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# Biogeographic reconstructions for the North Pacific Oligocene shelf zones: comparison of "warm" Eocene and "cold" Oligocene

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**Abstract:** Recent investigations in Kamchatka and Sakhalin in the active transitional zone from the Pacific Ocean to the Asian Continent have led to a new generation of Cenozoic stratigraphic schemes. Several regional stages recording distinctive phases of regional development and different biotic and abiotic events have been recognized. The following regional stages were distinguished in Kamchatka: the Yuzhno-Il'pinskii (Paleocene), Kylanskii, Kilakirnunskii, Gailkhavilanskii (Eocene), and the Aluginskii (Oligocene). All of them contain planktonic and benthic foraminifers, mollusks, macroflora, and diatoms. Therefore, standard stages and zones can be outlined there. The Paleocene and Eocene zones were established by means of planktonic foraminifers, and the Oligocene zones by diatoms. In addition, provincial zones based on benthic assemblages were recognized, which can be used for regional correlations. Recently some new data on magnetostratigraphy and biomarkers became available. The regional stages were also characterized in terms of lithology with outlining sedimentary cycles. In the warm Eocene conditions, carbonate plankton, warm-water mollusks, and paratropical flora were spread over the entire North Pacific, whereas a cold-water (boreal type) biota was formed during the Oligocene and the warm-water associations migrated southward. So, the main biotic differentiation took place during Eocene to Oligocene.

**Keywords:** North Pacific, Eocene, Oligocene, biogeography, mollusks, paratropical biota, boreal biota, Kamchatka, Sakhalin, Russian Far East

## 1. Introduction

Most recent publications on Paleogene geological events mainly are centered on low latitude regions (tropical and subtropical), in which stratigraphic schemes are mostly built on the base of calcareous plankton. However vast territories of the Earth are located outside the tropical and subtropical regions, particularly in the boreal and Arctic belts. Comparative studies of the latter regions are thus needed to reconstruct evolution of the biosphere as a whole and to correlate Paleogene events of different ecosystems (Gladenkov, 2004).

Studies carried out during many years on the North Pacific Paleogene, especially on key reference sections, has made it possible to decipher the paleobiospheric processes that occurred at high latitudes with confidence. These studies involved specialists in many different fields of geology, who performed a large amount of work, including the description of several hundreds of taxa.

This vast information is described comprehensively in a large monograph entitled "The North Pacific Cenozoic ecosystems: Eocene–Oligocene of West Kamchatka and adjacent regions" (Gladenkov *et al.*, 2005). The book includes information on more than 30 key sections of Japan, Sakhalin, Kamchatka, and Alaska, descriptions of nearly 250 taxa of fauna and flora, over 60 paleogeographic and paleobiogeographic maps, as well as a climatic curve built for the North Pacific Cenozoic.

Since that book is not easy to read by non-Russian speakers, the purpose of this paper is to briefly summarize that information, focusing on distinctive regional geological events of the "warm" Eocene and "cold" Oligocene. The Eocene (especially, the Early Eocene) was the warmest period of the Cenozoic. The Oligocene represents an important stage of the biosphere evolution when the green-house climatic regime was succeeded by the glacial one.

The new data provided by the studies carried out in sections of the North Pacific and surrounding enabled a comparative analysis of the Eocene and Oligocene events more precise than was earlier possible.

## 2. Summary description of reference sections

Of more than 50 Paleogene sections studied in Japan, Sakhalin, Kamchatka, and Alaska, the two most informative are, the East Kamchatka and the West Kamchatka sections. The former is situated in the Il'pinskii

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Peninsula, in Northeastern Kamchatka and the latter in the Chemurnaut Bay – Tigil district, in Northwestern Kamchatka (Fig. 1).

The East Kamchatka reference section is about 2700 m thick, and is composed of terrigenous and volcanogenous-terrigenous sediments (Fig. 2). The section is rather unique because of continuous deposition and abundant fossils (Gladenkov *et al.*, 1988; Beniamovski *et al.*, 1992; Volobueva *et al.*, 1994).

