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GEOLOGY

Breakup of the Late Cretaceous Achaivayam–Valagin Volcanic Arc in the Paleocene (Terranes of Southern Koryakia and Eastern Kamchatka)

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The origin and evolution of the Late Cretaceous and Late Cretaceous–Paleogene island arcs, which make up accreted terranes in the present-day structure of southern Koryakia and eastern Kamchatka, have actively been discussed in publications for the past 15 years. Principal debatable points mainly concerned kinematics of the dislocation of terranes prior to their accretion. Island-arc terranes of southern Koryakia and eastern Kamchatka were regarded as remains of ensimatic island arcs transported over considerable distances. It was believed that the Late Cretaceous Achaivayam–Valagin and the Late Cretaceous–Paleogene Kronotskii and Govena arcs started to form in the Late Cretaceous at close paleolatitudes of the Pacific. It was customary to assume that subduction zones under the Late Cretaceous Achaivayam–Valagin and Late Cretaceous–Paleogene Kronotskii and Govena arcs were oppositely directed. The causes of such an unusual phenomenon, which has no analogues in the present-day geodynamic setting in the western Pacific, and the geological substantiation of such a paleotectonic situation have not been considered so far.

The different-age terranes in southern Koryakia and eastern Kamchatka are characterized by parallel orientation (figure). The Late Cretaceous Achaivayam–Valagin arc terrane extends from the Olyutorka zone of Koryakia through the Kamchatka Isthmus to eastern ridges of Kamchatka and the eastern slope of the Sredinnyi Ridge. Accretion of this terrane proceeded by stages: its Kamchatka and Koryak parts joined the continent in the Early Eocene (50 Ma ago) and the first half of the Middle Eocene (45 Ma ago), respectively. The Kronotskii (eastern Kamchatka) and Govena (southern Koryakia) terranes were formed in the Late Cretaceous–Paleogene. The Kronotskii terrane was accreted at the end of the Miocene; the Govena terrane, in the Middle Miocene.

The model of the formation of the Late Cretaceous ensimatic arc after the closure of the subduction zone of the Okhotsk–Chukotsk belt was proposed for the first time for Upper Cretaceous island-arc complexes of southern Koryakia [1]. The model implied the completion of subduction of Pacific plates under the Asian margin, within which the Okhotsk–Chukotsk volcanic belt formed in the Albian–Senonian, and a new subduction zone appeared in the eastern area directly in the Pacific Ocean. According to the accepted scheme, this subduction zone cut a considerable portion of the oceanic plate of the Pacific Ocean and formed a new convergent boundary between oceanic plates and the “oceanic fringe” of the Asian continental plate.

Subsequent paleotectonic reconstructions for different-age island arcs in eastern Kamchatka and southern Koryakia apparently took into consideration the parallel orientation of the Late Cretaceous Achaivayam–Valagin [2] and Late Cretaceous–Paleogene Kronotskii and Govena island-arc terranes in the present-day structure, as well as a simultaneous beginning of their formation in the Late Cretaceous. According to paleomagnetic data, these island arcs were situated at close latitudes in the Campanian–Maestrichtian [3, 4]. Therefore, it was commonly supposed that they were arranged approximately along a common line but formed above oppositely directed subduction zones. With consideration for the extent of accreted island-arc terranes, the total extension of the new convergent boundary within the Pacific made up ~4000 km. Further displacement of these island arcs depended on the choice of a kinematic model and location of arcs on one or two oceanic plates of the Pacific. The main problem was to substantiate their parallel accretion at different times. For this purpose, the Late Cretaceous (Achaivayam–Valagin) island arc was placed on the leading edge of one of the oceanic plates in the proposed

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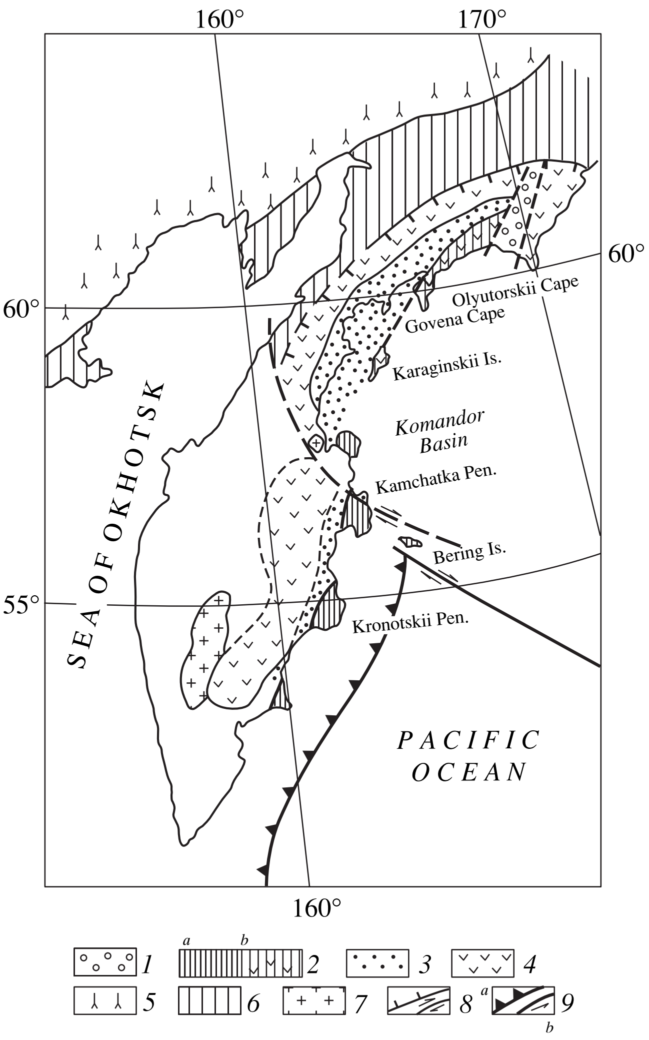

