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CONDITIONS OF FORMATION OF SULFIDE WATERS IN PARAGENESIS WITH EVAPORITE AND OIL AND GAS-BASED FORMATIONS IN THE ARTESIAN POOLS OF THE REPUBLIC OF UZBEKISTAN

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Abstract: The lithological-facies factor is considered with the aim of studying the natural and geological conditions in which hydrogen sulfide waters are formed in gas and oil fields in the artesian basins of the Republic of Uzbekistan. The distribution of hydrogen sulfide waters is closely related to the areas of joint development of halogen rocks and oil and gas complexes. Since the term “paragenesis” refers to the joint finding of minerals or chemical elements genetically related, this map is a map of the paragenesis of hydrogen sulfide waters with evaporites and oil and gas complexes. In the absence of one of the necessary conditions (sulfates or petroleum organics), hydrogen sulfide waters of high concentration are not formed. Hydrogen sulfide waters in the identified anticlinal structures are formed due to the presence of insignificant gas and oil deposits, which are not of industrial importance.

Key words: productive horizon, gas and oil field, artesian basin, oil and gas complexes, leaching of sulfate-bearing strata, paragenesis.

Introduction. In public health practice, the role of mineral waters as an important therapeutic and preventive effect on the human body is steadily increasing. Hydrogen sulfide mineral water is traditionally used in medical practice as a treatment for the skin, respiratory system and musculoskeletal system. However, thanks to recent intensive studies, the therapeutic effect of water has been established for pulmonary hypertension, arterial hypertension, atherosclerosis, ischemia-reperfusion injury, heart failure, peptic ulcer and acute and chronic inflammatory diseases [1].

During geological exploration in the oil and gas basins, local manifestations of hydrogen sulfide waters were noted. To identify the distribution areas of these waters, it is necessary to study the mechanisms and factors that contribute to the formation of hydrogen sulfide in water. The identification of promising areas for hydrogen sulfide waters in the republic is relevant for health care needs. The presence of hydrogen sulfide water was noted in the Ferghana, Surkhandarya and Bukhara-Khiva oil and gas regions (Fig. 1).
The degree of knowledge of the problem. The problem of the origin of hydrogen sulfide in the underground hydro- and lithosphere has attracted the attention of many researchers. At the end of the last century, hydrogeologists A. M. Ovchinnikov, V. V. Ivanov, G. N. Plotnikova, A. I. Rivman studied and analyzed the conditions for the formation of hydrogen sulfide deposits in the CIS countries (the former USSR) [2]. In Uzbekistan, D.S. Ibragimov studied the hydrogeology of hydrogen sulfide deposits in the southern part of the Ferghana artesian basin, L.S. Balashov - the conditions for the formation of groundwater in the Surkhandarya artesian basin [3]. All researchers analyzed hydrogeochemical factors and identified the main hydrochemical types of hydrogen sulfide waters. In recent years, in order to clarify the formation of hydrogen sulfide, a three-dimensional model has been developed for the formation of hydrogen sulfide in sealed anhydrite-carbonate reservoirs. The simulation results show that hydrogen sulfide is located at the interface between anhydrite and hydrocarbons [4].

Conditions for the formation of hydrogen sulfide. The areas of distribution of hydrogen sulfide waters are usually confined to the oil and gas (or oil-promising) basins of platform and folded areas, in the context of which evaporite deposits are developed. The greatest amount of hydrogen sulfide is observed in the waters of open and collapsing oil fields, i.e. where there is a connection with surface waters [5]. The formation of hydrogen sulfide in groundwater, their concentration and dispersion are determined by hydrodynamic and closely related hydrochemical conditions. The distribution of hydrogen sulfide, as a rule, depends on the development of sulfate-reducing bacteria in water, but they have not been detected in some hydrogeological enclosed structures with a high content of hydrogen sulfide. This gave rise to microbiologists to argue that the sulfate reduction process is carried out only in the presence of water exchange. In the life process of sulfate-reducing bacteria, sulfates of various minerals (gypsum, barite, celestine, etc.) and organic compounds are used [2]. The reaction proceeds according to the scheme:

\[ SO_4^{2-} + 2C_{org} + 2H_2O = H_2S + 2HCO_3^- \]

