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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
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НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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REMOTE SENSING AT THE STUDY OF THE THERMAL FIELD OF THE SOUTH USTYURT REGION TO FIND HYDROCARBON DEPOSITS

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Abstract. The article discusses the interpretation of remote sensing data at the study of the thermic field in the southeastern part of the South Mangyshlak-Ustyurt trough system in order to determine the possibility of involving thermic parameters to exploration hydrocarbon (HC) fields. The products derived from Remote Thermal Infrared Survey Data (RTISD) are analyzed in detail, providing a complementary analysis for the geological and geophysical approach generally used at the exploration oil and gas fields. Thermal properties of different horizontal and vertical sections of the area were estimated from regional and local components of ground infrared survey data, which provided the detection of geothermic anomalies. We interpreted that the Shakhpakhty tectonic step is characterized by relatively large positive thermal anomalies, which indicates the predominance of shallow set of rocks (< 2 km deep) with high values of thermophysical properties. Moreover, the intensity of the thermal infrared anomalies increases with depth in blocks, which apparently characterizes the position of geological and structural elements that differ of thermal and physical properties. The Central Ustyurt dislocation system and the Assakeudan depression, are characterized by low intensity thermal anomalies, indicating that they include rocks or sediment with low thermophysical properties. The Assakeudan depression is characterized by large thickness of sedimentary rocks, which mostly form the oil-source suites. Faults that disrupt the lateral continuity of these geological formations are considered as conduits for migration of hydrocarbons, deep fluids, heat and mass transfer. The results show that satellite infrared data can be used as exploration criterion for mapping potential hydrocarbon accumulations in the southern part of the Ustyurt region. The results of integrated analysis of geothermal, gravity, magnetic and radiometric anomalies allowed us to interpret on geological heterogeneity of large regional structures, about the depth of occurrence of gravity-disturbing masses and magnetically disturbed objects is revealed, about the characteristic of faults and the local structures in the geophysical fields. According to the analyze highlighted local structures Utezhan, Kozhantai, North Kozhantai, Otynshy with sufficiently high hydrocarbon potential, and recommended for further study by seismic and deep drilling methods.

Keywords: thermal anomalies, MODIS, anisotropic transformation method, transforms

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КӨМІРСУТЕК КЕН ОРЫНДАРЫН ІЗДЕУ МАҚСАТЫНДА ОҢТҮСТІК ҮСТІРТ АЙМАҒЫН ЖЕРДІ ҚАШЫҚТЫҚТАН ЗОНДТАУ КЕЗІНДЕ ЖЫЛУ ӨРІСІН ЗЕРТТЕУ

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Аннотация. Мақалада көмірсутектерді іздеуге термофизикалық параметрлерді тарту мүмкіндігін анықтау мақсатында Оңтүстік-Маңғышлақ-Үстірт науалы жүйесінің оңтүстік-шығыс бөлігіндегі жылу өрісін зерттеу кезінде Жерді қашықтықтан зондтау (ЖҚЗ) деректерін өңдеу және түсіндіру нәтижелері қарастырылған. (НС) депозиттері. Инфрақызыл түсірістердің нәтижелері егжей-тегжейлі талданады, бұл мұнай және газ кен орындарын іздеу және барлау кезінде қолданылатын геологиялық-геофизикалық деректердің дәстүрлі ақпараттық кешенін айтарлықтай толықтырады. Кен орындарын аймақтық және жергілікті құрамдас бөліктерге бөлу процедураларын пайдалана отырып, ИК түсіру деректерін өңдеу нәтижелері бойынша әртүрлі көлденең және тік қималар бойынша зерттелетін аймақтың жылу сипаттамалары зерттелді. Шахпахта сатысы жылу өрістерінде салыстырмалы түрде үлкен максимумдармен сипатталатыны анықталды, бұл термофизикалық қасиеттерінің жоғары мәндері бар тау жыныстарының басымдылығын көрсетеді. Сонымен қатар, жылу өрісінің амплитудалары блоктардағы тереңдікпен артады, бұл, шамасы, термофизикалық қасиеттерімен ерекшеленетін геологиялық және құрылымдық элементтердің орнын сипаттайды. Орталық Үстірт дислокация жүйесі мен Ассакеаудан ойпаты жылу өрістеріндегі төмен аномалиялармен бөлінген, бұл осы тектоникалық элементтердің жылу қасиеттері төмен тау жыныстарымен толтырылғанын көрсетеді. Ассакеаудан ойпаты негізінен мұнай көздерін құрайтын шөгінді жыныстардың үлкен қалыңдығымен ерекшеленеді. Бұл шұңқырдың геологиялық түзілімдерінің тұтастығын бұзатын бұзылулар көмірсутектердің, терең сұйықтықтардың миграциясы және жылу және масса алмасу үшін өткізгіш арналар ретінде қарастырылады. Жылу өрісінің ауытқуларын өңдеу және түсіндіру нәтижелерінен алынған мәліметтер оларды Үстірт аймағының оңтүстік бөлігіндегі көмірсутектердің жинақтауларын іздеуде іздеу критерийлері ретінде пайдалану мүмкіндігін көрсетеді. Жылулық, гравитациялық, геомагниттік және радиохимиялық өрістерді жан-жақты талдаудың нәтижелері гравитацияның пайда болу тереңдігі мен магниттік алаңдататын массалар туралы, ірі геоқұрылымдардың геологиялық біркелкі еместігінің дәрежесі туралы пайымдаулар жасауға, бұзылулардың сипаттамаларын зерттеуге, геофизикалық кен орындарында жергілікті құрылымдардың көріну сипатын қадағалау, сейсмикалық және терең бұрғылау әдістерімен одан әрі зерттеуге ұсынылатын жеткілікті жоғары көмірсутекті әлеуеті бар перспективалық объектілерді анықтау (жергілікті құрылыстар Өтежан, Қожантай, Солт.Қожантай, Отыншы).

