Nannoplankton from paleogene deposits in Eastern Kamchatka

Ekaterina Shcherbinina
Russian Academy of Sciences

Stratigraphy and Geological Correlation, Vol. 5, No. 2, 1997, pp. 156–166. Translated from Stratigrafiya. Geologicheskaya Korrelyatsiya, Vol. 5, No. 2, 1997, pp. 60–70.

Nannoplankton from Paleogene Deposits in Eastern Kamchatka

E. A. Shcherbinina

Geological Institute, Russian Academy of Sciences, Pyzhevskii per. 7, Moscow, 109017 Russia

Received December 28, 1994; in final form, January 31, 1996

Abstract—A detailed study of the Paleogene terrigenous–tuffogenic beds on Kronotskii Peninsula, Govena Peninsula, and in Karaginskii Island and the Komandor Islands has revealed several levels of nannoplankton occurrences, which allowed their correlation with the standard nannoplankton zonation. Therefore, not only was the principle of applicability of the group to the stratigraphy of the region established, but also the age of some of the beds, previously considered to be barren.

Key words: *Paleogene, zonal stratigraphy, nannoplankton, shales, siltstones, tuffs, flyschoid complex.*

INTRODUCTION

In the Far East, the problem of dating beds with complicated dislocations is now rather acute. The solution is fraught with considerable difficulties. First, the sedimentary rocks of this young and tectonically active region were so substantially reworked that the discovery of not only macro- but also microfossils in an unaltered state is an extremely difficult problem. Second, the complicated tectonic structure of the region does not allow reliable space correlation of sedimentary deposits in different structural–facies zones. Third, the location of the region in high latitudes encouraged the development of many specific, often endemic forms of fossils. The determination of stratigraphic distribution of fossils and the correlation of units identified by them with the better studied low-latitude stratigraphic scales is a challenge in itself.

In this situation, the study of plankton and, in particular, nannoplankton can help solve many stratigraphic problems in the region, because nannoplankton facilitates the construction of zonal scales of high stratigraphic resolution owing to its rapid evolution over time, extensive geographic distribution, and flexible climatic confinement of zonal species.

Until quite recently, the basic role in the Paleogene subdivision of northeastern Russia was played by mollusks; their study laid the basis of the regional stratigraphy, although the drawbacks of the group are evident. Recently, an intensive study of microfossils began (planktonic and benthic foraminifers, radiolarians, diatoms), thus allowing the datings of not only endemic mollusk complexes, but also of beds lacking malacofauna remains. The study of plankton foraminifers was of particular importance, because their well-developed Paleogene zonation, unlike that of siliceous microorganisms, allows more precise datings of the enclosing rocks than were previously achieved as well as the correlation of these rocks with sediments in adjacent regions (Serova, 1966; 1969a, 1969b, 1970, 1973; Krasheninnikov *et al.*, 1988; Ben'yamovskii *et al.*, 1992; Volobueva *et al.*, 1994; and others).

Not long ago, the nannoplankton group was considered to be of little value for the Cenozoic stratigraphy of northeastern Russia. In the region, the abundant carbonate rocks that usually contain nannoplankton have experienced such strong diagenetic transformations that the nannofossils, even if they were initially in the rocks, are now completely recrystallized. Probably, this is the reason why none of the specimens of carbonate rocks studied so far have yielded positive results. The terrigenous deposits, which are typical of these sections, also underwent substantial alterations brought about by fluids, which dissolve the carbonate component of the sediments, and by silicification and tectonic effects.

A few years ago, however, in the flyschoid beds on Il'pinskii Peninsula in northeastern Kamchatka, N.G. Muzylev and D.I. Vitukhin found nannoplankton assemblages that, even though greatly impoverished, have designated three stratigraphic levels of nannoplankton occurrences (Gladenkov *et al.*, 1988). The first level corresponds to the upper Paleocene (Thanetian), the second to the lower–middle Eocene interval (Ypresian–Lutetian), the third to the upper middle Eocene (Bartonian). These occurrences are promising for the use of nannoplankton remains for the subdivision of Paleogene rocks in the Far East regions.

The presence of nannoplankton is now established in several sections in eastern Kamchatka and the Bering Sea islands, i.e., on Govena Peninsula, in Karaginskii Island, on Kronotskii Peninsula, Kamchatskii Mys Peninsula, and in Komandor Islands (Fig. 1). In these

