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Bureya-Jiamusi Superterrane: Tectonic and Geodynamic Processes in Late Mesozoic - Cenozoic

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Abstract

Bureya-Jiamusi superterrane (BJS) is a component of the Amur plate. This is one of the most complex and controversial structures of the eastern Asia. The bulk of the “body” superterrane is located in China, where it is actively researched by the Chinese scientists. The northern border of the structure is directly on the territory of the Amur region and is defined by the boundary of the Mongol-Okhotsk orogenic belt. By Parfenov, the superterrane is bordered by the Paleozoic-early Mesozoic orogenic belts and the North China plate. But there are other ideas about the spatial location of the BJS. All the suggested geodynamic reconstructions of the studied region take into account the interdependence between North-Asian and China-Korea plates and plates of the Pacific basin oceanic crust. The suggested work attempts to show the dependence of the evolution of the Bureya-Jiamusi superterrane on the surrounding geological objects in the late Cretaceous-Cenozoic interval.

Keywords: tectonic, geodynamic, Bureya-Jiamusi superterrane, Mongol-Okhotsk orogenic belt, late Mesozoic, Cenozoic

1. Introduction

Bureya-Jiamusi superterrane is a component of the Amur plate [10, 11, 24, 25, 33]. It is situated in the southern frames of Mongol-Okhotsk orogenic belt, which was formed as a result of closure of Mongol-Okhotsk orogenic belt. The structure of the Mongol-Okhotsk orogenic belt, closure time of the basin and, correspondingly, so is the structure-tectonical situation of the framing structures at that moment have no certain definition by the scientists. One of the most difficult and debatable structures of the region is Bureya-Jiamusi superterrane. A significant part of the superterrane body is situated in the territory of China, where it is actively studied by the scientists of the country [2, 12, 14, 19, 20, 39, 42, 44–47].

The northern border of the Bureya-Jiamusi superterrane is situated directly at the territory of Amur region (Russia) and correlates with its border with Mongol-Okhotsk orogenic belt [26]. According to [25], superterrane borders with Paleozoic early Mesozoic orogenic belts on west and south: South Mongol-Khingian, Solonker, Wundurmiao and China-Korea plate (Figure 1). The Bureya-Jiamusi superterrane situation by [19] is the same as by [25].

As the author states [19], the southern border of superterrane is cut by Suolunshan-Central Jilin orogenic belt, which is an intermediate suture between the superterrane and the China-Korea plate. Li [19] suggests that Solonker orogenic belt includes the Bureya-Jiamusi superterrane in its structure. But there are also other ideas of the location of the Bureya-Jiamusi superterrane (Figure 1).

