Tectonic zoning scheme of the Bashkir Cis-Urals consolidated crust basement

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SUMMARY

We present the tectonic zoning diagram of the consolidated crust with a predictive assessment of the oil and gas potential of the pre-Devonian sediments of the Bashkir Cis-Ural region. The crust is divided into the Lower Archean megablock in the west and the Lower Proterozoic protogeosynclinal, partially granitized in the Riphean, in the east. Megablocks are separated by the Birsk-Aksenovsk zone, which is a part of the Kaltasin-Pre-Caspian border zone. Tuimazin latitudinal deep dislocation divides the territory into northern and southern sectors. It is shown that the Pre-Ural trough is an independent tectonic subdivision that is part of the Pre-Ural-Aral border zone.
Introduction

We analyzed the data on the methods of deep seismic sounding and the common-depth-point shooting to solve regional tectonic and forecast problems for the hydrocarbons deposits search in the Bashkir Cis-Urals. The first boundary in the common-depth-point sections corresponds to the consolidated crust $K_{01}^*$ surface, below which there is a reflecting horizon corresponding to the surface of the crystalline crust $K_0$. The consolidated basement of the Lower Proterozoic-Riphean age corresponds to the base of the intermediate megacomplex composed of predominantly carbonate-terrigenous-shale deposits of $R_1–V$ age, where the folded complexes $PR_{1–R}$ are present. The crystalline basement is composed mainly of ancient Lower Archean gneisses of various compositions. It corresponds to the initial stage of crust formation and is a kind of separator between the ancient crystalline crust and the active upper part of the earth's crust (Druzhinin et al., 2014).

The quasi-layering of the consolidated crust can lead to an overestimation of the sedimentary layer thickness due to the underlying sediments. This applies primarily to the Lower Proterozoic-Riphean fold formation of the Perm-Bashkir megablock with a thickness of 5–7 km. These folded formations are absent in the consolidated basement scheme compiled according to the regional common-depth-point profiles (Masagutov, 2002). Therefore, the $PR_{1–R}$ of Perm-Bashkir megacomplex was included in the sedimentary layer, which led to an increase in its thickness to 22 km. Accordingly, the scheme showed overestimated depths of the consolidated basement, which also affected the forecast of the oil content of the underlying sediments.

Investigation results

Based on the analysis of deep seismic studies in the Ural region, we justified a variant of the fault-block quasi-layered model of the consolidated crust. The term "quasi-layered" was introduced to distinguish it from the layered of sedimentary sub-horizontal strata. In this case, the earth's crust is represented by seismic-geological levels, delimited by interfaces, “separators” (Ivanov et al., 1986), which were formed during the multistage development of the geological environment. They correspond to thinly layered formation members up to 3 km thick, which, due to the summation of seismic signals, create a relatively increased reflectivity. The first regional separator is the surface of the Lower Archean crystalline basement, which is located: on the South Tatar uplift below the Paleozoic sediments; in negative scale structures (grabens, aulacogens, depressions), below the sediments of the intermediate complex $R_1–V$. The presence of such elements is possible in deeper horizons of the crystalline crust, in particular, in the 8–10 and 18–25 km depth intervals. A similar division exists at the level of the main seismological interface surface between the crust and the upper mantle $M$ on stable platform structures.

We have drawn up the tectonic zoning scheme of the consolidated crust of the Bashkir Cis-Urals, taking into account the $K_{01}^*$, $K_0$ surfaces’ depths, the qualitative characteristics of the gravitational field, the M surface relief scheme, the corrected seismogeological sections along geotraverse the Tatarseis and the deep seismic sounding profile Temirtau-Kuibyshev (Druzhinin et al., 2020). The scheme is new, significantly different from those previously drawn up (Figure 1). Corrections were made to the tectonic zoning of the pre-Riphean basement. The main subdivisions’ contours of the crystalline and consolidated crust were shown. The main fault zones position, emphasizing the division of the territory into megastructures and blocks in latitudinal and meridional directions, was clarified.

