https://doi.org/10.33271/nvngu/2023-5/005

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STRUCTURE AND INTERPRETATION OF THE ANOMALOUS MAGNETIC FIELD OF THE SOUTH TURGAY PETROLEUM REGION

Purpose. Study on the deep structure of the South Turgay petroleum region to assess the influence of magnetic causative masses on the processes of generation, migration, accumulation and conservation of hydrocarbon (HC) accumulations, taking into account the evolution of rift development modes of the same sedimentary basin.

Methodology. The combination of regional magnetometry data is applied with deep drilling data using a priori data on historical-geological, structural-formation, reservoir qualities and other factors. With the complex spatial anisotropy of the geomagnetic field and the distribution of magnetization of rocks in the Earth's crust, the physical prerequisites of magnetic survey data provide quite correct geological interpretation of the results obtained.

Findings. Classification and zoning of geomagnetic field anomalies by their morphology, intensity values, gradient and size was conducted, which made it possible to perform identification and geological forecast of magnetically causative bodies and determine their qualitative (structural) features.Various degrees of magnetization of different-age rocks of the South Torgay Petroleum region, as well as their relative location, structure, and depths of occurrence were established. It was revealed that the sedimentary cover and the upper part of the basement here are composed of low-magnetic and non-magnetic formations, and the upper edges of the magnetically disturbing masses lie at different depths in the consolidated crust, but, in general, deeper than the intervals of the section penetrated by deep drilling.

Originality. The genetic, historical, geological, and tectonic-magmatic features of the South Torgay basin differ sharply from those of the adjacent Lower Syrdariya arch and Shu-Sarysu Depression. At the present stage of evolution, South Torgay sedimentary basin has a significant endogenous warming of the lithosphere in contrast to the adjacent Lower Syrdariya arch and Shu-Sarysu depression. To some extent, it indicates the inheritance in the regime of development of the South Turgay sedimentary basin from the Paleozoic and Mesozoic stages of rifting.

Practical value. The depth of occurrence of magnetically causative objects significantly expand the stratigraphic interval of sediments that can be involved in the exploration process. The inherited mode of rift evolution of the basin suggests a favorable combination for the formation of a wide range of hydrocarbon traps, oil and gas source rocks, migration pathways, accumulation and preservation of HC accumulations.

Keywords: *geomagnetic field, deep faults, negative and positive anomalies, strength, magnetization, pre-Mesozoic basement, hydrocarbons*

Introduction. The South Torgay petroleum region (hereinafter abbreviated as PR) of Mesozoic oil and gas accumulations is controlled by the Meso-Cenozoic depression of the same name and belongs to the Central Kazakhstan oil and gas province.

The Aryskum trough is located in the south of the depression, and the Zhilanshik trough is located in the north, separated in the center by the Mynbulak sublatitudinal saddle (Fig. 1).

The heterogeneous basement of the South Torgay depression is submerged to a depth of 6500–7000 m in the Aryskum trough. Consequently, the sedimentary complex has a maximum thickness of up to 7000 m and is composed mainly of terrigenous(clastic) formations.

In the sedimentary section, two structural levels are identified [2]. The lower, intermediate structural level has certain prospects for oil and gas potential. It is primarily comprising ofUpper-Middle Paleozoic rocks and has a sporadic distribution. It has been penetrated by wells in the northwest of the Aryskum trough and in the western half of the Mynbulak saddle. The upper structural level, comprising of Mesozoic-Cenozoic rocks could be attributed to orthoplatform cover.

In the South Torgay oil and gas region, the Jurassic syngenetic regional oil and gas complex, the Neocomian (Lower Cretaceous) epigenetic oil and gas superstage, and the zonal oil and gas complex of the weathering crust of pre-Mesozoic formations were identified [3].

The structures, controlling mainly oil and gas-oil fields, are complexly constructed domed and brachianticlinal folds with the lower part of the section of pre-Mesozoic basement highs, on which the Upper Jurassic and Neocomian layers lie, inheriting the surface structure of these highs as brachianticlinal and domed structures up to and including Aptian-Upper Cretaceous sediments [4].

The following types of oil fields can be defined in the South Torgay PR: erosional highs, inherited brachyanticlinal and dome-shaped uplifts, buried and rootless brachianticlinal and dome-shaped structures [5].

According to the data of aforementioned researchers, the reservoir rocks of the identified and proven fields are weakly cemented gravelstones, and siltstones with high reservoir properties.