Paleogene beds lie on Upper Cretaceous deposits: spherulitic basalt lavas with K/Ar dates of 82.5±0.5 and 83.5±0.6 Ma and tuffaceous siltstones with acid tuffs, which enclose ammonoids, such as *Gaudryceras* cf. *tenuilratum* Yabe, and benthic foraminifers, including representatives of the *Rhabdammina cylindrica* Glaessn., *Rzehakina kakiyneica* Serova.

Several suites (formations) corresponding to regional stages were established from the base upsection:

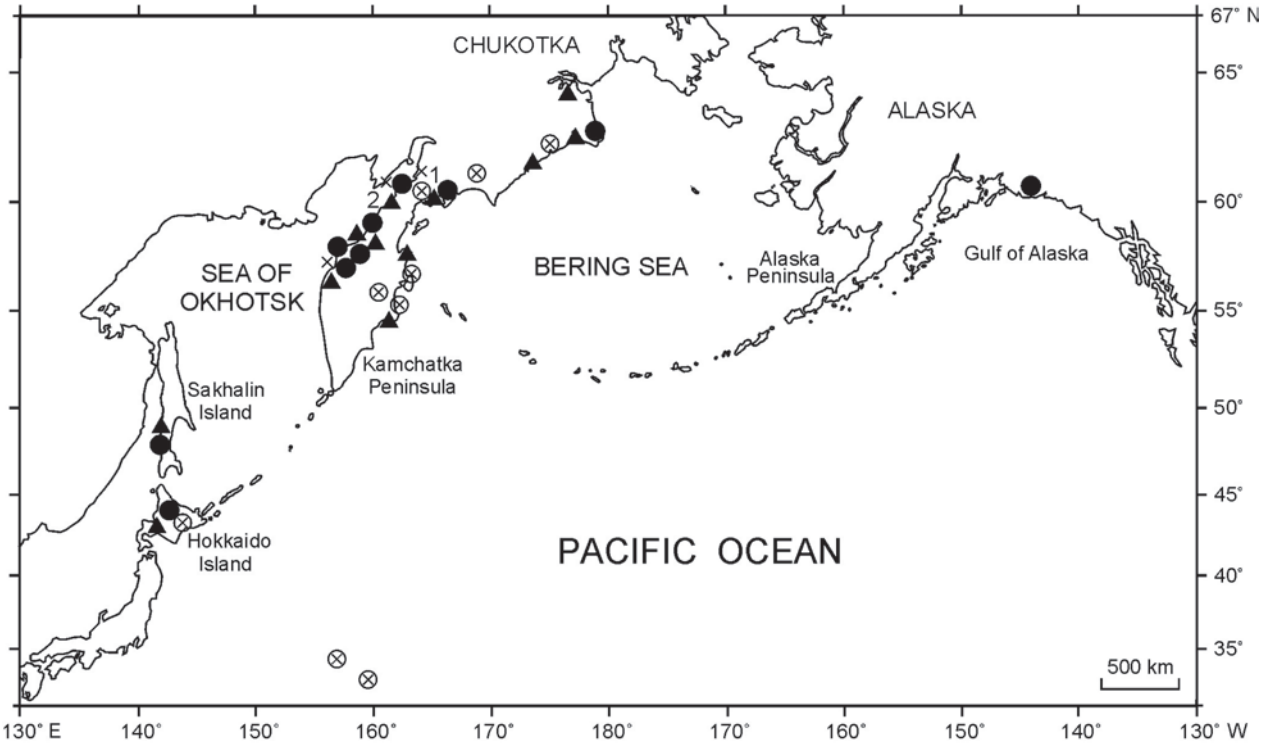
Yuzhno-Il'pinskaya suite (Danian-Thanetian) (345-370 m). It is represented by tuff conglomerates, basalts, and tuffaceous sandstones in the lower part and tuffaceous siltstones and tuffaceous sandstones in the upper part. The K/Ar age of the basalts is 57.1-58.0±2.1 Ma.

Kylanskaya suite (Thanetian-basal Lutetian) (685 m). This is a rhythmically alternating succession of tuffaceous mudstones and tuffaceous sandstones, with carbonate concretions. The Kylanskii marker "horizon" (acid lilac tuff, 10 m) is recognized in the lower part of this suite.

