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A MESOZOIC OCEAN IN THE ARCTIC: PALEONTOLOGICAL EVIDENCE

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The fauna of Mesozoic epicontinental seas that existed on the territory of the present-day Arctic margin of Eurasia, North America, and islands in the Arctic Ocean is dominated by stenohaline mollusks (ammonoids, coleoids, bivalves, gastropods, brachiopods, foraminifers, ostracodes, radiolarians, etc.). The marine biota consists of cosmopolitan taxa of the boreal Pacific and boreal Atlantic origin, Tethyan immigrants, and endemics, including hundreds of endemic species, tens of endemic genera, and six endemic families. Numerous lines of invertebrates in the Arctic basin evolved sustainably for tens of millions of years. The high taxonomic diversity of the specific marine biota and the ways of its panboreal migration could have been maintained by an oceanic basin occupying the territory of the present-day Arctic throughout the Mesozoic, as a great volume of oceanic water was necessary to provide stable salinity and temperature in the surrounding epicontinental basins through 180 Ma. Long and sustainable development of the specific Mesozoic marine biota was provided by the South Anyui ocean in the Triassic and Jurassic and by the Amerasian ocean in the Cretaceous. This evidence substantiates the hypothesis of the presence of oceans in the Arctic throughout the Mesozoic which was suggested proceeding from geodynamic reconstructions.

Mesozoic, paleoocean, paleontology, geodynamics, paleobiogeography, Arctic

INTRODUCTION

Zonenshain and Natapov [1–3] suggested that an oceanic or ocean-like sea basin existed in the Arctic as an indented part of the Paleopacific throughout the Mesozoic. Now the Arctic Ocean is divided by the Lomonosov Range into the Eurasian and Amerasian basins, each of which in turn consists of two large basins. The Eurasian basin is a typical oceanic basin, divided by the Nansen Cordillera (Gakkel mid-oceanic ridge) into the Nansen basin and the Amundsen basin, with the oceanic type crust formed since the Oligocene [4], whereas oceanic nature of the Amerasian subbasin, divided by the Alpha-Mendeleev ridge into the Makarov basin and the Canadian basin, is inferred only from abyssal depths, averaging 3,800 m. A thick (over 5 km) sedimentary cover made up of rocks of Late Mesozoic—Cenozoic age precludes an unambiguous conclusion on the nature of the basement of the largest Canadian deep water basin.

Different opinions exist on the time of formation of the oceanic basin as a direct precursor to the Arctic Ocean. Geologists however are almost unanimous in that a single basin shown on today's maps did not appear until the Late Cenozoic [5–8].

Paleontologists studying marine fauna and flora support the idea that a basin of oceanic depth should have been uninterruptedly present in the area of today's Arctic throughout the Mesozoic [9]. The Arctic basin was always connected by sea with the world ocean, since the arctic biota, although mostly composed of the panboreal

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†Deceased.

taxa, often included representatives of the predominantly Tethyan groups migrated to the high latitudes, whereas some boreal mollusks occasionally appeared in the peritethyan areas [10–13]. Although shallow eastern and western seas could have served as passages for faunal migrations, their influence would unlikely be sufficient for maintaining stable environmental conditions in large epicontinental basins throughout the Mesozoic (over 180 Ma). This would require a large body of water with parameters stable in time that only an ocean could provide. An oceanic-type basin was necessary to maintain the high diversity of specific marine biota that inhabited the epicontinental Mesozoic seas along the periphery of the Eurasian and North American continents. We therefore find plausible the hypotheses that an ocean existed on the territory of the present-day Arctic, at least, since the Triassic [1]. At the same time, paleontologic data cast doubt on validity of some palinspastic reconstructions and, in a few cases, modify them.

BIOTIC EVIDENCE (TAXONOMIC COMPOSITION, CHOROLOGY, AND PHYLETIC TRENDS) FOR SPECIFICITY, INTEGRITY, AND SUCCESSION OF THE ARCTIC BASIN DURING THE MESOZOIC ERA

The Arctic basin includes the seas inhabited by specific biota* whose formation, evolution and dispersal during the Mesozoic occurred under the subpolar conditions of high latitudes. The boundaries of the basin in each geologic time interval were defined by the geographic range of the most representative arctic taxonomic groups. Analysis of the geographical distribution of fossils shows that the findings of the most typical paleoarctic invertebrates are approximately confined within today's Arctic Circle.

Typical boreal complexes are spread southward until approximately 50° latitude, whereas the main localities with mixed Boreal-Tethyan complexes lie between 50° and 45°. Arctic genera and species are sometimes found even south of 45° in certain strata. For instance, *Cadoceras* was reported from the early Callovian of North Caucasus [14], and *Buchia*, from the Kimmeridgian of North Mexico [15], the Tithonian—Valanginian of Northern California [16], southern Primorsk Territory and Hokkaido Island [17, 18] and from the Late Berriassian—Early Valanginian of North Caucasus [19], Crimea [20], and Kopetdag [21].

The Arctic basin can thus be defined in biogeographic terms as a biochore localized during the Mesozoic in the area now occupied by the Arctic ocean and its shelf seas [22]. Regions permanently or intermittently flooded by Arctic seas definitely include all contemporary Arctic islands and northern peripheral areas of Eurasia and North America. Occasionally, the Arctic basin expanded at the expense of continental shores flooded by epicontinental seas (see Fig. 1), contracting again after their retreat. The southern boundary of the Arctic basin also moved according to climate fluctuations, which shifted southern boundaries of the Boreal climatic zone [23].

The boundaries of the basin were inferred from comparative analysis of geographical ranges of the arctic and boreal marine faunal groups. To outline the Arctic basin territory, the range continuity was considered together with the degree of dominance of arctic taxa in the boreal paleocoenoses. Phyletic trends of the endemic taxa were traced to decide upon stability or directional changes of major hydrologic parameters and assess succession of the Arctic basin at different stages of its progress throughout the Mesozoic. The continuity of phyletic lineages strongly argues for the existence of a stable Mesozoic arctic ecosystem.

The invertebrate macrofauna of Arctic Mesozoic seas was most abundantly represented by mollusk classes such as cephalopods (subclasses Ammonoidea and Coleoidea), bivalves, gastropods and scaphopods; polyplacophorans are also identified. Brachiopods appear as another well represented phylum. Echinoderms were scarce and much less diverse; fossilized crinoids, ophiuroids, and sea urchins are infrequent in Mesozoic rocks. Findings of bryozoans are extremely rare. Crustaceans were represented by malacostracans, ostracodes, and scarce cirripeds. Diverse and abundant trace fossils of soft-bodied invertebrates are attributed mostly to annelids. Also, polychaetans of the Serpulidae family were common though lacking variety. Throughout the Triassic the Arctic seas were inhabited by scarce conodonts. Protozoans were mainly represented by a variety of foraminifers and radiolarians. Marine vertebrates prevailing in fossils in sedimentary rocks include fishes and large reptiles such as ichtyosaurs and plesiosaurs. In different periods phytoplankton was dominated by green algae, diatoms, and chrysophytes.

All mentioned animals and plants were adapted to the life in relatively cold water, populating high-latitude marine habitats both in Mesozoic and at present. More importantly, these groups were stenohaline, consisting predominantly of truly marine organisms tolerating only a narrow range of seawater salinity normal at that time. This should be kept in mind when explaining why the geographical differentiation of the biota was related to the uneven Earth's surface temperature rather than the ocean salinity. Periodically occurring freshwater drainage may

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* This biota will be termed "arctic" with no quotation marks here, although it clearly was not the precursor of the modern Arctic ocean biota. The term "Arctic" is used for the geologic past to define an area contoured by today's Arctic circle.

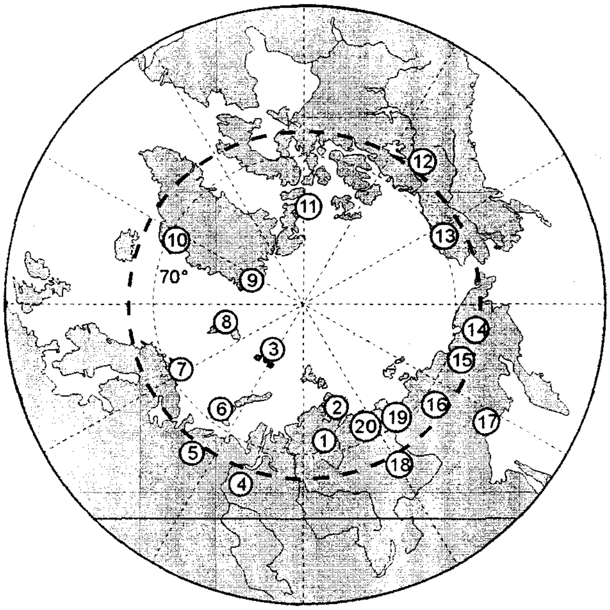

Fig. 1. Main localities of the Arctic marine Mesozoic biota groups. 1 — Khatanga basin, 2 — Taimyr Peninsula, 3 — Franz Josef Land, 4 — West Siberia and Polar Urals, 5 — Pechora basin, 6 — Novaya Zemlya, 7 — Lofoten Islands, 8 — Svalbard, 9 — Peary Land, 10 — northeastern Greenland, 11 — Canadian Arctic Archipelago, 12 — Richardson Mountains and Yukon basin, 13 — northern Alaska, 14 — Anyui basin, 15 — Omolon Massif and Alazei Plateau, 16 — Yana-Indigirka interfluve, 17 — North-Okhotsk region, 18 — Vilyui basin, 19 — lower Lena basin, 20 — Anabar and Olenek basins. The dashed line indicates the Arctic circle.

have had decreased the salinity near the continental shores but hardly determined the latitudinal distribution features of marine biota in the Northern hemisphere, despite several claims to the contrary [24, 25].

We are reminded in this context that typical tropical organisms from the peripheral Mesozoic seas of the Tethys — colonial corals, reefal bivalves (rudists) and gastropods (*Nerinea*), and other invertebrates whose orders number in the dozens, superfamilies and families in the hundreds and genera in the thousands — never occurred north of the present-day 55° N. The arctic biota was characteristically poor in taxa compared to the tropical and even lower boreal biota. During the Mesozoic, lower boreal and higher boreal (i.e., Arctic) seas witnessed the origin and evolution of hundreds of endemic species, tens of genera, and a few families.

The complete absence of large tropical marine taxa from the Mesozoic Paleoarctic and the presence of endemic taxa are suggestive for partial isolation of the arctic biota from the global biota. As mentioned, one of the isolating factors was climatic zoning that defined the global distribution of Mesozoic organisms. Extended bodies of deep water or dry land presented another barrier, just as they do today. Biotas usually undergo significant taxonomic diversification at the opposite sides of large water gaps. For example, no more than 5% of mollusk species now occur commonly at both sides of the Atlantic. Three million years of independent speciation following the separation of the Atlantic and Pacific biotas by the Isthmus of Panama led to 97% difference in the mollusk biodiversity at the species level.

Triassic marine biota of the Arctic basin. Analysis of the geographical ranges of nearly 350 ammonoid and bivalve genera in the Northeastern Asia during the Triassic revealed certain patterns in their distribution. The underlying climatic and paleogeographical reasons may be the presence of an oceanic basin from the North Pacific extending to the western sector of today's Arctic, and warm and cold currents at both sides of the paleoocean, named South-Anyui.

Specific marine boreal biota during the Triassic was restricted to the present-day Arctic, Northeast Asia and Alaska, as judged from the geographical ranges of endemic families and genera (Fig. 2). Analysis of ratio of boreal, cosmopolitan and Tethyan mollusk (ammonoid and bivalve) genera in the Arctic basin biocoenoses shows medium to high proportion of the endemic boreal genera (Fig. 3). Pooling the data on mollusk fossils obtained for the last 20 years, it is possible to define, starting from the early Triassic, two independent arctic provinces

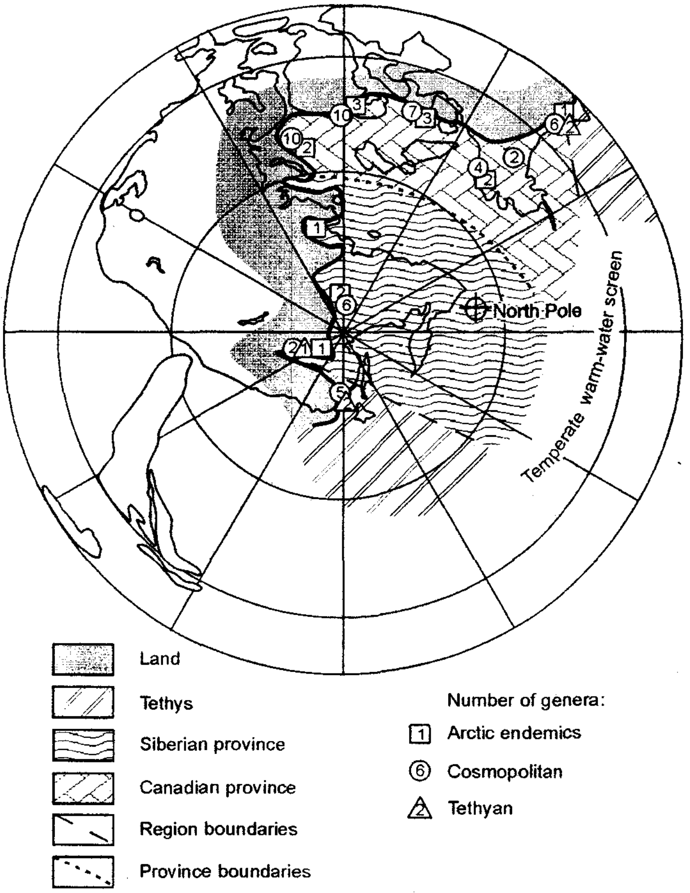

Fig. 2. Distribution of the molluskan genera (ammonoids and bivalves) in the Arctic basin in the Induan (early Triassic).

within the boreal biogeographical zone: the Siberian province inhabited by the most specific boreal fauna, and the Canadian province, sometimes significantly influenced by migrants from the Tethyan seas. The integrity of the early Triassic arctic biota is most clearly demonstrated by the geographical ranges of endemic genera confined within the boreal zone. One of those, the bivalve *Atomodesma*, did not occur outside of the Arctic in the Induan.

