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Significance of Absorbed Natural Gas for Petroleum Exploration. Ukhta-Izhma Region Case Study

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Abstract. The article offers a brief overview of geochemical methods for petroleum prospecting and testing results of the exploration method based on hydrocarbon gas content in soil. For interpretation of the materials a new criterion developed by the authors was used—the naphtide coefficient. As a result of the testing high efficiency of the method is confirmed and it lead to localizing prospects within the Ukhta-Izhma region. Use of this method can contribute to the expansion of the hydrocarbon resource base in the region and demonstrate petroleum potential of unconventional structures of the Timan ridge. Analog to this, structures of the Rocky Mountains thrust belt and other oil and gas-bearing regions in the world, might demonstrate unexpectedly high hydrocarbon potential.

1. Introduction

As early as 1929, V.A. Sokolov presented an idea of direct prospecting for oil and gas based on gas content in shallow deposits. This approach was supported by I.M. Gubkin. Sokolov's method made it possible to detect traces of individual hydrocarbons C2-C6, which was used as a basis for further research in the area.

Such research led to the development of multiple exploration methods: gas logging (A.V. Abramovich, 1933), lithogeochemical sampling (Levenson, 1934), oxidation-reduction potential method (Levenson, 1936), geomicrobiological method (Mogilevskiy, 1937), luminescence-bitumenological analysis (Schlesinger et al.), hydrochemical analysis (Sulin et al.), pedogenic method (V.A. Kovda).

Several researchers explored the possibilities of using helium (N.I. Musychenko, V.V. Ivanov et al.) and carbon isotopes (V.S. Lebedev, T.A. Krylova et al.) for petroleum exploration. A.A. Kartsev, one of the founders of geochemical prospecting, stated that most of geochemical methods are direct exploration methods, as they give indication of the presence of actual oil or gas [1].

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2. Theoretical basis for the study

In general, the history of geochemical exploration methods in Russia consists of periods of wide industry interest and periods of almost full phaseout due to uncertainty of results.

Theoretically the approach is based on the study of patterns of gas migration to the surface and physical understanding of gas diffusion and gas composition changes during migration.

Several pilot projects did not receive any further development. In 1945, for example, academy fellows P.A. Rebinder and V.A. Sokolov [2] organized sorbent-based gas survey. The method had a number of methodical inconsistencies and was not studied any further. Much later geochemists from the USA and Germany published studies on gas exploration in soil using artificial sorbents based on the same approach but with the possibility to detect a wider range of components.

The oldest well-established geochemical petroleum exploration method according to Russian scientists and the American Association of Petroleum Geologists [3, 4, 5, 6, 7] is the method of nonassociated and occluded subsurface gas analysis. Some way or other this method has been used by geochemists in all large petroleum-producing countries from the 1930s.

Methods of nonassociated gas analysis, however, has a number of significant drawbacks: 1) analysis results depend on external factors (pressure, temperature, humidity), which complicates data comparison; 2) samples have to be delivered to lab facilities as soon as possible; 3) nonassociated gas is difficult to sample and it is difficult to preserve the samples in transportation.

Studies of gas occluded in rock and soil in different regions (from Arctic and Antarctic to North Africa and East Pacific) and on numerous Russian oil and gas fields (around 30) show that this type of gas is not influenced by atmospheric conditions and provides more reliable information on gas fields. [8, 9].

3. Study results with explanation

Studies by L.S. Kondratov show that geochemical fields of adsorbed natural gas (ANG) of oil and gas deposits display arch and ring morphology and heavier hydrocarbon contents in naphtide anomalies [8]. This is clearly observed even if there are no obvious ANG accumulations over petroleum fields localized in various conditions: under salt seams, under tectonic plates or offshore [10].

The article summarizes the results of using the ANG analysis for petroleum exploration in the Ukhta-Izhma oil and gas region located in the southern part of the Timan ridge in the Timan-Pechora oil and gas province. There are several oil fields in the region: the large Yagerskoye field, the smaller Chibyusskoye and Nizhnechutinskoye oil fiels and the Vodnyy Promysel condensate field.

The Yagerskoye field is confined to the Ukhta fold of the Ukhta-Izhma swell of the Southern Timan Ridge. The sedimentary cover thickness is under 1000 m [11]. The field includes several deposits associated with the chain of local uplifts stretching from north to west. The size of a single oil-bearing contour is 37 by 6 km. The main oil deposit lies in sandstones of late Eifelian and early Frasnian strata at the depth of 120-210 m near the basis of the sedimentary cover. The deposit is layer-uplifted and lithologically limited, bounded by a fault in the north-west.

Soil in the area of the Ukhta-Izhma oil and gas region contains adsorbed methane and its homologous compounds (CH_4, C_2H_6, C_2H_4, C_3H_8, C_3H_6, iC_4H_{10}, nC_4H_{10}, C_4H_8, iC_5H_{12}, nC_5H_{12}). Gas content is lower in the central part of the Ukhta-Izhma oil and gas region and significantly higher in the outlying areas [12].

