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The Structure of the Mongol-Okhotsk Fold Belt and the Problem of Recognition of the Amur Microcontinent

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Abstract—The paper presents a new understanding of the geologic composition and geodynamic evolution of the Mongol–Okhotsk Fold Belt. It considers the issues related to recognition and substantiation of the Amur composite microcontinent (Amuria superterrane). We analyze the latest data on the geologic composition, age, and paleomagnetism of the Neoproterozoic–Paleozoic complexes, such as the Argun terrane and neighboring structures of Transbaikalia and Mongolia, as one of the key elements of Amuria. In particular, we have refined the age of a number of Precambrian and Paleozoic stratified and magmatic stages and demonstrated the absence of an Archean–Paleoproterozoic crystalline basement. Using a set of our own paleomagnetic and paleontological data, we have substantiated the equatorial position of the Argun terrane in the close proximity to Siberia at 560–525 Ma. The results of our study and the performed analysis of available geological data on the Argun terrane and neighboring Transbaikalia and Southeastern Asia territories point to the fallacy of previous arguments about the Amur composite microcontinent as a single tectonic unit, whose collision led to the formation of the folded structures of the Mongol-Okhotsk belt. This conclusion is of crucial importance for reconstructing the geodynamic evolution of the eastern part of the Central Asian Fold Belt in the Neoproterozoic, Paleozoic, and Mesozoic.

Keywords: Neoproterozoic, Vendian, early Cambrian, paleomagnetism, sedimentary basin, paleotectonic reconstruction, Mongol-Okhotsk fold belt, Amur microcontinent, Argun terrane, Siberian paleocontinent

INTRODUCTION

The Mongol-Okhotsk Fold (Orogenic) Belt (MOFB) was put on the map by Academician A.E. Fersman in 1926 and it is a set of mosaic structures that extends for 3000 km covering the distance from Central Mongolia over Transbaikalia, eastern Mongolia and the Amur River region to the Sea of Okhotsk. There have been so far several tectonic classifications suggested for this territory (Kuzmin and Fillipova, 1979; Zonenshain et al., 1990; Sengör et al., 1993; Belichenko et al., 1994; Gordienko, 1994, 1996, 2001; Parfenov et al., 1996, 1999, 2003; Zorin et al., 1998; Gordienko and Kuz'min, 1999). However, most researchers agree that the MOFB represents a complex composition of terranes different in age and geodynamic nature, which continues the analogous in composition Paleozoic formations of the Central Asian Fold Belt (CAFB) to the southeast, where it connects with the Mesozoic–Cenozoic orogenic structures of the Western Pacific margin (Sikhote-Alin belt, etc.).

A significant part of the MOFB or of its southeastern margins is commonly regarded as the Amur microcontinent that was first determined in the course of global Ordovician–Silurian and Devonian–Carboniferous reconstructions by L.P. Zonenshain et al. (Zonenshain and Gorodnitskii, 1977; Zonenshain et al., 1987). The microcontinent (later called Amuria superterrane) includes the Central Mongolian, Argun, Khingan–Bureya massifs as well as neighboring massifs with supposedly early Cambrian crystalline basement, whose tectonic history was isolated from the one of Siberia up to the end of the Permian (Zonenshain et al., 1990; Parfenov et al., 2003; Golonka et al., 2006). The first tectonic classifications assumed Amuria was a single superterrane that had been composed of ancient pieces during the Cambrian or even earlier (Zonenshain et al., 1990). Taking into account the wide development of carbonate rocks, one also assumed it could possibly be related to the North China or Tuva-Mongolian continents located at a significant distance from Siberia. Nevertheless, most early Paleozoic reconstructions, as a rule, do not contain any elements of Amuria (Zonenshain et al., 1990), while the late Paleozoic reconstruction of the Central Mongolian (including Argun) and Khingan-Bureya massifs are marked as independent microcontinents that, together with Kazakhstan, form large elevations inside the Paleoasian Ocean (PAO) between the continental margins of Siberia and North China (Zonenshain

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et al., 1990). The theory was that the gradual approaching of the microcontinents and Siberia led to their collision into the island arc of southern Mongolia to from a big accretionary belt embracing the Hercynian structures of the Gorny Altai, Mongolian Baidarag and Central Mongolian terranes, Transbaikalian Argun massif and its bordering Gonzha, Mamyn and Khingan-Bureya massifs of the Southeastern Asian margin. These pieces formed a single element that was named by L.P. Zonenshain et al. (1990) as the Amur composite microcontinent (superterrane).

The scientific strength of this theory was doubted by V.E. Khain and K.B. Seslavinskii (1991), who pointed out that the suggested "… dispositioning of Amuria's continental blocks is inappropriate since its late Carboniferous geological data made it a whole with Southern Siberia…" (pp. 294–295), which disproved any theories about the Amur microcontinent as an independent tectonic unit that could exist in neither the late Precambrian nor in the Paleozoic (Khain and Seslavinskii, 1991). Nevertheless, the late Paleozoic reconstructions that follow those by L.P. Zonenshain et al. depict Amuria either as a gigantic island or a peninsula that lays at a significant distance from Siberia's margin and goes deep into the ocean, bordering a significant water basin that was called the Mongol-Okhotsk Ocean (MOO) (Parfenov et al., 2003; Golonka et al., 2006). The boundary closed due further approaching of Amuria and the Siberian Craton that embraced the marginal Caledonian and Hercynian structures of western Transbaikalia and northern Mongolia (Zonenshain et al., 1990; Gordienko, 1994, 1996, 2001; Parfenov et al., 1996, 1999, 2003; Kravchinsky et al., 2002; Wilhem et al., 2012; Yang et al., 2015; Torsvik and Cocks, 2017). The collision was assumed to result in the formation of a narrow belt of orogenic structures in the folded margins that are usually marked as MOFB (Fig. 1). The described model has become widely spread, so in the majority of existing tectonic classifications the Amur superterrane unites a huge territory of northern, central and eastern Mongolia; the Russian Amur River basin and North China, while the MOFB is just a narrow belt of accretionary structures being a part of the Hentiyn-Daur, Tukuringra-Dzhagda, Lan and some other terranes (Khanchuk et al., 2015).

However, there are other theories about the formation time and evolution of the MOO. Some of them relate its origin to a retroarc or intercontinental (similar to the Red Sea) spreading at the early stage of the PAO's Siberian continental margin evolution (Badarch et al., 2002; Bussien et al., 2011; Ruppen et al., 2014; Torsvik and Cocks, 2017). Within the framework of this model, the MOFB can be considered as an orogenic structure formed *in situ* as a product of the evolution of the PAO's independent Mongol-Okhotsk basin that started its development in the early Paleozoic and maybe even earlier. This approach explains the findings of oceanic Ordovician and Silurian–Devonian crusts in many places of central and northern Mongolia, central and eastern Transbaikalia. The ophiolitic fragments are found close to faults among the overlapping folded structures including Neoproterozoic sedimentary metamorphic blocks and Paleozoic volcanogenic-sedimentary complexes.

The transformation mechanisms of the hypothetical late Precambrian–early Paleozoic Mongol-Okhotsk basin and Siberian continental margin, as well as MOFB formation time, may be different from the traditional understanding of

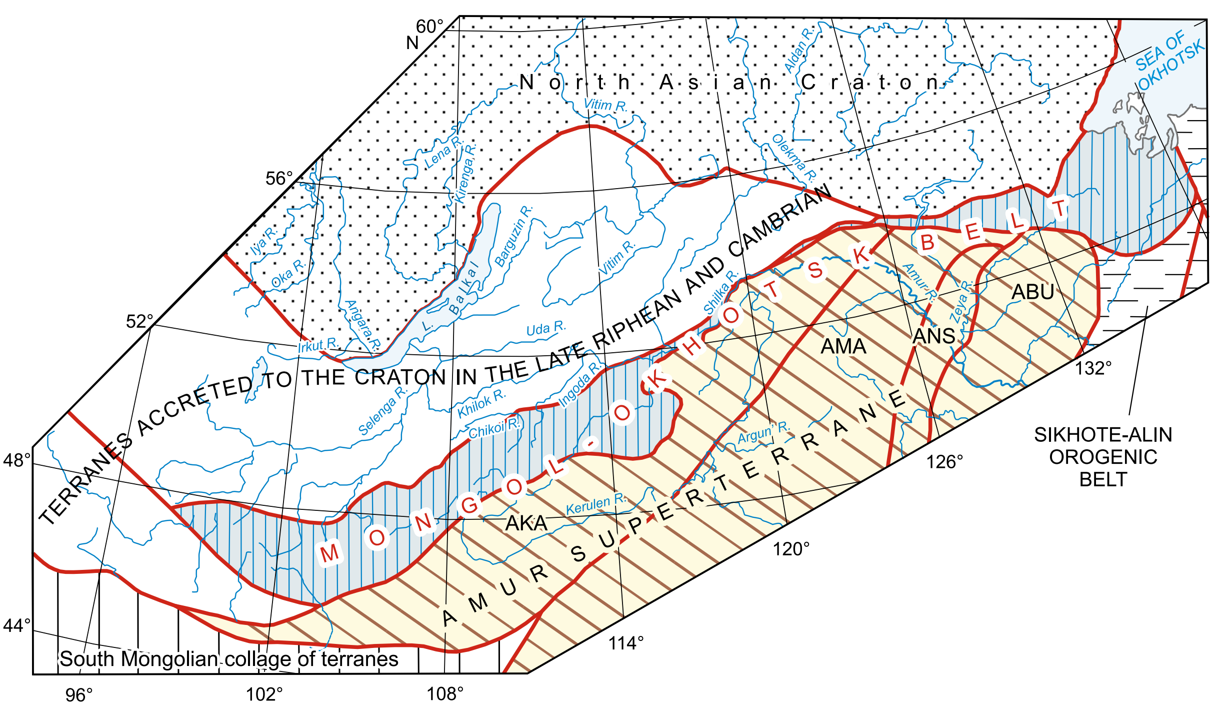

Fig. 1. Traditional zoning of the MOFB and its adjacent structures (Parfenov et al., 1999). The abbreviations mark the following elements of the Amur superterrane: AKA, Kerulen-Argun; AMA, Mamyn; ANS, Nora-Sukhotinsky; ABU, Bureya.

these processes. The only thing the geological data from Transbaikalia point at is that the ocean's closing started at the end of the Carboniferous—the beginning of the Permian in Hangayn, and in the middle of the Jurassic—in Transbaikalia. Moving to the east it ended up in Primorye only in the Early Cretaceous (Gordienko and Kuz'min, 1999; Parfenov et al., 1999; Zorin, 1999; Tomurtogoo, 2014). In general, this model is supported by paleomagnetic data, although different authors suggest different mechanisms of the ocean's transformation (Kravchinsky et al., 2002; Metelkin et al., 2004, 2007; Cogné et al., 2005; Hankard et al., 2005, 2007; Didenko et al., 2010; Metelkin et al., 2010; Torsvik and Cocks, 2017). So, all in all, the MOO's tectonic history since the time of its origin to the time of its assumed closure in the late Paleozoic–Mesozoic, as well as the tectonic—heredity degree of the late Cambrian–early Paleozoic and late Paleozoic–Mesozoic basins, and the role and place of the elements composing the assumed Amur microcontinent remain debatable.

An additional difficulty for justification of the different models is brought by the uncertainty of the real tectonic boundaries. For instance, the northern border of the MOFB can be more or less correlated with a cognominal lineament (Mongol-Okhotsk suture) where the Precambrian–Paleozoic complexes of the Siberian continental margin are separated into blocks by deep faults of different vergence with formation of extensive Mesozoic rift-induced basins. The traditional model insists that to the south of the suture up to Amurian structures, the late Paleozoic–Mesozoic structures of mostly volcanogenic nature should prevail to reflect the territory's oceanic evolution. However, within the MOFB's traditional boundaries, its accretionary structures include a large number of thick late Cambrian metamorphic and Cambrian–Ordovician terrigenous-carbonate structures as well as of early and late Paleozoic volcanogenic-sedimentary complexes and collisional granitoids that correlate with PAO evolution. In essence, they form a continuation of the Neoproterozoic–early Paleozoic accretionary structures of Siberian Craton's southwestern margin being a part of the CAFB. In addition, the southern boundary of the MOFB's folded structures becomes difficult to identify due to the multiple transformations of the territories of southern and western Mongolia. They include such big tectonic events as closing of the Solonker Ocean that restored in the early Permian (Golonka et al., 2006), and even more significant transformations of Jurassic–Early Cretaceous collisions and following intraplate deformations that occurred after MOO's closing (Metelkin et al., 2010). A combination of all these events almost destroyed any primary tectonic zonality, which, keeping in mind the uncertainty of the existing geodynamic models, makes classification of this territory a difficult issue and throws into question the very existence of the exotic Amuria.

Thus, for the time being, the most debatable issues of SE Asia tectonics have been justification of the Amur superterrane; reconstruction of its main elements during the Paleozoic; the time and process of the MOO's appearance; and zoning and boundaries of the tectonostratigraphic terranes to form within. To answer the questions above we suggest considering our results of generalization of our own and published geological, isotope-geochronological, biostratigraphic and paleomagnetic data including the results of our long-term studies of the Hangayn, Hentiyn-Daur, Ulaanbaatar, Aga and Argun terranes.

TECTONIC ZONING

The versions of the MOFB tectonic zoning presented above are different as in their internal composition as in the positions of the belt's external boundaries. In our interpretation, its northern folded structures have a wide band of contiguous sinistral slips united into the Mongol-Okhotsk lineament that contact with the basement highs of the Siberian Platform and the Sayan–Baikal set of Baikal, Caledonian and Hercynian terranes that got attached to the craton during the Neoproterozoic and Paleozoic (Fig. 2). Since it is impossible to separate the areas of the late Paleozoic–Mesozoic deformations caused by the MOO's closing from the folded sedimentary rocks in the south of Transbaikalia and Mongolia, we have included the whole classic Amuria to be a part of the MOFB making the Main Mongolian lineament its southern boundary that connects its structures with the Caledonian and Hercynian terranes of southern Mongolia forming the margins of the North China Craton (Fig. 2). The MOFB territory includes a number of big tectonic elements composed of structural and compositional complexes of different nature. In classic terrane analyses, they, to a certain degree, may correspond to the tectonostratigraphic terranes of two types: A-type (accretionary wedge terranes mainly composed of turbidites) and B-type (accretionary wedge terranes mainly composed of oceanic complexes). However, one has to keep in mind that this interpretation is of a rather simplified kind, for the separated tectonic units have a far more complex structure both in terms of their composition and genesis. In fact, they are an amalgamation of a number of smaller terranes (subterranes), and each of them can be considered either as a composite terrane or as an independent folded system. As a rule, they form heterochronous band-like structures that trend northeast for hundreds of kilometers and are limited by fault systems of different genesis.

Since most of our surveys took place in the central part of the MOFB (Mongolia and Transbaikalia), and keeping in mind that most of the studied terranes are located in Mongolia, in this paper we use the terrane names suggested in (Badarch et al., 2002; Bulgatov and Gordienko, 2014; Tomurtogoo, 2014). Accordingly, the western part of the MOFB to be the main object of the presented study is a sequence of the Hangayn, Central Mongolian, Hentiyn-Daur, Aga and Argun terranes extended in the east–west direction. The main features of their geological structure are presented in Fig. 3.

