USE OF PASSIVE SEISMIC TO PREVENT ERRORS RELATED TO INCORRECT ESTIMATION OF HYDROCARBON RESERVES

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ABSTRACT

One of the main problems in petroleum geology today is related to the hydrocarbon reserves' calculation process. 2D and 3D seismic exploration methods are typically applied for such purposes. However, the information received from them may prove to be insufficient for effective field development planning.

Even with the 2D and 3D seismic data available, sometimes it is not possible to identify oil- and gas-bearing structures having good prospects with precision as well as to calculate proven resources of hydrocarbons.

Among the most complex geological structures in the Udmurt Republic is the Karsovaysky field. Each of its oil- and gas-bearing bed was initially envisaged to have only one oil-water contact. Probable geological resources of this field were estimated at 994 million barrels, and recoverable ones totaled at 278 million barrels (equivalent to a recovery factor of 0.28).

However, it was demonstrated by drilling a significant number of prospecting and exploration wells that the field consists of three separate oil- and gas-bearing structures. Proven geological reserves accounted for 603 million barrels and proven recoverable reserves for 169 million barrels.

Initially, 259 production and injection wells were planned to be drilled in the field. Due to a significant decrease in the petroleum-bearing area, there were drilled only 158 wells.

The use of passive seismic as a Direct Hydrocarbon Indicator (DHI) can help to avoid such overestimation of hydrocarbon quantity.

Passive seismic principles are based on using low frequencies in the range of 1-10 Hz as seismic sources. This method is applied to give a corrected forecast for discovery of hydrocarbons accumulated in reservoirs. The 3D seismic data provide the identification of prospective geological structures, and the passive ones confirm the hydrocarbon existence more accurately.

The implementation of passive seismic will allow oil- and gas-saturated zones to be detected accurately and errors contained during the estimation of hydrocarbon quantities in a reservoir to be removed. Furthermore, it will help to reduce the number of prospecting and exploration wells as well as to avoid the drilling of dry wells.

Keywords: Passive Seismic, Hydrocarbon Reserves Estimation, Karsovaysky Field, Udmurt Republic

INTRODUCTION

In the Udmurt Republic (Russia) as well as in the world in general, the oil & gas industry faces a severe problem concerning the difficulties in accurate detecting and outlining of oil-water contact and precise reserves estimation for hydrocarbon-bearing fields. The main tools to conduct the researches for these purposes are seismic surveys using 2D and 3D common depth point methods.

However, in most cases, the information obtained through such researches may be insufficient both to perform geological analysis, including prospecting and exploration works, and to develop fields in the future with success.

During the process of searching for oil and gas deposits, the risks and uncertainties regarding the probable hydrocarbon resource estimation are inevitable due to the lithological and geological complexity of prospective structures as well as to high facies' changes of rock layers. Moreover, to calculate percent fill of a trap becomes a problematic challenge in this case. Use of passive seismic may ensure avoiding these issues.

METHOD

Passive seismic principles are based on using low frequencies in the range of 1-10 Hz as seismic sources. This method is applied to give a corrected forecast for the discovery of hydrocarbons accumulated in reservoirs. The 3D seismic data provide the identification of prospective geological structures, and the passive ones confirm the hydrocarbon existence precisely.