Kilakirnunskaya suite (Lutetian-basal Priabonian) (530 m). This suite is made up of tuffaceous sandstones and gritstones in the lower part (60-65 m) and tuffaceous mudstones with carbonate concretions in the upper part. The Kilakirnunskii marker "horizon" (conglomerates and gritstones, 20 m) is recognized in the lowermost part of this suite.

Gailkhavilanskaya suite (Priabonian) (250 m). It includes acid tuff (7.5 m) – the Gaikhavilanskii marker "horizon", with K/Ar date of about 37-38 Ma overlaying by tuffaceous siltstones and tuffaceous sandstones with concretions, mollusks, and crustaceans. The following fossil mollusks are typical of the suite: *Acesta kovatschensis* Sinelnikova, *Cyclocardia kovatschensis* (Slodkewitsch), *Variamissium pillarense ilpinense* Pronina, *Epitonium condone quimperense* Durham, Pronina *Orectospira wadana* (Yokoyama).

Aluginskaya suite (Oligocene) (900 m). It is composed of siltstones and tuffaceous sandstones in the lower part (60 m) and mostly tuffaceous siltstones with concretions. The Mulatkhanskii marker "horizon"




⊗ - calcareous plankton ( × = rare), ▲ - benthos, ● - macroflora.
1, 2 - Paleogene stratigraphic key sections in Kamchatka (1 - the Il'pinskii Peninsula, Northeastern Kamchatka, 2 - the Chemurnaut Bay-Tigil district, Northwestern Kamchatka)

Fig. 1 Localities of the most representative Paleocene - Early Eocene biotic assemblages in the Kamchatka region.