Geological scheme. (*1*) Late Cenozoic molasses of the Apuka graben; (*2*) Late Cretaceous–Paleogene Kronotskii (*a*) and Govena (*b*) island-arc terranes; (*3*) Cenozoic rocks of interarc troughs; (*4*) Late Cretaceous Achaivayam–Valagin island-arc terrane; (*5*) Okhotsk–Chukotsk continental–margin volcanic belt (Albian–Campanian); (*6*) nappe-fold area of late Mesozoides; (*7*) metamorphic and metamorphosed complexes of the Sredinnyi Ridge of Kamchatka and the Khavyvenka Highland; (*8*) regional overthrusts, strike-slips, and faults; (*9*) boundaries of lithospheric plates: (*a*) subduction, (*b*) transform.

kinematic models that allowed a rapid displacement of the arc. The arc formation was accounted for the hypothetical mechanism of the "rolling" of the underlying oceanic plate on the relict part of the oceanic crust, which remained after the skewing of the subduction zone and directly joined the Asian continental margin [5, 6]. The Pacific oceanic crust allegedly subducted under the Late Cretaceous–Paleogene Kronotskii and Govena arcs. As a result, the island arcs mentioned above apparently stayed in a fixed position till the Oligocene. No geological evidence other than paleomagnetic data were given to substantiate these reconstructions. Moreover, the cessation of active volcanism in the Achaivayam–Valagin island arc about 12 and 17 Ma prior to the collision of its southern and northern parts, respectively, with the continent remained unexplained.

The purpose of this work is to elaborate a new model based on the analysis of published materials and original geological data in order to solve some fundamental problems of the geodynamic evolution of island arcs under consideration.

Before proceeding to the analysis of geological materials, it should be noted that the long-existing idea on a consecutive extinction of one subduction zone of the Pacific (beneath the Asian continent) and its replacement by a new one in the Pacific Ocean remains unconfirmed. Unfortunately, the Coniacian–Santonian age of lower parts of the Kronotskii terrane based on radiolarian assemblages [7, 8] has not been taken into account in the paleotectonic reconstructions described above. However, if these data are taken into consideration, ensimatic island arcs in the Coniacian–Campanian should evolve synchronously with the Okhotsk–Chukotsk continental-margin volcanic belt.

Previous investigations carried out in the southern part of the Koryak Upland and near the Vatyna–Vyvenka overthrust, which represents the overthrust front of the Late Cretaceous Achaivayam–Valagin arc, revealed isolated fields of MORB-type basalts along the entire thrust zone extending for more than 500 km. The age of these basalts spans the interval from the Albian–Turonian to Campanian–Maestrichtian, e.g., Lake Gytgyn (Albian–Turonian), Anastasia Bay (Turonian–Coniacian and Campanian–Maestrichtian), the Nichakvayam River (Santonian–Campanian), and the Seinav Ridge (Coniacian–Santonian). This may suggest the existence of an actively evolving basin with ocean-type crust in the discussed time. The upper age limit of these basalts is restricted by the Campanian–Maestrichtian that corresponds to the final evolution period of the Achaivayam–Valagin arc. Hence, according to available data, the process of basin opening stopped simultaneously with the cessation of active volcanism in the arc and well before the collision of this already inactive arc (12–17 Ma) with the continent. It is remarkable that MORB-type basalts in sections of this basin alternate with sedimentary sequences. Thus, these sections differ from deep-sea drilling sections of the Late Cretaceous crust in the Pacific basins, which are mostly devoid of such a structure. In the plots of rare element distribution, MORB-type basalts of the frontal part of the Vatyna–Vyvenka overthrust exhibit a Nb–Ta minimum that is characteristic of back-arc basin basalts. The data presented above (age, structure, and geochemical characteristics of sections) suggest that basalts near the thrust front of the Achaivayam–Valagin arc are back-arc and continental-margin rocks. Moreover, a lateral series (back-arc basin—island arc—ocean) existed there in the Coniacian–Campanian. Such a lateral series implies that the oceanic crust subducted under the Late Cretaceous Achaivayam–Valagin arc from the south or southeast and, hence, this crust belonged to one of the lithospheric plates of the Pacific. In this situation, the Late Cretaceous arc could not move toward the Asian continent.