Түйін сөздер: жылу өрісі, Модис, анизотропты түрлендіру әдісі, трансформанттар

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ДИСТАНЦИОННОЕ ЗОНДИРОВАНИЕ ЗЕМЛИ ПРИ ИЗУЧЕНИИ ТЕПЛОВОГО ПОЛЯ ЮЖНО-УСТЮРТСКОГО РЕГИОНА С ЦЕЛЬЮ ПОИСКОВ МЕСТОРОЖДЕНИЙ УГЛЕВОДОРОДОВ

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Аннотация. В статье рассмотрены результаты обработки и интерпретации данных дистанционного зондирования Земли (ДЗЗ) при изучении теплового поля в юго-восточной части Южно-Мангышлак-Устюртской системы прогибов с целью определения возможности привлечения теплофизических параметров к поискам месторождений углеводородов (УВ). Детально проанализированы результаты инфракрасной съемки, существенно дополняющие традиционный информационный комплекс геолого-геофизических данных, применяемый при поисках и разведке месторождений нефти и газа. По результатам обработки данных ИК-съемки с использованием процедур разделения полей на региональную и локальную составляющие изучены тепловые характеристик региона исследований на разных горизонтальных и вертикальных срезах. Установлено, что Шахпахтинская ступень характеризуется относительными крупными максимумами в тепловых полях, что говорит о преобладании пород с высокими значениями теплофизических свойств. Причем амплитуды теплового поля с глубиной увеличиваются по блокам, что, по-видимому, характеризует положение геолого-структурных элементов, различающихся теплофизическими свойствами. Центрально-Устюртская система дислокаций и Ассакеауданский прогиб обособляются пониженными аномалиями в тепловых полях, что свидетельствует о выполнении этих тектонических элементов породами с низкими теплофизическими свойствами. Ассакеауданский прогиб отличается большой мощностью осадочных пород, которые формируют по большей части нефтематеринские свиты. Разломы, нарушающие целостность геологических формаций этого прогиба, рассматриваются как проводящие каналы для миграции углеводородов, глубинных флюидов и тепломассопереноса. Данные, полученные по результатам обработки и интерпретации аномалий теплового поля, свидетельствуют о возможности их использования в качестве поисковых критериев при поисках скоплений УВ в южной части Устюртского региона. Результаты комплексного анализа теплового, гравитационного, геомагнитного и радиохимического полей позволили высказать суждения о глубине залегания грави- и магнитовозмущающих масс, о степени геологической неоднородности крупных геоструктур, изучить характеристики разломов, проследить характер проявления локальных структур в геофизических полях, выделить перспективные объекты с достаточно высоким углеводородным потенциалом, которые рекомендуются к дальнейшему изучению методами сейсморазведки и глубокого бурения (локальные структуры Утежан, Кожантай, Сев.Кожантай, Отыншы).

Ключевые слова: тепловое поле, Модис, метод анизотропных преобразований, трансформанты

Introduction

South Mangyshlak-Ustyurt trough system is comprised by a set of faults that are potential conducts of hydrocarbon fluids. We assume that these faults can show thermal properties that differ from the geological background. This study aims to detect and interpret these possible geothermal anomalies based on Remote Thermal Infrared Survey Data (RTISD), acquired on the Central Ustyurt dislocation system and in the south-eastern part of the South Mangyshlak-Ustyurt trough system, and processed by the "KazZarubezhGeologiya" LLP in 2019.

Remote Thermal Infrared Survey Data (RTISD)

Remote measurements of the temperature of the Earth's surface in the infrared band, carried out from aircraft and spacecraft, for geological purposes are of particular interest because they are characterized by speed, considerable visibility and instantaneous registration of thermal characteristics over large areas (Kronberg, 1988).

In the central and southern parts of the Ustyurt region, we used the far-infrared band spectrum (8–14 microns) of the RTISD with the mis purpose to predict potential areas for oil and gas prospects. Thermal infrared data are widely used for solving various geological problems because of the constant of the natural availability of thermal radiation of objects on the earth's surface.

RTISD was performed in summer, in the predawn hours and in the cloudless time, when the solar-thermal inertial component is practically excluded, as well as the temperature influence of moistened soil and green vegetation. In addition, the influence of the terrain relief weakens and the own radiations of geological units are stronger due to the internal heat flow of the Earth through the weakened (fractured) zones, creating thermal anomalies (Kronberg, 1988).

The numerical data from the MODIS satellite Terra were used for studying the background thermal field. Seven spectral channels in the wavelength range from 9.58 to 14.385 μm were selected to process the thermal field.

The research is based on the results of processing the numerical data of the IR thermal survey on the Central Ustyurt system of dislocations and in the southeastern part of the South Mangyshlak-Ustyurt system of troughs, performed by KazZarubezhGeology LLP in 2019.

Thermal field processing methodology

The processing of the RTISD and MODIS thermal data were performed by KazZarubezhGeology LLP according to the following steps: We conducted the following procedures at the interpretation of RTISD:

The numerical data were processed by KazZarubezhGeology LLP using Erdas, ArcGIS, and COSCAD software.

