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Innovative Express-Technology of Direct Searching for Hydrocarbon Deposits by Geoelectric Methods: New Perspectives in Oil and Gas Prospecting

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Summary

The results of application of express-technology of direct searching and prospecting for hydrocarbon deposits by geoelectric methods are presented. The technology includes the method of forming of short-pulsed electromagnetic field (FSPEF), flux-meter survey and method of vertical electric-resonance sounding (VERS) (the FSPEF-VERS technology). Integrated application of these methods gives a possibility to find and map on the area the "deposit" type anomalies (DTA), and to define the total thickness and bedding depths of anomalous polarized layer (APL) of "oil layer", "gas layer", "water-saturated layer" type. The FSPEF-VERS technology can be used also for hydrocarbon reservoirs searching and prospecting in sea and ocean water area.

Introduction

State enterprise "Management and marketing Center in the field of Earth sciences research of the Institute of Geological Sciences of Ukrainian NAS **(MMC IGS NASU),** Institute of Applied Problems of Ecology, Geophysics and Geochemistry **(IAPEGG)** and "Geoprom" Research-and-production organization **(RPO "Geoprom") (Kiev, Ukraine)** have designed the innovative **express-technology** for operative solving the problems of ecology, engineering geology and geological-geophysical studies, which is based on geoelectric, seismic-acoustic and GPR methods of investigation. The original geoelectric methods (**know-how**) form also the base of efficient and economical technology of **direct searching and prospecting** for hydrocarbon deposits (Levashov et al., 2003, 2004a, 2004b). The generalized results of this technology application during 2001-2005 are given in this paper. The perspectives of the technology further application are discussed also.

Technology Components and Equipment

The express-technology includes the method of forming of short-pulsed electromagnetic field **(FSPEF)**, flux-meter survey, method of vertical electric-resonance sounding **(VERS)**, as well as compact and computerized equipment for field observations, GPS-receiver, software for measurement data registrations, processing and interpretation, methods of field observations conducting.
The geoelectric methods of investigation are based on studying the geoelectric parameter of the medium in the pulsed, not installed geoelectric fields, as well as the quasi-stationary electric field of the Earth and its spectral features over hydrocarbon deposits.

1. The FSPEF method is based on studying the process of the short-impulse electromagnetic field forming in small-sized dipole ferrite antennas. The application in this modification of the method of short but high-powered

electric pulses gives us an opportunity to refuse the use of long lines and to reduce the energy consumption. Moreover, small-sized dipole ferrite antennas and power supply let us reduce the observation period in the measurement points, consequently, to raise the productivity and efficiency of the developed modification in comparison with the traditional ones.

2. The flux-meter survey is carried out to measure the vertical component intensity of the Earth electrical field over the investigated objects. This information gives us an opportunity to get the thickness evaluation of the “anomaly polarized layers” in the anomalies zones

3. Vertical electric-resonance sounding is based on the studying the processes of natural medium polarization and spectral characteristics of natural electric field over the investigated object. As far as the horizontally stratified cross-sections are concerned, this technology gives a possibility to efficiently divide the cross-section on separate stratigraphic subsections in the sounding site and to determine its depth with high accuracy. Sounding effectiveness rises considerably if in the regions in view there are documented parametric boreholes which give the possibility to “standardize” sounding diagram – to link separate meaning intervals with the corresponding stratigraphic layers of the cross-section.

Joint use of these methods within the technology framework gives a chance to find and map on the area the **"deposit" type** anomalies **(DTA)**, to value the total thickness of **anomalous polarized layer (APL)** of the "oil layer", "gas layer", "water-saturated layer" type and etc and to define their bedding depths. The realized possibility of conducting the areal surveys from moving car allows to examine the vast on size territory during the short time periods.

The results of the geoelectric methods using during aerogeophysical investigation within the Sobynskoye oil-gas condensate field (Russia) testifies that FSPEF survey can be used with other aerogeophysical methods for reconnaissance investigation of big for area and difficult of access territories.

Technology Application

During 2001-2005 the technology had broad approbation on hydrocarbon deposits and perspective area on the territory of Ukraine, Western Kazakhstan, Bulgaria and Russia.

