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GEOPHYSICS

1957

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Fig. 1. Borehole seismogram

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Abstract

Full Text

GEOPHYSICS

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ON INTERVAL LOGGING OF ACOUSTIC WAVES

(Presented by Academician I. P. Bardin, 27 February 1957)

Seismic investigation of borehole sections is at present carried out as follows: a seismic receiver is moved in the borehole on a cable, while explosions are made near the mouth of the borehole. By measuring the travel time of elastic waves from the explosion point to the borehole seismic receiver, one can determine, for various depth intervals, the average velocities needed for the interpretation of field seismic prospecting. However, this does not provide sufficient accuracy in determining bed (interval) velocities, used in particular for subdividing geological sections according to elastic properties.

Fig. 1. Borehole seismogram

To measure interval velocities it is necessary to place in the borehole both a seismic receiver and a source of elastic waves. Recently, equipment for ultrasonic investigations of borehole sections has been developed and tested. The models discussed in the literature, along with positive qualities, have certain shortcomings: 1) mainly the first arrivals are used; 2) the elastic pulses emitted by the sensors are often not stable; 3) the measurement intervals are small; 4) the frequencies differ considerably from those adopted in field seismic prospecting (1-5).

For borehole acoustic investigations we have used an installation having the following features: 1) the electromagnetic sensor of elastic waves placed in the borehole provides an acoustic spectrum of the emitted pulses, thereby facilitating extrapolation of the conclusions obtained to field seismic prospecting; 2) the investigation interval reaches 5-10 m, which weakens false anomalies caused by "caverns" in the borehole walls; 3) the high repeatability of the emitted pulses makes it possible to make broad use of the dynamic characteristics of elastic waves; 4) an unshielded standard logging cable is used; 5) measurements are made at points, the distance between which is usually equal to the interval between the sensor and the seismic receiver.

Figure 2

Figure 2: Figure 2

The layout of the installation for interval logging of acoustic waves is as follows: the sensor of elastic waves is an electromagnet mounted in a sealed sleeve; when a current supplied from the surface is passed through it, the core of the electromagnet is drawn into the coil, striking the wall of the sleeve, and this impact is the source of elastic waves; at a distance of several meters from the sensor there is a piezo-segment seismic receiver, which converts elastic vibrations into electrical ones; po-

the signals are fed to the surface of the earth, where, after amplification, they are recorded by an MPO-2 magnetoelectric oscillograph.

Measurements with the installation were carried out in a number of boreholes with depths down to 280 m. The principal results for one of them are as follows. Depending on the seismogeological conditions of the section, the intensity and character of the records of elastic waves change sharply. With varying degrees of reliability, up to four types of waves have been identified which, by analogy of their characteristics with those obtained in ultrasonic investigations in boreholes (3-5), may

Fig. 2. Results of acoustic logging: **1**—vertical hodograph $t_p = t_p(H)$ of the Lamb wave; **2**—graph of the formation velocity $V_p = V_p(H)$ of the Lamb wave; **3**—graph of the maximum amplitude $A_m = A_m(H)$ of the Lamb wave; **4**—graph of the apparent specific resistivity $\rho_k = \rho_k(H)$; **5**—vertical hodograph $t_p = t_p(H)$ of the wave of subsequent arrivals (presumably *SH*); *a*—porphyrites, *b*—argillaceous shales, *v*—sandstones

be tentatively assigned to the transverse waves sometimes distinguished in surface seismic-prospecting measurements, to longitudinal waves in the drilling mud, to shock waves (or Lamb waves), and to *SH* waves.

Figure 1 gives records from one of the films, on which the last two waves are distinguished. This film was obtained with a distance of 5 m between the source and the seismic receiver. Here the upper trace consists of marks of the moment, the middle trace is that of the seismic receiver, and the sinusoid of frequency 500 Hz is the time marking. Figure 2 presents the results of processing the data for these two relatively most intense and stable waves. Only a general idea can be obtained about the intense wave with a velocity of 550-700 m/sec, since its arrivals cannot be determined with sufficient accuracy for determining formation velocities. It is merely noted that the velocity of this wave increases rather rapidly with depth.

By the velocity of the shock wave (Lamb wave) $V_p = V_p(H)$, four layers are distinguished in the section, correlating with the character of the apparent electrical-resistivity curve $\rho_k = \rho_k(H)$. The lowest velocity—about 1200 m/sec—

is observed in the layer of destroyed, weathered, porous varieties of porphyrites; the highest—on the order of 1440 m/sec—is observed in their monolithic varieties. Between these layers with constant velocity there is an interval where the velocity gradually increases with depth. In the lower part of the section, intervals differing from one another in velocity are noted, with predominant development of shales and sandstones.

The most important feature of the materials obtained should be considered the very strong dependence of the intensity of the Lamb wave on the properties of the rocks of the section. From Fig. 2 it is evident that the graph of maximum amplitude $A_m = A_m(H)$ correlates with the electrical-logging curves and with velocity. However, the relative velocity anomalies are of the order of the first tens of percent, whereas the corresponding amplitude anomalies reach hundreds of percent and often make it possible to identify structural details not indicated by other physical parameters.

General theoretical premises and the results of experiments make it possible to consider that the factor which, in a number of cases, determines the attenuation of an elastic wave is the porosity of the rocks. In this connection, the parameter under consideration may find application in the practice of geological exploration work, in particular in identifying reservoirs that are porous varieties of sections.

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Received
4 I 1957

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