diverse in boreal seas. In the Late Toarcian the representatives of subtethyan genus Vaugonia penetrate to the northeast of Asia (northern Okhotsk area). Jointly with them there dwelled *Grammatodon*, *Plagiostoma* and *Cucullaea*. These bivalve genera are not known from coeval deposits in the north of Siberia, however they were found in younger Middle Jurassic rocks. Consequently, in Asia the fauna migrated from east to west during the Toarcian and Aalenian. The assumed way of migration of vaugonians was along the Alaskan and Chukchi coasts. The other cited genera of bivalves have migrated from Eastern Tethys through Primorie and Northern Okhotsk area.

In the Aalenian the boundary between boreal and tethyan realms remained the same as in the Toarcian, but the boreal realm has been markedly isolated. In the Aalenian of the Asian part of Russia only two circumboreal genera of ammonites were recorded: *Pseudolioceras* (*Tugurites*) (Early Aalenian) and *Erycitoides* (Upper Aalenian). The Japanese sea in Aalenian was inhabited by tethyan ammonites: *Hosourites*, *Harpoceras*, *Tmetoceras*, *Hammatoceras*, *Graphoceras*. Essential differences are also recognized between benthic communities of boreal and tethyan realms. The boreal communities are dominated by *Retroceramus*, while *Arctotis*, *Mcleamia* and *Parvamussium* are very common but absent from the deposits of tethyan type. Tethyan benthic communities are dominated by trigoniids: *Trigonia*, *Vaugonia*, *Myophorella* and such genera as *Inoperna*, *Ctenostreon*, *Coelastarte* are common. In Early Aalenian some trigoniids penetrated to the seas in the northeast of the Asian part of Russia, though they were not among core-forming benthic communities, dominated by boreal genera. The Aalenian fauna freely exchanged between eastern and western boreal areas: such genera as *Retroceramus*, *Parvamussium*, *Arctica* and others moved from east to west (to northern Siberia) and *Arctotis* and *Tancredia* migrated from west to east (Okhotsk sea and Far East basins). Substantial leveling of fauna on

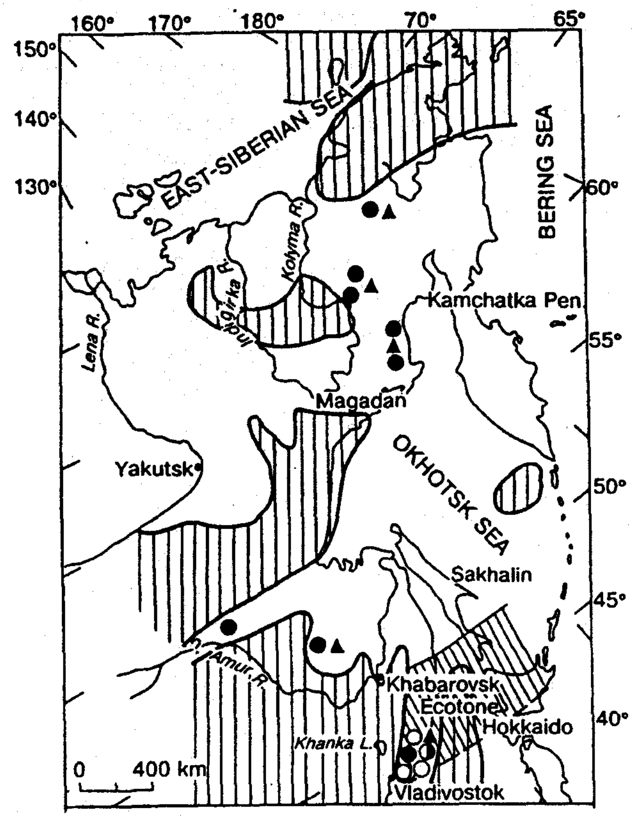


Fig. 4. Biogeographical range of mollusks in the Late Pliensbachian. Boreal taxa: *Amaltheus, Meleagrinella.* Tethyan taxa: *Arieticeras, Fontanelliceras, Protogrammoceras.* Cosmopolitan taxa: *Paltarpites, Uptonia.* For key to symbols, see Fig. 2.

extensive territory of East Asia was related to the general fall in temperature during the Aalenian in the circum-Polar basin, therefore bivalve-based boundary between boreal and tethyan realms is displaced to Southern Primorie.

In the Bajocian differentiation between boreal and tethyan realms became even more intensified. The ammonite-based boundary is shifted northward approximately at 46–48°C (Fig. 6). The ammonites of *Pseudolioceras* (*Tugurites*) and *Arkelloceras* occur jointly with numerous bivalves of the family *Retroceramidae* in the Bureya trough [62]. This is typical boreal mollusk assemblage. In the Southern Primorie Lower Bajocian rocks yielded tethyan ammonites *Lytoceras* and *Stephanoceras* occurring jointly with boreal genus *Retroceramus* and tethyan *Trigoniidae* [65]. In the Upper Bajocian only boreal bivalves are abundant.

The beginning of the Bajocian age was marked by a counter-migration of fauna along the western coast of the North Pacific. Relatively diverse mixed boreal-tethyan ammonite assemblages have been found at 50° N (Bureya trough). The tethyan group comprises: *Lissoceras, Oxycerites, Epizigzagiceras, Cobbanites*, and the boreal group consists of *Umaltites, Pseudocadoceras, Arctocephalites* [63]. North of this territory (Western Okhotsk area) the Bathonian deposits are characterized by diverse and abundant boreal bivalves retroceramids. In Southern Primorie the presence of the Lower Bathonian is proven by numerous findings of boreal *Retroceramus kystatymensis* [62]. Consequently, the ammonite-based boundary between boreal and tethyan realms occurred approximately in the northern part of Sakhalin, and the bivalve-based boundary in its southern part (Fig. 7).

