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GEOLOGY

The Cambrian Baltica–Arctida Collision, Pre-Uralide–Timanide Orogen, and Its Erosion Products in the Arctic

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Researchers have obtained in the last decade a considerable amount of new data on various aspects of the geological setting of high-latitude regions of the Arctic and northern regions of Russia. These data have made it possible to revise the tectonic scenario of the Late Precambrian–Cambrian evolution of the northeastern and eastern framing of the East European Craton (EEC) [3]. Collision of two Late Precambrian continents—Baltica (Neoproterozoic skeleton of the East European Craton) and Arctida (Fig. 1)—at the Late Precambrian/Cambrian boundary is the key issue in this scenario.

The Late Precambrian Arctida continent incorporated the following structures: blocks of an ancient sialic crust located now in the Arctic sector (Barents, Kara, and Novosibirsk blocks); the Arctic Alaska–Chukchi block; some fragments of the Innuitian foldbelt (the block of the northern parts of Peary Land and Ellesmere Island); and the Lomonosov Ridge block (Fig. 2). The blocks were separated and accreted at the Arctic periphery of northeastern Eurasia or North America owing to the origination of several different-aged spreading centers (systems) in the Late Mesozoic and Early Cenozoic. This process was accompanied by the opening of the Eurasian, Amerasian (Canadian), and other basins with the oceanic crust in the North Arctic Ocean. The multistage retrospective “closure” of oceanic basins served as a basis for the initial reconstruction of the Arctida continent [15]. In this model, Arctida existed as an autonomous large massif of the continental crust up to the Devonian and incorporated all sialic blocks mentioned above except the Barents block [15]. In later models, the Barents block was also included in Arctida. Moreover, Arctida was shown as an autonomous continent that was separated from other ancient massifs with the continental crust until the Late Precambrian/Cambrian boundary [1, 3] when the Bol’shaya Zemlya active margin of Arctida) collided with the Timan passive margin of Baltica. The collision of continents produced the new composite Arcteurope continent [1]. The pre-Uralide–Timanide collisional orogen appeared in the Baltica–Arctida collision zone [3].

Pre-Ordovician complexes of the northeastern and eastern framing of the East European Craton (Timanides and pre-Uralides) make up the Central Uralian Uplift and the basement of the Timan–Pechora basin, respectively. In works of N.S. Shatsky, N.P. Kheraskov, and A.S. Perfil’ev, these complexes are subdivided into two large groups characterized by significant compositional distinctions (Fig. 3).

(1) The southwestern Timanides (Late Precambrian complexes of Timan and the adjacent basement of the Timan–Pechora basin) and the southern pre-Uralides (pre-Ordovician complexes of the Kvarkush and Bashkir anticlinoriums of the Central Uralian Uplift) are mainly composed of sedimentary rocks [4, 11, and references therein].

(2) The northeastern Timanides (Late Precambrian complexes composed of the Bol’shaya Zemlya megablock of the Timan–Pechora basin basement) and the northern pre-Uralides (pre-Ordovician complexes of the Lyapin anticlinorium and all northern structures of the Central Uralian Uplift) are mainly composed of volcanosedimentary and volcanic rocks, granitoids, and rare ophiolites [2, 9, and references therein].

Pre-Uralides and Timanides of the first group formed at the Timan passive margin of Baltica. In contrast, pre-Uralides and Timanides of the second group formed at the Bol’shaya Zemlya active margin of Arctida and the Arctida–Baltica collision zone [3]. In the Timan–Pechora basin, boundary between pre-Uralides