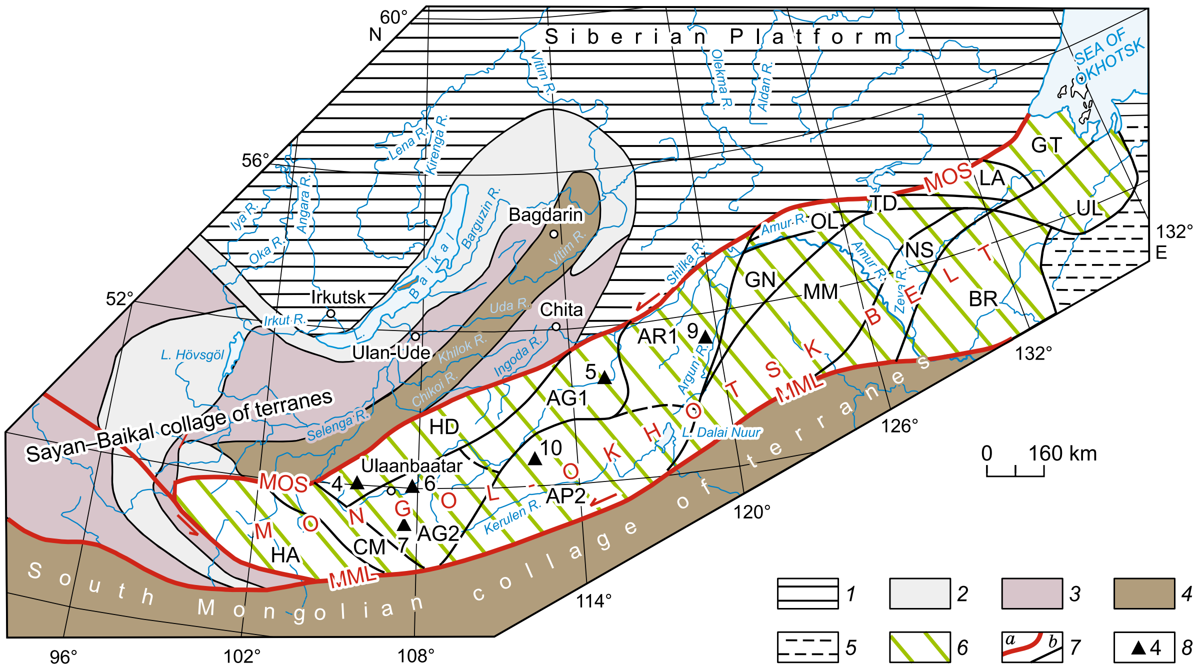

Fig. 2. New scheme of tectonic zoning of the MOFB and its adjacent structures in the southern margin of the Siberian Platform. *1*, Siberian platform; *2–4*, adjacent accretionary-collisional systems: *2*, Baikalian (NP); *3*, Caledonian (V–PZ_1); *4*, Hercynian (PZ_{2-3}); *5*, Cimmerian (MZ) of the Sikhote-Alin orogenic belt; *6*, MOFB terrane collage: AG, Aga (AG1, Eastern Transbaikalian subterrane, AG2, Eastern Hentiyn subterrane), AR, Argun (AR1, northern Argun area, AR2, southern Argun area), BR, Bureya, GT, Galam-Tugur, LA, Lan, NS, Nora-Sykhotinsky, OL, Ol'doi, GN, Gonzha, MM, Mamyn, TD, Tukuringra-Dzhagda, UL, Ulba, HA, Hangayn, HD, Hentiyn-Daur, CM, Central Mongolian; *7*, big fault systems, sutures (*a*): MOS, the Mongol-Okhotsk, MML, the Main Mongolian lineament; boundaries of folded structures and terranes (*b*); *8*, detailed work areas with figure numbers from the article.

The Hangayn terrane is located in central Mongolia in the western termination of the MOFB. Its basement is suggested to contain Neoproterozoic–early Cambrian oceanic crust blocks, whose outcrop can be traced to the southeast into the territories of the Central Mongolian and Hentiyn-Daur terranes (Vosnesenskaya, 1995). The oldest rocks in the Hangayn terrane has been the Vendian–early Cambrian Bayan-Khongor Formation composed of mainly island-arc volcanic rocks in association with the hemipelagic sediments that, closer to the margins, are replaced by shallow-water shelf sediments including reefogenic structures with archaeocyathid residues. This section in overlaid by the Cambrian–Ordovician Dzag Formation that mainly consist of flysch and includes a rich set of Middle and Late Ordovician brachiopods. After a break in succession (around 10 km), this sediments is overlaid by the thick Devonian–Carboniferous Hangayn Formation that determines the composition of the whole terrane. It replaced the long-forming throughs with mostly turbidite sedimentation. The source area for the terrigenous material was the surrounding Caledonian elevations in whose vicinity formed shallow-water sediments containing brachiopods, corals and crinoids. All these sediments were intruded by the granitoids of the late Paleozoic Hangayn interplate batholith (Fillipova, 1969; Yanshin, 1974; Vosnesenskaya, 1995; Yarmoluk et al., 2013).

The Central Mongolian terrane includes Kharkhorin and Tarbagatai elevations that are assumingly composed of early Cambrian crystalline complexes and the large fragments of Neoproterozoic metamorphic rocks related to the Hövsgöl-Darkhat and Dzabkhan-Orkhon active continental margins embracing the Hangayn and Hentiyn-Daur terranes from the southwest. All these structures got united into the Central Mongolian microcontinent at the end of the Cambrian and are assumed to overlay the active Caledonian margin of the Siberian continent (Tomurtogoo, 2014; Gordienko et al., 2017).

The Hentiyn-Daur terrane is one of the biggest structures included in the MOFB and is a combination of the oceanic and suprasubductional complexes of the early and middle Paleozoic. In fact, it is composed of three subterranes being different fragments of the Hentiyn-Daur active continental margin (Dorjsuren et al., 2004, Gordienko et al., 2012, 2017). The Dzabkhan-Orkhon, first of them, mainly corresponds to the upper Cambrian–Early Ordovician accretionary complex. The second (Kharagol) mainly includes the Middle Ordovician rocks of ophiolitic association. The third (Dzunmod-Erogol) subterrane corresponds to the fragment of the Devonian suprasubductional volcanic belt.

Within the boundaries of the Kharagol terrane we studied the Khara Formation and the magmatic bodies associated with and often interpreted as the Ordovician fragments of oceanic crust (Fig. 4). The formation is dominated by basalt pillow lavas with hyaloclastite and silica sublayers and inclusions. The upper part of the section often contains a tufo-

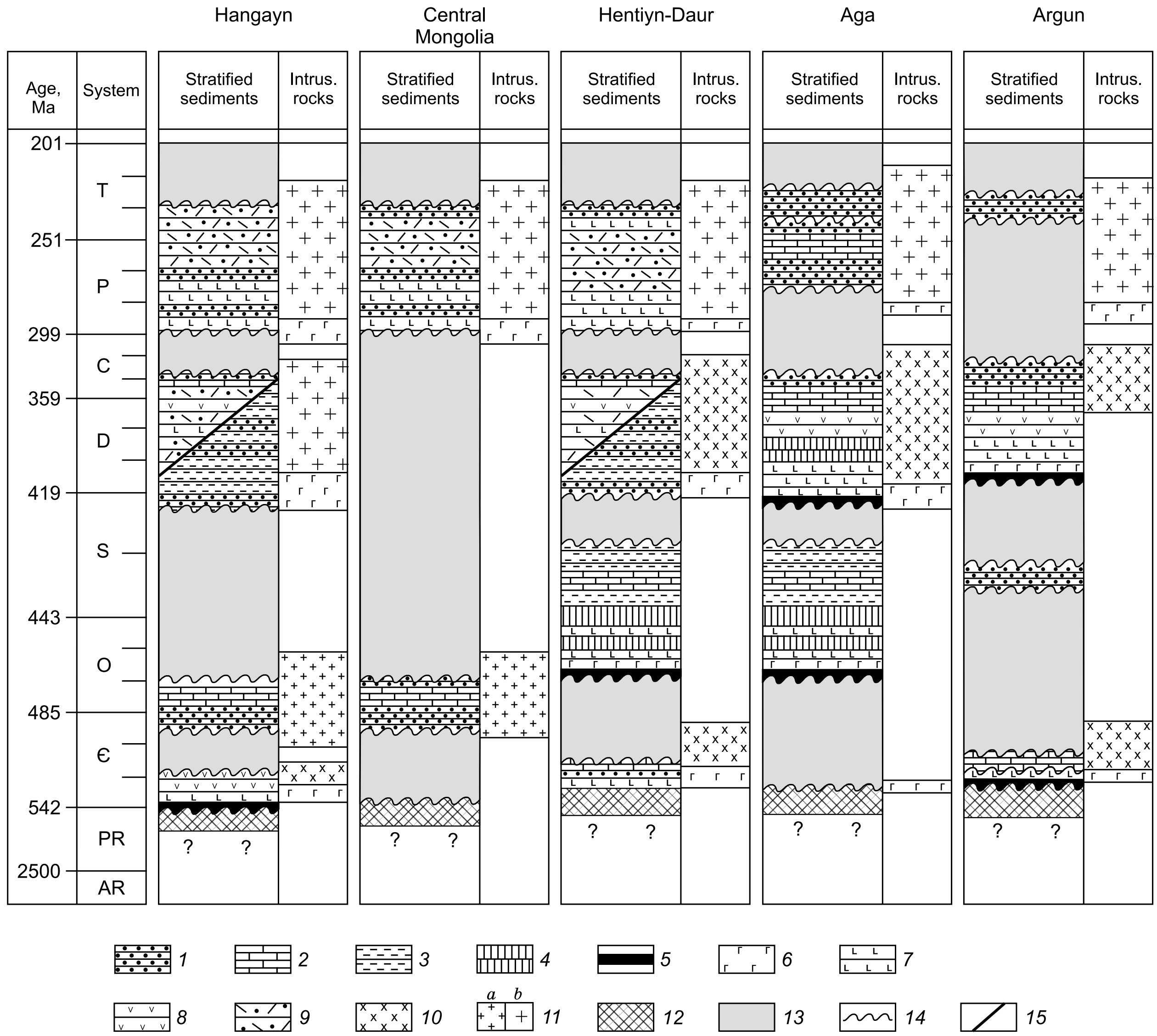

Fig. 3. Tectonostratigraphic columns of MOFB terranes. *1*, terrigenous marine sediments; *2*, carbonate and terrigenous-carbonate sediments; *3*, turbidite (flyschoid) sediments; *4*, siliceous marine sediments; *5*, ultrabasic rocks of ophiolitic complexes; *6*, gabbroids of different genetic types; *7*, oceanic and interplate basalts; *8*, island-arc volcanites; *9*, interplate volcanites; *10*, suprasubductional calc-alkaline granitoids; *11*, collisional (*a*) and interplate (*b*) granitoids; *12*, Meso- and Neoproterozoic basement complexes; *13*, lost strata; *14*, unconformity; *15*, tectonic boundaries.

genic quartzitic sand-slate horizon of turbidite genesis. The basalt-associated and mostly dike-like bodies of gabbro-dolerites form the comagmatic complex. Their common rare earth composition confirms their formation under spreading conditions. The modeled age of the T_{Nd}(DM) mantle source rock for gabbro-dolerites comprises 1338–1270 Ma, while their absolute age based on the results of U–Pb dating of zircon and baddelite is 450 ± 5, 460 ± 4 and 469 ± 8 Ma, respectively (our unpublished data). The tufogenic quartzitic sand-slate horizon contains detrital zircons whose U–Pb age varies from the middle Cambrian to the late Archean with the peaks at 570–600, 870–900 and around 1850 Ma, which in most cases correlates with the Siberian source areas (Kelty et al., 2008). While the Vendian–Cambrian Dzhida and Neoproterozoic Sarkhoi island arcs can be considered as "young" source areas, older zircons could have come from the gneiss-granites of the Sharyzhalgai, Tuva-Mongolian and Yablonovyi-Stanovoi massifs (Gordienko et al., 2012).

The much more metamorphosed turbidite sediments of the Kunalei paleobasin may be analogous to the Khara Formation in the Daur zone territory of Central Transbaikalia. The stratotypic area along the Kunalei and Bol'shaya Rivers has two-mica, and sometimes chlorite-sericite thinly laminated, puckered slates, and biotite-amphibolite gneisses with singular horizons and orthoamphibole lenses. Its typical characteristics include expressed cleavage, most probably corresponding to the primary foliation, and persistent lithology. We assume that the source for the metamorphic

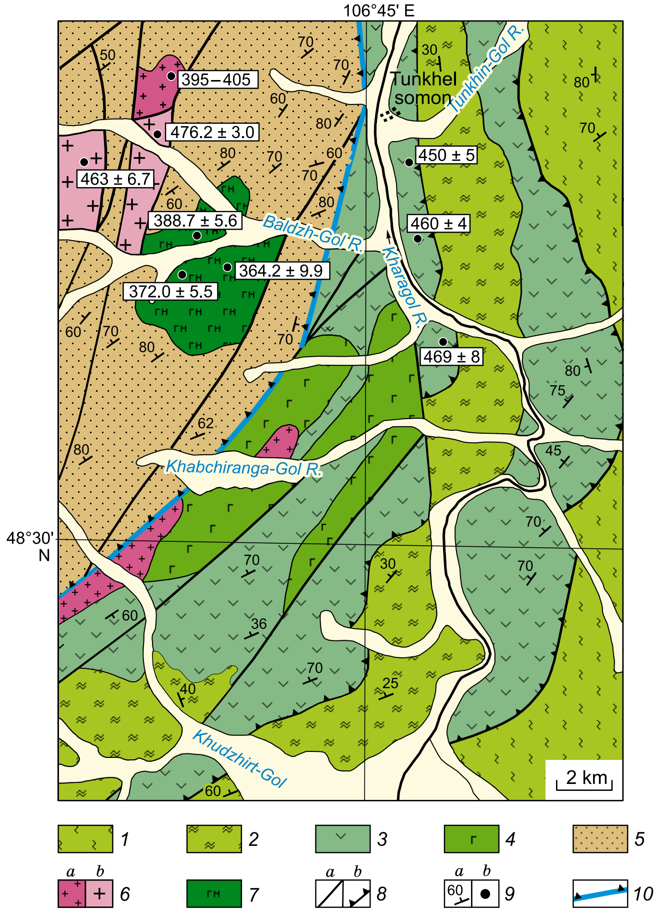

Fig. 4. Geological composition of the Kharagol territory of the Hentiyn-Daur terrane from (Gordienko at al., 2012) with additions: *1–4*, Khara Formation: *1*, flyschoid formation (S_1), *2*, tuff-turbidite formation ($O_{1–2}$), *3*, basalt pillow-lava/hyaloclastite/deep-water siliceous sedimentary formation with gabbro-dolerite and dolerite dikes (O_2), *4*, cumulative and slated gabbro and gabbro-pyroxenites (O_2); *5*, undivided carbonate–terrigenous–volcanogenic formation of active continental margin ($D_{2–3}$); *6*, Devonian (*a*) and Ordovician (*b*) island-arc granitoids; *7*, Middle–Upper Devonian island-arc gabbroids; *8*, discontinuities: *a*, faults; *b*, overthrusts; *9*, rock depositions (*a*), absolute-age points indicated in Ma (*b*); *10*, frontal boundary of Ordovician accretionary oceanic complexes of the Khara Formation and the Devonian Hentiyn-Daur Formation of active continental margin.

rock was an association similar to the Khara one, which is confirmed by the U–Pb age of zircons from two metamorphobolite samples to be 484 ± 2 and 482 ± 2 Ma, respectively. The bottom part of the section is mapped to be the Ulelei Formation gneissic considered as Paleoproterozoic. At the same time, the U–Pb age of the zircons from amphibolite plagiogneisses in the mouth of the Kunalei River is the evidence of their Ordovician age (490 ± 4 Ma), which correlates with the initial stage of the Kunalei paleobasin whose sediments were intensely metamorphosed under the conditions of its greenschist facies and are penetrated by the Early Ordovician granitoid intrusions of the Daur complex (472 ± 2 Ma, our unpublished data)

The Aga terrane is composed of mostly oceanic complexes discrete in age (Fig. 5). According to available data, the oceanic basin started to open in the Middle Ordovician and this process continued till the end of the Devonian. Both the facial and geochemical properties of the studied basalts and silica rocks portray a typical hemipelagic environment of their formation on the oceanic crust of the spreading zone that we identify as the mid-oceanic ridge of the Mongol-Okhotsk oceanic basin. We separated the Aga terrane into two parts: eastern Transbaikalian and eastern Hentiyn (Fig. 2). The Eastern Transbaikalian block includes the Onon-Kulinda and Agutsa-Kyran subterranes, while the Eastern Hentiyn block—the Ulaanbaatar and Adatsag subterranes, which were earlier considered as a part of the Argun zone of the Amur superterrane.

