TECTONICS AND GEODYNAMICS OF THE SOUTHERN PART OF KORYAK HIGHLANDS AND KAMCHATKA

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ABSTRACT

Analysis of the tectonic framework of Kamchatka and the southern part of the Koryak highlands allow us to describe four different terranes in the pre-Cenozoic basement of these regions: 1) tectono-stratigraphic, 2) disruptive, 3) composite and 4) metamorphic. A few of these terranes are similar in Koryak and Kamchatka and show evidence of a common origin in Cretaceous time. The geologic history of both regions shows that a number terranes are remnants of the ancient West Pacific zone, and others have an exotic origin.

INTRODUCTION

In recent years, it has been shown that many foldbelts of the Pacific rim are composed of fragments of ancient island-arcs, crust of back-arc and oceanic basins, or blocks of continental crust. The important task is to distinguish and describe such fragments (terranes), and to reconstruct the tectonic history of each of these belts. In this paper, we attempt to solve this problem using the example of Kamchatka and the southern part of the Koryak highlands. This region, a part of the young Eurasian continental margin, formed during Mesozoic-Cenozoic time at a convergent boundary between the Pacific and Eurasian plates. A large part of it is covered by Cenozoic formations (Fig. 1) and underlying Mesozoic basement, which is composed of volcanic, volcano-sedimentary, terrigenous, and metamorphic complexes. The rocks of this basement are very complexly deformed and contain almost no valid macrofauna remnants.

Geological analysis, with special emphasis on sedimentary facies, radiolarian biostratigraphy, geochemistry of effusives, and structural styles of pre-Cenozoic rocks, allowed us to come to the conclusion that pre-Cenozoic basement consists of different terranes that are regions of distinct stratigraphy, structure, petrology, and metamorphism with a different geological history from those of adjacent terranes.

To begin, it was necessary to answer the following questions: Is there any conformity to natural laws regarding the position and the distribution of terranes or tectonic framework of the Kamchatka and southern Koryak regions? Which terranes among them was not connected with neighboring terranes in the past?

A very important regional problem is the comparison of tectonic frameworks of both above mentioned regions. The modern tectonic framework of these regions is different, but their Cretaceous complexes are very similar, which is evidence of a common origin. Different tectonic models may be created to recreate their tectonic structures in Cretaceous time.

TERRANE ANALYSIS OF PRE-CENOZOIC BASEMENT OF KAMCHATKA AND SOUTHERN KORYAK

Terrane analysis of Koryak and Kamchatka allow the following terrane classification: 1) tectono-stratigraphic, 2) disruptive, 3) composite and 4) metamorphic (Fig. 2).

1) Tectono-stratigraphic terranes include Omgon, Central-Koryak West-Kamchatka, Iruney, Achaivayam-Ozernovsko-Valaginskiy, Olutorskiy, and Kronotsko-Shipunskiy terranes.

Omgon

This terrane is found in westernmost Kamchatka (Fig. 1), where Jurassic and Cretaceous rocks are exposed over an area approximately 25 km by 5 km. Recent studies of this region (Bogdanov et al., 1991 and Bondarenko and Sokolkov, 1990) showed that it consist of three thrust slices dipping to the southeast. The lower slab consist of basalts with lenses and bands of cherts and the middle one consists of volcano-sedimentary formations. The upper slab is composed of basalts interbedded with chert-carbonate members containing Middle Jurassic and Late Jurassic-Valanginian radiolarian, and in the upper section, Late Berriasian-Valanginian Buchia. The rocks of the middle slab are unconformable overlain by turbidities (K_{1-2}ap-al to K_2m). Petrochemical and geological data (Bondarenko and Sokolkov, 1990) indicate that these volcanogenic and volcano-sedimentary rocks were formed in the Middle Jurassic-Early Neocomian in an ensimatic island-arc setting. Island-arc formations of the Omgon

terrane have no analog in neighboring parts of Kamchatka, but are very similar to formations of the southern part of the Taigonos Peninsula in the northern Sea of Okhotsk.

