Aqueous Dispersion Halos of Hydrocarbon Deposits within the Southern Regions of West Siberia

A V Chernykh1, a)

1Federal State Budgetary Scientific Institution Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch of Russian Academy of Sciences, 630090, Novosibirsk, Koptug ave. 3

a)Corresponding author: ChernykhAV@ipgg.sbras.ru

Abstract. For the first time the features of regional and local hydrogeochemical background and hydrogeochemical anomalies was identified in the contiguous zones of hydrocarbon deposits. It was established the statistical patterns of behaviour of the main macro and micro components, water-dissolved gases and gas saturation at the distance from water-oil and gas-water contacts. The hydrogeological model of 37 reference hydrocarbon fields are made and in the first variant schemes of their water halos of dispersion are proposed. It has been established that a comprehensive interpretation of the available hydrogeochemical materials, based on statistical analysis methods, allows to substantiate the direction of prospecting for oil and gas with a high degree of reliability. The most reliable hydrogeological criteria are gas, since they are the most active components of the "water-rock-gas-organic matter" system.

1. Introduction

The method for oil and gas searching on hydrogeochemical data along with geophysical and geochemical methods become more actual. This puts high demands on the criteria for the detection and interpretation hydrogeochemical anomalies and the determination of the prospects for the area under study. Geochemical processes of accumulation, dispersion and migration of microcomponents in the sedimentary deposits of the basin acquire new features after the formation of hydrocarbons in the reservoir, the main one of which is the mass transfer in the accumulation-rock-water system.

The regularities of changes in the composition and concentrations of microcomponents in ground water when passing from empty structures to contour and then to marginal zones of oil and gas deposits were marked many times in the works of E.A. Bars, O.A. Marshaev, V.M. Matusevich, D.A. Novikov, O.I. Serebryakov et al. [1-19] This points to the fact that hydrocarbon deposits are geochemically not inert during hydrocarbon income into traps and during the subsequent time of their existence. They are in complicated interactions with the surrounding rocks and stratal water. One of the most important factors of these interactions is geochemical scattering of the components of deposits. These processes take place in the vertical and lateral directions in the gaseous and liquid phases into stratal water and host rocks of the deposits, as well as into the caps. Scattering processes are to a high extent determined by the same factors as those governing the composition of oil and gas in deposits. The major geochemical result of scattering is the formation of the zone of recovery of the rocks and aqueous aureoles of scattering of oil and gas deposits. The formation of aqueous scattering aureoles is connected mainly with diffusion processes, which is evidenced by rather clear differentiation of scattering of different groundwater
components depending on their mobility. An increase in the number of indices under analysis, the necessity to take into account various interconnections of these indices with the spatial regularities of their distributions bring about the use of the mathematical methods to describe the aureole space and determination of the promising nature of geological objects under study.

For the quantitative characteristic of hydrogeochemical indicators in the hydrocarbons searching are used the terms "background" and "anomaly" [7, 10, 14, 18, 20-22]. The hydrogeochemical background and anomalies depend on the scale of the forecast and are ranked into regional, zonal and local.

Multimodal distribution model seems the most appropriate values for the content of chemical elements in the water and makes it quite frequently to estimate the minimum anomalous element content of the material testing without special selection of background samples.

As a first approximation, the observed distribution of chemical elements in geological objects is considered as the distribution of random variables, and various methods of mathematical statistics are used for their processing. In the geological literature, the normal distribution function is used to distribute the frequencies of occurrence of element concentrations.

The object of research was groundwater of oil and gas bearing deposits within the southern regions of

![Map of West Siberia](image.png)

Western Siberia (Fig.1). The data bank of the actual material contained information on the test results and hydrogeochemical testing of 1374 objects.

**Figure 1.** Location of the studied area within West Siberia. 1 – administrative boundaries. Fields: 3 – oil, 4 – oil–gas–condensate, 5 – gas–condensate and condensate; Tectonic elements: 6 – negative, 7 – positive.

