Journal of Geotechnology and Energy | vol. 38 | no. 1 | 2021 | pp. 35–40

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THE USE OF PASSIVE SEISMIC EXPLORATION TO IDENTIFY OIL-BEARING RESERVOIRS IN THE UDMURT REPUBLIC (RUSSIA)

Date of submission:
22.05.2021

Date of acceptance:
22.06.2021

Date of publication:
31.07.2021

https://journals.agh.edu.pl/jge

Abstract: The level of oil production in the Udmurt Republic is currently experiencing a declining trend due to the depletion of large and medium-sized oil fields that have been in operation for a long time. Therefore, the main challenge in this region is to stabilize & increase oil extraction by means of exploring more promising oil fields of a smaller size. However, some issues cause difficulties. Firstly, 2D and 3D seismic data often do not provide the reliable mapping of small fields. Secondly, geological prospecting and exploration, along with exploratory drilling, make these works costly. Furthermore, the estimation of the reserves for such deposits often contains errors. Passive seismic exploration is proposed as a solution to these problems, reducing exploratory and exploitation drilling costs, with the time required for geological exploration also being diminished.

Keywords: passive seismic, Udmurt Republic, small-sized reservoir, oil and gas

1. Introduction

Rapid crude oil depletion is picking up speed in the Udmurt Republic, with a production rate decrease being common at all long-term operational oil fields of large and medium size. Therefore, the main challenge in this region is to stabilize and increase the amount of oil extraction by exploring the potentially more prospective small fields.

The oil fields of the Udmurt Republic contain nearly 6.4 billion barrels of proven reserves. Successfully discovered oil fields may supply the region with potential resources of up to 9.6 billion barrels [1].

Oil fields discovered in the region in 2017 have substantiated good prospects of searching for new hydrocarbon deposits in the Udmurt Republic. They included the Vesenny, Pikhtovsky, and Aleksandrovsky fields [2]. Besides, there are geological exploration works in progress in the Orosovsky and Vyazovsky fields.

The geological complexity of structures and considerable heterogeneity of facies formations leads to difficulties in converting theoretical resources into producible reserves. The most promising geological structures are small-sized reservoirs containing fewer than 2.1 million barrels of original oil in place (OOIP). However, it is often challenging to detect such structures using traditional exploratory methods because of some problems, complicated the process.

The exploration of the Oparinsky oil field, located in the Udmurt Republic (Fig. 1a), using a traditional set of works, was aimed at prospecting small reservoirs, but it became an example of ineffectiveness. The field was estimated to hold 6.3 million barrels of OOIP and 312,000 barrels of recoverable reserves. However, 10 of the 11 wells drilled turned out to be empty. Based on the data received from geological prospecting works, the Oparinsky field was reevaluated as having 312,000 barrels of OOIP and 64,000 barrels of recoverable reserves (Fig. 1b). Well drilling at the Oparinsky field alone cost $22 million (Tab. 1).

Problems which typically complicate the exploration and operation of small-sized reservoirs include:

- lithological and geological complexity of such structures;
- difficulties in proper detection of small-sized reservoirs having a limited number of prospecting and exploratory wells;
- errors during the reserves' calculation process and uncertainties in proper locating of exploratory wells;
- difficulties in detecting reservoirs of small size based on the 2D and 3D seismic data;
- costly prospecting, exploratory and exploitation drilling.

a)

b)

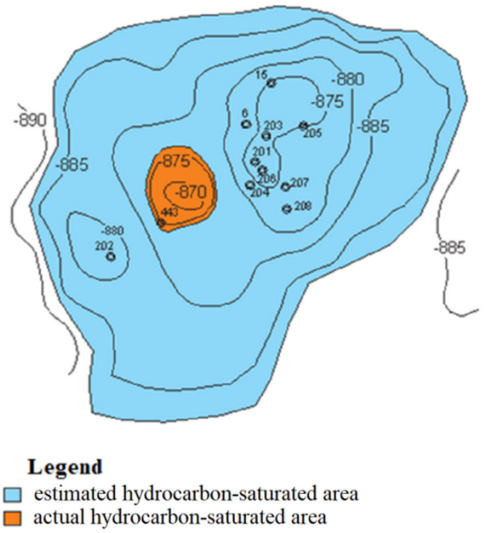

Fig. 1. Location of the Oparinsky field (a); structural map of the Oparinsky field (b), showing estimated and actual hydrocarbon saturated zones

Table 1. Results of prospecting and exploratory drilling at the Oparinsky field

No.	Parameter name	Parameter value
1	Estimated reserves (before prospecting drilling) [thousand bbls]	6 319
2	Original oil in place (OOIP) [thousand bbls]	312.4
3	Recoverable reserves [thousand bbls]	63.9
4	The number of wells	11
5	The number of empty wells	10
6	Well drilling cost [million USD]	22

Passive seismic exploration is proposed as a solution to these problems. The use of this technology could reduce the amount of time required for hydrocarbon exploration and enable a reduction of the exploration and development costs.

