EVALUATION OF THE APPLICABILITY OF BIODEGRADATION MARKERS FOR IDENTIFICATION OF THE BYPASSED OIL ZONES

Prof. Danis Nurgaliev
Rustam Ziniukov
Vladislav Sudakov
Nil Fakhriev
Aleksandr Averyanov

Kazan Federal University, **Russia**

ABSTRACT

The presented work highlights the general geochemical aspects and considers the theoretical basis of the method of geochemical monitoring of oil fields using the indicator of the quantitative ratio of organic compounds and their isomers - isobutane/butane. The object of the study are the microorganisms that can affect gas composition. The purpose of the work is to study the effect of microorganisms on the biodegradation of oil. The peculiarity of the oil composition will be used to search, delineate bypassed oil areas, and to monitor development of the field. Biodegradation of oils negatively affects its properties, thereby increasing the cost of its extraction and processing. In this regard, the study of biodegradation processes, namely, the establishment of the conditions for its course and the assessment of the microorganism activity effect on the composition of oil is an urgent task at the present time. In the course of the work, it was found that during the development of the field by the waterflooding method, the water cut of the reservoirs gradually increases and the area of the oil-water contact zone, where most of the microorganisms develop. As the intensity of field development increases, the isobutane / butane ratio increases. During the monitoring of the composition, it was noted that most of the deviations are accompanied by a noticeable change in the entire component composition of the gas. During the analysis, two large groups of anomalies were identified: anomalies associated with an increase in the gas compositional analysis and anomalies accompanied by a sharp increase in the percentage of methane in the total proportion of C1-C6.As a result of the analysis and comparison of the hydrodynamic and geochemical models of the site, maps of the density of residual mobile reserves were drawn, the most promising wells for additional development were identified.

Keywords: reservoir water flooding, oil biodegradation, bypassed oil zones, gas chromatography

RESERVOIR MICROBIOME

An anhydrous environment is an unfavorable environment for the development and life of the organism, bacteria are practically absent there. Active microorganisms live in the zone of contact between oil and water (OWC). Therefore, the first main factor that predetermines the very possibility of the course of biodegradation is the presence of OWC. Oil that is outside the OWC zone is practically not biodegradable. The strongest biodegradation is confined to the zones of the most permeable rocks within the OWC.

https://doi.org/10.5593/sgem2021/1.1/s06.113

Despite this, bacteria can be detected even above the OWC level. It is assumed that the residual water is quite sufficient for their life. However, it is important to remember that the number of active microorganisms decreases with distance from the OWC zone. [2, 3]

The second important factor of biodegradation is reservoir quality. Reservoir permeability in different directions affects both diffusion and the rate of movement of the products of biodegradation and methanogenesis from the OWC to the top of the reservoir, determines the trend of changes in the composition and properties of oil.

The spread of bacteria is also mainly temperature dependent. Most bacteria are mesophiles, the most active development of which is observed at 20-35 ° C. The upper limit fluctuates around 50-70 ° C, the lower one - -3 ° C.

Other important factors affecting the spread and vital activity of bacteria are the concentration of substances dissolved in water, salinity of formation waters, pH of the medium, chemical composition of oil and its specific gravity. [6,7]

The bacteria are quite strong at all pressures, and even a pressure of 10,000 atmospheres does not negatively affect the cell. As a result of a large number of studies and observations, it was revealed that the activity of the microflora of oil fields was detected, depending on the stage of development of the field, that the distance between wells and the intensity of oil extraction from them also does not affect the spread of bacteria in the reservoir. [8,9,10]

Bacteria feeding on normal alkanes have been found in the lower part of the oil zone, in the transition zone, and in the water. The concentration of these bacteria in the transition zone is 2 times higher than in the oil zone [2].

