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Oligocene Calcareous Plankton from the Kronotskii Peninsula, Eastern Kamchatka

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Abstract—Planktonic foraminifers and calcareous nannoplankton were first recorded along with benthic foraminifers in the Upper Paleogene section of the Kronotskii Peninsula, eastern Kamchatka. The fauna permits the assignment of the enclosing sediments to the *Globigerina ampliapertura* Zone of the foraminifer zonation of Bolli and Saunders, (1985) and to the nannoplankton zones CP17-CP18 of the Lower Oligocene. The sporadic occurrence of calcareous plankton in Oligocene sediments of high latitudes was most likely a consequence of the World Ocean level rise and relative climatic warming.

Key words: *Far East, eastern Kamchatka, foraminifers, nannoplankton, zone, Oligocene.*

INTRODUCTION

The correlation of regional stratigraphic subdivisions with standard zonations of different planktonic microfossils is an urgent problem in Cenozoic geology and stratigraphy in the Far East of Russia and, specifically, in eastern Kamchatka. The correlation is generally possible in two ways. The first one is a correlation of subdivisions distinguished by benthic fauna, namely, by mollusks and benthic foraminifers, with those of Japan or North America, where plankton occurs along with benthic fossils. The second way is an active search for plankton remains in the Far East sections to correlate them with the oceanic zonation. In the former case, the estimated age of deposits can be changed according to the verified dates of corresponding stratigraphic subdivisions in Japan or America. The disadvantage of the second way is the relatively scarce occurrence of plankton, especially of calcareous microfossils, in Cenozoic sediments of the Far East of Russia. The rarity of plankton remains is unfavorable for a detailed stratigraphic subdivision of sediments in contrast to the benthic fauna; however, the planktonic fossils may reveal some solid stratigraphic markers. The aim of this paper is to outline one such a marker, the *Globigerina ampliapertura* Zone, in the Cenozoic section of the Kronotskii Peninsula, eastern Kamchatka.

In 1994, Tsukanov and Pachkalov studied the Cenozoic deposits of the Tyushevskii Trough in the Rakitinskaya River basin, the Kronotskii Peninsula of eastern Kamchatka (Fig. 1). They collected samples for the microfaunal analysis and described the lithostratigraphy of the studied sections. Additionally they used the samples taken by V.N. Sinel'nikova (GIN RAS) from the sediments of the Rakitinskaya Formation in 1989 during field work with M.E. Boyarinova (Kamchatgeologiya). Other authors of the paper performed the following investigations. Serova and Stupin studied foraminifers, Shcherbinina studied nannoplankton, and Vitukhin attempted to extract radiolarian and diatom remains and considered the history of investigation of the Rakitinskaya Formation and its age estimates.

BRIEF GEOLOGICAL DESCRIPTION AND HISTORY OF INVESTIGATION OF THE RAKITINSKAYA FORMATION

The Rakitinskaya Formation is exposed within the Tyushevskii Trough that extends northeastward as a narrow, about 60-80 km wide, structure, from the Shipunskii Peninsula on the south to the Kamchatskii Cape on the north. It separates the eastern Kamchatka uplifts from the peninsulas of eastern Kamchatka and is composed of terrigenous and tuffaceous–terrigenous Cenozoic deposits. The trough is asymmetric; the thick sediments of the western flank are strongly deformed and experienced thrusting, whereas on the eastern flank the deposts of the same age compose a gentle monocline disturbed by faults.

Shtempel' and his colleagues (1935), the first researchers of the Kronotskii Peninsula, distinguished upward from the base the Kronotskii, Bogachevka, and Tyushevka formations ranging in age from the Paleogene to the Miocene. Later investigations of the region demonstrated that, because of the lithologic variability of rocks, their strong deformation, and poor paleonto-

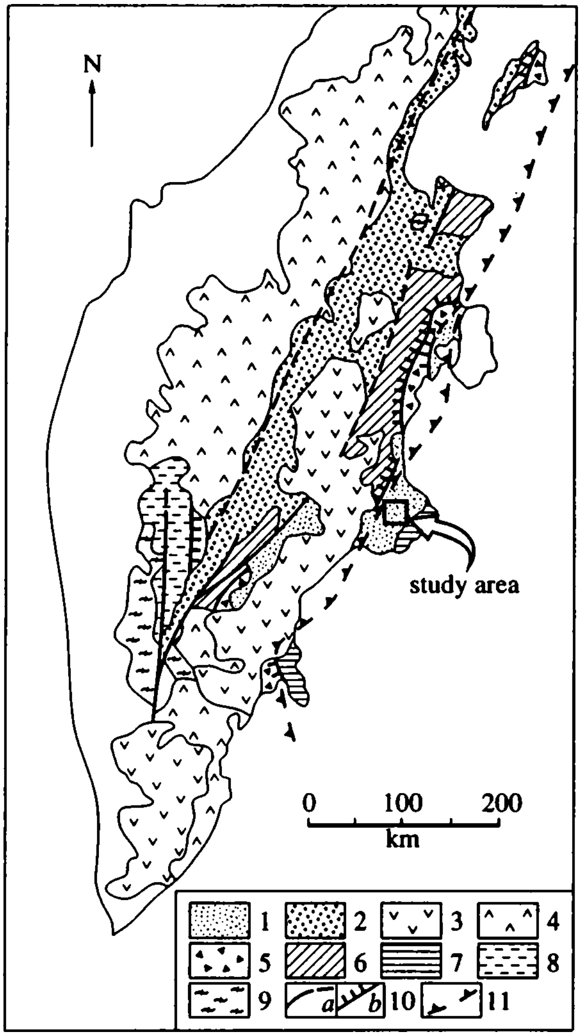


Fig. 1. Tectonic scheme of Kamchatka (after Zinkevich and Tsukanov, 1992): (1, 2) Cenozoic terrigenous deposits of the (1) Tyushevskii Trough and (2) Central Kamchatka graben; (3, 4) volcanogenic rocks of (3) East Kamchatka belt (N_2–Q) and (4) Central Kamchatka belt (P_3–N_1); (5) Vetlovka complex (K_2–P_2^2); (6) volcanogenic, volcanogenic–sedimentary, and terrigenous deposits of the Eastern Kamchatka zone (K_2–P_1); (7) complexly deformed terranes of the eastern peninsulas; (8) volcanogenic–sedimentary and terrigenous sediments of the Central Kamchatka zone; (9) metamorphic rocks (Mz-Kz); (10) proven and assumed faults (*a*) and thrust faults (*b*); (11) Vetlovka collision suture.

logic remains, the suggested stratigraphic scheme is discrepant and needs a revision.