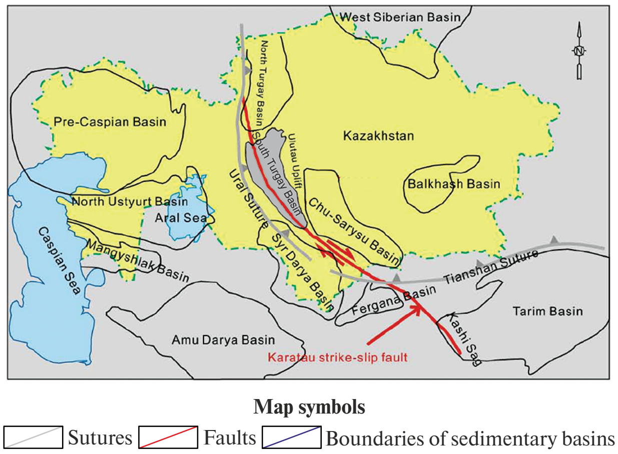

Fig. 1. Overview diagram of the South Torgay depression Paleogene-Neogene rocks, already laid almost horizontally [1]

Oil and gas accumulations could be attributed to tectonically, stratigraphically and lithologically bounded ones. In rare occasions there are hydrocarbon accumulation bounded on all sides (lenticular) and massive in weathering crust of the basement.

Taking that into account, it becomes evident that a large role in the formation of the oil and gas potential of the South – Turgay PR is given to the basement and transformations of its structural and mineral composition, in the research of which a special place is devoted to magnetic prospecting.

In turn, this circumstance predetermined the content of the present paper, which reflects the analysis and discussion of the results of the authors' studies on the regional magnetic survey data. Because the data obtained provide reliable information about the parameters and depth of occurrence of magnetically causative masses in the basement rocks, which, in turn, determines the direction and evolution of the South Torgay sedimentary basin.

Vintage data on magnetometer surveys. The first aeromagnetic survey in the South Turgay PB started in 1941 by the Kazakh Geological Survey with a Z-aerial magnetometer AM-9L at a scale of 1:500 000.

In 1945–1953 aeromagnetic surveys were continued at a scale of 1:1,000,000 to 1:100,000 by the Aerogeological Expedition, the Main Uzbek Geological Corporation the Central Asian, as well as the All-Union Aerogeological and Ural Geophysical Trusts and the Main Corporation of the Geophysical Survey. The surveys covered an area of about 750 thousand km^2 and obtained data on the general structure of the magnetic field.

Since the mid-1950s, the West Siberian Geophysical Trust has carried out surveys of 1:200,000–1:100,000 with an AEM-49 fluxgate magnetometer. In 1956–1957 the Kazakh, Uzbek and West Siberian geophysical trusts and the Kyrgyz Geological Corporation have begun regional and regional prospecting work on a scale from 1:500,000 to 1:100,000 with the ASGM-25 aerogamma-magnetic station. By 1962, an area of 667,000 km^2 was covered with this equipment [6].

In parallel with regional surveys, from 1955 prospecting (1:50,000 and 1:25,000) and detailed (1:10,000) surveys began to be conducted. From 1961, Kazgeofizthrust and West Siberian Department implemented photoreferencing of the routes, which increased the accuracy to ±35 nT, and the introduction of more advanced magnetometers AMF-21, stations ASGM-45, ASGM-46, ASGM-48 and AMM-13, wide-angle aerial cameras, the network development of frame routes increased the accuracy to ±15–25 nT.

Radio geodesic surveying of the routes began to be applied in 1963. It increased the accuracy of the survey up to ±25 m and the accuracy of active surveying up to ±30 m, which allowed developing detailed surveying networks up to 1:10,000 with an accuracy of ±10–20 nT.

Since 1969, proton and quantum aeromagnetometers and add-on units to ferroprobe magnetometers, which practically have no drift and make it possible to tie up relative measurements to absolute values of the magnetic field during the measurements themselves, have been used. These are VITR magnetometers AYAM-6 and AMP-7, attachments YAMP-1, YAMP-2, YAMP-3 and magnetometers MMS-214, MMV-215, KAM-28, MM-305 and station SKAT-77 [7].

The advance of new equipment, digital registration and automated processing raised the aeromagnetic exploration to a qualitatively new level, the accuracy of surveys increased to the first units and even fractions of nT.

As a result, the main part of the area of the South Torgay PR – up to 80 % is covered by high quality surveys of scale of 1:50,000, conducted in the late 1980s with digital equipment and radiogeodesic referencing. The errors are from ±1.43 to ±12.1 nT. The rest – the east and south-east of the region – are the old surveys of 1:100,000 scale with visual referencing.

The modern stage of magnetic prospecting in the South Torgay PR dates back to 2000, when foreign investors brought in new technology and modern software.

Results. ***Morphology, orientation and intensity of geomagnetic field anomalies.*** For the South Turgay PR indicative are continuous anomalous zones (ΔTa), extending from the Urals almost strictly to the south through all of Kazakhstan with a swinging to the southeast [2].