Within the Onon-Kulinda superterrane the metabasalts comprising the Kulinda and Onon Formations are widespread. Their rare-earth distribution spectra mainly correspond to those of oceanic island basalts (OIB) which are characterized by high concentrations of TiO_2 (2.40–3.86 wt.%), Zr (244 ppm), Nb (54 ppm) and high La/Yb values. There are also basalts with weakly-differentiated rare-earth spectra, moderate (1.14–3.37) La/Yb level and lower concentrations of TiO_2 (1.04–2.30 wt.%), Zr (67–190 ppm), Nb (22–63 ppm) which makes them close to the enriched basalts of mid-oceanic ridges (E-MORB).

Detrital zircon analysis of metabasalts samples from the Kulinda Formation yielded concordant Ordovician–Silurian ages from 475 ± 8 to 424 ± 5 Ma (Bulgatov at al., 2010). By no means unimportant is manifestation of the glaucophane slate metamorphism of Kulinda Formation basalts leading to crossite formation, which is a characteristic property of a subduction environment (Dobretsov at al., 1988). Another important geodynamic indicator is the Tsugol Ordovician–Silurian stratified gabbro-plagiogranite pluton of 448.2 ± 9.1 and 436 ± 4 Ma of age as well as the Devonian basalts from the Ust'-Borzya Formation whose geochemical characteristics are similar to those of the normal basalts of mid-oceanic ridges (N-MORB) (Ruzhentsev and Nekrasov, 2009). All these events are in good correlation with the development of the Kharagol spreading oceanic basin.

In the sedimentary parts of the Kulinda, Onon sections and the overlaying Ust'-Borzya and Chindant Formations different fauna residues have been found which confirms the respective Ordovician–Silurian age of the stratigraphic units and their contrast interaction determined by tectonic clustering (Popenko at al., 1993; Oleinikov, 2002).

Similar metabasalts can be found in the border zone between eastern Transbaikalia and Mongolia and within the Agutsa-Kyran subterrane. In modern geological maps, they are also referred to the Kulinda, Onon or Ust'-Borzya Formations, although their geochemical characteristics mainly correspond to N-MORB and E-MORB. Moreover, there is a wider occurrence of turbidites that correspond to distal facies. Metavolcanic rocks found together with deep-sea sediments allow us to assume that the metabasalts of the Agutsa-

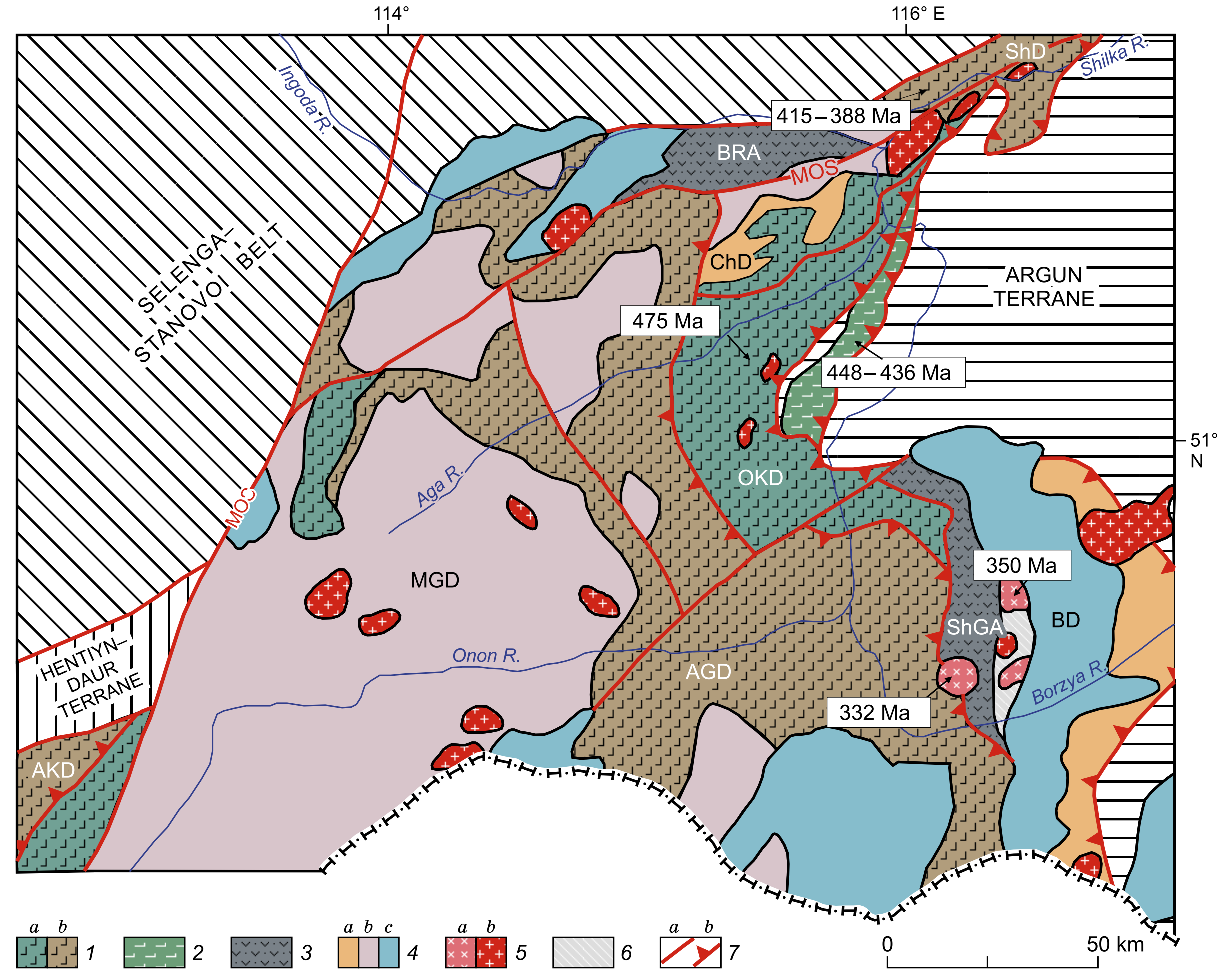

Fig. 5. Geological composition of the eastern Transbaikalian part of the Aga terrane from (Ruzhentsev and Nekrasov, 2009) with amendments and changes: *1–6*, complexes and structures: *1*, oceanic Ordovician (*a*) and Devonian (*b*): OKD, Onon-Kulinda depression; AKD, Agutsa-Kyran depression; AGD, Aga depression; SD, Shilka depression; *2*, Tsugol gabbro-plagiogranite intrusion (O–S); *3*, island-arc, primary volcanogenic (D_3–C_1): BRA, Bereino arc; ShGA, Sherlovaya Gora arc; *4*, overlaying Carboniferous–Permian (*a*), Triassic (*b*) and Jurassic–Cretaceous (*c*) sediments: BD, Borzya depression; ChD, Chiron depression; MGD, Mogotui depression; *5*, granitoids early Carboniferous (*a*) and Jurassic (*b*); *6*, serpentinite mélange; *7*, faults: of different kinematics (*a*), overthrusts (*b*). MOS, Mongol-Okhotsk suture. The numbers in rectangles indicate the rocks' U–Pb age.

Kyran basin formed within the mid-oceanic ridge. In the current bedding, the listed complexes form a composite lamina package (Medvedev et al., 2007).

The eastern Hentiyn part of the Aga terrane is the Ulaanbaatar subterrane that goes as far as 700 km from southern Hentiyn to eastern Transbaikalia (Dorjsuren et al., 2004; Gordienko et al., 2017; Kurilenko and Minina, 2017). In the southeast, it borders with the Adatsag subterrane, and in the northeast—with the Kharagol subterrane described above. A reason to distinguish the Ulaanbaatar subterrane is the Devonian accretionary complex unevenly overlaid by a turbidite complex of Carboniferous age jointed into the Hentiyn Formation. In Mongolia, the sections are includes Sergelen (Early Devonian), Gorkhi (Middle–Late Devonian), Altanovo (early Carboniferous) and Orgioch (end of early–late Carboniferous) Formations (Fig. 6).

The representative Gorkhi sections are located eastward of Ulaanbaatar in the upstream of the Tuul, Terelzh and Minzh Rivers. The section here is mainly involve sandstones, mudstones, and argillaceous and silica slates with radiolarians. It also includes marmorized limestone, while the slate horizons contain lens-like basalt bodies, dolerites and gabbro-dolerites. The age of the rock is verified by the findings of Devonian crinoids, radiolarians and conodonts (Kurihara et al., 2009).

We also studied the Gorkhi Formation in the Shokhoy Tsagaan Bulag area on the left bank of the Guul River. The accretionary complex occurring there contains olistolith bodies of different ages from the late Silurian to the Late Devonian that are composed of the argillaceous-silica rocks and limestones characteristic for shallow-water sedimentation. The available geochemical data qualify the section's

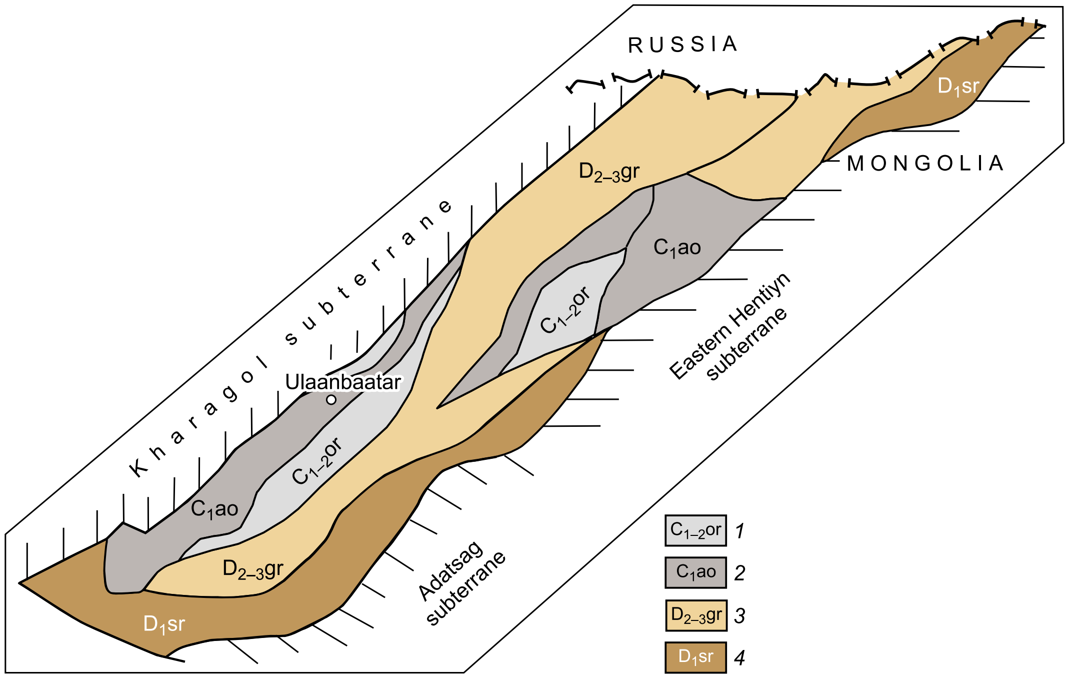

Fig. 6. Geological composition of the Ulaanbaatar subterrane of the Aga terrane (Dorjsuren et al., 2004). Formations: *1*, Orgioch (C_{1-2}); *2,* Altanovo (C_1); *3*, Gorkhi (D_{2-3}); *4*, Sergelen (D_1). For their composition and description see the article.

basalts as OIB, and the section as a whole—as a fragment of a large seamount (Ruppen et al., 2014).

Due to the formation of an extended subduction zone, the south-eastern margin of the East Hentiyn part of the Aga oceanic basin include the Silurian–Devonian ophiolitic complexes forming the Adatsag subterrane (Fig. 7), which is composed of serpentinite mélange, a cumulative laminated gabbro, dolerite dikes, silica rocks, and basalt/andesite-basalt lavas (Tomurtogoo et al., 2005; Gordienko, 2006). The latter has a typical tholeiitic trend with increasing Fe-enrichment. Their rare-earth level marks them as arc tholeiites, which is confirmed by the clear Nb, Ta, Zr, Hf, Ti minima. The dolerites and gabbro–pyroxenites have a similar rare-earth distribution and that allows us to unite them as a single island-arc complex typical for ensimatic island arcs. The Silurian–Devonian age of the ophiolitic complexes has been determined from the onlapping terrigenous Carboniferous formation widespread in the area (Fig. 7). However, it should be noted that the permatoid gabbro used to determine the middle Carboniferous ages of the ophiolites (325.4 ± 1.1 Ma) (Tomurtogoo et al., 2005) has been found in xenoliths among Mesozoic granites and, according to our data, it cannot be a member of an ophiolitic association.

The Argun terrane is composed of the tectonic elements of different geodynamic nature and extends from the upstream of the Kerulen River in northeastern Mongolia (southern Agrun region) to the basin of the Shilka and Argun' Rivers in Eastern Transbaikalia (northern Argun region) (Fig. 8). The terrane is composed of metamorphic rocks whose age was assumed to be early Precambrian, which was the initial reason to consider the whole terrane as a microcontinent forming the framework of the hypothetical Amuria (Zonenshain et al., 1990). However, our studies have demonstrated the invalidity of this theory. The most ancient formations that were assumed to form the microcontinent's crystalline basement were the deeply metamorphosed rocks the Dasatui and Ishaga gneiss-slate complexes and a greenschist complex including the Borshchovochnyi, Gasimur and Daur Formations of volcanoterrigenous and carbonate-terrigenous rocks and their analogs. The Ishaga granite-gneiss dome is located in the northeastern part of the northern Argun region (Figs. 8, 9). The dome is formed by gneisses, plagiogneisses, crystalline slates, marbles and amphibolites that are intruded by the Neoproterozoic granitoids of the Urtui (Uryumkan) complex. The central part of the dome embraces the small bodies of the early Mesozoic granites of the Shakhtama complex, and the periphery—the Permian granitoids of the Unda complex. Isotope-geochemical studies of the Ishaga gneisses indicate their significant similarity with the Urtui complex granitoids whose U–Pb age corresponds to 808–780 Ma (Golubev et al., 2010).