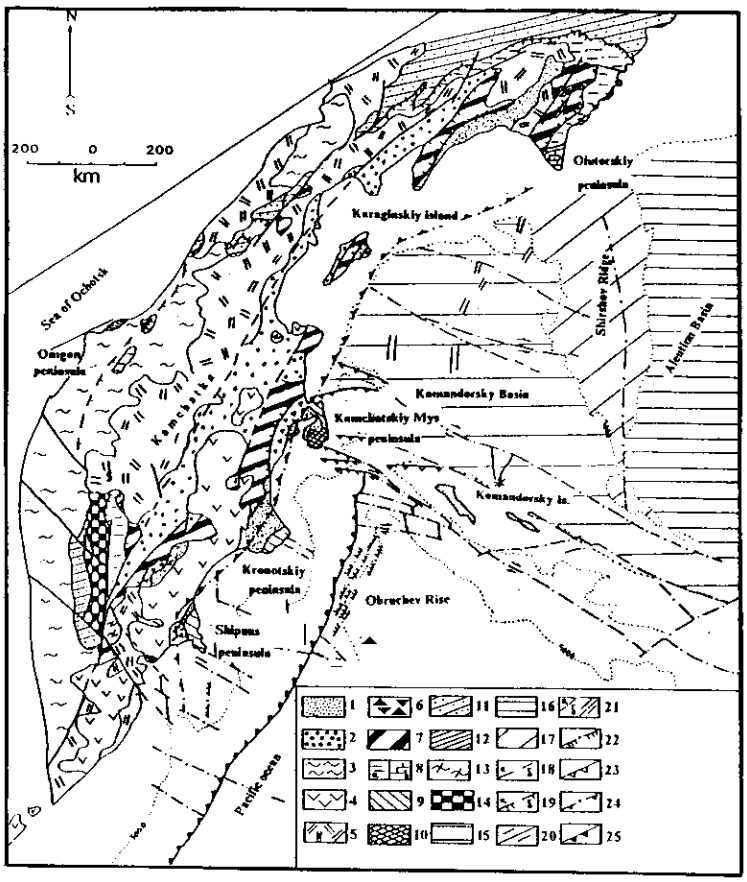

Fig 1. Geological sketch of Kamchatka and souther part of Koryak highlands.
Cenozoic clastic deposits: 1 - Tushevka and Pahachinskaya basins (P_2-N_1), 2 - Central Kamchatka-Govena graben (Kz), 3 - West Kamchatka basin (P_2-N_1); volcanic formations: 4 - East Kamchatka volcanic belt (N_2-Q), 5 - Central Kamchatka volcanic belt; 6 - vetlovskiy complex (K_2? -P_2), 7 - volcanic and volcanic-sedimentary formations (K_2 km - P_1), 8 - volcanic-sedimentary and sedimentary formations (K_1 al - K_2 km): backarc basins (a), oceanic complexes (K_2 km) (b), 9 - volcanic and tuffogenic-sedimentary rocks of the volcanic island arc of Eastern Peninsula of Kamchatka, 10 - mudstone-siliceous rocks, tholeitic basalt, and sedimentary deposit of the oceanic cover (K_{1-2}), 11 - sedimentary deposits (K_{1-2}), 12 - volcanic and volcanic-sedimentary complexes of island arc (J_2 - K_1), 13 - metamorphic complexes of Eastern Kamchatka, 14 - metamorphic complexes of the Central Kamchatka, 15 - oceanic crust of the Komandorsky basin, 16 - transitional crust of the Aleutian basin, 17 - transitional crust of the Shirshov Ridge, 18 - major faults undifferentiated, 19 - overthrustes undifferentiated, 20 - strike-slip fault, 21 - Vetlovskiy collision suture, 22 - tectonic axes of the Kurile-Kamchatka and Aleutian trenches, 23 - axes of the spreading zone on the Komandorskiy basins, 24 - modern volcanoes, 25 - isobath 3000 m.

Central-Koryak and West-Kamchatka

This terrane is composed of pre-Cenozoic terrigenous rocks in Western Kamchatka, extending northward to the Kamchatka isthmus, and to the Koryak highlands (Fig. 1). In West Kamchatka, clastic deposits (K_1ap to K_2) are uniform in composition and intensively deformed. No complete section is known, because of the strong tectonic reworking and small outcrops. The Cretaceous age of the clastic formations was determined on the basis of a very rare find of inoceramides and radiolaries (Geologiya, 1964 and Sidorchuk and Khanchuk, 1981). Sandstones, siltstones and mudstones are interbedded in relations indicating an origin as distal turbidities and more often, contourites formed in a deep-sea environment. These rocks sometimes consist of silica tuffs, tephroids, or cherts, including pure radiolarites (Shapiro et al., 1992). Coarse-grained clastic rocks are very rare and, very seldom tholeiite pillow basalts are documented (Fedorov, 1988). The sandstones are graywackes in which the clastic part consists predominantly of quartz, plagioclase, and fragments of various rocks - andesite, dacite, and various siliceous - tuffogenic, siliceous - clayey, and cherty rocks.