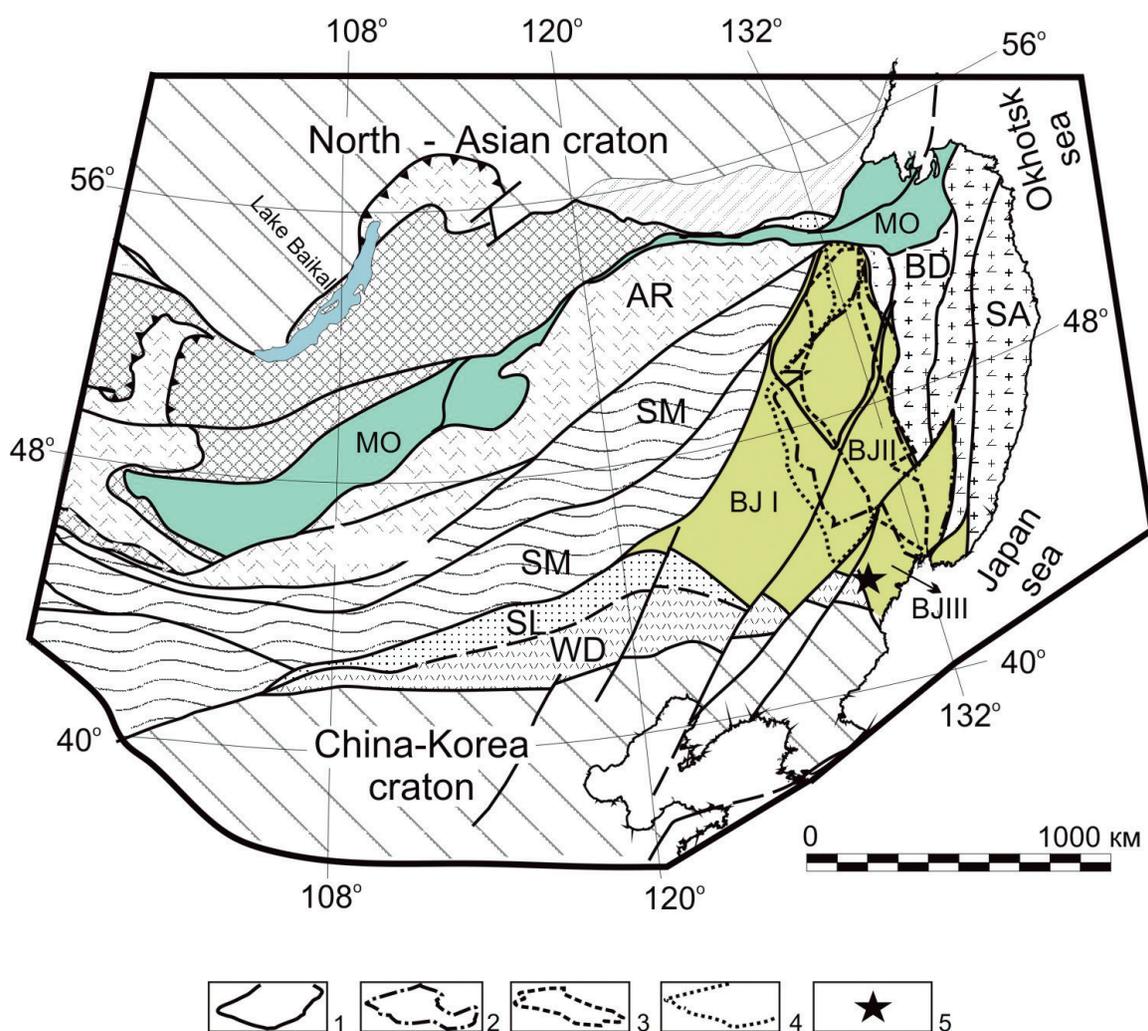


Figure 1. Scheme of the structurally tectonical composition of the Mongol-Okhotsk orogenic belt and its southern framing according to [25]. BJ – Bureya-Jiamusi superterrane and its forming terrains: I – Bureya, II – Jiamusi, III – Khanka. The outlines of the Bureya-Jiamusi superterrane are according to the data: 1 – [12]; 2 – [43]; 3 – [39]. 4 – The outline of Mudanjianiang belt is according to the data [31]. Adacitic fields with age 55.5 Myr are according to the data [2] – 5. Other alphabetic designations: MO – Mongol-Okhotsk orogenic belt, AR – Argun superterrane, SM – South Mongolian-Khingian orogenic belt, SL – Solonker orogenic belt, WD – Wundurmiao orogenic belt, BD – Badzhai terrain, SA – Honsu-Sikhotealin orogenic belt.

According to the idea, the spreading of the superterrane formations is significantly limited in the southwest direction [2, 12, 14, 20, 39, 40]. The author of the suggested article attempts to analyze the geodynamic processes in late Mesozoic-Cenozoic time, which could affect the structure-tectonical formation of Bureya-Jiamusi superterrane.

2. Geological structure of the Bureya-Jiamusi superterrane

It is considered that the Bureya-Jiamusi superterrane is formed with the comparable in geological structure terrains (**Figure 1**): I – Bureya, II – Jiamusi, III – Khanka [16, 25–27].

