ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 407A, No. 3, pp. 381–384. © Pleiades Publishing, Inc., 2006.
Original Russian Text © V.D. Chekhovich, A.N. Sukhov, N.I. Filatova, V.S. Vishnevskaya, I.A. Basov, 2006, published in Doklady Akademii Nauk, 2006, Vol. 407, No. 4, pp. 512–515.

GEOLOGY

New Data on Cretaceous Volcanic Arcs of the Northeastern Asian Margin

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Presented by Academician V. E. Khain June 1, 2005

Received June 28, 2005

DOI: 10.1134/S1028334X06030081

Various models of evolution of the northwestern Pacific folded fringing during the Cretaceous were proposed in recent decades [1–3]. Almost all of them consider the Late Cretaceous geodynamic evolution of the region as spatiotemporal succession of suprasubduction structures near the eastern margin of Asia that resulted from the subduction of the oceanic crust of the spreading Pacific.

At present, the Albian–early Campanian Okhotsk–Chukotka marginal volcanic belt (OCVB) and the Campanian–Maestrichtian Achaivayam–Valaginskii ensimatic island arc, which appeared after wedging of the OCVB subduction zone [4] and accreted in the Eocene, are defined in the present-day structure of northeastern Asia. However, during fieldwork of 2001–2003, new data were obtained that suggest the existence of an autonomous Western Kamchatka arc, which developed at least since the Coniacian (probably from the beginning of the Late Cretaceous), i.e., practically synchronously with the OCVB functioning.

Upper Cretaceous complexes of western Kamchatka are exposed in erosion and tectonic windows from under the Cenozoic sedimentary cover of different converged lithostructural complexes located in the Western Kamchatka paleoplate/Late Cretaceous continental margin collision zone [5].

The Upper Cretaceous island-arc complex occupies the central position in this collision zone between the alien Albian–Campanian siliciclastic complex of the Omgon Range of the Asian margin and, presumably, the para-autochthonous siliciclastic Santonian–Maestrichtian complex on the western slopes of the Sredinnyi Range.

The island-arc complex was studied in the Irunei and Palana areas (Fig. 1). The first area is located in the central part of western Kamchatka, with the Upper Cretaceous island-arc sequences developed in the Panshetovayam (Mt. Irunei), Medvezhii, Pensantain, and also partially in the Kanych and Berloga ridges in the Tikhaya River basin. In the northerly Palana area, island-arc sequences constitute a narrow discontinuous band along the Shelikhova Bay (Sea of Okhotsk) between the Kinkil and Kakhtaninskii capes. In both areas, the complex is largely represented by tuffaceous, subordinate volcanic (Palana area), and siliceous–tuffaceous rocks that are notably different in lithology.

In the Irunei area, volcanics are represented by basalt–andesite–dacite–rhyolite tuffs and dikes. Dominant mafic members of this tholeiitic-type association are highly ferruginous. The dacite–rhyolite rocks constituting approximately 20–30% of effusive varieties belong to the calc-alkaline series and are presumably considered as derivatives of crustal melts. As is known, the elevated share of intermediate and acid volcanics points to an ensialic trend in the island arc development [6], which is evident from the Th/Yb–Ta/Yb diagram compiled for intermediate and acid rocks (Fig. 2a). Data points of tuffs and dikes of the dacite–rhyolite composition in the Mt. Irunei area and Tikhaya River basin fall into the field of volcanic arcs with thickened crust.

The Palana area of the Western Kamchatka arc (WKA) is characterized by calc-alkaline basaltic andesite volcanism that was subsequently replaced by basaltoid absarokite–shoshonitic volcanism related to tension and rifting superimposed on the island-arc setting (Fig. 2b).

Thus, lithology and geochemistry of volcanics imply formation of the island-arc complex on the thickened crust. Taking into consideration the structural position of the complex, we believe that the WKA formation area corresponded to the western margin of the Kamchatka continental block. We assume also that the subduction zone dipped eastward.

