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Field-work automation of hydrocarbon exploration using a passive seismic-electric method

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Abstract. The paper proposes to exclude the active source of the seismic field from the measurement scheme, which is often a massive truck with equipment installed on it, which in its turn makes it difficult and increases the cost of field-work. The proposed passive measurement installation allows the detection of hydrocarbon deposits by registering the natural fields of the Earth. All measurements can be carried out by one person due to the use of magnetic antennas. A method of field measurements by means of such installation, as well as measurement data on a real gas condensate field are presented.

1. Introduction

Seismic-electric effects were predicted in the works of Ivanov [1] and Frenkel [2] who predicted these effects theoretically. In later works [3-5], experimental observations were carried out using porous structures at frequencies up to 10 kHz - 100 kHz. The authors of [6–8] showed that it is possible to use these effects to search for hydrocarbons at frequencies up to 100 Hz using standard seismic survey equipment and additional sources of electromagnetic field. In [9], the authors indicate that it is possible to observe seismic-electric effects without using an electromagnetic field source, but only by introducing electromagnetic field sensors to standard seismic equipment. It is worth noting that the use of seismic-electric effects in this case is associated with large labour costs, due to the fact that it is necessary to scatter an additional braid of electric dipoles.

The authors of this work have already cited data [10] that carrying out these works is possible without the use of active electromagnetic and seismic fields, but only by recording natural fields. To automate the field-work, the seismic-electric method in the passive and active way can be used both by standard seismic stations and with the help of specialized instruments for recording seismic and electromagnetic fields.

Thus, the recording of seismic-electrical effects data is reduced to the fact that it is possible to use a mobile recorder of natural seismic and electromagnetic fields, which will allow calculating the parameters of the seismic-electrical effect over the field by further processing. Seismic vibrations can be recorded using a standard sensitive seismic receiver, and to increase the productivity of work, a magnetic antenna can be used instead of a standard grounded electric dipole.

2. Methods and materials

When operating in a semi-active manner with excitation of a seismic-acoustic field by a pulsed striker, it is possible to use the spit inputs of a seismic survey station, thus without incurring additional costs during seismic exploration. In this case, it is possible to measure both by the completely passive method without using a striker, and using it, which practically does not affect the cost of field-work, and due to processing you it is possible to calculate the value of the seismic-electric coefficient as the maximum of the cross-correlation function using the following formula:

$$Res = \max\left(\int_0^T E_S(t)\cdot E_E(t-\tau)\cdot dt\right), \qquad (1)$$

where $E_S(t)$ is signal received by seismic receiver, $E_E(t)$ is signal received by the electric dipole.

And considering the delay of signals relative to each other, it is possible to estimate the depth of the productive formations. It is also worth mentioning that the registration of the magnetic and electric components of the responsible field of the Earth will make it possible to build the dependence of the conductivity on the depth by evaluating these effects at different frequencies. Thus, depth estimation is possible simultaneously in two ways. The measurement scheme of the standard seismic-electric method is shown in figure 1.

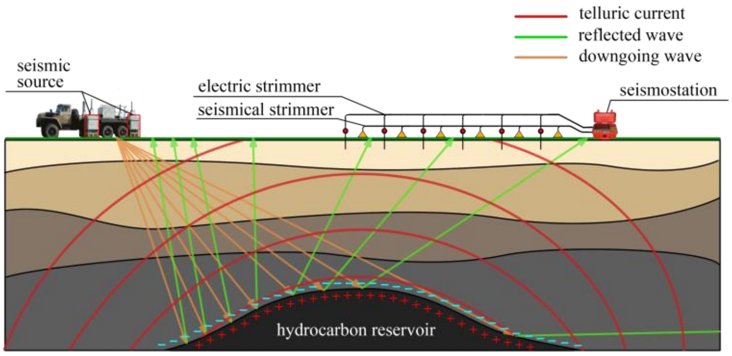

Figure 1. The scheme of measurements by the standard seismoelectric method.

The scheme of observation by a passive seismic-electric method is currently depicted in figure 2. In this case, a grounded electric dipole is used to register the Earth's electromagnetic field, and a sensitive seismic receiver is used to record seismic vibrations. This scheme has a number of drawbacks related to the productivity of work, due to the use of grounded electric dipoles.