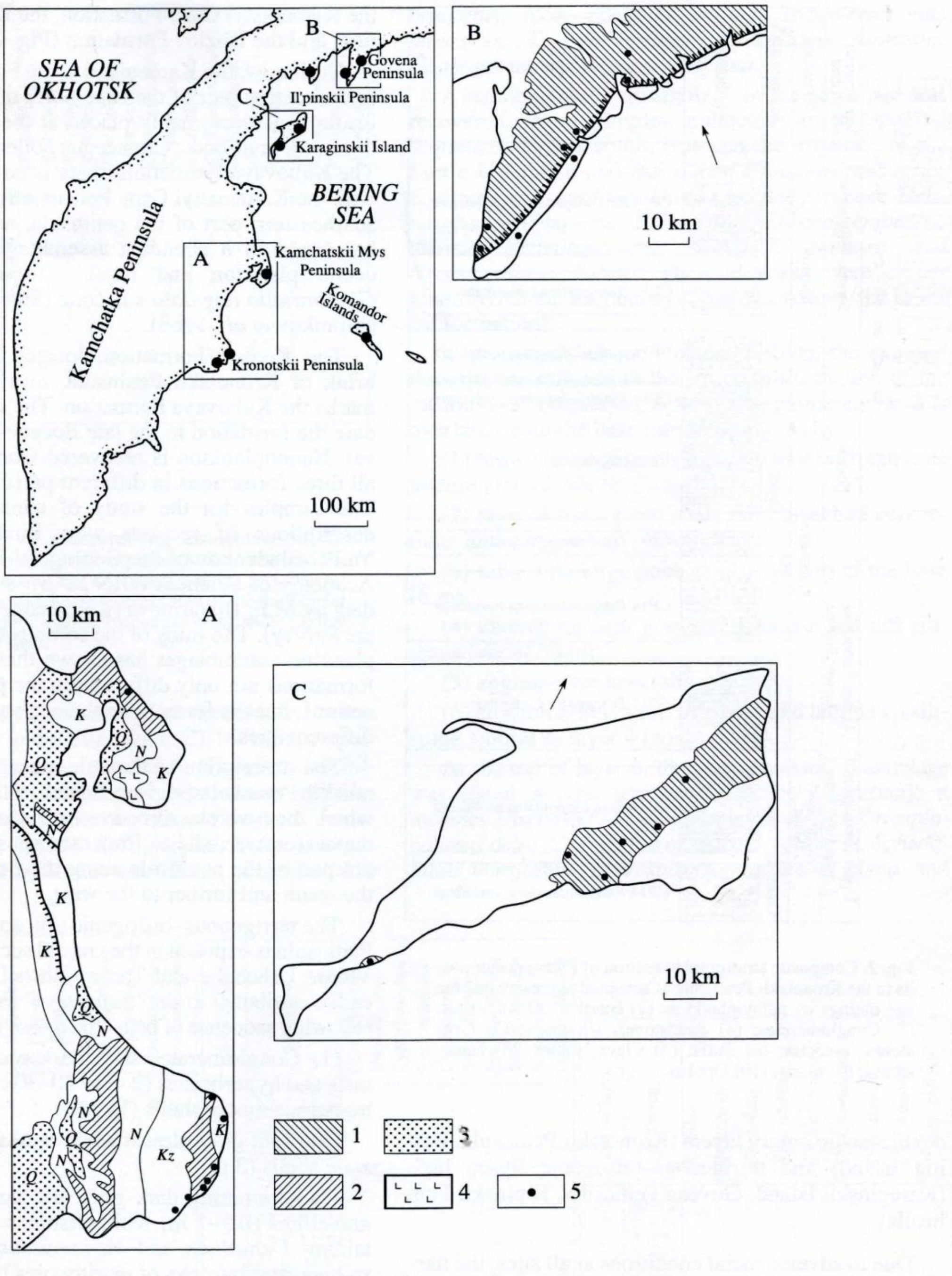

Fig. 1. Localities of the studied Paleogene sections in the Bering Sea region: (1) Flysch beds in the Govena Peninsula and Karaginskii Island; (2) Volcanic–sedimentary beds in the Kronotskii Peninsula and Kamchatskii Mys Peninsula; (3) Quaternary deposits; (4) Magmatic complexes; (5) Studied sections.

localities, the Paleogene deposits are represented mainly by thick terrigenous layers with frequent flows of effusives. Numerous tectonic dislocations, however, distort the normal bedding of the layers and considerably hamper stratigraphic studies and correlation of Paleogene deposits.

In eastern Kamchatka, the nannoplankton specimens were recovered from two types of rocks: volcan-

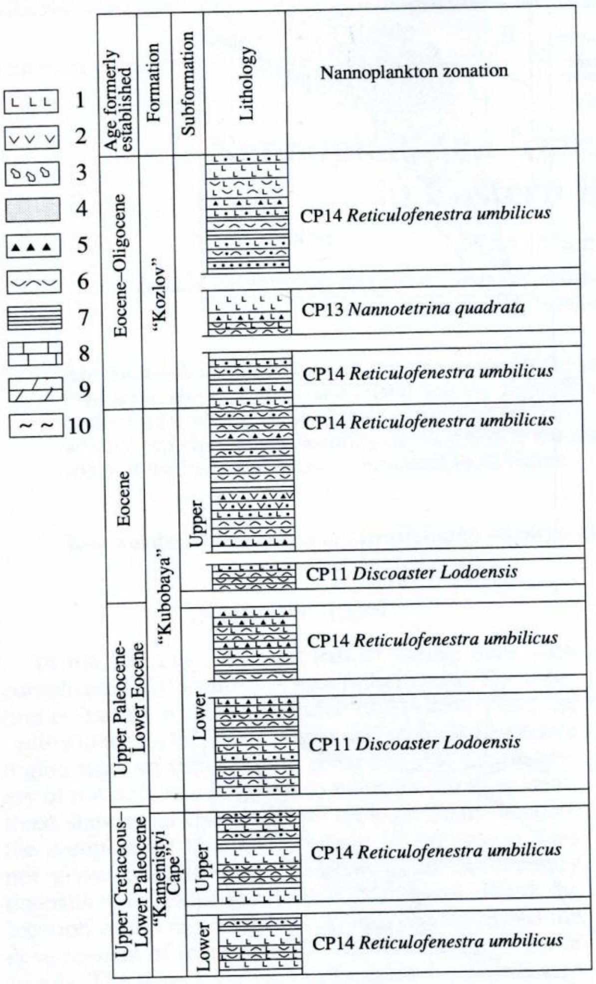

Fig. 2. Composite stratigraphic section of Paleogene deposits in the Kronotskii Peninsula as accepted at present and the age datings by nannoplankton: (1) Basalts; (2) Andesites; (3) Conglomerates; (4) Sandstones, siltstones; (5) Gritstones, breccias; (6) Tuffs; (7) Clays, shales; (8) Limestones; (9) Marls; (10) Opokas.

ogenic–sedimentary layers (Kronotskii Peninsula, Bering Island) and terrigenous–tuffogenic flysch beds (Karaginskii Island, Govena Peninsula, Il'pinskii Peninsula).

Due to adverse facial conditions at all sites, the nannoplankton assemblages are greatly impoverished and moderately or poorly preserved.

KRONOTSKII PENINSULA

The Paleogene deposits of Kronotskii Peninsula are thick volcanogenic–sedimentary rocks in which three formations were distinguished by geological survey: the Kamenistyi Cape Formation, the Kubovaya Formation, and the Kozlov Formation (Fig. 2).

Until now, the Kamenistyi Cape Formation, located in the eastern part of the cape north of Kronotskii Peninsula, was presumably placed at the base of the section, and, in its beds, Cretaceous pollen was discovered. The Kubovaya Formation (there is no apparent contact with the Kamenistyi Cape Formation) is situated in the southeastern part of the peninsula, and M.Ya. Serova has found in it abundant assemblages of early Paleocene plankton and benthic foraminifers of the *Globorotalia angulata* s.l. Zone (Serova, 1966; Krasheninnikov *et al.*, 1988).

The Kozlov Formation, located on the southern brink of Kronotskii Peninsula, overlies with erosion marks the Kubovaya Formation. The study of mollusks date the formation to the late Eocene–Oligocene interval. Nannoplankton is recovered from the deposits of all three formations in different parts of the peninsula. The samples for the study of nannofossils and the descriptions of sections were kindly provided by Yu.B. Gladenkov of the Geological Institute, Russian Academy of Sciences (GIN RAS), and the geological data by M.E. Boyarinova (Kamchatgeologiya Geological Survey). The study of the composition of the nannoplankton assemblages has shown that the age of these formations not only differs from the previous determinations, but the formations themselves include beds of different ages.

The description of the Paleogene deposits on Kronotskii Peninsula is given below in the succession, in which they were assumed to form the sequence "from the base upwards," i.e., from the exposures in the northern part of the peninsula along the Bering Sea coast to the south and further to the west.

The terrigenous–tuffogenic unit south of Kronotskii Peninsula is exposed in the coastal sections between the Vtoroe Ushchel'e and Tret'e Ushchel'e rivers and was earlier attributed to the "Kubovaya" Formation with the following sequence of beds (from base upwards) (Fig. 3).

(1) Conglomerates with dark rounded pebbles of tuffs and hyperbasites (2–3 to 20–30 cm), and also with numerous oyster shells (15 m).

(2) Light gray, almost white opokas with *Variamussium* shells (3 m).

(3) Alternating dark gray tuff sandstones and tuff gravellites (0.5–1 m) with siltstones (0.1–0.3 m) containing *Dentalium* and *Variamussium* shells, sponge spicula, and burrows of detritovores (10 m).

(4) Alternating hard light-colored opokas (0.3 m) and dark sandstones (0.3 m). Total thickness is about 20 m.