Previously, siliceous–volcanogenic sediments of the WKA complex were dated by inoceram fossils back to

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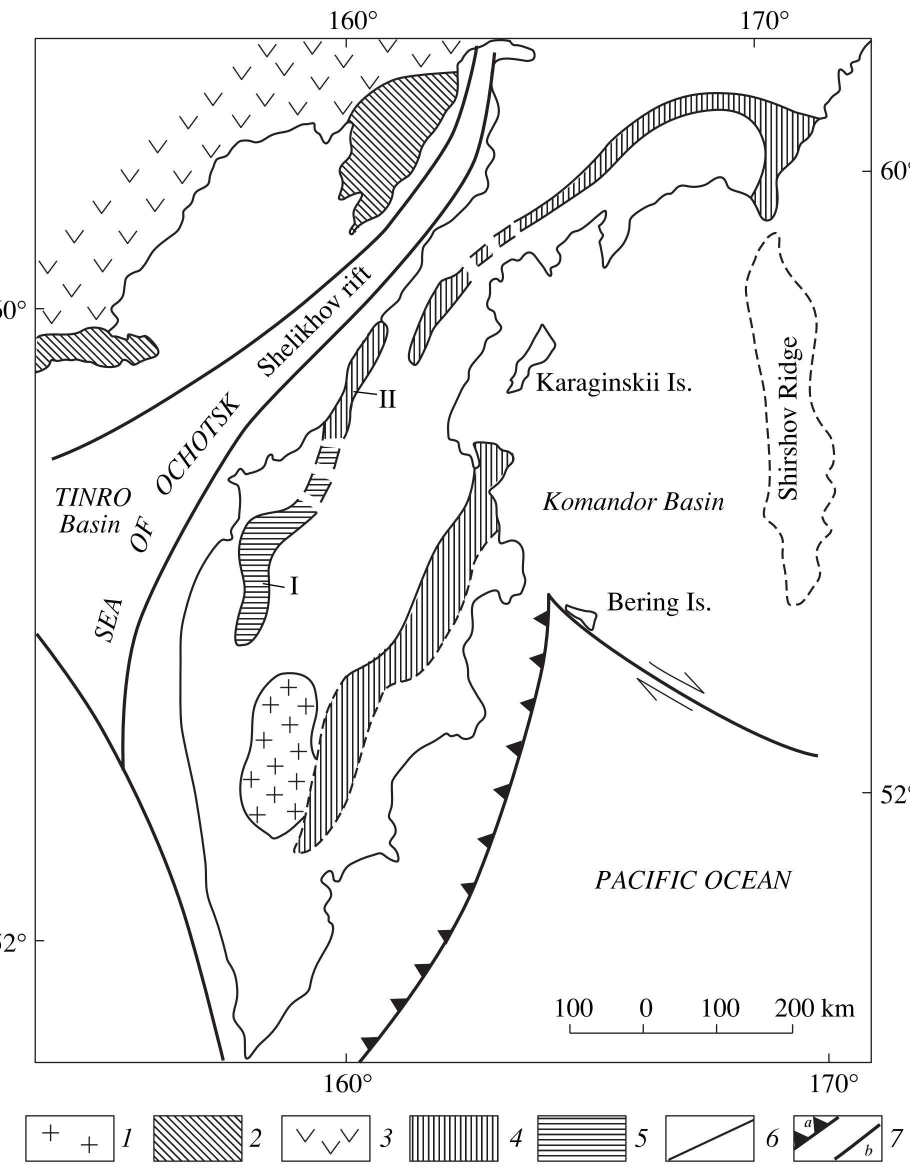

Fig. 1. Schematic distribution of suprasubduction complexes in the eastern margin of Asia. (*1*) Metamorphic complexes of the Sredinnyi Range of Kamchatka; (*2*) Kuyul–Taigonos fold zone (Upper Jurassic–Lower Cretaceous); (*3*) Okhotsk–Chukotka volcanic belt (Albian–lower Campanian); (*4*) Achaivayam–Valaginskii island arc (Coniacian–Lower Paleocene); (*5*) Western Kamchatka island arc (Coniacian–Santonian); (*6*) major faults; (*7*) boundaries between lithospheric plates: (*a*) subduction, (*b*) transform. Numbers in the map: (I) Irunei area, (II) Palana area.