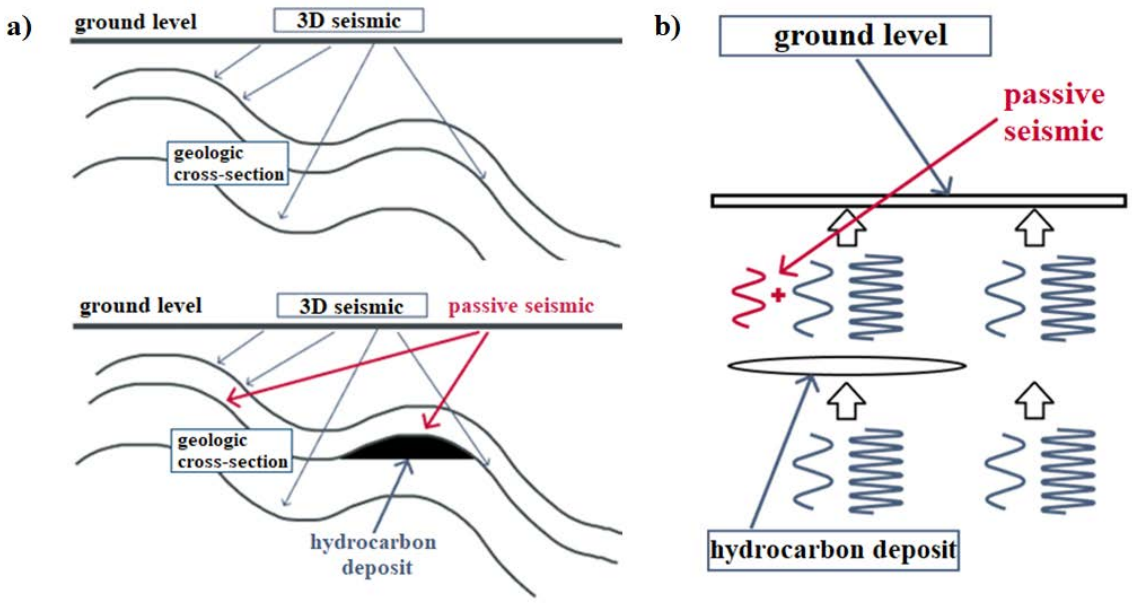

Figure 1 – General (a) and physical (b) principles of the passive seismic method

The main passive seismic feature is a specific nature of the low-frequency seismic signals, carrying valuable geological information in the subsurface (Figure 1). These

signals are produced by oil- & gas-bearing reservoirs, rather than reflected or refracted by the layer's surface (Science and Technology Complex “ANCHAR” LTD, 2010; Arutyunov et al., 2010).

EXAMPLES

Among the most complex geological structures in the Udmurt Republic is the Karsovaysky field. The Karsovaysky field is located in the Balezinsky and Kezsky Districts of the region, about 40 km east of Glazov and 25 km north-east of rural locality Balezino (Figure 2).

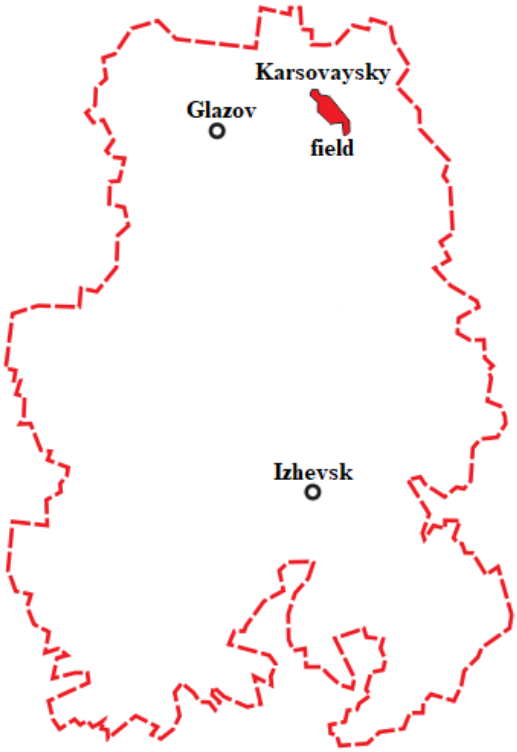

Figure 2 – Location of Karsovaysky field on the map of the Udmurt Republic

Industrially significant deposits of the Karsovaysky field include carbonate sediments of Kasimovian-Upper Carboniferous (layer named as C_3k), Podolsk (layers named as P_2, P_3) and Kashira Formations (layer named as K_4), Verey horizon (layers named as V-0, V-II, V-IIIa, V-IIIb), Bashkirian (layers named as $A_{4\text{-}0+1}$, $A_{4\text{-}2}$, $A_{4\text{-}3}$), Myachkov sediments (layer named as C_2mc-II).

Probable geological resources of this field were estimated at 994 million barrels, and recoverable ones totaled at 278 million barrels (equivalent to a recovery factor of 0.28) based on information received from seismic surveys and from prospect drilling. Each oil & gas-bearing bed was initially envisaged to have only one oil-water contact.

A business plan for field development was drawn up using the data collected. According to this plan, 259 production and injection wells were required to be drilled in the field in question.

However, drilling a large number of prospecting and exploration wells has demonstrated that the field consists of three separate oil- and gas-bearing structures (Figure 3). There were drilled only 158 wells due to a significant decrease in the petroleum-bearing area (JSC “Izhevsk Petroleum Research Center”, 2010).