The geoelectric investigation data on Western Kazakhstan oilfields (Levashov et al., 2003, 2004b), that were received with the help of suggested technologies applied, were compared with available data of geophysical studies in bore holes, borings and seismic. The results of such comparison have shown that: a) technology of "direct" searching and prospecting for oil and gas deposits by geoelectric methods is efficient enough and economical; b) the most efficient results with the technology help can be received first place on the stage of the search examinations of significant by size and perspective for hydrocarbon deposits area; c) the technology used for searching and prospecting for the oil and gas fields in integration with the other geological-geophysical methods of investigation (seismic included) will promote for increasing the cost-performance of geologic-prospecting process on oil and gas as a whole.

In March 2004, geoelectric investigation was carried out from shipboard in the water area of the Antarctic Peninsula near Ukrainian Antarctic station "Academician Vernadskiy" during the seasonal functioning of the 9-th Ukrainian Antarctic expedition. The received data indicate the possibility of the designed geoelectric methods use when conducting geologic-geophysical studies in the marine area. They can be used as well during the marine oil and gas deposits searching and prospecting.

In 2004 the geoelectric studies of regional and detailed character were carried out within some perspective areas and hydrocarbon deposits in Dnepr-Donetsk depression (DDD) (Levashov et al., 2005): a) Ichnyanskaya group of the structures in Chernigov region; b) Selyuhovskaya, Zapadno-Radchenkovskaya, Pokrovskaya, Pirkovskaya, Zagoryanskaya and Kharkoveckaya areas in Poltava region; c) Narizhnyanskaya area in Kharkov region; d) Golubovskaya, Uliyanovskaya and Proletarskaya area in Dnepropetrovsk region. Field work on Ichnyanskaya group of the structures and Selyuhovskaya area was done in winter period (January - February). Geoelectric studies of reconnaissance character were conducted also in this year on two perspective areas in Bulgaria, as well as on Buzuluk area in Orenburg region of Russia.

The experimental and detailed geoelectric investigations with the express-technology used were conducted also within the mine field of M.I. Kalinin mine in Donetsk city (Levashov et al., 2006). The main purposes of these investigations are finding and contouring the area with raised concourse of the gas in coal layers and in containing coal rocks. Within the mine field of M.I. Kalinin mine three anomalous zones with raised gas content were mapped by the FSPEF survey. The depths of bedding and also the thickness of the rock layers with raised gas content were determined by the VERS method. The data of the FSPEF and VERS geoelectric methods give additional information for the degassing boreholes optimum pawning. The possibility of these methods use for the coal layers mapping was shown also.

Application statistics. Geoelectric investigations with the express-technology used were conducted on **40 oil and gas fields**. The "deposit" type anomalies are fixed by FSPEF survey **on all (40!) oil and gas fields**. APL of "oil-and-gas layer" type was chosen by VERS sounding in cross-sections of all this oilfields. Geoelectric "deposit" type anomalies were also mapped by FSPEF method within **50** perspective for oil and gas **structures and separate areas** from 62 investigated. Some graphical results of the express-technology application with short explanation are shown on the f**ig. 1-11**.

Application Examples

Uaz oilfield (Western Kazakhstan). The geoelectric investigation (2002) show (fig. 1), that 1) five mapped separate "deposit" type anomalies can be connected with the zones of tectonic-shielded traps of hydrocarbons; 2) all bore holes in borders of anomalous areas are productive (G4, G11, G12, G14), bore holes, outside of borders of anomalies (G10, G9, G13) - unproductive. 3); the projected bore holes G15 (800 m), G6 (1400 m) and G5 (1200 m) are located outside of the anomalous contours and it is reasonable move them in points, disposed in central parts of the "deposit" type anomalies.

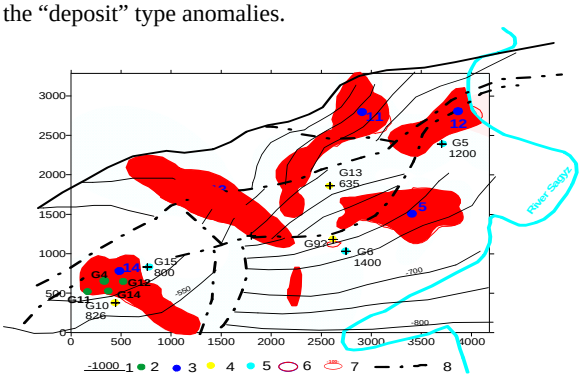

Figure 1. The map of the "deposit" type anomalies on the Uaz oilfield. *1* – surface of the 3rd reflecting horizon; *2* – productive wells; *3* – sounding points; *4* – empty wells; *5* - projected well; *6* – geoelectric anomalies zones; *7* – efficient thickness line of APL; *8* – tectonic fracture zones on seismic data.

