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Magnetic and atmogeochemical studies at the hydrocarbon area Nedilna, Ukraine

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SUMMARY

Hydrocarbons remain one of the most important fuels in the world, including Ukraine. The important is to look for new and refine existing methods of hydrocarbon exploration to improve the energy and economic level of our country. Magnetic method is one of the cheapest and most efficient technique, which includes magnetic survey, soil sampling and magnetic measurements, and studies of the deeper soil-forming rocks and near-surface layers. In this study, we combined the magnetic and atmogeochemical measurements of the soil gases related to the hydrocarbons microseepage. The study site is located on the outskirts of the village Balabanivka, Bohodukhiv district, Kharkiv region. The results confirmed that the measured magnetic and atmogeochemical parameters are the indicators of the halo effect of the hydrocarbons as well as the landscape factors. The decrease in the methane content versus the decrease in the soil magnetic susceptibility (MS) in the area of the productive well was registered. This information is promising for the application of the method at the areas of the hydrocarbon deposits at the initial stage of the exploration.

Introduction

Hydrocarbons remain one of the most important fuels in the world, including Ukraine. Thus, it is important to look for new and refine existing methods of hydrocarbon exploration to improve the energy and economic level of our country. At the same time there is the requirement of the environmentally friendly process of the hydrocarbon production and monitoring of the geological conditions near the deposits (*Pihulevskyi et al., 2019; Tiapkin et al., 2019*). The geophysical studies need to be based on the mathematical models (*Maslov et al., 2001*; *Vyzhva et al., 2010*) and statistical simulation (*Vyzhva et al., 2013, 2018*).
The traditional methods (i.e. seismic exploration) should be supplemented with new, superficial ones, among which the leading place is occupied by methods of magnetic survey and geochemistry. This increases the reliability of oil and gas production zones localization and improves the economic performance of exploration, considering the fact that seismic is a very expensive way. The need for integration of the geochemical survey, magnetic field measurements, and soil magnetic studies at the initial reconnaissance stage of hydrocarbon research is considered in the paper. *De la Rosa et al., 2021* integrate satellite image spectral analyses with rock magnetic and geochemical data.
Magnetic method is one of the cheapest and most efficient technique, which includes surveying the local magnetic field, soil magnetic properties measurements as well as the soil-forming rocks and near-surface layers. Magnetic methods can be considered as direct for the search for oil and gas. This is based on recording the changes that occur in soils and rocks under the influence of hydrocarbon fluid flow. The positive evidence of the magnetic method application for the oil and gas prospecting demonstrated in *Costanzo-Álvarez et al., 2019*. A combined study of rock-magnetism and electronic-paramagnetic resonance (EPR) was performed in core samples from an oil well in the Vaca Muerta Formation (SW Argentina). The aim of their work was to characterize the effects of hydrocarbon-related diagenesis on the magnetic signature of oil shales. The magnetic properties of soils were studied by *Khrustalev et al., 2019* in the territory of Khlebnovsky oil field (Saratov region). Anomalies were documented in 26 sample test points. Most of the anomalies were observed in thermomagnetic effect values ranging from 3 to 10 units, and in the Western part of the anomalous zone, a core was formed with values from 10 units and higher. The results of the magnetic studies at the areas of the hydrocarbon deposits in Ukraine confirmed the close relation of the microseepage and magnetic mineralogy changes in soil and nears-surface rocks in Ukraine (*Menshov et al., 2016*).
It is required to reject landscape anomalies that are not related to hydrocarbon deposits. Clear regularities related to the distribution of magnetic characteristics in soils of natural landscapes and agricultural (arable) lands are determined (*Menshov and Sukhorada, 2012; Menshov et al., 2020*). Since about 56% of the area in Ukraine is under the arable land, the agrogeophysical component of soil magnetism is significant (*Menshov et. al., 2021*).
This paper is dedicated to determining the patterns of magnetic susceptibility spatial distribution in soil and the content of some hydrocarbons in the soil air depending on the landscape factor as well as to assessing the prospects of complexing these methods.

Methods

The collection of soil samples represented by the deep medium humus chernozems was studied in this paper. The research site is located on the outskirts of the village Balabanivka, Bohodukhiv district, Kharkiv region (**see Fig. 1**). The terrain is a hilly and undulating well-drained plain. The productive well was located near the local hypsometric maximum.
The object of the study is the spatial distribution of soil 29 sample collected near the wells Nedilna-1,3 (productive well), Nedilna-2,5 (non-productive well). The mass-specific magnetic susceptibility (χ, MS) was determined separately under laboratory conditions for the selected samples using a KLY-2 kappa bridge and an MS2 magnetometer (at two frequencies).
The content of CO_2 and other hydrocarbons in soil were determined in the GSI laboratory Geological Sciences Institute at the National Academy of Sciences of Ukraine.