The Rakitinskaya Formation was first identified by Pleshakov and Nesvit (1958) as a unit (subformation) of the Tyushevka Formation. Subsequently, it was classified as a formation in the Tyushevka Group. In the Kronotskii region, these authors distinguished an upward succession of the Bogachevka, Ivanova, and Tyushevka formations divided into a series of subformations. According to Pleshakov and Nesvit, the Rakitinskaya Subformation is represented by flyschoid interlayering of tuffaceous opoka-like shales and sandstones about 400 m thick. Its stratotype was not indicated,[1] and it was only noted that deposits of the subformation are distributed along the axis of the Rakitinskaya syncline that extends northeastward along the isthmus of the Kronotskii Peninsula from the Ol'ga Bay to the Malaya Chazhma River mouth. According to Pleshakov and Nesvit (1958), the Rakitinskaya Subformation crowns the Miocene section in the region and is an analogue of the Goryachie Klyuchi Formation distinguished previously along the Tyushevka River and dated back to the Pliocene (Dvali, 1955). However, it was mentioned in the same paper (Pleshakov and Nesvit, 1958) that A.P. Il'ina and I.G. Pronina, who studied the mollusk fauna of the Rakitinskaya Subformation, inferred its middle (latest) to the late Miocene age. A discrepancy between the age estimates of the unit was not explained in the paper.

Subsequently, the age of the Rakitinskaya Formation was considered as ranging from the early Miocene to the Pliocene. At the Okha Stratigraphic Conference, its age interval was adopted as the late Miocene–early Pliocene (*Unifitsirovannye* ..., 1961). Il'ina (1963) defined the age of the formation as the late Miocene, and Pronina (1969) as the middle Miocene. Later on, Pronina and Berson (1978) assigned the Rakitinskaya Formation to the lower Miocene.

Arsanov (1978), who studied the geology of the Kronotskii region in 1963–1966, noted that the identification of the Rakitinskaya Formation with the top unit of the Miocene section was erroneous. He demonstrated that the Rakitinskaya Formation unconformably overlies the basalts of the Kronotskii Group and is in turn discordantly overlain by sediments of the Tyushevka Group. The unit was subdivided into three subformations: the lower one of interlayered sandstones, siltstones, and gravelstones; the middle one of conglomerates and sandstones crowned with spongolites incorporating opal cherts, whose beds are intercalated with glauconite sandstone layers bearing a nodular phosphorite interlayer; and the upper subformation mainly composed of sandstones and siltstones. Arsanov estimated the maximum thickness of the Rakitinskaya Formation to be 235 m.

According to his data, a single section of all three subformations is exposed at the right bank of the Tyushevka River near the Volch'ya River mouth and corresponds to the Goryachie Klyuchi Formation after D'yakov and Dvali (1955). The section is mainly composed of clastic rocks: boulder conglomerates, gravely sandstones, sandstones, and coquina. To the north, in the Rakitinskaya River basin, the formation is represented by sandstones and siltstones bearing the coquina, glauconite sandstone, and spongolite layers,

[1] Pronina (1969) stated that the stratotype of the Rakitinskaya Formation is situated in the upper reaches of the Rakitinskaya River without further details of its location.

with the boulder and pebble conglomerate bed at the base of the section.

Serova identified foraminifers of the Rakitinskaya Formation from the Arsanov's collection as representing an assemblage of the Oligocene age. On the basis of mollusks, Arsanov correlated the Rakitinskaya Formation with the Machigar Formation of northern Sakhalin and with the Alugivayam Formation of the southern Koryak Highland (Il'pinskii Peninsula), both of the Oligocene age as well. At the Second Interdepartmental Stratigraphic Conference of 1974, the Rakitinskaya Formation was included in the Alugivayam Horizon referred to the Oligocene (*Resheniya* ..., 1982). However, soon afterwards, the age of the formation was revised by Runeva (1979), who studied the radiolarian fauna from the Rakitinskaya Formation and dated it as middle Miocene in age. The tendency to rejuvenate the formation age is valid up to present. For instance, in the geologic report of Boyarinova, who studied recently the geology of the Kronotskii Peninsula, the formation is attributed to the middle Miocene. Based on the mollusk assemblages, Sinel'nikova (personal communication) is inclined to correlate it with the lower Miocene Kuluven Formation of the Tochilino section in western Kamchatka. Shapiro *et al.* (1996) correlated the Rakitinskaya Formation with the basal unit of the Kavran Group of western Kamchatka corresponding to the middle Miocene. Thus, there is no general agreement about the age of the Rakitinskaya Formation.

