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Geopolariton tomography (GPTS) hardware and software platform for study of Earth's deep structure

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Summary

The hardware part of the GPTS platform is represented by a passive remote geophysical scanner "DSF16C" and the software products "Points Remover", "DSF16", "LSpectr", "MODE" for data processing and interpretation. The platform provides profiling of speed (material) sections and their geometric representation. The field of application is the study of the Earth's deep structure. The method of estimating of the dynamic states of rock massifs allows estimating the resource of deposits at large depths and signs of replenishment of reserves even at the stage of selection of promising areas, as well as in previously identified deposits, until signs of their activity decrease appear to prevent reduction of their oil recovery.
A fundamentally new data processing algorithm simultaneously evaluates all geodynamic processes (stress-strain state, state of rupture disorders in all complexes and a complex system of their interactions), taking into account the activity indicators of the Earth's natural electromagnetic field.
It is possible to install the scanner on any mobile carrier: UAV, ship, aircraft, car.
Stress-strain state of rocks, energy of elastic natural vibration of the Earth's core, geopolariton tomography technology (GPTS).

Introduction. The traditional approach in geological exploration is to integrate seismic exploration and deep well drilling, but this is increasingly burdened by the growth in spendings associated with the complexity of the process, expensive equipment and increased labor costs. Despite improvements in geophysical data processing, technological development and interpretation methods over the past 30 years, the hopes of seismic explorers to develop reliable methods for a geosection predicting based on seismic data have not been realized. The seismic method works mainly in areas associated with massive hydrocarbon deposits, usually under conditions of shelf zones and water areas. At the moment, the seismic method lacks technologies for studying crystalline foundations to identify decompression and fluid saturation zones (Vinnichenko et al., 2014).

The Earth's geopolariton tomography (GPTS) method holds a special place in the range of modern innovative technologies for subsoil exploration, in applications of oil and gas geology based on fundamental physical laws. The method was widely tested in various oil and gas-bearing provinces of the globe. In such countries as Ukraine, Canada, China, the UAE, Peru, India, Egypt, Russia, Kazakhstan, Azerbaijan, Turkmenistan, Indonesia, Malaysia, etc. this method proved to be a working tool for studying structure of a geological environment, as well as an identification method for its geopolariton anomalies which are the electromagnetic prototypes of hydrocarbon deposits of various geological nature (Bogdanov et al., 2020; Bogdanov et al., 2019; Bogdanov and Prokopenko, 2018; Bogdanov and Prokopenko, 2017).

Features of propagation and reception of Earth's natural radiation signals. According to experimental observations and model estimates, the Earth's crust is an electrodynamically active environment capable of exciting the geoelectromagnetic field (Gohberg et al., 1985; Sobolev and Demin, 1980; Surkov, 2000; Levshenko, 1995; Astrakhantsev et al., 1998). The generation of lithospheric electromagnetic signals can occur both forcibly, due to the movement of rocks during seismic action, and spontaneously, out of direct connection with the cases of seismicity (Levshenko, 1995). The frequency spectrum of electromagnetic radiation of lithospheric origin covers the range in the field of radio frequencies from 1-100 kHz and above, the radiation is pulsating (Gohberg et al., 1985; Astrakhantsev et al., 1998). In connection with the simultaneous manifestation of acoustic and electromagnetic waves, the question arises for the comparative informativeness of these manifestations. Estimation of information value at radiation output from the subsoils in the simplest case is determined by values of transmission coefficients by the earth's crust-atmosphere interface.

Acoustic wave transmission through interface is equal to:

$$t_a = \frac{4}{\left(a + \frac{1}{a}\right)^2} \qquad \text{where } a = \frac{\rho_1 c_1}{\rho_2 c_2},$$

where ρ_1, ρ_2 – media density, c_1, c_2 – velocity of wave propagation in these media.

Taking the air density equal to $1{,}3 \cdot 10^{-3}$ g/cm^3, the speed of sound in air 300 m/s, the average density of the earth's crust rocks 2.7 g/cm^3, and the speed of sound in rocks 4000 m/s, we obtain the transmission coefficient of the boundary of the rock - atmosphere $t_a \approx 0{,}5 \cdot 10^{-8}$.

The transmission coefficient of electromagnetic radiation by the interface of two media for the case of a normal fall is:

$$T_e = \frac{2}{\sqrt{\varepsilon + 1}},$$

where ε – a relative dielectric constant of mountain environment. Considering that for the mountain environment $4 < \varepsilon < 50$, we obtain that the day surface transmittance of electromagnetic radiation is $0{,}66 > T_e > 0{,}25$.