The Callovian was the time of substantial fauna leveling in the boreal realm. In the Early Callovian in Northeastern Asia boreal cadoceratinas were widespread. They migrated southward to 51° N (Amur region). Typical tethyan assemblage of the genera *Choffatia, Zieteniceras, Lunuloceras* has been found in the north of the Koryak Upland at 62°N [21]. Since the early Callovian, representatives of the genus *Praebuchia* appeared for the first time in boreal seas. They are also known from Northeastern Asia [50]. During the Callovian only high-boreal (Arctic) bivalves and brachiopods, the genera and species widespread in the north of Siberia, inhabited the seas of Northeastern Asia. The Middle and Upper Callovian in the Far East of Russia are not strictly documented. Though one finding of boreal Longaeviceras is known from the Toromsk trough [62]. In

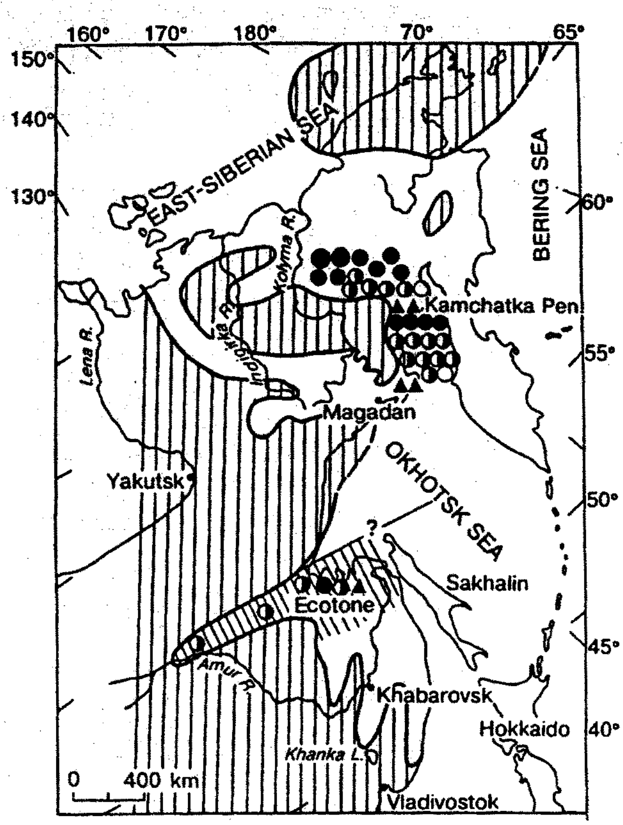


Fig. 5. Biogeographical range of mollusks in the Toarcian. Boreal taxa: *Kedonoceras*, *Kolymoceras*, *Pseudolioceras*, *Porpoceras*, *Pseudomytiloides*, *Meleagrinella*. Tethyan taxa: *Arctomercaticeras*. Cosmopolitan taxa: *Catacoeloceras*, *Collina*, *Dactylioceras*, *Eleganticeras*, *Harpoceras*, *Harpohildoceras*, *Hildoceratoides*, *Phylloceras*, *Tiltoniceras*, *Zugodactilites*. For key to symbols, see Fig. 2.

Southern Primorie the Callovian is not recognized. Therefore there is no paleontological evidence of the boundary between boreal and tethyan realms. With some degree of certainty this boundary may be drawn at the same place where it is established for the Bathonian (Fig. 8).

In the Oxfordian (Middle and Late) tethyan ammonites once again penetrated into the north as far as 54° N; they were representatives of the genus *Perisphinctes* (*Dichotomosphinctes*) and the genus *Maltoniceras* [21]. Boreal *Cardioceras* were moving to 52°N. In the northeast as well as in Far East of Russia benthos is dominated by boreal buchiids [50]. Consequently, the ammonite-based boundary between boreal and tethyan realms should be placed to the north of 54°, while bivalves suggest it to be south of this latitude. For lack of reliable Oxfordian fauna in Primorie, the boundary of biogeographical realms cannot be unambiguously established.

In the Kimmeridgian the range of boreal ammonites of the genus *Amoeboceras* covered entire Northeastern Asia [60]. In the south this genus reached latitude 54° and buchias migrated further down to 44°N. The Kimmeridgian ammonites in Southern Primorie were not recorded. Consequently, the bivalve-based boundary between boreal and tethyan realms at least in Early Kimmeridgian is drawn south of 44°N (Fig. 9). In Late Kimmeridgian tethyan *Ochetoceras* shifted upwards to 54°N (Bureya basin). Since typical boreal bivalve genera lived throughout the Northeastern and Far Eastern territories, and benthic communities were dominated by buchias, the boundary between boreal and tethyan realms should be drawn to the south of the Southern Primorie. With tethyan *Ochetoceras* found in the fairly high latitudes, it is reasonable to enlarge the ecotone from 44 to 54°N (Fig. 9).

In Early and Middle Tithonian (Volgian age) the ranges of boreal and tethyan ammonite fauna diverged considerably. The range of tethyan ammonites was bordered by Southern Primorie: *Virgatosphinctes* (Lower Tithonian), *Aulacosphinctes*, *Aulacosphinctoides*, *Glochiceras*, *Haploceras*, *Himalaites(?)*, *Lemencia*, *Parapallasiceras*, *Pseudolissoceras*, *Semiformiceras*, *Sublithacoceras*, *Subplanitoides*, *Torquatisphinctes* (Middle

