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# Physical and Technical Fundamentals of the Seismoelectric Method of Direct Hydrocarbon Prospecting in the Arctic Using Automatic Underwater Vehicles

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**Abstract.** The article deals with the problems of the implementation of underwater-surface variants of the seismo-electric method of direct search for hydrocarbons in the conditions of the Arctic waters. An estimate is given of the strength of the secondary electric field when a gas reservoir is excited by the action of a seismic source based on an accompanying geophysical vessel and receiving signals on an automatic underwater vehicle. The article also discusses the issues of hardware implementation and navigation binding of waterborne devices.

**Keywords:** hydrocarbon search, Arctic waters, seismoelectric method, underwater vehicles.

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## Introduction

The seismic-electric method of direct hydrocarbon prospecting is based on the excitation of an electric field in porous rocks under the influence of acoustic radiation in the form of seismic shocks. The first publications on this effect were made in the works [1–4].

In [5], the results of marine prospecting operations by a seismic survey complex based on a geophysical vessel and seismic braids towed behind it with pneumatic guns and hydrophones are presented. The so-called "binary" technology of parallel illumination of the geo-section by an artificial electric field created by a towed flooded cable with a current was used [6], which, according to the authors, provides a significant increase in the sensitivity of the method.

It is extremely difficult to implement this technology on land due to the need to create large illumination currents and install branched earths that require heavy vehicles for transportation.

In addition, due to the influence of the processes of the formation of an electric field in a layered inhomogeneous medium, additional interference uncorrelated with the seismic signal is

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received at the input of the sensors of the electric signal of the SE effect. In addition, there remains the problem of moving the grounding of the electric illumination cable along the observation profile.

Using the example of setting this method at the Minusinsk gas condensate field [7, 8] as a semi-active one, that is, without the use of illumination by a special electric field, and a passive method with extracting information from the seismic and electrical noise of the Earth, the author of this article with colleagues showed the possibility of such work on land to the depth of the gas reservoir more than 2 km.

In publications [9–15] It contains various aspects of underwater-subglacial marine seismic exploration based on the use of an accompanying geophysical vessel and towed or located on the bottom of the sea seismic braids.

There are projects to install seismic stations on the sea ground, which makes it possible to significantly reduce the impact of sea surface waves.

# 1. Calculation results

We will give a numerical estimate of the magnitude of the electric field strength on the sea surface for the specified search parameters: the depth of the position of the productive hydrocarbon reservoir; its power; the conductivity of the seawater reservoir and the surrounding rock.

The pressure of a seismic wave on the hydrocarbon interface with the surrounding rock leads to the appearance of an additional electric charge in the hydrocarbon medium due to the displacement of the deposit surface in the electrostatic field of the Earth. In this model, hydrocarbon deposits are represented as a capacitor whose potential fluctuates synchronously with the seismic pressure field.

In the design scheme, a pulsed non-explosive source is located in the stern area of the base geophysical vessel below the waterline, and the receivers of seismic and electrical signals are placed in the hull of the AUV moving ahead of the vessel on its course at a distance of 200 m (Fig. 1). The electrical conductivity of seawater corresponds to $\sigma_1$=4 S/m, and the depth of the sea $h_1$=100 m. Productive gas reservoir with an area of $S_G$=3000×1000 m and power $h_4$=10 m located at a depth of $h_2$=1000 m. Electrical conductivity of the gas medium of the formation $\sigma_2=10^{-5}$ S/m, density $\rho_2$=100 kg/m$^3$, velocity of propagation of longitudinal seismic waves in gas is $V_2$=500 m/s.