Our own Sm–Nd studies of Ishaga dome rocks have given the following results (Table 1). The age of the Ishaga T_{Nd}(DM) and T_{Nd}(DM-2st) source rocks is 1313 and 1413 Ma, respectively, at almost zero positive $\varepsilon_{\text{Nd}}(T)$ value. The source rocks of the Urumkan gneiss granites have similar Sm–Nd ratios and model age (1232, 1292 and 1077, 1163 Ma) with the positive $\varepsilon_{\text{Nd}}(T)$ values varying from +2.2 to +3.7 suggesting that juvenile sources have contributed to their formation. Another interesting fact is that the Middle

Table 1. Sm–Nd isotope data for Ishaga dome rocks

Rock sample	Complex	Age, Ma	Sm	Nd	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	Err	$\varepsilon_{Nd}(0)$	$\varepsilon_{Nd}(T)$	$T_{Nd}(DM)$	$T_{Nd}(DM\text{-}2st)$
			ppm							Ma	
ON-1, granite	Shakhtama complex	246	17.47	125.34	0.0843	0.512347	2	–5.7	–2.2	948	1215
ON-2, gneiss	Ishaga Formation	780	1.03	6.08	0.1023	0.512191	3	–8.7	0.7	1313	1413
ON-4, granite	Uryumkan complex	778	3.32	21.64	0.0928	0.512297	2	–6.6	3.7	1077	1163
ON-8, granite	Uryumkan complex	784	5.93	33.36	0.1074	0.512292	2	–6.8	2.2	1232	1292

Note. Sample analyses were performed in the Laboratory of Isotopic Geology of the Institute of Precambrian Geology and Geochronology, RAS by A.B. Kotov.

Triassic leucocratic granites of the Shakhtama complex located in the central part of the Ishaga dome have a similar model age (T_{Nd}(DM-2st) 1215 Ma) at negative $\varepsilon_{Nd}(T)$ = –2.2, which suggests the Shakhtama source melt was formed when melting a long-lived crustal source.

Thus, the obtained Sm–Nd measurements have nothing to confirm the suggested Archean–Paleoproterozoic model age of Ishaga dome continental crust complex, but they confirm its Mesoproterozoic–Neoproterozoic age. In our opinion, the formation of the gneiss–granite systems in the northern Argun region is related to the accretionary processes at the margin of Siberian Craton at the early stage of the PAO's development.

The Neoproterozoic metamorphic rocks and granitoids of the Ishaga dome contact across fault zones with the Vendian Beletui Formation of sedimentary-volcanogenic rocks, lower Cambrian Ernichnaya and Altachei Formations of the Argun Group. The last is widespread all over the Transbaikalian part of the Argun terrane and was studied by us within the Georgievka area (Fig. 9).

It has been found that the lower Cambrian sediments of the Bystraya Formation and the lower part of the Ernichnaya formation within the Georgievka area of the southeastern part of the Argun superterrane overlay the Beletui Formation and are a sequence of massive dolomites; limy dolomites; sandstone horizons; carbonaceous-argillaceous slate; slate limestone containing small interlayers of marls, alveolitis, silica rocks and phosphate-bearing limestones. Their total thickness is around 3800 m. The rocks contain different organic residues characteristic for the end of the Atdaba-

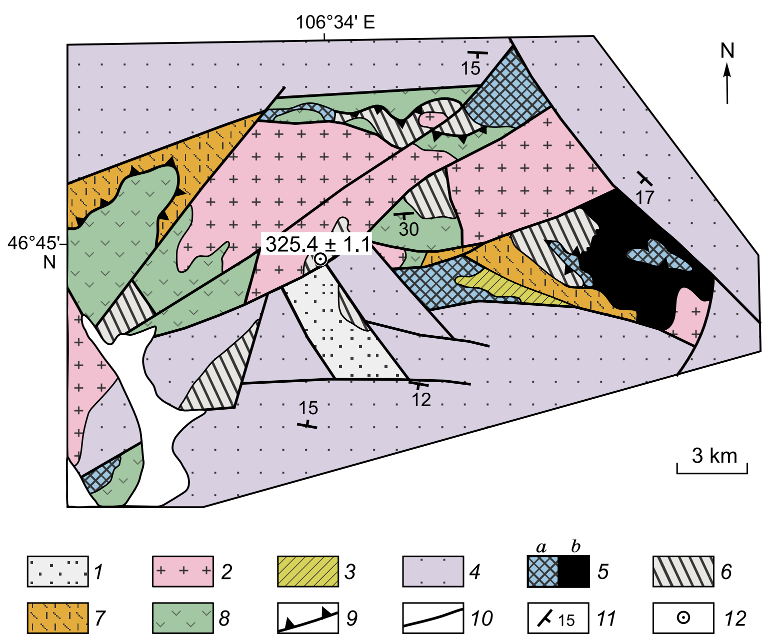

Fig. 7. Geological composition of the Adatsag subterrane (Tomurtogoo et al., 2005). *1*, early Cretaceous sandstones and conglomerates; *2*, Late Triassic and Early Jurassic granites; *3*, Permian rhyolites; *4*, late–middle Carboniferous conglomerates, sandstones, aleurites and agrellites; *5–8*, fragments of Silurian–Devonian ophiolites: *5*, serpentinites (*a*) and serpentinite mélange (*b*), *6*, gabbro, gabbro-pyroxenites, slates and cumulative gabbro, *7*, parallel dikes, *8*, pillow-like basalts and silica; *9*, overthrusts; *10*, faults and other geological boundaries; *11*, rock depositions; *12*, leucogabbro sampling spot to measure absolute age (Ma).

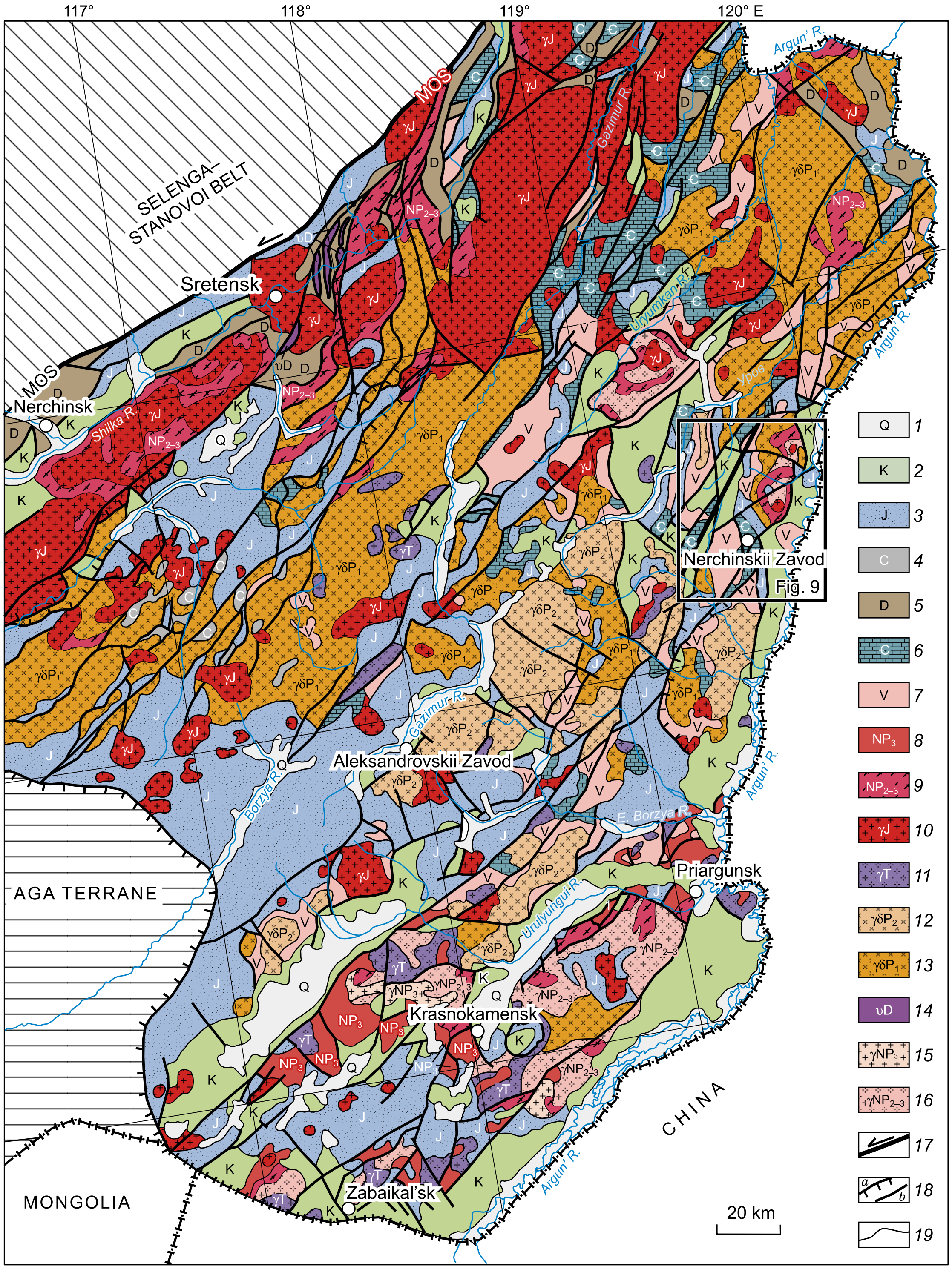

Fig. 8. Geological composition scheme with the authors' research addition of the eastern Transbaikalian part of the Argun terrane (composed based on the data obtained by the Chitageols'emka geological surveying team): *1*, Quaternary sediments; *2*, Lower Cretaceous continental sedimentary-volcanogenic sediments; *3*, Jurassic volcanogenic, volcanogenic-sedimentary sediments including Lower Jurassic marine sediments; *4*, Carboniferous, primary marine terrigenous sediments; *5*, Devonian marine, oceanic, island-arc and shelf sediments including dynamometamorphic rocks in ophiolitic zones; *6*, Cambrian marine, island-arc and shelf sediments; *7*, Vendian (Ediacaran) marine, island-arc sediments; *8*, Neoproterozoic marine and island-arc terrigenous and terrigenous-carbonate sediments; *9*, Mesoproterozoic marine, terrigenous and terrigenous-carbonate metamorphozed sediments including those in granite-gneiss domes; *10*, Triassic–Jurassic granitoids; *11*, Triassic granitoids; *12*, late Permian calc-alkaline granitoids; *13*, early Permian calc-alkaline granitoids; *14*, Devonian ophiolite complex; *15*, Neoproterozoic granitoids; *16*, Mesoproterozoic–Neoproterozoic gneiss-granites; *17*, the Mongol-Okhotsk suture (MOS); *18*, other discontinuities including overthrusts (*a*) and those of undefined kinematics (*b*); *19*, boundaries of structural and compositional complexes.

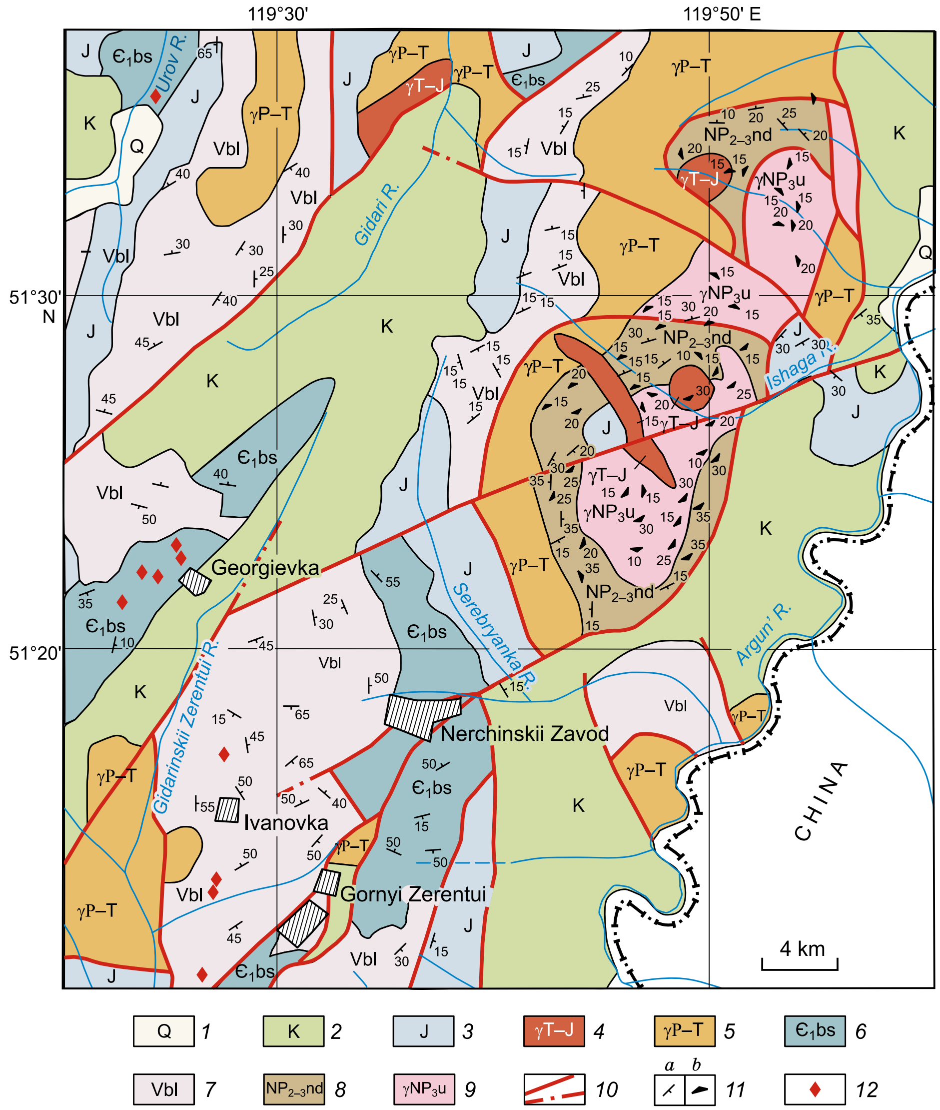

Fig. 9. Geological composition scheme with the authors' research addition of the Gazimur–Nerchinskii Zavod part of the northern Argun area (composed based on the data obtained by Chitageols'emka geological surveying team): *1*, Quaternary sediments (Q); *2*, Cretaceous sediments (K); *3*, Jurassic sediments (J); *4*, Shakhtama granite-leucogranite complex (γT–J); *5*, Kutomar (Unda) granite–granodiorite complex ($\gamma P\text{–}T_k$); *6*, Bystraya terrigenous-carbonate formation ($Є_1$bs); *7*, Beletui carbonate-terrigenous formation (Vbl); *8*, Nadarovskii (Ishaga) gneiss-slate-calc-dolomite Formation ($NP_{2\text{–}3}$nd); *9*, Urtui (Uryumkan) granitoid complex (γNP_3u); *10*, true and assumed discontinuities; *11*, rock depositions: *a*, laminations, *b*, cleavages and gneissic bandings; *12*, sampling spots for paleomagnetic studies (Gordienko et al., 2018).

nian—the beginning of the Botomian ages (Oleinikov, 2002). The tested layers of the Bystraya Formation near the Georgievka Village included trilobites *Proerbia sp.*; microphytolites of the *Vesicularites, Nubecularites, Vermiculites* and *Osagia* groups; columnar and nodular-columnar stromatolites.