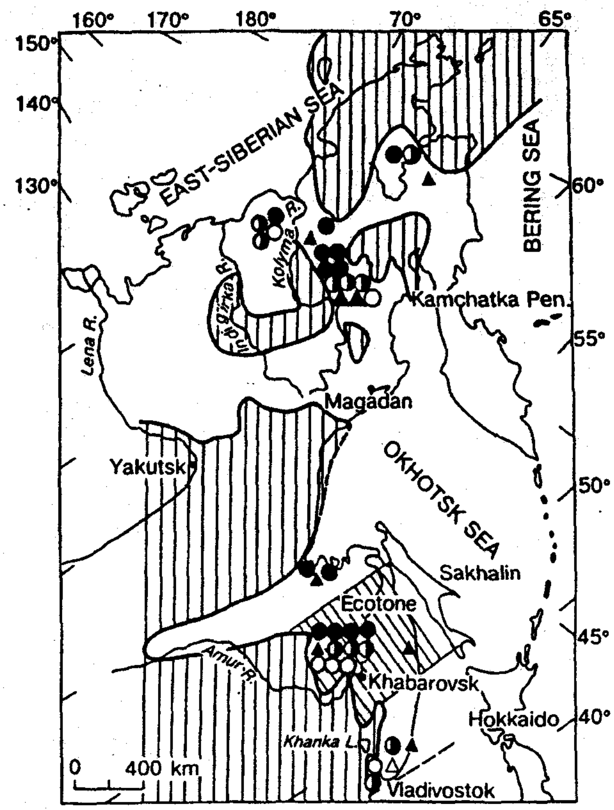
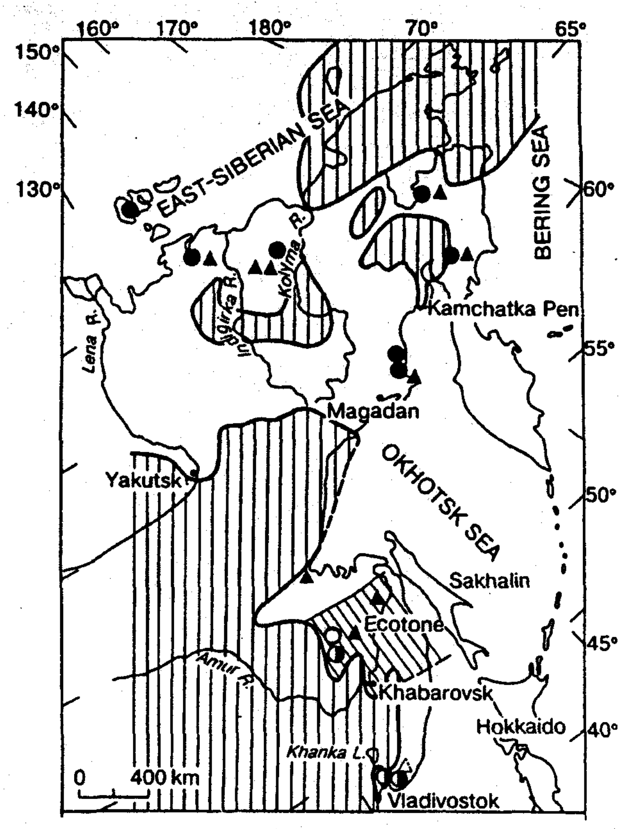


Fig. 6. Biogeographical range of mollusks in the Bajocian. Boreal taxa: *Arkelloceras, Boreiocephalites, Cranocephalites, Pseudolioceras (Tugurites), Arctotis, Retroceramidae.* Tethyan taxa: *Bradfordia, Epizigzagiceras, Lytoceras, Lyroxyites, Umaltites (=Megaspheroceras); Trigoniidae.* Cosmopolitan taxa: *Calliphylloceras, Chondroceras, Holcophylloceras, Partschiceras, Stephanoceras, Zetoceras.* For key to symbols, see Fig. 2.

Tithonian). Boreal ammonites *Dorsoplanites* came down no lower than latitude 64°N. Benthic communities in Northeastern Russia yielded no representatives of tethyan groups, with their cores consisting of boreal buchias. The Southern Primorie was inhabited by mixed boreal-tethyan bivalve groups among which buchias and trigoniids were dominant. In the late Tithonian (Late Volgian time) tethyan ammonites once again migrated northward. The genus *Durangites* was found in the Bureya basin at 54°N [21]. However, in the northeast, boreal ammonites (genus *Chetaites*) lived within the same ranges as they did in Early-Middle Volgian period [66]. It is probable that during the Volgian period the ammonites migrated to East-Asian seas from two regions: from the north of Siberia (*Dorsoplanites, Chetaites*) and Eastern Tethys (tethyan ammonites). The boundary between boreal and tethyan realms was in Southern Primorie. Nevertheless in the Late Volgian period there was an ecotone within the interval of 45–55° N (Fig. 10).

In the early Cretaceous (Berriasian, Valanginian) the biogeography of mollusk genera differed little from that of Late Jurassic. Benthic communities occurring from the Chukchi Peninsula through Southern Primorie were universally dominated by buchias, and boreal inocerams were also found. Among ammonites, boreal and cosmopolitan groups were widespread here and were also reported from Northern Siberia, while tethyan forms are known only from Primorie. Tethyan ammonites *Berriasella, Dalmasiceras(?), Pseudosubplanites* were found in the Berriasian of Southern Primorie [67, 68], and in Northern Primorie boreal and tethyan ammonite assemblages were discovered in close proximity: boreal *Praetollia* and *Tollia* near the town of Komsomolsk-na-Amure (between 50° and 51°N) and tethyan *Berriasella (Strambergella), Tauriella, Spiticeras (Spiticeras), Timovella* at 49°N (the basin of the rivers of Anyui, Khor, and Dzhaur) [69 and oral comm., 1992]. Thus, the boundary of boreal and tethyan realms based on ammonites lies between the mentioned occurrences. In addition numerous boreal buchias were found distributed as far as Southern Primorie. A bivalve-based ecotone was located between 45° and 50°N (Fig. 11).

The Valanginian and Lower Hauterivian mixed boreal-tethyan ammonite assemblage (*Tollia(?), Kilianella,*



· **Fig. 7. Biogeographical range of mollusks in the Bathonian. Boreal taxa: *Arcticoceras, Arctophalites, Catacadoceras, Costacadoceras, Arctotis*; Retroceramidae. Tethyan taxa: *Lissoceras*. Cosmopolitan genera: *Cobbanites, Oxycerites* (?), *Phylloceras*. For key to symbols, see Fig. 2.**

Homolsomites) was found in both above-mentioned Berriasian localities [69 and oral comm., 1992]. Typical tethyan assemblage (*Necocomites, Olcostephanus*) together with trigoniids were recorded in Middle Sikhote-Alin', Tigrovy Spring, Chernaya River [70]. Based on this evidence the northern boundary of the tethyan realm may be placed by ammonites between 45° and 48°N. Considering numerous records of buchias in Lower Valanginian of the Suchan region, the lower boundary of the boreal realm may be drawn based on bivalves through Southern Primorie (Fig. 12).

In the Late Hauterivian the paleogeographical situation in Northeastern Asia changed drastically as compared with that of the Early Neocomian. The contact with the polar basin slackened considerably and was realized through the narrow Anyui-Rauchan Strait. Most representative in benthos were inocerams of the family *Coloniceramidae*. In the south of the Chukchi Peninsula boreal simbirskitids were markedly dominant. Rare tethyan genera of heteromorphic ammonites (*Crioceratites*) are recorded only in Primorie. For lack of mollusk findings within the interval between 50° and 60°N there is no way of telling the position of boundaries between boreal and tethyan realms and presence of an ecotone.