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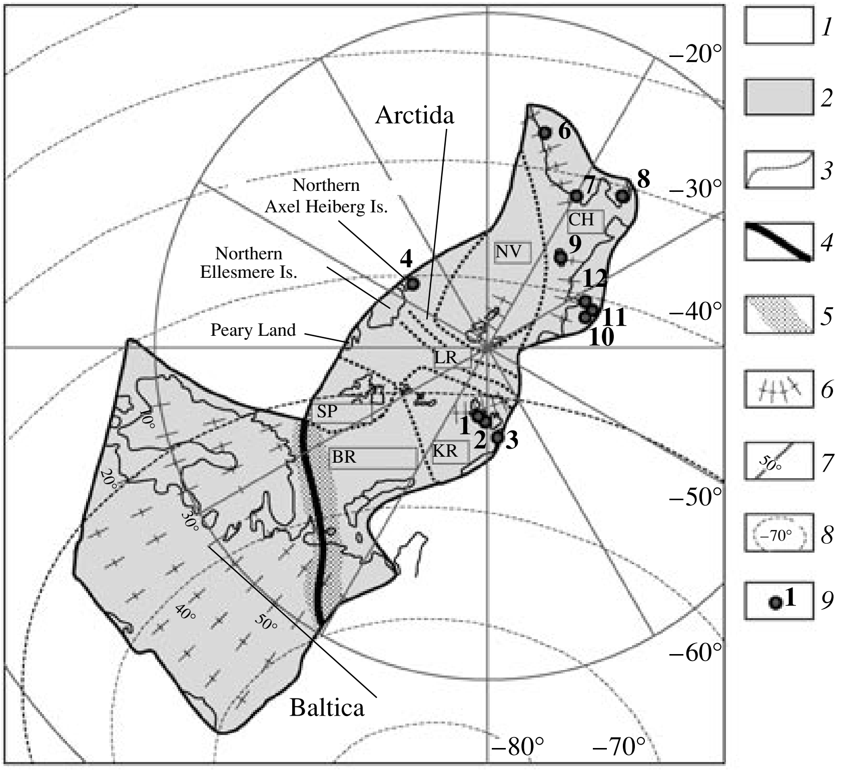


Fig. 1. The Arcteurope continent. Paleotectonic reconstruction for the Early Cambrian (modified after [1]). (*1*) Oceanic basins; (*2*) paleocontinents; (*3*) boundaries of blocks of the continental crust; (*4*) Baltica–Arctida collision zone; (*5*) Cambrian pre-Uralide–Timanide collisional orogen; (*6*) junctions of the modern coordination network (intersection of modern latitudes and longitudes); (*7*) modern coordination network; (*8*) ancient coordination network; (*9*) points of detection of erosion products of the pre-Uralide–Timanide orogen (numbers are as in Fig. 2). Letter designations in boxes: (BR) Barentsia (Barents block); (KR) Kara block; (LR) Lomonosov Ridge block; (NV) Novosibirsk block; (CH) Chukchi block; (SP) Spitsbergen block.

and Timanides of the first and second groups passes along the Pechora–Ilych–Chiksha suture zone (Fig. 3).

Pre-Uralides and Timanides of the second group incorporate the pre-Ordovician granitoids and associated volcanic complexes. Based on specific features and distinctive features of the chemical and mineral compositions according to the classification proposed by B. Chappel and A. White, the igneous rocks are subdivided into two types (I and A) [3, 5].

Volcanoplutonic granitoid associations of type I range from ~700 to 515 Ma in age. They are members of long continuously differentiated igneous (gabbro–diorite–granite and basalt–andesite–dacite–rhyolite) series. Based on lithological features, rocks of type I are referred to the calc-alkaline series and compared with the typical subduction-related and/or collision setting. Granitoids and felsic volcanics of type A range from ~560 to 500 Ma in age and represent parts of the bimodal gabbro–granite and basalt–rhyolite associations. Granitoids of type A make up elongate plutons confined to linear tectonic zones. Their chemical features and geological setting are typical of the local extension setting.

In general, pre-Uralide–Timanide granitoid magmatism encompasses the age interval ranging from ~700 to ~500 Ma [3]. We believe that early calc-alkaline granitoids and volcanics of type I (~700–560 Ma) are related to magmatic bodies formed above a subduction zone beneath the Bol'shaya Zemlya margin of Arctida. Late calc-alkaline granitoids and volcanics (~560–515 Ma) could be related to the collision of Baltica and Arctida. Granitoids and felsic volcanics of type A (565–500 Ma) mark settings of local extension and deep fracturing of the Earth's crust at late stages of collision. Figure 2 shows bar charts of the frequency of occurrence (hereafter, bar charts) of isotopic ages of pre-Uralide–Timanide granitoids.