Previously, it was stated that the foundations of these terrains are the metamorphic complexes of the Archean-Proterozoic [17, 22]. But at this time, data on the age of protoliths of metamorphic rocks of these complexes are obtained.

According to the data, the formation of the foundation occurred not earlier than late Proterozoic. Superimposed structural-metamorphic transformations are connected not with the Precambrian events but are the result of processes that occurred in the territory of Bureya-Jiamusi superterrane in Paleozoic-Mesozoic [34, 35, 40, 41].

Significant part of the Bureya-Jiamusi superterrane territory (more than 50%) is built with granitoids of Paleozoic age [17].

It is believed that the Paleozoic granites along with Devonian, Permian, and Silurian volcanogenic and terrigenous formations played a “stitching” and overlapping role in the structure of the studied terrains.

They built up more ancient formations. In turn, they were blocked and injected with Mesozoic rocks (Triassic and Cretaceous) [16]. According to the research results of the biota characteristics from terrigenous deposits of early Mesozoic (Triassic-Jurassic) of Bureya-Jiamusi superterrane, it was stated that the rocks were formed in the sea basin under conditions of significant climate changes. Such changes are characteristic of mid-latitude [21]. The formations of the Sikhote-Alin terrains that are the neighboring territory at the east were formed under tropical conditions of the marine environment of low latitudes. With all that, it was shown that the sedimentation accumulation of the rocks occurred in the single oceanic basin [21]. As the authors consider, the fact is “an important, evidence in favor of the interpretations, according to which, a number of Sikhote-Alin terrains, experienced large-scale displacement in the northern direction” [21]. Shallow marine sediments, which are replaced by coarse continental material, begin to form in Jurassic. The end of Jurassic is marked with magmatic activity in the region.

3. Stages of magmatic activity in the Bureya-Jiamusi superterrane territory

On the territory of the Bureya-Jiamusi superterrane, the continental volcanism correlates with the fore time periods: trachyriolitic complex was formed in the interval of the end of

Jurassic—135–136 Myr; the formation of calc-alkaline complexes of rocks of andesite composition occurred at 120–105 Myr. One of the complexes is a fragment of the island arc which is preserved along the border of Mongol-Okhotsk orogenic belt on Russian territory (**Figure 2**) [7]. The formation of an intraplate volcano-plutonic complex of rhyolites-alkaline trachydacites and their plutonic comagmatites occurred 101–99 Myr [3]. According to the geochronology data, the beginning of the fourth stage can be counted since 56 Myr till our time, practically. Impulsive outpouring of volcanites, predominantly of basic composition, occurs from this moment [2, 16].

3.1. First stage: late Jurassic to 135 Myr

The beginning of the magmatic activity of late Mesozoic is marked with the formation of trachyriolite volcanic complex. These are the rocks of Itikut complex located on Russian territory. It is represented by stratified volcanogenic-terrigenous formations and subvolcanic bodies [4, 16, 22]. Stratified formations perform rift-like depressions in the north–north eastern direction. The lower part of the cut is made with tuff terrigenous rocks. Belonging of the acid volcanites to the intraplate post-collisional formations is confirmed by petro-geochemical features of the rocks [4].

According to the findings of macro- and micro-palaeoflora from the tuff-terrigenous part of the section of the cover part of the complex, the time interval might be stated as the end of Jurassic-Hauterivian [16]. The age of the volcanites of the Itikut complex is 135–136 Myr ($^{40}\text{Ar}/^{39}\text{Ar}$ method) [37] by the geochronological data. According to these data, the time of the Itikut complex rocks formation was accepted as the end of the Jurassic—135 Myr.

