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Fig. 1

Figure 1: Fig. 1

Abstract**Full Text****GEOPHYSICS**M. P. VOLAROVICH, D. B. BALASHOV, I. S. TOMASHEVSKAYA,
V. A. PAVLOGRADSKII**INVESTIGATION OF THE VELOCITIES OF
ELASTIC WAVES IN ROCK SAMPLES UN-
DER THE COMBINED ACTION OF ALL-
AROUND PRESSURE AND UNIAXIAL COM-
PRESSION***(Presented by Academician P. A. Rebinder, 12 X 1962)*

For various areas of geophysics, in particular for the physics of earthquakes and tectonophysics, information on the velocities of elastic waves in rocks composing the Earth's crust under conditions of a complex stressed state, caused by the pressure of overlying rocks and by shear stresses associated with tectonic processes, is of substantial interest. In this connection it is expedient to carry out laboratory investigations that make it possible to create a specified stressed state with independently varied components.

Previously, the influence of both all-around pressure⁽¹⁻⁵⁾ and unilateral pressure⁽⁶⁾ on the velocities of elastic waves and other elastic parameters of rock samples had been studied. The present work is devoted to the study of the propagation velocities of longitudinal ultrasonic waves by the pulse method in rock samples subjected to the combined action of hydrostatic and uniaxial compression.

The high-pressure apparatus is shown schematically in Fig. 1. A rock sample 2, in the form of a cylinder 2 cm in diameter and 10 cm long, is mounted in the channel of a thick-walled steel chamber 1 on the housing of electrode 8. All-around pressure in chamber 1 is produced by multiplier 9. Solar oil serves as the pressure-transmitting medium. A preliminary pressure of up to 1200 kg/cm² is created by a hydraulic pump through pipeline 10. The uniaxial load on the sample is produced by press 4. The force of press 4 is transmitted to the sample by a steel sealed piston 3, 2 cm in diameter, through crosspiece 5 and the housing of the piezoelectric sensor 6. The compressive load on the sample may reach 20,000 kgf. Sample 2 has

Fig. 1

a sealed jacket preventing penetration of solar oil into the pores. Oil is supplied by the pump to the low-pressure system through pipeline 13, and discharge when the load is removed is through pipelines 11, 12, and 14. The oil supply is controlled by valves 15. The pressure in press cylinder 4 and in the low-pressure cylinder of multiplier 9 is measured by pressure gauges M_1 and M_2 , up to 2500 kg/cm². The pressure in chamber 1 is measured by a first-class pressure gauge M_3 , up to 16,000 kg/cm².

Rock	Density, g/cm ²	Porosity, %	Velocity of longitudinal waves v_p , m/sec, $P = 1$ kg/cm ²	Ratio of velocities at $P = 5000$ kg/cm ² and at atmospheric pressure v_{5000}/v_1	Ratio of longitudinal wave velocities at uniaxial compressive stress $\sigma = 600$ kg/cm ² and at different pressures P (kg/cm ²): 1	Ratio of longitudinal wave velocities at uniaxial compressive stress $\sigma = 600$ kg/cm ² and at different pressures P (kg/cm ²): 1000	Ratio of longitudinal wave velocities at uniaxial compressive stress $\sigma = 600$ kg/cm ² and at different pressures P (kg/cm ²): 5000
Granite 137	2.62	0.41	4500	1.38	1.26	1.02	1.00
Basalt 4	2.88	0.47	5570	1.11	1.06	1.00	1.00
Diabase 3	3.04	0.40	6370	1.09	1.04	1.02	1.00
Serpentine 240	2.70	0.40	6130	1.20	1.14	1.07	1.03
Limestone 246	2.62	1.80	4780	1.35	1.20	1.03	1.00

Measurement of the uniaxial load is carried out inside the high-pressure chamber

by means of strain-gauge resistance sensors glued to the crosspiece rod 5 along and perpendicular to its axis. The sensors were calibrated many times on the press at atmospheric pressure. The sensor readings were recorded by a bridge circuit with a special amplifier. The accuracy of measurement of the uniaxial load was $\mp 10 \text{ kg/cm}^2$.