The pressure of a seismic impact on the formation surface for the far zone of the source is estimated as [16]:

$$P_3 = \frac{4F_1\eta}{\pi R_U^2} \cdot \frac{\lambda_{S1}}{r_1 + r_2} e^{-\alpha r_{12} B_1} \cos\theta = 1.6 \cdot 10^4 Pa. \qquad (1)$$

Here, $\lambda_{S1} = \dfrac{V_1}{f_S}$ is the apparent wavelength corresponding to the first Fresnel zone;
$f_S = \dfrac{1}{2\tau} = 100Hz$ is the average frequency of the pulse spectrum of the source with a duration of $\tau = 5 \cdot 10^{-3}$ s;
$\theta$ is the angle of incidence of the wave on the formation;
$r_{12} = r_1 + r_2 = 1100$ m is the distance between the source and the reservoir surface;
$\alpha$=$10^{-4}$ 1/m is coefficient of absorption of a seismic wave by a rock.

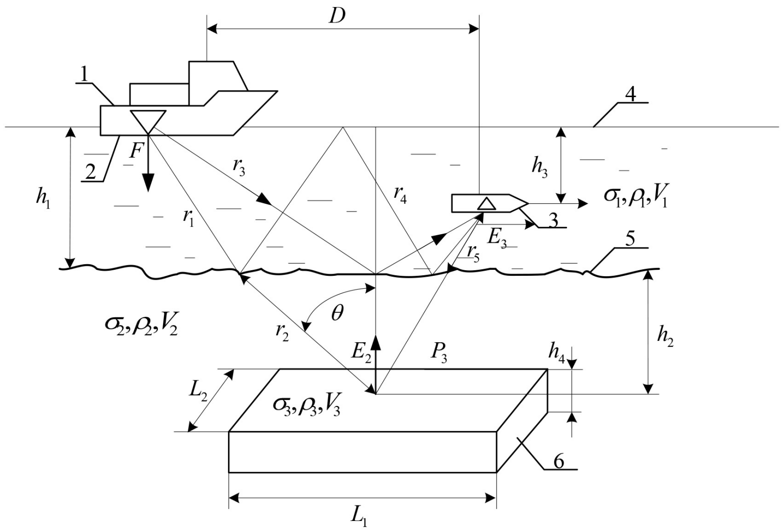


Fig. 1. Calculation scheme for estimating the electric field of the SE effect of a reservoir gas deposit. 1 — a geophysical vessel; 2 — a seismic emitter; 3 — an automatic underwater vehicle; 4 — the surface of the sea; 5 — the seabed; 6 — a productive reservoir of hydrocarbons

The coefficient of passage of a seismic wave into a productive reservoir:

$$B_{PP} = \frac{2\rho_2 V_2}{\rho_2 V_2 + \rho_3 V_3} \approx 1. \quad (2)$$

Absorption in water in the "radiator–bottom" section is not taken into account due to the smallness of its size. The displacement of the upper boundary of the reservoir under the action of a seismic shock is determined through the solution of the Newton differential equation:

$$m \cdot \frac{\delta^2 Z}{\delta t^2} + \frac{F_C}{V_3}\frac{\delta Z}{\delta t} - F_3 = 0. \quad (3)$$

Here, $m = V_3 \tau S_1 \rho_3$ is the mass of the displaced reservoir medium, determined by the depth of impact passage into the reservoir medium during a long pulse $\tau$;
$S_1 = \lambda_{S3}^2 = \left(\frac{V_3}{f_S}\right)^2$ is he area of the Fresnel wave zone on the formation surface;
$F_3 = P_3 S_1$ is impact force on the formation surface;
$F_C$ is resistance force of the formation medium;
$Z$ is displacement of the reservoir surface under the impact of a seismic pulse.

Solution (3), gives:

$$Z = \frac{1}{\left(1 + \frac{P_C}{V_3 m}\right)} \frac{P_3 \tau}{V_3 \rho_3}. \quad (4)$$

The intensity of the electric field in the formation created by the impact of a seismic wave can be estimated as:
Solution (3), gives:

$$E_2 = E_0 \frac{Z}{h_4}, \quad (5)$$

Here, $E_0$=120 V/m is the intensity of the natural electric field of the Earth, causing the full charge of the reservoir.