Kharkovetskaya area (Ukraine, DDD). There are two boreholes within area (fig. 2): #22 – productive, and #24 – non-productive. The FSPEF survey shown, that projected well #23 is within the maximum values of western part of anomaly. The APL layers of "oil and gas" type were revealed by VERS soundings near well ## 22 and 23.

The part of more intensive eastern anomaly was mapped at the same time during survey.

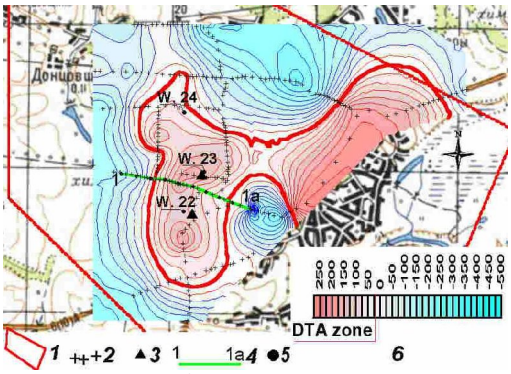

Figure 2. The map of DTA anomaly within the Kharkovetskaya area. *1* – area contour; *2* – points of FSPEF survey; *3* – VERS points; 4 – the VEF profile line; *5* – well ## 22,23 and projected #23; *6* – scale of intensity of FSPEF anomaly.

Zhdanovsko-Dykonskaya area (Ukraine, DDD). The map of FSPEF survey (fig. 3) show that "deposit" type anomalies are mapped within Ulyanovskaya structure (gas deposit) and Proletarskoye underground gas storage (UGS). The DTA anomaly of same dimension was mapped to south from Proletarskoye UGS. It is connected with anomaly within Ulyanovskaya structure.

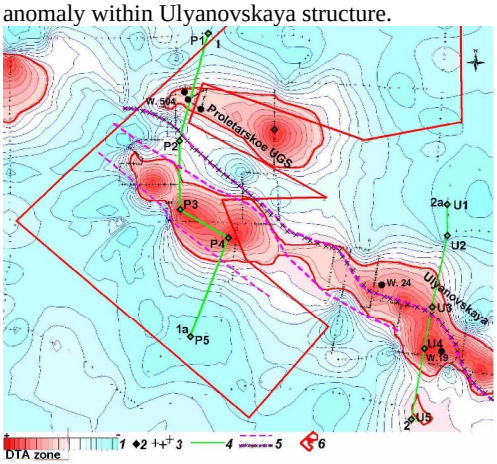

Figure 3. The map of DTA anomaly within Zhdanovsko-Dykonskaya area. *1* – scale of intensity of FSPEF anomaly; *2* – VERS points; *3* – points of FSPEF survey; *4* – line of the VERS profile; *5* – tectonic fracture zone on seismic data; *6* – area contour.

The APL layers were reveled within anomalies zone by VERS sounding, the thickness of layers was determined. The anomaly areas were recommended for detailed geologic-geophysical investigation and prospecting drilling.

The area of Simferopolskaya #1 borehole (Ukraine, Crimea). The FSPEF survey show, that DTA anomaly absent within investigated area (fig. 4). Usually, such type anomalies are

mapped on hydrocarbon deposits. The drilling has show that well is dry.

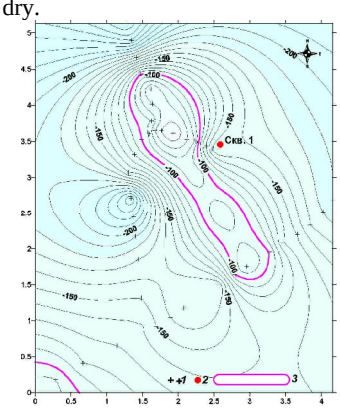

Figure 4. Map of FSPEF survey in the region of Simferopol #1 borehole drilling. *1* – survey points; *2* – borehole position; *3* – contour of prospective structure.

Pokrovskaya area (Ukraine, DDD). The DTA absent within investigated area (fig. 5). It is inexpedient to drilling the borehole in this area on geoelectric data.