The main factor determining the modern tectonic model of the consolidated crust of the Bashkir Cis-Urals is the border zones: the Pre-Ural-Aral (PUABZ) and the Kaltasin-Pre-Caspian (KPCBZ). The Kaltasin-Pre-Caspian border zone delimits the main subdivisions of the continental crust of the East European Platform (EEP): the oldest Lower Archean basement in the west and the Lower Proterozoic-Riphean with a protogeoysynclinal type of development in the east (Perm-Bashkir arch and similar structures). In the western part of the EEP territory, pre-Paleozoic complexes are located on the Lower Archean basement of the South Tatar and Orenburg arches and are represented mainly by Lower Riphean terrigenous-carbonate sediments, to which Vendian terrigenous sediments are added in places. Their thickness increases stepwise to the east from 2–4 km to 11–12 km in the Birsk-
Aksenovsk zone (BAZ), which is part of the KPCBZ. The boundary structure of the BAZ has been identified for the first time. It has a south-southwest direction. Its position is coherent with the Kaltasin rift-aulacogenic zone in the south of the Perm region, where its dimensions are increased to 75 km and the structure itself may correspond to the deep fluid-dynamic zone of the upper part of the lithosphere (Druzhinin et al., 2013). Such “blow-ups” are observed to the south; accordingly, the size of the BAZ varies widely from 25 to 65 km. The Pre-Ural-Aral border zone has a planetary character. It separates various large tectonic structures and is the eastern boundary of the EEP, to the east of which the Ural fold system (UFS), is located. The PUABZ is located on a folded Lower Proterozoic-Riphean basement.
Figure 1 Regional tectonic zoning scheme of the Bashkir Cis-Urals consolidated crust

Symbols. Tectonic zoning of the consolidated crust (1–4): 1 – the eastern boundary of the Ural fold system, 2 – the contours of the main units of the consolidated crust, 3 – deep sublatitudinal dislocations of the upper part of the lithosphere, 4 – deep submeridional and diagonal faults; 5 – border structures: I – Pre-Ural-Aral, II – Kaltasin-Pre-Caspian; 6 – Administrative border of the Bashkortostan Republic; 7 – prospective areas, promising in terms of the specifics of the deep structure of the earth's crust for the analysis and detailed exploration and prospecting to discover hydrocarbon deposits in the underlying sediments; 8 – known hydrocarbon deposits (Geological structure ...., 1997).

Block and zone designations. Bashkir-Chelyabinsk megablock (BCHMB), including zones: YuTZ – Yuzhno-Tabaskinskaya, YuKZ – Yukalenulevskaya, NGZ – Nugumskaya; southeastern margin of the EEP: South Tatar megablock (STMB) with the Lower Archean basement (AR), it includes blocks: NCHB – Naberezhno-Chelninsky, ALB – Almetyevsky, TRB – Tuimazin-Raevsky, ZHB – Zhigulevsko-Orenburgsky; Birsk-Aksenovsky border zone (BAZ), including the following zones: KZ – Kuedinskaya, BZ – Birskaya, ChZ – Chistinskaya, AZ – Aksenovskaya; Ufa megablock (UFMB) with the Lower Proterozoic basement (PR), it includes blocks: VAB – Vostochno-Aksinsky, KKB – Kushkulsky, IKB – Inklinsko-Kumertaussky; Sterlitamak-Sharlyky megablock (SSHB) with Archean-Lower Proterozoic basement (AR–RR), including blocks: STB – Sterlitamak, ISHB – Ishimbaevsky, ShB – Sharlyksky; South Ural megablock (SUMB)

