

Geoblocks in the Basement of Ancient Continental Platforms, Their Internal Divisibility, and Metallogeny of Ore Districts Based on Geological and Geophysical Data

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In [1], we discussed the hierarchical block divisibility of the consolidated basement of continental platforms (from global to regional levels and the internal structure of high-order tectonic units) with the East European Platform (EEP) as an example.¹ We outlined several versions of mechanisms suggested for the formation and evolution of lateral and vertical discreteness of basements of Katarchean, Early Archean, and Proterozoic, Riphean, Paleozoic, and Mesozoic plates and shields. The mechanisms were deduced from correlation of lithotectonic complexes in particular blocks and zones. Such correlation was based on the data of A.O. Schmidt (documentation of hundreds of outcrops of crystalline rocks in shields; geological mapping of territories in the Ukrainian Shield, Aldan Shield (western and central areas), and eastern Baltic Shield (Kola Peninsula, central and southern Karelia); examination of cores from deep boreholes that penetrated the basement, including the entire section of the Kola Superdeep SD-3; and interpretation of maps of potential fields [1–5] with consideration of the available CDP data and all published DSS sections [2, 5].

We propose for discussion a new model of pulsatory, keyboard–block (KB) style evolution of the Earth's primary undifferentiated (still at the stages of postaccretion heating and partial/total (?) melting) protocrust and its further transformation into the sialic (in some blocks) and sialic–femic (in other blocks) crust in the Early, Middle, and Late Archean. The aim of this communication is to recall the invalidity of the actualistic approach (from the Phanerozoic back to the Early Archean [6]) applied in the 20th century to the analysis and modeling of the primary formation and evolution of

geological formations and lithotectonic complexes of the Archean (AR₁, AR₂) and Proterozoic (PR₁, PR₂, PR₃–R₁). The available data on Pre-Riphean platforms support our statement.

The second and pivotal objective of this communication is to demonstrate the possibility to interpret the systematized factual material pertaining to the KB-type internal structure of the EEP basement [1] (global geoblocks, according to L.I. Krasnyi, 1984) by mechanisms of wave distribution of energy and mass of the protocrust at postaccretionary stages of its evolution. We give examples of the control of drastically different lithotectonic complexes and contrasting metallogeny of the adjacent basement blocks by these mechanisms.

As the result of avalanche-style accumulation of facts, the 20th century was characterized by relatively rapid replacement of the geosyncline–platform concept by the concurrently developing hypotheses of plate tectonics and block (geoblock) tectonics. The period of 1960s–1990s was marked by the accumulation of an enormous body of facts, as well as global and regional reviews of shields and basements of pre-Riphean platformal plates and ancient median masses within Phanerozoic foldbelts.² All these facts provided insight into the structure and composition of the basement of the Earth's continents. These data revealed lateral unevenness of intracrust discontinuities (based on numerous DSS velocity profiles of the EEP) confirmed by CDP profiles and other data, including data on the Kola Superdeep Borehole [4] and drilling at other platforms. The new data also demonstrated that contrasting reflectors with characteristic jumps of *P*- and *S*-waves occur at different depths and the crust has a distinct block structure, which was previously suggested from interpretation of gravity fields in the study region [3, 5, 6].

The 3D relationships between the block structure and delamination (i.e., lateral and vertical divisibility) of the crust, subcrustal geospheres, and the Moho discontinuity turned out to be highly individualized in

¹ We studied and used data on the Aldan, Anabar, Canadian, and Baltic Shields, as well as plates of the respective platforms, reported in 1962–2003.

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² These geostructures make up more than 75% of the area of the Earth's crust beneath all continents.

large geoblocks, megablocks (structures of the 1st order), and crustal blocks (structures of the 2nd and 3rd orders).

Four geoblocks (the largest subdivision of the Earth's crust) are recognized in the EEP (Fig. 1). The geoblocks are characterized by various compositions of megablocks and blocks with contrasting types of the deep crustal structure (from the basement surface to the *M* discontinuity). Blocks of higher orders with different crustal sections are clearly traced within their limits from the shields to the basement of plates [1, 3, 5] owing to distinct geophysical anomalies and compositions of cores recovered by deep boreholes.