the Santonian–Campanian [10]. The study of microfossils extracted chemically from siliceous rocks using hydrofluoric acid provided data on the older age of the complex. Of importance is the cooccurrence of radiolarians and planktonic foraminifers in some samples. Their examination allowed us to specify the age of the complex and restrict it by the Coniacian–Santonian interval (89–83 Ma). The most diverse foraminiferal and radiolarian assemblages were derived from siliceous rocks sampled near the Palana River mouth [11]. The foraminiferal assemblage consists largely of Coniacian–Santonian planktonic forms *Archaeoglobigerina* aff. *bosquensis* Pessagno, *Hedbergella delrioensis* (Carsey), *H. holmdelensis* Olsson, *Heterohelix globulosa* (Ehrenberg), and *Globigerinelloides ultramicra* (Subbotina). The radiolarian assemblage from the same samples includes *Archaeospongoprunum bipartitum* Pessagno, *Crucella plana* Pessagno, *Pseudoaulophacus praefloresensis* Pessagno, *Lipmanium? sacramentoensis* Pessagno, *Dictyomitra urakawaensis* Taketani, *D. densicostata* Pessagno, and *Amphipindax ellipticus* Nakaseko et Nishimura, which are also characteristic of the Coniacian–Santonian.

The coeval and compositionally similar foraminiferal and radiolarian assemblages were found also in the Pyatibratskii Cape and Kinkil Cape areas.

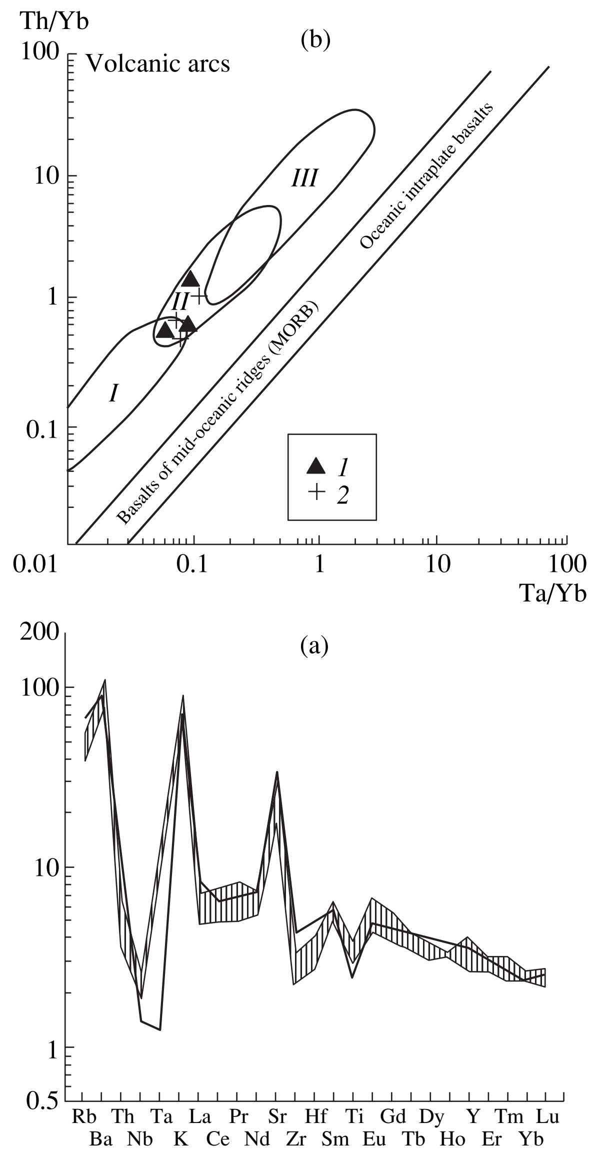

Fig. 2. Geochemical characteristic of Upper Cretaceous volcanics of the Western Kamchatka island arc (Panshetoyam Range, Mt. Irunei, Tikhaya River): (a) Th/Yb vs. Ta/Yb diagram for intermediate and acid rocks of the Irunei area (with the diagram from [7]): (*1*) dacite–rhyolite tuffs, (*2*) subvolcanic dacite–rhyolite intrusions; compositional fields: (*I*) Tonga–Kermadec, Idzu–Bonin, (*II*) Mexico, Alaska, Japan, Greece, (*III*) Andes; (b) spidergram of PM-normalized trace element contents [8] in high-K basalts (absarokites) of the Palana area (hatched field); for comparison, the composition of absarokite from the Tavua Volcano, Fiji Island [9] is shown (solid line).

