Journal of Environmental Treatment Techniques 2019, Volume 7, Issue 4, Pages: 723-730

J. Environ. Treat. Tech.
ISSN: 2309-1185

Journal web link: http://www.jett.dormaj.com

Forecast of Boundaries of Hydrocarbon Deposit Productivity Based on the Data of Land Geochemical Surveys, Seismic Exploration and Drilling

Mikhail ZAVATSKII*, Olga VEDUTA
Danil KOBYLINSKII, Olga VOLOBUEVA, Artur NIKIFOROV

Industrial University of Tyumen, Tyumen, Russia

Received: 27/05/2019 Accepted: 22/08/2019 Published: 03/09/2019

Abstract

The relevance of the research results from the increasing complexity of the structure of hydrocarbon deposits, which are objects of exploration and development in Western Siberia. Exploration efficiency can be improved by using a technique able to provide fundamentally new geological information – a land geochemical survey detecting oil migrational hydrocarbons on the surface. The purpose of the work is to improve interpretational models used when integrating seismic and drilling data with detailed geochemical survey results. To solve this problem, the authors analyzed the results of geochemical surveys carried out in two areas. In one area, the investigation was aimed at identifying the type of the reservoir fluid content prior to drilling, on the other – at delineating a gas deposit. It was discovered that surface gas shows depended on the reservoir fluid content (hydrocarbons or water) and the vertical permeability of overlying rocks. The discovered local zones of active hydrocarbon migration show that cap rocks lose their sealing properties, which allows identifying lateral boundaries of trap productivity.

Keywords: Land geochemical survey, Snow survey, Hydrocarbon migration, Geochemical indicators of oil and gas occurrence, Tazovskoye field, Vostochno-Terelsky prospecting block.

1 Introduction

In Western Siberia, as well as in other traditional oil and gas regions, large oil fields confined to amplitude anticlinal layer-arch traps tend to be exhausted. Currently, much attention is paid to the exploration of unconventional oil and gas deposits: deep-seated horizons of the sedimentary basin including the pre-Jurassic basement, unconventional traps with thinly bedded reservoirs having a complex structure, and others. It is difficult to simulate all these geological features using only seismic data.

Geophysicists try to increase efficiency by using new technologies for measuring the seismic signal and mathematical methods for interpreting it, but they do not manage to perform a unique interpretation of the seismic signal. Until 1976 with an accuracy of ± 25 m, the most frequently detected structure with an amplitude of 50 m was detected with a probability of 0.7. Currently, with an accuracy of ± 15 m, the most common structure with an amplitude of 15 m is detected with a probability of no more than 0.41 (1). The most informative is a 3D seismic survey, but it does not always solve the problems associated with thinly bedded reservoirs (2). The above said explains the fact that the efficiency of exploratory drilling in Western Siberia does not exceed 30-35% (3).

Thus, there are two parallel and interrelated processes – development of seismic exploration, as the main tool of oil and gas exploration geology, and the constant complication of target geological features. The seismic survey is indispensable for describing a sedimentary basin, but it remains an indirect method, since its search object is a potential trap and not a hydrocarbon accumulation. Exploration efficiency can be significantly increased by combining geophysical methods with a land survey, which gives a planar characteristic – the variability of the sedimentary cover in the plan. Currently, the land geochemical survey is the most reliable tool for mapping the lateral variability of the sedimentary cover (4, 5). In Western Siberia, the most technologically advanced and

Corresponding author: Mikhail ZAVATSKII, Industrial University of Tyumen, Tyumen, Russia. Email: eksis2005@yandex.ru.

informative method of land geochemical surveys is a snow survey (5, 6).

2 Materials and Methods

The research object is the data of multi-year geochemical research (1991-2017) in Western Siberia (5). This work considers in detail the results of two surveys conducted with different purposes: at the Vostochno-Terelsky prospecting block, the investigation was aimed at studying the local elevations identified by the seismic survey and at the Tazovskoye field, it was required to delineate a gas deposit in the Cenomanian layer PK_1. All the works under consideration were carried out using the snow survey technique: at the observation point, a surface snow sample with a volume of 200 ml was collected, then in the laboratory this sample was subjected to thermal vacuum degassing, the extracted gas was analyzed using a chromatograph with a hydrocarbon detection threshold of no more than $1\text{-}10^{-7}$% in volume. Saturated hydrocarbons from methane (CH_4) to hexane (C_6H_{14}) were determined. Before degassing and analysis, the sample was stored under refrigeration. The terrestrial positions of observation points were determined using a satellite topographic positioning system GPS with an error of no more than 5 m.

