Acoustic noises in boreholes: aspects of practical use

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This paper was prepared for presentation during the 11th International Congress of the Brazilian Geophysical Society held in Salvador, Brazil, August 24-28, 2009.

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Abstract

A distribution of acoustic noises in massifs of sedimental and crystalline rocks was considered. It was shown, that the level of acoustic noises is higher in crystalline rocks. Three-component geoacoustic logging allow to distinguish zones of an elliptical cross-section of a borehole shaft. Opportunities of geoacoustic noises to distinguish oil and water saturated stratums were shown.

Introduction

Measurement of acoustic noises of rocks in borehole allow to receive essentially new information about modern dynamic processes in geological medium. Maximum amplitudes of acoustic signals are being observed in the zones of present-day active micromovements and timed spatially to the zones of faults, areas of crushing and fracturing of rocks. The acoustic noises amplitude-frequency composition depends on the Physical-mechanical properties of rocks. Determination of character of collector's saturation in an encased borehole is possible when applying neutron methods, but interpretation of measurement's results becomes more complicated in case an oil bed is water-filed with mildly mineralized water. In this connection the work on investigating amplitude-frequency composition of acoustic noises of collectors, saturated with oil, gas and water, was carried out.

Method

During the last few years intensive research of acoustic noises in ore and oil boreholes was being earned out within the frequency range of 20-4000 Hz.

A new geophysical parameter specifying dynamic activity of the geophysical medium was developed. Certain results of spatial-temporal distribution of acoustic noises are given below to evaluate the opportunities of their practical application:

1. It has been established that in the earth's crust of seismically secure region acoustic noises are registered at the depths of up to 5 km.

2 The intensity of acoustic noises is higher in the rocks of crystalline complex and considerably lower in sedimentations (Fig. 1).

3. Maximum amplitudes of acoustic signals are being observed in the zones of present-day active micromovements and time spatially to the zones of faults, areas of crushing and fracturing of rocks (Fig. 2).

4. The same types of amplitudes are also specific for areas of fluid movement along the layer in oil deposits.

5. The acoustic noises amplitude-frequency composition depends on the physical-mechanical properties of rocks. Spectra may be continual and discrete. Their most common features is a rise of spectral density in a low frequency region (20-500 Hz). The basic component of acoustic noises in a region of high frequency (higher than 100 Hz) is a seismic-acoustic emission of rocks manifesting itself during the appearance of fractures Gas and gaseous factor of fluid is registered in the same region of frequencies

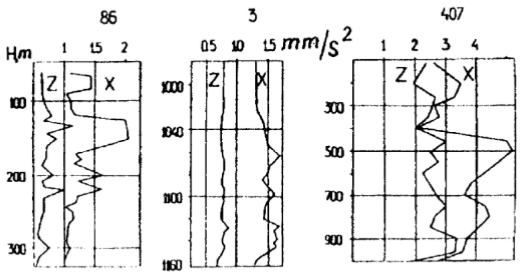

Figure 1: Amplitude levels of acoustic noises, being registered by vertical (Z) and horizontal (X) transducers in sedimcntal rocks (boreholes 86 and 3, Udmurtia) and in crystalline rocks (borehole 407, Northern Kazakhstan).

It's common knowledge that fractures in the medium appear at the value of acting stresses s_{st}, that depends on the linking between the atoms. If the material has a microfracture of *l* length, then its solidity is determined by the expression:

$$s_{st}=s_0\,(a/l)^{1/2}$$

where s_0 - theoretical material solidity, *a* - between-atom distance.

With values there arise conditions for development of microfractures.

A critical size of fracture l_{cr} corresponds to each stress, below which it is stable and above it opens spontaneously. This means that at the rise of stress in the medium only those fractures grow whose length exceeds the critical value. Fractures with length less than l_{cr} keep their stability, since for them $s_{st} > s$, that is in these conditions the medium is not dynamically active.

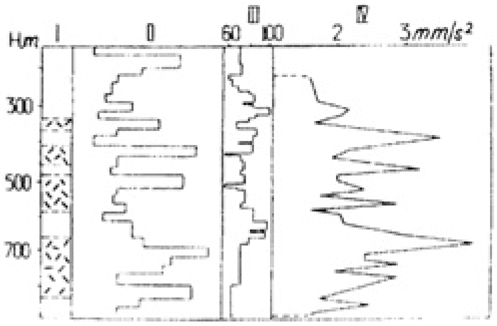

Figure 2: The distribution of acoustic noises in a massif of fractured rocks. Borehole 302, Lomonosovskoye iron ore deposit. I - the zone of fractured rocks; II - fracturing of rocks according to cores; HI - core output, %; IV - the diagram of amplitude level of acoustic.

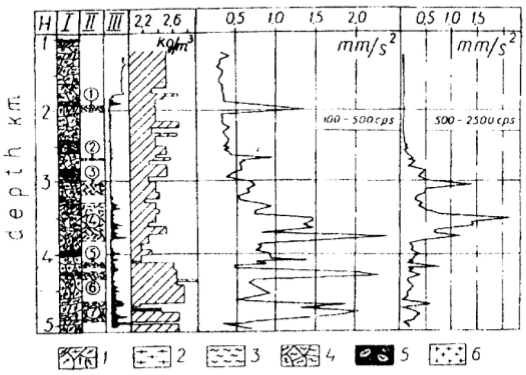

Figure 3: Distribution of acoustic noises in Vorotilov Borehole. I - geological column; II - zones of modern deformation processes (1-7), which are connected with tectonic disturbance of rocks. III - caliper log. Dash line is density log 1 - gneiss breccia, 2 - gneiss, 3 - amphibolites, 4 - amphibolite breccia, 5 - breccia with tagomite cement, 6 - dolerites.