The described sedimentary complex is either a set of interrelated depression or a single pericontinental basin whose faunistic complexes are comparable to Siberian ones (Metelkin et al., 2013; Gordienko et al., 2018), which contradicts to the early concepts of the Argun sedimentary basin located far from Siberia and its relation to the southern Gondwana blocks. This contradiction is confirmed by the similarity of the paleomagnetic pole coordinates of Siberia and the northern Argun region that have been like that since ~ 560 Ma. Moreover, the available data demonstrate that starting with the late Precambrian the Argun terrane and Siberian Craton have been in the position similar to the one they are today (Metelkin et al., 2013; Gordienko et al., 2018). As a consequence, the modern reconstructions postulating that a number of blocks (future Amuria) "ruptured" from the Transbaikalian margin of Siberia in the early Paleozoic to form the MOO (Torsvik and Cocks, 2017) should be reconsidered, at least when it comes to the Argun terrane.

Within the northern Agrun region, middle Paleozoic oceanic and island-arc complexes are widespread. Their crosssections are very similar to those of the Devonian and Carboniferous sediments of the Aga terrane. The oceanic complexes have long ago been detected in the Shilka zone of the Mongol-Okhotsk suture and back then were stratified as a part of the Neoproterozoic Kulinda Formation (Anashkina et al., 1997). However, recent isotope-geochronological studies have shown that they belong to E-MORB basalts and active continental margins, their source rock model T_{Nd}(DM) age = 583 Ma and positive ε_{Nd}(DM) values varying from +10.6 to +9.2 that suggests the ancient subduction processes has a mantle substrate. The absolute U–Pb zircon age of the layered gabbroids of Shilka area ophiolites is the Early–Middle Devonian: 412.7 (13 points), 415 ± 9 (9 points), 388 ± 6 (9 points) Ma (Dril' and Golubev, 2003; Ruzhentsev and Nekrasov, 2009).

Near to the Mongol-Okhotsk lineament, there has been found a big (about 14 km) carbonate-terrigenous complex whose diverse fauna set dates it back to the Silurian–Carboniferous (Anashkina et al., 1997). Its basement is the Omutnaya Formation with rare metabasalts bodies. The section is overlaid by the Oldoi and Tipara, mostly terrigenous, formations with interlayers of argillaceous and silica slates, acid-ash tuffs and tuffites. Their origination in the neighboring Oldoi terrane is related to the evolution of a mature island arc or an Andean-type margin (Sorokin et al., 2015b). The Gornyi Zerentui and Yamkun Formations taking the most part of the northern Argun area can be of the similar origin as well as the volcanogenic-terrigenous complex (Glubokaya Formation) in the Shilka River basin (Smirnova el al., 2017).

The presence of mostly Devonian ophiolites in the northern part of the Argun terrane enables to suggest a possible MOO opening through separation of some of the structures from the hypothetical Amuria in the middle Paleozoic (Kravchinsky and Sorokin, 2001; Kravchinsky et al., 2002; Parfenov et al., 2003). However, the abovementioned paleomagnetic data (Metelkin et al., 2013; Gordienko et al., 2018) do not support this hypothesis, for it is difficult to imagine that a big tectonic element being separated from a continental margin and having had a long terrane history can become a part of the same configuration after an oceanic closure.

The geological structure of the Argun terrane in the southern Argun area and eastern Mongolia is in many ways similar. The Neoproterozoic metamorphic complex has formed angular blocks of different size in the northeast of Mongolia, in the Erendabaa Ridge, the Onon River valley and in the downstream of the Shusyyn-Gol River jointly known as the Erendabaa terrane (Fig. 10). Analogous metamorphic structures have also been detected in the south in the valley of the Kerulen River near to the town of Underkhan and are usually considered as a part of the Kerulen or of Idermeg-Kerulen subterrane (Parfenov et al., 1999; Tomurtogoo, 2014).

The Erendabaa subterrane include the Khaichin-Gol and Erendabaa metamorphic complexes that are overlaid by the Silurian–Devonian sedimentary section and intruded by early Permian and Jurassic plutons. The age of the Khaichin-Gol Formation composed of gneisses, crystalline slates, quartzites and granite-bearing marbles is considered to be Paleoproterozoic. Above it, according to the available data, unconformably lays a metamorphosed, mostly metasedimentary formation of Neoproterozoic age (Marinov, 1973). However, according to our data, no contrast transition zone has been observed so far between the formations. The base of the Erendabaa Formation contains biotite and biotite–coniferous gneisses, plagiogneisses and amphibolites interlaid with metasandstone and metatuff horizons that are gradually replaced by the slates and slightly metamorphized terrigenous rocks prevailing in the upper part of the section. The feature is the presence of greenschist metabasalt horizons that are sometimes associated with dikes and metadolerite sills, while its upper part contains acid metavolcanites and metatuffs. The results of petrogeochemical studies demonstrate that the Erendabaa metabasalts and metadolerites are comagmatic. The SiO_2 content changes insignificantly (47–51 wt.%), the rock is low-alumina (al' = 0.63–0.75) moderately titanium-rich (TiO_2 = 0.9–2.0 wt.%), which is comparable to that of N-MORB.

The absence of contrast transition zone between the Khaichin-Gol and Erendabaa Formations confirms that they got formed at about the same time. Most likely the age of deeply metamorphozed rocks of the Khaichin-Gol Formation does not exceed the Neoproterozoic and the whole complex is of accretionary origin and forms a pack of the tectonic plates of initially oceanic and island-arc genesis that were transformed and imbricated due to collision processes leading to multiple injections of the quartz and granite-pegmatite veins which, due to dynamic metamorphism, got crushed and transformed into boudines. According to modern estimations, the injections' age varies from 154 ± 4 to 136 ± 6 Ma (Daoudene et al., 2013) making it similar to the one of the Transbaikalian metamorphic cores (Sklyarov, 2006).

In places, mostly in its eastern part, the described metamorphic complex is unconformably overlaid by a shallow-marine terrigenous formation including lower Silurian bryozoans and brachiopods (Fig. 10) whose fossils in significant amounts we found in the upstream of the Zamtu-Gol River. The sediments are intruded by granites and gabbro whose U–Pb zircon age is about 290 Ma (our own unpublished data).

The Kerulen subterrane of the southern Argun area and eastern Mongolia, as well as the Erendabaa, are often considered as an early Cambrian component of the Argun microcontinent with a sedimentary-volcanogenic sheath prevailing in this territory. On the left bank of the Kerulen River and in the vicinity of Underkhan town it includes terrigenous-carbonate and volcanogenic-terrigenous section (Marinov, 1973; Yanshin, 1974). The limestones of the terrigenous-carbonate formation are more than 1000 m thick and contain the significant amounts of the archaeocyathid fossils that are typical for the lower Cambrian Bograd and Sanashtyk-Gol horizons. It is gradually replaced by the vol-

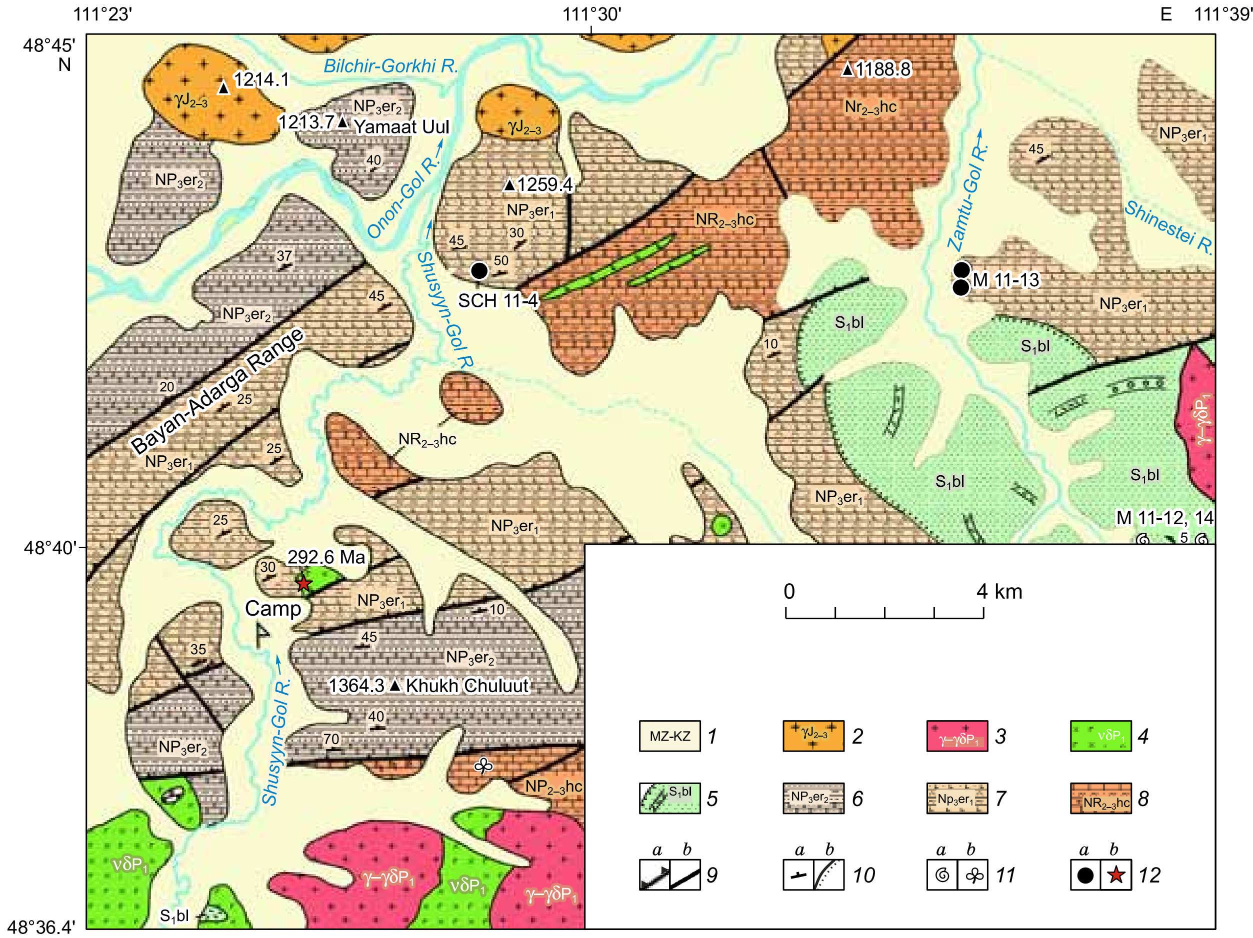

Fig. 10. Geological composition of the Erendabaa part of the southern Argun area. *1*, Mesozoic–Cenozoic sediments (MZ–CZ); *2*, granites, granosyenites, leucogranite and granite–porphyry dikes (γJ_{2-3}); *3*, granites, granodiorites (γ–$\gamma\delta P_1$); *4*, gabbro, gabbro-pyroxenites, gabbro-diorites, diorites ($\nu\delta P_1$); *5*, sandstones, gravelstones, conglomerates, acid volcanites, phyllites with bryozoans and brachiopods (S_1bl); *6*, quarzitic sandstones, quartzites, mica schists with small quartz injections, gravelstones, conglomerates (NP_3er_2); *7*, meta-amphibolites (basalts, andesibasalts, gabbro-dolerites, gabbro), metasandstones, metatuff rocks, biotites, biotite-coniferous gneisses, plagiogneisses (NP_3er_1); *8*, two-mica gneisses, plagiogneisses, crystalline slates with granite-pegmatite injections, quartzites, quartzitic sandstones, amphibolites, marmorized sandstones with microorganism(?) fossils ($NP_{2-3}hc$); *9*, overthrusts (*a*) and other faults (*b*); *10*, rock depositions (*a*), uncomfortable bedding (*b*); *11*, findings of fauna (*a*) and flora (*b*); *12*, sampling sites for geochemical studies (*a*) and sample with the absolute age.

canogenic-terrigenous section of about 2000 m thick that is composed of basalts, andesite-basalts, andesites and their tuffs interlaid by silica slate, quartzite, and (rarely) limestone horizons. The development area of the sedimentary-volcanogenic rock often includes a serpentine mélange of ultrabasites, pyroxenites, gabbro and diabase dikes that confirm the suprasubductional genesis of the whole association described.

Thus, the composition of the sheath within the Kerulen subterrane can hardly be related to the microcontinent plates, which makes us doubt the presence of early Cambrian crystalline basement within this territory. This complex has more similarities with the Bayan-Khongor and Ozernaya paleoisland-arc systems of western Vendian–Cambrian MOFB margin (Yarmoluk et al., 2002), or with the eastward Mamyn terrane with prevailing volcanic complexes of the active Cambrian–Ordovician continental margin (Sorokin and Kudryashov, 2015, 2017).

In its eastern periphery, the sedimentary-volcanogenic complex of the Kerulen subterrane, as the Erendabaa, is overlaid by Silurian–Devonian sediments. Their accumulation was probably related to the evolution of the basin of the Norovlin-Onon island-arc terrane. Together with the formations of the neighboring Oldoi island-arc terrane (Sorokin et al., 2015b) they could have composed the structure of the later and more active margin of Siberia (Gordienko, 1987; Zorin et al., 1998).

Finally, the Jurassic–Cretaceous volcanic rocks and granitoids of the Upper Amur volcanoplutonic belt indicate the youngest suprasubductional environment for the whole territory the Argun terrane (Gordienko et al., 2000).

Thus, the basement of the Argun terrane considered to be a typical microcontinent has no characteristics of Archean–early Proterozoic complexes and is mainly composed of the sediments whose source rock belong to Mesoproterozoic–early Proterozoic continental core. Just for that very reason, it has to be excluded from the set of craton terranes forming the framework of Amuria. The presence of a single plate complex is also not apparent, for most of the sheath's described associations are related to the environments of an active continental margin (Khanchuk, 2006; Sorokin et al., 2015b).

TECTONIC DEVELOPMENT HISTORY

The data presented above allow us to consider the MOFB as an accretionary-collisional orogen that formed in the southern periphery of the Siberian Craton as the result of the sequential stages of the MOO's evolution. The information about its pre-Ordovician history is vague. Possibly, such an oceanic basin existed between the continental margins of Siberia and North China, but available geological data do not allow one to separate it from the remaining part of the PAO. The reconstructed MOO spreading systems, on the one hand, are the extensions of the PAO, and on the other—are extended in the direction of the Paleopacific (Torsvik and Cocks, 2017). The MOO as a geological phenomenon can be traced starting the Ordovician and underwent a number of transformations since that time. At its final of development during the late Paleozoic–early Mesozoic, the MOO had been gradually losing its connection with the Paleoasian oceanic basin and after its closure, the MOO formed a gigantic bay to the Paleopacific.

In the following, we present the results of a comparative analysis of the abovementioned structural-formational complexes and available paleogeodynamic MOFB reconstructions and suggest our own version of its evolution within the Mongol-Transbaikalian region.

