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Research Article

REFINEMENT OF THE GEOLOGIC-STRUCTURAL FACTORS DURING THE FORMATION OF HYDROGEN-SULFIDE WATER IN THE BUKHARA-KHIVA BASIN

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ABSTRACT
When forming hydrogen sulfide mineral groundwater, certain specific natural signs should be present. When searching for the distribution of hydrogen sulfide water, it is necessary to study and analyze the entire geological factors (lithofacies, geological, structural, hydrodynamic, geochemical conditions and geothermal factors). However, during the formation of hydrogen sulfide water, the presence of specific geological and structural features of the region under study occupies special places. So, the article has studied in detail the geological and structural factors of the gas-oil field in the Bukhara-Khiva basin. In the Karaktay and Gazli oil fields, where hydrogen sulphide waters are formed, the productive horizon lies close to the surface of the earth, which provides it with oxygen and enhances the process of sulfate reduction due to the infiltration of infiltration water through tectonic fractures in the open asymmetric structure. In the evaporite (calcareous and gypsum) rocks, an oxidative reaction occurs, which is carried out due to the leaching of sulphate-containing strata. In the oil-bearing layer, a reducing reaction occurs with hydrogens with the participation of sulfate-reducing bacteria. As a result, hydrogen sulfide waters are formed on the basis of the biochemical process. Dengizkul gas field due to high pressure and temperature in the carbonate-sulphate pack is observed oxidative process, as well as with methanes, a reducing reaction occurs at a depth of more than 2000 m in a closed asymmetric structure. As a result of the thermochemical process of the productive horizon, hydrogen sulfide water is formed. The formation of hydrosulphuric underground waters of the gas and oil field of the Bukhara-Khiva basin in different structures was revealed: - in the form of open asymmetric anticlinal folds, in which there are tectonic faults; - in the form of closed asymmetric anticline folds, in which there are no tectonic disturbances. The areas according to the nature of the formation of the hydrogen sulphide underground waters of the gas and oil fields of the Bukhara-Khiva basin were identified: due to the biochemical process it is formed in the eastern (Karaktai) and central (Gazli) parts of the Bukhara stage; - due to the thermochemical process, it is formed in the southeastern part (Karim, Karakum) and the southwestern part (Uchkyr) of the Bukhara step, as well as the whole part of the Chardzhou step (Dengizkul) of the Bukhara-Khiva basin.

Keywords: *Artesian Basin, Tectonic Disturbances, Thermochemical Process*

INTRODUCTON

In health care practice, the role of mineral waters as an important therapeutic and prophylactic effect on the human body is steadily increasing. Mineral hydrogen sulphide water is traditionally used in balneology for treating skin, respiratory organs and the musculoskeletal system. However, thanks to recent intensive research, local treatment is beginning to show benefits for pulmonary hypertension, hypertension, atherosclerosis, ischemia-reperfusion injury, heart failure, peptic ulcer disease and acute and chronic inflammatory diseases (Carbajo, 2014; Carbajo *et al.*, 2015). Identification of promising areas for hydrogen sulphide water on the territory of the republic is relevant. There is information on the availability of hydrogen sulphide water in the Fergana, Surkhandarya and Bukhara-Khiva oil and gas regions. Below, we consider in detail the degree of prospects for the area of distribution of hydrogen sulfide water in the Bukhara-Khiva artesian basin (Fig. 1).

The degree of knowledge of the problem. The problem of the origin of hydrogen sulfide in the underground hydro and lithosphere attracted the attention of many researchers. At the end of the last

century, hydrogeological scientists A.M.Ovchinnikov, V.V. Ivanov, G.N.Plotnikova, A.I. Rivman studied and analyzed the conditions for the formation of hydrogen sulfide waters in the CIS countries (former USSR) (Plotnikova, 1981). In Uzbekistan, D.S. Ibrahimov (Zhuraev et al., 2014) studied the hydrogeology of hydrogen sulfide deposits in the southern part of the Fergana artesian basin. 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 anhydrite-sealed carbonate reservoirs. Here, simulation results show that hydrogen sulfide is at the interface between anhydrite and hydrocarbons (Yunjiao *et al.*, 2016). All researchers analyzed hydrogeochemical factors and identified the main hydrochemical types of hydrogen sulfide water.

Conditions for the formation of hydrogen sulfide. Distribution areas of hydrogen sulphide waters are usually confined to oil and gas bearing (or prospective for oil) basins of platform and folded areas, in the context of which evaporite sediments are developed. The greatest amount of hydrogen sulfide is observed in the waters of open and decaying oil fields, i.e. where there is a connection with surface waters (Plotnikova, 1981).