The current arising through the reservoir element is defined as:

$$I_3 = E_2 \lambda_{S3}^2 \sigma_3 \frac{Z}{h_4}. \tag{6}$$

The total current passing through the entire surface of the formation will be higher by an amount $n = \dfrac{L_1 L_2}{\lambda_{S3}^2}$:

$$I_{3\Sigma} = E_0 \sigma_3 L_1 L_2 \frac{Z}{h_4}. \tag{7}$$

According to our experiments at the Minusinsk gas condensate field, the calculated dependence of the intensity of the secondary electric field over the productive gas reservoir is of a two-humped nature, which corresponds to the field of a vertical electric dipole with a current $I_{3\Sigma}$.

Under the action of this current, the electric charge of the entire formation will be:

$$Q_S = I_{3\Sigma} \tau. \tag{8}$$

Taking into account (6, 7):

$$Q_S = \frac{E_0 \sigma_2 \tau L_1 L_2}{h_4}. \tag{9}$$

The current density caused by this charge at the observation point:

$$j_X = \frac{I_{3\Sigma} K}{4\pi (r_2 + r_6)^2}, \tag{10}$$

Here, $K = e^{-(\beta_1 r_5 + \beta_2 r_2)}$ is the absorption coefficient of the electric field in water and rock.

Because $j_X = \sigma_1 E_3$, then the modulus of the electric field strength at the receiving point:

$$E_3 = \frac{E_0 \sigma_3 L_1 L_2 Z e^{-(\beta_1 r_5 + \beta_2 r_2)}}{4\pi \sigma_2 h_4 (r_2 + r_6)^2}. \tag{11}$$

For the following private parameters: $E3$=120 V/m; $\sigma_3/\sigma_2=10^{-2}$; $L_1 \cdot L_2 = 3 \cdot 10^6$ m$^2$; $Z=1.6 \cdot 10^{-4}$ m; $r_{12}$=1100 m; $K$=0.22, value $E_3$=3.8 $\mu$V/m.

The obtained estimates are in good agreement with the experimental data [7], which allows us to recommend this technique for calculations before the fake search work. Unlike the known approaches, this technique allows to estimate the required impact force of a seismic source at a given depth of search at a simple engineering level.

The graphs of the envelope signals of the secondary electric field along the observation profile are of a two-humped nature, and correspond to the field of a vertical electric dipole created by a pulsating charge of a "capacitor" equivalent to a productive reservoir.

In a spherical coordinate system, the electric field strength of the dipole on the Earth's surface is estimated as [17]:

$$E_r(\theta) = \frac{2P \cos\theta}{4\pi \varepsilon_0 \varepsilon r^3} e^{-\alpha r}, \tag{12}$$

$$E_\theta(\theta) = \frac{2P \sin\theta}{4\pi \varepsilon_0 \varepsilon r^3} e^{-\alpha r}. \tag{13}$$

Here $P = I h_4$ is dipole moment at current $I$;

$r = r_2 + r_5$;
$\varepsilon_0$ is dielectric constant;
$\varepsilon$ is dielectric constant of rock;
$h_3$ is dipole length (productive reservoir capacity);
$\alpha = \sqrt{\dfrac{\omega\mu\sigma}{2}}$ is the attenuation coefficient of the electric field in the rock;
$\omega$ is operating frequency; $\sigma$ is electrical conductivity of the medium $\theta$ is spherical angle.

Fig. 2 shows a graph of the envelope of the horizontal component of the vertical electric field of the dipole along the motion profile of the search engine with the following parameters: $I$=1 A; $f$=10 Hz; $\varepsilon$=10; $\sigma$=$10^{-3}$ S/m; $h_2$=500, 1000 m.