Based on the field and analytical work results, the authors constructed maps of distributions of the main geochemical parameters – the content of methane and the sum of methane homologs (SMG) from ethane to hexane. In some cases, the authors used additional characteristics of the geochemical field – the sum of gaseous methane homologs (SGMG) and the ratio of methane to its homologs. The maps were compared with seismic plans of target potential oil-bearing horizons. When interpreting data, the authors used a fluid-dynamic model (Fig. 1) considering a hydrocarbon deposit as a system in dynamic equilibrium. On the one hand, there are processes leading to an increase in the formation pressure (water-oil emulsion inflow, thermal cracking of hydrocarbons, and hydrothermal injections); on the other hand, the overpressure is released causing a decrease in the rock pressure, i.e., generally vertically upwards. Hydrocarbon migration occurs along the zones of overlying rock decompaction of different genesis.

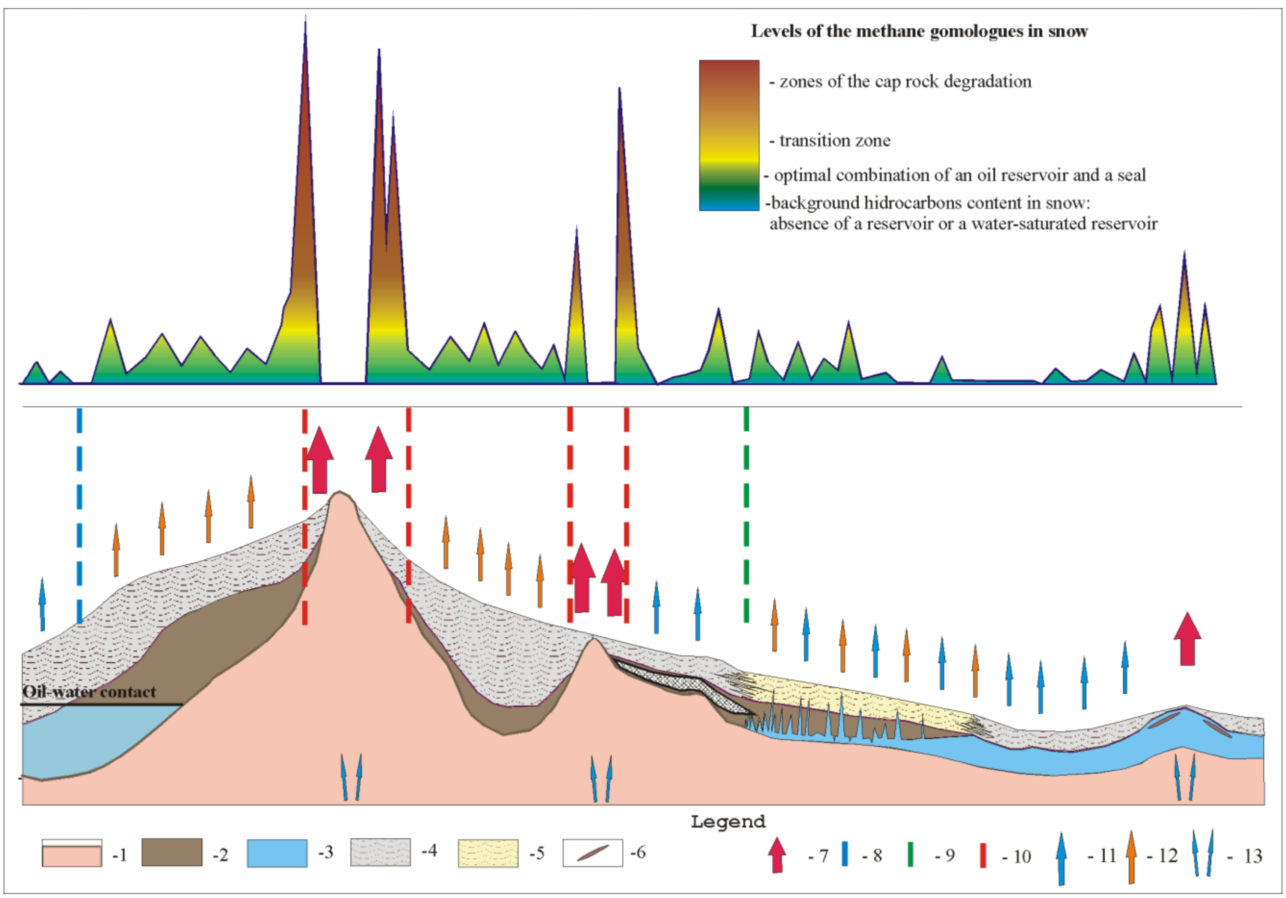

Fig. 1: Model of the reflection of geological boundaries of a ring-type bottom water-drive reservoir in gas saturation of the snow based on the results of the work at the Urnenskoye field. 1 – basal complex; 2 – oil-saturated reservoir; 3 – water-saturated reservoir; 4 – effective cap rock; 5 – zone of cap rock decompaction; 6 – oil reservoirs not covered with an effective cap rock; 7 – the most powerful migration channels resulting from the full or partial pinch of a cap rock; 8 – productivity boundaries caused by underlying waters; 9 – productivity boundaries caused by reservoir drainage; 10 – productivity boundaries resulting from the full or partial pinch of a cap rock; 11 – water microstream; 12 – water microstream enriched in hydrocarbons; 13 – hydrothermal inflow.

This may be a zone of tectonic activity, zones of overlying strata dynamic stresses, zones of hydrothermal activity, etc. Regardless of the genesis, such zones are boundaries of an effective seal (5-7).

3 Results

The main objective of the work at the Vostochno-Terelsky prospecting block was evaluating local elevation prospects including a primary forecast of the oil reservoir boundaries in the Jurassic sediments.

Oil and gas-bearing features in the eastern part of the prospecting block were predicted in the Sigovskaya formation (layer J_1^0), which is westerly pinched out (Fig. 2).

The layer J_1^1 (Nizhnesigovskaya subformation) is spread over the entire exploration area (Fig. 3). A number of local elevations were identified as prospective areas; the following of them were included in the geochemical research zone: Kutymsky, Zapadno-Terelsky, Terelsky, Yuzhno-Kypakynsky, Kypakynsky, Graviyny II, Ninelsky, Vostochno-Ninelsky, Lensky, Zapadno-Lensky.

The Terelsky, Lensky and Kypakynsky local elevations were investigated by drilling. The well at the Terelsky local elevation gave oil, gas, and condensate from the layer J_1^1; the Lensky local elevation showed gas (layer J_1^2) and oil (layer J_1^3).productivity. Three wells revealed water saturation of the studied layers in the marginal parts of the Kypakynsky structure.