Long-chain alkanes are used by many bacteria. The chain length is of decisive importance: as the paraffin chain lengthens, the number of species capable of using these compounds and the activity of their use increases. Whereas Methylomonas methanica develops mainly in enrichment cultures containing only pure methane, in cultures fueled by natural gas, which includes ethane along with methane, only ethane oxidizers grow. Most ethane-oxidizing microorganisms belong to the genera Mycobacterium, Flavobacterium and Nocardia.

Scientists have also identified a larger number of species of bacteria capable of oxidizing propane and butane (Mycobacterium and Pseudomonas). Propane- and butane-oxidizing Rhodococcus are characterized by a number of physiological and biochemical features, a kind of ultrafine and antigenic structure and strictly local distribution in nature. These are the most important components of natural biogeocenosis.

The ability to assimilate branched (isobutane) and aromatic (cyclohexane, toluene, benzene) hydrocarbons was found in propane-oxidizing bacteria belonging to the genera Arthrobacter, Nocardia, Mycobacterium, Brevibacterium. [5,4]

The study of the biology of gas-oxidizing Rhodococcus is of great interest for understanding their role in the carbon and nitrogen cycles of the biosphere, as well as for solving a wide range of problems in various fields of biotechnology, from biosynthesis processes based on natural gas to direct methods of detecting oil and gas deposits.

Resistance to biodegradation decreases in the series: naphthenes, alkanes of isometric structure, alkanes of normal structure. As a rule, n-alkanes and isoalkanes undergo microbiodegradation first. This is due to the molecular structure of aliphatic compounds,

namely, the number of branches from the main chain (the more side branches from the main chain, the more resistant to biodegradation the compound. Both n-alkanes and monocyclic compounds of the composition C5-C7 have a strong in relation to the lipid membrane of microorganisms, and therefore are toxic to most microorganisms used for the biodegradation of oil. [11]

Biodegradation

Alkanes of an isometric structure are oxidized more easily than the corresponding alkanes of a normal structure, therefore, during the chemical oxidation of oil, the amount of isoalkanes decreases.

On the other hand, during the biodegradation of oils, isoalkanes are more difficult than n-alkanes to be exposed to microorganisms; therefore, the geochemical index of i-alkanes / n-alkanes in such oils has rather high values. Thus, one of the signs of biodegradation is a decrease in the content and disappearance of light n-alkanes of the C3-C15 composition. [1]

The object of study is confined to the western-central part of the South Tatar arch. The main operational object of the area is the productive deposits of the Kynovian (D0) and Pashian (D1) horizons of the Lower Frasnian substage of the Upper Devonian, represented by interlayering of sandy, sandy-silty and mudstone rocks.

The development of the field is carried out using waterflooding and is at the last stage of development, this practice has led to the fact that the deposits within the field are currently partially or completely flooded. [6]

Identification of anomalies

Identification of anomalies in the dynamics of changes in the composition of associated gas samples is one of the primary tasks of research. This is due to the fact that the gas located in the areas of undrained stagnant zones (bypassed oil areas) not subjected to the biodegradation process, which means that it differs in its composition from the gas dissolved in the oil of the flushed areas. Thus, by identifying wells with anomalies it is possible to localize bypassed oil areas.

During the analysis, two large groups of anomalies were identified: anomalies associated with an increase of pentane and hexane composition and anomalies accompanied by a sharp increase in the percentage of methane in the total proportion of C1-C6.

Abnormal deviations of "isobutane / butane" are accompanied by an increase in the content of pentane and hexane. Possible cause is gas emission from non-drained zones. (Fig.1)

https://doi.org/10.5593/sgem2021/1.1/s06.113

Figure 1. Anomalies associated with an increase in the content of heavy components

Abnormal deviations of "isobutane / butane" are accompanied by an increase in methane content. Possible reason - extremely high water cut in the sample (Fig.2)

Figure 2. Anomalies associated with an increase in methane

The main principle of the mapping was to achieve consistency between the data from the hydrodynamic model and geochemical analysis. Geochemical analysis data were taken as reference data.