The early Triassic Arctic basin biota succeeds the taxonomically poor late Permian boreal biota [26, 27]. Its difference from the Tethyan biota is mostly established at the rank of species, although by the end of the Induan 5% of the bivalve genera and 30% of the ammonoid genera were restricted to the Arctic basin (see Fig. 3). The number of arctic endemics among ammonoids and bivalves significantly increased by the end of the Olenekian to 53% and 10%, respectively. High proportion of endemics persisted during the middle Triassic and in the beginning of the late Triassic (36% among ammonoids and 21% among bivalves in the Anisian, 44% and 14% in the Ladinian, 47% and 18% in the Carnian) but declined in the Late Triassic (10% of bivalve endemics in the Norian and the Rhaetian, and no known endemic ammonoid genera).

The gradual decline of invertebrate biodiversity in the Late Triassic Arctic may be related to the causes of the global extinction at the end of the Triassic. Geographical range contraction is known to have preceded the global extinction for many marine invertebrates taxa. We documented conodonts disappearing from the arctic biota in the Norian, and Inoceramus, at the end of the Cretaceous, before their total extinction in Tethyan seas in the Rhaetian and the Maastrichtian, respectively [28].

As mentioned above, during the most part of the Triassic, endemics were nearly a half of ammonoid taxa at the rank of genera. This strongly suggests the existence of an Arctic basin different in its unique hydrologic parameters from the basins to the south. The succession in evolution of the endemic mollusk and brachiopod genera throughout the Triassic confirms conservation or a directional change in their environment. For instance, endemic phyletic lineages at the rank of families are known for Triassic cephalopods (Tsvetkovitidae and

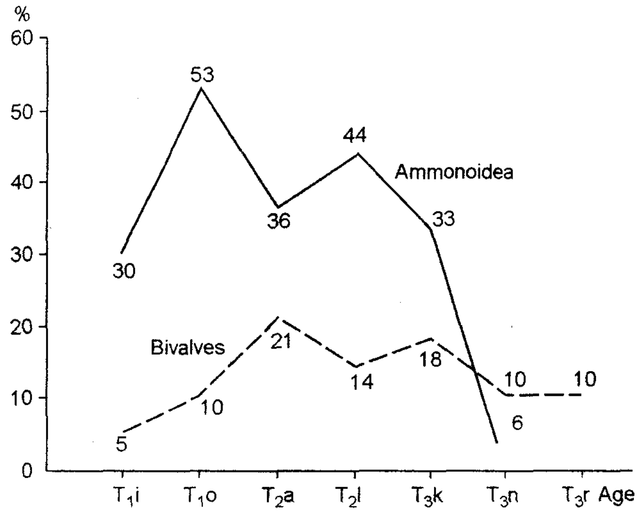

Fig. 3. Number (% of the total number) of genera of boreal mollusks (arctic endemics) in the Arctic basin at each stage of the Triassic.

Nathorstitidae in the Ladinian and the early Carnian [29]), nautiloids (Siberionautilidae in the Norian [30]) and brachiopods (Aulacothyroideidea in the late Triassic [31]). Endemic taxa best illustrate the succession of environments in the Arctic basin. The history of the bivalve genus *Bakevillia* is a good example (Fig. 4). Three subgenera of this genus evolved in the Arctic during the Triassic. The subgenus *Maizuria* comprised an uninterrupted lineage of twelve species during the Early and early Middle Triassic. The subgenus *Neobakevillia* (two species) existed from late Early Triassic to early Middle Triassic, whereas the subgenus *Boreiobakevillia* (five species) evolved over the time interval from Olenekian to Rhaetian.

The Triassic Arctic was the place of origin of several high-rank taxa. For example, brachyopods of the subfamily Pennospiriferininae appeared in Northwestern Asia in the Late Ladinian, spread into the Southern hemisphere by the Early Carnian and persisted only in New Zealand and New Caledonia in the Norian and the Rhaetian (also illustrating the concept of metachoresis [32]). On the other hand, invertebrates from the Tethys always found their way to the Arctic where they had favorable conditions for evolution. Invasion of nautiloid genera into the seas of Siberian biogeographical province occurred independently twelve times during the Triassic: twice in the Early Triassic (Olenekian), four times in the Middle Triassic, and six times in the Late Triassic. Each time they formed new genera and species endemic for the Arctic (prochoresis [33]). Tethyan ammonoids also recurrently invaded the Arctic basin. Six and five invasions of the Tethyan genera are documented from the Induan and the Olenekian, respectively. Only two southern genera are known among boreal ammonoids in the Ladinian, and two in the Carnian. A higher number (nine southern genera) is recorded in the Anisian, reflecting perhaps a large transgression. However, most (thirteen) Tethyan ammonoid genera — *Halorites*, *Rhabdoceras*, *Catenohalorites*, *Cyrtopleurites*, etc. — migrated to the high latitudes in the Norian. The arctic ammonoids of the early Rhaetian were represented by five cosmopolitan genera that were extinct by the end of the Rhaetian [34–38].

Multiple migrations of Tethyan bivalves into Boreal waters are also noted. The first invasion of five Tethyan genera (*Ornithopecten*, *Amphijanira*, *Rhynchopterus*, etc.) into the Canadian province (Svalbard) occurred in the late Ladinian but was only transient. This invasion could result from the warming of Arctic evident from the Carnian flora of Svalbard [39]. At this time, the Arctic seas were invaded by Halobiidae from the North Pacific. This group dominated the arctic marine biota in the Carnian and the early Norian, generating several regional phyletic lineages. The largest number of bivalve genera (nine) that migrated from the Tethys is known from the Norian: *Cassianella*, *Pteria*, *Trigonia*, *Minetrigonia*, *Monotis subcircularis* group, etc. At the same time, three Arctic regions — Bol'shoi Anyui basin, New Siberian Islands, and northern Alaska — are dominated by Boreal taxa but also are inhabited by genera and species that migrated from the Tethyan seas: *Cassianella*, *Pteria*, *Monotis subcircularis*, *Halobia alaskana*, *H. septentrionalis*, etc. Associations of dominating pelagic and quasipelagic bivalves in these three regions are very similar, suggesting continuous environmental conditions throughout a single epicontinental basin of the Canadian province. It should be noted that a significant number of pelagic and monotoid bivalves is shared between Alaska (Boreal seas), British Columbia (Tethyan seas), and California, indicating faunal exchange with the North Pacific.

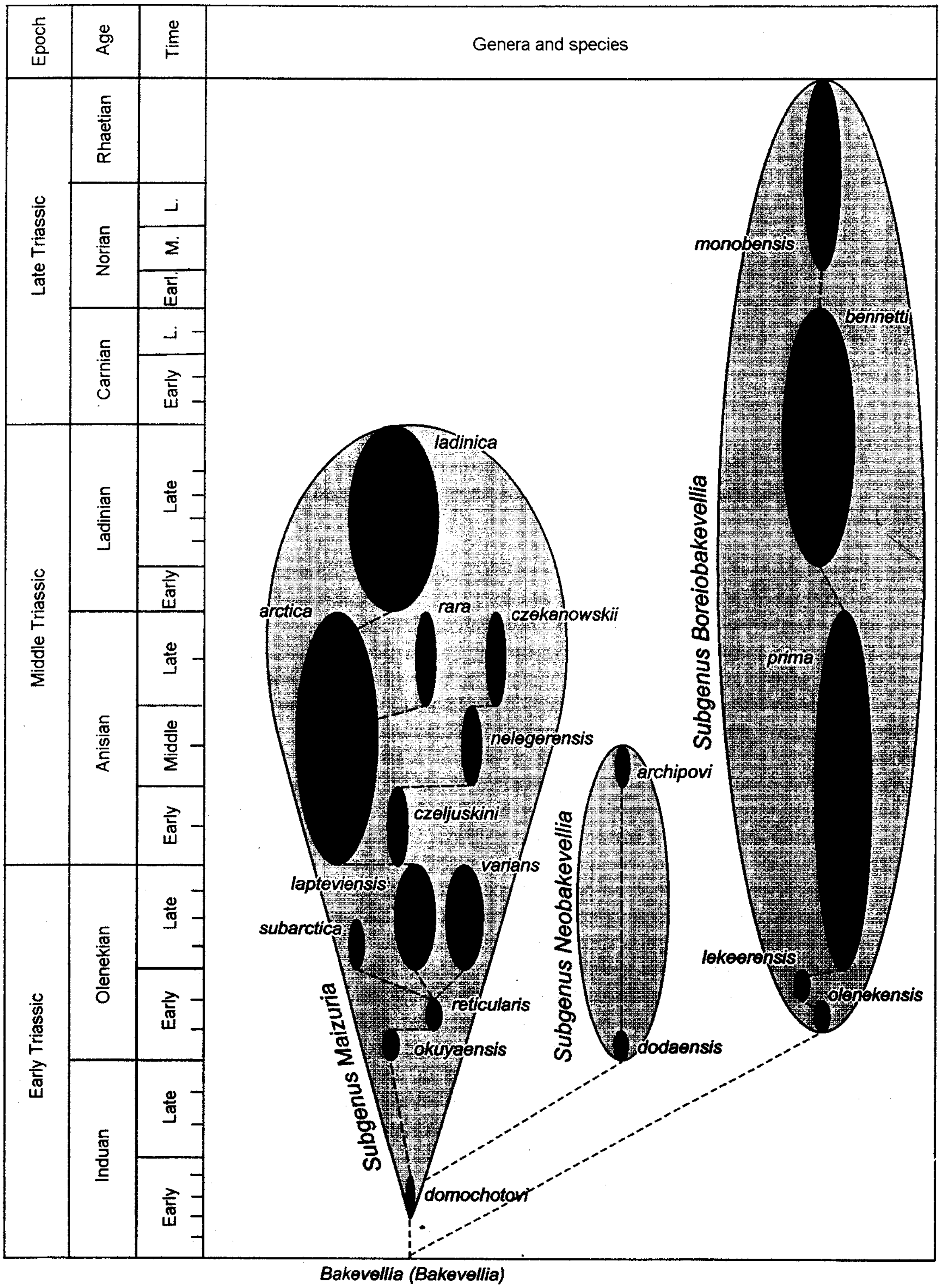

Fig. 4. Speciation of bivalves of the Boreal genus *Bakevillia* in the Siberian paleozoogeographical province in the Triassic.

Numerous examples of migration of just a few Tethyan groups of invertebrates to the high latitudes of the Arctic basin suggests the existence of a barrier that did not allow mixing of the Boreal and Tethyan biotas but allowed invasions of certain arctic taxa into the Tethys, and vice versa. The factor limiting migrations of the most taxa of marine invertebrates was the lower water temperature in the Arctic basin. Boreal-Tethyan migrants likely were more temperature-tolerant.

Within the Arctic basin, however, mollusks were distributed unevenly. The distribution of both benthic and pelagic bivalves was found to be significantly disproportional between the Siberian and Canadian paleobiogeographical provinces [40]. During the Triassic, associations of bivalve genera in the Canadian province were on average 5–8-fold poorer (even 40-fold in the Anisian) than in the Siberian province. Such a sharp difference in the composition of bivalve genera between opposite sides of a single basin may be explained by a barrier function of the South Anyui ocean that separated shallow seas of the Northwest Asia and the Arctic Canada and hampered the exchange of bivalve larvae. Since the bivalve associations inhabiting the seas around Svalbard were 3–4-fold poorer (11-fold in the Anisian) compared to the seas of the Siberian province, Svalbard in the Triassic must be grouped with the Canadian province. The opposite is true for ammonoids: The number of genera in the Canadian province was 2–3-fold higher than in the Siberian province, except the Olenekian and the Norian when the numbers of ammonoid genera were nearly equal in both. This pattern of distribution of cephalopods may be explained by the existence of a warm current running from the south along the coast of North America and increasing the temperature of surface water where ammonoids preferentially live (see Fig. 2).