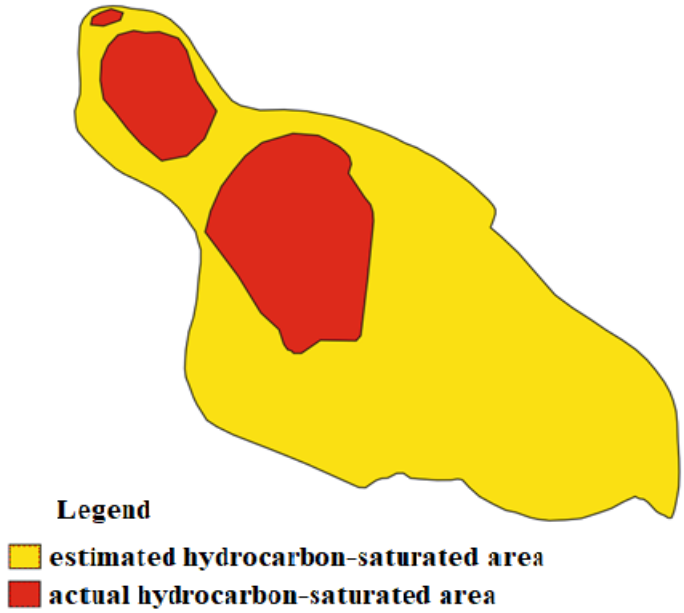

Figure 2 – Mismatch between estimated and actual hydrocarbon-saturated areas in the Karsovaysky field

Change in the estimated value of field reserves because of declining in the petroleum-bearing area is $3.8 billion (Table 1).

Overestimation of hydrocarbon reserves has resulted in the choice of the wrong strategy for field development, and high expenditure on prospecting and exploration works. The reason is that the plan of capital costs was approved on the basis of the estimated hydrocarbon-saturated area and the quantities of probable oil resources.

Also, this issue causes overstatement of the cost of the license to develop the field.

Table 1: Change in estimated value of field reserves

Reserves type, cost	2010 expected	2018 in fact	Over-estimated
Original oil-in-place, million bbl	994.00	503.50	390.50
Recoverable reserves (equivalent to a recovery factor of 0.28), million bbl	278.32	140,98	109.34
Estimated cost of recoverable reserves, $ billion ($35/bbl)	9.7	4.9	3.8

Other fields in the Udmurt Republic faced the problem of incorrect reserves estimation as well. Examples include the Oparinsky field (Sarapulsky District) and the Kuliginsky field (Kezsky District). The estimated hydrocarbon-saturated area of these fields turned out to be much larger than the actual one (Figure 4). Proven oil reserves were much lower than estimated resources. Furthermore, a large number of dry wells were drilled, causing high expenses.