In recent years, various experiments on the reduction of sulfate compounds at high temperatures and pressures have been performed. The experiments of S. M. Grigoriev in an autoclave showed that at t 100-150 °C and pressure up to 10 atm. the interaction of methane and sulfuric acid salts results in the formation of hydrogen sulfide by the reaction [2]:

\[ CaSO_4 + CH_4 \rightarrow CaCO_3 + H_2O + H_2S \]
\[ Na_2SO_4 + CH_4 \rightarrow Na_2CO_3 + H_2O + H_2S \]

Search criteria for the area of formation of hydrogen sulfide waters. The logical relationship between the distribution of hydrogen sulfide waters and sulfate-containing and oil-gas
sedimentary complexes determines the most important search criteria for hydrogen sulfide waters and the identification of promising areas. Among the natural factors and conditions, the decisive role in the process of formation of hydrogen sulfide waters is: 1) the lithological and facies composition of water-bearing rocks (primarily, the presence of sulfate-containing deposits) and the oil and gas content of the sedimentary sequence; 2) geological and structural conditions; 3) hydrogeochemical situation; 4) hydrodynamic and geothermal conditions [6]. The lithologic-facies composition of the productive complex associated with the formation of hydrogen sulfide waters in the oil and gas fields of the artesian basin of the Republic of Uzbekistan is considered below.

**Paragenesis of hydrogen sulfide waters with evaporites and oil and gas bearing formations.** A very important and long noticed by researchers feature of many oil fields is the development of the sulfate reduction process in the waters accompanying them, especially intensively occurring at the oil-water contact. Along with the confinement of hydrogen sulfide waters to the areas of oil fields, their formation is also established due to non-industrial accumulations of hydrocarbons and dispersed organic matter in water-bearing rocks.

The participation of hydrocarbon gases and hydrogen in the processes of sulfate reduction apparently plays an insignificant role. As for methane itself, it was experimentally proved that in the atmosphere methane and sulfate-reducing microbes did not produce hydrogen sulfide. Thus, analytical and empirical data indicate a close spatial and genetic relationship of hydrogen sulfide waters mainly with accumulations of liquid hydrocarbons [2].

**MATERIALS**

**Ferghana artesian pool.** According to the structural and tectonic structure, the Ferghana intermountain basin is divided into three parts: the southern side, the northern side and the central graben. The largest number of oil fields is located in the southern part of the Ferghana depression. In the developed oil fields in the southern part of the Ferghana depression, the manifestations of hydrogen sulfide water are often found in wells. Their manifestations were found in the oil fields of North Sokh, Chongara-Galcha, Chimion, Andijan, Palvantash, Khojaabad and South Alamyshik [7].

**Surkhandarin artesian pool.** Oil content. 13 deposits were discovered in the Surkhan oil and gas region (Haudag, Uchkyzyl, Kokayty, Lalmikar, Koshtar, Amudarya, Mirshadi, Jayrankhana, Aktau, Korsagly, Jalair, Hajak and Kagnysay). At these fields, oil and gas deposits are located in Paleogene deposits, and the productivity of the Upper and Lower Cretaceous deposits has been established at the Lalmikar, Gadzhak and Kagnysay deposits. Hydrogeological characteristics. The Surkhandarya megasynclinal is the largest in the territory and is characterized by the predominant development of hydrogen sulfide waters in the Paleogene sediments, mainly in the carbonate reservoirs of the Paleocene and, to a lesser extent, the Eocene (Uchkyzyl, Haudag, Lalmikar, Kokayty, Stary Termez, Jairankhana, South Kurgancha and others) [8].