The investigations of acoustic noises in two boreholes with the same quantitative fractuning show that in the borehole acoustic noises anomalies correspond to the zones of fracturing, in the other borehole anomalies are not observed.

This leads us to an important conclusion; the abnormal level of acoustic noises reflects the present-day dynamic activity of geological medium and not the degree of its fracturing.

The study of geological information on peculiarities of acoustic noises spatial distribution cannot be done without taking into account their frequency composition.

The informative value of the acoustic noises frequency composition consists in the possibility of dividing registered signals according to their physical nature. The low-frequency branch of the spectrum specifies the presence and intensity of acoustic noises in the medium volume, including the space around a borehole. The high-frequency part of the spectrum reflects the presence and probability of appearing in time of acts of seismoacoustic emission of-rocks in the neighboring zone.

Besides, the amplitudinal-frequency composition of acoustic noises depends on the nature of gas -water-oil saturation of layers. It is used in practice when supervising control over exploration of oil and gas deposits.

Examples

Figure 3 shows distribution of geoacoustic noises in the Vorotilov Deep Borehole.

Seven zones of technically disturbed rocks, where modern deformation processed take place, were separated in frequency range from 100 to 500 cps according to anomalies of acoustic, noises. The processes of cracking in the nearest zone characterize anomalies of acoustic noises within the range 500-2500 cps. amplitudes of acoustic signals are expressed in the registered values of acceleration of relative medium's displacement, and they are designated as mm/s2.

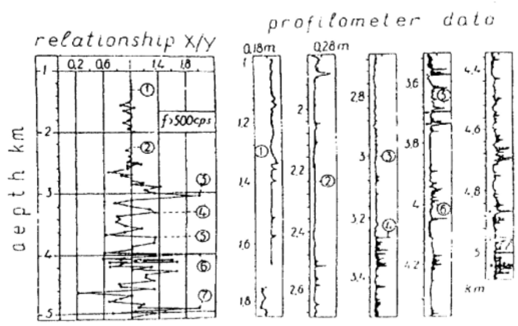

Figure 4: Diagram of vertical distribution of X/Y relation and data of profilemetry in the Vo-rotilov Deep Borehole (digits inside circles are points of comparison of the parameters under study).

The difference between amplitudes of high-frequency acoustic signals from horizontal transducers of the same sensitivity is indicative of anisotropy of properties of the geological medium under examination, and it is usually observed in points where cross-section of a borehole's shaft assumes a form of an ellipse. It is evident that deviation of the relation X/Y value from 1 is only observed where cross-section of borehole's shaft has the form of an ellipse according to profilemetry (Fig. 4).

From seven points, arbitrary selected for comparison, let us pay attention to point 3. With the relation X/Y = 2 that is observed in points 3, 6 and 7, the minimum deformation of borehole's diameter is in point 3. It may be explained by a greated rocks' strength in comparison with jointly gneiss (points 6 and 7) or by different stress, acting in the medium.

High-viscosity oils are characterized by a spectrum of acoustic noises with maximum: frequencies of 300-400 Hz (Gremikhinskoye field, Udmurtia; Karazhanbas field, Kazakhstan). Estimates of the effective coefficient of absorption for high-viscosity oil and water saturated zones, indicates that this parameter may be used to determine the character of the reservoir saturation.

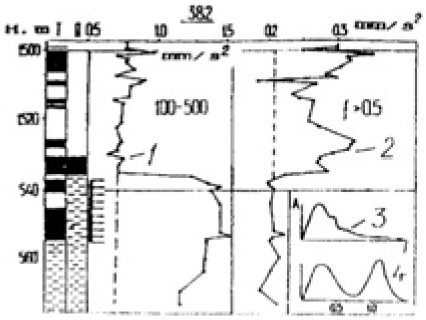

Figure 5: The detection of an interval of water encroachment. 1,2 - acoustic noises diagrams, 3, 4 - the spectra of water-saturated and oil-saturated seams.

An example of practical realization of acoustic noises measurement for evaluation of the nature of collectors' saturation in borehole 382 (Udmurtia) is given on Fig. 5.

The section of productive stratum opened by a borehole in 1975 is shown in column 1. The acoustic noises investigation have been carried out after the borehole exploitation during 11 years. Correlation of signals in the frequency bands of 100-500 Hz (curve 1) and 500-2500 Hz (curve 2) gives reason to consider two low oil layers, opened by perforation in 1975, filled with water (column II). It is true, the spectrum of water-saturated layer (3) does not show high-frequency signals (> 1 kHz), specific for the oils spectrum with a gas factor 17-27 m^3/ton. Water-filling of oil layers and a rise of water-oil contact up to the of mark of 1535 m have been checked and proved by testing in the process of work by oil and gas production department "Izhevskloir".

Conclusions

At present, oil-borehole equipment and the methodology of studying acoustical noises, developed at the Institute of Geophysics of the Urals Branch of the Russian Academy of Sciences, are used to control the exploitation of oil reservoirs

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