Neoproterozoic stage (850–630 Ma). This stage of the entire Central Asia's tectonic history is related to Rodinia's destruction and formation of the PAO's oceanic basins (Dobretsov and Buslov, 2007; Metelkin et al., 2012; Gordienko and Metelkin, 2016). One of these basins having separated the modern southeastern part of the Siberian Craton from the continental masses of North China could have been the MOO, but its reconstruction, as of the whole PAO, is complicated due to a lack of data. For this reason, we consider the assumed Neoproterozoic MOO space as the Transbaikalian oceanic basin being a part of the PAO. Despite the reconstruction difficulties, information about the Neoproterozoic stage has been preserved in all the described MOFB terranes, for all their metamorphic blocks are of this age. The composition of the blocks allows identifying the fragments of a transformed oceanic lithosphere and island arcs. Multiple petrogeochemical parameters and the similar ages of suprasubductional magmatism suggest that the evolution of the PAO (including the Transbaikalian oceanic basin) developed in a convergent regime. Respectively, even at the early stage of oceanic development, a significant part of the Siberian margin was characterized by discrete-in-time subductional magmatism and was rimmed by a set of island arcs of different magmatic types. Formation of these arcs was most active within 850–750, 650–630 Ma and later—570–550 Ma BP (Didenko at al., 1994; Gordienko, 2006; Kheraskova et al., 2010; Gordienko and Metelkin, 2016). In the Transbaikalian segment the relicts of the most ancient arcs, sometimes with granites of suprasubductional genesis, are preserved, for instance, in the Argun terrane. The age of Urtui complex (808–780 Ma) in the center of the Ishaga granite-gneiss dome is also in support of this conclusion. Analogous, but a bit older (888–859 Ma) island-arc granitoids were described in the Song fold in the western part of the Hangayn terrane (Yarmoluk et al., 2017). Most of these arcs were accreted to the Siberian paleocontinent even before the Vendian, but the ongoing plate convergence processes have resulted in the formation of new subduction systems on the formed accretionary basement (Gordienko and Metelkin, 2016).

Analogous processes have also been registered in the Gonzha Formation of the Argun terrane; the Amur Formation of the Malyi Khingan massif and the Iman Formation of the Khankai massif of the Bureya terrane (Kotov et al., 2009, 2013; Sorokin et al., 2004, 2015a, 2017). Therefore, it can be suggested that the majority of granite-gneiss folds and similar deeply-metamorphized rocks that are considered Amuria's early Cambrian basement are the product of transformations of the PAO's subduction–accretionary systems.

Early Caledonian stage (630–510 Ma). The Vendian–Cambrian interval has a much richer set of paleomagnetic data to characterize the PAO's development, including the Transbaikalian oceanic basin. Along the whole southwestern periphery of the Siberian paleocontinent located in the Earth's subequatorial zone a system of island-arcs and interconnected marginal basins has been registered (Fig. 11). The paleoisland arcs of modern Transbaikalia (Anga-Talachan, Uda-Vitim, Dzhida) top out the analogous fragments of the Kurtushiba, Northern Sayan and Gorny Altai terranes and extend into the Kuznetsk Alatau structures. We assume that this reconstructed active margin can be extended eastward into the Argun area and further up to the Bureya region.

Most of the Vendian–early Cambrian island arcs of Mongolia and the Altai–Sayan–Baikal region are characterized by tholeiitic magmatism that is typical for ensimatic arcs (Gordienko, 2006; Metelkin, 2013; Gordienko and Metelkin, 2016). The basement of that-time suprasubductional complexes within the MOFB often features rocks of oceanic genesis, but there are some exclusions that include the complexes of the Kerulen part of the Argun terrane whose magmatism type is closer to that of the differentiated calc-alkaline complexes of ensialic arcs. Similar magmatism characterizes the Uda–Vitim system (Gordienko et al., 2010). For that reason, we assume that some segments of the reconstructed Vendian–early Cambrian island-arc system (in particular, the Argun part) could have formed on a relatively thick suboceanic or continental crust that formed due to the accretionary processes of the previous Neoproterozoic tectonic stage. The Kerulen margin was most likely placed in

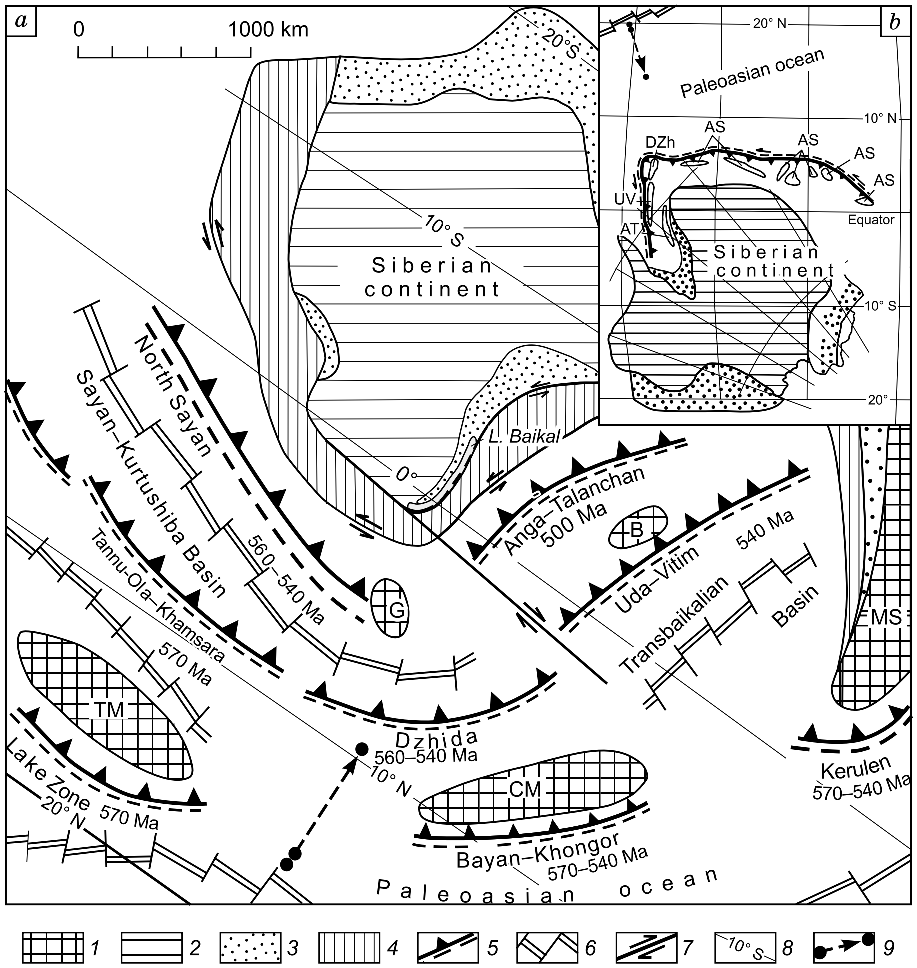

Fig. 11. Paleogeodynamic reconstruction of the Vendian–early Paleozoic oceanic basins, island arcs and microcontinents of the active continental margin of the Siberian continent and Paleoasian ocean: *a,* regional reconstruction after (Gordienko, 2006) with amendments and changes, *b*, global reconstruction after (Metelkin, 2013). *1*, cratonal terranes (TM, Tuva-Mongolian; G, Gargan; B, Baikal; CM, Central Mongolian; MS, Muya-Stanovoi), *2,* Siberian continent's platform complex; *3,* sedimentary basins of the continent's passive margin; *4,* Neoproterozoic accretionary orogen; *5,* island-arcs with subduction zone orientation (triangles) accretionary wedge positioning (dashed line); *6,* suggested spreading zones including backarc ones; *7,* large shears; *8,* paleolatitudes; *9*, reconstructed motion of an oceanic plate with guyots from the PAO's spreading zone into the subduction of the Dzhida arc, based on (Gordienko and Mikhal'tsov, 2001). *b,* Transbaikalian island arcs: DZh, Dzhida; UV, Uda-Vitim; AT, Anga-Talanchan; AS, Altai–Sayan scaled for Siberian Craton. The island arcs, spreading zones and microcontinents are not scaled.

the vicinity of the Muya–Stanovoi margin (Fig. 12), and eastward—the Mamyn island-arc systems with the large backarc basins including continental margin seas (Sorokin et al., 2015a). Sedimentation within the seas, even at a significant distance from the magmatic front, has little difference from the one of the passive continental margins, so the accumulation of the characteristic terrigenous—carbonate sequences of the Beletui and Bystraya Formations of the northern Argun area is directly related to these paleogeodynamic conditions. The basements of these basins probably feature granitized and metamorphozed accretionary early Neoproterozoic complexes, and the available paleomagnetic data prove they belong to the margin of the Siberian paleocontinent (Metelkin et al., 2013; Gordienko et al., 2018).

Late Caledonian stage (500–440 Ma). The early Caledonian stage of the PAO's evolution ended with a significant transformation related to the accretionary-collisional events between the Cambrian and the Ordovician. In Transbaikalia, these processes resulted in the formation of the Neoproterozoic–early Cambrian basement of the Central Mongolian terrane. Within this terrane formed rare island-arc complexes (Malkhan-Ul'dzutui arc, late Cambrian–Early Ordovician; backarc terrigenous-carbonate sections (Dzag and Khara), and collisional granitoids (Sorokin and Kudryashov, 2017). Simultaneously or a little later (Early–Middle Ordovician) the spreading Orkhon-Kharagol basin got formed and separated the Central Mongolian microcontinent from the Muya–Stanovoi margin (Fig. 12). This is the oceanic basin that is today considered to be the main stage of the MOO's opening (Badarch et al., 2002; Bussien et al., 2011; Ruppen et al., 2014; Gordienko et al., 2017). Its relicts have gotten preserved within the Hentiyn-Daur and Aga ter-

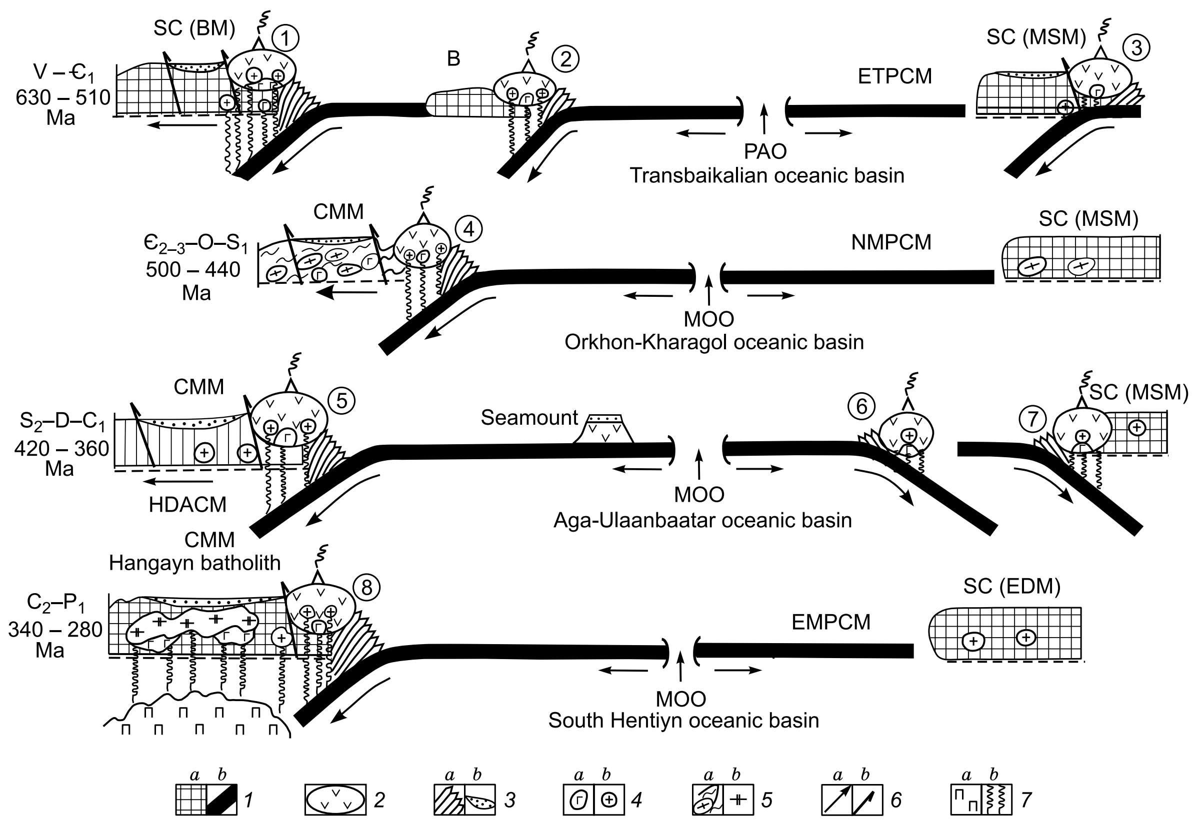

Fig. 12. Evolution model of the MOFB oceanic basins during late Neoproterozoic–Paleozoic: *1*, continental (*a*) and oceanic (*b*) crusts; *2*, island arcs (numbers in circles): 1, Anga-Talachan, 2, Uda-Vitim, 3, Kerulen, 4, Malkhan-Ul'dzutui, 5, Dzunmond, 6, Norovlin-Onon, 7, Oldoi, 8, Bereya; *3*, accretionary prisms forearc (*a*) and backarc (*b*) basins; *4*, gabbroids (*a*) and granitoids (*b*) in island arcs and active continental margins; *5*, collisional (*a*) and interplate (*b*) granitoids; *6*, motion directions of oceanic plates and spreading zones in oceans (*a*) and overthrust transitions in continents (*b*); *7*, mantle plumes (*a*) and fluid flows (*b*). Oceans: PAO, Paleoasian; MOO, Mongol-Okhotsk; SC (BM), Siberian continent (Baikal margin); SC (MSM), Siberian continent (Muya–Stanovoi margin); B, Baikal block of the Siberian continent basement; HDACM, Hentiyn-Daur active continental margin; ETPCM, eastern Transbaikalian passive continental margin; CMM, Central Mongolian microcontinent; NMPCM, northern Mongolian passive continental margin; SC (EDM), Siberian continent (Erendabaa margin); EMPCM, eastern Mongolian passive continental margin.

ranes (Fig. 4). The oceanic basin could have kept growing until the Devonian and even later, but the size of the basin and the general configuration of the main tectonic units are yet difficult to estimate considering the available paleomagnetic data for the Vendian–Cambrian northern Argun area. Most likely it had been a narrow rift gap opening southward (in modern coordinates). At all events, the paleomagnetic data contain no records to register the separation of the neighboring Argun terrane.

Early Hercynian stage (420–360 Ma). In all the described MOFB terranes, the early Hercynian stage is marked by appearance of the volcanic rocks of suprasubductional genesis and accompanying sedimentary basins (Fig. 12). We relate their formation to the subduction of the oceanic lithosphere of the MOO's Aga-Ulaanbaatar basin, whose opening may have been the result of formation of the earlier Orkhon-Kharagol basin and transformation of the neighboring Paleopacific structure. Inside the MOO and at its margins there are island-arc systems of significant size: Dzunmod, Norovlin-Onon, Oldoi and others (Fig. 12). Some of their basements feature paleoseamount relicts (Ruppen et al., 2014).

