Three-component geoacoustic logging in investigation of fluid-gas dynamic processes in gas boreholes

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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.

Abstract

In was shown that three-component geoacoustic logging allows to solve the problems of control over gas deposit mining. The examples of the method, applied to distinguish gas-saturated seams, detect overflows outside the column and study a profile of inflow in the intervals of seam perforation, were adduced.

Introduction

The method originated from investigation of geoacoustic emission (GAE) in widths of sedimentary rocks. It was established that in intervals of seams-collectors with different saturation (water, oil, gas) anomalous GAE level considerably increases and it is explained by the processes of fluid-gas-dynamics. Some investigators note in their works that geoacoustic signals caused by the movement of fluids in pore space (especially in the presence of gas fraction) may be appreciable. The analysis of amplitude-frequency spectra, obtained at measurement points of different depth along borehole shaft, showed their difference depending on the character of seam-collector saturation. Seam-collector saturation method (see e.g., Troyanov, Astrakhantsev, Outkin, Patent (2005)) was based on difference in amplitude-frequency GAE spectra.

Three-component geoacoustic logging

Investigations of amplitude-frequency GAE characteristics (acoustic noises) show that geoacoustic signal characteristics of filtration flow under seam and laboratory conditions are identical and determined by the structure and type of a collector (see e.g., Ignatov, Gorodnov and others(2004)). In this case, in fractured-porous collectors a flow is filtrated through fractured space and spectrum maximum is within units of kilohertz. Actually, the position of GAE spectrum maximum does not depend on filtration velocity, and flow velocity usually influences only signal amplitude (see e.g., Nikolayev, Ovchinnikov (1992)).

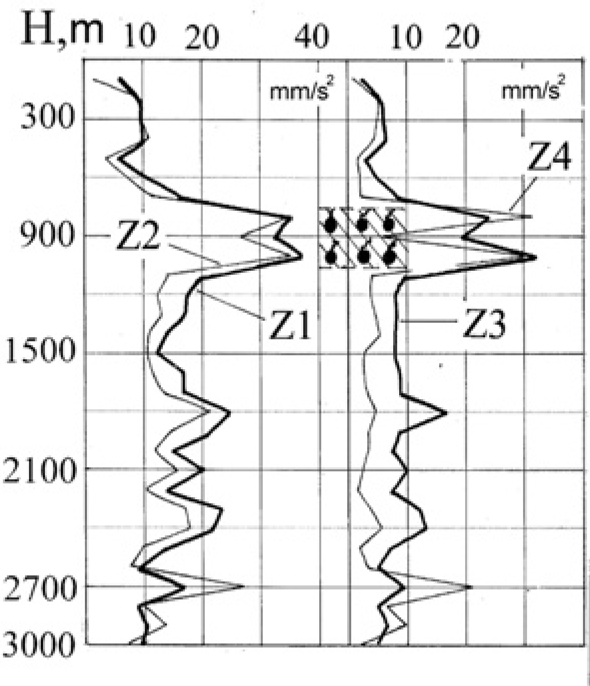

Figure 1: An example of gas-saturated seams-collectors, distinguished according to anomalies of geoacoustic signals from the vertical transducer Z in different frequency bands: Z1 - (0.1-0.5) kHz; Z2 – (0.5-5.0) kHz; Z3 – (0.5-1.5) kHz; Z4 – (2.5-5.0) kHz.

Investigations of effective pore dimensions and filtration parameters relation to amplitude-frequency GAE characteristics, which allowed quantitative evaluation (see e.g., Nikolayev, Ovchinnikov (1992)), are obviously interesting. Effective pore diameter is similar to the scale of pulsations and characterizes the length of GAE wave generated by a flow, and corresponding frequency of acoustic emission field. With increase of permeability more higher frequencies of acoustic emission, generated by fluid flow, will correspond to one and the same pore diameter. An important conclusion follows from the results of the work of Nikolayev and Ovchinnikov (1992) according to GAE spectra for permeable rock we may evaluate the structure of channels (effective diameter) mainly participating in the process of filtration (when permeability is known); or, on the contrary, the data on effective diameter may help to evaluate the parameter of fluidity, equal to the ratio of permeability coefficient to dynamic viscosity. Signal spectra of water-saturated seams are limited by the upper frequency 500 Hz, in this case amplitudes of dominating frequences may widely change, depending on a flow intensity. In oil seams with gas factor not more than 50 m3/t the upper frequency reaches 2500 Hz.

