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OIL AND GAS RESERVOIR AS A CAUSE OF MICRO-EARTHQUAKE

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Abstract

The paper discusses a specific impact on reducing environmental risks that is an urgent issue modern science is concerned with. At present, one of the social challenges is to solve an acute problem of geological research – seismology. This socio-economic challenge affects a significant part of the population. Numerous studies show that the precursors of large earthquakes are a great number of micro-shocks of the earth's surface, which are classified as micro-earthquakes and generally occur in an infrasonic frequency range. Another aspect of the problem is related to the fact that the seismic exploration is a dominant geophysical method, which refers to indirect exploration methods. Despite new modifications, including three-dimensional modeling, the "success rate" among a number of attempts to drill exploratory wells, according to seismic prospecting, still does not exceed 0.5, i.e. every second well drilled turns out to be unproductive. Seismic operations have a dramatic man-made impact on the environment, which significantly worsens an environmental situation in the area of operations. The solution to these problems can be based on the exceptional informativeness of infra-low-frequency microseismic noise signals. Recently, methods for processing and analyzing chaotic signals have been productively developing in different fields of science and technology, in particular in geological exploration. Noise signals are studied using the basic provisions of probability theory and mathematical statistics. For these purposes, various methods are widely used, in particular, Fourier and Chebyshev analysis.

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1. Introduction

The Congress is geared to discuss topical problems of modern science and, in particular, a specific impact on reducing environmental risks. Currently, one of the social challenges is to solve an acute problem of geological research – seismology (Nikolaev, 2003). In seismology, the infrasonic frequency range is crucial to predict effectively the precursors of strong earthquakes (Berger, 2018). This socio-economic challenge affects most of the population. In this regard, earthquake prediction needs to be addressed globally (Berger, 2018; Makhutov et al., 2013).

Numerous studies signify that the precursors of large earthquakes are a great number of micro-shocks of the earth's surface, which are referred to as micro-earthquakes and generally occur in an infrasonic frequency range (Rikitake, 1979).

The infrasonic frequency range has long been of interest to researchers for its exceptional information content.

2. Problem Statement

Recently, methods for processing and analysing chaotic (noise) signals have been increasingly developing in different fields of science and technology, in particular in geological exploration, which significantly contributes to sustainable development of the Caspian region.

3. Research Questions

Chaotic (noise) signals are studied using the basic provisions of probability theory and mathematical statistics. For these purposes, various methods are widely used, in particular, Fourier analysis (Timashev, 2007).

Currently, both in Russia and abroad, seismic exploration is a dominant geophysical method, which refers to indirect exploration methods (Adushkin & Spivak, 2012). Despite new modifications, including three-dimensional modeling, the "success rate" among a number of attempts to drill exploratory wells, according to seismic prospecting, still does not exceed 0.5, i.e. every second well drilled turns out to be unproductive.

Seismic operations have a dramatic man-made impact on the environment, which significantly worsens an environmental situation in the area of operations.

4. Purpose of the Study

A successful solution to the above problems was proposed by Institute of Physical Chemistry, Russian Academy of Sciences, together with OOO NTK ANCHAR, by creating the method for acoustic low-frequency exploration of ANCHAR oil and gas deposits (Arutyunov et al., 1997).

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5. Research Methods

Of all the components that constitute the geosphere, oil and gas alone are able to accumulate energy, thus providing a significant share of elastic energy. The coefficient of volume compressibility is a parameter characterizing the amount of accumulated energy, which is hundreds (for oil) and thousands (for gas) times greater than similar values for tires and reservoir rocks.

The ANCHAR method falls under direct methods, based on recording the energy of noise natural infrasonic micro-seismic oscillations emitted by oil-and-gas pools, referred to as oil and gas microseisms. In this case, hydrocarbons contained in a reservoir matrix are explored rather than the structure of deep geosphere. Fourier analysis is used to process the recorded signals. Micro-seismic signals emitted by oil-and-gas pools are a narrow-band noise in the form of a bell-shaped anomaly in the frequency range of 1.5–4.5 Hz, while the position of the frequency maximum characterizes the type of fluid (oil or gas).

Due to the fact that the ANCHAR method relies on Fourier analysis for processing recorded infrasonic signals, it does not provide complete information about the signals explored.

6. Findings

The paper provides a follow-up improvement of the ANCHAR method – a physical and chemical method for detecting infrasonic noise fields (DNF-method), which is based on the microscopic theory of electrochemical noise developed at the Institute of Physical Chemistry, Russian Academy of Sciences (Kuznetsov et al., 2003).

