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GEOLOGY

Terranes of the Eastern Arctic Shelf of Russia

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In this work, we propose the first tectonic subdivision of the basement of the East Antarctic shelf of Russia based on recent investigations of the block structure of the Eurasian continental margin of the Arctic Ocean [1] and extrapolation with continental and insular land [2, 3]. The proposed scheme of subdivision (figure) is based on principles of terrane analysis developed by Russian and foreign scientists.

The shelf basement of the Laptev, East Siberian, and Chukchi seas is composed of different-aged systems of the Arctic foldbelt: Caledonides, Ellesmerides, and Early and Late Kimmerides. The basement of the northern Chukchi Sea is presumably made up of an ancient continental block, the periphery of the Hyperborean platform. Its relicts are preserved in the Amerasian Basin of the Arctic Ocean (the Lomonosov, Mendeleev, and Northwind ridges) [4]. The basement was strongly transformed by superimposed destructive processes, which complicated the delineation of tectonic regions (terranes) and compelled researchers to draw wide boundary zones between the terranes.

The terranes of the Caledonian fold system are distinguished in the northern East Siberian Sea. Their lithostructural characteristics have been studied in the De Longa Islands.

The *Henrietta terrane* located on Henrietta Island is composed of volcanogenic turbidites, flows, sills, and dikes of island-arc calc-alkaline basaltic andesites, basalts, dolerites, and diorite porphyries. The rocks were subjected to epidote–chlorite–albite metamorphism, sheared, and unevenly dislocated. In addition to the known igneous rocks, the turbidites contain clasts of metamorphic schists, microcline granites, gneisses, micropegmatites, quartzites, rhyolites, and dacitic andesites. The Ordovician age of the volcanogenic complex of Henrietta Island is based on the Ar–Ar dating of diorite porphyrite and dolerite (440 and 444 ± 2 Ma, respectively) [5].

The *Bennett terrane* located on Bennett Island is composed of Cambrian splintery-foliated mudstones with rare interbeds of siltstones and trilobite-containing silicified limestones. They are overlain by alternating mudstones and siltstones with intercalations of quartzose sandstones with Tremadocian and Arenigian graptolites. The section is crowned by variegated quartzose sandstones. The Cambrian–Ordovician sequence composes a NNW-trending anticline up to 20 km wide within the island. The dip angle of limbs is up to 10° (occasionally up to 50°). The Ordovician graptolite facies presumably represents distal turbidites of the Caledonian deep-water basin.

The Caledonian fold system contains blocks of the Early Precambrian consolidation. This is evident from the composition of the clastic part in the section of Henrietta and Bennett terranes. Both terranes are overlain by Early Cretaceous terrigenous rocks, Early Cretaceous flood basalts, and alkaline basaltoids of Cenozoic stratovolcanoes.

The *Wainwright terrane* is the seaward extension of the Ellesmerian folded basement of the Arctic platform of Alaska. The Ellesmerian age is supported by the presence of Middle–Late Devonian coarse-grained sandstones, shales, and coal interbeds with the corresponding flora and pollen–spore assemblages in the boreholes drilled at the continent. These rocks are correlated with horizons of sedimentary cover in the Hanna Trough (eastern Chukchi Sea) [6], which rest on the acoustic basement [6]. Ellesmerides are abundant in the arctic islands of Canada. The Wainwright terrane is presumably a composite terrane consisting of blocks of pre-Ellesmerian consolidation.

The SE-trending structures of the Early Kimmerian Taimyr fold–thrust system are developed in the northwestern Laptev Sea. The basement of the water area is subdivided into the Chelyuskin composite terrane and Pronchishchev terrane.

The *Chelyuskin composite terrane* is the seaward continuation of the Central Taimyr zone [7]. As in