Groundwater and brines of the upper part of the Paleozoic aquifer complex are predominantly chloride sodium type (according to S.A. Shchukarev). The total mineralization of groundwater varies from 10 to 100 g/dm³. In the section predominates groundwater of sedimentogenic genesis with mineralization ranged from 30 to 60 g/dm³. The waters with the highest mineralization are characteristic of the Zapadno-Luginetskaya, Ostaninskaya, Archinskaya, Kalinova, Krylovskaya, Verkh-Tarska and Maloichskaya areas. Slightly saline waters with mineralization less than 10 g/dm³ of chloride-hydrocarbonate sodium composition are distributed locally (near water-oil contacts) in Yuzhno-Tambaevskaya, Verkhne-Kombarskaya and Severo-Luginetskaya areas.

The appropriate growth of the main salt-forming components was revealed with an increase in the total mineralization of groundwater. Statistical analyse of hydrogeochemical data allowed to establish the
characteristics of the hydrogeochemical background and anomalies. Groundwaters of pre-Jurassic complexes are characterized by a chloride sodium composition with a total mineralization of 40-45 g/dm³. The content of \( \text{HCO}_3^- \) does not exceed 700 mg/dm³, \( \text{SO}_4^{2-} \) – 55 mg/dm³, \( \text{Na}^+ \) – 14,8 g/dm³, \( \text{I}^- \) – not higher than 10,0 mg/dm³, \( \text{Br} \) up to 110,6 mg/dm³.

For example, within the upper part of the Paleozoic aquifers complex, nine types of hydrogeochemical anomalies have been identified and outlined (mg/dm³): 1 – \( \text{I}^- > 25 \), 2 – \( \text{Br} > 150 \), 3 – \( \text{B} > 30 \), 4 – \( \text{SiO}_2 > 100 \), 5 – \( \text{Rb} > 1 \), 6 – \( \text{Sr} > 450 \), 7 – \( \text{Zn} > 2 \), 8 – \( \text{Mn} > 2 \), 9 – \( \text{Li} > 7 \).

Most anomalies are confined to local uplifts with identified hydrocarbon deposits. The highest iodine concentrations up to 37,0 mg/dm³ were found in the upper Devonian carbonates in the interval 3116-3159 in well Selveykinskaya 2, bromine - more than 250 mg/dm³ were detected on Gerasimovskaya and Krylovskaya areas; boron - more than 40 mg/dm³ were found in brines on the Maloych, Urmansk and Tambayev areas. Among alkaline elements, the highest concentrations of rubidium above 1 mg/dm³ were detected at Kalganak, Zapadno-Ostaninskaya, Gerasimovskaya, Yuzhno-Tambaevskaya, Shirotmaya, Kulginskaya, Solonovo and Zarechnaya areas. Lithium concentrations of more than 7 mg/dm³ were detected at the Severo-Ostaninskoye, Ostaninskoye and Gerasimovskoye fields, as well as in the Selveykinsky and Kalganakskoye areas. Among the alkaline earth elements, the anomalous \( \text{Sr} \) values are noted in the brines at the Urmanskoye and Zapadno-Ostaninskoye deposits, as well as at the Kulginsky, Mirny and Selveykinskoye areas. High zinc concentrations are noted in the groundwaters and brines in the Chuzik-Chizapska oil and gas accumulation zone: Tambayevskoye, Gerasimovskoye, Yuzhno-Tambaevskoye, Urmanskoe, Archinskoye, Severo-Kalinovoe, and Nizhne-Tabaganskoye. The highest concentrations of manganese were recorded in the waters of the Nizhne-Tabagansk and Urmanskoye deposits. In general, all identified hydrogeochemical anomalies are confined to the central and northern part of the studied region [9, 17].

The gas saturation of groundwater varies within a significant range of 0,1-6,0 l/l, naturally decreasing as the aquifers are sunk, and as they move away from the water-oil and gas-water contacts. The water-dissolved gases have a methane composition with an average content of 85,90 vol.%. In the water-soluble gases, the role of methane homologues depends on the closeness of the gas-water and water-oil contact, and the value of \( \sum_{\text{homologues}} \) varies from 1,23 to 18,15 vol.% with average content 4,71 vol.%. The content of \( \text{N}_2 \) does not exceed 31.00 (Sibkraevskaya area), and in the overwhelming majority of cases 5.00% by volume, all other gases except heavy hydrocarbons are contained in smaller quantities.

