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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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AbetovA.*, Kudaibergenova S.

Satbayev University, Almaty, Kazakhstan.
E-mail: abetov.auez@mail.ru

INTEGRATED RESEARCH OF SUFFOSION AND KARST PROCESSES AT THE KOGCF BY GEOLOGICAL AND GEOPHYSICAL AND GEODESIC METHODS

Abstract. Thearticle analyzesthe results of research of suffosion and karst processes in the Karachaganak oil-gas- condensate field through high-precision gravity surveyingand electrical prospecting, satellite geodesy and laboratory soil research. The efficiency of the complex methods was evaluated.

The criteria of detection in geophysical fields, petrophysical features and forms of changes in the surface relief of suffusion and karst light holeswith the selection of areas of intensive development of the process and the definition of the area with the initial stage of deformations of the near-surface layers were revealed.

It was found that the suffusion light holes are well distinguished by specific (moderate) values of electrical resistance, negative local anomalies of the gravitationalfieldand positive forms of of the surface relief.

The results of the studies indicate that suffosion processes have developed at a depth of 2-12 m from the ground surface.

Key words: suffosion and karst processes, high-precision gravity surveying, electrical prospecting, satellite geodesy, soil laboratory tests.

Introduction. In modern conditions of a market economy, the issue of rational use of territories for the construction and operation of subsoil use objects is acute, since hazardous geological processes can significantly complicate the efficiency of development of mineral deposits.

Insufficient and untimely studied geological and technological and other regularities of occurrence and development of hazardous geological processes (landslides, devolution, karst hole, etc.) pose a potential threat of significant material damage, deformation or destruction of infrastructure facilities at the exploited hydrocarbon fields.

In this regard, the tasks of research and forecasting of dangerous natural and man-made phenomena, among which karst and suffosion occupy a special place in terms of the degree of latency of processes, sudden manifestation, catastrophic consequences and difficulties of forecasting, acquire special relevance.

The development of suffusion and karst processes cause anomalous decompaction and change in electrical conductivity in rocks of a geological section of various sizes and volumes, which makes it possible to effectively use high-precision gravity and electrical exploration to map the location of potential karst light holes.

Consequently, the change in time and space of the density and electrical conductivity of near-surface deposits in the presence of suffosion makes it possible to assess the successive stages of the development of karst processes, up to the possible formation of suffosion and karst light holes through repeated gravitmetric and electrical survey work.

Research History. In the Karachaganak oil and gas condensate field, the study of suffusion and karst processes has a long history. Back in 1989, based on the results of engineering and geological survey, the development of suffusion and karst processes and phenomena was noted here. A total of 15 suffosion and karst light holes were identified in three parallel zones.

During a long time of operation of this field, active suffusion processes were not observed. However, in November 2008, it was discovered that sinkhole No.9 had significantly increased in size. Its depth reached 4.5 m, and its diameter was 10 m.

On the territory of Karachaganak oil-gas-condensate field the areal arrangement of already formed light

holes has a linear character. Hence, it seems logical to study them by the method of repeated exact leveling. It was suggested [1] that the linear character of karst processes development is controlled by the zones of increased fracturing in the competent rocks, through which the fluid-dynamic (migration) processes take place.

Thus, the study of suffosion and karst formation developed in two directions. First, the possibility of mapping linear weakened zones along which karst-suffosion processes have developed was studied with the help of repeated deformation control methods.

Secondly, based on the results of the analyzes of variations in the geophysical fields, the possibility of performing areal mapping of suffosion and karst light holes proper and suffosion processes at various stages of development was investigated [2].

Methodology for conducting field geodetic and geophysical survey. The survey was carried out in 2 stages.At the first stage, repeated leveling and gravimetric measurements were carried out along the reference profile of the submeridional direction, 30-40 meters east of karst sinkhole No. 9.