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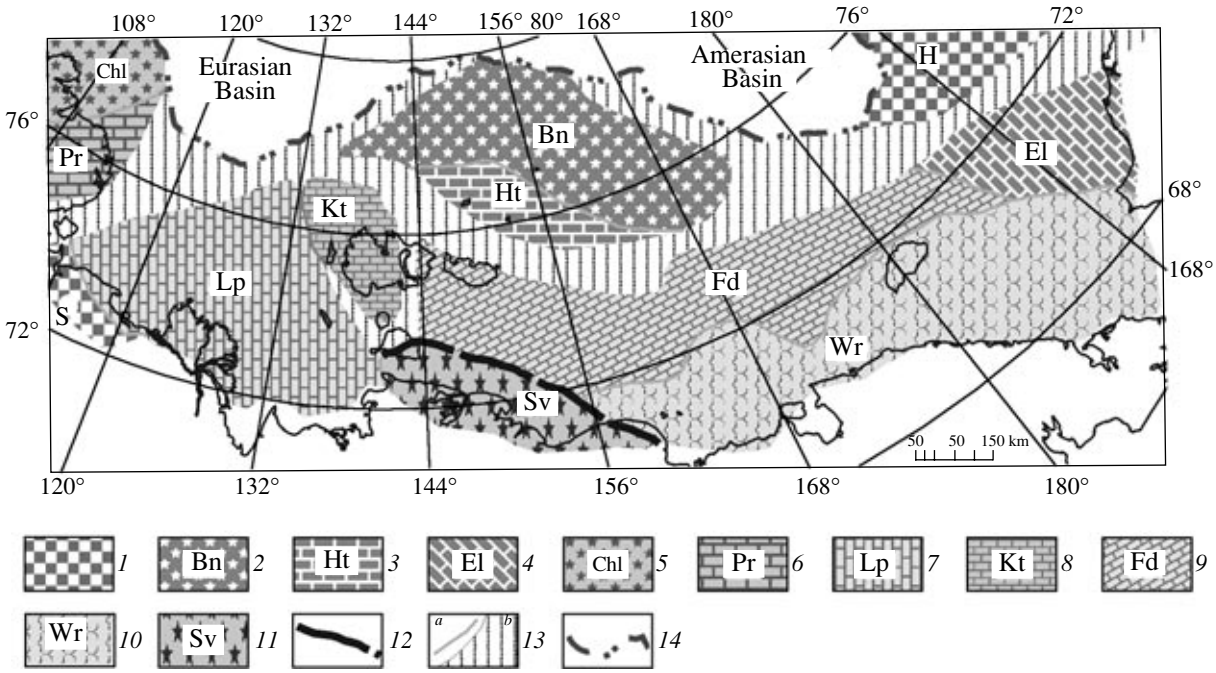

Terranes of the Eastern Arctic Shelf of Russia. (*1*) Ancient platforms: (S) Siberian, (H) Hyperborean. (*2–4*) Caledonian terranes: (*2*) Bennett turbidite (Bn), (*3*) Henrietta (Ht) island arc, (*4*) Wainwright Ellesmerian (El); (*5, 6*) Early Kimmerian: (*5*) composite Chelyuskin (Chl), (*6*) Pronchishchev (Pr); (*7–11*) Late Kimmerian: (*7*) Laptev (Lp), (*8*) Kotel'nyi (Kt), (*9*) Faddeev (Fd), (*10*) Wrangel (Wr), (*11*) Svyatoi Nos (Sv); (*12*) ophiolite suture; (*13*) terrane boundaries (*a*) and interterrane zones (*b*); (14) shelf edge.

Taimyr, nappes of this terrane are presumably composed of 920- to 850-Ma-old granites, Neoproterozoic carbonate sequences, island-arc complexes, ophiolites with plagiogranites (700–630 Ma old), and Vendian–Early Carboniferous sedimentary rocks. All these complexes are intruded by Late Paleozoic granites.

The *Pronchishchev terrane* is composed of Ordovician–Permian carbonate and terrigenous shallow-water sequences. The Upper Permian–Lower Triassic section is made up of volcanosedimentary and volcanic rocks including basaltic lavas, tuffs, and dolerite sills, which are accompanied by the dikes ascribed to the Siberian trap province. The terrane also includes granite and syenite bodies with an age of 249–241 Ma.

The Taimyr fold system is separated from the Siberian Craton by the Yenisei–Khatanga Trough outlined by exposures of Jurassic and Cretaceous rocks. The trough is a subsidence structure that inherited the Late Paleozoic–Triassic rift. The boundary of tectonic blocks marked by the rift is expressed in the structure of potential fields on the Laptev Sea shelf. The boundary extends further eastward parallel to the shelf edge. Individual faults crosscutting the sedimentary cover are recorded along this boundary.

Most of the basement of the Laptev, southern East Siberian, and Chukchi seas are occupied by Late Kimmeride terranes, which extend from the continent. In the north, the Late Kimmerides are bounded by northward-trending overthrusts and fore troughs, which are inherited by Late Cretaceous–Cenozoic rifts [2, 8].

The *Laptev terrane* is separated in the southwest from the Lena–Anabar Trough by the SSW-trending Olenek fold–thrust zone representing the surface expression of the extended regional overthrust along which Late Kimmerides were thrust onto the Siberian Craton margin [9]. In the east, the Laptev and Kotel'nyi terranes are separated by the Late Devonian Bel'kov–Nerpalakh Trough. In the northwest, the Early Kimmerian Pronchishchev terrane is separated from the Laptev terrane by a wide fault zone, which appeared no later than the Late Paleozoic. The Late Kimmerian age of final orogenic deformations of the terrane is indicated by a Late Jurassic–Early Cretaceous age of fold–thrust deformations in the Olenek zone and by a Middle (or Upper) Cretaceous age of the lower layers of the regional massive sedimentary cover [10]. The terrane consists of Late Riphean–Early Cretaceous carbonate and terrigenous sequences with exposures of ancient crystalline rocks. Individual CMP profiles below the regional acoustic basement show extended reflectors, which are interpreted as the roof of carbonates within the sedimentary section. This fact indicates an uneven and relatively weak deformation of the terrane.