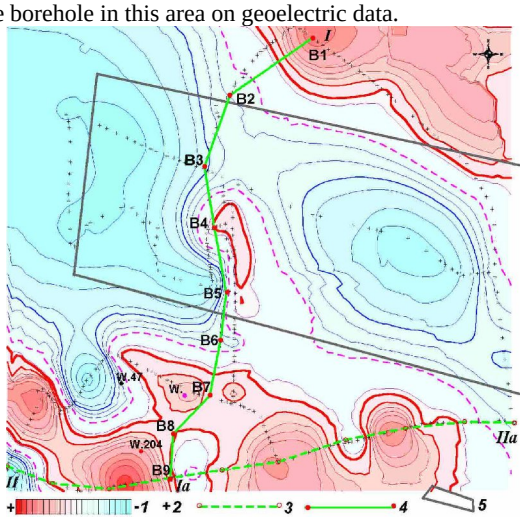

Figure 5. The FSPEF anomaly map for 1500-5000 m depth interval within Pokrovskaya area. *1* – scale of intensity of FSPEF anomaly; *2* – FSPEF survey points; *3* – points of variation survey (VS); *4* –VERS profile; *5* – area contour.

Western-Radchenky area (Ukraine, DDD). Within the investigated area (fig. 6) the 202bis borehole is productive, 202 –with "gas+water" layers and 203-204 are projected. The investigation showed that it is necessary to remove the position of projected borehole 204 within DTA anomaly contour.

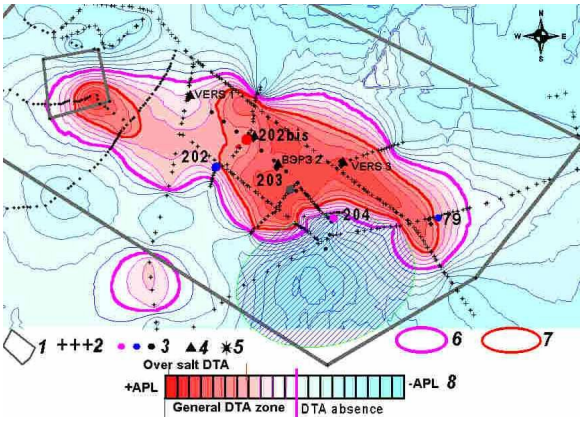

Figure 6. The FSPEF survey map within Western-Radchenky and Zubovka areas. *1* – area contour; *2* –FSPEF survey points; *3* – drilled and projected boreholes: *4* – VERS point; *5* – point of variation survey (VS); *6* – general contour of DTA anomaly; *7* – contour of productive hydrocarbon deposits, admittedly; *8* – scale of FSPEF anomaly intensity.

Proletarskoye underground gas storage (Ukraine, DDD). The VERS data within Proletarskoye UGS (fig. 3) is shown on fig.7.

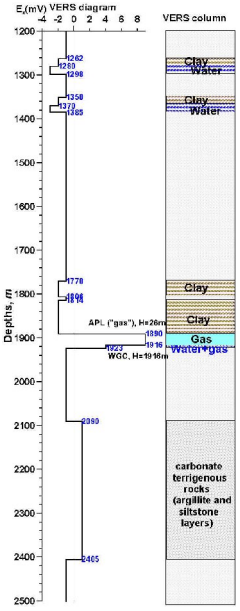

Figure 7. The VERS sounding data on Proletarskoye underground gas storage of geological type.

Ichnyanskaya area (Ukraine, DDD). The geoelectric studies resulted in finding two DTA anomalies within the block investigation area (fig. 8). The structures #1 and #5 – "Nezhnaya" and "Bereznaya" – are most perspective for oil deposit from six seismic structures in northern part of

block. The depth interval of APL of "oil layer" type are following: 2650-3200 m within plot #1, and 2200-2350 m, 2700-3050 m within plot #5.

Received data show, that it is necessary to conduct further detailed geophysical investigations only within structures #1 and #5.

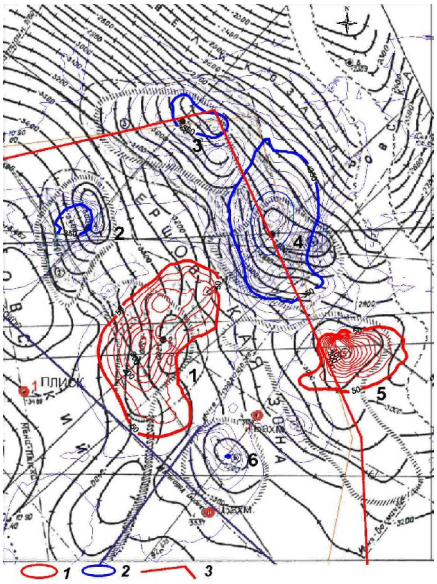

Figure 8. Geoelectric anomalies map combined with the structural map of Ichnyanskaya group of structures. *1* – "deposit" type anomaly zones; *2* – high conductivity zones; *3* – block boundaries. The figures designate following structures: 1 – Nezhnaya. 2 – Perova. 3 – Yershova, 4 – Yelskaya, 5 – Bereznaya, 6 – Gorlivka.