From the comparison of these values, it follows that the transmittance of electromagnetic radiation by the interface rock - atmosphere is hundreds of millions of times greater than of the acoustic one. In other words, electromagnetic radiation comes out of the subsoils with little or no attenuation. Therefore, electromagnetic radiation associated with various processes in the earth's crust (shifts and faults of the crust, earthquakes, avalanches, landslide movements of soils, etc.) can be considered as an extensive source of information on geodynamic processes (Bogdanov and Pavlovich, 2008).

The experience with the GPTS method is based on and largely supports the evolving new geological paradigm, which includes:

- theory of abiogenic - mantle origin of hydrocarbons (HC);
- an idea of the layered block structure of the earth's crust;
- understanding of deep faults - HC supply channels, as well as related destruction zones and resulting oil and gas distribution patterns in secondary collectors.

This allows us to outline fundamentally new approaches and determine methods for the effective development of the search and exploration process (Bogdanov et al., 2009). The GPTS method records the feed channels of HC deposits and feed tanks at almost any given depth.

The physical basis of the GPTS method is the postulate that the emitted electromagnetic energy, which is represented by a discrete spectrum of electromagnetic waves, is expressed by a physical parameter N, called the density (number) of emissions of the envelope of a stationary random process of fluctuations of the effective scattering area (ESA) of a geological object. The source of geopolariton waves that "shine through" the mantle, asthenosphere and lithosphere of the planet is the energy of slow waves and natural elastic vibrations of the Earth's core, which is accompanied by geopolariton radiation (GPR). The GPR forms an integral "image" on the Earth's surface from geopolariton waves diffracting on geological structural elements and carries information on all inhomogeneities of the structure and substance of the geo-environment (Bogdanov, 2017).

GPTS hardware and software. The DSF16C scanner is used to measure the geopolariton field. The small unmanned aerial vehicle (UAV) is the most effective platform for equipment hosting (Bogdanov, 2012). Such placement ensures high productivity and informative work, as well as irrespective of the relief. Pedestrian, automobile and ship fieldwork options are also acceptable. Figure 1 on the left shows the sequence of GPTS steps using airmobile fieldwork. To the right, this figure shows the appearance of the DSF16C equipment in the moisture-proof case.

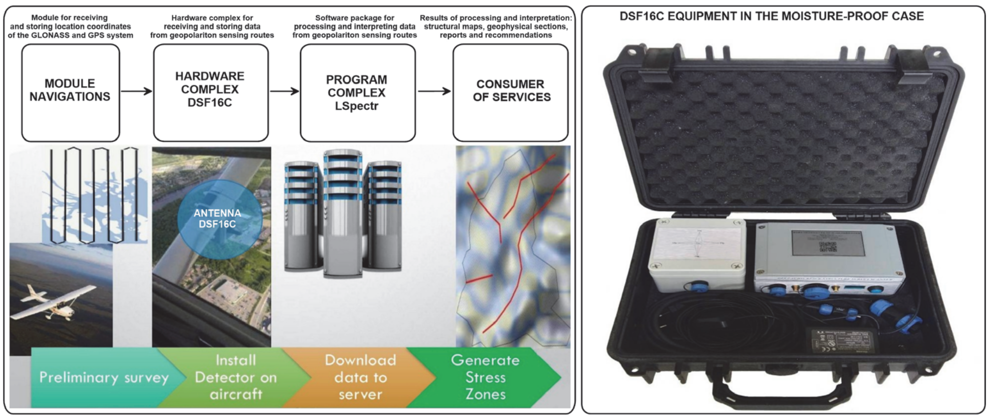

Figure 1 *On the left shows the sequence of GPTS steps using airmobile fieldwork. To the right, this figure shows the appearance of the DSF16C equipment in the moisture-proof case*

The scanner performs measurements along the line of the measuring profile, which has heterogeneity in the geological section and a strongly expressed internal relief. Intensity I, expressed in terms of magnetic field strength (A/m), is measured along the profile line. A three-component antenna is used to receive the signal. The signal is amplified and fed to a threshold device (Aleshin and Bogdanov, 2004) and then to a microcontroller in which the number of pulses exceeding a given threshold during exposure time is directly counted. Exposure time is set within 0.1 ... 10 seconds depending on profile transmission velocity. Then, the information processed by the microcontroller is bound to geographical coordinates and written to the scanner Flash memory.

