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NATURE-LIKE INNOVATIONS IN OIL EXPLORATION AS A FACTOR OF BALANCED SUSTAINABLE DEVELOPMENT

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Abstract

The article examines the challenges of the international UN Sustainable Development Goals project, focusing on the environmental costs of oil and gas development. It shows that implementing each stage of the fishery comes with some environmental costs. The authors proposed a private solution to the overall problem by applying modern, innovative technologies during the exploration phase. Modern seismoacoustic techniques, based on advances in science and technology, have great and not fully realized the potential in exploration. According to the study, using such techniques with conventional seismic surveying provides a significant reduction in environmental costs and risks. The methods reveal the suspected location for a deposit. The methods also allow identification of the type of deposit for oil or gas. About 85 % of the seismoacoustic sounding predictions are reliable. This allows a significant reduction in redundant exploratory drilling with dry wells. The methods belong to the category of nature-like, convergent, knowledge-intensive technologies, characterized by absolute environmental friendliness and low cost. Actual results have confirmed the effectiveness of the methods in various regions. In the Caspian Sea region, with intensive oil and gas development, the proposed methods will contribute to maintaining sustainable economic development of the territories while minimizing the negative impact on the natural environment. Such a decision would generally support the implementation of the Sustainable Development Goals project based on the fundamental sciences. This is fully in line with UNESCO's proclamation of the coming year 2022 as the International Year of Basic Sciences for Sustainable Development, 2022.

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Keywords: Ecology, oil and gas production, sustainable development, seismic exploration, seismoacoustic techniques

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1. Introduction

Sustainable development is currently of particular relevance as the 4th economic paradigm enters its final stage (United Nations, 2015). It is no coincidence that the recent UNESCO congress declared year 2022 as the International Year of Basic Sciences for Sustainable Development, 2022. Under such circumstances, the current implementation of the international UN Sustainable Development Goals (SDGs) requires a closer look at all kinds of innovative solutions (United Nations, 2021).

The SDGs cover various areas of society, economy, environment, culture, health, science, etc. Implementing each strand of the SDGs needs to consider their mutual influence (Karnib, 2017). However, we should consider that the economy has a decisive influence on all areas of the SDGs. In turn, the type of economic structure depends on the set of production technologies prevailing in a given historical period, i.e. the technological paradigm (Perez, 2009).

The modern 4th paradigm of our society is based on oil as the source of the FEC. Oil plays a key role in the current historical period. This consideration leads to the main conclusion that sustainable development in general and in each of the SDGs requires first the maintenance of a sustainable oil and gas (OG) production.

2. Problem Statement

Unfortunately, any industrial activity, especially oil and gas, inevitably has a negative impact on the environment. At the same time, the need to maintain the environment is one of the main criteria for sustainable development and is enshrined in the SDGs under the relevant items 14, 15. This conflict of objectives is one of the main challenges in implementing the SDGs (Karnib, 2017).

The most obvious and severe damage to the environment comes from oil spills. Such situations emerge during the production and transportation phase of oil production. But at the same time, we should consider that all other areas of the oil and gas industry, to some extent, also have a negative impact on the environment (Pikovskiy et al., 2019). We should pay particular attention to the stages of hydrocarbon prospecting and exploration.

3. Research Questions

Prospecting and exploring is a set of sequential activities that we can divide into two phases (Hyne, 2012). The first preliminary stage involves seismic surveying and the second and final stage involves drilling. Each of these stages has its own specific and grave environmental consequences. We will look at them closer.

3.1. Seismic survey

Seismic exploration has, until recently, extensively used blasting techniques to excite sounding waves. Obviously, these methods are detrimental to wildlife, especially the marine environment. Such work has often resulted in mass catastrophic deaths of entire fish schools. Seismic surveys are now trying

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to use more gentle, non-explosive methods, using special air guns and vibrators, but the negative impact on nature cannot be eliminated completely.

The situation is exacerbated by the fact that seismic surveys are usually conducted over large areas to obtain comprehensive geological information for the region as a whole. The studies are followed up regionally with a number of smaller-scale studies, but they are also quite intensive in terms of environmental impact. These are seismic surveys such as prospecting, detailing, field exploration, follow-up exploration, geotechnical surveys, etc.

The works cover vast areas and have fairly dense coverage, resulting in serious environmental costs already at the initial seismic survey stage.

After completing all the necessary seismic surveys, there is geological mapping of the region, building its geological model and conducting stratification analyses. Based on this material, we identify areas with structures characteristic of hydrocarbon deposits. The question of the real oil and gas content of these structures is resolved in the next stage.

3.2. Exploratory drilling

The next stage of prospecting and exploration involves drilling. The areas identified by the seismic survey are subject to exploratory drilling. From the total number of predicted structures, the wells should identify those that are actually oil and gas bearing. The drilling phase of exploratory wells comes with no less environmental costs and risks than drilling production wells (Pikovskiy et al., 2019). Many oil and gas producers are now proclaiming a zero discharge principle for process drilling waste (Beyer et al., 2020), which should reduce environmental impacts. But in reality, this principle is not always fulfilled. In addition, there are always risks of accidental discharges.