We explain the latitudinal differentiation of fauna along the western coast of the North Paleopacific by the existence of climatic zonality in the Mesozoic. In the interval between 45° and 55°N a biogeographical ecotone had existed since the Late Triassic throughout the Jurassic and Early Cretaceous, where boreal and tethyan ammonite and bivalve assemblages co-existed.

In the Late Sinemurian and Late Pliensbachian boreal ammonites penetrated to the Peritethyan seas and in the Late Sinemurian, Early Toarcian and Early Bajocian tethyan ammonites are recorded in the extremely high latitudes (Fig. 13). In the early and middle Jurassic boreal and tethyan ammonites often migrated in the opposite direction and combined boreal-tethyan assemblages were common. These events involved fauna both in epicontinental seas on the Siberian craton and in terrane seas of the Omolon, Okhotsk, Anyui, Alazeya, Tetyukhe, and Chukchi because, with the exception of the Koryak area, "the non-natives", which were always outnumbered, co-existed with "the natives". Taking into consideration relatively stable paleogeographical surroundings along western framing of the North Pacific, the periodicity in ammonite migration may hardly

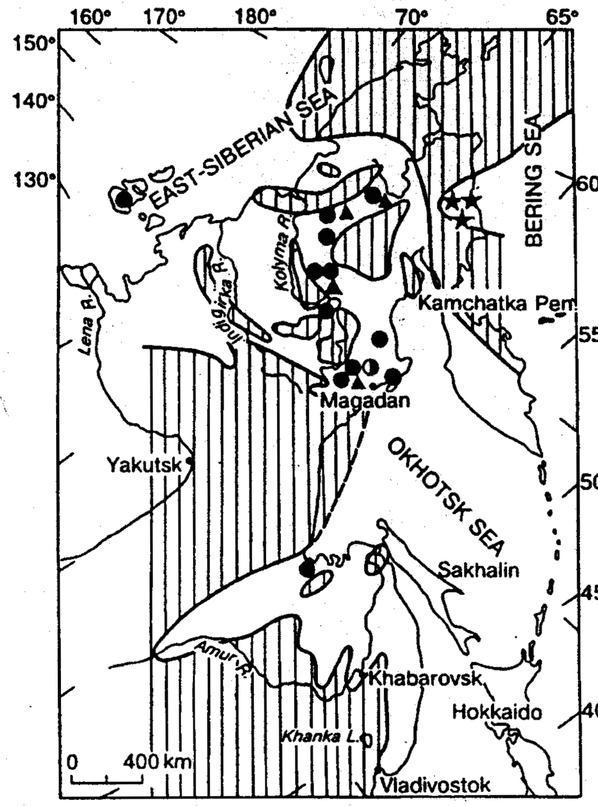


Fig. 8. Biogeographical range of mollusks in the Callovian. Boreal taxa: *Cadoceras, Costacadoceras, Iniskinites, Longaeviceras, Pseudocadoceras, Meleagrinella, Praebuchia; Retroceramidae.* Tethyan taxa: *Choffatia, Lunuloceras, Oxycerites, Zieteniceras.* Cosmopolitan taxa: *Partschiceras, Phylloceras, Macrophylloceras.* Asterisk indicates pure tethyan ammonite assemblage in the Koryak area. For key to other symbols, see Fig. 2.

be linked to any other event but climate fluctuation. Coolings and warmings resulted in the leveling of the temperature of sea water that favored counter migrations. The leveling of temperature and notably overall water warming in the north were probably caused by eustatic in the sea level, which were recorded in the late Sinemurian and Pliensbachian, in the early Toarcian and Callovian [71].

The penetration of tethyan groups into subpolar regions during the Late Triassic, Jurassic and Cretaceous times has been noted for the North Pacific as well as the North Atlantic; the ammonites and bivalves entering higher latitudes than they did in Northeastern Asia [24]. Thus at 75° N on the Taimyr Peninsula tethyan *Oxycerites* were found in the Middle Bathonian, *Virgataxioceras* and *Oxydiscites* in the Upper Kimmeridgian, *Aulacosphinctes* and *Berriasella* in the Upper Volgian (Tithonian). It is clear that tethyan ammonites entered the seas of the Taimyr Peninsula by water with no shifting of terranes from south to north.

The conclusions about biogeographical distribution of faunas under discussion are in agreement with sedimentary data. To the north of 55°N the Triassic (with the exception of Lower Olenek), Jurassic and Cretaceous sequences are markedly dominated by terrigenous and terrigenous-volcanic rocks and to the south of 45°N carbonate measures dominate. The ecotone between 45° and 55°N is dominated by carbonate-terrigenous rocks.

Considerable similarity of the Jurassic and Cretaceous circum-Arctic marine fauna makes us treat with due caution the idea of a wide (simetimes over 1500 km) water passage from North Pacific to the Arctic reconstructed on most palinspastic maps (Fig. 14). No matter where this passage was between Alaska and Chukchi, in the Verkhoyansk Ridge, or in the Chersky Ridge), it would have hampered the relationships between marine invertebrates (at larval stage) in the circum-Arctic region and would have caused (during 130 Ma of strait existence) considerable differentiation of fauna on either side. This is not the case however [25, 72]. The Jurassic mollusks from North Alaska, Arctic Canada and Northeastern Asia, for example, are extremely similar. Furthermore, the presence of a deep and wide strait opened on the Pacific side to the Arctic would be