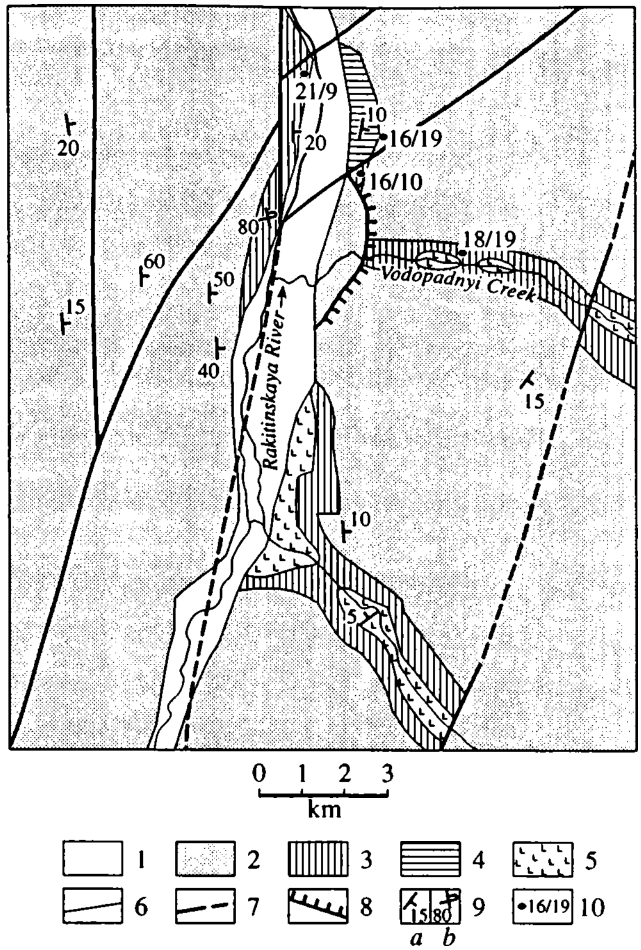


Fig. 2. Geologic scheme of the middle reaches of the Rakitinskaya River (after M.E. Boyarinova): (1) Quaternary alluvial deposits; (2) undivided Tyushevka Group; (3) Rakitinskaya Formation; (4) undivided Bogachevka Group; (5) undivided Kronotskii Group; (6) proven and assumed geological boundaries; (7) flaults; (8) thrust faults; (9) bed attitude (*a*) normal and (*b*) overturned; (10) site of samples bearing microfossils.

DESCRIPTION OF THE SECTIONS

Sections of the Rakitinskaya Formation were studied in 1994 by Tsukanov and Pachkalov in the middle reaches of the Rakitinskaya River (on the left bank) and in the area of the Vodopadnyi and a nameless creeks, the latter located one kilometer to the north of the former (Fig. 2).

In the middle reaches of the Vodopadnyi Creek, basalts of the Kronotskii Group are overlain by the following members (upward from the base, Fig. 3a):

(1) Medium- to fine-pebble (in the upper beds) conglomerates with reworked clastics of basic and intermediate extrusive rocks. The thickness is 1.5–2 m.

(2) Light gray medium-grained sandstones bearing fine pebbles of extrusive rocks and molluscan shell fragments. The thickness is 1.5 m.

(3) Pink gray coquina composed of 80% broken mollusk shells cemented by sandy or silty material. The thickness is 1.5 m.

(4) Slightly laminated opokas (Samples 18/18 and 18/19) enclosing foraminifers *Globigerina ampliapertura* Bolli, *G. ciperoensis angustiumbilicata* Bolli, *G. praebulloides* Blow subsp. indet., *Globocassidulina subglobosa* (Brady), *Islandiella excavata* (Volosh.), *Cibicidoides pulensis* Ten Dam et Reinhold, *C. tenellus* (Reuss), *Melonis shimokinensis* (Asano), *Bolivina marginata adeloidana* Cush. et Kleinpell, *Angulogerina gracilis germanica* Cush. et Edwards, *A. gracilis tenuistriata* (Reuss), and *Pullenia bulloides* (d'Orb.). The thickness is 1.5 m.

(5) Grayish green gravelstones with pebbles up to 1-2 mm in size. The thickness is 2 m.

(6) Dense tuffstones with the carbonate cement red on the weathered surface (Sample 18/21). The thickness is 15 m.

(7) Greenish, dense, poorly sorted sandstones (Sample 18/22). The thickness is 4 m.

(8) Loose sandstones of variable grain size. The thickness is 10 m.

In the section on the nameless creek, the Rakitinskaya Formation overlies the erosion surface of flyschoid–tuffaceous terrigenous sediments of the