Initially, using the ArcGIS software for each selected thermal channel from MODIS, a fragment in the form of a rectangle corresponding to the study area was selected. Then average values were obtained from all channels and scenes, which were further used for mathematical processing.

Given the large size of the study area, the thermal field was divided into two components using energy filtering and maximizing the signal-to-noise energy ratio.

As a result, the regional and local components of the heat flow, which play an important role in solving oil and gas exploration problems, were obtained.

However, weak, often comparable with hardware and natural disturbances, heat flow and temperature anomalies associated with faults and geodynamic zones, by traditional visual methods are highlighted with difficulty.

In order to solve this problem, to amplify the useful signal, the method of anisotropic field transformations (AFT) was applied, based on filtering with sweep of directions and subsequent extraction of the correlated component of the thermal field, which allows highlight extended anomalies of various orders according to the same thermal satellite image, depending on the accepted processing parameters.

Anisotropic transforms imply the use of non-isometric nomograms for isolation (or suppress) anomalies of a targeted orientation. The calculations are performed by changing the filter direction with a targeted angle step at each point.

As a result, using AFT, extended thermal field anomalies were isolated, which allowed to trace and map different large structural elements of the region of study, depending on the selected processing parameters,

A sufficiently clear correlation of anisotropic transforms with the features of the geological structure is confirmed by their comparison with the results of structural constructions by seismic and other geological data.

Interpretation of thermal field infrared anomalies

As the main purpose of this paper, we conducted the interpretation of the thermal field infrared anomalies using the ArcGis platform.

Regionally, the territory of the South Ustyurt is distinguished by a relatively high endogenous geothermal regime. Thus, on the "Scheme of geothermic zonation of the USSR territory" (1:10 000 000, 1983) it belongs to the area of evolutionary heat accumulation under the cover of weakly-lithified and thermal-insulated sediments with average heat flux density about 50 mW/m2 and temperature of about 300ºC at a depth of 10 km.

Mesozoic-Cenozoic sediments (Evreisky, 1990; Shaukenova, 2019) is represented by weakly dislocated and sub-horizontal bedded layering of unconsolidated rock, water-bearing in varying amounts, and unequal thermophysical properties. In these sediments, the main thermal fluid more or less are formation waters are everywhere. Therefore, there is a complex and tense thermal regime in them, causing the accumulation of endogenous heat on the structures at the study region.

The thermal field of the study area observed from space is characterized by a rather complex structure. But, in general, it is characterized by the following values of heat flux density.

a. Regional component of the thermic field

Considering the regional component values of the thermic field (Fig.1), For the Assakeaudan depression they vary between 6162.9 and 6713.3 mW/m2, in the Shakhpakhty step they are 6106.4 to 6608.5 mW/m2 and in the Central Ustyurt dislocation system they acquire values 6237.7 to 6462.4 mW/m2.

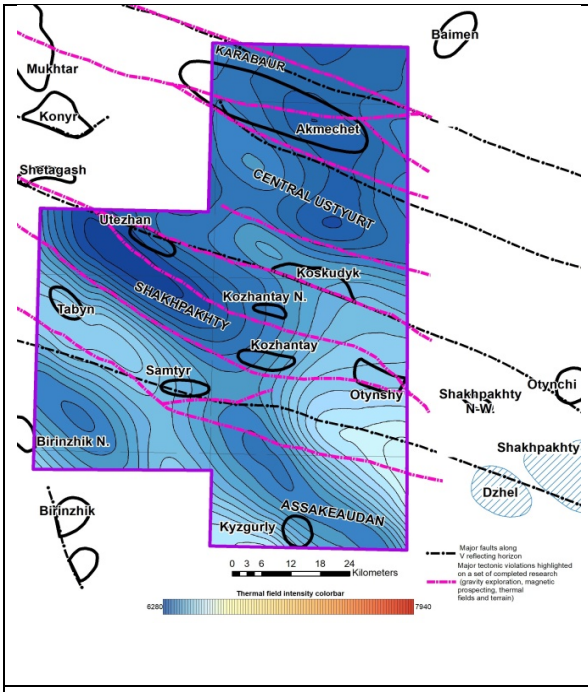

Fig. 1. Map of the regional component of the thermic field

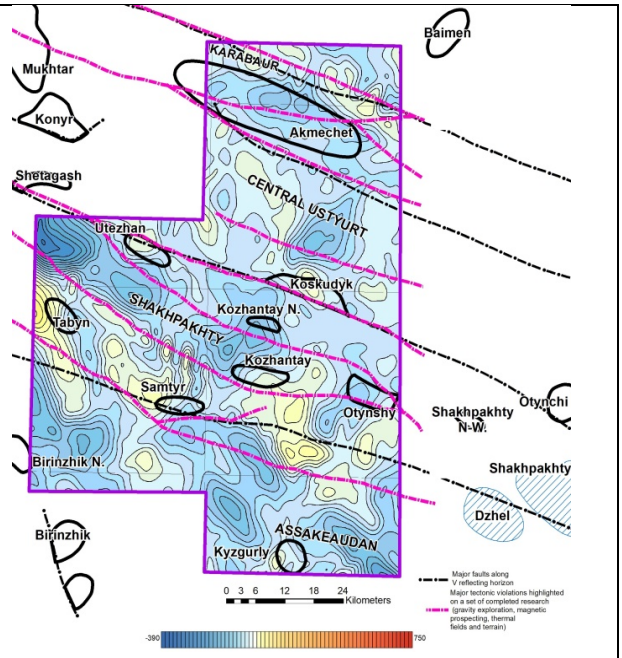

Fig. 2. Map of the local component of the thermic field

On the map of the regional component of the thermic field (Fig.1) the region of study is distinguished by the prevalence of minimum values of heat flux density (6163–6463 mW/m2). And, only in the west, south-west (area of local structures Tabyn and Samtyr) and south-east (area of local structure Otynshi) and further in the direction of hydrocarbon fields Shakhpakhty and Djel (in the Uzbek part of the South Ustyurt region) there is an increase in values of heat flux density to 6496–6525 mW/m2.