The maximum contrast of ΔTa anomalies is observed over the outcrops of the Pre-Mesozoic basement along the mountain framing in the east of the South Torgay Mountain Range (Fig. 2), where elements of the geological structure, deep faults, blocks of sedimentary-vulcanogenic and intrusive for-

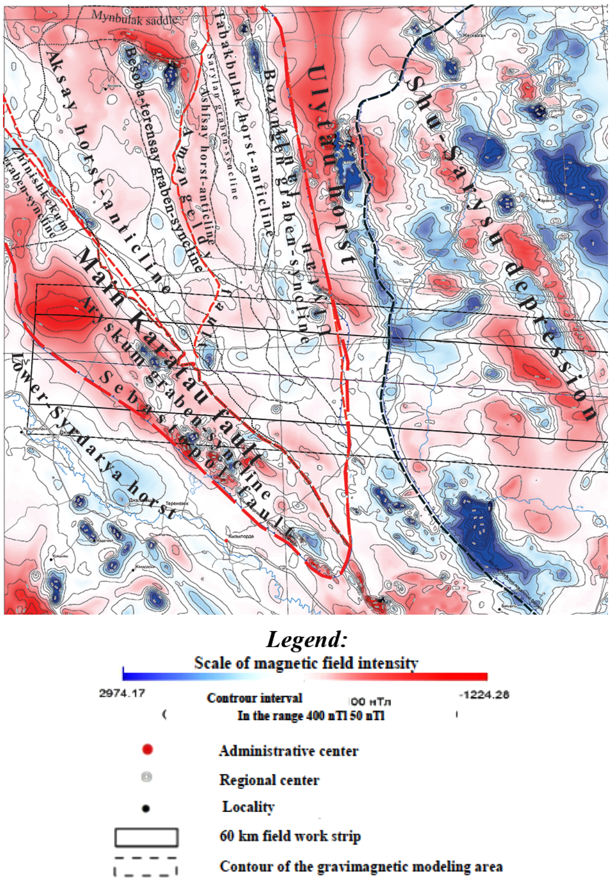

Fig. 2. Fragment of the map of the anomalous magnetic field with tectonic elements (built on the basis of the map of the anomalous magnetic field (ΔTa) of Kazakhstan at a scale of 1:1000000, edited by Akylbekov S.A., Mazurov A.K., et al., 2004) [8]

mations, places of secondary changes in the rocks are shown in the structure of the geomagnetic field [6].

In the magnetic field the following are distinguished: a) areas of quiet low-intensity anomalies of large size of different sign; b) isometric, oval, areas of mosaic field with a complex pattern of anomalies; c) bands of linearly-drawn anomalies.

The depths of the upper margins of the magnetically causative bodies and the surface of the Hercynian structural level were compared, and suggestions were made about the nature of the magnetic anomalies.

Linear anomalous zones form an extended, linear-elongated or arc-shaped anomalies. However, it is not uncommon to find isometric and polygonal forms of anomalies ΔTa with elevated or reduced values, located in chains, echelon-like, clearly oriented in a certain direction.

Bands of linear magnetic anomalies of submeridional and northwestern strike correspond to near-fault intrusive bodies and dikes of medium and basic and ultrabasic composition.

Isometric, ring and elliptical anomalies of various sizes correspond to the stocks, batholiths intrusive rocks (diorites and granodiorites), volcanic vents and other local geological formations.

***Aryskum graben* (*area 19,137 km*^{2}).** Anomalous geomagnetic field here is characterized by the presence of alternating values. The general orientation of ΔTa anomalies is northwestern, and their allocation is controlled by deep faults – the Main Karatau fault (MKF) and the Sevastopol deep fault (SDF).

The general background of geomagnetic field at the Aryskum graben forms negative anomalies, and their sizes and intensity decrease in the southeastern direction (Fig. 2).

In the northwestern part of this graben a large negative anomaly ΔTa (with the size of 17.7 × 25.2 km^2) of oval/subisometric shape with intensity –200 ÷ –300 nT can is delineated.

In the central part of the Aryskum graben, the character of geomagnetic anomalies acquires a mosaic pattern with increased concentration, with different sign and intensity. Geometric forms of these anomalies are subisometric, isometric, polygonal, etc.

Orientation of the anomalies is not subject to zoning. The intensity of the negative anomalies varies within –150–400 nT, and their sizes vary in a wide range (from 9.0 × 6.5 to 21.2 × 6.5 km). The intensity of the positive anomaly ΔTa is +100 ÷ +250 nT, and its sizes are 145 × 40 km (Fig. 2).

