Tectonics of the Basement of the Kara-Bogaz Arch (Turan Plate)

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Received May 21, 2021; revised November 16, 2021; repeatedly revised December 31, 2021; accepted January 12, 2022

Abstract—The Kara-Bogaz geoblock is interpreted by many researchers as a structure underlain by the Precambrian sialic crust, incorporated in the young (epi-Hercynian) Turan Plate. The paper presents the results of a detailed study of the material composition of igneous and metamorphic rocks making up the basement of the Kara-Bogaz Arch and recovered by deep boreholes. To subdivide and correlate the sections, we employed data of geophysical borehole surveys, including all types of logging. Microscopic examination of rocks was also performed to determine their composition, genesis, and degree of postsedimentation alterations. Data on absolute ages of rocks and paleontological data were also employed. The results of the work of our predecessors have been studied and critically analyzed. It is established that there are no direct indications of the continental crust older than Paleozoic in the basement of the Near-Kara-Bogaz region. The metamorphic units of the Kara-Bogaz Arch are represented by primary sedimentary and volcanosedimentary deposits that were altered at the stage of regional greenschist metamorphism. These rocks are intruded by granitoid bodies corresponding to the final stages of Hercynian tectogenesis. In parts spatially close to intrusions, the degree of secondary alterations in metamorphic rocks increases due to the thermal effect. Amphibolites of the Kara-Bogaz Arch are metamorphosed igneous rocks, which are closely associated with primary terrigenous deposits and have undergone subsequent metamorphosis (greenschist facies regional metamorphism). Gneisses of the discussed region refer to the marginal facies of granitoid plutons that formed as a result of metasomatic reworking of the host strata (protomagmatic gneissic banding). We think that the Kara-Bogaz Arch is a Hercynian megaanticlinorium of the young platform, and this does not exclude the possibility of fragments of more ancient crust in the structure of this arch. The sedimentary—metamorphic and volcanosedimentary rocks making it up and intruded by multiple granitoid bodies are units of the active margin.

Keywords: Turan Plate, Kara-Bogaz geoblock, metamorphic rocks, granitoid intrusions, basement, Paleozoic, Precambrian, Hercynides

DOI: 10.1134/S001685212201006X

INTRODUCTION

Recent research has revealed the broad distribution of Precambrian rocks within the terranes comprising the Phanerozoic fold belts in Europe, as borehole as in the southern and southeastern frames of the East European Platform (including the Scythian and Turan plates). It is believed that these terranes are fragments of the northern Late Neoproterozoic—Cambrian margin of the Gondwana paleocontinent (peri-Gondwanan terranes) [11, 25, 27, 30, 38], and this viewpoint has been reflected in many tectonic and palinspastic reconstructions [8, 13, 19–37].

The units made up of the Precambrian sialic crust within the epi-Hercynian Turan Plate are the North Ustyurt, South Mangyshlak, Kara-Bogaz, and other geoblocks occupying 60–75% of the area of this plate [1, 3, 5, 12]. This conclusion is based on the results of earlier geophysical studies (which were; however, not quite precise) and scarce materials of deep drilling, which recovered basement rocks.

Yu.G. Leonov et al. [16] proposed a novel approach to distinguishing and zoning the consolidated crust (basement) of the Caspian region, based on a different view on the formation of this crust; a tectonic map on a scale of 1 : 2500000 was compiled as a result of this work. Constructions involved a large body of seismic data. The study substantiated the broad development of Baikalian consolidated crust, in particular, within the Azov—Caspian segment, incorporating, among the others, the Kara-Bogaz geoblock. Within this geoblock, the Cape Peschany—Rakushechnoye Rise, and the northern Cis-Kara-Bogaz region, supposedly Proterozoic gneisses were recovered by drilling (Tamdy-1 borehole). Upper Proterozoic crystalline and metamorphic schists were found in the Tamdy-1, South Alamuryn-1, and Oimasha-9 boreholes; in the Karshi-3 borehole, amphibolite schists occurring among Paleozoic granitoids were described [16].

According to Leonov et al. [16], all this may argue for the Cadomian (Baikalian) age of the consolidated crust in the Azov—Caspian segment.