The seismic plan shows two prospective local elevations identified by the seismic survey at the top of layer J_1^0: Lensky (in the north of the site) and Kypakynsky (at the eastern boundary of the site). To identify the Jurassic deposit productivity within these structures, the authors constructed a map comparing the seismic plan with the SMG content in the snow cover. The actual absence of gas shows in the eastern part (Kypakynsky, Graviyny local elevations) indicates that these geological features are unproductive.

The comparative analysis of the maps presented in Figs. 2 and 3 showed that the geochemical signal structure was more influenced by the occurrence mode of the Nizhnesigovskaya subformation than by the overlying layer J_1^0 for which the main forecast was done. When analyzing the correlation of the geochemical field with the J_1^1 layer structural plan, one can see the intensive subsoil degassing lineaments coinciding with the 2900-2910 m isohypses contouring the structural plateau, which includes the Lensky elevation.

The data on oil and gas saturation of the underlying layers allows drawing the boundary of oil and gas occurrence in the Jurassic sediments along these lineaments taking into account the structural plan. The absence of geochemical sampling in the southwest of the identified zone did not allow closing the contour from this side. The delineated area is an anticline (a monocline) between the Verkhne-Chaselsky elevation in the north-west and the regional elevation slope in the east. At first glance, these are not good structural conditions, but the subsequent exploration confirmed oil and gas presence in the delineated area.

The Ninelsky and Vostochno-Ninelsky elevations are equally characterized by a low SMG content over the area, but they have local zones of active hydrocarbon migration along the enveloping isohypse. These characteristics allow giving a positive forecast for the prospects of these features. The Kutymsky elevation (southeast part) has similar characteristics and is characterized as a productive area. Taking into account the gas shows position relative to the seismic plan, the contour was predicted to be closed at 3140 m isohypse. The Zapadno-Terelsky structure did not have any gas shows so its productivity forecast was negative.

Exploratory drilling of the Vostochno-Terelsky site structures by the subsoil user "Noyabrskgazdobycha" basically confirmed this forecast. The Jurassic deposits proved to be productive within the Kutymsky, Ninelsky, Vostochno-Ninelsky and Lensky elevations within the predicted contours. The negative forecast for the Kypakynsky, Yuzhno-Kypakynsky and Graviyny elevations was partially confirmed: stratum water inflow was obtained at the Kypakynsky elevation, but the oil-wet core was lifted from the Upper Jurassic deposits within the Yuzhno-Kypakynsky elevation. The forecast error is likely to be caused by a low density of geochemical sampling. The sizes of this geological feature are comparable to the distance between the sampling profiles, so the local zone of formation fluid migration could be skipped. In general, the level of gas content in the structure is non-zero and stable over the entire area, which is a positive geochemical characteristic, but the zones of formation fluid migration, which are typical for marginal zones of commercial hydrocarbon accumulations, were not found.