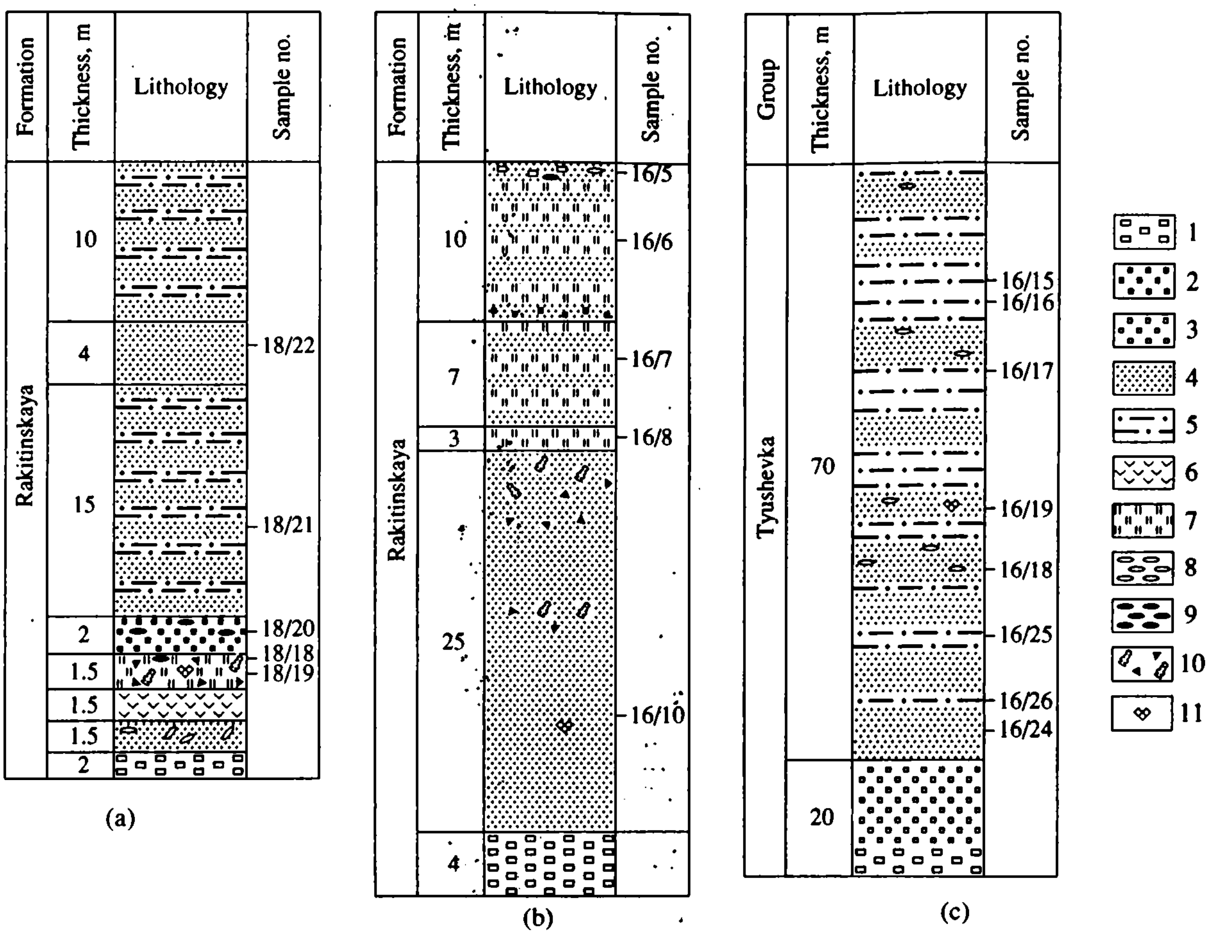


Fig. 3. Studied sections of the Rakitinskaya Formation and Tyushevka Group: (a) section of the Vodopadnyi Creek area (point 18/19 in Fig. 2), (b) section of the adjacent creek area (point 16/10), (c) section on the neighboring gulch (point 16/19); (1, 2) conglomerates (1) coarse pebble and (2) fine pebble; (3) gravelstones; (4) sandstones; (5) siltstones; (6) coquina; (7) opoka; (8) pebble; (9) carbonate concretions; (10) individual molluscan shells; (11) calcareous plankton.

Bogachevka (?) Group.[2] The formation is composed here of the following members (upward from the base, Fig. 3b):

(1) Fine-pebble conglomerates grading upward into gravelstones. The thickness is 4 m.

(2) Light gray to pinkish sandstones bearing dispersed molluscan fragments (Sample 16/10). A single nannoplankton species *Dictyococcites bisectus* (Hay, Mohler et Wade) is identified. The thickness is 25 m.

(3) Dense pinkish opoka bed with numerous molluscan fragments (Sample 16/8). The thickness is 3 m.

(4) Light gray opoka bed containing sandy admixture and interlayers of grey massive sandstones (Sample 16/7). The thickness is 7 m.

(5) Irregular interlayering of gray medium-grained massive sandstones and opokas bearing scarce pebbles of extrusive rocks and carbonate concretions (Samples 16/5 and 16/6). The thickness is 10 m.

A little northward of the nameless creek, in the adjacent gulch, the Rakitinskaya Formation is missing from the section, and turbidites of the Bogachevka (?) Group are overlain by sediments referred by Tsukanov and Pachkalov to the Tyushevka Group (Fig. 3c). At the base, the sediments are composed of fine-pebble conglomerates and gravelstones 20 m thick. The basal beds are overlain by a coarse rhythmic member of fine-grained feldspathic graywacke (Sample 16/24) with rare thin, up to 5 cm, silty graywacke beds (Samples 16/26 and 16/25). The rocks grade upward into sandy nodular lumpy siltstones (Samples 16/17, 16/16, and 16/15) bearing beds of fine-grained sandy graywacke and opoka (Sample 16/19). The opoka beds contain *Globocassidulina subglobosa* (Brady), *Cibicidoides tenellus* (Reuss), *Gavelinella californiensis* (Cush. et Hobson), *?Alabamina tangentialis* (Clodius), *Melonis pompilioides* (Fichtel et Moll), *Bolivina marginata adeloidana* Cush. et Kleinpell, and *B. fastigia* Cush. In addition, scarce reworked Cretaceous planktonic fora-

[2] Tsukanov and Pachkalov attributed these deposits to the Bogachevka Group with certain reservations. They differ from the rocks of the Rakitinskaya Formation and Tyushevka Group by a greater degree of lithification and deformation.

minifers *Globotruncana* sp. indet. and *Heterohelix* sp. indet. are recovered. They associate with the following nannoplankton forms: *Coccolithus pelagicus* (Wallich), *Cyclicargolithus floridanus* (Roth et Hay), *C. abisectus* (Muller), and *Reticulofenestra* cf. *minuta* Roth. The sandstones are characterized by graded bedding and yield the concretions of clayey-calcareous siltstones (Sample 16/18). The member as a whole is of a rhythmic structure, its siltstone and sandstone layers are 30-40 cm and 5-10 cm thick, correspondingly. The total thickness is 70 m.

Separated outcrops of the Rakitinskaya Formation occur at the left bank of the Rakitinskaya River valley, downstream of the Vodopadnyi Creek mouth. The sediments similar in lithologic composition with those exposed along the Vodopadnyi Creek were observed here. The fine-grained sandstones bearing siltstone and opoka lenses, and dispersed molluscan shell fragments are most common (Sample 21/9 collected from opoka beds two kilometers downstream of the Vodopadnyi Creek mouth; see Fig. 2). The opoka beds yielded *Globigerina ampliapertura* Bolli, *G. ciperoensis ciperoensis* Bolli, *G. praebulloides praebulloides* Blow, *Globorotalia opima nana* Bolli, *Fissurina soldanii* Seguenza, *Obliquina* cf. *hexagona* (Williamson), *O. semistriata* (Williamson), *O. substriata* (Williamson), *Globocassidulina subglobosa* (Brady), *Cibicidoides* aff. *elmaensis* Rau, *C. lopjanicus* Mjatl., *Gavelinella californiensis* (Cush. et Hobson), *Discorbis* aff. *globularis* (d'Orb.), *Valvulineria* aff. *willapaensis* Rau, *Bolivina marginata adeloidana* Cush. et Kleinpell, *Angulogerina gracilis germanica* Cush. et Edwards, *Islandiella excavata* (Volosh.), *Uvigerina* cf. *galloway blakeleyensis* Fulmer, and *Pullenia bulloides* (d'Orb.). Nannoplankton is represented by *Cyclicargolithus floridanus* (Roth et Hay) and *Reticulofenestra* cf. *minuta* Roth.