The reference profile included 17 permanent combined leveling and gravimetric points with an average distance of 16.5 meters and 34 temporary gravimetric points with a minimum distance between the points of 3-4 meters (Fig.1).

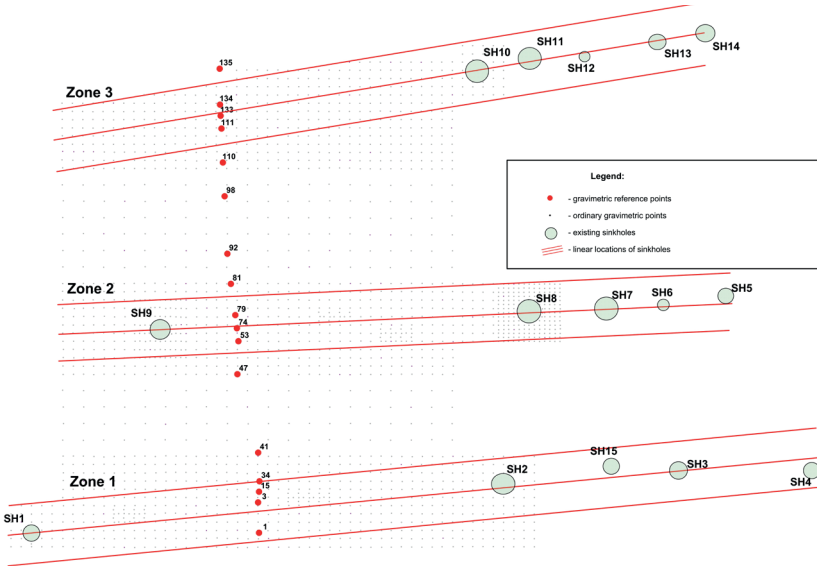

Figure 1 - Overview scheme of the work area

At the second stage to solve the problem of mapping of suffosion and karst light holes and physical (decompaction of rocks) and fluid-dynamic processes occurring in them, we carried out an area (47230 sq. m) micro-local gravitmetric survey and electrical prospecting by electromagnetic induction frequency sounding, studied petrophysical properties of rocks of near-surface layers based on the data of laboratory analyzes of core samples.

Areal gravimetric survey was performed in the volume of 2197 points (Fig. 1). According to its results the gravimetric map in Bouguer reduction with real density of intermediate layer 2.0 g/cm^3 in scale 1:500 was made. Automated gravimeters AutoGrav CG-5 were used to perform the area survey. The survey was performed in the conditional level from one central reference point.

Ordinarygravimetric survey at the work site was carried out along a network of 10 x 8 m, 5 x 4 m. In the area of light holes No. 9 and 8 that appeared, the work was carried out along a network of 2.5 x 2 m and 2.5 x 4 m, respectively (Fig. 1).

The constructed maps of gravity anomalies based on the performed measurement network show the sufficiency of the 5 x 4 m network to identify anomalies associated with rock decompaction at the site of work and further study of suffusion and karst processes.

Electrical prospecting measurements were carried out by a specialized hardware and software complex EMS 21 (electromagnetic scanner), operating according to the method of electromagnetic induction frequency sensing (CZ), designed to measure the apparent specific electrical conductivity of soils at frequencies in the range from 2.5 to 250 kHz. The range of measurement of electrical resistivity varies from 100 Ohm*m to 1 Ohm*m.

A total of 2868 measurements were made using the method of electromagnetic induction frequency sounding (CZ). The distance between adjacent sounding points along the profiles varied from 1 to 10 m, the interprofile distance varied from 4 to 8 m.

EMC 21 was located horizontally at a height of 23 cm above the ground surface. The sensing effect was achieved by making measurements at different frequencies.

Methods of processing and interpretation of the data obtained. The following tasks were solved during the processing and interpretation of the data obtained:

- the division of the fields into regional and local components was carried out;
- the volumetric models of the distribution of density parameters of the medium are calculated;
- the "stitching" of the observation networks was performed.