In oil saturated seams amplitude-frequency spectrum may be discrete and continuous, and spectrum range widens to 3000-5000 Hz and more. It should be noted that the adduced upper frequency limit for gas-saturated seams is stipulated by amplitude-frequency characteristic of transducers (by its linear part) and corresponding parameters of the equipment measuring section. Taking into account that acoustic signals from geoenvironment volume pass in different directions, we decided to record them by three orthogonal transducers – accelerometers with conversion coefficient and lateral sensitivity 6-10mV mm/s2 and 4-8 %, correspondingly. Borehole equipment was devised, taking into consideration amplitude-frequency GAE characteristics (see e.g., Astrakhantsev, Troyanov, Patent (1998)). Measurements were conducted at points with fixed depth step, determined by an operator for a specific task. Output information to the monitor of a personal computer was represented as LAS-files. After data processing we obtain 8 measured parameters and more than 10 calculated ones (see e.g., Beloglazova, Troyanov (2009)).

Examples

Thick gas-saturated seams may be distinguished according to measurements with the vertical transducer Z in different frequency bands (Fig. 1).When revising the boundaries of gas-saturated seam we use signals from horizontal transducers to define calculated parameters H4=(X42-Y42) ½, Nh (Fig. 2). Investigations in the borehole "Vostochnaya Poltava – 12 (the Ukraine) showed that an anomaly of geoacoustic signals in the area of high frequencies (parameters H4 and Z4, 2.5-5.0 kHz), caused by presence of gas (Fig. 2a), is distinguished lower than 2400m and at least to 3600m. Anomalies of parameters Nh and Nz – pointing to a fraction of high- frequency signals in the integral level of recorded geoacoustic signals (Fig. 2b), may confirm the presence of this anomalous zone, bound with gas-content of geoenvironment.

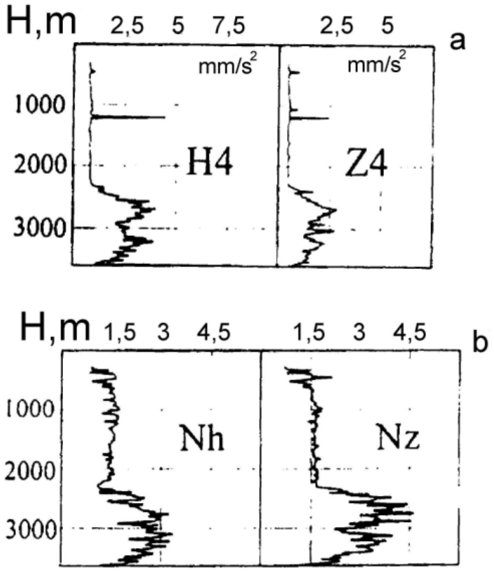

Figure 2: Distribution diagram of measured (a) and calculated (b) parameters of three- component geoacoustic logging in the borehole Vostochnaya Poltava – 12(the Ukraine).

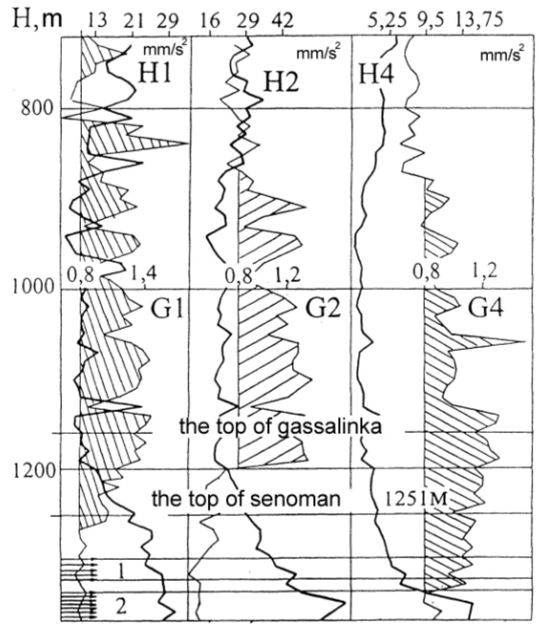

Figure 3: The change of parameters H and G under conditions of gas overflow outside the column. Borehole 1124, the Zapolyarniy deposit; 1,2 –perforation intervals of gas-saturated seam-collector. Anomalous values of parameters G1, G1 and G4 are marked by oblique hatching.

