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THE USE OF THE PIEZOELECTRIC EFFECT OF ROCKS FOR UNDERGROUND PROSPECTING FOR PIEZOELECTRIC BODIES

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Among the known methods of exploration geophysics there is not a single one that has been successfully applied in prospecting for quartz or pegmatite veins, which often differ little from the enclosing rocks in the parameters used in electrical, seismic, and gravity prospecting. Yet many deposits of gold, polymetals, piezo-optical raw materials, and other minerals are associated with such veins.

After A. V. Shubnikov' s discovery of piezoelectric textures ([1]) and the detection under laboratory conditions of piezoelectricity in quartz-bearing rocks ([2]), field investigations were carried out at the Institute of Physics of the Earth with the aim of developing a new geophysical method for prospecting for piezoelectric bodies in underground mine workings. The work proceeded along the following principal lines: 1. Study of the piezoelectric effect in masses of quartz-bearing rocks. 2. Investigation of the piezoelectric properties of quartz and pegmatite veins in surface areas. 3. Determination of the possibilities for recording the piezoelectric effect of veins under conditions of operating mines. 4. Creation of mine equipment for the piezoelectric method of prospecting. 5. Development of the procedure for application and of methods for interpreting the results obtained by the piezoelectric method. 6. Carrying out theoretical calculations to substantiate the physical foundations of the method. 7. Testing the prospecting and exploration capabilities of the piezoelectric method at various deposits.

As a result of investigations on masses of quartz-bearing rocks it was established ([3]): a) the piezoelectric effect is recorded in such rocks as gneisses, granite-gneisses, and quartzites; b) piezoelectric oscillations are recorded at receiving points earlier than elastic ones, and the time hodographs of waves of piezoelectric nature and of elastic waves are approximately parallel; c) the maxima of the frequency spectra of piezoelectric and elastic oscillations coincide.

The piezoelectric effect of veins differs in some of its properties from the effect of rock masses and is characterized by the following regularities ([4]): a) over veins, positive anomalies of the intensity of the piezoelectric field are observed even when they occur among piezoelectric rocks of the gneiss type; b) over veins, anomalies of the time hodographs of electrical oscillations are noted; c) the

Fig. 1. Type of oscillograms used in the piezoelectric method of exploration in underground workings. 1 —moment of explosion, 2 —elastic wave, 3 —piezoelectric impulse

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frequency of the piezoelectric oscillations of veins is higher than the frequency of elastic waves and the frequency of piezoelectric oscillations observed in rock masses.

At the next stage of investigations, carried out in operating mines, it was shown that a quartz vein can be detected by its inherent property—the piezoelectric effect. A seismic wave arising from the explosion of a small charge (100–200 g) of explosive, upon reaching a quartz vein, produces an electromagnetic disturbance of piezoelectric nature. The latter is picked up by receivers in the mine working, amplified, and recorded on oscillograph tape. Figure 1 gives a record of a piezoelectric pulse arriving from a quartz vein one and a half meters thick, located at a distance of 15 m from the blasting point.

On the basis of a study of the magnitude and frequency spectra of piezoelectric pulses of veins, as well as the properties of industrial electrical

noise in mines, the PEÉF-2 station was developed. The experimental models of this apparatus, intended for prospecting and exploration work under underground conditions, consist of an amplifying-generator semiconductor unit, a cable oscillograph, electrodes, and seismic receivers. The station operates in the frequency range 300–800 Hz and has a maximum sensitivity of 0.2 mm/μV. Under the conditions of operating mines, the apparatus is carried and serviced by a team of 4 people and ensures that exploration can be carried out at one site in 3–4 hours.

Fig. 1. Type of oscillograms used in the piezoelectric method of exploration in underground workings. 1 —moment of explosion, 2 —elastic wave, 3 —piezoelectric impulse

Reliable delineation of a quartz vein and determination of its elements of occurrence are possible when several shot points are fired. The position of the vein is determined on the basis of the relation $s_i = v\Delta t_i$, where s_i is the shortest distance from the given shot point to the vein, v is the velocity of the elastic wave used in the enclosing rocks, and Δt_i is the delay time of the piezoelectric impulse relative to the moment of the explosion, determined from the oscillogram. The position of the body being sought is determined unambiguously analytically when a definite arrangement of shot points is worked out, provided they do not lie in one plane.

Theoretical consideration of the question of the types and properties of waves

Fig. 2. Example of results of prospecting work carried out by the piezoelectric method at one of the sections of a gold-ore deposit.

Figure 2: Fig. 2. Example of results of prospecting work carried out by the piezoelectric method at one of the sections of a gold-ore deposit.

recorded in the piezoelectric method of exploration shows ([5]) that, in the mine variant of the method, piezoelectric oscillations propagating almost at the velocity of electromagnetic waves in the medium are received. In the surface variant of the method, waves of two types may be observed, propagating with the velocity of electromagnetic waves and with the velocity of elastic waves. For both types of waves a special distribution of the electric-field strength of piezoelectric origin is characteristic. It has been established that, as applied to the piezoelectric method of exploration, the form of the wave field does not change substantially depending on the type of piezoelectric textures and their spatial orientation.

Testing of the prospecting and exploration capabilities of the piezoelectric-effect method was carried out at a number of deposits of gold, polymetals, and piezooptical raw material, with deposits being selected that had sharply different geological conditions. For example, the magnitude of the piezoelectric moduli of vein quartz at these deposits varies within the range 0.1–10% of the piezoelectric modulus of a single crystal of X-cut quartz. In the course of the work, the possibility was tested of exploring veins of planar, irregular, and isometric form, occurring in various shales, sandstones, granodiorites, limestones, and other rocks. Figure 2 gives the plan of a section of one of the levels of a gold-ore deposit with anomalies of the piezoelectric effect and the results of check drilling. At the present time, considerable experimental material has already been accumulated for elucidating the prospecting and exploration capabilities of the piezoelectric-effect method. It has been established that the range of action of the method reaches 80 m, and the error in determining distances to veins is 10–20%. Piezoelectric impulses from flat quartz veins of considerable extent in two dimensions (tens of meters) have greater intensity than impulses from equidimensional

bodies of isometric form with identical piezoelectric properties; moreover, the thickness of flat veins has no substantial influence on the magnitude of the piezoelectric pulses. As a result of prospecting observations, about 100 anomalies of the piezoelectric effect were obtained; 65 anomalies were checked by mine workings and drilling, and 42 quartz bodies were exposed.

Fig. 2. Example of the results of prospecting work carried out by the piezoelectric method at one of the sections of a gold-ore deposit. **1–6** –shot points; **7–14** –anomalies of the piezoelectric effect; **15, 16** –quartz veins according to borehole data.

In addition to investigating the possibilities of the mine version of the piezoelectric method, the suitability of the mine apparatus PEÉF-2 for solving prospecting and exploration problems from the surface in the vicinity of deposits was also tested. From the work of the All-Union Institute of Methods and Techniques of Exploration, successes are known in the development of a surface version of this method (6). However, the use of the five-channel portable station PEÉF-2 requires a special methodology. A method of observations was successfully tested in which the shot points and the measuring setup are moved along one and the same profile across the presumed strike of the veins, while the latter are identified by the minima of the arrival times of piezoelectric pulses, using different types of elastic waves.

Experimental work carried out over a number of years shows that the piezoelectric method of exploration geophysics, under conditions of operating mines and in investigations from the surface, increases the effectiveness of geological exploration work. At present the method has been introduced at two deposits.

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Note: Figure translations are in progress. See original paper for figures.