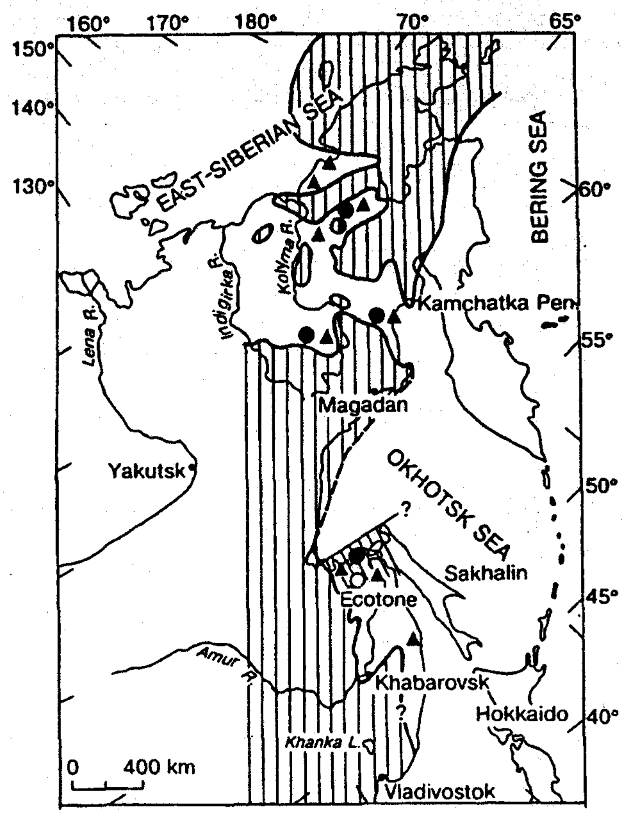


Fig. 9. Biogeographical range of mollusks in the Kimmeridgian. Boreal taxa: *Amoeboceras* (*Amoebites*), *Buchia*, *Meleagrinella*. Tethyan taxa: *Ochetoceras*. Cosmopolitan taxa: *Phylloceras*. For key to symbols, see Fig. 2.

certain to deprive Mesozoic Arctic marine fauna of its originality, represented by endemic taxa (many hundreds of species, tens of genera and some families), which is admitted by all researchers.

DISCUSSION OF GEOGRAPHICAL POSITION OF TERRANES BASED ON PALEOBIOGEOGRAPHICAL EVIDENCE

Paleobiogeographic analysis of the mollusks in the western margin of the North Pacific permits a hypothesis about the geographical position of some terranes in Northeastern Asia in the Mesozoic. It can be said with a certain assurance that the Anyui, Omolon and Okhotsk Massifs were located north of contemporary latitude 55°N, at least since the Late Triassic, because the Late Triassic invertebrates from these massifs are monotypic boreal, which is characteristic of coeval Verkhoyansk assemblage of Yano-Kolyma, Verkhoyansk-Chukchi, Mongolo-Okhotsk miogeosynclinal regions and of that of the northeastern margin of the Siberian craton. Patterns of fauna distribution over the ages throughout the Jurassic and the early Cretaceous support this conclusion. If the Omolon and Okhotsk Massifs were in the Late Triassic and Early Jurassic in low (tropical) latitudes (Fig. 15) no less than 3000 km south of "Siberian margin" (20°N), as it was assumed by Zonenshain and Kuzmin [45], then the fauna would be markedly dominated by tethyan (tropical) forms, but this is not the case. Moreover the two massifs could not cross the biogeographical ecotone during the Late Triassic and Early Jurassic period, otherwise at least at one stratigraphic level of the Upper Triassic and Lower Jurassic sequences mixed boreal-tethyan mollusk assemblages would be found in these massifs, and they were not. Actually 90 to 100% of genera comprised of Jurassic and Early Cretaceous mollusk assemblages from these three terranes are boreal. According to the Meyen viewpoint advanced 20 years ago [73], the Omolon Massif already in the Permian was located north of the Aldan shield so far as Permian floras found there are attributed to Angarian (boreal) ones. Probably closer to the truth are those adherents of terrane nature of the sialic massifs mentioned, who "move" them in Mesozoic not latitudinally but mainly longitudinally or (which is less probable) reconstruct their position in the high latitudes of the Northern

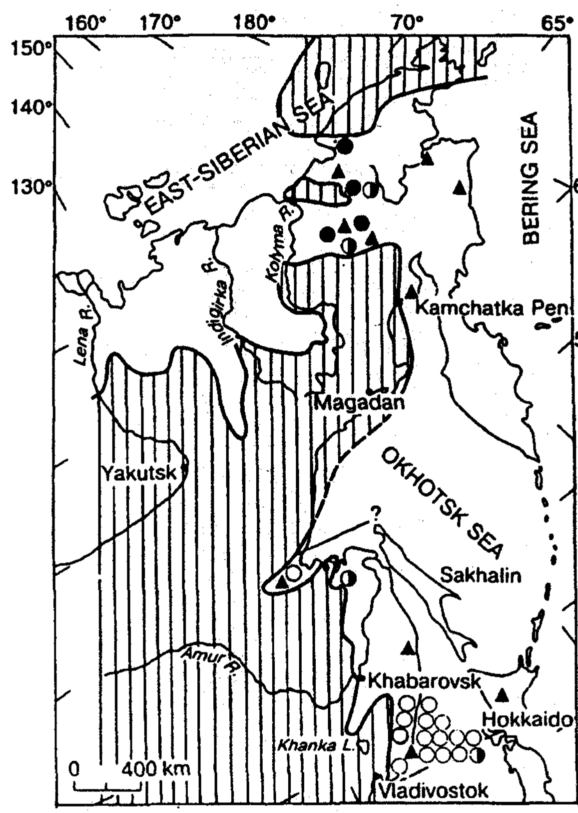


Fig. 10. Biogeographical range of mollusks in the Tithonian (Volgian age). Boreal taxa: *Chetaites, Dorsoplanites, Arctotis, Buchia*. Tethyan taxa: *Virgatosphinctes* (Lower Tithonian), *Aulacosphinctes, Aulacosphinctoides*; *Haploceratidae* (*Haploceras, Pseudolissoceras*); *Himalayites(?)*, *Lemencia*; *Oppeliidae* (*Glochiceras, Semiformiceras*); *Parapallasiceras, Sublithacoceras, Subplanitoides, Torquatisphinctes* (Middle Tithonian), *Durangites* (Upper Tithonian); *Trigoniidae*. Cosmopolitan taxa: *Partschiceras*. For key to symbols, see Fig. 2.

Hemisphere based on the concept of migration of the north magnetic (and geographical) pole far to the south from its present position [33, 38, 41]. To estimate the degree of possible remoteness of microplates from the Siberian craton within the boreal realm, a "subtle" comparative analysis of benthic assemblages structure in craton and microplate remains to be made.

Biogeographical data on the Alazeya, Novosibirsk, Prikolymsky and Chukchi sialic blocks are insufficient to make indisputable conclusions about their geographical position at a specific instant of geological time. The earliest evidence of high latitudinal, i.e., the boreal location of the Novosibirsk and Chukchi Terranes already date from the beginning of the Middle Jurassic, while the Alazeya and Prikolymsky blocks date from the beginning to the end of the Middle Jurassic.