The highest content of \( \text{N}_2 \) reaches 31,00 at Sibkraevskaya area, while in other areas the content does not exceed 5.00 vol.%, all other gases except heavy hydrocarbons are contained in smaller quantities. Other gases, except heavy hydrocarbons, contained in even smaller quantities.

During this work the 37 hydrogeological models of reference hydrocarbon deposits of the North-Kalinin, Kalinovoe, Nizhne-Tabagansk, Yuzhno-Tambayevskoye, Severo-Kalinovoe and other deposits have been compiled. The behavior of chemical elements, water-soluble gases and water-soluble organic matter has been established as they move away from water-oil contact. Thus, in the near-border zone waters of the Severo-Kalinovoye area (Fig. 2) high gas saturation values up to 1,7 l/l are observed, while in the wells behind border zone it is 0.9 l/l. The value of the background gas saturation is 1.0 l/l. As we approach the reservoir, an increase in the content of homologues of methane, naphthenic acids, nitrogen, helium, and other elements are observed, which directly or indirectly indicate the presence of hydrocarbon deposits. Reducing the concentrations of the above listed components as you move away from the water-oil contact is also observed up and down the section.

A detailed analysis and interpretation of all materials of hydrogeological materials, including the revealed deposits in Archinsk, Kalinov, North Kalinov, Tambayev, Nizhne-Tabagansk and other local uplifts, was based on the theoretical propositions developed by A.A. Kartsev, A.E. Kontorovich, V.M. Matusевич, A.D. Nazarov, N.N. Rostovtsev and others [1, 3, 4, 6, 7, 9, 17]. A direct dependence of the decrease in the value of the total gas saturation, and, first of all, the concentrations of heavy hydrocarbons as far as distance from water-oil contacts is established (Fig. 3). The relationship between existing hydrocarbon deposits and hydrogeochemical anomalies is traced. Analysis of hydrogeochemical sampling
data on empty structures and structures on which oil or gas inflows have been obtained has made it possible to construct probabilistic forecast curves for the presence of a deposit in the study of new objects by the content of methane homologues [6, 7, 10, 14]. Efficiency of recognition of productive structures was 30-40% for microelements and more than 80% for concentrations of water-soluble gases. According to the total number of abnormal concentrations characterizing the composition of formation water and water-soluble gases and a number of other characteristics, the discovered hydrocarbon deposits were confirmed. The obtained results make it possible to substantiate the direction of oil and gas prospecting for the discovery of new deposits based on the available reference sample within the Mesozoic and Paleozoic complexes of the southern regions of Western Siberia.

Figure 2. Hydrogeological model and scheme of aqueous dispersion halos of paleozoic deposits of the Severo-Kalinovoe field.

1 – groundwater chemical composition (M – Total dissolved solids g/dm3, Φ – value of total gas saturation of stratal water, l/l), 2 - the direction of migration of the components of the deposit, rock: 3 -
gas-saturated, 4 - oil-saturated, 5 - zone of water dispersion halo, 6 - water-saturated rocks, 7 - well and its number, 8 - tectonic disturbances.

Figure 3. Gas diffusion haloes of hydrocarbon deposits in the southern regions of western Siberia. Complexes: 1 – upper Jurassic, 2 - lower and middle Jurassic, 3 - paleozoic.

Acknowledgments
The research was carried out with the financial support from the Russian Foundation for Basic Research and the Government of the Novosibirsk Region within the framework of the scientific project № 17-45-540086.