The Cambrian pre-Uralide–Timanide orogen represented the major structural expression of the collision of Baltica and Arctida. The orogen represented a highland in the Early Paleozoic. Therefore, this region was intensely eroded and its erosion products were scattered as far as the Arcteurope continent. This is indicated by recent datings of detrital minerals in clastic and metaclastic rocks and xenogenous zircon crystals in igneous rocks from various Phanerozoic complexes of Arctida. At present, Late Precambrian and Early Paleozoic detrital and xenogenous minerals are known in rocks from the following points (Fig. 2).

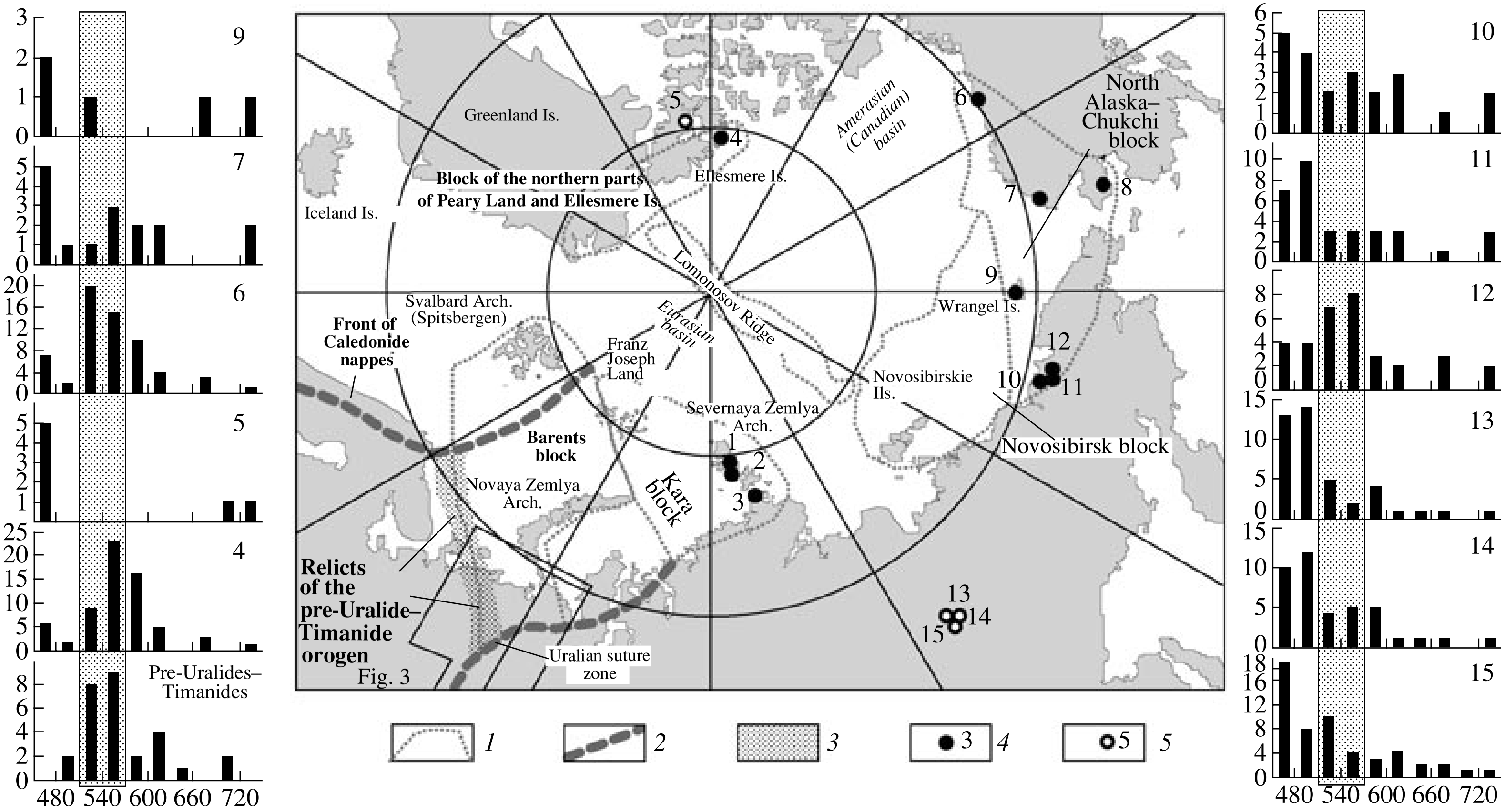
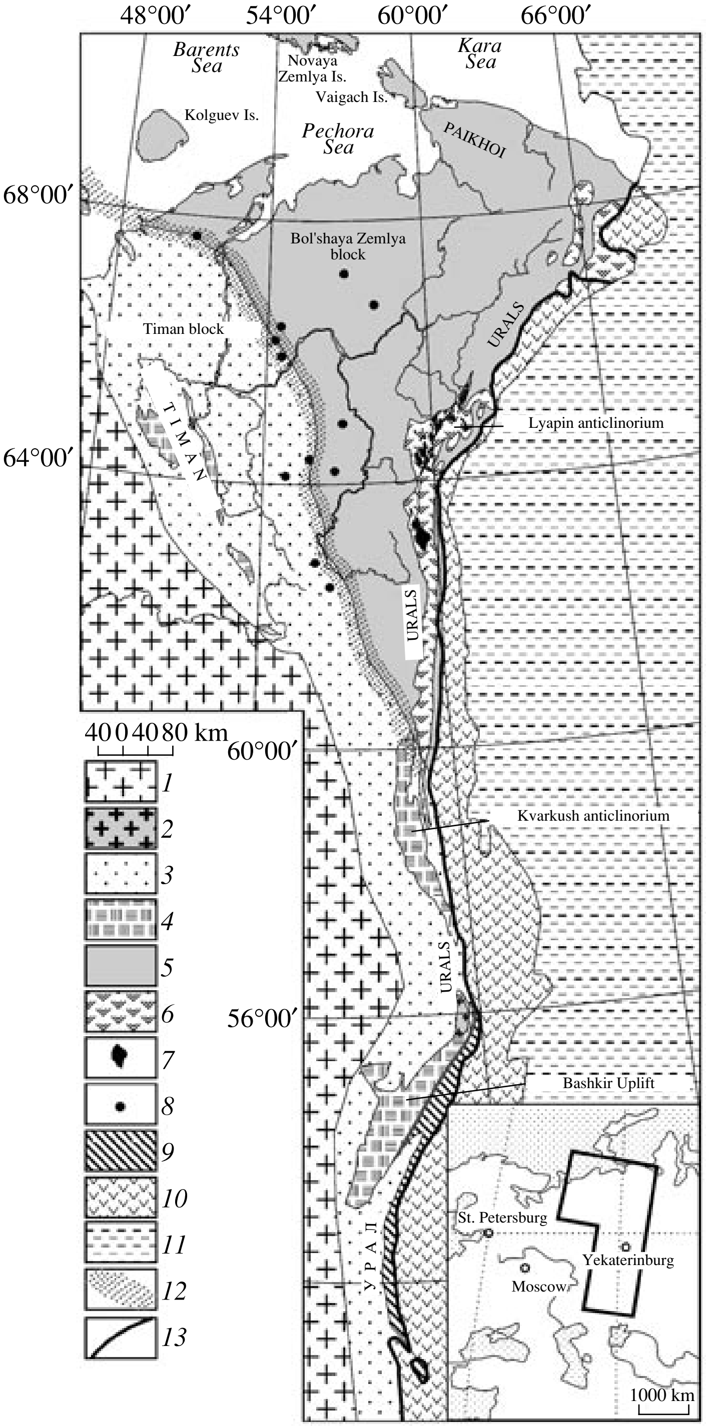