The formation of hydrogen sulfide in groundwater, their concentration and dispersion are determined by hydrodynamic and closely related hydrochemical conditions. Its distribution, as a rule, depends on the development of sulfate-reducing bacteria in them, but they have not been found in some hydrogeological closed structures with a high content of hydrogen sulfide. This gave grounds for

Fig. 1. Overview map.

microbiologists to assert that the process of sulfate reduction is carried out only if there is water exchange. In the course of the life of sulfate-reducing bacteria, sulfates of various minerals (gypsum, barite, celestine, etc.) and organic compounds are used (Plotnikova, 1981). The reaction goes according to the scheme:

$$SO_4^2 + 2C_{org} + 2\,H_2O = H_2S + 2HCO_3$$

In recent years, various experiments have been carried out on the reduction of sulfate compounds under conditions of high temperatures and pressures.

The experiments of S.M. Grigoriev (Plotnikova, 1981) in an autoclave showed that at a temperature of 100-150 ° C and a pressure of up to 10 atm. the interaction of methane and sulfate salts is the formation of hydrogen sulfide by the reaction:

$$CaSO_4 + CH_4 \rightarrow CaCO_3 + H_2O + H_2S$$

$$Na_2\,SO_4 + CH_4 \rightarrow Na_2CO_3 + H_2O + H_2S$$

H. Sakai proved the formation of hydrogen sulfide as a result of the chemical reduction of methane sulfate at a temperature of about 500 ° C (Plotnikova, 1981; Zhuraev *et al.*, 2015).

Search criteria for the formation of hydrogen sulfide waters. The regular relationship of the distribution of hydrogen sulfide waters with sulfate-containing and petroleum-bearing sedimentary complexes determines the main search criteria for hydrogen sulfide waters and the selection of promising areas. Among natural factors and conditions, the decisive importance in the process of forming hydrogen sulfide waters are: 1) the lithologic-facies composition of water-bearing rocks (primarily the presence of sulphate-containing sediments) and the oil and gas content of the sedimentary strata; 2) geological and structural conditions; 3) hydrogeochemical environment; 4) hydrodynamic and geothermal conditions (Plotnikova, 1981; Zhuraev *et al.*, 2015). The geological and structural factors associated with the formation of hydrogen sulphide water in the oil and gas fields of the Bukhara-Khiva artesian basin are reviewed and analyzed below.

TASKS OF RESEARCH

1. Study and synthesis of the actual material associated with the hydrogen sulfide waters of gas and oil-bearing fields of the Bukhara-Khiva artesian basin.
2. Clarification of the presence of geostructural factors in the formation of hydrogen sulfide water in gas and oil fields of the Bukhara-Khiva artesian basin.

MATERIALS AND METHODS

This term refers to the flat territory of South-Western and Western Uzbekistan, bounded from the north by the uplifts of the Central Kyzylkum, from the north-east by the spurs of the Turkestan and Zarafshan ranges, in the south-east by the south-western spurs of the Gissar Range. In the southwest, it ends at the border between Turkmenistan and Uzbekistan. The Bukhara-Khiva Oblast is the northeast side of the vast Amudarya oil and gas basin, for which the regional productivity of the Jurassic and Cretaceous sediments is indicative.

Geological structure. Paleozoic sediments. The nearest outcropping of Paleozoic rocks is located in the Zirabulak-Ziaetda mountains and in the South-Western Gissar, where the pre-Paleozoic formations were also revealed. Their total capacity exceeds 10 - 11 km. *Mesozoic group.* In Western Uzbekistan, the Late Gotriass sediments are reliably recorded in the lower reaches of the Amudarya (Pitniak uplift,

Tyuyamuyun and Sultansanjar structures), where they are expressed in a series of dark gray mudstones and siltstones overlapped by Lyas sediments. *Lower Jurassic sediments.* In the plains of Western Uzbekistan, the faunistic, characterized Lyassian deposits are distinguished in the Pitnyaksky area and, according to Yu. M. Kuzichkina, in the Kimirek Square. Undifferentiated Lower Middle Jurassic sediments are distinguished (N. A. Krylov, A. K. Maltsev) on Farab Square, and conventionally lower Jurassic - on Karabair Square (well 2), Aktepe, (well 1), Azlyartepe (well. 1). *Upper Jurassic.* In the plain areas of Western Uzbekistan, the faunistic characterized deposits of the Lower Callovian (according to Yu. M. Kuzichkina) were established in the areas of Northern Kamashi, Alat, Akkum, Kandym, Yangikazgan, Kimirik, Kulbesh, as well as others.) the section is composed of gray clays with thin layers of sandstone, and in the upper (52 m) light and dark gray sandstones, various-grained, quartz-glaukonitovye, calcareous, resistant layers of gravelites and dark gray clays. On the rocks of the Lower Callovian, a thick stratum of carbonate rocks accords with it. The age of this stratum is determined by the organic remains found in its various parts along the section (Darganata, Urta-Bulak, Kimirek, etc.) and the similarity of the petrographic composition with similar formations of the south-western spurs of the Gissar Range. *Kimeridzh-titon.* The gypsum-anhydrite deposits of the Gourdak Formation are opened by wells in almost all exploration areas, with the exception of the extreme northern ones — Sultansandzhar, Meshekli, Gazli, etc. The most complete sections of the evaporite formation have been opened in the area of the Chardzhou stage, where their thickness often reaches 700-1000 m.