(5) Alternating hard light-colored tuff shales that form a ledge among layered softer varieties of the same rock and contain coquina detritus and bryozoan remains (about 20 m).

The nannoplankton in these deposits was discovered in the samples from layer 3 and higher. It composes a

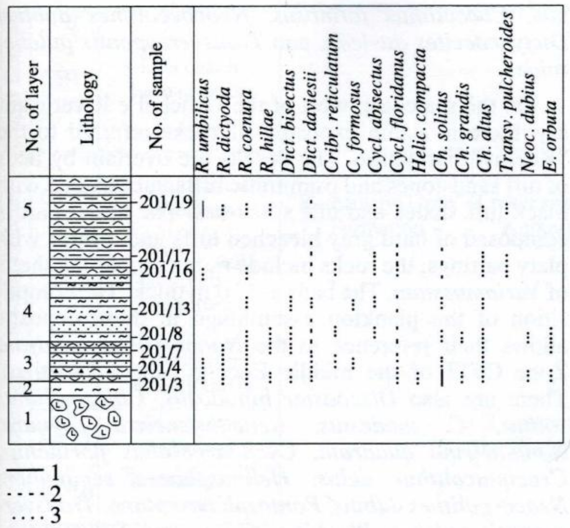

Fig. 3. Scheme of nannoplankton distribution in the "Kubovaya" Formation at the exposure located between the Vtoroe Ushchel'e and Tret'e Ushchel'e rivers (symbols as in Fig. 2): (1) few specimens in every row of the field under microscope; (2) more than 10 specimens in the slide; (3) few specimens in the slide.

rather representative assemblage of the middle Eocene *Reticulofenestra umbilicus,* Zone CP14 which, apart from the index species, includes *Reticulofenestra hillae, R. coenura, R. dutyoda, Cribrocentrum reticulatum, Dictyococcites bisectus, D. daviesii, Chiasmolithus modestus, C. solitus, C. grandis, Helicosphaera compacta, Cyclicargolithus floridanus, Zygrhablithus bijugatus, Neococcolithes dubius, Transversopontis duocavus, T. pulcheroides, Coccolithus formosus, C. pelagicus,* and *Ericsonia obruta.*

A nannoplankton assemblage of the same age was recovered from samples collected in the coastal sequences further south, between the estuaries of the Tret'e Ushchel'e and Bui rivers: *Chiasmolithus altus, C.expansus, C. solitus, Dictyococcites bisectus, Helicosphaera compacta, H.euphratis, Discoaster barbadiensis, Reticulofenestra hillae, R. coenura,* and *Neococcolithes dubius.* These deposits were earlier identified as the Kamenistyi Cape Formation (the lower subformation).

In the estuary of the Kubovaya River, the exposed deposits are referred to the lower subformation of the "Kubovaya" Formation. A flow of agglomerate lavas is overlain (from the base upwards; Fig. 4) by

(1) brown homogeneous tuff gritstone with intricate texture (10–12 m);

(2) layered hard green shale with bleached concretions in the upper part (4 m);

(3) tuffs with large pebbles (10–12 cm) at the base (6 m);

(4) alternating dark-gray tuff gritstone and tuff siltstone (about 30 m);

(5) agglomerate lava (about 8 m);

(6) an alternation of tuff gritstone and laminated siltstone similar to layer 4 (about 30 m).

At the top of layer 6, the nannoplankton assemblage was dated as the late early Eocene (Ypresian); it includes *Discoaster lodoensis, D. barbadiensis, Cruciplacolithus delus, Coccolithus crassus, C. pelagicus, Sphenolithus moriformis, Pontosphaera ocellata, P. plana,* and

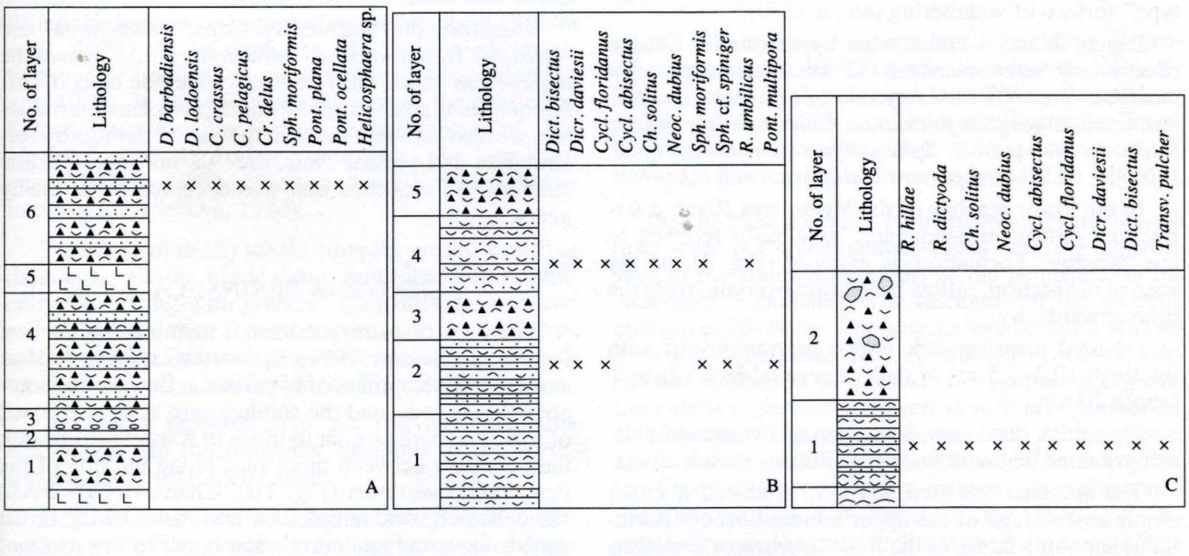

Fig. 4. Scheme of nannoplankton distribution in sections: (A) The Kubovaya River estuary; (B) The Izvilistyi Creek estuary; (C) The Vydrovaya River estuary (symbols as in Fig. 2).

Helicosphaera sp. of the *Discoaster lodoensis* Zone CP11.

South of the Baran'ya River on Cape Ostryi, deposits that were also earlier referred to the "Kubovaya" Formation contain two nannoplankton assemblages of different ages. The rock sequence in the bay north of the cape consists of alternating tuffs, tuff sandstones, tuff gritstones, and tuff siltstones containing a rather poor nannoplankton assemblage, probably of the upper part of the Eocene, bearing *Dictyococcites bisectus, Reticulofenestra umbilicus, Cyclicargolithus floridanus, Sphenolithus* cf. *spiniger, Ericsonia obruta,* and *Chiasmolithus* sp.