An example of identifying a site with a high value of residual reserves using a set of methods is shown in the figure. Wells characterized by the presence of abnormal values of associated petroleum gas, indicating the presence of zones with a high concentration of reserves near the drainage zones, are marked in the form of green circles.

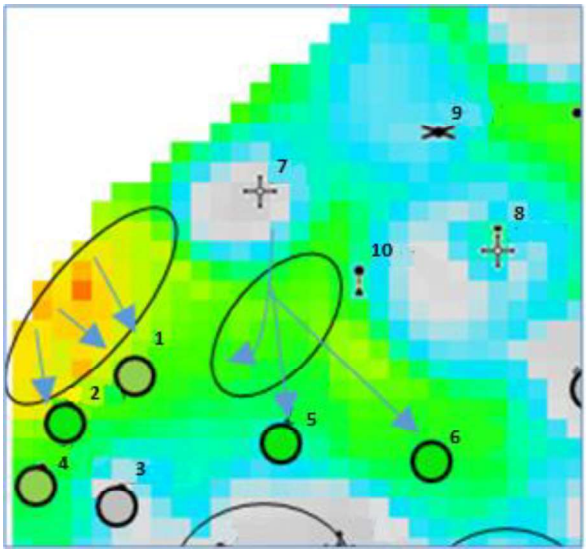

Figure 3. An example of the allocation of a zone of residual reserves according to the data of a comprehensive study of GM and HDM

Areas located in areas where, according to the results of hydrodynamic studies, the area is completely flushed and the density of residual reserves tends to zero, can be marked as promising if anomalous values of the composition of associated petroleum gas were detected in the producing wells of the area. An example of such a site is the area drained by well # 11.

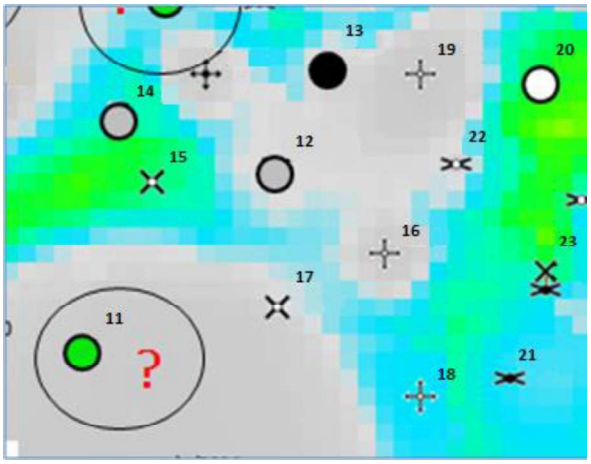

Figure 4. An example of the allocation of a zone of residual reserves according to geochemical analysis data

Areas characterized by the presence of type 2 anomalies or the complete absence of anomalies were marked as prospectless. An example of such a site is shown in the figure 5.

https://doi.org/10.5593/sgem2021/1.1/s06.113

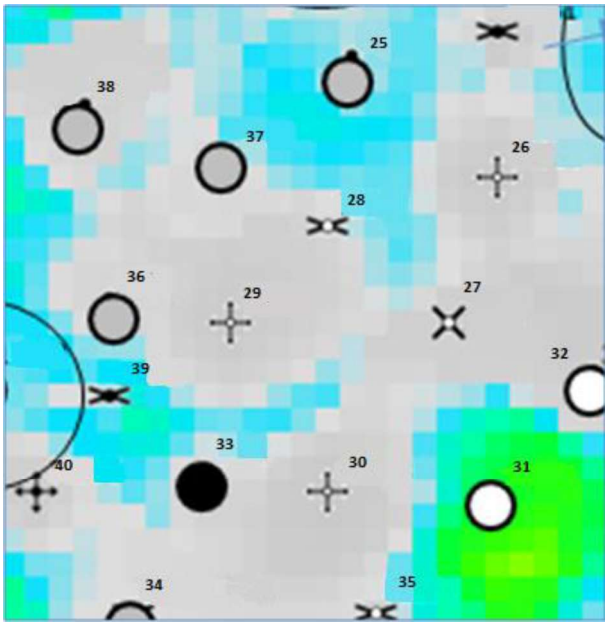

Figure 5. An example of the allocation of a zone of absence of residual reserves according to the data of a comprehensive study of GM and GM

CONCLUSION

The distribution of the isobutane/butane ratio at the border of the pilot site is traced. The results of the study show that in the process of biodegradation, the isobutane/butane coefficient has been increased.

