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Geomagnetic studies at Rubaniv gas field in outer zone of Carpathian Foredeep, Ukraine

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SUMMARY

The results of geomagnetic studies at the Rubaniv gas field in the Outer zone of the Carpathian Foredeep are considered. A detailed study of the anomalous magnetic field and the magnetic properties of rocks and soils at the zones of hydrocarbon deposits is a basement for the application of the magnetic prospecting for direct hydrocarbon prospecting. At the present study we investigate the structure of the local anomalous magnetic field in the zones of hydrocarbon fields within the Carpathian Foredeep for the identification of the genetic relation of the magnetic properties of surface rocks and soils with the microseepage of hydrocarbons. The total magnetic field vector T and its components (declination, inclination, horizontal and vertical components) along the 5 transect were measured. The soil magnetic susceptibility in transects and in the profiles (genetic horizons) were studied. The local positive magnetic anomalies with the amplitude from 2 to 8 nT and dispersion of the soil magnetic susceptibility above the Rubaniv gas field were detected. This data indicated the genetic relations between gas deposits, microseepage, and changes of the magnetic field and soil magnetism.

Introduction

A detailed study of the anomalous magnetic field and the magnetic properties of rocks and soils at the zones of hydrocarbon deposits is a basement for the application of the magnetic prospecting for direct searches of hydrocarbons. In the modern practice of geophysical studies, the use of geomagnetic data is increasingly growing (Ayoubi et al., 2019; Tedesco, 2017). The recent study (Costanzo-Álvarez, et al. 2018) characterized the effects of hydrocarbon-related diagenesis on the magnetic signature of oil shales. Ulfah et al., (2017) studied two zones near a producing well, a dry hole well and a discontinued well, and a background zone (a residential area near the oil field) to find the initial soil magnetic susceptibility value in the area. It was suggested that the accumulation of petroleum hydrocarbons and the fossil fuels generated in the study site soil may have increased the magnetic susceptibility values. The high values of magnetic susceptibility (MS) correspond to low permeability, while the low diamagnetic MS relates to high permeability of production zones (Ivakhnenko et al., 2016).

According to our previous results (Kuderavets et al., 2019; Gadirov et al., 2018; Menshov et al., 2018, Menshov et al., 2014) hydrocarbons generate changes in magnetic mineralogy of the rocks and soils. The valuable results were obtained for the Carpathian Region of Ukraine (Menshov et al., 2015; Menshov et al., 2016). The crucial aim of the present study is deeper investigation of the structure of the local anomalous magnetic field in the zones of hydrocarbon fields within the Carpathian Foredeep. Main goal is the identification of the genetic relation of the magnetic properties of surface rocks and soils with the microseepage of hydrocarbons. The joint geomagnetic studies were performed at the area of Rubaniv gas field.

Geological site and methods description

The Rubaniv gas field is located in the Bilche-Volytsia (Outer) zone of Carpathian Foredeep in the junction of two regional deep faults – Kalush and Gorodok between the well-known gas field Mala Horoganka, Bilche-Volytsia, and Medenychi. The gas deposit is associated with the Lower Sarmatian sand-silty horizons of the Dashava Beds at shallow depths of 200 to 500 m (Fig.1)