This experience is very important for using detailed land geochemical surveys for predicting boundaries of oil-bearing features. The survey results give an idea of productive stratum influence on the geochemical field. Initially, the Jurassic layer J_1^0 was expected to contain hydrocarbon accumulations, but after receiving information on its water saturation and oil detection in the underlying strata, the authors were faced with the problem of identifying the boundaries of oil and gas occurrence within the geological feature because the structure on the top of the layer J_1^0 is not hypsometric. This is the case when the seismic survey and drilling do not provide reliable information for locating the next exploratory well. The mismatch of the Lensky structure contour along the top of the Sigovskaya formation (Fig. 2) with the SMG distribution on the surface allows concluding that the hypsometry does not indicate hydrocarbon accumulations in the Jurassic sediments. Along the top of the layer J_1^0, this subsurface site is a non-amplitude fold between two higher-order anticlines, but it is its hypsometric boundaries that are spatially correlated with surface gas shows. This suggests that despite the effect of overlying strata, the gas shows are strongly influenced by the structure of oil and gas-bearing horizon.

The patterns of geochemical field distribution at the geological features of the Vostochno-Terelsky subsurface site correspond to the existing ideas about the confinedness of maximum gas shows to the periphery zones of productive anticlinal traps (8). As the surveys at the Tazovskoye field show, this effect is the most pronounced at large amplitude elevations, where the dimension of the individual elements of the pool structure far exceeds the sampling interval, which makes the geochemical picture on the surface more representative. The Tazovskoye field is confined to the cognominal elevation in the north-western part of the Ust-Tazovsky bar and contains productive reservoirs in the Middle Jurassic (condensate), Achimovsky (oil) and Cenomanian (gas with oil rim) deposits. The Cenomanian petroleum deposit is relatively well studied by drilling within the Tazovsky elevation dome.

The work was aimed at delineating the Cenomanian deposit by mapping the location of the petroleum reservoir and the cap rock. Special attention was paid to the northern slope of the elevation, which was not studied in such detail by drilling.