Tectonics. The Bukhara-Khiva region is an area of stepped foundation diving. According to this concept, there is no direct connection between the folds of the mountain frame and the flat part of the territory. In this variant, the Bukhara-Khiva region is divided into the northern or Bukhara and southern or Chardzhoy stages. The boundary between the steps is the zone of the Bukhara parogradnaya fault, reliably established on all structures of the fault zone. The northern (Bukhara) stage is separated from the structures located to the north of the basement, which reach the surface of the basement outcrops, by deep faults. The Chardzhous step from the south is also limited by the deep Amudarya fault. Since these faults and formed the basement steps, they were called parogradnye - step-forming. However, these faults not only caused the occurrence of steps in the basement, but at the same time turned out to be the boundary of the main fields of distribution of various sediments. Thus, the Amudarya Fault traces the northern boundary of the distribution of the Permian-Triassic deposits of the Pitnyak type, the Bukhara - Lower Jurassic, and the pre-Qyzkumsky - Lower Cretaceous deposits (Fig. 2).

Gas and oil. In the 60-70s of the last century, geological exploration work was carried out on a regional scale to search for oil and gas in the Bukhara-Khiva basin. Within its limits, 44 fields have already been identified, with gas and gas condensate deposits in the Cretaceous (IX, X, XI, XVa, XII, and XIII productive horizons) and Jurassic sediments (XV, XVa, and XVI productive horizons).

Hydrogeological characteristics. During the exploration, hydrogen sulphide waters in some gas and oil-bearing fields were also identified. Bukhara steps. The Kharaktay oil and gas field hydrogen sulfide in the stratum waters of the XV, XVa and XVI horizons was found 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 horizon XIII is present in the range from 62 mg / l (well 114) to 90 mg / l (well 27). The Uchkyr gas field, hydrogen sulfide in the reservoir waters of the XV horizon is in the range from 120 mg / l (well 28) to 132 mg / l (well 18). At the Karim deposit, the amount of hydrogen sulfide in the stratal waters ranges from 97 mg / l (well 5) to 115 mg / l (well 3).

Chardjou steps. At the Kulbeshkak deposit, hydrogen sulfide in the stratum waters of the XVI horizon was found in amounts from 99 mg / l (well 21) to 154 mg / l (well 16). At the Dengizkul-Khauzak deposit, industrial accumulations of gas are confined to the XV horizon of Callovian-Oxford deposits of the upper Jurassic. In the formation water there is dissolved hydrogen sulfide in the range from 14 mg / l

(well 9Dk) to 537 mg / l (Well 3Dk). The industrial gas content of the Urtabulak structure, the amount of dissolved hydrogen sulfide in the 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 reservoir waters of the XV horizon varies from 99mg / l (well 7) from 170 mg / l (well 17). The obtained hydrochemical parameters (the content of hydrogen sulfide and microcomponents in the reservoir waters), based on the results of the tested intervals of oil and gas wells, show the formation and distribution of hydrogen sulfide in various concentrations in the reservoir waters in almost all gas and oil fields of the Bukhara-Khiva basin.