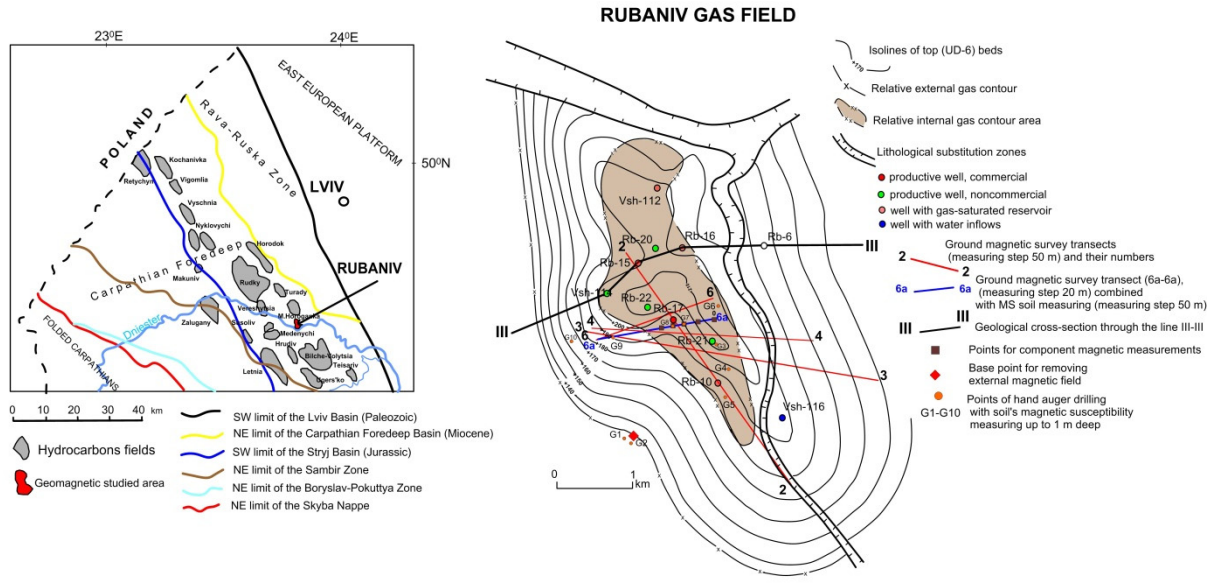

Figure 1 *Location of studied area in Outer zone of Carpathian Foredeep, NW fragment (left) of tectonic map of the Carpathian oil-and gas-bearing region (Vul et.al., 1998) and geomagnetic studies at Rubaniv gas field (right). Structural map of Rubaniv field (UD-6 horizon) were derived from Ukrgasvydobuvanny NAK Naftogaz Ukraine (Yaremchuk, et al., 2007)*

The geomagnetic studies included measurements of the value of vector of total magnetic field T. Step between points of observation is 50 m along transects 2-2 (3.85 km), 3-3 (4.05 km), 4-4 (3 km) and 6-6 (1.85 km). Along transect 6a-6a (1.64 km), the measurement step was 20 m. Absolute

measurements of the components of the geomagnetic field were carried out every 200 m at 5 points. The volume (field) soil magnetic susceptibility (MS) was measured every 50 m by portable meter PIMV-M and accompanied with top-soil sampling along the transect 6a-6a. The soil MS outside the Rubaniv gas field was studied at the extension of the transect 6a-6a. For the vertical distribution of the magnetic properties of soil, we use the manual auger drill. The vertical soil profile has the depth of 1 m, and soil sampling was performed every 10-20 cm. The ten points (G1-G10) were organized for vertical studies of the soil genetic horizons.

The total vector of magnetic field T was measured with the MMP-203 proton magnetometer with sensitivity of 1.0 nT. To remove the external magnetic field variation, the MV-01 proton magnetometer station (resolution 0.1 nT) was used at the base point synchronously in time with field measurements. The absolute measurements of the components of the geomagnetic field was performed at 5 points. This measurement included: measurements of the magnetic declination D, and magnetic inclination I using the LEMI-203 declinometer-inclinometer, measurements of the T module by the MV-01 proton magnetometer, and registration of magnetic field variations by the LEMI-417 magnetic variation station at the base point. Component measurements of the geomagnetic field at 5 points of transect 6a-6a were based on the methodology of absolute measurements at geomagnetic repeat stations (Maksymchuk et al., 2012).

The geomagnetic transects, points of component measurements of the magnetic field, points of the soil magnetic susceptibility, and structural map of the Rubaniv field along the UD-6 (Upper Dashava Bed) horizon are shown in Fig. 1. All transects are oriented sublatitudinal to the strike of the Rubaniv structure. The exception is 2-2, which has a submeridional orientation and runs along the vaulted part of the structure.