South of Cape Ostryi, there is a sequence of exposed green tuffs interbedded by layered bleached tuffs. The sequence contains a nannoplankton assemblage of the *Discoaster lodoensis* Zone CP11 of the upper lower Eocene (Ypresian): *Coccolithus formosus, C. gammation, Helicosphaera seminulum, Sphenolithus radians, Discoaster barbadiensis, D. lodoensis, Pontosphaera ocellata, Transversopontis pulcheroides,* and *Zygrhablithus bijugatus*. In the estuary of Izvilistyi Creek, there is an exposed terrigenous–tuffogenic sequence of the "Kubovaya" Formation (the upper subformation; Fig. 4) containing

(1) a bed of dark gray, if weathered then dark-brown, siltstone with interbeds of blue-gray, and black hard platy siltstone (more than 25 m);

(2) alternating blue-gray finely layered tuff sandstone, greenish-gray silty shale, and bleached thin-platy vitroclastic tuff (about 20 m);

(3) dark massive tuff gritstone with pumice (10–15 m);

(4) a layered reddish bed of tuff sandstone with fine interbeds of tuffite (about 20 m);

(5) massive tuff gritstone with a peculiar "pillow-type" surface of weathering (about 15 m).

Layers 2 and 4 contain the upper middle Eocene (Bartonian) nannoplankton of the *Reticulofenestra umbilicus* Zone CP14: *Dictyococcites bisectus, D. daviesii, Cyclicargolithus floridanus, Chiasmolithus solitus, Neococcolites dubius, Sphenolithus moriformis, S.* cf. *spiniger*, and *Pontosphaera multipora.*

In the lower reaches of the Vydrovaya River, a terrigenous–tuffogenic sequence, previously referred to the "Kozlov" Formation, is exposed (Fig. 4). At the base of the section, pillow basalts are overlain, from the base upwards, by

(1) hard massive dark brown psammitic tuff with interbeds (0.2–0.5 m) of dark gray and black siltstone (about 20 m);

(2) a thick dark gray, brown on the weathered side, tuff gritstone bed with lenses of siltstone (about 30 m).

The siltstone interbed, layer 1, produced a rather ample assemblage of the upper middle Eocene (Bartonian) nannoplankton, of the *Reticulofenestra umbilicus* Zone CP14: *Chiasmolithus solitus, C. grandis, Reticulofenestra hillae, R. dictyoda, Cyclicargolithus floridanus, Coccolithus formosus, Neococcolithes dubius, Dictyococcites daviesii,* and *Transversopontis pulcheroides.*

On the sea coast, west of the Ushchel'e River estuary, there is a thin exposure of rocks referred to the "Kozlov" Formation. The basalts are overlain by beds of tuff sandstones and psammitic tuffs interbedded with black tuff shales and tuff siltstones. The upper part is composed of hard gray bleached tuffs and tuffites with platy partings; the rocks include rather numerous shells of *Variamussium*. The beds are 10 m thick. The composition of the plankton assemblage in these deposits allows their reference to the *Nannotetrina quadrata* Zone CP13 of the middle Eocene (upper Lutetian). There are also *Discoaster binodosus, Chiasmolithus solitus, C. modestus, Reticulofenestra coenura, Nannotetrina quadrata, Cyclicargolithus floridanus, Cruciplacolithus delus, Helicosphaera seminulum, Neococcolithes dubius, Pontosphaera plana, Transversopontis pulcher, Blackites creber,* and *Sphenolithus moriformis.*

Consequently, the stratigraphic correlation between the Kamenistyi Cape, Kubovaya and Kozlov formations assumed earlier is, apparently, incorrect. The oldest rocks of the studied deposits compose the lower part of the "lower subformation of the Kubovaya Formation" (the upper Ypresian, *Discoaster lodoensis* Zone CP11). The age analogues are, obviously, the "Kamenistyi Cape Formation," the upper part of the "lower subformation of the Kubovaya Formation," and its "upper subformation," and the lower part of the "Kozlov Formation" (Fig. 5). These units correspond in age to the Bartonian (*Reticulofenestra umbilicus* Zone CP14). In the upper part of the "Kozlov Formation," a nannoplankton assemblage of the Lutetian is identified (*Nannotetrina quadrata* Zone CP13).

Therefore, the "Kamenistyi Cape," "Kubovaya" and "Kozlov" formations, as indicated earlier, cannot be regarded as valid. They obviously include beds of different ages if apart from the nannoplankton determination we also take into account the earlier datings by foraminifers and pollen. Thus, they do not represent the stratigraphic sequence that was accepted for so many years.

GOVENA PENINSULA

There are two structural zones identified on Govena Peninsula (Chamov, 1991): the northwestern zone of an extensive development of hyperbasite flows in monotonous flysch beds, and the southeastern zone composed of flyschoid beds similar to those in Karaginskii Island; the boundary between them runs along the line of the Primorskii overthrust (Fig. 1B). Chamov (GIN RAS) has collected rock samples on both sides of the thrust zone to infer the age correlation between the rocks of these structures. The presence of nannoplankton is established in both blocks.

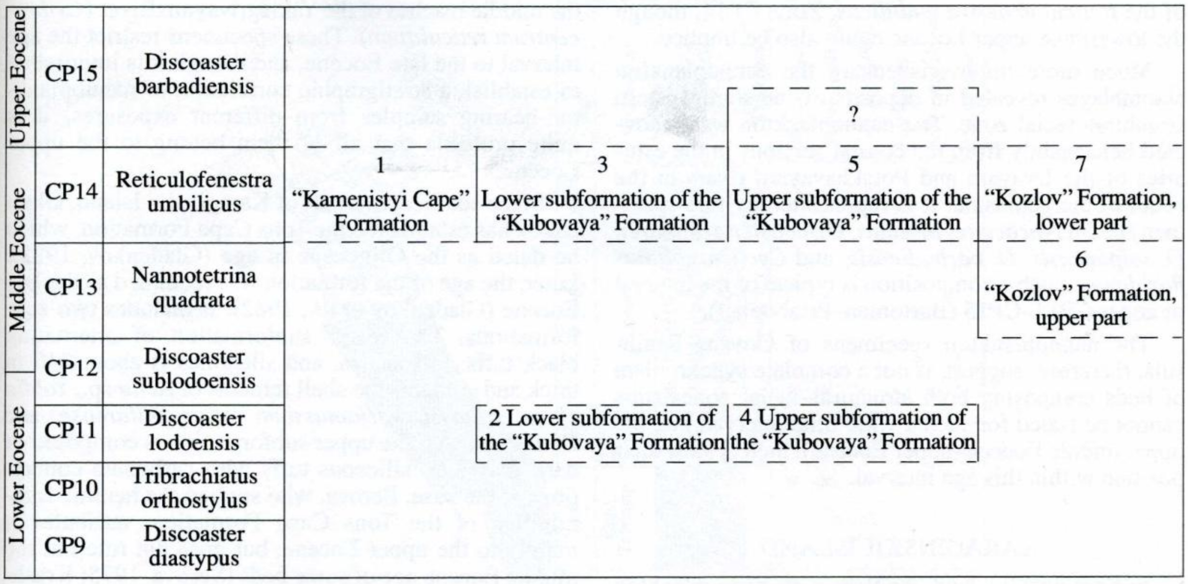

Fig. 5. Stratigraphic correlation of sedimentary formations of the Kronotskii Peninsula based on nannoplankton data: (1) exposure between the Tret'e Ushchel'e and Bui rivers estuaries; (2) the Kubovaya River estuary; (3) exposure between the Vtoroe Ushchel'e and Tret'e Ushchel'e rivers; (4) exposure south of the Cape Ostryi; (5) exposures south of the Baran'ya River and at Izvilistyi Creek estuary; (6) exposure west of the Ushchel'e River; (7) exposure at the Vydrovaya River estuary.