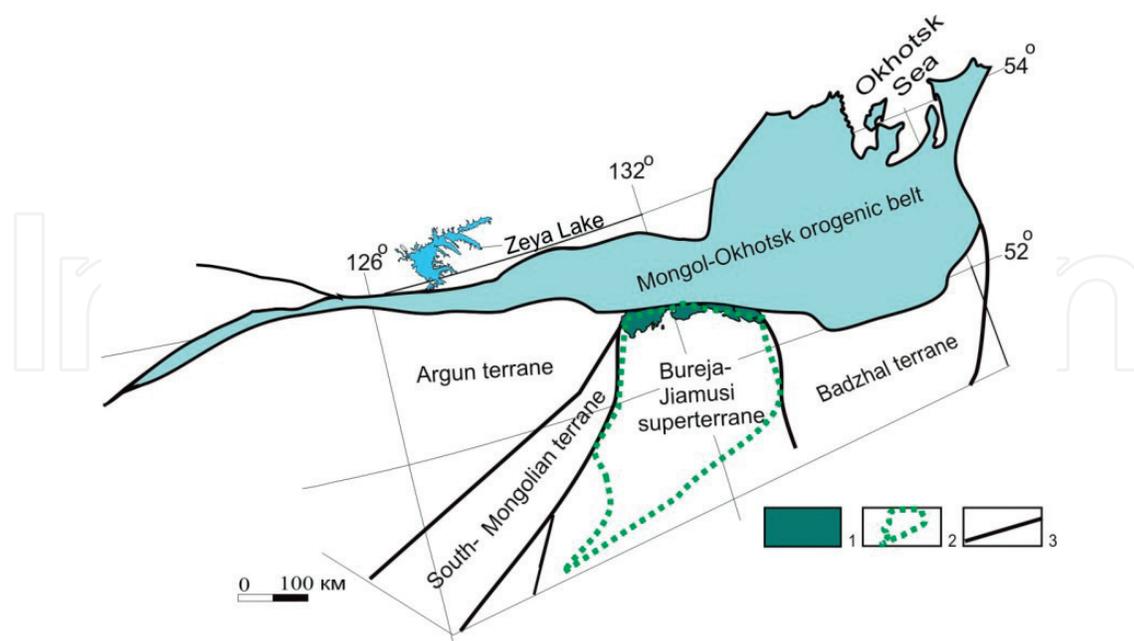


Figure 2. Spatial position of the rocks of the volcano-plutonic Burunda complex, according to the data [7] and Mudanjianiang magmatic belt, according to data [31]. The rock of the Burunda volcano-plutonic complex—(1). Outline of the northern flank Mudanjianiang belt—(2). Tectonic boundaries—(3).

3.2. Second stage: 120–105 Myr

The most widely spread volcanic complexes are of andesite composition and were formed 120–105 Myr. Geochronological data on volcanites and plutonic comagmates of the complexes correspond to the 118–105 Myr interval [2, 5]. Considering the stage of the accumulation of tuff-terrigenous coagulation at the base of stratigraphic sections of these complexes and the presence of fossil biological remains of Aptian age in the sediments, the time interval of the rock forming of the complexes is stated as 120–105 Myr [5]. Three volcanic complexes of this age have been identified on Russian territory: Pojarka, Stanolir, and Burunda [5, 16]. Rocks of Burunda complex correspond to island-arc formations by the petrochemical and geochemical characteristics [7].

It can be stated that the island arc was formed in late Mesozoic along the northern margin of superterrane (on the border with the Mongolo-Okhotsk orogenic belt in modern coordinates). Nowadays, it represents a fragment of the island arc that lies at a significant depth (about 3000 km) of the coastal-marine sediments [5, 7] (**Figure 2**). Concerning this, highlighting of the Mudanjianiang belt is of interest in the region of the Burunda rock complex island-arc development (**Figure 1**).

Age data of the Mudanjianiang belt rocks are ambiguous, which is shown by the researchers [43]. But the authors state that these formations are the analog of Burunda volcano-plutonic island-arc complex. The age interval of formation for the magmatites of Burunda complex is stated by the precision ($^{40}\text{Ar}/^{39}\text{Ar}$, Rb-Sr) methods as 111–105 Myr [5].