In the southeastern part of the Aryskum graben there is a large positive anomaly of submeridional orientation with sizes 16.8 × 8.7 km and intensity ΔTa –100 ÷ –250 nT. In the southeastern direction, it borders with a small in size negative anomaly ΔTa with an area of 16.8 km^2 and an intensity of 0–100 nT, confined to the SDF.

***Aksai horst* (*area 6710 km*^{2}).** A characteristic feature of the anomalies of the geomagnetic field of this tectonic element is a clear differentiation into the western and eastern parts.

In the western part of the Aksai horst, positive anomalies with a clearly pronounced linearity, oriented in the northwest direction and having an intensity of +50 ÷ +150 nT, were predominantly developed (Fig. 2).

In its eastern part, there is a predominance of large in size weakly gradient negative anomalies ΔTa and the absence of linearity in their forms. The intensity of geomagnetic field anomalies is –100 ÷ –150 nT.

Besoba-Terensay graben. It has a common submeridional strike and can be traced for a distance of up to 190 km. From the east, its strike ends with the Amangeldy Fault. In the west, the Besoba-Terensai graben is bounded by the Aksai horst, and in the north, by the Mynbulak saddle.

A characteristic feature of the geomagnetic field of this tectonic element is the presence of alternating maxima and minima of ΔTa anomalies, characterized by the development of polygonal forms and not subject to zoning (Fig. 2).

Large areas of a positive geomagnetic field are observed in the northern and central parts of the Besoba-Terensai graben. In its northern part, the intensity of ΔTa anomalies reaches +450 nT. The magnetic field here is strongly jagged and differentiated.

In the central part, the geomagnetic field character becomes magnetically quiet (weakly differentiated), and the intensity of the anomalies ΔTa decreases to +50 nT (Fig. 2).

Between the maxima of the geomagnetic field, there is the presence of zones of weakly negative minima with an intensity of –10 ÷ –50 nT and with sizes (42–60 × 12–46 km), which vary significantly in the area.

***Mynbulak saddle* (*area 4035 km*^{2}).** It is considered as a northern boundary tectonic element in the study on the structure of the geomagnetic field of the South Torgay PR. Within the Mynbulak saddle, negative anomalies of the geomagnetic field without sharp variations with background values of –100–200 nT have predominantly developed (Fig. 2).

In the southeastern part of the saddle, the geomagnetic field acquires a sharply gradient character. There is an increase in the intensity of anomalies ΔTa up to –200 ÷ –250 nT and with sizes reaching up to 50.5 × 7 km.

In the easternmost part of the Mynbulak saddle, in the zone of its junction with the Tabakbulak horst, the geomagnetic field changes its sign. Here, there is a weakly pronounced positive polygonal anomaly of meridional strike with a strength of 0–50 nT and with dimensions of 27 × 9 km (Fig. 2).

***Ashchisai horst* (*area 3850 km*^{2}).** It is controlled in the west by the Amangeldy fault, in the east by the Sarylansky graben, and in the north by the Mynbulak saddle.

From north to south, the Aschisai horst extends for 138.3 km. It is characterized mainly by a weakly differentiated negative geomagnetic field and the presence of ΔTa anomalies of low intensity, about –50 nT (Fig. 2).

***Sarylan graben* (*area 1,829 km*^{2}).** To the west and east, it borders, respectively, the Aschisai and Tabakbulak horsts. Sarylansky graben has a length of 155.8 km and is delineated mainly by a weakly pronounced negative background.

***Tabakbulak horst* (*area 4,950 km*^{2}).** It is characterized by the presence of variable geomagnetic field anomalies of submeridional strike. On this background, negative ΔTa anomalies with intensities up to –100 nT, in some places up to –150 nT were mainly pronounced (Fig. 2).

In the junction zone with the Bosingen and Sarylan grabens, linearly extended high-gradient positive anomalies ΔTa with an intensity of up to +200 nT appear. The sizes of the most contrasting and largest geomagnetic field anomaly is 30 × 10 km.

A similar in sizes (27 × 10 km), extent, but less contrasting positive anomaly ΔTa is also observed in the south of the Tabakbulak horst, where its intensity varies in a small range (0 ÷ +50 nT) (Fig. 2).

***Bozingen graben* (*area 19,137 km*^{2}).** It is characterized by a complex mosaic anomalous geomagnetic field. In the eastern part, it is bounded by the Ulytau fault. In the north of the graben there are mainly positive anomalies ΔTa with an intensity up to +200 nT linearly-drawn or oval shape and submeridian strike. Maximum dimensions of the anomalies can reach up to 29 × 9 km (Fig. 2).

Another positive oval anomaly of submeridional strike with ΔTa intensity up to 100 nT and dimensions of 14 × 22 km is observed in the central part of the Bozingen graben.