Let us consider distribution of informative parameters H and G under conditions of gas-fluid mixture overflow outside the column, using the example of GAE investigation results in borehole 1124 of Zapolarniy deposit. If we pay attention to the form of curves H1, H2, H4 and G1, G2, G4 (Fig. 3), we may notice that with decrease of anomalous values of parameter H, characterizing movement along horizontal, the value of parameter G=Z/H, responsible for vertical movement of gas-fluid mixture, begins to increase. When parameter G in frequency band 100-500 Hz (G1), 500-5000 Hz (G2) and 2500-5000 Hz (G4) exceeds a certain limit (0,8), we may single out an overflow outside the column whose intensity at qualitative level will be determined by the parameter G value. In this case gas overflow goes from the roof of Senomanian deposits.

Investigations in one hole of the Urengoy gasocondensate deposit (Fig.4) were conducted to solve the following problems:

1. Determination of an inflow profile in the interval of productive seam perforation.

2. Qualitative evaluation of saturation character of a seam, opened by perforation.

We may use only 2 GAE parameters, characterizing gas and fluid movement from a seam, to determine an inflow profile in perforation interval. The diagram of parameter H1 shows weak fluid movement (oil and water), parameter H4 – in the roof part of this seam there is observed movement of oil with high gas factor. Thus, water and oil with high gas factor arrive into the hole.

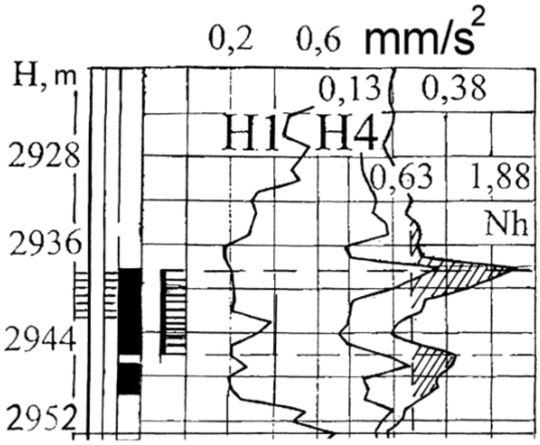

Figure 4: The study of an inflow profile in the interval of seam perforation with evaluation of collector saturation character. Borehole 6443, the Urengoy gasocondensate deposit.

The diagram of calculated parameter Nh confirms this conclusion. The seam under perforation zone in depth interval 2946,8-2949,0m is distinguished as oil-saturated (Nh=1,2) with weak fluid movement along horizontal. Oil arrival along an over flow outside the column from this interval to the bottom part of perforated oil seam (2938,0-2949,6m) is traced according to increase of Nh values.

Intervals of seam perforation are marked by arrows. An independent modification of borehole equipment, descended into a borehole on a wire, was developed for investigations at the Astrakhan gasocondensate deposit. The equipment allows independent recording of geoacoustic signals during 6 hours at depths of 3000-4000m and temperature up to 130° C. After ascent of independent borehole device and depths correlation the data are presented as LAS-files and processed with subsequent construction of a graph (diagram).

Figure 5 adduces diagrams of parameters H2 and H4, showing the change in time of gas-producing interval boundaries. Diagrams 1, 2 and 3 were obtained by measurements in 12 hours, besides, measurements 1 and 2 were fulfilled in static mode of borehole operation, measurements 3 and diagram H4 were obtained in dynamic mode of borehole operation.

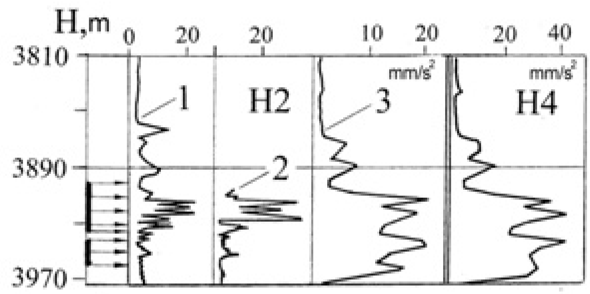

Figure 5: Investigation results of gas inflow profile in the intervals of seam-collector perforation; 1-diagram of initial measurements 2.3 – repeated ones in 12 and 24 hours, correspondingly; H4 – diagram, characterizing the presence and movement of gas from a seam.

Conclusions

Thus, the developed method – three-component geoacoustic logging – is used to solve a number of problems of gas deposit exploitation control.

Acknowledgments

The work was supported by Russian Fund of Fundamental Investigations (RFFI), grant 08-05-01084.

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