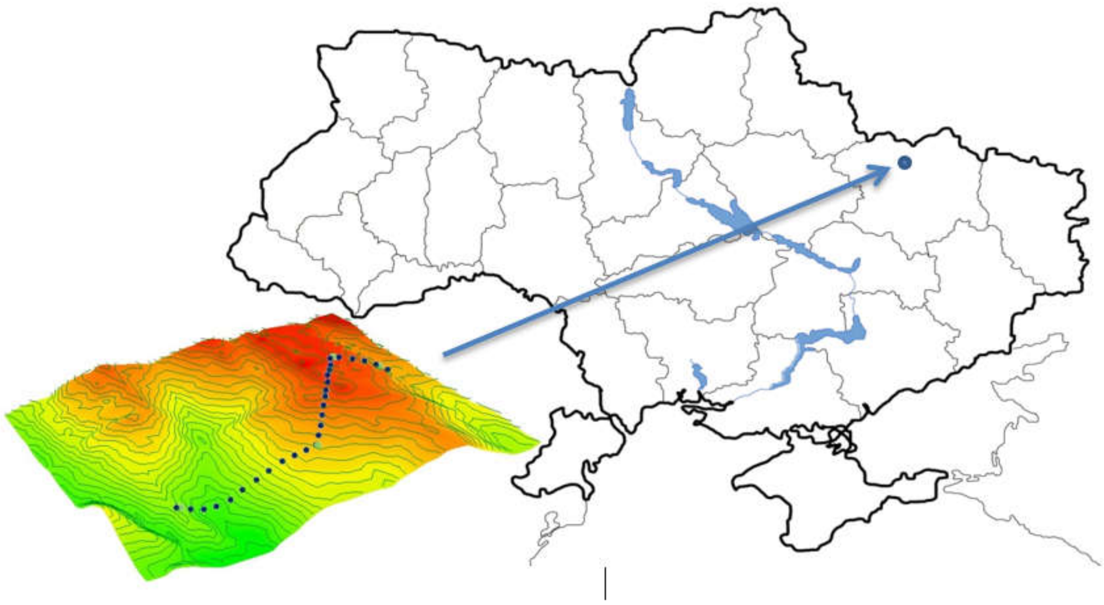

Figure 1 *The study area in Balabanivka, Bohodukhiv district, Kharkiv region.*

Results

Primary, the dependence of the soil gases composition in the landscape (hypsometric mark) related to the geological (site productivity) conditions was assessed. The content of basic gases in the soil air is shown in **Fig. 2**. The distribution of hypsometric mark values and information about the specific magnetic susceptibility of the soil surface layer (**see Fig. 3**).

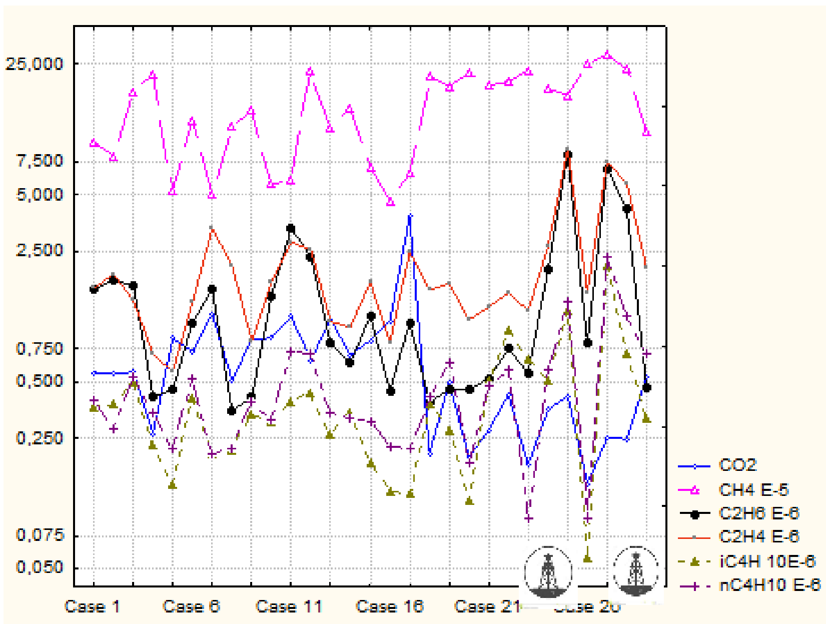

Figure 2 *The content of CO_2 and hydrocarbons in the soil air of the study area.*

The cross plot of the studied gases content is quite complex, which is difficult to relate to the landscape factor or the productivity of the site. The local maximum in the area of well 1 (**Fig. 2**) attracts attention, especially for the ethane and ethylene components. At the same time, these components at the area of well 2 demonstrated their minimum values.