We should also consider that exploratory drilling, although carried out at certain local points, covers a wide area in general. In this case, the works are a set of independent activities, such as exploratory drilling, exploratory drilling, appraisal drilling, parametric drilling, reservoir delineation drilling, etc.

3.3. The relevance of environmental issues in prospecting and exploring

From this consideration, we can see that the environmental impact of prospecting and exploring extends far beyond the actual deposits and encompasses the entire region in question, creating serious environmental problems in general. For the Caspian Sea region, this issue is of particular importance because of the recently adopted interstate agreement on delimitation of using the offshore oil and gas-bearing waters of the Caspian Sea. The legal uncertainties of the formerly disputed areas will now be removed and this will help boost the development of the region's natural resources. In such a situation, reducing the environmental costs of oil and gas exploration becomes extremely relevant.

4. Purpose of the Study

This paper looks at ways of reducing the environmental harm caused by exploration activities and limiting the areas affected. When choosing how to solve the problem, it is necessary to consider the fact that in practice the proportion of unproductive dry wells is unjustifiably high and exceeds half of all wells drilled. Significantly reducing environmental costs is possible by anticipating the futility of dry wells and not drilling them unnecessarily.

The existing problems with dry wells are because seismic surveys cannot in principle give unambiguous information about hydrocarbons in the inferred reservoir-structure geological formation. Even detailed 3D seismic surveys, while providing detailed information on the geological structure, cannot identify the fluid saturation of these layers. The proposed structure may or may not be oil and gas bearing.

We can only draw a conclusion after completing the drilling work. The result of drilling is not predictable in advance. Statistics show that the success rate is 0.5 on average, i.e. every second well is dry. In unfavourable seismo-geological conditions, the success rate drops significantly. In the pre-Caspian syneclise with salt tectonics, for example, the drilling success rate over the past 10 years has been less than 0.25. In such situations, the drilling has to be repeated many times to reach the desired productive well. Consequently, the burden on the environment increases manifold, which in such cases is totally unjustifiable.

From the above consideration, we can see that it is possible to reduce the environmental load to a certain extent by reducing unjustified dry wells. Addressing this issue is the specific aim of this paper.

We can radically address this issue by conducting an oil and gas prospecting prior to drilling in the selected areas. Only once there is a positive result, it is possible to move on to further drilling. Seismic surveys, as already mentioned, do not solve this problem. It is, therefore, necessary to use some alternative methods. Until recently, there were no reliable ways of doing this testing.

This paper examines the possibility of solving the problem of real oil and gas exploration using an innovative seismoacoustic method to reduce the unnecessary drilling of dry wells. This ultimately contributes to solving a set of topical problems of oil and gas field ecology in terms of the overall paradigm of sustainable development of society.

5. Research Methods

At present, innovative research methods based on the phenomenon of microseismic emission are intensively developing in geophysics. The most significant results have been achieved in the field of emission microseismic tomography, which allows the study of global processes in geological structures, such as earthquakes, volcanic processes, etc. (Brenguier et al., 2007; Gorbatikov et al., 2013). In applications, microseismic emission phenomena have also given rise to new methods. These are primarily low-frequency seismic-acoustic methods of oil and gas exploration.

5.1. The principle of seismoacoustic methods

These innovative methods of oil and gas exploration rely on the following natural phenomenon. The hydrocarbon reservoir is a multi-component, multi-phase, heterogeneous fluid reservoir located in a solid porous sedimentary medium. This complex system is dynamic and diverse in its processes. The emission of random microseisms accompanies this. Thus, a specific low-frequency noise field with a specific spectrum in the form of a bell-shaped anomaly in the characteristic frequency range of 1.5–4.5 Hz forms around the deposit. This external sign of the noise field can reveal a hidden deposit in a geological reservoir, which is what the ANCHAR acoustic low-frequency exploration is based on (Suntsov et al., 2006).

The ANCHAR method was implemented at the IPCE Institute of the Russian Academy of Sciences in cooperation with ANCHAR STC and has gained international recognition. Several firms are now replicating this approach in one form or another and are using it for practical purposes. But the practical implementation of this approach requires many high-tech solutions . To date, the method has not been widely used. Solutions are currently being developed to improve the reliability of noise field detection (NFD-method).

5.2. Specific requirements for implementing the NFD-method

We will look more closely at the essence of the approach in implementing the NFD-method. Implementing seismoacoustic techniques resembles traditional seismic exploration and, formally speaking, is, like seismic exploration, confined to the recording and processing of seismic signals. But, in doing so, we should consider the following crucial differences. In NFD, the reservoir itself generates the recorded noise signal and does not need the excitation of an external, powerful wave as in seismic exploration. So, the noise method uses natural signals and is completely environmentally friendly. This is a fundamental advantage of the NFD-method which relies on nature-based techniques.