Other researchers believe that the Upper Paleozoic folded-metamorphic sequences in the western Turan Plate are integrated with Upper Permian—Triassic
and depressions: (a) Caspian, Talysh Mountains, Alborz; (b) Kopet Dag; (c) Manych trough; (d) Near-Kuma uplift system; (e) Nogai block; (f) Middle Caspian–Kara-Bogaz anteclise; (g) East Mangyshlak–Ustyurt trough system; (h) Tuarkyr Zone; (i) Mangyshlak–Central Ustyurt Zone; (j) South Mangyshlak–Ustyurt trough system; (k) Lower Aras trough; (l) Talysh Mountains, Alborz; (m) Lesser Caucasus fold system; (n) Greater Caucasus fold system; (o) Kusary–Divichi trough; (p) Apsheron–Pre-Caucasus fold system; (q) Alpine fold-and-nappe systems: (r) land, (s) sea; (t) land, (u) sea; (v) Early Cimmerian: (w) land, (x) sea; (y) land, (z) sea; (a) land, (b) sea; (b) land, (c) sea; (c) land, (d) sea; (d) land, (e) sea; (f) land, (g) sea; (g) land, (h) sea; (h) land, (i) sea; (i) land, (j) sea; (j) land, (k) sea; (k) land, (l) sea; (l) land, (m) sea; (m) land, (n) sea; (n) land, (o) sea; (o) land, (p) sea; (p) land, (q) sea; (q) land, (r) sea; (r) land, (s) sea; (s) land, (t) sea; (t) land. Other large faults (encircled letters): (A) Buzachi Arch; (B) Karpinsky Rise; (C) Greater Caucasus fold system; (D) Lesser Caucasus fold system; (E) Apsheron–Pre-Caucasus fold system.}

Our previous studies dealt with the South Mangyshlak geoblock, where the basement was penetrated by more than 150 boreholes within 29 survey areas [22]. Studies of the material composition of basement rocks showed that the South Mangyshlak geoblock is composed of relatively weakly metamorphosed terrigenous units, intruded by Carboniferous granitoids within highs. We also revealed charred plant remains (syngenetic organic material) in metamorphic schists; together with paleontological data, this indicates the Paleozoic age of the rocks making up the basement of the South Mangyshlak petroleum-bearing region [23, 24]. The results of this study agree with high-precision aeromagnetic data survey on a scale of 1 : 50000, which detected WNW-trending linear magnetic anomalies within the Mangyshlak Peninsula; note that such features are not characteristic of Precambrian massifs, which typically have the magnetic field of large-scale mosaic structure [21]. The use of the new geophysical and drilling data has made it possible to devise a detailed scheme of the structure of the epi-Hercynian basement underlying the Mangyshlak Peninsula and to identify several structural and formational zones [23].

The objective of the present work is to study the nature of the Kara-Bogaz block, a structure ~800 km long and up to 250 km wide, located in the southwestern Turan Plate. In the platform sedimentary cover, this block corresponds to the Kara-Bogaz Arch. Our study of the Kara-Bogaz block systematizes the diverse opinions and suggestions about its structure and refines its tectonic features in the context that this object is a large structural element of the young Turan Plate.

**GEOLOGY**

The Kara-Bogaz Arch occupies the northern part of the Krasnovodsk Peninsula, the Kara-Bogaz Gol, and the South Mangyshlak Plateau, namely, its part adjoining the Kara-Bogaz region in the northwest (Fig. 1). In the most uplifted part of the arch, basement rocks occur at a depth of ≤800 m. Multiple Paleozoic intrusions have been emplaced in the metamorphic rocks making up the basement of the arch.

The basement is overlain by various horizons of Cretaceous deposits replaced with Cenozoic sediments upsection. In its north and northeast, the Kara-Bogaz Arch is framed by the Early Cimmerian Tuarkyr–Karashor dislocation system, which is located east of the Karashor zone, is an analog of the Tuarkyr–Karashor system [23]. A block of relatively simple structure is confined between them; in the northern part of this block, the Kumsebshen high with the base-
ment occurring at depths less than 2 km and dividing the Zhazgurli–Uchkguduk and Uchtagan troughs, is distinguished. Within this high, in the Kumsebshen and Alamanel areas, deep drilling recovered basement rocks.

On the southwestern slope of the Kara-Bogaz Arch, within the Callovian, Neocomian, and Aptian deposits, small gas reservoirs have been revealed (Tamdy and South Alamuryn petroleum areas). Gas seeps from metamorphic rocks have also been reported in particular metamorphic rocks.