Genesis of remnant magnetization of rocks. The natural remanent magnetization of the Southern Torgay PR is insufficiently studied, although it plays a major role in the creation of the magnetic field. The highest values of remanent magnetization are characteristic of magmatic rocks, and this magnetization is directly related to the basicity of the rocks, the degree of metamorphism, and the depth of occurrence.

In order to perform the geological interpretation of geomagnetic field anomalies, the information was used on the material composition of the basement rocks, reflected in Table.

The results of the studies indicated that the anomalous geomagnetic field of the Southern Torgay depression reflects the different degree of magnetization of rocks, as well as their

Table

Morphology of geomagnetic anomalies, structural-material composition and age of basement rocks penetrated by drilling

Title	Morphology of anomalies	Well name	Depth, m	Depth of Paleozoic, m	Indications magnetic field	Rock type category
Aksay horst	In the western part, linear maxima are predominantly developed, oriented in a northwestern direction. In the eastern part – there is a prevalence of negative anomalies ΔTa and the absence of linearity in their forms	Aksay 1	1683	1596–1683	100	granodiorites, – quartz-chlorite sericite schists
		Aksay 13	1941	1851–1941	60	Siliceous-sericite, chlorite-sericite schists: 30 %, gneisses: 35 %, porphyrites: 35 %
		Aksay 3	2200	2075–2200	150	Siliceous-sericite, chlorite-sericite schists: 30 %, gneisses: 35 %, porphyrites: 3 5%
		Aksay 17	1852	1731–1852	–10	Siliceous-sericite, chlorite-sericite schists: 30 %, gneisses: 35 %, porphyrites: 35 %
		Aksay 15	1800	1742–1800	–50	Siliceous-sericite, chlorite-sericite schists: 30 %, gneisses: 35 %, porphyrites: 35 %
		Aksay 6	1860	1796–1860	80	Siliceous-sericite, chlorite-sericite schists: 30 %, gneisses: 35 %, porphyrites: 35 %
		Aksay 18	1730	1709–1730	50	Siliceous-sericite, chlorite-sericite schists: 30 %, gneisses: 35 %, porphyrites: 35 %
		Kizylkiya 23	1883	–	–70	Siltstones, mudstones with interlayers of limestone
		Kizylkiya 10	–	–	–	Siltstones, mudstones with interlayers of limestone
		Kizylkiya –5	–	2300–1218	–	Liparite tuffs
		Kizylkiya 24	1985	1825.9–1832.9	–70	Green, fine- and medium-grained sandstones, firm, weakly cemented in places
Besoba-Terensai horst	Development of maximum anomalies ΔTa polygonal shape, not subject to zoning	Akshabulak 18	1949	1838–1949	–50	Quartz-chlorite schists
		Yespe 2-G	1646	–	–25	Quartz Chlorite
		Akshabulak 1	1972	1922–1972	–50	quartz-chlorite-sericite schists
		Akshabulak 3-P	1905	1876–1905	–50	Siliceous-sericite, chlorite-sericite schists: 30 %, gneisses: 35 %, porphyrites: 35 %
Aryskum graben	Large minima ΔTa polygonal, oval, isometric, subisometric shape	Konys 25	1989	1793–1814 Precambrian	–200	Coarse-clastic rocks (gravelites, conglomerates of gray-green color on carbonate cement)
	Large minima ΔTa polygonal, oval, isometric, subisometric shape	Konys 1	2449	–	–100	Argillites

mutual location, structure, and depth of occurrence.The Mesozoic-Cenozoic formations are practically nonmagnetic: their magnetic susceptibility does not exceed $15 \cdot 10^{-5}$, which is typical for diamagnetics [5].

The intervals of pre-Jurassic formations exposed by drilling are composed of non-magnetic and weakly magnetic rock varieties, as indicated by the contents of the Table.

For example, red-colored terrigenous(clastic) and carbonate-terrigenous rocks of the Upper Paleozoic belong to practically non-magnetic formations: their average magnetic susceptibility according to Li L.V., et al. (2017) does not exceed $5000 \cdot 10^{-5}$.

On the eastern margin of the South Torgay basin, rocks of the upper part of the Serpukhovian epoch (Beleutinskaya group) and the Bashkirian epochs (Taskuduk group) of the Middle Carboniferous $-23–140 \cdot 10^{-5}$ are characterized by slightly increased magnetic susceptibility [5].

According to Li L.V., et al. (2017), Ordovician and Devonian basement rocks, represented by acid volcanic rocks and their tuffs, are weakly magnetic or practically non-magnetic: the maximum values of magnetic susceptibility are not higher than $100 \cdot 10^{-5}$, which is characteristic of paramagnetics. The remanent magnetization of granites D_{1-2} is $13 \cdot 10^{-6}$, rhyolites $-492 \cdot 10^{-5}$.

