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Passive Infra-Frequency Microseismic Technology – Experience and Problems of Practical Use

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SUMMARY

Infra-frequency microseismic technology ANCHAR is based on the analysis of microseismic background of the Earth and is designed for prediction of oil bearing of formation rocks. Based on the 15-year experience of applying the microseismic technology to prediction of oil and gas, authors analyze the problems arising in microseismic technologies based on the use of amplitude characteristics (AC) of microseismic. Proposed is a new criterion based on the statistical analysis of displacement vector of the microseismic background considered as random time series (EC). Demonstrated is its benefits, particularly, better daily reproducibility as compared to approaches based on amplitude characteristics. Presented are case studies of applying the infra-frequency microseismic technology in hard-to-access areas of West Siberia in Russia and examples of ANCHAR applications in other world regions.

Introduction

In the last few years the interest to a microseismic survey which is considered as a new type of oil and gas survey technology has grown sharply. Infrasonic technology for microseismic survey of oil and gas ANCHAR was devised in Russia, first patents were taken in early 1992, next in 1998 [1]. First industrial application of the technology started in 1994 in Russia, later in Kazakhstan and in Morocco and Bulgaria. This technology is based on the ANCHAR effect defined as follows: "

*"…when an oil-and-gas pool is subject to an external **man-made or natural field of elastic vibrations** in the frequency range of effective interaction of a wavefield and hydrocarbon-enclosing material being in a stressed meta-stable state, this oil-and-gas pool is switched to a state of generating intrinsic infrasonic waves…"* [2].

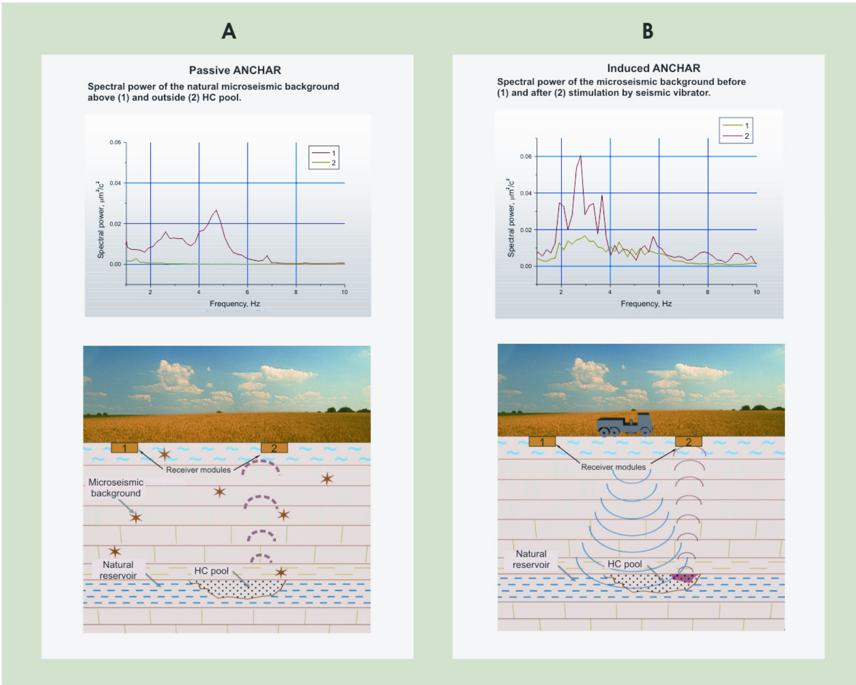

Fig.1 Schematics of ANCHAR observations
based on spontaneous (A) and induced (B) effects.

A few theoretical hypotheses explaining the ANCHAR effect are known among which the most adequate, in our opinion, are models of phase transitions, including non-equilibrium transitions in a system "HC – reservoir". The so-called "drop-bubble model" [3] fits these conceptions and quantitatively complies with experimental observations. This model relates the ANCHAR effect with intra-pore "gas-fluid" phase transitions in the presence of the natural geoelectric field.

From the above definition it follows that spontaneous (natural) and induced (man-made) ANCHAR effects exist (Fig.1). The spontaneous ANCHAR effect is applied in the passive version of ANCHAR technology without using any man-made seismic sources. Active version of ANCHAR technology is based on the induced ANCHAR effect, it assumes the use of a seismic vibration source. This source is applied to increase the number of active emission centers in productive beds.

Pilot and commercial implementation of these two versions of ANCHAR technology started in 1994. Within last decade authors have gained a large experience of applying this method. As the most simple criterion for identifying HC in both versions of ANCHAR the spectral amplitude anomaly can be applied (see Fig.1). A series of such criteria was named as "ANCHAR amplitude criteria" (AC).

