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GEOPHYSICS

1958

SovietRxiv

Abstract

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LABORATORY REPRODUCTION OF THE SEISMO-ELECTRIC EFFECT OF THE SECOND KIND

(Presented by Academician A. A. Skochinsky, 18 IV 1958)

GEOPHYSICS

A. G. Ivanov (^1), by means of experiments with pulse (explosive) processes in the field, discovered and investigated the seismoelectric effect of the second kind: the appearance, under the influence of a seismic wave, of a potential difference at two neighboring points of a rock without any preliminary polarization of this rock (in contrast to the effect of the first kind, which occurs in the presence of polarization by an external electric voltage). Ya. I. Frenkel (^2) gave a mathematical theory of the seismoelectric effect of the second kind, proceeding from ideas about the filtration potential arising as a result of the relative motion of ions of a dissociated solution of metallic salts in the pores of the solid skeleton of a rock.

As far as we know, the seismoelectric effect of the second kind had not been reproduced under laboratory conditions, although Mockly (^3), as early as 1918, observed a phenomenon very close to it: the formation of an e.m.f. in moistened sand under the influence of a pressure gradient. Mockly' s experiments were carried out in a quasistatic regime with a constant pressure gradient, producing, accordingly, a constant e.m.f., whereas the seismoelectric effect of A. G. Ivanov was observed under alternating mechanical excitation, which accordingly produced an alternating e.m.f. The magnitude of the e.m.f. excited in the seismoelectric effect of the second kind is extremely small; to detect it, Mockly used a very sensitive long-period galvanometer. Because of the absence of equally sensitive instruments for the range of seismic frequencies, A. G. Ivanov was able to observe the seismoelectric effect only with sufficiently powerful excitation produced by explosions in the immediate vicinity of the observation point. The absence of a sufficiently powerful exciter has until now been the main obstacle to reproducing the seismoelectric effect of the second kind under laboratory conditions. We succeeded in overcoming this difficulty by using the resonance properties of a rock sample having the form of a prismatic rod.

A rod 235 mm long, made of previously moistened shale, is set with its end on a vibrator, which excites in it oscillations of audio frequency. As the vibrator, a piezoelectric hydrophone was used, supplied with alternating voltage from an audio generator. To eliminate electrical coupling between the rod and the body of the vibrator, a thin mica gasket was placed between them. To ensure reliable mechanical contact, the rod to the gasket and the gasket to the vibrator were

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

lapped with castor oil.

In the middle of the rod and at one of its ends, copper bands with shielded conductors soldered to them were fastened. These bands served as electrodes, from which the e.m.f. was taken, arising as a consequence—

···of the seismoelectric effect. After preliminary amplification it was fed to a cathode-ray oscillograph (see Fig. 1).

Observing the image on the oscillograph screen, it was not difficult to detect the existence of very sharp and sufficiently intense resonances

Fig. 1. Block diagram of the laboratory reproduction of the seismoelectric effect of the second kind. 1 —audio-frequency generator, 2 —piezoelectric vibrator, 3 —mica gasket, 4 —slate rod, 5 —electrodes, 6 —audio-frequency amplifier, 7 —electronic oscillograph

at the natural frequencies of the rod. It proved possible to register two such resonances, whose frequencies—2800 Hz and somewhat above 5000 Hz (see Fig. 2)—agreed well with the natural frequencies of the rod determined by V. I. Bunz by another method. It is interesting to note that the resonances of the vibrator (some of them were very intense and were easily detected by ear) either did not appear at all on the oscillograph screen, or appeared only very weakly.

Fig. 2. Frequency characteristic of the e.m.f. of the seismoelectric effect in a rock rod (slate) under excitation by mechanical vibrations of audio frequency

It was established that the sharpness of the resonances in the seismoelectric effect depends strongly on the moisture content of the rock. The sharpest of the resonances observed by us had an absolute width of 10-20 Hz, which at frequencies of 3000-5000 Hz corresponds to a relative width of no more than 0.5%. The values of the e.m.f. observed at the resonant frequencies reached 10^{-4} volt. Outside the resonance regions, the e.m.f. arising in the rod is so small that it is practically impossible to observe it.

The amplitude of the oscillatory velocity of the ends of the rod, approximately estimated from the value of the sound level [4] (not less than 120-125 decibels in the immediate vicinity of the vibrator), is about 10 cm/sec, which corresponds to a displacement of the order of 3-5 μ. To excite more appreciable e.m.f.' s, still more intense motion is evidently necessary.

It should be added that the manifestation of the seismoelectric effect in the laboratory experiment described was facilitated not only by the considerable magnitude of the amplitude of the rod oscillations at resonance, but also by the properly chosen arrangement of the electrodes, one of which was placed at a node of the motion (in the middle of the rod), and the other at an antinode (at the end of the

of the rod). It is known that the magnitude of the filtration potential depends directly and immediately on the amplitude of the relative motion of the liquid phase and the solid framework. If the dissociated solution of salts filling the pores of the framework is considered immobile by virtue of its inertia (which, in a first approximation, corresponds to the truth), then it is easy to see that at the node of the rod' s motion the filtration potential will be equal to zero, while at the antinode it has its maximum value. Therefore the above-mentioned arrangement of the electrodes ensures the use of the maximum difference in filtration potentials.

In dry shale (with no moisture in the pores) we were unable to detect a seismo-electric effect. This agrees with the observations of Mokeley and, together with them, apparently confirms the dissociation hypothesis of Ya. I. Frenkel.

The observations described were carried out on the initiative and with the direct participation of the late Academician G. A. Gamburtsev.

Received16 IV 1958

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