Similar geodynamic conditions have been noted beyond the MOFB boundaries, in the neighboring Baikal–Vitim zone, where turbidite sedimentation prevailed during the Devonian and Carboniferous and led to formation of island-arc volcanic complexes (Donskaya et al., 2013). Thus, one can assume the formation and development of a single wide marginal-sea system (Hangayn–Hentiyn-Daur) within the MOO, whose relicts have now become a part of not only of the MOFB but also of the neighboring Transbaikalian part of the CAFB (Gordienko, 1987; Ruzhentsev et al., 2012).

Late Hercynian stage (340–280 Ma). This period in the MOO's history is dominated by collisional events. One of their earliest manifestations (359–358 Ma) can be the Olekma collisional-granitoid belt in the Western–Stanovoi margin of the Siberian continent (Larin et al., 2015). Nevertheless, in the middle–late Carboniferous the MOO kept developing in active subductional regime (for instance, the Bereya arc, Fig. 12). It was the time when the MOO's Sothern Hentiyn oceanic basin was in active development as well (Gordienko at al., 2017). The available paleomagnetic data demonstrate that the width of the ocean between the Permian and Triassic could have reached 2000 km (Kravchinsky and Sorokin, 2001). And it was the time when PAO basins closed as well as the Solonker ocean dividing the North China margin and the continental masses of southern Mongolia (Metelkin et al., 2010; Tomurtogoo, 2014). The indicators of these collisional and accompanying interplate events could be the granitoid batholiths of Hangayn, Hentiyn, western Transbaikalia and the southern Argun area that date back 325–275 Ma (Donskaya et al., 2013; Yarmoluk et al., 2013; Tsygankov, 2014).

The MOO's closing and formation of the modern MOFB structure is mainly related to the Cimmerian tectonic stage dominated by strike-slip processes (Metelkin et al., 2010) when the orthogenesis was slowly moving from the west to the east. Having started in the western part of the belt (Hangayn and western Transbaikalia) at the end of the Carboniferous–Permian, it reached its central part (eastern Transbaikalia) in the Middle Jurassic and ended up in the east (Primorye) only in the Early Cretaceous. The scissors-like kinematics of this process has been discussed multiple times since the first reconstructions were published (Zonenshain et al., 1990; Zhao et al., 1990; Delvaux et al., 1995; Parfenov et al., 1996, 2003; Kravchinsky et al., 2002; Hankard et al., 2007; Metelkin et al., 2007, 2008, 2010).

This model was further developed after reasoning of discontinuous, "key-driven" MOO closing (Didenko et al., 2010; Didenko, 2015; Khanchuk et al., 2015), which can be determined by a sequential collision of a few large tectonic blocks and not of a single continental massif as it was assumed earlier. This, once again, make us doubt the existence of the Amur superterrane during the late Paleozoic–Mesozoic stages of MOFB evolution.

CONCLUSIONS

The analysis of tectonic composition and geodynamic development of the described tectonic structures of Transbaikalia and Mongolia we have united as the MOFB has shown their similarity to the neighboring accretionary-collisional system of the southern and southwestern margins of the Siberian Craton. Most of the MOFB structures have been traditionally considered as the elements composing the Amur microcontinent. However, their composition features almost no early Cambrian craton blocks. The age of the protolith of the magmatic and metamorphic rocks considered as early Cambrian is, in fact, not older than late Mesoproterozoic, while their tectonic history is closely related with the PAO's evolution within which, as we assume, a big Mongol-Okhotsk basin (MOO) existed during the Ordovician–Devonian. Its formation may have even occurred earlier, at the earliest stage of the PAO opening, but the data available today do not allow us to separate the Transbaikalian oceanic basin from the remaining part of the PAO. The presented data suggest the tectonic history of the PAO's Siberian margin and its neighboring basins included at least three stages of active subduction: during the Vendian—at the beginning of the Cambrian; in the Middle Ordovician; and in the Devonian. We relate the first stage with the PAO's Transbaikalian oceanic basin that paved the way for the further transformations of the MOO space and became the accretionary basement that has been earlier considered as the early Cambrian craton elements of Amuria. The following stages are directly related to MOO evolution and are also finalized by accretionary-collisional events in the Silurian and early Carboniferous. As a result, they formed a crystalline basement of all the main terranes of the modern MOFB with significant-in-size late Paleozoic and early Mesozoic sedimentary basins. Consequently, the MOO lost its connection with the PAO and became a big gulf of the Paleopacific. Its final closing and formation of the MOFB occurred in the Late Jurassic–Early Cretaceous due to sequential (from the west to the east) convergence of the continental masses of the Siberian margin and North China with the defining role of tectonic strike-slips. In this case, most of the considered structures had, probably, been placed around the Siberian margin.

Thus, the MOFB tectonic history can be considered as an irreversible evolutionary sequence of different geodynamic environments featuring the transformation processes converting oceanic crust into a continental one followed by multiple destruction, accretion and collision processes that finally resulted in the formation of a large continental domain in the east of Asia. The formation of MOFB structural ensembles is mainly related to the Siberian continental margin that makes the existence of the Amur superterrane a doubtful issue.

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REFERENCES

Anashkina, K.K., Butin, K.S., Enikeev, F.I., Kinyakin, A.V., Krasnov, V.P., Krivenko, V.A., Oleksiv, B.I., Pinaeva, T.A., Rutshtein, I.G., Semenov, V.N., Starukhina, L.P., Chaban, N.N., Shulika, E.V., 1997. Geological composition of Chita Region. Explanatory note to geological map 1:500 000, Rutshtein, I.G., Chaban, N.N. (Eds.) [in Russian]. Chita, GGUP "Chitageols'emka".

Badarch, G., Cunningham, W.D., Windley, B.F., 2002. A new terrane subdivision for Mongolia: implications for the Phanerozoic crustal growth of Central Asia. J. Asian Earth Sci. 21, 87–110.

Belichenko, V.G., Sklyarov, E.V., Dobretsov, N.L., Tomurtogoo, O., 1994. Geodynamic map of Paleoasian Ocean: Eastern segment. Geologiya i Geofizika (Russian Geology and Geophysics) 35 (7–8), 29-40 (2332).

Bulgatov, A.N., Gordienko, I.V., 2014. Fold systems of the Sayan-Baikal mountain area, in: Tectonics of Northern, Central and Eastern

Asia. Explanatory Note to the Tectonic map of Northern-Central-Eastern Asia and Adjacent Areas at Scale 1:2,500,000. VSEGEI, St. Petersburg, pp. 53–59.

Bulgatov, A.N., Klimuk, V.S., Shivokhin, E.A., 2010. Kulundin Formation's stratotyping (eartern Transbaikalia, Mongol-Okhotsk folded belt). Otechstvennaya Geologiya, No. 4, 54–60.

Bussien, D., Gombojav, N., Winkler, W., Von Quadt, A., 2011. The Mongol-Okhotsk Belt in Mongolia—a new appraisal of the geodynamic development by the study of sand-stone provenance and detrital zircons. Tectonophysics 510, 132–150.

Cogné, J.-P., Kravchinsky, V.A., Halim, N., Hankard, F., 2005. Late Jurassic–Early Cretaceous closure of the Mongol-Okhotsk Ocean demonstrated by new Mesozoic palaeomagnetic results from the Trans-Baikal area (SE Siberia). Geophys. J. Int. 163, 813–832.

Daoudene, Y., Ruffet, G., Cocherie, A., Ledru, P., Gapais, D., 2013. Timing of exhumation of the Ereendavaa metamorphic core complex (north-eastern Mongolia)—U–Pb and $^{40}Ar/^{39}Ar$ constraints. J. Asian Earth Sci. 62, 98–116.

Delvaux, D., Moeyrs, R., Stapel, G., Melnikov, A., Ermikov, V., 1995. Palaeostress reconstruction and geodynamics of the Baikal region, Central Asia, Part I. Palaeozoic and Mesozoic pre-rift evolution. Tectonophysics 252, 61–101.

Didenko, A.N., 2015. The analysis of Meso–Cenozoic paleomagnetic poles and the apparent polar wander path of Siberia. Izvestiya. Phys. Solid Earth 51 (5), 674–688.

Didenko, A.N., Mossakovskii, A.A., Pecherskii, D.M., Ruzhentsev, S.V., Samygin, S.G., Kheraskova, T.N., 1994. Geodynamics of the Central-Asian Paleozoic oceans. Geologiya i Geofizika (Russian Geology and Geophysics) 35 (7–8), 59–75 (48–61).

Didenko, A.N., Kaplun, V.B., Malyshev, Yu.F., Shevchenko, B.F., 2010. Lithospheric structure and Mesozoic geodynamics of the eastern Central Asian orogen. Russian Geology and Geophysics (Geologiya i Geofizika) 51 (5), 492–506 (629–647).

Dobretsov, N.L., Buslov, M.M., 2007. Late Cambrian–Ordovician tectonics and geodynamics of Central Asia. Russian Geology and Geophysics (Geologiya i Geofizika) 48 (1), 71–82 (93–108).

Dobretsov, N.L., Karsakov, L.P., Sklyarov, E.V., 1988. Glaucophane belts of Southern Siberia and Priamur'e. Geologiya i Geofizika (Soviet Geology and Geophysics) 29 (1), 3–11 (1–8).

Donskaya, T.V., Gladkochub, D.P., Mazukabzov, A.M., Ivanov, A.V., 2013. Late Paleozoic–Masozoic subduction-related magmatism at the southern margin of the Siberian continent and the 150 million-year history of the Mongol-Okhotsk Ocean. J. Asian Earth Sci. 62, 79–97.

Dorjsuren, B., Tomurtogoo, O., Dejidmaa, G., Mahbadar, Ts., Bujinlkham, B., 2004. The new member of the Atan ovoo formation. Mongol. Geosci. 26, 53–56.

Dril, S.I., Golubev, V.N., 2003. Nd–Sr systematics and REE geochemistry of rocks from accretionary complexes, eastern Transbaikal part of the Mongol–Okhotsk belt. Dokl. Earth Sci. 389A (3), 375–379.

Fillipova, I.B., 1969. The Hangayn synclinorium: the main features of composition and development. Geotectonika, No. 5, 76–78.

Golonka, J., Krobicki, M., Pajak, J., Van Giang, N., Zuchiewicz, W., 2006. Global Plate Tectonics and Paleogeography of Southeast Asia. AGN Univ. Sci. Technol. Arkadia, Krakov.

Golubev, V.N., Chernyshev, I.V., Golzman, Y.V., Bairova, E.D., Yakovleva, S.Z., Kotov, A.B., Sal'nikova, E.B., 2010. The Strel'tsovka uranium district: Isotopic geochronological (U–Pb, Rb–Sr, Sm–Nd) characterization of granitoids and their place in the formation history of uranium deposits. Geology of Ore Deposits 52 (6), 496–513.

Gordienko, I.V., 1987. Paleozoic Magnetism and Geodynamics of Central Asian Folded Belt [in Russian]. Nauka, Moscow.

Gordienko, I.V., 1994. Paleozoic geodynamic evolution of the Mongol-Okhotsk fold belt. J. South. Asian Earth Sci. 9 (4), 429–433.

Gordienko, I.V., 1996. Correlation of Pre-Jurassic sections of ancient continents and microcontinents in East Asia. J. South. Asian Earth Sci. 13 (3–5), 215–221.

Gordienko, I.V., 2001. Geodynamic evolution of the Central-Asian and Mongol-Okhotsk fold belts and formation of the endogenic deposits. Geosci. J. 5 (3), 233–241.

Gordienko, I.V., 2006. Geodynamic evolution of late Baikalides and Paleozoids in the folded periphery of the Siberian craton. Russian Geology and Geophysics (Geologiya i Geofizika) 47 (1), 51–67 (53–70).

Gordienko, I.V., Kuz'min, M.I., 1999. Geodynamics and metallogeny of the Mongolo-Transbaikalian region. Geologiya i Geofizika (Russian Geology and Geophysics) 40 (11), 1545–1562 (1522–1538).

Gordienko, I.V., Metelkin, D.V., 2016. The evolution of the subduction zone magmatism on the Neoproterozoic and Early Paleozoic active margins of the Paleoasian Ocean. Russian Geology and Geophysics (Geologiya i Geofizika) 57 (1), 69–81 (91–108).

Gordienko, I.V., Mikhal'tsov, N.E., 2001. Position of Vendian–Early Cambrian Ophiolitic and Island-Arc Complexes of the Dzhida zone of Caledonides in Paleoasian oceanic structures: Interpretation of paleomagnetic data. Dokl. Earth Sci. 379A (6), 622–626.

Gordienko, I.V., Klimuk, V.S., Quan Heng, 2000. The Upper Amur volcanoplutonic belt in Eastern Asia: structure, composition, and geodynamic setting. Geologiya i Geofizika (Russian Geology and Geophysics) 41 (12),1655–1669 (1602–1618).

Gordienko, I.V., Bulgatov, A.N., Ruzhentsev, S.V., Minina, O.R., Klimuk, V.S., Vetluzhskikh, L.I., Nekrasov, G.E., Lastochkin, N.I., Sitnikova, V.S., Metelkin, D.V., Goneger, T.A., Lepekhina, E.N., 2010. The Late Riphean–Paleozoic history of the Uda–Vitim island arc system in the Transbaikalian sector of the Paleoasian ocean. Russian Geology and Geophysics (Geologiya i Geofizika) 51 (1), 461–481 (589–614).

Gordienko, I.V., Medvedev, A.Ya., Gornova, M.A., Tomurtogoo, O., Goneger, T.A., 2012. The Haraa Gol terrane in the western Hentiyn Mountains (northern Mongolia): geochemistry, geochronology, and geodynamics. Russian Geology and Geophysics (Geologiya i Geofizika) 53 (3), 281–292.

Gordienko, I.V., Minina, O.R., Vetluzhskikh, L.I., Elbaev, A.L., Tomuttogoo, O., Odgerel, D., Ariunchimeg, Ya., 2017. Hentiyn-Daurian active continental margin of Mongol-Okhotsk oceanic basin (sedimentation, magnetism, geodynamic evolution), in: Geodynamic Evolution of Central Asian Movable Belt (from Ocean to Continent), Vol. 15 [in Russian]. IZK SO RAN, Irkutsk, pp. 59–61.

Gordienko, I.V, Metelkin, D.V., Vetluzhskikh, L.I., Mikhaltsov, N.E., Kulakov, E.V., 2018. New palaeomagnetic data from Argun terrane. Testing its association with Amuria and the Mongol-Okhotsk Ocean. Geophys. J. Int. 213, 1463–1477.

Hankard, F., Cogné, J.P., Kravchinsky, V., 2005. A new Late Cretaceous paleomagnetic pole for the west of Amuria block (Khurmen Uul, Mongolia). Earth Planet. Sci. Lett. 236, 359–373.

Hankard, F., Cogné, J.-P., Quidelleur, X., Bayasgalan, A., Lkhagvadorj, P., 2007. Palaeomagnetism and K–Ar dating of Cretaceous basalts from Mongolia. Geophys. J. Int. 169, 898–908.

Kelty, T.K., An. Yin, Batulzii, Dash, Gehrels, G.E., Ribeiro, A.E., 2008. Detrital-zircon geochronology of Paleozoic sedimentary rocks in the Hangay-Hentey basin, north-central Mongolia: Implications for the tectonic evolution of the Mongol-Okhotsk Ocean in central Asia. Tectonophysics 451, 290–311.

Khain, V.E., Seslavinskii, K.B., 1991. Historical Geotectonics: The Paleozoic [in Russian]. Nedra, Moscow.