**Bukhara-Khiva artesian basin.** Oil and gas. In the 60-70 years of the last century, geological exploration was carried out in order to search for oil and gas in the territory of the Bukhara-Khiva basin. Within it, 44 deposits have already been identified, mainly gas and gas condensate in the Cretaceous (IX, X, XI, XVa, XII and XIII productive horizons) and Jurassic deposits (XV, XVa and XVI productive horizons) [9]. **Hydrogeological characteristics.** During the exploration, hydrogen sulfide waters were detected along the way in some gas and oil fields. The Karaktay oil and gas field of hydrogen sulfide in the formation waters of the XV, XVa and XVI horizons was found to be in the range from 39 (well 5) to 833 mg / l (well 39). In the Gazli oil and gas field, hydrogen sulfide in the reservoir waters of the XIII horizon is present in the range from 62 mg / l (well 114) to 90 mg / l (well 27). The Uchkir gas field, hydrogen sulfide in the reservoir waters of the XV horizon are in the range from 120 mg / l (well 28) to 132 mg / l (well 18). At the Karim field, the amount of hydrogen sulfide in produced water ranges from 97 mg / l (well 5) to 115 mg / l (well 3). At the Kulbeshkak field, hydrogen sulfide in the reservoir waters of the XVI horizon was found in an amount from 99 mg / l (well 21) to 154 mg / l (well 16). At
the Dengizkul-Khauzak field, industrial gas accumulations are confined to the XV horizon of the Callovian-Oxfordian deposits of the Upper Jurassic. In produced water, there is dissolved hydrogen sulfide ranging from 14 mg/l (well 9K) to 537 mg/l (Well 3D). The industrial gas content of the Urtabulak structure, the amount of dissolved hydrogen sulfide in formation waters is present from 54 mg/l (well 7) to 400 mg/l (well 13). At the Kandym field, the content of dissolved hydrogen sulfide in the formation waters of the XV horizon varies from 99 mg/l (well 7) to 170 mg/l (well 17). The hydrochemical indicators obtained (the content of hydrogen sulfide and microcomponents in the formation water) based on the results of the tested intervals of gas and oil wells show the formation and distribution of hydrogen sulfide of various concentrations in the formation water in almost all gas and oil fields of the Bukhara-Khiva basin [9].

**RESULTS**

**Ferghana artesian pool.** In order to study sulfate-bearing rocks, the water-bearing Paleogene rocks are analyzed by tiers (Bukhara, Suzak, Alai, Turkestan, Rishtan, Isfara, Khanabad and Sumsar), according to the scheme of O.S. Vyalov by comparing the Paleogene sediments of Fergana according to A.R. Khojaev (fig. 2).

![Fig. 2. Comparison of the Paleogene deposits of Ferghana. Compiled by M.R. Juraev, using materials of A. R. Khojaev (1967), 2014. 1 - clay; 2 - sandstone; 3 - limestone; 4 - marl; 5 - gypsum; 6 - gypsum.](image)

**Bukhara tier.** Its deposits are well distinguished in most areas of the Ferghana depression, represented in the lower part of the section by gypsum and anhydrite (X layer), in the upper part - by limestone and clay (VIII layer). The total thickness of deposits of the Bukhara layer varies from 5 m in the west to 50 m in the northeast. The **Suzak tier** is represented by clays with interlayers of sandstones, limestones and sometimes gypsum. The thickness of the tier varies from 12 m in the southwest to 30 m in the area of Mailisu and 90 m in the area of Andijan structures.

**Alai tier.** Its deposits are widespread and represented by marls and clays passing upstream into limestones and dolomites. The total thickness of Alai deposits in Northern Ferghana ranges from 33 m in the Mailisu-IV region to 51 m in Naryn. Turkestan tier. On the structures of the Andijan group, the tier is composed of clays, among which one or more layers of limestone, sandstone (V layer) or anhydrite (VI layer) are located. The thicknesses of the V and VI layers range from 5 to 14 m, the
The total thickness of the sediments that make up the section of the Turkestan layer varies from 27 m (Varzyk) to 55 m (Naryn), in the Andijan group of structures and in southern Ferghana, from 37 m (Shorsu) up to 86 m in Palvantash. **Rishtan tier.** In most sections, longline deposits are represented by clays, sandstones, sandy limestones with inclusions of small pebbles, marls. The X layer of Bukhara and the VI layer of the Turkestan tiers consist of gypsum and anhydrite, as well as clay with intercalations of gypsum in the Suzak tier of the Paleogene deposits of the Fergana Depression. Sulphate-containing rocks (gypsum and anhydrite) are in contact with aquifers. The thickness of the Paleogene sequence is relatively less in the northern side of the basin than in the southern side, however, a sulfate-containing layer is present in all regions of the basin.