In the case of using passive fields, the proposed installation consists of two orthogonally grounded electric dipoles with a distance between grounding points of 200 m and a three-component seismic receiver installed in the middle, as well as a specialized three-component magnetic antenna for recording the magnetic component of the Earth's electromagnetic field. To automate the field-work, it is possible to exclude grounded dipoles from the measurement scheme, which will speed up the observation process at the point and improve the performance of the field work.

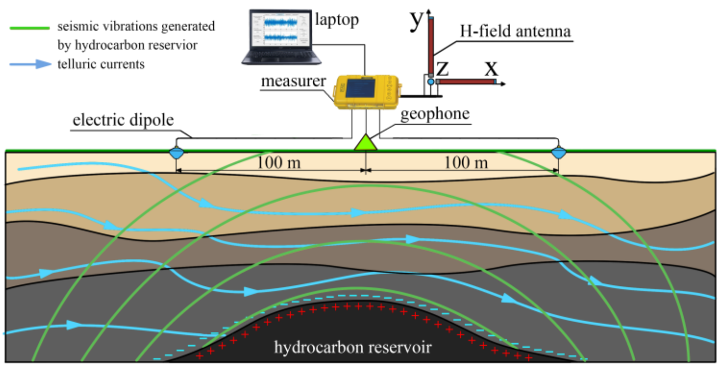

Figure 2. Measurement scheme for the passive seismic-electric method.

The technique of field-work is reduced to the following steps. In the normal zone, outside the productive anomaly, electromagnetic and seismic noises are measured by magnetic antennas, electric dipole and seismic receiver, respectively. After the signal has accumulated over time T, the cross-correlation function of the signal is calculated and its maximum is found using formula (1). Thus, the operability of the equipment is checked. In the course of these measurements, the level of the natural electric-magnetic field of the Earth and microseisms is estimated. The external view of the profile characteristics is shown in figure 3.

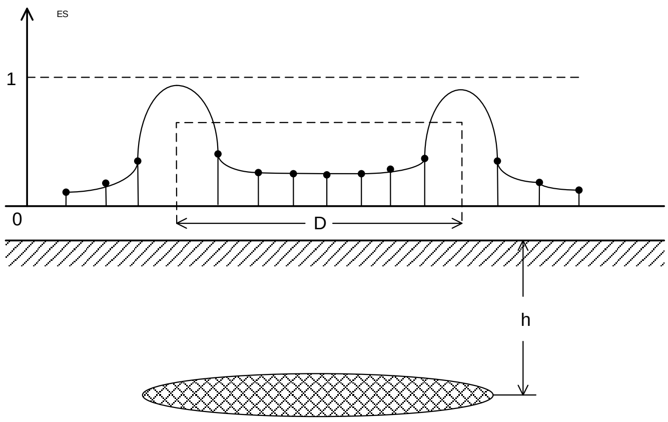

Figure 3. Visualization of the profile characteristic removal technique.

For work on the proposed site of research, observation profiles are selected. The squad should include an operator-engineer and two workers. The first observation point is established in the normal field by deploying a dipole L along the profile followed by grounding the electrodes. In the centre of L line a geophone with magnetic antennas is installed. The operator with the device is placed at a distance of not less than 20 m from the seismic receiver. The shift in the profile of observations is carried out at a predetermined measurement step (25, 50, 100, 150, 200 meters). For each measurement point, at least three Res measurements (maximum of the cross-correlation function) with duration of at least 180 seconds are recommended. The markup of L receiving line can be done during measurement. 5 minutes are required totally per point taking into account the transition. Thus, in 1 hour of working time it is possible to make up to 12 samples of Res, and in a working day of 8 hours it is possible to make 96 measuring points.

In the automatic mode, the recorded signals and the results of calculations of the seismic-electric effects are stored in the internal memory of the device. When the measurement work is finished, it is possible to construct profile characteristics and timing diagrams of the cross-correlation function maximum shift, which will allow the operator to predict the depth of the estimated productive formations.

3. Results and discussions

Figure 4 shows the data obtained by the passive seismic-electric method at the Novomikhailovsky gas condensate field (Russia, Republic of Khakassia) on the eastern slope of this field. The data were taken using a specialized meter for recording data fields. The observation time was 180 seconds, here are the observational data for a time window of 1 s, the sampling frequency of 256 Hz. The electric dipole was 200 meters long and a standard three-component seismic receiver manufactured by GS was used.