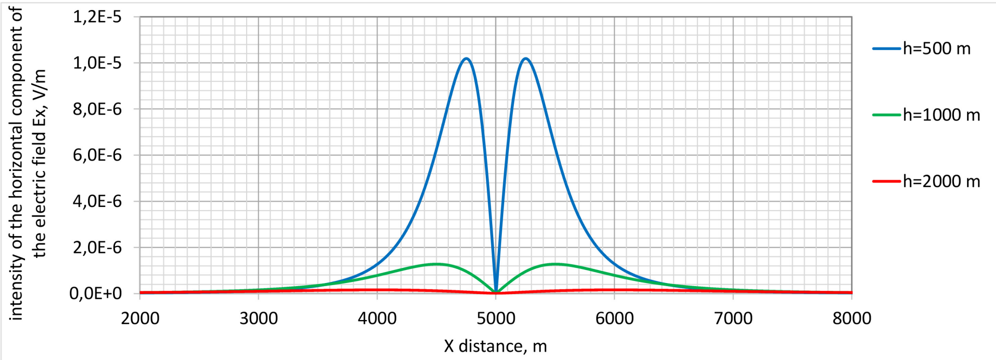


Fig. 2. Distribution of $E_x$(mV/m) at $h_2 = 1000$ m

In Fig. 3, the finite element method calculates the distribution of the field on the Earth's surface by area, which makes it possible to determine the search area in 3D modification. In this case, you can use several AUVs running a parallel course, capturing subglacial areas.

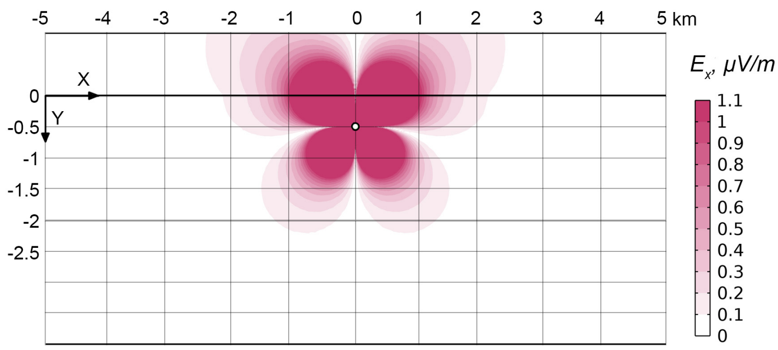


Fig. 3. Distribution of $E_x$(mV/m) at $h_2 = 1000$ m

The capacitance of a capacitor equivalent to a reservoir can be defined as:

$$C = \frac{\overline{\varepsilon}\varepsilon_0 L_1 L_2}{Z}, \tag{14}$$

where $\varepsilon_0$ is constant. $\varepsilon$ is dielectric constant of the «capacitor» medium.

Taking for example $\overline{\varepsilon}$=10; by $L_1 \cdot L_2 = 3{\cdot}10^6$ m$^2$; $Z$=1.6 $\cdot$ 10$^{-4}$ m, we get $C$=0.26 F. In this case, the time constant of the discharge of the formation on the surrounding rock:

$$T_p = C\frac{h_2}{G_2 L_1 L_2}. \tag{15}$$

By $\sigma_2 = 10^{-5}$ S/m, we get $T_p \approx 0.1$ s.

Since the duration of the seismic pulse was assumed as $\tau = 5{\cdot}10^{-3}$ c and relationships $T_p/\tau = 20$, then, with the continuous repetition of shocks, characteristic of the action of a seismic wave, there will be a constant increase in the intensity of the secondary electric field on the surface.

Due to the fact that the length of the anomaly along the motion profile of the search engine approximately corresponds to the double depth of the position of the productive reservoir, then at the speed of movement $V = 1$ m/s, this anomaly will be passed in time $T_n = 2h/V = 2 \cdot 10^3$ c and during this time, 200 seismic source impacts will act on the formation. If we take 20 periods of their repetition for averaging signals, then the signal-to-noise ratio increases in $\sqrt{20} = 4.5$ times, which corresponds to their group processing of classical seismic survey from 20 geophones.