References
[1] Rostovtsev N N Geological structure and prospects of oil and gas potential in the southern part of the West Siberian Lowland (Gosgeoltekhhizdat, Moscow, 1954), pp 120-167
[2] Bars E A Hydrochemical indexes of oil content and hydrochemical methods of oil deposits search (Geology of oil, 1957), pp 13-18
[3] Kartsev A A Theoretical bases of oil and gas hydrogeology. (Nedra, Moscow, 1992), p 320
[4] Matusevich V M, Rylkov A V, Ushatinsky I N Geofluidal systems and problems of oil and gas content of the West Siberian megabasin. (Oil and Gas University, Tyumen, 2005), p 340

[5] Shvartsev S L, Novikov D A 2004 The nature of vertical hydrogeochemical zoning of petroleum deposits (exemplified by the Nadym-Taz interfluve, West Siberia) Geologiya i geofizika 45(8)1008–1020

[6] Nazarov A D Oil and gas hydrogeochemistry of the southeastern part of the West Siberian oil and gas province (Idea-Press, Moscow, 2004), p 285

[7] Novikov D A, Lepokurov A V 2005 Hydrogeological conditions of petroleum potential deposits on the structures in the southern part of Yamalo-Karskoje depression Geologiya Nefti i Gaza (Oil and gas Geology 5 24-33

[8] Bukaty M B, Novikov D A, Ryzhenko B N, Shvartsev S L 2005 Fundamental problems of modern hydrogeochemistry Geochemistry International 43(8), pp 826-829

[9] Novikov D A, Shvartsev S L 2009 Hydrogeological conditions of the Pre-Yenisei petroleum subprovince Russian Geology and Geophysics 50(10) pp873–883

[10] Kokh A A, Novikov D A 2014 Hydrodynamic conditions and vertical hydrogeochemical zonality of groundwater in the Western Khantanga Artesian Basin Water Resources 41(4) pp 396-405

[11] Novikov D A, Sukhorukova A F 2015 Hydrogeology of petroleum deposits in the northwestern margin of the West Siberian Artesian Basin Arabian Journal of Geosciences 8(10) pp 8703-8719

[12] Trifonov NS, Novikov D A, Yamskikh A A 2015 Hydrogeological prerequisites for industrial waste injection during the development of priority area of the Yurubcheno–Tokhomo field Water Resources 42(7) pp 909–921

[13] Novikov D A, Trifonov N S 2016 Hydrogeologic Implications of Industrial Effluent Disposal of the Yurubcheno-Tokhomo Field (Siberian Craton, Russia) Arabian Journal of Geosciences 9(1) pp 1-14

[14] Novikov D A 2017 Hydrogeological conditions for the presence of oil and gas in the western segment of the Yenisei-Khatanga regional trough Geodynamics and Tectonophysics 8(4) pp 881-901

[15] Novikov D A Hydrogeochemistry of the Arctic areas of Siberian petroleum basins Petroleum Exploration and Development 44(5) 780-788 (2017).

[16] Novikov D A, Saraev M M 2017 Hydrogeochemistry of the Arctic areas of Siberian petroleum basins Shiyou Kantan Yu Kaifa/Petroleum Exploration and Development 44(5) pp 737-744

[17] Dultsev F F, Novikov D A 2017 Geothermal zoning of the Predenisey sedimentary basin Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering 328(11) pp 6-15

[18] Novikov D A 2018 Oil and gas fields exploration in the Jurassic-Cretaceous deposits of Yamal Peninsula based on the water - gas equilibrium Oil Industry 4 pp 16-21

[19] Novikov D A, Sadykova Y V, Chernykhh A V, Dultsev F F, Sukhorukova A F 2018 Paleohydrochemistry of Jurassic and Cretaceous deposits in arctic regions of Western Siberia IOP Conference Series: Earth and Environmental Science 193(1) 012051

[20] Novikov D A 2018 Theoretical substantiation of application of the hydrocarbon accumulation prospecting technique in Western Siberia based on the study of water-gas equilibria IOP Conference Series: Earth and Environmental Science 193(1) 012048

[21] Novikov D A 2018 Genetic classification of subsurface waters and brines of Arctic regions of Siberia IOP Conference Series: Earth and Environmental Science 193(1) 012049

[22] Bukaty M B, Novikov D A, Ryzhenko B N, Shvartsev S L 2005 Fundamental problems of modern hydrogeochemistry Geochemistry International 43(8) pp 826-829