**Surkhandarinsky artesian pool.** (Fig. 3). Oil is formed in the Bukhara and Akzhar layers of the Paleogene deposits of the Amudarya, Kokayty and Haudag oil fields. However, oil is absent in the Boyangoran anticlinal structure. The thickness of the Bukhara-Akzhar stratum is 470 meters in the Amudarya, 393 meters in the Kokayty, 172 meters in the Hudag oil fields and 182 meters in the Boyangoran anticline structure. The main water-bearing rocks of the Bukhara-Akzhar layer are limestones and dolomites with intercalations of gypsum and anhydrite (Fig. 3, A-A). Oil is formed in the Bukhara-Akzhar layer of the Paleogene of the Kokayty, Lalmikar, Koshtar and Mirshadi oil fields (Fig. 3, B-B). Oil is extracted from the Bukhara-Akzhar and Alai strata in the Uchkyzyl oil field. In the Uchkyzyl oil-bearing field, the thickness of the Alai layer is 50 meters and 280 meters in the Bukhara-Alai layer. The Bukhara-Akzhar stratum is 393 meters in Kokayty, 390 meters in Lalmikar and 180 meters in Koshtar oil fields. In the Uchkyzyl and Kokayty deposits, limestone and dolomites with intercalations of gypsum and anhydrite are water-bearing rocks. Water-bearing rocks in the Lalmikar, Koshtar, Mirshadi oil fields consist of limestone and dolomites with intercalations of gypsum and marl, as well as sandstone. Consequently, the Bukhara and Akzhar tiers consist mainly of sulfate-containing rocks (gypsum and anhydrite). Sulfate-containing formations are present in all regions of the depression.

![Fig. 3. Comparison scheme of Paleogene deposits of the Surkhandarya megasyncline. 1-oil stratum; 2-limestone; 3-dolomite; 4-gypsum; 5-anhydrite; 6-marl; 7-sandstone; 8-line matching.](image-url)
Bukhara-Khiva artesian basin. (Fig. 4). Gas condensate deposits on the Dayahatyn fold are confined to the XV-1 and XV-2 horizons of the Callovian-Oxfordian layers of the upper part of the Jurassic. Horizon XV-1 is represented by dense gray limestones with intercalations of anhydrites. Horizon XV-2 is represented by weakly cemented limestones of gray and dark gray. The terrigenous sequence consists of dark gray and gray fine-grained, dense sandstones with intercalations of siltstones and clays of the same color. Akkum-Parsankul gas condensate field. Horizon XV-1 lies in the uppermost part of the carbonate sequence. An impermeable layer of dense limestone this horizon is divided into two packs - A and B. Pack A occupies the upper part of the horizon and is composed of clastic rocks, interbedded with anhydrites with intercalations of limestone. Member B occupies the lower part of horizon XV-1 and is represented by limestone. Above the Callovian-Oxfordian deposits lies the salt-anhydrite stratum of the Kimmeridge-tithonian age, represented by anhydrites containing single thin layers of gypsum clays and sandstones, and rock salt. Industrial gas content of horizons XV-1 and XV-2 was established at the Kandym field. Horizon XV-1 is represented by limestones with rare interlayers of oolitic and loose “lumpy” limestones, fine-grained sandstones and gray dense clays with inclusions of anhydrites. Horizon XV-2 consists of gray, dense, cryptocrystalline detrital and, to a lesser extent, lumpy-clotted, sometimes fractured limestones.