The volcanic formations aged 118–105 Myr are widely developed within the Jiamusi terrain in China [2]. The authors subdivide the rocks into four formations here: Tuntianying – 118–116 Myr, Sanxianling – 117–115 Myr, Huoshanyan – 108 Myr, Jingouling – 106 Myr. The affinity of these formations with the rocks of the volcanic complexes listed above that was studied in the territory of Bureya terrain (Russia) and is not only limited by age compatibility. This is confirmed by their petro- and geochemical affinity. The volcanites of the Jiamusi terrain are also moderately enriched in Sr, Zr, Hf, Ti, Y, REE and depleted in Ta and Nb according to [2].

3.3. Third stage: 101–99 Myr

The third stage of the history of geological development of the Bureya-Jiamusi was the shortest one. Apparently, some catastrophic events took place at that period. They evoke the formation of the volcanic-plutonic complex of rhyolites-alkaline trachydacites (Solonechny). The complex is represented with the rocks of the cover, vent, subvolcanic facies and plutonic comagmates. They are depleted in Ba and Sr. and are enriched in Rb, Th, Nb, Hf, and Zr. The age of the volcanites determined by the $^{40}\text{Ar}/^{39}\text{Ar}$ method is 99–101 Myr [8, 36], which corresponds to the alb.

3.4. Forth stage: 56 Myr to Cenozoic

In the interval 99–56 Myr, the territory of Bureya-Jiamusi superterrane is in a state of rest; in fact, it is a platform where coarse clastic terrigenous deposits accumulate. Impulsive outpouring of volcanites, predominantly of basic composition, occurs about 56 Myr ago and, in

fact, up to our time—260 years ago (bass Nemanhe river—mineral spring Udalyanchi, China). Herewith, typical adakites were formed in the frames of the southern flank of the superterrane—on the border with the orogenic belt of Wundurmiao [2]. The age of adakitic rocks is 55 Myr. All the following magmatites (less than 20 Myr) correlate with the intraplate formations by their geochemical characteristics.

4. Tectonic position of the Bureya-Jiamusi superterrane

Ideas about the location of the Bureya-Jiamusi superterrane in the Late Mesozoic-Cenozoic are quite various. Thus, according to [33] the joining of Bureya-Jiamusi superterrane to Argun superterrane (through South Mongolian-Khingian belt or Sungliao block according to the views of the Chinese geologists) occurred in the second half of Paleozoic. It accreted to the Chinese-Korean craton in late Permian [46]. And later, being a part of Amur plate, together with the Chinese-Korean craton, superterrane moved north and accreted to Siberian platform, forming Mongol-Okhotsk orogenic belt and provoking closure of Mongol-Okhotsk basin. Different authors suggest various time stages of the process of the basin closure: in the early Cretaceous [32], in the Late Jurassic [46], or at the end of the Paleozoic [26].

It is known that the union of large geological objects, as a rule, is accompanied (fixed) by magmatic manifestations. The following stages of volcanic activity are set for the northern flanks of the Argun superterrane and the South Mongolian-Khingian (Sunglao) orogenic belt: 147–138 Myr—volcano-plutonic complex of adakite granites—trachyriolites; 140–122 Myr—differentiated calc-alkaline volcano-plutonic complex; 119–97 Myr—bimodal volcano-plutonic complex; 94-cognac (88?)—absarokite-trachyandesite intraplate [3, 6, 37]. Absolutely other age sequence of Bureya-Jiamusi superterrane magmatic activity is noted in late Mesozoic.