New dates were also obtained for island-arc rocks of the Mt. Irunei area (central part of western Kamchatka). The radiolarian assemblage from siliceous rocks of the Panshetoyam Range (Mt. Irunei) is represented by *Alievium* cf. *superbum* (Squinabol), *Archaeospongoprunum bipartitum* Pessagno, *Pseudoaulophacus* aff. *floresensis* Pessagno, *Orbiculiforma (?) septiterna* Pessagno, *O.* ex gr. *persenex* Pessagno, *Dorypyle* cf. *ovoidea* (Squinabol), *Dictyomitra densicostata* Pessagno, *Archaeodyctiomitra squinaboli* (Pessagno), *Stichomitra* cf. *livermorensis* (Campbell et Clark), *S. manifesta* (Campbell et Clark), and *Amphipyndax stocki* (Campbell et Clark) var. A Vishnevskaya.

A taxonomically similar radiolarian assemblage was established in light green laminated siliceous rocks in the middle reaches of the Tikhaya River.

The upper members of the island-arc complex are mostly dated by radiolarians back to the Campanian or, less commonly, Campanian–Maestrichtian. This fact makes the western Kamchatka sections different from their eastern Kamchatka and southern Koryak counterparts, where Maestrichtian and Paleocene radiolarian and foraminiferal assemblages are widespread in volcanogenic–siliceous formations.

Coaliferous molasses of the Lower Paleocene Khulgun and Sosopkhan formations and Lower Eocene Napan Formation in the central western Kamchatka, as well as the Paleocene Anadyrka and Getkelnin formations of the northern coastal area, serve as a neoautochthon for the allochthonous Coniacian–Santonian island-arc sequences. The composition of conglomerate-hosted pebbles from these Lower Paleogene formations of the neoautochthon indicate erosion of the siliceous–volcanogenic island-arc complex. Thus, thrusting of the Coniacian–Santonian island-arc sequences should terminate by the end of the Maestrichtian.

The important aspect of the inference on the Coniacian–Santonian age of Western Kamchatka island-arc sediments is their synchronism with the OCVB formation. The belt is of pivotal significance because it formed immediately on the continental margin of Asia in the course of subduction of the oceanic or, probably, marginal sea plate beneath the continental margin. Although the timing of the OCVB is debatable [12–14], geological and paleofloral studies [15], as well as chronostratigraphic data [12], indicate its late Albian–early Campanian age. When comparing activity phases in the OCVB and western Kamchatka development, one should keep in mind that the oldest rocks of the island arc are unexposed and the Coniacian–Campanian age is probably determined only for some part of its section.

Thus, the data obtained suggest the synchronous development of two suprasubduction structures at the northeastern margin of Asia in the Cretaceous. The first structure (OCVB) formed immediately on the continental margin, while the second structure (Western Kamchatka island arc) developed along the western margin of the Kamchatka microcontinent. The third Late Cretaceous structure (Achaivayam–Valaginskii island arc) developed in a far southern area away from the Kamchatka microcontinent and collided with the microcontinent only in the Early Eocene.

The proposed model revises the concept of successive development of volcanic arcs in the northwestern Pacific during the Cretaceous and their accretion to the continental margin. According to this model, two volcanic arcs developed synchronously along the active margin of the Asian continent. The Okhotsk–Chukotka belt was immediately superimposed on its margin, whereas the Western Kamchatka island arc formed along the western margin of the Kamchatka continental block.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (project nos. 04-05-64025 and 05-05-64917) and the Foundation of the President of the Russian Federation for the support of Leading Scientific Schools (project no. NSh-1980.2003.5).

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