The oil/water interface is a favorable environment for the existence and development of bacteria that feed on butane. Therefore, it can be assumed that with an increase in the water cut of production, a change in the chemical composition of the fluid occurs and the concentration of bacteria will grow, thus the isobutane/butane ratio becomes higher. The development of the field under study was carried out by the waterflooding method, which gradually led to water encroachment and an increase in the area of the water-oil zone.

As a result, anomalies were identified and divided into 2 groups associated with high levels of heavy components and associated with methane levels. After the mapping of residual reserves, wells characterized by the presence of anomalous values of the component composition were located in zones with a high density of oil reserves, which may indicate the presence of bypassed oil.

ACKNOWLEDGEMENTS

The work was carried out with the financial support of the Ministry of Science and Higher Education of the Russian Federation in accordance with Agreement No. 075-11-2019-032 of 26.11.2019 within the framework of the project " Creation of a high-tech software and hardware complex based on neural network algorithms to improve the efficiency of the development of large hydrocarbon deposits at a late stage"

REFERENCES

[1] YANG Weiwei Microbial alteration of natural gas in Xinglongtai field of the Bohai Bay Basin, China/YANG Weiwei, LIU Guangdi, GONG Yaojin, and FENG Yuan// Chin.J. Geochem.(2012)31:055–063

[2] B. Bennett The controls on the composition of biodegraded oils in the deep subsurface – Part 3. The impact of microorganism distribution on petroleum geochemical gradients in biodegraded petroleum reservoirs/ B. Bennett, J.J. Adams, N.D. Gray, A. Sherry, T.B.P. Oldenburg, H. Huang, S.R. Larter, I.M. Head// Organic Geochemistry 56 (2013) 94–105

[3] Jiang Kaixi The controls on the composition of biodegraded oils in the Liuhua11-1 Oilfield, Pearl River Mouth Basin, South China Sea/ Jiang Kaixi, He Wenxiang, Xiang Nian, Peng Li, Han Changchun, Guo Qingzheng// Chin. J. Geochem. (2015) 34(3):320–329

[4] Ivshina I.B., Pshenichnov R.A., Oboronin A.A. Propanookislyauchie Rodokokk. Sverdlovsk UNC AN SSSR, 1897

[5] Patel N, Hou C.T., Laskin A.I. et al. Oxidation of alkanes by organisms grown on C2-C4 alkanes – j.Appl. Biochem., 1983, v. 5, N 1-2. P 107-120

[6] Muslimov, R.Kh., 2003. Modern Methods of Oil Pool Development Using Flood Methods. Kazan Univ. Press, Kazan. 596 pp. (in Russian).

[7] Geomicrobiology of prospecting and development of oil fields. Sat. articles. Sverdlovsk, 1979 (USC AN SSSRE. Birshteher. Neftyannaya micobiologiya, M. Gostophezdat, 1957

[8] Dostalek M. Biologiya, (Chehoslavakiya), 1956, 2-6

[9] S. I. Rozanova, Kuznetcov M. V., Microflora neftyannyh mestorozhdenyi, M. ‘Nauka’, 1974

[10] L.D. Shturm, Trudy In-ta microbiologii AN SSSR, 1961, 9,23

[11] X.B. Wang, C.Q. Chi, Y. Nie, Bioresource Technology, 102, 7755-7761 (2011).

https://doi.org/10.5593/sgem2021/1.1/s06.113