Implementing this method places increased demands on the measuring equipment and on signal processing techniques. First, we must remember the emission intensity of oil and gas microseisms is extremely low. Therefore, such a weak signal is barely detectable at the level of the natural background. Second, the signal is random, which creates its own problems of identification against the general noise background, an additional problem of detecting 'noise in noise'. All this places special increased demands on implementing the TAB method and requires the development of special solutions for the given tasks.

6. Findings

6.1. Special solutions offered by the NFD-method

We will consider in more detail the original author's approaches in the development of the NFD-method.

It is well known that conventional Fourier spectroscopy is widely used in the analysis of noise signals. One feature of this method is its increased sensitivity to the temporal trend of the signal, to its instability, which distorts the result. NDF technology uses a different method of spectral analysis called Chebyshev Noise Spectroscopy. This method gives a representation of the signal in the form of discrete Chebyshev polynomials and turns out to significantly reduce the distorting influence of the temporal trend (Tsivadze et al., 2018).

The NFD-method also applies the approach of analysing a noise signal based on its Gaussianity. The non-Gaussian component of the 3D microseismic noise field of the NGN is a very promising information parameter. The isolation of a non-Gaussian component against a background of near-

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Gaussian natural microseismic noise allows us to significantly expand our understanding of the oil and gas microseismic phenomenon, as well as identify previously unknown hydrocarbon reservoir properties (Tsivadze et al., 2018).

When implementing the method, we must also consider the fact that the random noise nature of the measured signal requires the use of mathematical statistical methods and the processing of sufficiently large data sets. Obtaining such arrays is only possible with a long procedure (more than a day) of 3D-monitoring measurements in the study area. With such long-term monitoring, many global geocosmic factors affect the measurement results. These are primarily tidal processes, circadian rhythms and baric atmospheric phenomena. All of this needs comprehensive consideration and adjustment.

The above methods of noise signal processing and analysis aim in general to improve the reliability of oil and gas reservoir prediction in the NFD-method.

6.2. Software and hardware implementation of the proposed solution

The principles of the NFD-method provided the basis for the design and development of a hardware and software system (HSS).

The fundamental unit of the complex is an autonomous 3D seismic module. The signals are measured at three spatial coordinates with synchronous recording in a digital off-line memory for long-term, multi-day monitoring. The digitizing frequency of the signal is on the order of 100Hz, allowing the recording of signals in the frequency range of 0.5–40 Hz. The dynamic range is 120dB, with an ultimate sensitivity of at least 0.5 nm×Hz-1/2. The seismic module is equipped with a GPS for navigation and for time synchronization in coherent operation with other seismic modules. The weight of the ground module is about 5.5 kg. The marine version features a more reliable seal for offshore operation.

The seismic module is clearly a highly technical unit, yet at the same time quite compact. It can be applied quickly without the use of special transport vehicles in any hard-to-reach areas on land, at sea and in transit zones, without disturbing the ecology of the area.

The hardware package also includes a standard laptop computer for setting up, running and reading the seismic data from the seismic module, under the control of a special author's software. The laptop communicates with the seismic module using a dedicated unit via a USB link. Communication via the standard Bluetooth channel is also provided. It is possible to view recorded signals on-line in the field and also to operate the seismic module offline, recording the signals in its own memory. Subsequent processing and detailed analysis of the signals occurs in stationary conditions according to special author's programmes. The result of the analysis is presented in the form of appropriate microseismic emission maps of the study area, with conclusions on the inferred oil and gas bearing capacity.

6.3. Approbation of the HSS

Researchers conducted validation tests of the described NFD instrumentation under low-level microseismic conditions in the Arctic zone on the Kola Peninsula. The special features of this region are because the Kola Peninsula lies on the Baltic Shield, which features very stable and low-movement geological structures. The measurements showed high instrumentation sensitivity reaching exceptionally

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low levels of natural microseismic background in this region. Such hardware capabilities should ensure sufficiently high reliability of the NFD-method forecast, including in the Caspian Sea conditions.

Numerous field surveys have confirmed the effectiveness and efficiency of seismoacoustic exploration methods in general. The drilling success rate rises from the usual 0.3–0.5 to 0.85. This high confidence significantly reduces the number of unnecessary redundant exploration wells.

7. Conclusion

Addressing the issues of the SDG project highlighted the issue of environmental costs in the development of OG production. The authors have proposed a private solution to the problem through the use of modern, innovative technologies in geological prospecting. The study showed that the use of NFD with conventional seismic surveying provides a significant reduction in environmental costs and risks. This reduces the need for exploratory drilling by several times. The method belongs to the category of nature-like, convergent, knowledge-intensive technologies and has absolute eco-friendliness and low cost. In the Caspian Sea region, under the conditions of intensive oil and gas field development, the proposed NFD-method will contribute to maintaining sustainable economic development of the territories while minimizing the negative impact on the natural environment. Such a solution would generally facilitate the implementation of the SDG project based on the fundamental sciences.

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