The Paleogene nannoplankton in the northwestern structural–facial zone was discovered in the volcanogenic–sedimentary bed of the flyschoid complex. The macrofauna in these deposits is extremely rare and characteristic of the wide Paleocene–Eocene age interval (Gladenkov, 1972). The plankton foraminifers, recovered from different parts of the peninsula, were identified by Serova. In the northern part of Govena Peninsula (the Pylgovayam River basin), she established the Paleocene foraminiferal assemblage (Serova *et al.*, 1973). At the same site, M.I. Polishchuk identified the late Eocene foraminifers (Kravchenko-Berezhnoi, 1989). In the southwestern part of the peninsula, Serova discovered the foraminifer assemblage of *Globigerina nana–Acarinina primitiva* of the late Paleocene (Serova, 1969a, 1969b) and, presumably, Eocene foraminifers (Serova, 1970).

The rocks of the flyschoid complex are composed of dark gray, almost black shales and siltstones rythmically alternating with greenish-gray tuffs, tuffites, and tuff siltstones; they form a sequence several hundred meters thick. This rock sequence includes numerous basalt flows and is referred to the Il'pinskii Formation.

The most representative are the nannoplankton assemblages in the following localities of the northwestern structural–facial zone:

(1) The Ustavayam River basin, Porog Creek, northeastern part of the peninsula. Nannoplankton is discovered only in one shale sample located 80 m above the lower lava flow. The assemblage includes *Dictyococcites bisectus, Coccolithus formosus, C. pelagicus, Cyclicargolithus floridanus, Reticulofenestra umbilicus, R. coenura, Sphenolithus moriformis*, and *Discoaster deflandrei*. This nannoplankton is composed of species of a rather wide stratigraphic range, which indicate the age of the host rocks in the interval from Bartonian (*Reticulofenestra umbilicus* Zone CP14) to the lower Oligocene (*Heliocosphaera reticulata* Zone CP16.)

(2) A very poor assemblage, including *Reticulofenestra umbilicus, Dictyococcites bisectus, Coccolithus formosus, C. pelagicus*, and *Sphenolithus moriformis* of the same age interval (Bartonian–lower Oligocene), is recovered from the exposure near the Euvayam glacier, 140 m from the base of the section.

(3) The most abundant nannoplankton remains were discovered in the sedimentary rocks covering hyperbasites in the southwestern part of the peninsula, in the Atavropel' Mountains. The thickness of the bedrock outcrop is 70–80 m. The assemblage contains species *Reticulofenestra umbilicus, R. hillae, R. coenura, Discoaster nodifer, D. deflandrei, Coccolithus pelagicus, Coccolithus formosus, Cyclicargolithus floridanus, C. abisectus, Dictyococcites bisectus, D. scrippsae, Sphenolithus radians, S. moriformis, Helicosphaera* sp., *Chiasmolithus* sp., and numerous indefinable small reticulofenestrids and forms of the *Dictyococcites* genus. Despite the relative diversity of the assemblage, only *Sphenolithus radians* indicates that the age of deposits is, apparently, restricted to the lower interval

of the *Reticulofenestra umbilicus*, Zone CP14, though the lowermost upper Eocene could also be implied.

Much more impoverished are the nannoplankton assemblages revealed in deposits of the southwestern structural–facial zone. The nannoplankton was recovered here mainly from the coastal sections in the estuaries of the Irvayam and Potakhavayam rivers in the south of the peninsula. It is represented by rare specimens of *Dictyococcites bisectus, Discoaster deflandrei, D. saipanensis, D. barbadiensis,* and *Cyclicargolithus floridanus.* Such a composition is typical of the interval of zones CP14–CP15 (Bartonian–Priabonian).

The nannoplankton specimens of Govena Peninsula, therefore, suggest, if not a complete synchronism of beds composing both structural–facial zones (this cannot be stated for such a wide time interval, i.e., the upper middle Eocene–upper Eocene), then at least their position within this age interval.

KARAGINSKII ISLAND

In Karaginskii Island, the Paleogene nannoplankton was discovered in two beds of different facies, i.e., in the flyschoid deposits overlying basalts in the central part of the island (similar to the deposits described on the Govena Peninsula), and in the Tons Cape Formation at its southwestern tip (Fig. 1e).

The flysch deposits in Karaginskii Island are represented by alternating sandstones and silty shales with admixtures of tuff material and lava flows at the base. The samples for nannoplankton studies were collected by Chamov (GIN RAS).

The most diverse nannoplankton assemblage was recovered in the lower reaches of the Kulutuvayam River from the flyschoid member of alternating siltstones and shales (the latter prevailing), which enclose pillow-basalt interbeds. The total thickness of the member is about 100 m and the assemblage includes *Reticulofenestra umbilicus, R. hillae, R. coenura, Dictyococcites bisectus, D. scrippsae, D. daviesii, Sphenolithus moriformis, Cyclicargolithus floridanus, Discoaster deflandrei, Coccolithus formosus, C. pelagicus,* and *Isthmolithus recurvus*. The assemblage with this composition dates the enclosing rocks as corresponding to the upper Eocene–lower Oligocene or the *Discoaster barbadiensis* (CP15)–*Helicosphaera reticulata* (CP16) interval.

A less diverse assemblage of the same Eocene–Oligocene boundary interval is established in the sandy siltstone beds exposed in the middle and upper reaches of the Yaklegrivayam River and on the northwestern slope of the Pai Mountain. It consists of *Dictyococcites bisectus, D.* cf. *daviesii, Reticulofenestra umbilicus, R. coenura, R.* cf. *oamaruensis, Discoaster deflandrei,* and *Cyclicargolithus floridanus*.

The accessory elements of the nannoplankton appear only in the samples from the upper reaches of the Kakukvayam River (*Discoaster saipanensis*) and the middle reaches of the Yaklegrivayam River (*Cribrocentrum reticulatum*). These specimens restrict the age interval to the late Eocene, and though it is impossible to establish a stratigraphic correlation of nannoplankton-bearing samples from different exposures, it is quite probable that all of them belong to the upper Eocene.

In the southeastern part of Karaginskii Island, Gladenkov has established the Tons Cape Formation, which he dated as the Oligocene in age (Gladenkov, 1972). Later, the age of the formation was redefined as the late Eocene (Gladenkov *et al.*, 1982). It includes two subformations. The lower subformation of alternating black tuffs, tuff shales, and siltstones is about 240 m thick and contains the shell remains of *Acila* sp., *Yoldia* ex gr. *watasei, Variamussium* ex gr. *pillarense,* and *Dentalium* sp.. The upper subformation is composed of dark gray hard siliceous tuffs with carbonate concretions at the base. Serova, who studied the benthic foraminifers of the Tons Cape Formation, attributes it mainly to the upper Eocene, but does not rule out the middle Eocene age of some beds (Serova, 1975; Krasheninnikov *et al.*, 1988).