Geological and geophysical principles of interpretation of the gravitational and electric fields are derived from the existing ideas about the engineering-geological and hydrogeological structure of the Karachaganak oil-gas-condensate field territory [3, 9].

Interpretation was performed by modeling according to the principle of analogy. All studied geological and geophysical objects were divided in advance into a given number of classes, each of which has its benchmark of comparison (working model). Parameters of the working model acted as features describing the studied objects.

The etalons were created on the basis of a priori information about 5 suffosion and karst light holes located in the study area, two of which are filled with water. The created etalons became the basis for the qualitative selection of the studied objects.

The density characteristics of the studied objects were obtained from laboratory measurements of soil samples taken in the vicinity of the existing suffusion and karst light holes in the depth interval of 0-3 m (Table 1).

The average value of soil density in the natural setting in the areas captured by erosion was 1.77 g/cm^3. The density of the soil sample in the 0-3 m interval, taken during drilling of the borehole located in the area least susceptible to suffosion(according to geophysical data), was 1.98 g/cm^3. The density difference (0.21 g/cm^3) was taken as one of the quantitative criteria for distinguishing the objects under study.

Table 1 - Quantitative parameters of existing light holes , based on results of sampling, analyzes of geophysical fields and relief

Sinkhole	Testing results					Maximum value of anomaly				Distribution of density parameters by depth in m, g/cm^3					Dimensions, m	
	Sampling depth	Natural moisture, d.q.	Density, g/cm^3	Porosity coefficient, d.q.	Water saturation coefficient, d.q.	of gravity, mGal	exceedances, m	SER at depth in Ohm*m							x-axis width	depth
								2.5	7.0	2.5	4.5	7	10	15		
SH1	1.1-1.2	0.11	1.843	0.578	0.499	0.02	0.1	16	15	2.00	2.00	2.00	2.01	2.03	12	7
SH2	2.4-2.5	0.181	1.868	0.637	0.735	0.02	0.1	11	9.5	2.00	1.99	2.00	2.00	1.99	22	12
SH8	2.0-2.1	0.187	1.956	0.608	0.815	-0.02	0.3	18	14	1.99	1.98	1.98	1.96	1.97	11	8
SH9	1.2-1.3	0.102	1.741	0.639	0.413	-0.06	0.45	12	9.5	1.97	1.94	1.92	1.90	1.89	25	20
SH10	1.5-1.6	0.181	1.692	0.836	0.57	-0.03	0.2	15	15	1.98	1.97	1.96	1.96	1.97	15	12

The basis for the interpretation were: a) digital models of gravity field anomalies in the Bouguer reduction, reduced to a conventional level (σ = 2.0 g/cm^3); b) distribution of apparent resistivity at different depths; c) forms of the relief of the day surface of the site according to the results of GPS surveys.

Research results. GPS survey. The relief map of the studied area (Fig. 2), made according to the results

of high-precision GPS survey, is a vivid confirmation that the processes of karst, suffusion, subsidence and swelling of soils are expressed in the development of positive (hillocks) and negative (suffusion saucers, karst-suffosionlight holes) relief forms.

Areas with lower values are located in the northeastern part of the study area (up to 75.3 m), where they form an arc of northeastern strike. This may be an old surface water flow blocked by sediments.

Areas of relatively elevated values of hypsometric elevations (up to 76.5 m), complex and irregular in shape, are in the south of the site, where they form bands of latitudinal extent, stretching from west to east. In the central part there is a latitudinally directed chain of isometric local anomalies, caused by the rise of the Earth's surface.

All five etalonsuffusion and karst light holes located in areas of local uplifts of the day surface relief with an amplitude of 0.1 m to 0.45 m (Fig. 2, Table 1), based on which, the first sign for the qualitative selection of the studied objects are local positive anomalies (local uplifts of the earth surface) in the relief of the studied area [5,6].