In the author's opinion, the final closure of the Mongolian-Okhotsk basin occurred in the interval 119–97 Myr and was accompanied by the formation of bimodal volcano-plutonic complexes in the frames of the Mongolo-Okhotsk belt [3]. So far, it can be stated that an entirely different age sequence of magmatic activity is noted in the late Mesozoic within the Bureya-Jiamusi superterrane. And the magmatites formed at the same time have disparate material characteristics with late Mesozoic volcanites of the Argun superterrane and the South Mongolian orogenic belt. The fact that the closure of Mongol-Okhotsk orogenic belt was accompanied by the formation of riftogenic structures in its frames, made by the bimodal complexes formations, is confirmed by the evolution of the western flank of the Mongol-Okhotsk orogenic belt [1]. The absence of bimodal complexes in the territory of Bureya-Jiamusi superterrane [4, 5] can be an evidence of the fact that the studied superterrane did not participate in the closure of the Mongol-Okhotsk basin, that this geological object represented an independent structure in the late Mesozoic.

The idea of the tectonic boundary of the Bureya-Jiamusi superterrane with the Badzhal and Honshu-Sikhotealin orogenic belts is almost unambiguous for all authors. And the ideas of the researchers of the eastern structures and the Bureya-Jiamusi superterrane collision time, which fits into the interval 155–125 Myr [16], are close.

5. Geodynamic evolution of the Bureya-Jiamusi superterrane

The Bureya-Jiamusi superterrane tectonic development scheme for the territory of China was developed back in 1994 by Liu Zhaojun with co-authors [47]. According to this scheme, the stretching prevailed in the region in late Jurassic-early Chalk. It was triggered by changes in the movement of the Izanagi oceanic plate. As a result, rift-like structures were formed about 135 Myr ago. These structures were filled with coal-bearing precipitates and volcanites of acid composition. In the territory of Russia, within the Bureya-Jiamusi superterrane, a similar volcanic complex with an age of magmatic component of 136–135 Myr [4, 37] is formed during this period. The territory of Bureya-Jiamusi superterrane represented a passive continental margin and, probably, was at rest approximately 135–120 Myr. According to palinspastic reconstructions (Bretshtein and Klimov [16] and Didenko with coauthors [9]), Bureya-Jiamusi superterrane was an independent geological body during this period. It drifted on the Izanagi oceanic plate in the northwestern (close to northern) direction with a speed of 30–20 cm per year [23]. Magmatic activity occurred throughout the territory of Bureya-Jiamusi superterrane during the interval of 120–99 Myr actually [4, 5, 30, 38].

According to the palinspastic data of Bretshtein and Klimov [16], the Bureya-Jiamusi superterrane accretion to the Badzhal terrain occurred in post-Jurassic. It was shown that the formation of volcanites with geochemical marks of the suprasubduction type took place 120–105 Myr [2, 4, 5, 7]. Based on the data, it can be assumed that the subduction processes covered almost the entire territory of the Bureya-Jiamusi superterrane during this period. We can consider the following as one of the possible tectonic scenarios: subduction processes are caused by the displacement of a younger and, therefore, more plastic Badzhal terrain to older formations of the Bureya-Jiamusi superterrane, which has more power and rigidity.

What was the cause of this? According to paleomagnetic definitions [23], the Izanagi plate reversed its direction from north-west to northeast 119 Myr. And although the angle of rotation was insignificant, and the speed changed by only 0.6 cm per year (from 21.1 to 20.5 cm/year), it could be enough for the interaction of these geological objects to occur. Proceeding from such a tectonic scenario, the next stage of magmatic activity will be more understandable. Catastrophic events that were accompanied by the formation of an intraplate volcano-plutonic complex of acidic-alkaline rocks at the contact of Bureya-Jiamusi superterrane and Badzhal terrain occurred about 101–99 Myr [8, 36]. Therefore, it is assumed as the most likely scenario, that during the subduction process a sharp break (breakage) and a plunge of the slab of Badzhal terrain into the asthenospheric “window” occurred. This was, naturally, accompanied by an active and short-term formation of the rocks of the intraplate volcano-plutonic complex [4, 8, 36] (**Figure 3**).