The samples of the Tons Cape Formation deposits, presented by D.V. Kovalenko (Institute of the Lithosphere, RAS) for nannoplankton studies, were collected from the upper part of the lower subformation near the Okno Cape. The nannofossils include here *Dictyococcites bisectus, D. daviesii, Reticulofenestra umbilicus, R. hillae, Cyclicargolithus floridanus, Discoaster deflandrei, Braarudosphaera bigelowi, Coccolithus formosus, Chiasmolithus solitus,* and *Sphenolithus moriformis,* thus indicating the upper middle Eocene (Bartonian) age of the rocks, the *Reticulofenestra umbilicus* Zone CP14.

KOMANDOR ISLANDS

There are now two adopted stratigraphic scales of Paleogene deposits in the Komandor Islands (Zhegalov, 1964; Shmidt, 1978) with different ranges of the identified formations and obscure spatial and age correlations. In this paper, I am using Zhegalov's scale and the geological data of Tsvetkov *et al.* (1990). According to their evidence, three formations are identified in the Paleogene section of Bering Island (Fig. 6). At the base of the section, there is the terrigenous Tolstogo Cape Formation with Eocene mollusks (Gladenkov, 1984). The overlying Buyanova Formation is composed of tuffs and conglomerates. The two-member Kamenka Formation in the upper part of the section includes a lower unit of alternating opokas, tuff sandstones, siltstones and shales, whereas the upper one consists of diatomites and tuff diatomites. An assemblage of Oligocene diatoms is established in the upper part of the Kamenka Formation (Gladenkov and Shcherbinina, 1991). From the Nikol'skoe Formation partly correlative with the Kamenka Formation, Serova has recovered the upper Eocene–lower Oligocene foraminifers and L.M. Dolmatova identified diatoms of the

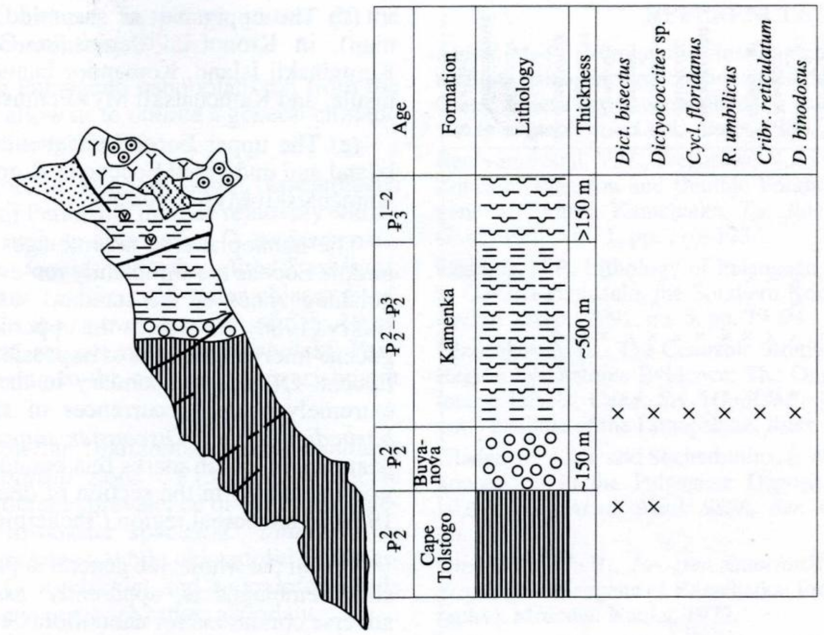

Fig. 6. Levels of nannoplankton occurrences in Paleogene deposits of Bering Island (symbols as in Fig. 2).

lower Miocene and, probably, Oligocene (Shmidt *et al.*, 1973).

Nannoplankton was also discovered in the samples collected from the Kamenka Formation by Gladenkov and from the Tolstogo Cape Formation and Mednyi Island by V.I. Grechin (GIN RAS). The Kamenka Formation yielded nannoplankton only from the base; its assemblage is impoverished and contains single specimens of *Coccolithus pelagicus, Dictyococcites bisectus, Cyclicargolithus floridanus, Reticulofenestra umbilicus, Discoaster binodosus, Cribrocentrum reticulatum,* small reticulofenestrids and species of *Dictyococcites* genus. This assemblage is typical of the upper middle Eocene (Bartonian) and, probably, the lower upper Eocene (Priabonian), i.e., of the interval of the *Reticulofenestra umbilicus* CP14–*Discoaster barbadiensis* CP15 zones.

At the top of the Tolstogo Cape Formation, single finds are represented by *Coccolithus pelagicus, Dictyococcites bisectus,* and small indefinable forms of *Dictyococcites.* The representatives of this genus are known from the Bartonian *Reticulofenestra umbilicus* Zone CP14 and suggest the upper part of the Tolstogo Cape Formation to be no older than the late middle Eocene. Consequently, the overlying deposits of the Kamenka Formation either belong to the top of the designated age interval or are coeval with the Tolstogo Cape Formation. The latter assumption agrees with M.N. Shapiro's viewpoint that the former is thrust over the latter. At present, the data on nannoplankton are insufficient for an unambiguous solution to the problem of the stratigraphic relation between these formations.

The preliminary results of study also showed the presence of nannoplankton in the deposits of the Tolstogo Cape Formation in Mednyi Island. A rather poor assemblage was recovered, containing *Dictyococcites bisectus, Reticulofenestra umbilicus, Cyclicargolithus floridanus, Sphenolithus moriformis, Discoaster nodifer,* and *Helicosphaera* sp. of the same age interval (Bartonian–Priabonian).

KAMCHATSKII MYS PENINSULA

The geological survey revealed three formations in the Paleogene deposits of the Kamchatskii Peninsula Cape: the Vereshchagin (lower Paleocene), the Rifovyi Cape (upper Paleocene), and the Baklan (Eocene). Oleinikov (GIN RAS) recovered nannoplankton specimens from the top of the Rifovyi Cape Formation and from the Baklan Formation north of the Soldatskii Bay (Cape Nos). In the Rifovyi Formation, nannoplankton was not detected.

The Baklan Formation is composed of shallow-water rudaceous terrigenic deposits with an admixture of volcanogenic material (Fig. 7). The lower Baklan subformation is represented by tuff conglomerates, psammitic and silty tuffs, siltstones, marls, limestones, and diatomites. These deposits contain Eocene mollusks (Gladenkov, 1972). The upper Baklan subformation includes tuff conglomerates, tuff gritstones, siltstones, andesites, and tuffites with mollusks *Variamussium* ex gr. *kamchaticum.*

The deposits in the lower part of the lower Baklan subformation contain extremely rare nannoplankton