At the same time, Devonian volcanic rocks (deposits of the Zhaksykonskaya group (D_{2-3}) of medium and basic composition are marked by increased and high values of magnetic susceptibility up to $5000 \cdot 10^{-5}$ [5].

The magnetic susceptibility of Precambrian rocks, in general, is slightly increased in comparison with the overlying Paleozoic strata.

As a part of the composition of Precambrian formations, the highest values of magnetic susceptibility have greenstone rocks (up to $3000 \cdot 10^{-5}$), amphibolites (up to $6000 \cdot 10^{-5}$), feldspar-amphibole rocks (up to $16,000 \cdot 10^{-5}$), amphibole rocks (up to $4400 \cdot 10^{-5}$), and chlorides (up to $1900 \cdot 10^{-5}$), chlorite-epidote (up to $43,000 \cdot 10^{-5}$) shales, volcanites of primary composition (up to $5500 \cdot 10^{-5}$ SI units) and ferruginous quartzites (up to $7700 \cdot 10^{-5}$). Although there are lighter nonmagnetic granitized varieties of rocks, quartzites and quartzite shales.

Discussion. According to some authors, the magnetic field of the South Torgay PR, in general, is negative ($-10 \div -750$ nT). Against this background, meridionally located chains of local maxima to $+100 \div +550$ nT are traced, reflecting the southern submerged continuation of the Ural structures [9].

According to the results of authors' research, in the South Torgay PR polygonal isometric, subisometric, oval anomalies ΔTa large in size, of both signs are extremely common. The presence of such anomalies does not quite “fit” in the general concept of genesis of rifts which should be characterized by linear forms of magnetic causative bodies in the zones of deep faults. The phenomenon also requires additional study.

At the fragment of the Shu-Sarysu depression located to the east (the Dzhezkazgan depression), linearly elongated anomalies of the geomagnetic field of a positive sign, oriented submeridionally, from southeast to northwest, are predominantly distributed. The intensity of these anomalies varies in a wide range (+50 ÷ +600 nT and more). The orientation of the ΔTa anomalies coincides with the strike of the Dzhezkazgan depression [6].

The genesis of anomalies is probably caused by latent (non-eroded) near-fault intrusive bodies and dikes of intermediate, basic, and ultrabasic compositions and effusives of basic-intermediate compositions [10].

Regional geomagnetic field anomalies of predominantly polygonal, isometric, subisometric, or oval shape, which cannot be zoned, are common within the Lower Syrdariya arch located to the southwest of the South Torgay PR. These anomalies form groups of complex geometric shapes.

Thus, it can be argued that in terms of morphology (geometric shapes), the geomagnetic field anomalies of the South Torgay PR occupy an intermediate position between the Lower Syrdarya arch and the Shu-Sarysu depression.

Relative to the size and intensity of geomagnetic field anomalies, they obtain minimal values at the South Torgay PR, which indirectly confirms the fact of deep subsidence of magnetically causative masses. Based on the sign and the intensity of geomagnetic field anomalies, the genesis of magnetically causative masses here occurred in geological times other than the Lower Syrdariya arch and the Shu-Sarysu Depression.

There is no definite unambiguous conclusion on the nature of the remanent magnetization of the basement rocks of the South Torgay PR.

As suggested by [11] in the Bolshoi Karatau Ridge located to the southeast, its formation is associated with the Paleozoic folding, when within the Middle Bashkir-Early Mesozoic there was a rotational restructuring of large blocks associated with the occurence of systems of large strike-slip faults, along which they rotated in a counterclockwise direction in the range from 20 to 60°. The magnitude of the observed vertical axis rotation decreases with decreasing magnetization age.

According to the studies of [13], primary (Devonian) and synfolding (Permian) magnetization identified among three sections of the Greater Karatau Ridge (Zhanatas, Akkol, and Zhankurgan) in the adjacent South Torgay sedimentary basin. All these strike-slip faults could not but affect the rocks of the Pre-Mezozoic formations of the South Torgay sedimentary basin.

The results of our studies indicate that the formation of magnetically causative masses in the submerged basement of the South Torgay PR could have taken place twice [12].

The rocks, presumably have acquired magnetization for the first time in the Late Ordovician, when compression processes, tectonic inversion, active dislocations, and extensive magmatism occurred during the regression and closure of the Paleo-Asian Ocean. These events led to the formation of a large Kazakhstan Early Paleozoic continent [13, 14].

Another period of formation of magnetically causative masses is likely associated with the end of the early-beginning of the middle Devonian [12], when a spreading zone was formed in the Turkestan paleo-ocean, under the influence of which an active continental margin with the Turgay Devonian marginal volcanic belt [15] existed until the end of the Early Carboniferous.