The northwestern direction of the relative maximums and minimums of the heat flow is consistent with the direction of the main Paleozoic tectonic structures (Zhakashev et al., 2019), as well as with large uplifts and depression in the basement topography.

Hence, the fact of correlation of the geothermic field minimums with the zones of deep basement occurrence, development of thick strata of the sedimentary cover and Paleozoic formations, which may spatially coincide with the contours of the Paleozoic rift system, is not excluded.

In this context, the zones of high values of gradients of the regional component of the thermic field map areas of a sharp change in the thermophysical characteristics of rocks, usually associated with regional faults. These zones have a predominantly northwestern strike, although there are submeridional and other orientations.

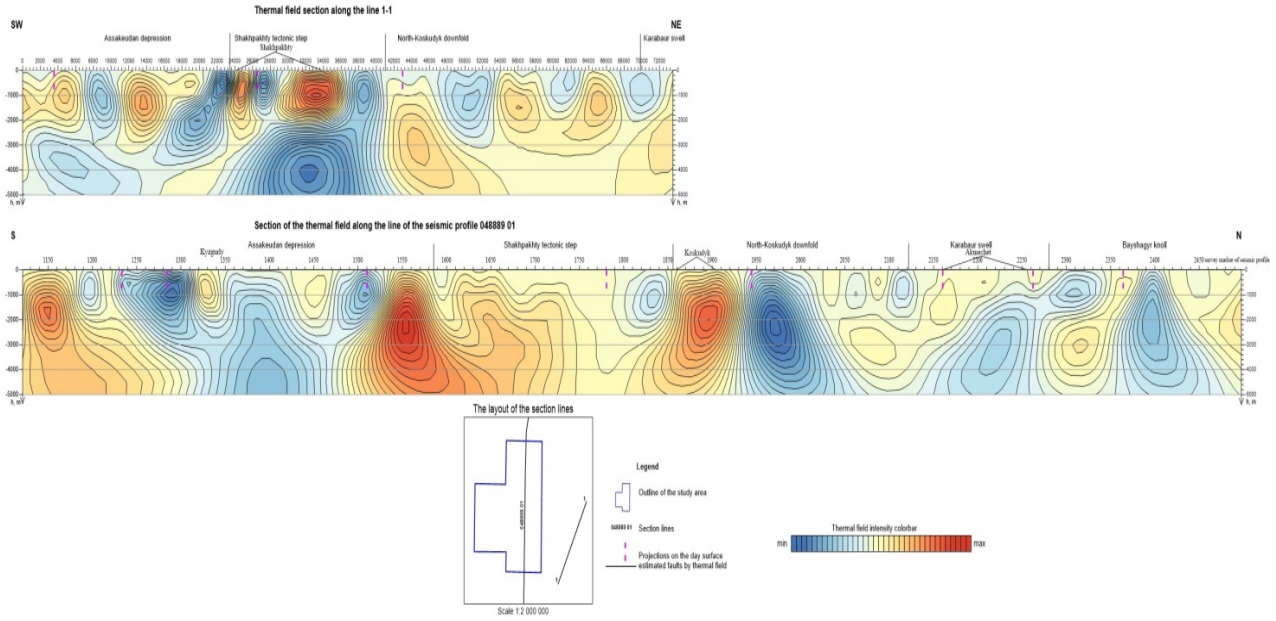

Fig.3 Thermic field sections (based on data by Mersheeva and Petrovsky, 2019)

Recalculation procedures were applied to the lower half-space for analysis propagation of the thermal field in the geological section (Mersheeva, and Petrovsky, 2019). In figures 4 and 5 show horizontal slices of the thermic field at depths of 1500 m and 2500 m, congruently, and Figure 3 shows two sections, one crossing the Shakhpakhty field and the other in the meridional direction across the entire region of study along the seismic profile 04888901.

The obtained data demonstrate the situation, in accordance with each major regional tectonic element prove oneself in its own way in the geothermic fields.

b. Local component of the thermic field

On the map of local anomalies (Fig. 2) and maps of the thermic field recalculated in the lower half-space at the 1500m and 2500m levels, there are a number of objects that are not subject to the indicated trend and tend to increase in size with depth (Figs. 4 and 5). This is especially evident in the decomposition into components obtained using the energy filtering algorithm (local structures: Samtyr, Otynshi, Kozhantai, North Kozhantai, etc.).