At the Dengizkul field, industrial gas accumulations are confined to the XV horizon. Although the deposit has a single gas-water contact, it consists of two floors. The lower of them is formed by several undivided impermeable interlayers of layers of granular reservoirs filled with gas. The upper one, on the contrary, consists of a series of low-power reservoirs separated from each other by poorly permeable carbonate rocks. Low-power reservoirs consist of porous limestone with intercalations of anhydrites (carbonate-sulfate pack). The Kimmeridge-tithonian section is represented by a thickness of anhydrites and rock salt, the thickness of which varies from 350 to 636 m. At the Karim field, industrial gas inflows are established in the XV + XVa horizons.
Horizons XV + XVa form the upper half of the section in the Callovian-Oxfordian deposits of the Upper Jurassic and are represented by loose, finely similar limestones in the lower part (XVa is the horizon) and gray dense fractured in the upper part (XV horizon). In permeable horizons there are lenses and interlayers of impermeable rocks. The total thickness of the horizons is 269 - 337 m. The Jurassic section ends with white, strong, fractured anhydrites. Upper Jurassic deposits of the Khojihairam deposit. They are represented by two lithologically distinct packs of rocks: the lower one is composed of limestones, massive dense clay. The upper is represented by dense anhydrites with a thickness of up to 36m. Industrial gas deposits of the Karaktay oil and gas field are associated with the XII and XIII horizons, oil deposits - in the XV, XVa and XVI horizons. Three packs are distinguished in the carbonate sequence: the lower — strong sandy limestones (XVI horizon), the middle — finely-shaped limestones and dense cryptocrystalline limestones (XVa horizon), and the upper — strong cryptocrystalline limestones with intercalations of anhydrite (XV horizon). Jurassic section ends with strong anhydrites of kimeridge-titon.

The analysis shows that in the compiled scheme for comparing the gas and oil horizons of the Jurassic deposits of the Bukhara-Khiva basin, almost all rocks of the productive horizon consist of limestone with intercalations of anhydrite. The reef zone of the Dengizkul-Khauzak deposits is a permeable reservoir, which consists of carbonate-sulfate packs (limestone and anhydrite). The host rocks of the productive horizon are composed of limestone without anhydrite in the Karim and Khodzhihairam deposits, however, the productive horizons are covered by the thick anhydrite-salt strata of the Kimmeridge-Tithonian layer in all deposits.

**DISCUSSION**

*Ferghana artesian pool.* To compare the areas of distribution of hydrogen sulfide waters with oil and gas territories and halogen formations, we compiled a map of the main areas of distribution of hydrogen sulfide waters within the Ferghana Basin (Fig. 5). The map shows the territories of the established development of hydrogen sulfide waters and their boundaries, corresponding to the distribution of evaporite sediments of water-bearing Paleogene rocks, contoured by developed and operating oil and gas deposits promising for hydrogen sulfide waters. The developed and existing oil and gas bearing fields confined to the Paleogene are located in the southwestern part of the basin (Varyk, Nefteabad, Shorsu IV, Rawat, Central Kurgancha, Kanibadam, Ayritan, Ob-Shifo, Aksaray, Togap, Kairagach, Kim, etc.), parts of the southern side (Chongara-Galcha, Northern Sokh, Sarykamysh, Northern Rishtan, Sarytok, Chaur, Yarkutan, Chimirchon, Khandizes and Avval), the south-eastern part (Western Palvantash, Palvantash, Khojaosman, Andijan, Boston, South Alamyshik, Khartu Northern Alamyshik, Khojaabad and Changyrtash), in the central area graben (Mingbulak, Karajid and Gumkhan), the northern side (Tergachi, Kasansay, Shorbulak and Namangan) and the north-eastern part (Mailisu IV and Izbaskent). Hydrogen sulfide waters are formed in the following oil and gas fields: in the southwestern part - Shorsu, Ob-Shifo and Kim; in the central part - Northern Sokh, Chongara-Galcha, Sarykamysh, Sarytok, Northern Rishtan, Chimirchon and Kashkaryr; in the southeastern part - West Palvantash, Palvantash, Andijan, Khojaabad, South Alamyshik and Changyrtash; in the northeastern part of the Ferghana depression - Izbaskent and Mailisu IV. Sulfate-containing formation is present in all regions of the depression.
Fig. 5. Map of the paragenetic relationship of hydrogen sulfide waters with evaporites and oil and gas complexes of the Ferghana depression. Compiled by MR Zhuraev using materials from IGIRNIGM OJSC (2012), 2014. 1 - outcrops of folded base rocks to the day surface; 2 - the boundaries of the depression; 3 - boundaries of tectonic zones; 4 - the main violations; 5 - state border. Deposits: 6 - oil, 7 - oil and gas; 8 - local structures; 9 - tectonic elements; 10 - distribution boundaries of evaporite sediments; 11 - the boundaries of developed and existing oil and gas fields; 12 - areas promising hydrogen sulfide waters; 13 - territories of the established development of hydrogen sulfide waters and their boundaries; 14 - lines of comparison of thickness. Deposits and local structures: 10-Tergachi, 12-Kasansay, 19-Shorbula, 20-Namangan, 30-Mingbulak, 37-Karajida, 44-Gumkhan, 68-Shorsu-IV, 74-Chimion, 75-Gulkucha, 77-Kashakyr, 86-West Palvantash, 90-Palvantash, 97-Andijan, 98-Shahrikhan-Khojaabad, 99-Buston, 105-South Alamyshik.