There is no documented steady tendency toward a north-south change in composition of sandstones along West Kamchatka (Shapiro et al., 1992). The central part of the Koryak highlands is composed of Cretaceous terrigenous rocks of Albian to Maastrichtian age (Ermakov, 1975; Vorogushin, 1992; and Kazimirov et al., 1987). Campanian rocks are more wide-spread and show a change in facies from coarse-grained slope sediments to deep-sea debris and contour flows, in a northwest to southeast trend through the region (Kazimirov et al., 1987). Apparently, these deposits were formed near the upper part of a continental slope and in the neighboring part of the marginal basin near the Koryak continental margin.

Iruney

As seen in Fig. 1, this terrane consists of a folded packet of tectonic nappes that have been thrusted westward onto the Central-Koryak and West Kamchatka terrane. In the central part of Kamchatka, this terrane includes tectonic slices consisting of clay-jasper, clay-chert-tuff, and tuffogenic rocks of Santonian(?), Campanian, and Maastrichtian age (Zinkevich et al., 1993). Clay-jasper rocks formed in the central parts of a paleobasin, far from sources of clastic material, below wave-base, and during slow biogenic siliceous sedimentation with a periodic

influx of clay material. The clay-chert-tuff association was formed in a zone near the source of tuffogenic fragmental material, above the carbonate compensation level in an environment favorable for the activity of benthic organisms. The tuffogenic rocks were deposited on the smooth slopes of volcanic uplifts. The composition and structure of these tectonic slices reflects conditions of their formation in different parts of the Iruney marginal (back-arc) basin.