Since in these conditions it is not required to accurately determine the coordinates, it is quite possible to use in the work a navigation reference to the difference-dimensional long-wave systems such as "Laurent" (USA), "Zeus" (Russia) in the frequency range of 100 kHz.

## 2. Hardware

It is possible to create the following complexes of the seismoelectric method:

1. is a small-sized submarine (seismic source) and a group of automatic underwater vehicles (AUV).
2. is a basic geophysical vessel with a seismic source and an AUV group.
3. is a basic underwater robot with a group of seismic sources and a group of PPR.
4. is a basic geophysical vessel without a seismic source and an AUV group with reception of electrical and seismic noise of the earth in the frequency range 0.1–20 Hz [11].

According to the first variant of the seismic source, it is located on a submarine (GROOVE) of a small class with a displacement of 100–200 tons (Fig. 4). The AUVs are placed in the bow torpedo tubes, through which they are pushed along the course of movement at a distance of 100–200 m. When working with the 3D AUV method, they are positioned orthogonally to the course. The AUV is controlled from the PA via a hydroacoustic channel. Navigation binding is implemented either from the accompanying vessel, or directly by receiving signals from the above-mentioned long-wave navigation systems. It is advisable to use broadband electromechanical emitters with pseudorandom coding of a sequence of seismic signals providing a minimum power level as an on-board seismic source [18, 19].

The second option (Fig. 1) does not require the development of a special submarine. The third option (Fig. 4) differs from the first by placing the seismic source on an autonomous underwater operation.

Finally, the fourth modification of the system does not require illumination of the geo-section by an artificial seismic source. The natural noise fields of the Earth are used with the processing of

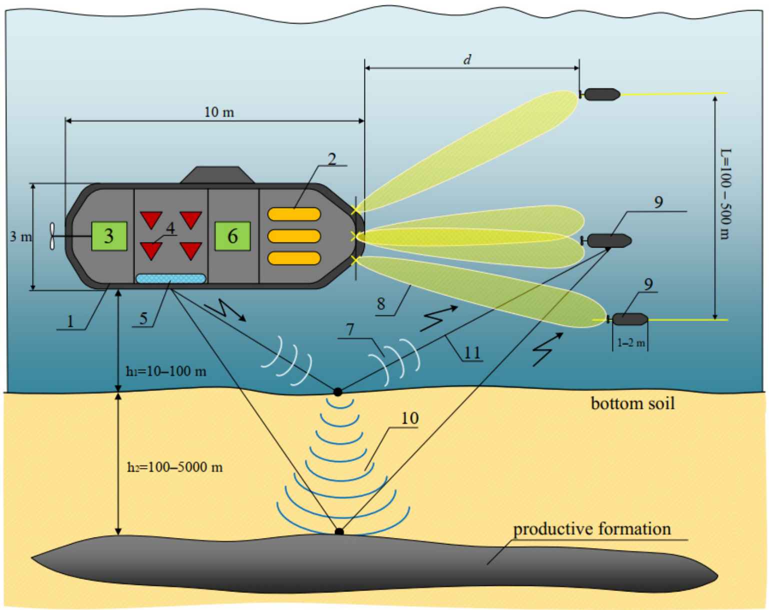


Fig. 4. Underwater seismic survey system USSS-M-1: 1 — submarine hull; 2 — torpedo tubes; 3 — screw drive; 4 — seismic emitters; 5 — shock plate; 6 — deckhouse; 7 — reflected wave from the ground; 8 — hydroacoustic rays of the control channel; 9 — automatic underwater vehicles; 10 — shock wave in the geological environment

electrical and seismic signals by the method of mutual correlation according to the algorithm [8]:

$$R(\tau) \approx \frac{1}{T} \int \overline{E}(t) \cdot \overline{S}(t-\tau)dt. \qquad (16)$$

Here $\overline{E}(t)\cdot$ and $\overline{S}(t-\tau)$ is accordingly, signals from sensors of electric and seismic noise fields, normalized by dispersion [8];
$T$ is observation time.