Sobynskoye oil-gas condensate field (Russia). The experimental ground geoelectric investigations by methods of FSPEF, flux-meter survey and VERS, as well as FSPEF survey from the airplane within oilfield were performed in August 2006. The main objective is to study the possibilities of using the FSPEF and VERS methods for oil and gas exploration in condition of the Siberian platform. For the first time the possibility of using the FSPEF method in aerial variant at height up to 100 m was investigated.

The results of geoelectric investigation (fig. 9, 10) on Sobinskoye oil-and-gas field have shown that FSPEF-VERS technology can be used for searching and prospecting the hydrocarbons in difficult tectonic and geological condition of the Siberian platform. It's completely obvious that the FSPEF and VERS methods can effectively solve such problems on this territory, which repeatedly solved in condition Kazakhstan, Ukraine, Bulgaria.

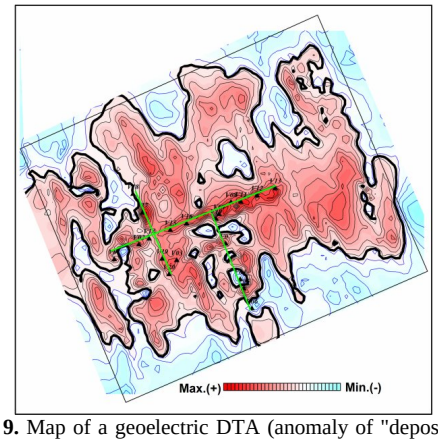

Figure 9. Map of a geoelectric DTA (anomaly of "deposit" type) over the area by aerial survey data (Sobinskoye oil-and-gas field).

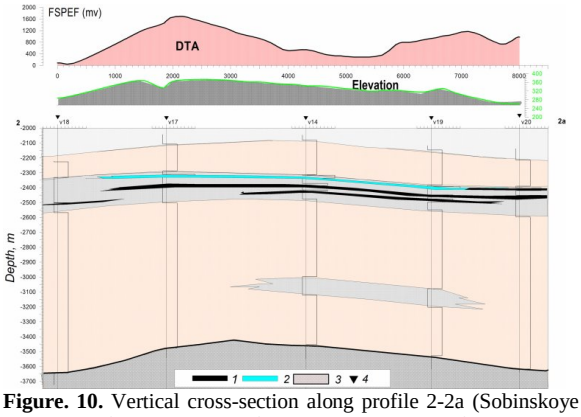

Figure. 10. Vertical cross-section along profile 2-2a (Sobinskoye oil-and-gas field). *1* – APL of "oil " type; *2* – APL of " gas " type; *3* – APL of "basement" type; *4* – VERS points; 5 – tectonic fructure by geoelectric data.

Antarctic Peninsula region. In water area near Antarctic Peninsula the "deposit" type anomaly was mapped by FSPEF survey and APL's of "hydrocarbon deposit" type were chosen by VERS sounding in interval of this anomaly (fig. 11). This indicates not only of principal, but also of practical possibility of the FSPEF-VERS technology using for searching and prospecting the hydrocarbon reservoirs in the sea and ocean water areas.

Technology Application Perspectives

The practical application results of express-technology of "direct" searching for the hydrocarbon accumulation by geoelectric methods show that this technology is enough operative, efficient and economical.