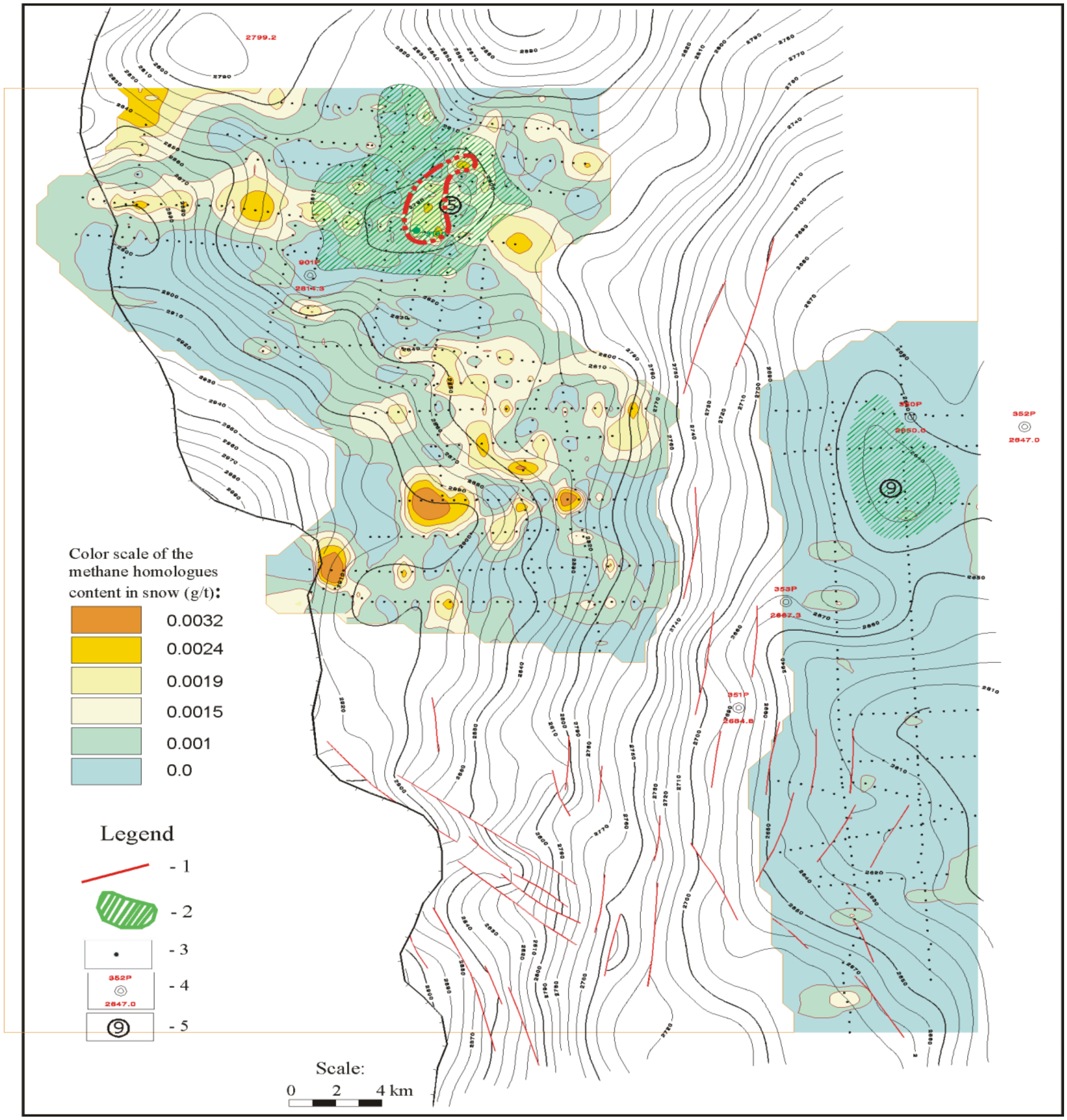

Fig. 2: The content of methane homologs in the snow relative to the seismic plan for the layer top of the Sigovskaya formation (J_1^0 stratum). 1 – fractures; 2 – boundaries of promising local elevations identified by the results of the seismic survey and prospecting drilling; 3 – sampling point.

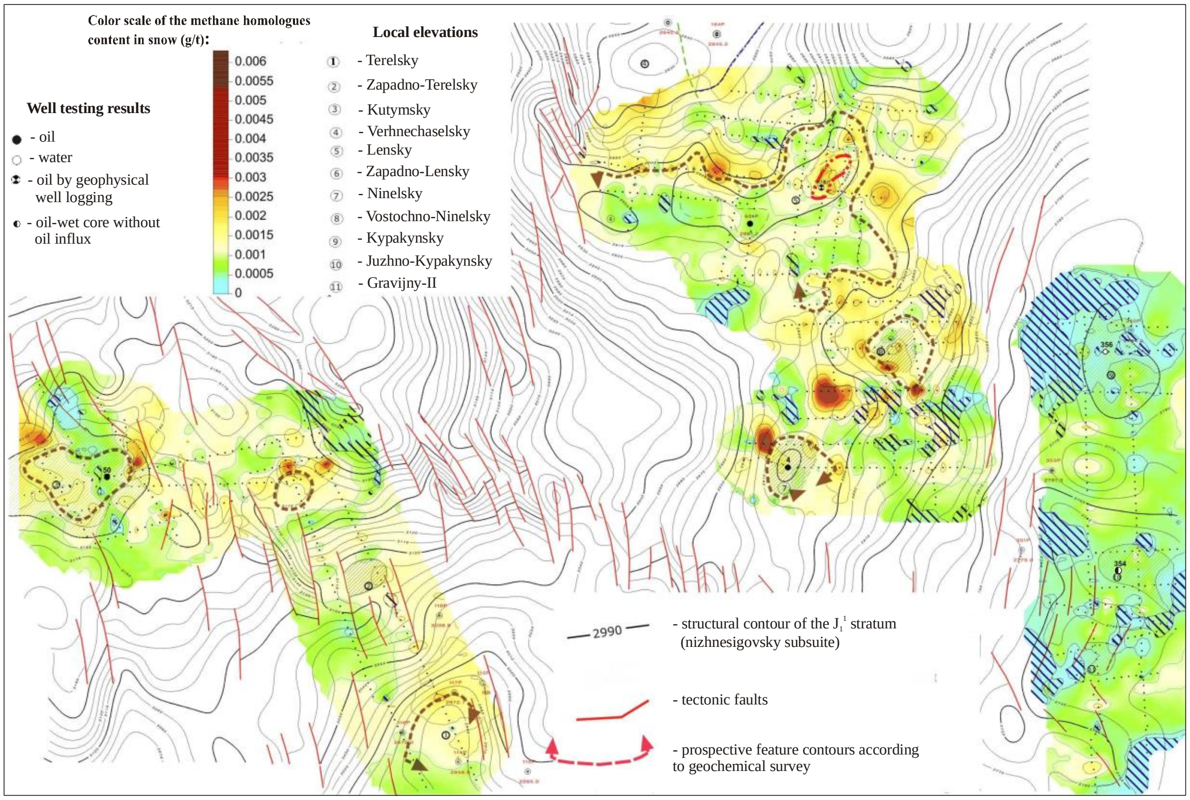

Fig. 3: The content of methane homologs in the snow relative to the seismic plan for the top of Nizhnesigovskaya subsuite (J_1^1 stratum)