According to paleomagnetic data, for the main tectonic units of the Far East south [16] in the Jurassic-Neogenic interval, the Bureya-Jiamusi superterrane was at a very considerable distance from the continental margin of Asia. Similar research works [18] prove that the width of the Mongolo-Okhotsk paleobasin in the late Jurassic was about 3000 km. Paleomagnetic

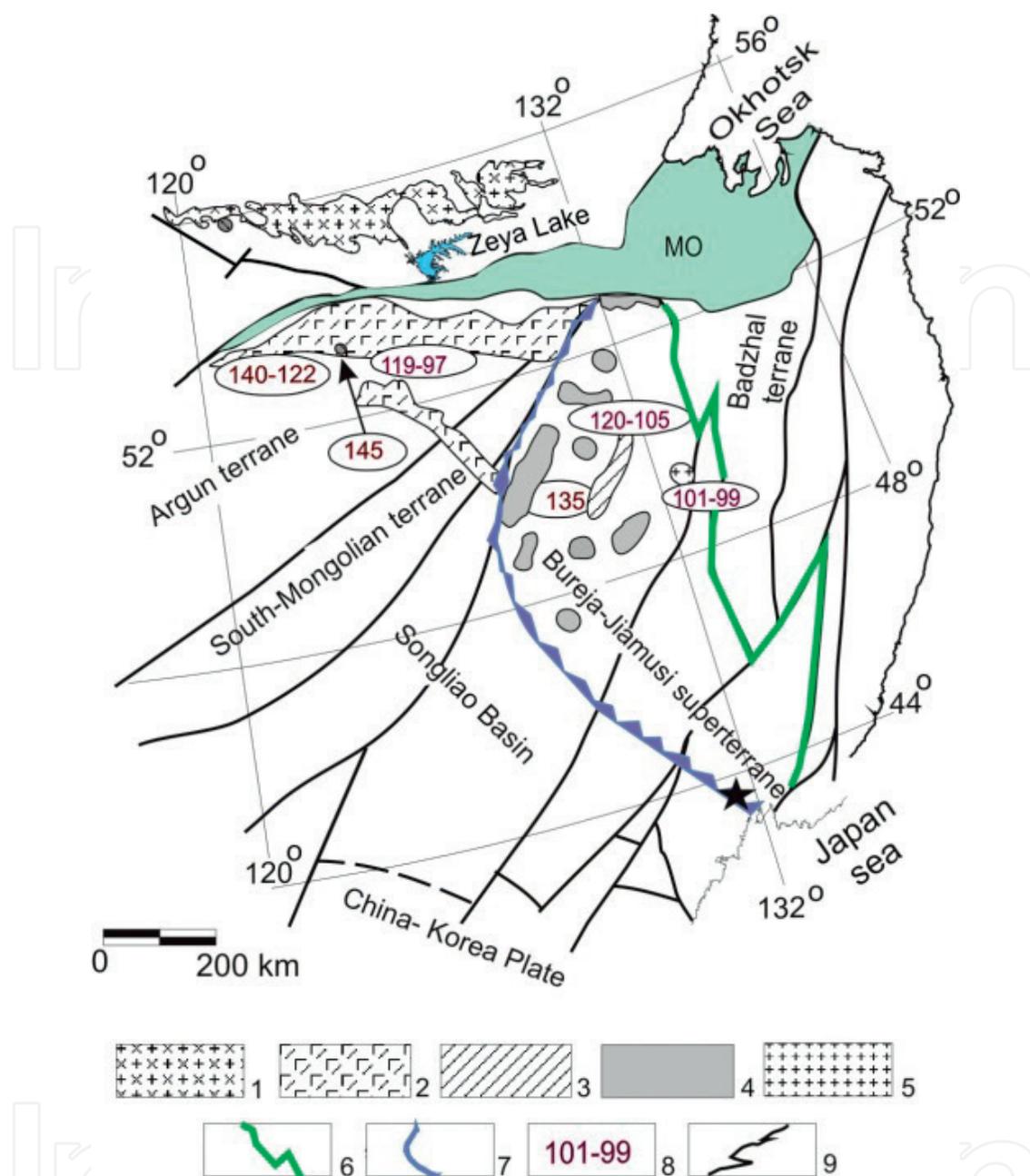


Figure 3. Hypothetical scheme of the spatial position of the Bureya-Jiamusi superterrane, compiled from original data and materials [2, 12, 25, 31, 39, 43]. Areas of distribution of rocks of late Mesozoic volcano-plutonic complexes: (1–2) differentiated and bimodal: mainly plutonic (1), mainly volcanic (2); volcano-plutonic complexes of Bureya-Jiamusi superterrane; (3–5) with the late Jurassic age—135 Myr (3), 120–105 Myr (4), 101–99 Myr (5). The boundaries of superterrane (6–7): subduction boundaries (6), transforming boundaries (7). Age of the magmatic rocks (8). Other tectonic boundaries (9).

determinations for the terrains of the Sikhote-Alin orogenic belt structures bordering the superterrane from the east [9, 28, 29] showed that they were much more south of the 30th parallel 123 ± 22 Myr. All this confirms the assumption that Bureya-Jiamusi superterrane was located at a considerable distance from its current location and was an independent geological object in late Mesozoic. Any magmatic activity in the Bureya-Jiamusi superterrane is absent (not established) in the interval 99–56 Myr.

Most likely, the drift of a collage of terrains, now, according to the motion of the ocean plate Izanagi, occurred in this period. The Izanagi plate moved to the northwest at a speed of 23.5 cm per year, and then in the western direction (85–74 Myr) at a speed of 20.2 cm per year [23] during 100–85 Myr time period. It can be assumed that this movement continued until the final joining of the Bureya-Jiamusi superterrane to the eastern edge of the Asian continent. If we accept the fact that tectonic rearrangements are usually accompanied by magmatic events, it can be stated that its accession to the east of the Asian continent took place approximately 56–55 Myr. This is confirmed by the appearance of adakite fields in the accretion place of the Bureya-Jiamusi superterrane and the orogenic belt of Wundurmiao and the China-Korean plateau (**Figure 1**) aged 55.5 Myr [2].