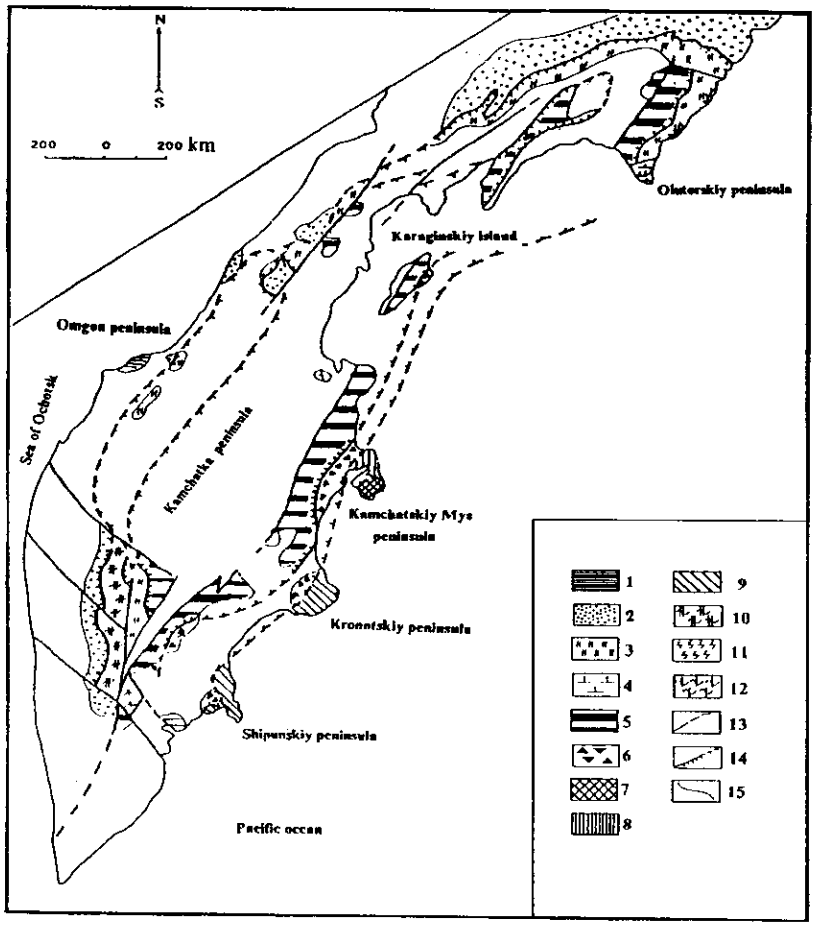

Fig 2. The sketch of terranes of Kamchatka and southern part of Koryak Highland.
Tectono-stratigraphic terranes: 1 - Omgon, 2 - Central-Koryak-Western Kamchatka, 3 - Iruney, 4 - Olutorskiy, 5 - Achaivayam-Ozernovsko-Valaginskiy, 6 - Vetlovskiy; Kamchatka Cape: 7 - southern part, 8 - northern part; 9 - Kronotsko - Shipunskiy; metamorphic terranes: 10 - Zentralno - Kamchatskiy, 11 - Havyvenskiy, 12 - Ganalskiy; 13 - major faults undifferentiated, 14 - overthrust undifferentiated, 15 - board of terranes in the modern structure.

To the north, most of the Iruney terrane is overlain by flat-lying Cenozoic formations. However, in the Kamchatka isthmus, tectonic nappes of this terrane, composed of basalts, cherts and jaspers, are exposed among Cenozoic volcanics (Shantser et al., 1985 and Fedorchuk and Izvekov, 1992).

In the southern part of the Koryak highlands, this terrane includes tectonic nappes, composed by tholeiitic basalts, hyaloclystes, cherts, jaspers and limestones (K_1al to K_2km) (Bogdanov et al., 1982; Chekhovich, 1993; and Kazimirov et al., 1987). The allochthonous complexes in this region are underlain by olistostrome of Maastrichtian age (Mitrofanov, 1977).

Achaivayam-Ozernovsko-Valaginskiy

This terrane extends northward from Kamchatka to Karaginskiy Island and to the Koryak highlands, and has been described in detail; Kamchatka by Zinkevich et al. (1993); Karaginskiy Island by Kravchenko-Berezhnoy (1989); and the Koryak highlands by Bogdanov et al. (1982), Chekhovich (1993) and Kazimirov et al. (1987).

In Kamchatka, the terrane consists of tectonically superposed volcanogenic (K_2km-m), cherty-clastic (K_2m_2-P_1), tuff-clastic (K_2km_3-P_1d) and polimict flyshoid (K_2m-P_1) complexes, usually divided by thrusts and sometimes serpentinite melanges. The volcanogenic complex consists of basalts, andesites, and less often of andesite-dacite flows, tuffs, tuff-breccias, siliceous tuffites, and tuff-silicites. The volcanics correspond to an association of a primitive island-arc series consisting of tholeiitic, calc-alkaline, and high-alumina types, characteristic of early stages of island-arc evolution (Zinkevich et al., 1993). The tuff-clastic complex consists of various tuffs, tephroides, volcanomict clastic, and cherty rocks that formed on volcanic shelves and at their base. The siliceous-clastic complex, consisting of various tuffogenic and tuffogenic-siliceous rocks, is characterized by volcanoclastic and siliceous deposits of a fore-arc basin. The polimict flyshoid complex, composed chiefly of fine-grained, fragmental sedimentary and tuffogenic rocks, characterizes the final stage of activity in an island-arc, when local volcanogenic material was deposited.

On Karaginskiy Island, the Achaivayam-Ozernovsko-Valaginskiy terrane is traced in the central part as tectonic slices, composed of chert-volcanogenic and volcanogenic-clastic complexes (K_2km-m) (Kravchenko-Berezhnoy, 1989).

In southern Koryak, this terrane comprises different volcanogenic complexes of island-arc origin, composed of a chert-volcanogenic formation comparable with oceanic crust (Bogdanov et al., 1982; Chekhovich 1993; and Kazimirov et al., 1987).

Olutorskiy

The Olutorskiy terrane comprises a small tectonic block in southern part of the Olutorskiy peninsula. It consists of a packet of tectonic sheets composed of oceanic basalts, and rare cherts and radiolarites and is separated from neighboring terranes by normal faults. The volcanics correspond to an alkali-rich association typical for seamounts at transform zones (Chekhovich 1993).