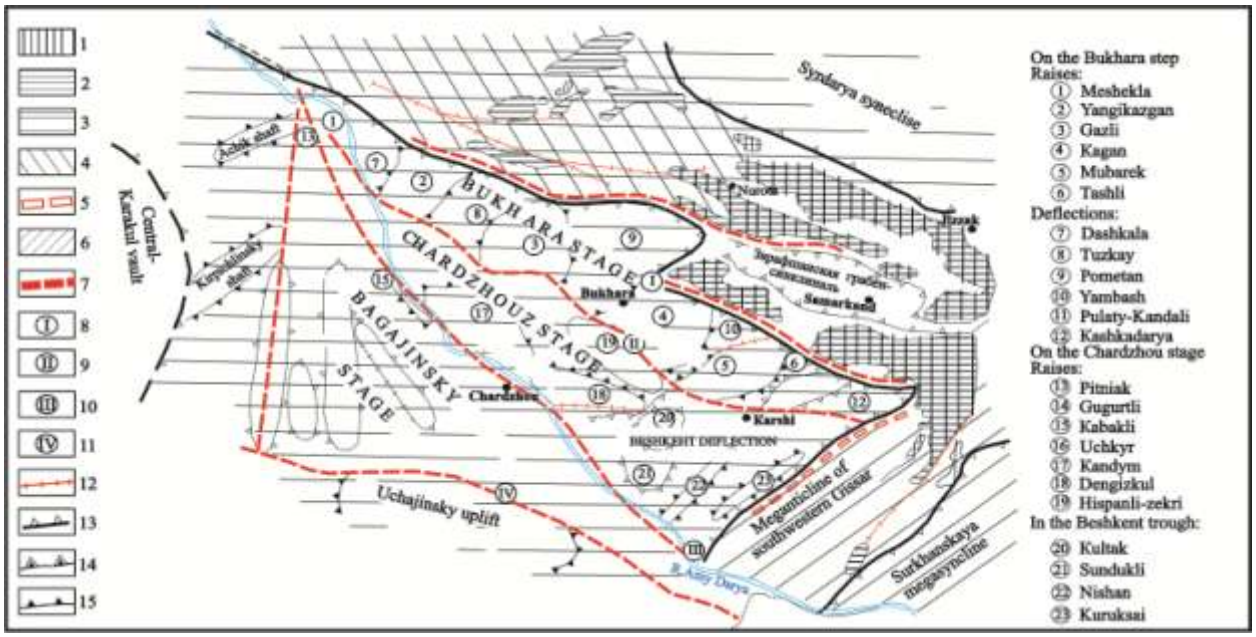

Fig. 2. Tectonic map of the Bukhara-Khiva oil and gas region. Compiled by AG Babayev

1-fold systems composed of base structures with highly or relatively high elevated complex of basement rocks exposed; 2-exits to the surface of the folded foundation deposits; 3-Turan plate of epipaleozoic platform area; 4-Kyzylkum zone of arch-horst uplifts of the basement and gentle structures with a sharply reduced and thin sedimentary cover; 5-transverse deep break separating the plate from the post-platform activation area; 6-area post-platform activation; 7-depth, vapor-gradient (step-forming) faults; 8-system of pre-layered pre-kyzkumkh faults; 9-Bukhara fault; 10 Amudarya fault; 11-Repetek fault, 12-other faults of large and medium length; 13-border structural elements of the first order; 14-border of the second order structural elements; 15-border third order structural elements.

RESULTS

Geological and structural factor. In the northern part of the Bukhara step, the base of the Upper Jurassic deposits lies at a depth of (-900) to (-1600) m in absolute elevation. In the eastern (Pl. Yakkasaray) and southern (Pl. Karakum, South Muborek, Northern Maimanak) deposits are submerged up to (-2000) m. West Tashly is absent from Lower Middle Jurassic sediments. All existing gas-oil fields are asymmetrical brachy-anticlinal structures. Almost many anticlinal structures that are located in the eastern part of the Bukhara step intersect tectonic faults directed to the northeast (Fig. 3).

Hydrogen sulphide waters with an average concentration of Cretaceous sediments in reservoir waters XII and XIII were found in the Gazli oil and gas field. The deposit is confined to an asymmetrical anticlinal fold of sublatitudinal strike. The fold in the south wing is complicated by a fault. The sole of the productive horizon lies at a depth of -1200m.

In the Karaktay oil and gas field, hydrosulphuric waters were found in water-bearing formations XII, XIII of gas bearing horizons of Cretaceous sediments and XV and XVa of oil-bearing horizons of Jurassic deposits. The Karaktay field is an asymmetrical northwesterly brachyanticline. A longitudinal tectonic fault passes through it. The sole of the XV-productive horizon lies at a depth of (-400) m in absolute value. The productive horizon consists of strong, cryptocrystalline limestones with anhydrite beds Fig. 4.