Jurassic marine biota of the Arctic basin. Jurassic marine biota of the Arctic basin included much less high-rank endemic taxa than the Triassic biota. This may seem paradoxical given that in the Triassic the basin was wider open towards the Pacific than in the Jurassic. An explanation is that the situation with the Arctic basin in the Triassic was different from that in the Jurassic. At least, since the Late Pliensbachian, it has constantly been connected through epicontinental seas not only with the North Pacific, as it was in Triassic, but also with North Atlantic [41, 42]. Better accessibility of the Arctic seas provided for more efficient connections between biotas of different paleobiochores, thus lowering the rank of endemic taxa. In addition, the global biotic crisis at the end of the Triassic greatly reduced the biodiversity of marine invertebrates in the boreal zone. The worst affected groups were cephalopods (the whole order Ceratidida extinct), brachiopods (several families extinct), foraminifers and conodonts (completely extinct in the Norian). In bivalves, the species composition changed completely in the transition from Triassic to Jurassic, and the number of genera dropped significantly (24%) [13]. This is another reason for low endemism of invertebrates of the Early Jurassic. Nevertheless, almost all large groups of invertebrates — cephalopods (ammonites, belemnites), bivalves, gastropods, brachiopods, ostracodes — support both the integrity of the Arctic basin and its connection with the world ocean.

Integrity and uniqueness of the paleobasin are best defined by endemic taxa unknown outside the biochore. Arctic endemics ranked families in the Jurassic and Early Cretaceous included only brachiopods (fam. Boreiothiridae), and ammonoids in the Early Jurassic (fam. Yukagiritidae of the order Phylloceratida) [43, 44]. The endemism in mollusks was most pronounced at the level of genera and subgenera. For example, in the Early Jurassic, endemic ammonites included the genus *Primapsiloceras* and the genera *Kolymophylloceras* and *Platyphylloceras* of the mentioned endemic family Yukagiritidae — in the Hettangian; the genera *Turomchites*, *Yukagirites* of the same family, and the subgenera *Paracoroniceras* and *Gydanoceras* — in the Sinemurian; the genus *Nordamaltheus* — in the Late Pliensbachian; the genera *Kedonoceras**, *Kolymoceras*, *Arctomercaticeras*, *Platyphylloceras* — in the Early Toarcian [45–49]. In the Middle Jurassic, they included the genera *Erycitoides* and *Tugurites* — in the Aalenian and Early Bajocian [50–52]; the genera *Arkelloceras*, *Boreiocephalites*, *Cranocephalites*, the subgenus *Pachycephalites* — in the Bajocian; the genera *Arctocephalites*, *Arcticoceras*, *Costacadoceras*, the subgenera *Catacadoceras* and *Streptocadoceras* — in the Bathonian; the genera *Pseudocadoceras*, *Rondiceras*, the subgenera *Paracadoceras*, *Bryocadoceras*, *Stenocadoceras*, *Soaniceras* — in the Callovian [53–55]. The Oxfordian and the Kimmeridgian lack endemic genera; *Taimyrosphinctes* is known from the middle Volgian [56]; *Taimyroceras*, *Schulginites* and *Ronkinites*, from the Late Volgian [57]. Several endemic taxa ranked genera are known for bivalves: the genera *Lupherella* (from Hettangian to Sinemurian), *Arctotis* (Middle Jurassic and Early Cretaceous), *Praebuchia* (from Callovian to Oxfordian), *Canadotis* (from Toarcian through Kimmeridgian to Volgian), the subgenera *Harpax* (Early Jurassic), *Boreioxytoma*, *Canadarctotis* (Volgian) [58–62].

Several families originated in the Jurassic Arctic, which existed for a long time afterwards both in the Arctic and lower Boreal seas. The best known phyletic lineages of the Middle and Late Jurassic are those formed by ammonites of the family Cardioceratidae (Fig. 5). The most ancient representatives of Cardioceratidae, the subfamily Arctocephalitinae, emerged in the Arctic in the beginning of the Late Bajocian [64]. It is generally agreed that the ancestor for this phyletic lineage was the genus *Chondroceras* (Sphaeroceratidae). According to the phyletic scheme by J. Callomon [65], in addition to the Arctocephalitinae Meled., another subfamily, Eurycephalitinae Thierry, branched off Sphaeroceratidae in the early Late Bajocian, and evolved in the North Pacific seas

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* Howard [63] considers this genus synonymous to the genus *Ortodactylites*.

independently of the Arctocephalitinae in the Arctic until the Kimmeridgian (see Fig. 5). Cardioceratidae genera and species forming distinctive associations in the Arctic seas (Northern Eurasia, Arctic Canada, northern Alaska, eastern Greenland, Arctic islands) were also widespread in the periphery of the Boreal extended region ("Boreal belt" in the nomenclature of [66]) adjacent to the Tethyan extended region. In the sea ecotones the arctic genera of the family Cardioceratidae coexisted with peritethyan ammonites.

Another group of cephalopods specific mostly for the Arctic includes belemnites of the family Cylindroteuthidae (Middle Jurassic to Early Cretaceous). Ancestors of this phyletic lineage most likely migrated from the Boreal-Pacific paleobiogeographical zone [64]. The benthic communities of the Arctic in the Middle Jurassic are dominated by bivalves of the family Retroceramiidae [22, 47, 67–69]. Similarly to belemnites, this phyletic lineage originated in the Early Jurassic in the Boreal-Pacific paleobiogeographic zone. Bivalves of the family Buchiidae evolved in the same paleobiochore in the Triassic and nearly supplanted the Retroceramiidae by the Late Jurassic (Fig. 6). The Buchiidae were widespread in the Boreal seas in the late Jurassic and the Neocomian but were dominating in bionomic zones of all Arctic basins in Northern Eurasia and North America [60].

Direct dependence of the level of taxonogenesis on a degree of isolation of the Arctic basin is well illustrated by a history of the endemic group of homeomorphic genera *"Canadotis" — Arctotis — Canadotis — Canadarctotis — "Arctotis*"* [58, 59, 61, 62]. We suggest that this sequence of genera observed in geologic time developed by iterative evolution from a phyletic stock of the genus *Meleagrinella* (Fig. 7). Two independent phyletic lineages of "Arctotis" appeared during the times of the maximum isolation of the Arctic basin: the Middle Jurassic and the Volgian (Late Jurassic). On the other hand, taxogenesis occured at the low (species) level during a long period of the early Jurassic and in the late Middle—early Late Jurassic when stable connections to the North Paleopacific existed.

The Arctic basin was substantially isolated in the Aalenian, the Bajocian and a good part of the Bathonian, as evident from the highest endemism of ammonites in the Jurassic: 67% in the Aalenian, 50% in the Bajocian, and 54% in the Bathonian (Fig. 8). This view is further supported by a very peculiar composition of bivalves [61, 70]. Specific arctic groups of pteriomorphs — *Arctotis*, *Oxytoma jacksoni*, and *Retroceramus* — dominated benthic communities of the Aalenian seas of the Northern Eurasia and North America. Probably at the end of the Toarcian, the Arctic was invaded by first representatives of the subfamily Arcticinae (the order Heterodonta). In the early Aalenian they were represented by an endemic species *Isocyprina humiliculminata*. In the seas of northern Siberia, Arcticinae produced several phyletic lineages of species in the genera *Hartwellia*, *Pronoella*, *Proveniella*, *Stafficallista*, and *Tenea* during the Late Jurassic and Early Cretaceous [71].

The Arctic microbiota also acquired large groups in the early Aalenian. The subgenus *Anabarocythere* appeared within the circumarctic ostracode genus *Camptocythere*. The phyletic lineage is traced back to the Early Toarcian when the Arctic basin was wide open both from the east and from the west (Fig. 9). A burst of speciation in the genus *Camptocythere* occurred in the Middle Jurassic. This genus was widespread in Northern Eurasia and sporadically appeared in the seas of Northern Alaska. The circumarctic nature of the geographical range of this species in the Toarcian and the Middle Jurassic underscores the integrity of the Arctic basin (Fig. 10).

The uniqueness and integrity of the Arctic basin biota in the Early Callovian is isllustrated by the geographical ranges of the typical boreal genera of Cadoceratinae: *Cadoceras* and *Pseudocadoceras*. Fossilized remains belonging to these genera are circumboreal, occurring north of 50° N in eastern England, East European Plain, northern Siberia, northern and southern Alaska, and a number of Arctic islands, including northeastern Greenland (Fig. 11). However, in the seas of the boreal-Atlantic paleozoogeographical zone bordering the Tethys or the boreal-Pacific paleozoogeographical zone these genera are found along with peritethyan genera that never moved to the high latitudes [42, 66, 72]. This may be regarded as evidence for existence of thermal barriers preventing migration of the southern mollusks to the Arctic basin and the northern species to the Tethys through open meridional sea passages.

In the Oxfordian and the Kimmeridgian, the Arctic basin was stably connected mostly with the seas of the Boreal-Atlantic paleozoogeographical zone. This explains the scarcity of the endemics of high taxonomic rank in the Arctic during these ages. This is further supported by rather high identity of mollusk genera and even many species of Northwestern and Northeastern Europe and Nortwestern Asia [66]. The Arctic lacked high-rank invertebrate endemics at that time. However, the lack of Tethyan genera of cephalopods and their scarcity among

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* North Siberian Volgian and Valanginian species of *Arctotis* Bodyl. had been included in the same genus. The Volgian species *A. intermedia* Bodyl. should probably be classified as the subgenus *Canadarctotis* Jel. et Poul., with its status elevated to genus. However, the classification of the North Siberian Valanginian species *"Arctotis" anabarensis* Petr. cannot be regarded as final since morphologically it is significantly different from the Volgian species [59]. If iterative evolution of *Arctotis* is accepted, in the absence of findings of *Arctotis* from the boreal Berriassian, the Valanginian species may turn out to be another genus of *"Arctotis"*.

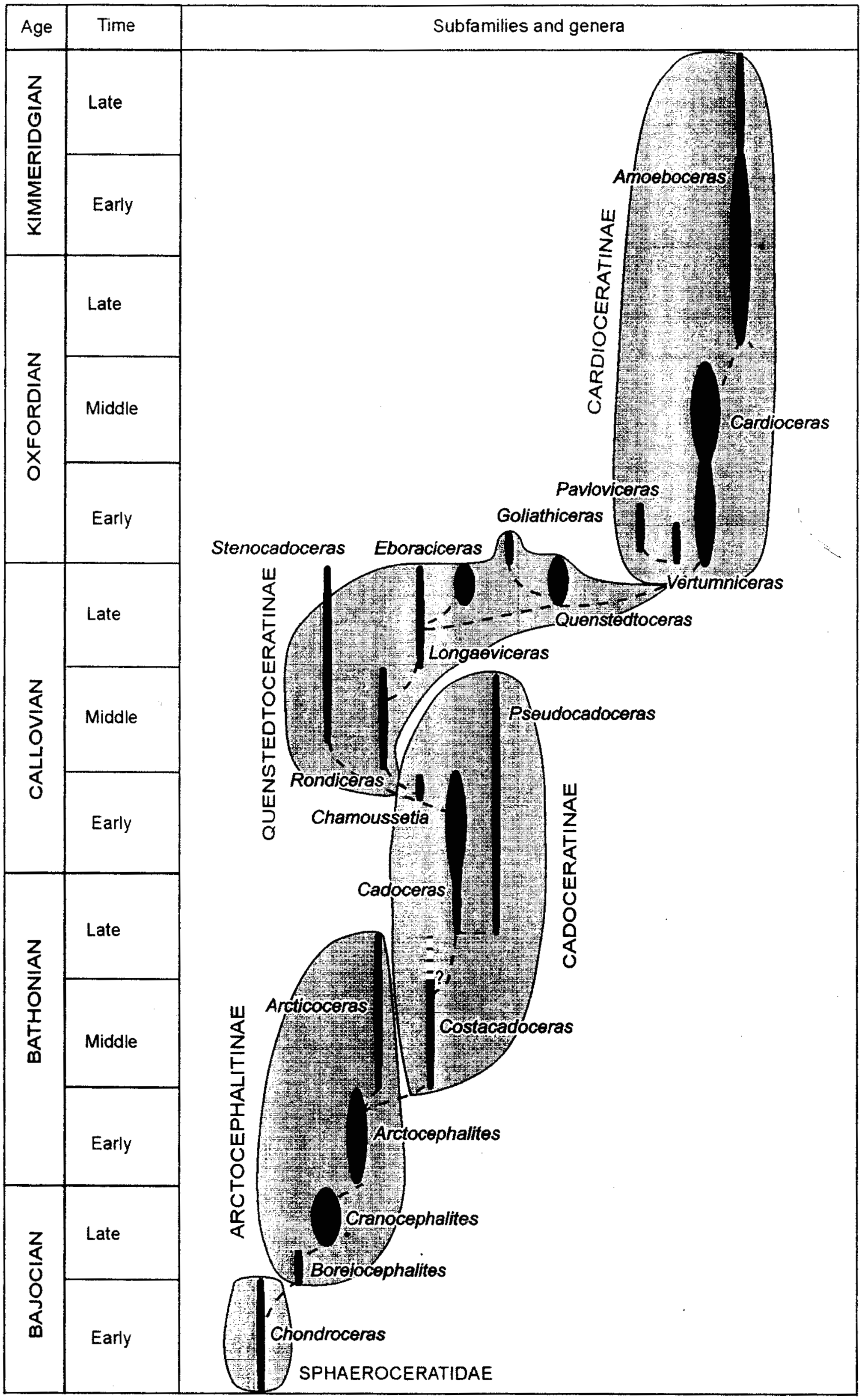

Fig. 5. Evolution of ammonites of the family Cardioceratidae in the Arctic zoogeographical region in the Middle and Late Jurassic.