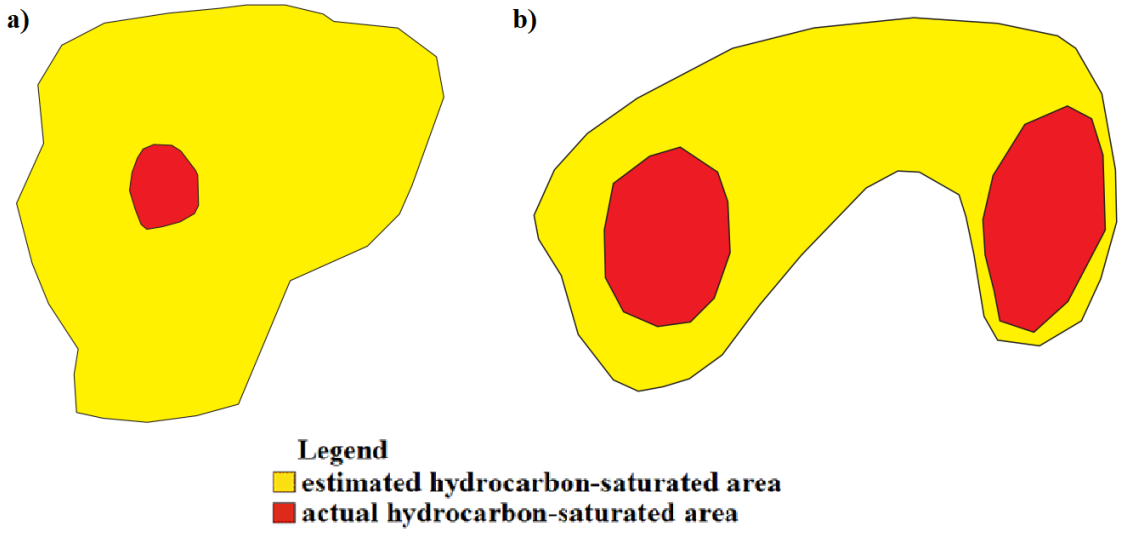

Figure 4 – Difference in hydrocarbon-saturated area of the Oparinsky (a) and Kuliginsky (b) fields

RESULTS

Passive seismic may help to prevent before-mentioned errors during the evaluating process regarding other fields. There are 65 promising oil- and gas-bearing structures in the north-east part of the Udmurt Republic (Figure 5). The total number of such structures in the region is more than 250.

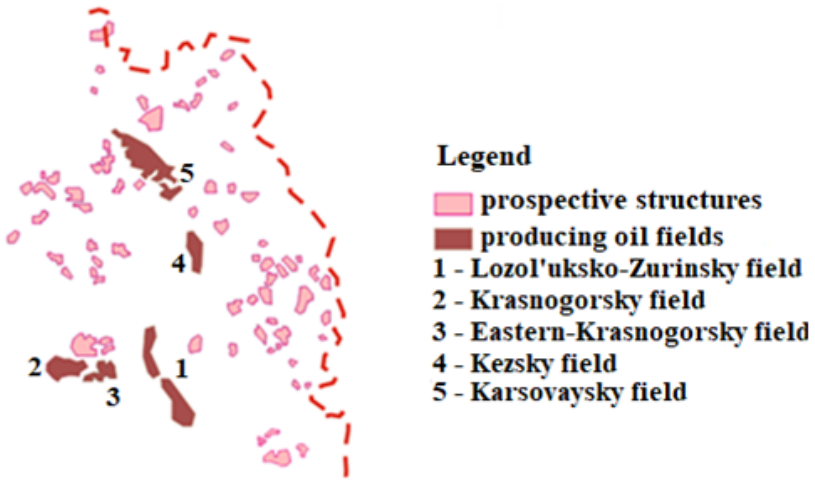

Figure 5 – Prospective oil-bearing structures in the north-east of the Udmurt Republic

The data, obtained by the passive seismic survey, may be employed to these structures for discerning a petroleum reservoir in detail, accurately detecting hydrocarbon-saturated zones with good prospects, and avoiding errors relevant to incorrect reserves estimation (Science and Technology Complex “ANCHAR” LTD, 2010; Arutyunov et al., 2010).

Passive seismic survey has a slight drawback of increasing the expenses for exploring a field. However, at the same time, the use of this technique will influence the drilling cost, diminishing it significantly.

The methods of passive seismic started to develop rapidly in Russia in the 1990's (Shabalin et al., 2013). Nevertheless, the accuracy and amount of data derived from passive seismic surveys were far less than it is possible to receive now. It is related to considerable improvements in computing equipment which is employed to interpret the data obtained.

Moreover, passive seismic may hold out good promises if being applied to developed fields at regular intervals. This method makes it possible to monitor the changes in oil-water contact of a reservoir as well as to detect prospective pay zones that are poorly operated in the productive formation. Also, such an approach provides reducing the number of dry and ineffective wells, minimizing the shortcomings in horizontal sidetrack drilling, and correct determining of water saturation. These may all significantly increase a recovery factor and economic efficiency of field development.

CONCLUSION

Challenges that may be solved by implementing passive seismic include the following (Science and Technology Complex "ANCHAR" LTD, 2010; Arutyunov et al., 2010; Kuznetsov et al., 2010):

- Accurate discerning of petroleum reservoirs.
- To estimate the hydrocarbon-saturated areas of a field with precision.
- To determine oil-water contact (OWC).
- Reliable calculation of hydrocarbon reserves contained in a reservoir.
- To determine more appropriate and prospective placements for well drilling.
- To reduce the expenses for deep-well drilling.
- Identification of prospective pay zones that are poorly operated in a productive formation.
- Optimization of the process for additional drilling of production and injection wells.
- To increase a recovery factor of a field.

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