Methodology of geochemical search for hydrocarbon deposits in lithological complexes of North-Yarudeysky rampart in Western Siberia

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Abstract. The technology of passive adsorption of hydrocarbons in soil-ground gases (more than 80 hydrocarbon compounds from ethane C₂ to C₂₀ phytane) with the use of special sorbent modules is a new and very effective method for oil and gas fields’ exploration. This technique being relatively inexpensive and easy to use for fieldwork is applied in almost all oil and gas regions of the world. In recent decades it has also been effectively used in Russia (Volga-Ural, Timan-Pechora, West Siberian and other oil and gas basins). The article presents the outcomes of geochemical explorations at the Shugin site of the Yarudeyskaya license area of the Nadym district in Western Siberia.

1. Introduction

Intensive exploitation of hydrocarbons resulting in the rapid depletion of deposits with easily recoverable reserves requires a new method of industrial deposits search and exploration, namely, deposits delineation, and grading the areas with previously established oil and gas potential. Until recently such problems were solved by applying a complex of geophysical methods, i.e. recording perturbances of natural electric and magnetic fields. However, nowadays using only geophysical methods does not meet the reliability requirements for the fossil fuels deposits prognosticating [1, 2].

More reliable industrial outcomes were obtained by geophysical and gas-geochemical methods integration. Initially gas-geochemical studies were carried out by drilling shallow wells (5–6 m deep) within a certain network with the subsequent soil sampling and extraction for being exposed to hydrocarbon analysis. It turned out later that higher quality testing results could be obtained by applying special sorbent modules in the holes with a diameter of up to 1.5 cm at the depth of 50 cm. In this case, no drilling is required and laying sorbent modules is implemented manually, which greatly reduces the cost of field work.

The methodology is based on a well-known Pearson’s theory of the so-called hydrocarbon earth depth breathing. It is the phenomenon of diffused penetration of hydrocarbons into the space above deposits in the form of microfiltration, which is confirmed by being used in numerous oil and gas fields. The main goal of geochemical studies is to forecast deep deposits of gas, oil and condensate basing on the interpretation of soil gas sampling data, which are the basis for deciphering ascending gas emanations.
2. Materials and methods

Ground gas samples are taken from a relatively shallow depth by special sorbent modules introduced into the bore holes at the depth of about 50 cm and a diameter of up to 1.5 cm for a period of 17 to 21 days depending on the season of work. The proposed system of passive adsorption of the gas fraction significantly differs from the previous one, which used 5–6-meter wells for sampling deep gases. It dramatically reduces the cost of fieldwork. All samples of ground gas are analyzed using thermal desorption with the further gas chromatographic separation and mass spectrometric detection of a wide profile of organic compounds (including the thermogenic ones) in the range of C₂–C₂₀, which enables to make conclusions concerning not only the intensity of hydrocarbon breathing but also the qualitative composition. A distinguishing characteristic of the technique is a reliable and detailed deep gases diagnosis enabling to distinguish background hydrocarbons and to categorize the gases according to the genesis, specifically, plant, microbiological, surface contamination, source rock, etc.

3. Results and discussions

Let us consider the results of applying this methodology. These results were obtained after conducting geochemical studies at the Shuginsky local uplift in the Yamalo-Nenets Autonomous Okrug in 2011. Additionally, the results were processed in 2019. Geochemical studies based on passive ground gas adsorption technology were first carried out at the Yarudeysky uplift in winter 2005–2006 along seismic profiles with a sampling step of 500 and 1000 m. One profile (transect) was passed through the Yarudeyskoye – South Shuginsky – Shuginsky uplift and detected positive geochemical anomalies interpreted as predicted hydrocarbon deposits. According to the outcomes of geochemical studies conducted within the identified anomalies, the prospects of the structure aimed to be used for drilling a prospecting well were confirmed. In 2007, a well P-5 was drilled in the Yarudeyskaya structure with regards to the results of geochemical work. An industrial inflow of gas condensate and gas with a flow rate of more than 100 thousand m³ per a day in this well was obtained when testing the interval from 3030 to 3050 m from the reservoir UN₁₂. In winter 2007–2008, geochemical studies of the Shuginsky structure over a network of 1000x1000 m with condensation of up to 500 m in the areas of the proposed wells drilling was also carried out. The set of hydrocarbon compounds in the samples at the Shuginsky uplift under study correlates with the set of similar compounds in the productive gas condensate well Yarudeiskaya 5 used as a reference.