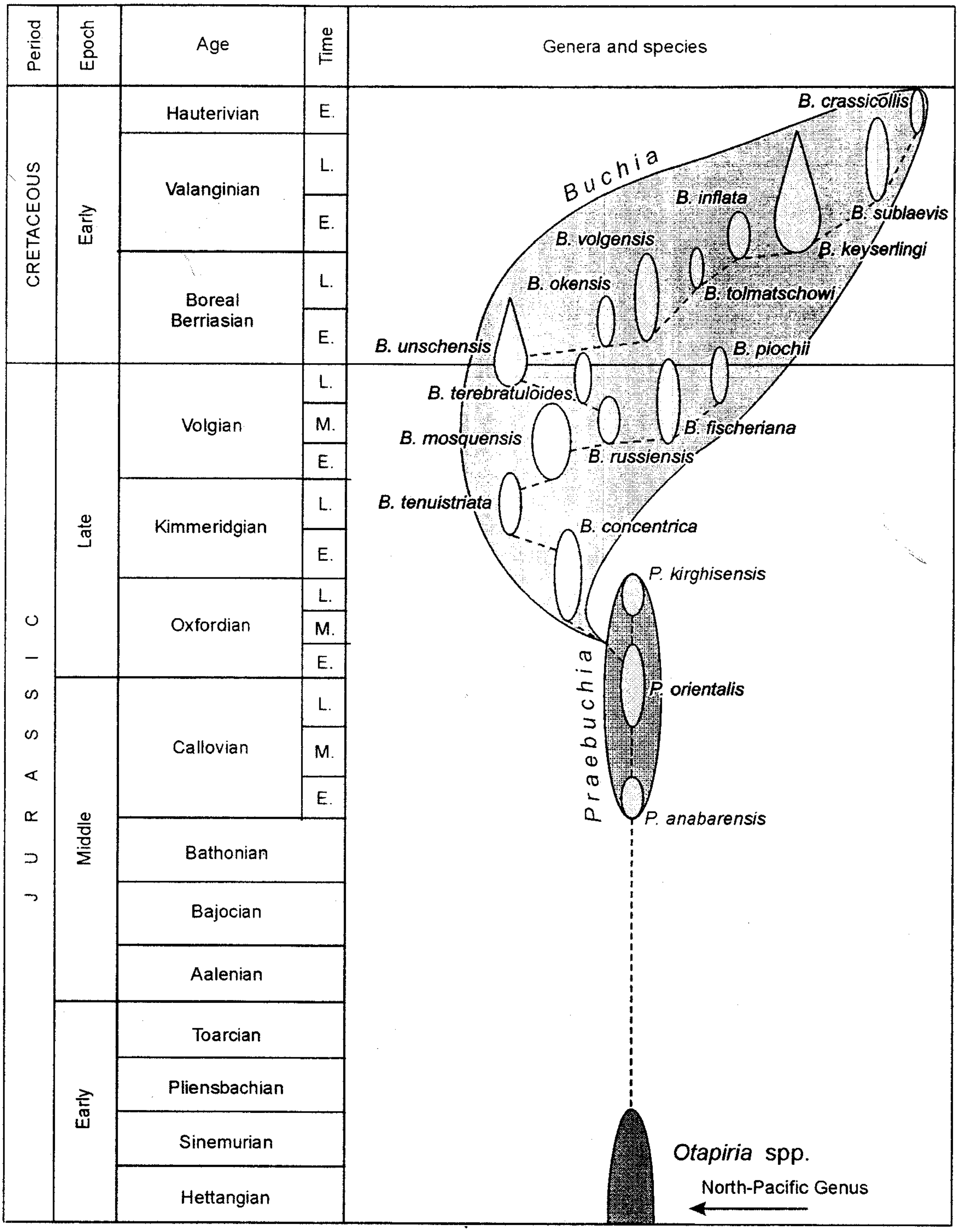

Fig. 6. Evolution of bivalves of the Boreal family Buchiidae in the Arctic zoogeographical region in the Jurassic and Early Cretaceous (Neocomian).

bivalves and brachyopods suggests that latitudinal thermal barriers between the Tethyan, Boreal and Arctic waters persisted during the Oxfordian and the Kimmeridgian.

The nature of the connections of the Arctic basin with the Western European seas had drastically changed at the end of the Jurassic (Volgian) following sea regression in the north of Western Europe. During the Volgian, the East European seas and the Arctic seas connected with their northeastern part became progressively more isolated [22]. This resulted in significant separation between the Volgian invertebrate faunas of Western and Eastern

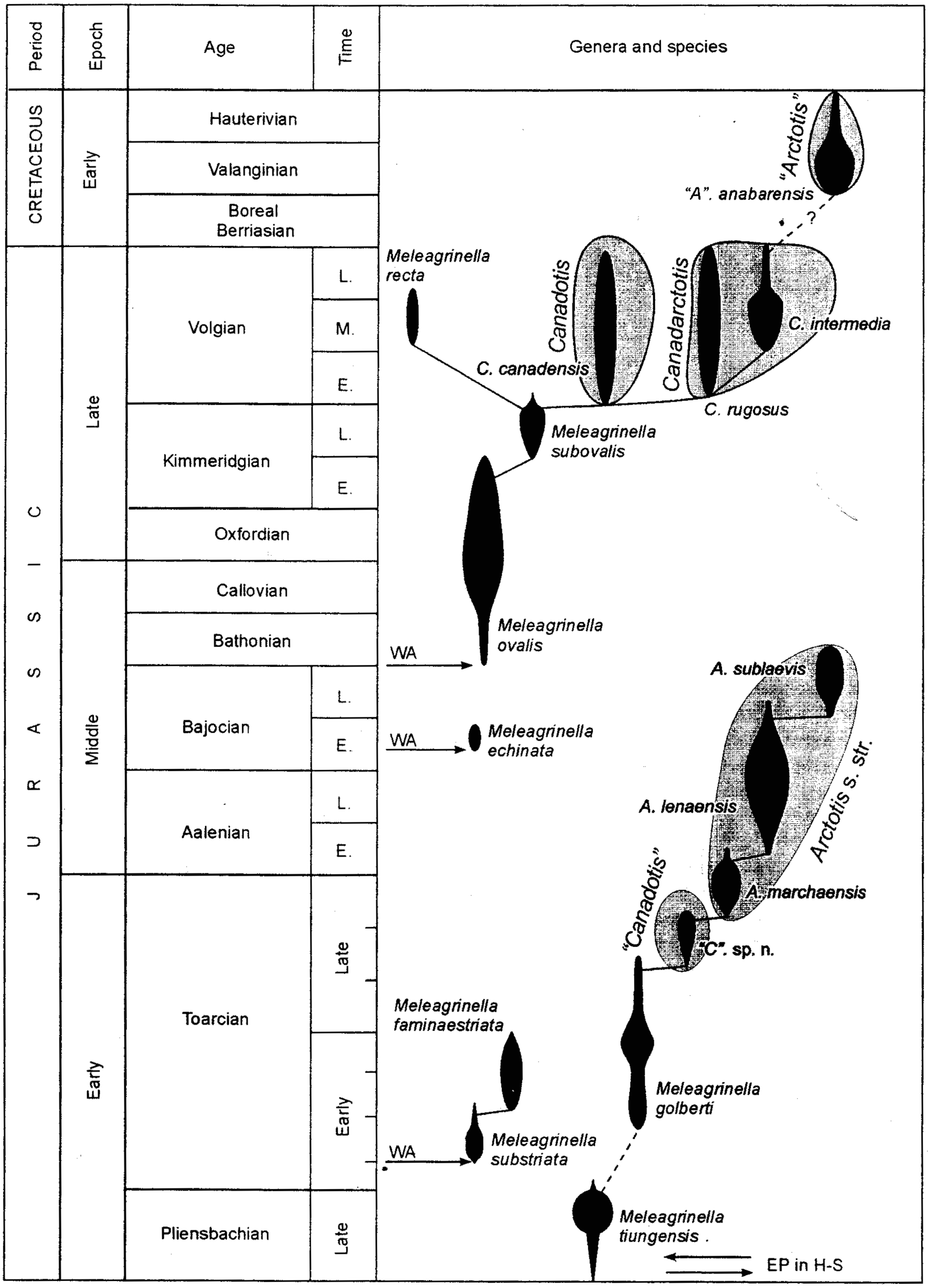

Fig. 7. Iterative appearance of the genus *Arctotis* in the Arctic province in the Jurassic. WA — West Atlantic, EP — East Pacific in the Hettangian-Sinemurian.

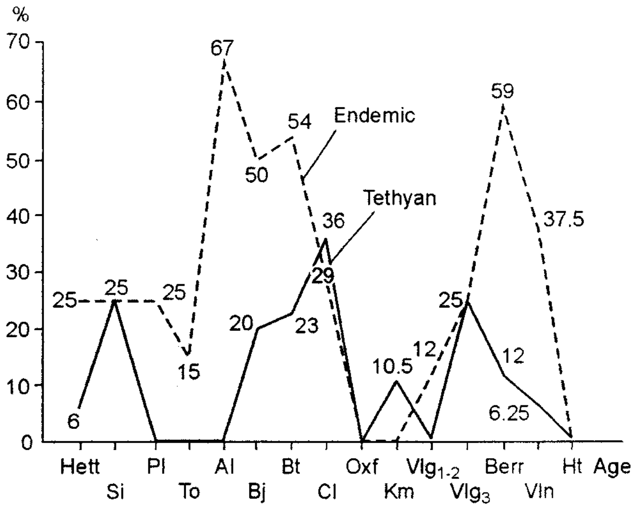

Fig. 8. Number (% of the total number) of genera of boreal (arctic endemics) ant Tethyan (immigrant) ammonites in the Arctic basin at each stage of the Jurassic and Early Cretaceous.

Europe. The isolation of the Southwestern European seas from the seas of North Atlantic led to the late Volgian invasion of specific Arctic fauna (e.g., ammonites of the family Craspeditidae, or the genera *Buchia* and *Inoceramus*) along Scandinavian and Greenland shores into the North Sea and Northeastern England. These mollusks were widespread in northern Canada, northern and northeastern Greenland [73–75]. This view is best illustrated by ammonites of the genus *Craspedites*, typical of the specific biota of Eastern European seas and the Arctic paleozoogeographical zone as part of the boreal paleozoogeographic extended area (Fig. 12). Thus, mollusks of the Arctic basin became isolated in a circumpolar fashion in the Volgian (as they later did in the Boreal-Berriasian) but were not differentiated between provinces of the Arctic paleobiogeographical zone.

Cretaceous marine biota of the Arctic basin. The Arctic basin kept its Jurassic features in the Early Cretaceous through the Early Hauterivian. The Berriasian biota was identical to the Volgian one. All major phyletic lineages of ammonites (Fig. 13), belemnites, bivalves (Fig. 6) and brachyopods were continuing. All these groups had high rate of endemism at the level of genera, which, in ammonites, reached 59% in the Boreal-Berriasian and 37.5% in the Valanginian (see Fig. 8). The geographical range of genera of ammonites and *Buchia* was still circumboreal and circumarctic. Thus, in the Neocomian, like in the middle and late Jurassic, the Arctic was occupied by a single Arctic biogeographical zone not differentiated into provinces.

Areas of the epicontinental seas contracted significantly during the Hauterivian. At the same time diversity of marine invertebrates dropped. Only three ammonite genera are established from the Hauterivian: ***Homolsomites***, ***Speetoniceras*** (Early Hauterivian) and ***Simbirskites*** (Late Hauterivian). These are typical Boreal genera but only the first two are known in northern Siberia. The range of last genus included Svalbard and the Timan-Pechora regions [76] in the West Arctic, and West Siberian [77] and the Anadyr-Koryak regions [78] in the East Arctic. The Arctic seas became separated from the Paleopacific in Northeastern Asia at the end of the Hauterivian [78]. During the Barremian and the Early Aptian, the regression affected most of the Arctic shelf of both Eurasia and North America. The taxonomic composition of marine invertebrates became substantially poorer. Ammonites of the Lower Aptian (the genus *Deshayesites*) is known only from glaciation boulders of the Timan-Pechora region and Novaya Zemlya [79]. Bivalves of the genus *Inoceramus* are evidently found in the Lower Aptian in Svalbard [76]. The North Siberian shelf lacks epicontinental sea sediments of the Barremian, most of the Aptian and part of the Cenomanian. Since the Late Aptian, sea beds with ammonites *Troepaerum* and *Sanmartinoceras* have appeared only in Svalbard [76]. As judged from the range of marine bivalve and ammonite fossils of Aptian and Albian ages, the sea transgression of the late Early Cretaceous began in the early Aptian, proceeding from the North Atlantic towards Western Arctic. Later, the Barents Sea plate was completely flooded, and the transgression affected the whole Arctic basin at the beginning of the Early Albian. Early Albian sea sediments are deposited over northern Alaska, Sverdrup basin [80], Barents sea and Kara Sea shelf, Timan-Pechora basin [79, 81] and West Siberian plate, as evident from findings of the genera *Arcthoplites* (*Subarcthoplites*), *Cleoniceras* and *Pseudopulchellia* in the Latitudinal Ob' region [82, 83]. Alhough ammonite associations of Northern Eurasia are taxonomically much poorer than those of western Arctic, reflecting variations in the completeness of investigated