Microlocal gravimetric survey. The gravity field of the study area is flat, with a well-pronounced trend, where its relatively elevated values [(+0.4)-(+0.5) mGal] are located in the southwestern part of the study area, and the negative values [(-0.5)-(-0.6) mGal] are clustered in the north-east of the latter. In the first approximation, the anomalies correlate well with variations in the relief of the day surface.

The field is complicated by individual local isometric anomalies of oval, circular and irregular shapes in plan, which are characterized by relatively reduced values of gravity anomalies.

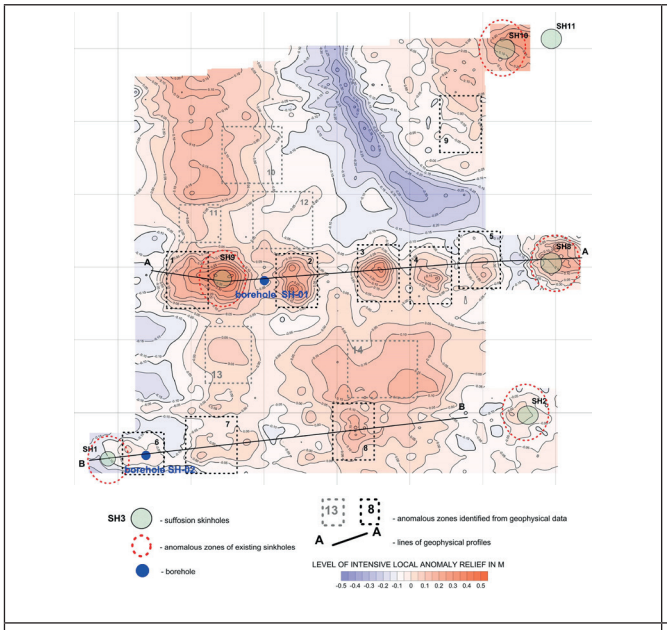

Figure 2 - Scheme of local anomalies of relief of the work site based on the results of high-precision GPS survey

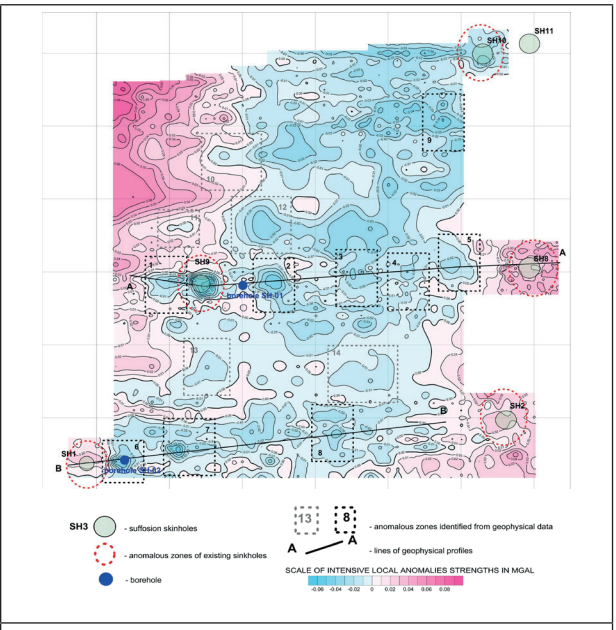

Figure 3 - Scheme of local gravity anomalies.

For geological interpretation we used a map of local gravity anomalies, which was obtained by subtraction from the initial field of its regional component, selected by regression polynomial of 1st degree (Fig. 3).

Electromagnetic Survey. Suffosionlight holes are well manifested in the field of specific electric resistance, the values of which characterize the lithological composition of sediments, porosity, moisture, water saturation, as well as their constituent ionic conductive medium [7,8].

The study area according to the character of resistivity distribution at a depth of 2.5 m can be divided into two zones: a zone of low resistivity from 5 to 10 Ohm*m and a zone of moderately high resistivity from 12 to 21 Ohm*m (Fig. 4). The latter is located in the northeastern part of the study area and consists of two local anomalies.