Based on the patterns of adsorbed natural gas distribution described by L.S. Kondratov [8] we have developed a naphtide content coefficient (Cnph) that is calculated as a ratio of the product of anomaly coefficients of five heaviest ANGs to the product of anomaly coefficients of five lightest ANGs [13,14].

In all studied regions, large oil and gas fields are located within the outlines of the anomaly Cnph zones or in their immediate vicinity. Smaller oil and gas fields usually lie outside such zones. Generally, the stronger the Cnph anomaly the higher the prospects. As a rule, high potential areas have Cnph over 4.0, medium potential from 1.0 to 4.0 and low potential under 1.0.

The Yagerskaya (III) oil and gas anomaly area is located in the center of the Ukhta-Izhma oil and gas region. The Cnph anomaly area has an arch and ring structure with an unpronounced arch area and internal and external ring zones. The internal zone is almost a closed ring. The highest Cnph value is 30.3. Yagerskoye oil field is located in the northern part of the internal ring.

The western outline of the outer circle coincides with a thrust fault, so oil and gas deposits are likely located to the north-west under the thrust fault. The western part of the area coincides with the north-east outline of a large negative anomaly of the gravity field with the minimum value (- 0,00025 m/s2). This gravity anomaly is interpreted as a strong decompression zone that may indicate a location of oil and gas fields. Three more prospect areas (Ukhta (I), Izhma (II) and Volsk (IV)) are located on the fringes of the Ukhta-Izhma oil and gas region. Composition, structure and geological position of Cnph anomalies in this area are similar to the anomaly associated with the Yagerskaya area, which indicates petroleum potential.

The Volsk prospect area (IV) shows the closes similarity to the Yagerskaya anomaly with the elements of the same arch and ring structure. Cnph in the area reaches a maximum of 62.3, which indicates high potential even though the area is not delineated to the southeast.

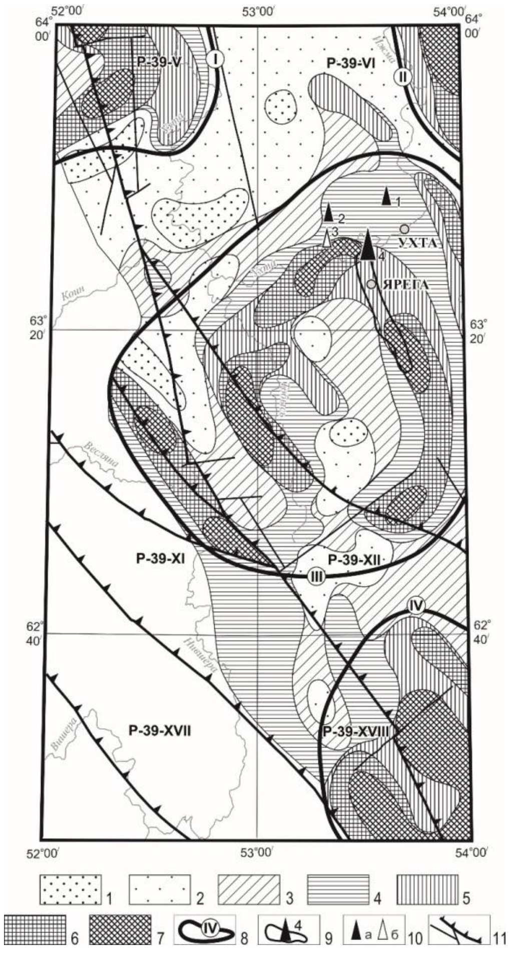

Figure 1: Results of studies in Timan-Pechora oil and gas province.
1 – 7. Prospects: 1 – 3. Low 1 – Cnph< 0.25, 2 – Cnph= 0.25 – 0.5, 3- Cnph= 0.5-1.0; 4 – 5. Medium: 4 – Cnph= 1.0-2.0, 5 – Cnph= 2.0-4.0; 6 – 7. High 6 - Cnph= 4.0-8.0, 7 – Cnph>8.0; 8 - oil and gas regions with numbers; 9 - deposit of the large Yagerskoye oil and gas field; 10 - small oil (a) and gas (b) fields; 11 - large folds (with bergstrichs) and small faults.

4. Conclusions

Testing of the ANG analysis method in the Ukhta-Izhma oil and gas region allowed the research team to

- outline the anomaly area of the Yagerskaya oil and gas area, thus proving high reliability of the method, and

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- localize high potential areas in the region.

In general, study of new high potential areas within the region might not only help expand the resource base, but also give scientific credence to further exploration of the unconventional areas of the Timan ridge, Analog to this, the Rocky Mountains thrust belt, Appalachian fold belt and other petroleum districts worldwide they might turn out to have high potential.

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