Structurally, the scanner consists of two units - receiving antennas unit and signal processing unit. Block enclosures have a certain degree of environmental protection IP64 (Prokopenko, 2017). The receiving antennas unit contains three antennas, the radiation pattern of which are located in three mutually perpendicular planes and an antenna amplifier with a symmetrical output, which makes it possible to reduce induced electrical interference during signal transmission through the communication line. The receiving antennas are made in such a way that their magnetic moments are quite constant in the entire operating frequency band of the scanner. The signal processing unit consists of an analogue processing module with a symmetrical input, a digital processing module, a power supply module, Flash memory, GSM, GPS, Bluetooth and Wi-Fi modules. The scanner is powered by an internal Li-ion battery. Continuous operation time from fully charged battery is not less than 20 hours.

Processing and interpretation of data from geopolariton sounding is performed using the "Points Remover", "DSF16", "LSpectr", "MODE" software complexes. These software are developed by Hebei DSF-GEOS Technology Co., Ltd specialists.

In particular, the algorithm of the program complex LSpectr uses a search for the transfer function operator according to the signal measured along the profile, taking into account the input action – the Earth's core vibration. The algorithm is implemented on the .NET Framework/WPF platform using the C# programming language. The data is pre-processing: spline approximating, moving averaging and median normalizing. A piece of data is allocated; it is decomposed according to generalized Laguerre orthogonal functions with specified parameters. The obtained decomposition coefficients are used to calculate the transfer function. The order of the transfer function is not given, as in other methods, but is calculated according to the author's methodology. The calculated transfer function is used to calculate the stratum undulation velocities of geological objects (Bogdanov and Vodopianov, 2017). Operating windows of software systems are given in Figure 2.

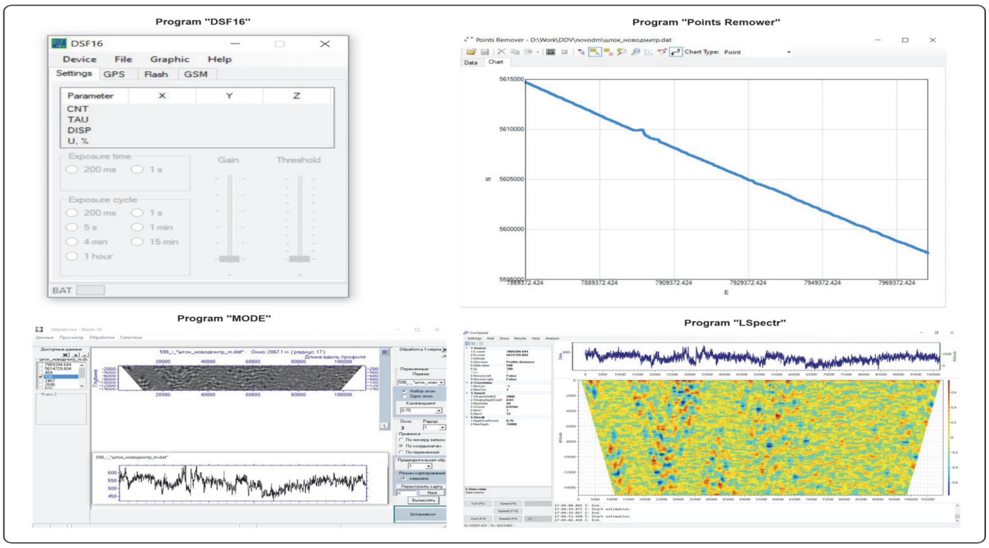

***Figure 2** Operating windows of software systems*

Research results. Experimental and methodological works by the GPTS method were carried out at geophysical landfills in the period 2012-2020. The main task was to assess the accuracy of determining the boundaries of radiating horizons and cross-sectional fault mapping. As an example, 3 sites of hydrocarbon deposits with actual data of drilling results located in different geographical areas, such as Ukraine, Egypt and China, were considered. Models of the deep structure up to a depth of 30 km were obtained using the GPTS method. The interpretation results with the legend are shown in Figure 3. The sections clearly reflect the layered structure of the strata and lines of multi-rank discontinuous dislocations. Large faults at angles of about 45 ° intersect the entire plane of the profile. Their "roots" are confidently traced to a depth of 30 km, probably deeper. A mosaic view in the distribution of density characteristics of sedimentary formations or velocities in sedimentary rocks shows their heterogeneity within the boundaries of individual blocks (Kolomiets et al., 2013). Rock decompression centers are installed at depths of up to 30 km, probable source of hydrocarbon fluids accumulation, paths of their movement along bursting disturbances and decompression zones are traced. Since fluids delay the transmission of electromagnetic waves, part of the energy is lost due to them, and fluids (HC) in the pore or fractured space of secondary collectors "look" low-density against the background of dense consolidated containing rocks (Bogdanov et al., 2009).