The first zone is formed by irregularly shaped anomalies, close to isometric, with intensities up to 14-15 Ohm*m. The form of the anomalies of the second zone is arc-shaped, linearly isometric. Characterized by

high values of resistivities up to 21 Ohm*m. Apparently, it is confined to the contact zone of rocks different in their physical and chemical properties.

Analyzes of apparent resistivity distribution at the depth of 2.5 m showed that in the section of sinkhole SH9 resistivity is 12 Ohm*m, in sinkhole SH10 - 15 Ohm*m at values of water saturation coefficient of 0.413 and 0.570 d.q. respectively.

Light holes with water at a depth of 2.5 m have resistivity from 16 Ohm*m (SH1) to 18 Ohm*m (SH8) (Table 1). The values of apparent resistivity were also determined for the sections of existing light holes at a depth of 7 m, which vary from 9.5 Ohm*m (SH9, SH2) to 14-15 Ohm*m (SH8, SH1, SH10).

Thus, based on the distribution of apparent resistivity, suffusion light holes are well distinguished by specific (moderate) values of electrical resistivity.

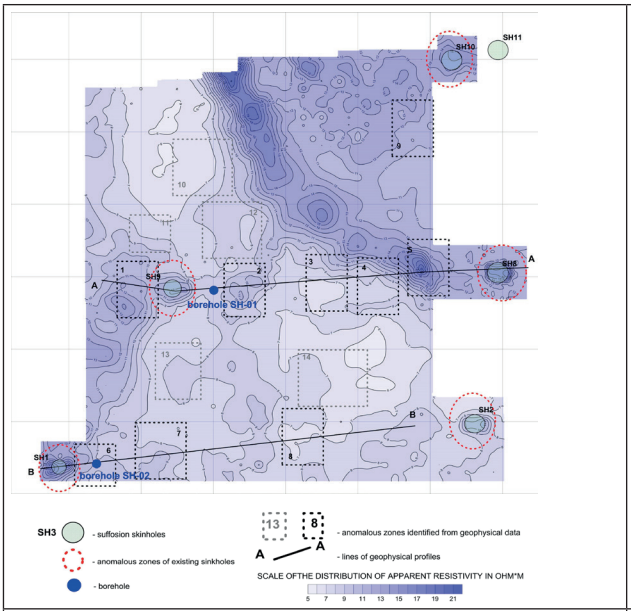

Figure 4 – Scheme of the distribution of apparent resistivity in the work area at a depth of 2.5 м.

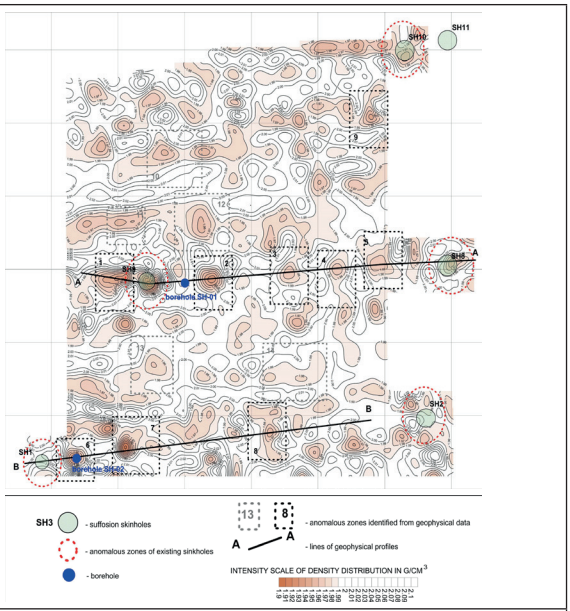

Figure 5 - Scheme of the density parameter distribution at a depth of 10 m.

Geologic results. Joint analyzesof geological, geophysical and geodetic data made it us to identify criteria for the detection of anomalous zones with a developed process of decompaction of sedimentary rocks.