Surkhandarin artesian pool. A map of the main areas of hydrogen sulfide distribution within the Surkhandarya megasyncline has been compiled (Fig. 6). The developed and existing oil and gas deposits confined to the Paleogene are located in the southern part of the depression (Uchkyzyl, Jairankhan, Amudarya, Korsagly, Aktau, Kokayty, Haudag, Dzhalair), the central part (Gadzhak and Kagnysay) and the eastern part (Lalmikar, Koshtar and Mirshadi). Hydrogen sulfide waters are promising in the following oil and gas fields: in the southern part - Uchkyzyl, Jairankhan, Amudarya, Korsagly, Aktau, Kokayty, Haudag, Jalair; in the eastern part - Lalmikar, Koshtar, Mirshadi and the revealed anticlinal structure of
**Fig. 6.** Map of the paragenetic relationship of hydrogen sulfide waters with evaporites and oil and gas complexes of the Surkhandarya oil and gas region. 1 - tectonic blocks and their number; 2 - oil field; 3 - gas field; 4 - perspective areas; 5 - areas identified; 6 - outputs of sediments of the Jurassic; 7 - Paleozoic outcrops on the surface of formations; 8 - discontinuous violations; 9 - shifts and boundaries of latitudinal steps (blocks according to ancient deposits; 10 - boundaries of the distribution of evaporite sediments; 11 - boundaries of developed and existing oil and gas deposits; 12 - territories of established development of hydrogen sulfide waters; 13 - territories promising for hydrogen sulfide waters; 14 - thickness comparison lines.

**Oil and gas deposits:** 1-Hajjak, 2-Mirshadi, 3-Koshar, 4-Lalmikar, 5-Dzhalair, 6-Haudag, 7-Kokayte, 8-Uchkyzyl, 9-Jairanhana, 10-Aktau, 11-Korsagly, 12-Amudarya, 13-Kagnysay Shorbulak and Kurgancha. The distribution contour of sulfate-bearing rocks on the Surkhandarya megasyncline along the Paleogene deposits was noted (Fig. 6). As can be seen on the map, the distribution of hydrogen sulfide waters is closely related to the areas of joint development of halogen rocks and oil and gas complexes. Since the term paragenesis (paragenesis) refers to the joint finding of minerals or chemical elements that are genetically related, this map is a map of the paragenesis of hydrogen sulfide waters with evaporites and oil and gas complexes. Therefore, the oxidation reaction is carried out due to leaching of sulfate-containing strata, and in the oil-bearing stratum a reduction reaction occurs with hydrogen and the participation of sulfate-reducing bacteria. In the absence of one of the necessary conditions (sulfates or petroleum organics), hydrogen sulfide waters of high concentration are not formed.
**Bukhara-Khiva artesian basin.** After summarizing the analyzes, it was revealed that sulfate-bearing rocks spread in the form of layers of anhydrite in the gas-oil strata of carbonates, as well as gypsum-anhydrite strata of Kimmeridge-tition covers over the productive horizon throughout the basin.