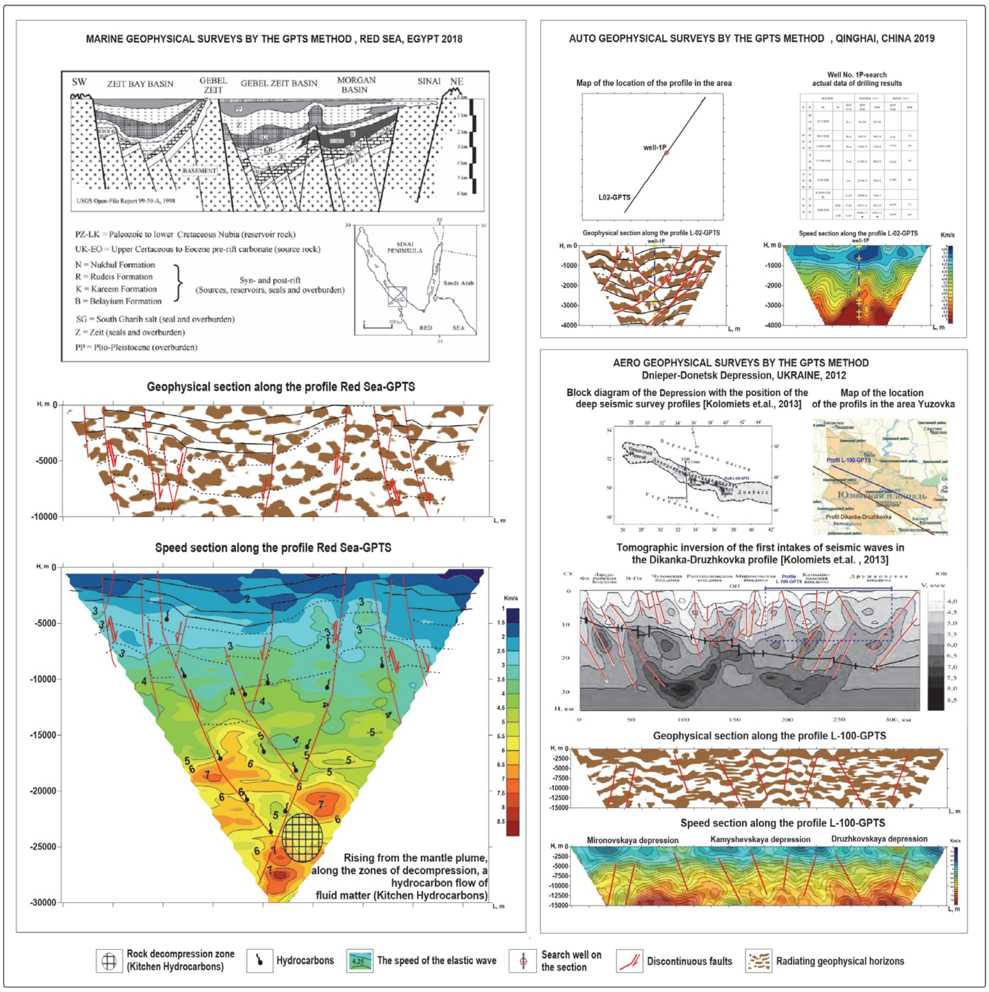

***Figure 3** The interpretation results by the method of GPTS*

Conclusion. As a result of geophysical surveys using the GPTS method using the hardware complex "DSF16C" and the software complexes "LSpectr" and "MODE", structural and speed characteristics of the Earth's deep structure were obtained using examples of 3 hydrocarbon deposits located in different geographical areas up to a depth of 30 km. Based on the results of actual drilling data, the metrological indicator for determining the accuracy of the boundaries of radiating horizons and mapping in the section of rupture violations amounted to more than 85%.

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