Fig. 2. Schematic location of some tectonic elements of the Arctic region. (*1*) Boundaries of blocks of the continental crust incorporated into the Late Precambrian Arctida continent; (*2*) relicts of the Cambrian pre-Uralide–Timanide collisional orogen; (*3*) Paleozoic structures bounding relicts of the pre-Uralide–Timanide orogen (Scandinavian Caledonian nappe front in the northwest and Uralian suture zone in the southeast); (*4*) points of the detection of erosion products of the pre-Uralide–Timanide orogen; (*5*) points of the detection of erosion products of Late Precambrian–Early Paleozoic complexes of North America and southern Siberia. Margins of the figure also present the following plots: (i) the pre-Uralide–Timanide reference plots, which demonstrate the integral occurrence frequency of ages of pre-Ordovician granitoids of the pre-Uralides (Lyapin anticlinorium) and Timanides (basement of the Timan–Pechora basin); (ii) the occurrence frequency of ages of detrital zircons with the age range of 450–750 Ma in Triassic sandstones from different regions of the Arctic. The dotted background shows the age range of granitoid magmatism in the pre-Uralide–Timanide orogen. Plot numbers in the bar charts are as in the scheme. See the text for commentary.


48°00′
54°00′
60°00′
66°00′
Barents Sea
Novaya Zemlya Is.
Vaigach Is.
Kara Sea
Kolguev Is.
Pechora Sea
PAIKHOI
68°00′
68°00′
Bol'shaya Zemlya block
Timan block
URALS
TIMAN
Lyapin anticlinorium
64°00′
64°00′
URALS
60°00′
60°00′
40 0 40 80 km
Kvarkush anticlinorium
URALS
56°00′
56°00′
Bashkir Uplift
УРАЛ
St. Petersburg
Yekaterinburg
Moscow
1000 km
1
2
3
4
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6
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Fig. 3. Tectonic scheme of the distribution of Late Precambrian–Cambrian complexes in the northeastern (Timan–Pechora) and eastern (Uralian) realm of the East European Craton. (*1*) Early Precambrian metamorphic complexes of the East European Craton realm (Baltica) with the platformal cover; (*2*) the same, exhumed in the Central Uralian Uplift (Taratash Uplift); (*3*) nonuniformly metamorphosed (primarily, sedimentary) Late Precambrian complexes of the southwestern Timanides (Timan megablock of the Timan–Pechora basin basement) and southern pre-Uralides—complexes of the Late Precambrian Timan passive margin of Baltica; (*4*) exhumed varieties of (*3*); (*5*) nonuniformly metamorphosed (primarily, volcanic and volcanosedimentary) Late Precambrian complexes, granitoids, and rare ophiolites of the northeastern Timanides (Bol'shaya Zemlya megablock of the Timan–Pechora basin basement) and northern pre-Uralides—complexes of the Late Precambrian Bol'shaya Zemlya active margin of Baltica; (*6*) the same, exhumed in the Lyapin anticlinorium, northern structures of the Central Uralian Uplift, northern Paikhoi (Amderma region), northern Vaigach Island, and southern area of Novaya Zemlya Island; (*7*) pre-Ordovician granitoids in the pre-Uralides; (*8*) pre-Ordovician granitoids recovered by boreholes at the Timan–Pechora basin basement (borehole locations are adopted from E.G. Dovzhikova); (*9*) nonuniformly metamorphosed pre-Ordovician sedimentary, volcanosedimentary, and volcanic complexes, granitoids, and rare ophiolites that are alien for the southern pre-Uralides; (*10*) mainly unmetamorphosed Paleozoic and less common Precambrian volcanic, volcanosedimentary, and sedimentary complexes, ophiolites, and granitoids of the eastern Urals; (*11*) Meso–Cenozoic (primarily, sedimentary) complexes of the West Siberian Plate cover; (*12*) Baltica–Arctida collision zone (near-Pechora–Ilych–Chiksha suture zone); (*13*) western boundary of rock complexes of the eastern Urals (Main Uralian Fault).