**RESEARCH METHODS**

Basement rocks of the Kara-Bogaz Arch were recovered in 23 boreholes (Fig. 2), of which eight were located south of the Kara-Bogaz Gol within the territory of Turkmenistan (e.g., boreholes Karshi 1–3, Omchaly-159 and -161, Akpar-1, Dardzha-179, and Adzhigir-1). Fifteen boreholes were located northwest of the Kara-Bogaz Gol and drilled by Kazakh geological survey organizations (Tamdy, boreholes 1 and 2; Bukbas, boreholes 1–3; Kuduk, boreholes 1 and 3; Birbas-1, South Alamuryn–Dzhanaorpa, boreholes 1–7).

Earlier studies by various researchers present the results of studying the compositions of the basement, detailed descriptions of borehole sections from the southern zone, and fragmentary descriptions of borehole sections from the northwestern zone [7–9, 14, 15].

In this article, we present the results of detailed lithologic–petrographic studies of the core material. A macroscopic description of the rocks from the collected cores was done to determine the characteristic textures and structures. To subdivide and correlate the sections, we employed geophysical borehole survey data, including all types of logging. Microscopic examinations of rocks were also performed to determine their compositions, genesis, and degrees of post-sedimentation alteration. Data on absolute ages of rocks and paleontological data were also employed.

**TECTONICS AND COMPOSITION OF ROCKS FROM BOREHOLES DRILLED IN THE KARA-BOGAZ ARCH**

Metamorphic rocks in the area to the south of the Kara-Bogaz Gol were recovered only within the Karshi area, in Karshi-3 borehole (Fig. 2). They are represented by amphibolite schists possessing nematoblastic texture and consisting of hornblende, plagioclase, and quartz. In some samples, amphibolites are schistose and have blastopasmatic texture. The composition of amphibolites is dominated by amphibole of the actinolite–tremolite series, andesine, and quartz. These amphibolite schists formed as a result of metamorphism (amphibolite or epidote–amphibolite facies) of sedimentary–effusive rocks, which probably occurred as xenoliths among Paleozoic granitoids [8]. The age of these schists has not been reliably deter-
mined; however, their high degree of metamorphism suggests Precambrian age [8, 9].

In boreholes Karshi-1, Omchaly-159, Omchaly-161, Adzhigir-1, and Dardzha-179, microcline granites attributed to normal-series granitoids were recovered. These granites also belong to the class of silicified rocks with varying alkali contents (e.g., granites from the Omchaly area are characterized by enrichment in potassium. In terms of the mineral composition, granitoids correspond to granites and granodiorites, or, in some cases, to granite–aplite [8]. The age of granites from the Adzhigir area was K–Ar dated at 300 ± 10 Ma [13]. The same method used on biotite yielded an age for granites from the Omchaly area (borehole 161) of 310–295 Ma (C3) [15]. Granitoids recovered from the Karshi-1 borehole demonstrated sharply different absolute ages, 440 Ma (or 310, 313, and 352 Ma, according to other determinations); in this respect, it was supposed that there were two generations of granitoids (the older of which was attributed to the Silurian–Ordovician complex) making up a xenolith body in the younger Carboniferous granitoid generation [8]. Granites from the Dardzha area yielded a K–Ar biotite age of 240 Ma [13].

In Karshi-2, quartz porphyries and felsites were recovered, supposedly of Late Carboniferous–Permian age; in the Akpar area, dacite porphyrites were recovered [8]. The K–Ar age of these rocks was estimated at 220 ± 10 Ma [11].

In the area northwest of Kara-Bogaz Gol, the basement was penetrated by 15 boreholes; however, the material composition was available only for rocks recovered by boreholes South Alamuryn-1, Tamdy-1, South Alamuryn-2, Dzhanaorpa-4, and Bukbash-2; as a result, five intervals were studied [9, 13, 14] (Fig. 2). The data on the other boreholes had not been studied and, in this respect, we provide more detailed characteristics of the basement in this zone.