The initial comparison of the maps of the methane and SMG content in the snow with the key bed hypsometry revealed the maximum correspondence of the zonal distribution of gas shows to the structure of the PK_1 (Cenomanian) layer. The SMG maxima were confined to disjunctive faults on the eastern side of the structure, which is a structural seal of the Cenomanian gas reservoir. Lower intensity gas shows are mainly localized on the elevation slopes, forming concentric zonality lineaments, consistent with the layer top hypsometry (Fig. 4). The structure dome, the productivity of which is proven, was displayed by low values of SMG.

Taking into consideration these phenomena, the Cenomanian gas reservoir contours were forecasted not only by methane but also by SMG, the most likely source of which could be the Jurassic and Achimovsky oil-bearing strata, since the gas reservoir seal in the Cenomanian sediments must stop the migration flow from deep-lying sources.

One of the research tasks was identifying the structure of the northern undrilled part of the field. The subsoil user "Yamburggazdobycha" drilled four exploratory wells – Nos. 85-R, 86-R, 80-R, 82-R. As can be seen from Fig. 5, the forecast for two of them was contradictory – the earlier reservoir model (Tyumen NIIGIPROGAS contour) suggested the presence of an oil rim in the 85-R well area and gas saturation of the layer at the 82-R well area. The forecast for these wells done taking into account the land geochemical survey data was negative. The boundaries of gas occurrence in the Cenomanian deposits predicted using the land geochemical survey results were confirmed by well tests.

4 Conclusions

The work carried out at the Tazovskoye field showed that the land geochemical survey data provided significant geological information even about explored areas. The Tazovskoye field has been explored for about 50 years. Its structure was identified in 1959, and the first inflow was received in 1962 (9). By the time of the work start, 105 geological features had been tested by 52 wells. Seismic surveys were carried out twice in 1985-1988 and in 2002. However, the obtained data were insufficient for reliable simulation of the undrilled part of the field. The use of data on the lateral variability of the sedimentary basin horizons markedly detailed the ideas about the hydrocarbon potential of the Tazovskoye field.