Spontaneous (Passive) Effect ANCHAR

The interest to exploration of mineral deposits using a natural noise field of elastic oscillations has grown sharply. It is obvious that spontaneous effect ANCHAR and passive version of ANCHAR technology are related to the same research field. Actually most of known passive microseismic technologies are making use of amplitude characteristics of a spectrum of natural microseismic background to identify HC reservoirs [4]. More than a 10-year experience of applying the spontaneous ANCHAR effect as a passive monitoring technique has shown that the use of such characteristics without man-made vibration sources meets a number of difficulties:

- it is necessary to take into account daily natural rhythms (variations) of the microseismic field during long-term survey of oil-and-gas promising areas;
- it is necessary to have wells with a known production rate in studied areas, since the level of microseismic oscillations near such wells is used as the threshold value;
- it is necessary perform a long-time observation at each point – this means the lower performance and high dependence of such method on man-made interferences, and etc.

Nevertheless, a rejection of man-made vibration sources makes passive microseismic methods very valuable under severe climatic and complicated geological conditions. It is obvious that any criterion of the presence-absence of a HC reservoir based on amplitude characteristics of the background microseismic wavefield will face the above-mentioned difficulties. The authors spent much time for observation of the microseismic background in a number of oil fields trying to solve these problems. As a result we established a new feature of natural microseisms above HC reservoir – the so-called "**oil-and-gas microseisms**." This feature is the **Microseism Ordering Effect** and it is defined as follows:

"The Ordering of Microseismic Background inside the outline of HC reservoir is higher as compared to that outside the HC reservoir."

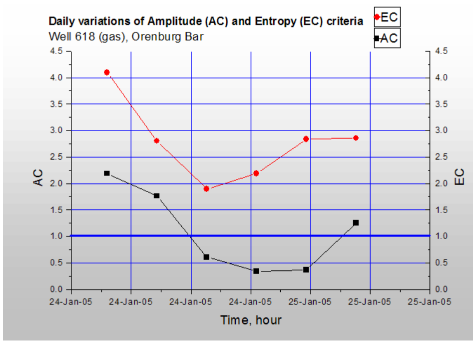

Fig.2. Comparison of daily reproducibility of Amplitude and Entropy Criteria (Values are rated to daily maxima of AC and EC values outside the HC reservoir).

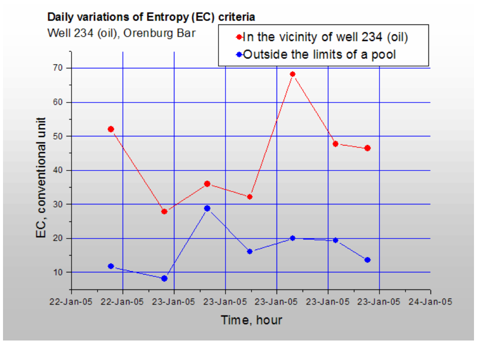

Fig.3. daily variations of Entropy Criterion above and outside the outline of HC field. Ranges of EC-values above and outside the field are clearly differentiated throughout the day.

As known the entropy is a measure of disorder (consequently, a measure of order) in a statistical ensemble. That is why the established effect was called as "**Entropy Criterion of ANCHAR Effect (EC)**." Fig.2 demonstrates an independence of this criterion on daily rhythms of natural microseisms and its time stability throughout day period for one of the fields of the Orenburg region. Similar studies were performed adjacent to 4 productive and 2 dry wells in other 3 fields of Orenburg.

Figs.2 and 3 are typical for all experimental observations. Sharply defined are daily instability of the prediction criterion based on Amplitude Criterion of the natural microseismic background and high stability of Entropy Criterion demonstrated by the EC diagram. Values of EC above the HC field are higher as compared to values outside the outline of HC field throughout the day. The wavefield of the Earth's elastic natural microseisms above the HC field is characterized by a higher ordering as compared to that outside the field.

First commercial survey based on the use of Entropy Criterion were successfully performed in summer 2005 (Fig.4), in the Sablunsky area of Khanty-Mansiysk autonomous district (West Siberia) . East part of the 20-km latitudinal profile passes through an oil well No.6. We, also, performed daily measurement of microseismic background in the vicinity of a dry well No.9. A maximum daily value of EC near the dry well was selected as a threshold value. This survey has produced a detail information about position of the outline of HC reservoir.