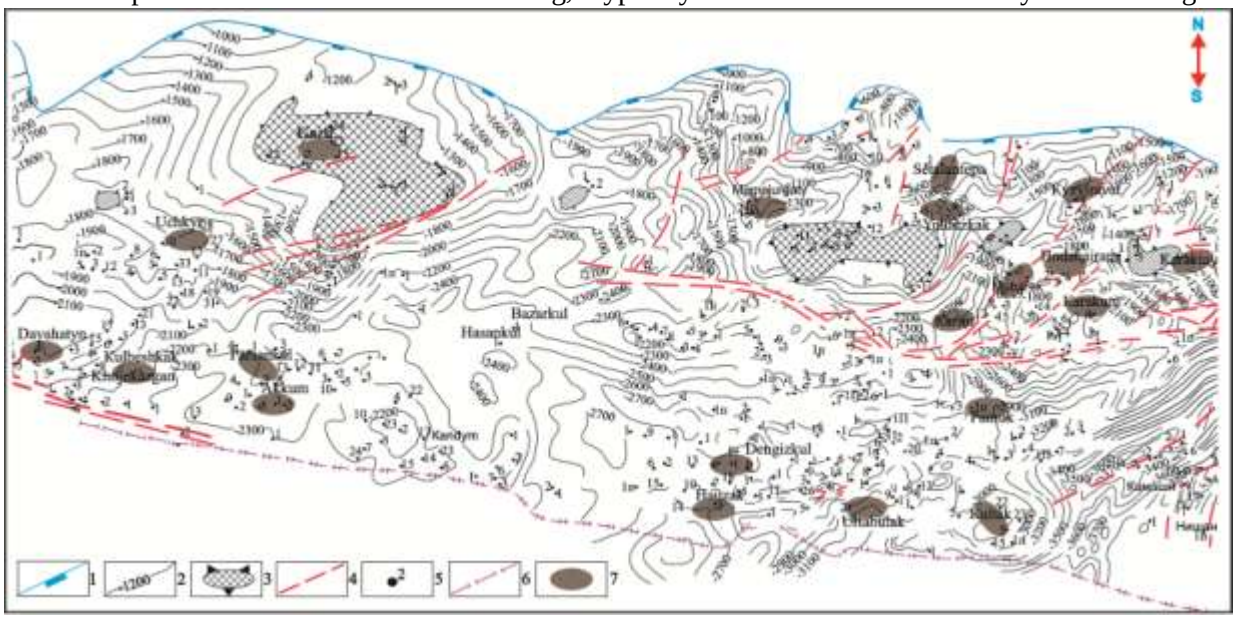

Fig. 3. Structural map of the roof of the Middle Jurassic terrigenous deposits of the Bukhara-Khiva region, with the selection of promising areas for hydrogen sulfide waters. Compiled by R.A. Gabrilyan (IGIRNIGM OJSC, 2004). 1 - boundary of the distribution of Lower Middle Jurassic sediments; 2 - absolute mark of the roof of the Middle Jurassic deposits (the soles of the XVI - horizon); 3 - areas of the absence of Lower Central Jurassic sediments; 4 - tectonic disturbances; 5 - exploration wells; 6 - state border; 7 - gas-oil field, which detected hydrogen sulfide water.

At the Chardzhou stage, the Upper Jurassic basement lies at a depth of (-2000) m (Kulbeshkak Square) to (-3000) m (Kultak Square) in absolute value. In the southeastern and eastern parts, these deposits sink to a depth of (-3800) m (Pl. Northern Nishan). All existing gas and oil fields are asymmetric anticlinal structures. However, intersecting tectonic faults are absent at the Chardzhou stage, with the exception of deposits in the eastern part (Beshkent Square, Karakyr and Nishan).

At the Dengizkul deposit, industrial gas accumulations are confined to the XV horizon of Callovian-Oxford deposits of the Upper Jurassic. Although the deposit has a single gas-water contact, it consists of two floors. The bottom of them is formed by several unseparated impermeable layers of layers of granular reservoirs filled with gas. The upper one, on the contrary, is made up of a series of thin reservoirs separated from each other by poorly permeable carbonate rocks. Low-thickness reservoirs consist of pore limestone with anhydrite beds (carbonate-sulphate pack). The Kimeridi-Titon section is represented by anhydrite and rock salt stratum, whose thickness ranges from 350 to 636 m (Fig.5).