The sediments of the Rakitinskaya Formation and Tyushevka Group as a whole are slightly deformed and dip at angles of 10–15°. The intense degree of deformations was observed only close to faults. For example, the beds of the formation are overturned at the left bank of the Rakitinskaya River and in the nameless creek area we recorded the rock foliation near the faults and small folds of the northwest vergence.

INVESTIGATION METHODS

The studied thin-sections opokas indicated that the rocks are largely composed of recrystallized diatom, radiolarian, and sponge remains constituting 50–70% of the total detritus. Sponge spicules are far better preserved than the siliceous plankton. It is possible that, in some cases, Arsanov (1978) described opokas as spongolites (our data show that proportions between siliceous plankton and sponges in opokas are roughly equal). We failed to extract distinguishable diatom and radiolarian remains from these rocks and concretions.

In the sections described above, the opoka beds rich in biogenic carbonate constituting about 30% of the total detrital components and incorporating the well-preserved foraminifer shells and nannoplankton (Samples 18/19, 16/10, 16/19, and 21/9) are most interesting.

Because of the great hardness of opokas, the traditional maceration method, which was used for other samples, was inappropriate for extraction of foraminifers. They were extracted by processing samples with the concentrated hydrofluoric acid (HF) to substitute their shell carbonate by fluorite. The texture and structure of shells remain preserved after this treatment. Nannoplankton was extracted by the standard procedure and examined under the microscope.

Remains of planktonic and benthic foraminifers and nannoplankton were recorded in four samples (18/19, 16/10, 16/19, and 21/9) from collection of Tsukanov and Pachkalov and in nine samples (1031g/1, 1031/4, 1035/12, 1036/2, 1036/4, 1037/3, 99a, 103, and 107) from collection of Sinel'nikova.

ANALYSIS OF FORAMINIFER AND NANNOPLANKTON ASSEMBLAGES AND AGE ESTIMATES

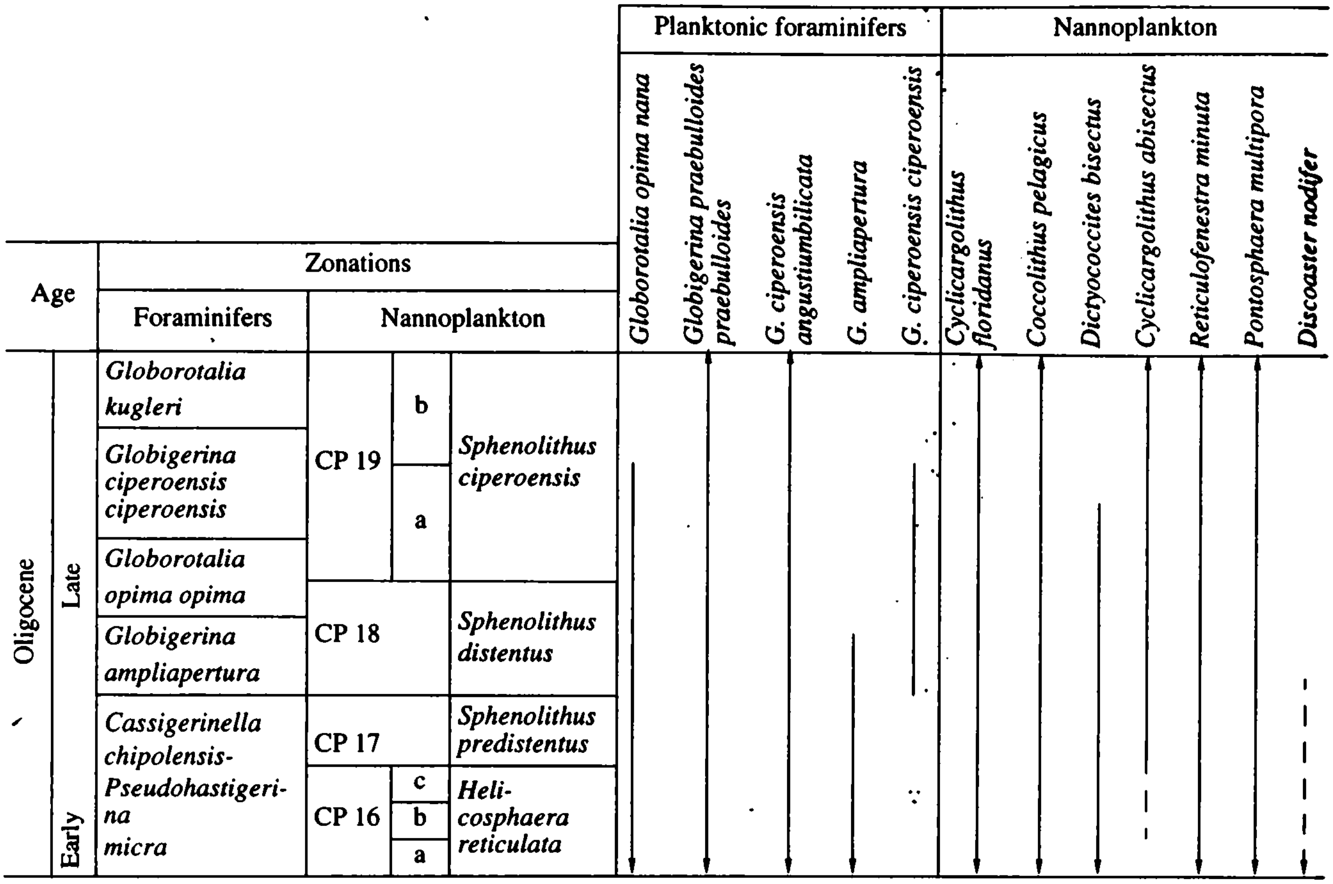
Before we turn to the discussion of the encountered assemblages, we should note that the examined planktonic foraminifers have some morphological peculiarities characteristic of the Cenozoic plankton from high latitudes (Asano and Hatai, 1967; Serova, 1978a; Krasheninnikov *et al.*, 1988). Globigerinas from the studied assemblage, like their specimens from the Paleocene–Eocene sediments of the northwestern Pacific, have not globular, but compressed chambers more tightly arranged as compared with the same species from the tropical and subtropical regions. They also have a narrower umbilicus and a less open aperture.