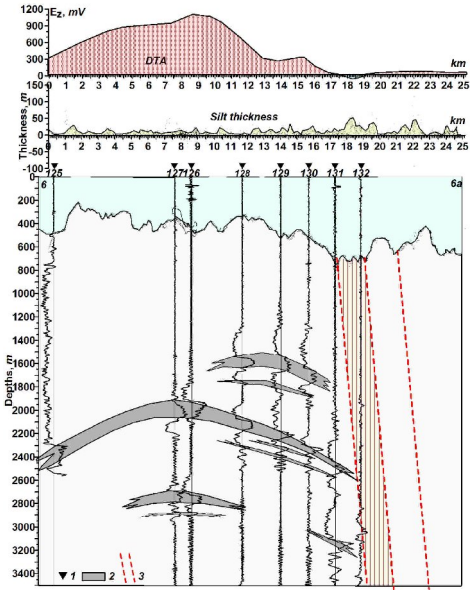

Figure 11. The VERS sounding data over geoelectric anomalous zone of the "hydrocarbon deposit" type in the Antarctic Peninsula region. *1* – sounding points 125-132; *2* – anomalous polarized layers of "hydrocarbon deposit" type; *3* – tectonic fracture zone.

It is reasonable to include this technology in the complex of geologic-geophysical methods for the hydrocarbon deposits searching and prospecting. We are sure that technology used on oil and gas fields and perspective area will allow raising the efficiency of geologic-prospecting process for oil and gas as a whole.

The following directions are general for the further express-technology application:

1. To carry out reconnaissance geoelectric investigation within the perspective for the hydrocarbon accumulation areas: a) the geoelectric "deposit" type anomalies searching and mapping by FSPEF survey; b) the thickness and bedding depths of anomalous polarized layer determination within the chosen geoelectric anomalies by VERS method; c) the areas selection for the detailed seismic and other geologic-geophysical studying.

On the reconnaissance investigation level the technology can be used for solving the problem of large and middle hydrocarbon deposits searching. So, the mapped geoelectric anomaly was compared with productive and empty boreholes location within Ulyanovskaya structure (fig. 3). The comparison shows that the geoelectric anomalies sidebars enough objectively display the sidebars of the productive horizons spreading. It is possible to do such conclusion from the geoelectric investigation data within the Western Kazakhstan oilfields as well. This circumstance enables to consider, in the first approximations that the geoelectric anomaly areas are close to the productive horizon spreading areas. On the other hand, the VERS sounding data also show that for the more intensive geoelectric anomaly, mapped by FSPEF survey, there is the more thicker the anomalous polarized layers of the "oil and gas layer" type. Consequently, the area of the "deposit" type anomalies, as well as its intensity can be in the first approximations by a value of the sizes and thickness of anomalous polarized layer of the "oil and gas layer" type in cross-section.

2. To conduct the detailed geoelectric studies within separate oil and gas field and area for the optimum places choice for the parametric, exploratory and production bore holes pawning.

3. The express-technologies using for hydrocarbon accumulation searching and prospecting of in sea and ocean water area.

4. To carry out reconnaissance geoelectric investigation for the license area examinations with the reason to choice the most perspective for detailed geologic-geophysical studying and following development.

5. The express-technology application for the fractured zones and collectors searching and mapping in the crystalline basement rocks and in the "closed" sedimentary basins.

Conclusions

The results of practical application of the technology of direct searching and prospecting for hydrocarbon accumulations at oil-and-gas deposits and on hydrocarbon-promising territories in Western Kazakhstan and Ukraine (including the above ones) show that the express-technology enables us to effectively solve the problems of: a) "deposit" type anomalous zones contours determination; b) depth ranges of anomalous hydrocarbon-containing zones finding; c) total thicknesses of anomalous layers evaluating; d) depths of the bedding of salt roofing and footing determination; e) the structure of under-cornice anomalous zones mapping and studying.

The technology of direct searching and prospecting of hydrocarbon accumulations applying can prove very effective on newly-explored and, therefore, poorly examined territories. The procedure of conducting reconnaissance survey from car allows us to significantly reduce the amount of time needed for examining the extensive territories. In this connection, there is a possibility for combining the geoelectric and seismic works with the aim of marking out zones with increased density of

seismic profiles and sections with their decreased density. This will enable us to reduce the cost of seismic works.
Vertical electric-resonance sounding technology is an effective method of geophysical research, which allows us to promptly divide a geological cross-section into separate stratigraphic types and to determine with a high precision the depths of their bedding. The method's effectiveness can be greatly increased by carrying out prior to research works an additional procedure of the sounding diagrams calibration. Such calibration is conducted usually within investigated area on points with known stratigraphic cross-section, which, in their turn, were constructed in accordance with drilling and logging data.

The apparatus systems for FSPEF survey and electric-resonance sounding are compact, relatively light and convenient for transporting. The system allows us to carry out the survey and sounding works both under field conditions and in residential areas.

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