Vetlovskiy

This terrane is found in the eastern part of Kamchatka, east of the Achaivayam-Ozernovsko-Valaginskiy terrane and apparently beneath the clastic deposits (P_2 - N_1) of the Tyushevskiy basin. It extends in a single 700 km-long linear belt from Petropavlovsk in the south, to Karaginskiy Island in the north (Fig. 1). A very complex tectonic structure is characteristic of this feature. In fact, it is a tectonic mega-melange, involving different size blocks, sheets, and pieces, often separated by cataclased rocks and mylonites (Tsukanov, 1991; Zinkevich et al., 1993; and Zinkevich and Tsukanov, 1993). The age of these rocks has a wide range - from Upper Cretaceous(?) to Middle Eocene. The terrane consists of fragments from different sequences. Tectonic sheets and blocks are composed of: 1) tuffogenic-sedimentary formations (K_2m to P_1d) age, which are typical for deep trenches and island-arc slope adjacent to trenches; 2) associations, composed of thin-laminated siliceous rocks, cherts, and limestones (P_{1-2}), formed in an open-sea basin environment; 3) complexes, composed of tholeiitic basalts, which are typical of oceanic crust.

Composite Kamchatka Cape

The Composite Kamchatka Cape terrane, described in detail by Zinkevich et al. (1993), consists of two different parts divided by a normal fault and traced to the Bering Sea. The northern part, made up of volcano-sedimentary and terrigenous formations (K_2m - P_2), is typical for island-arc slopes. The southern part, made up of oceanic effusives, cherts, and limestones (K_{1-2}) with Tethys province microfauna, tuffagenous, sedimentary sequences (K_2km-m), and basalts (P_1), is characteristic of island-arcs. There are various gabbro and ultramafic rocks, usually deformed as a serpentinite melange. The layers in the northern part of this terrane are not very deformed, but the tectonic framework of the southern part is very complex and consists of tectonic nappes. Intense tectonic movements took place during a few episodes from the end of Cretaceous time to recent time and caused a combined occurrence in the unified tectonic structure of oceanic and island-arc complexes. The Kamchatka Cape terrane is thought to be of accretionary origin. It is important that all formations of the southern part of this terrane differ from those in the main Kamchatka block.

Kronotsky-Shipunsky

This terrane yields the oldest Cretaceous (Coniacian) rocks of island-arc origin in East Kamchatka; older than neighboring paleo island-arc complexes of Kamchatka. It is exposed in tectonic sheets of Kronotsky and Shipunsky peninsulas (Fig. 1) and is composed of very similar complexes; island-arc effusives and tuffaceous-sedimentary rocks (Tsukanov, et al., 1991).

Metamorphic

The Metamorphic terrane includes Khavyvenskiy, Ganalskiy, and Central Kamchatkan terranes. Not too long ago, many geologists thought that these metamorphic complexes were the basement for Mesozoic formations (Shapiro, 1976; Ocherki .., 1987). This point of view was based on the interpretation of the ancient age of these metamorphic rocks, but geological and reliable isotopic data were absent. In recent years, new geological data were obtained.

Central Kamchatka

As seen in Figs. 1 and 2, this terrane consists of two units: the lower, Kolpakovskaya series (various gneiss, plagiogneiss, and scarce garnet amphibolites), and the upper, Malkinskaya series (rocks of different metamorphism facies - from gneiss to greenshists). Both are covered by a Campanian terrigenous complex.

Isotopic age measurements of metamorphic rocks from the Kolpakovskaya series using the Rb-Sr method reveal that their formation occurred 140 - 130 Ma (Vinogradov et al., 1991). The last episodes of metamorphism took place 75 ± 7 to 62 ± 6 Ma (Grigor'ev and Lobzeva, 1993). Now, it is not possible to define the tectonic role

of this terrane (part of an ancient massif, exotic microcontinent, or fragmented metamorphic zone, formed at the time of origin for the continental crust).

Khavivenka and Ganalskiy metamorphic

These metamorphic terranes of Eastern Kamchatka are exposed in two small areas (Figs. 1 and 2). Geological mapping of the Khavivenka terrane revealed that it is composed of two tectonic complexes consisting of metamorphic rocks; from amphibolites to greenschists (Litvinov, 1990). Protolite for one of them are rocks typical of volcanic belts, for the other it is complexes of oceanic origin. The results of $^{39}Ar/^{40}Ar$ dating of both metamorphic complexes indicate that they appeared in the early Cenozoic (Zinkevich et al., 1993).