The methane content can be compared directly with the hypsometry of the site (**Fig. 2**). In terms of landscape, the profile passes through two patches, the first – an active ravine with slopes (points 1-15 in **Fig. 3**) and a plain area (points 16-29). First of all, it should be noted the high variability of methane content. In the first case – 53 %, and much lower (although quite high) in the second – 29%. The arithmetic mean of the indicator in the second case is also about 1.9 times higher. The similar behavior was registered for the magnetic susceptibility, which also differs significantly in the two subsections (**Fig. 3**).

The CO_2 content demonstrated the increase in the slope area. If we accept the idea of the direct relationship between the values of MS and the content of organic carbon in the soils of the accumulative series, we suggest that the content of carbon dioxide in the soil air and the content of humus are not related. The MS of the soil, in this case, demonstrates consistency with the elevations ($\rho \geq 0.61$). The minimum value attracts attention in the area of the productive well (**Fig. 3**). We suggest two possible ways of the anomaly formation. The first assumption is the direct impact of methane on soil ORP. The second impact is the result of reclamation work in the well area. However, the decrease in methane content against the background of reduced soil MS in the area of the productive well creates the preconditions for the combination of geochemical and magnetic methods.

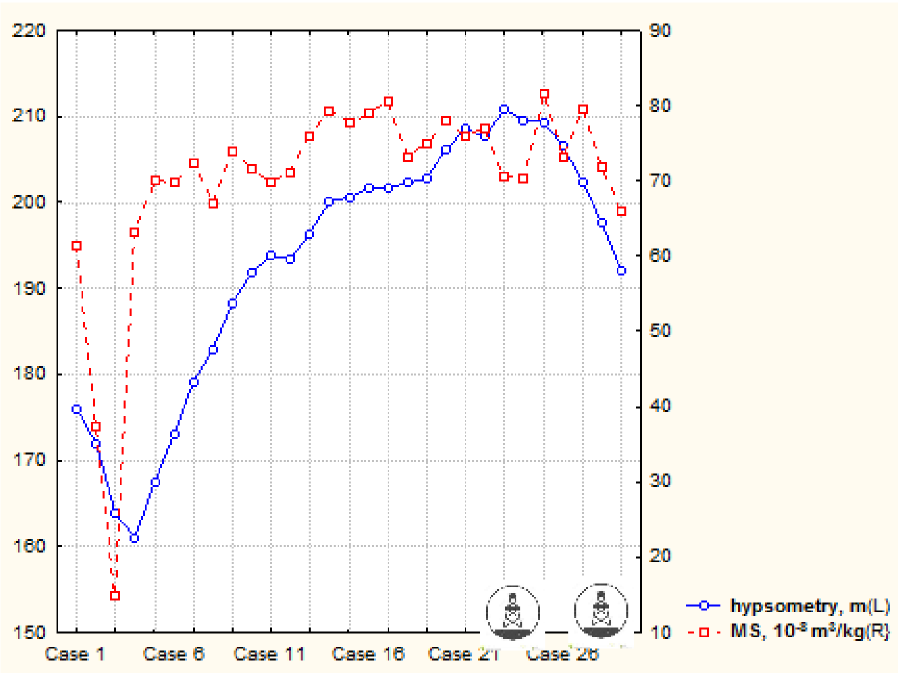

Figure 3 *Hypsometric marks and MS of soil sampling points of the study area.*

Conclusions

On the example of the oil and gas perspective site, the approbation of geochemical and magnetic methods of hydrocarbon prospecting confirmed the possibility of the joint studies. The behavior of the studied indicators depending on the landscape factor is determined. The decrease in the methane content against the decrease in the soil MS in the area of the productive well are promising for the application of the method at the areas of the hydrocarbon deposits at the initial stage of the exploration for the identification of the "hot spots" for the next expensive methods application.

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