2. Method section

Passive seismic exploration uses low frequencies as seismic sources. This technique makes it possible to give the correct forecast for the discovery of oil and gas accumulated in reservoirs. 3D seismic is applied to detect geological structures, having good prospects [3, 4], while the passive seismic data confirms the hydrocarbon presence with precision. The main feature of passive seismic exploration is the specific nature of the low-frequency seismic signals, carrying valuable geological information in the subsurface [5]. These signals are produced by the oil- and gas-bearing reservoir rather than reflected or refracted by the layer's surface (Fig. 2).

3. Examples

In the Udmurt Republic, passive seismic exploration was applied in a variant of the "ANCHAR" method in 1999. The territory of implementation included the Debyosy, Eastern Tylovay fields, and Mar'inskaya structure (Fig. 3). The aim was to detect and estimate geological structures for the subsequent prospecting and exploration work planning. The use of "ANCHAR" technique in the Debyosy, Eastern Tylovay fields and Mar'inskaya structure allowed it to be determined that fluid contacts of reservoirs did not correspond with the subsurface structures, which were detected by 3D seismic exploration and exploration well drilling. Locations for further deep-well drilling were selected according to passive seismic data [6].

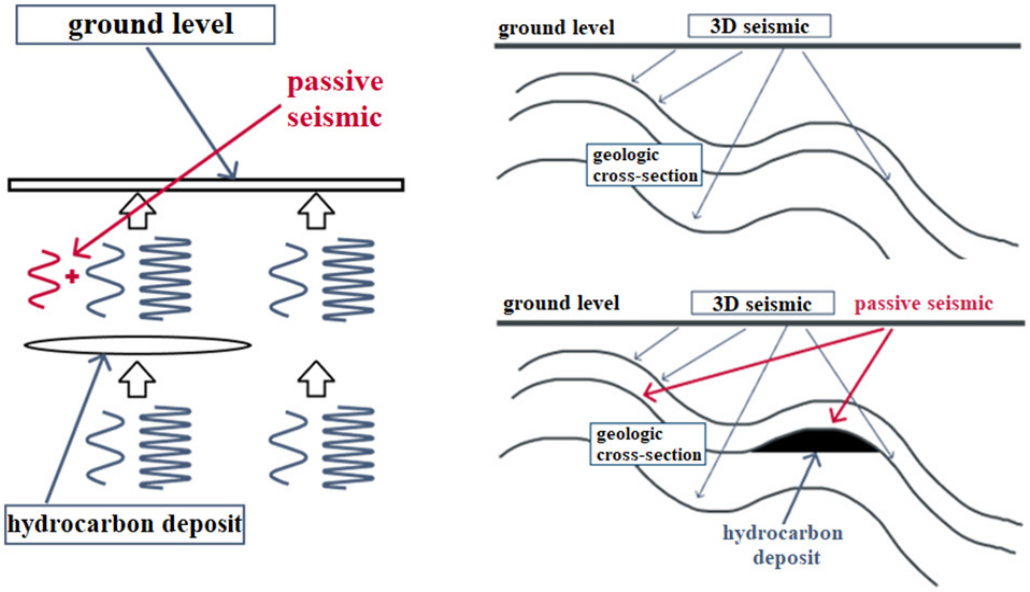

Fig. 2. Passive seismic principles

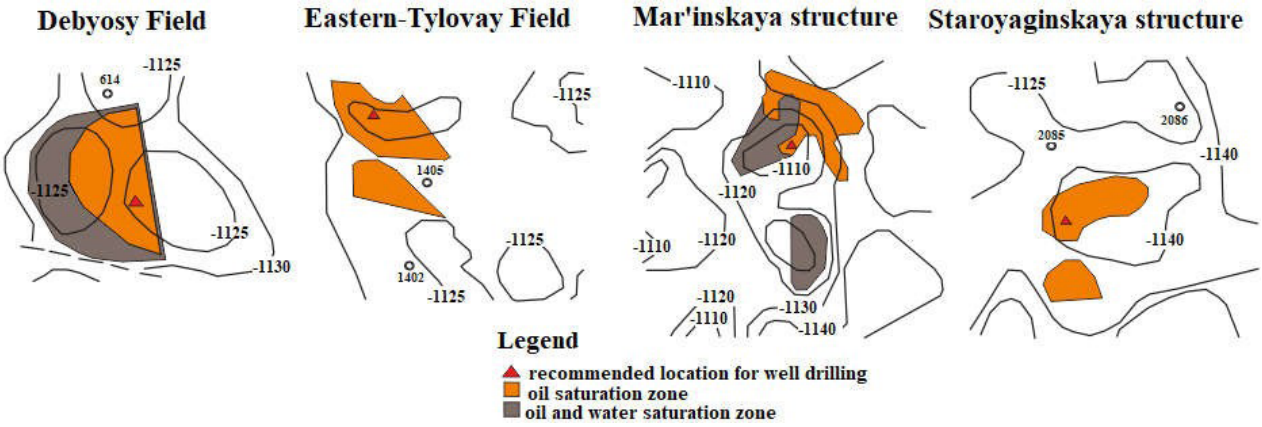

Fig. 3. Estimated hydrocarbon saturation of the Debyosy, Eastern Tylovay fields, Mar'inskaya, Staroyaginskaya structures, according to the "ANCHAR" method

Passive seismic exploration may become a way to detect previously missed oil-bearing reservoirs. An exploration of the Staroyaginskaya geological structure with the use of "ANCHAR" method enabled the identification of hydrocarbons accumulated in a synclinal part of the structure (Fig. 3). Based on the obtained results, oil and gas saturation of this structure was forecast, and more proper locations for exploration well drilling were recommended. Hydrocarbon accumulation in synclines is uncommon in the Udmurt Republic. Without the data provided by the "ANCHAR" method, this oil-bearing structure would have been missed.