The occurrence depth of the roof of the basement in this area (based on drilling data) ranges from 2426 m for borehole Kuduk-1 to 2841 m for Bukbash-2. The maximum thickness of the complex (538 m) was revealed in Tamdy-1, while the minimum (76 m), in Bukbash-2. The rock complex is composed of igneous rocks of the granitoid series and primary sedimentary sequences that often coincides with the primary lamination. The deposits are dislocated. The dip angles most often reported for rock layers are 45°–65°. Rocks are dense (2.80–2.95 g/cm³), excluding the top part of the section, where densities of 2.45–2.50 g/cm³ were reported.

Granitoids recovered by drilling within the study region are leucocratic, characterized by the composition typical of these rocks: quartz, oligoclase, and orthoclase present in approximately equal amounts (30–35%). The texture is hypidiomorphic or granitic. These granites are either fresh or carry signatures of secondary alteration. In South Alamuryn-6 in depth intervals of 2722–2737, 2772–2785, 2870–2880, 2950–2953, and 2997–3006 m, intensively cataclasized and mylonitized granites were recovered; in contrast, gneissic granites were found in a depth interval of 2895–2900 m in the same borehole. These recovered rocks underwent intensive silicification, quartz is crushed and granular, feldspars are sericitized, and a small admixture of kaolinite has been reported; i.e., these rocks were reworked by deep fluids that circulated along the fracture zone. The granitoids recovered in Bukbash-2 at a depth of 2990–2994 m underwent analogous hydrothermal reworking and cataclasism. Macroscopic observations of rocks from the intervals
mentioned above revealed multiple slickensides oriented at 75°–90° with respect to the horizontal plane.

In South Alamuryn-1, in a depth interval of 3866–3869 m, signatures of higher-temperature postmagmatic processes were observed; these processes led to the formation of greisenized zones, e.g., near-contact facies of granites were studied in the core recovered from this borehole, and it was shown that the granites contained xenoliths of host schists and hornfels (a depth interval of 2778–2869 m) [9]. We found similar rocks when examining the cores from South Alamuryn-6 in a depth interval of 2722–2737 m: granites from this interval are cataclased and clearly porphyritic.

In the Bukbash area, in addition to biotite granites, granitoids were found (Bukbash-2 borehole, a depth interval 2969–2972 m) corresponding to tonalites in the chemical composition [14].

In Tamdy-1, in a depth interval of 3147–3153 m, sillimanite–biotite gneisses with granoblastic (or lepidoblastic in some areas) texture was revealed earlier. These gneisses are composed of quartz (30–35%), biotite and muscovite (40–45%), and fibrolite (sillimanite) (10–15%), as well as singular grains of feldspars, pyrite, and zircon.

These rocks were formed as a result of regional amphibolite or epidote–amphibolite facies metamorphism [9].

Our studies have shown that the granite–gneiss complex was recovered by Tamdy-1 at a depth of 2769 m down to the very bottom of this borehole (3153 m). The core material was taken from the following depth intervals: 2796–2810, 2882–2887, 3000–3020, 3070–3080, and 3147–3153 m. In a depth interval of 2796–2810 m, we found rocks of the following three types:

- Quartz–feldspar–mica schists with granolepidoblastic texture and clearly visible segregation schistosity. High muscovite and biotite contents have been reported. The degree of postdiagenetic alteration corresponds to the muscovite–biotite subfacies of greenschist facies regional metamorphism.
- Feldspar–muscovite–biotite–quartz (two-mica) gneiss. The rock is leucocratic, characterized by alteration of broader (1.5–2 mm) leucocratic quartz–feldspar and narrower (0.5–1.0 mm) muscovite–biotite bands. The structure is gneissic and banded; the texture is coarse granoblastic (within quartz–feldspar bands) or lepidoblastic (within mica bands).
- Fresh leucocratic granites.

In the depth intervals of 2882–2887 and 3070–3080 m, gneisses of similar appearance were reported, and in a depth interval of 3000–3020 m, quartz–mica schists were found together with gneisses. In the near-bottom part of the borehole (a depth interval 3147–3153 m), two-mica gneisses analogous to those in a depth interval of 2796–2810 m, as well as coarse-grained, fresh, non-cataclased granites, possessing the typical granitic texture, as well as quartz–albite–mica schists characterized by high muscovite and biotite contents with granoblastic and lepidogranoblastic textures, which had undergone greenschist facies (muscovite–biotite subfacies) metamorphism. Multiple subvertical slickensides were reported in all mentioned intervals of the core.