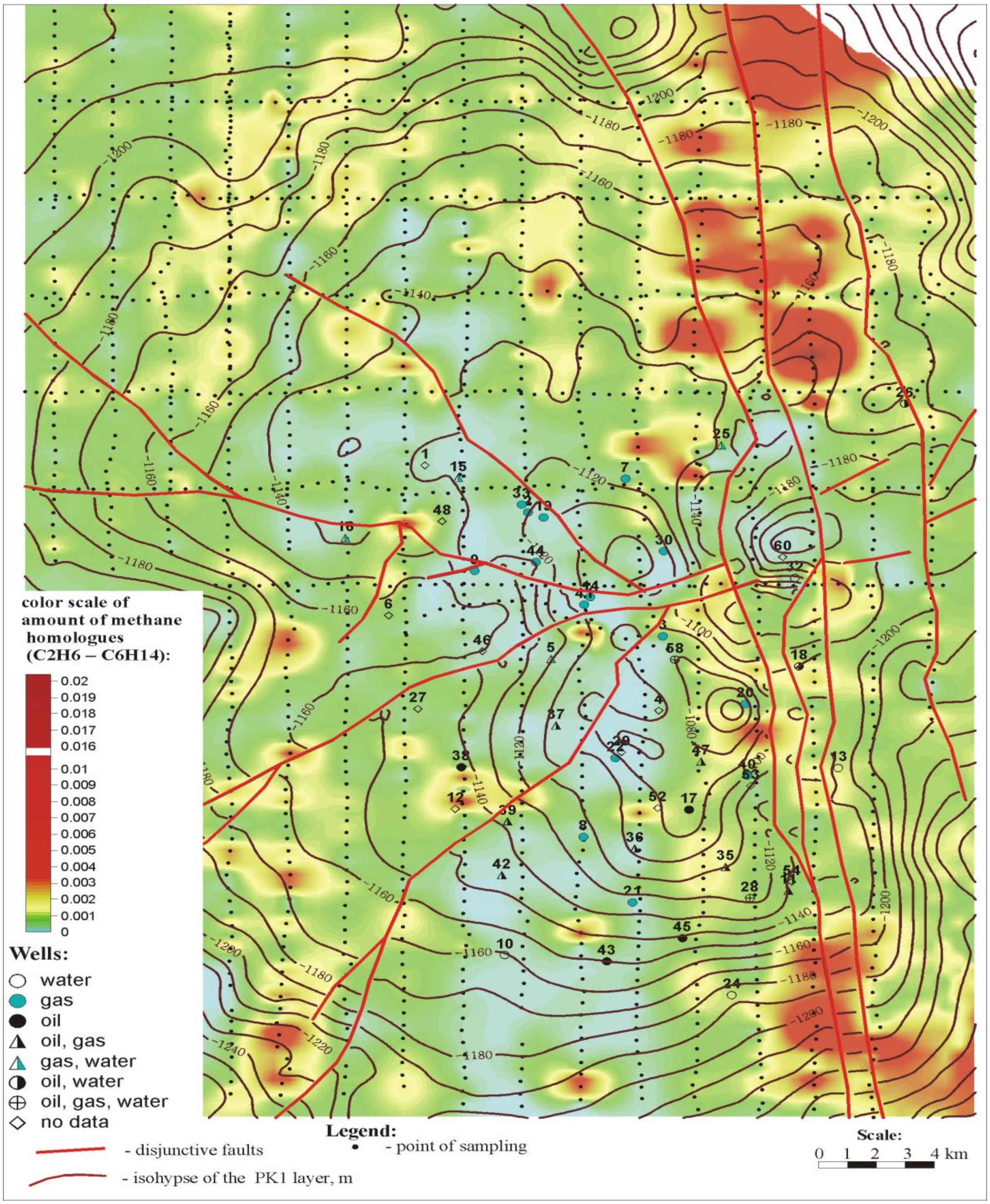

Fig. 4: The content of methane homologs in the snow relative to the structure of the oil and gas deposit in the PK_1 layer (Cenomanian) in the Tazovskoye field