Metamorphic rocks of Ganalskiy terrane were characterized by A.V. Rikhter (Zinkevich et al., 1993). He described oceanic and island-arc complexes of this region as a system of tectonic slices. The results of isotopic dating also show evidence of an early Cenozoic metamorphism (Zinkevich et al., 1993).

DISCUSSION

Comparison of Kamchatka and southern Koryak pre-Cenozoic basement terranes reveals many similar structural features. Many of them (Central-Koryak - West-Kamchatka, Iruney, and Achaivayam- Ozernovsko-Valaginskiy terranes) are large tectonic units, contain complexes of almost the same age and they exhibit corresponding environments of island-arc and adjacent parts of back-arc and fore-arc basins of Late Cretaceous time. These similarities indicate that they originated in a single paleozone with the same structure as the modern West Pacific. However, in addition to the above tectonic units, there are a few small terranes (Omgon, Olutorskiy, Kronotsko-Schipunskiy, Kamchatka Cape, and Vetlovskiy) that differ from the main block of Kamchatka by their ages and origin. Analysis of these terranes demonstrate the complex formational history of the accretionary framework. The tectonic history of the region since Cretaceous time is fairly reliably reconstructed (Zinkevich et al., 1993 and Zinkevich and Tsukanov, 1993), while the earlier evolution is problematic. The similarity between rocks of the Omgon terrane and rocks of the same age in the Taigonos peninsula shows that in the Jurassic to Early Cretaceous (end of the Hauterivian), this region was an active continental margin of Asia (Fig. 3a). The above mentioned isotopic data for metamorphism in the Central Kamchatka terrane shows evidence that a general thickening of the crust in the western part of the region took place 140 - 130 Ma. Cherts with microfauna of the Tethys type, contained in blocks of serpentinite melanges of Eastern Kamchatka, are fragments of sedimentary cover of the crust of an ocean to east of Kamchatka. In Coniacian time, the Kronotsko-Shipunskiy island-arc was established somewhere in the southern part of this paleo-ocean (Fig. 3). It was a primitive island-arc of the Tonga-Kermadec type (Khubunaya, 1987). Paleomagnetic data from the Kronotskiy terrane are absent and therefore, the true position of the Kronotsky island-arc is uncertain. In Campanian to Maastrichtian time, the ensimatic Achaivayam-Ozernovsko-Valaginskaya island-arc appeared near the Kamchatka-Koryak orogene. Paleomagnetic data indicate that the position of this island-arc was near 40-43°N. (Kovalenko, 1990 and Savostin and Kheifetz, 1988). The Iruney back-arc basin existed in this time to the west of Achaivayam-Ozernovsko-Valaginskaya arc; the subduction zone was to east of it (Fig. 3c).

At the end of the Maastrichtian to the beginning of the Paleocene, volcanic activity in the Achaivayam-Ozernovsko-Valaginskaya island-arc died out and the newly created Vetlovskiy oceanic basin started forming east of the arc (Fig. 3d). A new subduction zone appeared to the southwest and gave rise to island-arc type of magmatism. At this same time, in the northern and western parts of this region, the early Iruney basin was closing and there was a tectonic superposition of back-arc and island-arc complexes (West-Kamchatka - Central-Koryak, Iruney, and Achaivayam-Ozernovsko-Valaginskiy terranes).

Apparently, the existence of the Vetlovskiy basin was rather brief, and by the middle of the Eocene it no longer existed. The attachment of fragments of the Kronotsko-Schipunskiy arc and Kamchatka Cape terrane to the Kamchatka block apparently had occurred by the middle Eocene. This Middle Eocene compressional event was large in scale and led to complete closing of the Iruney basin and the closing of the Vetlovskiy basin with formation of Vetlovskiy collisional suture that was later masked by clastic deposits of the Tyushevka basin. In addition, a considerable overall increase in crustal thickness and thus augmentation of the continental block took place at this time. Intense metamorphism occurred in the lower part of the crust during the tectonic superposition of the sequences of various facies that crop out in Khavivenka and Ganalskiy metamorphic terranes.