These data suggest complicated geological relationships between igneous and metamorphic rocks in the section. Probably, gneisses and crystalline schists were intruded by younger granites and are xenoliths hosted by an intrusive body. However, the mineral composition and structural features of gneisses and crystalline schists demonstrate clear similarities, giving grounds to consider gneisses as marginal facies of a granitic pluton that formed as a result of metasomatic reworking of the host rocks (referred to as protomagmatic gneissic banding, after [19]).

Sporadically developed weakly metamorphosed terrigenous rocks in the upper part of the basement section constitute a geologic peculiarity of this region. These rocks have been reported in boreholes Tamdy 1 and 2, Bukbash 1–3, and South Alamuryn-6. Their maximum thickness (154 m) was documented in Tamdy-1, whereas the minimum one (34 m) was measured in South Alamuryn-6. In the lower part of the sequence, a sandstone member with interbeds of fine-pebble conglomerate commonly occurs; the thickness of this member locally is up to 30–40 m. Clastic material is represented by fragments of schists, hornfels, milky white quartz, and quartzites up to 1.5–2 cm in size. Interstices between pebbles are filled with gravel—sandy material. In the upper part of the sequence, silty–argillic rock varieties are predominant, as clearly reflected in electric well logs. Rocks are gray or dark gray in color, less frequently black or greenish.

Varieties are predominated by sandstones, siltstones, and subarkosic, greywacke, and subgreywacke gravelites. The detrital part of rock consists of angular and subrounded grains of quartz, K-feldspars, plagioclase; flakes of muscovite, biotite, and chlorite; and splintered fragments of schists and siliceous rocks with varying proportions. In some interbeds, a high content of charred plant detritus is reported. The cement has a chlorite–sericite composition. Silty–argillic units contain the same clastic material.

The rocks underwent intensive secondary alteration (metagenesis). Quartz grains are granular and corroded; development of aul-shaped units has been reported, as well as overgrowth of grains with “beardy” quartz [18]. Rocks are weakly schistose, segregation structures are noted, and mica is oriented along the schistosity. In some sandy–silty interbeds that are more homogeneously composed and sorted, granoblastic and lepidoblastic textures occur. Conversely, in siltstones and sandstones with basal-type cement, the initial clastic texture is preserved relatively well so that rocks are seen as less altered (deep catagenesis).
These rocks are similar in composition to Upper Paleozoic sediments from the Cape Peschany–Rakushchennaya Zone of the South Mangyshlak geoblock, which, in our opinion, belong to Upper Paleozoic lower molasse [20, 22]. The overlying Middle Jurassic continental sequences underwent much less secondary alteration, corresponding to the initial stages of catagenesis.

From a depth interval of 2943–2950 m in Bukbash-2, we recovered intensively weathered granites, overlain by lower molasses. In the other six boreholes where this molasse sequence was reported, an analogous zone was identified below it based on electric logging data: this zone is characterized by a lower resistivity of rocks and a higher borehole diameter. Remarkably, core material of this part of the section is not available in other boreholes.

K–Ar dating of granites from a depth interval of 2866–2869 m in the South Alamuryn-1 borehole yielded an age of 300 ± 8 Ma (i.e., Late Carboniferous). The age of tonalites recovered in Bukbash-2 was measured at 365–370 Ma [14]. According to the absolute age dating of these granitoids performed at the Satpaev Institute of Geological Sciences (Almaty, Kazakhstan; analyst G.A. Radchenko), these rocks formed 335–364 Ma ago (Late Devonian–Early Carboniferous).

The K–Ar age of schists in the South Alamuryn-2 borehole has been determined at 278 Ma versus 228 Ma in borehole South Alamuryn-1 [9, 13]. The most probable age is Early Permian. These dates characterize the time of the terminal phase of tectonomagmatic action on rock formed during the Variscan orogeny. The rocks that underwent metamorphism may be more ancient.

In a depth interval of 2943–2950 m in Bukbash-2, ancient myospora (Coniferae sp. indet., Stenozonotriletes sp., and Hymenozonotriletes sp.) were found in metamorphic rocks; these finds indicate the Paleozoic age of the host rocks.

