ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 412, No. 1, pp. 39–42. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © Yu.A. Zorin, E.V. Sklyarov, V.G. Belichenko, A.M. Mazukabzov, 2007, published in Doklady Akademii Nauk, 2007, Vol. 412, No. 3, pp. 369–372.

GEOLOGY

Evolution of Island Arcs and Geodynamics of the Eastern Central Asian Foldbelt in the Neogea

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Received July 21, 2006

DOI: 10.1134/S1028334X07010096

The eastern part of the Central Asian foldbelt comprises the region located between the ancient Siberian and North China platforms. Some researchers believe that the Central Asian foldbelt is a collage of terranes formed in different geodynamic settings and that this foldbelt appeared after the opening of the Paleoasian ocean [1–4]. Proponents of the concept of Altaides [5] believe that all stratified rocks of the foldbelt are related to accretion–subduction wedges. However, proponents of both concepts admit the significant role of Riphean, Vendian–Lower Paleozoic, and middle Paleozoic island-arc formations in the foldbelt structure. These works paid little attention, however, to formations of back-arc (marginal) seas. The paleogeodynamic reconstructions proposed in them sometimes lack analogues in modern (Mesozoic–Cenozoic) plate tectonics. Taking into consideration recent data on the formation mechanism of island arcs and marginal seas, we propose in this communication a more rigorous and actualistic approach to paleogeodynamic reconstructions that can change (or specify) views on geodynamics of the eastern Central Asian foldbelt.

Rollback of the trench toward the ocean due to successive subduction of a thick cold slab with negative buoyancy is considered the main process responsible for the formation of island arcs and back-arc (marginal) seas [6]. Numerical thermomechanical simulations of the subduction process show that the rollback rate increases during stagnation of the slab in the transitional mantle zone [7]. The thick relatively cold slab subsides into the mantle with a high rate. Therefore, it is not heated to the temperature necessary for the transformation of olivine into its spinel-type phases. Since the density of olivine in the metastable state is lower as compared with that of the last phases, the lower part of the slab loses its negative buoyancy and bends to acquire a horizontal position in the transitional zone (stagnation). The inclined segment of the slab retains negative buoyancy and continues to subside into the mantle to overcome the resistance of its stagnated part. This results in the increased rate of the trench rollback toward the ocean [7]. The slab should be thick and cold (i.e., sufficiently old) to provide the conditions required for the latter processes. That is why present-day island arcs are developed only at the western Pacific margin with the Early Cretaceous and Jurassic oceanic lithosphere near the subduction zone, while island arcs are absent in the eastern part of the ocean where the slab is younger [8, 9].

The negative buoyancy of old parts of oceanic slabs is probably only one of the factors governing the dynamics of lithospheric plates. Of importance are forces related to the structure of mid-ocean ridges and convection within the asthenosphere, where elongated cells are induced by the cooling influence of subducting slabs [10]. These forces produce compression near the subduction zone and counteract extension of the overlying lithosphere.

We believe that the dynamic equilibrium is disturbed in the course of oceanic slab stagnation, resulting in trench rollback toward the ocean. The continental magmatic arc is transformed into an island arc with the formation of a new oceanic crust beneath the marginal sea in the back-arc zone due to extension and diffused spreading. At present, this process is probably developing near the Japan and Tonga island arcs with the stagnated subducting slab [11]. If the horizontal segment of the stagnated slab experiences strong resistance to its movement, the mass-induced force acting on its inclined segment may provoke splitting of these segments and subsidence of the slab into the mantle without stagnation. In this case, extension in the marginal sea may give way to compression leading to closure of the sea. The last process is likely taking place now in the Bonin and Mariana arc region, where the oceanic slab is not subjected to stagnation [11]. At the same time, closure of the Philippine Sea is in progress, which is evident from the subduction of its lithosphere under the Asian continent [8]. Such an environment should

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promote subduction of the mantle part of the lithosphere, which is detached from the crust of the marginal sea. The oceanic crust of the marginal sea together with a thick sedimentary sequence should be deformed into intricate folds and large thrusts with the exhumation of subduction-related ophiolites in allochthons. It should be noted that precisely such ophiolites are characteristic of the Baikalides and Paleozoides in the Central Asian foldbelt [12]. Naturally, these ophiolites do not mark any boundaries between terranes, but simply reflect particular deformations of the crust beneath marginal seas.

There may be multiple repeating processes responsible for the formation of island arcs and the opening and closure of marginal seas [1, 2]. However, the facts mentioned above indicate that these processes require a sufficiently old age of the subducting slab; i.e., the ocean with island arcs forming at its margins should be relatively wide. Therefore, we should assume that the southern (in present-day coordinates) boundary of the Siberian continent was facing the spacious ocean in the Riphean (since 1100 Ma B.P. [12]) and Vendian–Early Paleozoic, when island arcs existed near this boundary [1, 2, 12]. This setting is consistent with reconstructions of the positions of large continental blocks [13], which we used for reconstructing paleogeodynamic settings at key stages in the development of the eastern Central Asian foldbelt (Fig. 1).