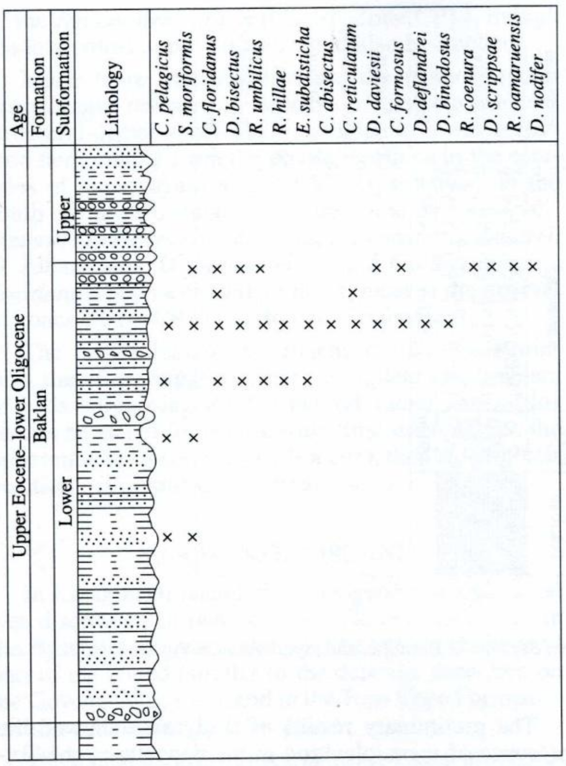

Fig. 7. Scheme of nannoplankton distribution in the Baklan Formation of the Kamchatskii Mys Peninsula (symbols as in Fig. 2).

fossils, mainly single specimens of *Coccolithus pelagicus* and *Sphenolithus moriformis.*

A more ample nannoplankton assemblage was found at the top of the lower Baklan Formation: *Cyclicargolithus floridanus, Coccolithus formosus, C. pelagicus, Discoaster deflandrei, D. nodifer, Dictyococcites bisectus, D. daviesii, D. scrippsae, Reticulofenestra umbilicus,* and *R. coenura.* This assemblage suggests a rather wide stratigraphic range for the upper part of the lower Baklan subformation, i.e., from the top of the middle Eocene (Bartonian) to the base of the Oligocene (zones *Reticulofenestra umbilicus* CP14–*Helicosphaera reticulata* CP16).

CONCLUSION

(1) The study of the Paleogene deposits in Eastern Kamchatka region revealed five nannoplankton assemblages from the following age intervals:

(a) The upper Paleocene (Thanetian), determined by Muzylev and Vitukhin in the Il'pinskii Peninsula;

(b) The upper part of the lower Eocene (upper Ypresian) in the Kronotskii Peninsula;

(c) The lower part of the middle Eocene (Lutetian) in the Kronotskii and Il'pinskii peninsulas;

(d) The upper part of the middle Eocene (Bartonian), in Kronotskii Peninsula, Govena Peninsula, Karaginskii Island, Komandor Islands, Il'pinskii Peninsula, and Kamchatskii Mys Peninsula;

(e) The upper Eocene (Priabonian) in Karaginskii Island and undivided Eocene in Komandor Islands and Kamchatskii Mys Peninsula.

The nannoplankton assemblages of the lower and middle Eocene are sufficiently representative for distinguishing zones of the standard scale by Okada and Bukry (1980). As regards the upper Eocene–lower Oligocene interval, it is almost impossible to determine the Eocene–Oligocene boundary in the region owing to extremely scarce occurrences of species *Discoaster barbadiensis,* and *Discoaster saipanensis*, the disappearance of which marks this boundary. This situation was noted also in the section of deep-sea drilling Site 192A in the boreal region (Shcherbinina, 1992).

(2) On the whole, the general depletion of nannofossil assemblages is, apparently, associated with the adverse conditions for nannoflora development and the accumulation of its remains in the sediments of Far East regions with high tectonic activity. The extensive amount of tuffs in the deposits of the region is evidence of abundant ash suspension in the Paleogene oceanic waters and considerable "dilution" of biogenic components in the sediments. Moreover, significant diagenetic transformations often preclude the investigation of nannoplankton. It is interesting to note that for this purpose the terrigenous deposits (shales and siltstones) are more promising than the carbonate rocks with abundant epigenetic calcite. The studied samples from the limestone interbeds and carbonate concretions were disappointing owing to considerable recrystallization. Evidently, the combination of diagenetic processes of recrystallization and dissolution in terrigenous deposits were more favorable for nannoplankton conservation.

(3) Of all the studied cases only the nannoplankton assemblages from the Kronotskii Peninsula included forms typical of shallow-water shelf deposits (pontosphaerids and helicosphaerids). All other areas of the region yielded assemblages that, though much impoverished, are still typical enough of open marine environments. Mollusks discovered from the "Kubovaya" and "Kozlov" formations likewise testify to sedimentation in the shelf zone (personal communication by V.N. Sinel'nikova). The appearance of nannoplankton in shallow-water environments apparently indicates the transgression maximums. In fact, the nannoplankton levels in Paleogene deposits of the Kronotskii Peninsula coincide with the late Ypresian, late Lutetian and Bartonian transgressions marked on the eustatic curve (Vail *et al.*, 1977) and clearly expressed also in the shallow-water Paleogene deposits of Eastern Europe (Aubry, 1983). The absence of the early Ypresian (zone CP9–CP10) and early Lutetian (zone CP12) nannoplankton coincides with regression periods correlative

with the regional hiatuses in pelagic facies of the Pacific Ocean (Shcherbinina, 1992).

(4) Data on the Paleogene nannoplankton from the Bering Sea region allow us to outline a general climatic trend in this area during the Eocene.

The lower Eocene nannoplankton assemblages from the Kronotskii Peninsula include relatively warm-water organisms, such as discoasters *D. barbadiensis, D. binodosus, D. lodoensis* and spheноliths *S. radians, S. moriformis.* However, the cold-water chiasmoliths, well represented in the coeval deposits of Site 192A on the Meiji Guyot, are not found on Kronotskii Peninsula, perhaps owing to the general impoverishment of the association.

The upper Lutetian nannoplankton assemblage (*Nannotetrina quadrata* Zone CP13) already shows features of a considerable prevalence of cold-water elements. The only discoaster species *D. binodosus* is found as single specimens, while chiasmoliths (*Chiasmolithus solitus, C. modestus*) and reticulofenestrids (*Reticulofenestra coenura*) are rather abundant.

The Bartonian deposits (*Reticulofenestra umbilicus* Zone CP14) are widespread in the region and include nannoplankton assemblages with abundant and diverse cold-water forms (chiasmoliths, reticulofenestrids, genus *Dictyococcites*), but they almost completely lack warm-water nannoplankton representatives.

The upper Eocene deposits in Karaginskii Island, are also poor in warm-water species, except for a few specimens of discoasters, as it is established in drilling Site 192A.

Therefore, the nannoplankton assemblages of the East Kamchatka region demonstrate a distinct tendency of changing their composition from the rather thermophilic early Eocene to the cold-water late Eocene nannoplankton. On the whole, this scheme is well compatible with the recent idea that, after the early Paleogene temperature optimum, a colder period was triggered by the formation of the circum-Antarctic current in the middle Eocene. The ensuing thermoisolation of Antarctica resulted in a sharply delineated climatic zoning and a considerable cooling in high latitudes. The starting point of this process in the early Oligocene coincides with the disappearance of nannoplankton from the high latitudes of the North Pacific. Therefore, in the boreal region, the potential of this group for the stratigraphy, when the age of deposits is younger than the early Oligocene, is, apparently, not high.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (project no. 93-85-68).