In the local gravity field this process is characterized by anomalies of intensity from -0.02 mGal to -0.05 mGal (Fig. 3). On the relief map of the day surface - positive forms with amplitudes from 0.1 m to 0.35 m (Fig. 2). In the resistivity distribution - moderate values from 8 Ohm*m to 16 Ohm*m at a depth of 2.5 m (Fig. 4) and from 6 Ohm*m to 12 Ohm*m at a depth of 7 m.

According to the identified criteria, 5 anomalous areas were additionally identified where the process of suffosion is at its initial stage. They are marked by reduced values of parameters, both in the gravity field and in the relief of the day surface (Table 2). The selected anomalies are located between the linear zones of the location of the existing light holes: 10, 11 and 12 between 3 and 2 linear zones, 13 and 14 between 2 and 1 linear zones (Fig. 2, 3, 4).

In order to determine the spatial distribution of existing and predicted sites of suffosionlight holes, a volumetric model of the distribution of density parameters of the medium was calculated.

The obtained series of analyses shows that for the majority of highlighted suffusion light holes SH9, SH8, and SH10 correspond to a decrease in density characteristics with depth. At a depth of 10 m, the minimum values of rock density are noted (Fig. 5). The exceptions are the anomalous section of sinkhole SH9 and anomalous sections 1 and 2.

For light holes SH1 and SH2, the density characteristics practically do not change with depth, which indicates the “maturity” of these light holes [9].

The obtained result allows us to assume that the interval of 2-12 m from the ground surface is currently the most favorable for the development of the process of suffosion. This is also confirmed by the results of testing samples from well SH-1, which is located in the same line with the selected anomalous zones 1-5, light holes SH9 and SH8.

Judging by the distribution of density parameters, the most active at present are sinkhole SH9 and newly discovered anomalous areas 1 and 2 (linear zone 2) and 6 (linear zone 3). Determination of the depth of the identified areas of decompression was carried out according to the constructed geophysical sections (Fig. 6).

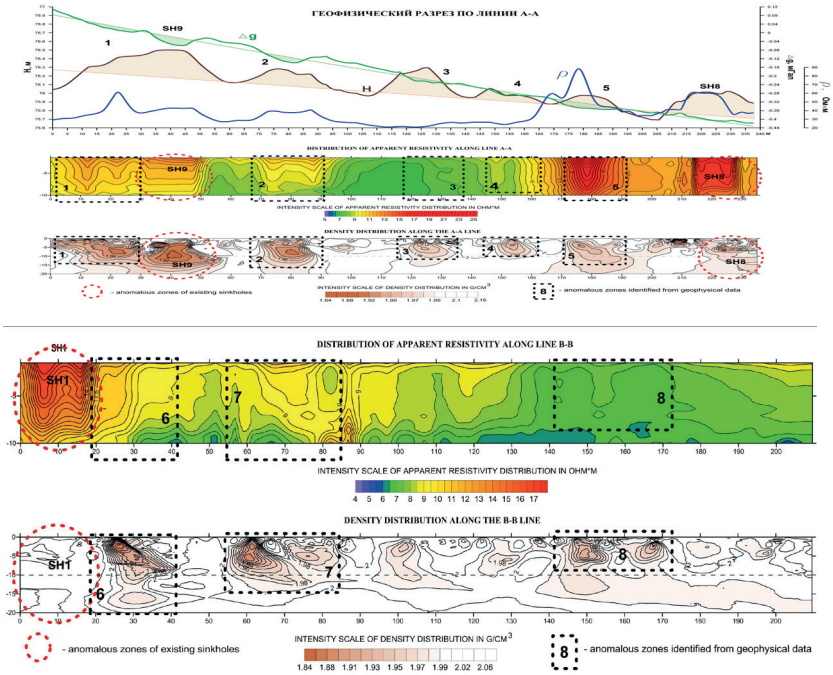

Figure 6 - Geophysical sections along lines A-A and B-B.