![Figure 1. Histogram of hydrocarbon compounds significance](image-url)

Figure 1 shows a histogram of the significance of hydrocarbon compounds from ethane C₂ to phytane C₂₀ according to samples taken around the production well Yarudeiskaya 10 for determining emanations over hydrocarbon deposits. The higher the bar of the histogram, the more significant this compound is
for identifying the oil-like qualitative characteristics of emanation. This is a robust model because it is independent of one or more compounds. Such a complex characteristic of hydrocarbon models remains stable in most hydrocarbon deposits.

A mathematical projection of each sample on the axis dividing the centroid of the classes of finite members is constructed for reliable interpretation of geochemical data (oil/gas or dry class). At the same time, the dry class centroid has a zero probability of membership in the oil/gas interval while the oil/gas class centroid has a 100% probability in its interval (Fig. 2).

![Figure 2. Schematic illustration of separating centroids of model classes by the discriminant analysis method. The probability value is assigned to each sample by mathematical projection (dashed lines) on the axis of maximum separation between the final members of the model (thick line)](image)

Several maps of the object prospectivity are issued for each standard (or for a standard well Yarudeiskaya 10 and cluster analysis as in the case under consideration) in case when several reference wells are used to determine the prospectivity of a site with regards to oil and gas [3]. The results of work within the Shuginsky site are presented on geochemical probability maps (Figure 3). According to these maps, potential oil and gas deposits in the study area are elongated and submeridional. The results obtained may indicate the oil and gas potential of local structural traps within the Shuginsko-Yarudeysky small rampart. Geochemical profile (transect), passed in winter 2005–2006 from the Yarudeysky uplift through the Shuginsky and South Shuginsky uplifts confirms the local nature of the potential hydrocarbon deposits distribution separately in each structure.

The reasons for this focal distribution of geochemical anomalies have not been fully figured out. Perhaps the main role is played by the presence of small closed local uplifts with a changing lithological composition of reservoir rocks along the lateral.

Nowadays it is possible to compare all materials and make a considered conclusion about the oil and gas potential of the Yarudeysky licensed area. The linear geochemical anomalies elongated in the submeridional direction indicate the significant role of the faults of both conducting and localizing structures.

Unfortunately, the insignificant area of research prevents from estimating the localizing role of the Shuginsko-Yarudeysky small rampart as a whole.
The results of drilling exploratory wells have appeared to be essential for assessing the oil and gas potential of the Yarudeysky licensed area. In total, six exploratory wells (Yarudeyskaya 1, 2, 3, 4, and 81, 82) had been drilled in the past years before the geochemical work started and only one of them received a small inflow. Industrial flow rates were obtained following the application of the hydrocarbons passive adsorption technology in 2006 and 2008 and in all four wells (well Yarudeyskaya 5 at the Yarudeisky uplift and the wells Yarudeyskaya 7, 8 and 10 at the Shuginsky uplift) drilled before 2011. Indisputably, a rather costly drilling of deep wells in the area proved to be more effective taking into account the obtained geochemical results.

Geochemical exploration work based on the proposed methodology was also carried out at other sites in the West Siberian oil and gas basin. In addition to the Yarudeysky and Shuginsky sections considered in the article, similar work was carried out on a large number of other objects. The oil content of the structures with the revealed positive geochemical anomalies was confirmed by drilling pioneer and exploration wells. In addition, hydraulic fracturing was planned. Geochemical studies carried out at, say, the East-Yetypurovskaya structure proved to be dead-end, which led to cancelling the planned well drilling.
4. Conclusion
The article states that the considered technology of passive adsorbing soil-ground air hydrocarbons with their subsequent statistical processing (resulting in geochemical mapping of the probabilities of the forecast hydrocarbon deposits distribution in the studied area) by means of sorbent modules is a direct method for searching and exploring oil and gas fields with a fairly high reliability (up to 90%). It was used in all outlined areas of work as a means for sorting seismic structures with the objective to select the targets for exploratory drilling. Based on experience of other countries, this method can also be used at the stages of exploration and exploitation of hydrocarbon deposits for selecting the optimal location of production wells. The cost of implementing the described method per unit of work in Western Siberia is less than 25% of the cost of 2D seismic work. The minimum cost of a geochemical project does not exceed 5% of the cost of a prospecting well.

5. References
[1] Khan S D and Jacobson S 2008 Geol Soc Am Bull. 120(1/2) 95–105
[2] Schumacher D 2000 The leading edge 19(3) 258–61
[3] Suslick S B and Schiozer D J 2004 J. Pet Sci Eng 442(1–2) 1–9