According to [1, 5], 5–7 types of generalized versions of deep lithotectonic sections of the consolidated crust are distinguishable in the mosaic high-order blocks of the EEP basement. The sketch columns of these sections are presented in [1, 3] and characterized in detail in [1]. The transverse dimension of such blocks in the basement of plates and shields of the EEP and other platforms in the Northern Hemisphere is equal to 1–3 distances to the base of the crust.

The lithotectonic diversity of the adjacent contacting blocks of higher orders (with respect to the composition of the basement surface and deep structure) is one of the most important specific features in the KB-type structure system of the consolidated crust. The contacting blocks of the 3rd order (e.g., the Murmansk Block with TTG-type crust and granulite-facies metamorphism), the Central Kola Block (gneisses of the Kola Group and amphibolite-facies metamorphism), and the Keivy Block (potassic granites and migmatites and low-grade metamorphism) are striking examples.

Discordant relationships are absent in the distribution of lithotectonic formations in the Archean basement of EEP blocks, as well as the banding and lineation of metamorphic complexes at boundaries of the adjacent blocks. In general, these elements are always conformable and parallel to the high-order block boundaries without faulting. Exceptions are rare and observed only at specific borders of blocks that experienced either inherited tectonomagmatic activation (e.g., the Kirovograd block in the Ukrainian Shield) or autonomous activation according to A.D. Shcheglov (e.g., El'kon-type blocks in the central Aldan Shield). These features are also noted at other platforms.

Regularities in the block structure of the Archean basement of platforms may be explained only in terms of the pulsatory-wave concept of the Early Archean KB-type tectonics partly developed in the Middle Archean. This is evident from theoretical works of Milonovskiy [7], recent data [8], and our observations [2, 3, 9] during geological mapping of shield areas in the EEP [2, 3, 9].

It should be kept in mind that the concept of volume pulsations of the early Earth at the initial postaccretion stages, when the undifferentiated outer crust had just appeared, was postulated in [10] and other publica-

tions. These pulsations stimulated development of local compositional inhomogeneities already in the Katarchean, in particular, as blocks of trondhjemite-tonalite sialic material [4, 5, 10], which were transformed in the Early Archean into tonalite-plagiogranite formations of relict blocks (dated at 3.3–3.5 Ga in the EEP) and their analogues, or more femic blocks (relicts of the Early Archean formations that make up less common blocks with metabasic and granulite-metabasic materials even at the basement surface). The alternation of such closely spaced blocks of the 2nd and 3rd orders is clearly seen in lithogeological maps of the basement of this ancient platform [5]. These blocks are also observable in the metallogenic map of the EEP included into a set of eight maps. Figure 2 demonstrates a small-scale map of metallogenic zones and sutures. It shows the metallogenic specialization of geoblocks and megablocks that correspond to metallogenic provinces with different associations of metals in geological formations and associated ore deposits. The alternation of zones with different metallogenic specialization within ore districts (blocks of the 2nd and 3rd orders) are still more pictorial and contrasting.³

The cardinal rearrangement of the lithospheric structure and probably the first global partial rearrangement of the crustal structure 3.5 Ga ago [1, 10] resulted in complication of the intrablock composition in only some blocks of different orders, development of Middle Archean greenstone belts, their evolution in the Late Archean, the growth of granitic domes in granite-greenstone domains, and the origin of gold deposits. According to our data [1, 3, 5], this process was in progress until the Early Proterozoic and, in some places, embraced the entire Paleoproterozoic (Lower-Middle Proterozoic) recognized by L.I. Salop.

The next (probably, the second) radical change of the character and style of terrestrial tectonic evolution was expressed in the initial rifting and the appearance of geosynclinal systems in the Riphean or Proterozoic. The first rift systems at ancient platforms were formed in the Middle-Late Archean or Early Proterozoic, e.g., the Krivoi Rog-Kremenchug zone, which is a protoriftogenic geosyncline that did not undergo inversion and was composed of an incomplete set of continental, transitional (molassoid), and geosynclinal rock associations without orogenic complexes. The orogenic complexes were revealed in other systems of the same age [2, 10, 11, 13].

Finally, the third radical rearrangement is marked by the appearance of initially riftogenic aulacogen systems at ancient platforms included into the early (Riphean-Paleozoic) megazones of platform activation [3] (Fig. 1, EEP).