Judging from these reconstructions, the present-day southern margin of the Siberian Craton was facing in the northern direction toward Panthalassa when the supercontinent Rodinia started to disintegrate (750 to 650 Ma B.P.). The northern (in modern coordinates) boundaries of the Siberian and East European cratons adjoined each other (Fig. 1, reconstruction for 700 Ma B.P.). The Paleoasian ocean (the space between the Siberian and North China cratons) already existed at that time as a wide gulf of Panthalassa. The breakup of Rodinia and formation of Laurasia and Gondwana changed the configuration of the ocean, which was gradually reduced and ultimately isolated from Panthalassa in the Ordovician (Fig. 1, reconstructions for 700, 560, and 450 Ma B.P.).

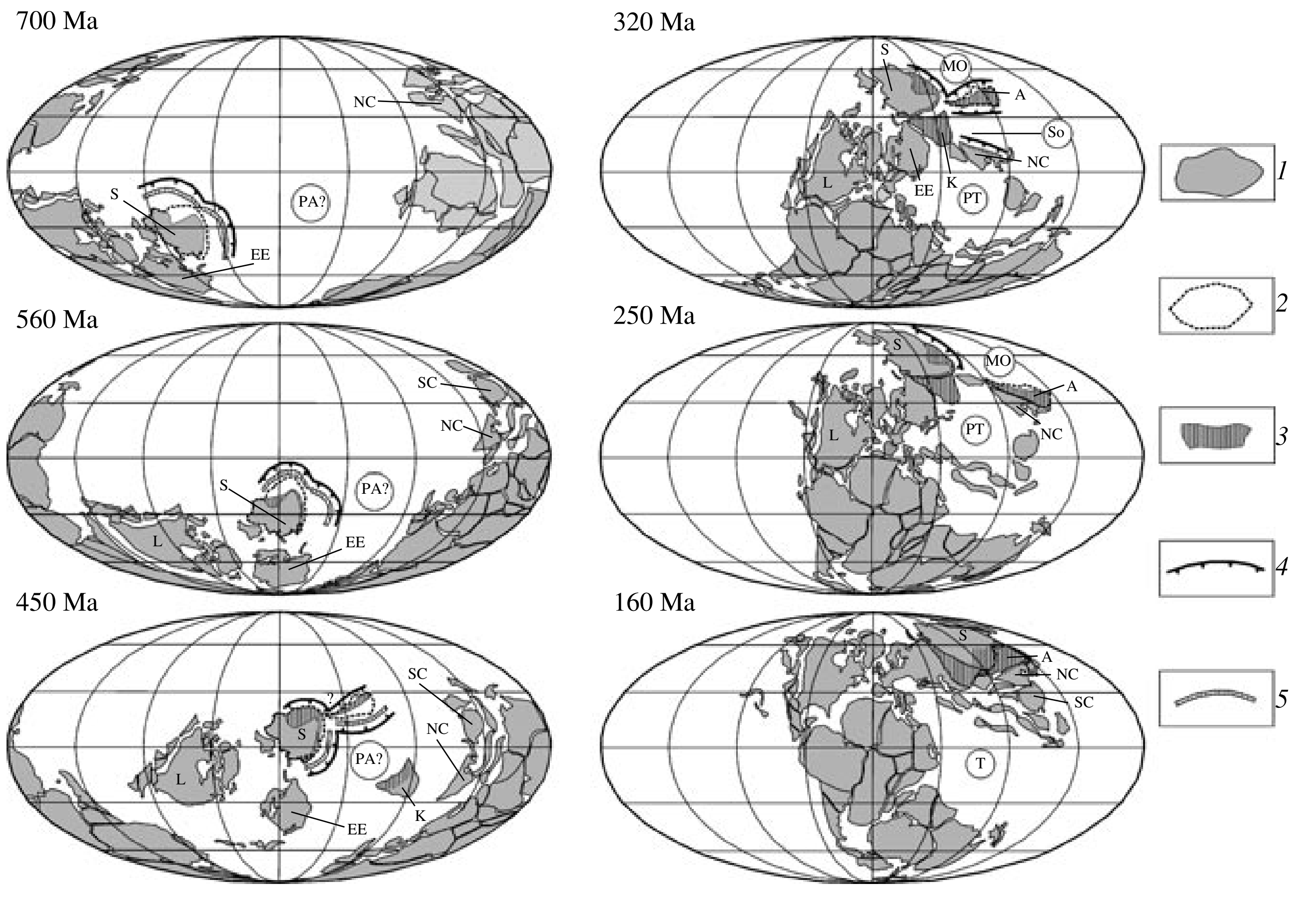
The decisive role of island-arc geodynamic settings at the Riphean and Vendian–Early Proterozoic stages in the geological history of the Central Asian foldbelt compels us to revise the geodynamic nature of sedimentary rocks developed in the Siberian Craton framework. These rocks were traditionally referred to passive continental margins [1–3]. However, judging from present-day geodynamic settings [8], coexistence of island arcs and spatially close passive continental margins of the Atlantic type is hardly possible. In our opinion, shelf series adjacent to the platform and their proxies in the deep-sea zone should be attributed to marginal seas. In the Baikal–Patom zone with the allegedly classical geological section of the Riphean passive margin [2, 14], the thickness of sequences increases and the role of carbonate rocks decreases in the southern direction. The Bodaibo Trough located in the southernmost part of the zone is characterized by development of black shales (indicator of significant depths of the sea) and graywackes (erosion of a proximal volcanic arc). In terms of lithology, the sediments of the passive continental margin and near-continental part of the marginal sea should be very similar. The marginal sea is, however, an element of the active continental margin of the West Pacific type and its near-continental part should not be referred to the passive margin. At the same time, rifting should accompany both the opening of a large oceanic basin and the formation of a smaller marginal sea.