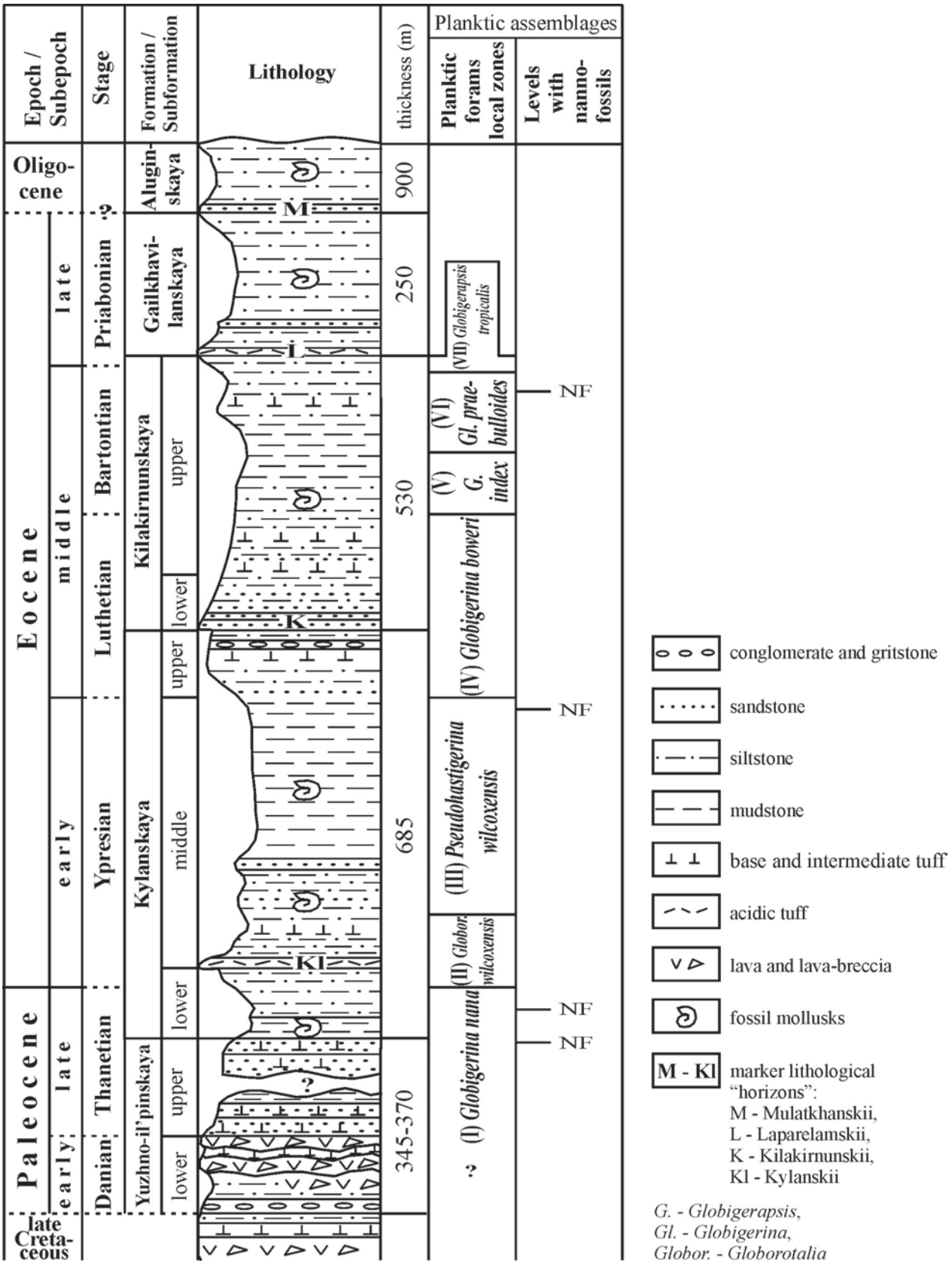



Fig. 2 Generalized stratigraphic column of the Paleogene at the Il'pinskii Peninsula stratigraphic section, western part of Il'pinskii Peninsula, Northeastern Kamchatka (after Gladenkov *et al.*, 1988; Beniamovski *et al.*, 1992; Volobueva *et al.* 1994).

(tuffaceous sandstones, 10 m) is recognized in the lower part of suite - at 120 m above a boundary with underlying Gailkhavilanskaya suite. Abundant fossil cold-water mollusks are typical of this suite (*Acila praedivaricata* Nagao et Hizioka, *Yoldia longissima* Slodkewitsch, *Portlandella watasei* (Kanehara), *Modiolus solea* Slodkewitsch, *Cyclocardia ilpinensis* Pronina, *Periploma besshoensis* (Yokoyama), *Neptunea ezoana* Takeda).

In the Paleocene and Eocene deposits seven local zones (= lones) of planktonic foraminifers were distinguished (Gladenkov *et al.*, 1988; Beniamovski *et al.*, 1992; Volobueva *et al.*, 1994; Fig. 2). From base to upward, these zones are: *Globigerina nana* (Yuzhno-Il'pinskaya suite and the lowermost part of Kylanskaya suite), *Globorotalia wilcoxensis* (the lower part Kylanskaya suite), *Pseudohastigerina wilcoxensis* (the middle part Kylanskaya suite), *Globigerina loweri* (the upper part of Kylanskaya suite to lower part of Kilakirnunskaya suite), *Globigerapsis index* (the middle part of Kilakirnunskaya suite), *Globigerina praebulloides* (the upper part of the Kilakirnunskaya suite), and *Globigerapsis tropicalis* (the uppermost part of the Kilakirnunskaya suite and possibly, the lowermost part of the Gailkhavilanskaya suite). Some Eocene levels yielded nannoplankton. Several beds contain marine mollusks. In addition, 12 zones of benthic foraminifers were established. It should be pointed out that the Eocene/Oligocene boundary is marked by change in benthic foraminifera assemblages: from *Plectofrondicularia packardi – Caucasina eocaenica* kamtschatica local zone to *Haplophragmoides laminatus – Melonis chimokiensis* local zone. Paleomagnetic characteristics of the section made it possible to outline some Paleogene orthozones (Volobueva *et al.*, 1994; Minyuk and Gladenkov, 2007).

The Oligocene deposits of the section contain no carbonate plankton but fossil diatoms appear in the lowermost part of the in the Aluginskaya suite (A. Gladenkov and Yu. Gladenkov, 2007). In particular, immediately above the Mulatkhanskii marker "horizon" diatom assemblage containing *Cavitatus* cf. *jouseanus* Williams, *Odontella sawamurae* Akiba referred to the upper part of the Early Oligocene *Rhizosolenia oligocaenica* Zone is found (A. Gladenkov and Yu. Gladenkov, 2007).