The systems of terranes of the Koryak Upland and Sikhote-Alin' are of the most interest in the context of "mollusk" paleobiogeography. As to the Koryak Terranes (Koryak area, Olyutor, etc.) it can be safely suggested that in the Triassic and Jurassic they were outside the boreal seas, i.e., in the range of tethyan fauna distribution. This is supported by the assemblages of mollusks and other macro- and microfauna (radiolarians in particular) tethyan (tropical) in their biogeographical nature, found in both carbonate olistostromes and enclosing cherty measures of the Triassic and Jurassic age. Boreal taxa are rare or not found with them. Bivalve assemblages of the Norian age in the Koryak area comprise 50–55% of warm water-loving genera, cosmopolitan forms constitute 40–45%, the portion of boreal genera is no more than 6%, and the Callovian ammonite assemblage (*Choffatia, Lunoloceras, Zieteliceras*) at 72°N consists of tethyan forms only. To explain such extraordinary northern occurrence of Triassic and Jurassic tropical faunas two hypotheses are proposed: (1) a significant horizontal shift of terranes during the Cretaceous period due to the paleoplate of Kula that was drifting from southeast to northwest [44]; (2) displacement of boundaries of tropical and boreal realms caused by strong ocean paleocurrents [74]. According to Kononov's calculations, the system of the Koryak terranes was

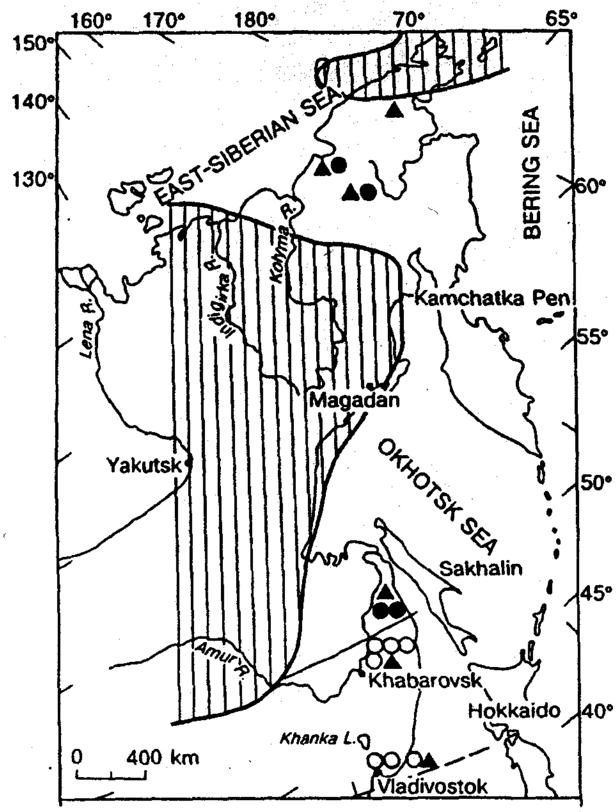


Fig. 11. Biogeographical range of mollusks in the Berriassian. Boreal taxa: *Chetaites, Praetollia, Surites, Tollia* (boreal Berriassian), *Buchia*; *Inoceramidae*. Tethyan taxa: *Berriasella, Dalmasiceras, Euthymiceras, Spiticeras (Spiticeras), Pseudosubplanites, Tirnovella* (Berriassian). Cosmopolitan taxa: *Lytoceras, Phylloceras*. For key to symbols, see Fig. 2.

located "when on mark" at a distance possibly of 5000–6000 km from the Eurasian margin. The time of their accretion to the Eurasian margin is either Middle-Late Cretaceous [38] or, more definitely, Maastrichtian [75]. The displacement of warm waters from the tropical zone to the north by currents is not supported by computed models [76]. To complete the alternative hypotheses we must mention one more, exotic, but quite important hypothesis: the burial of shells of tethyan ammonites on the territory of Koryak sialic blocks can be also explained by the transportation of live mollusks or their empty shells by warm currents, which flowed from south to north or from east to west away from the coasts of present British Columbia, from where the same ammonites are known. Empty shells of modern *Nautilus* are transported from the Philippine sea to the Madagascar coast, i.e., for a distance of 4000–5000 km. We failed as yet to dispute or to confirm any of these assumptions based on paleobiogeographical methods.

The farthest southern position assumed by some researchers for the system of the Sikhote-Alin' terranes virtually throughout the Mesozoic is questionable in our opinion. The fact that in the Early Jurassic (Pliensbachian) biogeographical ecotone had already been recognized in Primorie, i.e., that local seas were inhabited by mixed boreal-tethyan faunal assemblages is doubtful. Two biogeographical arguments may be adduced to support the view that the system of the Sikhote-Alin' terranes in the Jurassic and Early Cretaceous periods was not located north of 50°N and it is hardly probable that, moving southward, they passed over 40°N. 1. The Jurassic and Lower Cretaceous marine invertebrates in Primorie never yielded "pure" boreal assemblages typical of northern latitudes. Semipelagic forms (ammonites) are normally dominated by tethyan and cosmopolitan taxa, together with the frequently encountered and abundant boreal benthonic mollusks. 2. Among benthic communities even in Southern Primorie, boreal bivalves were often dominant (retroceramas in Middle Jurassic, buchias in Late Jurassic and Neocomian). Nowhere in the Northern Hemisphere and boreal buchias dominate in communities from seas south of 38°N (e.g., in North California, Kopet Dag, North Caucasus). Therefore there are grounds to believe that Southern Primorie land was situated north of 40°N by the early Jurassic assemblages.