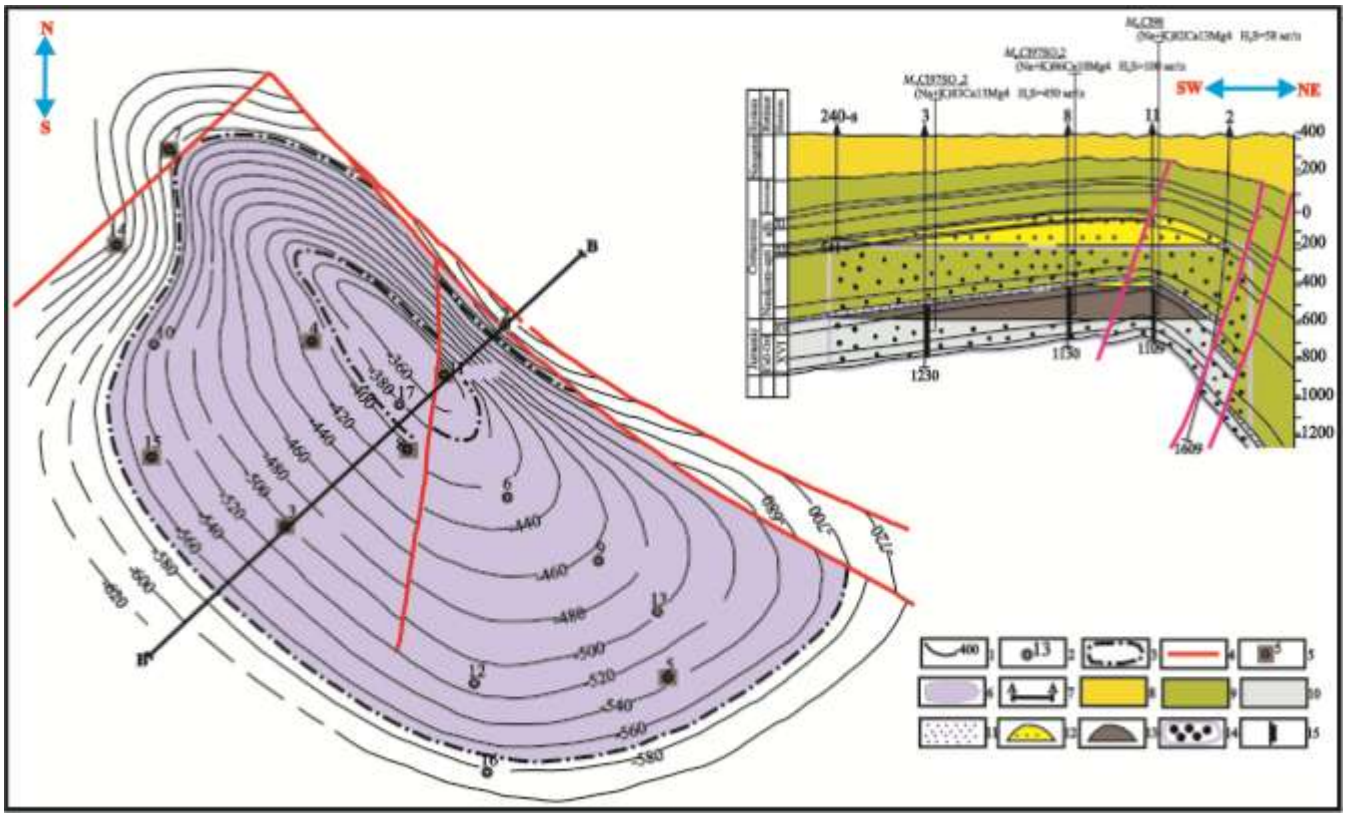

Fig. 4 Map of the distribution of hydrogen sulfide water in the XV gas-bearing horizon of the Jurassic deposits of the Karactay gas and oil field and geological and hydrogeological section. Compiled by M.R. Zhuraev, using materials by A.A. Bogdanov (1966). 2017. 1-iso-gypsum on the roof of the XV-horizon; 2 exploration wells; 3 -primary oil-bearing contour; 4 - rupture violation; 5 - wells with hydrogen sulfide water; 6 - identified contour distribution of hydrogen sulfide water; 7 - geological profile; 8 - neogenic system; 9 - chalk system; 10 - Jurassic system; 11 - angdritas; 12 - gas reservoir; 13 - oil reservoir; 14 - carbonate reservoir saturated with hydrogen sulfide water; 15 - tested intervals.

DISCUSSIONS

Bukhara step. There is a longitudinal tectonic violation in the Karaktay oil and gas field, due to which there are thrust and thrust faults, i.e. there is a displacement of the layers. The studied productive oil reservoir, where hydrogen sulfide waters are found, lies at a depth of from -200 to -1000 m in absolute value. It was revealed that all elements of the structures create the possibility of the formation of hydrogen sulfide waters in this structure. Due to the longitudinal tectonic disturbances, hydrodynamic processes occur. The guide layers of the water from the northeast become water-bearing, and as a result, they unload in the area of faults, as well as infiltration waters seep to the oil-bearing horizons. It has been established experimentally that in the process of infiltration water exchange for a long geological time, dissolved free oxygen penetrates to considerable depths (up to 2 km and more) and spreads through permeable formations to a distance of tens of kilometers (Germanov, 1955; Zhuraev, 2016). In oil fields, where hydrogen sulphide waters are formed, the productive horizon lies close to the surface of the earth, which provides it with oxygen and enhances the process of sulfate reduction due to the infiltration of infiltration water through tectonic faults. In the evaporite (calcareous and gypsum) rocks, an oxidative