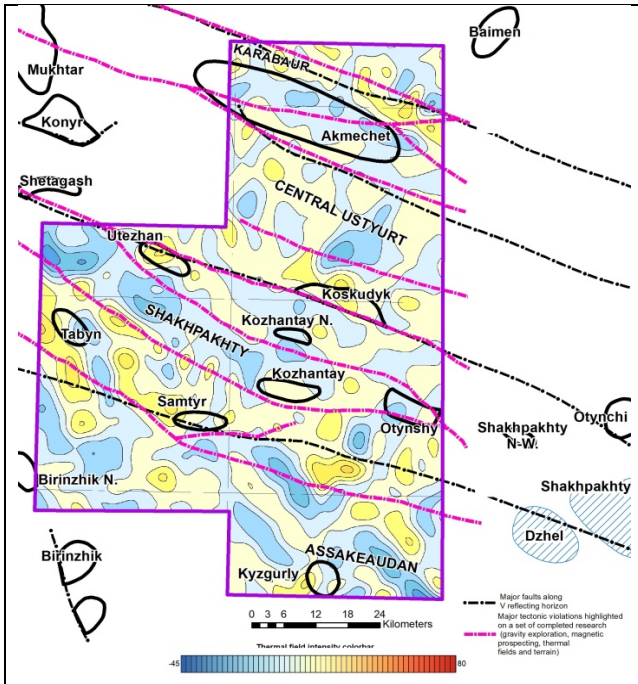

Fig. 4. Map of the thermic field recalculated in the lower half-space. A slice at 1500 m

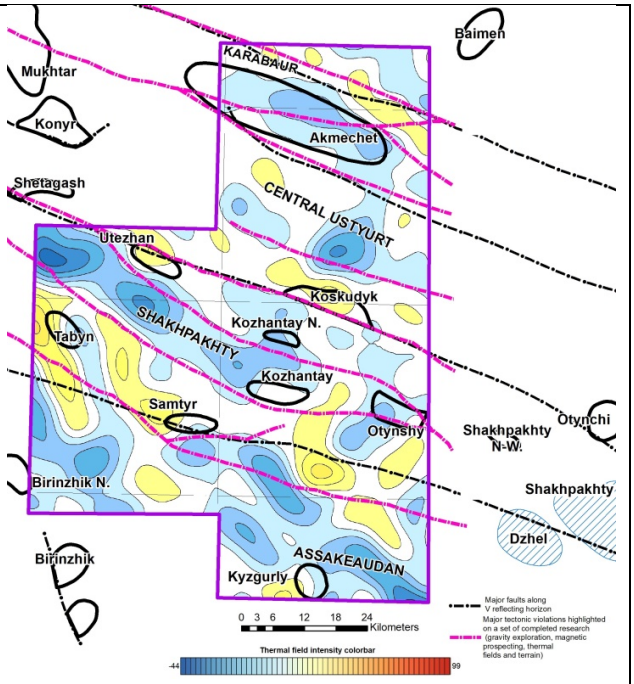

Fig. 5. Map of the thermic field recalculated in the lower half-space. A slice at 2500 m

The genesis of these anomalous objects may be associated with changes in the thermic rocks properties in the sedimentary cover, but may also be due to active tectonic faults (Dalyan and Sydykov, 1972; Khutorskoy et al., 2010), through which heat and mass transfer and migration of deep fluids from the subsurface be conducted.

A detailed analysis of a set of well logging and drilling data from existing wells and, in the future, from the seismic together with the materials of airborne gamma ray, gravity survey and magnetic survey should be carried out in order to clarify this assumption.

Similar experience with complexing has shown its effectiveness in the North Ustyurt region (Abetov et al., 2017).

Attention is drawn to the fact that most of the local structures previously identified by CDP -2D seismic data are confined to extended thermal field anomalies. For example, local structures Utezhan, Otynshi, Samtyr, Kozhantai, Kyzgurly, Tabyn, Koskudyk and others are located on the axes of extended positive thermal anomalies (Fig.4 and 5).

The Shakhpakhty and Djel gas fields explored in the Uzbek part of the South Ustyurt region are also confined to such anomalies in plan. A similar pattern has been noted earlier in other oil and gas bearing basins (Demeeva, 2017; Ozdoev, 2012; Volozh and Kuandykov, 2014), which gives reason to use the results as a prospecting criteria in planning of exploration, interpretation and modeling based on a set of geological and geophysical data.

It is important to consider that the relatively low extended negative thermic field anomalies probably map tectonic faults, along the planes of which the downward infiltration of surface water prevails. This information may be useful in placing seismic profiles and, in the future, wells as well.

Discussion

Assakeaudan depression. In general, up to a depth of 5 km stands out an extensive area of reduced geothermal anomalies with small local maximums in the upper part of the geological section to a depth of 2.0 km, isolated in the area of the local structure Kazgurly and to the north of it (Fig. 3).

Such a picture is evidence in favor of the fact that this depression is completed by rocks with low thermophysical properties and relatively isotropic in its geological structure. The latter is related to the minimal values of the Bouguer anomaly horizontal and vertical gradient module transforms, local negative gravity anomalies (recalculated in the upper half-space at a height of 2.5 km), autotrace of the axes of the Ta magnetic field anomalies, reduced values of TDR transform (Abetov and Yessirkepova and Curto, 2021), (Table 1).

Table 1. Statistics on the values of transformants of the anomalous magnetic and gravitational, thermal and radiogeochemical fields