Mesozoic adakite granitoids and their volcanic analogs are identified and studied during the last decade in such regions as Romania, Turkey, Korea, East, and Southwest China. According to the generalized analysis of petro- and geochemical characteristics, these rocks are associated with subduction processes [13].

Complex tectonic rearrangements comparable to the transformational situation of the Californian type occurred when the Bureya-Jiamusi superterrane collided with the continental margin of Asia [15]. Surely, the subduction moments were present among the processes accompanying the transformational interaction of the two continental margins. And farther, the pulsation outflow of lavas of the main-medium composition with increased alkalinity and geochemical characteristics of intraplate magmatism [4] takes place actually up to now.

6. Conclusion

All the suggested geodynamic reconstructions of the studied region take into account the interdependence between North-Asian and China-Korea plates and plates of the Pacific basin oceanic crust [16]. The suggested work attempts to show the dependence of the evolution of the Bureya-Jiamusi superterrane on the surrounding geological objects in the late Cretaceous-Cenozoic interval. As a result of the analysis of the original and extensive literature, it is suggested that magmatic activity—its manifestations and activity changes—in the Bureya-Jiamusi superterrane territory correlates quite well with the geodynamic events occurring in the late Mesozoic-Cenozoic, not only on the continental margin of Asia but also within the evolution of oceanic plates of the Pacific basin (plate Izanagi). Comparison of the time stages, material composition, and tectonic positions of the Bureya-Jiamusi superterrane in this time interval indicates its belonging to the structures of the Pacific mobile belt.

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