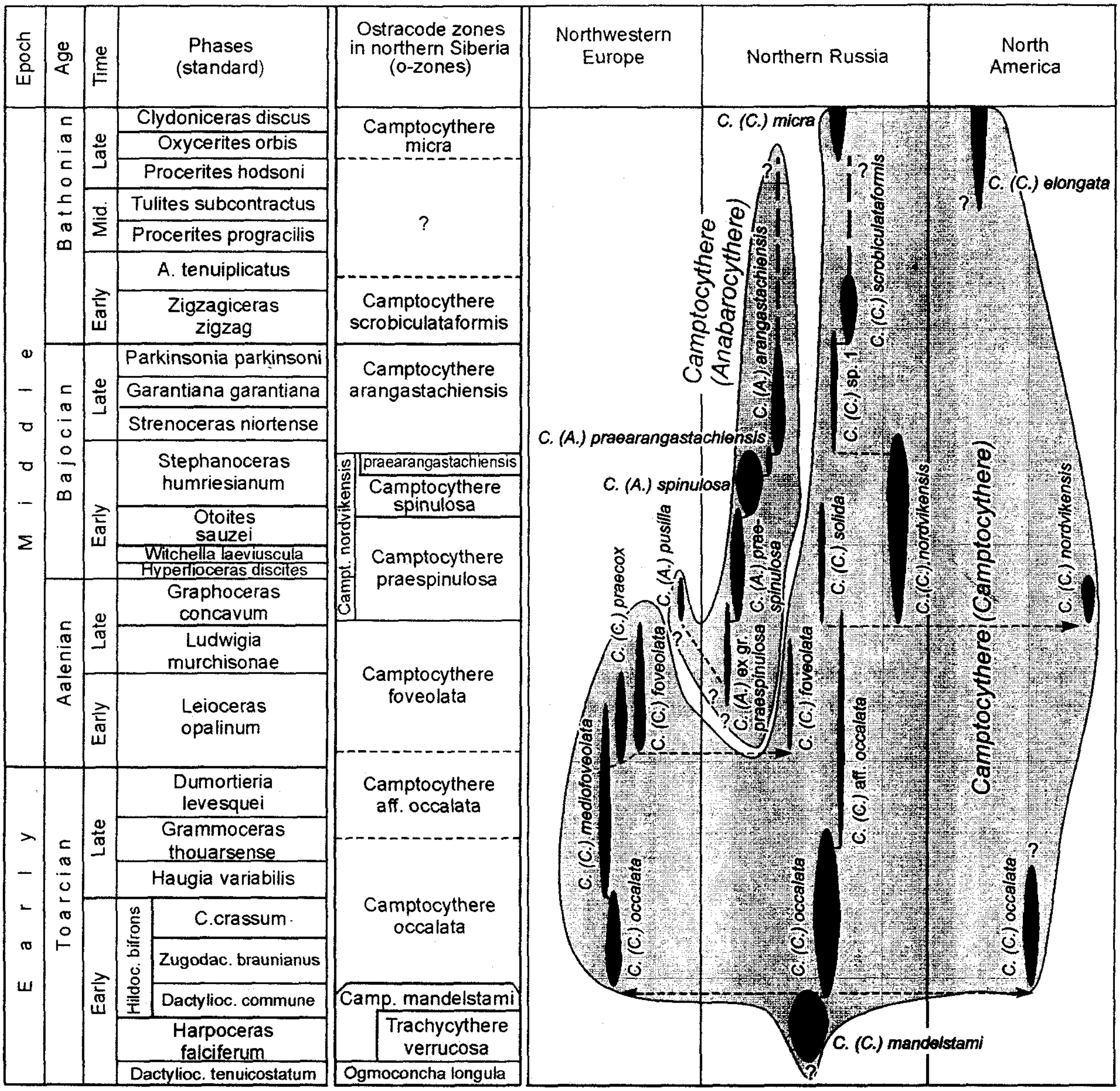

Fig. 9. Speciation of ostracodes of the arctic genus *Camptocythere* in the Early and Middle Jurassic.

paleontologic data, the similarity of Albian ammonites at the level of genera of the subfamilies Gastroplitinae and Cleoniceratinae may be traced in arctic Canada, northwestern Greenland, Svalbard, Northern European and Siberian parts of Russia [76, 79, 83, 84]. These territories may therefore be integrated, at least in the Early and Middle Albian, into a single Arctic biogeographical province.

The Trans-North-American sea passage, formed in the Albian and persisting over the late Cretaceous, directly connected the Arctic basin with the Caribbean seas of the Tethys [80]. The late Cretaceous biota of both North American and North Siberian seas is characterized, in general, by a mixed composition including Lower Boreal and arctic endemic forms, with a small number of Tethyan and cosmopolitan taxa [12, 85]. The Arctic basin completely lacked colonial corals, nerinoid and neritid gastropods, orbitoid foraminifers and dozens of genera of ammonites and bivalves, including all rudists, typical of the Tethyan seas to the south [12, 66]. Several North Pacific species of *Inoceramus* were briefly present in northern Siberia during the Late Cenomanian [86]. This episode of immigration coincided with the eustatic rise in the late Cenomanian. During the Late Cretaceous, no channels existed between shallow seas of the Arctic and the North Pacific [78]. The late Cretaceous biota of the American Arctic was heavily influenced by the sea biota of the inner regions of North America, while the North

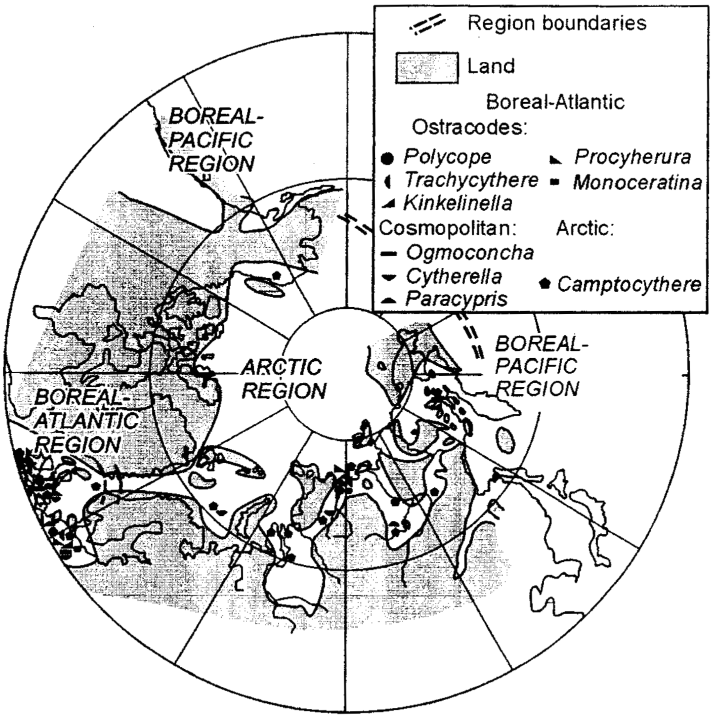

Fig. 10. Distribution of the ostracode genera in the Arctic basin at the beginning of the Toarcian (Early Jurassic).

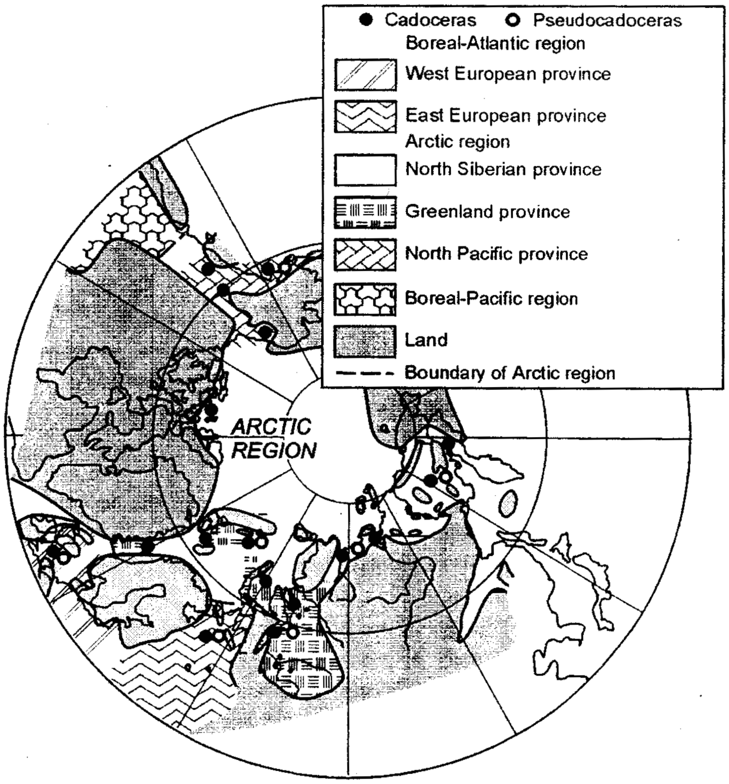

Fig. 11. Distribution of the ammonite genera *Cadoceras* (filled circles) and *Pseudocadoceras* (open circles) in the Arctic basin in the Callovian (Middle Jurassic), and paleobiogeographical zoning.

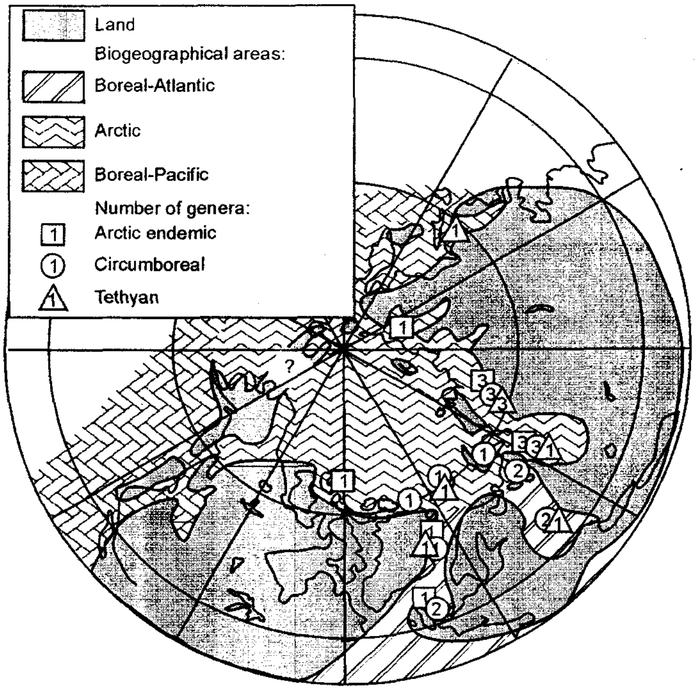

Fig. 12. Distribution of ammonites in the Arctic basin in the Late Volgian (Late Jurassic) and paleobiogeographical zoning.

Siberian biota was under the influence of the biota of the North Atlantic biogeographical province. The permanent connections with the seas of the Russian Platform and Northwestern Europe is well illustrated by *Inoceramus*, whose cosmopolitan species *Inoceramus* (*Inoceramus*) *pictus* appeared in the North Siberian seas at the end of the Cenomanian. After that different, mostly cosmopolitan, *Inoceramus* species continued to play a pivotal role in marine benthic communities until at least Early Campanian: *I. (Mytiloides) labiatus*, *I. (I.) cuvieri*, *I. (I.) lamarcki* in the Turonian; *Volviceramus subinvolutus*, *I. (Cremnoceramus) incostans*, *I. (Haenlenia) russiensis* in the Coniacian; *Sphenoceramus cardissoides*, *S. lingua*, *S. patootensis* in the Santonian; *S. patootensiformis* in the Early Campanian. Endemic North Siberian species such as *I. (I.) crassicollis*, *I. (I.) pseudocancellatus*, *I. (I.) ecostatus*, *I. (I.) schulginae*, *I. (I.) jangodaensis*, *I. (I.) sachsi* originated from the lamarckoids and existed only in the Late Turonian and Coniacian. Given that in the Late Cretaceous (except the Maastrichtian) the North Siberian seas were not directly connected with the seas to the south via the Turgai trough, the migrations were likely routed through the Northern Urals. At the same time there were no barriers for circumarctic exchange of *Inoceramus* (see Fig. 15). Distribution of at least some of their groups was controlled by water temperature. For example, despite the trans-American sea passages were open to the south (in the inner regions of North America), species of the Santonian genus *Sphenoceramus* were absent from the North Pacific province (Fig. 16) [12]. We reason that lack of findings of *Inoceramus* in the Campanian (except their base) and Maastrichtian sections supports the contraction of this group's geographical range in the seas of the Northern hemisphere following cooling in the Arctic. The connection of the North Siberian seas with the seas of the Caspian Depression via the Turgai trough is known to have had opened in the Maastrichtian, but *Inoceramus* inhabiting the Peritethys did not invade even the southernmost parts of the West Siberian basin [87]. At the same time, formation of the Maastrichtian gastropod associations of West Siberia represented by the genera *Turritelia*, *Haustator*, *Drepanochelius*, *Graphidula* involved migrants from both the inner North American seas and the Eastern Peritethys accessible via the Turgai Strait [88]. If an oceanic type basin existed in the Late Cretaceous in the place of the Canadian basin, it could not prevent the exchange of invertebrates between North Siberian and North American shallow epicontinental seas.