Potential fields data	Transforms	Tectonic elements		
		Assakeaudan depression	Shakhpakhty step	Central Ustyurt dislocation system
Geomagnetic anomalies field	Anomalous magnetic field reduced-to-the-pole, nT	from 100 to 300	from -50 to 100	from 100 to 400
	Analytic signal, nT/m	from 0 to 0.005	from 0.005 to 0.008	from 0.002 to 0.02
	Tilt derivative (TDR) of the magnetic field anomalies, radian	from 0 to 1.560	from -1.567 to 0	from -1.200 to 1.560
	Vertical derivative of the anomalous magnetic field, nT/m	from -0.002 to 0.006	from 0 to -0.006	from -0.01 to 0.01
	Horizontal derivative of the modulus magnetic field, nT/m	from 0 to 0.006	from 0 to 0.002	from 0.002 to 0.010
	Transformation of the magnetic field anisotropy, cu.	from 0 to 0.002	from 0 to 0.0005	from 0 to 0.002
	Tracing of axes of magnetic field anomaly, cu	from -0.5 to 1	from -3 to 0.5	from -5 to 5
Gravity anomalies field	Module of horizontal derivate of Bouguer anomaly, mGl/m	from 0 to 0.0015	from 0 to 0.0015	from 0 to 0.0033
	Module of the vertical derivate of Bouguer anomaly, mGl/m	from -0.002 to 0.001	from -0.001 to 0.001	from -0.003 to 0.004
	Local gravity anomaly (recalculated in the upper half-space at a height of 2.5 km), mGl	from -3 to 1	from -1.5 to 3	from -2 to 8
	Anisotropy transform, the accent of maximum gravity anomaly. Sliding window size 5 km x 2km, cu	from 0.1 to 0.46	from 0.1 to 0.48	from 0.1 to 0.50
Thermal anomalies field	Thermal field according to satellite imagery	from 6162.9 to 6713.3	from 6106.4 to 6608.5	from 6237.7 to 6462.4
	Map of the regional component of the thermal field	from 6297.8 to 6601.5	from 6283.1 to 6543.4	from 6319.8 to 6395
	Map of the local component of the thermal field	from -182.2 to 152.8	from -211.2 to 64.8	from -65 to 69
	Map of the thermal field recalculated in the lower half-space. A cut at 1500 m	from -17.2 to 16.6	from -17.9 to 12.6	from -10.5 to 12.6
	Map of the thermal field recalculated in the lower half-space. A cut at 2500 m	from -20.8 to 20.9	from -22.2 to 12.1	from -8.9 to 9.8
Radiogeochemical anomalies field	Potassium value (K), %	from 0.5 to 1.3	from 0.4 to 1.3	from 0.6 to 1.3
	Thorium value (Th), ·10–4 %	from 1.4 to 4.0	from 1.4 to 4.0	from 1.5 to 4.0
	Uranium value (U), ·10–4 %	from 1.5 to 3.5	from 1.0 to 3.0	from 1.1 to 3.1
	Dose rate gamma radioactivity (DR)	from 16.6 to 38.2	from 13.9 to 36.5	from 16.7 to 37.2
	U/K, cu	from 1.7 to 4.1	from 1.6 to 3.7	from 1.7 to 3.5
	K/Th, cu	from 2.1 to 3.3	from 2.4 to 3.3	from 2.5 to 3.3
	U/Th, cu	from 0.6 to 2.0	from 0.7 to 2.3	from 0.7 to 2.0

Within the Assakeaudan depression, the upper edge of gravity-disturbing masses stands out at depths of 1000–2000m and is confined to the III reflecting horizon (according to seismic CDP -2D) and

reflects the transition of unconsolidated and weakly consolidated Lower Cretaceous rocks to Upper Jurassic sediments.

The upper edge of the causative magnetic masses here drops to a depth of 8–10 km, which corresponds to the depths of the basement rocks (according to seismic CDP -2Da) and reflects the level of maximum propagation of basic and ultrabasic rocks in the basement (Abetov et al., 2021).

The spatial location of special Euler points in the gravity field calculated in the Geosoft Oasis MoptajTM software indicates the presence of rock density heterogeneity up to a depth of 8.0 km. Deeper, the differences in the depths of the Euler points in terms of density inhomogeneities are significantly leveled.

Within the Assakeaudan depression according to the airborne gamma-spectrometric survey data identified 4 anomalous zones with a relatively reduced background of total radioactivity; low isoconcentrations of potassium; reduced uranium content in relation to the background values (Table 1). The formation of these zones is associated with the effect of hydrocarbon microseepage along the regmatic faults network and macrofracture systems. Indirectly that may indicate the presence of gas or oil fields (Abetov et al., 2021).

Shakhpakhty step. It is characterized by relatively large positive anomalies in the thermic fields, which indicates the predominance of rocks with high values of thermophysical properties (Fig. 3, Table 1).

On the geological section intersecting the Shakhpakhty gas field explored in the Uzbek part of Ustyurt, there is a powerful relatively negative anomaly to depths of 3000m, complicated in the upper part by two positive anomalies with maximum depths of 2200–2500m (Fig. 3).

However, it is known from literary sources (Shilin, 1980; Gorny et al., 1993) that large gas field are marked by relatively negative thermal field anomalies, and positive anomalies in the upper part of the section, probably, are associated with compaction, providing a good "seal". However, this interpretation of thermic anomalies requires additional study in the process of complex analysis, including data of high-precision gravity survey, seismic survey and drilling.

As in the Assakeaudan depression, the Shakhpakhty step the reduced values of the transforms of the modules of the horizontal gravitational and the geomagnetical fields, the reduced values of the transforms of the analytical signal, magnetic anisotropy, autotracing of the axes of magnetic field anomalies are kept apart (Abetov et al., 2021). In sum, these characteristics indicate the continuity along strike of the rock assemblage.

At the same time, in contrast to the Assakeaudan depression, at the Shakhpakhty step, increased values of the vertical gradient of gravity anomalies were revealed (Table 1), which indirectly may indicate an increased vertical variability of rocks.

Other characteristics of geophysical potential fields can be attributed weakly and moderately intense local positive and negative Bouguer anomalies (recalculated to a height of 2.5 km), increased values of intensity of negative anomalies Ta. Intermediate values of transforms of horizontal and vertical magnetic field gradients, minimal values of TDR transformant of this field are observed here (Table 1).