Results of geomagnetic studies

In Fig. 2 the results of complex geomagnetic studies are presented. The graphs of the residual magnetic field ΔT, curves of the ΔT, ΔZ, ΔH, ΔD, ΔI, soil MS and a geological section along the line III-III are visualised. The absolute measurements of the components of the geomagnetic field were performed at 5 points along 6a-6a transect, and projected into the zone of the Rubaniv field.

The performed analysis of the available geophysical parameters allows us to identified certain patterns that can be considered as the criteria for searching the oil and gas within the geological structures:

- In the all transects, the positive small magnetic anomaly of the 2-4 nT and the width of the 700-1250 m was detected. This anomaly is against the background of a smoothed regional curve of the difference anomalous magnetic field ΔT.
- More precision measurements along 6a-6a give more accurate local magnetic anomaly within PK-450 -1150 with about 700 m width. It has a wavy shape with two maxima (PK-110 with amplitude +10 nT, and PK-550 with amplitude 7 nT).
- Local positive magnetic anomaly is observed by ΔT measurements with a width of 800 m and an amplitude of 2-4 nT along the 4-4 transect.
- At the points of the components of the geomagnetic field observation along the transect 6a-6a (5 points) the increase in the values of magnetic declination (D), decrease in I (inclination), negative anomaly in the horizontal component H over the projection of the gas reservoir are observed in the zone of the deposit and its halo.

The proper interpretation of the changes of soil MS must be given attracting both possible hydrocarbon impact to soil magnetism and pedogenic changes according to soil types and landscape. We identified three landscape patches. The first one lies from -1200 to -1600 m of the transect 6a-6a. The soils are podzolic (Umbric Albeluvisols Abruptic in WRB classification). The landscape is related to pine forest. The second patch lies at the area of the gas field (from -1200 to -300 m). Soil is Haplic Gleysols Dystric in WRB classification. The third patch is located at the area of forest with predominance of the Greyic Phaeozems Albic (from -300 to 0 m). The visible growth of the MS is detected at the patch 2. This anomaly matches with anomaly of magnetic field. The dispersion of MS at the marginal zones (from -1200 to -1000 and from -500 to -300 m) may be expressed as a halo-effect (the first description was in *Horvitz, 1939*).

The vertical distribution of MS in genetic horizons of soil changes according to the patches of studies. For the patch 1, soil is very weakly magnetic (MS=3-8×10^{-8} m^3/kg). The differentiation in soil profile is small. Such picture is common for the slightly magnetic soils of Ukraine (Menshov and Sukhorada, 2012; Menshov et al., 2012). The similar behavior was detected for two points of observation (G9 and G10). Two soil profiles (G7 and G8) organized at the area of patch 2 (gas pool) demonstrated higher values of MS (but still small). At the depth of 0-30 cm MS=11-16×10^{-8} m^3/kg. Deeper, we registered decrease when transition to the underlying rocks. Such values of MS a promising for the identification of the hydrocarbon impact to the magnetic minerals changes. More detailed interpretation is expected after preforming thermomagnetic analyzes of this samples. The soil of patch three (G6) is more magnetic according to the soil type. The MS of top-soil is 21×10^{-8} m^3/kg.