The joint occurrence of planktonic foraminifers *Globigerina ampliapertura* Bolli and *G. ciperoensis ciperoensis* Bolli indicates that the enclosing sediments correspond to the *Globigerina ampliapertura* Zone (the top of the Lower Oligocene) or, most likely, to a part of this zone (Table).

The recorded benthic foraminifers represent an integral assemblage. Changes in their taxonomic composition recorded in certain samples seem to be a result of different bionomic environments.

Many of the constituent benthic species are widespread in the Oligocene deposits of the Far East. *Gavelinella californiensis* (Cush. et Hobson) is known from the Amanina Formation and *Fissurina soldanii* Seguenza from the Utkholok Formation of western Kamchatka (*Atlas fauny* ..., 1984). *Globocassidulina subglobosa* (Brady) is recorded in the Amanina and Gakkh formations of western Kamchatka (*Atlas fauny* ..., 1984), in the Gennoishi Formation of western Sakhalin (Serova, 1985), and in the Mutnaya and Pilenga forma-

Stratigraphic ranges of calcareous plankton species from the Oligocene sediments of the Kronotskii Peninsula, eastern Kamchatka (after Bolli and Saunders, 1985; Perch-Nielsen, 1985)



tions of eastern Sakhalin. In the last case, this species coexist with *Cibicidoides lopjanicus* Mjatl. (Mitrofanova and Melent'eva, 1991). *Melonis pompilioides* (Fichtel et Moll) is known from the top of the upper Eocene Gailkhavilanvayam Formation of the Il'pinskii Peninsula (*Opornyi razrez* ..., 1994); from the top of the Ionaivayam Formation of the Koryak uplift (Serova *et al.*, 1977); from the Oligocene?–lower Miocene Bora Formation of eastern Sakhalin (Mitrofanova, 1984); and from the Poronai (upper Eocene–lower Oligocene) and Momijiyama (Oligocene) formations of Hokkaido, Japan, (Kaiho, 1984a, 1984b). *Melonis shimokinensis* (Asano) occurs in the Oligocene-middle Miocene sediments of western Kamchatka (Serova, 1978b; *Atlas fauny* ..., 1984), in the Il'khatunvayam Formation of the Karaginskii Island (Serova, 1978b), at the top of the Gailkhavilanvayam and in the Alugivayam Formation of the Il'pinskii Peninsula (*Opornyi razrez* ..., 1994), in the lower part of the Oligocene?–lower Miocene Kholmsk Formation of southeastern Sakhalin (*Opornyi razrez* ..., 1992), in the Mutnaya and Pilenga formations of eastern Sakhalin (Mitrofanova and Melent'eva, 1991), and in the Gennoishi Formation of western Sakhalin (Serova, 1985). *Islandiella exavata* (Volosh.) was found in the Oligocene–Miocene deposits of western Kamchatka (Serova, 1978b; *Atlas fauny* ..., 1984) and in the lower part of the Bora Formation of eastern Sakhalin (Mitrofanova, 1984; Mitrofanova and Melent'eva, 1991).

According to nannoplankton, the enclosing sediments are most likely not older than the early Oligocene, as the recorded *Cyclicargolithus abisectus* (Muller) appeared at that time.

Let us now consider the micropaleontological characteristic of the samples collected by Sinel'nikova in the same region, mainly along the right-hand tributaries of the Rakitinskaya River in its middle courses, the Krivoi and Borodavkin creeks. We should note that the microfauna was extracted from the samples collected for the malacologic analysis. The rocks are chiefly represented by sandstones and sandy siltstones bearing numerous mollusk remains.

All samples yielded an assemblage of benthic foraminifers and calcareous nannoplankton. Benthic foraminifers are represented by *Fissurina laevigata laevigata* Reuss, *Sigmomorphina* cf. *vaughani* Cush. et Ozawa, *Buccella* sp., *B.* ex gr. *subconica* Budasheva, *Cibicidoides tenellus* (Reuss), *C. lopjanicus* Mjatl., *Cibicides* cf. *lobatulus* (Walker et Jakob), *C.* ex gr. *celebrus* Bandy, *Melonis* cf. *shimokinensis* (Asano), *M. affine* (Reuss), *Bolivina marginata adeloidana* Cush. et Kleinpell, *Cassidulina galvinensis* Cush. et Frizzell, *C. depressa* Asano et Nakomura, *C. menneri* Serova, *C.* sp., *Globocassidulina globosa* (Hantken), *G. subglobosa* (Brady), *Cassidulinoides howei* Cush., C. sp., *Islandiella exavata* (Volosh.), *I.* sp., and *Pullenia* ex gr. *salisburyi* R.E. et K.C. Stewart. Additionally, we recorded scarce planktonic foraminifers, whose taxa are undeterminable because of poor preservation.

This assemblage certainly resembles the previous one, but differs in a less diverse composition, occurrence of *Buccella*, and predominance of Cassidulinidae. This is most likely a result of sediment accumulation in the somewhat different settings of the outer subtidal or upper bathyal zone.