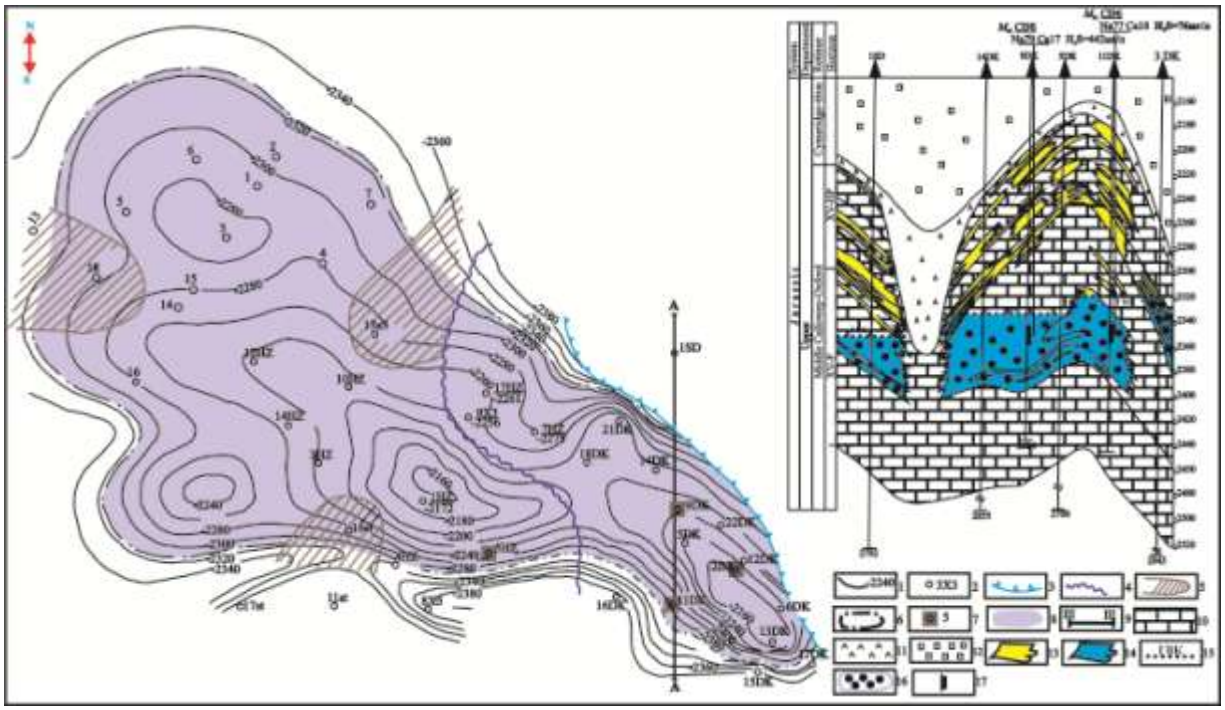

Fig. 5 Map of the distribution of hydrogen sulfide water in the XV gas-bearing horizon of the Jurassic sediments of the Dengizkul gas-bearing field and geological and hydrogeological section. Compiled by M.R. Zhuraev, using materials by G.I. Mogilevsky (1975). 2017. 1 - iso-gypsum on the roof of the XV-HP horizon; 2 - exploration wells; 3 - border reef; 4 - border transition of reef limestone with layered; 5 - zone deterioration of reservoir properties of horizon XV-HP reservoir rocks; 6 - gas circuit; 7 - wells with hydrogen sulfide water; 8 - identified contour of hydrogen sulfide water distribution; 9 - geological profile; 10 - limestone dense, impenetrable; 11 - angdritas; 12 - salt; 13 - carbonate sulphate pack saturated with gas; 14 - granular reservoir filled with water; 15 - gas contact; 16 - granular carbonate reservoir saturated with hydrogen sulfide water; 17 - tested intervals.

reaction occurs, which is carried out due to the leaching of sulphate-containing strata. In the oil-bearing layer, a reducing reaction occurs with hydrogens with the participation of sulfate-reducing bacteria. As a result, hydrogen sulfide waters are formed on the basis of the biochemical process.

Chardzhou stage. Almost all deposits are brachianticline sublatitudinal strike. Gas deposits are formed in the reef zone. Gas-water-bearing rocks in the reef zone consist of dense impermeable limestones with interlayers in the form of packs of granular, fractured, porous and loose limestones saturated with gas and water. Above it is overlapped by a thick anhydrite stratum main fluid stop. The sole of the XV-productive horizon lies closer to (-2000) m in absolute value. All gas condensate deposits are presented in the form of closed asymmetric anticlinal folds, in which there are no tectonic disturbances (Fig. 3).

It is necessary to identify from where the hydrogen sulfide in the composition of formation waters productive horizon Uchkyr gas and oil field, the Karakum, Karim, Hodzhihayram, Mamadzhurgaty on stage and Bukhara Urtabulak, Kulbeshkak, Batteries, Parsankul, Kultak, Kandy Dayahatyn, Dengizkul Chardzhou stage Bukhara-Khiva pool? For example, Dengizkul gas field can be considered. Productive horizon lies in sufficient depth (more than 2000m). From the top overlaps powerful anhydrite strata. The carbonate sulphate pack is saturated with gas. Produced water is common in pore and loose granular

limestone. The reservoir pressure is in the range of 250-300 atm and the reservoir temperature is about 90-100 ° C. Based on the generalization of the identified signs and taking into account the results of experiments on the interaction of methane and sulfate salts, as well as the developed three-dimensional model for the formation of hydrogen sulfide water, the following conclusions were made: due to the high pressure and temperature in the carbonate-sulphate pack, an oxidizing process is observed, as well as with methane a reducing reaction occurs. As a result of the thermochemical process of the productive horizon, hydrogen sulfide water is formed. Hydrogen sulfide water is formed on the basis of the thermochemical process in the remaining gas condensate field.