We believe that the anomalous polarity of the Riphean and Vendian–Early Paleozoic subduction zones (their dipping toward the ocean), which is evident from the vergence of structures and lateral variability of formations in areas located south of the Baikal–Patom zone [2, 14], was characteristic of not primary island arcs but secondary subduction zones that formed during the closure of marginal basins.

Blocks of ancient (pre-Riphean) rocks within the Baikalides and early Caledonides are usually considered microcontinents, which collided with island arcs [2, 3]. The study region includes the Muya and Gargan blocks only a few tens kilometers in size. They most likely represent cores of separate islands of ensialic island arcs [14]. Along the strike, such arcs may grade into ensimatic ones just as the present-day ensialic Japan arc successively grades along the common subduction system into the ensimatic Izu–Bonin and Mariana island arcs. The difference between these two types of island arcs is as follows: in some cases, blocks detached from continents are involved in the trench rollback toward the ocean; in other cases, this process takes place without the detachment of blocks.

During the formation of Pangea in the Late Paleozoic–Early Mesozoic, substantial changes in the configuration of Panthalassa (prototype of the Pacific Ocean) produced the Solonker and Mongol–Okhotsk gulfs, which are usually called oceans in the geological literature [1, 2, 15] (Fig. 1, reconstruction for 320 Ma B.P.). These oceanic basins were small. If oceanic rifts were present within such basins, the relatively young crust should have subducted beneath the adjacent continents. As was shown above, such a situation is unfavorable for the formation of island arcs. Therefore, the prolonged domination of island-arc settings was replaced in the Late Paleozoic by a period of active Andean-type continental margins. The Permian–Triassic transition was marked by the closure of the Solonker Ocean [2], which was followed by the closure of the Mongol–Okhotsk basin at the Middle–Late Jurassic transition [15]. These events terminated the formation of the Central Asian foldbelt (Fig. 1, reconstructions for 250 and 160 Ma B.P.).

Thus, a more rigorous actualistic coordination of geological events leading to the formation of the Cen-



Paleogeodynamic reconstructions for the main development stages of the Central Asian foldbelt. Positions of large continental blocks are given after [13]. Only island arcs and subduction zones related to development of the eastern Central Asian foldbelt are shown. (*1*) Continental blocks (Siberian continent and Amur continental terrane are shown in boundaries corresponding to their original position; other continents are given in their present-day boundaries); (*2*) modern boundaries of the Siberian continent and Amur continental terrane; (*3*) areas of a newly formed continental crust related to accretion of island arcs, marginal seas, and accretion-subduction wedges to older continental blocks; (*4*) subduction zones; (*5*) island arcs. Continental blocks: (S) Siberia, (L) Laurentia, (EE) East Europe, (A) Amuria, (NC) North China, (SC) South China, (K) Kazakhstan. Oceans (encircled letters): (PA) Paleoasian, (So) Solonker, (MO) Mongol–Okhotsk, (PT) Paleotethys, (T) Tethys.

tral Asian foldbelt and present-day geodynamic settings, combined with new concepts of the mechanism responsible for the development of island arcs and marginal seas, allows the following inferences.

(1) Displacement of large continental blocks resulted in the breakup of Rodinia and the formation of Laurasia, Gondwana, and Pangea. These processes changed the configuration of Panthalassa and produced large gulfs, such as the Paleoasian Ocean and the younger Solonker and Mongol–Okhotsk oceans.

(2) Island-arc geodynamic settings were characteristic of areas surrounding the southern (in modern coordinates) Siberian continent in the Riphean, Vendian–Early Paleozoic, and Middle Paleozoic, when oceans were sufficiently wide and the subducting lithosphere was relatively old.

(3) Stratified Riphean and Vendian–Lower Paleozoic formations in the Siberian Craton framework should be viewed as near-continental parts of marginal seas rather than as passive continental margins.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, project nos. 06-05-64117 and 05-05-64761.

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