The West Kamchatka section is mainly made up of Paleogene shallow-water deposits. They lack plankton and were dated with benthic assemblages. The following regional stages were established from base upward. Paleocene: Uleveneiskii (up to 2500 m, volcanites, conglomerates, coals); Getkilninskii (1000 m, siltstones); Kamchikskii (1000 m, sandstones, conglomerates); Lower Eocene: Tkapravayamskii (1000 m, coals, sandstones, gritstones, siltstones with abundant paratropical flora). The regional stages include some beds with abundant warm-water mollusks from genera *Modiolus*, *Miltha*, *Ostrea*, *Barbatia*, *Turcicula*, etc. The Middle and Upper Eocene deposits constitute two regional stages characterized by abundant benthic fauna: Snatolskii (500-1500 m, gritstones, sandstones) and Kovachinskii (600-1500 m, sandstones, siltstones). Molluskian assemblages include typical representatives of warm-water genera *Miltha*, *Ostrea*, *Pitar*, *Trominina*. Regional Oligocene stages are Amaninsko-Gakkhinskii (up to 1000 m, siltstones, siliceous mudstones) and Utkholoksko-Viventekskii (up to 600-700 m, siliceous tuffaceous mudstones). They include some beds with relatively cold-water mollusks (*Yoldia longissima* Slodkewitsch, *Portlandella watasei* (Kanehara), *Periploma besshoensis* (Yokoyama), *Modiolus solea* Slodkewitsch) and locally diatoms (*Pyxilla prolongata* Brun, *Pseudotriceratium radiosoreticulatum* Grunow, *Stephanopyxis spinosissima* Grunow) (Gladenkov, 1997; Gladenkov *et al.*, 2005).