DISCUSSION

Since the major localities with Arctic fossils are distributed around the pole, usually north of 55° N, it seems unreasonable to search for geographical situations in the geologic past different from the current one is (Fig. 1). Although formally true, such a static model would yield the climate differentiation identical to the contemporary

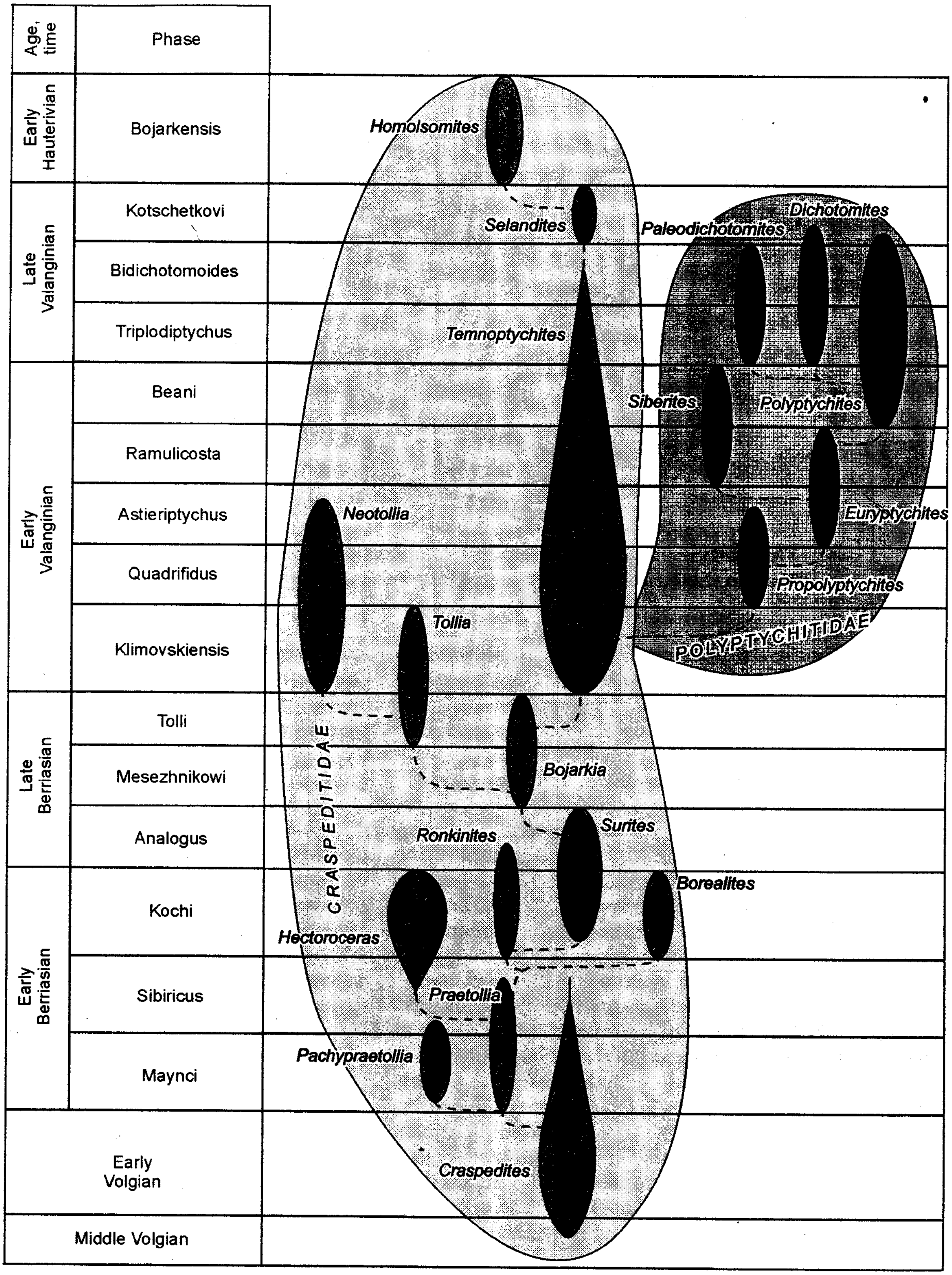

Fig. 13. Evolution of ammonites of the families Craspeditidae and Polyptichitidae in the Arctic zoogeographical region in the Late Jurassic and Early Cretaceous (Neocomian).

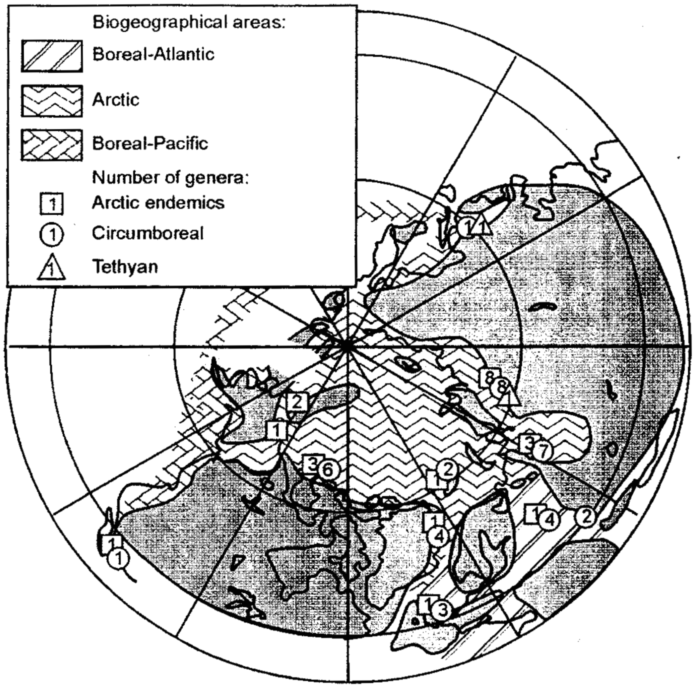

Fig. 14. Distribution of ammonites in the Arctic basin in the Early Valanginian (Early Cretaceous) and paleobiogeographical zoning.

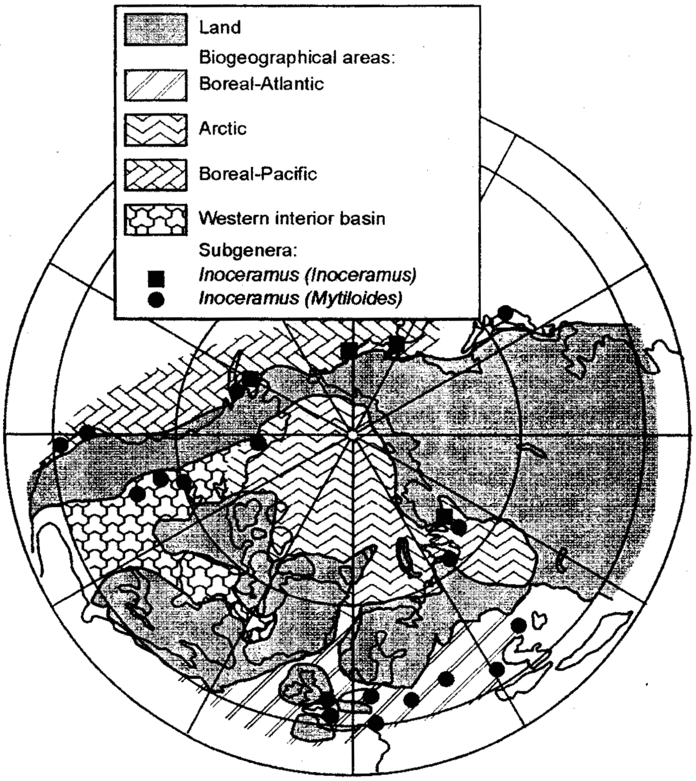

Fig. 15. Distribution of subgenera of the bivalve genus *Inoceramus* in the Arctic basin in the Turonian (Late Cretaceous) and paleobiogeographical zoning.

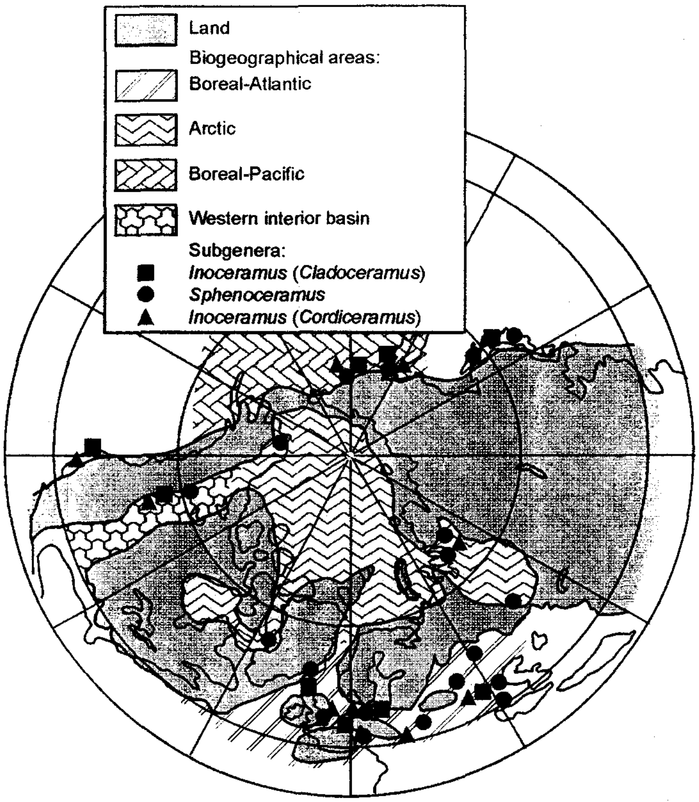

Fig. 16. Distribution of genera of the bivalve family *Inoceramidae* in the Arctic basin in the Santonian (Late Cretaceous) and paleobiogeographical zoning.

one, with polar ice caps and negative annual mean temperatures north of the Arctic circle. On the contrary, the marine and terrestrial Mesozoic biota, both faunal and floral, unequivocally indicate the stable, considerably warm (close to present-day subtropical) climate in the area of today's Arctic. This inevitably leads to the conclusion that a warm basin existed in the Arctic during the Mesozoic. Such a basin should have had parameters of an ocean — abyssal depths and large area — and thus contain a large volume of seawater to maintain normal salinity and relatively high water temperatures, the conditions necessary for the existence of a diverse marine biota on the shelf and the surrounding epicontinental seas. At the same time, the Arctic basin should have had been open and involved in the global water circulation. We tried to substantiate these points with the factual material outlined above.

The Arctic basin was a large extention of the Paleopacific, approximately triangular in shape, and stably existed as such from Devonian to Late Jurassic [89]. This picture is based on a number of palinspastic reconstructions [90, 91]. For the Triassic and the Jurassic, this oceanic gulf lying along the eastern and northern margins of Asia is called South Anyui [1, 2, 92]. Oceanic facies of the Late Triassic can be reconstructed in the present-day Koryak region and Southern Chukchi Peninsula [37]. The similarity of mollusk associations in the sections from the Northern Chukchi Peninsula and New Siberian islands to those of the Canadian province does not contradict the palinspastic reconstructions claiming that in the Triassic these territories were close to the Canadian Arctic Archipelago and northern Alaska and were separated by the South Anyui Ocean from Northeastern Asia (Fig. 17) [1].

The ocean, however, did not intrude the Lena-Yenisei trough in the Triassic, and thus did not separate Taimyr and Lena-Anabar region, as judged from the lack of significant difference between mollusk complexes from all Triassic sections of Northeastern Taimyr, Olenek basin and lower Lena. The lithofacies profile across the Lena-Anabar structure-facies zone (Fig. 18), together with paleobathymetric models based on catena analysis of benthic communities (Fig. 19), show uninterrupted sequences of shallow-sea facies that can be robustly traced from Tsvetkov Cape through Stanakh-Khocho Cape to the delta of Lena in the east [31, 93–95]. The ocean may have had extended, north of the Taimyr Peninsula, to the Svalbard island, where the warm-loving biota was similar to that of the Canadian province (Fig. 20). The permanent presence of the Tethyan ammonoid genera in the shallow seas of Alaska and Canadian Arctic Archipelago may be explained either by location of the deepwater axial part

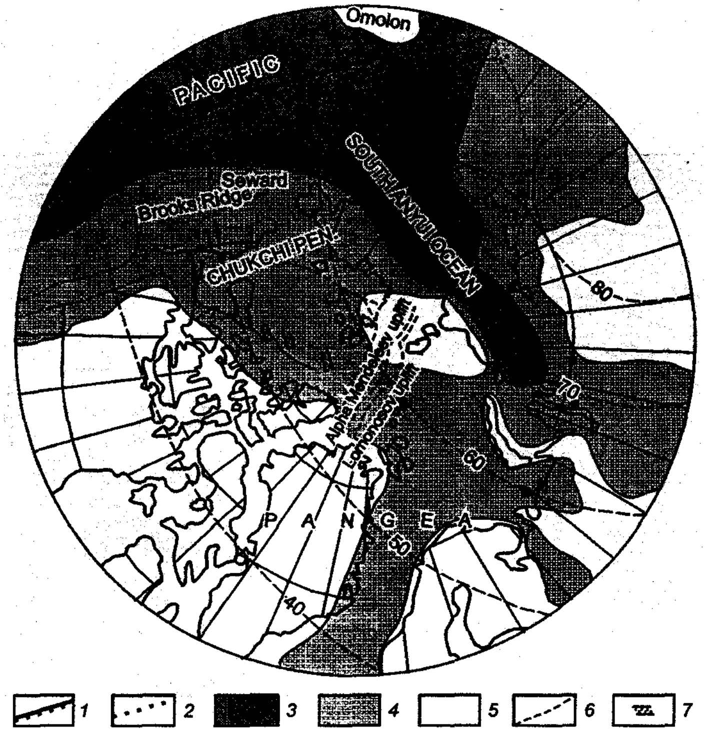

Fig. 17. Palinspastic reconstruction of the Arctic in the late Triassic (190 Ma) [1]. ***1*** **— plate convergence boundaries,** ***2*** **— manifestations of calc-alkaline volcanism,** ***3*** **— oceanic basins,** ***4*** **— shallow seas,** ***5*** **— land,** ***6*** **— contours of blocks,** ***7*** **— rifts.**

of the South Anyui paleoocean near the Alaskan coast, or by the warm current running from the south. The geographic pole must have been then situated in the ocean closer to the Asian continent (Fig. 20). This location of the pole would establish a "thermal shield" — a zone of cool water close to the North Pacific — thus maintaining moderately warm conditions in the seas of Northeastern Asia. The thermal shield did not allow mixing of tropical and boreal marine biotas while the moderately warm water conditions generated the unique Triassic biota of the Siberian paleobiogeographical province.