FINDINGS

In the oil fields of Karaktay and Gazli, where hydrogen sulfide waters are formed, the productive horizon lies close to the surface of the earth, which provides it with oxygen and enhances the process of sulfate reduction due to the infiltration of infiltration water through tectonic faults in an open asymmetric structure. In the evaporite (calcareous and gypsum) rocks, an oxidative reaction occurs, which is carried out due to the leaching of sulphate-containing strata. In the oil-bearing layer, a reducing reaction occurs with hydrogens with the participation of sulfate-reducing bacteria. As a result, hydrogen sulfide waters are formed on the basis of the biochemical process.

At the Dengizkul gas field, due to the high pressure and temperature in the carbonate-sulphate pack, an oxidative process is observed, as in methanes, the reduction reaction occurs at a depth of more than 2000 m in a closed asymmetric structure. As a result of the thermochemical process of the productive horizon, hydrogen sulfide water is formed.

The formation of hydrosulphuric underground waters of the gas and oil field of the Bukhara-Khiva basin in different structures was revealed: - in the form of open asymmetric anticlinal folds, in which there are tectonic faults; - in the form of closed asymmetric anticline folds, in which there are no tectonic disturbances.

The areas according to the nature of the formation of the hydrogen sulphide underground waters of the gas and oil fields of the Bukhara-Khiva basin were identified: due to the biochemical process it is formed in the eastern (Karaktai) and central (Gazli) parts of the Bukhara stage; - due to the thermochemical process, it is formed in the southeastern part (Karim, Karakum) and the southwestern part (Uchkyr) of the Bukhara step, as well as the whole part of the Chardzhou step (Dengizkul) of the Bukhara-Khiva basin.

The presence of specific geological and structural features during the formation of hydrogen sulphide water is revealed: for the implementation of the biochemical process - an open asymmetric structure, the presence of a longitudinal tectonic disturbance, productive horizons closer to the surface of the earth; for the implementation of the thermochemical process - closed asymmetric structure without tectonic disturbance, productive horizons more deep.

The remaining geological factors (lithofacies, hydrodynamic, geochemical conditions and geothermal) during the formation of groundwater sulphide mineral water must be studied and considered. When searching for the distribution of hydrogen sulfide water in a particular region, it is necessary to analyze the complex orders of the entire geological factors. After summarizing the presence of specific natural features, we can recommend a promising area for the distribution of hydrogen sulfide mineral groundwater for the production of detailed geological exploration.

REFERENCES

Germanov AI (1955). Oxygen of groundwater and its geological significance. *News of the Academy of Sciences of the USSR. Ser. Geology,* **6** 70-81.

Zhuraev MR, Djuraev RE (2014). Justification of promising areas of hydrogen sulfide water in the developed oil fields (using the Cimion structure as an example). *Exploration and protection of mineral resources.* **10** 52-57.

Zhuraev MR, Bakiyev SA, Nagevich PP, Kulichkina MA (2015). The main groups of hydrogen sulfide waters, their chemical composition and genesis in the oil fields of the Fergana depression. *Bulletin of Voronezh State University. Geology.* **2** 109-116.
Zhuraev MR, Bakiyev SA, Tursunmetov RA (2015). The characteristic hydrogeochemical situation of hydrogen sulfide-containing oil and gas fields on the southern side of the Fergana depression. *New ideas in earth sciences: T. XII / Intern. scientific-practical conf. - M .: Russian State Geological and Exploration University* 328-329.
Zhuraev MR (2016) Refinement of geostructural and hydrodynamic factors during the formation of hydrogen sulphide water in the Surkhandarya megasyncline. *Exploration and protection of mineral resources* **4** 37-43.
Plotnikova GN (1981). Hydrogen sulfide waters of the USSR. *M .: Nedra* 15-25.
Carbajo JM (2014). Evaluación de los cambios en la piel tras la aplicación de cosméticos elaborados a partir del sedimento de las aguas minero-medicinales Lanjarón-Capuchina mediante métodos de bioingenieria cutánea [Ph.D. thesis] Universidad Complutense de Madrid *[Google Scholar]*.
Carbajo JM, Maraver F (2015). Hydrogen sulfide and health. New insights. *Proceedings of the IV Congreso Iberoamericano de Peloides (IV CIBAP BOI '15), Caldes de Boi, Spain. 93–105. [Google Scholar]*
Yunjiao Fu, Wolfgang van Berk, Hans-Martin Schulz (2016). Hydrogen sulfide formation, fate, and behavior in anhydrite-sealed carbonate gas reservoirs: A three-dimensional reactive mass transport modeling approach. *AAPG Bulletin* **100 (5)** 843-865.