The method for measuring propagation velocities of longitudinal waves by the pulsed ultrasonic method has been described earlier (¹⁻⁶). Barium titanate disks 0.8 cm in diameter and 0.22 cm high, with a natural frequency of about 1 MHz, were used as piezoelectric transducers for impact excitation. Pulses of this frequency propagate in the specimen as in an unbounded medium. Sensor 7 is placed in a blind channel of electrode holder 8, communicating with the atmosphere. Sensor 6 is located in a sealed channel of a thick-walled housing situated in the high-pressure chamber, having an insulated electrode and transmitting the load to the specimen. Thus, both sensors 6 and 7 operate at atmospheric pressure. To measure the travel times of elastic waves, a pulsed ultrasonic instrument—a cable and line tester—is used, in which the pulse and time-mark generators have been replaced, and the signal amplification factor has been increased to 200,000. The accuracy of measuring the pulse travel times was 0.5 μsec . In calculating longitudinal-wave velocities, the travel time of elastic pulses through the specimen was determined as the difference between the travel time recorded by the instrument and the correction for the travel time of pulses from the sensors to the specimen through the massive channel walls of the sensor housings. This correction was determined experimentally over the entire range of pressures and uniaxial loads. The accuracy of measuring longitudinal-wave velocities in rock specimens 10 cm long was 3-4%.

The propagation velocities of longitudinal waves in rock specimens were measured as a function of increasing uniaxial load at constant all-around pressure of 1; 500; 1000; 2000; 4000 kg/cm^2 and higher. The uniaxial load was increased in steps. The investigations were carried out at room temperature. The following were investigated: granite 137 from the Novodanilovskoye deposit, basalt 4 from the Kutaiskoye deposit, diabase 3 from the Onega deposit, serpentinite 240 from the Middle Urals (Serebry quarry), and limestone 246 from the Vazelemskoye deposit. A petrographic description of the listed rocks was given earlier (^{5,7,8}).

Figure 2 gives the dependences of the velocity of longitudinal waves v_p in a diabase specimen on the uniaxial-compression stress σ at various confining pressures P , indicated on curves b , as well as the dependence of the velocity v_p on pressure P at $\sigma = 0$ (a). From Fig. 2a it is seen that the most intense increase in the velocity v_p occurs under hydrostatic pressure up to 1000 kg/cm^2 , and is associated with the closing of pores. At higher pressures P , the increase in v_p is much less intense. Fig. 2b shows that the velocities v_p increase intensively with increasing uniaxial-compression stress σ at pressure P up to 1000 kg/cm^2 , which apparently is also associated with the closing of pores. At higher pressures P , the intensity of the increase in v_p with increasing σ decreases significantly. At pressures P above 2000 kg/cm^2 , the change in v_p with change in the uni-

Fig. 2

Figure 2: Fig. 2

axial stress σ lies within the measurement error. At such pressures, uniaxial compression does not cause substantial changes in the elastic parameters in the longitudinal direction.

Fig. 2. 1 $-P = 5300 \text{ kg/cm}^2$; 2 -4000 kg/cm^2 ; 3 -2000 kg/cm^2 ; 4 -1000 kg/cm^2 ; 5 -1 kg/cm^2

Similar dependences are also found for the other rocks studied, the data for which are given in Table 1. The data obtained, in particular, agree well with studies carried out earlier for the velocities of longitudinal waves in these same rocks under the action of confining pressure alone ⁽⁹⁾. The porosity of all the rocks studied, except limestone, is almost the same; however, the grain size and mineralogical composition differ. In granite, which has relatively large grains, the changes in the velocities of longitudinal waves are maximal. For serpentinite these velocities also change quite significantly; possibly this is associated with the presence of large carbonate grains in its porphyritic structure. In diabase and basalt, under conditions of confining pressure, the velocities of elastic waves under uniaxial loading practically do not change. Comparing the data obtained in Fig. 2 and in Table 1, one may conclude that both in the case of uniaxial loading alone and in the case of confining pressure, pore closure occurs, but the nature of pore closure is evidently different.

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