The term *megazone of activation* [3] designates a polychronous regional lineament zone of elevated permeability in the lithosphere that controlled formation of

³ They are demonstrated in the set of maps (scale 1 : 500 000–1 : 2 500 000) [5] compiled by the All-Russia Research Institute of Geology, VSEGEI.



Fig. 1. Tectonic units in the basement of the East European Platform (scale 1: 10 000 000). (I) Geoblocks: (I) Lapland-Belomorian-Karelian, (II) Baltic-Svecofennian, (III) Voronezh-Ukrainian, (IV) Volga-Ural; (2) megablocks (Arabic numbers in circles): (1) Kola, (2) Belomorian, (3) Karelian (Onega-Karelian), (4) Svecofennian, (5) Baltic (Belarus-Baltic), (5a) West Norwegian, (6) West Ukrainian, (7) Rostov-Kursk, (8) Central Ukrainian (Kirovograd); (3) belts between geoblocks: (Ia, Ib) Volyn-Dvina: (Ia) Volyn branch, (Ib) Saratov-Dvina branch; (IIa) Ladoga-Bothnia, (IIb) Ryazan-Saratov (Kalach-Ertil); (4) suture zones between megablocks: (1) Pechenga-Imandra-Varzuga, (2) Vetrennyi-Transonega (Lapland-Belomorian structural suture), (3) Belarus-Norwegian structural suture, (4) Krivoi Rog-Kremenchug-Kursk zone, (5) Odessa-Tal'noe (Odessa-Kiev), (6) Dalsland zone; (5) interblock faults (fault zones): (2) Teterev, (3, 4) Dzhurin-Nemirov, (5) Zvenigorod-Novoukrainka, (6) Kirovograd, (7) Orekhovo-Pavlograd, (8) Kursk (and Novyi Oskol in the east), (9) Central Azov, (10) Krivoi Rog-Kursk; (6) separate zones of deep marginal sutures along boundaries (walls) of interblock belts: (11) East Belarus, (12) Sushchanyi-Perga, (13) Goryn (other faults of groups 5 and 6 shown in the scheme have no proper names); (7) main megazones of activation: (1) North Kola (Barents Sea), (2) Khibiny, (3) Veksozero-Kudal Guba and Polkanov zone, (4) Pechenga-Mezen, (5) Belomorian-Dvina, (6) Volga-Timan, (7) Novgorod, (8) Kazhim, (9) Upper Kama, (10) Belorechka, (11) Polotsk-Saratov-Pachelma, (12) Goryn-Perga, (13) Pripyat-Dnieper-Donets (a fragment of the Karpinsky lineament), (14) Moldovian, (15) Central, (16) Rossosha-Azov, (17) Central Ukrainian, (18) Ukrainian-Belarus (Voronezh-Ukrainian), (19) Neva (Timan-Finland); (8) most distinct transblock faults; (9) tectonic sutures along platform boundaries.

asthenospheric plumes in the course of tectonic or tectonomagmatic activation of platforms in the Early and Middle Proterozoic (Novoukrainka and Korsun plutons in the central Ukrainian Shield), in the Vendian-Paleozoic (Khibiny and other plutons in the Baltic Shield), and in the Mesozoic (Central Aldan and other zones in

the Aldan Shield). All rapakivi granite plutons are also controlled by megazones of activation.

The geological evolution of aulacogens likely started concurrently with emplacement of the first granitic plutons in the course of inherited tectonomagmatic protoactivation. The Early-Middle Proterozoic