The upper edge of the magnetically disturbing masses submerged to a depth of 8–12 km, whereas the gravity disturbing objects are buried down to 6.0-7.0 km (Abetov et al., 2022). Apparently, such a character of their distribution demonstrates the difference in the depths of the basement and intermediate structural floor.

Consequently, we can say that in the Shakhpakhty step, the upper edges of the gravity- and magnetically-disturbing masses are distinguished by the maximum depth in the South Ustyurt region.

In turn, this fact is evidence in favor of the high total thickness of the sedimentary cover and the intermediate structural floor on the Shakhpakhty step, which unambiguously puts it in the category of prospective for hydrocarbon accumulation discoveries.

On this step according to airborne gamma-spectrometric survey on the ground surface the maximum number of zones (9 out of 15 in the South and Central Ustyurt regions) with anomalously low potassium and uranium concentration in relation to the background values was detected, which may indicate increased prospects for oil and gas content in local structures (Abetov et al., 2021).

Central Ustyurt dislocation system. Everywhere is characterized by increased values of local gravity anomalies (recalculated in the upper half-space at a height of 2.5 km). Here, intermediate values of the transforms of the modules of the horizontal and vertical gradients of the Bouguer gravity anomalies are observed (Table 1).

The Central Ustyurt dislocation system is characterized by increased values of analytical signal transforms, magnetic anisotropy, and horizontal magnetic field gradient, as well as maximum values of vertical gradient transforms and angles of inclination of the magnetic field TDR gradient vector, auto-trace axes of Ta anomalies (Abetov et al., 2021).

In the complex, the values of the transforms of the gravity and geomagnetic fields may indicate an increased lateral and vertical heterogeneity of the rocks assemblage forming the Central Ustyurt dislocation system.

The maximum number of Euler points on the surface of gravity-disturbing bodies is concentrated at depths of -4000–5000m.

In the Central Ustyurt dislocation system, the depths of gravity- and magnetically-disturbing masses coincide and their confinement to the basement surface, identified by CDP-2D seismic survey data.

According to airborne gamma-spectrometric survey in this geostructure two zones with relatively low background of total radioactivity; low isoconcentrations of potassium and reduced uranium content in relation to the background values are identified (Abetov et al., 2021).

At the same time, this geostructure is characterized by elevated deformation of sedimentary rock assemblage that do not contribute to the preservation of hydrocarbon accumulations.

Recommendations for exploration work

The focus of attention in the regional study should be placed on conducting exploration work on local structures at the Shakhpakhty step, within which there is a deep plunge of the basement, the presence of thick strata of sedimentary cover and intermediate structural floor, and the increased positive anomalies of the thermal field were identified.

The obtained results of the integrated interpretation of data on the thermic field and transforms of the gravity and magnetic fields, airborne gamma-ray spectrometer (radiometric) data, processed and interpreted by the thorium normalization method indicate in favor of the prospects of oil and gas bearing of local structures Utezhan, Kozhantai, North Kozhantai, Otynshi with regard to favorable historical-geological, structural and litho facies factors (tab. 2).

Table 2. Statistics on transform values for anomalous magnetic, gravity, thermal and radiogeochemical field transformants by local structures over the study region

Potential fields	Transforms	Structures of Jurassic-Cretaceous deposits revealed by CDP-2D seismic survey			
		Utezhan	Kozhantai N.	Kozhantai	Otynshi
Geomagnetic anomalies field	Anomalous magnetic field reduced-to-the-pole, nT	from -5.50 to 2.21	from -5.04 to 1.93	from 21.41 to 53.67	from 8.18 to 31.04
	Analytic signal, nT/m	from 0.006 to 0.008	from 0.005 to 0.008	from 0.005 to 0.008	from 0.005 to 0.012
	Tilt derivative (TDR) of the magnetic field anomalies, radian	from -1.56 to -1.23	from -1.36 to -0.94	from -0.80 to -0.05	from -1.36 to -0.24
	Vertical derivative of the anomalous magnetic field, nT/m	from -0.004 to -0.001	from -0.003 to -0.001	from -0.003 to 0.00001	from -0.004 to 0.001
	Horizontal derivative of the modulus magnetic field, nT/m	from 0.000 to 0.002	from 0.001 to 0.003	from 0.005 to 0.006	from 0.003 to 0.005
	Transformation of the magnetic field anisotropy, cu.	from 0 to 0.0003	from 0 to 0.0001	from 0.0005 to 0.001	from 0 to 0.0005
	Tracing of axes of magnetic field anomaly, cu	from -0.57 to 0.53	from -0.68 to 0.26	from -1.92 to 0.39	from -1.77 to 0.34
Gravity anomalies field	Module of horizontal derivate of Bouguer anomaly, mGl/m	from 0.0002 to 0.0010	from 0.0003 to 0.0008	from 0.00003 to 0.0007	from 0.0004 to 0.0010
	Module of the vertical derivate of Bouguer anomaly, mGl/m	from -0.0004 to0.0005	from -0.0007 to 0.0001	from -0.0006 to0.0004	from -0.0004 to 0.0008
	Local gravity anomaly (recalculated in the upper half-space at a height of 2.5 km), mGl	from -0.84 to -0.23	from -1.19 to -0.83	from -1.15 to -0.70	from -1.03 to -0.02
	Anisotropy transform, the accent of maximum gravity anomaly. Sliding window size 5 km x 2km, , cu	from 0.1 to 0.12	from 0.1 to 0.11	from 0.1 to 0.14	from 0.1 to 0.14
	Thermal field according to	from 6266.32	from 6281.45	from 6333.09	from 6442.89