Some benthic foraminifers from samples of Sinel'nikova have wide stratigraphic ranges within the Eocene-Miocene interval. However, the forms known from the Upper Paleogene sediments predominate. For instance, *Sigmomorphina vaughani* Cush. et Ozawa and *Cibicidoides celebrus* Bandy occur in the Eocene deposits of North America; and in the Gakkh Formation (Oligocene) of western Kamchatka. *Cassidulina menneri* Serova was also described from the last locality (*Atlas fauny* ..., 1984). *Cassidulina galvinensis* Cush. et Frizzell was recorded in the Eocene and Oligocene sediments of North America; in the Kovachina (Eocene), Amanina, and Gakkh (Oligocene) formations of western Kamchatka; in the Alugivayam Formation (Oligocene) of eastern Kamchatka; and in the Krasnopol'e (Eocene) and Arakai (Oligocene) formations of Sakhalin (*Atlas fauny* ..., 1984; *Opornyi razrez* ..., 1994). *Globocassidulina globosa* (Hantken) was found in the Eocene-Oligocene beds of North America; in the Kovachina, Snatol (Eocene), and Amanina (Oligocene) formations of western Kamchatka; and in the Kholmsk (Oligocene?-lower Miocene) Formation of Sakhalin (*Atlas fauny* ..., 1984). *Melonis affine* (Reuss) is known from the Eocene of North America and the Amanina Formation of western Kamchatka (*Atlas fauny* ..., 1984). *Cassidulinoides howei* Cush. occurs in the upper part of the Poronai Formation (upper Eocene-Oligocene) and in the Nuibetzu Formation (Oligocene) of Hokkaido (Kaiho, 1984a, b). The available data on distribution of benthic foraminifers suggest the Oligocene age of enclosing deposits.

The following species of calcareous nannoplankton were identified in the same samples: *Reticulofenestra minuta* Roth, *Dictyococcites bisectus* (Hay, Mohler et Wade), *Cyclicargolithus floridanus* (Roth et Hay), *Pontosphaera multipora* (Kamptner), *Discoaster nodifer* (Bramlett et Riedel), and *Coccolithus pelagicus* (Wallich). This assemblage testifies to the fact that the sediments are not younger than the late early Oligocene, as the last occurrence level of *Discoaster nodifer* (Bramlett et Riedel) was recorded in the lower part of zone CP18, (*Sphenolithus distentus* zone (in table). Therefore, the joint occurrence of *Cyclicargolithus abisectus* (Muller) and *Discoaster nodifer* (Bramlett et Riedel) found in collections of Tsukanov and Pachkalov and Sinel'nikova, correspondingly, permits us to attribute the enclosing sediments to the lower Oligocene quite concordantly with data on planktonic foraminifers.

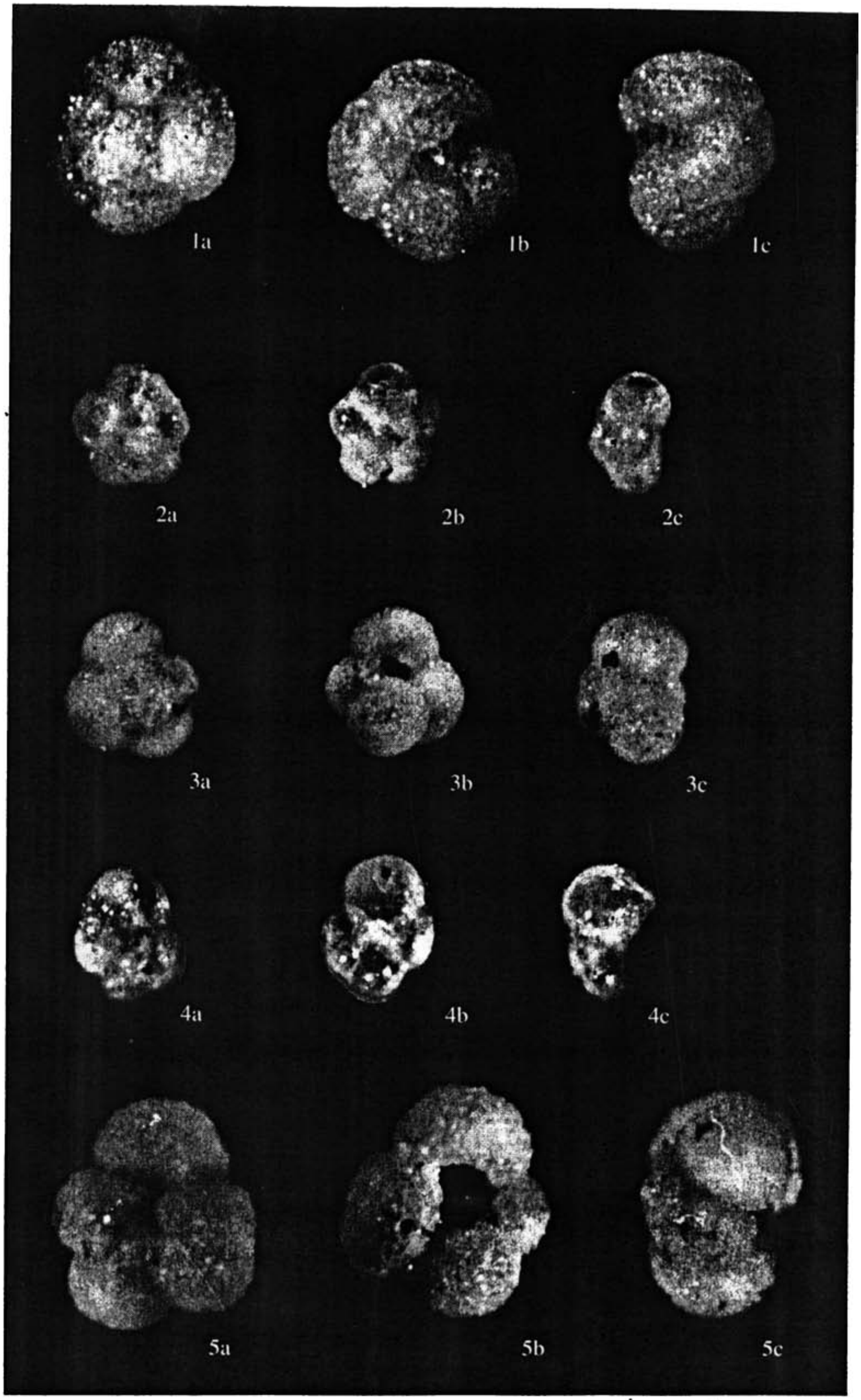
Data on Paleogene foraminifer assemblages from the Far East as a whole show that planktonic foraminifers with dominant globigerinas occur sporadically and have an impoverished taxonomic composition as compared with those from the low latitudes. The appearance of planktonic foraminifers in the Cenozoic deposits of high latitudes was mainly associated with transgressions and relative climatic warmings recorded by the oxygen-isotope data (Shackleton and Kennett, 1975; Letolle, 1979; Vergnaud-Grazzini, 1984). In the Paleogene of the Far East, these events are marked by the occurrence of calcareous plankton in the lower Paleocene, at the Paleocene-Eocene boundary, at the beginning of the early and late Ypresian, in the Lutetian, and in the lower and upper Bartonian (Serova, 1966; Serova, 1967; Serova, 1969a; 1969b; Krasheninnikov *et al.*, 1988; *Opornyi razrez* ..., 1994).