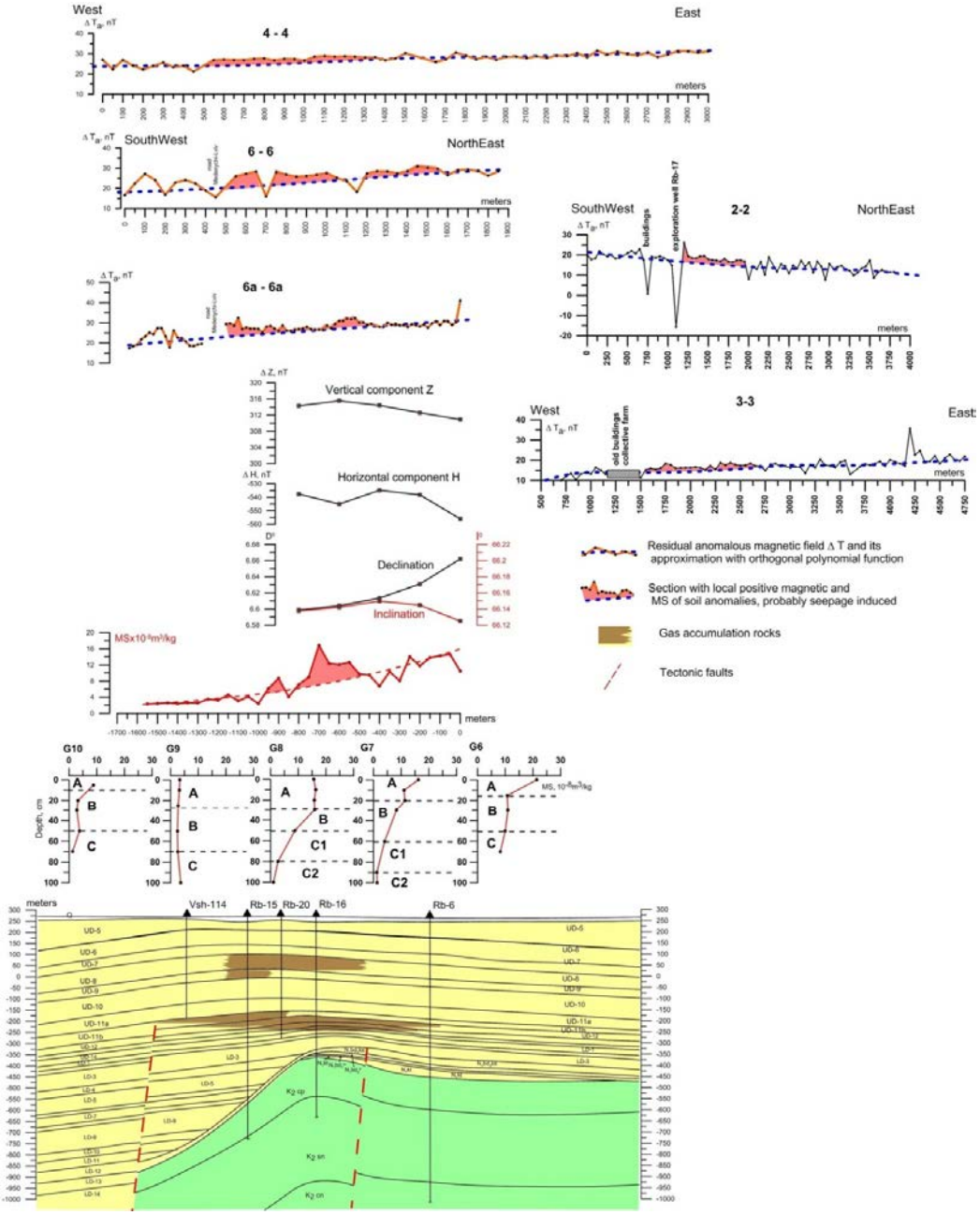

Figure 2 *Residual anomalous of magnetic field ΔT along the transects 2-2, 3-3, 4-4, 6-6, and 6a-6a with the section of local positive magnetic and soil magnetic susceptibility (MS) anomalies, probably seepage induced; components of the geomagnetic field ΔZ, ΔH, D, and ΔI along transect 6a-6a; MS of soil along transect 6a-6a, points (G6-G10) of soil MS studying, geological section along the III-III line at the Rubaniv gas field (Yaremchuk, et al., 2007)*

Conclusions

The case study from the Rubaniv gas field confirmed the presence of the anomalous of the geomagnetic field and soil magnetic susceptibility at the areas of hydrocarbons (gas) spread. At the same time further magnetic mineralogy analyzes are expected. For the proper interpretation of the magnetic studies results the additional geochemistry and electrical studies are required.

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