Within the Kumsebshen block that adjoins the Kara–Bogaz Arch on its east, Pre-Mesozoic rocks were recovered by two reference boreholes, Kumsebshen-2 and Alamanel-1. In Kumsebshen-2, Paleozoic rocks from a depth of 1257 m down to the bottom of the borehole at 1660 m were identified. Based on the electric logging data, this section is clearly subdivided into two parts: (1) the lower (1606–1660 m), which differs by a higher resistivity, and (2) upper (1527–1606 m), characterized by a more dissected apparent resistivity curve.

The lower sequence was characterized by the core material from the depth intervals 1656–1646, 1639–1636, and 1609–1606 m. Based on our macroscopic examinations, these are black, solid, dense, silicified phyllitic units with an irregular shell–like fracture. In the upper interval, an admixture of tuffogenic material occurs.

Microscopic examination of rocks showed that phyllitic schists formed after initially clayey rock with a high mica content. Silty–psammitic interbeds possess quite clearly distinguishable primary clastic texture of the rock: acutely angled splintered grains of quartz, feldspars, mica flakes, quartzites, and effusive units. Deposits sometimes bear clear signatures of schistosity. Volcanic material is represented by vitriclastic and crystalloclastic tuffs.

The upper part of the section consists of the same rocks, but differs from the lower one by finer alternation of sediments. All rocks within the study region demonstrated quite pronounced secondary alteration typical of moderate and deep metagenesis. A characteristic peculiarity of these units is a considerable degree of dislocation; e.g., some beds in the core were documented as oriented at dip angles as high as 50°–60°.

Rocks of similar appearance and composition were recovered in the Alamanel area, borehole no. 1, from a depth interval of 2180–2316 m. The clastic material making up the sandstones is represented by quartz and acid plagioclase; fragments of siliceous–sericite, siliceous, and chlorite schists, as well as fragments of siliceous–chalcedonic and acid effusive rocks, aplites, and granite–aplitic; and mica flakes. The fragments are virtually unrounded. The cement is chlorite–clayey or siliceous–sericite in composition.

The absolute age of phyllitic schists recovered from a depth interval of 1646–1650 m of the Kumsebshen borehole is 262 Ma (Early Permian). These units are clearly correlated with the lower molasse complex of Upper Carboniferous–Lower Permian age, which was found in the Cape Rakushcheynaya area and within the Zhetybai–Uzen’ Zone of the South Mangyshlak geoblock [22]; in addition, based on the data from the boreholes presented above, these units are also present in the northwestern Kara-Bogaz Arch.

**DISCUSSION**

Our research within the Kara-Bogaz Arch indicate the absence of any direct geological evidence for the presence of the continental crust older than Paleozoic in the basement of the arch. The Precambrian age of the basement of the Kara–Bogaz Arch is usually supported by the gneisses recovered in Tamdy-1 and by metamorphic schists of the South Alamuryn area and amphibolites of the Karshi area [8, 9, 16]. The only argument for the Precambrian age of the basement is the high degree of metamorphic alteration in these rocks. Nevertheless, the local increase in the degree of metamorphic alteration in rocks may be related to the proximity of intrusive bodies; as a result, contact thermal metamorphism has overprinted regional metamorphism, and this is quite normal. As an example, we can mention the Oimasha area of the South Mangyshlak geoblock: here, a granitic intrusive body and host metamorphic rocks were recovered in multi-
ple boreholes with a high core removal rate [22, 24]. However, the degree of metamorphism is a relative parameter of the age of rocks, as indicated, in particular, by researchers who suggested the Precambrian age of the discussed rocks [8].

Amphibolites of the study region are apo-igneous metamorphic rocks associated with primary terrigenous rocks. Igneous rocks were metamorphosed (greenschist facies regional metamorphism), with the overprinted thermal effect from granitoids intrusions, so that they cannot serve as an argument for the Precambrian age.

Our detailed petrographic examination of gneisses recovered within the Tamdy area has shown that these gneisses alternate in the section with crystalline schists. Notably, gneisses and schists have similar mineral compositions and structural features, suggesting that gneisses represent marginal facies of the granitoid pluton recovered by borehole Tamdy-1, and they formed as a result of metasomatic reworking of the host rocks (protomagmatic gneissic banding). Taking into account the abundance of Devonian–Carboniferous granitoids in the Karshi area, singular measured K–Ar absolute ages of ca. 440 Ma (Silurian–Ordovician) cannot be considered a solid argument for the ubiquitously developed Precambrian crust within the Kara-Bogaz Arch; however, we suggest that some individual fragments of the more ancient folded basement may be found in this area, as well as in the basement of the southwestern Turan Plate. Given that the K–Ar absolute ages for granites from the Karshi area sharply differ from each other (440, 352, 313, and 310 Ma), we should not exclude that such scatter is caused by insufficient accuracy of the method itself.