The *Kotel'nyi terrane* is composed of the Ordovician–Mesozoic miogeosynclinal carbonate and terrigenous rocks, which are unconformably overlain by Aptian–Albian coaliferous molasse [3]. The rocks are unevenly lithified. The Paleozoic limestones are intercalated with plastic clays, while Triassic–Jurassic rocks are represented by lithified aleuropelites and clays in

some places. Late Jurassic–Early Cretaceous flyschoid rocks of a Late Kimmerian orogenic trough deformed into low-angle asymmetric sublatitudinal folds compose Malyi Lyakhov Island in the southern Kotel'nyi terrane [11]. In the east and southeast, the terrane is framed by zones with numerous postcollisional granitoids. The Late Kimmerian tectonogenesis produced a structure of insignificantly NE-shifted thrust blocks. The structure of blocks is characterized by gentle folds and extended and wide monoclines. In the thrust zones, the rocks are often sheared. One can see small strained folds with vertical hinges indicating the presence of strike-slip components. The terrane is cut by Cenozoic dextral strike-slip faults.

The *Faddeev terrane* composes the peripheral zone of the Late Kimmerides. In the north, it is bounded by a wide disintegration zone of the Cenozoic continental crust, which obliterates the initial boundaries of the terranes. In the west, the Faddeev terrane is separated from the Kotel'nyi terrane by a chain of postcollisional granitoids. The southern boundary is the N-trending zone of strike-slip faults, which are reliably distinguished by ophiolites of the Anyui–Lyakhov suture in the west. Thrusts in the central and eastern segments of the southern boundary of the terrane are extrapolated from the Chukchi Sea area, where they were identified by a seismic survey. Jurassic dislocated terrigenous rocks, Lower Cretaceous molasses, and indirect signs of postcollisional magmatism were found within the Faddeev terrane in the Anzhu Islands. In the west of the terrane below the regional acoustic basement, the bottom of post-Kimmerian sedimentary cover is marked by a seismic velocity ranging from 3.4 to 6.1 km/s [12]. Such a scatter suggests uneven lithification of the rocks, presumably related to variable tectonic strains. The lowest velocity corresponds to unmetamorphosed and undeformed sedimentary rocks. The terrane represents a zone of weak orogenesis in the late Kimmerian with relicts of Kimmerian miogeosynclinal segments.

The *Wrangel terrane.* The Late Kimmerian nappe structure of the Wrangel terrane retained relicts of previous geodynamic settings: (1) the Baikalian active margin, (2) Silurian–Early Devonian plate setting; (3) probably active Middle–Late Devonian continental margin with thick turbidites; (4) Early Carboniferous tectonic stabilization and subsequent rifting; and (5) Late Triassic active margin with turbidites [13]. The northern and northeastern boundary of the terrane extends along regional thrusts, while the southern boundary is marked by the fault along the Chukchi shore. In the south, the terrane is overlain by Early Cretaceous molasse of the Southern Chukchi orogenic trough. The western part of the terrane extending from Chuna Bay to the Medvezhi Islands is marked by the presence of postcollisional granitoid massifs. The nappe-style structure of this part is inferred on the basis of extrapolation from the continent and Wrangel Island.

The *Svyatoi Nos terrane* is made up of Late Jurassic island-arc volcanic rocks and a Late Jurassic–Early Cretaceous orogenic flyschoid complex, which are thrust along the Anyui–Lyakhov ophiolite suture onto the Faddeev and Kotel'nyi terranes and are intruded by postcollisional granites [11]. The island-arc volcanic rocks outcrop in the Svyatoi Nos Cape and extend southeast beneath the Cenozoic cover. The andesites and diorite porphyries, which predated postcollisional granitoids in the southeast of Bol'shoi Lyakhov Island, are likely related to these rocks. Gabbrodolerites, N-MORB pillow basalts, gabbros, paraamphibolites, orthoamphibolites, glaucophane schists, serpentinites, shales, and turbidites compose slices and wedges in the rear zone of the suture. The available isotope datings of orthoamphibolites and pillow basalts by different methods vary from 473 ± 14 Ma [14] to 133.5 ± 4.5 Ma [15]. This suggests that the suture zone contains relicts of oceanic crust ranging from the Caledonian to the Late Mesozoic. However, some datings are unreliable and can hardly be used for estimating the age of events defining the geodynamic setting.

The presence of sectors with weakly deformed flat rocks and their insignificant lithification in the Laptev, Kotel'nyi, and Faddeev terranes of Late Kimmerides, on the one hand, and the absence of signs of the continuation of the Anyui–Lyakhov suture to the west of Bol'shoi Lyakhov Island, on the other hand, are consistent with the inferred cessation of Late Kimmerian orogenesis in the northern and northwestern areas of the eastern Arctic shelf.

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