However the Late Jurassic assemblages even of benthic mollusks consist of tethyan and cosmopolitan

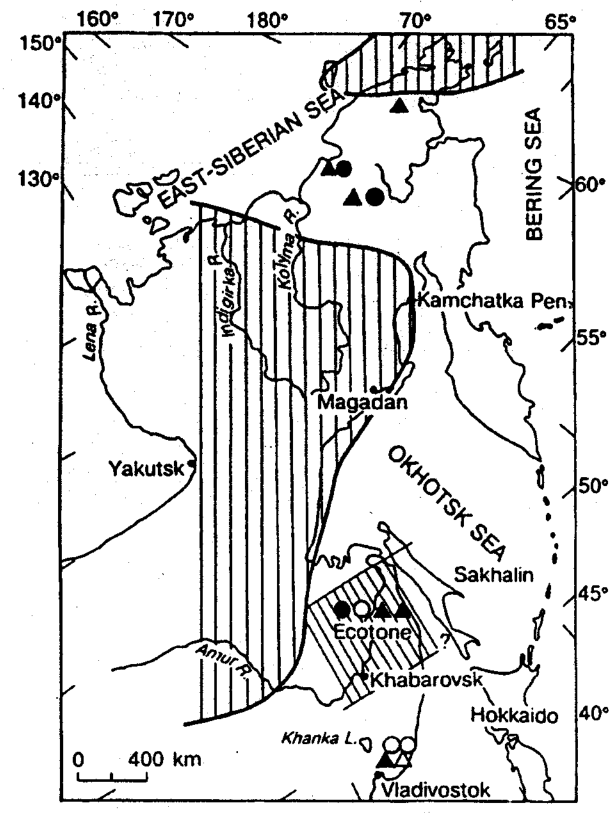


Fig. 12. Biogeographical range of mollusks in the Valanginian and Early Hauterivian. Boreal taxa: *Homolsomites*, *Polyptychites*, *Tollia* (boreal Valanginian). Tethyan taxa: *Killianella*, *Neocomites*, *Olcosptephanus*, *Thurmanniceras*. For key to symbols, see Fig. 2.

genera for 95%. This is indicative of the fact that in the Late Triassic the system of the Sikhote-Alin' terranes was situated in the area of tropical fauna predominance. It is pertinent to reiterate that unusual high-latitudinal occurrence of Late Triassic tropical fauna including reef bodies is also recorded on the other side of the North Pacific: on the island of Vancouver and in South Alaska [10, 11]. Biogeographical analysis of this fauna (which by the way has much in common with the Late Triassic fauna from Koryak and Sikhote-Alin' areas) made by Tozer [15] permitted him to discover exotic blocks (suspect terranes), whose origin he relates to low (tropical) latitudes of eastern North Pacific.

The comparative historical biogeography of Mesozoic marine faunas in the western sector of the Pacific has shown that the terranes in Northeastern Asia, as distinct from those of North America, cannot for the most part be attributed to exotic ones, i.e., which for a long time were far from the Siberian craton in the southern space of the Mesozoic Pacific ocean, but rather they are local sialic "erratic mass" wandering within the boreal part of the North Paleopacific. Results of the analysis suggest that only systems of the Koryak and, probably, Sikhote Alin' terrane may be considered allochthonous. The former were supposedly accreted to the massifs in Northeastern Asia in the Late Cretaceous and the latter in the early Jurassic.

CONCLUSIONS

The biogeographic analysis of Mesozoic mollusk genera has shown a regular distribution of tethyan and boreal taxa remains along the Asian margin of the North Pacific. The vast majority of present-day tethyan ammonite genera occur south of 45°N and boreal genera occur north of 55°N. Mixed boreal-tethyan mollusks assemblages occur in the territory between 45° and 55°N. There is a biogeographical ecotone in this space. The boundary between the tethyan (tropical) and boreal (northern) realms changed its position several times during the Late Triassic, Jurassic and Early Cretaceous, but it would rarely leave a zone bounded by 45° and 55°N. This fact can be explained by the existence of climatic zonation in the Mesozoic, which controlled fauna distribution. Some warm water-loving mollusks (mainly ammonites) during the leveling of water temperature caused