Some researchers define the Pre-Ural trough as the eastern boundary of the EEP, the other as the western boundary of the UFS. If we perform tectonic zoning along the upper structures, then the contour of the exposed Urals is taken as the eastern boundary of the EEP and, accordingly, the Pre-Ural trough belongs to its platform part (Puchkov, 2010). Other researchers, taking into account the deep structure, included the deflection in the UFS (Sobolev, 1966). According to the drawn tectonic scheme (see Figure 1), the Pre-Ural trough, according to the features of the deep structure, belongs to an independent tectonic subdivision of the modern upper part of the lithosphere model within the Pre-Ural-Aral border zone. Sublatitudinal dislocations divide the crystalline crust into megablocks and blocks. The main one is Tuimazin, located in the central part of the territory and combining sublatitudinal dislocations in the west and east and faults in the southwestern direction. Tuimazin dislocation is interregional; it can be traced in the tectonics of the UFS and on the territory of the Volga-Ural anticlise. It is the border zone between the northern and southern parts of the area under consideration. In the northern sector there are megablocks: South-Tatar, Ufa, Bashkir-Chelyabinsk. In turn, the megablocks are divided by dislocations into similar but less significant blocks. The nonlinear character of the KPCBZ, PUABZ, apparently, is due to deep sublatitudinal shifts. Dislocations in the central part of the scheme are of great importance. A very interesting feature of the location of dislocations should be noted – to the east of the South Tatar arch, their radial divergence towards the Urals is observed. It can be assumed that the South Tatar arch, apparently, took an active part in the formation and modern position of the Ufa amphitheater, the Bashkir anticlinorium, and the Timan-Pechora plate. The problem of searching for hydrocarbon deposits in deeper horizons, below the known productive ones, is very relevant for the Bashkir gas region. Highlighted in Figure 1, the boundary structures of the KPCBZ and PUABZ are of interest for prospecting for hydrocarbon deposits in the underlying sediments. A significant number of deposits in the Paleozoic sedimentary complex, sometimes very large, such as in the Kaltasin region and in the north-west of the Republic of Bashkortostan, are confined to the KPCBZ. The PUABZ is located on the folded Lower Proterozoic-Riphean basement of the UFS, which probably did not contribute to the formation and preservation of hydrocarbon deposits. In the northeast of Bashkortostan, there are mainly small deposits in the Paleozoic complex; large deposits are absent there. When predicting the oil and gas potential of the pre-Paleozoic complex, the tectonic factor, the confinement of most of the fields to deep shear dislocations, upper part lithosphere faults, and the type of the earth's crust favoring the generation of hydrocarbon deposits and their migration to the near-surface part of the earth's crust were taken into account (Druzhinin et al., 2014; Druzhinin et al., 2017). In the absence of specific information on
hydrocarbon deposits prospecting results in the underlying sediments in the study area, at this stage, from the deep structure position, five promising areas in the KPCBZ and four in the PUABZ are outlined. Riphean dolomites especially noteworthy in the search. For example, the well-known oil fields of China, Mexico and the United States have been found in this complexes at depths of up to 10-11 km. A large oil deposit was discovered at a 6.5 km depth in the rocks of the Lower Riphean on the North China platform (Li YUnhun, 2007). Within the Kaltasin-Caspian border zone, drilling revealed Lower Riphean dolomites with velocities \( V = 6.8-7.0 \text{ km/s} \), 2.5 km thick, below which there is a terrigenous-shale stratum of the same age (R1). According to seismic data, dolomites occur at a depth of 2.5–5.0 km in the Kuedinsky region of the Perm region. This greatly facilitates the searching and exploration task. It is necessary to take into account the tectonic setting and deposits formation conditions.

Conclusions

The scheme of regional tectonic zoning of the consolidated crust of the Bashkir Cis-Urals region has been drawn up. Unlike the existing schemes, it is linked to the specifics of the structure of the earth's crust and surface M, and is new, both in content and in the geological results obtained. The Kaltasin-Caspian and Pre-Ural-Aral border structures have been identified within the study area. Latitudinal Tuimazinsk dislocation divides the study area into northern and southern sectors. An assessment of the prospects of hydrocarbon prospecting in pre-Paleozoic complexes is given. It is shown that the Pre-Ural trough is an independent tectonic subdivision within the Pre-Ural-Aral border zone. It is recommended to continue work on the creation of volumetric fault-block density models of the consolidated crust and the pre-Paleozoic complex, which are necessary for determining and assessing the averaged petrophysical characteristics of blocks of underlying sediments, compiling a tectonic map and, on this basis, increasing the level of regional forecasting.

References


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