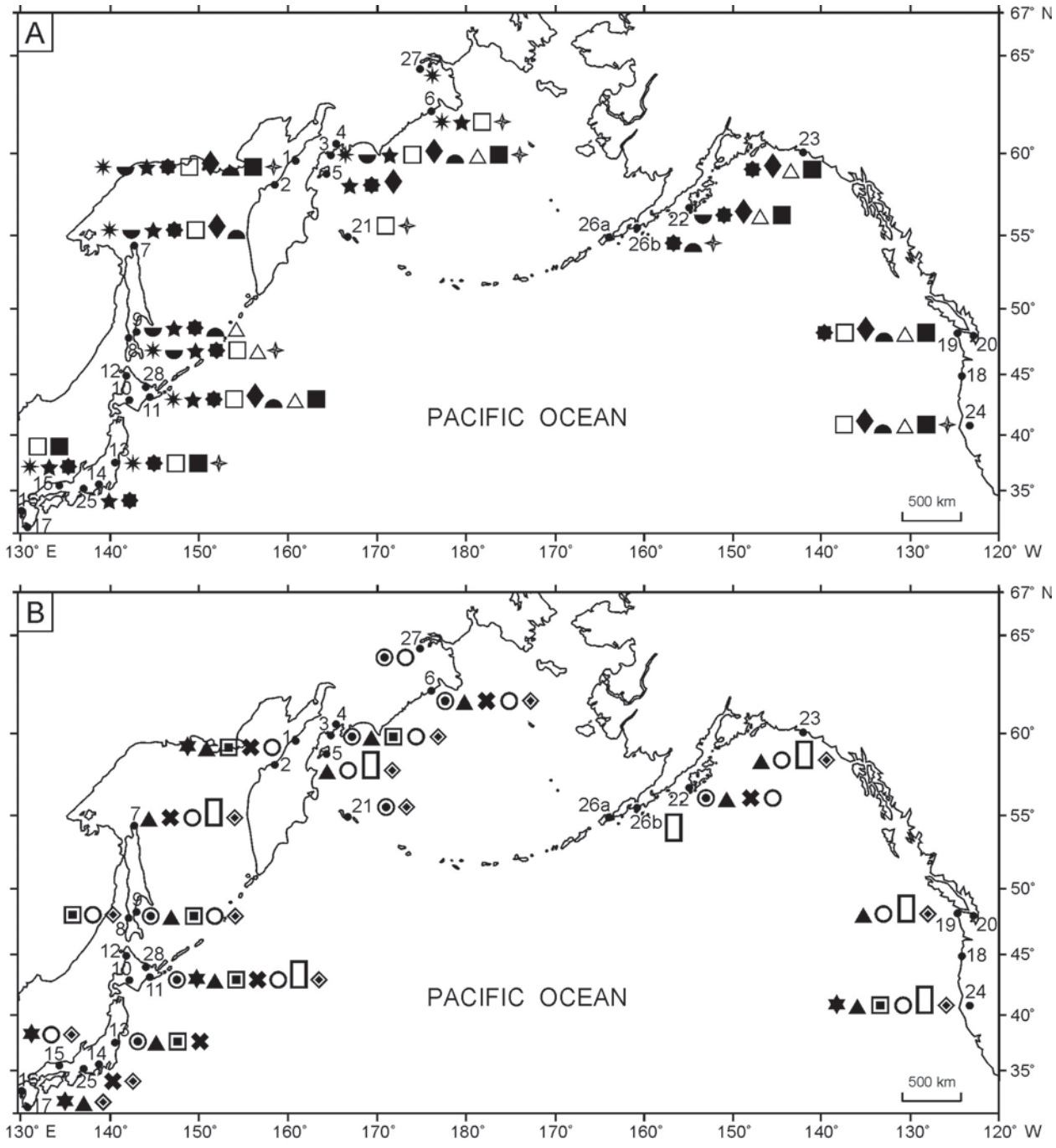
## 3. Discussion

It should be noted that in the Eocene through Oligocene the North Pacific was closed to the north because the Bering Strait was not opened at that time (according to the latest data (Gladenkov *et al.*, 2002; A. Gladenkov and Yu. Gladenkov, 2004; the Bering Strait first opened at about 5.4–5.3 Ma). This determined a different hydroregime, particularly in the formation and direction of sea currents, which "displaced" sometimes areas of distribution of shelf biota.

Comparative analysis of fossil assemblages from two Kamchatka sections described above, which were found at two intervals corresponding to the Eocene (including the Early Eocene as the warmest period of the Cenozoic) and the Oligocene (the relative cooling), revealed the following phenomena. In the Early Eocene carbonate plankton assemblages migrated from the south to the north up to northern Kamchatka and Koryak Upland (62-63° N). There also occur numerous warm-water molluscan genera (*Glycymeris*, *Miltha*, *Pitar*, *Ostrea*, *Gari*, *Barbatia*, etc.). The molluscan assemblages show a great similarity with their analogs of California. This indicates a stable connection between the Asian and North American shelf biotas. The North Kamchatka flora was represented by paratropical associations (palms, *Macginitica*, *Catalpa*, *Osmanthus*, etc.) (Fig. 1).

The Oligocene paleobiogeographic setting was quite different. The area of carbonate plankton was displaced several hundred of kilometers southward. Carbonate plankton have not been found in the Oligocene of the Kamchatka region. The paratropical flora disappeared. The molluscan assemblages changed: the first elements typical of cold-water (boreal) fauna appeared (representatives of genera *Acila*, *Yoldia*, *Macoma*, *Periploma*, *Buccinum*, *Neptunea*, etc.).

More than 50 paleobiogeographic maps were compiled for several time intervals of the Eocene and




A - warm-water molluscan genera: ✳ - *Chlamys*, ◡ - *Mya*, ★ - *Trominina*, ✹ - *Turitella*, □ - *Glycymeris*, ♦ - *Fulgoraria*, ◠ - *Crepidula*, △ - *Crenella*, ■ - *Calyptraea*, ✦ - *Ostrea*.

B - cold-water molluscan genera: ⊙ - *Neptunea*, ✸ - *Siphonalia*, ▲ - *Macoma*, ▣ - *Peronidia*, ✖ - *Buccinum*, ○ - *Periploma*, ▯ - *Nuculana* (*Nuculana*), ◈ - *Acila* (*Acila*).