Of course, all four options require the management of the commands of the base geophysical vessel through the sonar channel, which is simultaneously the carrier of all outboard means. Today, there are many developments of underwater robots of the required class all over the world, so it is only necessary to create the hardware and software necessary for conducting search operations [20].

## 3. Navigation binding of coordinates of underwater vehicles

Next, we will consider the methods of radio navigation anchoring the coordinates of the AUV in an underwater position relative to the accompanying vessel or by signals from long-wave navigation systems such as "Loran" (USA or "Zeus" (Russia) [21]. In any case, it is necessary to ensure the reception of navigation signals under water or under ice. In [22], the authors described a parametric method for receiving electromagnetic signals in seawater based on controlling its conductivity by acoustic radiation. If an electromagnetic signal with vertical polarization comes from a third-party radio station on the surface of the water, then a horizontal component with an electric field strength is formed under the surface (Fig. 5) [23]:

$$E_X = \frac{E_{Z0}}{\sqrt{60\lambda\sigma}}. \quad (17)$$

Here $\lambda$ is the length of the electromagnetic wave, and the $\sigma$ is electrical conductivity of water. $E_Z$ is the intensity of the vertical component of the field on the sea surface. It can be seen from (17) that seawater, due to the refraction effect, greatly reduces the signal energy.

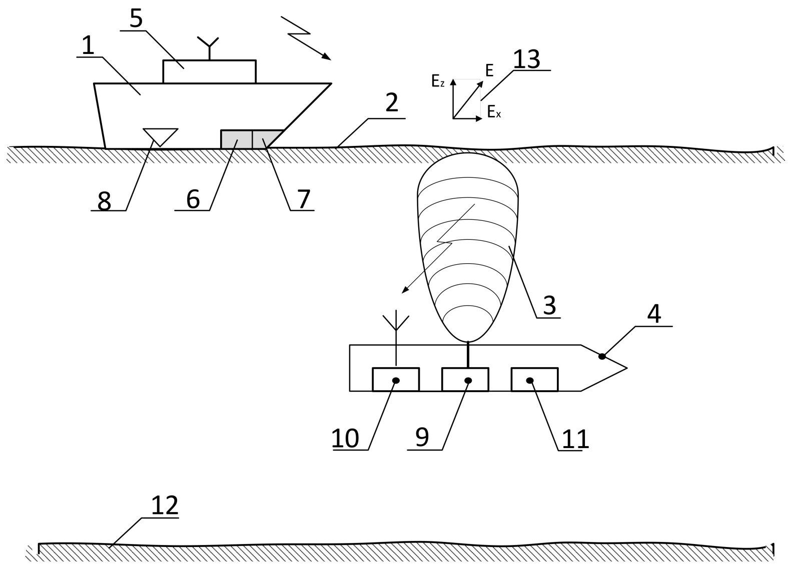


Fig. 5. The scheme of reception of the control signal of underwater vehicles: 1 — the hull of the vessel; 2 — the surface of the sea; 3 — acoustic beam parametric channel (PC); 4 — autonomous underwater vehicle (AUV); 5 — radio control AUV; 6 — equipment hydroacoustic control channel (HCC); 7 — antenna HCC; 8 — seismic emitter; 9 — PC transmitter; 10 — PC navigation signal receiver; 11 — hydrophone and magnetic receiver; 12 — seabed; 13 — PC electromagnetic field vector

For example, when $\lambda$= 3000 m (frequency 100 kHz) and $\sigma$ = 4 S/m, the refractive index is $\sqrt{60\lambda\sigma}$= 848. When taken under ice due to a significant decrease in their conductivity, the refractive index is reduced by 60 times. The parametric effect of controlling the conductivity of seawater additionally reduces the signal level by the modulation coefficient $m$=$10^{-3}$ at the density of the acoustic radiation power flux $I$=1 W/m$^2$.