Point 1. Early Paleozoic turbidites of Ortyabr'skaya Revolyutsiya Island contain detrital muscovite with an Ar/Ar age of 545 Ma [8].

Point 2. Ordovician quartz porphyres and basalts from Ortyabr'skaya Revolyutsiya Island contain xenogenous zircon crystals with a U/Pb age of ~560 Ma [10].

Point 3. Early Paleozoic turbidites of northern Taimyr include a xenogenous zircon population with a U/Pb age of ~560 Ma [13].

Points 4–7. Detrital zircons with a U/Pb and/or Pb/Pb age of ~550 Ma were found in Triassic sandstones from the northern wall of the Sverdrup basin in Axel Heiberg Island (Point 4), the Sadlerochit Mountains (Point 6), and the Lisburne Hills in Arctic Alaska (Point 7) [12].

Point 8. Gneisses of the Tompson Creek Formation (Seward Peninsula, western Alaska) include zonal zircons with a U/Pb age of 565 ± 6 Ma in the crystal core and of 94 ± 2 Ma in the metamorphic rim. In addition, metasedimentary rocks of the Nomo Group in this region contain numerous detrital zircons with an age of ~683 Ma and Middle–Late Cambrian zircons [7].

Point 9. Clastic zircon aggregates from Triassic sandstones in Wrangel Island contain rare detrital zircon crystals with ages of 510.7 ± 15.7 and 667.6 ± 17.7 Ma [12].

Points 10–12. Triassic sandstones from the Myrgovaam basin (Rauchua trough) in northwestern Chukotka also contain detrital zircons with ages ranging from 510 to 680 Ma [6, 12].

Points 13–15. Isotope–geochronological datings of detrital zircons from Triassic sandstones in the Verkhoyansk Complex at the passive margin of the Siberian paleocontinent are reported in [12].

Bar charts (Fig. 2) based on the literature data show that isotopic datings of single zircon grains in samples taken from points 4–7 and 9–15 range from 450 to 750 Ma. In these bar charts, the dotted background shows the age range of granitoid magmatism related to the Baltica–Arctida collision.

Let us emphasize the following points:

1. Bar charts related to ages of detrital zircons in Triassic sandstones from the southern wall of the Sverdrup basin (Fig. 2, point 5) clearly lack the 480–720 Ma interval, because the clastic material of these sandstones are derived from North America. Indeed, Late Precambrian–Early Paleozoic crystalline rocks are only developed in epi-Gondwana terranes within small areas of the Appalachians in North America [14].

2. Samples from points 4 and 6–8 (Fig. 2) taken from the Arctida blocks, which are now located along the periphery of North America (the block of the northern parts of Peary Land and Ellesmere Island, as well as the eastern part of the Arctic Alaska–Chukotka block), show that Triassic rocks contain Late Paleozoic–Cambrian zircons that are atypical of provenances located in North America. Meanwhile, bar charts of detrital zircons distinctly show populations with ages corresponding to the timing of rock complexes of the pre-Uralide–Timanide orogen.

3. Zircons with an age of 450–750 Ma in the Verkhoyansk Complex (points 13–15) could be derived from Late Precambrian–Early Paleozoic complexes that are widespread in southern Siberia. However, the Arctic Alaska–Chukchi (points 9–12) and Kara blocks (points 1–3) were separated from Siberia by structures of the Mesozoic Anui Ocean and its western Late Paleozoic–Early Mesozoic extension, respectively. Therefore, detrital and xenogenous minerals with Late Precambrian and Cambrian signatures found at these points cannot be related to Siberia.

CONCLUSIONS

The detection of populations of detrital and xenogenous zircons and other minerals with an age of ~560 Ma in various parts of the Arctic sector suggests that these minerals were most probably derived from rock complexes of the Bol'shaya Zemlya active margin of Arctida and the pre-Uralide–Timanide orogeny. The study region lacks large oceanic basins, which could separate blocks of the Arctida continental crust and hamper the transport of erosion products of the pre-Uralide–Timanide orogen throughout the entire Arctida continent. This fact is an additional independent piece of evidence in favor of the existence of Arctida.

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