Analyzesof geophysical sections made it possible to determine the size of the distribution of new areas of decompaction and existing light holes (with a radius varying from 11 m to 30 m) and their depths (from 7 m to 20 m) along lines A-A and B-B. The sizes of the identified areas of decompaction 9-14 were determined from the map of density parameters distribution at a depth of 10 m and vary from 7 to 14 m (tab. 2).

Table 2 - Quantitative parameters of selected anomalous areas obtained from the analyzes of geophysical fields and relief

Sinkhole	Maximum value of the intensity of the anomaly				Distribution of density parameters by depth in m, g/cm^3					Dimensions, m	
	of gravity, mGal	heights, m	resistivity, Ohm*m								
			at a depth of 2.5 m	at a depth of 7.0 m	2.5	4.5	7	10	15	x-axis width	depth
1	-0.03	0.25	10	8	1.98	1.97	1.96	1.93	1.93	30	15
2	-0.04	0.35	10	8	1.98	1.96	1.95	1.94	1.93	20	18
3	-0.03	0.3	8	6	1.99	1.98	1.98	1.97	1.99	15	12
4	-0.02	0.2	8	8	1.99	1.98	1.97	1.97	1.98	15	10
5	-0.02	0.15	16	12	1.99	1.98	1.97	1.97	1.97	18	15
6	-0.05	0.10	10	8	1.97	1.95	1.94	1.94	1.96	17	18
7	-0.05	0.15	8	6	1.97	1.95	1.95	1.91	1.96	22	14
8	-0.03	0.2	8	6	1.98	1.98	1.97	1.96	1.98	22	10
9	-0.04	0.15	11.5	11.5	1.98	1.97	1.97	1.95	1.98	15	10
10	-0.02	0.1	7	6.5	1.99	1.98	1.97	1.96	1.97	13	10
11	-0.02	0.15	8	7.5	1.98	1.97	1.97	1.96	1.96	14	10
12	-0.03	0.05	8	7.5	1.99	1.98	1.97	1.96	1.96	11	11
13	-0.01	0.15	8	7.5	1.99	1.98	1.98	1.97	1.98	13	10
14	-0.01	0.2	7	6.5	1.99	1.99	1.98	1.98	1.99	7	10

Analyzes of changes in the density characteristics of anomalies with depth shows that, starting from a depth of 15 m, the density of rocks increases, which implies that the areas of decompaction are formed above this horizon and is 10-11 m.

Conclusions. Based on the results of the geological interpretation of high-precision gravity and electrical survey data, satellite geodesy and soil laboratory tests.

− The results obtained showed a high efficiency of the applied set of methods to determine the areas of area and depth development of the suffosion and karst process and can be recommended for further use in solving similar problems in other hydrocarbon fields.

− Nine anomalous areas with developed suffosion and karst processes, well manifested in the local gravity field, in the distribution of resistivity, petrophysical properties, in the forms of relief of the day surface are identified.

− Five anomalous areas, where the process of suffosion is in the initial stage, characterized by reduced values of parameters, both in the gravitational field and in the relief, are identified.

− According to the combination of features, the most active at the moment are sinkholeSH9 and selected anomalous areas 1 and 2.

− The depth interval of 2-12 m from the surfaceof the earth is the most favorable for the development of suffosion.

Абетов А.Е., Құдайбергенова С.С.