*To compare the distribution areas of hydrogen sulfide waters* with gas and oil-bearing territories and halogen formations, a map of the main distribution areas of hydrogen sulfide waters within the Bukhara-Khiva basin has been compiled. The map shows the territories of the established development of hydrogen sulfide waters and their boundaries, corresponding to the distribution of evaporite sediments of water-bearing rocks of Jurassic sediments, contoured by developed and operating oil and gas deposits promising for hydrogen sulfide waters (Fig. 7). The developed and existing oil and gas fields associated with the Jurassic deposits are located in the western part of the basin (Kulbeshkak, Uchkyr, Parsankul, Akkum, Kandym, Gazli, Dayahatyn, Khodzhikazgan, Khoji, Atamurad, Uchburgan, Garbi), the central part (Khauzak, Alat, Tegermen, Shady, Dengizkul, Matonat, Zekr, Kruk, Pamuk, Pirnazar, Urtabulak, Kamashi, Beshkent, Girsan, Northern Nishan, Aknazar and Kultak), the northeastern part (Dzharak, Karaulbazar, Shurtep, Khojairam, Karajbaram, Kara Akjar, North Muborak and Kyzylrabot) and the eastern part (Karaktay, Tashli, Sarych, Shurtan, Buzakhur, Adamtash, South Tandyrcha, Pachkamar and Gumbulak).

![Fig. 7. Map of the paragenetic relationship of hydrogen sulfide waters with evaporites and gas-oil complexes of the Bukhara-Khiva basin. Exploration Deposits: 1-oil; 2-oil and gas; 3-oil and gas condensate; 4-gas; 5-gas condensate. 6- distribution path of evaporite sediments; 7- contour of the developed and existing oil and gas field; 8- areas promising hydrogen sulfide waters; 9 - Jurassic Comparison Line.

Hydrogen sulfide waters are promising in the following oil and gas fields: in the western part - Kulbeshkak, Uchkyr, Parsankul, Akkum, Kandym and Dayahatyn; in the central part - Khauzak, Dengizkul, Urtabulak, Karim and Pamuk; in the north-eastern part - Khojahairam, Karakum; in the eastern part - Karaktay, Adamtash and Gumbulak. The distribution contours of sulfate-bearing rocks of the Bukhara-Khiva basin along Jurassic deposits are noted. Almost all productive horizons...
(XV and XVI) are limestones with intercalations of anhydrite. Also, productive strata cover thick gypsum-anhydrite deposits of Kimmeridge-tithon. Consequently, the distribution of the sulfate-containing stratum covers the entire basin.

**FINDINGS**

Ferghana and Surkhandarya artesian basin. Sulphate-containing rocks (gypsum and anhydrite) are in contact with aquifers. Sulfate-containing formations are present in all regions of the depression. The oxidative reaction is carried out due to leaching of sulfate-containing strata, and a reduction reaction with hydrogen and the participation of sulfate-reducing bacteria occurs in the oil-bearing stratum. In the absence of one of the necessary conditions (sulfates or petroleum organics), hydrogen sulfide waters of high concentration are not formed.

Bukhara-Khiva artesian basin. Almost all rocks of the productive horizon are composed of limestone with intercalations of anhydrite. The distribution of sulfate-containing strata covers the entire basin. The host rocks of the productive horizon are composed of limestone without anhydrite in the Karim and Khodzhairam deposits, however, the productive horizons are covered by the thick anhydrite-salt strata of the Kimmeridge-Tithonian layer in all deposits. The formation of hydrogen sulfide occurs in the productive horizon of gas and oil fields in the Bukhara-Khiva basin, due to high pressure and temperature, a thermochemical reaction occurs, i.e. in the interaction of methane and sulfate salts. The distribution of hydrogen sulfide waters is closely related to the areas of joint development of halogen rocks and gas-oil complexes.

Hydrogen sulfide water in the identified anticlinal structures is formed due to the presence of insignificant gas and oil deposits, which are not of industrial importance.

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