In southern Koryakia, the northern part of the Late Cretaceous Achaivayam–Valagin terrane is separated from the Late Cretaceous–Paleogene Govena terrane by the Il'pin–Pakhacha Trough filled with Cenozoic sediments. The structural position of this trough suggests its interarc nature. Analysis of the section shows that Early Paleocene rocks in the trough are represented by siliceous sediments in the northern part bordering with Coniacian–Maestrichtian island-arc rocks and by tuffs in the southern part. The continuous Cretaceous–Paleogene section of the Govena arc has been reliably dated on the basis of planktonic foraminifers [9]. In the Cenozoic section of the Il'pin–Pakhacha Trough, terrigenous rocks with different contents of the tuffaceous component play a great part in the interval that stratigraphically overlies the Lower Paleocene rocks. The whole Cenozoic section exhibits no unconformities or hiatuses right up to the Middle Miocene. The southern part of the Il'pin–Pakhacha Trough borders Paleogene volcanogenic sequences of the Govena terrane along a major suture zone marked by a gravity anomaly.

The southern part of the Achaivayam–Valagin island-arc terrane is also separated from the Late Cretaceous–Paleogene Kronotskii terrane by thick Cenozoic sedimentary sequences. However, owing to intense faulting and thrusting within these rocks, it is difficult to draw a direct analogy with the structure of the Il'pin–Pakhacha basin. Nevertheless, judging from different sources, Oligocene–Miocene rocks of the Tyushe Group developed between the Late Cretaceous and Paleogene Kronotskii arcs are replaced downsection without unconformities and hiatuses by the Eocene Pravaya Rechka sequence (the southern Valagin Range) or the Tundra Formation (the Tyushe zone). It should also be noted that Upper Cretaceous rocks of the Kronotskii terrane are replaced upsection by Lower Paleocene rocks according to the scenario in the Govena terrane [9]. The situation in the northern Kamchatskii Mys Peninsula (Stolbovskie Ranges) is simpler. Here, a continuous (mainly, Paleogene sedimentary and tuffaceous–sedimentary) section more than 6000 m thick conformably overlies the Cretaceous volcanites [10]. The continuous nature of the section suggests the accumulation of sediments in a slightly dislocated part of the basin. By contrast, rocks in the central part of the basin are represented by the intensely dislocated (Paleocene–Early Eocene) Vetlov Complex, which is widespread east of the Upper Cretaceous volcanogenic rock field in the southern part of the Achaivayam–Valagin arc. The Vetlov Complex locally represents a megamelange of blocks of terrigenous–sedimentary and siliceous–tuffaceous rocks and individual sheets of MORB-type basalts with interlayers of hyaloclastite, jasper, and cherts. There are grounds to believe that these sheets of deepwater sediments and "oceanic" basalts represent fragments of the opening basin basement [8, 11].

It is worth noting that recent data on the composition of ultrabasic–basic rock massifs of the Kamchatskii Mys Peninsula make it possible to interpret them as structures formed during the Early Paleogene interarc rifting [12, 13]. Data points of spinels and pyroxenes of the Soldatskii Massif fall into compositional fields of peridotites of the Mariana interarc trough. Moreover, the study of the ultrabasic rocks of Mt. Poputnaya in the Valagin Range (the southern Achaivayam–Valagin paleoarc) and their correlation with the ophiolite massif of the Kronotskii Peninsula (Kronotskii paleoarc) show that the ophiolites can be tectonicoutliers detached from the paleoarc base [13]. In general, the data presented in this paper testify to the existence of an interarc basin between the southern Late Cretaceous Achaivayam–Valagin arc and the Late Cretaceous–Paleogene Kronotskii island arc of eastern peninsulas.

Hence, the age similarity of island-arc sequences of the Achaivayam–Valagin terrane and the Late Cretaceous part of the Kronotskii and Govena terranes, as well as the existence of the Paleogene trough (with characteristics of an interarc basin) between the Late Cretaceous (Achaivayam–Valagin) and Late Cretaceous–Paleogene (Govena–Kronotskii) terranes, suggest the breakup of the single Late Cretaceous arc in the Paleocene and the subsequent opening of the interarc basin bounded by the remnant Late Cretaceous arc in the west and by the Paleogene active arc in the east.

The breakup of the Late Cretaceous Achaivayam–Valagin island arc could be caused by an abrupt retardation of the spreading of Pacific oceanic plates in the Paleocene. The spreading rate decreased from 120–140 mm/yr in the Late Cretaceous to 30–40 mm/yr in the Eocene. Further evolution was governed by a slow opening of the interarc basin with a corresponding displacement of the inactive Late Cretaceous Achaivayam–Valagin arc toward the continent, to which the northern and southern parts were accreted at different times. It is likely that this accretion indicates the existence of a transform fault that separated the Il'pin–Pakhacha interarc basin and Govena arc system from the Tyushe Trough and Kronotskii arc system [14].

Our model logically explains the cause of termination of the Late Cretaceous Achaivayam–Valagin arc activity prior to its collision with the continent and the parallel orientation of accreted different-age ensimatic island-arc terranes in the present-day structure. Moreover, the model can be directly correlated with the well-studied Late Cenozoic geodynamic setting in the western Pacific.

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