If the power of the acoustic emitter on the underwater vehicle is $P_a$ [W], then , when the sea surface is irradiated from below , the power flux density will be:

$$\Pi_a = \frac{P_a Q}{4\pi h^2} e^{-\beta h}. \quad (18)$$

Here $h$ is depth of the underwater vehicle position UV, $\beta$ is absorption coefficient of acoustic radiation of seawater; $Q$ is the directivity coefficient of the acoustic antenna UV.

From (17), the required power of the acoustic emitter will be:

$$P_a = \frac{4\pi h^2 \Pi_a}{Q} e^{\beta h}. \quad (19)$$

For example, let the depth of movement of the AUV, relative to the sea surface, be $h = 10$ m. If an acoustic transmitter is used on the AUV for a parametric navigation channel, highlighting the surface of the sea with a power flow density $\Pi_a = 1$ W/m$^2$ on the frequency $f_a = 100$ kHz, then at the wavelength $\lambda_a$=0.15 m and effective area of the acoustic antenna $S_a = 0.01$ m$^2$, at the absorption coefficient $\beta$=0.36 $f_a^{3/2}$ dB/km, we get $P_a = 2$ W. According to the graphs, Fig. 3, the required accuracy of the navigation reference of the AUV, at the depth of the position of the productive reservoir of hydrocarbons $h_2 = 1000$ m, will make $\Delta x = 1/2,\ h_2 = 500$ m.

Such accuracy can be achieved using signals from long-wave navigation systems, or by receiving signals to the AUV by parametric method by direct reading from the sea surface, or by broadcasting satellite navigation system signals via the onboard radio station of the accompanying vessel.

## Conclusion

A quantitative assessment of the intensity of the secondary electric field of the seismoelectric effect of a productive gas reservoir of hydrocarbons is given for the specified search parameters: the depth of the reservoir position; its size; the electrical conductivity of the host rock and the hydrocarbon medium; the position of the carriers of the field sensors in the marine environment and the impact force of the seismic source.

To work in Arctic conditions of difficult ice conditions, it is recommended to use automatic underwater vehicles that allow the implementation of the seismic-electric method, including under ice.

The problems of navigation binding of automatic underwater vehicles are discussed.

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## References

[1] A.G.Ivanov, The effect of electrification of layers of the earth when elastic waves pass through them, *Dokl. AN SSSR*, **24**(1939), no. 1, 41–43 (in Russian).

[2] A.G.Ivanov, Seismoelectric effect of the second kind, *Izv. Akad. Nauk SSSR. Ser. Geograf. Geofiz*, (1940), no. 5, 699–727 (in Russian).

[3] Ya.I.Frenkel, To the theory of seismic and seismoelectric phenomena in moist soil, *Izv. USSR Academy of Sciences. Geology and Geophysics*, **8**(1944), no. 4, 133–150 (in Russian).

[4] M.A.Biot, Theory of Propagation of Elastic Waves in a Fluid?Saturated Porous Solid, *Journal of the Acoustical Society of America*, **28**(1956), no. 168.

[5] S.I.Dobrynin, S.V.Golovin, L.Bobrovnikov, D.V.Milyaev, Innovative technology of assessment and monitoring of hydrocarbon reserves in the oil and gas reservoir under development, *Oil engineer. M.: LLC "AI DI Es Drilling"*, **1**(2012), no. 2, 24–29 (in Russian).

[6] A.Berg, Method of Seismo-Electromagnite Detecting of Hydrocarbon Deposit, Patent no. 7330790 (October 2005).

[7] G.Ya.Shaidurov, Method of system analysis of signals of the seismoelectric effect in the search for hydrocarbons, *Instruments and systems of exploration geophysics. Saratov, EAGO*, **71**(2020), no. 4, 33–37 (in Russian).