The Cenozoic stage of evolution, beginning in the Middle Eocene, was characterized by a complex combination of various regimes. Against a back-ground of its overall growth and formation, conti-nental crust was destroyed, and beginning in the Oligocene, tensional structures arose, including volcano-plutonic belts and

grabens. After the Middle Eocene tectonic phase, the Koryak-Central Kamchatkan volcanic belt ($P_{2?-3}$-Q_1) developed, with rocks of the basalt-trachyite-comendite series (Volynets et al., 1990) geochemically similar to the series of volcanics of intracontinental and marginal-continental regions. This belt marked the boundary of the newly formed continental crust. The Komandorskiy basin began to open at the back of the Aleutian arc 20-10 Ma and a young oceanic crust began to form in it (Baranov et al., 1992). Its formation was compensated on the east by the pile-up and engulfment of oceanic crust at the junction with the old crust of the Aleutian basin (Neprochnov et al., 1985) and on the west by general complication of the structure of the adjacent continental margin, best reflected in accretionary structure of Karaginskiy Island (Chekhovich et al., 1989) (Fig. 3e).

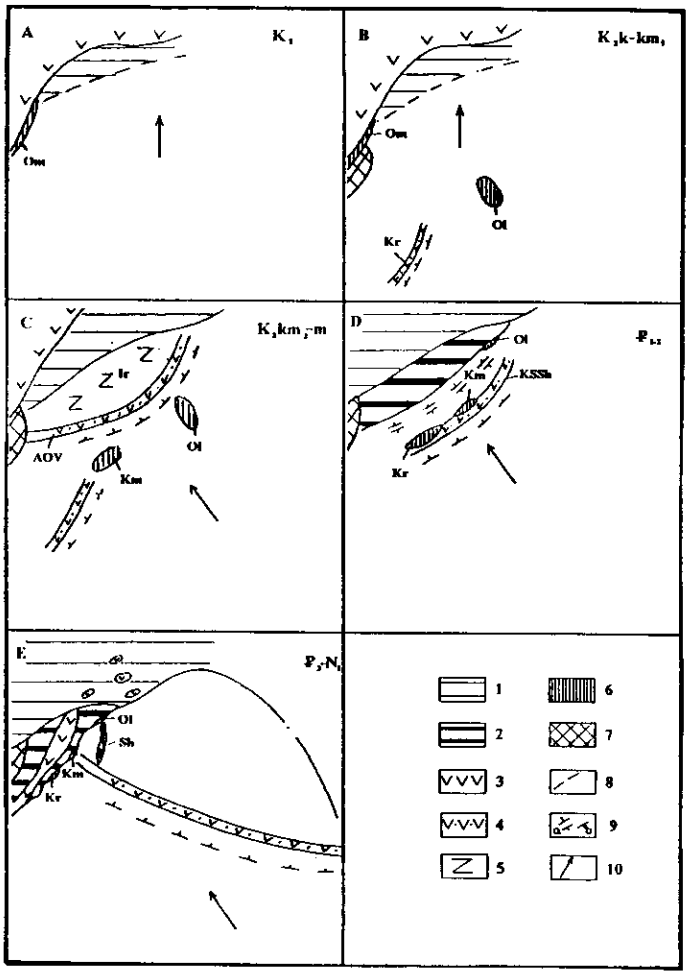

Fig 3. Paleotectonic reconstruction of Kamchatka and southern part Koryak highlands.
Accretionary system: 1 - Koryak, 2 - Kamchatka; 3 - continental-margin volcanic belts, 4 - volcanic island arcs, 5 - Iruney marginal sea, 6 - terranes: Ol - Olutorskiy, Ck - Kamchatka Cape, Kr - Kronotskiy, Om - Omgon, 7 - metamorphic rocks of the margin of the Asian continent, 8 - board of accretionary system, 9 - spreading axes (a), subduction zones (b), 10 - direction of movement of oceanic plates.

The appearance in middle Miocene of East Kamchatkan volcanic belt (N_2 - Q) created very similar conditions to the modern tectonic structure of the region. In Pliocene to Quaternary time, substantial uplift of the region occurred episodically, accompanied by high-amplitude block movements. At the same time, as shown by Seliverstov (1987), the continental border of Kurile-Kamchatka trench continued to increase as a result of the attachment and tectonic reworking of adjacent parts of the Pacific plate. The zones of compression were displaced to the eastern part of the region, apparently in connection with the process of subduction of the Pacific Ocean crust in Kurile-Kamchatka and Aleutian trenches.

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