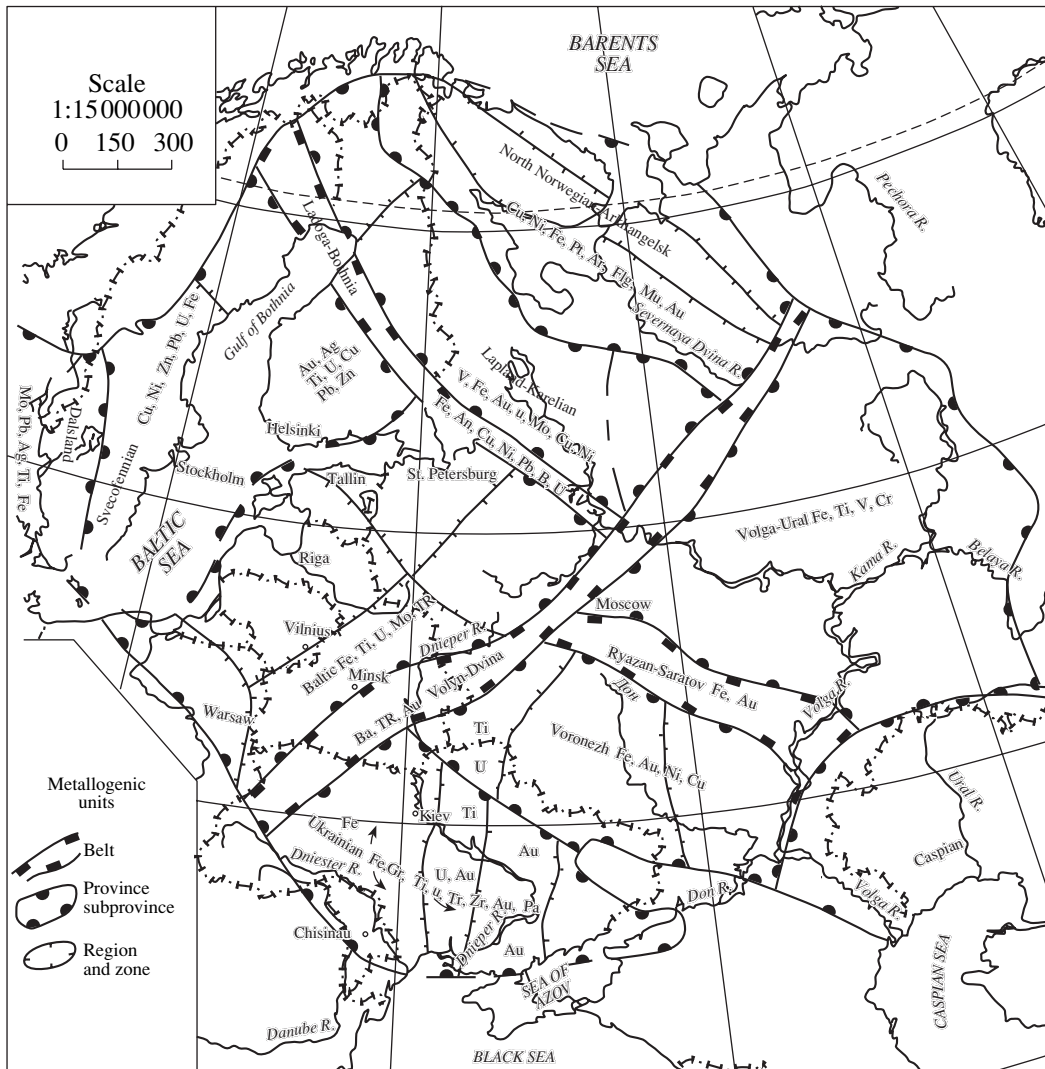


Fig. 2. Regional metallogenic demarcation of the East European Platform (scale 1 : 15 000 000).

and Early Riphean Kirovograd–Novoukrainka pluton of potassic granites in the most sialic Middle–Late Archean granitic gneiss block (Ingul Group), the Belozersk and other blocks at the margin of the Baltic Shield with poorly exposed plutons, and Middle–Late Proterozoic and Early Riphean rapakivi granites are typical examples of such plutons.

Virtually all the aforementioned complexes and other granitic, alkaline, and ultramafic complexes of activation zones are localized in the long-lived (Middle Archean–Middle Proterozoic) granite gneiss domes in shields and the basement of plates of ancient platforms [1, 6, 13].

Aulacogens in the EEP continued to develop in the Paleozoic and Mesozoic. This is evident from data on boreholes that penetrated deep-seated basic volcanics beneath continental and marine sedimentary sequences (Pripyat–Dnieper–Donets, Pachelma, and other aulaco-

gens). The same may be said about igneous and volcanic rocks related to plutons of the Paleozoic (Khibiny pluton in the EEP and others) and Mesozoic (Siberian Craton) epochs of tectonomagmatic activation. They were related to autonomous (“extraevolutional,” according to A.D. Shcheglov) processes with respect to the time of crust formation or inherited processes with respect to selective development in high-order blocks with a similar type of the crust [1, 5] that underwent protoactivation [6] in the Late Archean and Proterozoic [1, 5, 14].