Қ.Сәтбаев университеті, Алматы, Қазақстан
E-mail: abetov.auez@mail.ru

ҚАРАШЫҒАНАҚ МҰНАЙ-ГАЗ КОНДЕНСАТ КЕНОРНЫНДАҒЫ СУФФОЗИЯ-КАРСТ ПРОЦЕССТЕРІН ГЕОЛОГИЯ-ГЕОФИЗИКАЛЫҚ ЖӘНЕ ГЕОДЕЗИКАЛЫҚ ӘДІСТЕР АРҚЫЛЫ КЕШЕНДІ ЗЕРТТЕУ

Аннотация. Мақалада Қарашығанақ мұнай-газ конденсатты кенорнындағы суффозия-карсттық процестерді жоғары дәлдікті гравиметрлік және электрлік барлау, спутниктік геодезия және топырақты зертханалық зерттеу әдістерінің кешенін қолдана отырып жүргізілген зерттеу нәтижелері талқыланады. Әдістер жиынтығының тиімділігіне баға беріледі.

Геофизикалық өрістерде, петрофизикалық ерекшеліктерімен және тәулік бетіндегі рельефтің өзгеру формалары арқылы суффозия-карсттық шұңқырлардың пайда болу белгілерін анықтау жолдары көрсетілген, сонымен қатар процестің қарқынды даму аймағын және жер бетіне жақын қабаттарда деформациялар дамуының бастапқы сатысында ауданды анықтау тәсілдері қарастырылған.

Суффозиялық шұңқырлар электр кедергісінің ерекше (орташа) мәндерімен, гравитациялық өрістің теріс жергілікті (локальды) ауытқуларымен, тәуліктік беттің оң рельефтік формаларымен жақсы ерекшеленетіндігі анықталды.

Жүргізілген зерттеулердің нәтижелері суффозия процестерінің жер бетінен 2-12 м тереңдікте дамығандығын нақты көрсетеді.

Түйінді сөздер: суффозия-карст процестері, жоғары дәлдікті гравитациялық барлау, электрлік барлау, жерсеріктік геодезия, топырақты зертханалық зерттеу.

Абетов А.Е., Кудайбергенова С.С.

Университет Сатпаева, Алматы, Казахстан.
E-mail: abetov.auez@mail.ru

КОМПЛЕКСНЫЕ ИССЛЕДОВАНИЯ СУФФОЗИОННО-КАРСТОВЫХ ПРОЦЕССОВ НА НЕФТЕГАЗОКОНДЕСАТНОМ МЕСТОРОЖДЕНИИ КАРАЧАГАНАК ГЕОЛОГО-ГЕОФИЗИЧЕСКИМИ И ГЕОДЕЗИЧЕСКИМИ МЕТОДАМИ

Аннотация. В статье анализируются результаты исследований суффозионно-карстовых процессов на Карачаганакском нефтегазоконденсатном месторождении комплексом методов высокоточной гравиразведки и электроразведки, спутниковой геодезии и лабораторных исследований грунтов. Дана оценка эффективности комплекса методов.

Выявлены критерии обнаружения в геофизических полях, петрофизических особенностях и формах изменений рельефа дневной поверхности суффозионно-карстовых воронок с выделением участков интенсивного развития процесса и определением площади с начальной стадией развития деформаций приповерхностных слоев.

Установлено, что суффозионные воронки хорошо обособляются по специфическим (умеренным) значениями удельного электрического сопротивления, отрицательными локальными аномалиями гравитационного поля, положительными формами рельефа дневной поверхности.

Результаты проведенных исследований свидетельствуют, что процессы суффозии получили развития на глубинах 2-12 м от поверхности земли.

Ключевые слова: суффозионно-карстовые процессы, высокоточная гравиразведка, электроразведка, спутниковая геодезия, лабораторные исследования грунтов.

Information about authors:

Abetov Auez – Geophysics Department Chairman, Satbayev University, Doctor of Sciences in Geology and Mineralogy, Professor, Corresponding Member of the National Academy of Sciences of the Republic of Kazakhstan, Almaty, Kazakhstan; abetov.auez@mail.ru; *https://orcid.org/0000-0002-1866-7677;*

Kudaibergenova Sabina – 2nd year doctoral student of Geophysics Department Satbayev University, *sabina_kudaybergenova@inbox.ru*; *https://orcid.org/0000-0002-9194-4685.*

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