The DNF method followed the best practices of the Institute of Physical Chemistry, Russian Academy of Sciences, involved in studies of non-Gaussian noise in electrochemical reactions (Grafov, 2014).

DNF method is based on Chebyshev noise infrasonic spectroscopy (CNS), which, unlike Fourier spectroscopy, is specially designed to analyse noise (chaotic) components of the studied signals. The CNS confirms the noise “origin” of the radiated hydrocarbon reservoir oscillations (Tsivadze et al., 2019).

Unlike classical methods of geological exploration, DNF predicts hydrocarbon deposits with a long, at least one hour, synchronous “listening” of deep zones in geological structures and picking of oil-gas microseisms caused by physical and chemical fluid transitions in a pore (cavity, crack) from liquid to gaseous state and back by a special program (Tsivadze, 2014).

A fundamental problem of detecting “noise in noise” is being solved. In this case, DNF can also be considered as a source of micro-earthquakes.

A non-Gaussian component of the DNF 3D micro-seismic noise field, based on the use of discrete polynomials of Chebyshev noise spectroscopy, is a very promising informative parameter. Being locally inhomogeneous, Chebyshev spectra signify stationarity and measure of the Gaussian noise processes (Klyuev et al., 2016).

DNF method will increase the current “success rate” for oil and gas forecasting, from 0.5 (with every second drilled well-being non-productive) to at least 0.8 (with only every fifth drilled well-being non-productive). This significantly improves the environmental situation in the area of operations.

DNF method differs in that it is original and has neither national nor foreign counterparts.

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DNF method can be effectively used both for seismic exploration and for seismology.

The development of DNF method will broaden understanding of the oil-and-gas pool phenomenon (Suntsov & Grafov, 2010).

The processing algorithms were created, including software for field recording, which ends with recommended well locations for subsequent drilling. Figure 01 shows the appearance and output parameters of the UHF-3 seismic module.

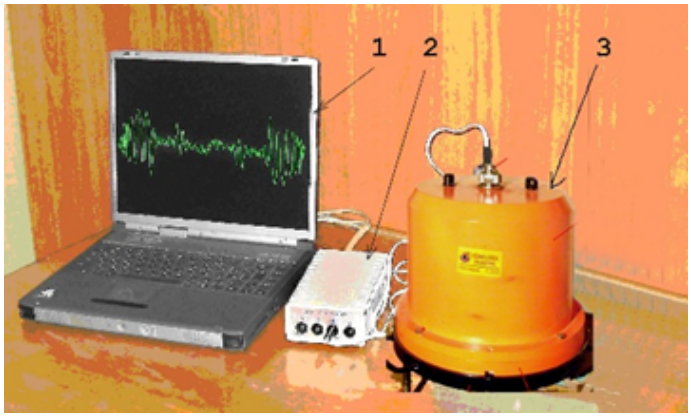

Figure 1. Appearance and output parameters of UHF-3 seismic module.

1. PC with special software for recording, processing and analyzing recorded signals
2. Communication unit for synchronous multichannel signal recording
3. Telemetric digital standalone three-component infrasonic seismic module

Output parameters are frequency range 0.5 – 50 Hz, dynamic range – 120 dB, sensitivity threshold – 0.4 nm, number of channels – 3, power supply – 12 V.

7. Conclusion

The findings suggest the following advantages of the DNF method:

i. Virtually no impact on the environmental situation in the area of operations.
ii. Oil-and-gas pool is considered as a deep source of emission of natural noise infrasonic waves – oil and gas microseisms.
iii. Oil-and-gas pool is considered as a source of micro-earthquakes.
iv. Natural oil-and-gas intrinsic noise field is picked and analyzed using the CNS method.
v. Hydrocarbon deposits are predicted in the mode of long-term 3D monitoring of the target area.
vi. “Success rate” of hydrocarbon deposit forecasting is not less than 0.8.
vii. Possibility of qualitative evaluation of a fluid (oil, gas).
viii. Possibility of exploring hard-to-reach land, coastal and especially sea areas;
ix. Full autonomy during field operations.

To date, over 100 wells prepared for drilling with depths of productive horizons from 700 m to 6500 m have been surveyed by the DNF method together with pre-drilling seismic exploration. All target wells – testers were subsequently drilled according to seismic data. Besides, only 50 % of them produced

commercial oil or gas rates (every second drilled well is unproductive). In the same wells, a positive or negative forecast of oil and gas content is confirmed through the DNF method in 80 % of cases (only every fifth drilled well is unproductive).

The infrasonic method for forecasting hydrocarbon deposits by measuring non-Gaussian noise can be very effective for developing fields in the Caspian region.

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