[8] G.Ya.Shaidurov, D.S.Kudinov, V.S.Potylitsyn, G.N.Romanova, On the observation of a seismic-electric effect at a gas condensate field in natural electromagnetic and seismic noises of the Earth in the range of 0.1 – 20 Hz, *Russian Geology and Geophysics*, **59**(2018), no. 5, 566–570. DOI: 10.1016/j.rgg.2018.04.009

[9] N.V.Levitsky, V.A.Detkov, V.M.Megerya, G.Ya.Shaidurov, On the technology of seismic research of deep-water areas of the Arctic Ocean floor, *Technologies of seismic exploration*, **1**(2010), no. 3 (in Russian).

[10] S.P.Pilikin, Underwater seismic exploration on the Arctic shelf, Patent RU 2457515. Oil and Gas Journal, (2014), no. 3 (in Russian).

[11] G.Ya.Shaidurov, System of underwater seismic exploration at sea, RF Patent 2755001 (08.09.2021) (in Russian).

[12] S.L.Rice, T.Dudley, K.Schneider et al., Registration and processing of seismic data in Arctic conditions, *Instruments and systems of exploration geophysics*, **45**(2013), no. 4, 83–95.

[13] T.Brizard, Jet-pump operated autonomous underwater vehicle and method for coupling to ocean bottom during marine seismic survey, Patent **AU2014213981**(2014.02.06.).

[14] T.Brizard, A.Have, E.Postic et al., Deployment and recovery vessel for autonomous underwater vehicle for seismic survey, Patent **US 20130081564 A1**(2014).

[15] K.A.Kostylev, V.A.Zuev, Underwater-subglacial bottom seismic exploration, *Modern problems of science and education*, **1**(2014), no. 6 (in Russian).

[16] I.I Gurevich, G.N Boganik, Seismic exploration, Nedra, 1980 (in Russian).

[17] M.S.Zhdanov, Electrical exploration: Textbook for universities., Nedra, 1986 (in Russian).

[18] Yu.P Kostrygin, D.A.Kolesnikov, Investigation of the possibilities of the code-pulse method of seismic exploration., *Instruments and systems of exploration geophysics. Saratov, EAGO*, **41**(2012), no. 3, 73 (in Russian).

[19] B.Askeland, H.Hobak, R.Mjelde, Marine seismics with a pulsed combustion source and Pseudo Noise codes, *Marine Geophysical Researches*, (2012), no. 28, 109–117 (in Russian).

[20] B.A.Gaikovich, V.Yu.Zanin, V.S.Taradanov et al., The concept of robotic underwater seismic exploration in subglacial waters, JSC NPP PT "Oceanos", St. Petersburg State Technical University, REC "Oil and Gas Center of Moscow State University", LLC "Split" Collection of works of laureates of the International Competition of scientific and technical developments aimed at the development and development of the Arctic and continental shelfl, 2018 (in Russian).

[21] V.I.Soloviev, L.I.Novik, I.D.Morozov, Communication at sea, Leningrad: Sudostroyeniye, 1978 (in Russian).

[22] G.Ya.Shaidurov, G.N.Romanova, D.S.Kudinov, Parametric Method of Underwater Radio Navigation in Arctic Condition, *Radio engineering and electronics*, **65**(2020), no. 8, 888–893. DOI: 10.1134/S1064226920070116

[23] M.P.Dolukhanov, Propagation of radio waves, Textbook for universities. 4th ed., Moscow: Svyaz, 1972 (in Russian).

# Физико-технические основы сейсмоэлектрического метода прямых поисков углеводородов в условиях Арктики с использованием автоматических подводных аппаратов

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**Аннотация.** В статье рассматриваются проблемы реализации подводно-надводных вариантов сейсмоэлектрического метода прямых поисков углеводородов в условиях арктических морей. Дается оценка напряженности вторичного электрического поля при возбуждении газового пласта ударами сейсмического источника, базирующегося на сопровождающем геофизическом судне, и приема сигналов на автоматическом подводном аппарате. Обсуждаются вопросы аппаратурной реализации и навигационной привязки роботов в подводном положении.

**Ключевые слова:** поиск углеводородов, арктические воды, сейсмоэлектрический метод, подводные аппараты.