As shown by Zonenshain and Natapov [1], the South Anyui paleoocean somewhat contracted but still persisted in the Early Jurassic. This reconstruction agrees with details of formation and evolution of the Jurassic biota of the Arctic basin, heavily influenced by the North Pacific biota. It can be, however, convincingly stated that the ocean never intruded the Lena-Yenisei trough during the Jurassic. The well-studied fauna of Late and Middle Jurassic invertebrates at both sides of the trough (Northeastern Taimyr, Begichev Island, Yuryung-Tumus Peninsula, and Anabar Bay) is absolutely identical not only in the taxonomic composition of semipelagic and benthic groups at the species level, but also in catenas and structure of benthic communities at both sides of the paleobasin (Fig. 21) [55, 61, 64, 69, 70, 96]. Considering highly similar taxonomic composition of the Early and Middle Jurassic mollusks and microfauna (foraminifers and ostracodes) of the Northern Eurasian and North American waters, we suggest that the South Anyui paleoocean shrank significantly in its western part and its indented portion moved to the east in the late Middle Jurassic (Fig. 22). Contraction of the eastern part of ocean accelerated in the Late Jurassic because of rifting that started in the Middle Jurassic (Aalenian) in the Canadian basin [97]. In the Western Arctic, connections of the epicontinental seas with the North Atlantic seas continued to open. In the Early and Middle Jurassic such connections were sporadic, but they became permanent since the end of the Middle Jurassic [22, 41]. The influence of the North Paleopacific on the arctic biota progressively decreased during the Late Jurassic. The sharp drop in the taxonomic diversity of Northeastern Asian fauna characteristic for the Middle and Late Jurassic may be explained by contraction of the South Anyui paleoocean and moving the geographical pole closer to the Bering Strait. This double action may have led to a drastic decrease in water temperature in the "thermal shield" zone, thus significantly restricting the migration of the warm-loving fauna from the Tethys. On the contrary, the influence of the boreal and arctic biotas on the oecumenic North Paleopacific biota increased.

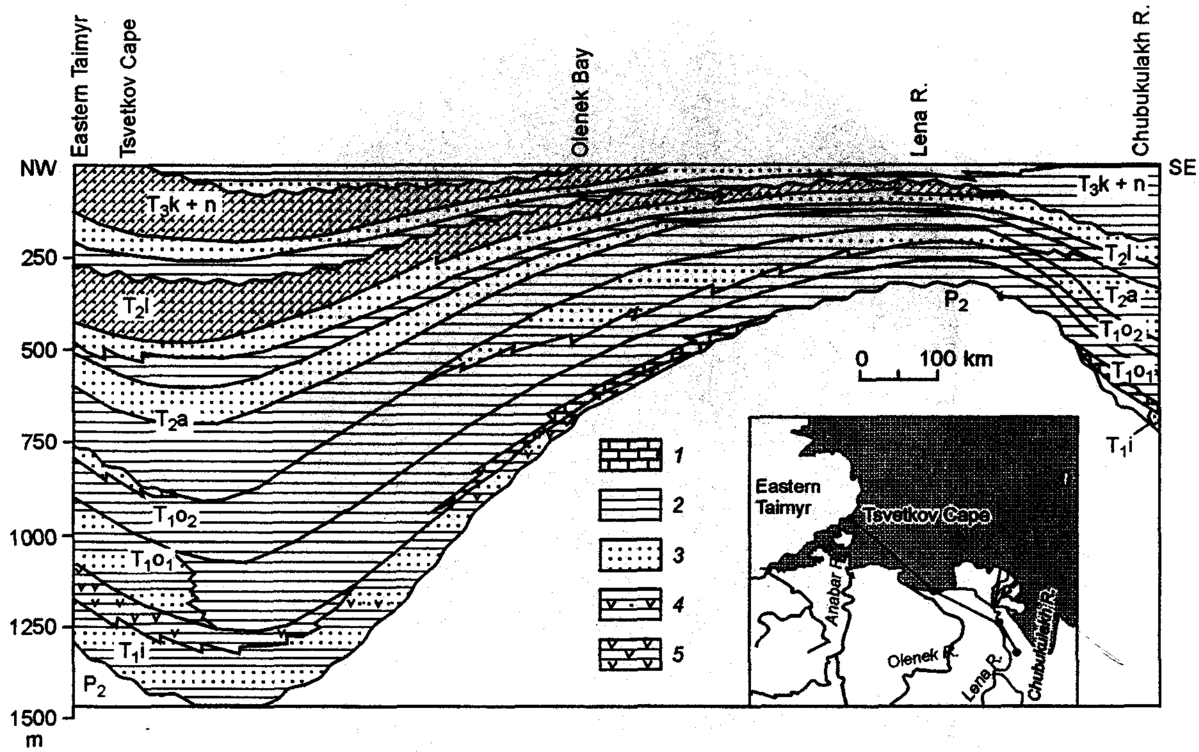

Fig. 18. Lithofacies profile of the Lena-Anabar structure-facies zone [31]. ***1*** **— limestone,** ***2*** **— mudstone-siltstone masses,** ***3*** **— predominantly sandstone masses,** ***4*** **— tuffs and tuffites,** ***5*** **— lava flows; continental rock masses are indicated by diagonal hatching.**

At the beginning of the Early Cretaceous, boreal mollusks such as *Buchia*, *Cylindoteuthis*, *Tollia*, *Neotollia* traversed the Arctic to invade the North American shore of the Paleopacific down to Northern California [12, 57]. In the late Hauterivian, the seas of the Anadyr'-Chukchi region were inhabited by the boreal genus *Simbirskites* [78]. The advance of normally boreal groups into the North Paleopacific was caused by the continuing water cooling due to steady narrowing of the straits connecting the North Pacific and the Arctic in the Berriasian, Valanginian, and Hauterivian. If the Mesozoan system of winds resembled the present-day one, a process analogous to today's upwelling along the North American shore likely existed, explaining the abundance of cold-water-loving benthos (*Buchia* and *Inoceramus*) in the Neocomian peripheral seas of the North Paleopacific.

The features of distribution and evolution of the Neocomian mollusks unequivocally suggest preserved connections of the Arctic waters with the world ocean. As mentioned above, the western epicontinental seas provided extensive connections of the Arctic basin with the North Atlantic, and the straits in the east, with the North Paleopacific. However, starting from the Early Cretaceous, an independent oceanic-type basin was established in the Arctic, named Amerasia. Modern geodynamic models treat the Canadian basin as formed during the Middle Cretaceous. Embry and Dixon [97] believe that the opening of the Amerasia basin was preceded by continental rifting that started in the Middle Jurassic (Aalenian, 175 Ma)*. Over the next 40 Ma (Middle and Late Jurassic and Early Cretaceous) the basin was opening through counterclockwise rotation of the northern Alaska and northern Chukchi Peninsula, with the pivot at the mouth of the Mackenzie River. The spreading of sea bottom began in the Hauterivian (135 Ma), lasted for 45 Ma, and ended by the Early Cenomanian (95 Ma). This model is based on analysis of structural features of Late Devonian and Early Carboniferous series of sediments, the nature of the Late Paleozoic to Jurassic sedimentary basins and their facies boundaries in the Sverdrup basin and northern Alaska [97].

Consequently, the features of arctic marine biota, starting at least in the Hauterivian, must have been determined by the oceanic body existing in the Arctic itself. The scarcity of data on the Barremian and Aptian marine biota precludes the analysis of the nature of the Arctic basin at that time. The Albian marine biota indicates preserved moderately warm normal seawater conditions in the Arctic basin and its wide connections with the seas

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* This age is also marked by rifting in the Western Arctic sector associated with the separation of a narrow strip of continental crust, now the Lomonosov Range, from the Barents Sea Plate.

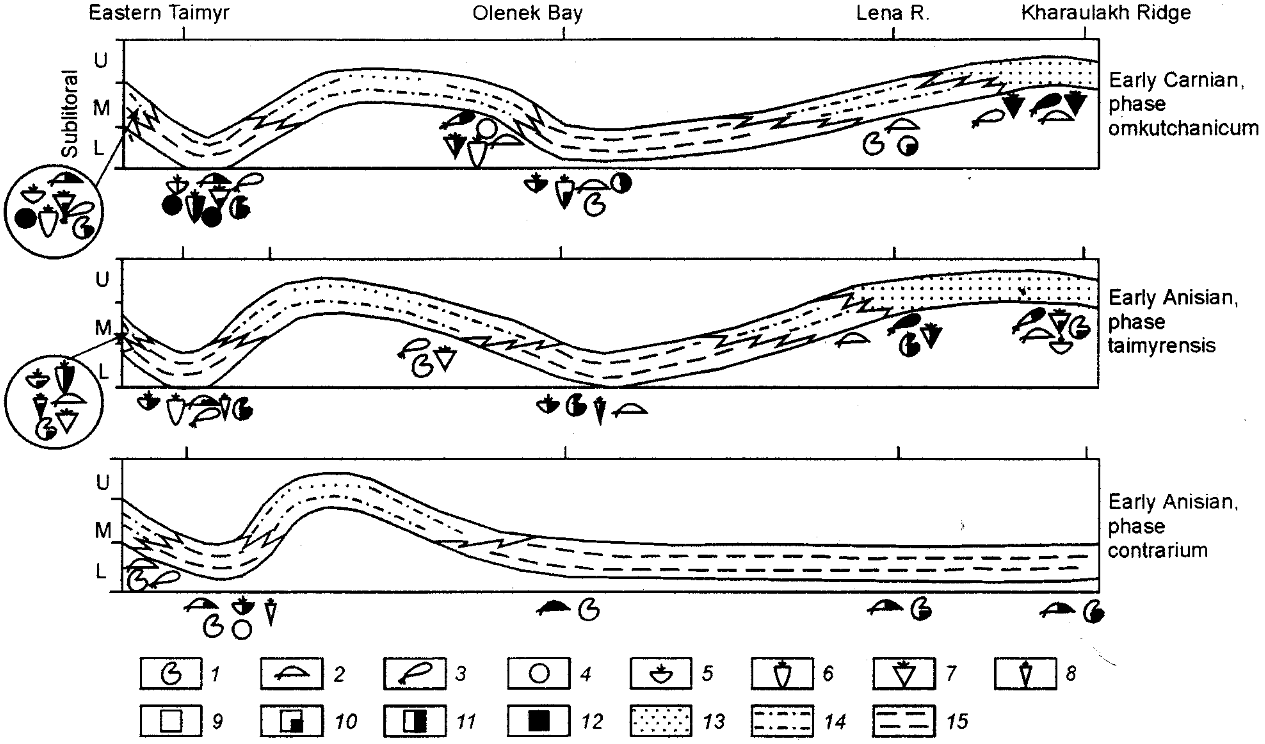

Fig. 19. Benthic catenas in the Siberian Triassic basin along Tsvetkov Cape (East Taimyr)—Stannakh-Khocho (Olenek Bay)—Taas-Ary island (Lena River) profile. ***1*** **— nectobenthic mollusks (cephalopods);** ***2*** **— sestonophages B, sedentary, soft-ground;** ***3*** **— sestonophages B, sedentary, solid-ground;** ***4*** **— sestonophages B, pelagic;** ***5*** **— detritophages B;** ***6*** **— detritophages A;** ***7*** **— sestonophages A, mobile, solid-ground;** ***8*** **— sestonophages A, mobile, soft-ground;** ***9*** **— rare (less than 5 findings);** ***10*** **— common (5–20);** ***11*** **— abundant (20–100);** ***12*** **— very abundant (over 100);** ***13*** **— sand;** ***14*** **— siltstones;** ***15*** **— clays.**

of North Atlantic and inner regions of North America [80]. The paleogeographic situation established by the beginning of the Late Cretaceous probably existed until the end of the Cretaceous, as judged from the steady evolution of the major mollusk groups and the stable structure of benthic communities of marine invertebrates. The stability of hydrologic parameters of the Arctic basin was provided by the Amerasia oceanic basin. Since the geographic pole was located within the Arctic, permanently open meridional straits, connecting it to the warm peripheral seas of the west part of North America, the Gulf of Mexico, and the seas of the European Western Peritethys (Fig. 23), were extremely important in keepng waters of the Arctic basin moderately warm. Sea connections with the Eastern Peritethys via the East Siberian Sea and Turgai Strait are definitely known only from the Maastrichtian [87].