Thermal anomalies field	satellite imagery	to 6428.80	to 6404.68	to 6509.25	to 6556.22
	Map of the regional component of the thermal field	from 6311.40 to 6357.90	from 6369.59 to 6399.50	from 6380.17 to 6449.76	from 6495.36 to 6524.38
	Map of the local component of the thermal field	from -26.54 to 50.10	from -76.65 to -17.70	from -38.34 to 51.75	from -49.79 to 29.48
	Map of the thermal field recalculated in the lower half-space. A cut at 1500 m	from -3.1 to 10.6	from -5.3 to 2.3	from -3.6 to 4.2	from -7.3 to 3.6
	Map of the thermal field recalculated in the lower half-space. A cut at 2500 m	from -0.4 to 10.4	from -7.3 to -0.6	from -4.4 to 4.5	from -7.6 to 3.8
Radiogeochemical anomalies field	Potassium value (K), %	from 0.57 to 1.05	from 0.71 to 1.04	from 0.68 to 1.07	from 0.70 to 1.12
	Thorium value (Th), ·10–4 %	from 1.54 to 3.30	from 1.94 to 3.14	from 1.92 to 3.29	from 1.89 to 3.45
	Uranium value (U), ·10–4 %	from 1.70 to 2.56	from 1.64 to 2.46	from 1.61 to 2.47	from 1.90 to 2.51
	Dose rate gamma radioactivity (DR)	from 19.27 to 31.88	from 22.90 to 31.64	from 21.30 to 32.15	from 21.89 to 32.91
	U/K, cu	from 1.90 to 3.15	from 2.01 to 2.83	from 2.02 to 3.04	from 1.99 to 3.11
	K/Th, cu	from 2.66 to 3.18	from 2.70 to 3.12	from 2.68 to 3.09	from 2.58 to 3.13
	U/Th, cu	from 0.88 to 1.78	from 1.04 to 1.63	from 0.93 to 1.62	from 0.88 to 1.67

Note: TF-thermc field; MF-magnetic field

The CDP-3D seismic survey and deep exploratory drilling with obligatory penetration of deposits of the intermediate structural flower are recommended on these structures.

Conclusion

By applying AFT to the regional component, faults were identified, and by the local component, a regular confinement in terms of positive thermal field anomalies to local structures in the Jurassic sediments, previously identified by CDP-2D seismic survey, was explored.

In general, the data obtained from the results of thermic field processing can be used as exploration criteria for hydrocarbon accumulations in the southern part of the Ustyurt region.

The results of the integrated analysis of thermic, gravity, geomagnetic and radiochemical fields allowed us to study the behavior and characteristics of tectonic disturbances, to make some judgments about the depth of occurrence of gravity and magnetic disturbing masses, the degree of geological heterogeneity of regional geostructures, to trace the character of local structures in the geophysical fields.

In the regional gravity, geomagnetic and thermal fields, the Shakhpakhty step with a relatively elevated thermal field in some local structures is quite clearly distinguished and has a continuation in the Uzbek part of this step, where large gas fields Shakhpakhty and Dzhel have been explored in the Jurassic sediments.

The Shakhpakhty step is bounded by deep faults, identified by the gradients of the anomalies of the regional geophysical fields. Three major regional faults are traced in the northwestern direction. On the southeastern flank of these faults, the Shakhpakhty and Dzhel gas fields are explored. On the western flank, the local structures Otynshi, Kozhantai, North Kozhantai, Utezhan and others, which are close in geological structure, are isolated.

In the presence of a good rock seal in the upper part of the geological section, these local structures can be considered as prospective with respect to the localization of hydrocarbon accumulations. All of the aforementioned criteria give reason to recommend local structures within the Shakhpakhty step for priority study.

The Assakeaudan depression is characterized by thick sedimentary rock assemblages, which mostly form the oil-source suites. Faults that disrupt the integrity of the geological formations of this depression are considered as conduits for migration of hydrocarbons, deep fluids, heat and mass transfer.

This statement is confirmed by airborne gamma-ray spectrometer (radiometric) data, processed and interpreted by the method of thorium normalization. A total of 15 anomalous zones were identified in the study region, 9 of which are located in the Shakhpakhty step, 2 – in the Central Ustyurt system of dislocations and 4 – in the Assakeaudan depression.

The selected anomalous zones have low values of isoconcentrations of potassium and reduced uranium concentration in relation to the background values and are considered as indicative criteria for the possible presence of hydrocarbon accumulations.

An attempt to relate the depth and nature of the spread of the magnetoactive layer with areas prospective for the detection of hydrocarbon (HC) accumulations was made, using the following transforms of this field: analytical signal magnetic anisotropy, autotracing axes of magnetic field anomalies, increased values of negative anomaly Ta, horizontal and vertical magnetic field gradients, the minimum values of the TDR.

The obtained results of the integrated interpretation of gravity and magnetic field transforms, airborne gamma-ray spectrometer (radiometric) data, processed and interpreted by the thorium normalization method, unambiguously indicate the prospects of oil and gas bearing structures of local structures Utezhan, Kojantai, North Kojantai, Otynshi with regard to favorable historical-geological, structural and lithofacies factors.

In a complex the above-mentioned advanced geophysical methods will serve as a reliable basis for updating and detailing of geological and structural-tectonic models of the study region with attraction of existing information on spatial location of already known fields and oil and gas shows, which can be used as a basis for design of geological exploration for prospecting and exploration of new hydrocarbon accumulations.

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