Since the Mid-Carboniferous, subduction along the western margin of the Turgay-Syrdarya region with the formation of the Valerian-Kuramin marginal-continental volcanic belt became more active. Collision and orogenesis began [10, 16].

Being that the magnetic susceptibility in the Earth’s crust increases with depth, as the basicity of rocks rises, the probability of the connection between the observed geomagnetic field of the lithosphere and the temperature becomes plausible.

It is known that the Curie point for rocks of the lithosphere is low and work out several hundred degrees. Therefore, weak and negative fields may correspond to more heated rocks of the Earth's crust, and less heated rocks form positive fields, magnetizing in the field of the dipole current component of the Earth’s main planetary field [17].

Based on the paradigm, it is possible to infer that in the South Torgay sedimentary basin, the Earth’s crust is characterized by increased warming.

In contrast, the crust of the Lower Syrdariya arch and the Shu-Sarysu depression is relatively less heated. Since large maxima of the vertical component Bz of the magnetic field (up to +25 nT) are detected here (Fig. 3).

In accordance with our previous studies, the South Torgay sedimentary basin in the Paleozoic and Mesozoic by different estimates from two to three times rifted [12]. In the Paleozoic it can be attributed to a complete cycle with a wide exposure of tectonic-magmatic dislocations. In the Mesozoic, this basin remained in the extension phase, without manifestation of folding and magmatism [13, 19].

This suggests a direct conclusion about the inherited regime of rift evolution in the South Torgai sedimentary basin. The results obtained indirectly indicate a significant endogenous heating of the lithosphere in this sedimentary basin also at the present stage of its evolution, in contrast to the adjacent Lower Syrdarya dome and Shu-Sarysu depression.

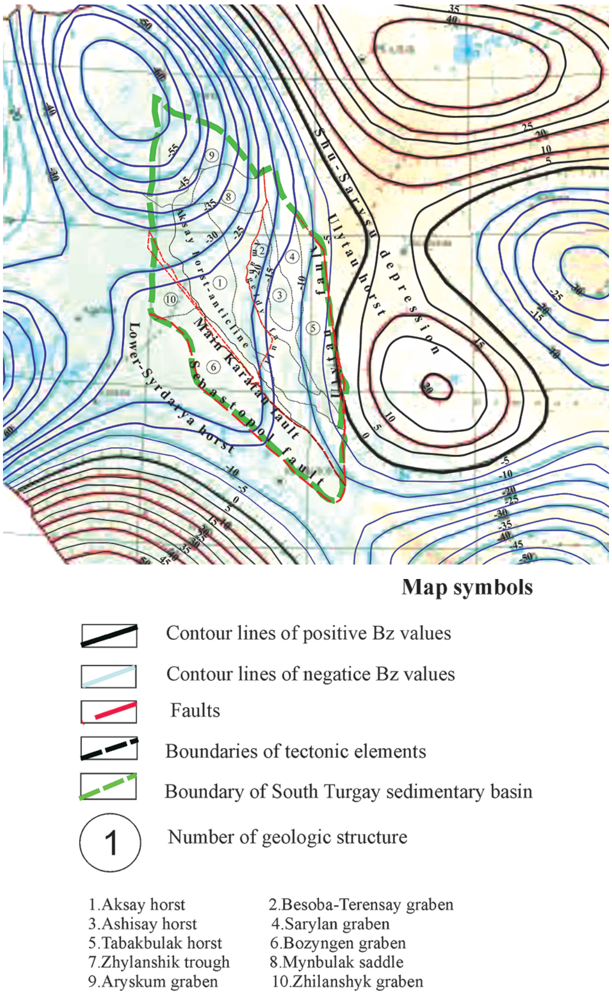

Fig. 3. A fragment of the map of the vertical component Bz of the magnetic field of the lithosphere of Kazakhstan according to the MF3 POMME model for the 2001 epoch [18]

Thus, the relationship between the magnetization of rocks and the vertical component Bz of the magnetic field with the endogenous regime of the South Torgay sedimentary basin is traceable.

Conclusion. Based on the above, it seems possible to formulate the following conclusions on the structure and results of the interpretation of the regional anomalous geomagnetic field of the Southern Torgay PR:

1. The physical prerequisites for the use of magnetic survey data provide a valid geological interpretation of the results obtained with a complex spatial anisotropy of the geomagnetic field and the distribution of rock magnetization in the Earth's crust and upper mantle.

2. Morphology, intensity and size of geomagnetic anomalies provide an opportunity for identification and geological prediction, whereas the differentiation of these anomalies, their gradient characterize the qualitative (structural) features of magnetic causative bodies.