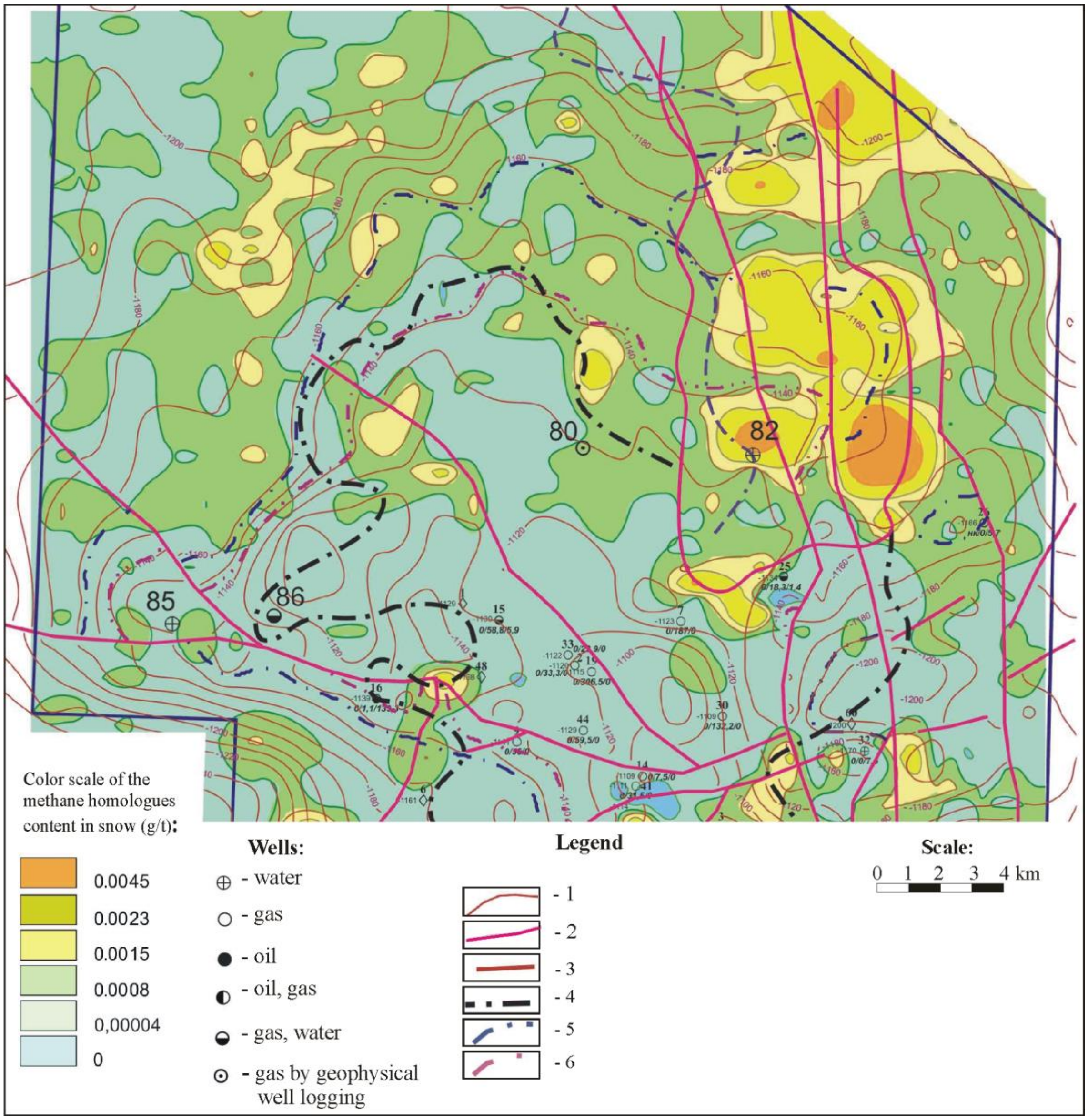

Fig. 5: Forecast of the oil and gas reservoir contour in the PK_1 (Cenomanian) stratum based on the results of the complex interpretation of the geochemical survey, seismic exploration and drilling. 1 – isohypses of the PK_1 stratum (Cenomanian); 2 – tectonic faults; 3 – boundary of the cap rock decompaction zone; 4 – oil and gas reservoir contour based on the results of the complex interpretation of the geochemical survey, seismic exploration and drilling; 5 – oil productivity contour according to the Tyumen NIIGIPROGAS model; 6 – gas productivity contour according to the Tyumen NIIGIPROGAS model.

In methodological terms, it became clear that the "readability" of the land geochemical field depended on correspondence between dimensions of a geological feature under investigation and sampling frequency. The correlation between surface gas shows and the structure of the main productive horizons at the Tazovskoye field was much stronger than at the Vostochno-Terelsky site, where the geological features under investigation had small sizes and the use of the same sampling interval resulted in taking less than ten samples at each of them.

The obtained data indicate that the differences in hydrocarbon gas concentrations on the surface reflect real geological boundaries, to some extent related to the petroleum occurrence within the earth. However, fixing anomalies of the hydrocarbon gas content on the surface is insufficient for effective use of land geochemical survey data in oil exploration. To identify geological boundaries, it is necessary to obtain reliable information on the correlation between the geochemical field and the sedimentary cover structure.

References

1. Brekhuntsov AM, Bevzenko YuP. About the economics and technology of searching for oil and gas deposits in Western Siberia. Petroleum Geology. 2000;3: 22-26.
2. Cherepanov EA, Kychkin AN, Khasanov RN. Prediction of the geological structure of the arch part of the Usanovskaya structure

based on 3D seismic data using geoacoustic simulation. Information on http://www.tngf.ru/tngf/dnirnst.html
3. Grekova LS. The forecast of the oil and gas potential of local structural traps (using the example of the J_1 horizon of the southeast of Western Siberia. Petroleum Geology. 2011;5: 84-91.
4. Andreeva NN, Borkovsky AA, Veres SP, et al. Prospects for using direct geochemical methods for searching for relatively small sized petroleum deposits in Western Siberia. Petroleum Geology. 2001;4: 26-29.
5. Zavatsky MD. Study of the Fields of Hydrocarbon Gas Concentrations in Surface Natural Sorbents while Exploring Oil and Gas Deposits in Western Siberia. Abstract of PhD dissertation. Tyumen. 2009.
6. Zavatsky MD, Tseplyaeva AI. Informative value of geochemical indicators when searching for hydrocarbons in Western Siberia (based on snow survey results). Natural and Technical Sciences. 2016;10(100): 9-15.
7. Nwaogu C, Abrakasa S, Nwankwoala H, Uzoegbu M, Nwogu J. Evaluating some aspects of gas geochemistry of some North Sea oil fields. Chemical Sciences Journal. 2015;6(2).
8. Zorkin LM, Carus EV, Kuznetsov OL, et al., About the nature of the “ring” physical-chemical anomalies in the sedimentary cover. Reports of the USSR Academy of Sciences. 1978;2(243): 477-479.
9. Nesterov II, Salmanov FK, Shpilman KA. Oil and gas fields in Western Siberia, Nedra, Moscow, 1971.