According to the reconstructions by Zonenshain and Natapov [1], a narrow oceanic type basin (primordial Eurasia basin) existed from the late Cretaceous at the today's location of the Nansen Cordillera. However, the oceanic type crust started to form in the Eurasia basin along the Nansen Cordillera mid-oceanic ridge only in the Oligocene (55 Ma), as determined from the age of sediments first deposited onto the crust [4, 98]. Therefore, there is no direct evidence for the earlier existence of the ocean. It should be noted that the transition between the Mesozoic (Jurassic) and the Cenozoic (Paleogene) is very poorly studied because of scarcity of paleontologic data. The Arctic basin is known to contract extensively due to shelf draining at that time, causing degradation of its biota, aggravated by the global crisis at the Cretaceous-Paleogene transition.

CONCLUSIONS

The earliest evidence for existence of a boreal province come from the Visean—Serpukhovian (about 330 Ma) in Northeastern Asia [4, 99]. This province persisted around the North Pole. Its area enlarged during the Mesozoic, covering tens of millions of km^2 in the Jurassic and the Cretaceous. The boundaries of the boreal province are most robustly marked with the specific faunal and floral remains. The Mesozoic marine biota of the Paleoarctic

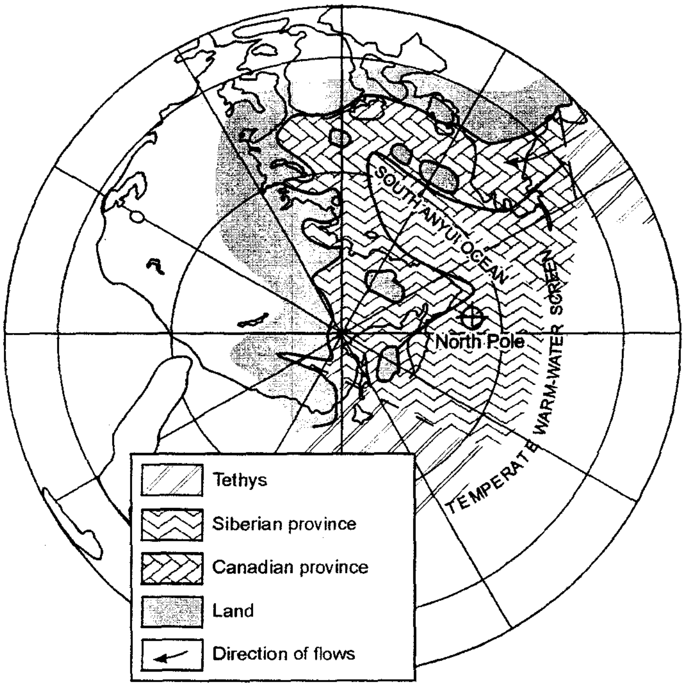

Fig. 20. Reconstruction of the South Anyui paleoocean in the Triassic based on paleobiogeographic data.

continental periphery was dominated by boreal taxa, generally inhabiting the seas north of the present-day 45° N. However, its most prominent feature was the low taxonomic diversity compared to the Tethyan provinces located in the Northern hemisphere south of the present-day 40° N.

The uniqueness of the marine boreal biota is generally believed to result from the existence of relatively cold sea waters around the North paleopole. Unique features of the boreal fauna were most pronounced in the northern waters covering the territory of today's Arctic: Arctic islands, northern Eurasia, and North America. This necessitates description of a regional biochore during most of the Jurassic and Cretaceous.

Despite significant differences between the Boreal and Tethyan marine faunas, both were connected during the Mesozoic; therefore, permanent sea passages existed supporting exchange between these faunas. Such connections are indicated by bidirectional migrations of ammonites and bivalves and by the presence of identical groups of marine invertebrates in both Arctic and peritethyan Mesozoic seas.

The arctic endemics mostly occurred at the species level, endemic genera were less frequent and even less so were endemic families, indicating lack of lasting isolation of the Arctic basin from the world ocean in the Mesozoic.

Stable long-term (over 180 Ma) existence of specific Arctic Mesozoic marine biota was supported by the oceanic-type basins that existed in the Arctic in the Triassic and the Jurassic (South Anyui) and the Cretaceous (Amerasia). In the Triassic, the ocean extended well into the Arctic, opening wide into the North Pacific in the East and reaching Svalbard in the West. The South Anyui ocean was sufficiently wide to prevent exchange of marine invertebrate faunas between the North American and Northern Asian seas. In the Jurassic, the ocean likely shortened and narrowed, impeding such exchanges no more: the differences between Canadian and Siberian communities were small. In the Cretaceous, an oceanic type basin formed in the Arctic itself, connected to the world ocean mostly through meridional straits. The oceanic basin was most likely colocalized with the Canadian Basin. The invertebrate fauna (primarily mollusks) moved unrestricted around it along both North American and Northern Asian shores. There are no faunal evidence for the existence of an oceanic basin in western Arctic in the Late Cretaceous.

The major barrier preventing migrations of the warm-loving Tethyan fauna from the south during the Triassic and Jurassic was represented by a cold water area in the northern part of the North Pacific, near the North geographical pole that was localized in today's Bering Sea. Recurrent climate fluctuations, related perhaps to eustasy, sometimes allowed individual Tethyan taxa to penetrate the "thermal shield" and invade the Arctic basin;

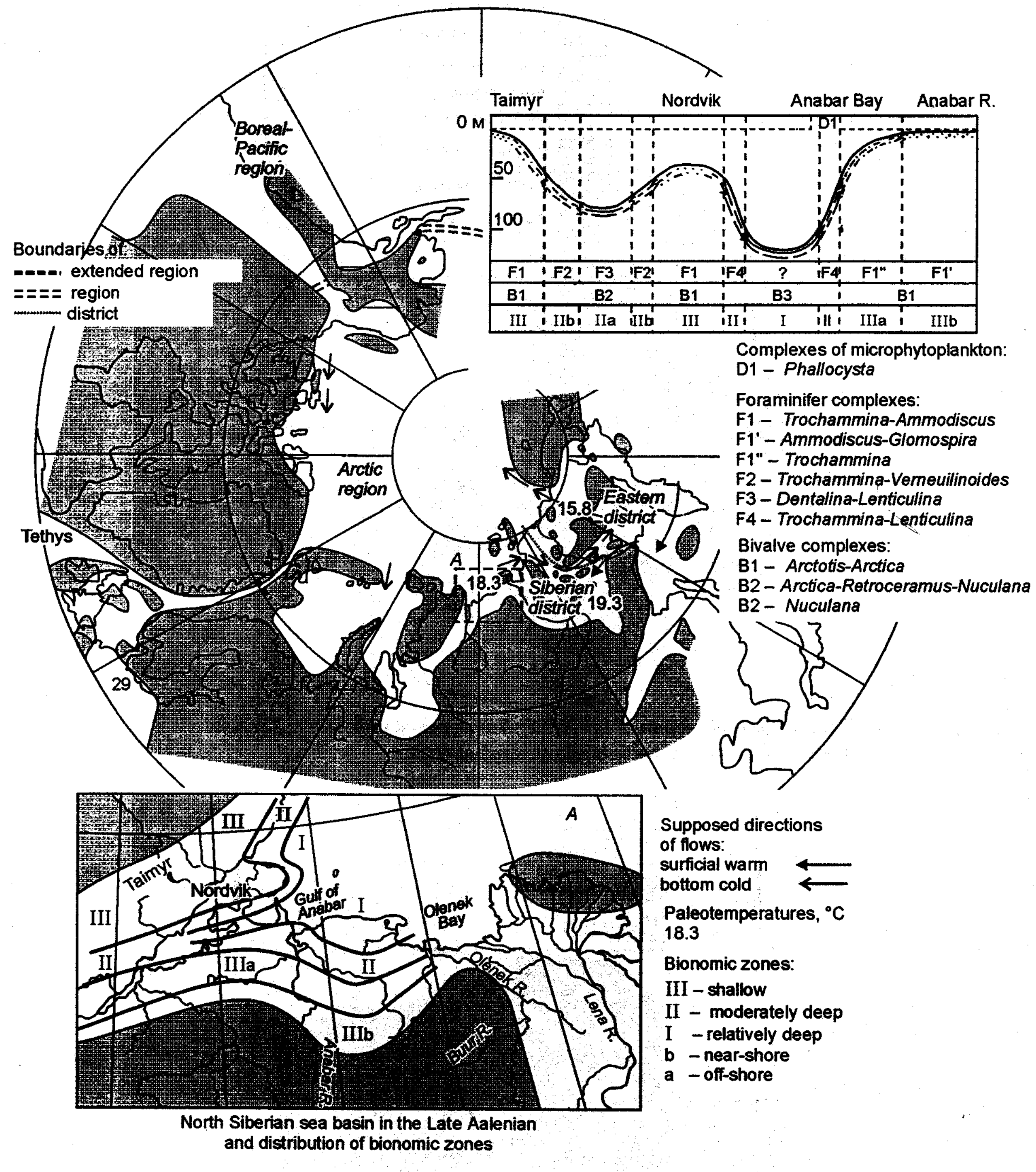

Fig. 21. Biogeography of the Arctic basin in the late Aalenian, bionomic zones and the bathymetric profile of the North Siberian paleobasin (*A* on the biogeographical map) with the distribution of associations of microphytoplankton, foraminifers and bivalves.

the same applies to invasions of the Peritethyan seas by boreal groups. Thus, the connections between the Arctic, lower Boreal and Peritethyan seas persisted over the Mesozoic. The features of biogeographic faunal distribution in the Arctic at every stage of the Mesozoic cannot be explained only from horizontal movements of sialic crust blocks; data on climate fluctuations and paleocurrents must also be considered.

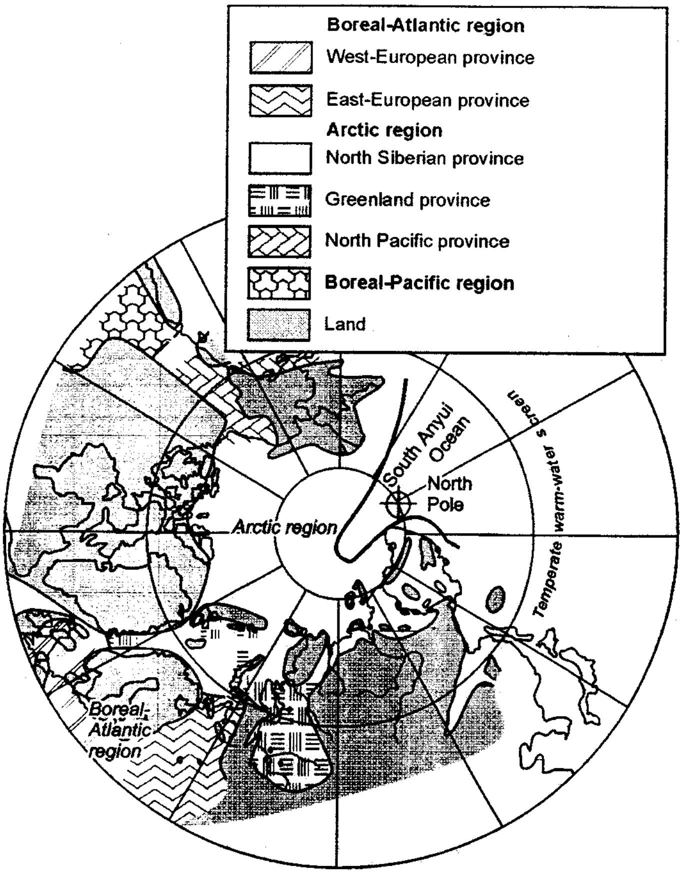

Fig. 22. Reconstruction of the South Anyui paleoocean in the Jurassic (Callovian) based on paleobiogeographical data.

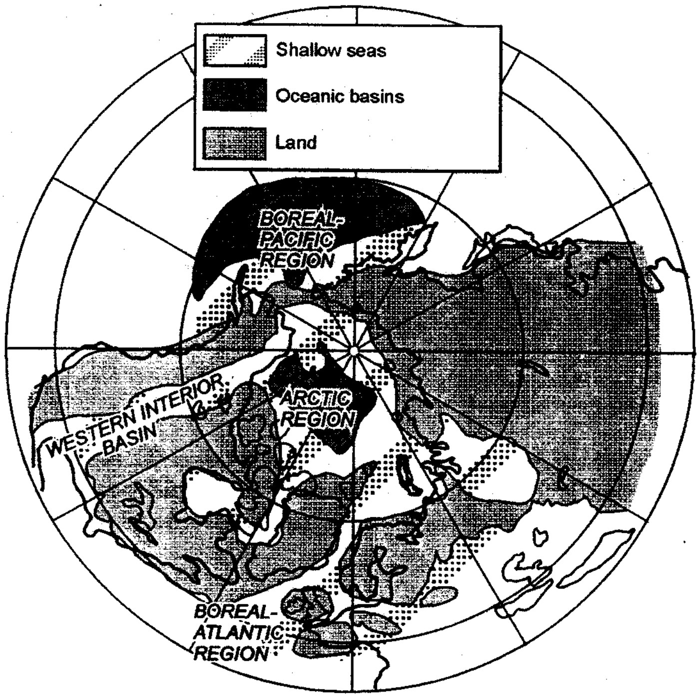

Fig. 23. Reconstruction of the Arctic basin in the late Cretaceous.

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