3. Anomalous geomagnetic field of the South Torgay PR is represented by the most different forms of magnetic anomalies: linear-elongated and arc-shaped, convoluted with a clearly expressed predominance of the larger axis, polygonal, subisometric, oval, ring, mosaic and complex configuration in plan; intense and low intensity; low and high gradient (contrast), finally, large and very small in the area.

4. The sizes and values of the geomagnetic field anomalies intensity in the South Torgay PR acquire minimal values compared to the adjacent regional geostructures, which implicitly confirms the fact of deep subsidence of the magnetically causative masses.

5. The anomalous geomagnetic field of the South Torgay PR displays a different degree of magnetization of different-age rocks, as well as their relative location, structure, and depth of occurrence. It can be assumed that the sedimentary cover and the upper part of the basement in this region are composed of low-magnetic and non-magnetic formations. The upper edges of the magnetically causative masses in the South Torgay PR occur at different depths in the consolidated crust, but, in general, deeper than the intervals of the section exposed by deep drilling.

6. The character of differentiation of the anomalous geomagnetic field reflects the geological structure of the South Torgay depression and indicates the genetic and tectonic-magmatic aspects of its geological structure and evolution history. According to the intensity sign, the formation of magnetically causative masses in the South Torgay basin occurred in other geological epochs than in the Lower Syrdarya uplift and the Shu-Sarysu depression.

7. The quantitative values of the vertical component Bz of the magnetic field indicate that the consolidated crust of the South Turgay basin is relatively warmed. On the contrary, the values of this component in the Shu-Sarysu depression and the Lower Syrdarya uplift indicate that the consolidated crust is considerably less warmed by endogenous heat and mass transfer.

8. Inherited in the mode of evolution of the South Torgay sedimentary basin from the Paleozoic and Mesozoic stages of rifting has been established. The obtained results indirectly demonstrate that even at the modern stage of evolution this sedimentary basin has a significant endogenous warming of the lithosphere in contrast to the adjacent Lower Syrdarya arch and Shu-Sarysu depression.

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Структура та інтерпретація аномального геомагнітного поля Південно-Торгайської нафтогазоносної області

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Мета. Дослідження глибинної будови Південно-Торгайської нафтогазоносної області (НГО) для оцінки впливу магнітозбурюючих мас на процеси генерації, міграції, акумуляції та консервації скупчень вуглеводнів (ВВ) з урахуванням успадкованості режимів рифтового розвитку однойменного осадового басейну.

Методика. Комплексування даних регіональної магнітометрії з матеріалами глибокого буріння із залученням апріорних відомостей з історико-геологічного, структурно-формаційного, фільтраційно-ємнісного та інших факторів. При складній просторовій анізотропії геомагнітного поля й розподілу намагніченості гірських порід у земній корі, фізичні передумови застосування даних магніторозвідки забезпечують цілком коректну геологічну інтерпретацію одержуваних результатів.

Результати. Проведена класифікація та районування аномалій геомагнітного поля за їхньою морфологією, значеннями інтенсивності, градієнтності та розмірами, що дало можливість виконати ідентифікацію й геологічний прогноз магнітозбурюючих тіл, визначити їх якісні (структурні) ознаки. Встановлено різний ступінь намагніченості різновікових гірських порід Південно-Торгайської НГО, а також їхнє відносне взаєморозташування, структура та глибина залягання. Виявлено, що осадовий чохол і верхня частина фундаменту тут складені маломагнітними й немагнітними утвореннями, а верхні кромки магнітозбурюючих мас залягають на різній глибині в консолідованій корі, але, загалом, глибші за інтервали розрізу, розкриті глибоким бурінням.

Наукова новизна. Генетичні, історико-геологічні й тектоно-магматичні особливості Південно-Торгайського прогину різко відрізняються від суміжних з ним Нижньосирдар'їнського склепіння та Шу-Сарисуйської депресії. На сучасному етапі розвитку Південно-Торгайський осадовий басейн має значну ендогенну прогрітість літосфери на відміну від суміжних з ним Нижньосирдар'їнського склепіння та Шу-Сарисуйської депресії. Певною мірою це свідчить про успадкованість у режимі розвитку Південно-Торгайського осадового басейну від палеозойського й мезозойського етапів рифтогенезу.

Практична значимість. Глибоке залягання об'єктів магнітозбурення значною мірою розширює стратиграфічний інтервал відкладень, що можуть бути залучені до геологорозвідувального процесу. Успадкований режим рифтового розвитку басейну передбачає сприятливе поєднання утворення пасток ВВ широкого спектра, нафтогазоматеринських світ, шляхів міграції, акумуляції та консервації скупчень ВВ.

Ключові слова: *геомагнітне поле, глибинний розлом, негативні й позитивні аномалії, напруженість, намагніченість, домезозойський фундамент, вуглеводні*

The manuscript was submitted 07.06.23.