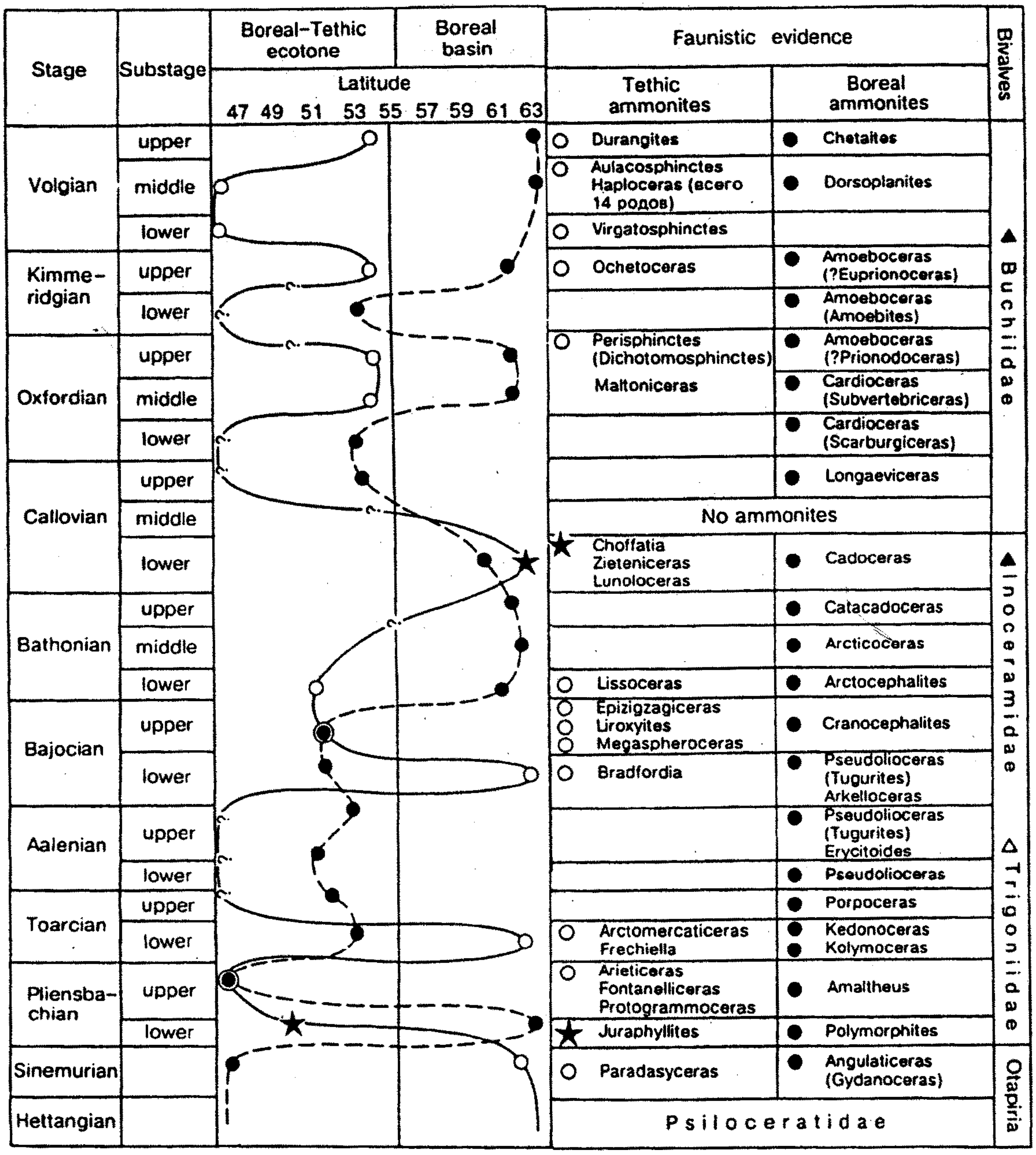


Fig. 13. Boreal-tethyan counter migrations (south-north-south) of marine invertebrates during the Jurassic period in western sector of the North Pacific. Stars indicate exotic tethyan associations.

by (?) eustatic rises in sea level penetrated at times to 70–72° N while individual boreal bivalves moved at the same time southward (south of 45° N). However neither of them "got accustomed" to new places (in "terrane" seas) and their phylogenetic lines are not traceable through geological time.

It might be asserted from the above that sialic massifs and blocks in Northeastern Asia such as Anyui, Omolon, Okhotsk beginning as early as the Late Triassic were situated at the same latitude as the northern part of the Siberian craton, i.e., to the north from 55°N. Their longitudinal position can be determined after similarity-difference factors of North-American and North-Asian mollusk assemblages are estimated. The geographical position of the Alazeya, Novosibirsk, Prikolymsky and Chukchi blocks cannot be traced continuously during most of the Mesozoic ages, because of the fragmentary character of the available stratigraphic

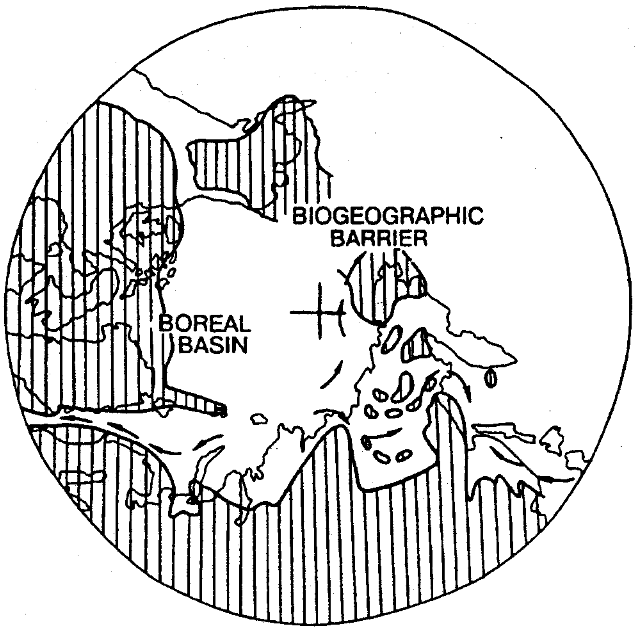


Fig. 14. Possible ways of boreal mollusk migration (indicated with arrows) to "terrane seas" during the Bathonian age, Middle Jurassic (palinspastic reconstruction [77]).

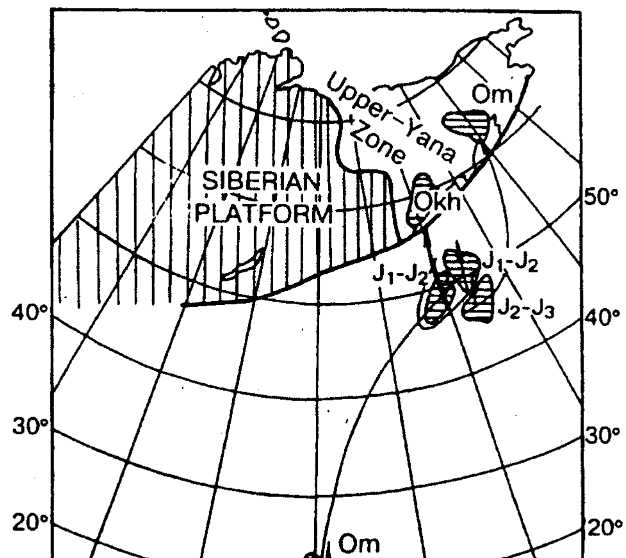


Fig. 15. The scheme of location and horizontal movement (indicated with arrows) of the Omolon and Okhotsk Massifs in Late Triassic and Jurassic periods in the North Pacific (according to [39]) (simplified). ***1*** **– Siberian Platform,** ***2*** **– Omolon (Om) and Okhotsk (Okh) terranes. T_3 – Late Triassic, T_3–J_1 – Late Triassic-Early Jurassic, J_1–J_2 – Early-Middle Jurassic, J_2–J_3 – Middle-Late Jurassic.**

and paleontological material. There is little evidence however in favor of their para-autochthonous position at least in the early Jurassic time.

In the Mesozoic the system of the Koryak blocks occurred most probably south of the land that currently lies to the north from 45°N. These blocks were probably disposed prior to the Late Cretaceous in the tropical latitudes of the Paleopacific. The Sikhote-Alin' system of blocks in the Late Triassic should be located based on biogeography in the zone of tropical climate influence. But already in the Early Jurassic (Pliensbachian) it was found in the ecotone situated to the north from 40°N in the Northern Hemisphere.

All sections of Late Triassic, Jurassic and Early Cretaceous age in Northeastern Asia located to the north from 55°N including those in massifs and sialic blocks, are made up mainly of terrigenous, volcanic-terrigenous or cherty sediments, which is indicative of their deposition in cool water. Carbonate rocks in warm water are widespread south of 45°N. In high latitudes carbonate rocks are known only as olistostromes from the Upper Triassic and Middle Jurassic of the Koryak area, from the Lower Pliensbachian of the Russian Far East and in the Upper Jurassic on Sakhalin. Mixed terrigenous and carbonate rocks occur just in the zone of the Mesozoic biogeographical ecotone, i.e., between 45° and 55°N. Thus, analysis of both paleontologiacal and sedimentary data leads to a similar conclusion in the reconstruction of the geographical position of a number of terranes of Northeastern Asia in the Mesozoic.

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