1 - 28: studied stratigraphic sections

Fig. 3 Distribution of relatively warm-water (A) and cold-water (boreal) (B) molluscan genera in the North Pacific Oligocene.

Oligocene. They demonstrate areas of distribution of different species and assemblages of mollusks. They show two separate Oligocene biogeographic provinces, i.e., the North Asian (Japan-Sakhalin-Kamchatka) and North American ones with transitional zones. The provinces were displaced sometimes. Their assemblages had different dominating and characteristics species and include endemics.

At the same time, a differentiation of biotic assemblages took place within these provinces. Oligocene warm-water and relatively cold-water biotic assemblages began to separate. Warm-water assemblages migrated toward South Japan, while cold-water associations were confined to the Kamchatka and adjacent basins. This biota became the main part of boreal type fauna to be developed in the Neogene and Quaternary.

Formation of the boreal fauna was probably induced by a climatic cooling of the Oligocene. The fauna inherited a high species diversity of the former Indo-Polynesian Province.

The Oligocene cooling is indicated by occurrence of glendonites, erratic blocks and ice-rafting debris as well as a wide distribution of diatom assemblages marking representing upwelling zones.

Evidently, the cooling was not pronounced sharply in the North Pacific shelves, as evidenced by co-existence of two groups of taxa in the Oligocene molluscan assemblages: cold-water (*Acila*, *Nuculana*, *Periploma*, *Buccinum*, *Neptunea*, etc.) and sometimes warm-water (*Chlamys*, *Ostrea*, *Glycymeris*, *Turritella*, *Trominina*, *Crepidula*, *Crenella*, etc.) (Figs. 3). Both cold-water (boreal type) and warm-water genera occur all over the Bering Sea.

However, an additional comment should be made. The Paleogene relative cooling evidently began in the late Eocene rather than in the Oligocene. Evidence of seasonal cooling events (ice-rafting debris, scarce small glendonites, and others) appeared first in deposits of that age. Areas of distribution of relatively warm-water faunal and floral assemblages were gradually reduced. Virtually paratropical environments were changed into boreal ones.

## 4. Conclusions

The data from the study area, summarized in this paper, clearly demonstrate that many Paleogene global phenomena and events were recorded in the North Pacific in different way than in the tropical and subtropical regions. The regional peculiarities were mainly determined by the development of semiclosed sea ecosystems of boreal type. Reconstruction of events in other regions may improve our understanding of Paleogene evolution of the biosphere in its different blocks.

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# 北太平洋大陸棚地域の生物地理復元：暖温な始新世と冷温な漸新世の比較から

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## 要　旨

最近のカムチャッカとサハリンの地質調査研究は，太平洋の海からアジア大陸の陸域へと漸移する地域の新生界層序に新たな展開を見せてくれている．これらの地域では，多くの地域層序の「階区分」や異なる生物群や非生物のイベントが認められてきた．カムチャッカでは次のような地域的な階区分を識別している：ユージノーイルピンスキイ階（暁新世），クランスキー・キラキーヌンスキイ・ガイルクハビランスキイ階（始新世），それにアルギンスキイ階（漸新統）である．これらすべての「階」は，浮遊性と底生有孔虫，貝類，大型植物それに珪藻化石を産する．それゆえ，本論でこれらの化石に基づいて，標準的な「階」とその階を細分する「帯」についてその概要を要約する．

暁新統と始新統の「帯」は浮遊性有孔虫の化石帯を，漸新統は珪藻化石帯を用いて確立されている．加えて，底生有孔虫化石に基づいて地域的化石帯が設定され，これは地域の層序対比に用いられている．最近これのデータに，古地磁気層序とマイオマーカーの新たなものが加わった．これらの地域的層序の「階」は基本的に岩相と堆積サイクルに基づいている．暖かい始新世の環境では，炭酸塩の浮遊性生物や貝類，それに亜熱帯的な植物が北太平洋全域に広がり，一方，漸新世に寒冷型の生物が出現したが，この次期，暖水系の生物群は暖かい南方に移動した．それゆえ，主要生物の温暖と寒冷系の相違は，この始新世から漸新世にかけて北太平洋で生じたことになる．