Reviewers I.A. Basov, M.Ya. Serova, and Yu.B. Gladenkov

REFERENCES

Aubry, M.-P., Correlations biostratigraphiques entre les formations paleogenes epicontinentales de l'Europe du Nord-Ouest, basees sur la nannoplankton calcaire, *These Universite Pierre et Marie Curie,* Paris, 1983.

Ben'yamovskii, V.N., Fregatova, N.A., Spirina, L.V., *et al.,* Zones of Plankton and Benthic Foraminifera in the Paleogene of Eastern Kamchatka, *Izv. Ross. Akad. Nauk, Ser. Geol.,* 1992, vol. 1, pp. 110–123.

Chamov, N.P., Lithology of Paleogene Volcanogenic Rocks in Govena Peninsula, the Southern Koryak Highland, *Litol. Polezn. Iskop.,* 1991, no. 5, pp. 79–94.

Gladenkov A.Yu., The Cenozoic Stratigraphy in Kamchatka Region by Diatoms Evidence: The Oligocene and Eopleistocene Levels, *Cand. Sci. (Geol.-Min.) Dissertation,* Moscow: Institute of the Lithopshere, Russ. Acad. Sci., 1991.

Gladenkov A.Yu. and Shcherbinina, E.A., First Finds of Nannoplankton in the Paleogene Deposits of the Komandor Islands, *Izv. Akad. Nauk SSSR, Ser. Geol.,* 1991, vol. 1, pp. 126–128.

Gladenkov, Yu.B., *Neogen Kamchatki (voprosy biostratigrafii)* (The Neogene of Kamchatka: Problems of Biostratigraphy), Moscow: Nauka, 1972.

Gladenkov, Yu.B., Molluscan Assemblages Recovered from the Tertiary Deposits of the Komandor Islands, *Dokl. Akad. Nauk SSSR,* 1984, vol. 274, no. 3, pp. 64–82.

Gladenkov, Yu.B., Vitukhin, D.I., and Oreshkina, T.V., Correlation of the Cenozoic in Eastern Kamchatka with the Oceanic Deposits, in *Neogen Tikhookeanskoi oblasti* (The Neogene of the Pacific Region), Moscow: Nauka, 1982, pp. 62–65.

Gladenkov, Yu.B., Muzylev, N.G., Vitukhin, D.I., *et al.,* The Paleogene Nannoplankton of the Koryak Highland, *Dokl. Akad. Nauk SSSR,* 1988, vol. 299, no. 5, pp. 1198–1201.

Kravchenko-Berezhnoi, I.R., The Geological Position of Magmatic Complexes in the Western Framing of the Komandor Basin, *Cand.Sci. (Geol.-Min.) Dissertation,* Moscow: Institute of the Lithosphere, Russ. Acad. Sci., 1989.

Krasheninnikov, V.A., Serova, M.Ya., and Basov, I.A., *Stratigrafiya i planktonnye foraminifery paleogena vysokikh shirot Tikhogo okeana* (The Paleogene Stratigraphy and Plankton Foraminifera in the High Latitudes of the Pacific Ocean), Moscow: Nauka, 1988.

Okada, H. and Bukry, D., Supplementary Modification and Introduction of Code Number to the Low-Latitude Coccolith Biostratigraphic Zonation (Bukry, 1973, 1975), *Micropaleontology,* 1980, vol. 5, no. 3, pp. 321–325.

Serova, M.Ya., *Foraminifery paleotsenovykh otlozhenii Vostochnoi Kamchatki* (Foraminifera in the Paleocene Deposits of Eastern Kamchatka), Moscow: Nauka, 1966.

Serova, M.Ya., Zonation and Correlation of Paleogene Deposits in the Northwestern Part of the Pacific Province, in *Biostratigraphiya, Fauna i flora kainozoya severo-zapadnoi chasti Tikhookeanskogo podvizhnogo poyasa* (Biostratigrapgy, Fauna and Flora of the Cenozoic in the Northwestern Part of the Pacific Mobile Belt), Moscow: Nauka, 1969a, pp. 101–114.

Serova, M.Ya., New Data on the Age of the Volcanogenic–Sedimentary Rocks in the Southeastern Part of the Koryak Highland (Govena Peninsula), *Dokl. Akad. Nauk SSSR,* 1969b, vol. 182, no. 2, pp. 412–415.

Serova, M.Ya., Planktonic Foraminifers in the Upper Paleocene Deposits of the Govena Peninsula, *Vopr. Micropaleontol.*, 1970, no. 12, pp. 168–182.

Serova, M.Ya., Danilesko, L.A., Koleda, A.A., and Petrina, N.M., Subdivision of the Upper Cretaceous and Paleogene Deposits of the Koryak Highland, *Izv. Akad. Nauk SSSR, Ser. Geol.*, 1973, no. 10, pp. 73–83.

Serova, M.Ya., Borzunova, G.P., and Shapiro, M.N., The Paleogene of the Southern Part of the Karaginskii Island, Eastern Kamchatka, *Izv. Akad. Nauk SSSR, Ser. Geol.*, 1975, no. 11, pp. 73–83.

Shcherbinina, E.A., Stratigraphy and Paleooceanography of the Pacific Ocean in the Paleogene, *Cand. Sci.* (*Geol.-Min.*) *Dissertation*, Moscow: Institute of the Lithosphere, Russ. Acad. Sci., 1992.

Shmidt, O.A., *Tektonika Komandorskikh ostrovov i struktura Aleutskoi Gryady* (Tectonics of the Komandor Islands and the Structure of the Aleut Ridge), Moscow: Nauka, 1978.

Shmidt, O.A., Serova, M.Ya., and Dolmatova, L.M., Stratigraphy and Paleontological Description of Volcanogenic Rocks in the Komandor Islands, *Izv. Akad. Nauk SSSR, Ser. Geol.*, 1973, no. 11, pp. 77–87.

Tsvetkov, A.A., Fedorchuk, A.V., and Gladenkov, A.Yu., Geological Structure and Magmatism of the Bering Island (Komandor Islands), *Izv. Akad. Nauk SSSR, Ser. Geol.*, 1990, no. 7, pp. 40–56.

Vail, P.R., Mitchum, K.M., and Thompson, S., Seismic Stratigraphy and Global Changes of Sea Level, *Seismic Stratigraphy—Application to Hydrocarbon Exploration*, Payton, C.L., Ed., Mem.-Am. Assoc. Petr. Geol., vol. 26, pp. 83–93.

Volobueva, V.I., Gladenkov, Yu.B., Ben'yamovskii, V.N., *et al.*, *Opornyi razrez morskogo paleogena severa Dal'nego Vostoka (p-ov Il'pinskii)* (Reference Section of the Marine Paleogene in the Northern Part of the Far East, the Il'pinskii Peninsula), Magadan: Sev.-Vost. Kompl. Nauch.-Issled. Inst., 1994.

Zhegalov, Yu.V., Komandor Islands, in *Geologiya SSSR. Tom 31* (Geology of the USSR. vol. 31), Moscow: Nedra, 1964.