Passive seismic exploration, in combination with traditional exploratory methods, provides a forecast of hydrocarbon saturation. Reduction of the number of empty wells achieved using passive seismic exploration can decrease the amount of time required for field exploration [7]. Hence, it results in economical expenses for exploration and exploitation works.

The lack of accurate mapping and costly exploratory drilling makes it unprofitable to discover fields with less than 2 million barrels of OOIP, but passive seismic exploration can address this issue. Also, small-sized reservoirs and non-structural traps of complex geology can be explored by means of passive seismic, with their oil and gas saturation being forecast. Moreover, this technology serves for detecting fluid contacts which do not correspond with the subsurface structures.

There are nearly two hundred promising oil fields of small and tiny size that have been discovered in the Udmurt Republic. The north-eastern part of the region has 65 such oil fields (Fig. 4). The estimated OOIP of these fields are shown in Table 2.

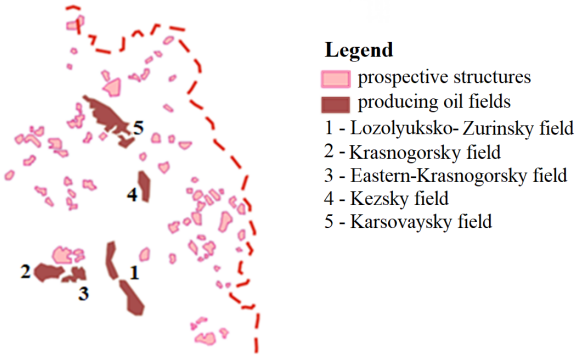

Fig. 4. Prospective structures located in the north-eastern part of the Udmurt Republic

The projects using passive seismic have been effectively implemented for geological prospecting and exploration of various production areas in the Volga-Ural Petroleum Province, including Melekess, Buzuluk depressions and Kama, Zhigulevsko-Orenburg, Tatar, Sol-Iletsk arches. This technology has improved the chance of the success of exploration wells by up to 85%. The depth of the accurately explored zone was 400 m to 7 000 m [5, 8].

Table 2. Estimated oil reserves of 65 perspective structures

No.	Parameter name	Parameter value
1	Estimated OOIP [million bbls]	1 420–1 775
2	Recoverable reserves [million bbls] (recovery factor is 0.35)	497–618
3	Estimated cost of recoverable reserves [billion USD] ($35/bbl)	17–22

4. Conclusions

1. Due to the depletion of large oil fields in the Udmurt Republic, more attention is being paid to the development of very small ones containing significant hydrocarbon reserves. However, detecting them is extremely difficult in the case of a traditional techniques.
2. Success in the exploration and production of well drilling depends on accurate geological model and a clear delineation of the reservoir. The results of the first well drilling largely determine the fate of oil field.
3. Proper detection of small-sized reservoirs may be much more difficult without data received by passive seismic exploration works.
4. This exploration technique of finding hydrocarbons uses low frequencies as the seismic sources. The main purpose of the method is to discern the geological structures that have good prospects.
5. Passive seismic may be applied to find the most appropriate locations for proposing and exploration well drilling with the further use of these wells as production ones during the subsequent process of oilfield development. This will make the operation of very small fields much more profitable.
6. Passive seismic exploration provides a correct forecast for the discovery of hydrocarbon reservoirs occupying structurally complicated small-sized and non-structural traps. Also, such an exploration method allows the fluid contacts of deposits to be detected if they do not correspond with the subsurface structure.
7. The proposed technology can also be successfully applied to already discovered and exploited oil fields in order to determine accurate reservoir oil-water contact as well as to monitor the process of development.

8. Passive seismic surveys may be conducted further at regular intervals during the oilfield development to control the conditions of hydrocarbon reservoirs. It will rationalize the process of oilfield development, increasing the productivity index.
9. Passive seismic exploration may not only be applied in the Udmurt Republic but also in other regions all over the world with success. This technique can enable valuable exploration information to be obtained, regardless of geological structure complexity and reservoir depth, for oil fields located anywhere in the world.

Author Contributions: conceptualization, G.K.; methodology, V.M.; software, G.K.; validation, G.K., O.L., V.M.; formal analysis, O.L.; investigation, G.K.; resources, G.K.; data curation, V.M.; writing – original draft preparation, G.K., O.L.; writing – review and editing, O.L.; visualization, O.L.; supervision, V.M.; project administration, G.K.; funding acquisition, G.K., O.L. All authors have read and agreed to the published version of the manuscript.

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