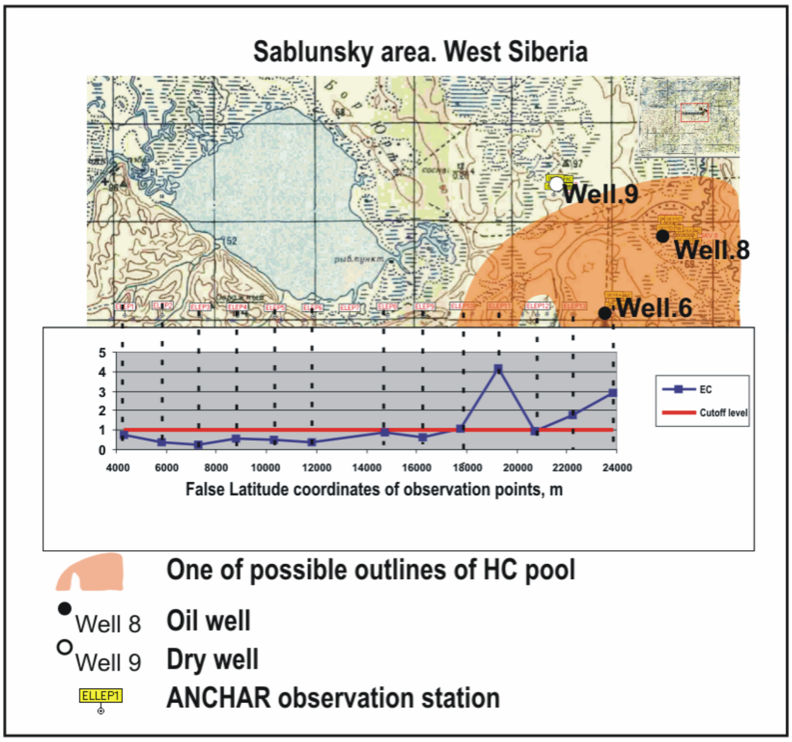

Fig.4 Applying the passive ANCHAR method
to refining the outline of oil field in the West Siberia.

Induced Effect ANCHAR: Application Results

By exciting geological formations when applying a seismic vibrator (and making the technology more complicated) we manage to materially enhance the performance of infrasonic survey and improve the reliability of predictions. However, "easy and fast operation" features of field observations and data processing (as compared to convemntional seismic) are still retained. Moreover, the above-mentioned problems of Spontaneous ANCHAR method are excluded. High efficiency of such approach to microseismic mapping when solving the problems of oil and gas prediction is confirmed by projects performed in Russia, Kazakhstan, and Morocco and Bulgaria (method ADD HR).

Within more then a 10-year period authors have collected test results acquired in 75 prospecting and exploratory wells at 43 targets (areas, structures) where the depth of pay zones varies from 700 m to 7000 m. These targets, surveyed by ANCHAR method, are located within the limits of 16 oil-and-gas regions in the areas where different oil-and-gas production and geological explorations companies are operating. The all these wells were drilled upon completion of ANCHAR prediction. Among these 75 sites, where wells were drilled, positive and negative ANCHAR predictions of oil-and-gas presence were confirmed in 61 cases (more than 80%).

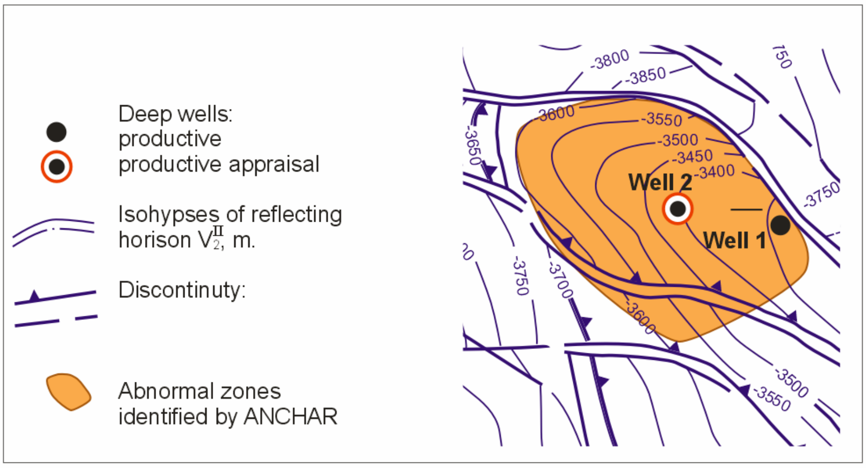

Fig.5. Prediction of oil-and-gas
bearing by the ANCHAR method, West Kazakhstan.

An example of the last ANCHAR prediction confirmed by deep drilling (in 2005) is the site of oil well No.2 in one of the fields of West Kazakhstan (Fig.5).

Conclusions

- It is demonstrated that Entropy Criterion (EC) features the best daily reproducibility and depends much less on the natural daily rhythms of microseisms contrary to Amplitude Criterions.
- Active version of ANCHAR technology (based on induced microseismic effect) like the passive (spontaneous) version also relates to the category of microseismic methods and technologies.
- Established is the effect of ordering of microseismic background noise above HC fields and a new entropy-based criterion of HC identification (EC) is successfully tested.

References

[1] Patent of Russian Federation No.2045079 (1992); Patent of Russian Federation No.2054697 (1992); Patent of Russian Federation No.2161809 (1998).

[2] Scientific discover № 129, 1997.

[3] Kuznetsov, O.L., Grafov, B.M., Aroutunov, S.L., Suntsov, A.E. 2003, ANCHAR Technology. About the theory of ANCHAR method. Geofizika, special issue “Seismic Exploration Technologies”, II, pp.103-107 (in Russian).

[4]. Holzner R., Eschle P. and others: Applying microtremor analysis to identify hydrocarbon reservoirs. // First Break, Vol.23, May, 2005.