The Kara-Bogaz geoblock is a heterogeneous geological body: its northeastern part is characterized by weakly negative magnetic field, whereas the magnetic field in the southwestern part becomes weakly positive. It can be assumed that primary terrigenous rocks predominate in the metamorphic complex within the northeastern part of this geoblock, while intermediate and mafic effusive rocks predominate in the southwestern part. The possibility of distinguishing two zones of slightly different extents within the Kara-Bogaz block has been also suggested by other researchers [17]. Employing geological data on adjacent areas, as well as magnetic and gravity survey data, we compiled a map schematically showing the structure of this region (Fig. 3).

**Fig. 3.** Schematic inner structure of basement of Kara-Bogaz Arch. Legend: (1) supposedly Baikalian (?) fold-metamorphic complexes; (2, 3) units of marginal-see-like troughs: (2) terrigenous-shale, (3) carbonate-shale; (4) metamorphosed volcanosedimentary units; (5) granitoids; (6) intrusive bodies with higher content of mafic component; (7) hyperbasites; (8) undifferentiated basites and ultrabasites; (9, 10) faults: (9) main, (10) secondary; (11) boundaries of tectonic zones; (12) Alpine fold system.
More detailed structures within the identified zones have yet to be obtained. Note that new magnetometric data that may be obtained sometime in the future can radically alter the ideas about the regional structure, similarly to how it occurred in the case of the South Mangyshlak geoblock, which was earlier believed to be a large massif underlain by the Precambrian sialic crust [3]. A condition for such a revision is the presence of NW-oriented magnetic anomalies within the Kara-Bogaz Arch, which are the characteristic features of Paleozoic structural elements [4]. Magnetic anomalies with the same orientation have been revealed in the northwestern part of the arch, partially covered by high-precision aeromagnetic survey [21].

The results obtained in the present work can be applied not only for regional tectonic reconstructions and paleoreconstructions, but also when solving applied petroleum geology problems, since the Caspian region in general and the Kara-Bogaz Arch in particular are of interest to petroleum companies.

CONCLUSIONS

(1) The study of core material has shown that the primary sedimentary and volcanic rocks making up the basement of the Kara-Bogaz Arch were altered at the stage of greenish scheist facies metamorphism. Such an insignificant degree of metamorphism is characteristic of epi-Hercynian fold zones. In zones with intensive granitoids reworking, the degree of secondary alteration in host rocks increases (up to muscovite–biotite subfacies). The material composition of these rocks is close to that of metamorphic rocks from the Paleozoic basement of the South Mangyshlak geoblock, recovered by more than 150 boreholes.

(2) On the slopes of basement highs, weakly metamorphosed terrigenous rocks of supposedly Carboniferous–Early Permian age preserved; these rocks may correspond to lower molasse. The age of granitoid intrusions corresponds to the formation time of the new continental crust of the Hercynides.

(3) We consider the Kara-Bogaz geoblock to be a Hercynian megaanticlinorium of the young Turan Plate; nevertheless, the block may still contain individual, probably large fragments of Precambrian sialic crust. The sedimentary–metamorphic and volcanosedimentary rocks making it up and intruded by multiple granitoid bodies are units of the active margin.

ACKNOWLEDGMENTS

The authors thank the reviewers, Yu.A. Volozh, Dr. (GIN RAS, Moscow, Russia), T.N. Kheraskova, Dr. (GIN RAS, Moscow, Russia), and M.P. Antipov, PhD. (GIN RAS, Moscow, Russia), and the anonymous reviewer for useful comments that improved the manuscript. The authors are grateful to the editor M.N. Shoupletsova (GIN RAS, Moscow, Russia) for thorough editing.

FUNDING

The study was supported by the Russian Foundation for Basic Research (project no. 19–05–00165-a).

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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Translated by N. Astafev