The above-mentioned epochs of radical transformation of the lithosphere, composition, and structure of the early crust were accompanied (or caused) by wave pulsations of dynamic stresses in its outer spheres. These pulsations were realized in substantially different *PT* conditions of protomaterial in high-order domains of the protocrust. Their relicts have been retained as blocks of the 2nd and 3rd orders in shields

and the basement of plates of ancient platforms, which are clearly identified in small- and medium-scale gravimetric maps (Bouguer reduction) with the geological structure of the basement deduced from the results of drilling, CDP seismic survey, and other data.

Processes described above allow us to explain appreciable differences in rock composition in the adjacent (even contacting) blocks of the 2nd and 3rd orders [1, 5, 9] and in the vertical section of their crust. In order to explain the phenomena described in [6], we do not have to use hypothetical concepts of a great difference in the erosion depth of blocks (up to 10–20 km) or various sets of elementary different-order blocks (often devoid of fault boundaries) within megablocks and geoblocks.

The concept described above is the essence of the KB-type pulsatory model proposed in the 1990s [1, 3, 5] for the early evolution of the continental crust. This model has been confirmed by the analysis of data on ancient platforms.

The geological consequences of pulsatory–wave distribution of energy and mass transfer during formation of KB-type internal structure of the platform basement and shields are confirmed by new results of mapping in different platformal regions. Therefore, the metallogenic implications of regularities described above have become evident and essential for the compilation of prognostic charts and the choice of prospecting areas. For example, the data mentioned above are widely used in the regional forecasting of uranium deposits commonly localized in sialic blocks of the 2nd and 3rd orders confined to megablocks of shields and platform basements [12, 13]. Endogenic uranium deposits are known to date only in such blocks (especially reactivated blocks with potassic and subalkali granites) within and around rock massifs. This statement is valid for deposits of the unconformity type [10, 13, 14], but is not applicable to exogenic deposits.

The abovementioned and other regularities in the localization of ore districts in the crust of ancient platforms is clearly exemplified in the Kirovograd ore district, which is located in a sialic block of the 3rd order within the Central Ukrainian Megablock [1, 5]. According to our models, the sialic material extends here to a depth of 15–20 km.

In [5], devoted to metallogeny of the EEP, we described specific features of the localization of ore districts (e.g., the West Novgorod, Belozersk, and other districts with high ore potential) in crustal blocks of the 3rd order.

Regularities of the confinement of ore districts to the KB-type structures of the platform basement with unique lithostructural section and composition of the crust within the specified block [1] are used in our forecasting works. For example, we have recommended the West Novgorod (Chudskoe) and North Belozersk potential ore districts as targets of prospecting (scales 1 : 200 000–1 : 50 000) for lithophile ore mineraliza-

tion within the limits of the 3rd order blocks similar to the Kirovograd block (Ukrainian Shield) in terms of geophysical properties. Deposits of the unconformity type with complex ores are also expected at the northern extension of this reference block [14].

Thus, the early (Middle–Late Archean and Early–Middle Proterozoic) epochs of the formation of KB-type structural cells in the ancient platform basement of continents played the basic role in the distinct geostructural distribution of ore districts and their confinement to lithotectonic zones of the basement of specific composition and age that govern the type of mineral deposits.

The geostructural regularities are revealed from the joint analysis of physical fields and other geological–geophysical data on regional minerageny. Such regularities have been noted in many ore provinces and belts with chalcophile and lithophile mineralizations [10, 14, 15]. It is evident that ore districts⁴ are structurally separated blocks of the 2nd and 3rd orders with a specific style of evolution and characteristic lithotectonic complexes of the consolidated crust, while the ore provinces are the largest lithospheric geoblocks [1, 13, 15] with specific assemblages of blocks and megablocks.

Regularities in the localization of ore districts in connection with the KB-type structure of the ancient platform basement, which are considered in this communication and references therein, should be taken into consideration in the practice of geological forecasting and prospecting on small and medium scales.

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