Khanchuk, A.I. (Ed.), 2006. Geodynamics, Magnetism, and Metallogenesis of Eastern Russia: In 2 books [in Russian]. Dal'nauka, Vladivostok, Vol. 1.

Khanchuk, A.I., Didenko, A.N., Popeko, L.I., Sorokin, A.A., Shevchenko, B.F., 2015. Structure and Evolution of the Mongol-Okhotsk Orogenic Belt. The Central Asian Orogenic Belt (Geology, Evolution, Tectonics, and Models), Kröner, A. (Ed.). Borntraeger Science Publishers, Stuttgart, pp. 211–235.

Kheraskova, T.N., Bush, V.A., Didenko, A.N., Samygin, S.G., 2010. Breakup of Rodinia and early stages of evolution of the Paleoasian ocean. Geotectonics 44 (1), 3–24.

Kotov, A.B., Sorokin, A.A., Sal'nikova, E.B., Sorokin, A.P., Velikoslavinskii, S.D., Anisimova, I.V., Yakovleva, S.Z., 2009. Early Paleozoic age of gabbroids of the Amur complex (Bureya–Jiamusi Superterrane of the Central Asian Fold Belt). Dokl. Earth Sci. 425 (1), 185–188

Kotov, A.B., Mazukabzov, A.M., Skovitina, T.M., Velikoslavinsky, S.D., Sorokin, A.A., Sorokin, A.P., 2013. Structural evolution and geodynamic position of the Gonzha Block, Upper Amur region. Geotectonics 47 (5), 351–361.

Kravchinsky, V.A., Sorokin, A.A., 2001. Paleomagnetism of Devonian rocks in the Ol'doi terrane, upper Amur region. Dokl. Earth Sci. 377 (2), 147–151.

Kravchinsky, V.A., Cogne, J.-P., Harbert, W.P., Kuzmin, M.I., 2002. Evolution of the Mongol-Okhotsk Ocean as constrained by new palaeomagnetic data from the Mongol-Okhotsk suture zone, Siberia. Geophys. J. Int. 148, 34–57.

Kurihara, T., Tsukada, K., Otoh, S., Kashiwagi, K., Chuluun, M., Byambadash, D., Boijir, B., Gonchigdorj, S., Nuramkhan, M., Niwa, M., Tokiwa, T., Hikichic, G., Kozuka, T., 2009. Upper Silurian and Devonian pelagic deep-water radiolarian chert from the Khangai-Khentei belt of Central Mongolia: Evidence for Middle Paleozoic subduction-accretion activity in the Central Asian Orogenic Belt. J. Asian Earth Sci. 34, 209–225.

Kurilenko, A.V., Minina, O.R., 2017. The Devonian of Transbaikal: biostratigraphy and correlation. Palaeobiodivers. Palaeoenviron. 97 (3), 469–479.

Kuzmin, M.I., Fillipova, I.B., 1979. Middle–late Paleozoic and Mesozoic development history of Mongol-Okhotsk belt, in: Continental Plate Composition [in Russian]. IO AN SSSR, Moscow, pp. 189–226.

Larin, A.M., Kotov, A.B., Kovach, V.P., Sal'nikova, E.B., Yarmolyuk, V.V., Velikoslavinskii, S.D., Yakovleva, S.Z., Plotkina, Yu.V., 2015. Granitoids of the Olekma Complex in the Selenga–Stanovoi superterrane of the central Asian mobile belt: Age and tectonic position. Dokl. Earth Sci. 464 (1), 903–906.

Marinov, N.A. (Ed.), 1973. Geology of the People's Republic of Mongolia [in Russian]. Nauka, Moscow, Vol. 1: Stratigraphy.

Medvedev, A.Ya., Bulgatov, A.N., Gornova, M.A., Gordienko, I.V., Al'mukhammedov, A.I., 2007. Kyryn block metavulcanites (Eastern Transbaikalia). Litosfera, No. 1, 138–146.

Metelkin, D.V., 2013. Kinematic reconstruction of the Early Caledonian accretion in the southwest of the Siberian paleocontinent based on paleomagnetic results. Russian Geology and Geophysics (Geologiya i Geofizika) 54 (4), 381–398 (500–522).

Metelkin, D.V., Gordienko, I.V., Zhao, X., 2004. Paleomagnetism of Early Cretaceous volcanic rocks from Transbaikalia: argument for Mesozoic strike-slip motions in Central Asian structure. Geologiya i Geofizika (Russian Geology and Geophysics) 45 (12), 1404–1417 (1349–1363).

Metelkin, D.V., Gordienko, I.V., Klimuk, V.S., 2007. Paleomagnetism of Upper Jurassic basalts from Transbaikalia: new data on the time of closure of the Mongol-Okhotsk Ocean and Mesozoic intraplate tectonics of Central Asia. Russian Geology and Geophysics (Geologiya i Geofizika) 48 (10), 825–834 (1061–1073).

Metelkin, D.V., Vernikovsky, V.A., Kazansky, A.Yu., Kashirtsev, V.A., Bragin, V.Yu., Kungurtsev, L.V., 2008. The Mesozoic apparent polar wander path for the Siberian domain of the Eurasian plate. Dokl. Earth Sci. 418 (1), 62–67.

Metelkin, D.V., Vernikovsky, V.A., Kazansky, A.Yu., Wingate, M.T.D., 2010. Late Mesozoic tectonics of Central Asia based on paleomagnetic evidence. Gondwana Res. 18 (2–3), 400–419.

Metelkin, D.V., Vernikovsky, V.A., Kazansky, A.Yu., 2012. Tectonic evolution of the Siberian paleocontinent from the Neoproterozoic to the Late Mesozoic: paleomagnetic record and reconstructions. Russian Geology and Geophysics (Geologiya i Geofizika) 53 (7), 675–688 (883–899).

Metelkin, D.V., Gordienko, I.V., Vetluzhskikh, L.I., Mikhaltsov, N.E., 2013. Geology and paleomagnetism of the Vendian and lower Cambrian deposits from Argun terrane (Eastern Transbaikalia). Dokl. Earth Sci. 449 (1), 284–289.

Oleinikov, A.N. (Ed.), 2002. Atlas of Paleozoic–Mesozoic Flora and Fauna of Transbaikalia [in Russian]. Novsibirsk, Nauka.

Parfenov, L.M., Bulgatov, A.N., Gordienko, I.V., 1996. Terranes and formation of orogenic belts in Transbaikalia. Tikhookeanskaya Geologiya, 15 (4), 3–15.

Parfenov, L.M., Popenko, L.I., Tomurtogoo, O., 1999. Problems of Mongol-Okhotsk orogenic belt's tectonics. Tikhookeanskaya Geologiya 18 (5), 24–43.

Parfenov, L.M., Bersin, N.A., Khanchuk, A.I., Badarch, G., Belichenko, V.G., Bulgatov, A.N., Dril', S.I., Kirillova, G.L., Kuzmin, M.I., Nokleberg, U., Prokopiev, A.V., Timofeev, V.F., Tomurtogoo, O., Yan', Kh., 2003. Model of orogenic belt formation in Central and Northeastern Asia. Tikhookeanskaya Geologiya 22 (6), 7–41.

Popeko, L.I., Natal'in, B.A., Belyaeva, G.V., Kotlyar, G.V., Shishkina, G.R., 1993. Paleozoic paleobiogeographic zonality and geodynamics of the southern part of the Russian Far East. Tikhookeanskaya Geologiya 13 (5), 19–30.

Ruppen, D., Knaf, A., Bussien, D., Winkler, W., Chimedtseren, A., Quadt, A., 2014. Restoring the Silurian to Carboniferous northern active continental margin of the Mongol–Okhotsk Ocean in Mongolia: Hangay–Hentey accretionary wedge and seamount collision. Gondwana Res. 25 (4), 1517–1534.

Ruzhentsev, S.V., Minina, O.R., Nekrasov, G.E., Aristov, V.A., Golionko, B.G., Doronina, N.A., Lykhin, D.A., 2012. The Baikal-Vitim Fold System: Structure and geodynamic evolution. Geotectonics 46 (2), 87–110.

Ruzhentsev, S.V., Nekrasov, G.E., 2009. Tectonics of the Aga Zone, Mongolia-Okhotsk belt. Geotectonics 43 (1), 34–50.

Sengör, A.M.C., Natal'in, B.A., Burtman, V.S., 1993. Evolution of the Altaid tectonic collage and Paleozoic crustal growth in Eurasia. Nature 364, 299–307.

Sklyarov, E.V., 2006. Exhumation of metamorphic complexes: basic mechanisms. Russian Geology and Geophysics (Geologiya i Geofizika) 47 (1), 68–72 (71–75).

Smirnova, Yu.N., Popeko, L.I., Sorokin, A.A., 2017. Age, geochemistry, and sources of clastic materials and accumulation settings of the Glubokin Formation (Eastern Transbaikalia). Russ. J. Pacific Geol. 36 (3), 163–177.

Sorokin, A.A., Kudryashov, N.M., 2015. The first U–Pb geochronological and geochemical data on Late Vendian and Early Paleozoic acid volcanic rocks of the Mamyn Terrane (Central Asian Fold Belt). Dokl. Earth Sci. 465 (2), 1237–1242.

Sorokin, A.A., Kudryashov, N.M., 2017. The Cambrian–Ordovician diorite–granodiorite–granite association of the Mamyn Terrane (Central Asian Fold Belt): U–Pb geochronological and geochemical data. Dokl. Earth Sci. 472 (1), 113–118.

Sorokin, A.A., Ponomarchuk, V.A., Sorokin, A.P., Kozyrev, S.K., 2004. Geochronology and correlation of Mesozoic magmatic formations of the Amur superterrane's northern margin. Stratigraphiya. Geologicheskaya Korrelyatsiya 12 (6), 38–54.

Sorokin, A.A., Kotov, A.B., Kudryashov, N.M., Kovach, V.P., 2015. First evidence of Ediacaran magmatism in the geological history of the Mamyn Terrane of the Central Asian fold belt. Russ. J. Pacific Geol. 34 (6), 399–410.

Sorokin, A.A., Smirnova, Yu.N., Kotov, A.B., Kovach, V.P., Sal'nikova, E.B., Popeko, L.I., 2015. Provenances of the paleozoic terrigenous sequences of the Oldoi terrane of the Central Asian orogenic belt: Sm–Nd isotope geochemistry and U–Pb geochronology (LA-ICP-MS). Geochem. Int. 53(6), 534–544.

Sorokin, A.A., Smirnova, Yu.N., Kudryashov, N.M., Sorokin, A.P., 2017. Middle Triassic age of metarhyolite of the Bondikha Formation, Argun Continental Massif, Central Asian Fold Belt. Dokl. Earth Sci. 473 (1), 296–299.

Tomurtogoo, O., 2005. Tectonics and structural evolution of Mongolia, in: Seltman, R., Gerel, O., Kirwin, D.J. (Eds.), Geodynamics and

Metallogeny of Mongolia with a Special Emphasis on Copper and Gold Deposits, SEG-IAGOD Field Trip, 14–16 August 2005, 8th Biennial SGA Meeting. IAGOD Guidebook Series 11. CERCAMS/ NHM, London, pp. 5–12.

Tomurtogoo, O., 2014. Tectonics of Mongolia, in: Tectonics of Northern, Central and Eastern Asia. Explanatory Note to the Tectonic Map of Northern-Central-Eastern Asia and Adjacent Areas at Scale 1:2 500 000. VSEGEI, St. Petersburg, pp. 110–126.

Tomurtogoo, O., Windley, B.F., Kröner, A., Badarch, G., Liu, D.Y., 2005. Zircon age and occurrence of the Adaatsag ophiolite and Muron shear zone, central Mongolia: constraints on the evolution of the Mongol-Okhotsk ocean, suture and orogeny. J. Geol. Soc., London. 162, 125–134.

Torsvik, T.H., Cocks, L.R.M., 2017. Earth History and Palaeogeography. Cambridge University Press.

Tsygankov, A.A., 2014. Late Paleozoic granitoids in western Transbaikalia: sequence of formation, sources of magmas, and geodynamics. Russian Geology and Geophysics (Geologiya i Geofizika) 55 (2), 153–176.

Vosnesenskaya, T.A., 1995. Sedimentary evolution of HangaynCaledonian basin (Mongolia). Litologiya i Poleznye Iskopaemye, No. 5, 537–547.

Wilhem, C., Windley, B.F., Stampfli, G.M., 2012. The Altaids of Central Asia: a tectonic and evolutionary innovative review. Earth Sci. Rev. 113, 303–341.

Yang, Y.-T., Guo, Z.-X., Song, C.-C., Li, X.-B., He, S., 2015. A short-lived but significant Mongol–Okhotsk collisional orogeny in latest Jurassic–earliest Cretaceous. Gondwana Res. 28 (3), 1096–1116.

Yanshin, A.L. (Ed.), 1974. Tectonics of the People's Republic of Mongolia (Trans. Joint Soviet-Mongolian Geological Expedition, Issue 9) [in Russian]. Nauka, Moscow.

Yarmolyuk, V.V., Kovalenko, V.I., Kovach, V.P., Kozakov, I.K., Kotov, A.B., Sal'nikova, E.B., 2002. Isotopic composition, sources of crustal magmatism, and crustal structure of Caledonides of the Ozernaya Zone, Central Asian Foldbelt. Dokl. Earth Sci. 387A (9), 1043–1047.

Yarmolyuk, V.V., Kozlovsky, A.M., Sal'nikova E.B., Kozakov, I.K., Kotov, A.B., Lebedev, V.I., Eenjin, G., 2013. Age of the Khangai batholith and challenge of polychronic batholith formation in Central Asia. Dokl. Earth Sci. 452 (2), 1001–1007.

Yarmolyuk, V.V., Kozlovsky, A.M., Lebedev, V.I., 2017. Neoproterozoic magmatic complexes of the Songino block (Mongolia): A problem of formation and correlation of Precambrian terranes in the Central-Asian Orogenic Belt. Petrology 25 (4), 365–395.

Zhao, X., Coe, R.S., Zhou, Y.X., Wu, H.R., Wang, J., 1990. New palaeomagnetic results from northern China: collision and suturing with Siberia and Kazakhstan. Tectonophysics 181, 43–81.

Zonenshain, L.P., Gorodnitskii, A.M., 1977. Paleozoic and Mesozoic reconstructions of continents and oceans. Geotektonika, No. 2, 3–22.

Zonenshain, L.P., Kuzmin, M.I., Kononov, M.V., 1987. Absolute reconstructions of Paleozoic and Early Mesozoic continental positions. Geotektonika, No. 3, 16–27.

Zonenshain, L.P., Kuzmin, M.I., Natapov, L.M., 1990. Continental Plate Tectonics in USSR's Territory, Vol. 2 [in Russian]. Nedra, Moscow.

Zorin, Y.A., 1999. Geodynamics of the western part of the Mongolia-Okhotsk collisional belt, Trans-Baikal region (Russia) and Mongolia. Tectonophysics 306, 33–56.

Zorin, Yu.A., Belichenko, V.G., Rutshtein, I.G., Zorina, L.D., Spiridonov, A.M., 1998. Geodynamics of the western part of the Mongolia-Okhotsk fold belt and tectonic framework of gold mineralization in the Transbaikal area. Geologiya i Geofizika (Russian Geology and Geophysics) 39 (11), 1578–1587 (1578–1586).

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