Findings of calcareous plankton in the Oligocene deposits of the Far East of Russia are very scarce. By now, planktonic foraminifers are known from the Nikol'skoe Formation of the Bering Island (Komandorskie Isles), where Serova recovered *Globorotalia pseudokugleri* Blow, later classed with *Gl. gemma* Jenkins (Krasheninnikov *et al.*, 1988), and *Gl.* sp. (Schmidt *et al.*, 1973). At the base of the Il'khatunvayam Formation, Karaginskii Island, Serova identified *Pseudohastigerina micra* (Cole) as reported by (Krasheninnikov *et al.* (1988).

According to oxygen-isotope records, the middle Oligocene (nannoplankton zones CP17-CP18) peak of warming against the background of the general decrease of surface water temperatures was manifested in the North and South Atlantic, Indian Ocean, and in the North and Central Pacific (Borshchevskii *et al.*, 1993; Corfield and Cartlidge, 1993).

According to recent data of Shcherbinina (1997), the occurrence levels of nannoplankton in the Paleogene sediments of the Kronotskii Peninsula is directly correlated with transgressive maxima of the eustatic curve of Haq *et al.* (1987). We can suggest that the occurrence of a bed rich in biogenic carbonate and calcareous plankton within the studied substantially siliceous sequence corresponds to the transgression in the second half of the early Oligocene.

It should be noted that some benthic foraminifers from this level, such as *Bolivina marginata adeloidana* Cush. et Kleinpell, *Gavelinella californiensis* (Cush. et Hobson), *Uvigerina* cf. *galloway blakeleyensis* Fulmer, *Valvulineria* aff. *willapaensis* Rau, and *Cibicidoides* aff. *elmaensis* Rau (all of them occur in the Oligocene Blakeley Formation of California studied by Fulmer, 1975), are typical of the Pacific and coexist with the fol-



Oligocene planktonic foraminifers of the Kronotskii Peninsula.

(1) *Globigerina ciperoensis angustiumbilicata* Bolli, Sample 18/19; (2) *Globigerina ciperoensis ciperoensis* Bolli, Sample 21/9; (3) *Globigerina ampliapertura* Bolli, Sample 21/9; (4) *Globorotalia opima nana* Bolli, Sample 21/9; (5) *Globigerina praebulloides praebulloides* Blow, Sample 21/9. For all images: (a) spiral side; (b) umbilical side; (c) lateral side; × 125.

lowing North Atlantic forms also characteristic of the Oligocene in Europe: *Cibicidoides lopjanicus* Mjatl., *C. tenellus* (Reuss), *Alabamina tangentialis* (Clodius), *Globocassidulina subglobosa* (Brady), *Bolivina fastigia* Cush., *Angulogerina gracilis germanica* Cush. et Edwards, *A. gracilis tenuistriata* (Reuss), *Pullenia bulloides* (d'Orb.), *Obliquina substriata* (Williamson), *O. semistriata* (Williamson), and *Fissurina soldanii* Seguenza. These forms were recorded in foraminifer assemblages of Carpathians (Myatlyuk, 1950), in septarium Clay of northern Germany (Kiesel, 1962), in the Boom Clay of Belgium (Batjes, 1958), and in the Hempsted Beds of England (Murray and Wright, 1974).

The coexisence of Atlantic and Pacific faunas and the occurrence of planktonic forms in the Oligocene of the Far East most likely resulted from a short-term warming in the middle Oligocene and from the global rise of sea level favorable for broader connections and, correspondingly, for migration of biota between the Atlantic and Pacific oceans. Assumptions agreeable to our results were made on the basis of study of the Oligocene radiolarian and diatom assemblages from the Bering Island, Komandorskie Isles (Vitukhin, 1993; Fedorchuk *et al.*, 1987).

CONCLUSIONS

(1) The detected assemblages of planktonic foraminifers and nannoplankton representative for the high latitudes were used to discriminate a unit of the lower Oligocene deposits corresponding to the *Globigerina ampliapertura* Zone and to nannoplankton zones CP17–CP18 in the Cenozoic section of the Kronotskii Peninsula.

(2) The diverse assemblage of benthic foraminifers associated with planktonic forms characteristic of Late Paleogene deposits of the Far East and adjacent Pacific regions is reliably correlated now with the chronostratigraphic scale.

(3) Within the Kronotskii Peninsula of eastern Kamchatka, we revealed an important correlation marker of the biostratigraphic and event type. Its level supposedly corresponds to the transgression and a short-term climatic warming in the middle of the Oligocene.

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