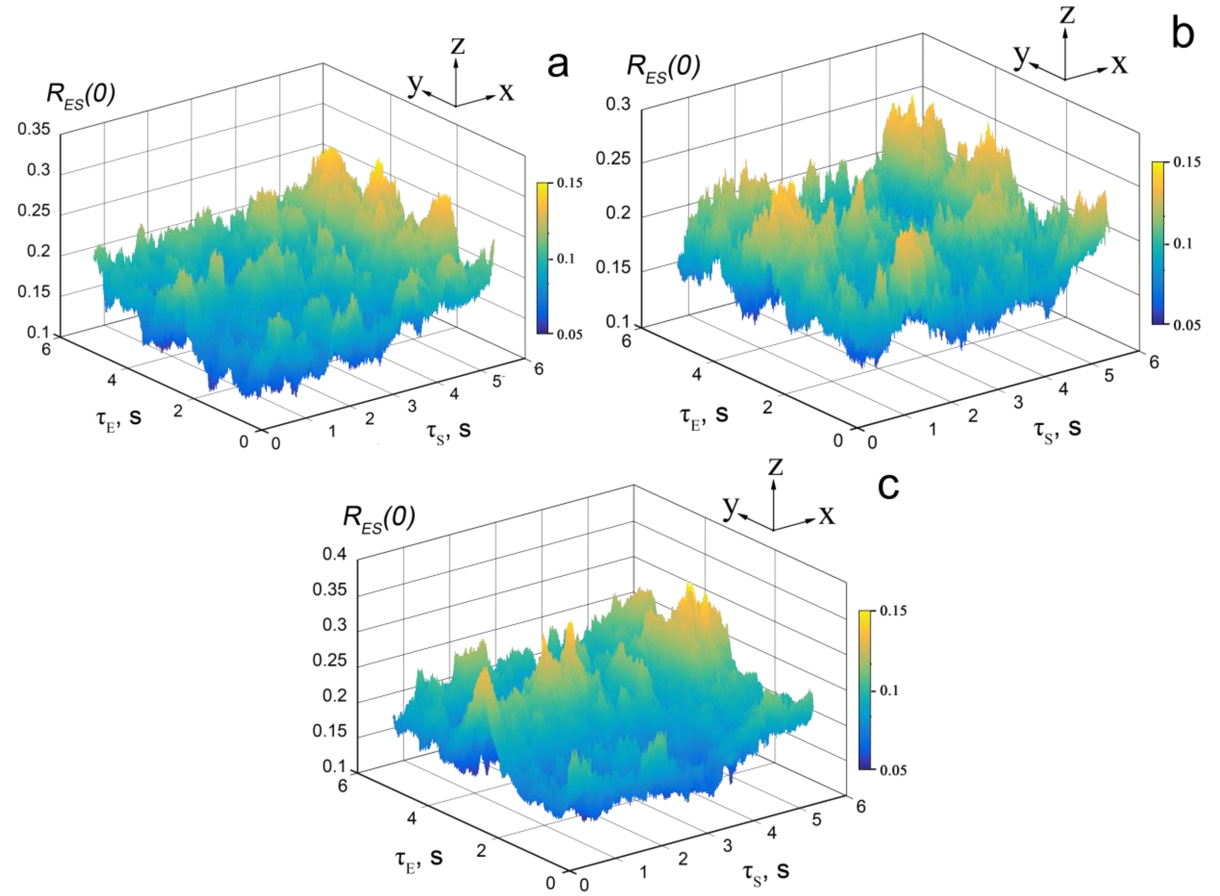

Figure 4. The results of observations by a passive seismic-electric method with components of X, Y, Z seismic field.

In this case, the processing was carried out using a sliding window, and the maximum of the cross-correlation function was calculated. As it can be seen from the graphs, a “crest” is observed for virtually all components of the seismic-acoustic field with a sliding window delay time of 4 seconds for measurements, while measurements on the Y component, noise is observed with an amplitude of about 0.17. It should be said that such a pattern is observed only at the edge of the field, in the centre of the field or in the normal field these effects are not observed and the noise level does not exceed 0.1, which can also serve as a sign of the discovery of the field.

4. Conclusion

Thus, this paper shows that the use of modern proximity sensors and the above measurement method for recording seismic-electric effects in passive fields will automate and improve the temporal characteristics of the deployment and measurement process at the observation point.

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